Wireless Communications 2021: An Industry Update

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KEYSIGHT TECHNOLOGIES

Cellular Communications Technology Waves

Over 40 Years of Innovation

We are here

…and the Wireless Revolution is Just Getting Started

	1980s	1990s	2000s	2010s	2020s	2030s	2040s
	1G Carry your phone around the country	2G Carry your phone around the world & text	3G Check e-mail from anywhere	4G Surf the web & watch video from anywhere	5G Connect to the digital fabric from anywhere	6G H2M & M2M automation anywhere	7G Augment your intelligence everywhere
							
New Device Types	Mobile Phone	Feature Phone	Smartphone	Smartphones, Hotspots, IoT Sensors	Smartphones, Hotspots, Cars, Robots, Drones, Mass IoT…	Intelligent Devices Mass M2M	Mobile Virtual Assistants?
New Use Cases	Mobile Voice Calls	SMS MMS	Mobile Internet Video Call	Streaming Video Voice over IP	4K/8K Video AR & 3D AI	Holographic Multi-sense Comms Real-time Intelligence	TBD TBD
Technology Attributes – Data Rates:	19.2 kbps	384 kbps	43 Mbps	1 Gbps	20 Gbps	1 Tbps	XX Tbps
Technology Attributes – Frequency:	FR1	FR1	FR1	FR1	FR1, FR2	FR1, FR2, FR3/4?	TBD
Technology Attributes – Transmission:	Analog	Digital	Digital	Digital	Digital	Digital	Digital
Technology Attributes – RAT:	NMT, AMPS, TACS	GSM, GPRS, EDGE, IS-95	CDMA2000, UMTS	LTE, LTE-A, LTE-A Pro	NR SA & NSA	"ManyNets"	TBD
Technology Attributes – Multiple Access:	FDMA	TDMA, CDMA	CDMA	OFDMA	OFDMA	Any approach is OK	TBD
Technology Attributes – Switching:	Circuit	Circuit & Packet	Packet	Packet	Packet	"New IP"	TBD
Technology Attributes – Core Network:	PSTN	PSTN	Packet	Packet	Virtual	Virtual	TBD
Technology Attributes – Roaming:	National	Global	Global	Global	Global	Global	Global

Racing to Realize the Vision of 5G

WHERE WE HAVE BEEN AND WHAT'S NEXT?

5G PHASES

2010 - 2015
Research

2016 - 2019
Prototyping, Standards and Trials

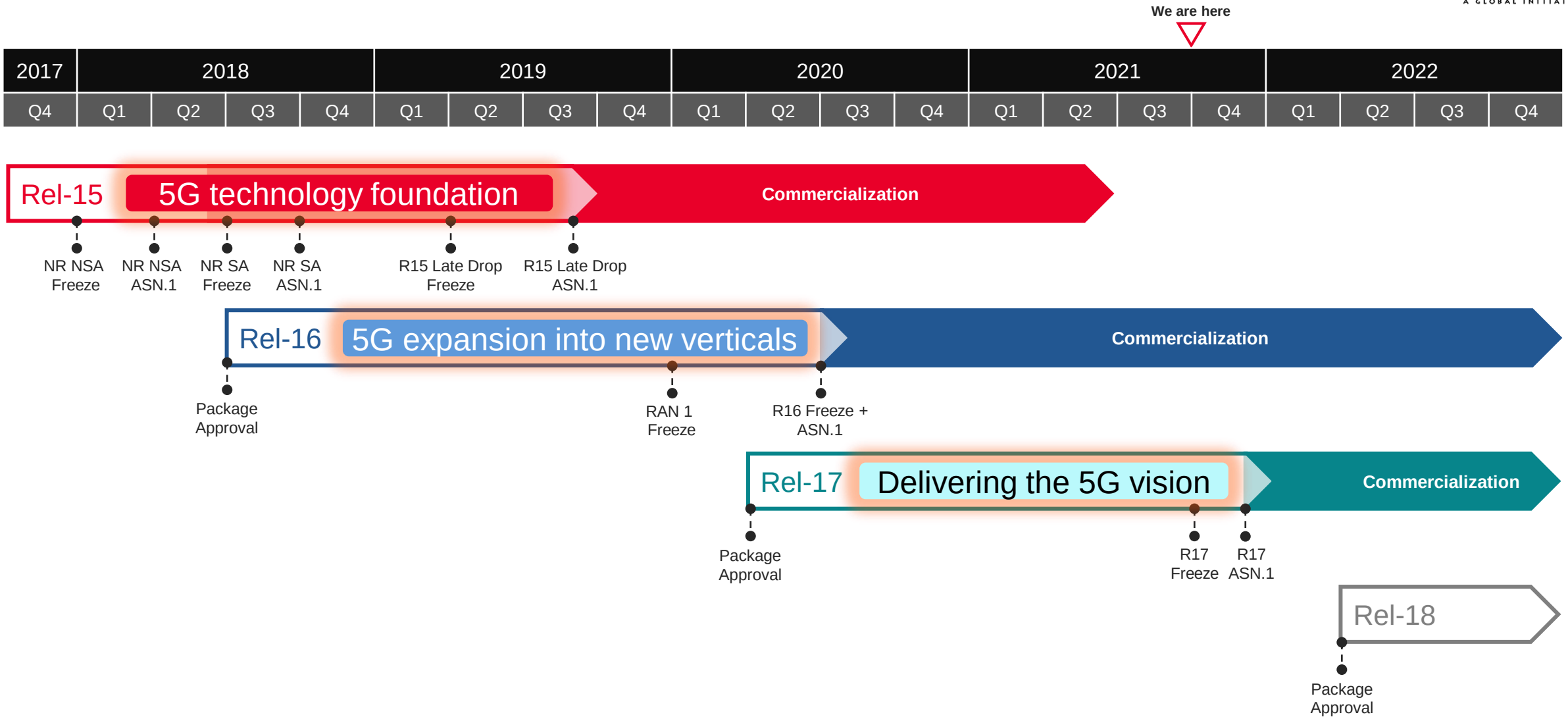
2020 – 2025+
Commercialize, Deploy & Ramp

We've Come a Long Way…

	2 years ago	Now (2020-2021)	2021-2025
5G Device Ecosystem	Less than **40** **vendors** had announced **90** 5G devices	More than **120** **vendors** have announced **700** **5G devices**	Proliferation of 5G in different form factors will continue
Mobile network operator (MNO) investments	**280** MNOs in 94 countries were investing in 5G	**435** MNOs in 133 countries now investing in 5G	MNOs continue to invest as many countries complete **5G spectrum auctions**
5G connections	Only a **handful of mobile operators** offered commercial 5G services	More than 400 million **5G subscribers** around the world	**5G** to account for **20%** of global connections by **2025**

