



KEYSIGHT
WORLD 2019

5G New Radio Standards, Trends and Opportunities – a reality check

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Keysight Technologies*



5G Is Changing the World

1M

5G subscribers in Korea

9

commercial 5G phones

26

commercially launched 5G networks

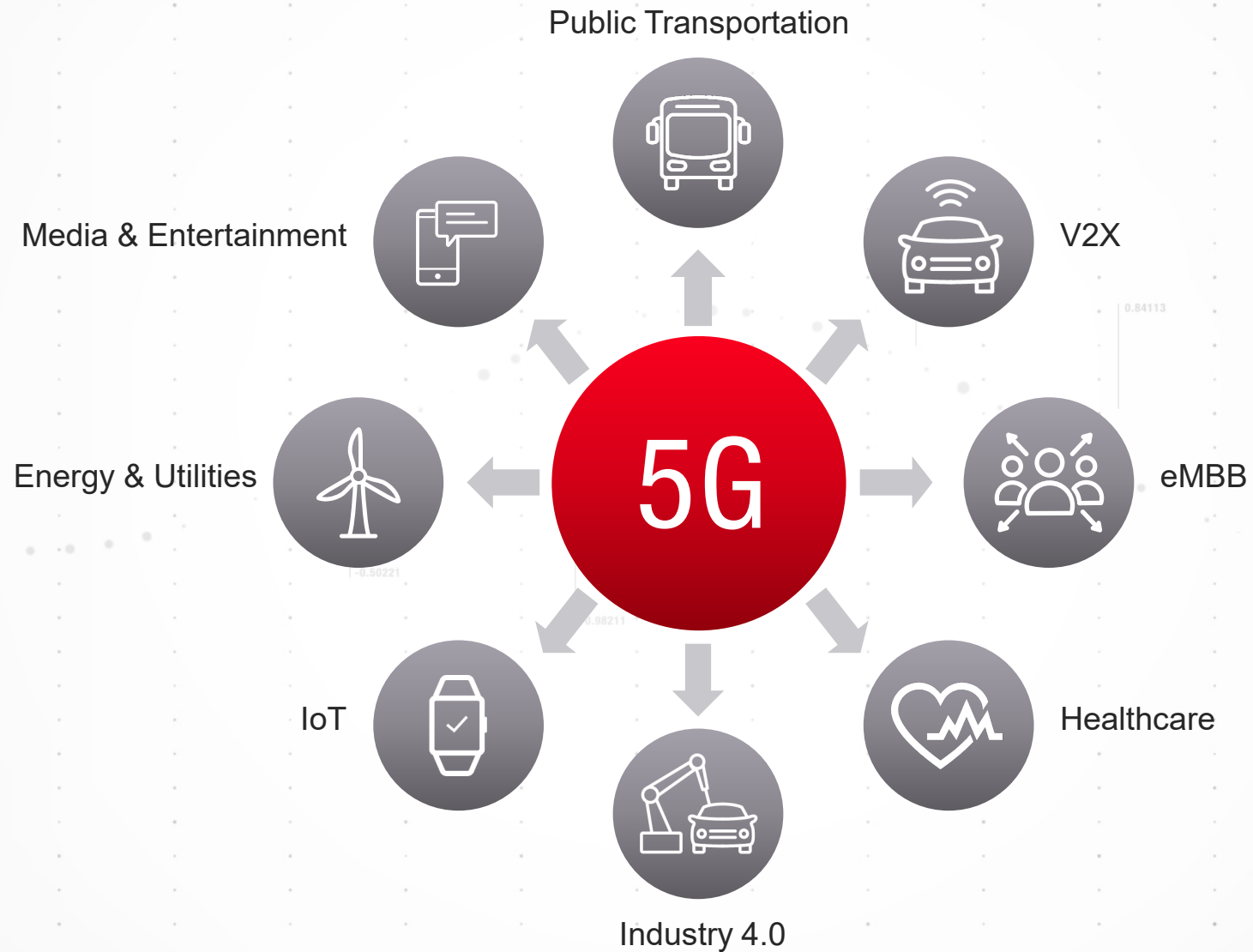
33

vendors have announced
5G devices

16

countries have deployed
5G services

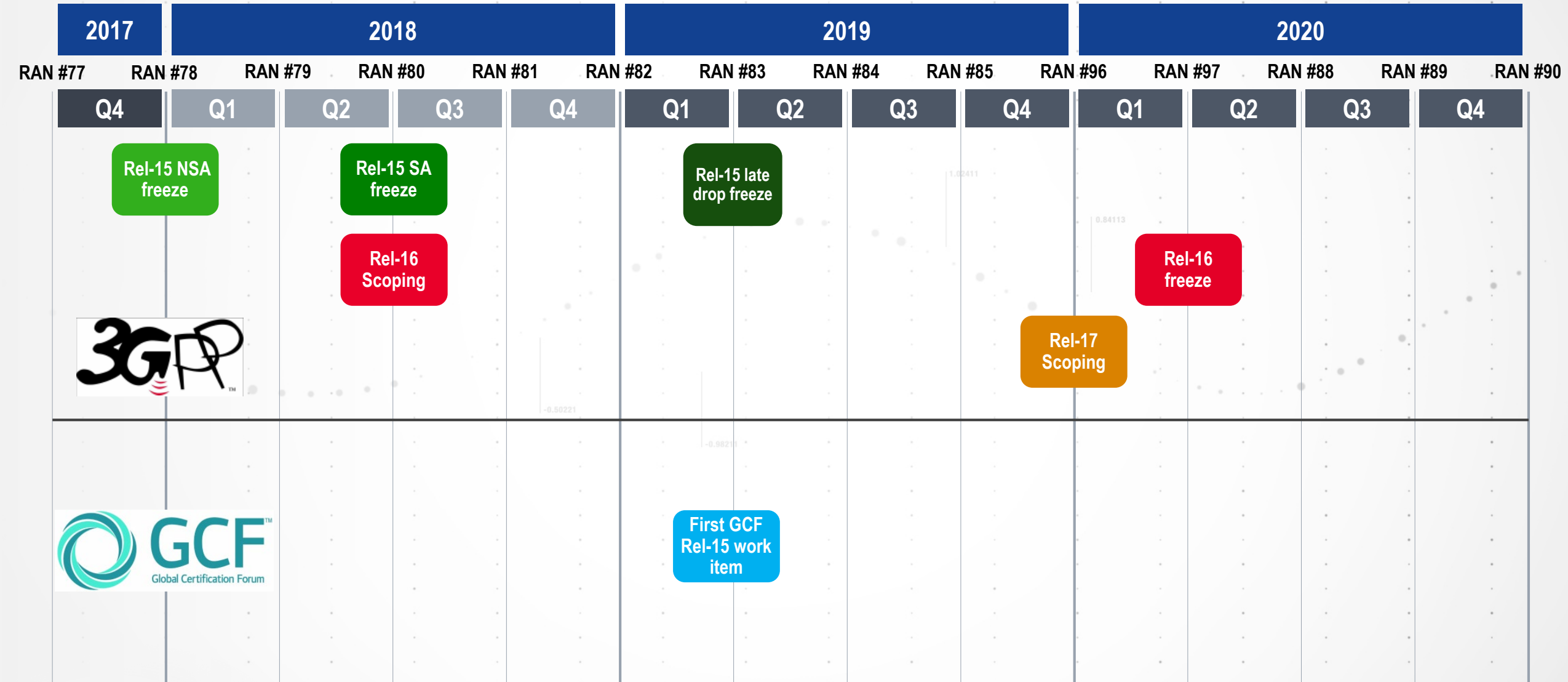
Realizing the Vision of 5G



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 **400 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."

