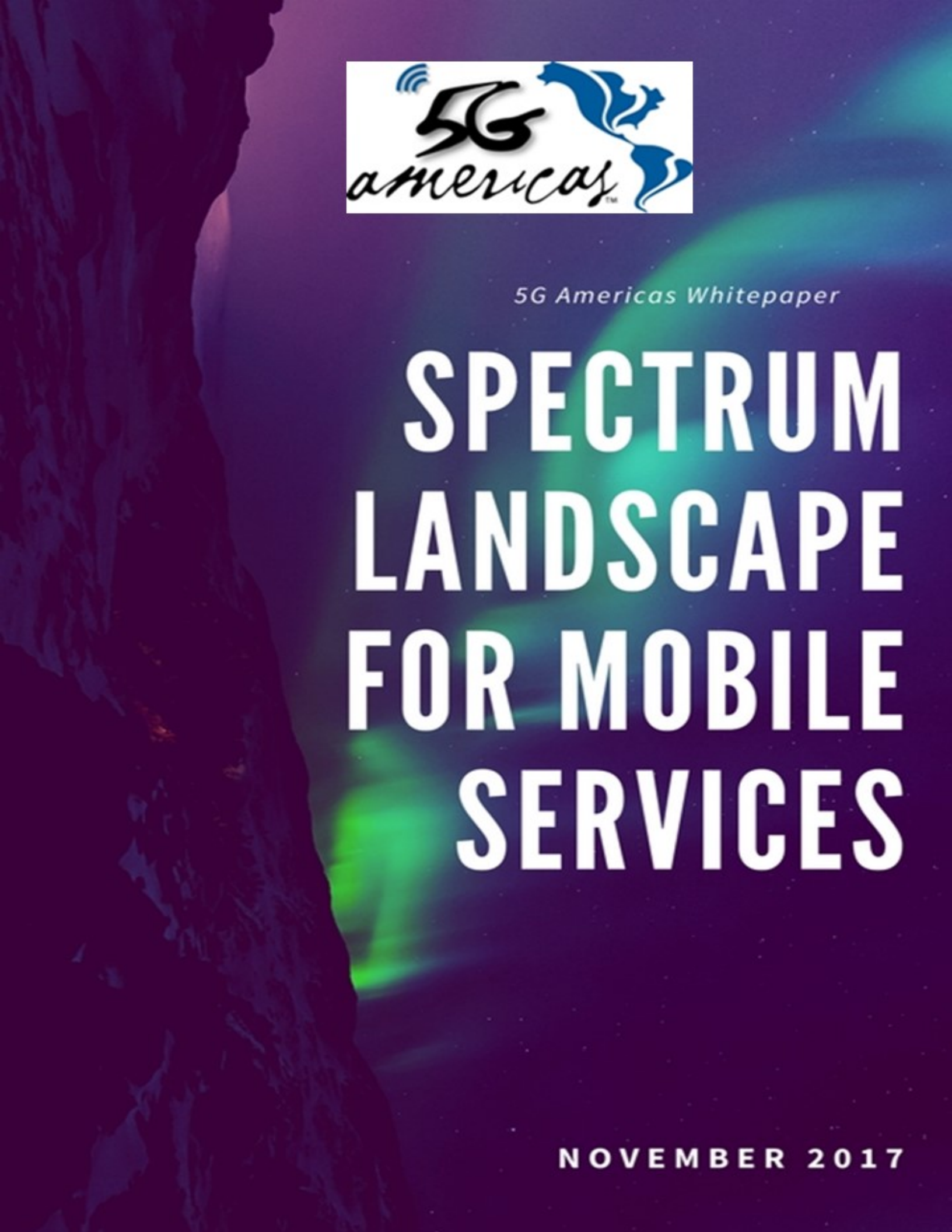

5G Americas Whitepaper

SPECTRUM LANDSCAPE FOR MOBILE SERVICES

NOVEMBER 2017

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EXECUTIVE SUMMARY

Spectrum continues to be the resource that is in the greatest demand to meet the voracious needs of a data-hungry mobile public. Exponential growth in mobile data demand, in conjunction with the spectrum needs of upcoming bandwidth-intensive applications envisioned for 5G, necessitate the availability of newly licensed spectrum pools.

This paper reviews the potential spectrum resources below and above 6 GHz and highlights the allocated licensed and unlicensed spectrum below 6 GHz. Most of this existing spectrum will not be repurposed for 5G for many years to come. Thus, it's important that other licensed spectrum bands below 6 GHz be made available for 5G applications within the next couple of years. Additionally, examination of the potential spectrum bands across all bands shows that all spectrum is suitable for 5G applications and that action is needed now to ensure that adequate spectrum resources are made available to meet the demands of connected consumers.

Furthermore, studying the bands below and above 6 GHz shows that almost all new spectrum resources that have a potential to be used for 5G services are encumbered. These spectrum resources are mainly shared spectrum that require clearing and/or development of sharing mechanisms. This leads to the need for regulators and government agencies to take immediate actions in making sure that a reasonable amount of licensed spectrum, preferably with a good chance of global harmonization, becomes available for initial 5G deployments.

1 INTRODUCTION

With the advent and popularity of the smartphone, mobile data usage has been steadily increasing year over year, a trend that's unlikely to subside anytime soon. Although technology continues to advance to improve spectrum efficiency, it won't be enough to reduce the need for additional spectrum. Ideally, most of the new spectrum should be in licensed bands, with additional unlicensed spectrum used to offload traffic from licensed bands.

With 5G targeting improvements across three fronts, enhanced mobile broadband, massive-scale connectivity, and ultra-reliable low latency service, there will be different spectrum needs than previous generations of cellular technology. The ever-growing need for use of wireless applications everywhere and the need for higher throughputs, drives the need for not only higher swaths of spectrum, but, also the spectrum that has reasonable propagation characteristic that allows wide area use. mmWave bands provide an excellent resource for large swaths of spectrum, but generally, are not considered as suitable for wide area coverage. To meet the projected data demand and requirements for all use cases cellular operators will need both breadth of spectrum assets across all these type of bands and depth of spectrum assets within bands.

Spectrum sharing is another opportunity. Incumbents that don't utilize their spectrum very often in both the temporal or geographical domain could share those channels with mobile services when the incumbent is not operating. Future spectrum should be allocated in bands where it can provide the most benefit to wireless consumers.

The paper explores the spectrum needs of 5G applications. The first section examines the growth of data usage over time, including how traffic type changes increase data consumption and affect the types of spectrum that are suitable.

The second section reviews the spectrum landscapes for mobile services below and above 6 GHz. Looking specifically at likely and possible FCC allocations for 5G, this section also examines sharing, integration and allocation issues. Further in this section, the action needed to be taken by regulatory and standards organizations is explored to make some of these spectrum possibilities a reality. The last section deals with spectrum harmonization and how the U.S. can ensure global harmonization.

From this point, 5G Americas then makes several recommendations and defines actions that need to take place for the identified spectrum to be utilized for future mobile data services.

2 SPECTRUM NEEDS OF 5G APPLICATIONS

Wireless data consumption has been exponentially increasing over the past two decades, and the trend shows no signs of leveling off anytime soon—if ever. This trend highlights how consumers and businesses depend on wireless data and in turn highlights the importance of licensed spectrum, which is the only type of spectrum that can offer a guaranteed quality level of service. For best-effort applications, unlicensed spectrum can augment the licensed spectrum in certain cases.

Starting with 3G and continuing in 4G, consumption of mobile data has been accelerating in an almost an exponential fashion. Forecasts such as Figure 2.1 predict mobile data traffic of 49 exabytes per month by 2021 and 71 exabytes per month by 2022. As Figure 2.2 shows, video applications will be the lion's share of mobile traffic.

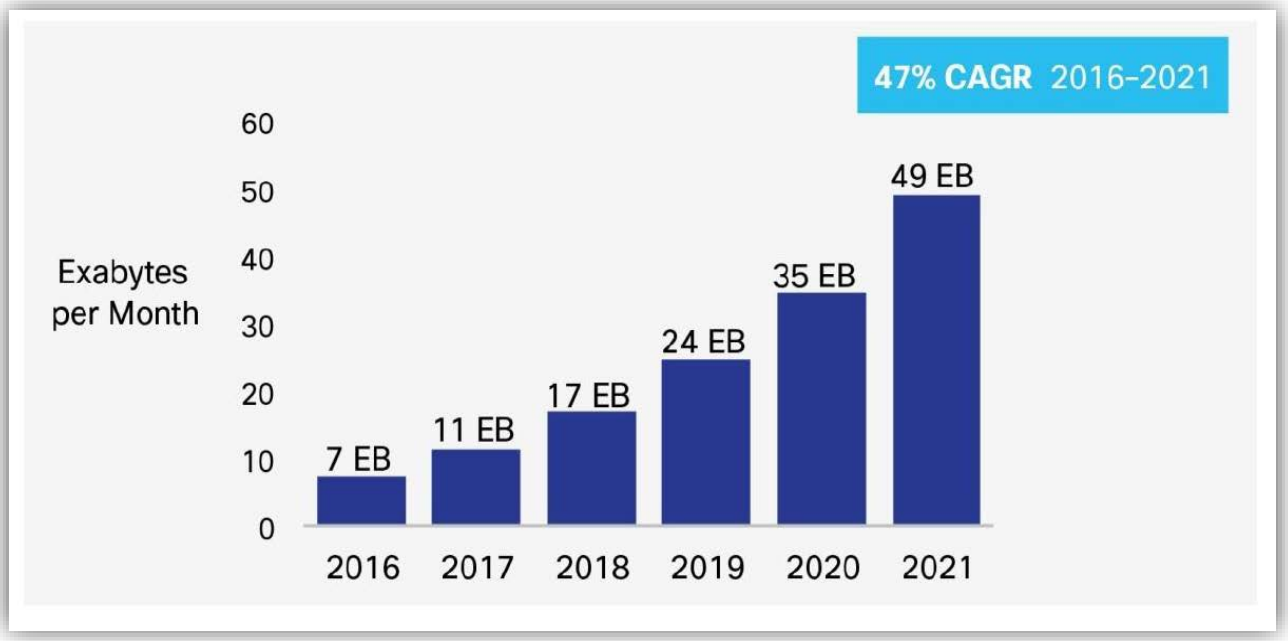

Figure 2.1: Cisco's Mobile Data Traffic Forecast.[1]

[1] Cisco VNI Mobile, 2017

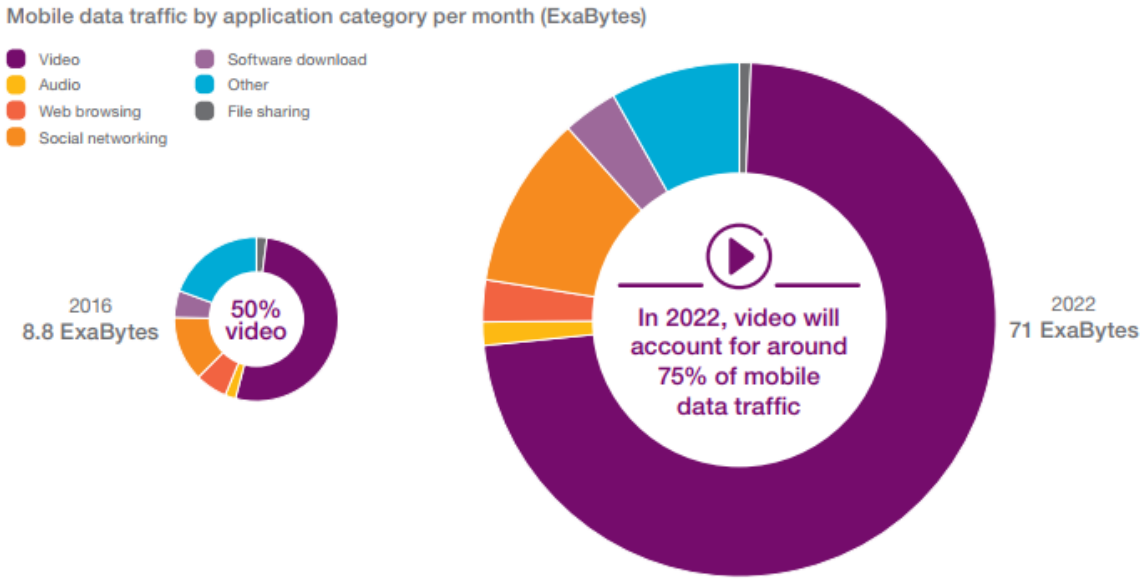

Figure 2.2: Ericsson's Mobile Data Traffic Demand Forecast.[2]

The chart effectively shows that the traffic in 2021-2022 will be about 7-8 times more than today. Additional spectrum is the only way to accommodate that demand. This amount depends on multiple factors, including application types, deployment configuration, radio access technology, spectrum efficiency, geographic location and quality of service requirements. Some of the additional spectrum needs to be at very high frequencies, which can support higher data rates, and some of it needs to be at lower frequencies, such as to ensure reliable indoor service.

