CREATING THE LIVING NETWORK™

Wireless Access and Systems Technologies for Next Generation Customers

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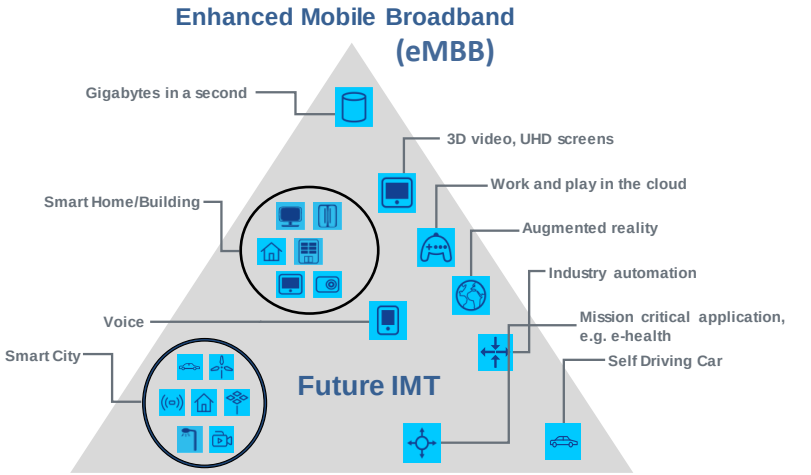
INTERDIGITAL.

How is 5G Different from Previous Generations?

	2G	3G	4G	5G
Uses Cases & Services	Voice + SMS	Voice + Small Data	Mobile Broadband	Enhanced Mobile Broadband Massive Machine Type Communications Ultra Reliable and Low Latency Communications
Spectrum	200 KHz Channels Below 2 GHz	5 MHz Channels Below 3.6 GHz	Up to 20 MHz Channels Below 3.8 GHz	Up to 1 GHz Channels Below 100 GHz
Radio Technology	GSM/GPRS (Single Technology)	UMTS/HSPA (Single Technology)	LTE/LTE-A (Single Technology)	Multiple Radio Access Technologies Integrated in a 5G Network: LTE Advanced Pro, NB-IoT, 5G New Radio, WiFi…
Network Topology	Macro Cells	Macro and Small Cells	Heterogeneous Macro and Small Cells	Challenging Traditional Cell and Network Concepts: Small Cells, Mobile Edge Computing, Network Slicing, …

5G Use Cases and Key Requirements

Support for different services having diverging requirements is a key challenge for 5G Systems