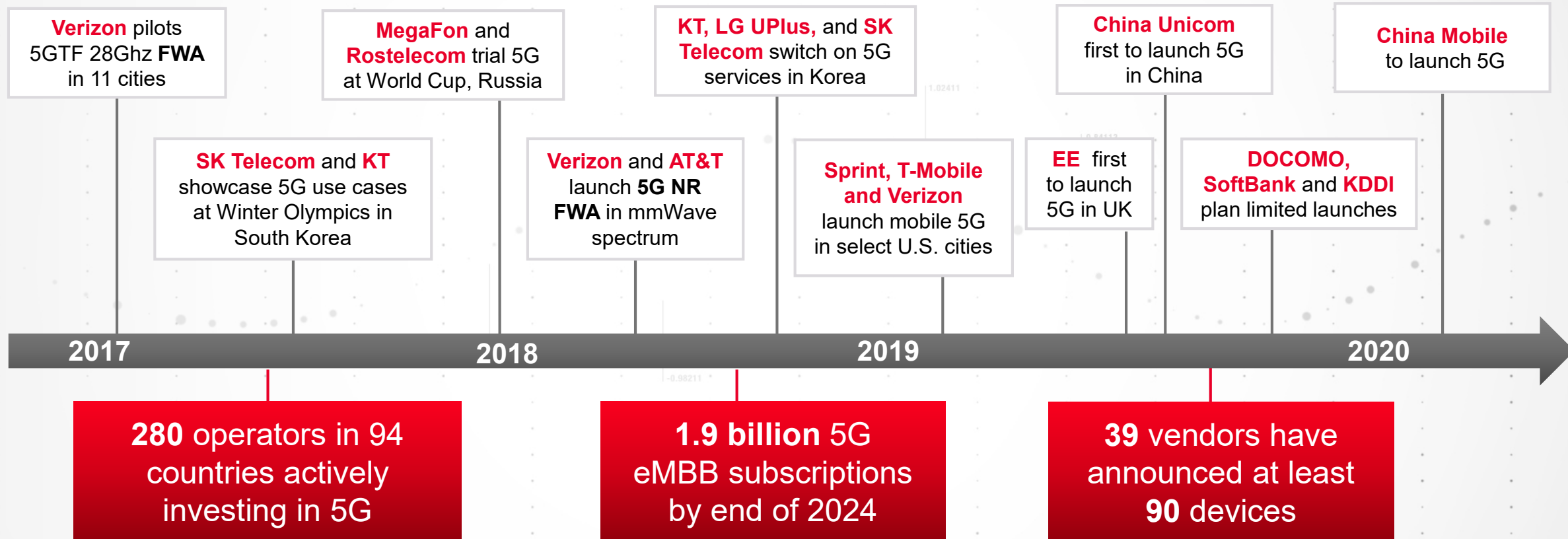
Tony Schwarz, Senior VP of Engineering, Qualcomm Technologies

Mobile Operator Deployments Accelerating Around the World



















Switching on 5G – In Country After Country

DEPLOYMENTS ARE ACCELERATING



