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Saint-Petersburg

Qualcomm

5G - technology, spectrum, early use cases

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Qualcomm Incorporated

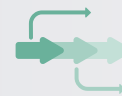
A large graphic on the left side of the slide consists of three concentric circles. The innermost circle is a dark teal color and contains the text '5G' in white. The middle circle is a lighter teal color, and the outermost circle is a very light teal color. The circles have a slight drop shadow, giving them a 3D appearance.

5G

A new kind of network to drive innovation and growth



Significant connectivity upgrade



Smartphone tech is extending into many industries



Consumers want 5G smartphones

\$4.4 Trillion



Enhanced mobile broadband

\$7.9 Trillion



Massive Internet of Things



Mission-critical services

5G NR Rel. 15: eMBB (NSA & SA)

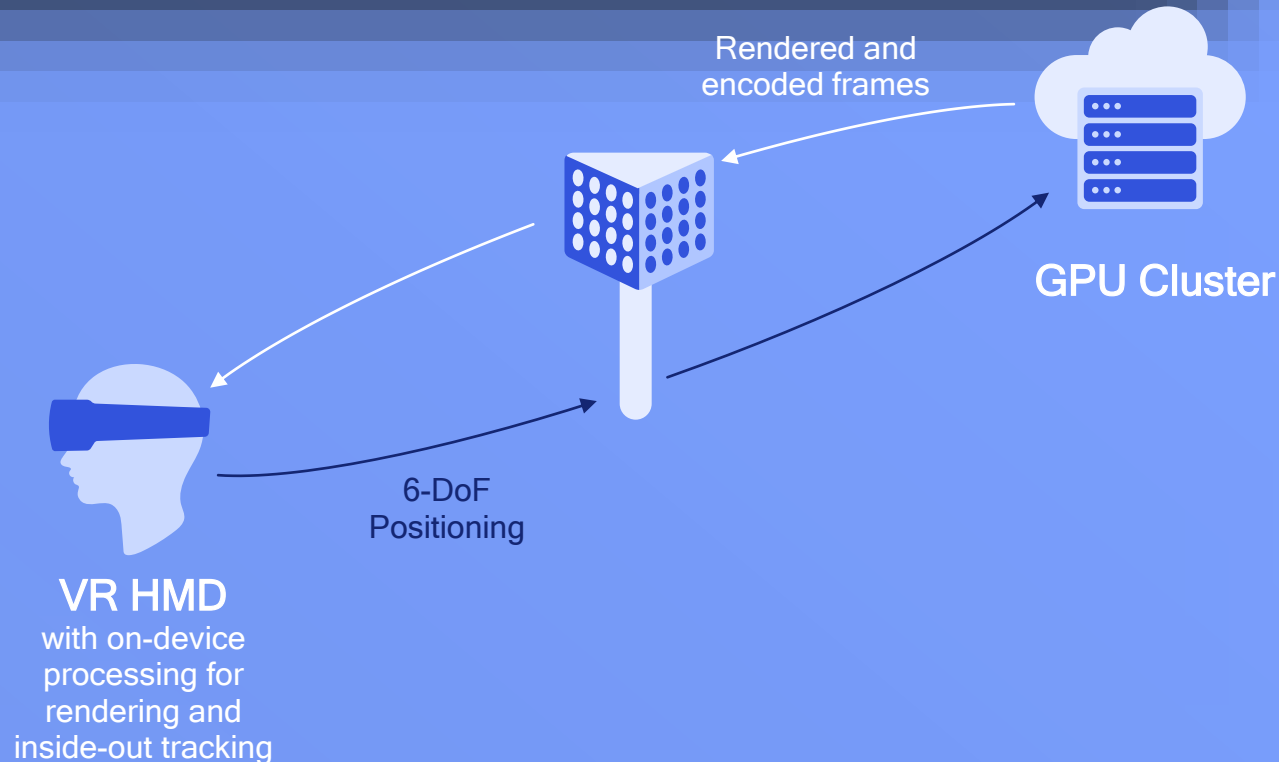
5G NR Rel 16+: Spectrum Sharing, URLLC, C-V2X, NOMA, IAB

Gigabit LTE, LTE Unlicensed, C-V2X, LTE IoT and more...

