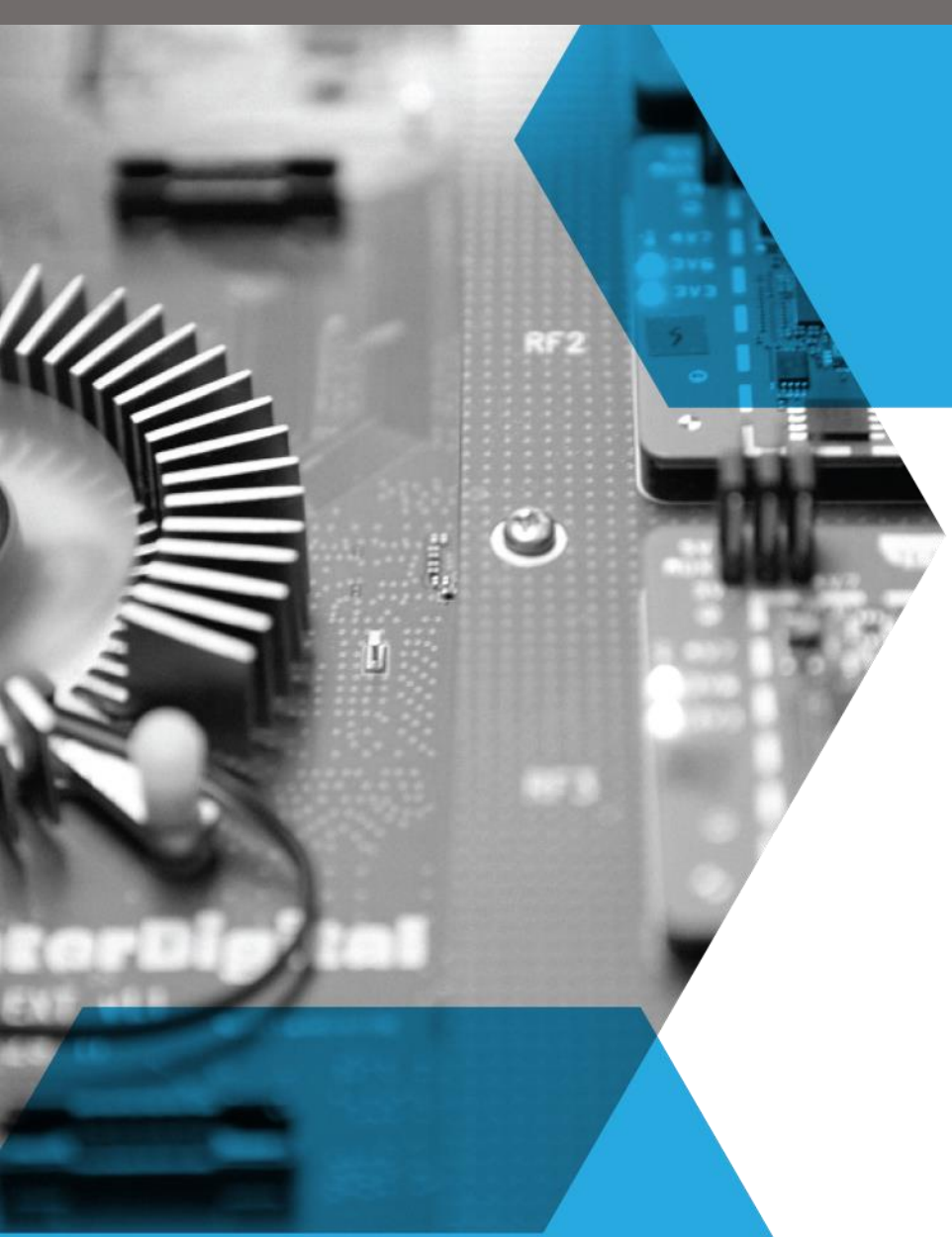

Millimeter wave: An excursion in a new radio interface for 5G

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Cambridge Wireless, London
03 February 2015