Interoperability Key for Global Deployments

	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								<div></div> <div></div>					<div></div> <div></div> <div></div>	

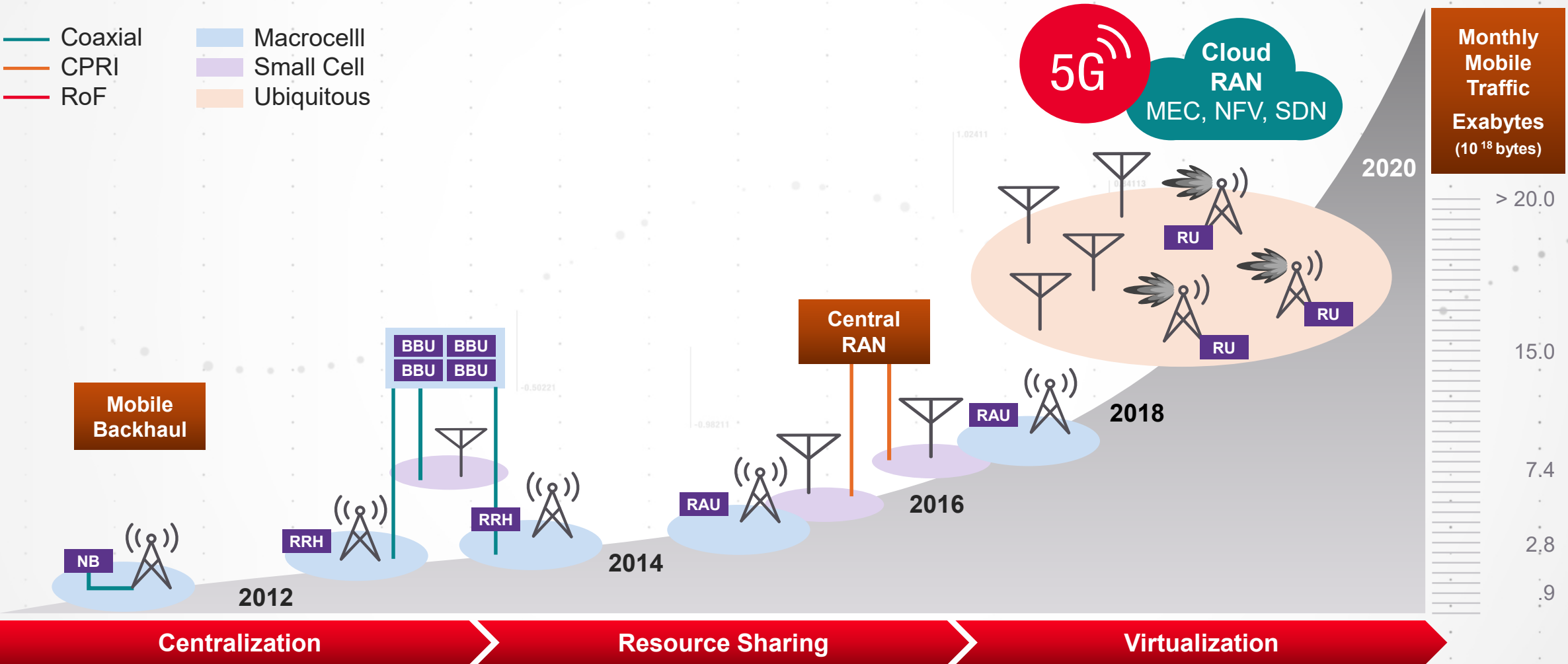
To date 562 5G trials using more than 40 different frequency bands

