



KEYSIGHT
WORLD 2019

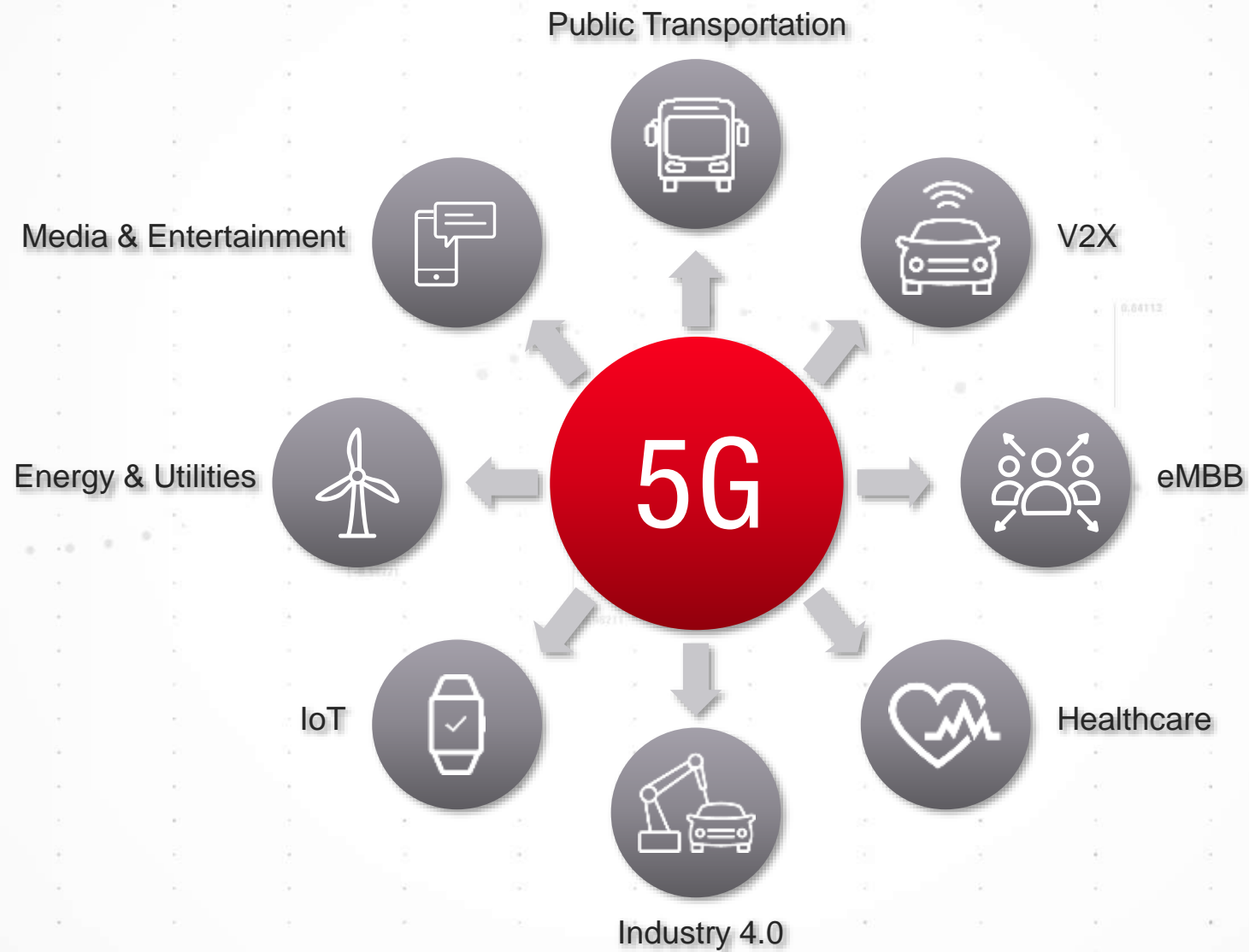
5G New Radio standards, Trends and Opportunities

