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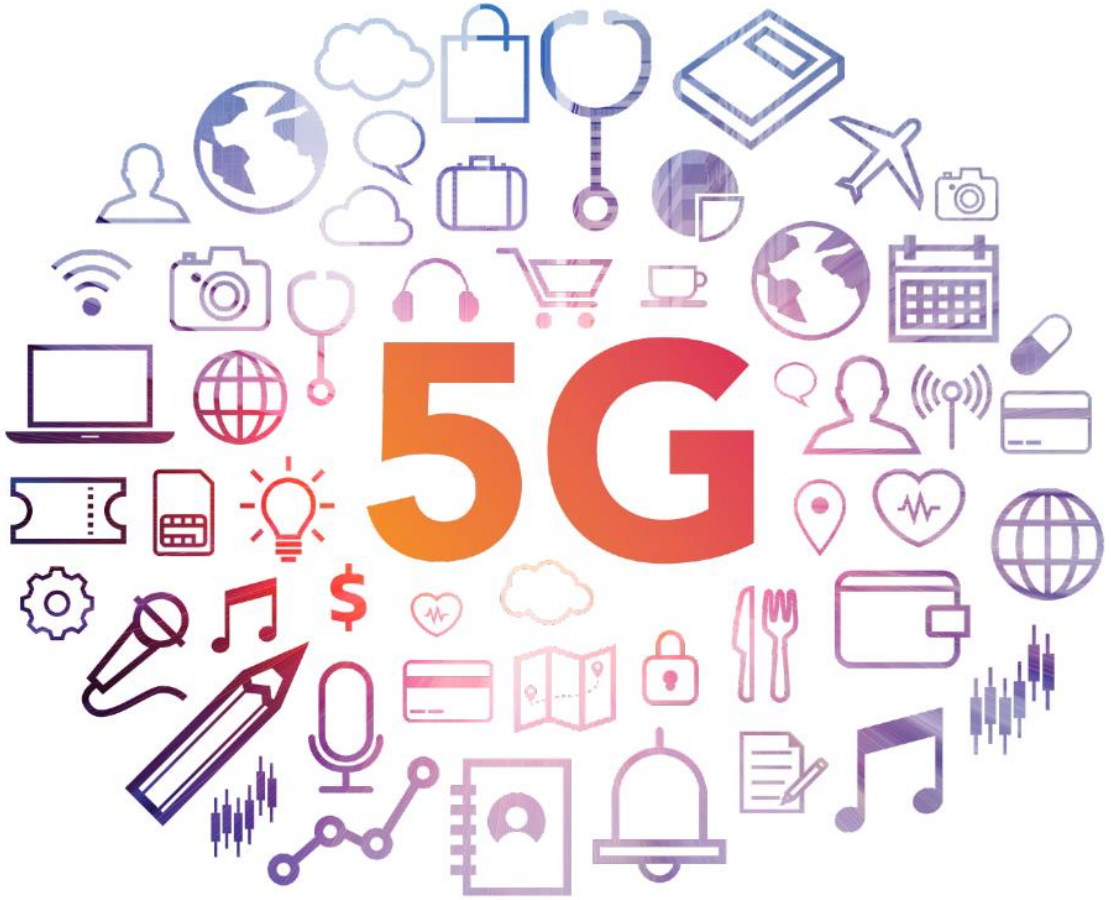
A Teradyne Company

5G Latest Update： Spectrum、Deploy and Production Testing

5G – Elixir of The Next Decade



- 5G contribution to the global economy
- Cellular market penetration
- 5G deployment status
- 5G chipset launches in 2020
- 5G device ecosystem & shipment projections
- 5G IoT testing Consideration

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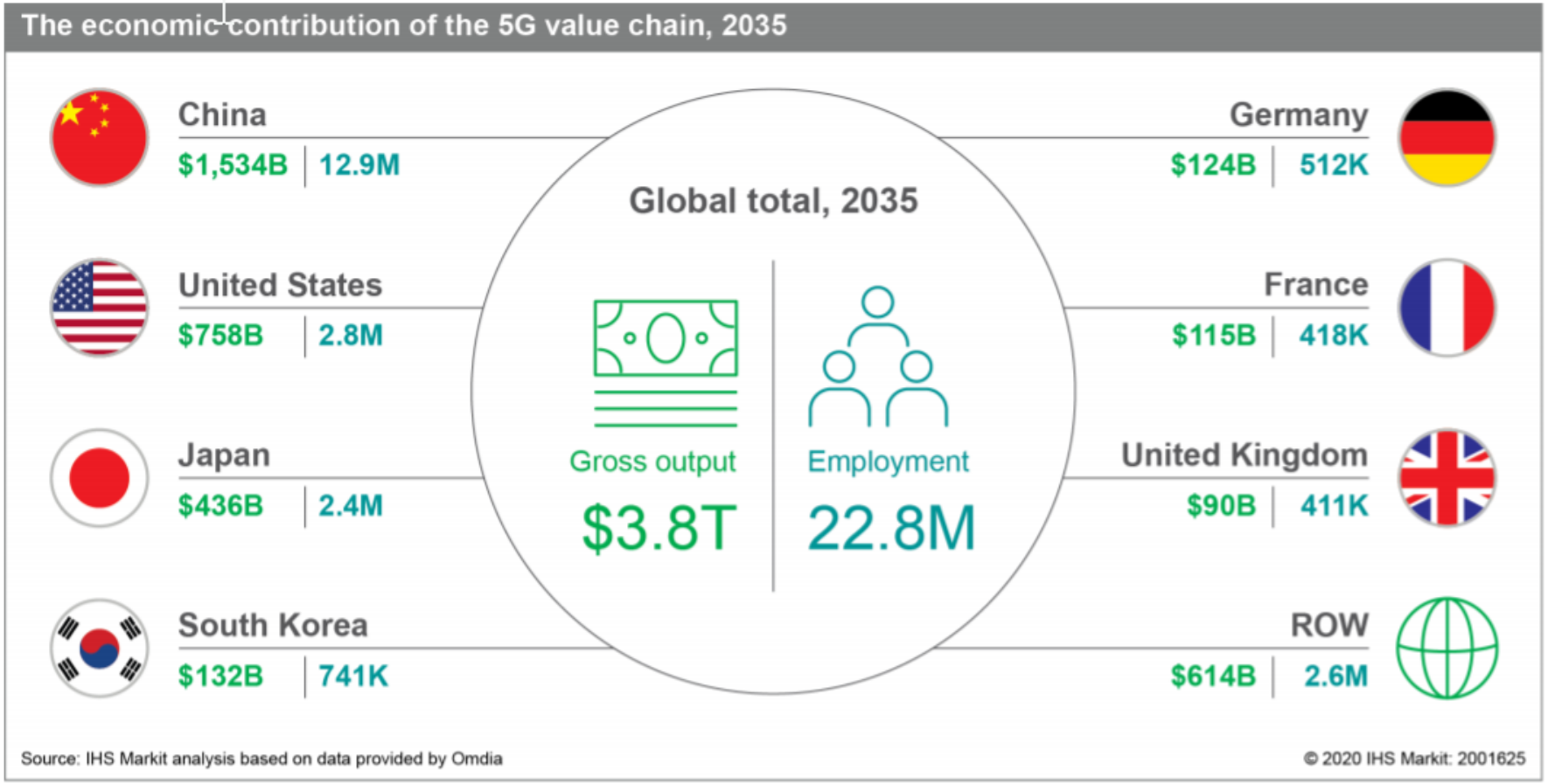
5G Contribution To The Global Economy

1162%

574%

330%

100%



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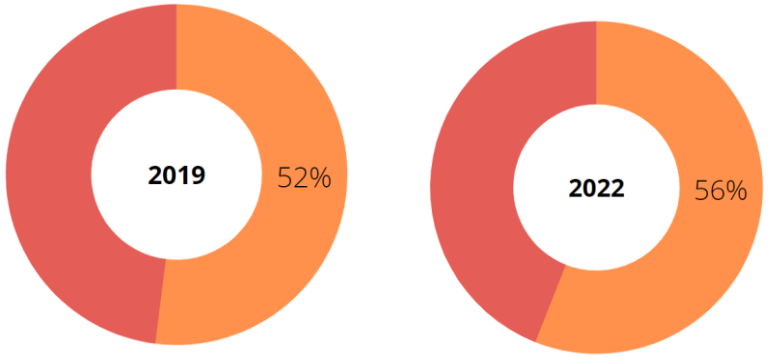
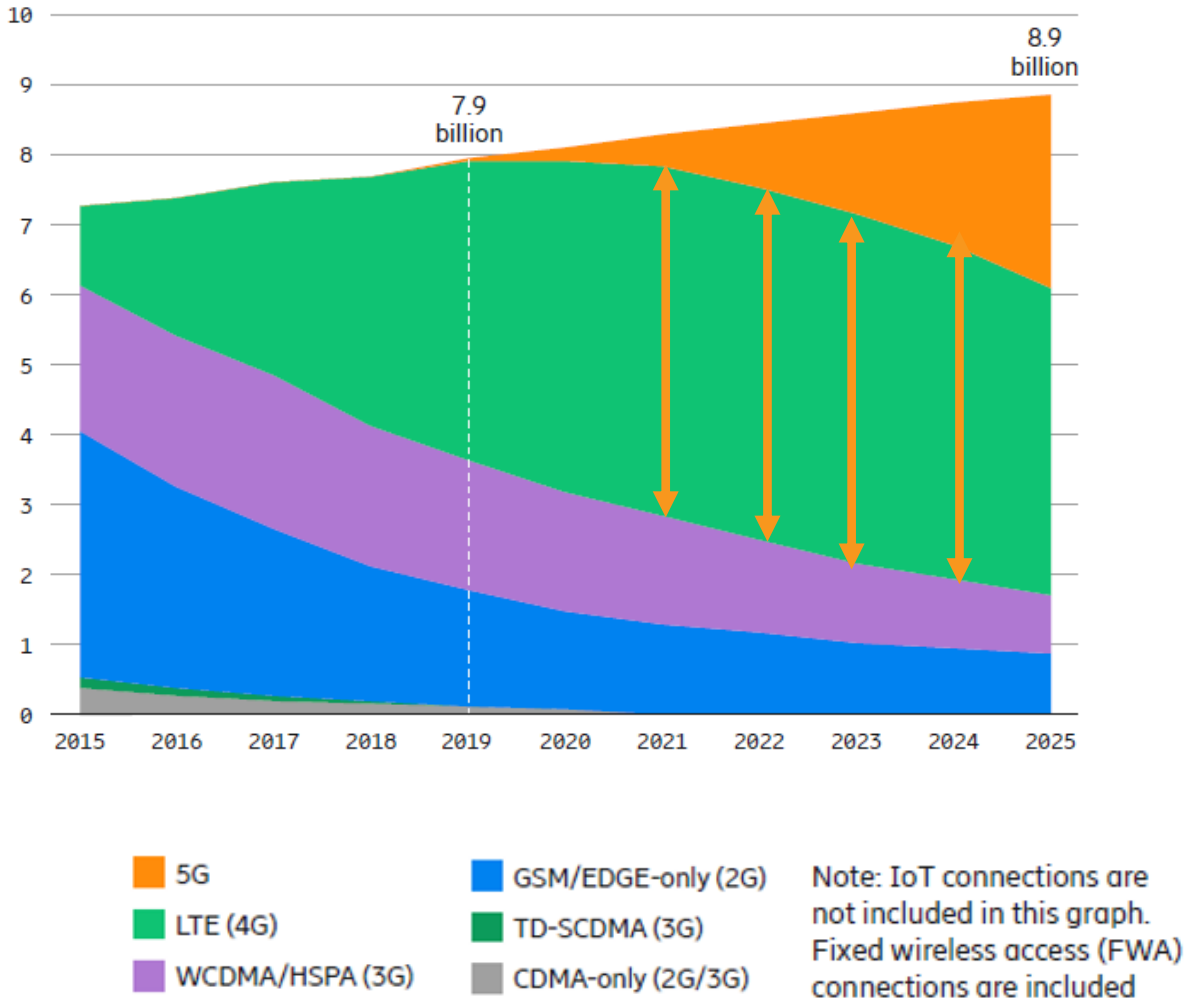
Cellular Market Penetration To Grow Up To 107%