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

n78 (3300-3800MHz) band most popular 3GPP-specified band: >120 trials

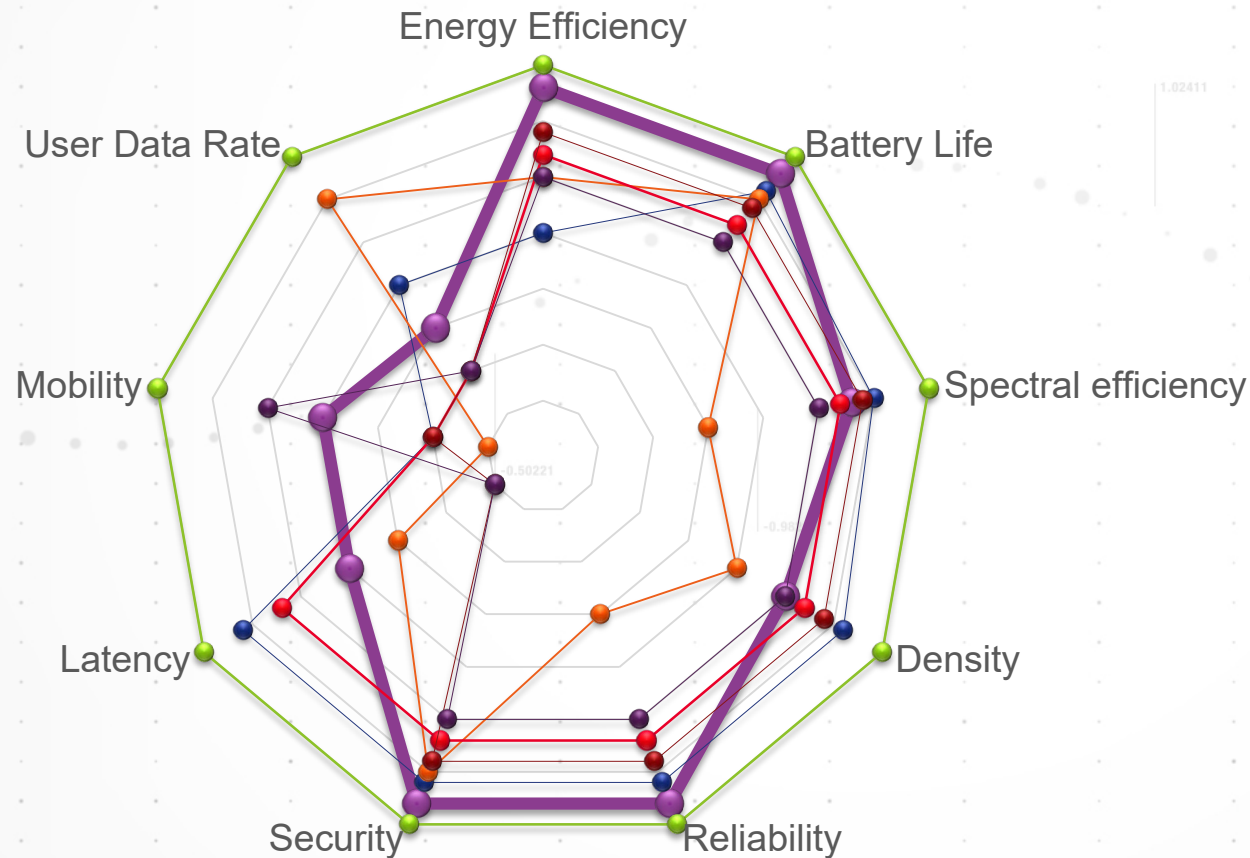
New Network Architecture

ENABLING NEW BUSINESS MODELS



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

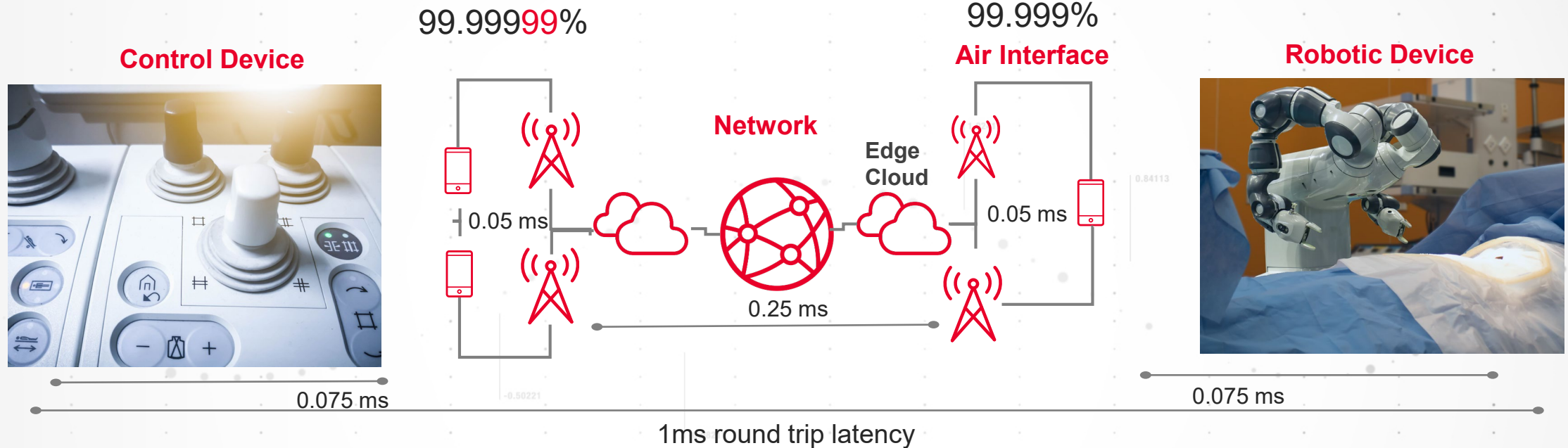
Promise of 5G

New Use Cases and Business Models



First Remote Surgical Intervention Over 5G

DRIVE TEST AND ANALYTICS SOLUTIONS VERIFY QOS & OPTIMIZE 5G NR NETWORK



Specialist surgeon used 5G technology to guide an operation performed by another surgeon without being physically present

