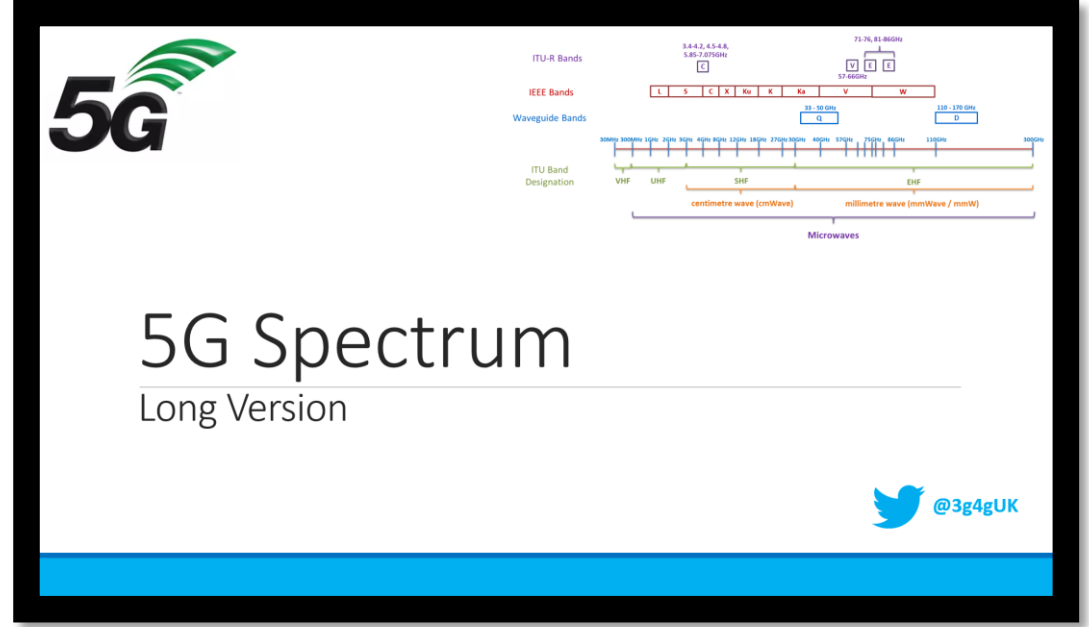
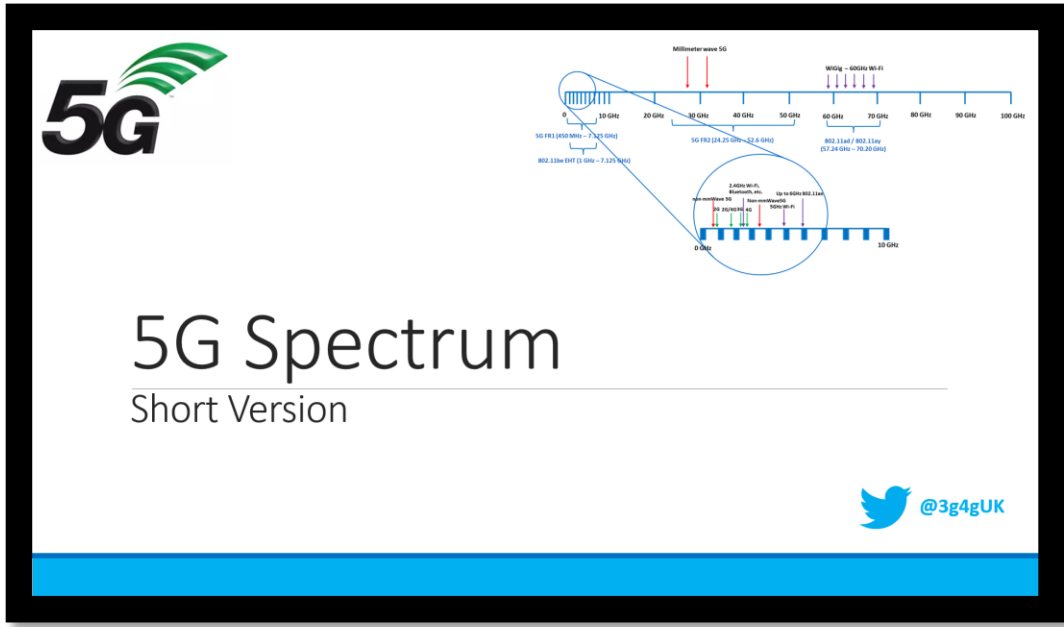