Source: GSA Reports July 2019 & July 2020
https://gsacom.com/

3GPP Standards Evolution



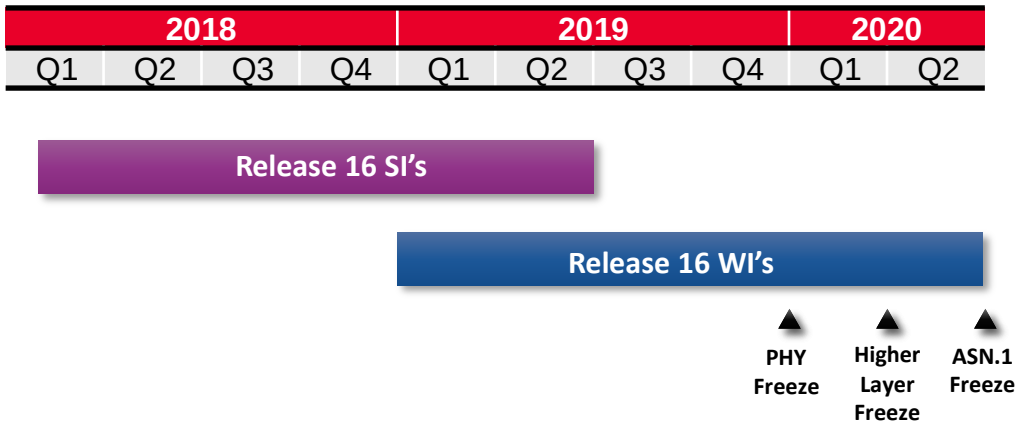
Release 16 - Overview

EFFICIENCY ENHANCEMENTS FOLLOWED BY VERTICAL EXPANSION

Focus

- Capacity enhancement
- Operation efficiency
- Expansion to vertical markets

Timeline



Main Features

Capacity and Operational efficiency

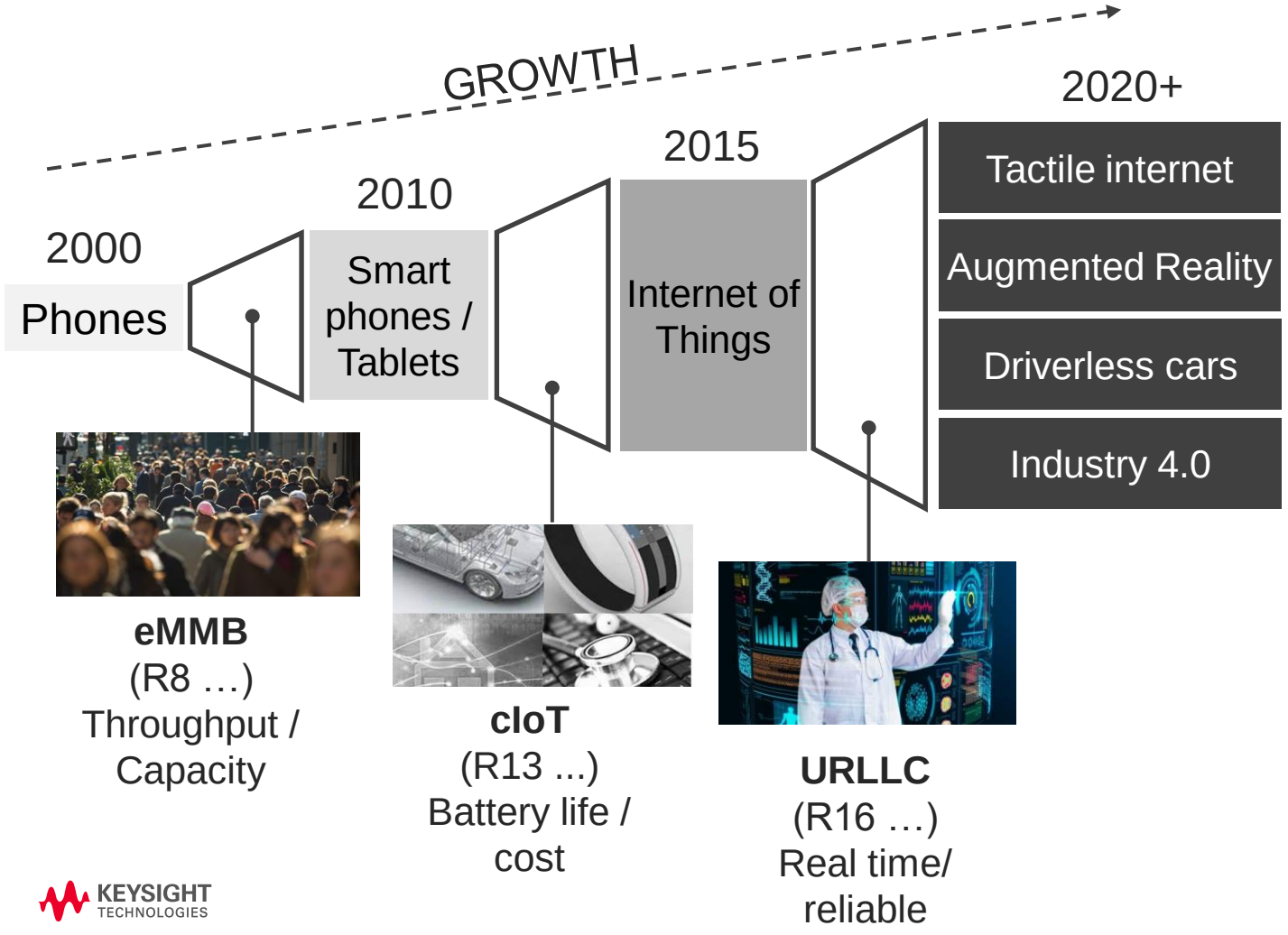
- MIMO enhancements
- MR-DC (Multi-RAT Dual Connectivity)
- IAB (Integrated Access and Backhaul)
- Mobility enhancements
- CLI/RIM
- UE power savings
- NR positioning

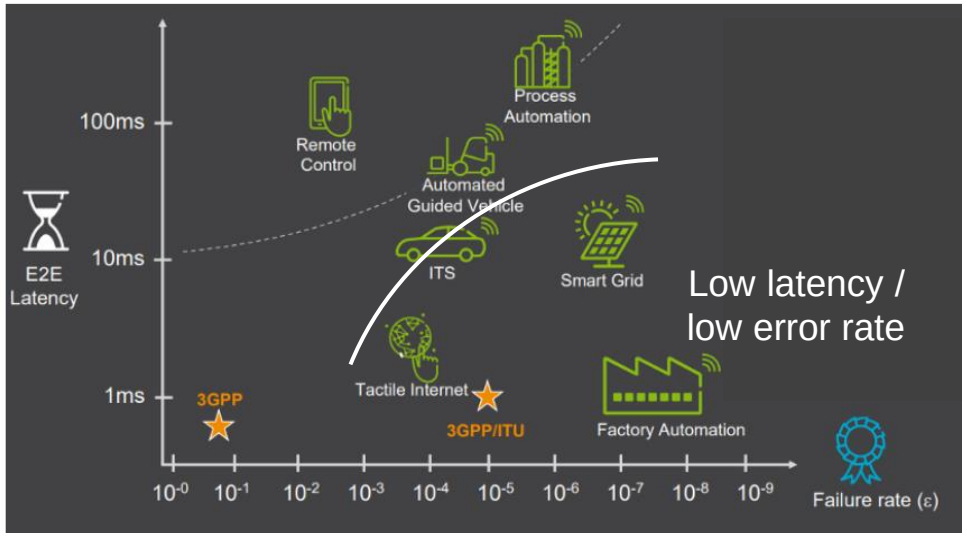
Vertical expansion

- IIoT (Industrial IoT)
- URLLC (Ultra Reliable Low Latency Communications)
- 2-step RACH
- NR unlicensed
- V2X (Vehicle to Everything)

R16 5G Enables more Device Types

INDUSTRY 4.0, DRIVERLESS CARS, AUGMENTED REALITY, TACTILE INTERNET



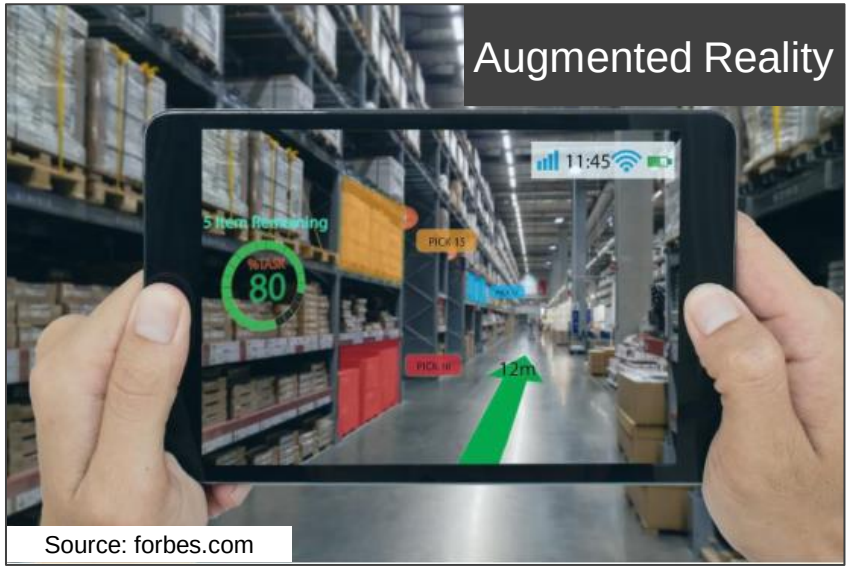


Source: Ericsson

New Devices and New Applications

ENABLED THROUGH R16 VERTICAL EXPANSION

- Human / machine interaction in real time via the internet
- Remote surgery

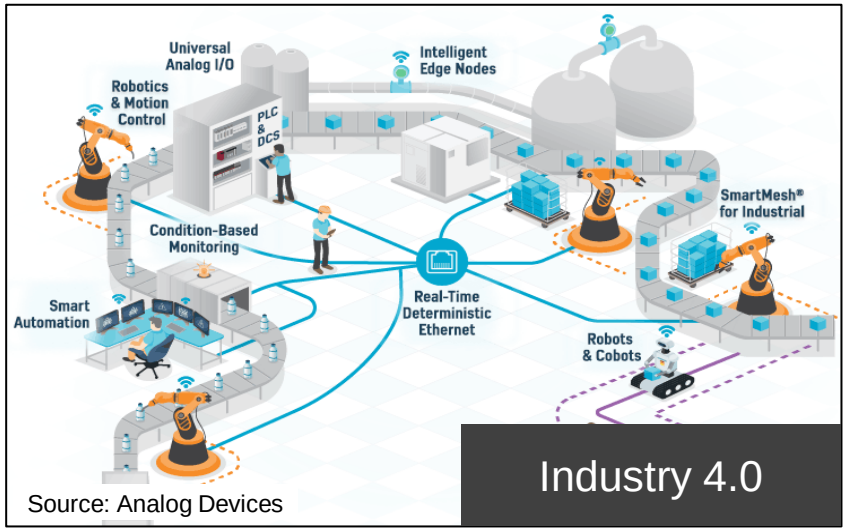


Source: forbes.com

- Superimpose intelligent computer-generated images on real world views
- Made more powerful by new devices