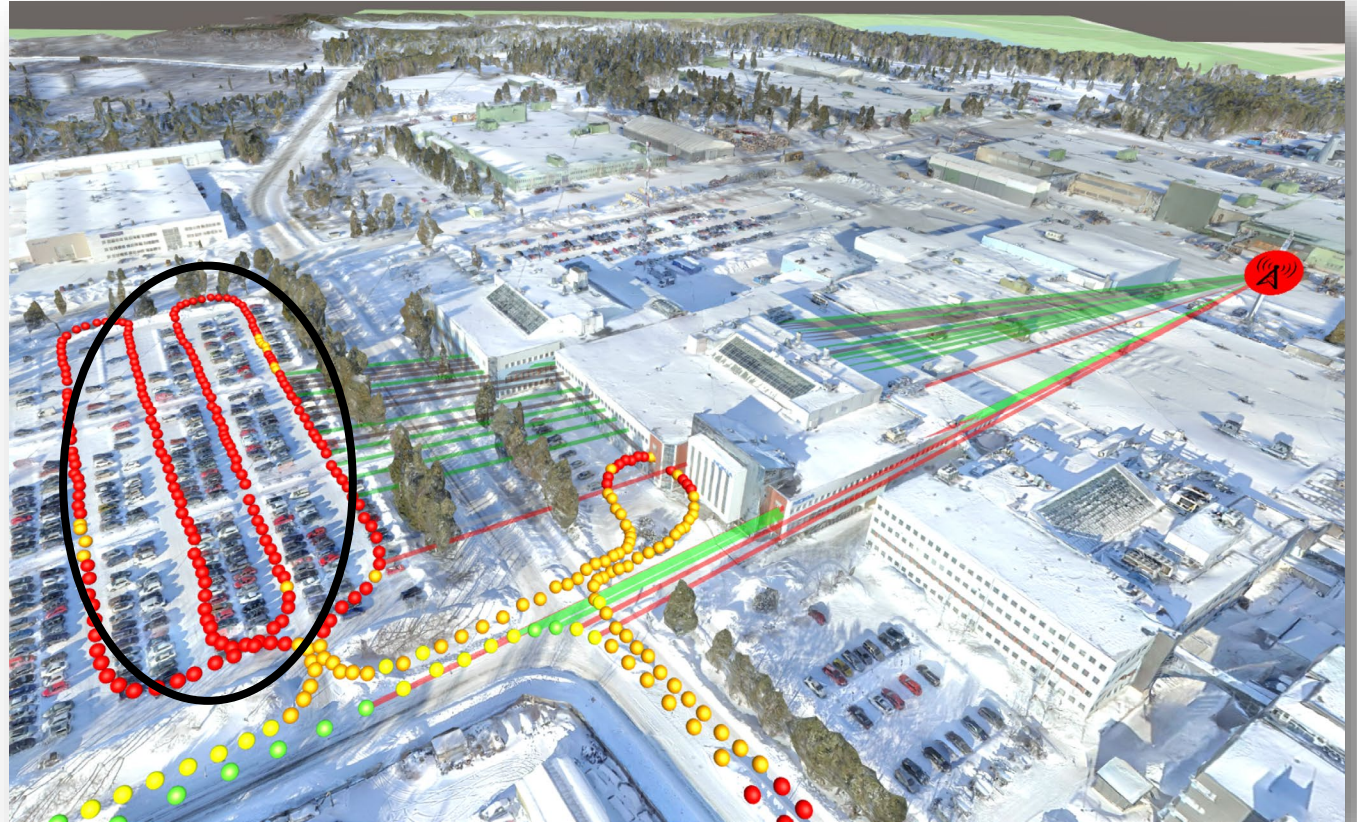
QoS

- Near-zero connection downtime
- **Minimum packet loss and no video freeze**
- Malware and intruder proof

3D Visualization of 5G Field Test Results

LINE OF SIGHT, BLOCKAGE, SHADOWING, ETC. AT MMWAVE FREQUENCIES

- Massive MIMO and antenna beamforming are the key technologies enabling 5G
- From static cell based coverage to beam based coverage
- 3D Beam performance is closer to light than traditional radio signal
- Major challenge for Operators and NEM's to verify and understand the quality and coverage of the cell capacity in dynamic user-based coverage