ITU-R WP5D in preparation for IMT-2020 considered two approaches in estimating the spectrum needs of terrestrial component of IMT in the 24.5 GHz to 86 GHz frequency range, an application-based approach and a technical performance-based approach.

2.1 APPLICATION-BASED APPROACH

This methodology focuses on the advanced applications for IMT-2020, using a frequency range between 24.25 GHz and 86 GHz, which are mainly expected to require higher data rate than IMT-Advanced. Table 2.1 summarizes some example use cases.

[2] Ericsson Mobility Report June 2017

Table 2.1: IMT-2020 Estimated Spectrum Needs Based on the Application-based Approach for the Frequency Ranges Above 24 GHz.

Example	Tele-densities	24.25-33.4 GHz	37-52.6 GHz	66-86 GHz	Total
Example 1	Overcrowded, Dense urban and Urban areas	3.3 GHz	6.1 GHz	9.3 GHz	18.7 GHz
	Dense urban and Urban areas	2.0 GHz	3.7 GHz	5.7 GHz	11.4 GHz
Example 2	Highly crowded area	666 MHz	1.2 GHz	1.9 GHz	3.7 GHz
	Crowded area	333 MHz	608 MHz	933 MHz	1.8 GHz

METIS-II (the Mobile and wireless communications Enablers for Twenty-twenty (2020) Information Society) has expanded the frequency range of the above IMT-2020 estimates and included both below and above 6 GHz frequency ranges. The bandwidth demand of extreme mobile broadband (eMBB or xMBB) has been estimated for three use cases (UCs) described in Table 2.2. The results are illustrated in Figure 2.3. Note that the estimated bandwidth demand is dependent on many factors, such as the assumed deployment scenario, user density and spectral efficiency (SE).

Table 2.2: Deployment Assumptions and Performance Requirements Use Cases in METIS-II xMBB Bandwidth Estimation.[3]

	UC1 Dense urban information society	UC2 Virtual reality office	UC3 Broadband access everywhere
BS deployment	HetNet (macro layer with ISD of 200m and micro layer with multiple small cells per macro sector)	12 sites per floor with ISD of 20m	Macro layer with ISD of 1732m
Carrier frequency	Below 6 GHz for macro layer and above 6 GHz for micro layer	Both below and above 6 GHz	Below 6 GHz
Experienced user throughput (requirement)	DL: 300Mbps, UL: 50Mbps	DL: 1Gbps, UL: 1Gbps	DL: 50Mbps, UL: 20Mbps

[3] METIS II

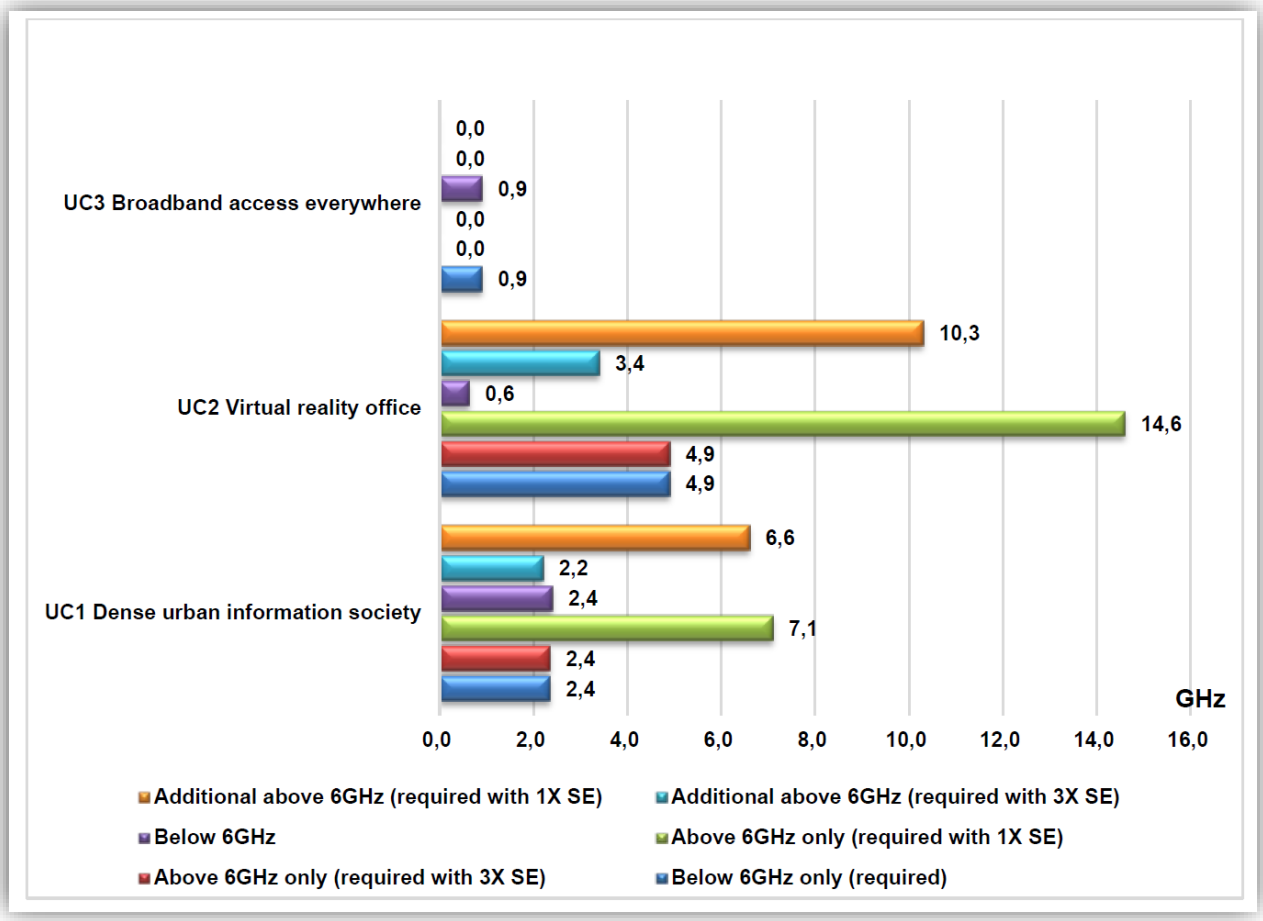

Figure 2.3: Spectrum Bandwidth Demand of METIS-II xMBB Use Cases.[4]

Other use cases, such as mMTC and URLLC, are not considered in the demand estimation shown in Figure 2.3. METIS-II does not provide a definite value of bandwidth demand for these use cases, but rather provides spectrum demand analysis for connected cars as an example of MTC, illustrated in Figure 2.4. This vehicle-to-vehicle (V2V) example shows how different assumptions affect the spectrum efficiency (EC) demand of mMTC and URLLC use cases.

[4] METIS II

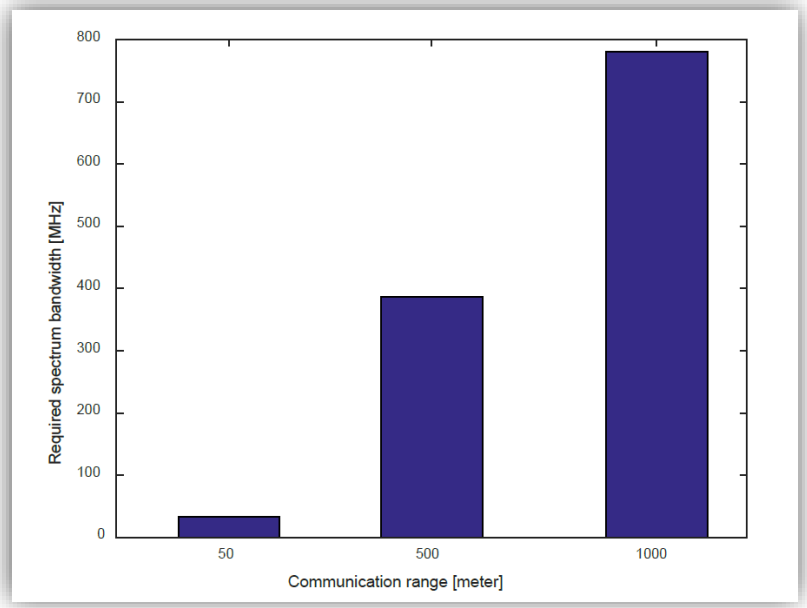

Figure 2.4: Spectrum Demand for a V2V Example MTC Use Case (METIS-II).[5]

2.2 TECHNICAL PERFORMANCE-BASED APPROACH

This methodology uses factors such as peak data rate, spectral efficiency, user experienced data rate and expected device density. In addition, usage scenarios—including their associated expected coverage area, deployment environments and target applications—introduce technical requirements and conditions on a radio system that directly or indirectly impact spectrum needs.

Using the technical performance-based approach, ITU has provided a spectrum needs estimate for frequency ranges below 6 GHz and above 24 GHz. Although the 6-24 GHz spectrum range hasn't explicitly been considered in this estimation, that swath is very much needed to supplement the spectrum below 6 GHz and provide further resource for the spectrum below 30 GHz.

The ITU has estimated the spectrum needs for the frequency ranges below 6 GHz and above 24 GHz for all the IMT-2020 deployment scenarios including into indoor hotspot, micro and macro layers in dense urban and urban macro.[6] Table 2.3 shows these deployment scenarios and their associated frequency ranges. Table 2.4 provides the spectrum needs estimates, which are based on IMT-2020 requirements for user experienced data rate, peak data rate and area traffic capacity.

[5] METIS II

[6] *Spectrum needs and characteristics for the terrestrial component of IMT in the frequency range between 24.25 GHz and 86 GHz*, ITU-R,: https://www.itu.int/md/R15-TG5.1-C-0036/en; *Spectrum requirements for IMT related to WRC-15 agenda item 1.1*, ITU-R, https://www.itu.int/md/R12-JTG4567-C-0237/en (under 6 GHz).

Table 2.3: Deployment Scenarios and Frequency Ranges Assumed in the IMT-2020 Technical Performance Approach.

Deployment scenarios	Indoor hotspot	Dense urban		Urban macro
		Micro	Macro	
Frequency range	24.25-86 GHz	24.25-43.5 GHz	<6 GHz	<6 GHz

Table 2.4: Spectrum Needs Estimate Result of IMT-2020 for Below 6 GHz and Above 24 GHz.

Deployment scenario	Macro	Micro		Indoor hotspot
Total spectrum needs for below 6 GHz	808-1078 MHz*	–	–	
Total spectrum needs for 24.25-86 GHz	–	14.8-19.7 GHz*		
Spectrum needs for 24.25-43.5 GHz	–	5.8-7.7 GHz		9-12 GHz
Spectrum needs for 45.5-86 GHz	–	–**		

* Considering the coexistence between multiple network operators (e.g. the guard band(s) may be required in the case of multiple network operator scenarios), the total spectrum needs are expected to be increased.

** The division in this table regarding frequency ranges and deployment scenarios is just an indicative example how spectrum needs could be distributed for different spectrum sub-ranges within 24.25-86 GHz and different deployment scenarios. This table should not be understood nor used to exclude any possible IMT-2020 deployment options in these sub-ranges.

