Key Component of 4G and 5G Golden Mid-band Spectrum

GTI 2300MHz Industry White Paper

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Table of contents

1. Executive Summary

For mobile broadband, spectrum is the foundation. In order to provide affordable and high quality mobile services, adequate spectrum is needed, particularly in mid-bands– defined by the ITU as 1 to 6 GHz- which offer a good combination of capacity and coverage. The 2300 MHz band (3GPP LTE band 40 and 5G NR band N40) is a key harmonized TDD band in that range.

The 2300 MHz spectrum band was Identified for International Mobile Telecommunications (IMT) services at the World Radio-communications Conference (WRC-07) of the ITU. As of 2020, the 2300 MHz spectrum band is the most popular global TDD 4G/LTE band deployed by Mobile Network Operators (MNOs). It has become the TDD frequency band most supported by device manufacturers. The 2300MHz band is attractive to operators because there is a 3GPP specification for LTE TDD (band 40) as well as 5G (band N40). The commercial deployment of 5G-NR in 2300MHz already started in Australia with Optus in 2019.

This white paper will provide:

- The advantages of TDD spectrum, and the 2300MHz band is a crucial TDD mid-band spectrum resource for mobile broadband.
- 2300MHz TDD spectrum frequency band is already widely used for LTE and is becoming a key resource for 5G.
- Information of 2300MHz ecosystem. As of June 2020, 5827 2300MHz LTE TDD devices are available and the 2300MHz 5G ecosystem is already in place.
- Suggestions for facilitating the efficient utilization and fast deployment of LTE TDD globally and smooth evolution to 5G. Spectrum-related issues on TDD applications and network deployment are discussed and corresponding solutions for commercial deployment are presented.
- Policy recommendations for regulators to facilitate high use of spectrum efficiency.

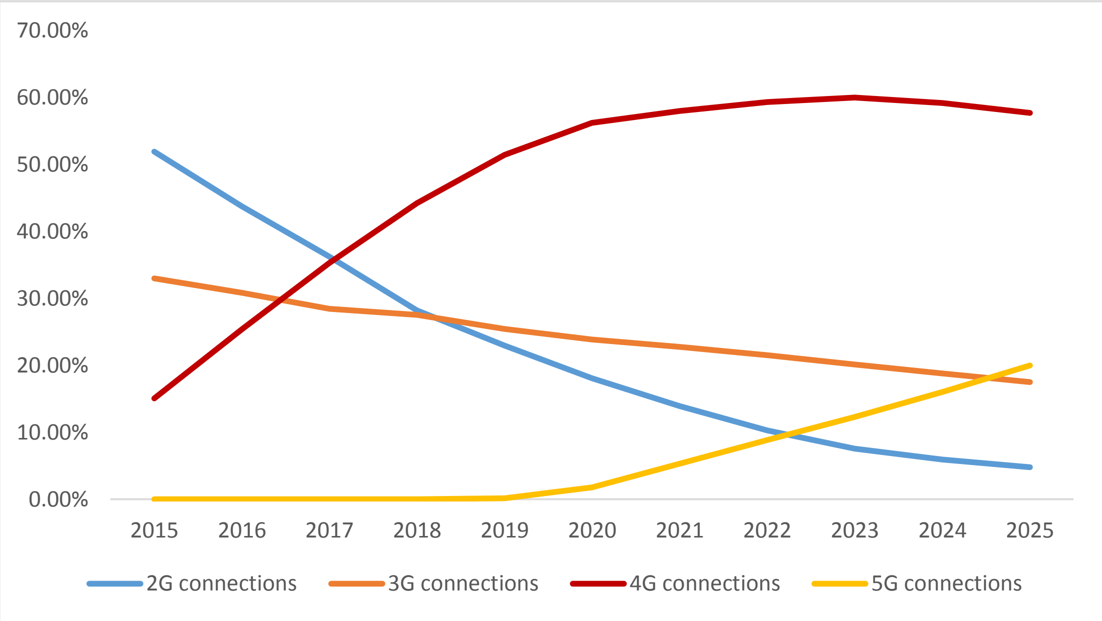
2. Abbreviations

Term	Description
TDD	Time Division Duplexing mode
LTE TDD	Long Term Evolution Time Division
5G NR	5G New Radio
FWA	Fixed Wireless Access
CA	Carrier Aggregation
MIMO	multiple-input multiple-output
LTE FDD	Long Term Evolution Frequency-Division Duplexing
MBB	Mobile broadband
MIIT	Ministry of Industry and Information Technology of China
ITU-R	International Telecommunication Union - Radio communication Sector
WRC	World Radio communication Conferences
IMT	International Mobile Telecommunications
TTM	Time To Market
TCO	Total Cost of Ownership

3. The Need for 2300MHz Spectrum Frequency

Over the last few decades, mobile communications have developed rapidly from analog to digital, voice to data, narrowband to broadband. This innovation consists of a number of generations and is still going on. The journey of mobile communication began with 1G followed by 2G, 3G, 4G, and upcoming 5G. In many countries, mobile has become the primary means of Internet access. 4G become the dominant mobile technology, surpassing half of all global mobile connections in 2019. Meanwhile, 5G is now a reality, with Korea, the United States and Saudi Arabia at the forefront of 5G deployment and more major markets expected to launch 5G networks by the end of 2019.[1]

Figure 1 Share of mobile connections by technology generation, global



Source: GSMA Intelligence

LTE/4G can utilize both FDD - frequency division duplex and TDD - time division duplex, often referred to as LTE TDD. Where LTE TDD favored by a majority of implementations because of flexibility in choosing uplink to downlink data rate ratios, ability to exploit channel reciprocity, ability to implement in non-paired spectrum and less complex transceiver design.

3.1 Advantages of TDD Technology

Utilization of TDD technology offers significant advantages with respect to spectrum efficiency, network performance and capacity and it offers a viable evolution path from 4G towards 5G networks and services.

3.1.1 TDD Facilitates Multi-antenna Techniques Due to its Ability to Exploit Channel Reciprocity

Beamforming and MIMO techniques that are powerful tools for improving end-user experience, network capacity and coverage. Knowledge of the radio channels between the antennas of the user and those of the base station is a key enabler for beamforming and

MIMO.[2]

For TDD, the same frequency is used for both UL and DL transmission. Since the radio channel is reciprocal (the same in UL and DL), detailed short-term channel estimates from UL transmission of known signals can be used to determine the DL transmission beams. Due to the uplink and downlink reciprocity, TDD has great advantages in Beamforming and MIMO techniques.

3.1.2 Flexible Uplink/Downlink Configuration Makes TDD Ideal for Most of Asymmetric Internet Traffic

TDD allows uplink and downlink to use the entire frequency spectrum, but in different time slots. Time is divided up into short slots and some are designated for uplink while others are designated for downlink. This approach enables asymmetric traffic and time-varying uplink and downlink demands which suits mobile internet traffic better. As shown in **错误!未找到引用源。**, typical UL:DL traffic ratio in mobile networks is 1:4-6.

Table 1 Typical UL:DL ratio in mobile broadband Era[3]

Services	Web browsing	1:9-10
	Video	1:4.5-12
	Interactive service	1:2.6
Markets	China Mobile	1:4-6
	Hong Kong	1:4
	Singapore	1:4.3
	Spain	1:4.2
	Romania	1:5.4

Source: GSMA & China Mobile

3.1.3 Unpaired TDD Spectrum Bands Can be Made Available More Easily than Paired Bands

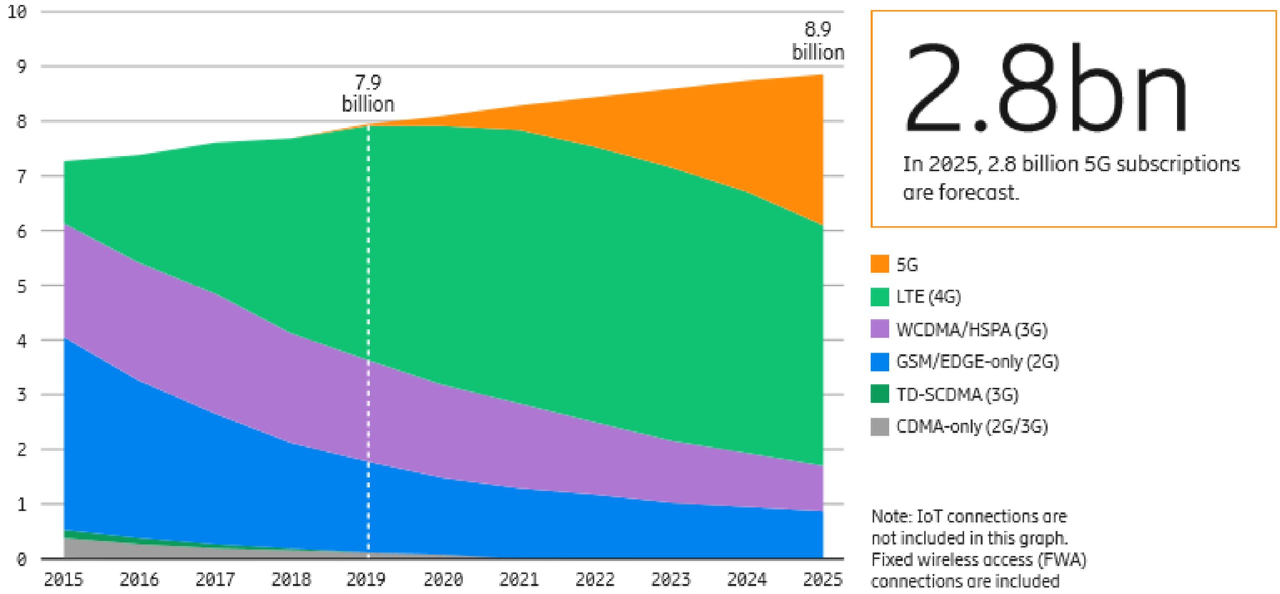
TDD does not require a paired spectrum since transmission and reception occurs in the same channel. High performing mobile networks requires wide channel bandwidths. Currently spectrum between 2GHz to and 6GHz are the best candidates for obtaining these wide channels. From a spectrum management perspective there are challenges making sufficient spectrum and wide channels available. Unpaired spectrum bands are generally easier to make available than paired bands simply.