4G dominates with 4 billion connections (~52%) across the world (excluding licensed cellular IoT).



By 2025, 5G will account for 30% of global connections, with a forecast of 2.8 billion 5G subscriptions

Overall cellular penetration rate of 103% is projected to grow up to 107%



Source : Ericsson mobility report

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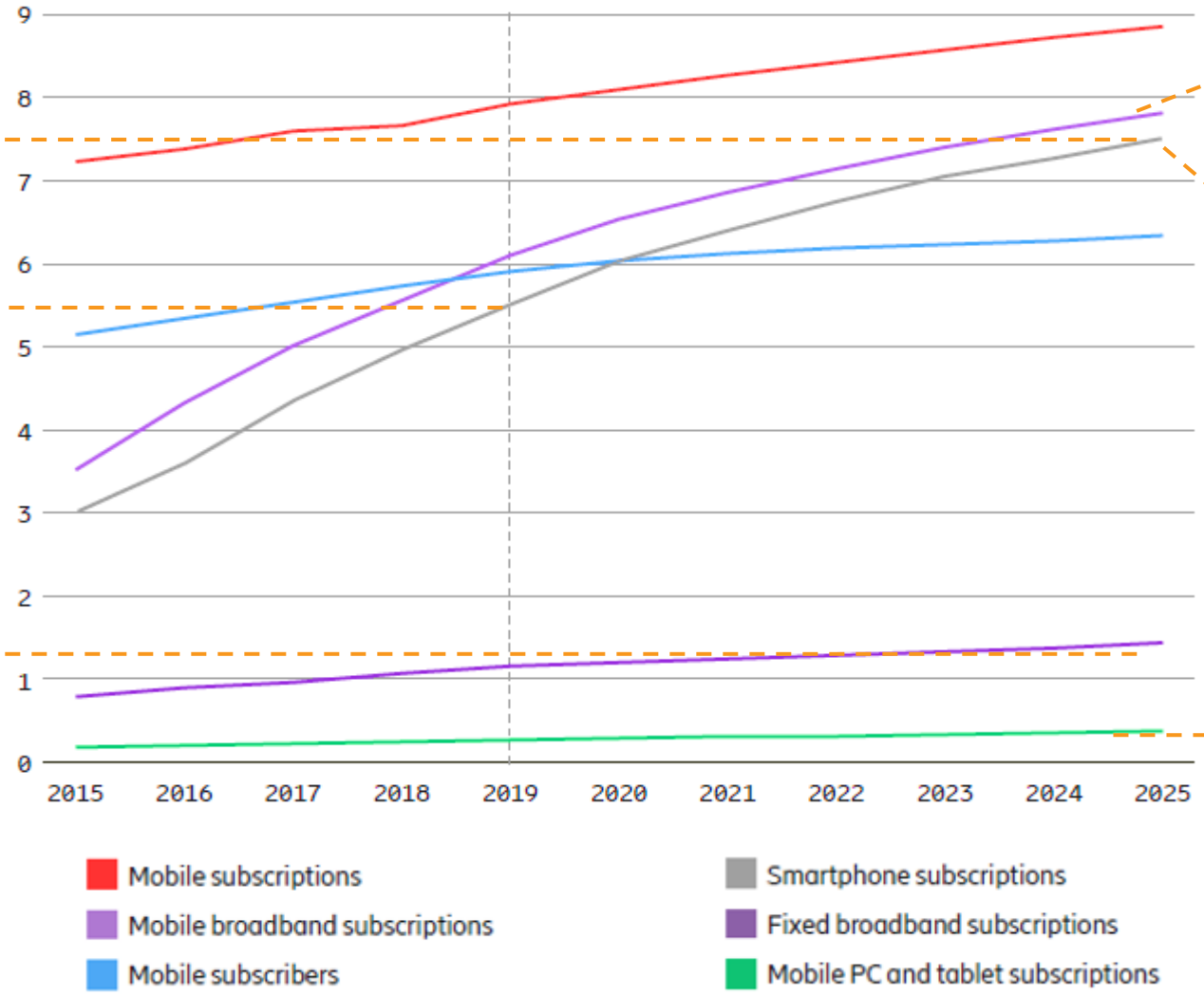
Mobile Subscription Growth

By 2025, its expected to reach 7.5-7.8bn (85%)

5.5bn smartphone subs in 2019

Fixed broadband subs expected to grow by 4% per year through 2025



By 2025, 88% subscriptions are projected to be for mobile broadband

70% of which will come from smartphones

Mobile PCs & tablets subs to reach ~390mil by 2025

Source : Ericsson mobility report

*** FWA subscriptions are not part of the fixed broadband subscription estimate

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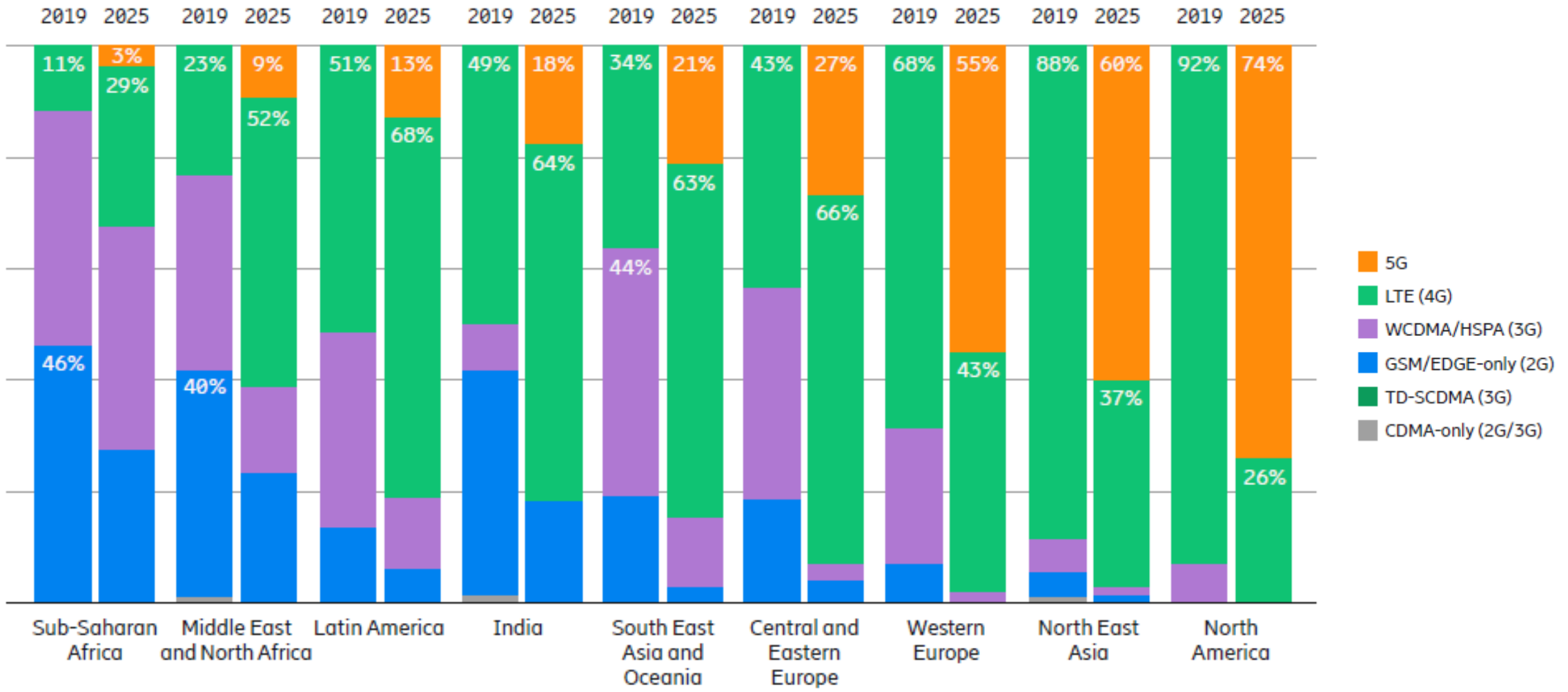
Technology Mix and Global Growth



