

Accelerating 5G Innovations: 5G NR Trends & Opportunities

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Sales Director ME

NOV. 2019

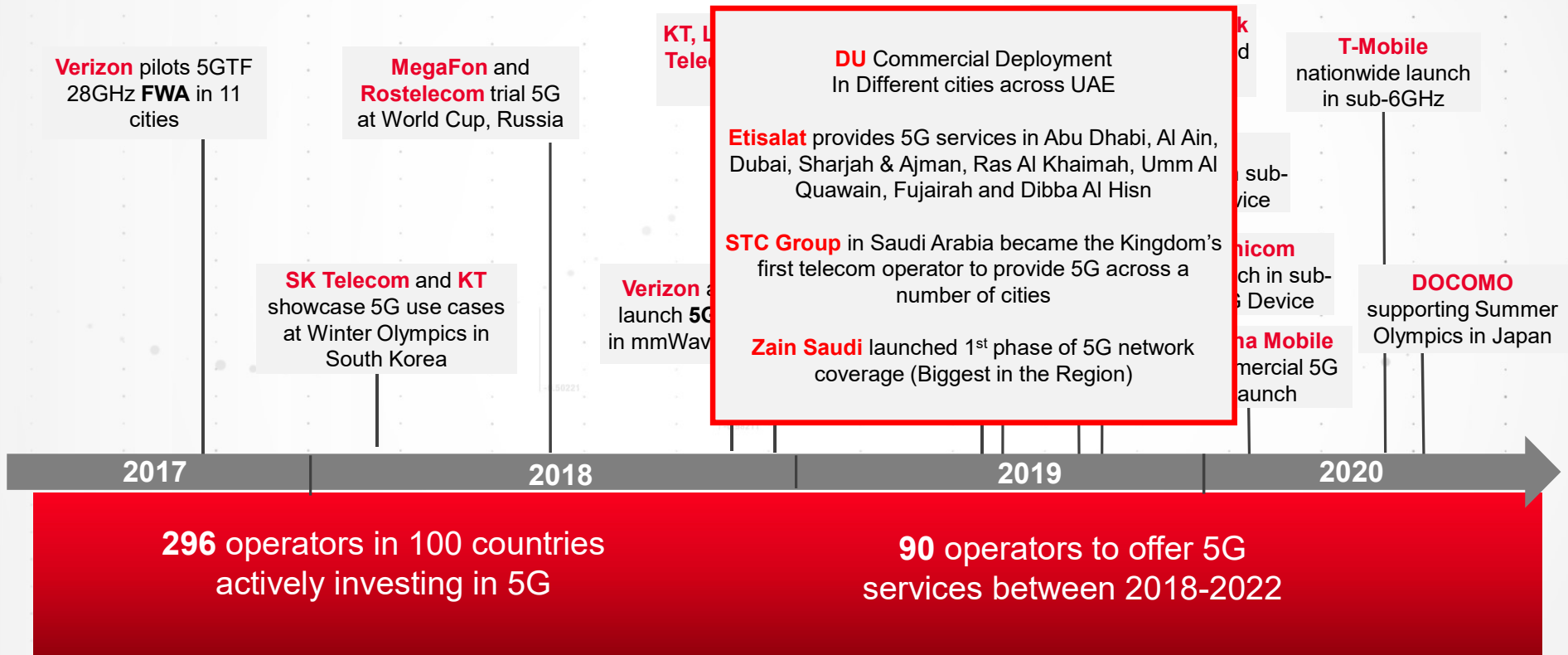
Keysight Technologies



5G is a Reality!



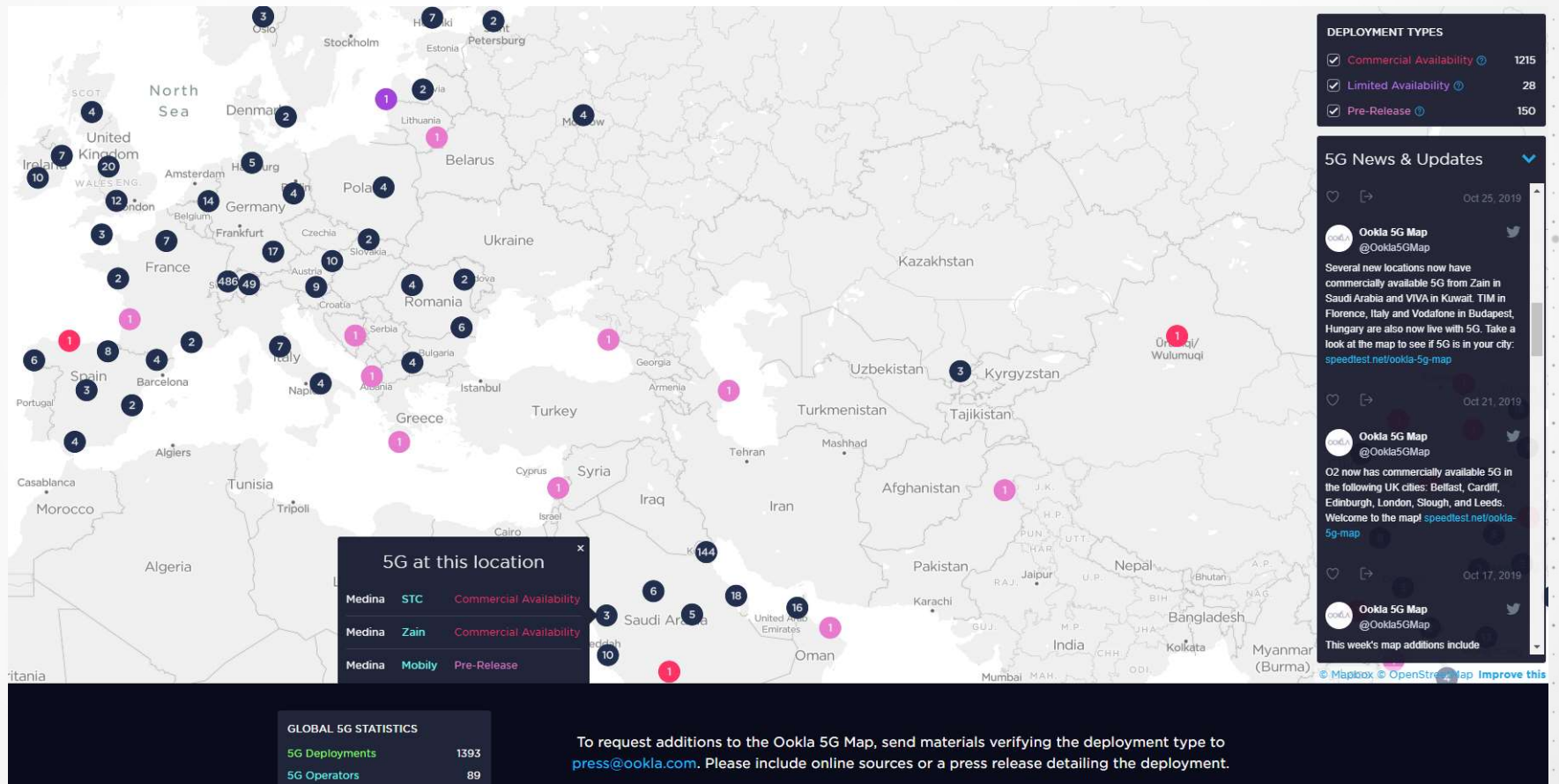
GLOBAL 5G DEPLOYMENTS - KEY MILESTONES



5G Network Deployments

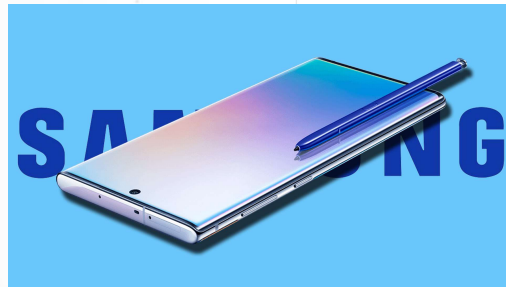
Commercial and Limited Availability Deployments > 1200
46 commercially launched 5G networks, 27 countries (Sept. 2019)