2.3 SUITABLE SPECTRUM FOR 5G APPLICATIONS

To date, the most suitable spectrum has been licensed bands because they're the only spectrum capable of meeting goals such as coverage, quality of service and congestion/load balancing. The ITU-R WP 5D reviews spectrum needs for mobile services and makes recommendations to regional regulatory authorities. The ITU-R's spectrum needs estimate, shown in Table 2.4, considers frequency ranges below 6 GHz and above 24 GHz for 5G applications. The propagation characteristics of spectrum in the 24-86 GHz range are suitable for certain applications, mainly outdoor hotspot and indoor micro and pico-deployment environments. Most of the frequency ranges below 6 GHz are suitable for all deployment scenarios.

To support all 5G applications in different deployment environments, spectrum both below and above 6 GHz are necessary. Table 2.5 considers this notion and specifies the suitable spectrum ranges below 6 GHz and above 24 GHz for a variety of 5G applications. The spectrum in the 6-24 GHz range hasn't been included in Table 2.5, but that spectrum is definitely suitable for 5G

applications. The lower part of 6-24 GHz spectrum can be used in similar scenarios as the spectrum below 6 GHz, and its upper part has similar characteristics as the spectrum above 24 GHz.

Table 2.5: Spectrum Ranges Considered Suitable for 5G Applications.

Usage Scenario	High-level Requirement	Potential Spectrum-Related Implications	Spectrum Ranges Considered Suitable
Enhanced Mobile Broadband	Ultra-high-speed radio links	Ultra-wide carrier bandwidths, e.g. 500 MHz Multi-gigabit front haul/backhaul, indoor	> 24 GHz
	High speed radio links	Wide carrier bandwidths, e.g. 100 MHz Gigabit fronthaul/backhaul	3-6 GHz
	Support for low to high-Doppler environment	Depends on the throughput requirement	All ranges
	Ultra-low latency	Short range implications	3-6 GHz, > 24 GHz
	Low latency	Mid-short-range implications	3-6 GHz
	Ultra-high reliability radio links	Severe impact of rain and other atmospheric effects on link availability in higher frequencies, e.g. mm-wave, for outdoor operations	< 6 GHz
	High reliability radio links	Impact of rain and other atmospheric effects on link availability in higher frequencies, e.g. mm-wave, for outdoor operations	< 6 GHz
Ultra-reliable Communications	Short range	Higher frequencies, e.g. mm-wave	> 24 GHz

	Medium-Long range	Lower frequencies, e.g. sub-6 GHz	< 6 GHz
	Ground/obstacle penetration	Lower frequencies, e.g. sub-1 GHz	< 1.5 GHz
Massive Machine-Type Communications	Operation in cluttered environment	Diffraction dominated environment in lower frequencies Reflection dominated environment in higher frequencies	All ranges
	Operation near fast-moving obstacles	Frequency-selective fading channels	All ranges, especially below 6 GHz
	Mesh networking	High-speed distributed wireless backhauls operating in-band or out-of-band	> 24 GHz

Source: 5G America paper on spectrum recommendation, April 2017

3 SPECTRUM LANDSCAPE FOR MOBILE SERVICES

3.1 SPECTRUM BELOW 6 GHZ

Using the criteria provided in Table 2.4, this section reviews the spectrum allocations below 6 GHz for their ability to support 5G mobile services. The section focuses on allocations between 1300 MHz and 7125 MHz. The lower boundary is based upon a proposed Congressional direction to NTIA to prepare a report relating to the relocation of incumbent federal stations starting at 1300 MHz.[7] The upper boundary of the 6 GHz band is typically 7125 MHz, which is also the upper limit of 6 GHz band in FCC's mid-band Notice Of Inquiry (NOI).

The following tables discuss the spectrum landscape for mobile services below 6 GHz. Table 2-1 lists the allocations and assignments for mobile use at 1695-3700 MHz. The table briefly describes the use and sharing status, if any. It should be noted that wireless operators are currently using some the spectrum listed in this table for 4G and other broadband applications and that most of this spectrum won't be repurposed to 5G for many years to come. An exception could be the 3550-3770 MHz band, which, if the FCC adopts the changes it has proposed to the license term and scope and other conditions to encourage investment, could become a leading 5G band. It's important that other licensed spectrum below 6 GHz be made available for 5G applications within the next couple of years. 3GPP is currently defining bands for 5G and is establishing band-definition criteria and which current allocated frequencies will be defined for 5G use.

Table 3.1: Spectrum Allocated that also May Be Used for 5G.

Frequency Range (MHz)		BW	Use	Sharing Status
Low	**High**			
1695	1780	85 MHz	Pt. 27 MOBILE (AWS Uplink)	Initial transitional sharing with Federal systems while they relocate. No long-term sharing.
1850	2025	175 MHz	Pt. 27 MOBILE PCS & AWS (Downlink)	
2110	2200	100 MHz	Pt. 27 AWS (Downlink)	
2305	2310	5 MHz	Pt. 27, 97 WCS Band 2305-2320 / 2345-2360	
2310	2320	10 MHz	Pt. 27 WCS Band 2305-2320 / 2345-2360	Adjacent-band sharing with SDARS (2320-2345)
2495	2500	5 MHz	Pt. 18, 25, 27 BRS	
2500	2655	155 MHz	Pt. 27 BRS & EBS Bands Thousands of licenses in both services	
2655	2690	35 MHz	Pt. 27 BRS & EBS Bands	

[7] See AIRWAVES Act, S.1682, Aug 1, 2017

			Thousands of licenses in both services	
3550	3600	150 MHz	Pt. 96 (CBRS)	Sharing with Navy radar via Spectrum Access System
3600	3650		Pt. 25 & 96 (CBRS)	Sharing with FSS and Pt. 90 users (until 2020) via Spectrum Access System
3650	3700			

Table 3.2 shows allocations that could likely be used for 5G mobile services based upon whether the allocation is being considered for 5G, whether as part of the Spectrum Pipeline[8] (e.g., 1300-1350 MHz) or the subject of FCC interest (e.g., spectrum in the 3700 MHz-24 GHz NOI). The total bandwidth of allocations in this table is 1.65 GHz. The table shows the current sharing status and number of assignments. It also discusses actions needed to advance the allocations to 5G, which for these allocations is to essentially complete the rulemaking proceedings. Finally, the table identifies suggestions or issues integrating the allocations into the 5G spectrum pool strictly from the perspective of spectrum regulatory policy or sharing issues.

Table 3.2: Spectrum Likely to be Used for 5G.

Frequency Range (MHz)		BW	Use	Sharing Status	Necessary Actions	5G Integration Issues
Low	**High**					
1300	1350	50 MHz	Pt. 87 ASR Part of Spectrum Pipeline	TBD Likely relocation Over 360 Fed assignments Spectrum Efficient National Surveillance Radar Program (SENSR) solicitation open	Need to address sharing/relocation with existing ASR Needs MOBILE allocation Need rulemaking Time frame is ~2020	Possible pair with 1780-1830 MHz
3700	4200	500 MHz	Pt. 25 & 101 FSS & FS Band Paired with 6 lower GHz	Under study in FCC's NOI (FCC 17-183) Over 4600 licensed FSS stations	Comment on NOI and resulting NPRM More study needed on sharing methodologies and feasibility of relocation	5G use of the band will require relocation, sharing or both
5925	6425	500 MHz	Pt. 15, 25, 101 FSS & FS Band	Under study in FCC's NOI (FCC 17-183) Over 23000	Comment on NOI and resulting NPRM More study	5G use of the band will require relocation, sharing or both

[8] Id

			(Lower 6 GHz Band)	FS paths Over 1500 FSS stations	needed on sharing methodologies and feasibility of relocation	
6425	6525	100 MHz	Pt. 15, 25, 74F, 78, 101 FSS & FS Band (Upper 6 GHz Band)	Under study in FCC's NOI (FCC 17-183) Over 15000 FS paths		
6525	6700	175 MHz	Pt. 15, 25, 101 FSS & FS Band (Upper 6 GHz Band)			
6700	6875	175 MHz	Pt. 15, 25, 101 FSS & FS Band (Upper 6 GHz Band)			
6875	7025	50 MHz	Pt. 15, 25, 74F, 78 FSS & FS Band (Upper 6 GHz Band)			
7025	7075	50 MHz	Pt. 15, 74F, 78 FSS & FS Band (Upper 6 GHz Band)			
7075	7125	50 MHz				

Table 3.3 describes allocations that could be reallocated for 5G use generally based upon the following:

a. The allocation already has a mobile designation (e.g., 1390-1395 MHz)
b. The allocation is similar to other allocations that have been re-designated (e.g., 1785-1850 MHz)
c. The allocation appears to be lightly used and could provide additional spectrum to the 5G pool (e.g., 5000-5150 MHz)
d. The allocation is part of an allocation that could be used for 5G (e.g., 2360-2400 MHz)

The total bandwidth of allocations in this table is 987.5 MHz. As with Table 3.2, this table identifies the current sharing status and number of assignments where possible. The table also indicates

actions needed to advance the allocations to 5G, which for these allocations is to essentially study the applicability of reallocation and sharing issues. The table identifies suggestions or issues integrating the allocations into the 5G spectrum pool strictly from the perspective of spectrum regulatory policy or sharing issues.

Table 3.3: Spectrum for Possible 5G Use.

Frequency Range (MHz)		BW	Use	Sharing Status	Necessary Actions	5G Integration Issues
Low	**High**					
1390	1395	5 MHz	Pt. 27 TerreStar Unpaired (1390-1392) TerreStar 1392-1395 paired with 1432-1435 TerreStar working on waiver	Possible adjacent-band issues with ASR and WMTS.	Depends on waiver and ultimate licensing status. TerreStar plans to lease to WMTS users if waiver is granted. If not, they may lose licenses and bands will become available.	Total only 8 MHz Asymmetric pairing Possible application for IoT
1432	1435	3 MHz	Pt. 27 TerreStar 1432-1435 paired with 1392-1395 TerreStar working on waiver	Possible adjacent-band issues with WMTS and AMT.		
1525	1559	34 MHz	Pt. 25, 80, 87 LightSquared MSS downlink (w/ATC) Inmarsat Paired with 1626.5-1660.5	Upper end (1559 MHz) adjacent to GPS LightSquared and Inmarsat share	Work with licensees to use or with FCC to repurpose	Total of 68 MHz with paired uplink. Depends upon ultimate status of band. Sharing may be possible, but need to study. Band 24 downlink
1610	1626.5	16.5 MHz	Pt. 25, 87 Globalstar MSS downlink (w/ATC) Paired: 1610-1617.775 / 2483.5-2495		Work with licensees to use or with FCC to repurpose	Total of 33 MHz with paired uplink. Need to study.
1626.5	1660.5	34 MHz	Pt. 25, 80, 87 LightSquared MSS uplink (w/ATC) Inmarsat Paired with 1525-1559	LightSquared and Inmarsat share Adjacent to radio astronomy above 1660.5	Work with licensees to use or with FCC to repurpose as needed	Total of 68 MHz with paired uplink. Depends upon ultimate status of band. Sharing may be possible, but need to study. RA Adjacency

						may be an issue. Band 24 uplink
1670	1675	5 MHz	Pt. 25, 80, 87 Crown Castle (OP, LLC) unpaired Nationwide Federal meteorological	Shared with meteorological satellites Adjacent to radio astronomy below 1670	Work with licensees to use or with FCC to repurpose as needed	Depends upon ultimate status of band. Sharing may be possible, but need to study. RA Adjacency may be an issue.
1780	1850	70 MHz	Relocation band for Federal systems moving from 1755-1780.	CSMAC concluded sharing not possible, but could revisit.	Study again for sharing or relocation	70 MHz available, but sharing might be difficult.
2360	2400	40 MHz	Pt. 87, 95 AMT MBANS Amateur	AMT shares with MBANS (Pt. 95). Complex coexistence analyses with AMT	More study, particularly regarding sharing with AMT.	40 MHz available, but need to find band to pair. Part of Band 40 (2300-2400)
4400	4490	90 MHz	Fixed LOS & transportable -fixed PTP microwave systems, drone vehicle control and telemetry systems. Military training. Nuclear emergencies and law enforcement activities	Possible sharing, but situation similar to 1.7 GHz band with Federal equities. Over 1400 Federal assignments.	More study regarding sharing with several different Federal systems (similar to CSMAC work for AWS). Possible reallocation or reassignment or compression into portions of band(s)	580 MHz total spectrum available across 4400-4490
4500	4800	300 MHz	LOS and trans-horizon radio communications Air-to-ground operations for command and control, telemetry to relay data,	Over 2600 Federal assignments.	More study Possible reallocation or reassignment or compression into portions of band(s)	

			various range systems, video, law enforcement, drug interdiction missions and nuclear emergency response activities.			
4800	4990	190 MHz	Military at test ranges and naval ports around the US. Law enforcement, drug interdiction and radio astronomy.	Over 1400 Federal assignments.	More study Possible reallocation or reassignment or compression into portions of band(s)	
4940	4990	50 MHz	Pt. 90Y Public Safety WiFi	Over 3100 commercial and ~ 190 Fed. Assignments.	FCC rulemaking to allocate for non-PS mobile. Study relocation or sharing issues.	
5000	5010	10 MHz	Pt. 87 Microwave Landing Systems (few installed) Future GPS applications Testing use of local area networks to support air traffic on the surface of airports.	Approx. 300 Federal assignments across 5000-5250	More study on sharing with airport-based systems. Need to also analyze current spectrum assignments.	150 MHz across 5000-5150
5010	5030	20 MHz				
5030	5091	61 MHz				
5091	5150	59 MHz	Pt. 25 & 87 Microwave Landing Systems (few installed) AeroMACS Future GPS applications			

Table 3.4 describes unlicensed spectrum allocations under 6 GHz. As the chart showcases, there is a considerable amount of spectrum allocated for unlicensed use.