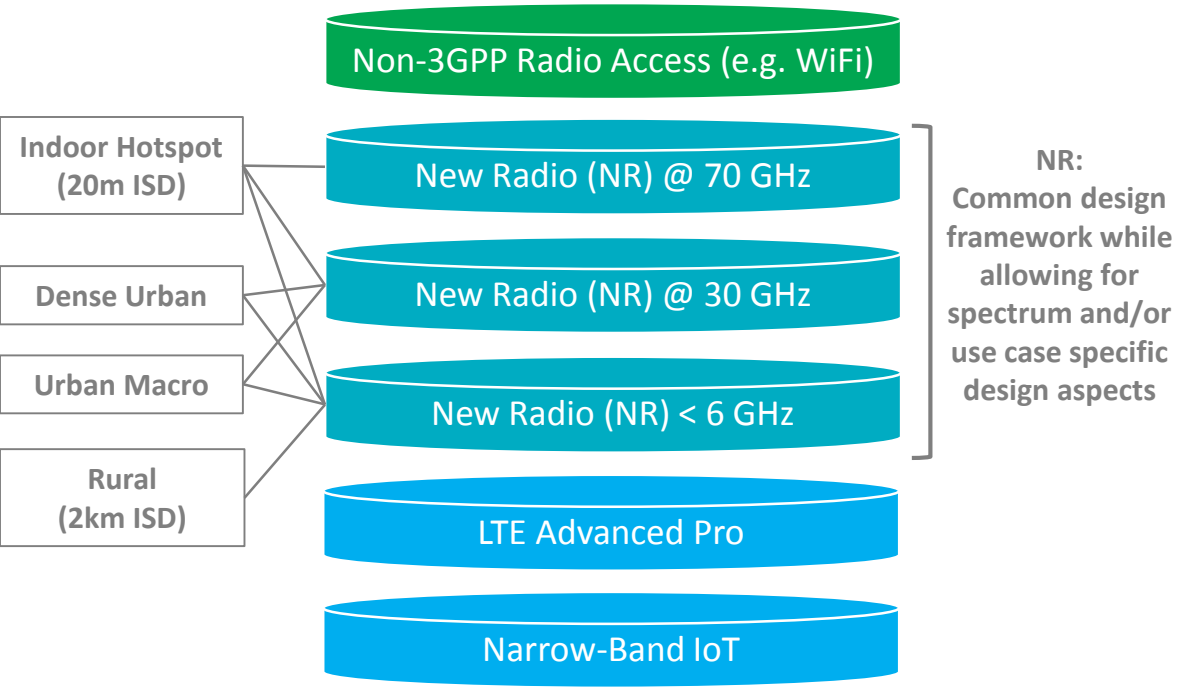


Source: ITU-R SG5 WP-5D

eMBB	mMTC	URLLC
▪ Peak Data Rate of 20 Gbps ▪ 1 ms Latency (air interface) ▪ 10 $Tbps$ per k $m2$ Area Traffic ▪ Indoor/hotspot and enhanced wide-area coverage	▪ Low data rate (1 to 100 kbps) ▪ High device density (up to 200,000/km2) ▪ Latency: seconds to hours ▪ Low power: up to 15 years battery life	▪ Low to medium data rates (50 kbps to 10 Mbps) ▪ < 1 ms air interface latency ▪ 99.999% reliability and availability ▪ High mobility

5G: A Multi-Layer Radio Network

5G will be designed with native support for connectivity across multiple radio layers



- Radio Layers could be deployed as "Standalone" or using multi-connectivity framework
- Framework should enable splitting of data and control functions across layers
- 5G operators should have flexibility to deploy radio layers based on their individual roll out plans for 5G services and spectrum availability
- Mature 5G networks (i.e. 2025+) envisioned to include all radio layers working together
- LTE and NB-IoT expected to evolve as a components within 5G networks

5G New Radio (NR) – Whole New System Design

3GPP designing new non-backwards compatible air interface and radio network architecture for 5G

NR Terminal Devices

NR Air Interface

New L2/L3 User and Control Plan Architecture and Protocols

- More efficient initial access protocols (e.g. on-demand system information)
- New mobility management approaches (e.g. terminal-centric mobility)
- New protocol function split across network nodes

New Physical Layer Design

- New non-backwards compatible physical layer: waveform, multiple access scheme, ….
- Massive number of antennas (i.e. massive MIMO)
- Exploiting new spectrum: mmWave, unlicensed/shared spectrum, ...