Interactive map of 5G deployments available at: www.speedtest.net/ookla-5g-map



5G Device Availability Enabling Commercial Launches

- 100 announced 5G devices from 41 vendors (some not commercially available yet)
- 13 form factors, including phones, hotspots, CPEs, modules, adapters, routers, laptop, drones, robots...
- Chipsets from Qualcomm, Huawei, Samsung, and Mediatek
- Most devices are sub-6 GHz, but mmWave is growing. mmWave supported by some CPEs, modules, hotspots, and a few phones.

















HUAWEI Mate20 X 5G
CO-ENGINEERED WITH 
WORLD'S FIRST 5G SMARTPHONE TO ACHIEVE
5G CERTIFICATION BY GCF



Source: GSA report on 5G Device Ecosystem (Aug 2019)

Spectrum Availability Enabling 5G

Recent trials and deployments

Spectrum (GHz)	Sub-1 GHz			Sub-6 GHz							mmWave				
	0.6	0.7	0.8	2.5	3.3 – 4.2		4.4 – 5		ISM	26/28	37 – 43.5				
Country	 USA	 Europe	 Europe	 USA	 China	 Europe	 China	 Japan	 China	 Japan		 Europe	 USA	 Japan	 USA
				MENA 5G Spectrum Now											

- To date over 560 5G trials using more than 40 different frequency bands
- n78 band (3300 MHz to 3800 MHz) most frequently used band in trials and tests, followed by n257 band (26.5-29.5 GHz)
- 34 countries have completed auctions for at least one band for 5G
- 39 countries have announced plans for spectrum allocations or auctions between now and 2021
- Spectrum for MENA – sub 6GHz, 2.6GHz & 3.5GHz in Saudi Arabia and 3.5GHz in the Gulf

5G Scenarios and Use Cases

BROAD RANGE OF NEW SERVICES AND PARADIGMS

Amazingly Fast

Great Service in a Crowd

Best Experience Follows You

Ubiquitous Things Communicating

Real-time & Reliable Communications

eMBB

Mobile Broadband Access



- All data, all the time
- 2 billion people on social media

mMTC

Massive Machine Communication



- 30 billion 'things' connected
- Low cost, low energy

URLLC

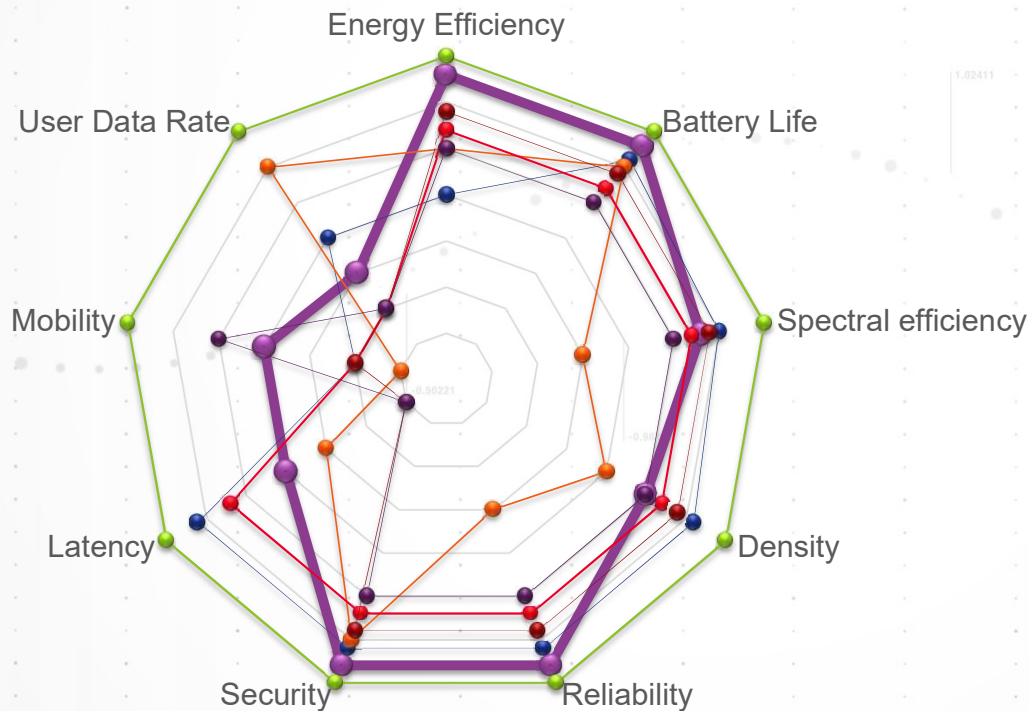
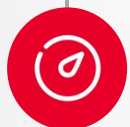
Mission-Critical Machine Communication



- Ultra-high reliability
- Ultra-low latency

Vertical Industry Applications Require Dedicated SLAs

MULTI-DOMAIN KPIS DEFINE QOS AND QOE



QoS and QoE depend on the cumulative performance of the entire network:

- Devices
- RAN
- Core
- Transport layer
- Cloud

SLA – Service Level Agreement
QoS – Quality of Service
QoE – Quality of Experience
KPI – Key Performance Indicator

