Roadmap for 5G Radio Standardization in 3GPP

RWS-150030

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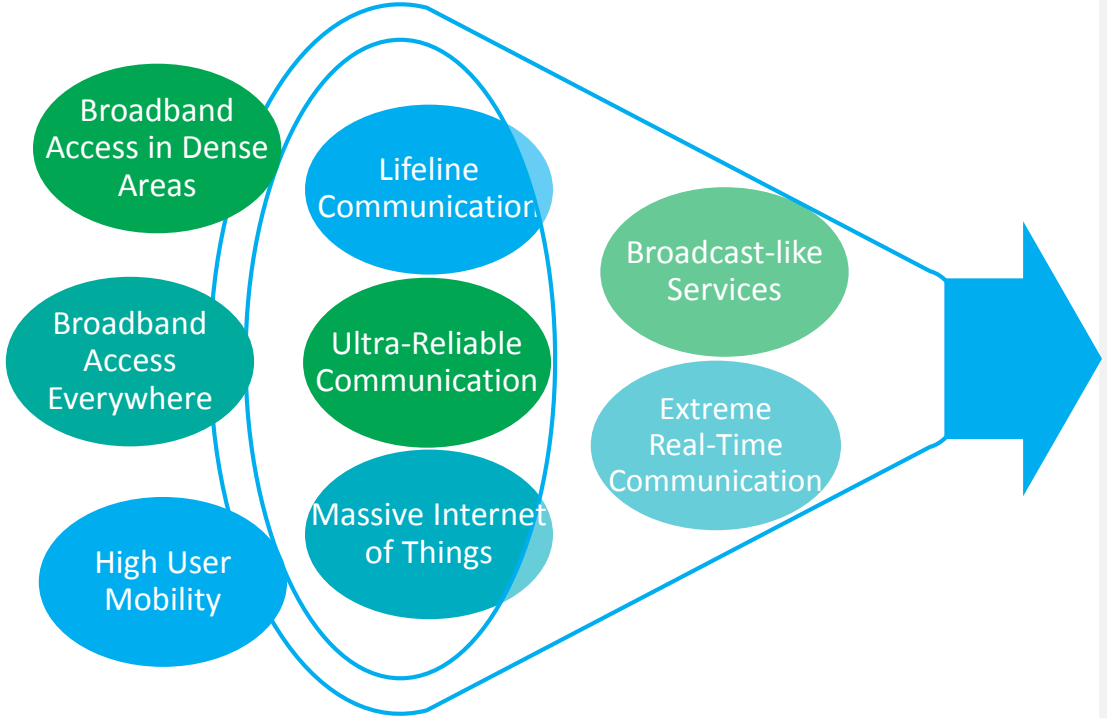
Use Cases for 5G Radio Design

Many Use Case Families[1] Already Identified for 5G…



[1] Source: NGMN 5G White Paper, February 2015

… Can We Simplify Further?

(1) 5G Mobile Broadband

- **Higher performance targets across the board relative to 4G**
- **Includes: Ultra mobile broadband for indoor/hotspot and enhanced mobile broadband everywhere**

(2) 5G for the Connected World

- **Native support for use cases having highly divergent requirements**
- **Includes: massive number of connected devices, low power/low cost devices, low latency/ultra-reliable communication and more…**

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5G – Spectrum Outlook

f	What Spectrum should be considered?	What should it be used for?	How should it be used?
	New Spectrum above 6 GHz: ▪ Larger bandwidths available (cmWave & mmWave) ▪ Different propagation characteristics and hardware constraints	Ultra-Mobile Broadband for Indoor/Hotspot Access	New Radio: 5G Ultra-Mobile Broadband (Above 6 GHz)
6 GHz	**New spectrum below 6 GHz:** ▪ Opportunity to design a new non-backward compatible radio design **Existing spectrum below 6 GHz:** ▪ Leverage existing 4G deployments towards 5G	Enhanced Mobile Broadband Everywhere & Connected World Use Cases (diverging requirements)	New Radio: 5G Flexible Access (Below 6 GHz) & Existing Radio: LTE Evolution