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Keysight Technologies



Realizing the Vision of 5G



5G Trends Driving Industry Evolution

Deployments are accelerating

Rollout Announcements

2019: 20
2020: More than 40

Investments

200 operators
in 83 countries

Ecosystems

>18 device makers using
Qualcomm's 5G modem

Standards are evolving

Acceleration

5G NR NSA freeze
pulled in 6 mos. to Dec '17

Maturation

R15 5G NR Jun '18 freeze
& Mar '19 late drop freeze

Extension

R16/17/18 5G NR
extensions
for V2X, URLLC & beyond

Technical complexity is high

Global Diversity

5G NR NSA vs. SA
progressing in parallel

More Bands and BW

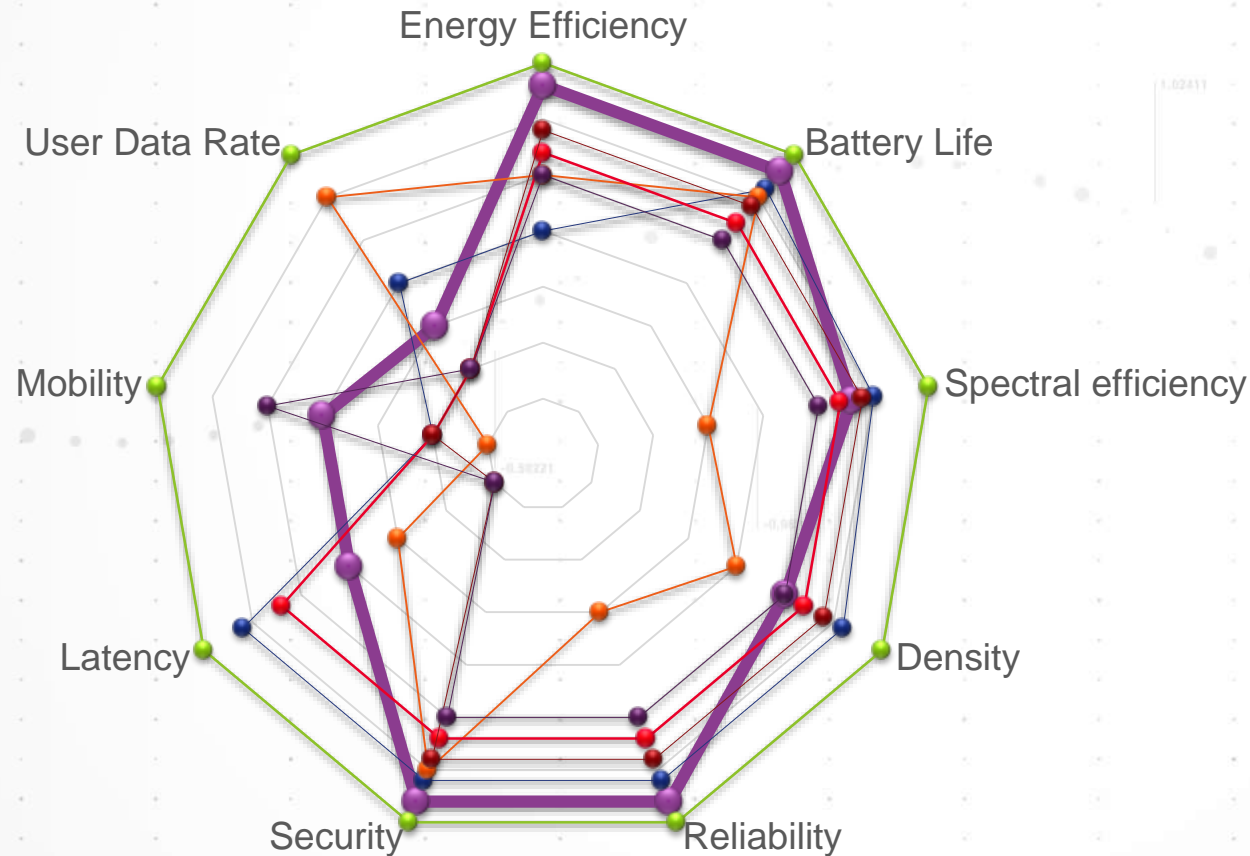
New bands: 32 FR1 & 4
FR2, with more BW options

Spatial Challenges

Beamforming, tracking,
and link management

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:

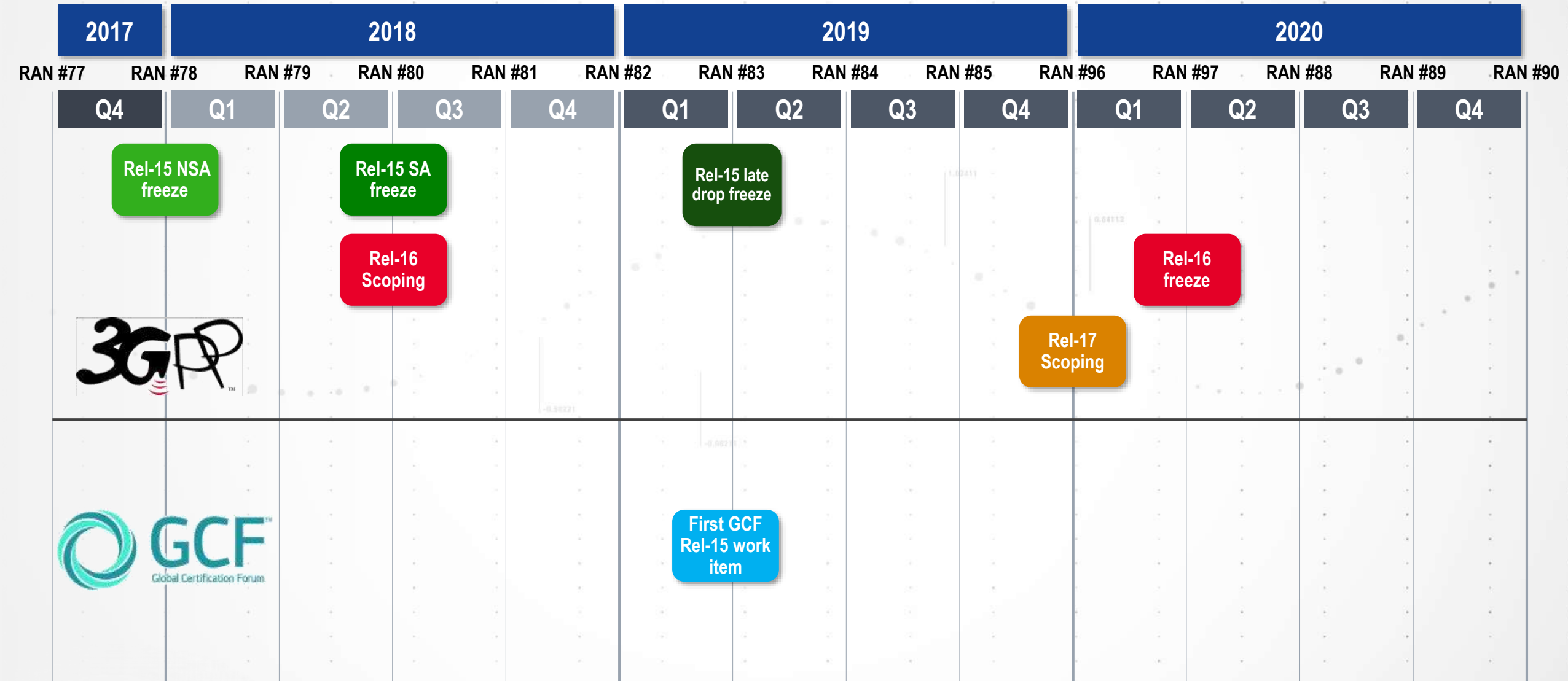
- Devices
- RAN
- Core
- Transport layer
- Cloud

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

Standards Continue to Evolve



5G NR Standards Are Evolving



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."