5G Verticals in EU

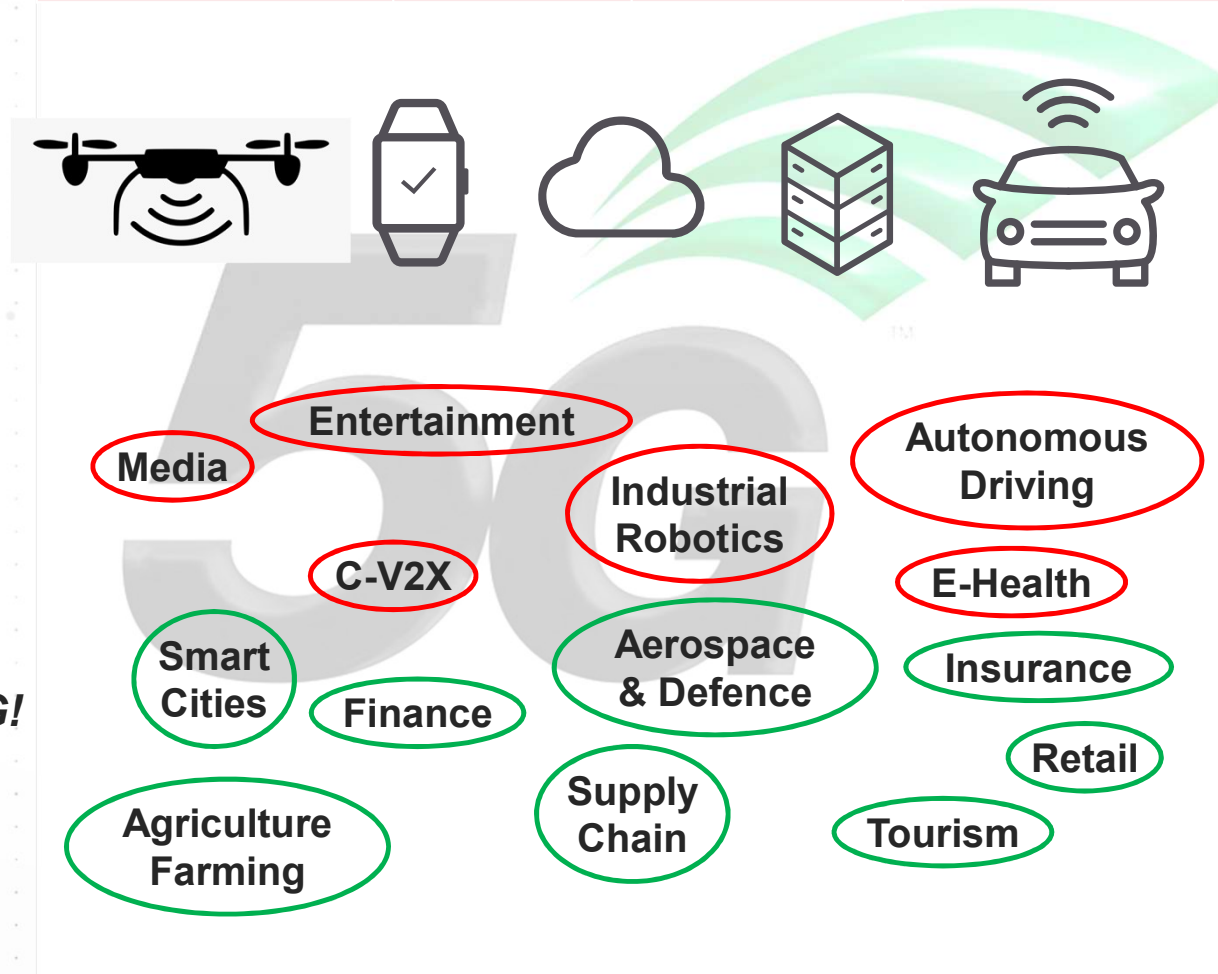
eMBB, URLLC, mMTC & MORE

Top verticals (5G aspects):

1. Media (eMBB)
2. Transports (URLLC & mMTC)
3. Automotive (eMBB & URLLC)
4. Industry 4.0 (URLLC & mMTC)
5. Healthcare (URLLC & eMBB)

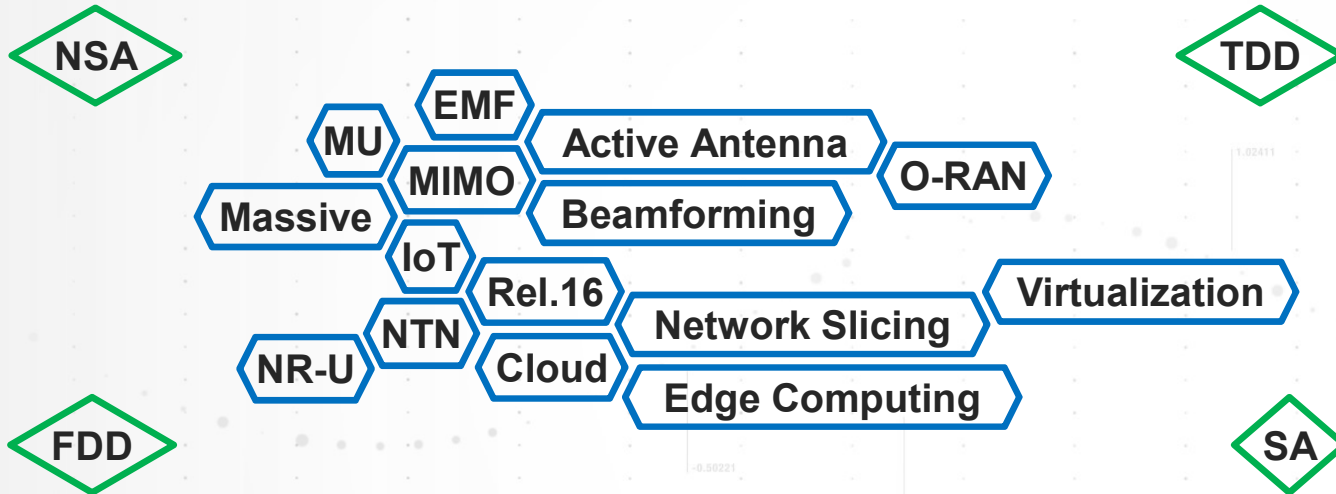
What we couldn't do with 2G, 3G & 4G!

Frequency	700MHz	2-4GHz	24GHz & above
Coverage	HIGH	MEDIUM	LOW
Throughput	LOW	MEDIUM	HIGH



5G Technical Complexity

MAIN ADDITIONS & PoC PROJECTS



"I want you to draw up plans for a city that can be built in a day."

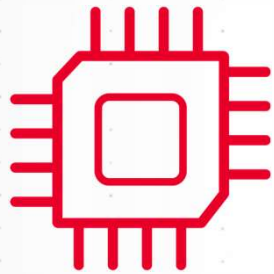
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5G PPP E2E Infrastructure supporting verticals pilots



Example of an industry challenge

DEVICE DEVELOPMENT WORKFLOW



Create



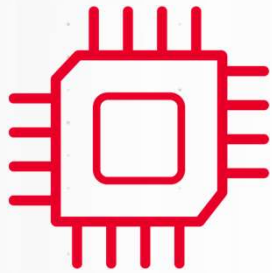
Integrate



Deploy

Chipset Vendor Challenge

DEVICE DEVELOPMENT WORKFLOW



Create

Protocol Development

- L1 development
- L2/L3 on host
- BB, IF, RF, mmwave

Bring-up

- Full Signaling ready
- Interoperability
- UE Calibration

Support

- Verification of customer issues
- Report to internal teams
- Global footprint

UE Supplier Challenge

DEVICE DEVELOPMENT WORKFLOW



Integrate

RF

- Transmitter: EVM, ACLR, SEM
- Receiver: Sensitivity, MIMO
- Power : EIS, TRP, EIRP¹¹³

Performance

- Data Throughput
- Beam Characterization
- Fading
- Multiple AoA (Angle of Arrival)