Source : Ericsson mobility report

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5G Deployment Status

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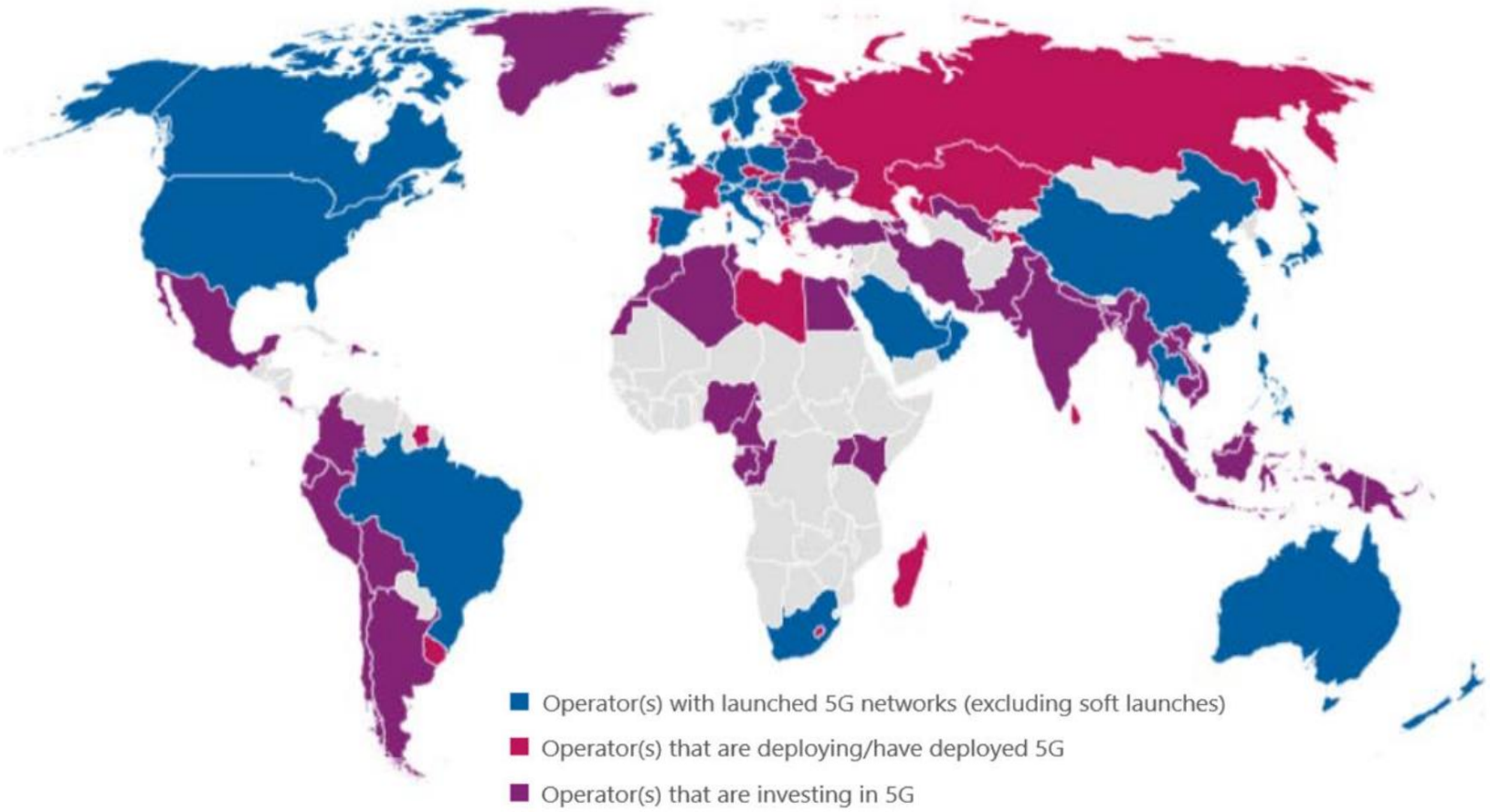
5G Network Deployment Status



- 397 operators in 129 countries are actively investing in 5G
- **96 commercial 5G networks in 41 countries have launched one or more 3GPP-compliant 5G services**.
- ~88 operators had launched 3GPP compliant 5G mobile services
- ~37 operators had launched 5G FWA or home broadband services
- Major build-out in the USA, Greater China & South Korea, and parts of Europe

Source : GSA

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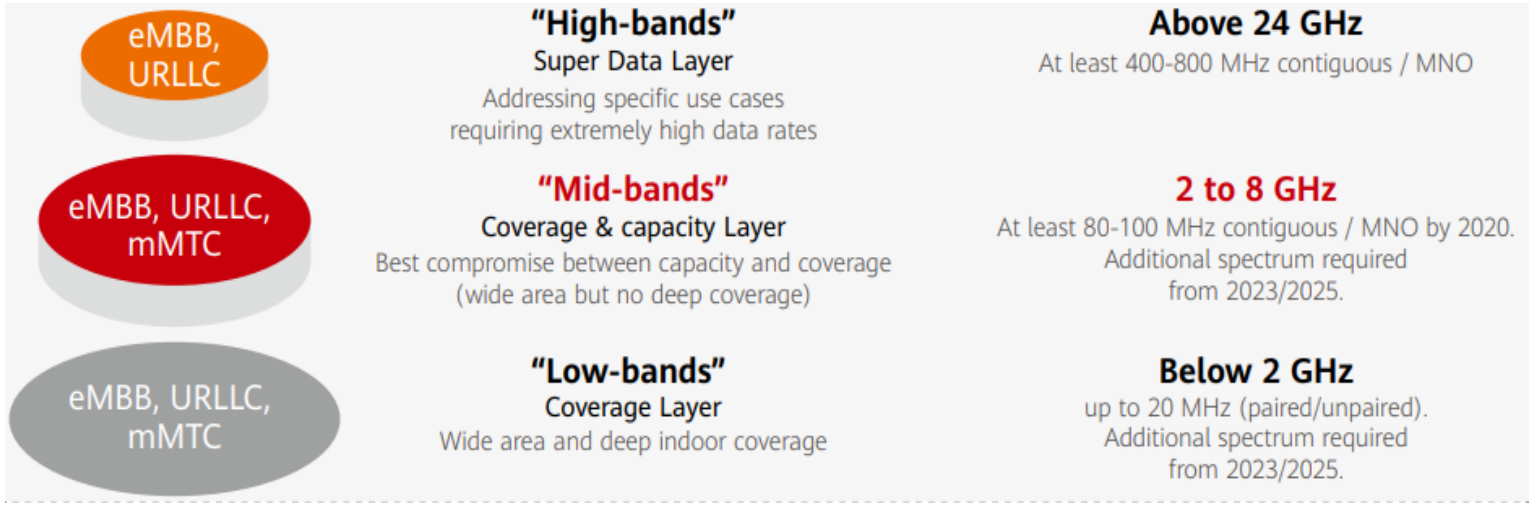
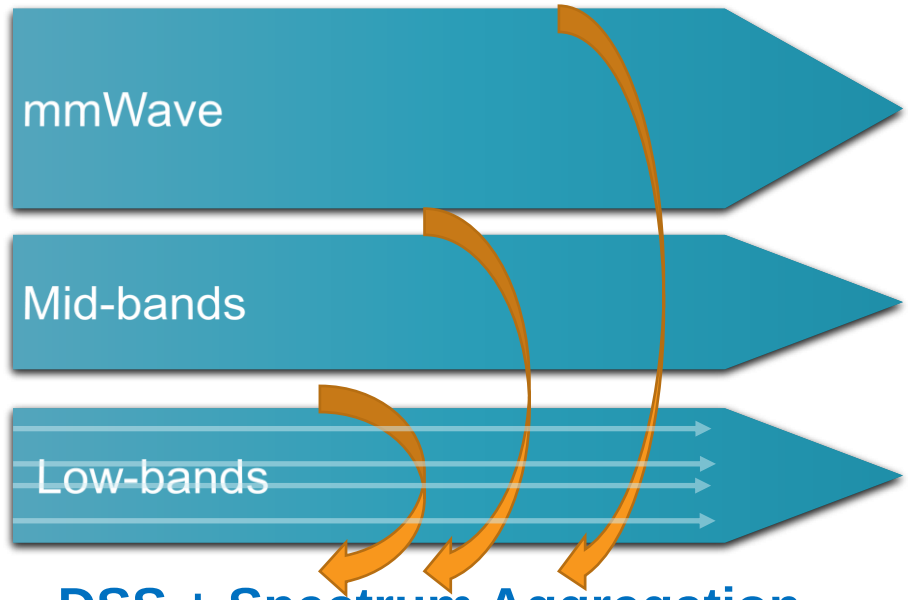
5G Use Cases and Spectrum Support



Source : Huawei



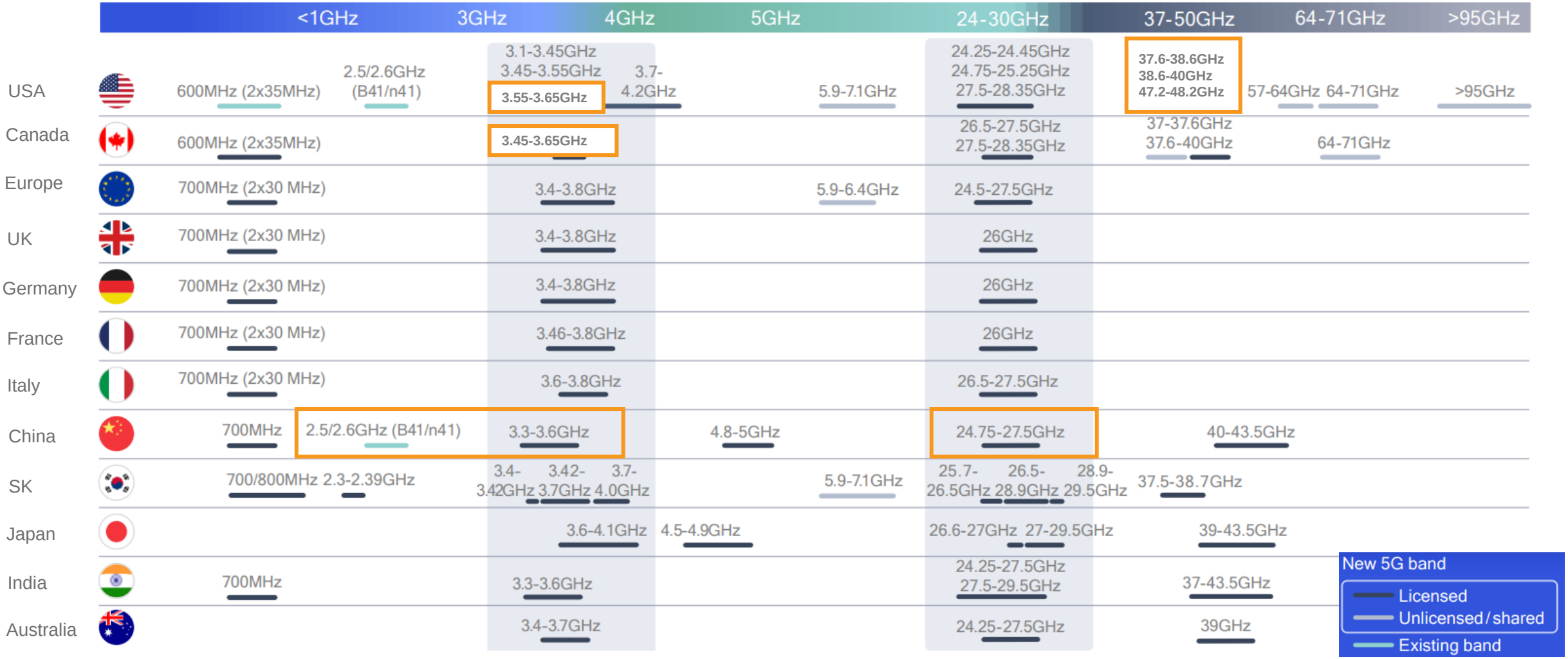
DSS + Spectrum Aggregation
mmWave + sub6