5G Spectrum

Short Version






THIS IS SHORT VERSION – FOR LONG VERSION CLICK ON THE LINK ON **TOP RIGHT**

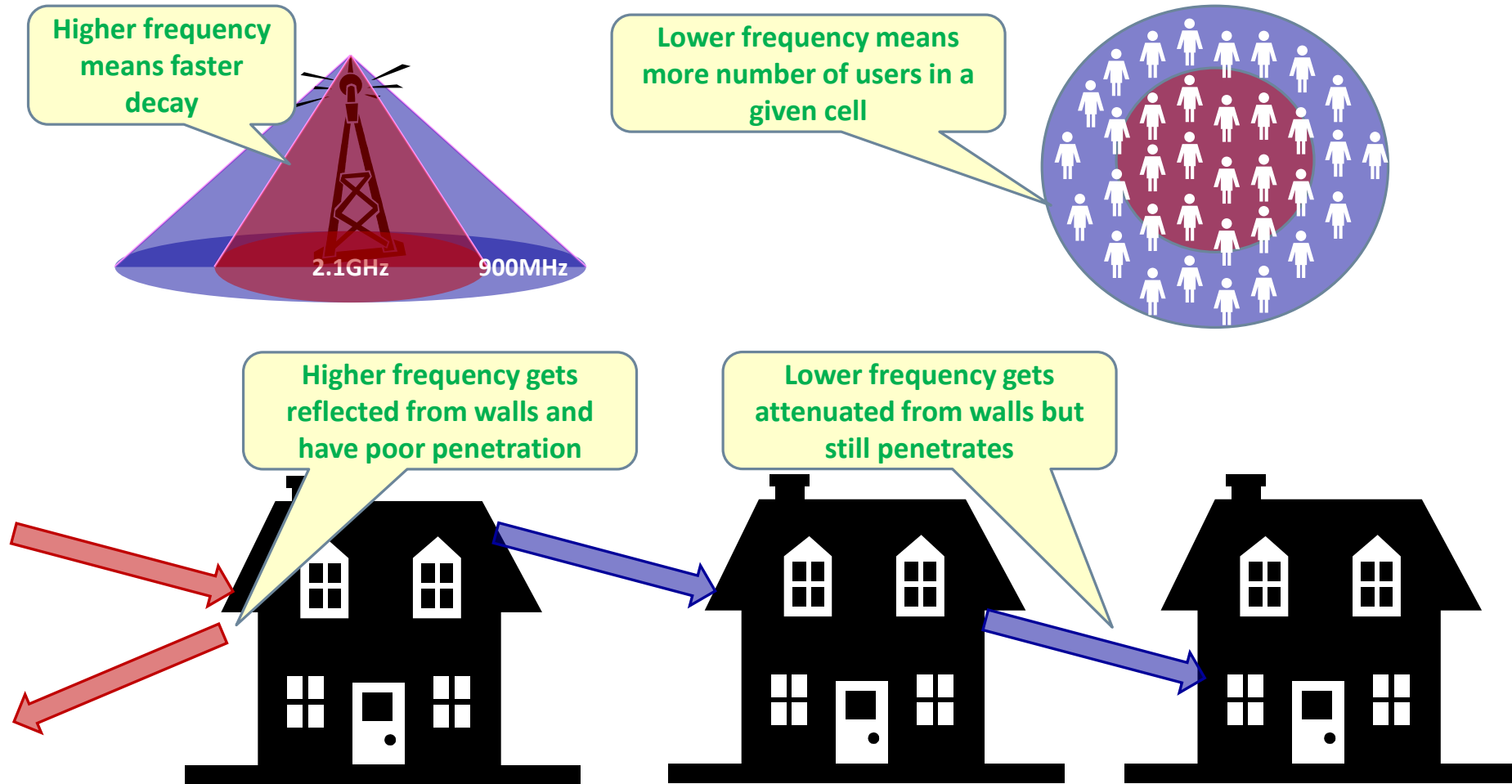


Non millimeter-Wave
(mmWave) 5G

 @3g4gUK

FOR NON-MMWAVE 5G CLICK ON THE LINK ON **TOP RIGHT**

Importance of Frequency selection

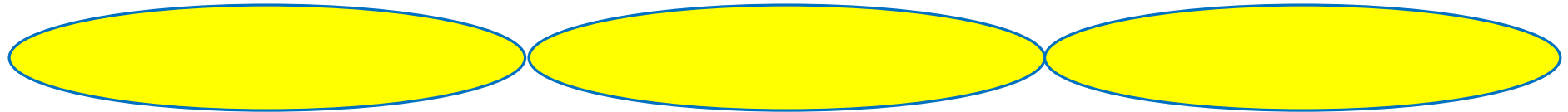


5G: Multiple Layers for multiple needs

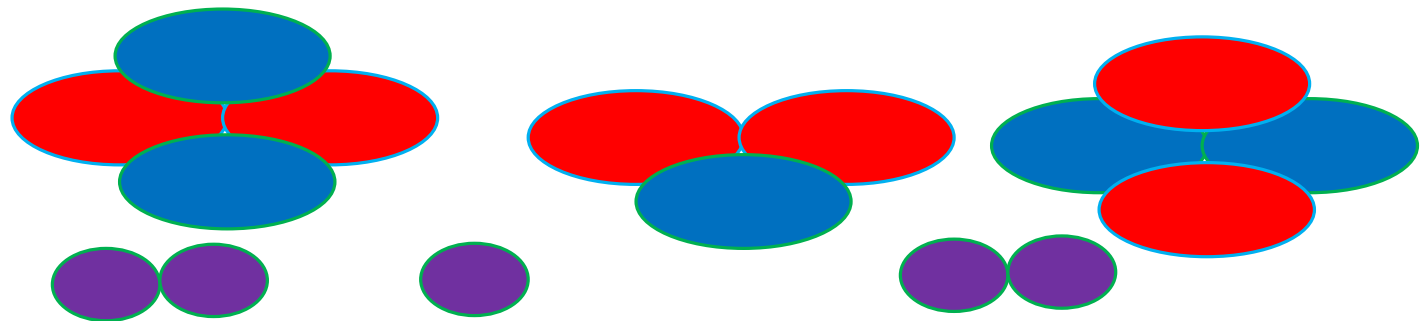
Coverage Layer
Sub-1GHz



Capacity Layer
1GHz – 6GHz



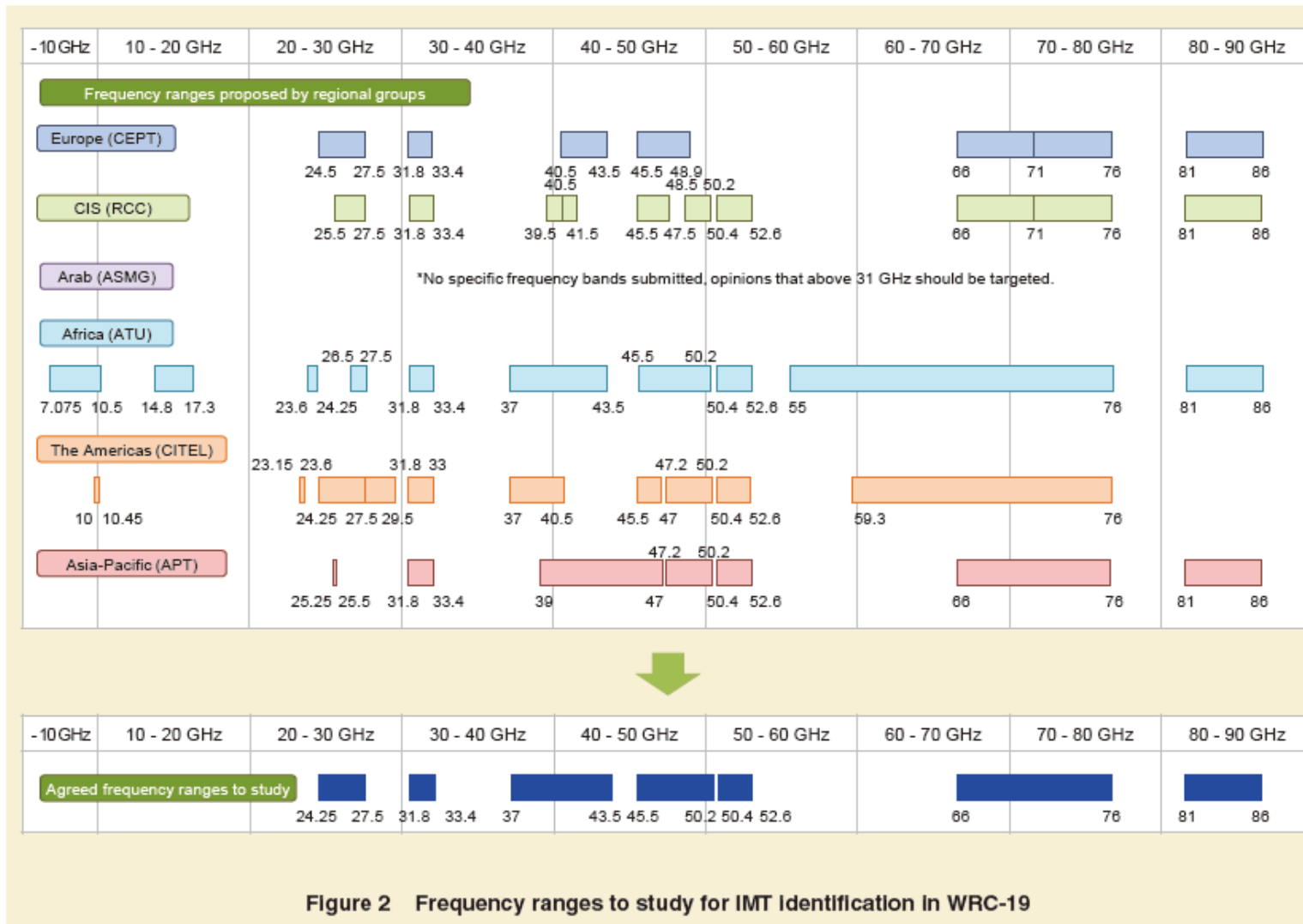
High Throughput Layers
6GHz – 100GHz



3GPP defined 5G Spectrum Ranges

- 3GPP defines new NR (New Radio) bands in FR1 and FR2 in 3GPP Rel.15 NR
- FR1: 450 MHz – 6 GHz
 - Upper range is changing to **7.125 GHz**
- FR2: 24.25 GHz – 52.6 GHz

5G Spectrum



ITU WRC-15 Report from [NTT Docomo Technical Journal](#)

5G or IMT-2020 Frequencies being studied by ITU.