NR Radio Access Network

TRP*

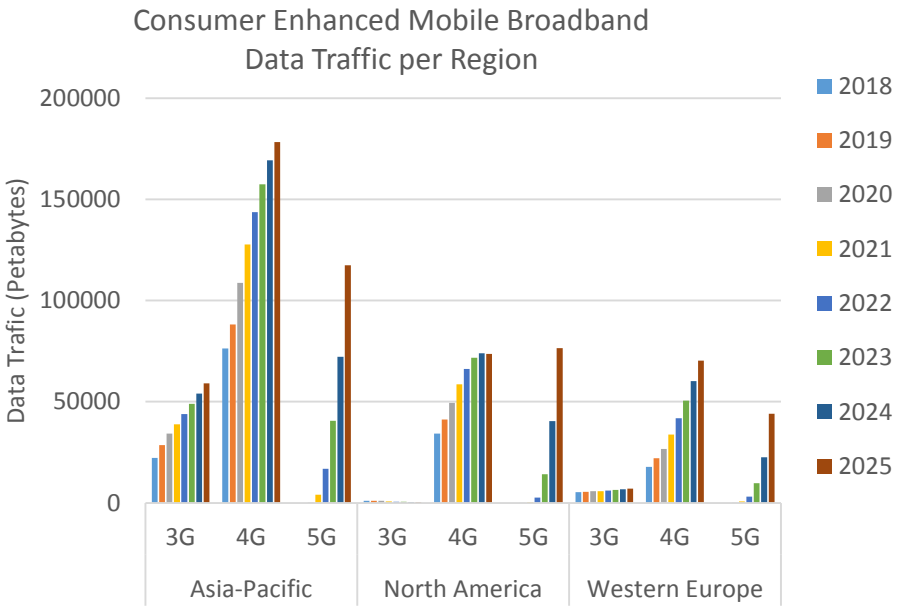
New Radio Access Network Architecture

- Centralized/Cloud RAN architecture
- Fronthaul protocol split and design
- Tight interworking with LTE

*Transmission/Reception Point

5G Use Case Spotlight: eMBB

Enhanced Mobile Broadband (eMBB) expected to drive early deployment of 5G service



Source: ABI Research "5G Market Data: Consumer Enhanced Mobile Broadband" Report, March 2016

- Asia-Pacific region expected to take the lead in terms of 5G eMBB service roll out

  ➔ Japan using Tokyo 2020 Olympic games as early 5G technology showcase

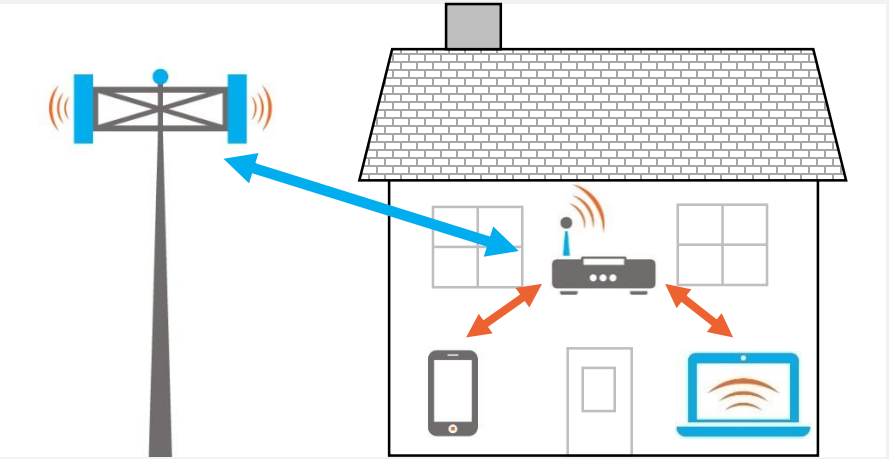
- Many new use cases beyond today's mainstream mobile broadband services:
  - Pervasive video (e.g. high resolution video communication, UHD multimedia streaming, …)
  - Smart office environment (i.e. all devices wirelessly connected)
  - High-speed mobile broadband (e.g. eMBB in car, train, airplane)
  - Virtual Reality and Augmented Reality
  - And more…