Calibration

- Calibration routines
- FR2 specific challenges

MNO Challenge

DEVICE DEVELOPMENT WORKFLOW



Deploy

Regulatory

- Spurious (Harmonics Emissions)
- SAR

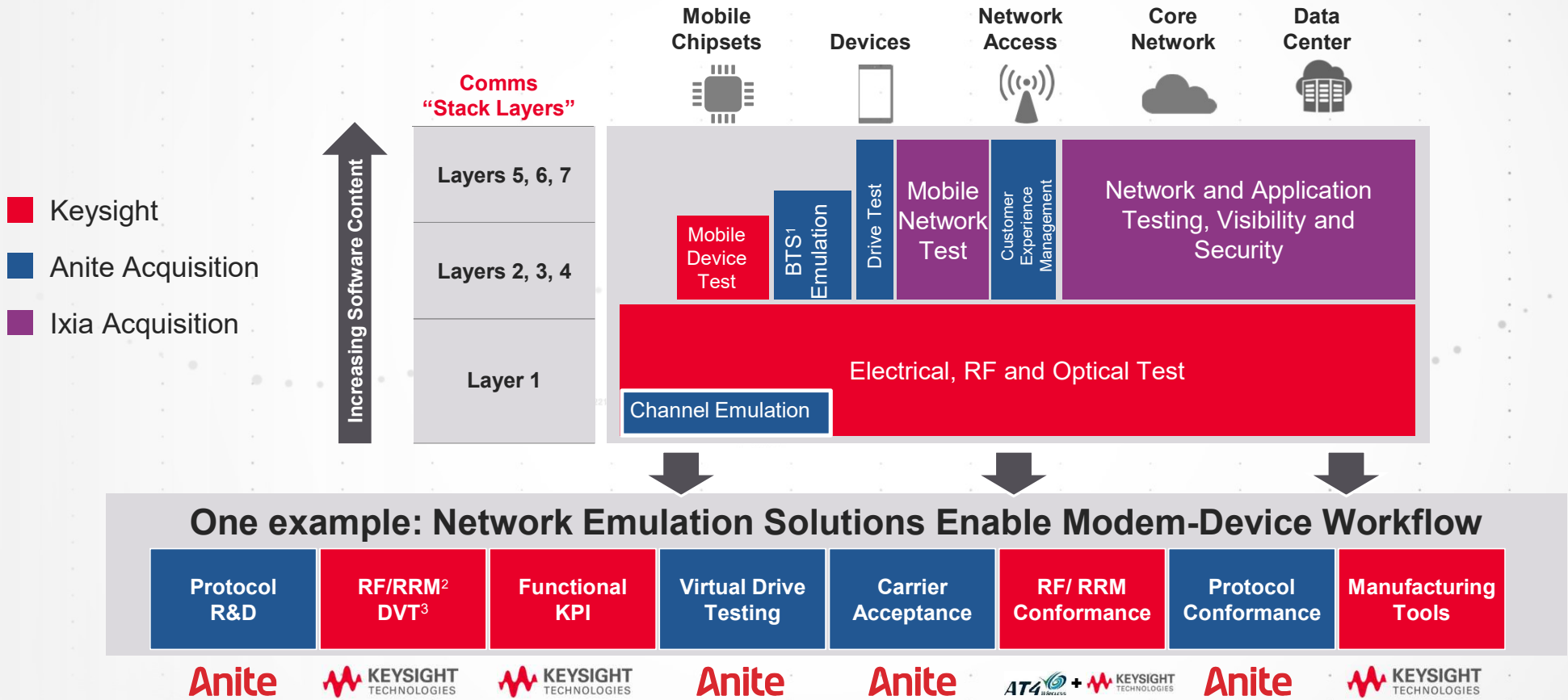
Conformance

- GCF
- PTCRB
- CTIA

MNO test plans

- Chinese ecosystem
- NS-IOT
- GTI
- US, Japan and Korean Carriers

Acquisitions Have Expanded Addressable Market and Enable Us to Offer Complete Solutions

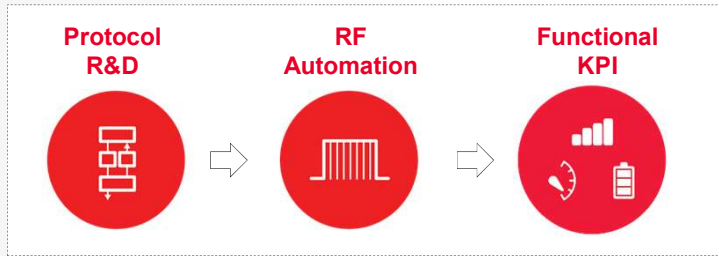


KEYSIGHT TECHNOLOGIES ¹ Base transceiver station ² Radio Frequency / Radio Resource Management ³ Design Validation Test

5G Device End-To-End Solutions

ACCELERATING INNOVATION FOR NEW 5G DEVICES

5G Device Development Solutions



5G Device Acceptance Solutions



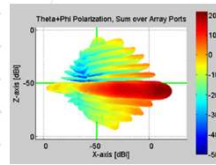
5G MFG Solutions



Network Emulator



Channel Emulator



mmWave OTA Solutions



Non-Signaling Test Set

5G Network Emulation Solution Platform Overview

ACCELERATING COMMERCIALIZATION OF FIRST 5G SMARTPHONES



UXM 5G Wireless Test Platform

- 5G NR 8CC DL and 4 CC UL 2x2, with LTE 2CC
- Wide and scalable bandwidth
 - 8Tx/4Rx @800MHz
 - 4Tx/2Rx @1600MHz
- Multi angle of arrival test
- Internal fading

Common Interfacing Unit (CIU)

- Seamlessly integrates with multiple solutions
 - ✓ PROPSIM F64 Channel Emulator
 - ✓ EXM 5G Wireless Test Set
 - ✓ UXM 5G Wireless Test Platform
 - ✓ 5G BTS Manufacturing Solution
- Up to 8 remote radio heads
- High IF connection (6-12 GHz)

24/44GHz Remote Radio Head (RRH)

- Industry's most versatile and advanced mmWave RRH
- Supports both OTA and conducted test

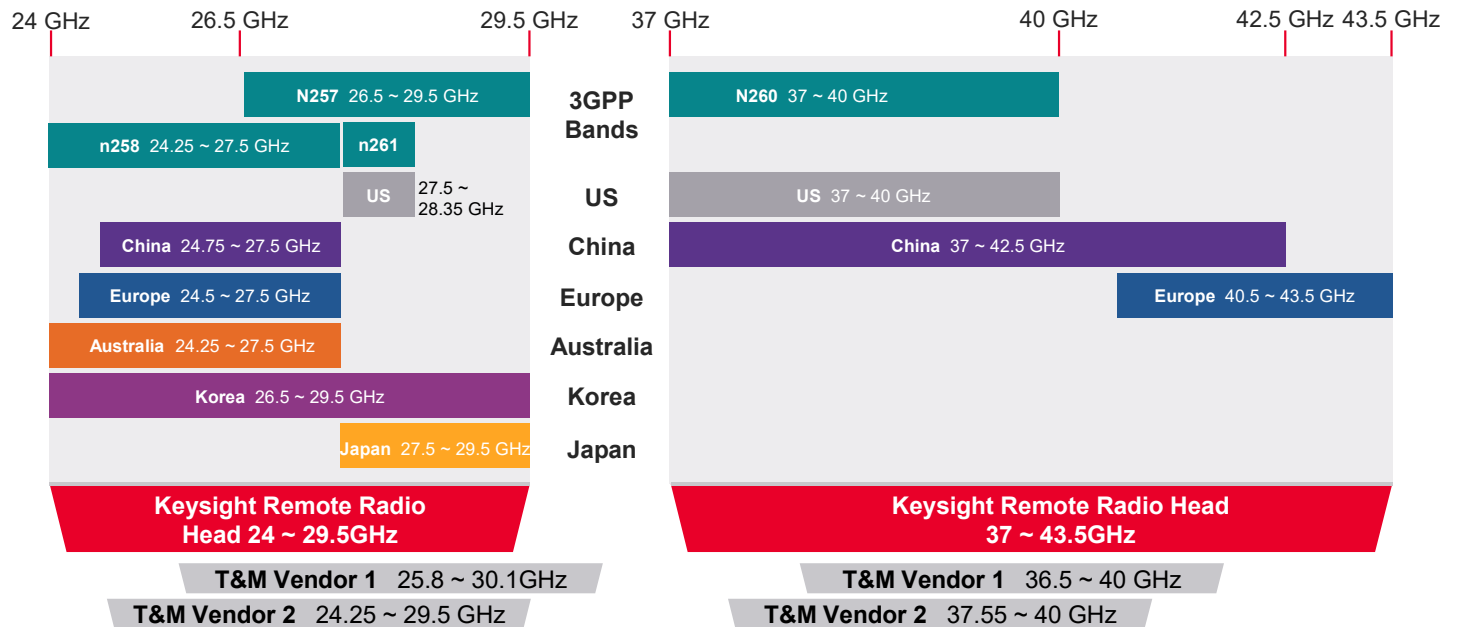
Industry's Broadest Support for Validation in mmWave