We are just beginning to unlock the full value of 5G

5G improving today's MBB use cases and enabling new ones

Instantaneous, on-demand ability to complement edge computing power



Low latency

Optimized 5G air interface reduces network delays, local processing closes remaining gap

High speed at cell edge

Speeds up to several hundred Mbps even indoors

Augmenting local compute

Powerful on-device VR processing handles 6-DoF tracking + local rendering to reduce perceived latency

Photo-realistic VR gaming

Powerful combination of optimized, high performance mobile GPU with high-end gaming GPU.

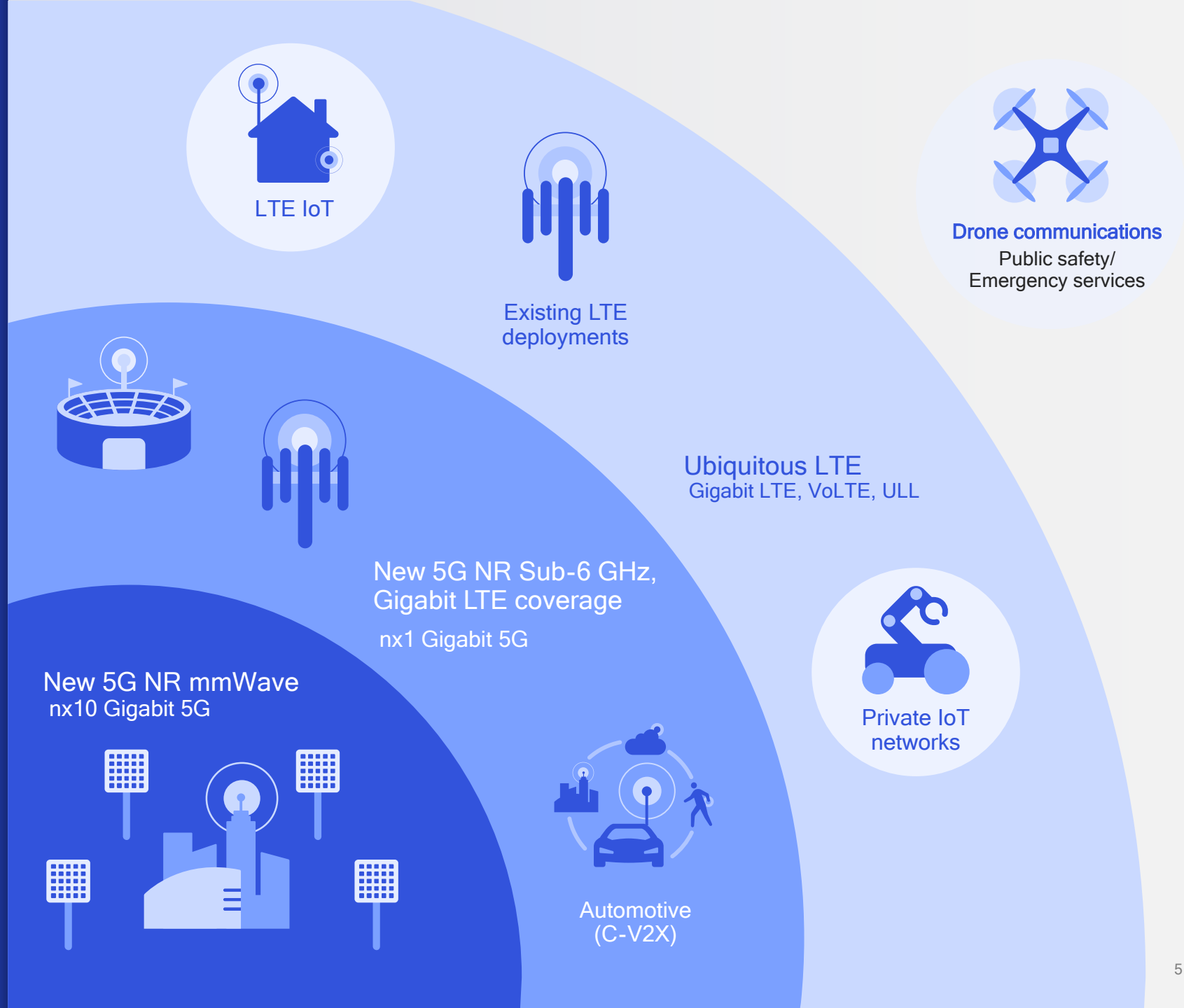