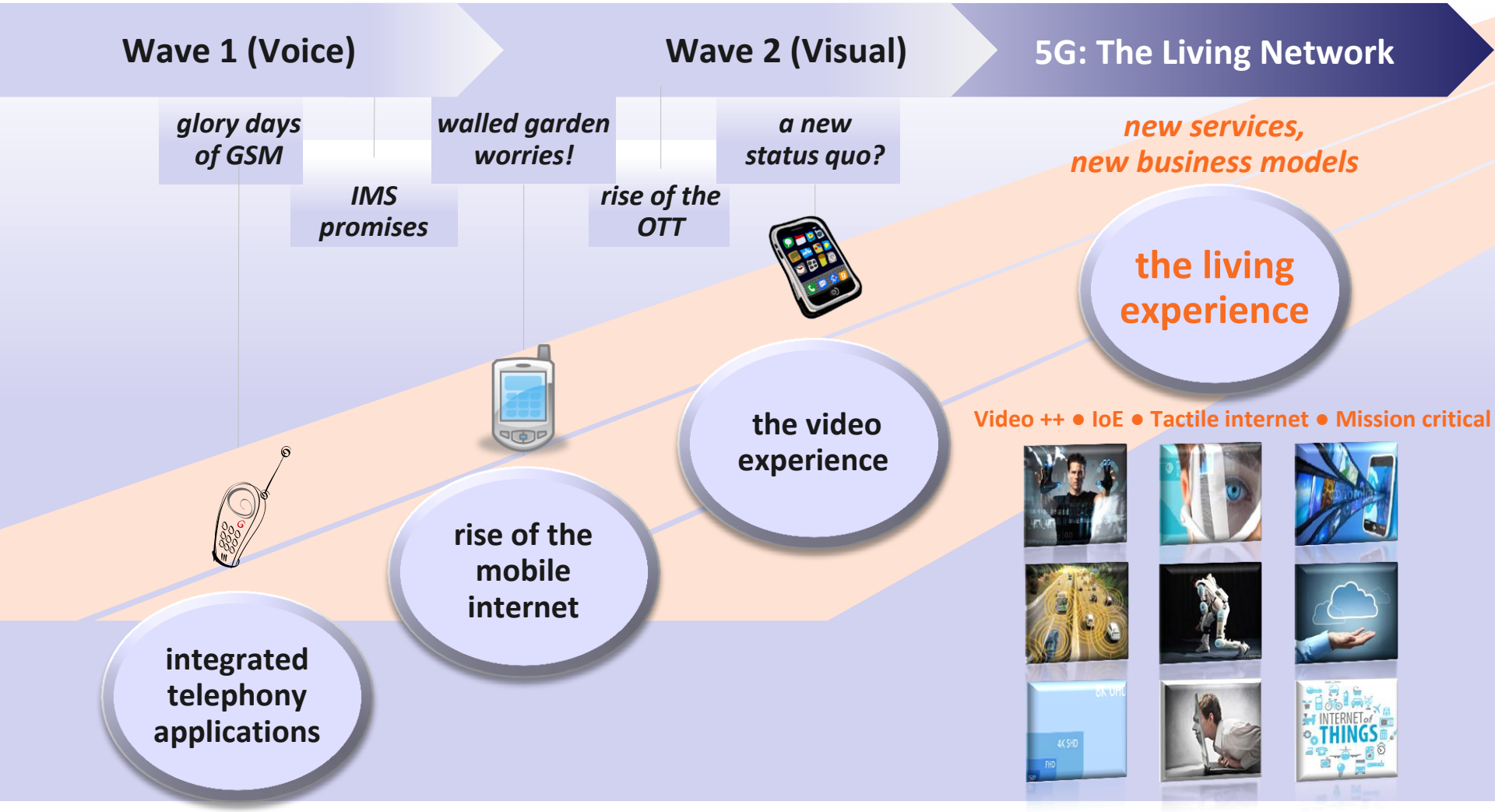
INTERDIGITAL®

Creating the Living Network

Outline

- 5G radio interface outlook
- Millimeter wave – A new interface
- Few Takeaways

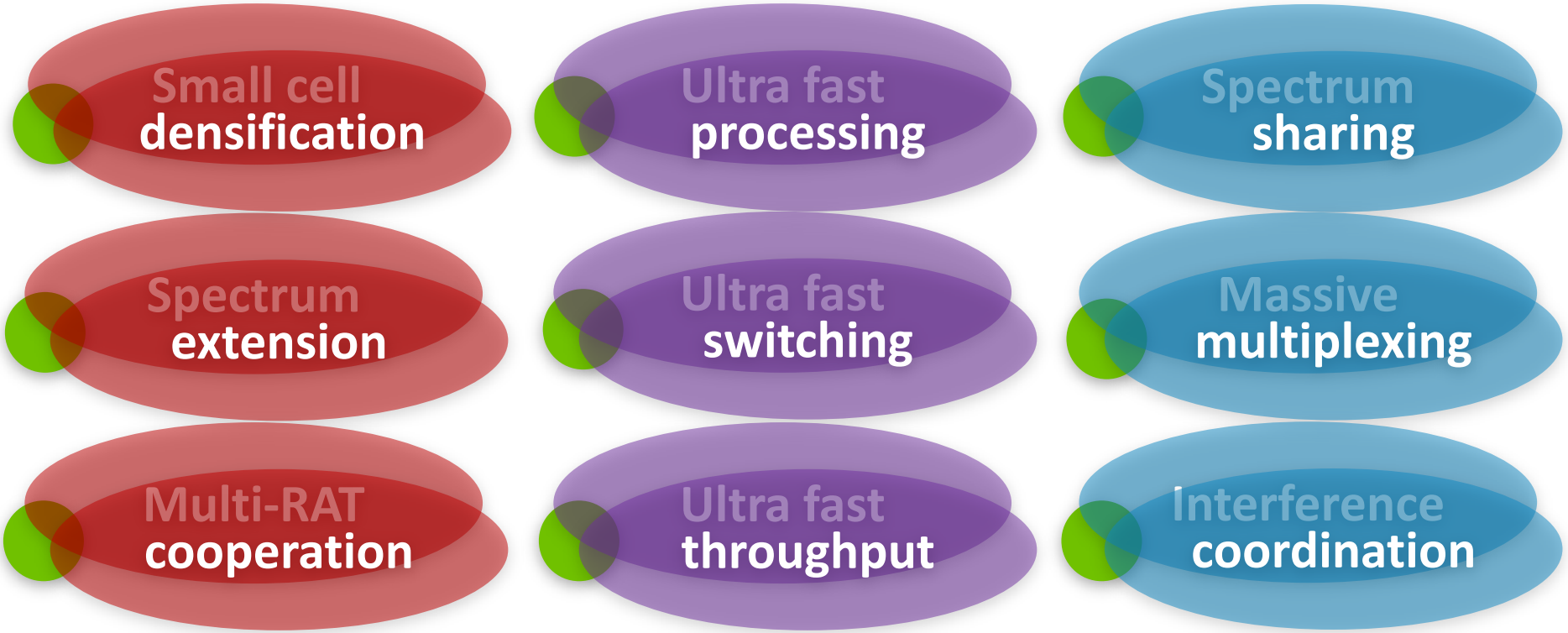
5G: the evolution to the smarter living network



5G radio interface: initial requirements & enablers

Global consensus emerging on initial requirements and enabling concepts [ITU-R] …

100 Mbps to 1 Gbps	10 to 50 Gbps	1 to 10 TBps/Km^2	1 ms	5 to 15 times 4G	50 to 100 times 4G
User experienced data rate	Peak data rate	Area traffic capacity	Latency	Spectral efficiency	Energy efficiency