Figure 2 Frequency ranges to study for IMT Identification in WRC-19




Most Popular 5G Frequency Bands

	<1GHz	3GHz	4GHz	5GHz	24-28GHz	37-40GHz	64-71GHz		
	600MHz (2x35MHz) <u>Existing band</u>	2.5GHz (LTE B41) <u>Existing band</u>	3.45-3.55GHz <u>Existing band</u>	3.55-3.7GHz <u>Existing band</u>	3.7-4.2GHz <u>Existing band</u>	5.9-7.1GHz <u>Existing band</u>	24.25-24.45GHz 24.75-25.25GHz 27.5-28.35GHz <u>Existing band</u>	37-37.6GHz 37.6-40GHz 47.2-48.2GHz <u>Existing band</u>	64-71GHz <u>Existing band</u>
	600MHz (2x35MHz) <u>Existing band</u>	3.55-3.7 GHz <u>Existing band</u>				27.5-28.35GHz <u>Existing band</u>		37-37.6GHz 37.6-40GHz <u>Existing band</u>	64-71GHz <u>Existing band</u>
	700MHz (2x30 MHz) <u>Existing band</u>		3.4-3.8GHz <u>Existing band</u>		5.9-6.4GHz <u>Existing band</u>	24.5-27.5GHz <u>Existing band</u>			
	700MHz (2x30 MHz) <u>Existing band</u>		3.4-3.8GHz <u>Existing band</u>			26GHz <u>Existing band</u>			
	700MHz (2x30 MHz) <u>Existing band</u>		3.4-3.8GHz <u>Existing band</u>			26GHz <u>Existing band</u>			
	700MHz (2x30 MHz) <u>Existing band</u>		3.46-3.8GHz <u>Existing band</u>			26GHz <u>Existing band</u>			
	700MHz (2x30 MHz) <u>Existing band</u>		3.6-3.8GHz <u>Existing band</u>			26.5-27.5GHz <u>Existing band</u>			
		3.3-3.6GHz <u>Existing band</u>		4.8-5GHz <u>Existing band</u>		24.5-27.5GHz <u>Existing band</u>		37.5-42.5GHz <u>Existing band</u>	
		3.4-3.7GHz <u>Existing band</u>				26.5- 29.5GHz <u>Existing band</u>			
		3.6-4.2GHz <u>Existing band</u>		4.4-4.9GHz <u>Existing band</u>		26.5- 28.5GHz <u>Existing band</u>			
		3.4-3.7GHz <u>Existing band</u>				24.25-27.5GHz <u>Existing band</u>		39GHz <u>Existing band</u>	

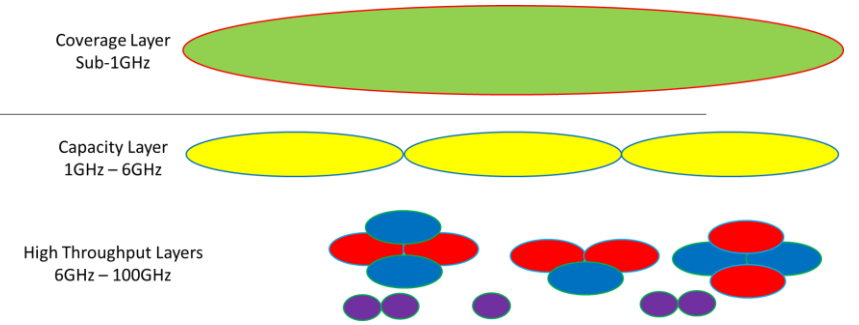
Source: Qualcomm

Red highlights frequencies not approved for ITU study

New 5G band

-  Licensed
-  Unlicensed/shared
-  Existing band

Most Popular 5G Frequency Bands



26/28 GHz – most popular band

3.5 GHz – most popular band

700 MHz – most popular band

Picture Source: Deutsche Telekom / T-Mobile USA

FR1 5G Bands Defined by 3GPP

Release 15

3GPP TS 38.101-1 V15.3.0 (2018-09)

Table 5.2-1: NR operating bands in FR1

NR operating band	Uplink (UL) operating band	Downlink (DL) operating band	Duplex Mode
	BS receive / UE transmit F _{UL_low} – F _{UL_high}	BS transmit / UE receive F _{DL_low} – F _{DL_high}	
n1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	FDD
n2	1850 MHz – 1910 MHz	1930 MHz – 1990 MHz	FDD
n3	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	FDD
n5	824 MHz – 849 MHz	869 MHz – 894 MHz	FDD
n7	2500 MHz – 2570 MHz	2620 MHz – 2690 MHz	FDD
n8	880 MHz – 915 MHz	925 MHz – 960 MHz	FDD
n12	699 MHz – 716 MHz	729 MHz – 746 MHz	FDD
n20	832 MHz – 862 MHz	791 MHz – 821 MHz	FDD
n25	1850 MHz – 1915 MHz	1930 MHz – 1995 MHz	FDD
n28	703 MHz – 748 MHz	758 MHz – 803 MHz	FDD
n34	2010 MHz – 2025 MHz	2010 MHz – 2025 MHz	TDD
n38	2570 MHz – 2620 MHz	2570 MHz – 2620 MHz	TDD
n39	1880 MHz – 1920 MHz	1880 MHz – 1920 MHz	TDD
n40	2300 MHz – 2400 MHz	2300 MHz – 2400 MHz	TDD

n41	2496 MHz – 2690 MHz	2496 MHz – 2690 MHz	TDD
n50	1432 MHz – 1517 MHz	1432 MHz – 1517 MHz	TDD ¹
n51	1427 MHz – 1432 MHz	1427 MHz – 1432 MHz	TDD
n66	1710 MHz – 1780 MHz	2110 MHz – 2200 MHz	FDD
n70	1695 MHz – 1710 MHz	1995 MHz – 2020 MHz	FDD
n71	663 MHz – 698 MHz	617 MHz – 652 MHz	FDD
n74	1427 MHz – 1470 MHz	1475 MHz – 1518 MHz	FDD
n75	N/A	1432 MHz – 1517 MHz	SDL
n76	N/A	1427 MHz – 1432 MHz	SDL
n77	3300 MHz – 4200 MHz	3300 MHz – 4200 MHz	TDD
n78	3300 MHz – 3800 MHz	3300 MHz – 3800 MHz	TDD
n79	4400 MHz – 5000 MHz	4400 MHz – 5000 MHz	TDD
n80	1710 MHz – 1785 MHz	N/A	SUL
n81	880 MHz – 915 MHz	N/A	SUL
n82	832 MHz – 862 MHz	N/A	SUL
n83	703 MHz – 748 MHz	N/A	SUL
n84	1920 MHz – 1980 MHz	N/A	SUL
n86	1710 MHz – 1780MHz	N/A	SUL

NOTE 1: UE that complies with the NR Band n50 minimum requirements in this specification shall also comply with the NR Band n51 minimum requirements.

New Bands in 5G, not in LTE

Bandwidth of FR1 5G bands

Release 15

24

3GPP TS 38.101-1 V15.3.0 (2018-09)

NR Band	NR band / SCS / UE Channel bandwidth												
	SCS kHz	5 MHz	10 ^{1,2} MHz	15 ² MHz	20 ² MHz	25 ² MHz	30 MHz	40 MHz	50 MHz	60 MHz	80 MHz	90 MHz	100 MHz
n1	15	Yes	Yes	Yes	Yes								
	30		Yes	Yes	Yes								
	60		Yes	Yes	Yes								
n2	15	Yes	Yes	Yes	Yes								
	30		Yes	Yes	Yes								
	60		Yes	Yes	Yes								
n3	15	Yes	Yes	Yes	Yes	Yes	Yes						
	30		Yes	Yes	Yes	Yes	Yes						
	60		Yes	Yes	Yes	Yes	Yes						
n5	15	Yes	Yes	Yes	Yes								
	30		Yes	Yes	Yes								
	60												
n7	15	Yes	Yes	Yes	Yes								
	30		Yes	Yes	Yes								
	60		Yes	Yes	Yes								
n8	15	Yes	Yes	Yes	Yes								
	30		Yes	Yes	Yes								
	60												
n12	15	Yes	Yes	Yes									
	30		Yes	Yes									
	60												
n20	15	Yes	Yes	Yes	Yes								
	30		Yes	Yes	Yes								
	60												
n25	15	Yes	Yes	Yes	Yes								
	30		Yes	Yes	Yes								
	60		Yes	Yes	Yes								
n28	15	Yes	Yes	Yes	Yes								
	30		Yes	Yes	Yes								
	60												
n34	15	Yes	Yes	Yes									
	30		Yes	Yes									
	60		Yes	Yes									
n38	15	Yes	Yes	Yes	Yes								
	30		Yes	Yes	Yes								
	60		Yes	Yes	Yes								
n39	15	Yes	Yes	Yes	Yes	Yes	Yes	Yes					
	30		Yes	Yes	Yes	Yes	Yes	Yes					
	60		Yes	Yes	Yes	Yes	Yes	Yes					