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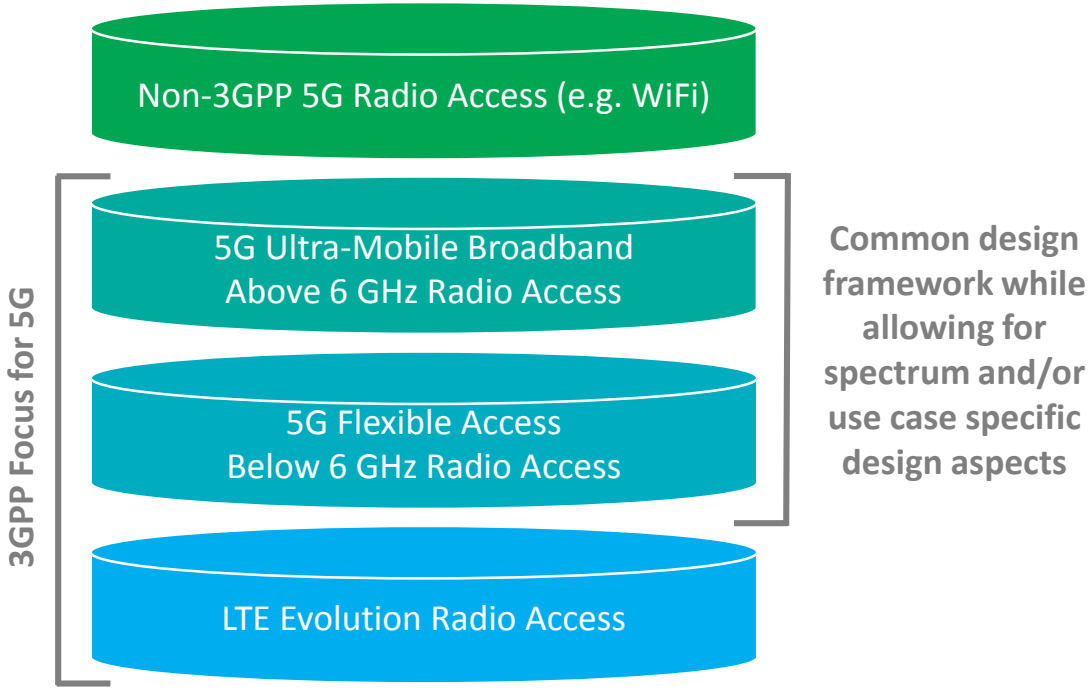
5G – Multiple-Layers of Connectivity

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



- Radio Layers could be deployed as "Standalone" or using multi-connectivity framework (e.g. R12 Dual-Connectivity)
- Framework should enable splitting of data and control functions across layers
- 5G operators have flexibility to initially 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 expected to evolve as a component within 5G Multi-Layer framework

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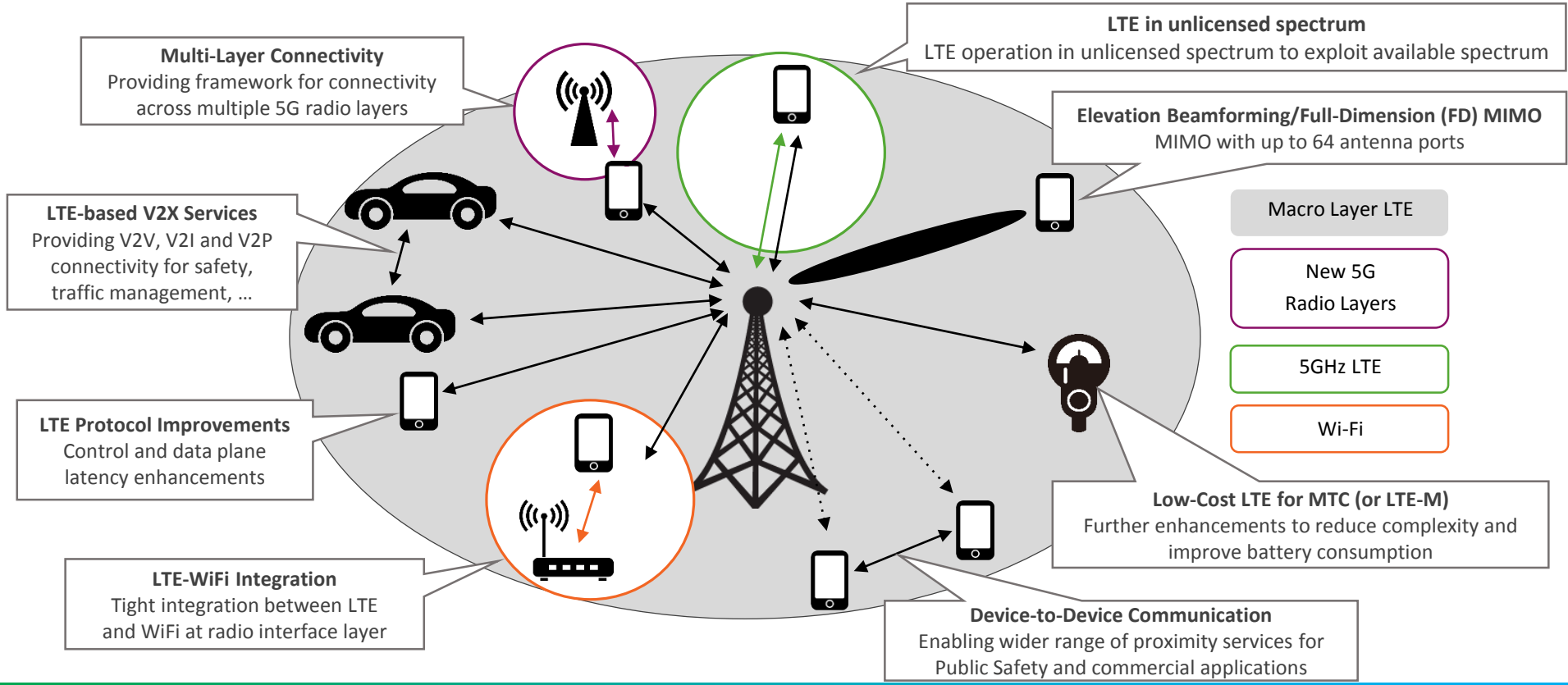
LTE Evolution (R14+)