ADDRESSING GLOBAL SPECTRUM REQUIREMENTS

mmWave
Remote Radio Head



- 5G OTA ready
- Broadest band coverage
- Versatile & compact



Scale From Benchtop R&D to Full Rack Acceptance Test

END-TO-END TEST COVERAGE

FR1 (sub-6GHz)

Protocol, RF, RRM
and Functional

Industry leading
GCF and PTCRB test
case support for
5G NR SA and NSA

Add FR2 (mmWave)
and OTA

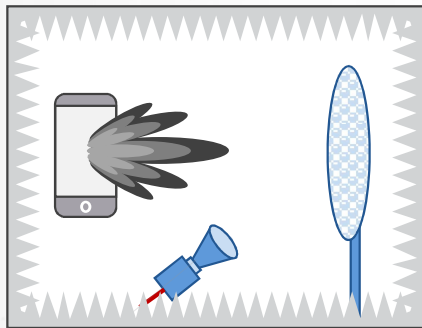
Add spurious
and interference



Industry's Most Complete mmWave OTA Portfolio

VALIDATE MMWAVE 5G DEVICES ACROSS WORKFLOW

RF/Antenna/RCT

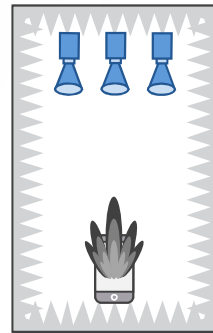


CATR

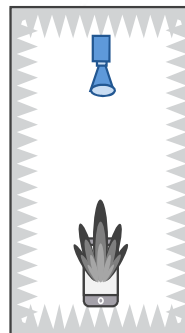


- Indirect far field
- Module to full device testing
- 30 cm device size

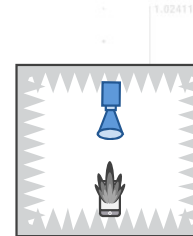
Protocol/Functional/PCT



2DMPAC



RMTC

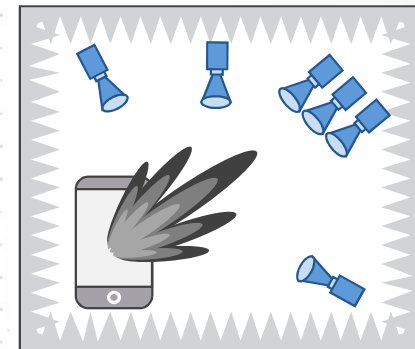


mini-RMTC



- Direct far field
- Module to full device testing
- Light weight and bench top

Mobility and Performance



3D MPAC



- Direct far field
- Module to full device testing
- Supports fading models with Channel Emulator

Keeping Pace With 5G NR Standards

ENABLING FIRST-TO-MARKET SOLUTIONS THAT ACCELERATE INDUSTRY READINESS

- Keysight contributes more to the development of **5G NR** than any other test vendor:
 - Authored more than **300 RAN4/5 5G NR** contributions
 - **Leading in GCF/PTCRB** test case validation for 5G NR RF SA and NSA device certification
 - **Simplified OTA testing** with compact antenna test range (CATR) method adopted by 3GPP
- **Stay ahead** of the standards using Keysight's:
 - 5G Conformance Toolset
 - 5G mmWave Testbed
 - 5G NR Software Solutions



"Keysight's 5G test solutions are instrumental in accelerating commercial 5G development and rollout."

Tony Schwarz, Senior VP of Engineering, Qualcomm Technologies

PROPSIM F64 5G Channel Emulator

VALIDATE 5G FOR REAL WORLD OPERATION IN LAB

- Adopted by Tier 1 Operators, NEMs and Chipset & Device Makers
- Supports all 3GPP defined 5G NR bands and bandwidths
- Most advanced test scenario and channel modeling for 5G/4G/WLAN 802.11ax
- 5G NR and LTE-Pro Base Stations and Mobile Devices test
- Fair laboratory test conditions against vast range of field conditions
- 3GPP channel models per 3GPP 38.901. Urban Micro, Urban Macro, Indoor office. Custom deployment scenario support
- Primary building block for solutions like GCM, VDT, FR2 OTA measurements...

More channels, more BW per channel, more flexibility for more CE solutions



**GTI Award
2019**

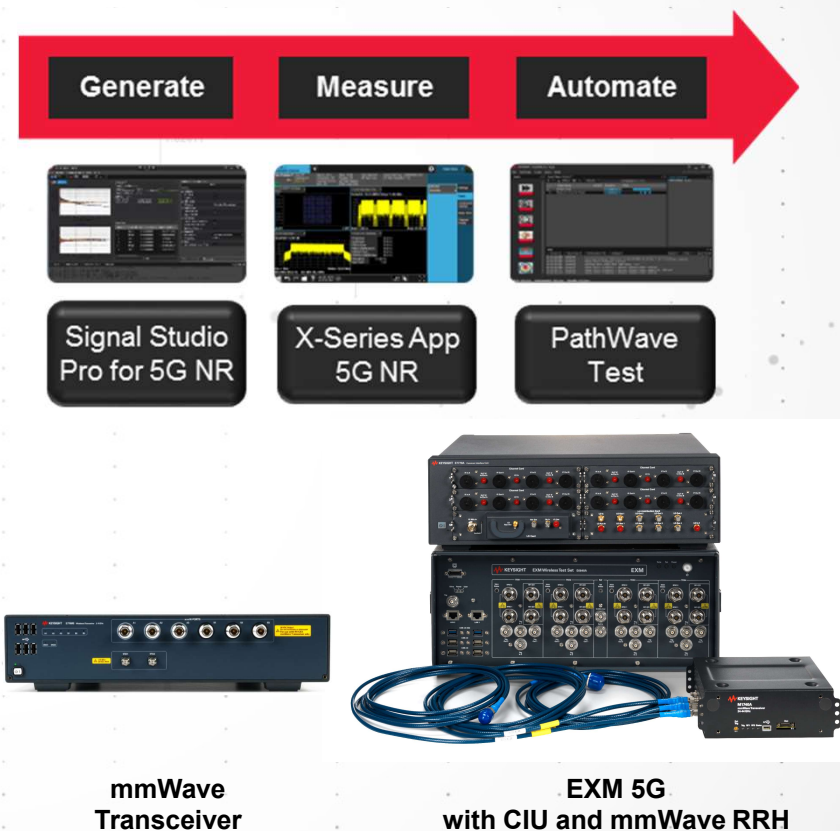
**Innovative
Breakthrough
in Mobile
Technology**