5G/NR - Operating in Frequency Range 1			
Band	Frequencies [MHz]	BW [MHz]	Duplex mode
n77	3300 - 4200	10 - 100	TDD
n78	3300 - 3800	10 - 100	TDD
n79	4400 - 5000	40 - 100	TDD
n80	1710 - 1785 / N/A	5 - 30	SUL
n81	880 - 915 / N/A	5 - 20	SUL
n82	832 - 862 / N/A	5 - 20	SUL
n83	703 - 748 / N/A	5 - 20	SUL
n84	1920 - 1980 / N/A	5 - 20	SUL
n86	1710 - 1780 / N/A	5 - 40	SUL
n90	2496 - 2690	10 - 100	TDD

5G/NR - Operating in Frequency Range 2			
Band	Frequencies [GHz]	BW [MHz]	Duplex mode
n257	26.5 - 29.5	50 - 400	TDD
n258	24.25 - 27.5	50 - 400	TDD
n259	39.5 - 43.5	50 - 400	TDD
n260	37.0 - 40.0	50 - 400	TDD
n261	27.5 - 28.35	50 - 400	TDD

Source : Ericsson

Global Snapshot of 5G Spectrum



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Source : Qualcomm

5G Availability in USA

verizon

- Primary 5G spectrum n261 (28GHz), n260(39GHz)
- Focus on ultra wide band (mobile) and fixed wireless internet
- Recently earned CBRS spectrum 3.55-3.65GHz
- Plans to use Dynamic Spectrum Sharing (DSS) across 700 MHz, 1700MHz band
- Plans to re-farm - 850 MHz, 1900 MHz from 3G to 4G by end of 2020

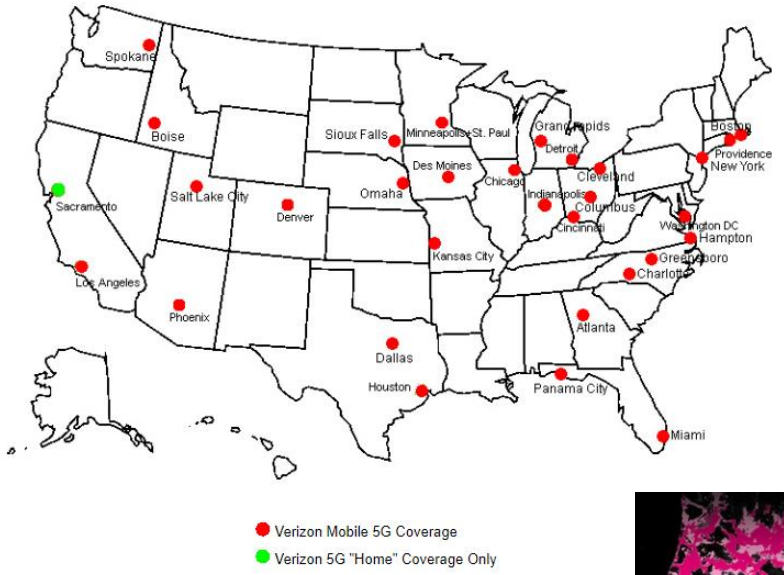
- Primary 5G spectrum on 850MHz, 1900MHz, n260(39GHz)
- DSS in use in 1-2 cities in Texas and Florida
- Plans to turn off 3G network by 2022

Sprint
Now part of
T-Mobile

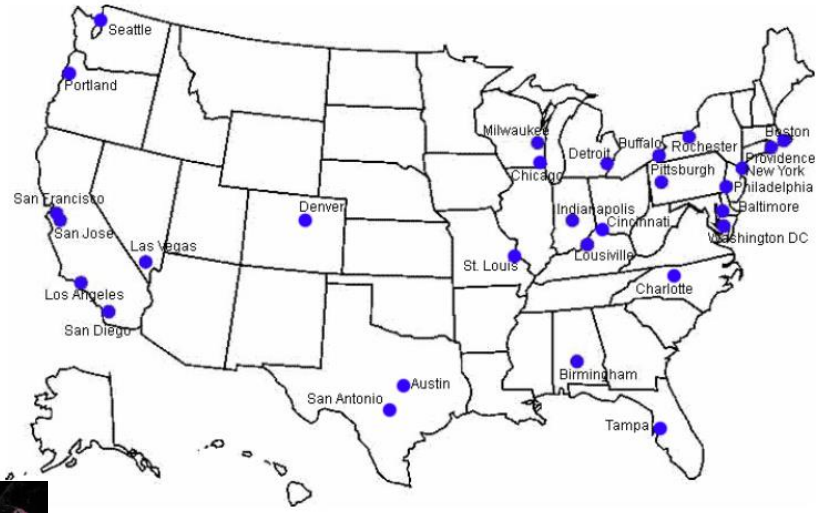
- Primary 5G spectrum - n71 (600MHz), n41 (2.5 GHz), n260 (39GHz), n261 (28GHz)
- Uses “5G layer cake strategy” for coverage and capacity
- Refarming sprint’s 5G
- Launched first 5G standalone network in 600MHz

5G Deployment Across USA

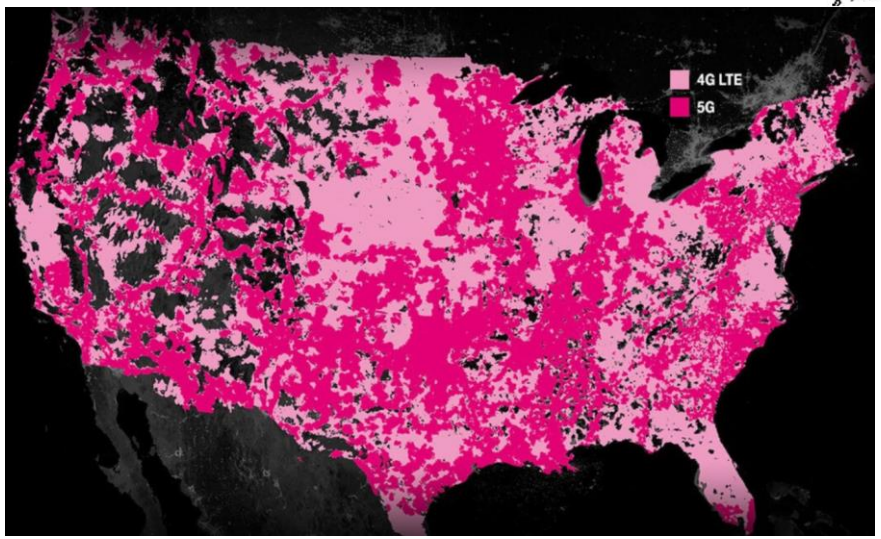
verizon wireless



AT&T Wireless



T-Mobile



Source : Cellularmaps.com

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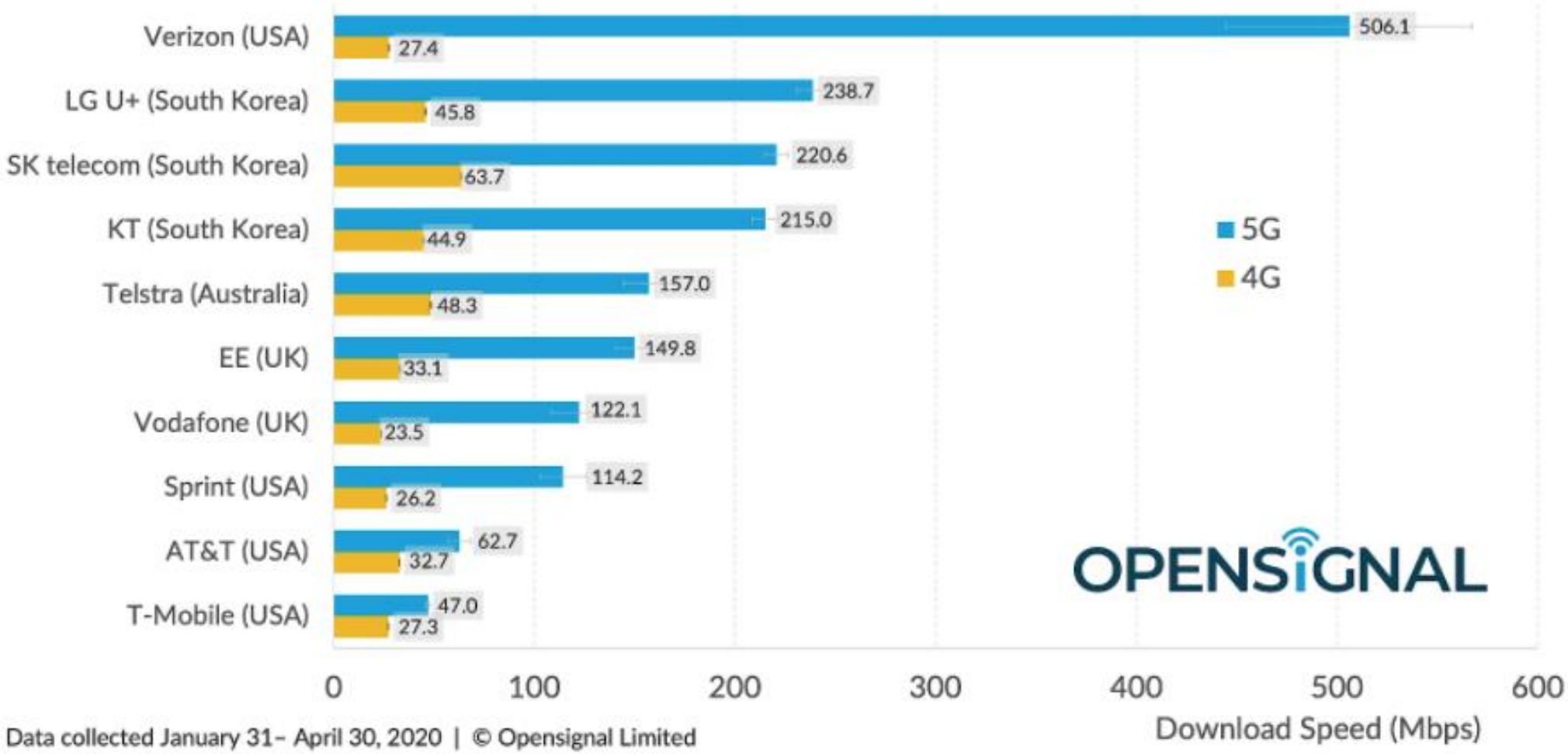
5G Average Download Speeds