- Cars that can drive themselves
- Cars that can manage themselves

Source: The Motley Fool

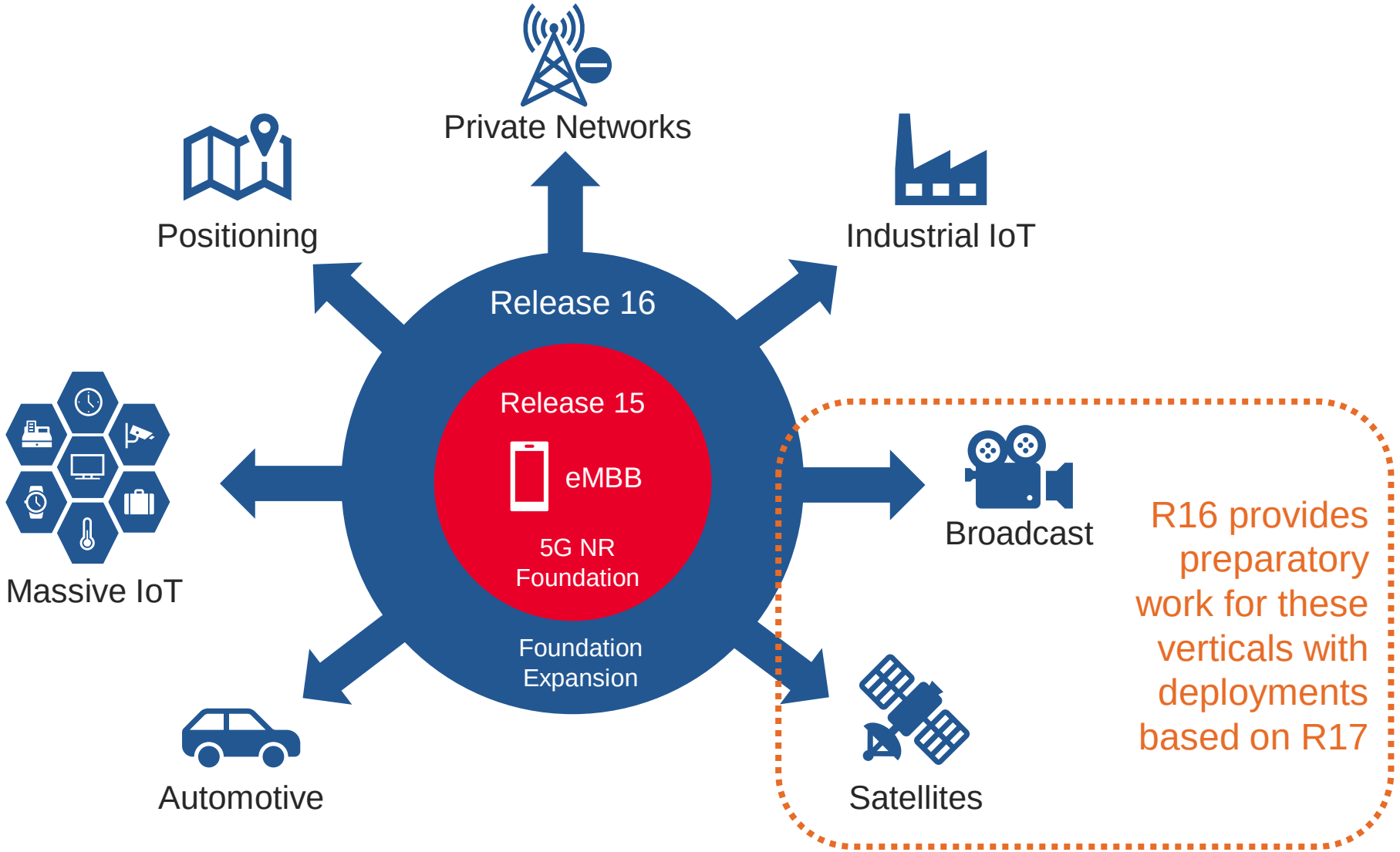


Source: Analog Devices

- Cyber physical systems
- Integrating computing, networking and physical processes
- Security is vital

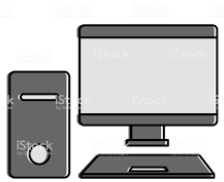
KEYSIGHT TECHNOLOGIES

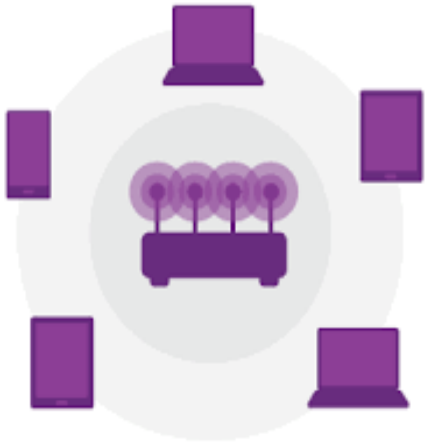
Rel-16: Driving 5G expansion into new verticals



Evolution of WLAN Technologies

Data Throughput Requirement (keep up with 5G)