Release 15

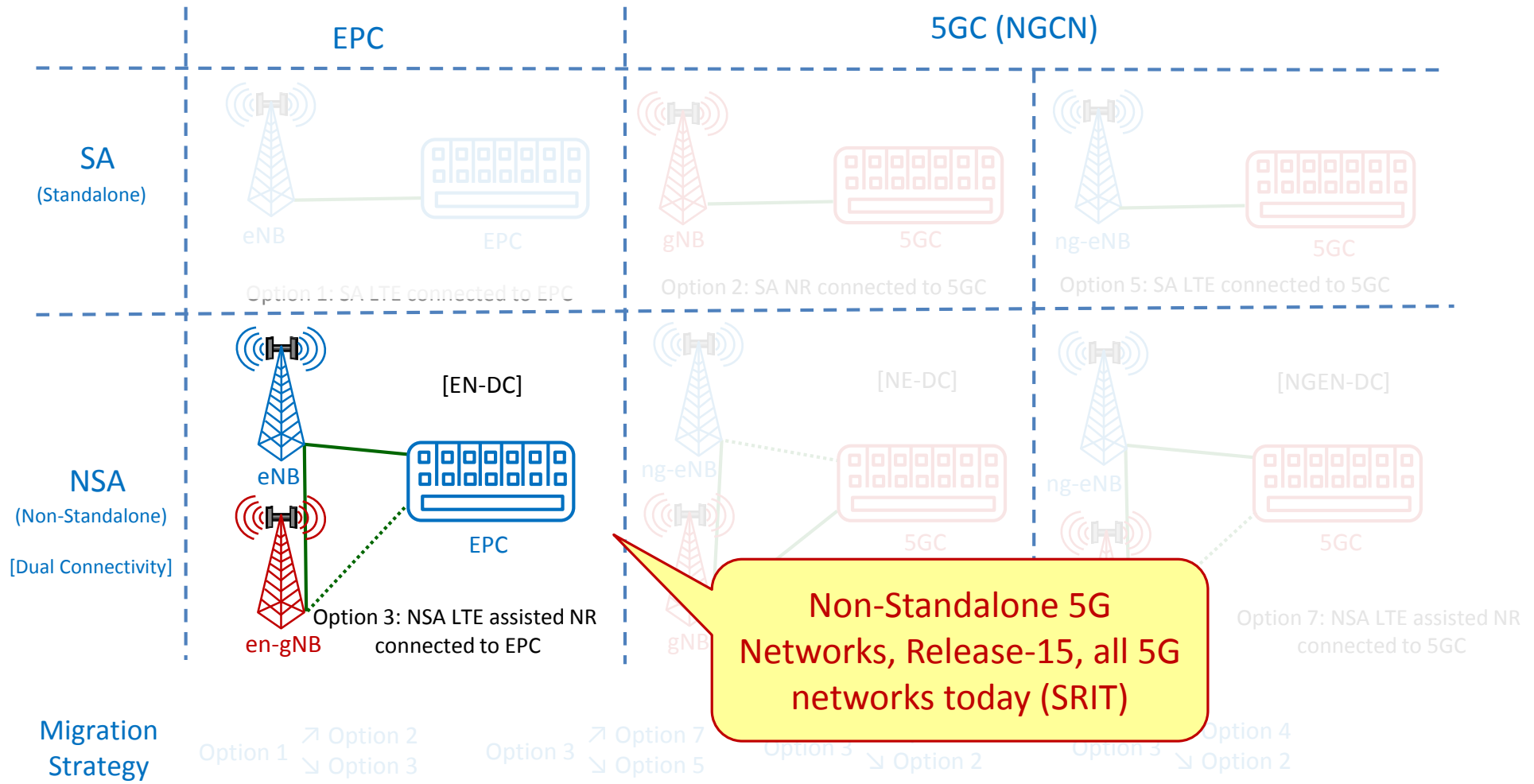
25

3GPP TS 38.101-1 V15.3.0 (2018-09)

NR Band	NR band / SCS / UE Channel bandwidth												
	SCS kHz	5 MHz	10 ^{1,2} MHz	15 ² MHz	20 ² MHz	25 ² MHz	30 MHz	40 MHz	50 MHz	60 MHz	80 MHz	90 MHz	100 MHz
n71	15	Yes	Yes	Yes	Yes								
	30		Yes	Yes	Yes								
	60												
n74	15	Yes	Yes	Yes	Yes								
	30		Yes	Yes	Yes								
	60		Yes	Yes	Yes								
n75	15	Yes	Yes	Yes	Yes								
	30		Yes	Yes	Yes								
	60		Yes	Yes	Yes								
n76	15	Yes											
	30												
	60												
n77	15		Yes	Yes	Yes			Yes	Yes				
	30		Yes	Yes	Yes			Yes	Yes	Yes	Yes	Yes	Yes
	60		Yes	Yes	Yes			Yes	Yes	Yes	Yes	Yes	Yes
n78	15		Yes	Yes	Yes			Yes	Yes				
	30		Yes	Yes	Yes			Yes	Yes	Yes	Yes	Yes	Yes
	60		Yes	Yes	Yes			Yes	Yes	Yes	Yes	Yes	Yes
n79	15							Yes	Yes				
	30							Yes	Yes	Yes	Yes		Yes
	60							Yes	Yes	Yes	Yes		Yes
n80	15	Yes	Yes	Yes	Yes	Yes	Yes						
	30		Yes	Yes	Yes	Yes	Yes						
	60		Yes	Yes	Yes	Yes	Yes						
n81	15	Yes	Yes	Yes	Yes								
	30		Yes	Yes	Yes								
	60												
n82	15	Yes	Yes	Yes	Yes								
	30		Yes	Yes	Yes								
	60												
n83	15	Yes	Yes	Yes	Yes								
	30		Yes	Yes	Yes								
	60												
n84	15	Yes	Yes	Yes	Yes								
	30		Yes	Yes	Yes								
	60		Yes	Yes	Yes								
n86	15	Yes	Yes	Yes	Yes				Yes				
	30		Yes	Yes	Yes				Yes				
	60		Yes	Yes	Yes				Yes				