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5G Device Ecosystem

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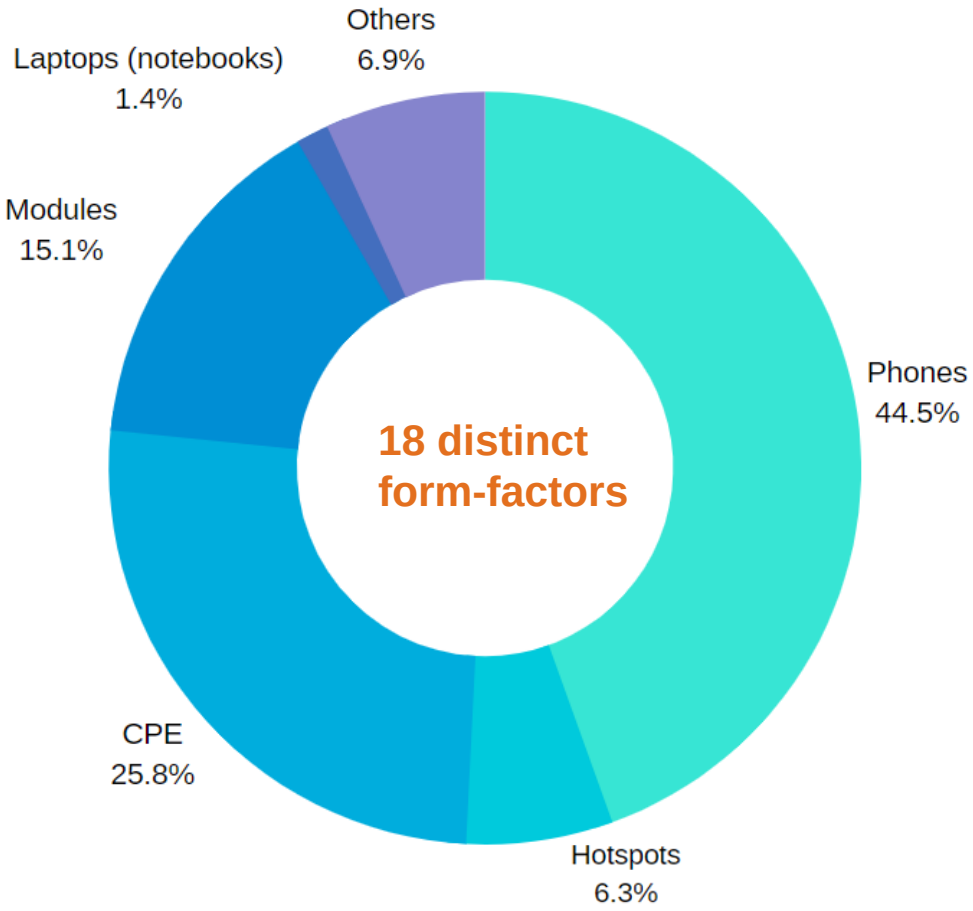
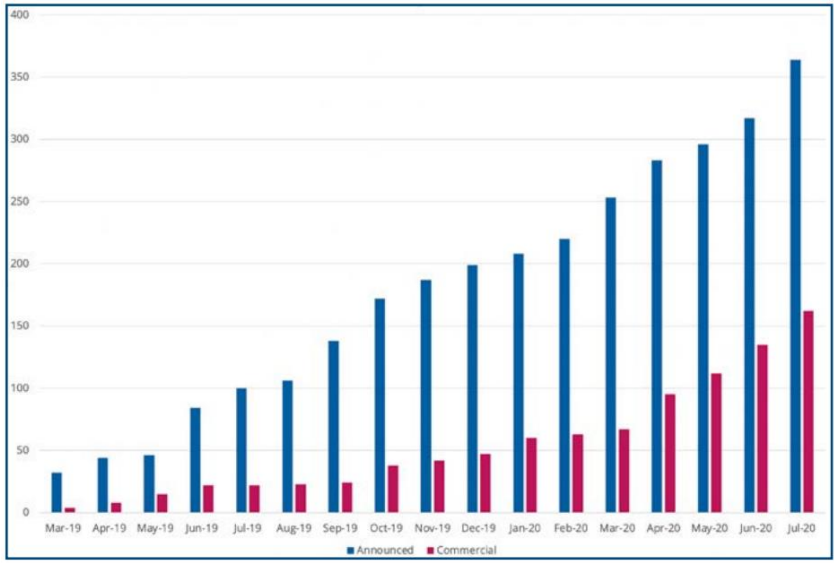
Nearly 162 5G Devices Commercially Available



Total 364 5G devices announced



Product by spectrum (total announced devices)

Product by spectrum (commercially devices)

- 87% - Support Sub-6GHz
- 19.1% - Support mmWave

Source: GSA

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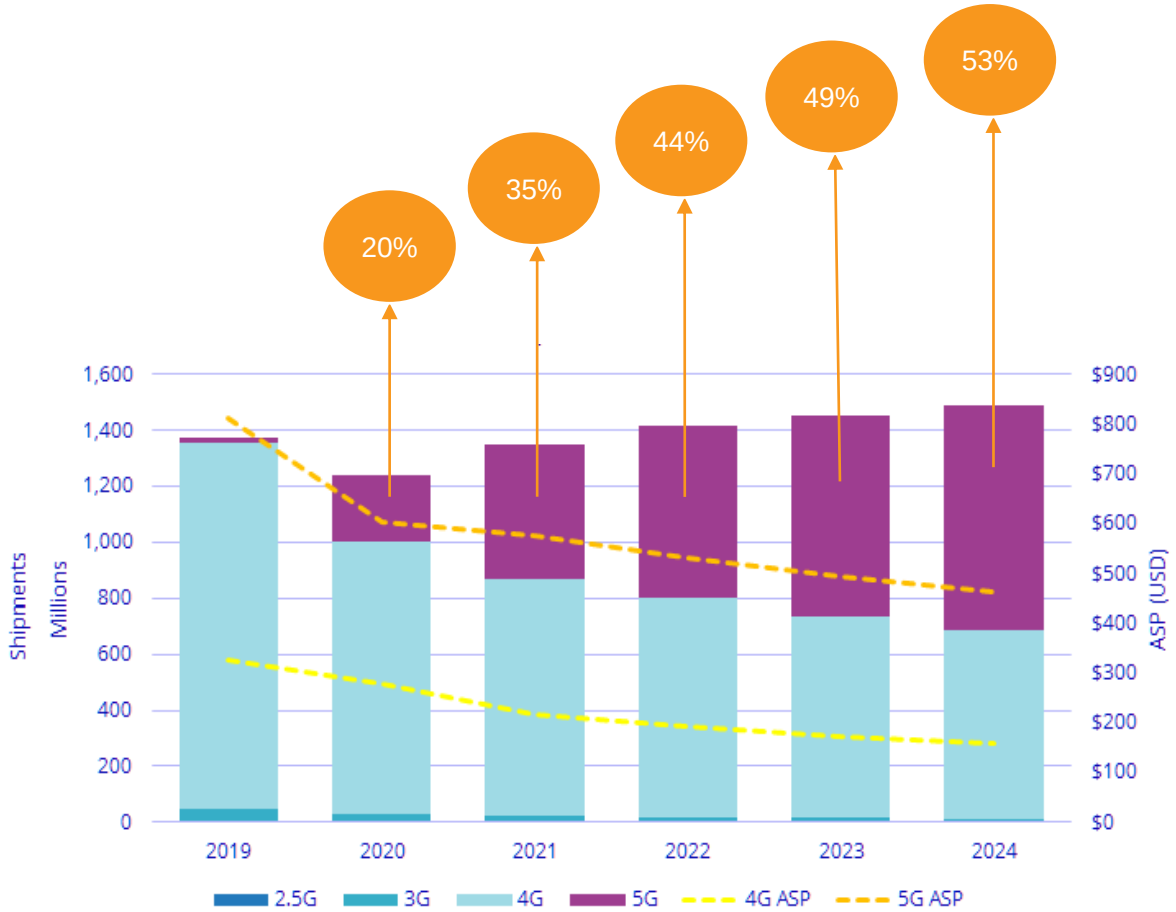
5G Smartphone Shipment Projections

Shipment by spectrum	2019	2020	2021	2022
Sub-6GHz	22	177	373	462
mmWave	0	2	60	160
LTE	1275	922	791	727
Total (million)	1297	1101	1225	1349