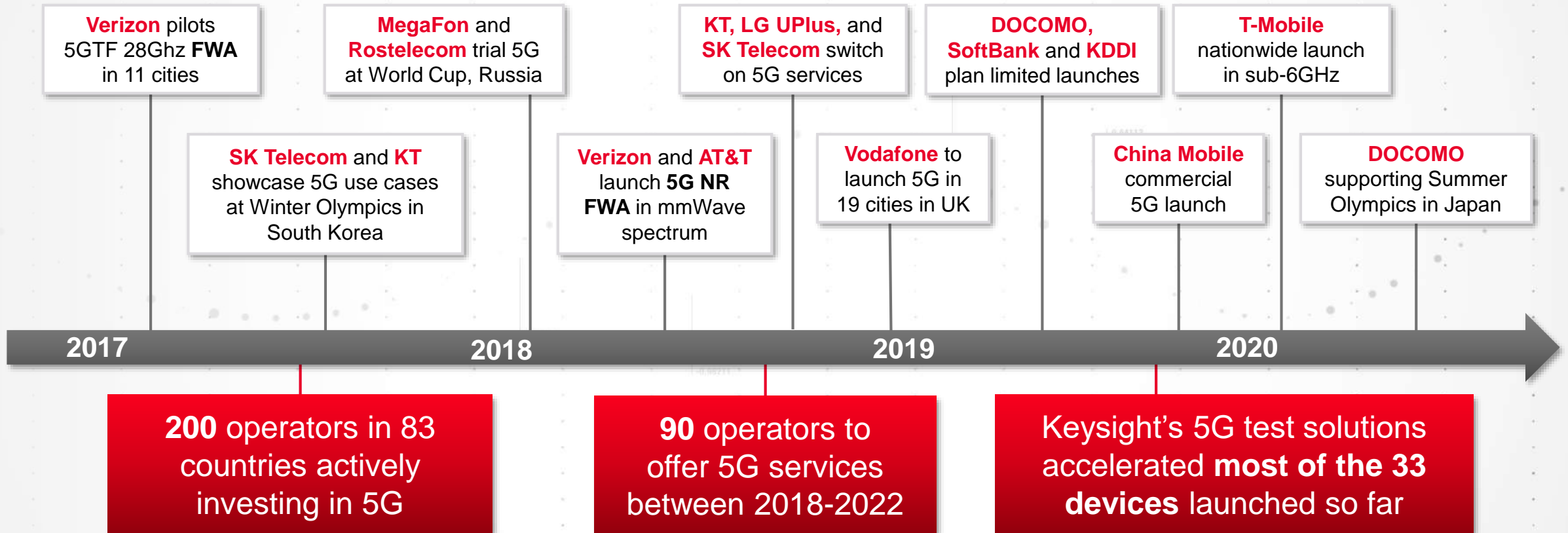
Tony Schwarz, Senior VP of Engineering, **Qualcomm Technologies**

Mobile Operator Deployments Accelerating Around the World



















Global 5G Deployments

KEY MILESTONES



Interoperability - Key for Global Deployments

TRIALS ON VARIOUS BANDS FROM SUB-1GHz, SUB-6GHz & MILLIMETER WAVE

| | sub-1GHz | | | sub-6GHz | | | | | | | mmWave | | | |
|----------------|---|---|---|---|--|---|---|--|---|---|--------|---|---|---|
| Spectrum (GHz) | 0.6 | 0.7 | 0.8 | 2.5 | | 3.3 – 4.2 | | | 4.4 – 5 | | ISM | 26/28 | | 37 – 43.5 |
| Country |  |  |  |  |  |  |  |   |  |  | |  |    |  |

To date 562 5G trials using more than 40 different frequency bands

More than 90 of these have taken place in the 28 GHz band

n257 band is most popular 3GPP specified band with more than 200 trials

Heterogenous Networks

INCREASING DEPLOYMENT COMPLEXITY



Core Network

- Multi-RAT Management
- Routing/Scheduling to address each vertical
- Interference management



Small Cell



Macro

More complex:

- Site acquisition
- Network planning
- Resource management



Multi-Mode Devices

- NSA & SA
- FDD & TDD
- FR1 & FR2



How does Keysight Enable the Industry?