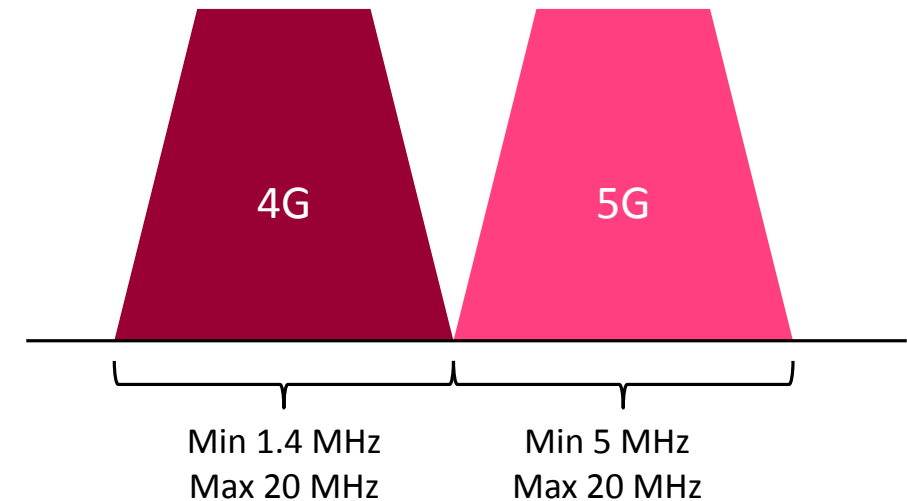
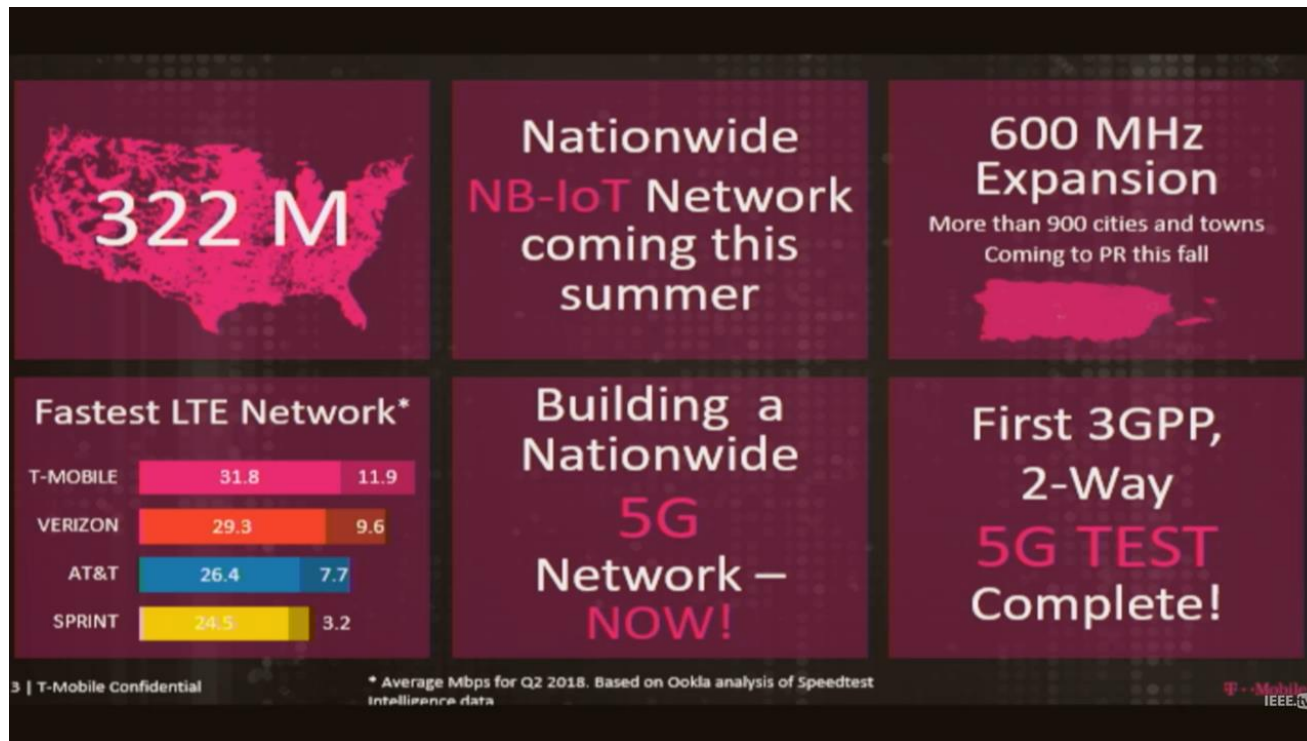
NOTE 1: 90% spectrum utilization may not be achieved for 30kHz SCS.
 NOTE 2: 90% spectrum utilization may not be achieved for 60kHz SCS.
 NOTE 3: This UE channel bandwidth is applicable only to downlink.

5G Deployment Options and Migration Strategy



Refarming the existing frequency bands

- T-Mobile USA launching 5G in 600 MHz
 - 600 MHz used for 4G at present

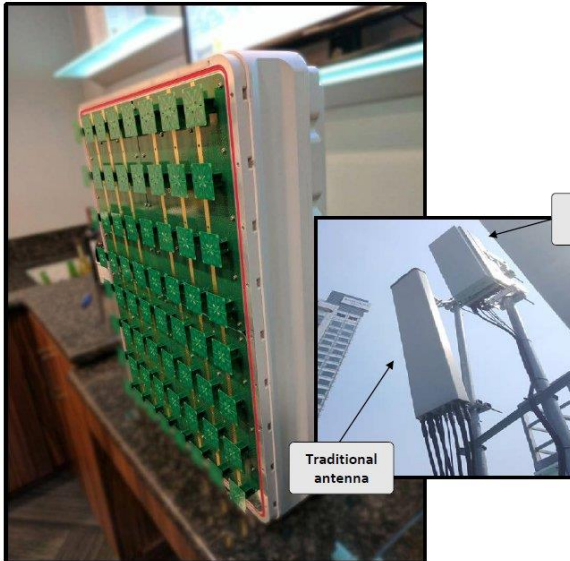


		NR band / SCS / UE Channel bandwidth							
NR Band	SCS kHz	5 MHz	10 ^{1,2} MHz	15 ² MHz	20 ² MHz	25 ² MHz	30 MHz	40 MHz	50 MHz
n71	15	Yes	Yes	Yes	Yes				
	30		Yes	Yes	Yes				
	60								

Refarming the existing frequency bands

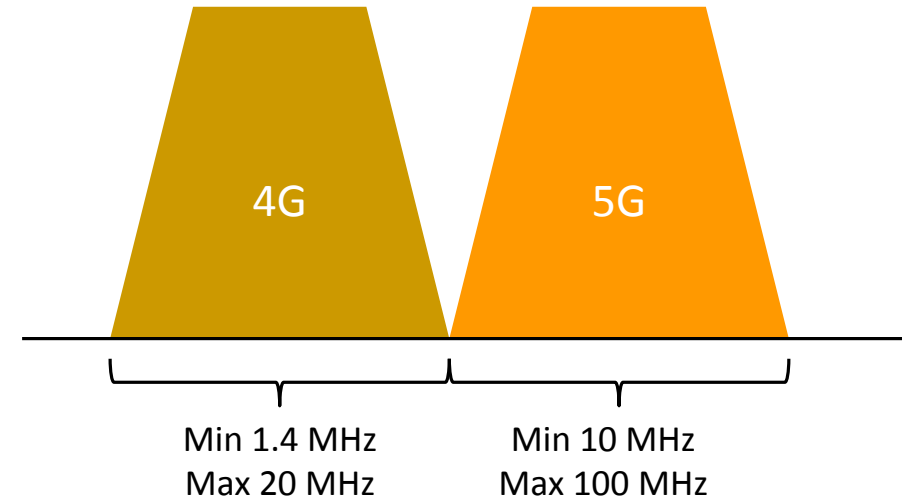
- Sprint USA launching 5G in 2.5 GHz
 - 2.5 GHz used for 4G at present

TDD-LTE Massive MIMO for 5G



Massive MIMO leverages a massive number of antennas and advanced antenna beamforming to improve performance

- Sprint will deploy 64T64R Massive MIMO (128 Antenna Elements) at 2.5 GHz
- Upgrade thousands of 2.5 GHz sites with Massive MIMO to support LTE and 5G simultaneously at existing sites



NR Band	SCS kHz	NR band / SCS / UE Channel bandwidth							
		5 MHz	10 ^{1,2} MHz	15 ² MHz	20 ² MHz	25 ² MHz	30 MHz	40 MHz	50 MHz
n41	15		Yes	Yes	Yes			Yes	Yes
	30		Yes	Yes	Yes			Yes	Yes
	60		Yes	Yes	Yes			Yes	Yes

3GPP defined 5G Spectrum Ranges

- 3GPP defines new NR (New Radio) bands in FR1 and FR2 in 3GPP Rel.15 NR
- FR1: 450 MHz – 6 GHz
 - Upper range is changing to 7.125 GHz
- FR2: 24.25 GHz – 52.6 GHz