Global smartphone shipments

mmWave smartphone shipments will see a surge in year 2021 and beyond

Source: IDC

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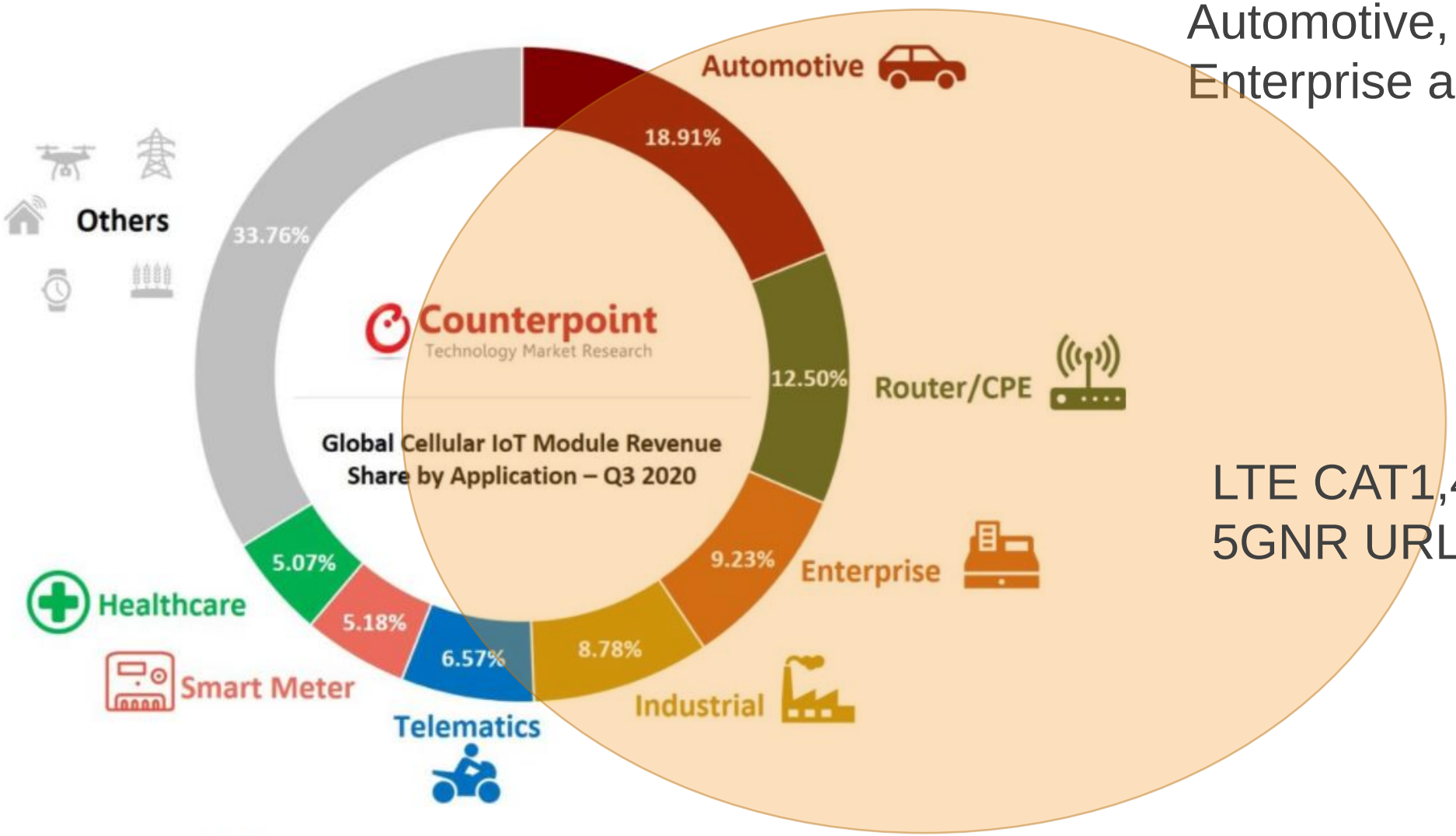
Applications for cellular IoT modules



Automotive, Router/CPE and Enterprise are the top three

LTE CAT1,4 low cost to 5GNR URLLC & eMBB

Source: Global Cellular IoT Module by Brand by Tech by Application Tracker, Q3 2020

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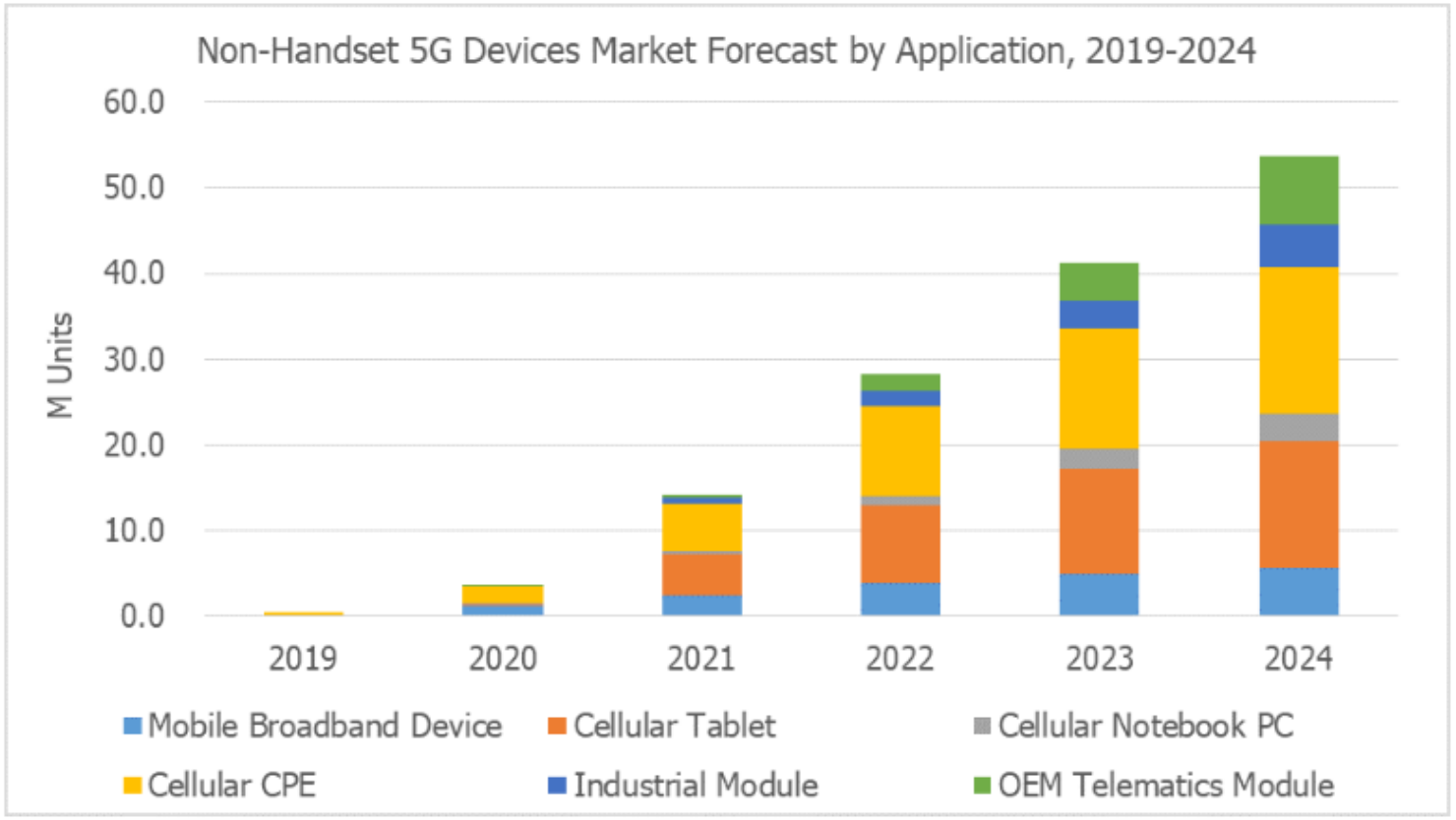
5G Non-handset Device Market

Primary drivers: **Cellular CPE (#1)** and Cellular tablets



Source: IoT Business News

Total 5G devices forecast to reach ~200 million units in 2020 & ~900 million in 2024.

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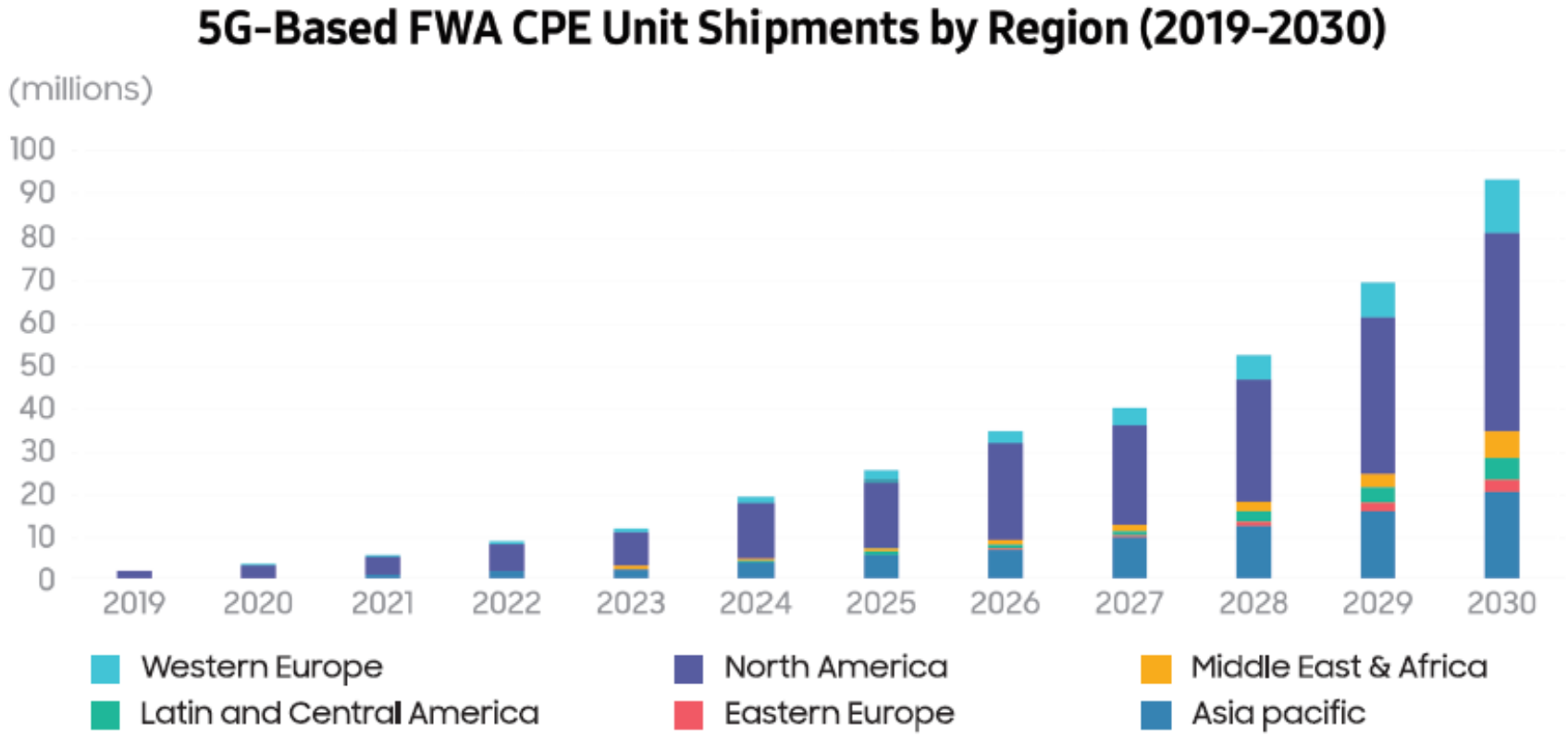
5G FWA CPE Units Shipments by Region