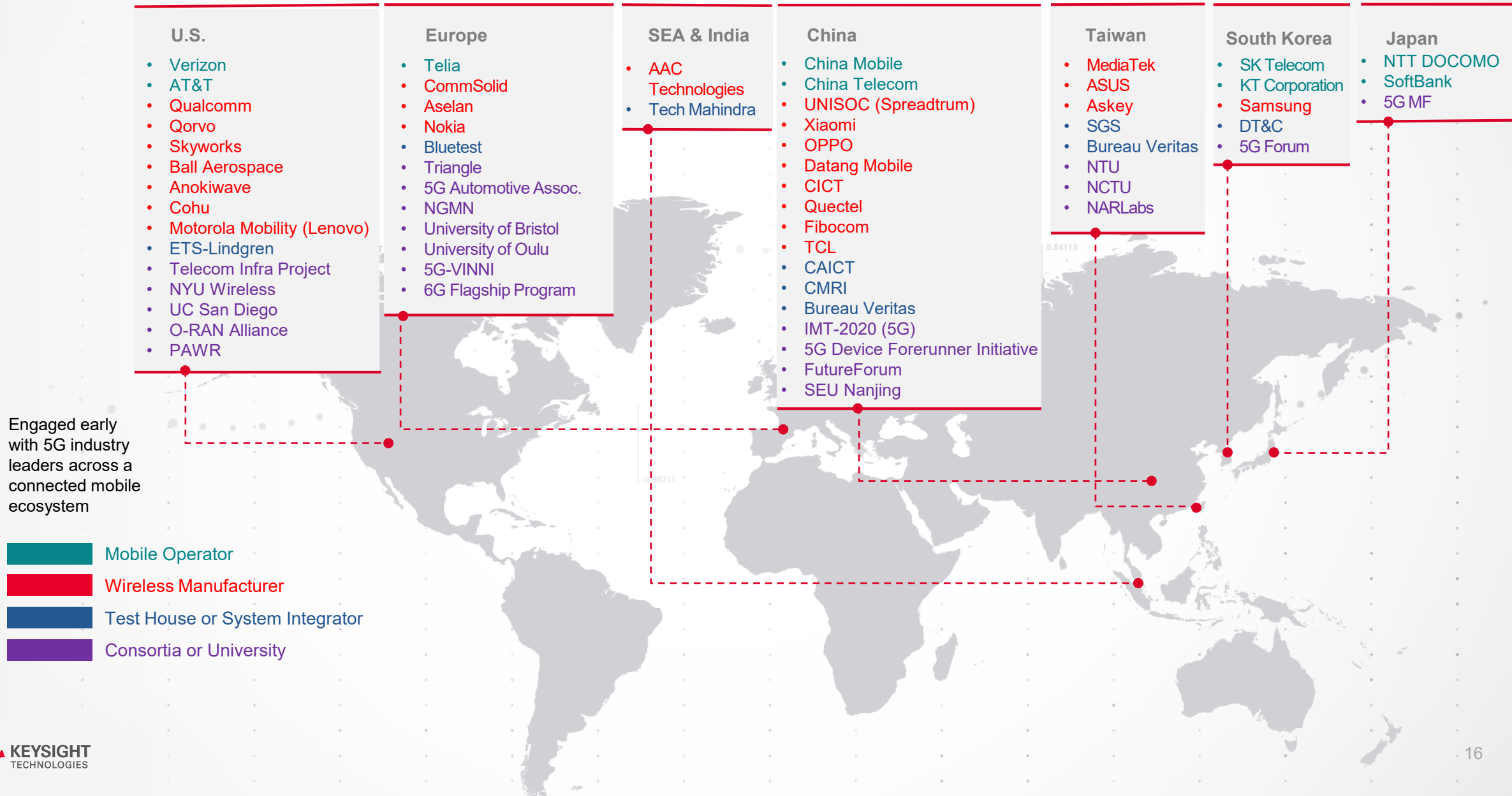


How does Keysight Enable the Industry?