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5G Flexible Access Below 6 GHz

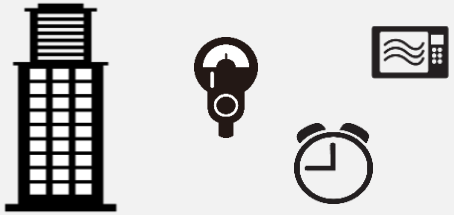
Air interface design must be flexible to support diverging requirements in the same spectrum

At least 3 Operating Modes identified so far (with potentially more):

Enhanced Mobile Broadband

- Macro and small cells
- 1 ms Latency (air interface)
- Spectrum allocated at WRC-15 may lead up to 8Gbps of additional throughput
- Support for high mobility

Low Power & Complexity



- Low data rate (1~100kbps)
- High density of devices (up to 200,000/km^2)
- Latency: seconds to hours
- Low power: up to 15 years battery autonomy
- Asynchronous access

Ultra-High Reliability & Ultra-Low Latency

- Low to medium data rates (50kbps~10Mbps)
- <1 ms air interface latency
- 99.999% reliability and availability
- Low connection establishment latency
- 0-500 km/h mobility

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5G Ultra-Mobile Broadband Above 6 GHz

New spectrum above 6 GHz provides opportunity for Ultra-Mobile Broadband for indoor and hotspots

- However, frequencies above 6 GHz suffer from much higher pathloss, lower diffraction and higher losses due to penetration and human/self-blockage
- Massive antenna arrays are feasible due to shorter wavelengths
  - Leads to compact antenna array structures
  - Provides beamforming gains required to overcome high pathloss

Free-Space Path Loss

Distance	2.4GHz	28GHz	60GHz
d = 1m	-40 dB	-62 dB	-68 dB
d = 100m	-80 dB	-102 dB	-108 dB

28 dB

Key Requirements

- 20 Gbps (peak user throughput)
- 1 ms Latency (air interface)
- Standalone and/or macro-assisted access
- Joint access/backhaul

Key Enablers

- Large amounts of spectrum
- Massive antenna arrays
- Cell densification

Key Challenges

- Timely availability of globally harmonized spectrum
- Low-cost and low-complexity implementations
- Discovery and initial access
- Frequent and abrupt loss of radio link(s)

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New 5G Radio – Spectrum Flexibility

Spectrum usage should allow dynamic multiplexing of services with different transmission characteristics