**5G
Performance
Test Solution**
accelerates
launch by
enabling
realistic
End-to-End,
RF-to-RF
validation of
mobile
network &
device in lab

5G Device Non-Signaling Test Solutions

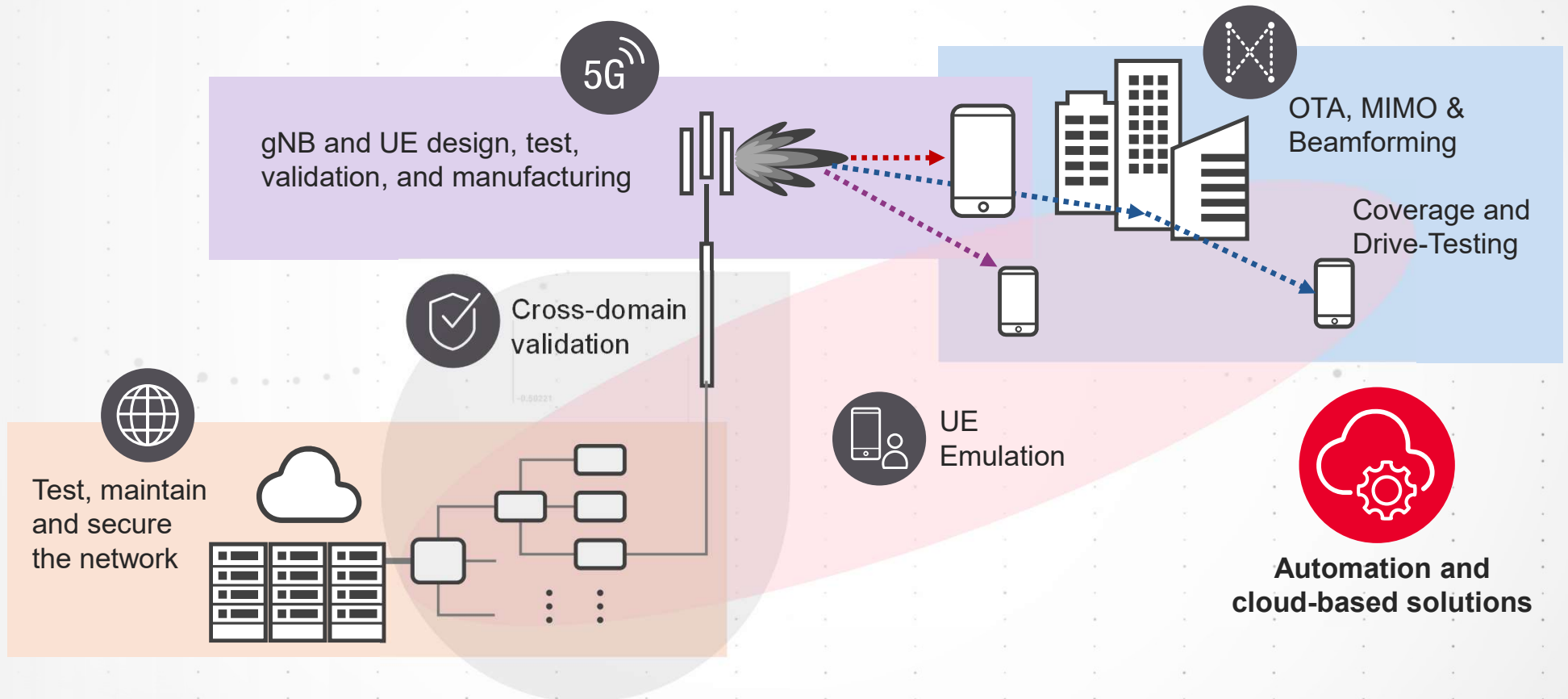
CONFIDENTLY VERIFY 5G MODULES AND DEVICES IN DVT AND MANUFACTURING

- The only 5G MFG solution with support across both sub-6GHz and mmWave
- Industry's most compact mmWave DVT solution for IF/mmWave
- Develop automated test plans with Keysight's PathWave Test
- Reduce manufacturing cost with sequencing and multi-DUT test



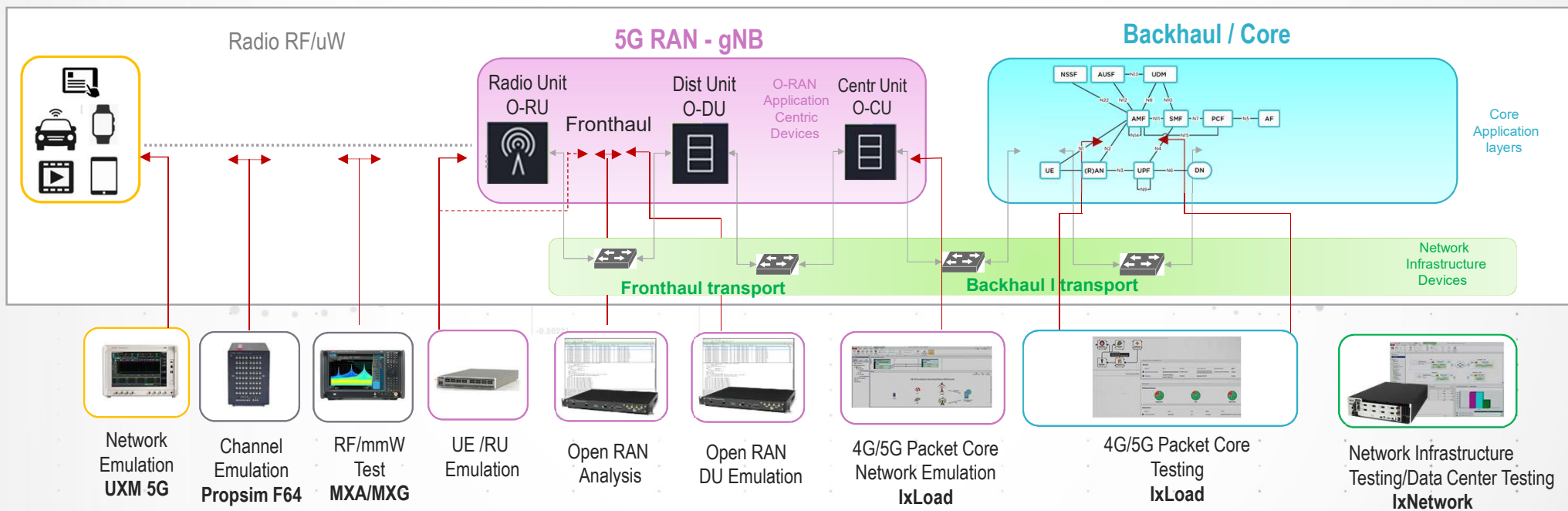
New Test Strategies Are Needed to Offer New Insights

ACROSS MULTIPLE RF AND PROTOCOL DOMAINS



Keysight 5G RAN Solution Portfolio

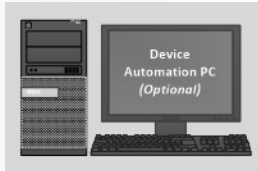
TOP LEVEL VIEW



5G Device Benchmarking (Lab, NW Emulator)

- One click test automation for test execution and reporting.
- Pre-made and easy to modify test script to be run from Nemo Outdoor to control device.