3.2 2300MHz Spectrum Frequency Band is Important for Mobile Broadband

The need for IMT spectrum

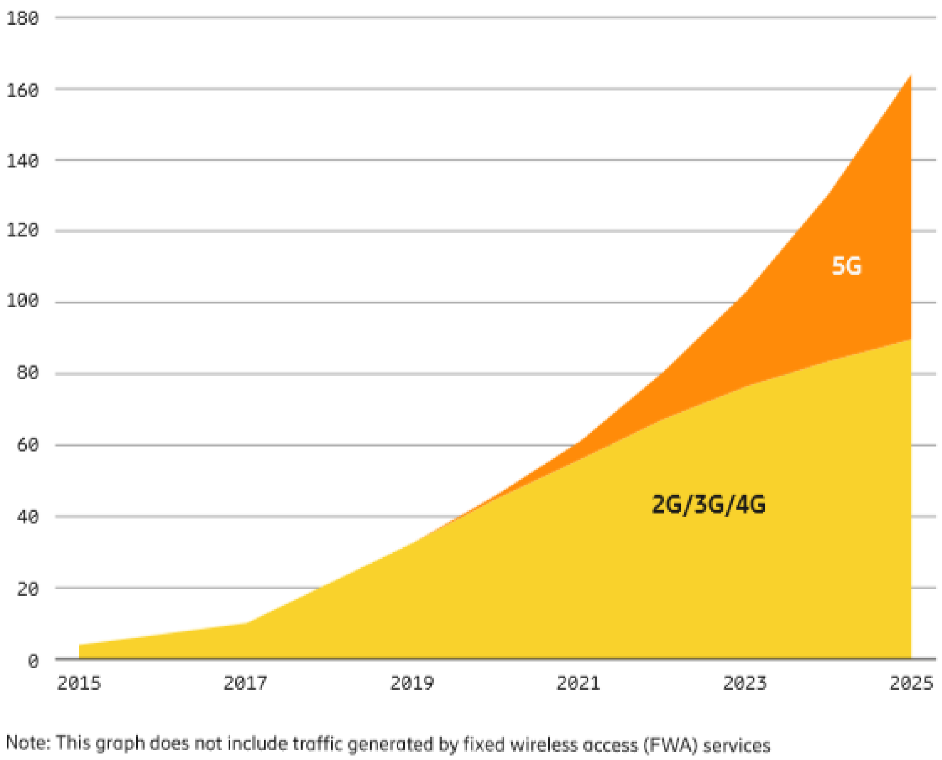
According to the forecast of Ericsson Mobility report, mobile subscriptions will reach 8.9 billion in 2025 which is 1 billion more subscriptions than 2019, and global total mobile data traffic reached around 33EB per month by the end of 2019, and is projected to grow by a factor close to 5 to reach 164EB per month in 2025.As showed in Figure 2 and Figure 3.

Figure 2 Mobile subscriptions by technology (billion)



Source: Ericsson Mobility Report, June 2020

Figure 3 Global mobile data traffic (EB per month)



Source: Ericsson Mobility Report, June 2020

The following approached can be considered to cope with increasing traffic growth [4]:

- **Spectrum availability:** Sufficient and suitable spectrum resources are key factors to facilitate the development of innovative services and applications and stimulate competition in mobile broadband landscape.
- **Technical enhancement:** Migration to innovative, more efficient techniques such as new radio interfaces (4G or 5G) and MIMO technique are needed to keep traffic increase affordable.
- **New station sites:** The number of base stations is important elements for capacity increase.

Driven by a limited supply of appropriate FDD spectrum, the 3GPP standard also recognized the benefit of embracing TDD spectrum bands. The designation of spectrum holdings as TDD or FDD has been commonly perceived as a key decision factor in an operator's selection of 4G technology. The 2300MHzHz Band 40 is a worldwide harmonized spectrum band for IMT. The 2300MHzHz offers 100MHz bandwidth that is well suited to providing capacity in areas where lack of capacity is a key issue.

2300MHz is a key component of mid band spectrum for 5G

The 2300MHz band is already widely used for LTE TDD and is now becoming a key resource for 5G. According to the ITU IMT-2020 requirements, 5G must deliver a ten-fold increase in the user experienced data rate from 10 Mbit/s to 100 Mbit/s in downlink, a factor 100 increase in area traffic capacity to 10 Mbit/s/m^2, and a 10 fold reduction in latency to 1 milli-second. The ability to deploy 5G in a wide channel with massive MIMO is critical to reducing the cost per bit. The 2300MHz is a rare mid-band where it is possible to deploy massive MIMO in a contiguous 100 MHz wide channel. Deploying 2300MHz with massive MIMO in a 100 MHz wide channel maximizes spectral efficiency which is a key objectives for operators and regulators.[5]

In addition, LTE TDD and 5G share the same hardware, including end-to-end network infrastructure such as radio frequency and baseband modules and power supply system. The flexible Software Defined Radio technology enables the smooth evolution from LTE TDD to 5G NR. Thus, LTE TDD and 5G networks can be jointly planned, deployed and optimized.

2300MHz is suitable for Fixed Wireless access (FWA) broadband

FWA/WTTx is a combination of FBB and MBB. It connects households and organizations through cellular technology for last-mile access. FWA delivered over 4G or 5G is an increasingly cost-efficient broadband alternative in areas with limited availability of fixed services such as DSL, cable or fiber. The continuous evolution of 4G and the high performance of 5G make FWA/WTTx as one of the options to provide a high-performance broadband connection for households and organizations.[2]

Large bandwidth of TDD spectrum and multiple-antenna technologies to significantly reduce the cost per bit for fixed wireless broadband services and improve user experience of mobile broadband services. Sufficient spectrum is essential for FWA. According to the analysis, 60 MHz to 100 MHz is needed to meet 50–100Mbps home broadband requirements. The total spectrum of 2300MHz is 100MHz, which is ideal for Wireless Fiber. [6]

Adequate spectrum is needed to strengthen network resilience

The first months of 2020 saw the spread of a novel coronavirus around the globe. COVID-19 pandemic has created complications and challenges for maintaining normal telecommunication services, including:

- The extreme demand for services from households;
- The requirements of health services and hospitals under stress;
- New and unusual patterns of demand; and
- The operation of lockdowns and associated barriers to ensure social distancing.

These and other related forms of disruption all increase demands on telecommunications. A substantial increase in the volume and duration of mobile voice calls across networks – ranging from 20 to 70 percent – was observed in the most impacted regions during the initial lockdown phase. Mobile data traffic growth was typically moderate, or even negative, ranging from -10 to 20 percent in different networks. However, the traffic increase was unevenly distributed, with some cells experiencing a large increase despite overall moderate or even decreasing traffic growth throughout the network. In markets with limited penetration of fixed residential networks, the mobile data demand increase was especially high.

It is very important that MNOs maintain the resilience and quality of the networks to help consumers to cope with everyday life. Indeed, the 100MHz portion of available spectrum in the 2300-2400MHz band (the 2300MHz band) will play a role in helping to meet demand increases arising from the pandemic.[7]

4. 2300MHz TDD Spectrum Ecosystem Status

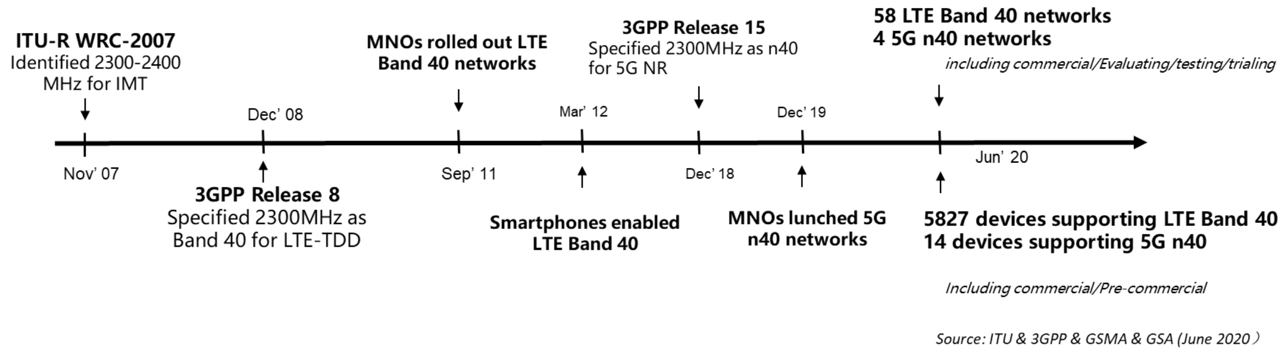
4.1 2300 MHz Spectrum Global Harmonization

Spectrum harmonization is a global effort by the ITU which aims to reduce cross-border interference and allocate spectrum to capacity-constrained users, which can help maximize efficient spectrum usage. Harmonization also aims to facilitate interoperability and roaming across jurisdictions, delivering benefits for equipment and device users.[8]
Harmonized spectrum is necessary to ensure sustainable public mobile broadband services and meet national policy goals. Spectrum harmonization can ensure:

- Economies of scale for standardized products,
- Smoother cross-border coordination,
- Roaming capabilities within the region where harmonization is implemented.

Regarding the 2300MHz band, ITU-R WRC-07 identified the 2300MHz band as suitable for the IMT family of technologies in all three ITU-R regions.

Figure 4 2300MHz TDD spectrum key milestones globally



4.1.1 ITU-R

ITU-R WRC-07 identified the 2300MHz band as suitable for the IMT family of technologies in all three ITU-R regions, as shown in Table 2.

Table 2: ITU-R allocation in 2300-2400 MHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
2 300-2 450 FIXED MOBILE 5.384A Amateur Radiolocation	**2 300-2 450** FIXED MOBILE 5.384A RADIOLOCATION Amateur	

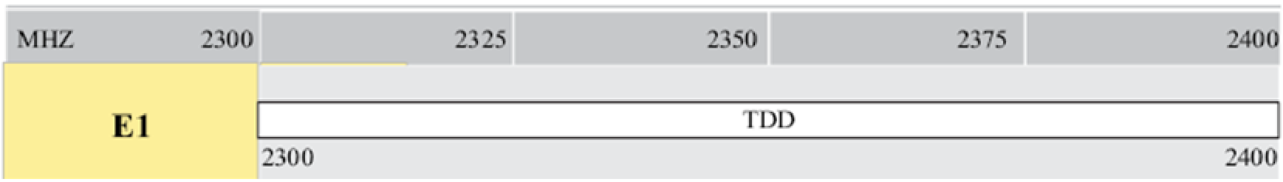
The provision 5.384A of Radio Regulations states : “The bands, or portions of the bands, 1 710-1 885 MHz, 2 300-2 400 MHz and 2 500- 2 690 MHz, are identified for use by administrations wishing to implement International Mobile Telecommunications (IMT) in accordance with Resolution 223 (Rev.WRC-07). This identification does not preclude the use of these bands by any application of the services to which they are allocated and does not establish priority in the Radio Regulations. (WRC-07)”.