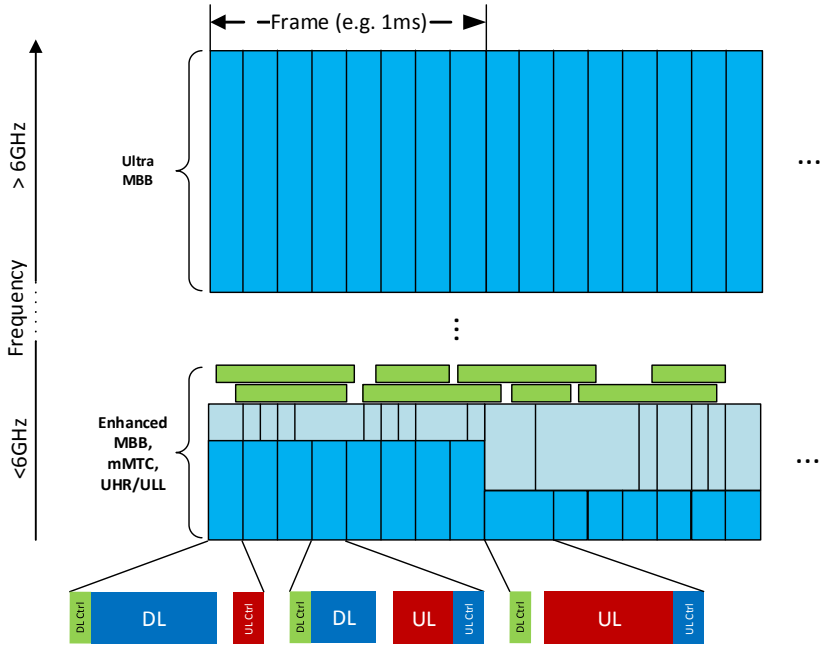
Flexible Duplexing
- TDD (new spectrum) with dynamic UL/DL configuration
- FDD (for refarming and new spectrum)

Flexible Bandwidth and Spectrum Configuration
- Multi-band operation
- Support of licensed, licensed shared and unlicensed bands

Flexible Resource Allocation
- Native carrier aggregation support (intra/inter-band) and native support for spectrum sharing
- Dynamic Spectrum Partitioning and Coordination

Flexible Frame Structure
- Flexible configuration of frame UL/DL control and data
- Native support of D2D, inband relays and Listen-Before-Talk

Flexible Scheduling
- Synchronous / asynchronous operations
- Opportunistic scheduling
- Unscheduled transmissions



TDD Flexible subframe structure:

New 5G Radio – Waveform Considerations

Waveform selection should consider trade-offs across usage scenarios and target bands

	Enhanced Mobile Broadband & Connected World	Ultra Mobile Broadband	
		cmWave (6 GHz)	mmWave
Most Desirable Characteristics	**Improved spectral containment to enable:** ▪ Multiplexing in frequency of signals with non-orthogonal characteristics (e.g. different subcarrier spacing) ▪ Baseband aggregation of fragmented pieces of spectrum **Reduced synchronization requirements:** ▪ Co-existence of asynchronous signals ▪ Reduced synchronization signaling	**High spectral efficiency:** ▪ Reduced symbol overhead, e.g. C.P. in OFDMA, needs to be flexible to achieve higher efficiency **Efficient resource allocation:** ▪ Native support for FDMA to enable efficient resource utilization	**Robustness to radio impairments:** ▪ RF impairments (CFO, phase noise, etc…) are more challenging at mmWave frequencies **Low PAPR and ADC complexity:** ▪ Favor limiting PA non-linearity and reducing ADC bit resolution to enable practical implementations at higher frequencies
Candidate Waveforms	Filtered OFDM and other OFDM variants (e.g. DTF-S-OFDM, ZT DTF-S-OFDM, UW DFT-S-OFDM), FBMC, Time domain SC (for mmWaves) and others…		

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New 5G Radio – Spatial Processing (1/2)