802.11b 1999

802.11a/g 2003

802.11n Wi-Fi 4 2009

802.11ac Wi-Fi 5 2013

802.11ax Wi-Fi 6 2019 Wi-Fi 6E 2020

802.11be 2023

Wi-Fi 6/6E Applications

High-density environments

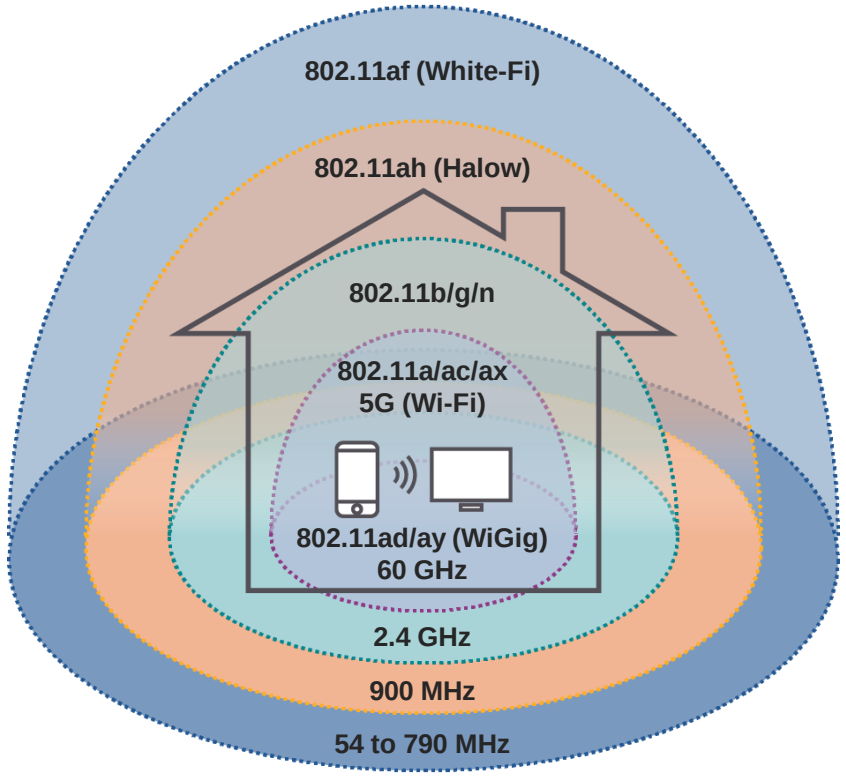
IoT

High usage homes

High BW applications

- video conferencing
- 4K, 8K video
- AR, VR

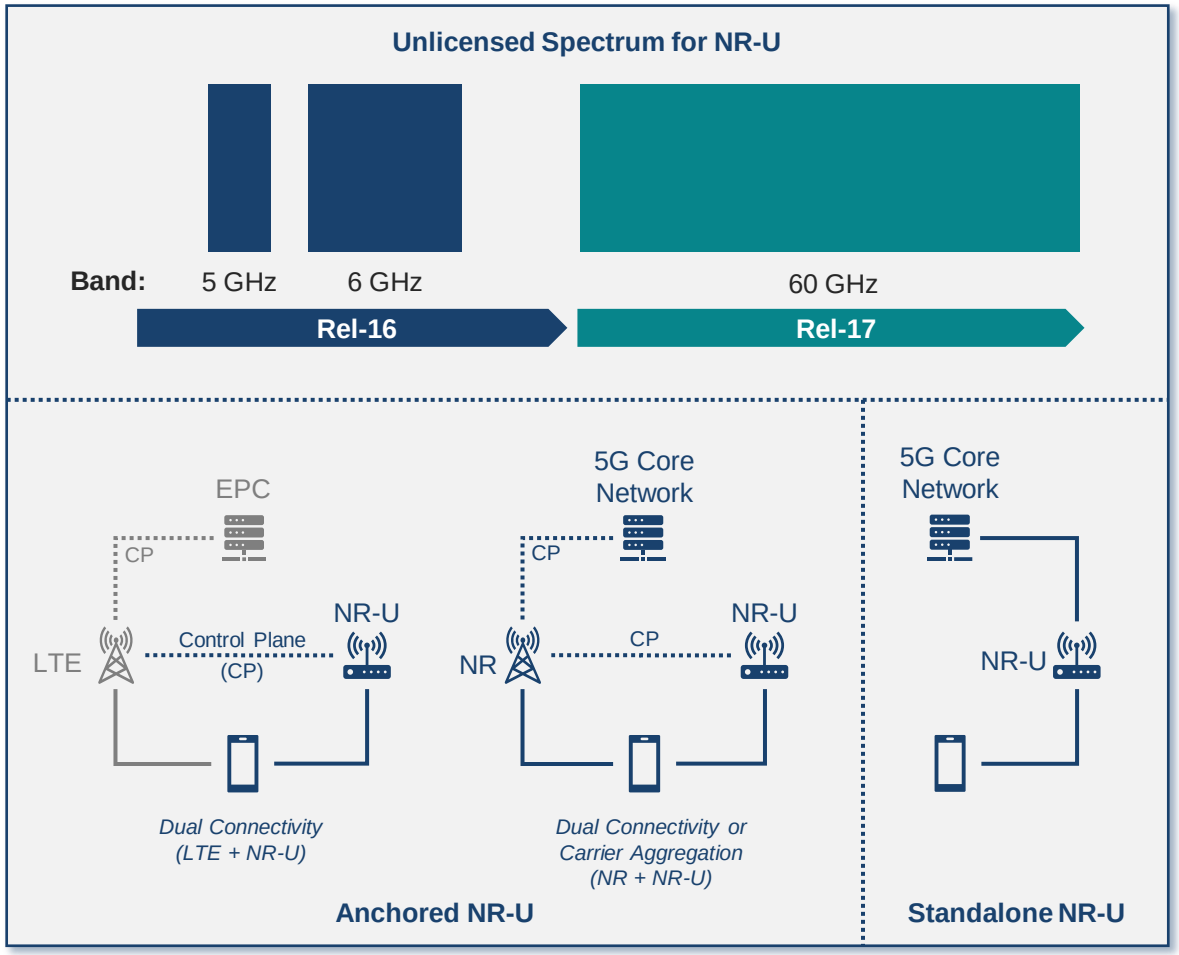
Evolution of WLAN Standards



Standard	Frequency (GHz)	Bandwidth (MHz)	Modulation	Max Data Rate
802.11b	2.4	22	DSSS	11 Mbps
802.11a	5	20	OFDM	54 Mbps
802.11g	2.4	20	OFDM	54 Mbps
802.11n (Wi-Fi 4)	2.4, 5	20, 40	MIMO-OFDM	600 Mbps
802.11ac (Wi-Fi 5)	5	20,40,80,160	MIMO-OFDM	7 Gbps
802.11ax (Wi-Fi 6/6E)	**2.4, 5, 6**	**20,40,80,160**	**MU-MIMO OFDMA**	**10 Gbps**
802.11be (EHT)	**2.4, 5, 6**	**320**	**MU-MIMO OFDMA**	**30 Gbps**
802.11ad	60	2160	SC/QAM	~8 Gbps
802.11ay	60	(2160) x2, x3, x4	SC/QAM, MIMO-OFDM	> 20 Gbps

5G Rel-16 Unlicensed Spectrum (NR-U)

- Allows 5G deployments in unlicensed spectrum
  - Existing 5 GHz band
  - New 6 GHz band (6 – 7.125 GHz), providing an extra 1200 MHz spectrum for 5G / Wi-Fi use
- Enables
  - More spectrum to be unlocked globally
  - Boost to LTE deployments
  - New markets and verticals (e.g. private networks)
  - New deployment scenarios (e.g. indoor events)
- Anchored NR-U
  - Unlicensed spectrum combined with licensed or shared spectrum as anchor
- Standalone NR-U
  - Only unlicensed spectrum is used



Drivers for Open RAN

COTS & Cloud

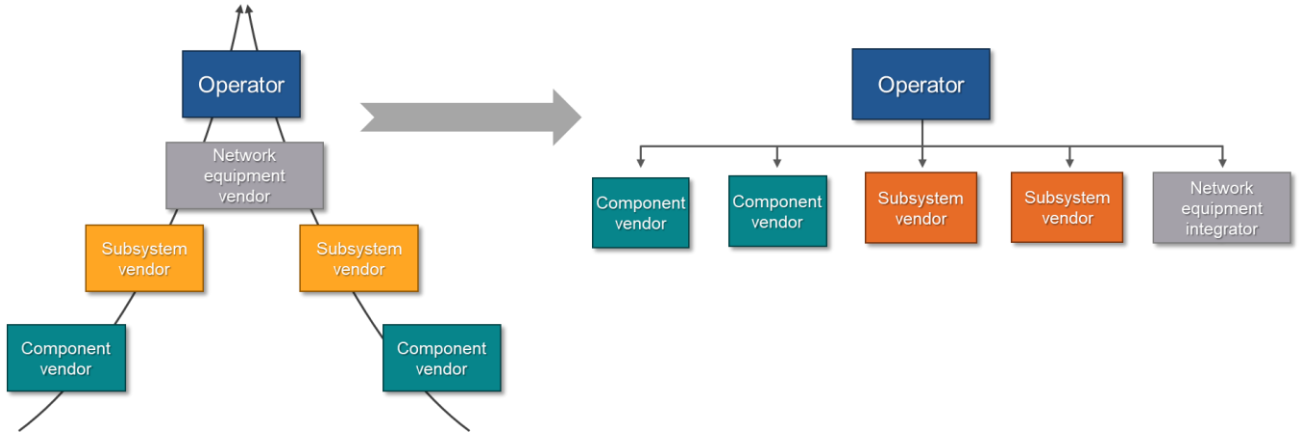
- COTS-based solutions help decouple HW, SW, and system innovations
- Platform-based design enables virtualization and cloudification

Disaggregation for Aggregation

- RAN disaggregation allows aggregation along different axes, leading to optimized resource usage and lower cost
  - Power and bandwidth in RU
  - Baseband/MAC pooling in the DU
  - Call processing aggregation in CU-CP
  - User plane aggregation in edge cloud CU-UP

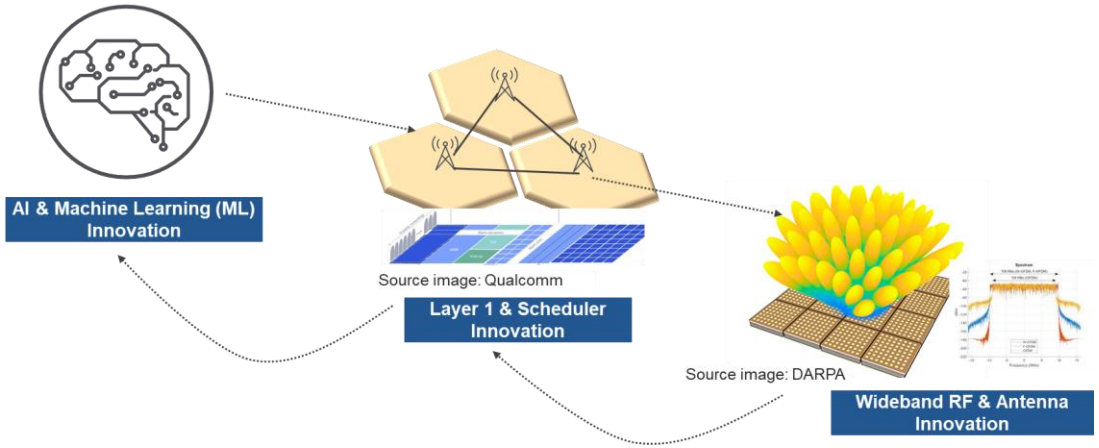
Flattening the Pyramid

- Open RAN minimizes customization and interoperability burden from closed subsystem interfaces
- Subsystem vendors focus on innovation



Cross-Pollination from 'Outsiders'

- Entry of non-telecom players
- Cross-domain innovation
  - Compute server vendors become wireless aware and radio experts understand AI



What is O-RAN?

XRAN AND CRAN MERGED TO FORM O-RAN IN SUMMER 2018

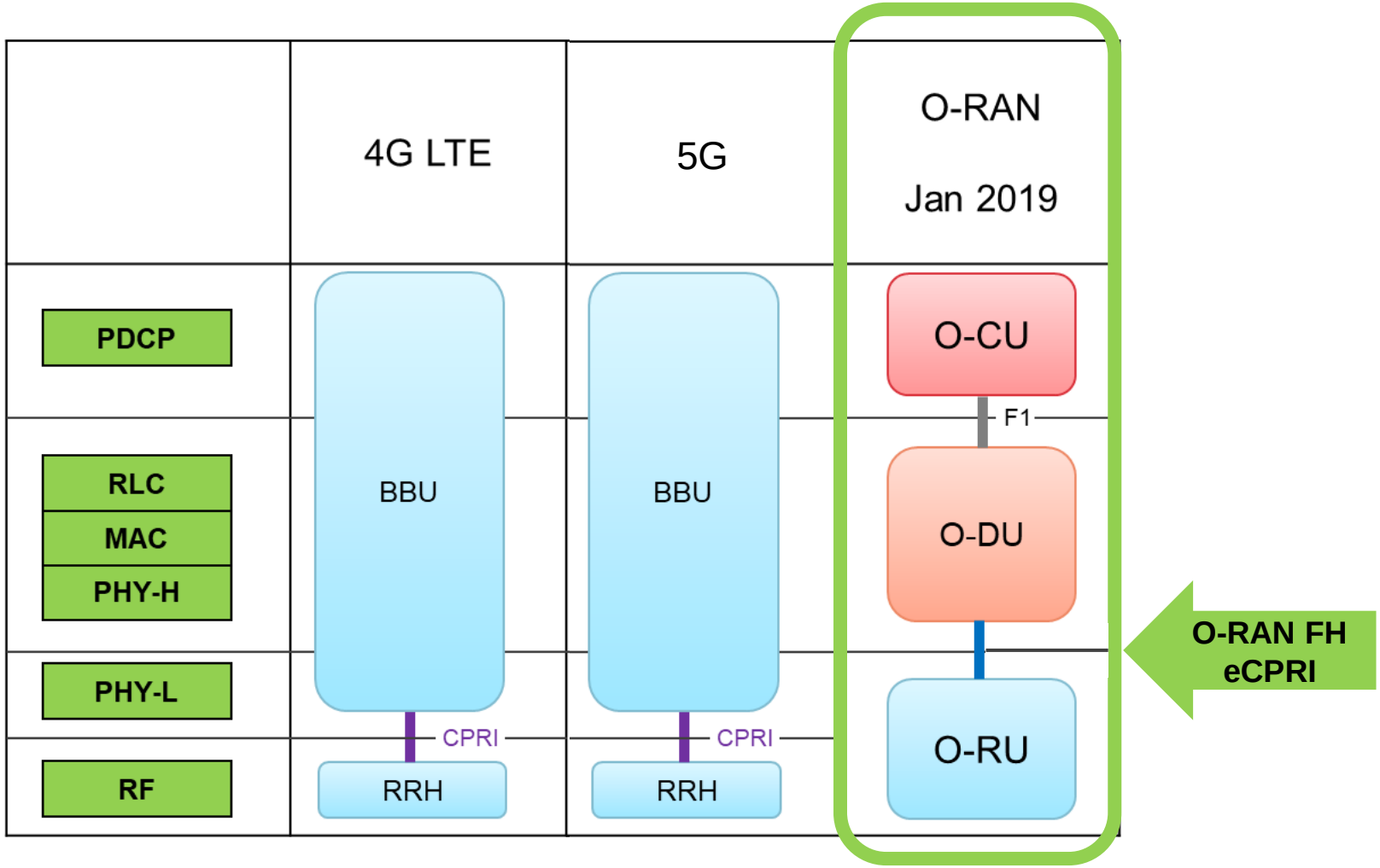
These carriers formed an O-RAN Alliance (https://www.o-ran.org/) summer 2018