Table 3.4: Unlicensed Spectrum.

Frequency Range (MHz)		BW	Use	Sharing Status
Low	**High**			
2400	2450	50 MHz	Pt. 18, 97 ISM Band	
2450	2483.5	33.5 MHz	Pt. 18, 74F, 90, 101 ISM Band	
5150	5250	100 MHz	Pt. 15, 25, & 87 U-NII-1	One FCC license for WXD (high power) Several Federal applications for aviation, NASA sensors
5250	5350	100 MHz	Pt. 15 & 90 U-NII-2A	Radar 5250-5600 including high power WXD Several Federal applications for NASA (EESS) & NOAA Possible relocation band for SPN-43 radar: SPN-50 (5250-5900)
5350	5460	120 MHz	Pt. 15, 87 & 90 U-NII-2B	U-NII-2B part of rulemaking (ET 13-49) ULS shows over 130 assignments for WXD Federal uses include AMT and radar (~300 assignments)
5460	5470		Pt. 15, 80, 87 & 90 U-NII-2B	
5470	5570	255 MHz	Pt. 15, 80 & 90 U-NII-2C	ULS shows ~120 assignments for TDWR WXD (5500-5650) Federal use includes AMT, radar, radiolocation (~ 300 assignments) TDWR sharing has been problematic using DSA
5570	5650			
5570	5600			
5600	5650		Pt. 15, 80 & 90 (TDWR) U-NII-2C	
5650	5725		Pt. 15, 80 & 90 U-NII-2C	
5725	5830	125 MHz	Pt. 15, 18 & 97 U-NII-3	ULS shows assignments for aviation radar Federal use includes AMT, radar, radiolocation
5830	5850			

5850	5925	75 MHz	Pt. 15, 18, 90 (DSRC), 95, 97 U-NII-4	U-NII-4 part of rulemaking (ET 13-49) ULS shows over 70 assignments for DSRC Federal use includes AMT, radar, radiolocation

3.2 SPECTRUM FRONTIERS >6 GHZ

There has been significant progress in the U.S. toward making spectrum above 6 GHz available for 5G. These bands have traditionally been used for fixed and satellite services. The FCC has been driving this process in several steps:

- Notice of Inquiry (NOI) issued in end of 2014
- Notice of Proposed Rulemaking (NPRM) issued in end of 2015
- Report and Order (R&O) and a Further Notice of Proposed Rulemaking (FNPRM) issued in mid-2016
- Mid-band NOI issued August 2017

On July 14, 2016, the FCC adopted and released an R&O and FNPRM making spectrum in certain bands above 24 GHz available for 5G in an arrangement referred to as Upper Microwave Flexible Use Service (UMFUS). In the process, the FCC asked additional questions regarding implementation of the rules governing those bands, and proposed making additional spectrum available for 5G.

The FCC created a new Part 30 of its rules governing the 28 GHz, 39 GHz and 37 GHz bands (i.e., the UMFUS). There were several petitions for reconsideration urging the FCC to revisit some of the proposed rules under Part 30. The FCC's decisions on these petitions have not yet been made public.

Satellite operations will be secondary in the 28 GHz and 37/39 GHz bands. Existing satellite operations are grandfathered and additional limited use will be permitted in non-populous areas. The FCC imposed a hard cap of 1250 MHz in auctions and the same level as a screen in transactions. End-of-license-term performance metrics for different applications were established. The technical rules adopted were generally endorsed by the wireless industry.

The FCC also wants to make the 64-71GHz band available for unlicensed use using the same rules (Part 15) applicable to the unlicensed 57-64 GHz band. In addition, FCC is studying several other bands in 24 GHz and above. In August 2017, it issued an NOI for 3.7 GHz through 24 GHz.

3.3 CHARACTERISTICS, INCUMBENTS AND ISSUES OF EACH BAND ABOVE 6 GHZ

3.3.1 MID-BAND SPECTRUM (3.7-24 GHZ)

The FCC sought input on "potential opportunities for additional flexible access particularly for wireless broadband services in spectrum bands between 3.7 and 24 GHz (mid-band spectrum). In particular, the FCC is seeking detailed comment on three specific bands: 3.7-4.2 GHz; 5.925-6.425 GHz; and 6.425-7.125 GHz. These three bands have already garnered interest from industry stakeholders—both domestically and internationally—for expanded flexible broadband use." The FCC asked for comments on other potential bands that could allocated for exclusive non-federal use or shared federal and non-federal use.

3.3.2 3.7- 4.2 GHZ BAND

The 500 MHz of bandwidth in this band is currently allocated for non-federal use on a primary basis for Fixed Satellite Service (FSS or space-to-Earth) and Fixed Service (FS).

FIXED SATELLITE SERVICE

- Associated with the 5.925-6.425 GHz band (Earth-to-space or uplink)
- 48 satellites use this band to provide downlink signals of various bandwidths
- 4,700 registered Earth stations throughout the U.S.
- Geostationary orbit (GSO) FSS satellites typically have 24 transponders, each with a bandwidth of 36 MHz received by one or more Earth stations
- Uses include delivery of programming content to television and radio broadcasters, cable television and small master antenna systems
- Backhaul of international telephone and data traffic
- Also used for reception of telemetry signals transmitted by satellites, typically near 3.7 or 4.2 GHz
- Most of the earth stations are receive-only (RO)

FIXED SERVICE

These 20 MHz paired channels are assigned for point-to-point common carrier or private operational fixed microwave links. In 1988, there were 39,000 licenses; today, there are 119.

3.3.3 5.925 - 6.425 GHZ BAND

The 500 MHz bandwidth is currently allocated for non-Federal use on a primary basis for FSS and FS.

FIXED SATELLITE SERVICE

The FSS Earth-to-space band is associated with the 3.7-4.2 GHz band (space-to-Earth) and 1,535 earth station licenses. Most of the Earth stations operate at fixed locations, but some operate on vessels. One licensee, Higher Ground, has been granted a waiver to operate mobile devices that transmit to geostationary satellites to provide consumer-based text messaging/light email and Internet of Things (IoT). This waiver protects terrestrial operations by using a database-driven, permission-based, self-coordination authorization system. This band is also used for the transmission of command signals transmitted by Earth stations, typically near 5.925 or 6.425 GHz.

FIXED SERVICE

This service may be authorized to operate point-to-point microwave links with up to 120 MHz of paired spectrum. Paired channels may be assigned bandwidths 400 kHz to 60 MHz and there are more than 27,000 licenses.

Uses of this band include:

- Public safety (including backhaul for police and fire vehicle dispatch)
- Coordination of railroad train movements

- Control of natural gas and oil pipelines
- Regulation of electric grids
- Backhaul for commercial wireless traffic

3.3.4 6.425 – 7.125 GHZ BAND

The 700 MHz of bandwidth in this band is currently allocated for non-federal use on a primary basis for:

- FS: 6.525-7.125 GHz
- Mobile service: 6.425-6.525 GHz and 6.875-7.125 GHz
- FSS UL: 6.425-6.700 GHz and 7.025-7.075 GHz
- FSS UL & DL: 6.700-7.025 GHz

FIXED SATELLITE SERVICE

- FSS operations in the 6.425-7.125 GHz band (Earth-to-space) are less intensive than in the 5.925-6.425 GHz band.
- Currently, there are about 65 FSS earth station licenses in the 6.425-7.075 GHz band. One foreign licensed FSS space station is authorized the Earth-to-space direction in the 6.725-7.025 GHz band.
- In the 6.615-6.687 GHz band, only feeder links for one radio-navigation satellite are currently authorized.
- FSS operations in the 6.700-7.075 GHz band (space-to-Earth) are limited by rule to feeder links for NGSO MSS in the space-to-Earth direction. In the 7.025-7.075 GHz band, such operations are further limited to two grandfathered satellite systems.

FIXED SERVICE

- FS licensees in the 6.525-6.875 GHz and 6.875-7.125 GHz bands may be authorized to operate point-to-point microwave links on paired channels assigned in specified bandwidths ranging from, respectively, 400 kHz to 30 MHz and 5 MHz to 25 MHz.
- Fixed BAS operations are also authorized in these bands.
    - Approximately 18,000 and 4900 licenses have been issued for point-to-point operations, respectively, in the 6.525-6.875 GHz and 6.875-7.125 GHz bands.

The FCC's Spectrum Frontiers R&O addressed the following bands:

28 GHZ BAND (27.5-28.35 GHZ)

This band is currently licensed for Local Multipoint Distribution Service (LMDS) operations. Existing licensees will receive two 425 MHz authorizations on a county basis in exchange for their current 850 MHz licenses issued on a basic trading area (BTA) basis. The FCC permits existing LMDS licensees to exercise the full extent of their rights—including mobile rights—for geographic areas and bands in which they currently hold licenses. Remaining spectrum will be auctioned.

There is no primary federal allocation.

There is also a FSS Earth-to-space allocation, but FSS is secondary to LMDS in that band. FSS is also secondary to the UMFUS in the 27.5-28.35 GHz band. The FCC concluded that the satellite industry has not shown that it has a legal right to protection from aggregate interference or that harmful aggregate interference is likely to occur from the mobile operations. Notwithstanding that secondary status, an earth station in the 27.5-28.35 GHz band that meets one of the criteria listed below may operate consistent with the terms of its authorization without providing any additional interference protection to stations in the UMFUS:

> (1) The FSS licensee also holds the relevant Upper Microwave Flexible Use Service license(s) for the area in which the earth station generates a Power Flux Density (PFD), at 10 meters above ground level, of greater than or equal to -77.6 dBm/m^2/MHz
>
> (2) The FSS earth station was authorized prior to July 14, 2016 or
>
> (3) The application for the FSS earth station was filed prior to July 14, 2016 and has been subsequently granted or
>
> (4) The applicant demonstrates compliance with all of the following criteria in its application:
>
> > (i) There are no more than two other authorized earth stations operating in the 27.5-28.35 GHz band within the county where the proposed earth station is located that meet the criteria contained in either paragraphs (a)(1), (2), (3), or (4) of this section. For purposes of this requirement, multiple earth stations that are collocated with or at a location contiguous to each other shall be considered as one earth station.
> >
> > (ii) The area in which the earth station generates a PFD, at 10 meters above ground level, of greater than or equal to -77.6 dBm/m^2/MHz, together with the similar area of any other earth station authorized pursuant to section (a) of this rule, does not cover, in the aggregate, more than 0.1 percent of the population of the county within which the earth station is located.
> >
> > (iii) The area in which the earth station generates a PFD, at 10 meters above ground level, of greater than or equal to -77.6 dBm/m^2/MHz does not contain any major event venue, arterial street, interstate or U.S. highway, urban mass transit route, passenger railroad or cruise ship port and
> >
> > (iv) The applicant has successfully completed frequency coordination with the UMFUS licensees within the area in which the earth station generates a PFD, at 10 meters above ground level, of greater than or equal to -77.6 dBm/m^2/MHz with respect to existing facilities constructed and in operation by the UMFUS licensee. In coordinating with UMFUS licensees, the applicant shall use the applicable processes contained in § 101.103(d) of this part.