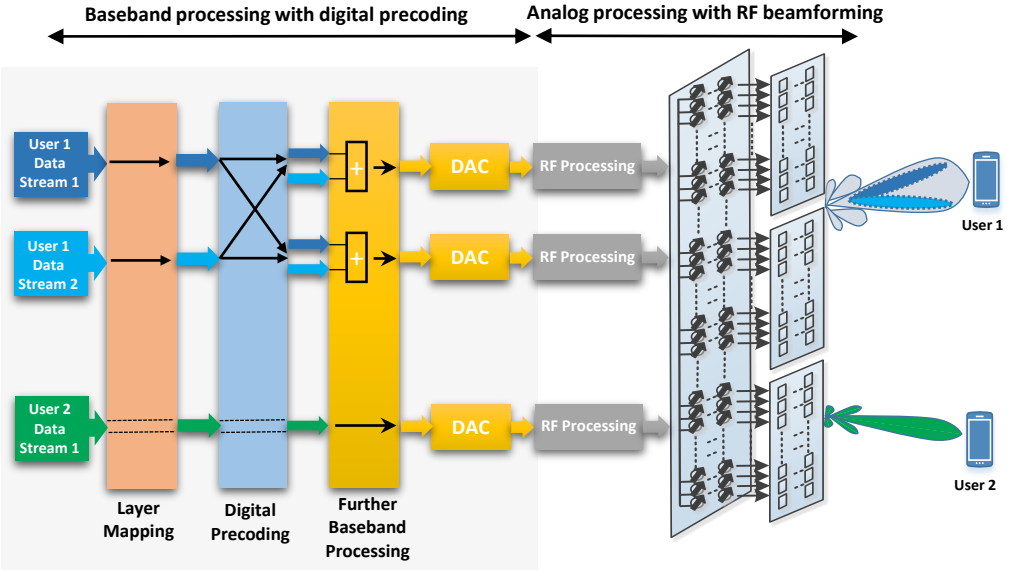
Massive antenna arrays are critical to overcome challenging propagation characteristics at high frequency

Spatial processing with MAA

- Massive antenna arrays (MAA) are key technology enabler at higher frequencies
- Provides flexibility in terms of combining:
  - Beamforming (analog, digital or hybrid)
  - SU-MIMO (channel rank tends to be lower in mmW)
  - MU-MIMO / SDMA

MU-MIMO / SDMA

- SDMA capabilities reach new levels with hundreds of antenna elements at the eNB
- Ideally suited for indoor and hotspot deployments



User1: SU 2-Layer Spatial Multiplexing with Hybrid Beamforming
User2: Rank-1 Analog Beamforming

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New 5G Radio – Spatial Processing (2/2)

Use of Massive Antenna Arrays introduces new challenges to protocol design

Dynamic blockage/self-blockage causes abrupt loss in radio link

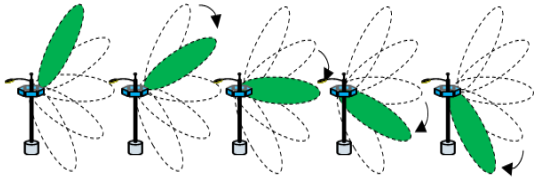
- Fast intra-node beamtracking
- Fast intra-layer mobility and intra/inter-node cooperation built-in
- Tight multi-layer coordination with other radio layers (e.g. LTE)

Beamforming essential for coverage

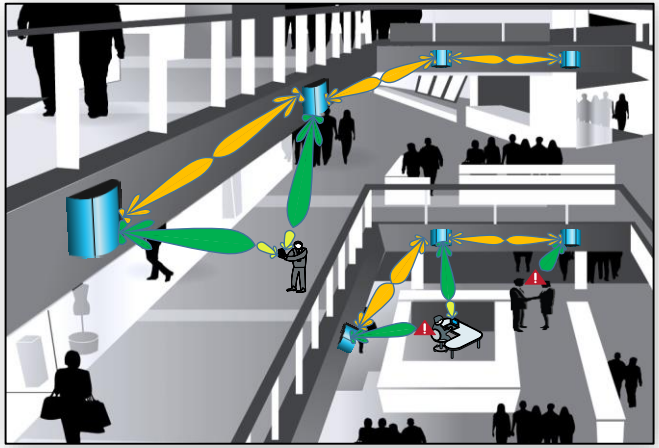
- Native support of directional broadcast channels
- Beamforming support for both *control* and *data* channels

Small cell deployment and flexible network topologies

- Native support of self-backhauling
- Robustness to intra-layer interference
- Adaptive beam steering for low-cost self-organizing deployments