Our Role in Making 5G a Reality



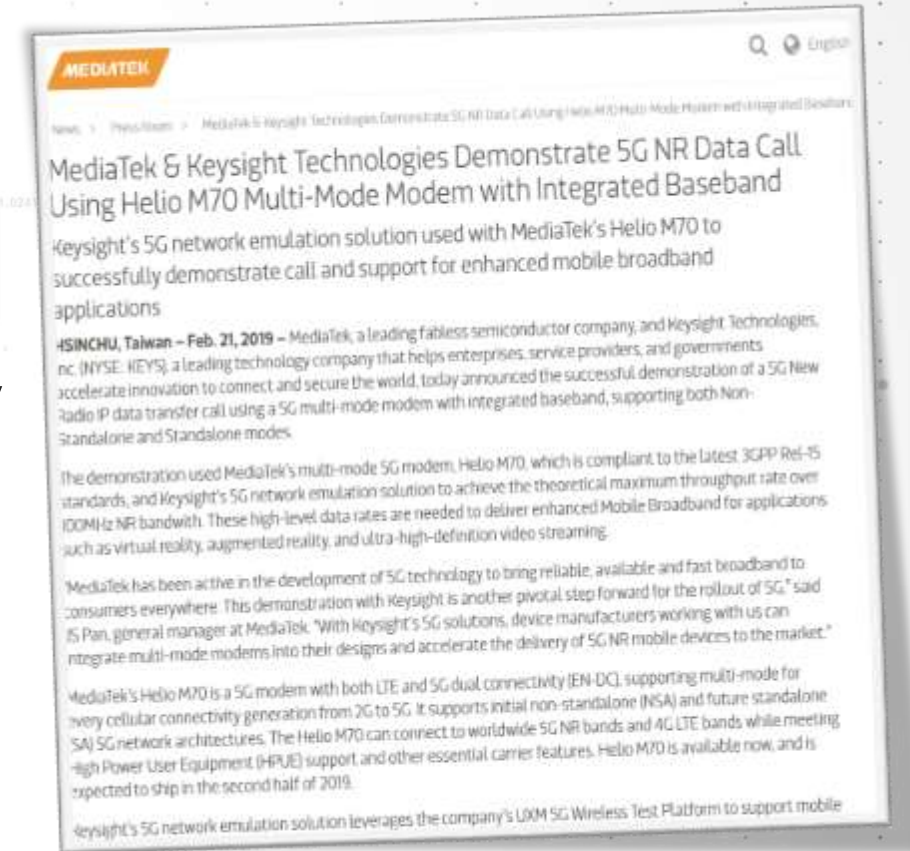
Demonstrating Data Call with 5G NR Multi-Mode Modem

MEDIATEK'S 5G NR MODEM & KEYSIGHT'S 5G NETWORK EMULATION SOLUTION

- Keysight's E7515B UXM 5G network emulation solution used with MediaTek's Helio M70 to successfully demonstrate call and support for enhanced mobile broadband applications
- M70 is a 5G modem with both LTE and 5G dual connectivity (EN-DC), supporting multi-mode for every cellular connectivity generation from 2G to 5G non-standalone (NSA) and standalone (SA) 5G network architectures.

"This demonstration with Keysight is another pivotal step forward for the rollout of 5G. With Keysight's 5G solutions, device manufacturers working with us can integrate multi-mode modems into their designs and accelerate the delivery of 5G NR mobile devices to the market."