In Recommendation ITU-R M.1036-4, frequency arrangements are recommended for the implementation of IMT in the band 2300-2400 MHz. The details are shown in Table 3 and Figure 5 below:

Table 3 Frequency arrangements in the band 2 300-2 400 MHz in Recommendation ITU-R M.1036-4

Frequency arrangement	**Paired Arrangements**				**Un-paired arrangements (e.g. for TDD) (MHz)**
	Mobile station transmitter (MHz)	**Centre gap (MHz)**	**Base station transmitter (MHz)**	**Duplex separation (MHz)**	
E1					2 300 – 2 400 TDD

Figure 5 Frequency arrangement in 2300-2400 MHz



4.1.2 3GPP

As shown in Table 4 and Table 5， the 2300MHz band is already specified as a 3GPP band for LTE-TDD since LTE Release 8 and for NR since Release 15.

Table 4 3GPP E-UTRA frequency bands

E-UTRA Operating Band	**Uplink （UL）operating band BS receive， UE transmit**	**Downlink （DL）operating band BS transmit， UE receive**	**Duplex Mode**
	F_{UL_low} – F_{UL_high}	F_{DL_low} – F_{DL_high}	
40	2300 MHz – 2400 MHz	2300 MHz – 2400 MHz	TDD

There are 101 CA configurations for LTE B40 defined in 3GPP, including:

- Intra-band: max. aggregated bandwidth is 5 x 20 MHz
- Inter-band: aggregate with 700MHz(B28), 800MHz(B20), 850MHz(B5), 900MHz(B8), 1800MHz(B3), 1900MHz(B39), 2100m(B1), 2600(B7/B38/B41), 3500(B42/B43), 5200(B46) MHz bands. Max. aggregated operating bands are 4 bands.

There are 12 NSA configurations for LTE B40 defined in 3GPP, including:

- Inter-band EN-DC within FR1: aggregated with 2100(n1), 2600(n41), 3500(n77,n78), 4900(n79) MHz bands, and for
  - ■ Downlink EN-DC configuration:
    - ◆ LTE B40 supports Intra-band contiguous CA when aggregated with 2600(n41), 3500(n78), or 4900(n79) MHz bands.
    - ◆ LTE B40 supports to be aggregated with Inter-band NR CA operating bands of 2600(n41) and 4900(n79) MHz bands.
  - ■ Uplink EN-DC configuration:
    - ◆ LTE B40 supports Intra-band contiguous CA when aggregated with 3500(n78) MHz bands.

Table 5 3GPP NR frequency bands

NR Operating Band	Uplink （UL）operating band BS receive， UE transmit	Downlink （DL）operating band BS transmit， UE receive	Duplex Mode
	F_{UL_low} – F_{UL_high}	F_{DL_low} – F_{DL_high}	
n40	2300 MHz – 2400 MHz	2300 MHz – 2400 MHz	TDD

There are 14 CA configurations for NR n40 defined in 3GPP, including:

- Intra-band: max. aggregated bandwidth is 2 x 50 or (20+80) MHz
- Inter-band: aggregate with 700MHz(n28), 900MHz(n8), 1800MHz(n3), 1900MHz(n39), 2100m(n1), 2600(n41), 3500(n78), 4900(n79) MHz bands. Max. aggregated operating bands are 3 bands.

There are 41 NSA configurations for NR n40 defined in 3GPP, including:

- Inter-band EN-DC within FR1: aggregated with 700MHz(B28), 900MHz(B8), 1800MHz(B3), 1900MHz(B39), 2100m(B1), 2600(B7), 850(B5)MHz bands, and for
  - Downlink EN-DC configuration:
    - NR n40 supports Inter-band CA aggregated with 700MHz(n28), 900MHz(n8), 2100m(n1), 2600(n41), 3500(n78), or 4900(n79) MHz bands.
    - Max. aggregated operating bands are 5 bands.
- Inter-band EN-DC within FR2: aggregated with 26(n258) GHz bands.

4.1.3 CEPT/ECC

On 27 June 2014， the frequency band 2300-2400 MHz was made available for mobile/fixed communications networks （MFCN） in ECC decision of ECC/DEC/(14)/02. The harmonized frequency arrangement is given in Figure 6.[9]

Figure 6 Harmonized frequency arrangement for MFCN in the 2300-2400 MHz band

TDD (MHz)																			
2300 MHz 2305 MHz	2305 MHz 2310 MHz	2310 MHz 2315 MHz	2315 MHz 2320 MHz	2320 MHz 2325 MHz	2325 MHz 2330 MHz	2330 MHz 2335 MHz	2335 MHz 2340 MHz	2340 MHz 2345 MHz	2345 MHz 2350 MHz	2350 MHz 2355 MHz	2355 MHz 2360 MHz	2360 MHz 2365 MHz	2365 MHz 2370 MHz	2370 MHz 2375 MHz	2375 MHz 2380 MHz	2380 MHz 2385 MHz	2385 MHz 2390 MHz	2390 MHz 2395 MHz	2395 MHz 2400 MHz
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5

- Frequency arrangement should be based on 20 blocks of 5 MHz.
- An operator can aggregate several channels of 5 MHz to obtain a new channel.

The ECC has now started the revision of the existing framework to ensure its suitability for 5G-NR, the ECC new framework is expected in the coming months and will include new emission limits which will be more suitable for AAS base stations implementing beamforming (“massive MIMO”). To this extent, the TRP metric will be introduced replacing the EIRP metric that has been used for non-AAS basestations with passive MIMO antennas.

4.1.4 APT

On September 2012, APT released a report on APT frequency arrangement on 2300-2400 MHz for

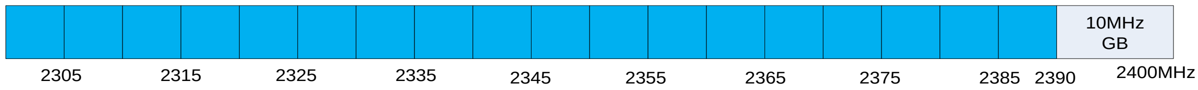
IMT/BWA. Considering the responses of 2300-2400 MHz Questionnaire from APT member countries, AWF recognizes the followings as APT Regional View on the frequency arrangement in the band 2300-2400MHz: [10]

- Full TDD arrangement is preferred. However, flexible FDD/TDD arrangement is also considered for administrations that are required to meet local conditions.
- Channel raster of 5MHz and 9 MHz are used.
- 10MHz or wider/narrower guard band to 2.4GHz ISM band is considered.

Illustrations for band plan options based on the views are as follows:

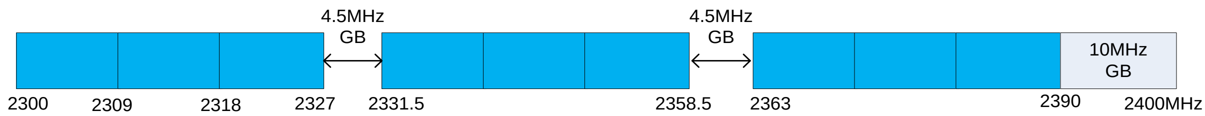
- Option 1: Full TDD without specific arrangement

- Option 2 : implementation of 5MHz channel raster

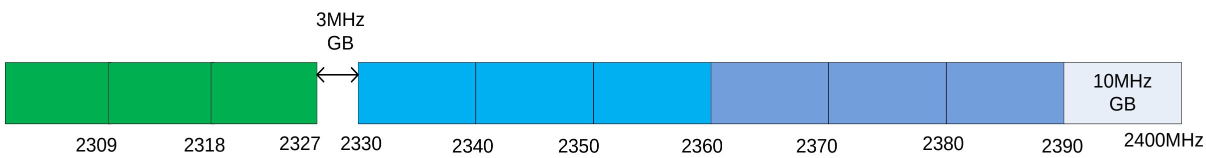


It is noted that in Option 2, the guard band at 2400 MHz edge could be wider/narrower than 10 MHz.

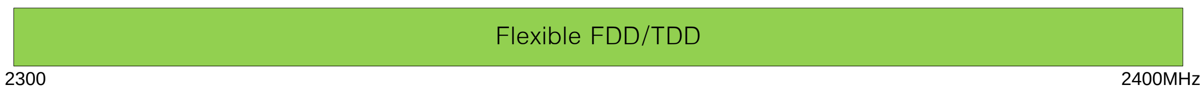
- Option 3: implementation of 9 MHz channel raster
  - Case A : 9 MHz only



  - Case B : 9 MHz and 10MHz
    - Technical condition for coexistence between 9 MHz and 10MHz is being considered.



- Option 4: Flexible FDD/TDD



4.2 2300MHz Ecosystem Readiness

4.2.1 Network Readiness

The criteria set for a 2300MHz-ready ecosystem is based on the readiness and availability of devices and network equipment makers that can provide 2300MHz products for the market.
On the 2300MHz network equipment availability, the GTI has gathered information from major network equipment vendors. All major vendors have already support the 2300 MHz Band40 LTE

TDD base stations. By end-June 2020, GSMA had identified 50 operators holding 2300MHz Band 40 spectrum licenses to provide LTE TDD services. On the availability and roadmap towards the 5G 2300MHz n40 base station as shown in Table 6. Optus Australia has already build the 2300MHz n40 network since 2020.

Table 6 2300MHz band n40 supported by network equipment providers

Spectrum	Available	2019 H1	2019 H2	2020 H1	2020 H2	2021 H1	2021 H2
2300MHzHz (n40)							

Source: Huawei, Ericsson, ZTE, Nokia And Samsung

4.2.2 Terminal Readiness

The LTE-TDD user devices ecosystem is well established with 7,377 devices. Bands 40 (2300MHz) has the largest choice of TDD terminals.

Table 7 The main TDD frequency bands supported by LTE-capable devices

LTE TDD Band	Number of devices
2300 MHz Band 40	5921
2600 MHz Band 38	4600
2600 MHz Band 41	4568
1900 MHz Band 39	3214
2000 MHz Band 34	484
3500 MHz Band 42	355
3700 MHz Band 43	260

Source: GSA, July 2020

Since 2019, chipsets already support for 5G band N40.