5G Use Case Spotlight: Indoor Connectivity

5G design requirements for eMBB could enable connectivity to and inside the home

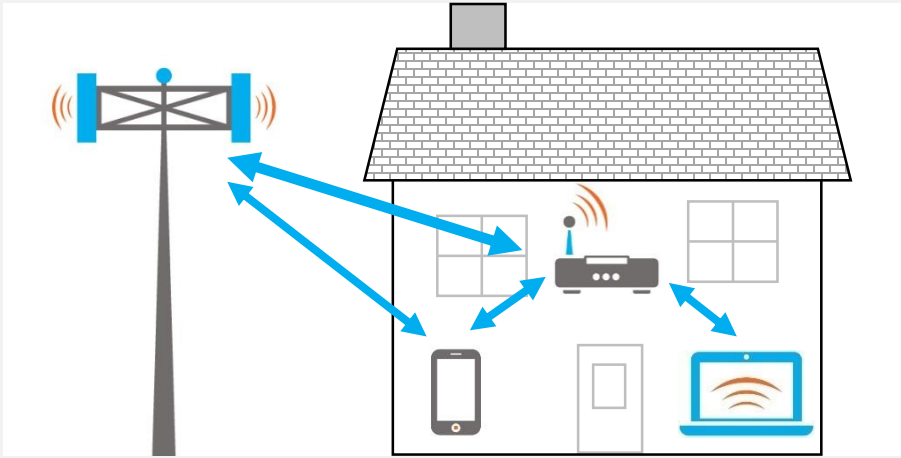
Scenario 1: 5G Connectivity to the home

- Large bandwidth in mmWave spectrum could provide connectivity to access point within the home
- Other technology (e.g. WiFi) used for connectivity inside home



Scenario 2: 5G Connectivity inside the home

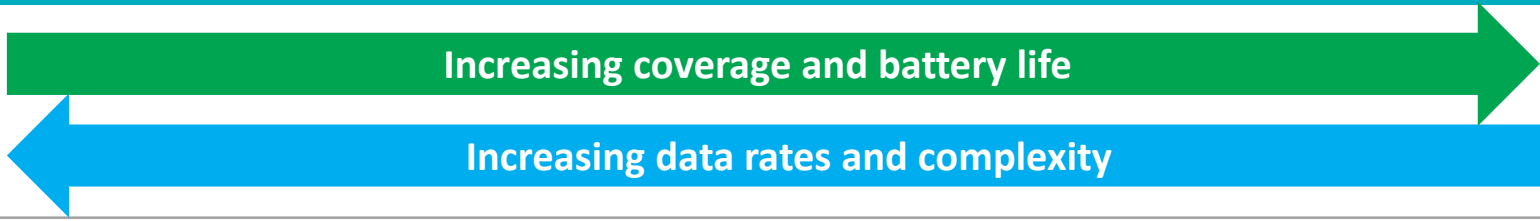
- 5G connectivity to access point within the home
- Devices inside home connected using 5G NR (e.g. mmWave unlicensed or shared spectrum) through access point and 3GPP radio network



WiFi Connectivity 3GPP 5G Connectivity

IoT Connectivity: Cellular-Based Technologies

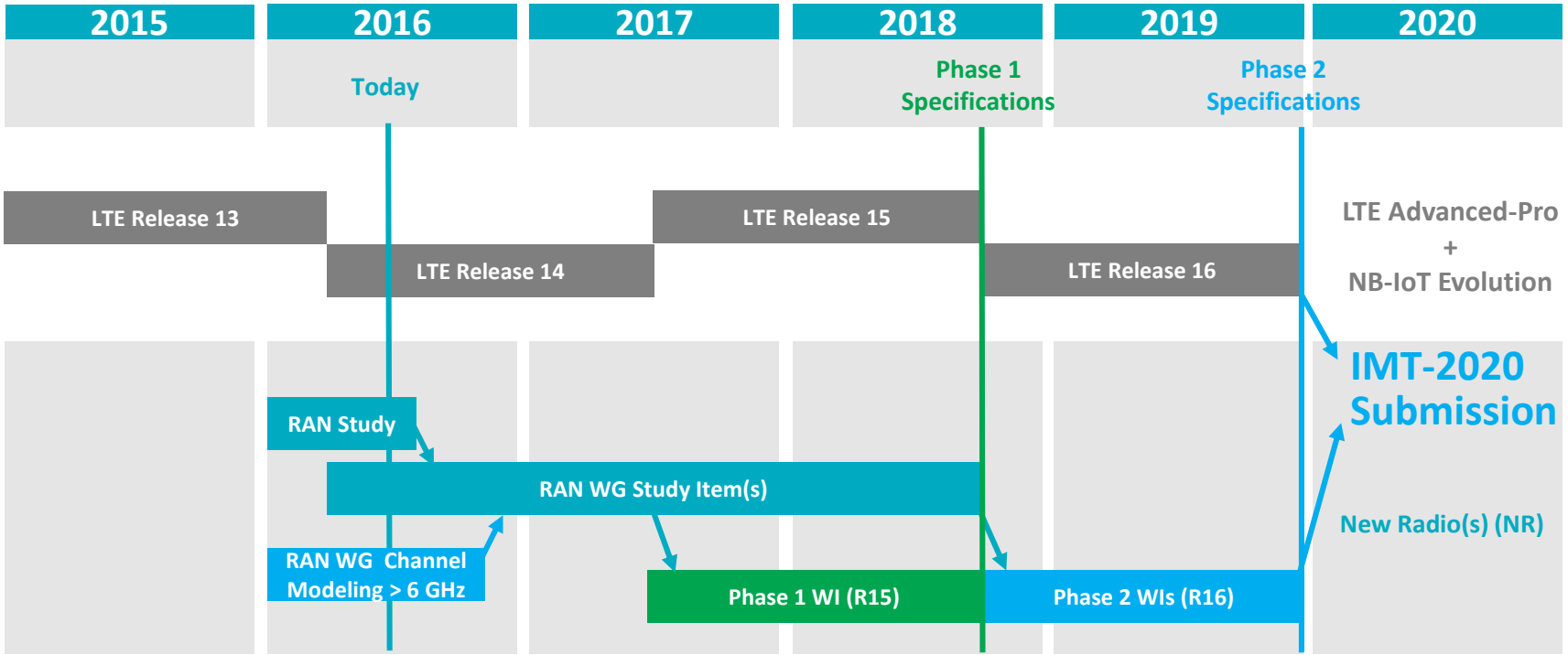
Optimal access technology depends on the nature and needs of the IoT application