A multi-layer, multi-service 5G network

Supported by strong gigabit LTE operator and OEM momentum

45 Operators

26 Countries

17 Gigabit LTE Devices



Bands for 5G New Radio (NR)

Frequency range designation n	Corresponding frequency range
FR1	450 - 6000 MHz
FR2	24250 - 52600 MHz

The frequency ranges in 3GPP Release 15 for 5G NR designed for the frequency ranges FR1 and FR2

NR operating band	Uplink (UL) and Downlink (DL)	Duplex Mode
n257	26500 MHz - 29500 MHz	TDD
n258	24250 MHz - 27500 MHz	TDD
n260	37000 MHz - 40000 MHz	TDD

5G NR bands in FR2

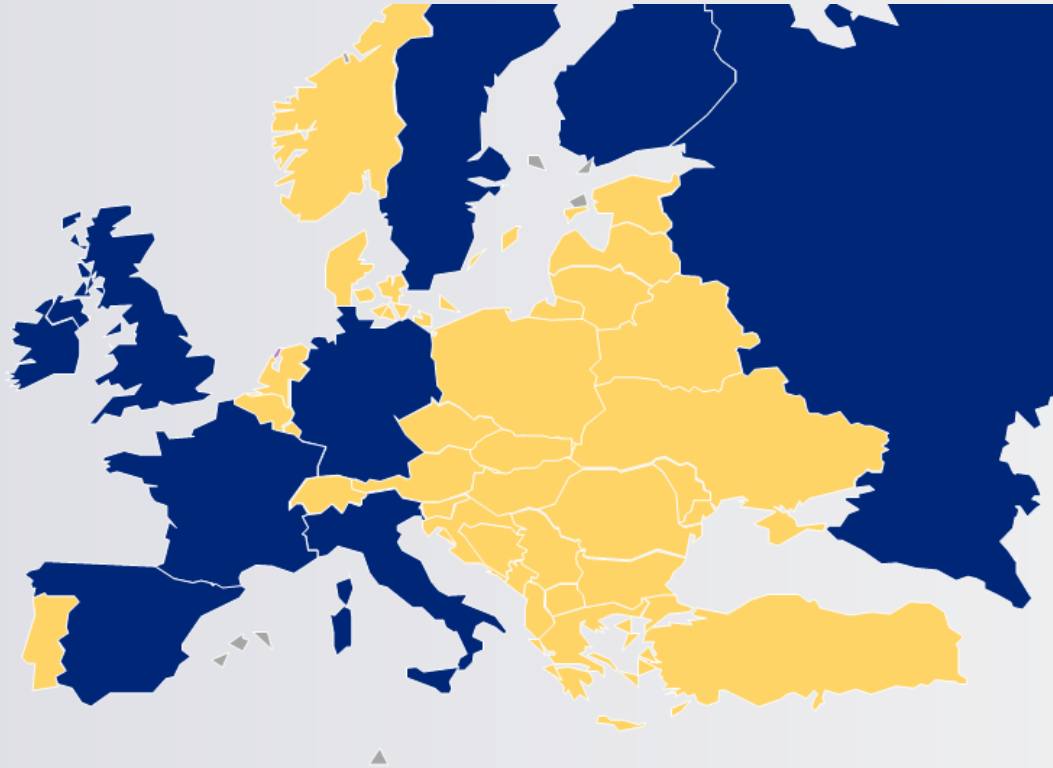
All the European harmonized bands for MFCN are specified as 5G NR bands by 3GPP