As show in Table 8, By June 2020, 15 devices supporting N40 announced and 8 of them commercially available. It is expected N40 supported devices will grow quickly

Table 8 5G Band n40 commercial devices

Vendor	Model	Form Factor	Status
Apple	iPhone 12 mini/Pro/Pro MAX	Phone	Commercial
Samsung	Galaxy S20 5G (Europe & Asia)	Phone	Commercial
Realme	X50 Pro 5G (Europe)	Phone	Commercial
Oppo	Find X2 Lite	Phone	Commercial
Oppo	Find X2 Neo	Phone	Commercial
Oppo	5G CPE Omni	Indoor CPE	Commercial
Simcom W.	SIM8200-EA-M2	Module	Commercial
Huawei	5G CPE Pro 2	Indoor CPE	Commercial

Source: GSA, June 2020&Open source

In 2nd July 2020, GTI released the Global 5G device initiative in GTI summit 2020, requiring devices to support 2300 MHz and other frequency bands, which will greatly accelerate the maturity of the 2300MHz industry and ecosystem. As required in GTI 5G Global device whitepaper, based on globally auctioned spectrum, operator's refarming plans, and GTI survey response, GTI has identified the lists of overall 5G NR bands as shown in Table 9 below. [11]

Table 9 NR Bands - GTI operator survey

# of Operators	NR Band	TDD/FDD	Band name	DL Freq	UL Freq
4	n77	TDD	3700	3300-4200	
4	n78	TDD	3500	3300-3800	
3	n41	TDD	2600	2496-2690	
3	n1	FDD	2100	2110-270	1920-1980
3	n3	FDD	1800	1805-1880	1710-1785
3	n28	FDD	700	758-803	703-748
2	n66	FDD	AWS-3	2110-2200	1710-1780
2	n40	TDD	2300	2300-2400	
2	n79	TDD	4700	4400-5000	
2	n8	FDD	900	925-960	880-915
2	n71	FDD	600	617-652	663-698
1	n25	FDD	1900+	1930-1995	1850-1915
1	n38	TDD	2600	2570-2620	
1	n70	FDD	AWS-4	1995-2020	1695-1710
1	n74	FDD	L- Band	1475-1518	1427-1470

A total of 15 NR bands have been requested by GTI operators for the 5G Global device including 2300MHz n40.

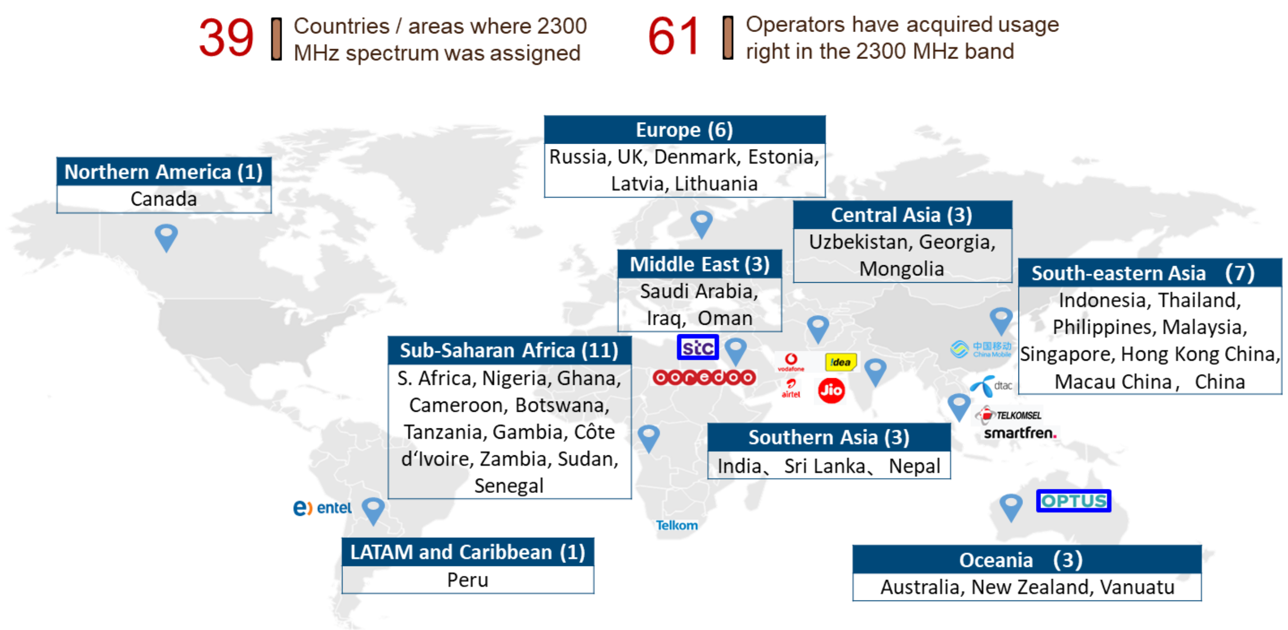
5. 2300MHz Spectrum Allocation and Commercial Deployment

5.1 Global 2300MHz Spectrum Allocation Map and Application

5.1.1 Global 2300MHz Spectrum Allocation Map

As ITU-R WRC-07 identified the 2300MHz band as suitable for IMT applications globally, around 39 countries worldwide have assigned the 2300MHz band to mobile operators as shown in Figure 7.

Figure 7 2300MHz TDD spectrum allocation map



The following Table 10 provides detail information on assignments among key 2300MHz markets.

Table 10 300MHz TDD spectrum allocation table

Region	**Country**	Operator
Region 1 (Europe)	Denmark	TDC
	Estonia	Tele2
	Georgia	Silknet
	Latvia	Bite
		LMT
	Lithuania	Mezon
	Russia	Rostelecom
	UK	O2
Region 1(MEAN & Africa)	Botswana	BTC(BeMobile)
		Mascom
	Cameroon	MTN
	Côte d'Ivoire	Orange
		BasicSA
		YooMee
	Gambia	Netpage
	Ghana	Busy
	Iraq	Goran Net
	Nigeria	Spectranet
		SKY
		Mobitel
		BFC
	Saudi Arabia	STC
	Oman	Omantel
		Ooredoo
	Senegal	Arc Telecom
	South Africa	Telekom
	Sudan	Canar
	Tanzania	TTCL

		Smart
	Uzbekistan	EVO
	Zambia	Zamtel
		Afrimax
		Liquid
		UZI
Region 2	Peru	Entel
	Canada	Cogeco
		ISED
Region 3	China	China Mobile
	Indonesia	Smartfren
		Telkomsel
	Australia	Optus
	Thailand	TOT/DTAC
	India	Rjio
		Vodafone Idea
		Bharti Airtel
	New Zealand	Spark
	Philippines	Globe
		SMART
	Malaysia	YTL Communications
		Telekom Malaysia
		U Mobile
	Macau	CTM
	Mongolia	Unitel
	Nepal	Nepal Telecom
	Singapore	TPG Telecom
	Sri Lanka	Dialog Axiata
		Lanka Bell
	Hong Kong	21 Vianet Group
		3 HK
		China Mobile Hong Kong
	Vanuatu	WanTok

According to GSA, as shown in Table 11, growing availability of 2300MHz in this year or next.

Table 11 2300MHz spectrum auction calendar 2020

Region	**Country**	**Auction/allocation award date**
Region 1 （Europe）	Austria	August 2020
	Norway	From 2021
	Slovenia	End 2020
	Sweden	November 2020
	Ireland	2020/21

Region 1(MEAN & Africa)	South Africa	2020
Region 2	Brazil	H1 2021
	Peru	2020 (possible delay to 2021)
Region 3	India	Q3 2020
	Myanmar	2020

Source: GSA, Spectrum Auctions: CALENDAR July 2020

5.1.2 Technology and Service Neutrality: Mobile or fixed wireless access flexibility

In several countries 2300MHz spectrum was originally licensed for LTE FWA. FWA is also one of the 5G use cases. However, rather than restricting the use of spectrum a technology i.e. 4G or 5G, and to either FWA or mobile, technology and service neutral licensing constitutes regulatory best practice. Service and technology neutral licenses maximize the socio-economic benefit of spectrum because operators can use the spectrum for FWA and mobile. The 2300MHz band is no exception to this. For example, in an urban environment the 2300MHz band can be deployed on macro site and small cells to deliver citywide 5G mobile speed coverage. In rural areas with lower mobile traffic density, the band could be used for 4G and 5G FWA as well as 5G mobile.

As the 2300MHz band is a TDD band, depending on customer demand, MNO business plans and likely commercial returns, there is an opportunity for MNOs to:

1) To augment their mobile broadband offerings which are typically asymmetrical by utilizing such spectrum for 4G and/or 5G services. Examples of this include Bharti Airtel in India, Telkomsel in Indonesia. Airtel is the first in India to launch LTE TDD and has up to 30MHz bandwidth in each circle, carrying 65 percent of the mobile data traffic on their network currently. This indicates the importance of TDD 2300MHz for Airtel.
2) To deploy FWA networks. Example of this include Telkom in South Africa where the 2300MHz band has been able to scale to become South Africa’s largest data network and meet the challenges during COVZID-19 pandemic. Telkom are now looking to deploy 5G utilizing this spectrum.

5.2 2300MHz TDD Network Deployment Related Aspects

As 2300 MHz grows in popularity more regulators are looking to make TDD channel assignments. Before the release of the spectrum and during the 2300 MHz network deployment, some operators and regulators seek help from the GTI to resolve some coexistence issues they face. In this section, we summarize the common issues that are mentioned by regulators and operators

and also recommend solutions to make 2300 MHz deployment easier.
The most common coexistence issues related to 2300 MHz deployment can be classified into the following scenarios:

- Between multiple LTE TDD networks
- Between LTE TDD/NR networks and unlicensed ISM (WiFI, Bluetooth and Zigbee etc.) band networks
- Between LTE TDD networks and 5G networks
- Between LTE TDD networks and Satellite/Radar networks

5.2.1 Multiple LTE TDD networks coexistence issues

When several LTE TDD networks are overlaid in the same geographic areas in the same band with adjacent channels, severe interferences of DL to UL or UL to DL may happen if the networks are uncoordinated. Using techniques like synchronization, sub-band filtering, site coordination and restricted blocks can efficiently resolve interference between TDD networks.
A better way to avoid interference is to synchronize neighbor BSs in order to make them transmit and receive at the same time. There are three mechanisms which are often used and have been mostly standardized by 3GPP, including synchronization by GPS/GNSS, synchronization over the backhaul network, and over-the-air synchronization. Synchronization is not only needed for the cells operating in the same frequency, but also for the cells operating in the same band if the guard band is not sufficient. This way to avoid interference is not only suitable for multiple LTE TDD networks but also suitable for multiple 5G networks, which actually have the same interference as LTE TDD networks.