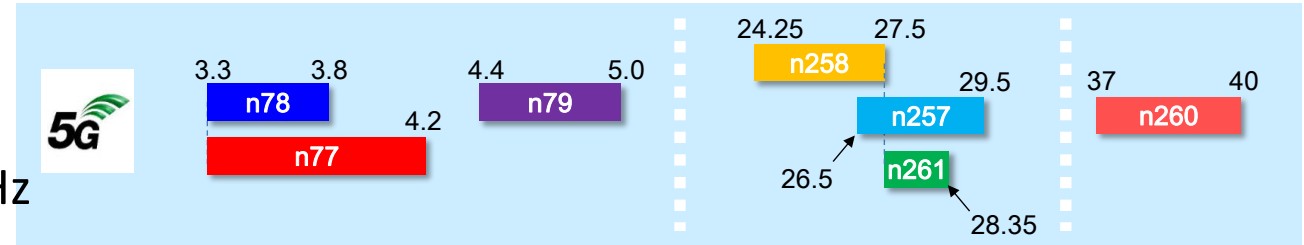


Table 2 NR bands specified in this WI

NR operating band	Uplink (UL) operating band	Downlink (DL) operating band	Duplex Mode	Bandwidth
n77	3300 MHz – 4200 MHz	3300 MHz – 4200 MHz	TDD	900 MHz
n78	3300 MHz – 3800 MHz	3300 MHz – 3800 MHz	TDD	500 MHz
n79	4400 MHz – 5000 MHz	4400 MHz – 5000 MHz	TDD	600 MHz
n257	26500 MHz – 29500 MHz	26500 MHz – 29500 MHz	TDD	3000 MHz (3 GHz)
n258	24250 MHz – 27500 MHz	24250 MHz – 27500 MHz	TDD	3250 MHz (3.25 GHz)
n260	37000 MHz – 40000 MHz	37000 MHz – 40000 MHz	TDD	3000 MHz (3 GHz)
n261	27500 MHz – 28350 MHz	27500 MHz – 28350 MHz	TDD	850 MHz

Bandwidth of FR2 5G bands

Release 15

3GPP TS 38.101-2 V15.3.0 (2018-09)

Table 5.3.5-1: Channel bandwidths for each NR band

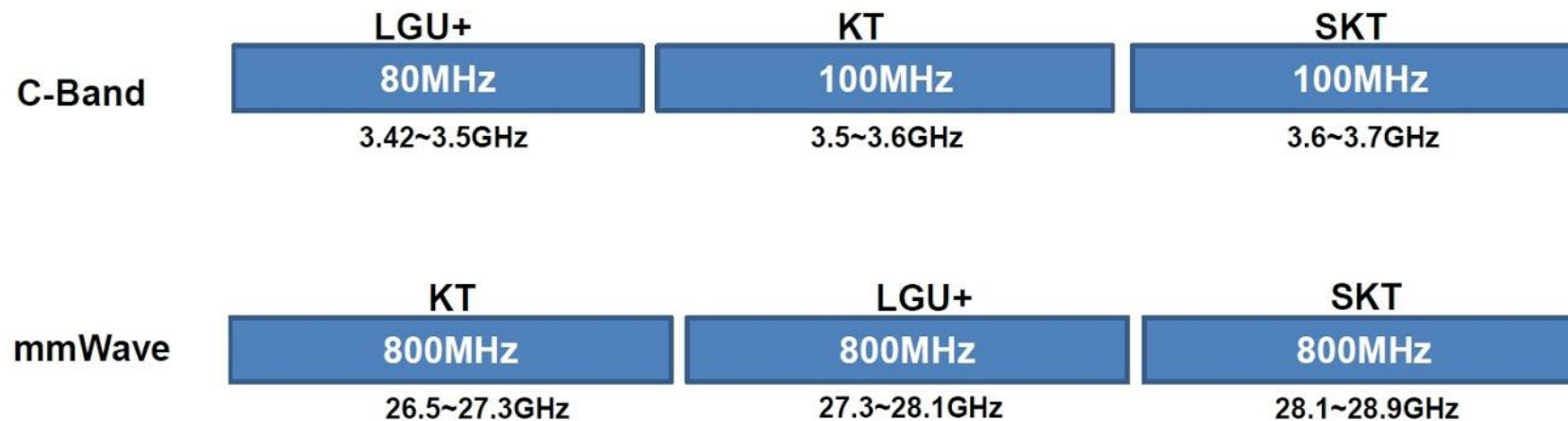
Operating band / SCS / UE channel bandwidth					
Operating band	SCS kHz	50 MHz	100 MHz	200 MHz	400 MHz
n257	60	Yes	Yes	Yes	
	120	Yes	Yes	Yes	Yes
n258	60	Yes	Yes	Yes	
	120	Yes	Yes	Yes	Yes
n260	60	Yes	Yes	Yes	
	120	Yes	Yes	Yes	Yes
n261	60	Yes	Yes	Yes	
	120	Yes	Yes	Yes	Yes

5G Spectrum Plans / Allocation – South Korea

Korea: finish C Bands and mmWave Auction

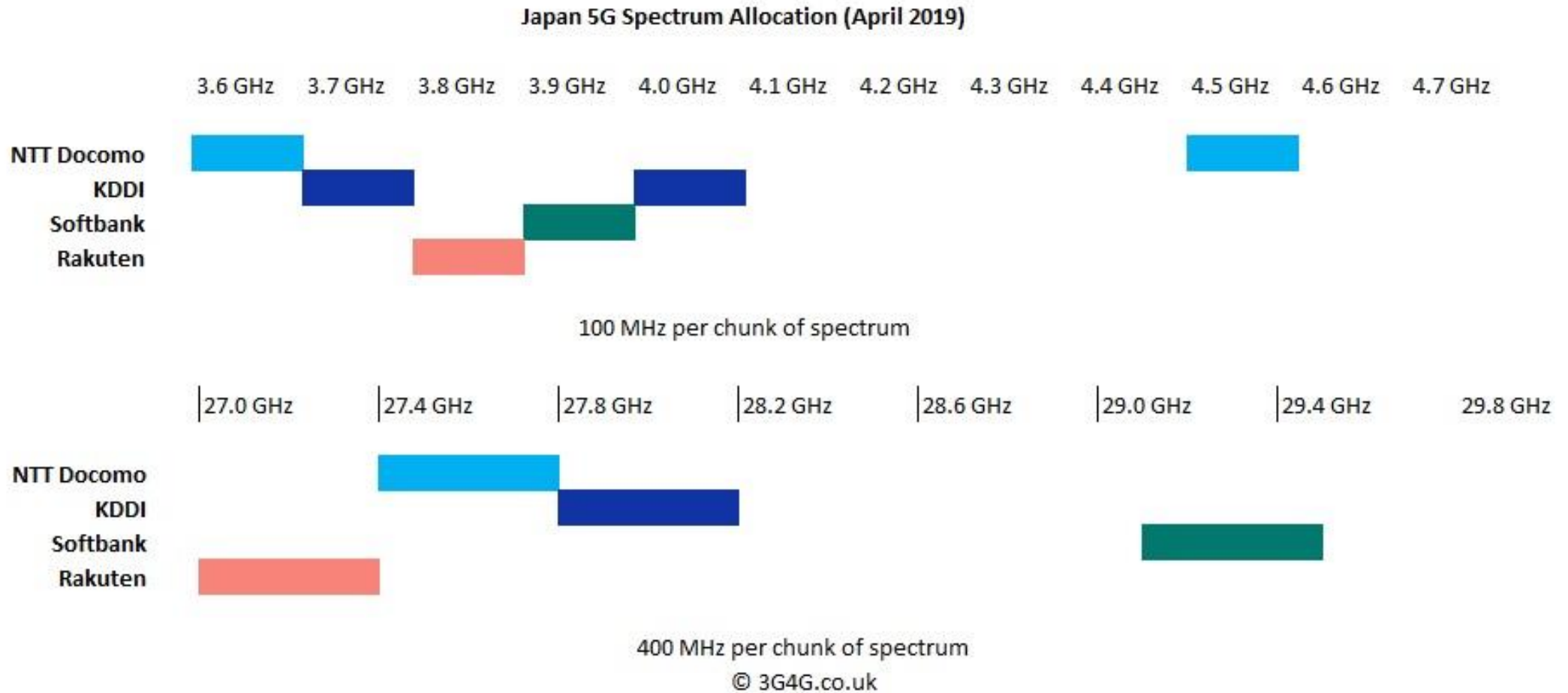


Band plan according to the auction in June, 2018



Further Reading: [Operator Watch Blog](#)