	LTE Cat 1	LTE Cat 0/Cat M	EC-GSM	NB-IoT
Standards Release	3GPP Release 8 (initial LTE release)	3GPP Releases 12-13	3GPP Release 13	3GPP Release 13
Data Rates	Up to 10 Mbps Downlink and 5 Mbps Uplink	~ 1 Mbps	~ 500 kbps	~ 100 kbps
Highlights	Early market lead for IoT services on 4G networks	▪ Supports wide-range of IoT services ▪ Co-exists with MBB	▪ Supported on legacy 2G equipment ▪ 20 dB coverage improvement of 2G	▪ Native low power wide area coverage technology ▪ Up to 10 year battery life

3GPP RAN Standardization Timeline

Next Generation System Specification Work to Complete for 2020



5G Timeline: Early Commercial Trials and Rollouts

Looking back at what happened with 4G, will early rollouts be 5G or 4.75G?

Verizon forms the Verizon 5G Technical Forum (V5GTF) in 2015

- Creating platform for Verizon's 28/39 GHz fixed wireless access trials and deployments
- Testing mmW equipment with Cisco, Ericsson, Nokia, Samsung, …
- Announced completion of Verizon 5G Specifications in July 2016

AT&T

- Conducting 5G trials with the intent to "pivot to compliant commercial deployments once 5G technology standards are set"
- Trialing mmW technology at 15 GHz and 28 GHz in Austin, Texas with Ericsson and Intel

Bell Canada trials 5G with Nokia

- Demonstrated 6x data speeds compared to 4G in 73 GHz band

2018 Pyeongchang Winter Olympics, South Korea

- Ministry of Science, ICT & Future Planning, KT, SKT, …
- Demo broadcasting equipment, holograms, virtual reality, safety drones, …
- Projecting: 16,000 smartphones, 13,000 PCs, 3,500 WiFi spots and 1,500 tablet PCs

2018 FIFA World Cup, Russia

- MTS and Ericsson team up to demonstrate 5G
- Huawei also planning 5G demonstrations/trials

2020 Tokyo Summer Olympics, Japan

- Ongoing trials: Fujitsu (4.65 GHz), Huawei (6 GHz), Ericsson (15 GHz), Nokia networks, test equipment vendors, …
- Ministry of Internal Affairs and Communications established commercialization plan with NTT Docomo, KDDI, Sony, Sharp, …

Thank you.