5.2.2 LTE TDD/NR network and unlicensed ISM network coexistence issues

Immediately adjacent to 2300MHz is the industrial, scientific and medical (ISM) band between 2400MHz and 2483.5MHz, which is an unlicensed spectrum band available to all users provided the equipment satisfies restrictions on radiated power, duty cycle and out of band emissions. If LTE band 40 and/or NR n40 is deployed in 2300MHz there will be the possibility of interference from systems operating at the high frequency end of 2300 MHz into systems operating at the low frequency end of the ISM band. Ofcom had done a series tests to verify that the TDD LTE signal in the frequency range 2350~2390MHz causing a non-observable effect when Bluetooth devices operate with frequency hopping enabled[12]. Telefonica UK got the license for 2350~2390MHz in 12 April 2018[12] and use it to provide MBB service. After acquiring Vivid Wireless in 2012 Optus secured 98 MHz of spectrum in the 2300 MHz band, which the company has since refarmed into B40 (2300 MHz) LTE. In 24 Jan. 2020, Saudi Arabia's Communications and Information Technology Commission (CITC) has awarded 100MHz of spectrum in the 2300 MHz band to STC for 4G/5G use.
In 3GPP release 16, the maximum channel bandwidth is 80MHz. According to the agreement in [14], the limitation for maximum UE channel bandwidth is the relative bandwidth, which is the key to ensure the MPR performance. During the study of In-Device Coexistence (IDC), it was concluded that either a FDM solution or a TDM based solution can be utilized to solve this co-existence issue for LTE or NR [15]. For BS side, this is no special issue for BS side to consider the co-existence with WLAN even to support 100MHz channel bandwidth for NR n40 and 3GPP RAN4 is considering to specify 90MHz and 100MHz UE channel bandwidth for n40 as optional channel bandwidths.

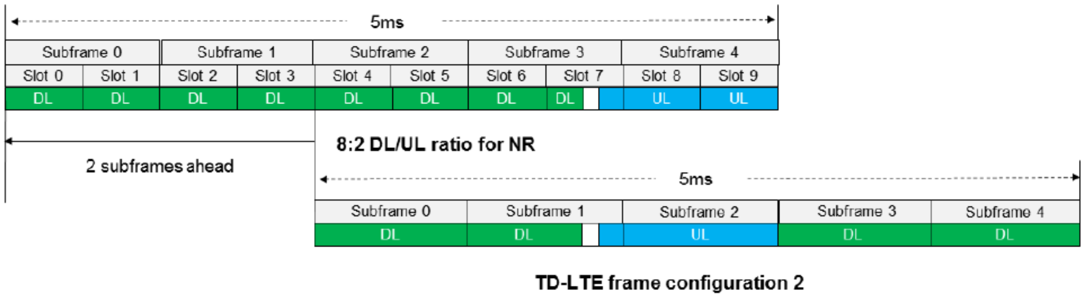
5.2300MHz LTE TDD network and 5G coexistence issues

LTE network and 5G network coexistence will last a long time when 5G begins and some regions and countries have already deployed 5G network on 2.6GHz and 3.5GHz, where there're already LTE TDD network deployed for many years, like China and UK etc.

The interference between LTE TDD and 5G NR can be easily mitigated by the synchronization operation with aligned sub-frame configuration.

For LTE TDD, as shown in Figure 8， frame configuration 2 is the most widely used frame structure, i.e., 3:1 DL/UL ratio with 5-ms DL/UL switching period, over 90 percent of commercial TDD networks adopted such configuration according to statistics. Then, the frame structure of 8:2 DL/UL ratio with 5-ms DL/UL switching period can be adopted for NR to attain synchronization with LTE TDD. In addition, the slot format configuration in NR is very flexible which can match all the configurations of special subframes in LTE. The only modification is to adjust the starting point of the frame as shown in below:

Figure 8 Frame structure of 5 ms DL/UL switching period



If 8:2 DL/UL is not applied to 5G configuration, extra guard bandwidth together with extra transceiver filters is required to mitigate Intra-site adjacent-frequency interference.

5.2.4 Between LTE TDD/NR networks and Radar deployments

Military land based, ship-borne & airborne Radar's operate below 3400 MHz and will need to be protected from Interference from mobile use in adjacent band. Whilst is possible to avoid interference to fixed land based & ship based Radar's with exclusion zone around Radar deployments, avoiding interference to airborne Radar's may require guard bands between mobile and Radar allocation nationally. Co-existence is facilitated with a frequency separation between the Radar system and the Mobile allocation or with additional power restrictions. The adoption of an UL only frame structure could be an interesting option meeting the growing UL connectivity demand while facilitating coexistence between 5G NR network and radiolocation service.

5.3 2300MHz Spectrum Technology Solution Recommendations

The main application scenario of 2300 MHz is used as basic capacity layer to provide MBB service and/or WBB service for users. How to increase the spectrum efficiency is the key for business success. The following solutions are recommended to fully leverage the advantages of TDD spectrum space division technologies in network construction. From the network construction side, 8T8R is the basic configuration, Massive MIMO is a key component of 5G-NR enabling technology and can be used in 4G network to provide 3~5 times capacity compared traditional macro site, spectrum sharing is better way to build 5G network, which can balance the 5G ecosystem development and 4G capacity requirement. From the UE side, transmit antenna selection is recommended to fully make full of the antenna information to increase the downlink spectrum efficiency of Massive MIMO.

5.3.1 TDD Network and 5G Network Coexistence will Last for a Long Time. TDD and NR Spectrum Sharing is a Key Technology to Facilitate TDD Network Smooth Evolution to 5G

5.3.1.1 One Network Dual Usages Introduction

It takes time to establish the 5G ecosystem and LTE network: it is therefore expected that 5G-NR and LTE-TDD networks in the 2300 MHz band will need to coexist for a long time. Many operators deploy TDD networks for both current revenue and smooth evolution to 5G NR in the future. Some operators choose the strategy called One Network, Dual Usages, i.e. performing both 5G and 4G services on the same network, mainly on 2.6 GHz or 3.5 GHz band, the strategy can also apply to the 2300MHz. The following Table 12 shows three phases of 4G evolution to 5G.

1) In the early stage of network deployment, 4G services are mainly provisioned, which brings quick return and a better brand image for 5G services.
2) The LTE TDD and 5G NR spectrum sharing technology can dynamically allocate the spectrum for LTE TDD or 5G NR based on the traffic load to maximize the spectrum value.
3) In the late stage of network deployment, spectrum can be refarmed for 5G NR when the penetration rate of 5G terminals reaches a preset threshold.

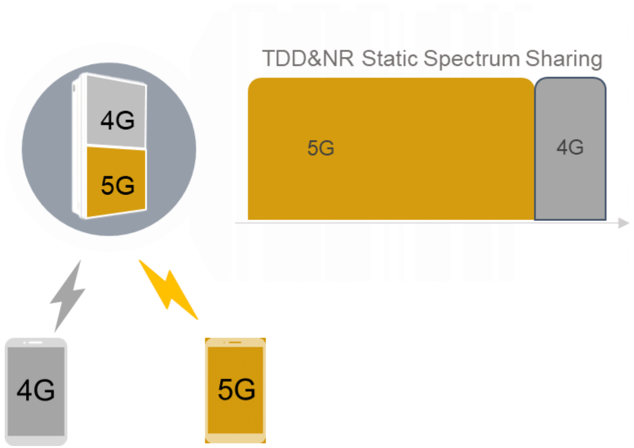
Table 12 Three phases of 4G evolution to 5G

	Short-term	**Medium-term**	**Long-term**
VIP user	NR (LTE)	NR	NR
High-end user	LTE	NR/LTE	NR
Mid-end user	LTE	LTE	NR/LTE
Low-end user	LTE	LTE	LTE
Most profit comes from	4G	4G and 5G	5G

5.3.1.2 Spectrum Sharing Technology

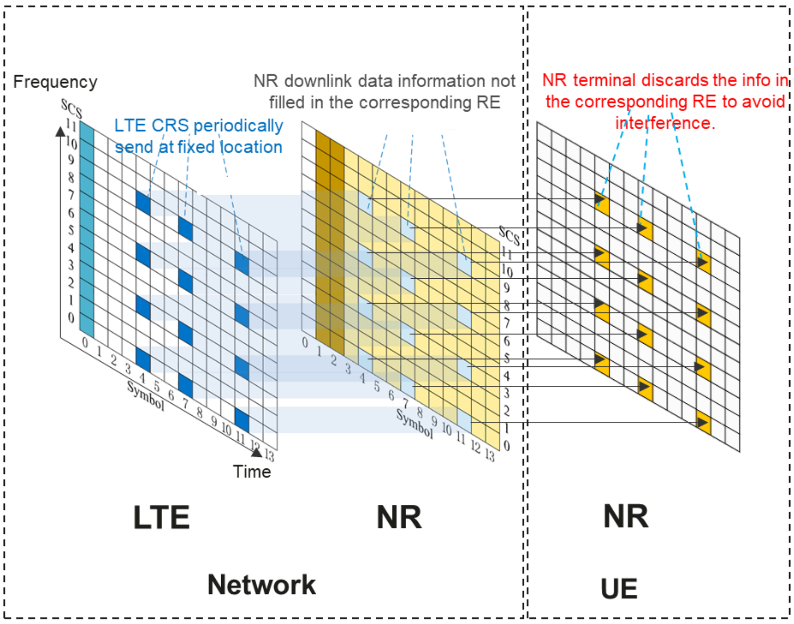
For operators, static spectrum sharing and dynamic spectrum sharing (DSS) technologies are both recommended which depends on deployment scenario. If bandwidth is big enough (usually more than 80MHz), we recommend static spectrum sharing which is easier to deploy and has no dependency on terminal.

Figure 9 TDD&NR Static Spectrum Sharing



For smaller bandwidth, dynamic sharing is very important for 5G. DSS enables both LTE TDD and 5G-NR network operation, in a common frequency band, potentially re-using existing LTE infrastructure, which is essential for operators to quickly offer 5G services in existing LTE band. As shown in Figure 10, 3GPP Release 15 specify that rate matching of LTE-CRS is mandatory for 5G UEs. The gNodeB will punch out resource element (RE) corresponding to LTE CRS and will not fill the data. The 5G terminals need to punch out the CRS resource element as well. In 3GPP specification, it is mandatory for the UE to signal to whether is supports DSS and in which band.