5G Spectrum Plans / Allocation – Japan



Further Reading: [Operator Watch Blog](#)

5G Spectrum Plans / Allocation – Italy

Final award prices

Band	Lot	Spectrum [MHz]	Winner	Price [€]	+% vs reserve price
700 MHz FDD	700_R	2x10	Iliad	676.472.792	0%
	700_FDD	2x5	Vodafone	345.000.000	2%
	700_FDD	2x5	Vodafone	338.236.396	0%
	700_FDD	2x5	TIM	340.100.000	0,6%
	700_FDD	2x5	TIM	340.100.000	0,6%
			2x30		2.039.909.188
3.7 GHz	3700_C1	80	TIM	1.694.000.000	970%
	3700_C2	80	Vodafone	1.685.000.000	962%
	3700_C3	20	Wind Tre	483.920.000	1120%
	3700_C4	20	Iliad	483.900.000	1120%
			200		4.346.820.000
26 GHz	26G	200	TIM	33.020.000	1,3%
	26G	200	Iliad	32.900.000	1,0%
	26G	200	Fastweb	32.600.000	0,04%
	26G	200	Wind Tre	32.586.535	0%
	26G	200	Vodafone	32.586.535	0%
			1000		163.693.070
ALL		1260		6.550.422.258	162,0%

Mauro Martino



[Source](#)

UK mobile spectrum holdings (present)

Figure 5.2: UK mobile spectrum holdings⁸²

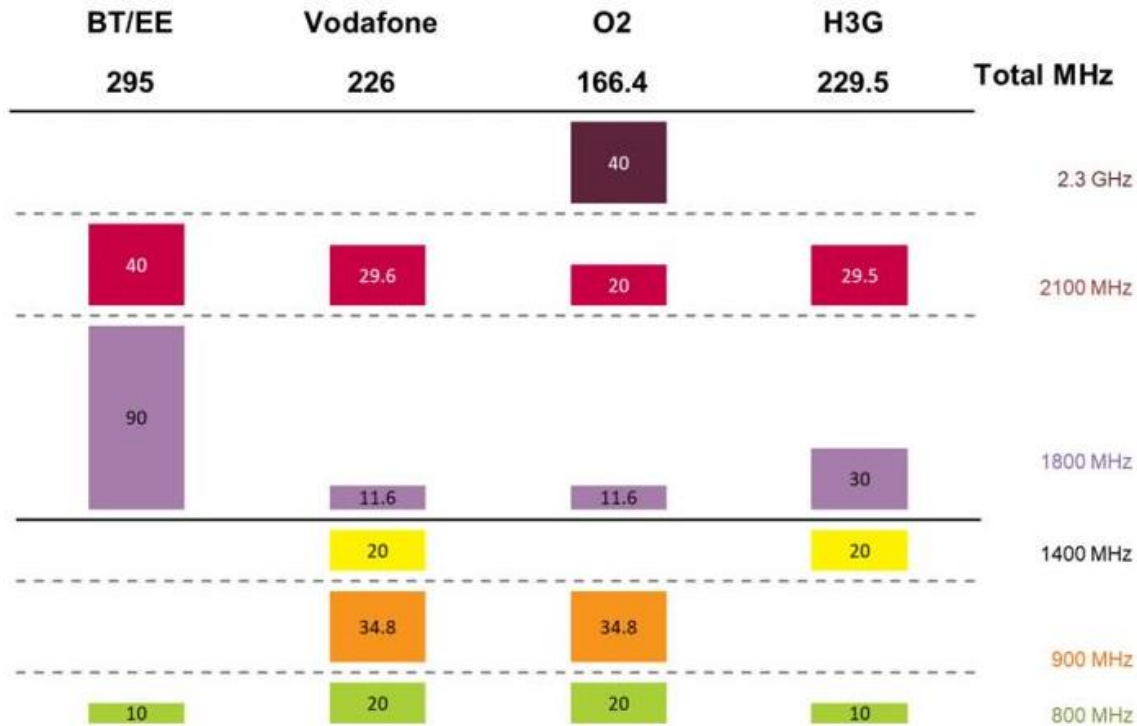
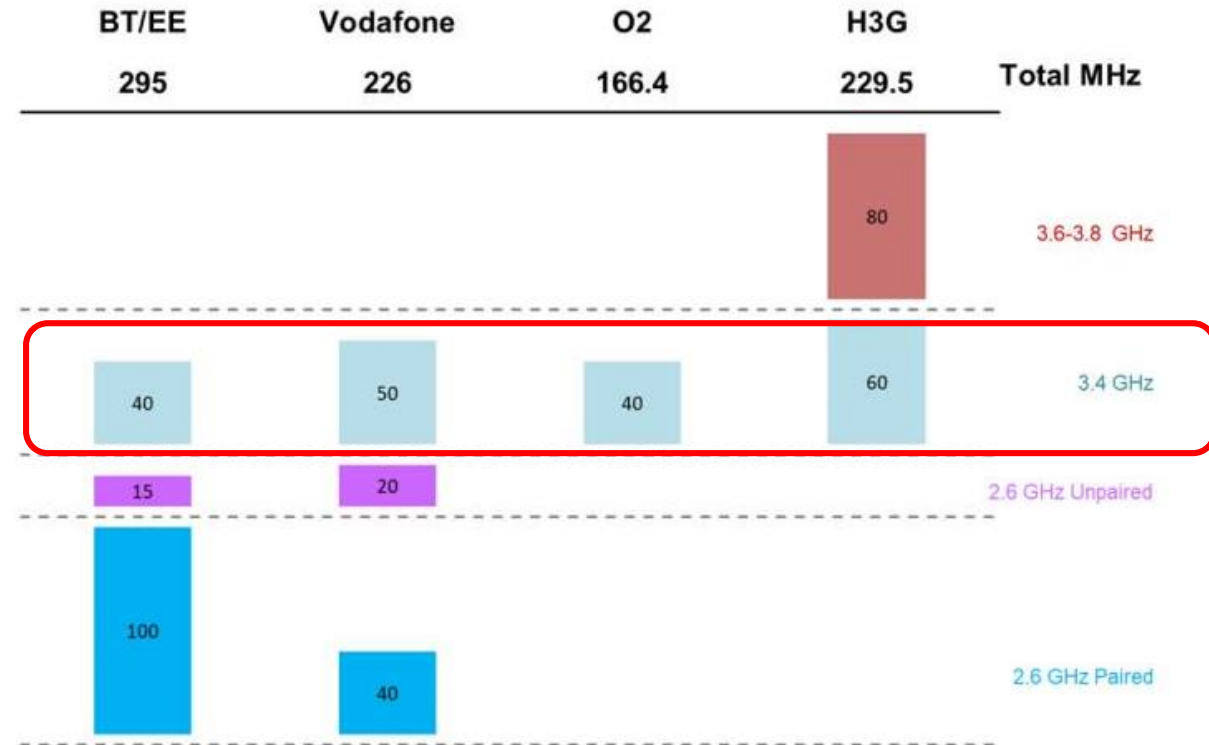