"O-RAN Alliance members and contributors have committed to evolving radio access networks around the world. Future RANs will be built on a foundation of virtualized network elements, white-box hardware and standardized interfaces that fully embrace O-RAN's core principles of intelligence and openness. An ecosystem of innovative new products is already emerging that will form the underpinnings of the multi-vendor, interoperable, autonomous, RAN, envisioned by many in the past, but only now enabled by the global industry-wide vision, commitment and leadership of O-RAN Alliance members and contributors."

Why O-RAN? They wanted a RAN network architecture that allowed them to rapidly deploy new services they expect to offer in 5G.

RAN Terminology

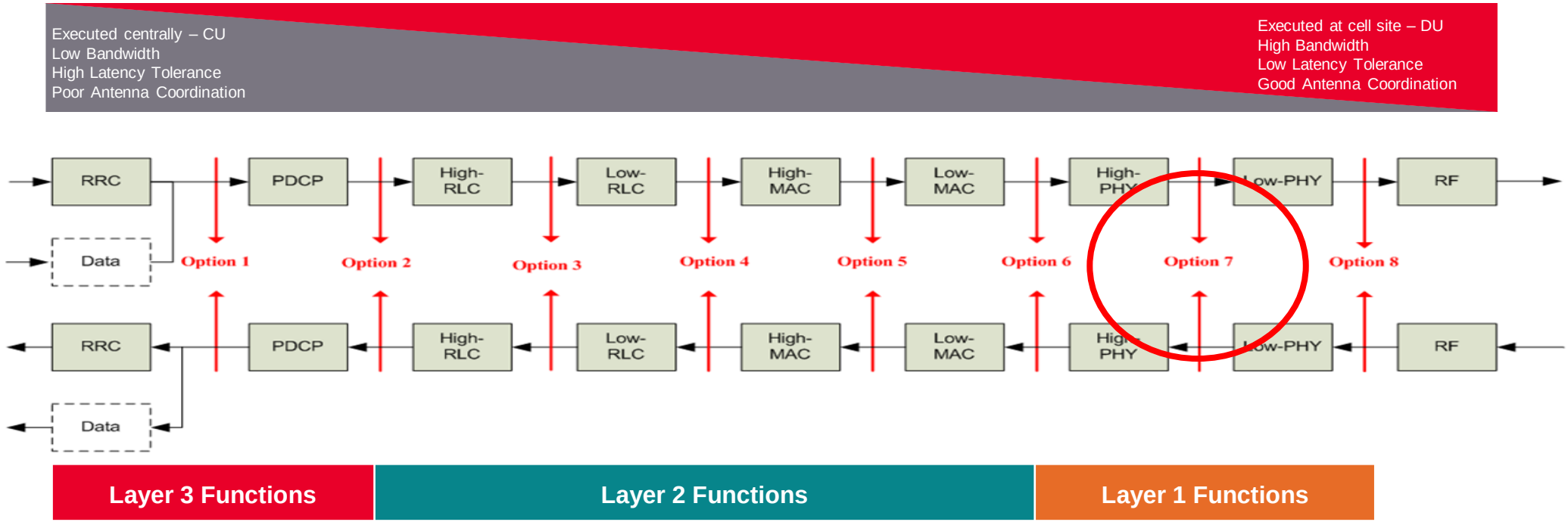
NEW TERMINOLOGY & NEW SPLITS FOR O-RAN



"One Vendor" "One Vendor" Can be Multiple Vendors

Functional Splits

Based on 3GPP 38.801



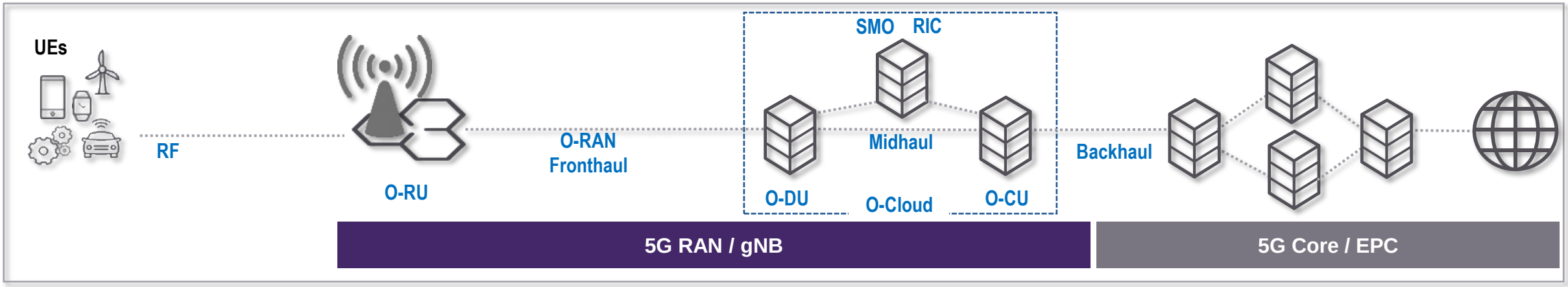
- A set of full radio protocol stack functional splits between distributed units (DUs) and Centralised Units (CUs)
- Main purpose is to lower bit-rates on fronthaul interfaces

What is ORAN

QUICK OVERVIEW OF ARCHITECTURE AND ACRONYMS

O-RAN Fronthaul (Open Fronthaul)
The protocol defining the transport layer between the RU and DU. Can include the use of eCPRI.

RAN Intelligent Controller (RIC)
Enables real-time and non-real-time control and optimization of the ORAN/RAN elements and resources. AI/ML can be added to the non-real-itme RIC



RU (Radio Unit)
Similar to an RRU, this is the analog RF part of the base station. Unlike a traditional base station, more physical layer processing is done on the RU.

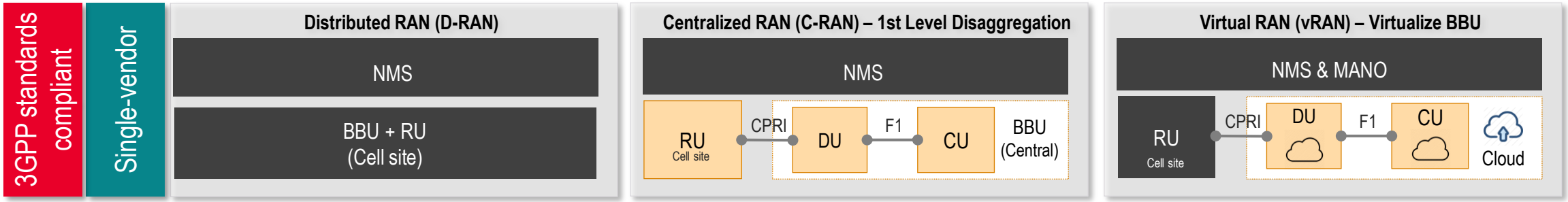
DU (Distributed Unit)
The lower layers of the protocol stack happen on the DU (RLC, MAC, and high phy). It can be virtualized or containerized. It processes and distributes traffic to one or more RUs

CU (Centralized Unit)
The less time-sensitive higher layers of the protocol stack happen on the CU (SDAP, RRC, and PDCP). It can connect to one or more DU and can also be virtualized.