Beam sweep for broadcast signaling



Multi-connectivity within mmW layer

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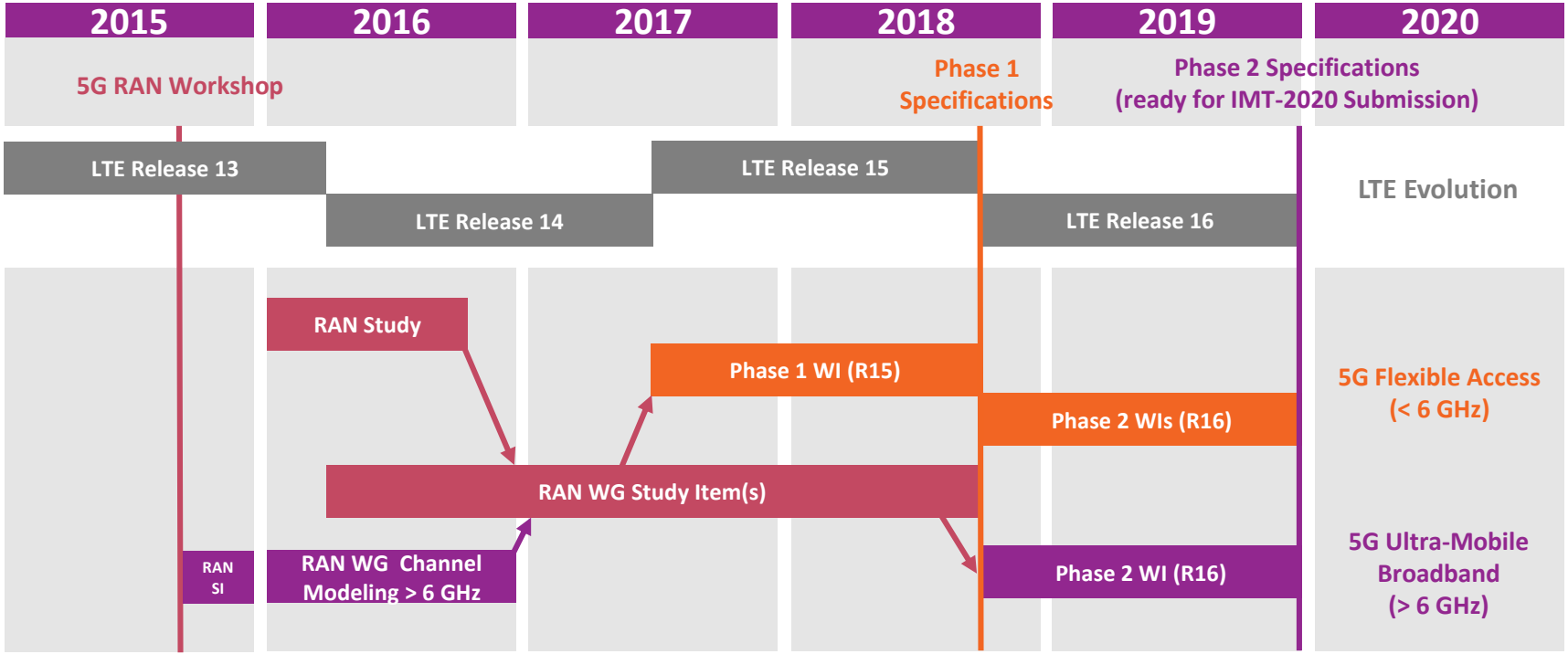
5G – Standardization Timeline (1/2)

Phased approach enables early deployment of Phase 1 in 2020 and Phase 2 in 2022+



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5G – Standardization Timeline (2/2)

Phase 1 allows early 5G implementations while Phase 2 work continues towards IMT-2020 submission

Radio Technology	Phase 1 – Completion in Q3 2018	Phase 2 – Completion in Q4 2019
LTE Evolution	LTE Release 15	LTE Release 16

New Radio Design (non-backwards compatible)	*Highest Priority:*
	▪ Flexible Access Radio Below 6 GHz for Enhanced Mobile Broadband operating mode
	  ▪ Designed with Forward-compatibility for Connected World operating modes
	Lower Priority:
	▪ Initial design for Ultra Mobile Broadband Above 6 GHz in specific bands with forward compatibility for Phase 2 optimized radio above 6 GHz
		▪ Flexible Access Radio Below 6 GHz with support for 3 operating modes:
		1. Enhanced Mobile Broadband
		2. Low Power & Complexity
		3. Ultra-High Reliability & Ultra-Low Latency
		  ▪ Maintain Forward Compatibility for future Connected World operating modes
		▪ Ultra-Mobile Broadband above 6 GHz in cmWave and mmWave spectrum

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Thank You!

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