3.3.6 39 GHZ BAND (38.6-40 GHZ)

The band is currently licensed for fixed microwave (point-to-point and point-to-multipoint operations). Existing licensees will be permitted to repack the band to create 200 MHz-wide channels (rather than the current 50 + 50 MHz channels). Licenses will be re-issued on a Partial Economic Area (PEA) basis. Remaining spectrum will be auctioned. Just like the 28 GHz band, the FCC proposed allowing existing 39 GHz licensees to exercise the full extent of their rights—including mobile rights—for geographic areas and bands in which they currently hold licenses.

The 39.5-40 GHz portion of the 39 GHz band is allocated to the federal FSS and MSS a primary basis, limited to Space-to-Earth (downlink) operations. The FCC concluded that it is possible for federal operations to share the band with non-federal fixed and mobile terrestrial operations because the protections offered by footnote US382 are sufficient to protect both federal and non-federal operations in this band.

The U.S. Table of Frequency Allocations also accords co-primary status to FSS Earth stations in the 37.5-40 GHz frequencies. But the FCC rules provide that gateway earth stations in the 39 GHz band may be deployed only if the FSS licensee obtains a 39 GHz license for the area where the earth station will be located, or if it enters into an agreement with the corresponding 39 GHz licensee.

3.3.7 37 GHZ BAND (37-38.6 GHZ)

The 37 GHz band presents a number of opportunities because, other than a limited number of existing federal uses that need protection, the band is a greenfield: There are no existing non-federal operations, terrestrial or mobile. In addition, it is adjacent to the 39 GHz band, which presents an opportunity to create a larger, contiguous 37/39 GHz band, subject to similar technical and operational rules. Also, the federal fixed and mobile service allocations are lightly used. There are no current non-federal terrestrial operations in the band.

The 37-38.6 GHz band is also allocated for primary federal use. The FCC has proposed a series of measures in the R&O to enable coexistence between federal and non-federal operations. The FCC also proposed several measures to protect Earth Exploration-Satellite Service (passive) and Space Research Service (passive) in the 36-37 GHz band.

The FCC is considering making the lower segment (37-37.6 GHz) available on a shared basis between federal and non-federal users. The FCC wants non-federal users, which FCC identifies as Shared Access Licensees (SAL), to be authorized by rule. Under this framework, federal and non-federal users will access the band through a coordination mechanism, including exploration of potential dynamic sharing through technology in the lower 600 MHz, which will be more fully developed through the FNPRM and through government/industry collaboration.

The upper segment (37.6-38.6 GHz) will be auctioned in 200 MHz blocks on a PEA basis, which is consistent with the licenses in the 39 GHz band.

The FCC also has an operability requirement for devices operating in either the 37 GHz or 39 GHz band to be capable of operating across the entirety of both bands, from 37 GHz to 40 GHz (including the 37-37.6 MHz lower block). Several petitions asked the FCC to reconsider and/or clarify this operability requirement since the upper segment of the 37/39 GHz band (37.6-40 GHz) will almost certainly be available for use before a licensing and/or sharing regime is adopted for the 37 GHz lower band segment (37-37.6 GHz).

3.3.8 64-71 GHZ BAND

There are no licensed operations in 64-71 GHz. Frequencies from 64-71GHz are not among those listed in the FCC's rules as available for licenses issued in the terrestrial fixed service or for any satellite services except for inter-satellite service (ISS), but there are no current ISS licenses. There are currently no active satellite licenses in that band.

The FCC wants to make the band available for unlicensed use using the same rules (Part 15) applicable to the unlicensed 57-64 GHz band. However, several petitions have asked the FCC to reconsider allocating the entire 64-71 GHz band to unlicensed operations.

In the Further Notice issued at the same time as the Report and Order, the FCC sought comment on the following:

- Use of additional millimeter wave bands, and under what conditions
- How the lower segment of the 37 GHz band should be shared between federal and non-federal users (as well as other questions regarding operations in that band)
- Proposed shared use of the upper segment of the 37 GHz band, either by federal users, or under a use-it-or-share-it approach
- Whether there should be additional performance metrics to qualify for renewal (including the possibility of imposing use-it-or-share-it throughout the millimeter wave bands)
- Implementation of the spectrum aggregation limits at auction, how to apply them to new millimeter wave bands, and holding periods for auctioned licenses
- Potential increase in PFD limits for satellite operations in the 39 GHz band and permitting satellite user equipment in the band
- Digital station identification

Technical issues such as permitted antenna heights, smaller authorized bandwidths for certain devices, coordination criteria at market borders for fixed operations and appropriate sharing analysis and modeling.

Table 3.5 summarizes information about the additional bands included for further comments in the FCC's FNPRM on Spectrum Frontiers.

Table 3.5: Summary of Proposals in FCC's FNPRM on Spectrum Frontiers.

24 GHz Bands (24.25-24.45 GHz and 24.75-25.25 GHz)	• Adding a mobile allocation to the 24.25-24.45 and 24.75-25.25 GHz segments of the 24 GHz band and a fixed allocation to 24.75-25.05 GHz • Authorizing both mobile and fixed operations in those segments on a co-primary basis under the Part 30 UMFUS rules • Licensing the 24.25-24.45 GHz band segment as a single, unpaired block of 200 megahertz, and the 24.75-25.25 GHz band segment as two unpaired blocks of 250 megahertz each • Promoting effective sharing between satellite and mobile uses

32 GHz Band (31.8-33.4 GHz)	• Adding primary non-federal fixed and mobile service allocations to the 32 GHz band, and authorizing fixed and mobile allocations there under the Part 30 UMFUS rules • Licensing the band using either 200- or 400-megahertz wide channels • protecting radio navigation operations in the 32 GHz band; and protecting radio astronomy observations in the adjacent 31.3-31.8 GHz band
42 GHz Band (42-42.5 GHz)	• Authorizing fixed and mobile service to operate in the 42 GHz band under the Part 30 UMFUS rules, as long as adjacent-channel RAS services are protected • Geographic area licensing using PEAs as the geographic area • Denying the Fixed Wireless Communications Coalition ("FWCC")'s request for establishing point-to-point-only rules for fixed service in the band, but keeping FWCC's request pending for the 42.5-43.5 GHz band. • Establishing protections for RAS observations (e.g., special OOBE limits or a guard band) in the 42.5-43.5 GHz band • Appropriate band plan for the 42 GHz band • Adding federal fixed and mobile allocations into the band • Establishing a framework under which federal and non-federal users could share the band (potentially on a co-primary basis)
47 GHz Band (47.2-50.2 GHz)	• Authorizing fixed and mobile operations in the 47 GHz band under the Part 30 UMFUS rules • Adopting the sharing framework adopted for the 28 GHz band • The best approach for sharing between FSS user equipment and terrestrial operations • Sharing with co-primary federal services in the 48.2-50.2 GHz band • Protection of passive services in the adjacent 50.2-50.4 GHz band. • Appropriate band plan for the 47 GHz band and notes, as a possibility, dividing the band into six channels of 500 megahertz each
50 GHz Band (50.4-52.6 GHz)	• Authorizing fixed and mobile operations in the 50 GHz band under the Part 30 UMFUS rules • Using geographic area licensing on a PEA basis. • Non-federal satellite allocations in the 50.4-51.4 GHz band • Sharing between terrestrial and satellite operations • Sharing with co-primary federal services in the 50.4-52.6 GHz band • Protecting passive services in the adjacent 50.2-50.4 GHz and 52.6-54.25 GHz bands • Appropriate band plan for the 50 GHz band and notes, as a possibility, establishing ten channels of 200 megahertz each, consistent with the 39 GHz band

70/80 GHz Bands (71-76 GHz and 81-86 GHz)	• Establishing a Spectrum Access System ("SAS")-based regulatory framework under either the Part 96 CBRS rules or the new Part 30 UMFUS rules • Protecting mechanism for existing 70/80 GHz licensees • Appropriate means for protection of federal incumbents • Feasibility of authorizing Part 15 unlicensed, indoor-only operations • Establishing a separate regulatory framework for the 16 counties already heavily registered with incumbent users
Bands above 95 GHz	• Most attractive parts of the spectrum from the standpoint of technology development and successful coexistence with existing services • Licensed or unlicensed use • Appropriate technical rules • Permitting mobile and fixed service

Commenters generally applauded the FCC for considering more bands in addition to the R&O bands for 5G services. Some commenters, including 5G Americas, asked the FCC to also consider bands that WRC-15 agreed to study over the current cycle and that are not among the FNPRM bands.

5G Americas also urged the FCC to adopt the following:

- Repurpose all of the FNPRM bands for flexible use, and do so on a solely licensed basis
- A SAS approach is not appropriate for the millimeter wave bands under consideration
- Reject Use or Share (UoS) in the Upper Band Segment (UBS) of 37.6-38.6 GHz
- The 70/80 GHz bands should be considered for flexible licensed use, including mobile
- Co-equal federal and non-federal users should meet the same technical requirements and use a common coordination framework
- The FCC's early adoption of secondary market rules provides sufficient incentives for efficient use of spectrum

With respect to the question of potential increase in PFD limits for satellite operations in the 39 GHz band and permitting satellite user equipment, the mobile industry generally rejected such considerations.

4 NECESSARY ACTIONS: REGULATORY, STANDARDS, INDUSTRY, ETC.

5G has the potential to change the way we live, work and play. Mobile wireless technology could be considered just as important as other societal services like electricity, roads, sewers and water. However, there is much to be done to continue the great progress of 4G technology advancements as the industry moves toward the 5G era.

4.1 EQUIPMENT AUTHORIZATION

The FCC's Office of Engineering and Technology (OET) was delegated authority to administer the equipment authorization program for RF devices under Part 2 of its rules. All RF devices subject to equipment authorization must comply with the FCC's rules prior to importation or marketing by being tested for compliance with the applicable technical requirements. This process uses measurement procedures that either follow guidance issued by OET through its Knowledge Database (KDB) publications or that have been found to be acceptable to the FCC in accordance with Section 2.947 of the rules.

The FCC recognized that there are some unique technical challenges specific to demonstrating compliance for the purpose of equipment authorization of millimeter wave devices. For example, certain parties oppose using effective isotropic radiated power (EIRP) as the metric for measuring out-of-band emission limits, proposing instead a different metric using total radiated power (TRP), claiming consistency with recent academic research for multiple input, multiple output (MIMO) antenna arrays. However, TRP is not presently part of the FCC's measurement procedure guidance for devices using MIMO antennas. The FCC OET is working with interested parties to develop acceptable measurement techniques for millimeter wave devices through its KDB publications as products are developed.

RF exposure compliance is an ongoing requirement for all transmitters authorized by the FCC. Specific guidance on evaluating devices operating in this service will similarly be issued by OET.

4.2 3GPP SPECIFICATIONS

The FCC's licensed frequency bands in the R&O are part of the bands being specified in 3GPP:

- 26.5-29.5 GHz covering the U.S. 28GHz band
- 37-43.5 GHz covering the U.S. 37/39GHz bands

3GPP also has a study item on 5G in unlicensed bands below and above 6 GHz. Unlicensed bands above 52.6 GHz covering the FCC's 64-71 GHz swath will be considered to the extent that waveform design principles remain unchanged with respect to below 52.6 GHz bands. This study item is a lower priority than the work on licensed spectrum.

5 INTERNATIONAL SPECTRUM HARMONIZATION

Globally harmonized spectrum remains integral to the continued growth of the mobile industry and should be the touchstone for selecting spectrum for IMT-2020 (5G).[9] That's because globally harmonized spectrum allocations result in a broader ecosystem for technology, equipment and engineering expertise. This in turn enables economies of scale, lower costs for deployment, more rapid roll-out of new services and enhanced competition among suppliers to the global markets.