- Test automation through TAP interface



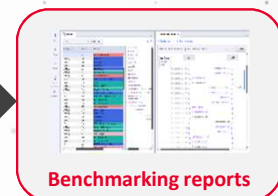
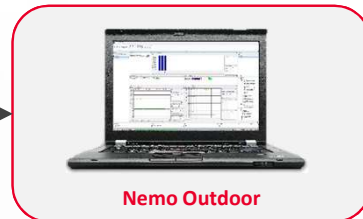
UE with SW build 1



UE with SW build 2



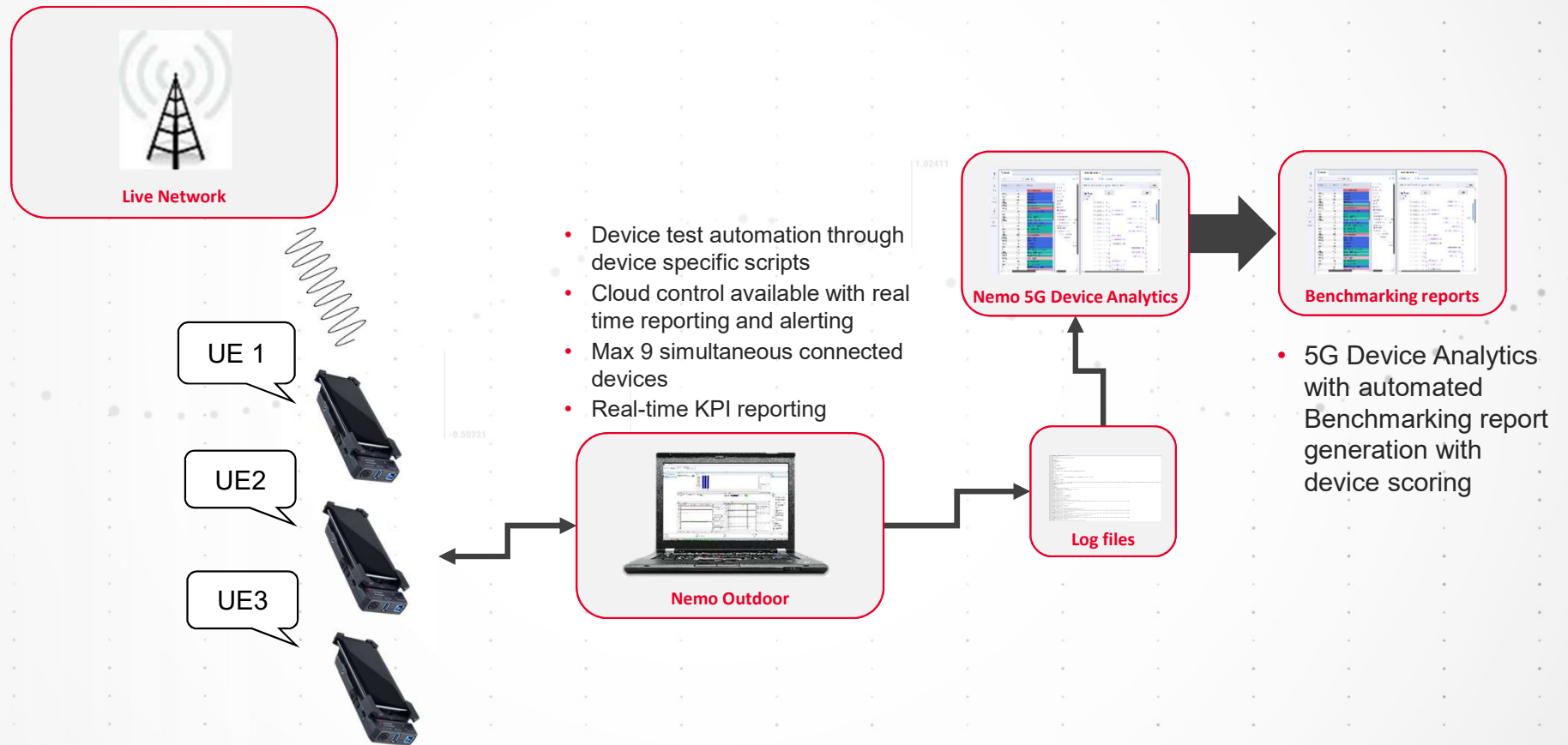
- Benchmarking between
 - Software daily builds
 - Golden device
 - Competitor device



- 5G Device Analytics offers Benchmarking report generation and device scoring

Solution for 5G Device Benchmarking (Live Network)

- Multi-device support for device benchmarking using live network in office or drive test conditions.



5G Verticals in EU

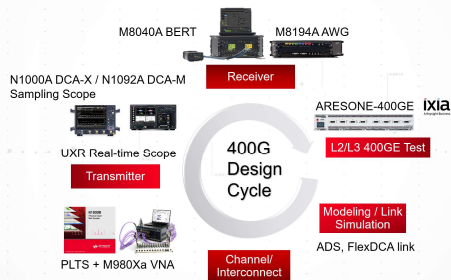
eMBB, URLLC, mMTC & MORE

Top verticals (5G aspects):

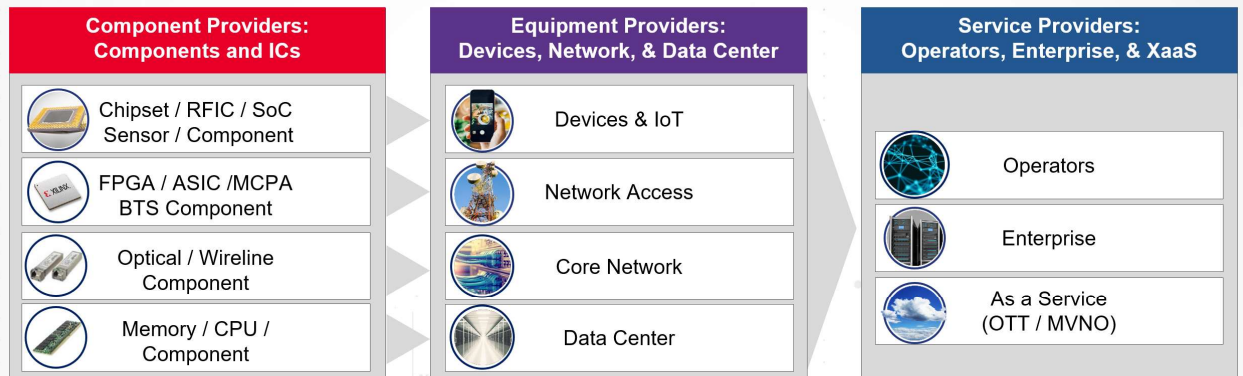
1. Media (eMBB)
2. Transports (URLLC & mMTC)
3. Automotive (eMBB & URLLC)
4. Industry 4.0 (URLLC & mMTC)
5. Healthcare (URLLC & eMBB)

400G - Keysight Provides Industry Leading Tools

FAST AND ACCURATE CHARACTERIZATION OF PAM4 DESIGNS



Keysight Solutions for the Communications Ecosystem



Solutions: ■ Keysight Classic
 ■ Anite
 ■ Ixia

Load Modules: Network Infrastructure, Mobility, Impairment Emulators, Applications & Security
Network Visibility: Tap, Bypass, Packet Broker
Security: Network, Threat Intel, Application
Network Quality: Drive Test, Live Mobile Network Test, Quality of Service