Distributed RAN, Centralized RAN, Virtual RAN

A single-vendor implementation

D-RAN, C-RAN, & vRAN are typically associated with single-vendor RAN implementations



BBU: Baseband unit
NMS: Network management system
CU: Central unit
DU: Distributed unit
RU: Radio unit
RRH: Remote radio head

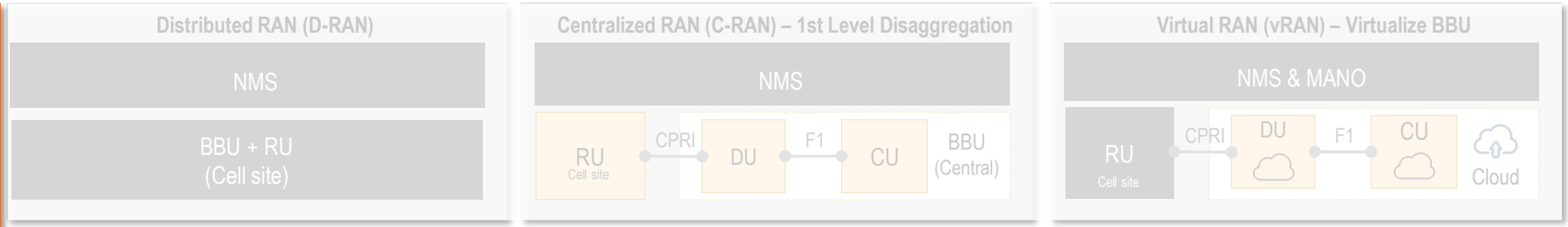
Open RAN - Further Disaggregation & Full Openness

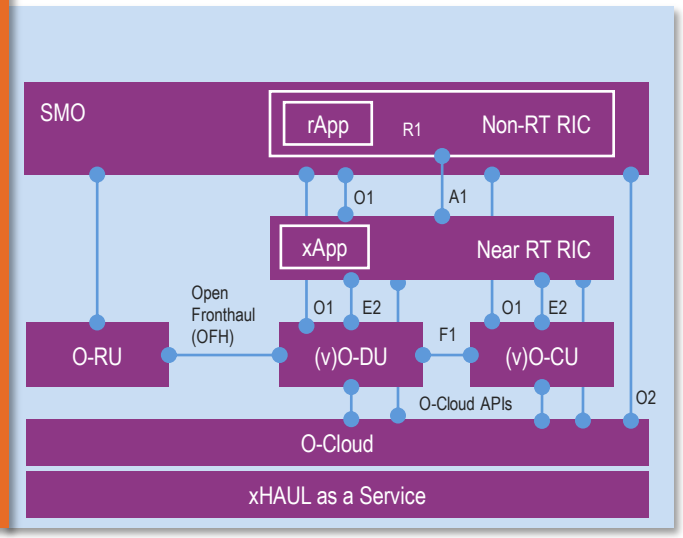
Multi-vendor interoperability & conformance becomes critical

D-RAN, C-RAN, & vRAN are typically associated with single-vendor RAN implementations

3GPP standards compliant

Multi-vendor interoperability





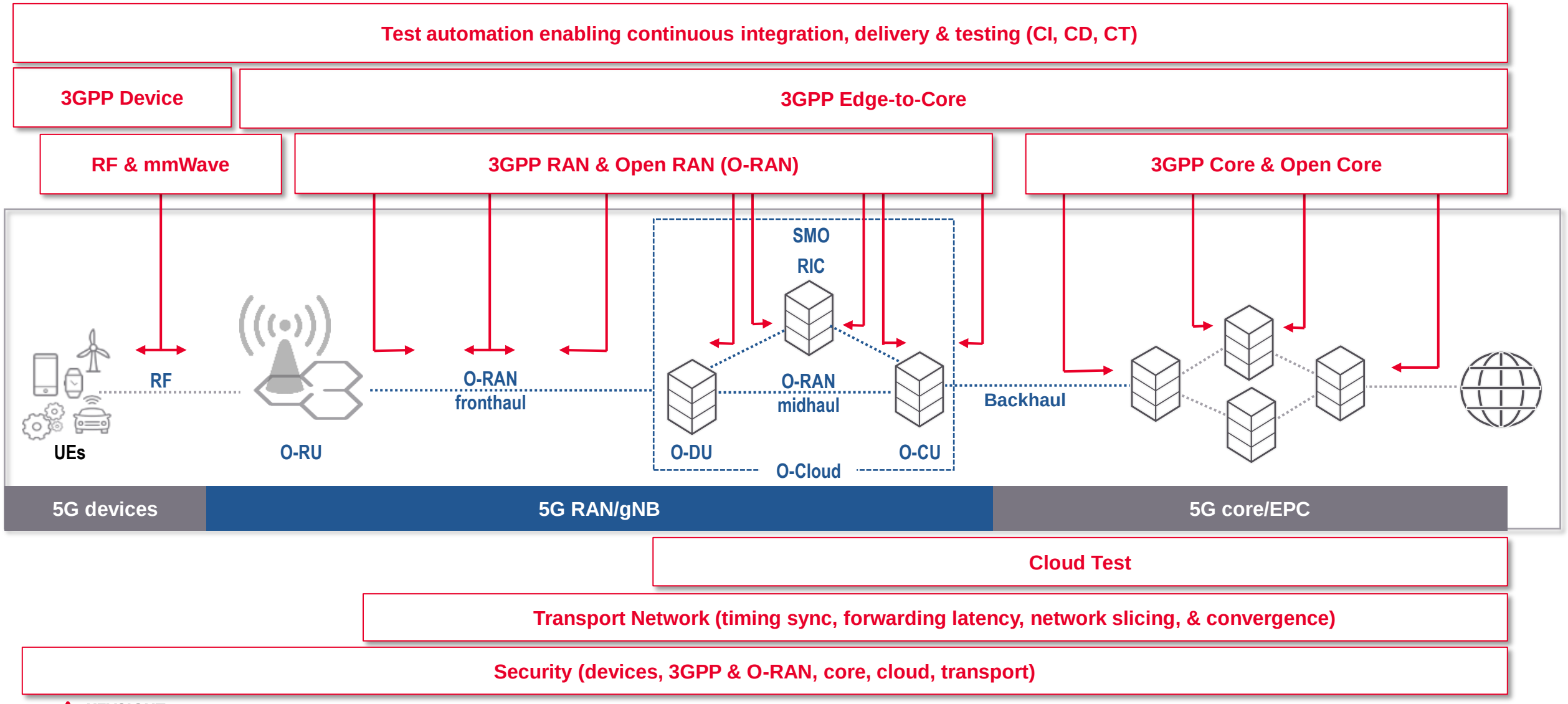
O-RAN ALLIANCE

1. **Open interfaces**
2. **Open subsystems & virtualization**
3. **Open management & orchestration**
4. **Open RAN intelligence & automation**
5. **Open security for Open RAN**

BBU: Baseband Unit
NMS: Network management system
CU: Central unit
DU: Distributed unit
RU: Radio unit
RRH: Remote radio head
RIC: RAN intelligent controller
SMO: Service management and orchestration

Keysight 5G Radio Access & Core Network Test Portfolio

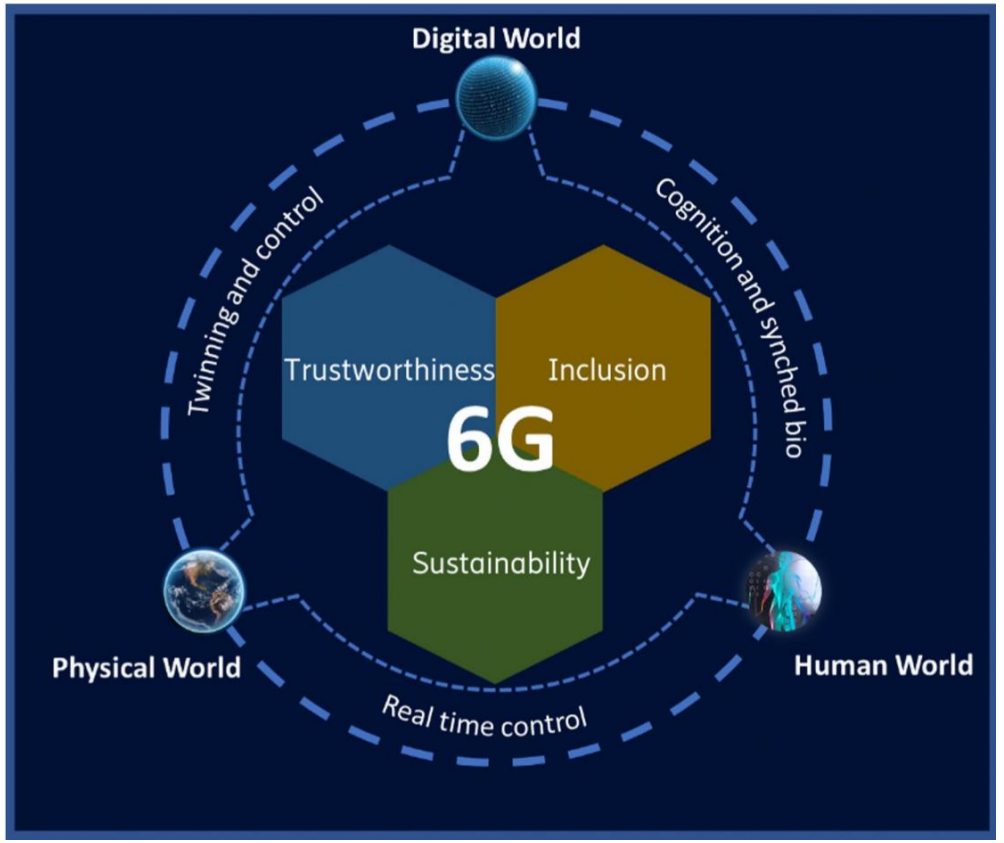
KEYSIGHT OPEN RAN ARCHITECT (KORA)



6G Vision

6G will fully connect the physical, digital and human worlds, facing the opportunities and challenges of growth and sustainability.