Figure 10 Rate Mating of LTE-CRS



For TDD&NR dynamic spectrum sharing, frequency alignment between LTE and NR is necessary to avoid inter-subcarrier interference:

- 100 kHz channel raster is supported for n40 in Rel-15.
- The 30 KHz SS block SCS support in band n40 has already agreed upon in RAN4, which is required to achieve UL-DL coexistence and for avoiding LTE CRS REs allocation.
- UL 7.5kHz frequency shift for 15KHz data SCS

The inclusion of band n40 for the list of bands supporting UL 7.5 kHz shift is required for 15 kHz SCS. DSS with 15 kHz SCS gives better spectral efficiency using RE level rate matching than RB level rate matching.

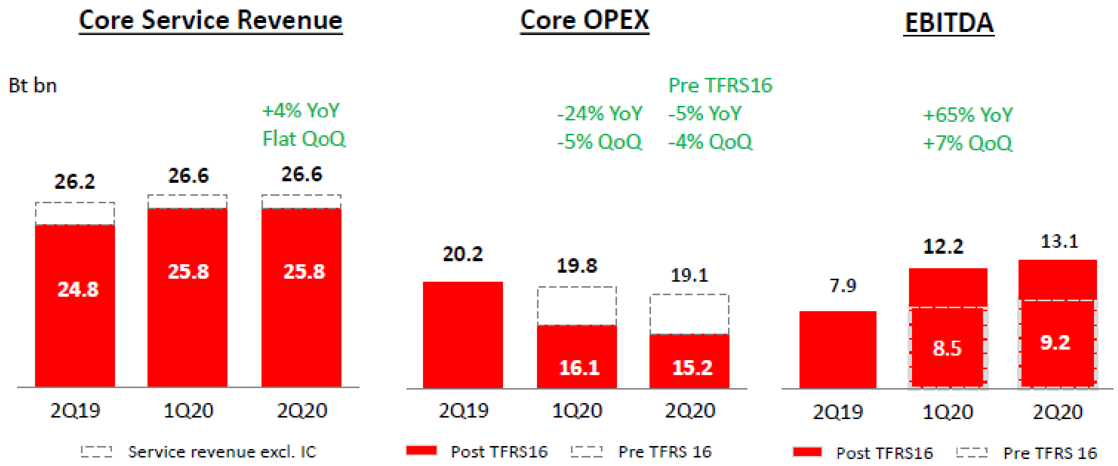
5.3.1.3 Best Practices

Since the release of the GTI TDD spectrum white paper[16] last year, we have seen a good result of

94% of the operators with 2.6 GHz (NR) had deployed LTE TDD and 5G-NR on the same band, including China Mobile, Thailand AIS/TRUE, Philippine Smart/Globe, UAE Etisalat/DU, Saudi Arabia Mobily and etc.

True Move, the second-largest operator by subscribers in Thailand, acquired 90MHz of 2.6GHz spectrum in February 2020 and switched on 4G carriers on 5G sites. With Massive MIMO and dynamic 4G/5G spectrum sharing (DSS), it can provide 3 times of 4G capacity. According to the data from analyst conference 2020Q2 from TRUE, 4G traffic still dominates and 62% of the 4G devices support 4G 2.6GHz. 4G traffic stays majority in next few years, so TURE 5G network focus on city and strategic areas with high data and top-tier users in 77 provinces. With good network quality, core service revenue rose 4% YoY on mobile and broadband service in 2020Q2 despite the full-quarter CVOID-19 impact.

Figure 11 TRUE Revenue and EBITDA growth amid COVID-19 impact



China Mobile and Huawei jointly verified the LTETDD and 5G-NR dynamic spectrum sharing on 2.6 GHz in Zhejiang province in November 2019. When the 4G network is heavily loaded and the 5G network is lightly loaded, the 4G network preempts the spectrum, and the user-perceived rate of 4G CA UEs increases by 109%, the service throughput increases by 17%. When the 4G network is lightly loaded and the 5G network is heavily loaded, the 5G network preempts the spectrum. Compared with the 4G network preempting the spectrum, the 5G user experience rate increases by up to 40%.

For 2300MHz，the same as 2600MHz, we recommend LTE TDD and NR spectrum sharing for One Network Dual Usages is a good choice for operators.

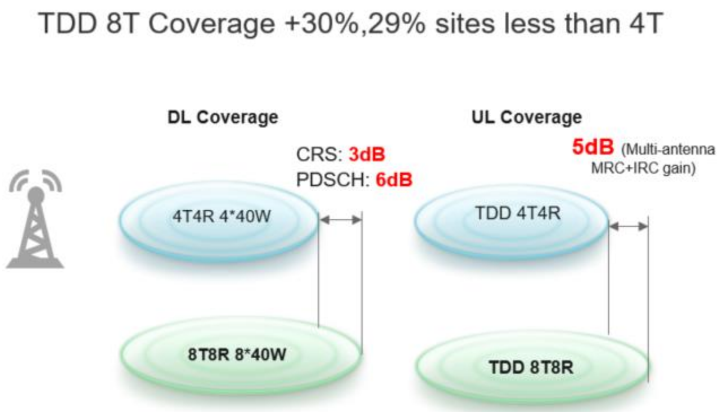
5.3.2 Multiple-antenna technologies and transmit antenna selection are recommended to increase spectrum efficiency

From the base station side, continuous large bandwidth and multi-antenna technology are recommended to fully leverage the advantages of TDD spectrum space division technologies and provide affordable service for users. From the UE side, transmit antenna selection is recommended to fully make full of the antenna information to increase the downlink spectrum efficiency of Massive MIMO.

5.3.2.1 Starting with 8T8R is recommended in TDD networking facing 5G evolution and it is easy to deploy 8T8R in recent network

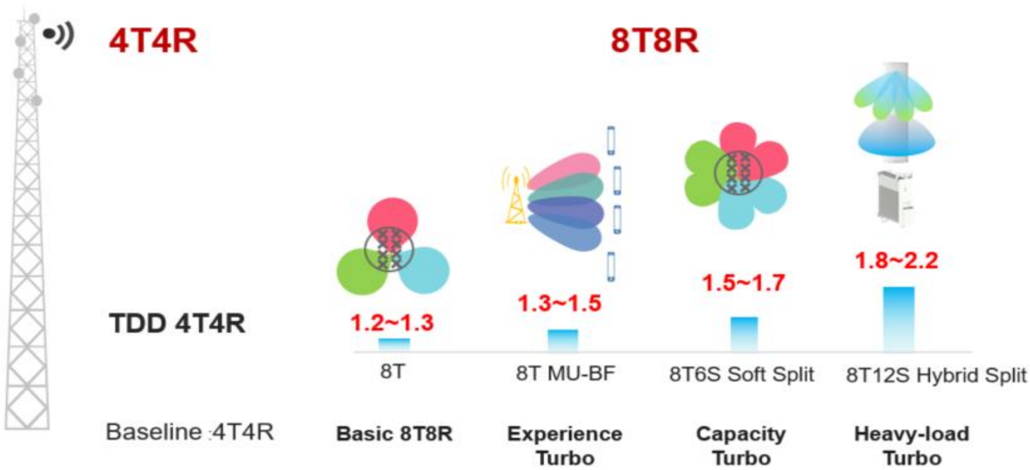
TDD 8T8R uses 8 transmit antennas and 8 receive antennas for better capacity and coverage. 8T8R has already become the major deployment mode for TDD networks. TDD 8T8R can improve network capacity by up to 2.2 times (vs 4T4R). 8T8R can also improve 5 dB in uplink coverage, 3 dB in CRS coverage and 6 dB in PDSCH coverage (vs 4T4R, consider same power in every channel.

Figure 112 TDD 8T8R Coverage Comparison with TDD 4T4R



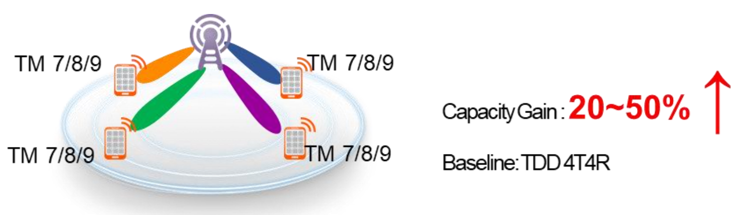
8T8R also has much better capacity than 4T4R because of multi-antenna technology. 8T8R has more flexible solutions facing different capacity requirements.

Figure 123 TDD 8T8R Capacity Comparison with TDD 4T4R



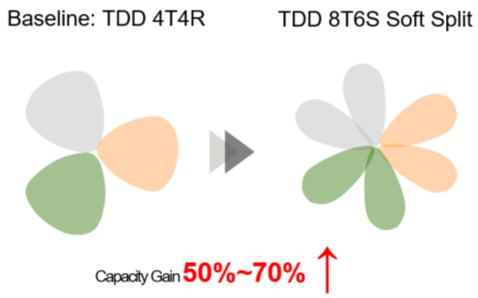
- Multi-User Beamforming: 8T8R with 4 layers pairing in MU-BF can provide maximum 1.5 times capacity gain when compared with TDD 4T4R.

Figure 134 TDD 8T8R Multi-User Beamforming



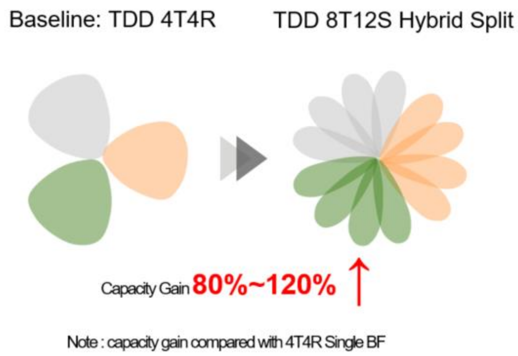
- 8T6S Soft Split: With soft split, 8T3S (3 cells) upgrades to 8T6S (6 cells). With some interference rejection technology, 8T6S Soft Split can raise up to 70% capacity compare with TDD 4T4R. And Soft Split has much more benefits than Hard Split solution which splits one 8T8R cell into two 4T4R cells. First, TDD 8T8R soft split only needs one nine port antenna and one 8T8R RRU which saves more space for antennas and poles. Second, soft split keeps every cell with eight receive antennas which means no uplink coverage loss.