Emulators: Channel Emulators, Network Emulators, WiFi Emulators, UE Emulators, Conformance & Acceptance: Protocol, RF
RF, MW and mm-Wave: Network Analyzers, Signal Analyzers, Signal Sources, Modular Solutions, Handheld
Wireline & Optical: ARBs and Digitizers, Scopes & Logic Analyzers, Optical Analyzers, BERTs
Simulation: Electronic Design Automation
Services: Professional Services: Startup, Calibration, Uptime, Repair, Custom Solutions..., Customer Experience Management

COST EFFICIENCY

Reduce unnecessary field testing by virtualizing important field test routes for pre-field tests in lab

ENVIRONMENT

Debug and solve more field found errors in lab
 Develop and validate new features and devices for better maturity and performance

SOLUTION

Integrated Lab testing and Field testing solution streamlines the entire performance testing process



Enabling Market Leaders

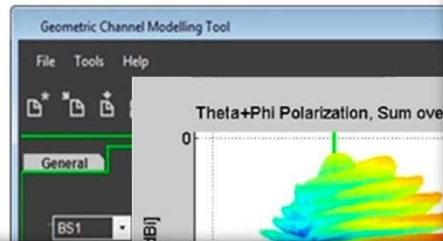
FierceWireless

WIRELESS TECH 5G IOT

Wireless

Keysight going strong

by Monica Allevan | Aug 23, 2018 7:35am



telecoms.com

Keysight claims first 5G device testing toolset



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KEYSIGHT TECHNOLOG...

Keysight Technologies inks 5G deal with China Telecom

The U.S. firm also secured a 5G collaboration agreement with Korean carrier SK Telecom

RCR Wireless News

INTELLIGENCE ON ALL THINGS WIRELESS

Keysight Technologies inks 5G deal with China Telecom



SD-WAN Security 5G AI Edge Data Center IoT Storage SDN APM/NPM NFV Containers

Keysight Provides NTT DoCoMo With 5G Network Emulation for 5G NR Devices



Ali Longwell
August 21, 2018
11:45 am MT

ASPEN CORE NETWORK ABOUT US SUBSCRIBE

EE Times

HOME NEWS PERSPECTIVES DESIGNLINES VIDEOS RADIO EDUCATION IOT TIMES

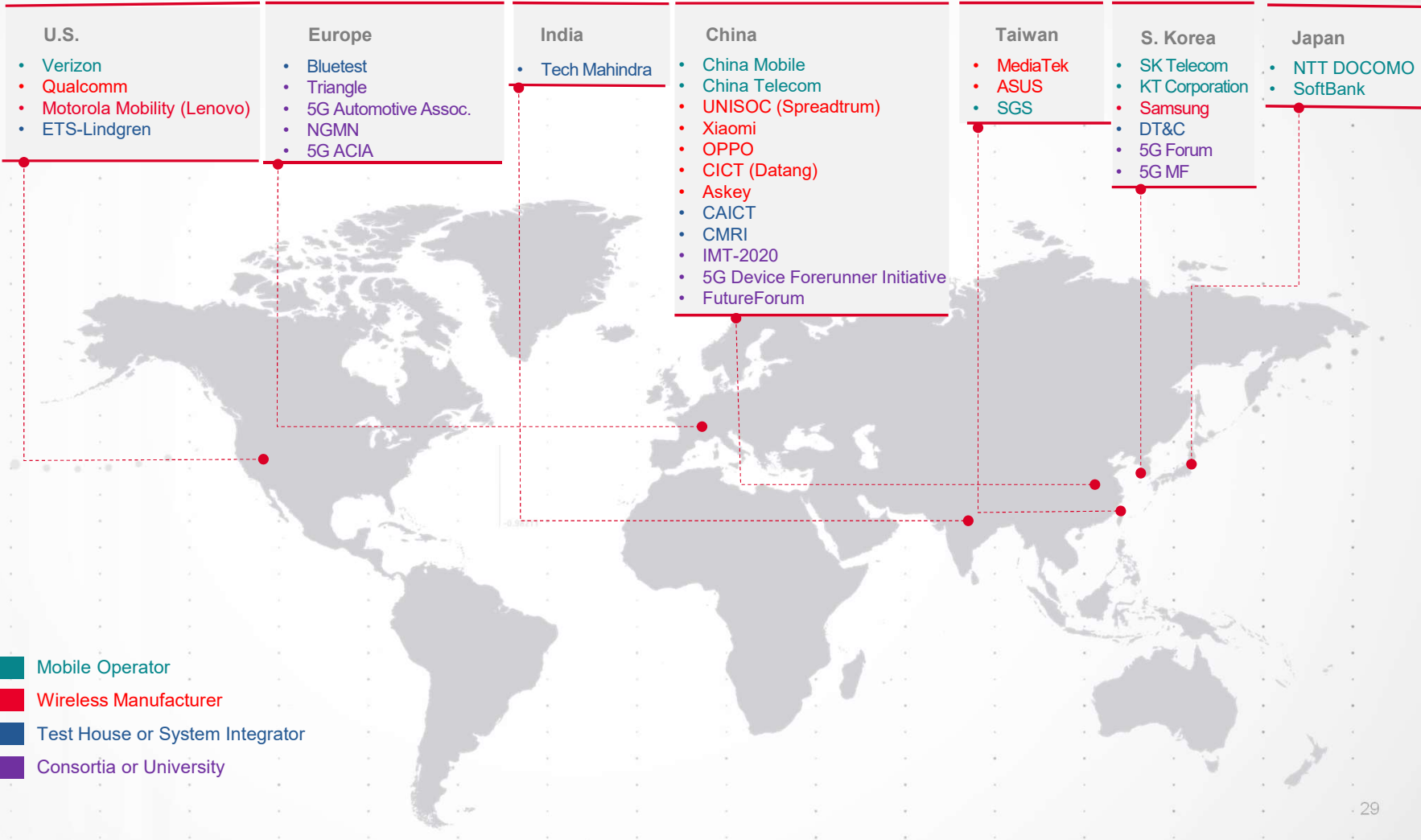
DESIGNLINES | TEST & MEASUREMENT DESIGNLINE

Qualcomm, Keysight Achieve 2-Gbps Wireless Downloads

PODCA

E2E Workflow Solutions Adopted by Global Ecosystems

- First-to-market protocol and RF development solutions for 5G NR SA and NSA
- First-to-market RCT and PCT solutions for 5G NR device acceptance
- Support latest 3GPP R15 standards – Across FR1 and FR2



The Key to Success in Technology

We deliver what's next. First.

Industry's first and largest 5G library

Keysight 5G Baseband Exploration Library for SystemVue
Industry's first 5G Exploration Library for researchers

Keysight N7608B Signal Studio
for custom modulation

Keysight 89600 VSA software

Keysight N9040B UXA signal analyzer
with 89600 VSA software and M1U/TL smart mixer

Keysight E8267D PSG vector signal generator

Keysight M8190A arbitrary waveform generator

Keysight M9703A high-speed digitizer/wideband digital receiver

Keysight DSOZ634A Infinium oscilloscope
with 89600 VSA software

Keysight MIMO PXI test solution
M9353A PXI VSA and M9303A PXI VSA - 100 GHz phase-coherent MIMO measurement

Keysight N5247A PNA-X microwave network analyzer, 67 GHz

Keysight N5152A 5-GHz/60-GHz upconverter
Keysight N1999A 60-GHz/5-GHz downconverter

1.02411

HARDWARE + SOFTWARE + PEOPLE = 5G INSIGHTS



KEYSIGHT
TECHNOLOGIES