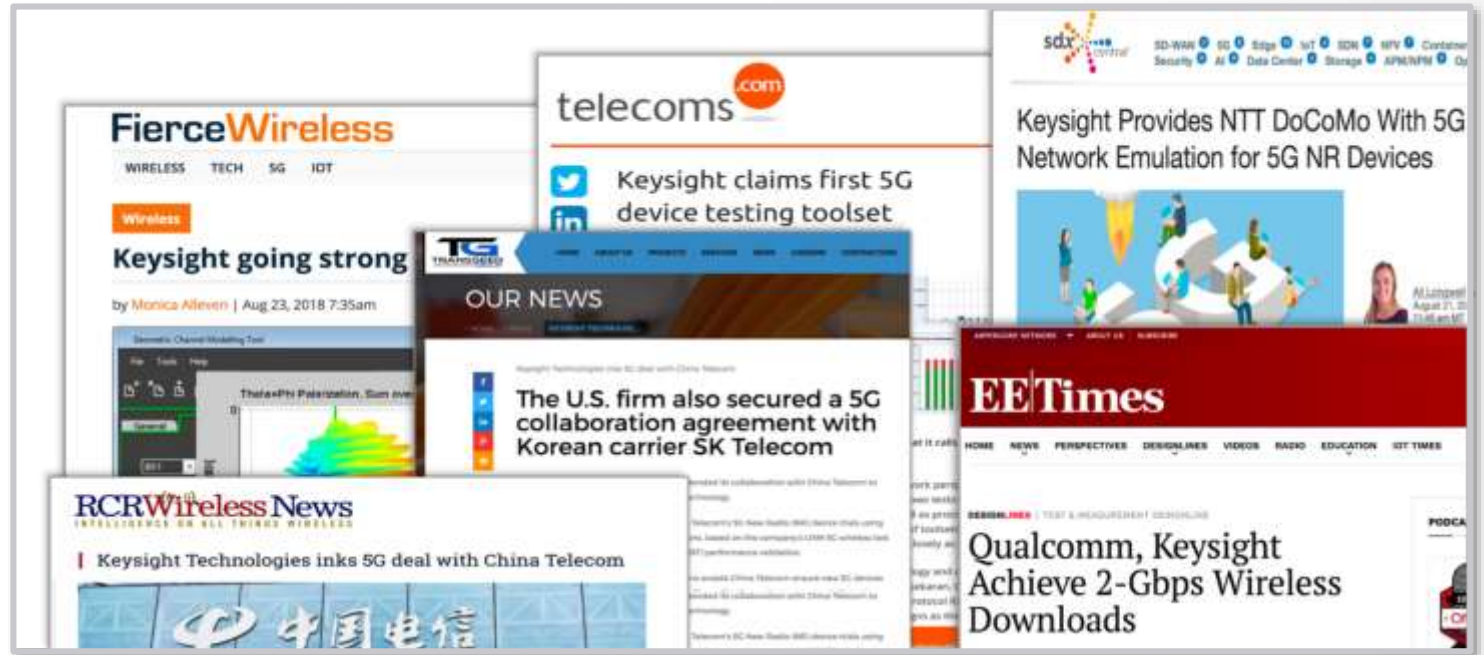
JS Pan
General Manager
Mediatek



Demonstrating Industry-Leading Data Rates for FWA

ASKEY'S 5G NR CPE & KEYSIGHT'S 5G NETWORK EMULATION SOLUTION

- High performing mmWave CPEs deliver wireless broadband services to customers' homes
- New CPE from Askey that leverages Qualcomm's Snapdragon X50 modem



"Keysight's 5G solutions enable us to accelerate development of 5G designs in support of emerging opportunities around the world."

Robert Lin
Chief Executive Officer
Askey

Keysight Powers China's Mobile Ecosystem

- Close collaborations with entire Chinese mobile ecosystem
 - China Mobile, China Telecom, CICT, UNISOC, CAICT, Datang, etc.
- Industry-first 5G solutions (across layer 1-7) help China launch early 5G trials
- Playing a key role in accelerating deployments by participating in industry consortia
 - 5G Device Forerunner Initiative
 - IMT-2020 (5G) Promotion Group
 - Future Forum
- Chinese mobile device makers (e.g. Xiaomi, OnePlus, Vivo, OPPO, etc.) use Keysight's 5G solutions to accelerate design, development and acceptance



5G Services in Japan by 2020

PRE-COMMERCIAL LAUNCHES IN 2019

- **NTT DOCOMO & SoftBank** use Keysight's 5G network emulation solutions for characterizing and validating 5G NR mobile devices
- NTT DOCOMO use Keysight's **channel sounding solutions** for 5G research project

"Keysight's proven expertise in 5G and end-to-end test solutions enable us to accelerate our 5G commercialization plans."

Toshiyuki Futakata

Vice president and general manager

Communication Device Development Department

NTT DOCOMO



30% of Korea's Mobile Users to Access 5G by 2020

ACCELERATING COMMERCIALIZATION IN KOREA WITH MARKET MAKERS

- **Samsung & Keysight** accomplish 5G NR IODT milestone
 - Maximum achievable 5G NR data throughput demo
 - Keysight's 5G Network Emulation Solutions (UXM 5G) used for protocol and RF development & validation
- 5G collaboration with **SK Telecom** covers
 - 5G network design development
 - 5G device performance validation technology
 - Test cases and processes
- 5G collaboration with **KT Corporation** to
 - Support commercial 5G NR deployment plans
 - Test 5G infrastructure and UE across sub-6GHz & mmWave



"We are pleased to collaborate with Keysight, the company with 5G expertise and solutions in this field, to help support our ambitious 5G deployment goals."