Figure 145 TDD 8T8R Six Sectors Soft Split



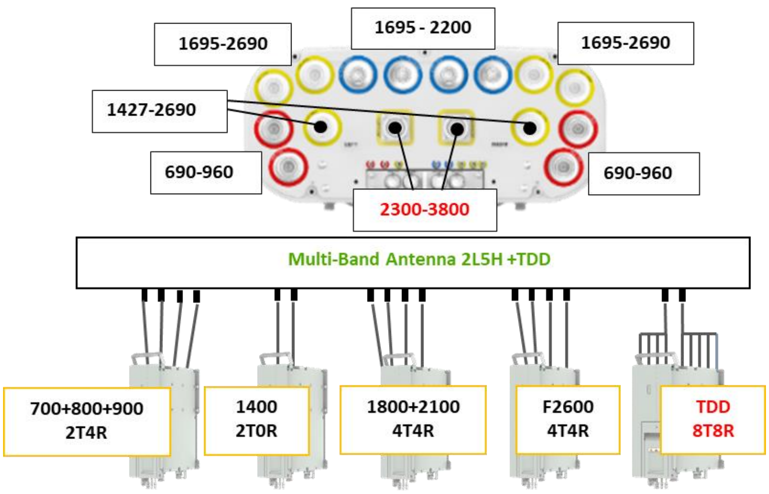
- 8T12S Hybrid Split: This solution is the upgrade solution of 8T6S Soft Split. With digital-analog hybrid antenna, 8T3S can split into 8T12S with no uplink coverage loss. With split, capacity gain raises up 120% compared with 4T4R.

Figure 156 TDD 8T8R Twelve Sectors Hybrid Split



Multi-layer interleaved design reduces antenna width by 50%, compared to traditional antennas. TDD 8T8R and FDD 4T4R on all Sub-3GHz bands can be easily integrated in one antenna, which makes clean site and saves site space and rent cost. In some Europe countries, only one pole in one sector, no space to deploy Massive MIMO and site permission time for new pole is more than 9 months. With the 2L5H+TDD antenna, we can quickly activate the dual TDD spectrum, meanwhile, the antenna can be shared with other operators, and can be deployed in other vendors' RAN regions to save TTM and TCO.

Figure 167 FDD+TDD 8T8R Deployment



25.3.2.2 Massive MIMO is a key component of 5G enabling technology

Massive MIMO has been widely regarded as an ever energizing technology since 4G rollout. It leverages the unrivaled advantages of TDD spectrum to achieve revolutionary breakthroughs in network performance for operators. By adopting massive antenna arrays, massive MIMO brings about three- to five-fold increase in spectral efficiency when compared with traditional macro sites. Massive MIMO on 2.6G and C-band have been widely deployed in live network especially with the help of 5G large-scale deployment in China. The size and weight of Massive MIMO on 2300MHz is the same as 2.6G Massive MIMO, because they use the same antenna elements. For example, DTAC from Thailand had deployed 2300MHz Massive MIMO to triple network capacity and ensure users can stay connected and productive.

Massive MIMO has more antenna elements. This advantage brings more aggregated energy and more beamforming layers which means better coverage and better capacity.

Figure 178 TDD Massive MIMO Comparison with TDD 4T4R/8T8R

Massive MIMO has flexible 3D sharping capability so that massive MIMO has much better adaptability in many scenarios.

Figure 189 TDD Massive MIMO Flexible 3D-sharping

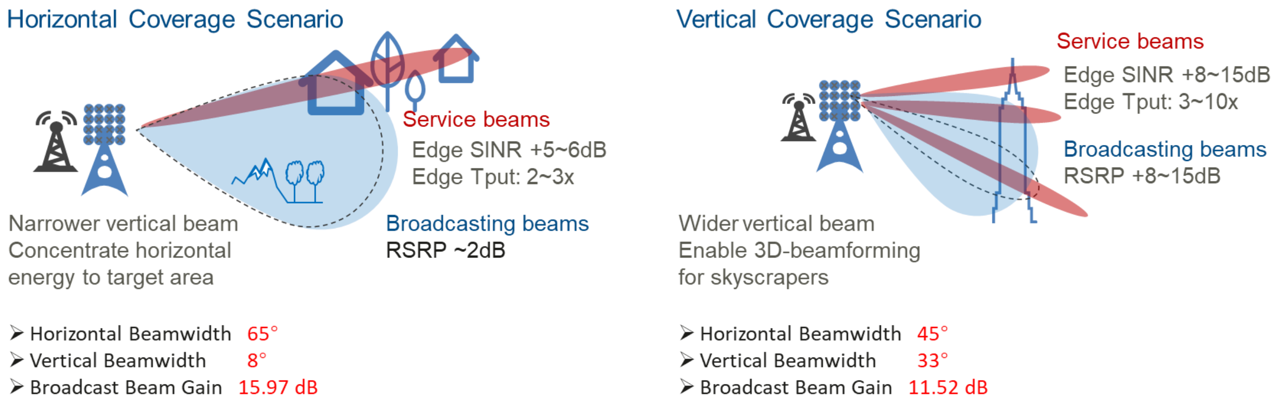
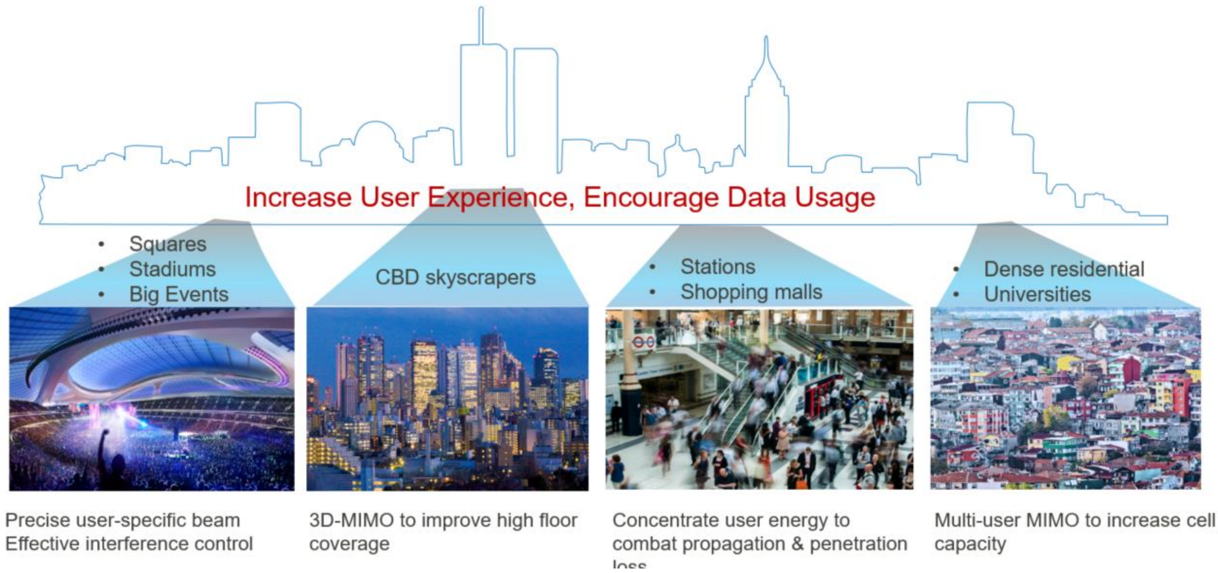


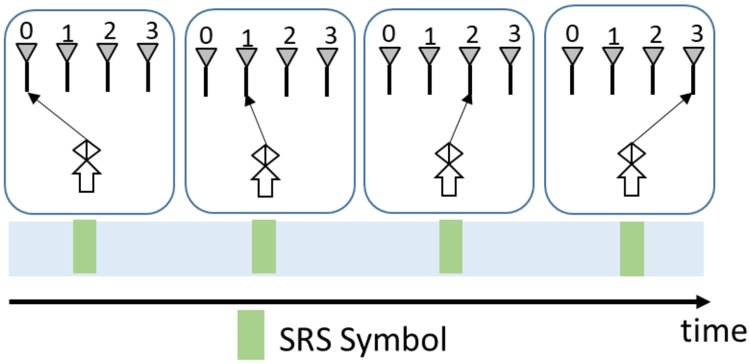
Figure 20 TDD Massive MIMO Typical Application Scenarios



5.3.2300MHz Transmit Antenna Selection Technology can Facilitate TDD Network Experience to a Upper Stage

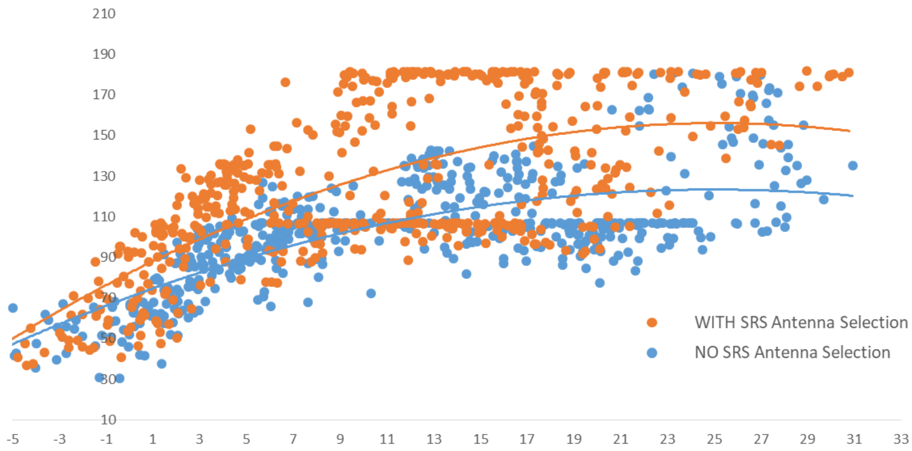
To get a higher experience in TDD network, capacity is usually sacrificed because it is not easy for UE without transmit antenna selection to enter into TM8 or TM9 open-loop two layers/four layers. This means, when UE get two streams, RBs for this UE cannot be reused in spatial-multiplexing pairing. Transmit antenna selection UE has much better performance. SRS antenna selection is to transmit SRS on different UE antennas in different time so as to enable base station to get full channel information. With that, UE will get a more precise downlink weight for beamforming to increase downlink user experience throughput.

Figure 191 Four Antenna SRS Selection



From drive test in operator's network of Peru, up to 30% user downlink throughput gain achieved with SRS antenna selection when compared with no SRS antenna section.