5G networks are expected to operate over a wide range of licensed and unlicensed frequencies in low, medium and high spectrum bands, but those frequencies have yet to be specifically defined by 3GPP. It can be assumed that most of the bands currently being used for 4G networks will be reallocated in time to 5G technologies. Meanwhile, activity around the world has already begun to explore a number of bands both in the context of bands between 24.25 GHz and 86 GHz that are being studied for the 2019 World Radiocommunication Conference (WRC) Agenda Item 1.13 and on bands not included in the WRC agenda item.

6 5G SPECTRUM ACROSS DIFFERENT REGIONS

Different bands may be optimized for particular uses, depending on their varying technical characteristics, the details of national or regional spectrum usage, and competing demands for spectrum. For example, no single band will provide a complete solution for 5G requirements, given the diversity of future applications and their requirements for wider bandwidth, reduced latency and extended coverage area. Because licensed spectrum is able to consistently be used in such a way to guarantee a level of service, it will remain the best possible optimized spectrum solution. To that end, there are significant on-going global activities to identify and trial suitable spectrum for 5G. The bands being consider are both part of the frequencies considered under Agenda Item 1.13, but also include bands that are not part of the agenda item.

The following sections highlight efforts to identify and allocate spectrum for 5G, primarily mid-band and high-band efforts, globally. The list of regulatory activity in the following regions is not exhaustive but provides informative data examples on the status of spectrum considerations in certain regions.

6.1 REGION 1

6.1.1 FRANCE

France (ARCEP) announced plans to allocate spectrum for 5G by the September 2017 timeframe in the 3400-3800 MHz range. The plan is to establish band plan allocations of more than 300 MHz of contiguous spectrum by 2020. Additional reorganization is planned to extend the amount of spectrum to 340 MHz by year 2026.[10]

[9] The ITU program to develop international mobile telecommunications systems for 2020 and beyond is known as "IMT-2020." See ITU-R Working Party 5D, *ITU Towards "IMT for 2020 and beyond,"* http://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2020/Pages/default.aspx.

[10] *France to allocate 5G spectrum in September*, Nick Wood, Total Telecom. 26 June 17. https://www.totaltele.com/497381/France-to-allocate-5G-spectrum-in-September

6.1.2 GERMANY

Germany's federal network regulator Bundesnetzagentur published a framework document on June 28, 2017, with plans for 5G spectrum.[11] In 2018, the 3400-3700 MHz band will be awarded as national licenses in 10MHz blocks. The 3700-3800 MHz band will be awarded at a later stage depending on demand for local/regional licenses. The regulator also announced plans to develop an application procedure to allow access to the 26 GHz (24.25 GHz-27.5 GHz) band for 5G. Other millimeter wave bands may be considered over time.

6.1.3 IRELAND

Ireland completed its 5G auction in the 3.6 GHz band, which included 350 MHz in the 3475-3800 MHz band.[12] Three Ireland CEO Robert Finnegan stated that the company wanted to acquire the optimum bandwidth for 5G of 100 MHz in the auction, in a band that was internationally recognized as capable to support 5G use cases below 6 GHz.[13]

6.1.4 UNITED KINGDOM

The United Kingdom's Ofcom is taking a leading role internationally in identifying spectrum bands for 5G and has published a report on 5G Spectrum in the UK."[14] Ofcom has already begun the role of identification and allocation of spectrum for 5G. In the mid-band, Ofcom has taken action in the 3.4-3.6 GHz band, where 150 MHz is ready for auction later this year.

Ofcom also released a consultation in October 2016 proposing to repurpose 116 MHz in the 3.6-3.8 GHz band. A further consultation on this topic is planned for later this year. In the millimeter wave band, Ofcom has said that it fully supports the identification of the 26 GHz band by Radio Spectrum Policy Group and has started efforts to determine what actions are necessary to make this spectrum available for 5G.[15]

6.1.5 THE RADIO SPECTRUM POLICY GROUP

The Radio Spectrum Policy Group (RSPG) is a high-level advisory group that assists the European Commission in the development of radio spectrum policy.[16] The RSPG developed an opinion on spectrum bands for next generation wireless systems (5G) as agreed to in the RSPG Work Programme for 2016. The opinion[17] was finalized November 2016 and identified a strategic roadmap for 5G in Europe. In particular, the roadmap identified the following main building blocks for 5G spectrum:

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[11] *Germany unveils 5G spectrum framework, plans auction in 2018*. Telecompaper. 29 June 2017. http://gtigroup.org/news/ind/2017-06-29/10751.html

[12] *Irish 5G spectrum auction raises €78m*, Nick Wood, Total Telecom, 25 May 17. https://www.totaltele.com/497141/Irish-5G-spectrum-auction-raises-78m

[13] *Five firms win Ireland's first 5G licenses in €78m auction*, John Kennedy, 22 May 2017. https://www.siliconrepublic.com/comms/5g-auctions-ireland

[14] https://www.ofcom.org.uk/__data/assets/pdf_file/0021/97023/5G-update-08022017.pdf

[15] *Ofcom updates 5G spectrum plans,* TeleGeography, 9 Feb 2017. https://www.telegeography.com/products/commsupdate/articles/2017/02/09/ofcom-updates-5g-spectrum-plans/

[16] http://rspg-spectrum.eu/

[17] *Opinion on spectrum related aspects for next-generation wireless systems (5G)* http://rspg-spectrum.eu/wp-content/uploads/2013/05/RPSG16-032-Opinion_5G.pdf

- Medium bandwidth spectrum at 3.4-3.8 GHz as a “primary” band, which will provide capacity for new 5G services

  High-bandwidth spectrum at 24.25-27.5 GHz as the “pioneer” millimeter wave band to give ultra-high capacity for innovative new services, enabling new business models and sectors of the economy to benefit from 5G.

6.2 REGION 2

6.2.1 U.S.

The FCC finalized its rules on July 14, 2016, allowing access to spectrum for next generation (5G) wireless broadband in the 28 GHz (27.5-28.35 GHz), 37 GHz (37-38.6 GHz) and 39 GHz (38.6-40 GHz) bands, as well as an unlicensed band at 64-71 GHz. The new rules make available almost 11 GHz of spectrum consisting of 3.85 GHz of licensed spectrum and 7 GHz of unlicensed spectrum.

The FCC also issued a further public consultation seeking comment on an additional 18 GHz of spectrum for next-generation services.[18] Different use cases require access to spectrum in different frequency bands including low, mid and high-spectrum bands. Mid-band spectrum frequencies offer a unique balance of coverage and capacity. The FCC released a R&O defining its technical and service rules for the creation of the Citizens Broadband Radio Service (CBRS) on March 27, 2015, a shared spectrum scheme dividing up 150 MHz in the 3.5 GHz band. Within the order, the band 3550-3700 MHz would be governed under a three-tier system. All tiers would be controlled by the Spectrum Access System (SAS), a cloud-based frequency coordinator.[19] Additionally, the FCC is seeking public comment on expanding access in three specific mid-band spectrum bands: 3.7-4.2 GHz for possible mobile broadband use and 5.925-6.425 GHz and 6.425-7.125 GHz for more flexible use. The FCC also asks whether there are other bands that would be suitable in the range 3.7 GHz to 24 GHz.[20]

6.2.2 CANADA

Innovation, Science and Economic Development Canada (ISED) issued a consultation for spectrum in the 28 GHz, 37-40 GHz and 64-71 GHz frequency bands to support 5G deployments. Comments were due September 15, 2017.[21]

6.3 REGION 3

6.3.1 CHINA

[18] *Rules to Facilitate Next Generation Wireless Technologies,* FCC, https://www.fcc.gov/document/rules-facilitate-next-generation-wireless-technologies

[19] *FCC Releases Order for Spectrum Sharing in 3.5 GHz Band*, Ben Munson, Wireless Week. 27 March 2015. https://www.wirelessweek.com/news/2015/03/fcc-releases-order-spectrum-sharing-35-ghz-band

[20] cite

[21] *Consultation on Releasing Millimetre Wave Spectrum to Support 5G*, June 2017. http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11298.html

In July 2017, China's Ministry of Industry and Information Technology approved the 4.8-5.0 GHz, 24.75-27.5 GHz and 37-42.5 GHz bands for China's 5G technology research and development testing.[22] This action follows MIIT approval of the frequency band 3.4-3.6 GHz in January of 2016, which is to be used for 5G trial in both Beijing and Shenzhen. These tests are meant to verify the various aspects of the 5G technologies and provide a foundation to facilitate early ecosystem development. In June 2017, the Ministry of Industry and Information Technology Radio Administration expanded the frequency range to 3.3-3.6 GHz, with 3.3-3.4 GHz limited to indoor use and 4.8-5.0 GHz. It also issued a public consultation to seek comments on the spectrum use for 5G.[23]

6.3.2 JAPAN

No decisions have been taken in Japan. However, the analysis of potential frequency bands nevertheless indicates that the frequency ranges which currently have priority for 5G in the millimeter wave bands are 24.25-29.5 GHz, 37.0-40 GHz and 40.5-43.5 GHz, with 27.5-29.5 GHz receiving priority attention. In mid-band spectrum, Japan is currently considering 3.6-4.2 GHz and 4.4-4.9 GHz for 5G.[24] Japan also has already allocated spectrum in the 3.5 GHz band.[25] After summer 2017, its Ministry of Internal Affairs and Communications plans to identify which bands will be available for 5G initial deployment and when that will happen for mobile broadband.

6.3.3 SOUTH KOREA

South Korea plans to launch a 5G network at the 2018 Winter Olympics, which will be held in Pyeongchang in February 2018. In a press release, SK Telecom announced in June 2017 that it has successfully demonstrated 5G communications using the 3.5 GHz band.[26] SKT plans to use both the 3.5 GHz and 28 GHz bands for 5G network rollouts. A national broadband plan was published early 2017 and indicates 3.4-3.7 GHz and 27.5-28.5 GHz, with the latter possibly to be extended by up to 2 GHz to give a total of 3 GHz, 26.5 – 29.5 GHz. There is an interest in more spectrum for 5G in the longer term, though not decided which frequency band.[27]

6.3.4 AUSTRALIA

In February 2016, the Australian Communications and Media released the occasional paper *5G and Mobile network developments—Emerging issues.*[28] It recognized that supporting international harmonization played a critical role in leveraging the economies of scale achieved and the resulting benefits for Australia arising from lower device costs. The Australian Communications and Media Authority also issued a discussion paper seeking comment on whether and how to proceed with making the 3575-3700 MHz band

[22] *Ministry of Industry and Information Technology approved the new 5G technology test frequency*, Radio Authority. 14 July 2017. http://www.miit.gov.cn/n1146285/n1146352/n3054355/n3057735/n3057743/c5730476/content.html?from=groupmessage&isappinstalled=0

[23] *China issues plan to use 3300-3600 MHz, 4800-5000 MHz for 5G*, Monica Alleven, Wireless Week. 7 June 2017. http://www.fiercewireless.com/wireless/china-issues-plan-to-use-3300-3600-mhz-4800-5000-mhz-for-5g

[24] *Japan's Radio Policy to realize 5G in 2020*, Presentation by Kuniko Ogawa, Director for Land Mobile Communications Division, Ministry of Internal Affairs and Communications. June 28, 2016. https://www.gsma.com/spectrum/wp-content/uploads/2016/08/MIC_Spectrum-for-5G-MIC-Kuniko-OGAWA.pdf

[25] http://www.gtigroup.org/news/ind/2014-12-25/5208.html

[26] *SK Telecom demos 5G trial network using 3.5Hz spectrum.* 29 June 2017. https://www.telegeography.com/products/commsupdate/articles/2017/06/29/sk-telecom-demos-5g-trial-network-using-3-5hz-spectrum/

[27] *K-ICT Spectrum Plan,* Ministry of Science, ICT and Future Planning(MSIP) of Korea, January 2017. http://blog.naver.com/with_msip/220917986508

[28] http://www.acma.gov.au/theACMA/5g-and-mobile-network-developments

(ACMA also is interested in examining spectrum from 3400-3700 MHz) available for mobile broadband services.[29]

7 OPPORTUNITIES FOR HARMONIZATION

The benefits of global harmonization are not limited to situations where all regions have identical spectrum allocations. These benefits can also be derived from "tuning range" solutions, in which adjacent or nearly adjacent bands can be considered harmonized so long as equipment can be reconfigured to operate over multiple bands. In other words, they are within the same "tuning range."[30] Such operational flexibility may sometimes involve radio equipment that operates across a superset of band allocations over several regulatory jurisdictions. It may also entail using specific hardware configurations that are tailored for one or more markets. In considering spectrum allocations, therefore, policymakers should consider not only frequencies that can be allocated domestically, but also the possibilities provided by such global tuning range solutions.