Jongkwan Park
Head of Network Technology R&D Center
SK Telecom

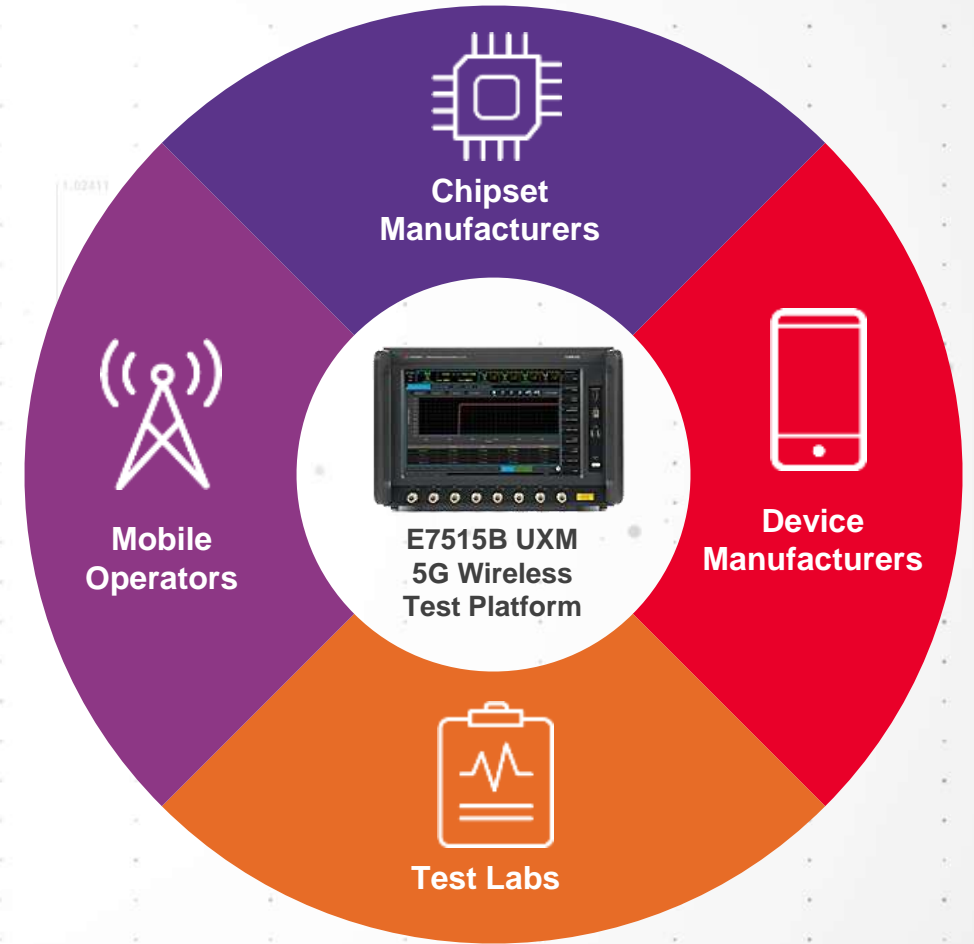
Supporting the Entire 5G Mobile Ecosystem in the U.S.

ACCELERATING DELIVERY OF FIXED WIRELESS AND EMBB SERVICES

- Keysight supports all major U.S. mobile operators in their goals to validate new mobile devices prior to deployment
- Keysight offers leading test case coverage, supporting device acceptance test plans mandated by each mobile operator
- Keysight's Nemo RAN analytics solutions automate operator's 5G NR site acceptance

“With 5G commercialization starting in the first half of 2019, Qualcomm Technologies joining forces with Keysight, helps enable the entire mobile ecosystem to make 5G a commercial reality.”

Jon Detra
Vice President, Engineering
Qualcomm Technologies, Inc





Performance Test Requirements 5G Device Testing

The 5G Race Is On...

AROUND THE WORLD

Deployments are accelerating

More mobile operators launching 5G networks to capture new business models

Standards are evolving

New use cases driving new standards evolution

Technical complexity is high

Diversity driven by multiple regional ecosystems progressing in parallel





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