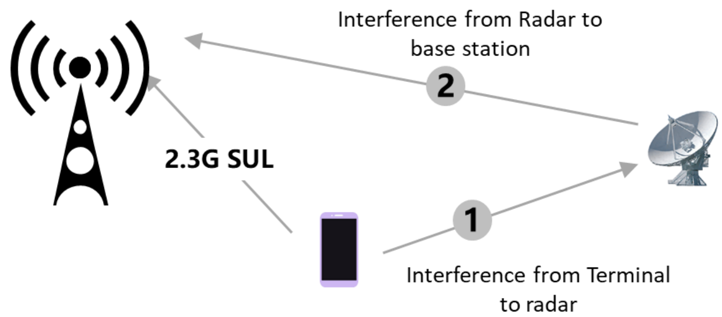
Figure 20 Test Result from Live Network in Peru Operator A



5.3.3 SUL is a Potential Solution to Resolve Co-existence between Base Station and Radar System

According to ITU-R M.1461-2, compatibility between radars and systems in other services is largely determined by emissions from radars on receiving functions of other services and potential desensitization of radar receivers by emissions from modulated continuous-wave (CW) systems in other services. SUL is a potential solution to resolve co-existence between 5G base station and radar. As 5G terminal transmit power is only 23dBm and many building blocks exist between the terminal and radar to decrease the interference signal from 5G terminal. In general cases, a signal from 5G terminal resulting in an *I*/*N* ratio below −6 dB is acceptable by the radar users. From system level Monte-carlo simulation, 3km~10km isolation distance is required to avoid the interference from terminal to radar service and 1~5km isolation distance is required to avoid the avoid the interference from the radar to 5G base station. 3GPP RAN4 has established a work item (WI) and a new SUL band (2300-2400MHz) will be defined. This WI is expected to be closed by the end of this year.

Figure 213 Radar and Base Station Interference Analysis



6. 2300MHz Spectrum Policy Recommendations

Spectrum is a finite resource essential for telecommunications services. However, it holds no value until used by mobile operators to build networks and create valued services for all citizens. Sufficient internationally harmonized spectrum is essential to ensure the quality that consumers and businesses have come to expect, and rely on, from mobile networks. Therefore, policies need to foster widespread coverage and affordable, high-speed services. Government plays the key role in maximizing the spectrum value.

Spectrum roadmap

A spectrum roadmap is essential to ensure there is enough spectrum to meet surging demand for mobile services and support the national digital strategy. A spectrum roadmap helps:

- Government forecasts future trends and manage its work and risks;
- Industry with increased certainty about the government's future allocation plans and management of radio spectrum.

When governments publish national broadband plans setting out how targets for widespread broadband will be achieved and a spectrum roadmap providing a schedule for forthcoming spectrum releases to meet the government's broadband plan as well as other demands on spectrum.

Key themes for a spectrum roadmap [17]:

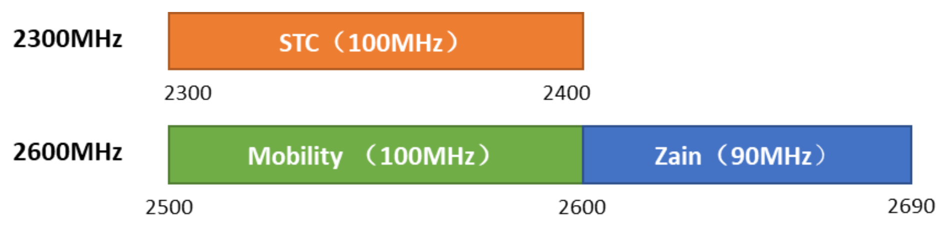
- Emerging challenges and opportunities to radio spectrum management framework and approach, at least 3 – 5 years into the future
- Identify future technological trends and drivers, and assess their impact on spectrum policy and planning
- Spectrum management work projects and programmer planned to address the identified challenges and opportunities
- A roadmap is an evolving document, to be reviewed and updated regularly (annual review is recommended)

2300MHz spectrum release aims to promote large scale network investments

Mobile operators require additional spectrum, particularly in mid-bands which offer a good balance in capacity and coverage performance. With a 100 MHz of spectrum, the 2300MHz band (LTE band 40 LTE and 5G-NR band N40) is a crucial TDD mid-band spectrum resource for mobile broadband. It has become the TDD frequency band most supported by device manufacturers. Given such widespread industry support the 2300MHz band will become a premium spectrum band for 4G and 5G services. We recommend regulators to release 2300MHz spectrum frequency band as soon as possible when there are business needs.

Meanwhile, for the 5G economics to work, mobile operators must be able to dramatically reduce the cost per bit. The ability to deploy 5G-NR in a wide channel, 80-100MHz per operator, with massive MIMO is critical to reducing the cost per bit. So, deploying 2300MHz with massive MIMO in a wide channel maximizes spectral efficiency is a objectives for operators and regulators. For example, as shown in Figure 22, Saudi Arabia's Communications and Information Technology Commission (CITC) has awarded a total of 290MHz in the 2300MHz and 2600MHz bands for 4G/5G use to Saudi Telecom Company (STC), Etihad Etisalat (Mobily) and Zain Saudi Arabia in 2019.

Figure 224 2300/2600MHz spectrum assignments in the Kingdom of Saudi Arabia



- **Reasonable Spectrum pricing**

To accelerate the delivery of affordable, high quality MBB services to end users, a reasonable spectrum price is essential. The excessive spectrum pricing imposes a heavy burden on the mobile operators, and eventually a highly negative impact on the network development and on the consumers. Governments should avoid the temptation to use spectrum auctions to maximize revenue. Instead, governments should allocate spectrum with the aim of fulfilling their connectivity objectives. Furthermore, using spectrum to maximize government's revenue can result in spectrum going unsold after an auction. In this case, the spectrum would remain unused, causing an irrecoverable loss of commercial and public value.

In addition, the spectrum in many countries in the world is currently assigned by auction, and auction fees are expected to be paid by the operators in a one-off payment way within a specific time. This greatly affects the financial status of operators in the initial stages of network deployment and hinders the progress of network rollout. To alleviate the negative effect brought about by one-off payments of spectrum auction fees, it would be preferable for the operators to be allowed to pay the auction fees in annual instalments during the spectrum authorisation period.

Moreover, in order to enable effective network construction, the regulator may stipulate appropriate network obligations, such as population/ geographic coverage and network data rates. Policies could be put into place for the relevant spectrum fees to be reduced if the operator is able to meet the requirements of these network obligations.

- **Technology and service neutrality license**

Spectrum assignments for specific mobile technologies and in some countries for specific services, 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 technology neutrality is a best practice that has been followed by most countries. Such an approach has allowed operators to swiftly respond to the changes in market demands with tangible benefits for society and end users.

In several countries 2300MHz spectrum was originally licensed for fixed wireless services. However, rather than restricting the use of spectrum either fixed or mobile, service neutral licensing constitutes regulatory best practice.

Service and technology neutral licenses maximize the socio-economic benefit of spectrum because operators can use the spectrum for its max value. The 2300MHz band is no exception to this.

- **Individual nationwide assignments**

Exclusive national licenses give mobile operators certainty that they can deploy their networks when and where there is demand from their customers, and at the required level of quality, free from concerns in relation to co-channel interference. It is important to note that regional licences have significant disadvantages compared to national licences:

- Regional licenses require buffer zones at their boundaries to mitigate co-channel interference between licensees. This can result in inefficient use of spectrum.
- There is an additional burden for the spectrum regulator to define, issue and manage regional licences, and for the operators to plan their networks.
- Seamless coverage along transport paths (railways, roads) becomes challenging with regional licences.
- Regional licences do not have a good track record: past initiatives to allocate spectrum licences on a regional or local basis have not been very successful. Many small players acquired these regional licences but did not deploy extensively.

Network synchronization

In order to avoid interference between TDD networks operating in adjacent frequency carriers, radio transmissions of adjacent TDD networks should be synchronised and with the uplink and downlink frames aligned in time. Such synchronisation of TDD networks is very important because it is the best way to avoid interference between networks and ensure efficient use of spectrum resources by avoiding inter-operator guard bands and additional base stations filtering.

Network synchronisation has been successfully implemented in LTE TDD networks ensuring efficient use of the spectrum resource by avoiding the need for guard bands between operators' assignments.

Similarly, inter-operator synchronisation and time alignment of uplink/downlink transmissions (slot and frame synchronisation) are also necessary for efficient deploymentof 5G-NR networks in unpaired band assignments.

Therefore, regulations should facilitate synchronised operation among TDD networks operating in adjacent frequency blocks to make the best use of the valuable spectrum resource.

Coordination with neighboring countries

Synchronized operation should be achieved within each country, and as much as possible between countries. After the alignment of TDD frame configuration between neighboring countries, the potential of interference cases is minimized in border areas.

Policy to ensure high spectrum usage

One of the government's key objectives in relation to spectrum is ensuring the efficient use of spectrum, including preventing un-utilisation or under-utilisation. In order minimize the threat of spectrum hoarding，regulatory policies are considered:

- **Spectrum license Obligations**

Many regulators have imposed obligations on licensees to provide a particular level of service coverage within a specified timeframe or included requirements to offer certain services, or quality of service.

- **Secondary spectrum mechanism**

Secondary spectrum markets allow MNOs to buy or lease spectrum from each other via commercial arrangements. This added flexibility results in a more efficient use of spectrum, since spectrum can be transferred to the actors that value it most at any given time. This gain in efficiency can have direct impact on coverage, by transferring the spectrum to actors willing make the necessary investments to make a better use of the available spectrum.[18]

"Use it or lose it" policy

The concept of 'use it or lose it' for spectrum creates a power where the regulator can specify a minimum level of use in the spectrum license. This threshold can be met by third party use through trading or leasing access to the relevant spectrum. The regulator would be able to withdraw rights of use if this minimum threshold was not met. [19]

- **Spectrum consolidations**

While initially 2300MHz spectrum is allocated to the ISPs or MNOs for WiMax in a 20 or 30 MHz spectrum block allocations, these are too small for an optimal 5G deployment and for MNOs to be deploy integrated 4G/5G networks. In addition, some spectrum owners cannot provide large-scale network construction and communication services and spectrum fragmentation also affects the investment efficiency of operators. In such scenarios, regulatory should make spectrum consolidations through spectrum recovery and reallocation or allowing spectrum trading or leasing to enable operators with large-scale network construction capabilities to have a large continuous bandwidth to improve spectrum efficiency.

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