Based on early 5G strategic plans detailed in the previous section, there are several immediate possibilities for global harmonization, considering the "tuning range" for bands 3.3-4.2 GHz, 24.25-29.5 GHz and 37-43.5 GHz. Specifically, 3GPP has included 24.25-29.5 GHz in its 5G Non-Standalone NR that will be part of its Release 15 to enable large-scale trials and commercial 5G deployments as early as 2019. This 3GPP 5G NR is expected to cover the spectrum blocks 27.5-28.35 GHz (U.S., Japan, Sweden, Estonia), 26.5-29.5 GHz (Korea) and 24.25-27.5 GHz (EU, China). These are considered for potential 5G deployments by different administrations around the world, enabling a larger 5G ecosystem to facilitate service adoption, roaming and achieve greater economies of scales.

8 NECESSARY ACTIONS

Since 5G is targeting improvements across three fronts, enhanced mobile broadband, massive-scale connectivity, and ultra-reliable low latency service, there are different spectrum requirements than previous generations of cellular technology. To meet the new and emerging use cases it will most likely be best to utilize a portfolio of spectrum assets consisting of low-band, mid-band, and mm-Wave spectrum.

It is envisioned that low-band spectrum, with its propagation and penetration characteristics, could be used to provide inbuilding coverage in urban areas and wide-area coverage in more rural areas. Mid-band spectrum could be utilized for capacity and high speed in both urban and suburban zones. The large bandwidths available in the mmWave bands can achieve high data throughput speeds but the somewhat limited propagation distances and penetration at these higher frequencies could possibly confine usage to more concentrated areas. It is therefore important that regulators take actions to ensure adequate spectrum resources are available in all bands and allocate adequate bandwidth to support the varied use cases of 5G.

[29] *Future use of 1.5 GHz and 3.6 GHz bands*, Australian Communications And Media Authority. October 2016. http://www.acma.gov.au/theACMA/future-use-of-the-1_5-ghz-and-3_6-ghz-bands

[30] The "tuning range" concept emerged from a pan-European plan for temporary terrestrial audio and video links for electronic news gathering, remote broadcasting, and similar applications. Under this approach, a designated "tuning range" represented a range of frequencies over which radio equipment was envisaged to be capable of operating, and within this tuning range the equipment would be limited to the subset of frequencies identified nationally within a given country for those purposes. *See* Electronic Communications Committee, European Conference of Postal and Telecommunications Administrations ("ECC/CEPT"), *Frequency Ranges for the Use of Temporary Terrestrial Audio and Video SAP/SAB Links (Incl. ENG/OB)*, ERC/REC 25-10 (Feb. 2003),http://www.ecodocdb.dk/doks/filedownload.aspx?fileid=1665&fileurl=http://www.erodocdb.dk/Docs/doc98/official/Word/REC2510E.DOC .

Additional studies may be necessary to determine the practical extent of a particular tuning range, especially when considering additional bands identified under WRC 2019 Agenda Item 1.13. Tuning ranges allow the development of equipment that accommodates multiple bands and thereby facilitates the development of an ecosystem that can serve multiple markets. Developers and manufacturers can potentially customize equipment for deployment countries and provide flexibility for regulators to manage spectrum resources within any given jurisdiction.

Therefore, administrations should consider how 5G services can be harmonized internationally, even if identical allocations cannot be used everywhere. To that end, administrations should consider their specific allocations within a broader globally harmonized and licensed band that accounts for the needs in various regions or countries. Under this approach, each administration would apply the tuning range concept, with a focus on specific bands appropriate for its needs. The near-term bands for mid-band and high-band consideration are 3.3-4.2 GHz, 24.25-29.5 and 37-43.5 GHz. Beyond these bands, it is proposed that global harmonization remain as a priority in the identification and allocation of spectrum for 5G, especially bands that have been identified under WRC 2019 Agenda Item 1.13.

9 CONCLUSION AND RECOMMENDATIONS

The paper highlights the spectrum requirements of 5G applications and analyzes the potential spectrum resources below and above 6 GHz 5G use cases, including enhanced Mobile Broadband (eMBB), Massive Machine Type Communications (mMTC) and Ultra-Reliable Low Latency Communications (URLLC), which may have different spectrum requirements to a varying degree. However all the use cases need spectrum both below and above 6 GHz. Below 6 GHz, mmWave bands and the 6-24 GHz bands, the subject of a recent mid-band NOI, are all important spectrum resources for 5G deployments. One key characteristic of all of these potential 5G spectrum resources is that they're mainly shared spectrum and require clearing and/or development of sharing mechanisms. This leads to the need for regulators and government agencies to take concrete measurable actions in making sure that a reasonable amount of licensed spectrum becomes available for initial 5G deployment in licensed spectrum.

Exponential growth in mobile data demand in conjunction with the spectrum needs of upcoming bandwidth intensive applications envisioned for 5G necessitate the availability of new licensed spectrum pools. The regulatory actions around spectrum seem to have been focused on the mmWave spectrum resource and not as much as spectrum below 6 GHz. Yet, 5G use cases have varied spectrum needs and effectively require spectrum across all bands. It's important that regulators take immediate actions in this regard so that low-band, mid-band and mmWave spectrum resources are available for the initial 5G rollouts.

It's highly desirable to have globally harmonized spectrum allocations for 5G applications, and thus regulators should allocate spectrum with international harmonization as a consideration. The benefits of global harmonization are not limited to situations where all regions have identical spectrum allocations. These benefits can also be derived from "tuning range" solutions, in which adjacent or nearly adjacent bands can be considered harmonized so long as equipment can be reconfigured to operate over multiple bands.

APPENDIX

Spectrum Allocation Table

Frequency Range		BW	Allocations			Use	Sharing Status	Necessary Actions	5G Integration Issues
Low	High		Region 2	U.S. Federal	U.S Non-Federal				
1300	1350	50 MHz	RADIOLOCATION AERONAUTICAL RADIONAVIGATION RADIONAVIGATION -SATELLITE (E-S)	AERONAUTICAL RADIONAVIGATION Radiolocation	AERONAUTICAL RADIONAVIGATION	Pt. 87 ASR Part of Spectrum Pipeline Spectrum Efficient National Surveillance Radar Program (SENSR) Possible pair with 1780-1830 MHz	TBD Likely Relocation Over 360 Fed assignments.	Need to address sharing/relocation with existing ASR Needs MOBILE allocation Time frame is ~2020	50 MHz
1350	1400		FIXED MOBILE RADIOLOCATION						
1350	1390	40 MHz		FIXED MOBILE RADIOLOCATION		ASR DoD AMT & GPS position data at test ranges, PTP, ship-to-ship communications. May become relocation band for 1300-1350	TBD Almost 780 Fed assignments.		
1390	1395	5 MHz			FIXED MOBILE	Pt. 27 TerreStar Unpaired, A&B Only 5 MHz TerreStar working on waiver to repurpose for WMTS			
1395	1400	5 MHz		LAND MOBILE (WMTS)		Pt. 95 Wireless Medical Telemetry Service	Unlikely due to WMTS incumbency		
1427	1429		SPACE OPERATION (E-S) FIXED MOBILE						
1427	1432	5 MHz		LAND MOBILE (WMTS)		Pt. 90, 95 Wireless Medical Telemetry Service	Unlikely due to WMTS incumbency		
1432	1435	3 MHz			FIXED MOBILE	Pt. 27 TerreStar Unpaired, A&B Only 3 MHz TerreStar working on waiver to repurpose for WMTS			
1525	1559	34 MHz	SPACE OPERATION (S-E) MOBILE SATELLITE (S-E) Earth Exploration Satellite Fixed Mobile	MOBILE SATELLITE (S-E)		Pt. 25, 80, 87 LightSquared MSS Band Paired with 1626.5-1660.5 NOTE: Upper end (1559 MHz) Adjacent to GPS			

Frequency Range		BW	Allocations			Use	Sharing Status	Necessary Actions	5G Integration Issues
Low	High		Region 2	U.S. Federal	U.S Non-Federal				
1610	1626.5	16.5 MHz	MOBILE SATELLITE (E-S) AERONAUTICAL RADIONAVIGATION RADIODETERMINATION-SATELLITE (E-S) RADIOASTRONOMY (1610.6-1613.8)	MOBILE SATELLITE (E-S) AERONAUTICAL RADIONAVIGATION RADIODETERMINATION-SATELLITE (E-S) RADIOASTRONOMY (1610.6-1613.8)		Pt. 25, 87 MSS Big LEO (Globalstar 1610-1617.775/2483.5-2495)			
1626.5	1660.5	34 MHz		MOBILE SATELLITE (E-S) RADIOASTRONOMY (1660-1660.5)		Pt. 25, 80, 87 LightSquared/ Inmarsat shared MSS Band Paired with 1525-1559			
1670	1675	5 MHz	METEROLOGICAL AIDS FIXED METERLOGICAL SATELLITE (S-E) MOBILE MOBILE SATELLITE (E-S)		FIXED MOBILE	Pt. 27 LightSquared (OP, LLC) Nationwide			
1675	1695	20 MHz	METEROLOGICAL AIDS FIXED METERLOGICAL SATELLITE (S-E) MOBILE	METEROLOGICAL AIDS (Radiosonde) METERLOGICAL SATELLITE (S-E)					
1695	1780					MOBILE (AWS Uplink)			
1710	1930		FIXED MOBILE						
1780	1850	70 MHz		FIXED MOBILE SPACE OPERATION (E-S)		Bands were used to accommodate federal systems relocating from 1755-1780	CSMAC concluded sharing not possible, but could revisit.		
1850	2025					MOBILE PCS & AWS (Downlink)			
2025	2110	85 MHz	SPACE OPERATION (E-S/S-S) EARTH EXPLORATION SATELLITE (E-S/S-S) FIXED MOBILE SPACE RESEARCH (E-S/S-S)		FIXED MOBILE	Pt. 74, 80, 101J Used for ENG, Cable Relay, LTTV Relocation band for Federal systems in 1755-1780	Currently under study by NSC for sharing of Fed systems with incumbents		
2110	2200					AWS (Downlink)			
2200	2290	90 MHz	SPACE OPERATION (E-S/S-S) EARTH EXPLORATION SATELLITE (E-S/S-S) FIXED MOBILE SPACE RESEARCH (E-S/S-S)	SPACE OPERATION (E-S/S-S) EARTH EXPLORATION SATELLITE (E-S/S-S) FIXED MOBILE SPACE RESEARCH (E-S/S-S)					
2290	2300	10 MHz	FIXED MOBILE SPACE RESEARCH (Deep Space/S-E)	FIXED MOBILE SPACE RESEARCH (Deep Space, S-E)	SPACE RESEARCH (Deep Space, S-E)				