- 5G-based FWA CPE shipment growth (forecast)
  - 2020: 2 Million+ units
  - 2025: 25 Million+ units
  - CAGR of 57% from 2019 to 2025



(Source : SNS Telecom)

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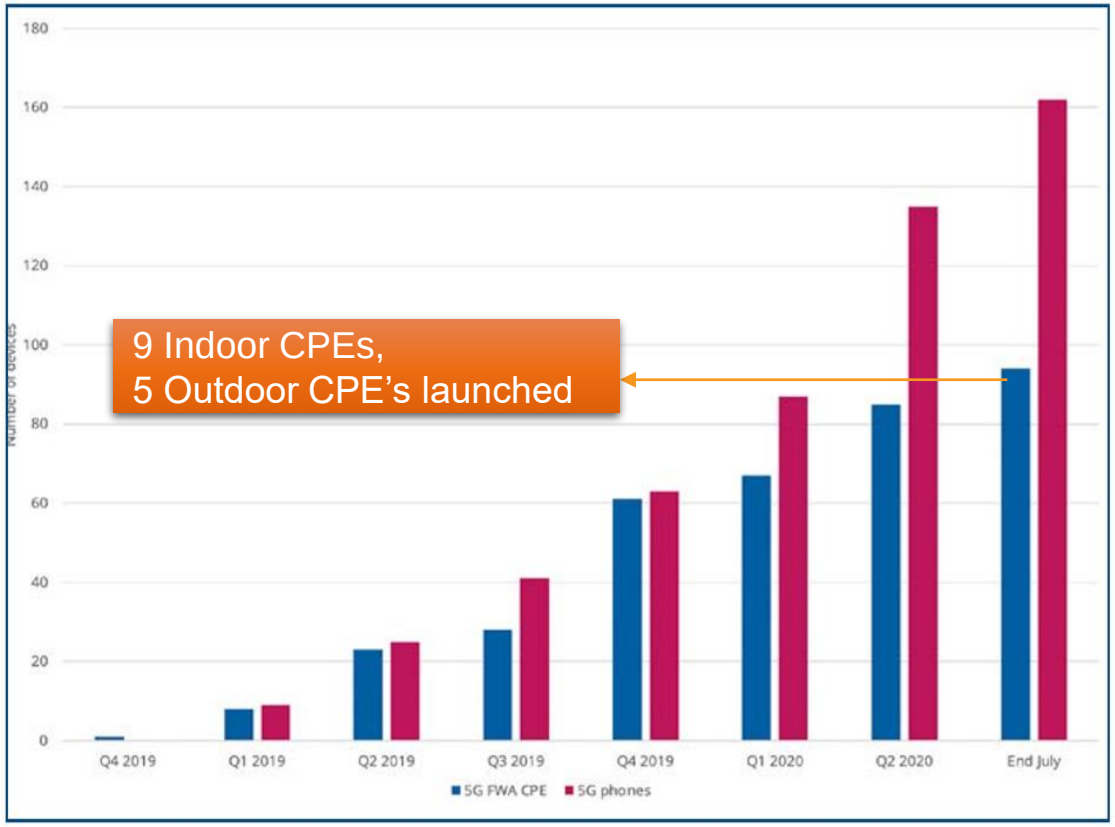
Why 5G Fixed Wireless Access (FWA) ?

Counterpoint research estimates that only 45.1% of households worldwide have dedicated broadband access (by the end of 2019), off which a third exists in China and US alone.

- Low barrier to entry
- Higher bandwidth and extremely high data rates
- Enhanced MIMO
- Beamforming
- Higher spectral efficiency

As of July, 31 nearly 54 vendors & 30 operators have announced plans to launch 5G CPE devices and services

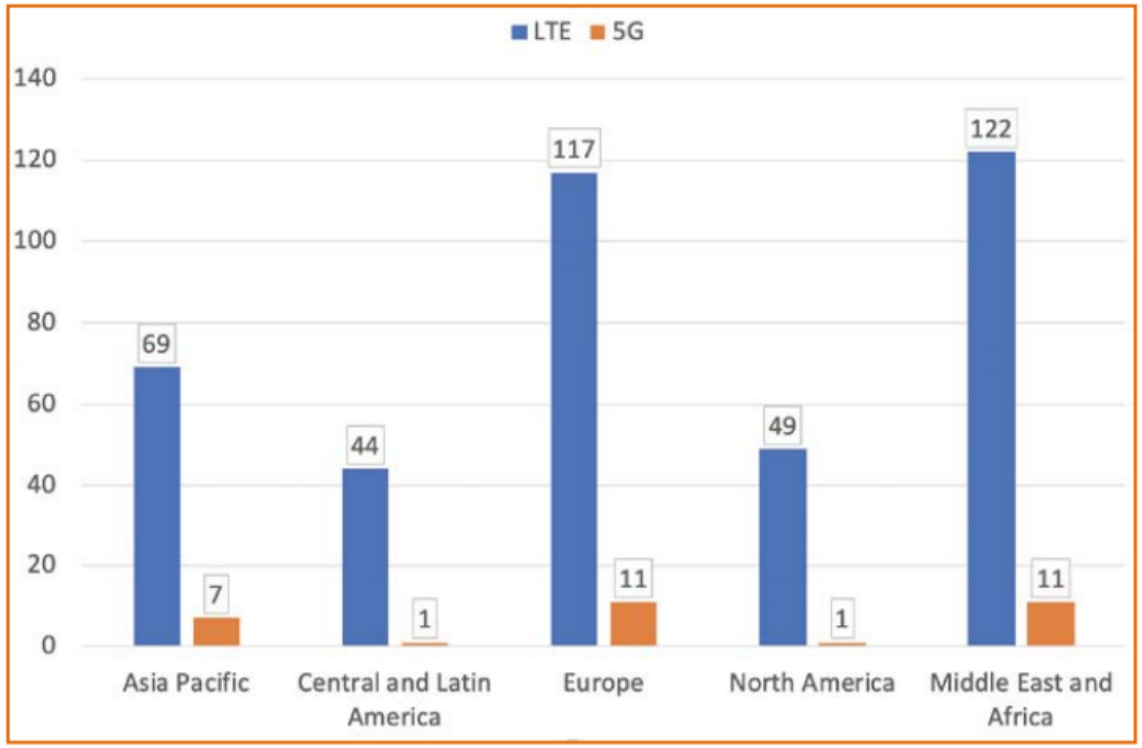


Source : GSA

5G FWA Deployment

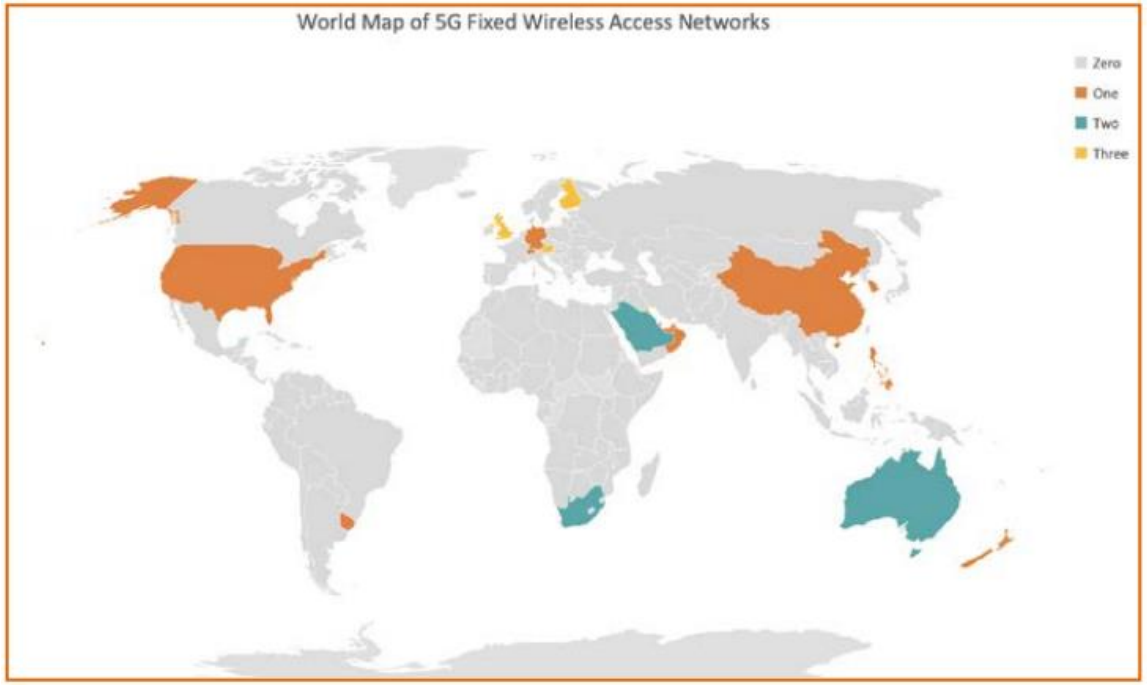
- Major growth and adoption will be seen in Europe, Middle East and Africa with focus on Sub-6GHz
- In US, mmWave CPE's are expected to be deployed in metro areas and CBRS in rural and remote areas.
- Verizon Wireless in US and China Mobile are the leading operators driving the market