NR operating band	Uplink (UL) operating band	Downlink (DL) operating band	Duplex Mode
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
n20	832 MHz - 862 MHz	791 MHz - 821 MHz	FDD
n28	703 MHz - 748 MHz	758 MHz - 803 MHz	FDD
n38	2570 MHz - 2620 MHz	2570 MHz - 2620 MHz	TDD
n41	2496 MHz - 2690 MHz	2496 MHz - 2690 MHz	TDD
n50	1432 MHz - 1517 MHz	1432 MHz - 1517 MHz	TDD
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

5G NR bands in FR1


EUROPEAN COMMISSION DRIVING A GIGABIT SOCIETY¹

Deploying 5G across Europe by 2020 with pre-commercial trials starting in 2018




 Band	Award
--	-------


- 3.4 - 3.8 GHz (350 Mhz) 2017
- 26 GHz 2018

 Band	Award
--	-------


- 3.46 - 3.8 GHz 2018/2019
- 26 GHz 2019/2020

 Band	Award
--	-------

- 3.6-3.8 GHz 2018
- 26.5 - 27.5 GHz 2019/2020

 Band	Award
--	-------


- 3.6 - 3.8 GHz 2018
- 26.5 - 27.5 GHz 2018

 Band	Award
--	-------

- 3.4 - 3.6 GHz (150 MHz) 2018
- 3.6 - 3.8 GHz (116 MHz) 2019
- 26.5 - 27.5 GHz 2019/2020

 Band	Award
--	-------

- 3.4 - 3.8 GHz 2018
- 26.5 - 27.5 GHz 2018?

 Band	Award
--	-------

- 3.4 - 3.8 GHz 2018
- 26.5 - 27.5 GHz 2019

 Band	Award
--	-------

- 3.4-3.8 GHz 2019/20*
- 26 GHz 2020+*

 Band	Award
--	-------

- 3.4 - 3.8 GHz 2019
- 26.5 - 27.5 GHz 2019

Industry-first evaluation

of real world performance reveals
immense 5G user experience
gains over 4G

Median streaming video quality

8K at 120 FPS with 10-bit color and beyond

from 2K at 30 FPS with 8-bit color for LTE users

Source: Company data and internal analysis
Frankfurt: 3.5 GHz 5G NR + Gigabit LTE multimode vs. Gigabit LTE
San Francisco: 28 GHz 5G NR + Gigabit LTE multimode vs. Gigabit LTE