6G will benefit humanity for decades, providing connected intelligence, global coverage, digital inclusion, and the assurance of health and safety.



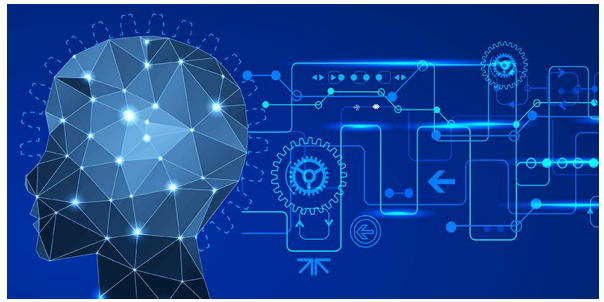
Hexa-X vision for 6G

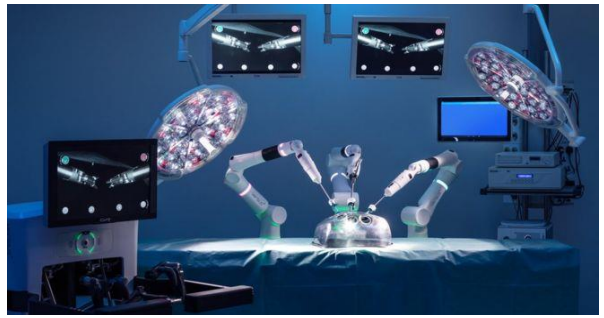
6G – Ubiquitous Wireless Intelligence

A FUSION OF DIGITAL AND REAL WORLDS ACROSS ALL DIMENSIONS

6G will enable new Use Models:

- Holographic and Multi-Sensory Communications
- All-inclusive Social Internet Of Things (SIoT)
- AI-powered H2H, H2M and M2M networks
- Widespread use of Digital Twins
- Advanced Industrial, Transportation and Cloud-Native IoT
- New communication environments: land, sea, air and space
- Emergency and Disaster management supported by critical infrastructure





The Vision for 6G supports the United Nations Sustainable Development Goals

- 6G will be integral to the quality and opportunities of human society

6G Global Connectivity Within a Secure Framework

TECHNOLOGY REQUIREMENTS

Next Generation Radio
- Ultra-wide bandwidths & Sub-THz spectrum
- 6G use of existing bands <100GHz
- Waveforms, coding, multiple access schemes
- Intelligent reconfigurable surfaces
- Spectral & energy efficiency

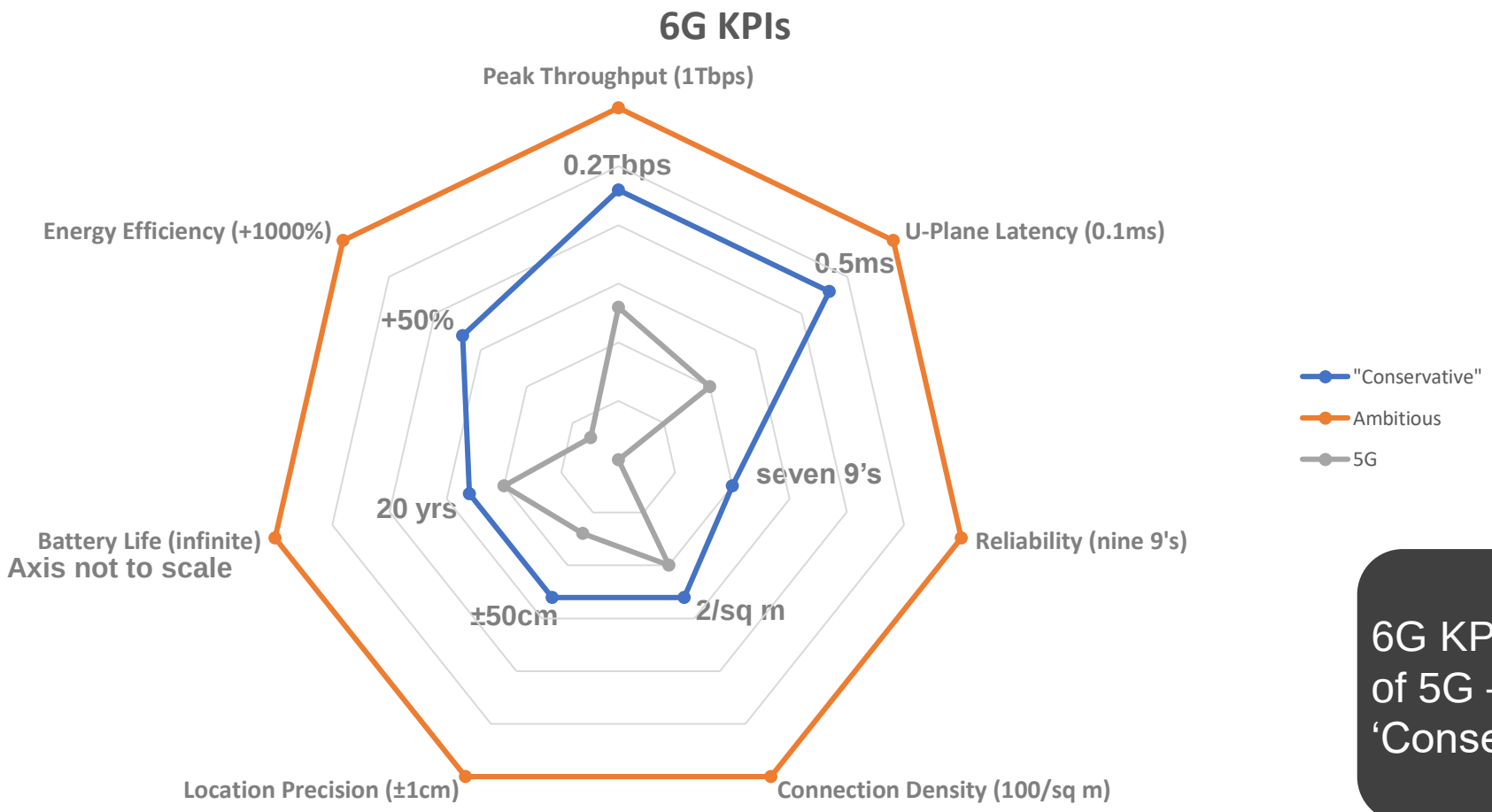
Integrated Multi-RAT systems
- Real-Time spectrum sharing
- Seamless co-existence and integration
- Non-Terrestrial Networks
- Next generation massive MIMO
- Advanced UP/CP deployment

Time-Engineered Networks
- 10x latency improvement
- Predictive & Application-Aware Routing
- Split-Compute Architectures
- Wireless-Wireline-Cloud Convergence

AI Driven Networks
- PHY/MAC dynamic provisioning
- Session-level slicing
- Management of Heterogenous Data
- Fully-automated infrastructure
- Autonomous service provisioning

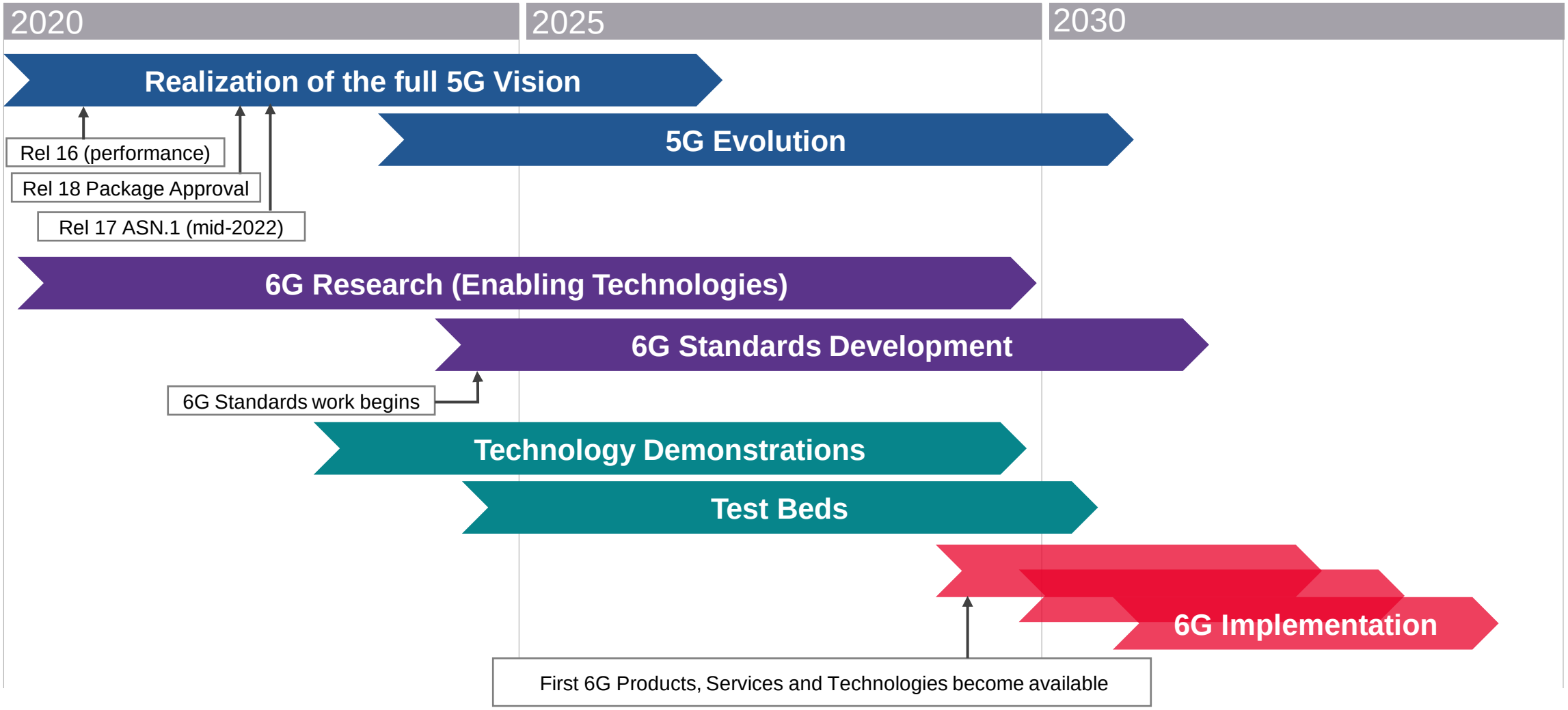
Trust & Security
- Advanced detection, prevention and recovery across a wider threat surface
- Next generation encryption
- E2E security in heterogenous links
- Post-quantum cryptography techniques