FWA operators by region



Source: GSA

FWA networks by country



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5G FWA OEM’s

ZTE 5G MC801A

Huawei CPE Pro 2

OPPO 5G CPE Omni

ASKEY Gemtek LINKSYS

Fibocom MEIG 美格 inseego

WINGTECH 闻泰科技股份有限公司 WINGTECH TECHNOLOGY CO., LTD. AVM FIH

GOSUNCN COMPAL Sagemcom

ZTE technicolor SERCOM NETGEAR

SUNSEA AIOT 日海智能 Qualcomm snapdragon X55 5G modem-RF system oppo SAMSUNG

NOKIA SHARP Quanta Computer

Franklin Wireless WNC Wistron NeWeb Corp. QUECTEL Build a Smarter World

WEWINS SIERRA WIRELESS Telit

arcadyan cradlepoint casa systems

Panasonic Mobile Communications LG T&W LITEPOINT

5G Production Test Consideration

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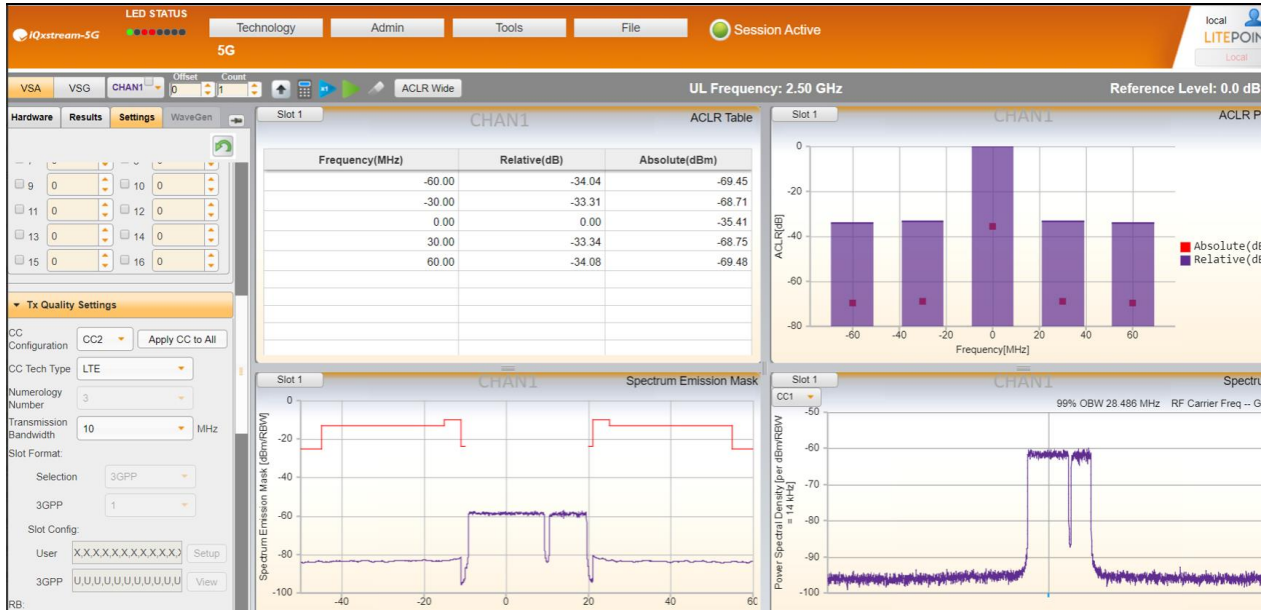
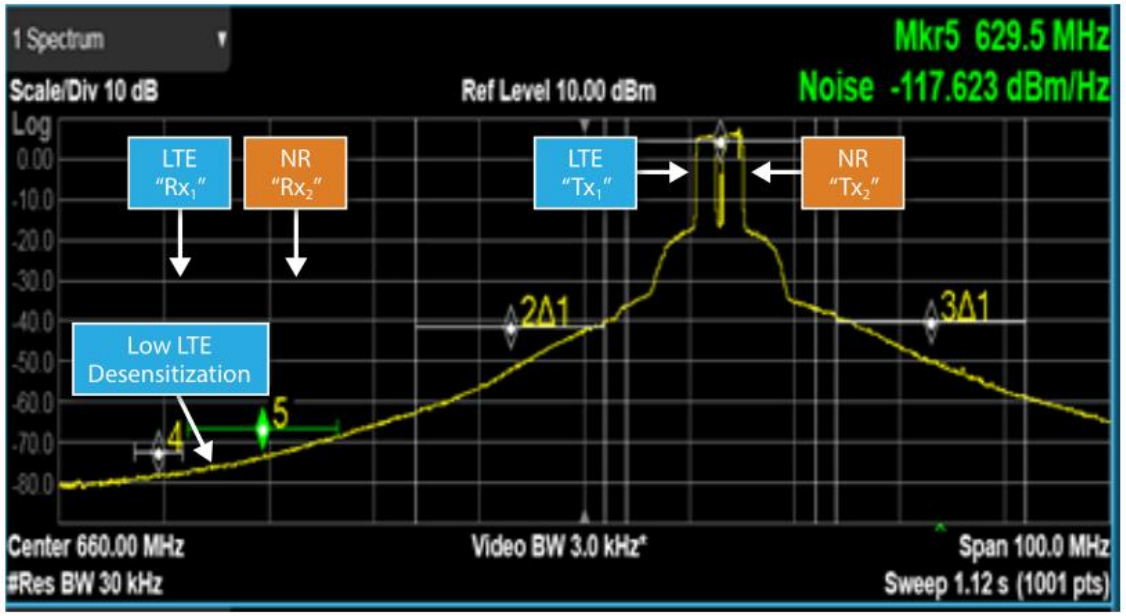
EN-DC challenges LTE-NR coexistence challenge

- NR Tx & LTE Tx IMD may desensitize to NR Rx/LTE Rx receiving sensitivity.
- EN-DC spectrum measurement is required to catch out-of-band emission.





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5G Test for Different Device/Module

	Chip / LGA module on board device	M.2 module on board device	M.2/LGA module	mmWave antenna module
Sub-6 Non-signaling	Full calibration and verification	Simple verification	Full calibration and verification	
IF Non-signaling			Full verification	Full characterization and verification
mmWave Non-signaling	Full characterization, calibration and verification	Full characterization, calibration and verification		Full characterization and verification

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LitePoint 5G mmWave Product Portfolio

mmWave Test Equipment 23 – 45 GHz

4 Port

2 Port

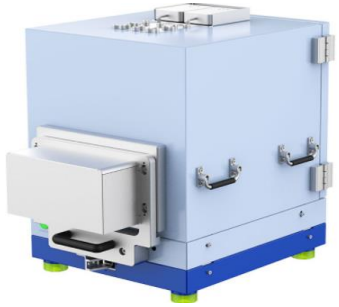
Horn Antennas & Switches

High Gain

Low gain

SP4T Switch + Control Box

OTA Chamber

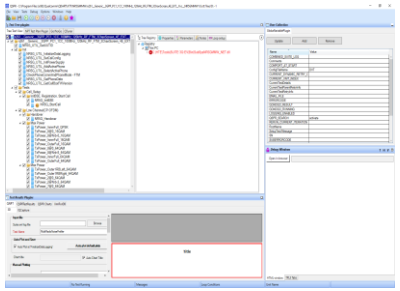


Optimized for production

Optimized for design verification (DVT)

Software Tool

Automation tool optimized for multi-DUT efficiencies



Chipset Tool (Eg - QDART)

Remote/On-site Support

Global footprint. Support teams in US, Asia & Europe

Onsite/ remote support/ documents/ videos available to enable customers.

- New feature support, bug fix & verification
- HW/ SW tool integration
- Understanding OTA chamber & DUT measurement
- OTA setup calibration
- Advise optimal HW & SW production setup
- Technology training

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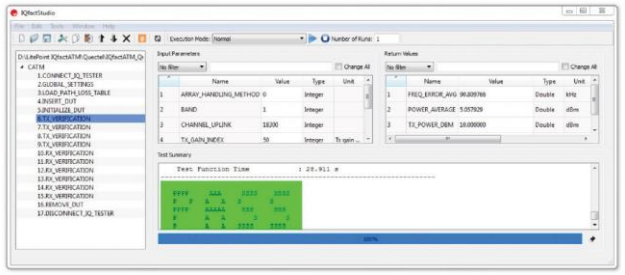
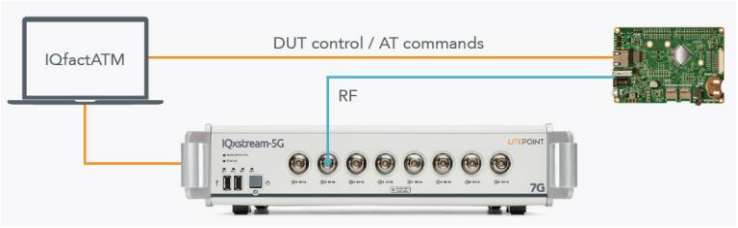
IQfactATM for Quick Production Testing on M.2 Cellular Module



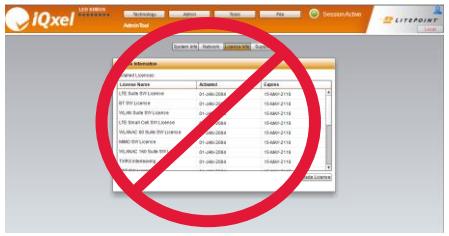
Typical RF Tests	
	Transmitter Power (CW or Modulated)
	Frequency Accuracy (CW)
	Receiver RSSI (CW or Modulated)



Uses vendor specific “AT commands” or similar for DUT control. These are documented and easily available from most module vendors

LitePoint RF Test Platforms		
	IQxel-MW	IQxstream-M
	IQxel-MW 7G	IQxstream-5G
	IQxstream	

IQfactATM works with most LitePoint platforms – anything that supports the main cellular bands



IQfactATM does NOT require any on tester licenses – we use GPRF only

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Solution Comparison

	Non-signaling Test by LitePoint IQ tester with IQfactATM	Non-signaling Test by Power Meter or Spectrum Analyzer	Non-signaling Test by Signal Generator + Spectrum Analyzer	Signaling Test by Call Box	Signaling Test by Real Base Station
Cost	Low	Low	Medium	High	Very Low
Test Time	Short	Short	Short	Long	Long
Stability	High	High	High	High	Low
By Antenna Test Capability	Yes	Yes	Yes	No	No
Tx and Rx Test Capability	Yes	No	Yes	Yes	Yes
Turnkey Software	Yes	No	No	No	No

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Thank You

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