5G NR Multimode



3.5GHz (sub-6GHz)
Frankfurt

5x

Increase in
capacity

>490Mbps

Median
browsing speed

~7x

Faster
responsiveness



28GHz mmWave
San Francisco

5x

Increase in
capacity

1.4Gbps

Median
browsing speed

~23x

Faster
responsiveness

Frankfurt

Active Devices

13,375

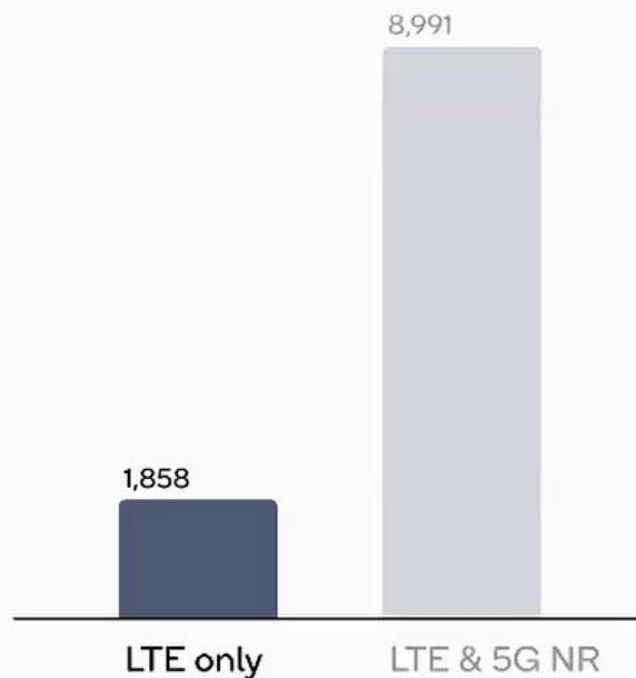
Cell sites

11

Cell loading

65%

Total throughput
(Mbps)