New Performance Indicators for 6G Networks and Devices

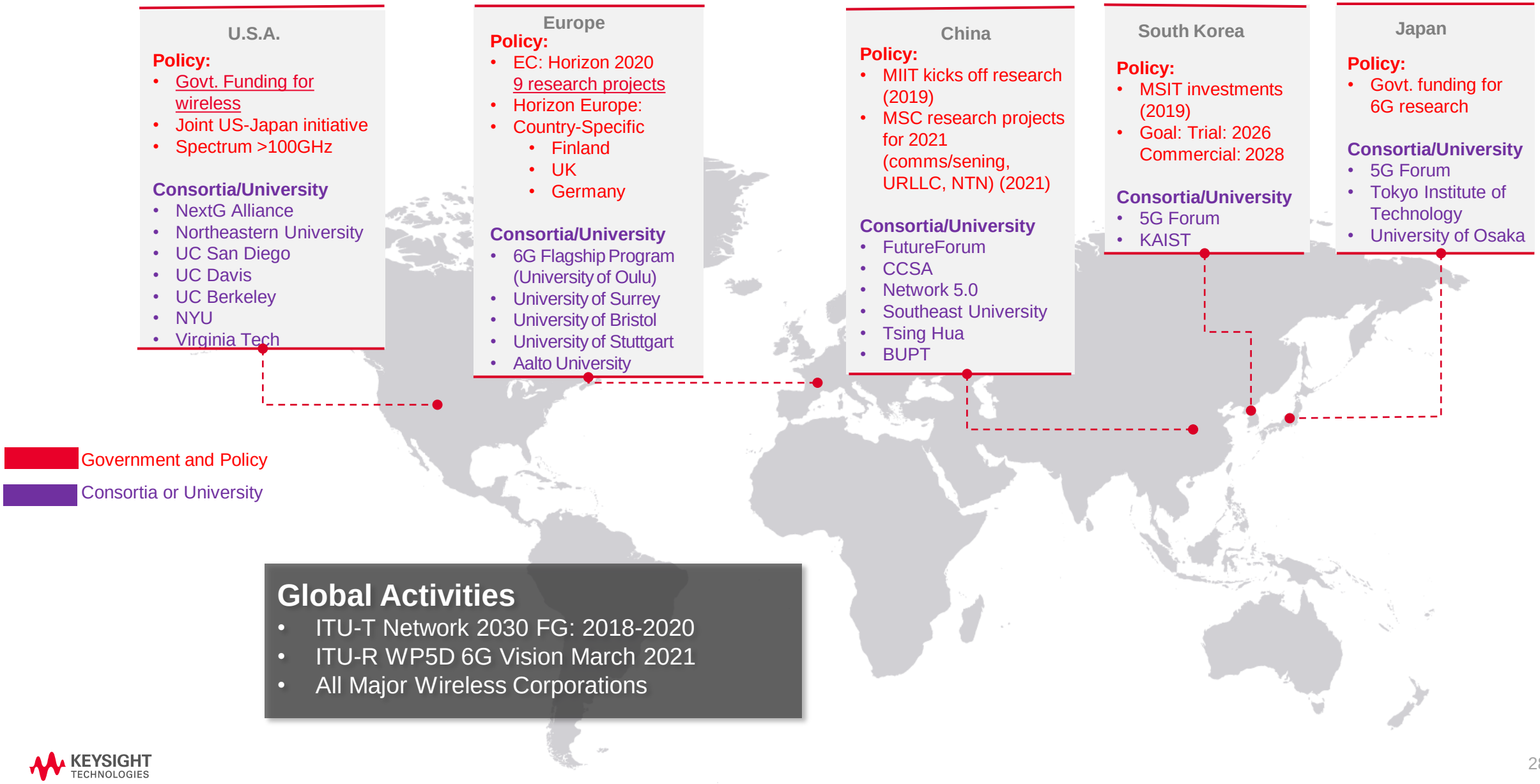


6G KPIs go well beyond the targets of 5G – opinions range from ‘Conservative’ to ‘Ambitious’

5G Towards 6G Timeline



6G Action Worldwide



U.S.A.

Policy:
- Govt. Funding for wireless
- Joint US-Japan initiative
- Spectrum >100GHz

Consortia/University
- NextG Alliance
- Northeastern University
- UC San Diego
- UC Davis
- UC Berkeley
- NYU
- Virginia Tech

Europe

Policy:
- EC: Horizon 2020 9 research projects
- Horizon Europe:
- Country-Specific
  - Finland
  - UK
  - Germany

Consortia/University
- 6G Flagship Program (University of Oulu)
- University of Surrey
- University of Bristol
- University of Stuttgart
- Aalto University

China

Policy:
- MIIT kicks off research (2019)
- MSC research projects for 2021 (comms/sening, URLLC, NTN) (2021)

Consortia/University
- FutureForum
- CCSA
- Network 5.0
- Southeast University
- Tsing Hua
- BUPT

South Korea

Policy:
- MSIT investments (2019)
- Goal: Trial: 2026 Commercial: 2028

Consortia/University
- 5G Forum
- KAIST

Japan

Policy:
- Govt. funding for 6G research

Consortia/University
- 5G Forum
- Tokyo Institute of Technology
- University of Osaka

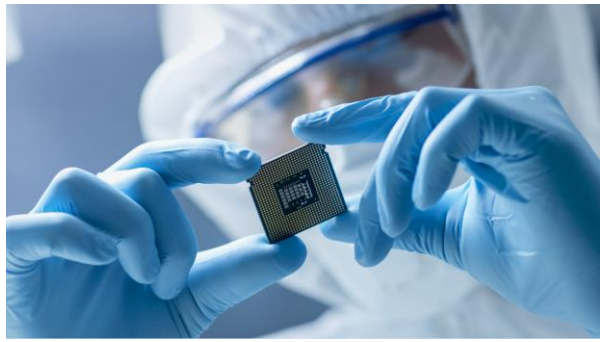
Government and Policy

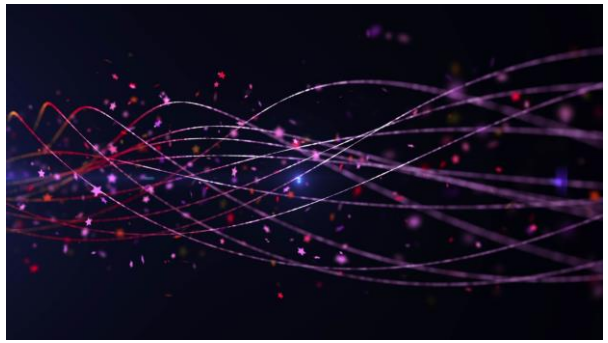
Consortia or University

Global Activities

- ITU-T Network 2030 FG: 2018-2020
- ITU-R WP5D 6G Vision March 2021
- All Major Wireless Corporations

Today’s 6G Research Challenges





- Sub THz research – semiconductors, components, transmitters, receivers, antennas to 350GHz
- Channel modeling and characterization at Sub-THz frequencies
- Ultra-low latency and time-deterministic processes
- Non-terrestrial network design
- Computing, semiconductor and optical architectures required for Tb/s data transfer
- Energy efficiency, energy harvesting, battery-less techniques
- Edge intelligence modeling and AI
- Modeling Network Security requirements, encryption and recovery techniques

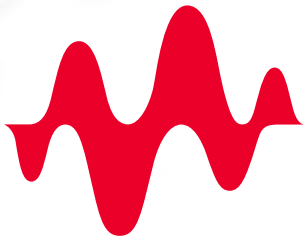
6G Resources

LINKS FOR FURTHER READING

- 6G Technology **Keysight**

  - ITU Network 2030 Focus Group Papers:
  - University of Oulu 6G Flagship Papers
  - 6G White Paper from DOCOMO (Jan 2020)
  - 6G White Paper from Samsung (July 2020)
  - 5G Americas: The Evolution of 5G Towards the Next G (Dec 2020)
  - Hexa-X 1st Deliverable: 6G Vision, Use-Cases, and Key Societal Values (Feb 2021)

Questions?



KEYSIGHT
TECHNOLOGIES