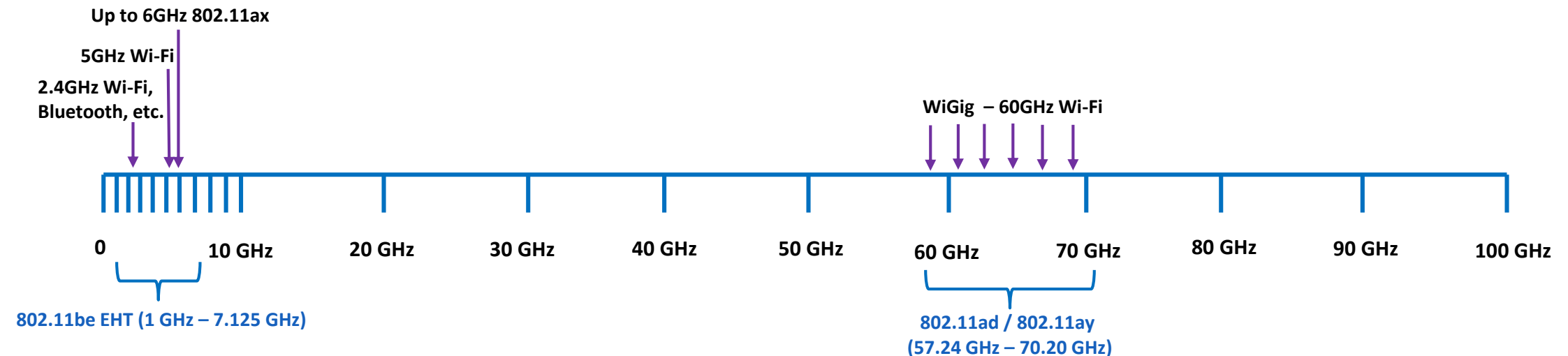
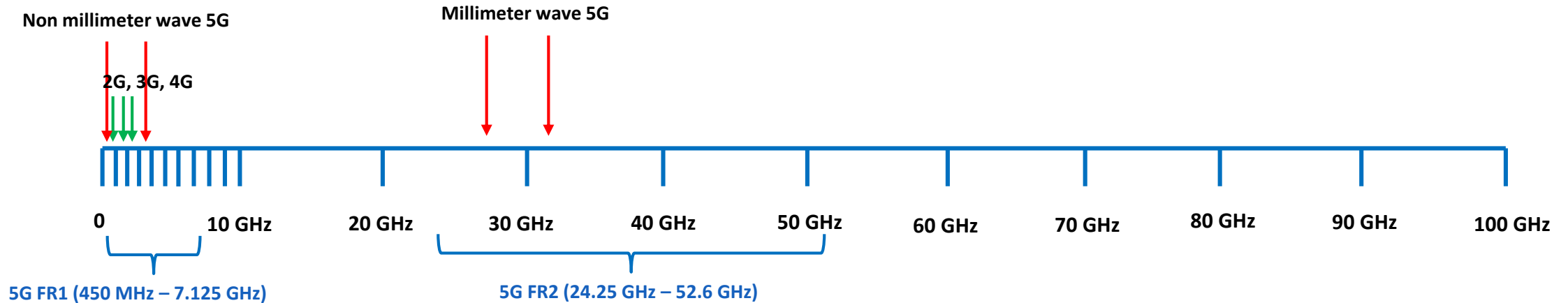
Figure 5.2: UK mobile spectrum holdings⁸²



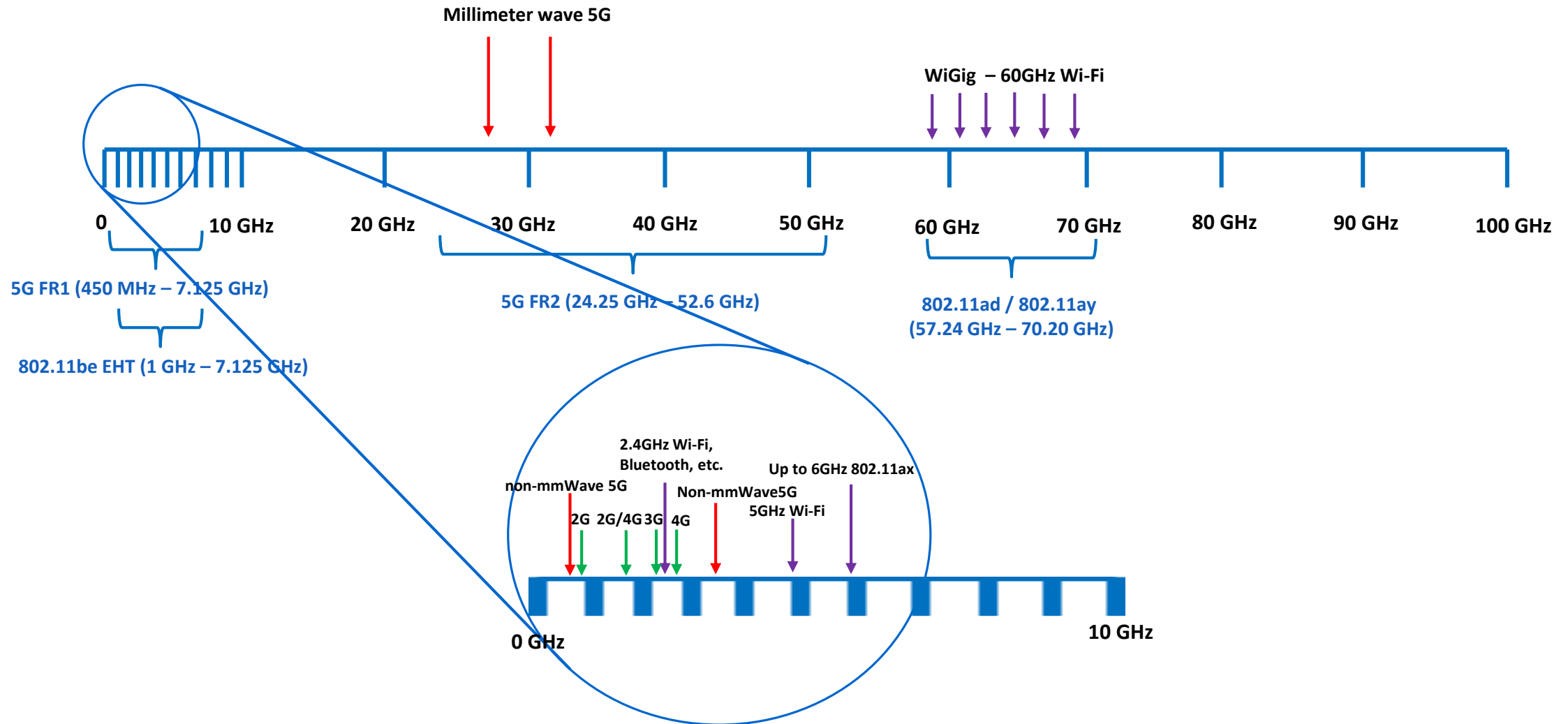
Total amount of spectrum with MNOs = **919.9 MHz**

Source: [Ofcom](http://www.ofcom.gov.uk)

Popular Frequency bands for different Technologies



Popular Frequency bands for different Technologies



Thank You

To learn more, visit:

3G4G Website – <http://www.3g4g.co.uk/>

3G4G Blog – <http://blog.3g4g.co.uk/>

3G4G Small Cells Blog – <http://smallcells.3g4g.co.uk/>

Operator Watch - <http://operatorwatch.3g4g.co.uk/>

Follow us on Twitter: <https://twitter.com/3g4gUK>

Follow us on Facebook: <https://www.facebook.com/3g4gUK/>

Follow us on LinkedIn: <https://www.linkedin.com/company/3g4g>

Follow us on Slideshare: <https://www.slideshare.net/3G4GLtd>

Follow us on Youtube: <https://www.youtube.com/3G4G5G>