Frequency Range		BW	Allocations			Use	Sharing Status	Necessary Actions	5G Integration Issues
Low	High		Region 2	U.S. Federal	U.S Non-Federal				
2300	2450		FIXED MOBILE RADIOLOCATION Amateur						
2305	2310	5 MHz			FIXED MOBILE RADIOLOCATION Amateur	Pt. 27, 97 WCS Band 2305-2320/2345-2360			
2310	2320	10 MHz		Fixed Mobile Radiolocation	FIXED MOBILE BROADCASTING-SATELLITE RADIOLOCATION	Pt. 27 WCS Band 2305-2320/2345-2360			
2320	2345	25 MHz		Fixed Radiolocation	BROADCASTING-SATELLITE	Pt. 25 SDARS (SiriusXM)	Unlikely due to SDARS incumbency		
2345	2360	15 MHz		Fixed Mobile Radiolocation	FIXED MOBILE BROADCASTING-SATELLITE RADIOLOCATION	Pt. 25 SDARS (SiriusXM)	Unlikely due to SDARS incumbency		
2360	2400	40 MHz		MOBILE RADIOLOCATION Fixed	MOBILE	Pt. 87, 95 AMT MBANS	AMT shares with MBANS (Pt. 95)	More study.	
2400	2450	50 MHz			Amateur	Pt. 18, 97 ISM Band			
2450	2483.5	33.5 MHz			FIXED MOBILE Radiolocation	Pt. 18, 74F, 90, 101 ISM Band			
2483.5	2500		FIXED MOBILE MOBILE SATELLITE (S-E) RADIOLOCATION RADIODETERMINATION-SATELLITE (S-E)	MOBILE SATELLITE (S-E) RADIODETERMINATION-SATELLITE (S-E)					
2483.5	2495	11.5 MHz			MOBILE SATELLITE (S-E) RADIODETERMINATION-SATELLITE (S-E)	Pt. 18, 25 Globalstar (1610-1617.775/2483.5-2495)			
2495	2500	5 MHz			FIXED MOBILE MOBILE SATELLITE (S-E) RADIODETERMINATION-SATELLITE (S-E)	Pt. 18, 25, 27 BRS			
2500	2520		FIXED FIXED SATELLITE (S-E) MOBILE						
2520	2655		FIXED FIXED SATELLITE (S-E) MOBILE BROADCAST SATELLITE						
2500	2655	155 MHz			FIXED MOBILE	Pt. 27 BRS & EBS Bands Thousands of licenses in both services			

Frequency Range		BW	Allocations			Use	Sharing Status	Necessary Actions	5G Integration Issues
Low	High		Region 2	U.S. Federal	U.S Non-Federal				
2655	2670		FIXED FIXED SATELLITE (S-E) MOBILE BROADCAST SATELLITE Earth Exploration Satellllite (Passive) Radioastronomy Space Research (Passive)						
2670	2690		FIXED FIXED SATELLITE (E-S/S-E) MOBILE BROADCAST SATELLITE Earth Exploration Satellllite (Passive) Radioastronomy Space Research (Passive)						
2655	2690	35 MHz		Earth Exploration Satellllite (Passive) Radioastronomy Space Research (Passive)	FIXED MOBILE Earth Exploration Satellllite (Passive) Radioastronomy Space Research (Passive)	Pt. 27 BRS & EBS Bands Thousands of licenses in both services			
2670	2690		EARTH EXPLORATION SATELLITE (Passive) RADIOASTRONOMY SPACE RESEARCH (Passive)						
2700	2900	20 MHz	AERONAUTICAL RADIONAVIGATION Radiolocation	METEROLOGICAL AIDS AERONAUTICAL RADIONAVIGATION Radiolocation		Pt. 87 ASR & WXD (NEXRAD)			
2900	3100	20 MHz	RADIOLOCATION RADIONAVIGATION	RADIOLOCATION MARITIME RADIONAVIGATION	MARITIME RADIONAVIGATION Radiolocation	Pt. 80 & 90 Radar			
3100	3300	200 MHz	RADIOLOCATION Earth exploration-satellite (active) Space research (active)	RADIOLOCATION Earth exploration-satellite (active) Space research (active)	Earth exploration-satellite (active) Space research (active) Radiolocation	Pt. 90 Radar			
3300	3400		RADIOLOCATION Amateur Fixed Mobile						
3300	3500	200 MHz		RADIOLOCATION	Amateur Radiolocation	Pt. 90, 97 Radar (WXD)			
3400	3500		FIXED FIXED-SATELLITE (space-to-Earth) Amateur Mobile Radiolocation						
3500	3700		FIXED FIXED-SATELLITE (space-to-Earth) MOBILE Radiolocation						
3500	3550			RADIOLOCATION AERONAUTICAL RADIONAVIGATION					

Frequency Range		BW	Allocations			Use	Sharing Status	Necessary Actions	5G Integration Issues
Low	High		Region 2	U.S. Federal	U.S Non-Federal				
3550	3600	150 MHz			FIXED MOBILE	Pt. 96 (CBRS)			
3600	3650				FIXED FIXED-SATELLITE (space-to-Earth) MOBILE	Pt. 25 & 96 (CBRS)			
3650	3700				FIXED FIXED-SATELLITE (space-to-Earth) MOBILE				
3700	4200		FIXED FIXED-SATELLITE (space-to-Earth) MOBILE		FIXED FIXED-SATELLITE (space-to-Earth)	Pt. 25 & 101 FSS & FS Band	Under study in FCC's NOI		
4200	4400		AERONAUTICAL RADIONAVIGATION	AERONAUTICAL RADIONAVIGATION		Pt. 87 (Radar Altimeters)	Unlikely due to Radar Altimeter incumbency		
4400	4500		FIXED MOBILE						
4400	4490	90 MHz		FIXED MOBILE Fixed LOS & transportable-fixed PTP microwave systems, drone vehicle control and telemetry systems. Military training.		Nuclear emergencies and law enforcement activities	Possible sharing, but situation similar to 1.7 GHz band with Federal equities. Over 1400 assignments.	More study.	
4400	4500								
4500	4800	300 MHz	FIXED FIXED-SATELLITE (space-to-Earth)	LOS and trans-horizon radio communications air-to-ground operations for command and control, telemetry to relay data, various range systems, video, law enforcement, drug interdiction missions and nuclear emergency response activities.	FIXED-SATELLITE (space-to-Earth)		Over 2600 Federal assignments.	More study.	
4800	4890				?				
4800	4990	190 MHz	FIXED MOBILE	Military at test ranges and naval ports around the US. Law enforcement, drug interdiction and radio astronomy.			Over 1400 Federal assignments.	More study.	
4940	4990	50 MHz			FIXED MOBILE	Pt. 90Y Public Safety WiFi	Over 3100 commercial and ~ 190 Fed. Assignments.		
4990	5000	10 MHz	FIXED MOBILE RADIO ASTRONOMY Space research (passive)	RADIO ASTRONOMY Space research (passive)			Unlikely due to passive RA.		

Frequency Range		BW	Allocations			Use	Sharing Status	Necessary Actions	5G Integration Issues
Low	High		Region 2	U.S. Federal	U.S Non-Federal				
5000	5010	10 MHz	AERONAUTICAL MOBILE-SATELLITE (R) AERONAUTICAL RADIONAVIGATION RADIONAVIGATION -SATELLITE (Earth-to-space)	AERONAUTICAL MOBILE (R) AERONAUTICAL MOBILE-SATELLITE (R) AERONAUTICAL RADIONAVIGATION RADIONAVIGATION-SATELLITE (Earth-to-space) Future GPS Testing use local area networks to support air traffic on the surface of airports.		Pt. 87 Microwave Landing Systems (few installed)		More study.	
5010	5030	20 MHz	AERONAUTICAL RADIONAVIGATION RADIONAVIGATION -SATELLITE (space-to-Earth) (space-to-space)	AERONAUTICAL MOBILE-SATELLITE (R) AERONAUTICAL RADIONAVIGATION RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space) Future GPS Testing use local area networks to support air traffic on the surface of airports.					
5030	5091	60 MHz	AERONAUTICAL MOBILE (R) AERONAUTICAL MOBILE-SATELLITE (R) AERONAUTICAL RADIONAVIGATION	AERONAUTICAL MOBILE (R) AERONAUTICAL MOBILE-SATELLITE (R) AERONAUTICAL RADIONAVIGATION Transportable MLS installed at several Air Force bases					
5091	5150		AERONAUTICAL MOBILE AERONAUTICAL MOBILE-SATELLITE (R) AERONAUTICAL RADIONAVIGATION	AERONAUTICAL MOBILE AERONAUTICAL MOBILE-SATELLITE (R) AERONAUTICAL RADIONAVIGATION		Pt. 25 & 87 Microwave Landing Systems (few installed)			
5150	5250	100 MHz	FIXED-SATELLITE (Earth-to-space) MOBILE except aeronautical mobile AERONAUTICAL RADIONAVIGATION	AERONAUTICAL RADIONAVIGATION	FIXED-SATELLITE (Earth-to-space) AERONAUTICAL RADIONAVIGATION	Pt. 15, 25, & 87 U-NII-1			
5250	5350	100 MHz	EARTH EXPLORATION-SATELLITE (active) MOBILE RADIOLOCATION SPACE RESEARCH (active)	EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION SPACE RESEARCH (active)	Earth exploration-satellite (active) Radiolocation Space research	Pt. 15 & 90 U-NII-2A			
5350	5460	120 MHz	EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION AERONAUTICAL RADIONAVIGATION SPACE RESEARCH (active)	EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION AERONAUTICAL RADIONAVIGATION SPACE RESEARCH (active)	AERONAUTICAL RADIONAVIGATION Earth exploration-satellite (active) Radiolocation Space research (active)	Pt. 15(?), 87 & 90 U-NII-2B			
5460	5470		EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION RADIONAVIGATION SPACE RESEARCH (active)	EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION RADIONAVIGATION SPACE RESEARCH (active)	RADIONAVIGATION Earth exploration-satellite (active) Radiolocation Space research (active)	Pt. 15(?), 80, 87 & 90 U-NII-2B			
5470	5570	255 MHz	EARTH EXPLORATION-SATELLITE (active) MOBILE RADIOLOCATION MARITIME RADIONAVIGATION SPACE RESEARCH (active)	EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION MARITIME RADIONAVIGATION SPACE RESEARCH (active)	RADIOLOCATION MARITIME RADIONAVIGATION Earth exploration-satellite (active) Space research (active)	Pt. 15(?), 80 & 90 U-NII-2C			
5570	5650		MOBILE RADIOLOCATION MARITIME RADIONAVIGATION	METEOROLOGICAL AIDS RADIOLOCATION MARITIME RADIONAVIGATION					

Frequency Range		BW	Allocations			Use	Sharing Status	Necessary Actions	5G Integration Issues
Low	High		Region 2	U.S. Federal	U.S Non-Federal				
5570	5600			RADIOLOCATION MARITIME RADIONAVIGATION					
5600	5650			METEOROLOGICAL AIDS RADIOLOCATION MARITIME RADIONAVIGATION		Pt. 15(?), 80 & 90 (TDWR) U-NII-2C			
5650	5725		MOBILE RADIOLOCATION Amateur Space research (deep space)	RADIOLOCATION		Pt. 15(?), 80 & 90 U-NII-2C			
5725	5830	125 MHz	RADIOLOCATION Amateur	RADIOLOCATION	Amateur	Pt. 15, 18 & 97 U-NII-3			
5830	5850		RADIOLOCATION Amateur	RADIOLOCATION	Amateur Amateur-satellite (space-to-Earth)				
5850	5925	75 MHz	FIXED FIXED-SATELLITE (Earth-to-space) MOBILE Amateur Radiolocation	RADIOLOCATION	FIXED-SATELLITE (Earth-to-space) MOBILE Amateur	Pt. 15(?) 18, 90 (DSRC) , 95, 97 U-NII-4			
5925	6700		FIXED FIXED-SATELLITE (Earth-to-space) MOBILE						
5925	6425				FIXED FIXED-SATELLITE (Earth-to-space)	Pt. 15, 25, 101	Under study in FCC's NOI		
6425	6525				FIXED-SATELLITE (Earth-to-space) MOBILE	Pt. 15, 25, 74F, 78, 101			
6525	6700				FIXED FIXED-SATELLITE (Earth-to-space)	Pt. 15, 25, 101			
6700	7075		FIXED FIXED-SATELLITE (Earth-to-space) (space-to-Earth) MOBILE						
6700	6875				FIXED FIXED-SATELLITE (Earth-to-space) (space-to-Earth)	Pt. 15, 25, 101	Under study in FCC's NOI		
6875	7025				FIXED FIXED-SATELLITE (Earth-to-space) (space-to-Earth) MOBILE	Pt. 15, 25, 74F, 78			
7025	7075				FIXED FIXED-SATELLITE (Earth-to-space) MOBILE	Pt. 15, 74F, 78			
7075	7125				FIXED MOBILE				

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