Our Role in Making 5G a Reality

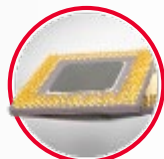


Extensive Collaborations Around The World



A Comprehensive Solutions Portfolio

COVERAGE OF ENTIRE COMMUNICATIONS INDUSTRY



Components &
Chipsets



Devices



Base
Stations



Hyperscale and
Data Centers



Enterprise

Layers
2-7

Protocol Design & Acceptance

Field &
Drive Test

Network Security

Over-The-Air (OTA)
Test

Key Performance
Indicators

WiFi Coexistence

Network Monitoring

Beamforming

MIPI¹ Digital Test
and LP/DDR5

Channel Emulation

Network Loading

mmWave
Parametric





Circuit Simulators

5G Waveforms

100G / 400G

Gen 5
PCIe & Memory

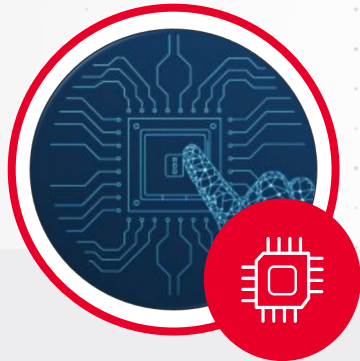
Layer 1

Solutions:  Keysight Classic  Ixia  Anite  AT4

5G Solutions To Connect The Workflow

STREAMLINING TIME-TO-MARKET

**Design
& Validation**



Advanced Design Simulation
mmWave Test Bed
Network & UE Emulation

**Conformance
& Acceptance**



Protocol Conformance
RF/RRM Conformance
Carrier Acceptance

Manufacturing



RFFE / RFIC Mfg.
Base Station Mfg.
Device Mfg.

**Deployment
& Operations**



Field Test
Drive Test
Monitoring & Security

PATHWAVE Connects the Workflow: Open, Scalable, Predictive

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

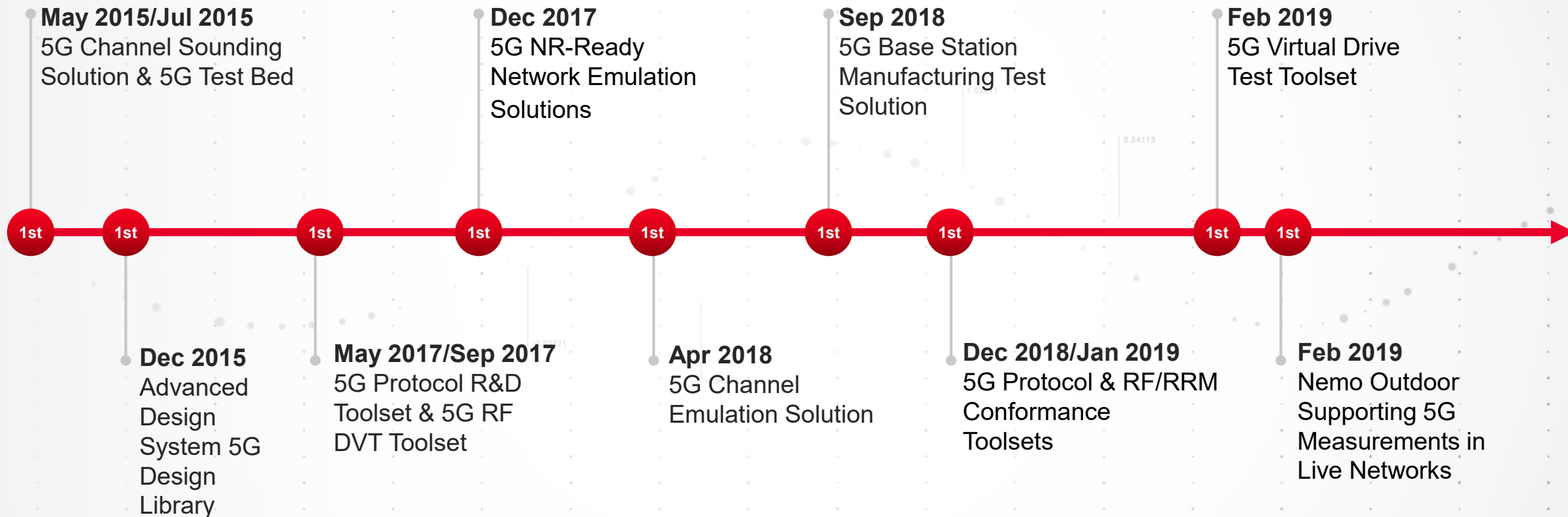


"We are pleased to collaborate with Keysight, the company with 5G expertise and solutions in this field, to help support our ambitious 5G deployment goals."

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

Keysight's Contributions & Proof Points

INDUSTRY-FIRST SOLUTIONS



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





Partner with Keysight and gain market
leading end-to-end insights to innovate,
transform, and realize your 5G goals

Thank you!



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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