User location

 49%

Indoor

 51%

Outdoor

LTE only

Cat 4
10%

Cat 6
20%

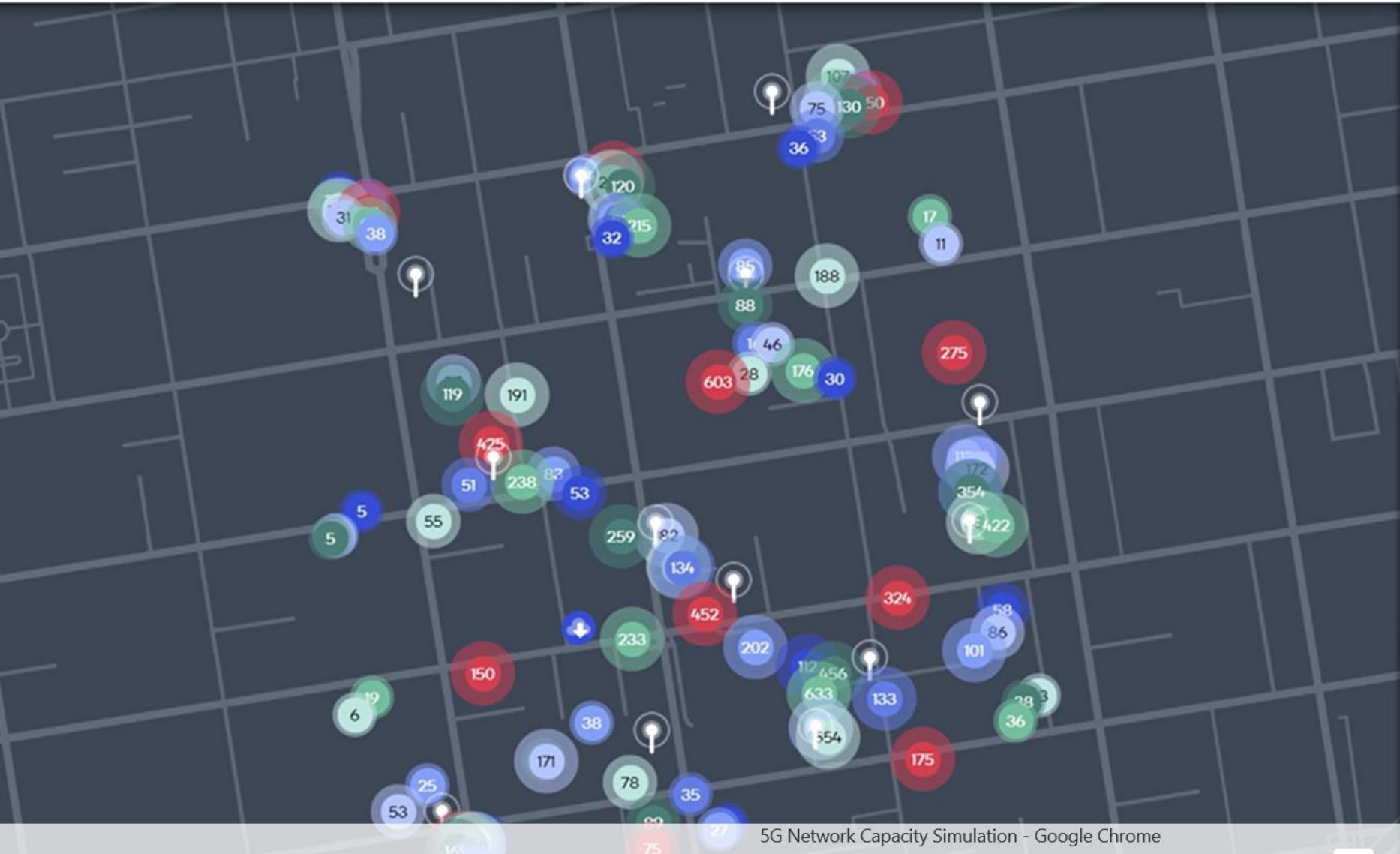
Cat 9
40%

Cat 12
15%

Cat 16
7%

18
5%

20
3%



Device Mix

LTE devices only

LTE + 5G NR devices

Legacy LTE
22%

Gigabit LTE
51%

5G NR
26%

Cat 4 3%

Cat 16 13%

mmWave 26%

Cat 6 5%

Cat 18 17%

Cat 9 6%

Cat 20 21%

Cat 12 8%

Traffic Type



Stream



Download



Browse



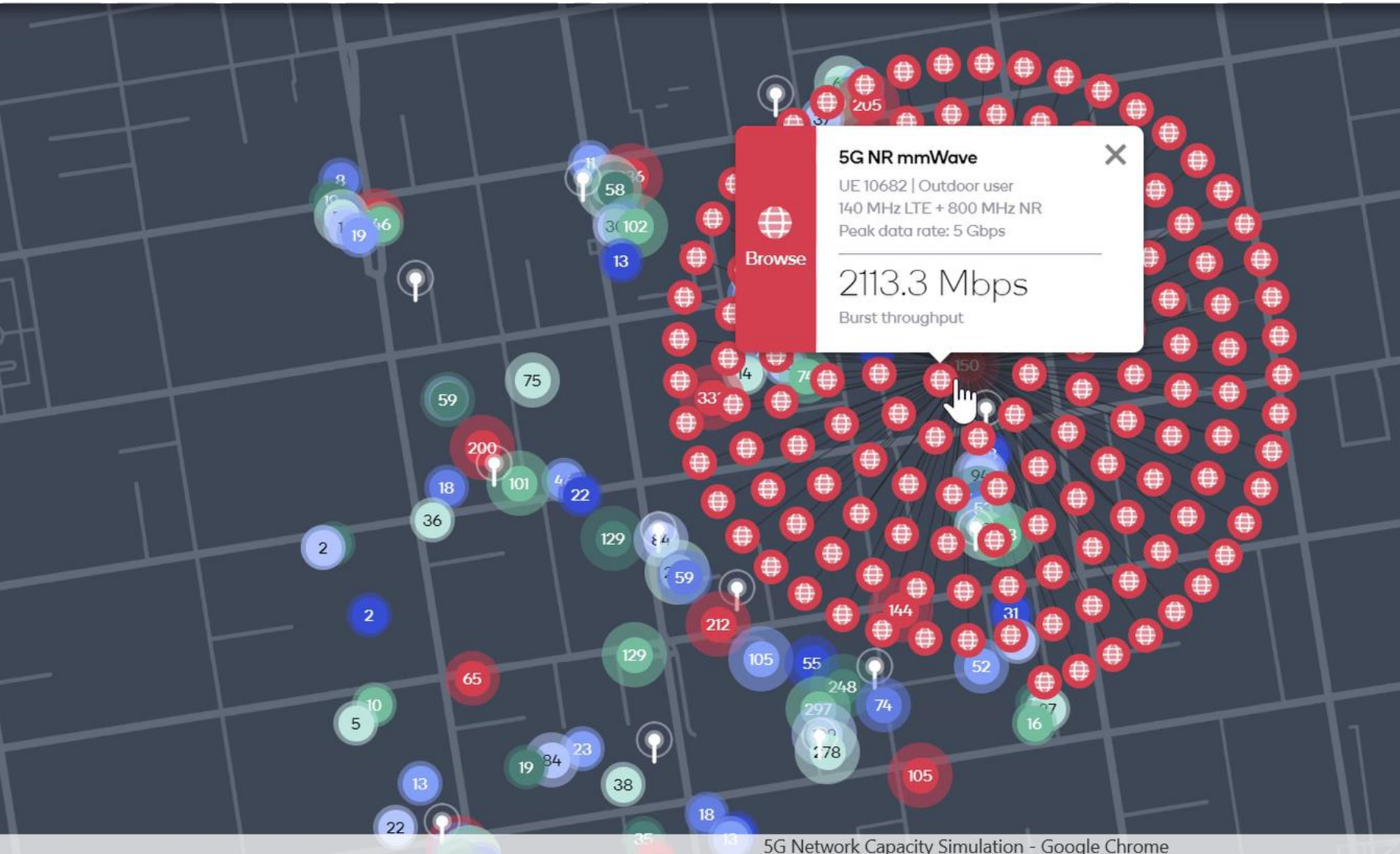
Explore



Compare



Data



Device Mix

LTE devices only

LTE + 5G NR devices

Legacy LTE

22%

Gigabit LTE

51%

5G NR

26%

Cat 4 3%

Cat 6 5%

Cat 9 6%

Cat 12 8%

Cat 16 13%

Cat 18 17%

Cat 20 21%

mmWave 26%

Traffic Type



Stream



Download



Browse



Data



Traffic type
Bursty



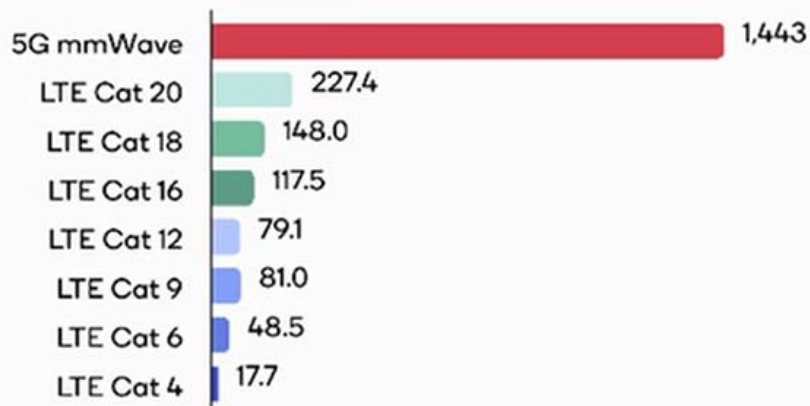
Zone
Entire
Network



Device ranking
50th
percentile

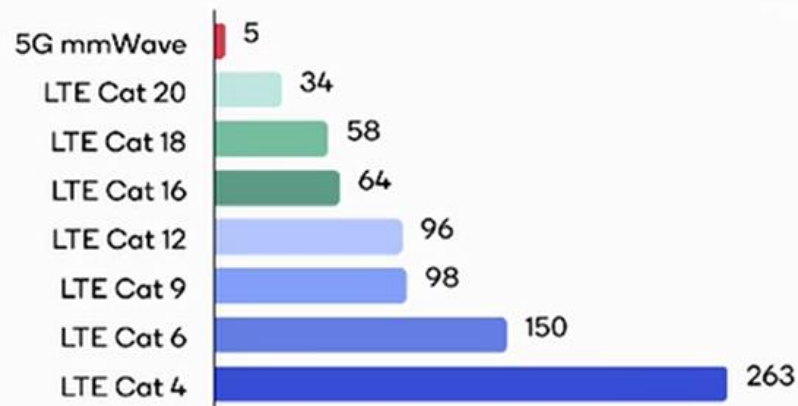
Throughput

Data rate (Mbps) | Higher is better



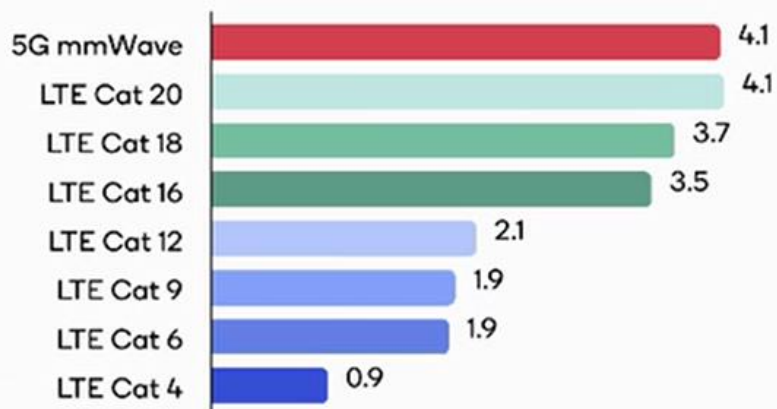
Download Latency

Milliseconds | Lower is better



Spectral efficiency

bps / Hz | Higher is better



MIMO Rank

Higher is better



LTE & 5G NR

4

Cat 6

Cat 9

Cat 12

Cat 16

Cat 18

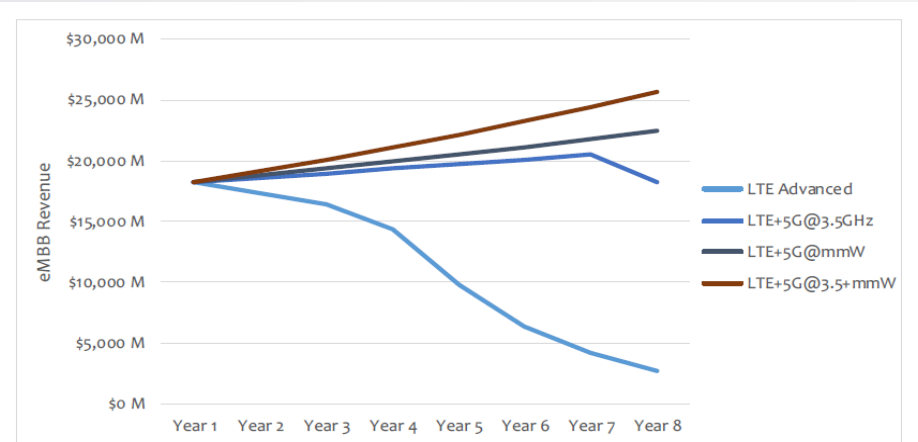
Cat 20

NR mmWave

Economic Modeling

Cost per bit in 5G is by far more lower than in LTE, especially in mmW

Source: Mobile Experts



Source: Mobile Experts

Figure 15. Mobile Broadband (eMBB) Revenue across LTE/5G network scenarios

BUSINESS CASE: 5G ULTRA-BROADBAND

5G eMBB Summary	NPV (8-year)	weighted avg. cost per GB (at year 8)
LTE Advanced	\$31,658 M	\$ 1.25
LTE + 5G@3.5GHz	\$40,597 M	\$ 0.61
LTE + 5G@mmW	\$53,509 M	\$ 0.39
LTE + 5G@3.5GHz + 5G@mmW	\$42,579 M	\$ 0.32
5G@3.5GHz standalone	\$188 M	\$ 0.16
5G@mmW standalone	-\$1,036 M	\$ 0.03

Source: Mobile Experts

Figure 16. 5G mobile broadband ROI analysis

Winning the race to 5G

Key takeaways

5G is essential to future economic growth





The industry is ready for commercialization in 2019

The full realization of 5G is a multi-year effort

Significant opportunity for public-private partnership to support rapid deployment and long term investment



Thank you

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