5G radio interface: technology trends

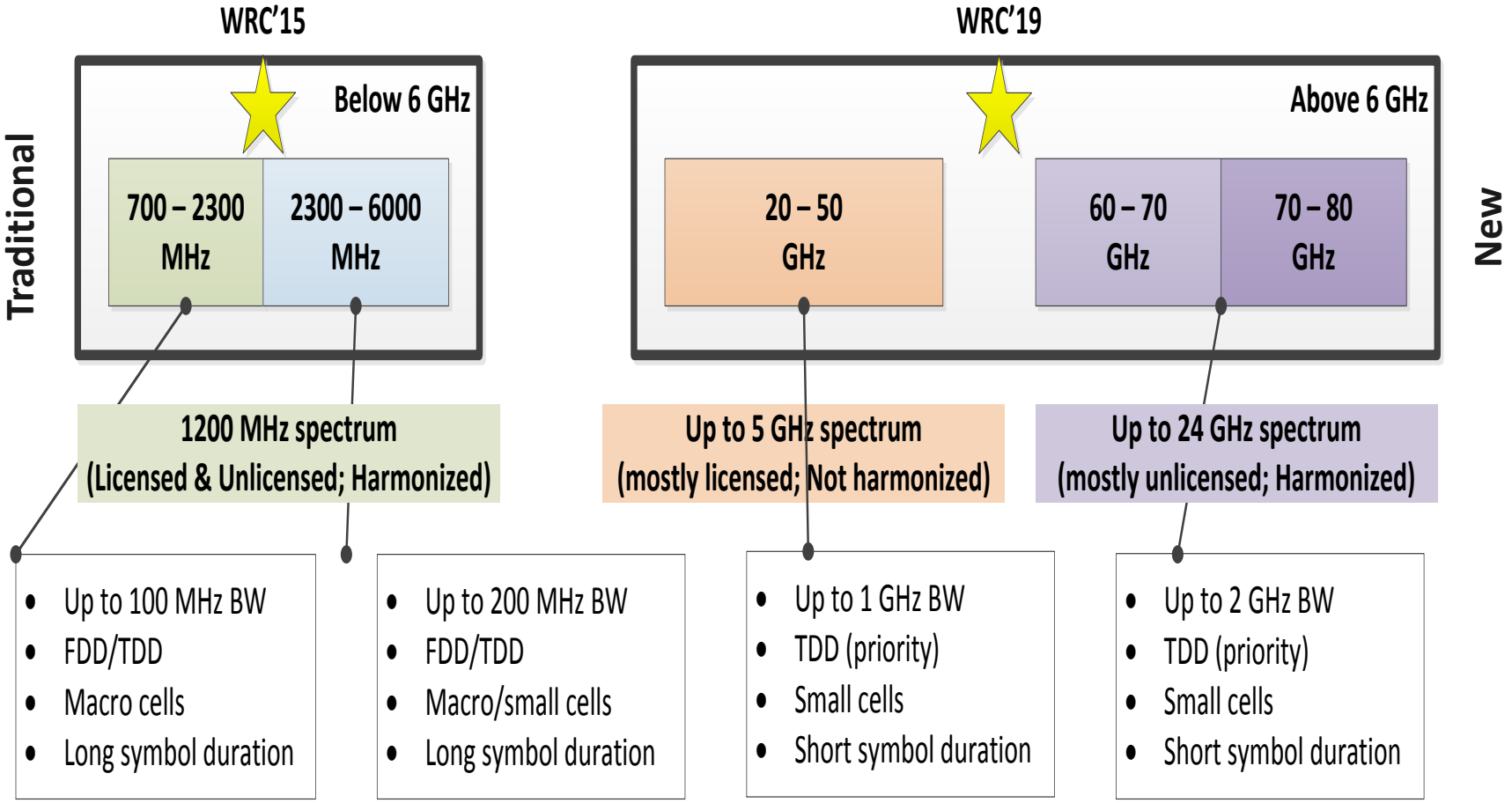
Advanced waveforms and multiple access	Advanced antenna and multi-site technologies	Novel duplexing schemes	New and flexible spectrum usage
• More flexible waveforms than pure OFDM (e.g. RBF-OFDM; FBMC; etc.) • Non-orthogonal multiple access (NOMA) • Broader set of modulation and coding schemes	• 3D-beamforming and MU-MIMO • Active Antenna System (AAS) • Massive MIMO • Network MIMO (Adv. CoMP)	• Joint TDD-FDD operation • Dynamic TDD • Single channel full duplexing	Our focus next • New large spectrum at mmW frequencies • Carrier Aggregation of discontinuous bands • Dual band split user and control planes • Joint multi-RATs management • Cognitive techniques (Spectrum Sensing)

Advanced **interference** coordination and cancellation techniques

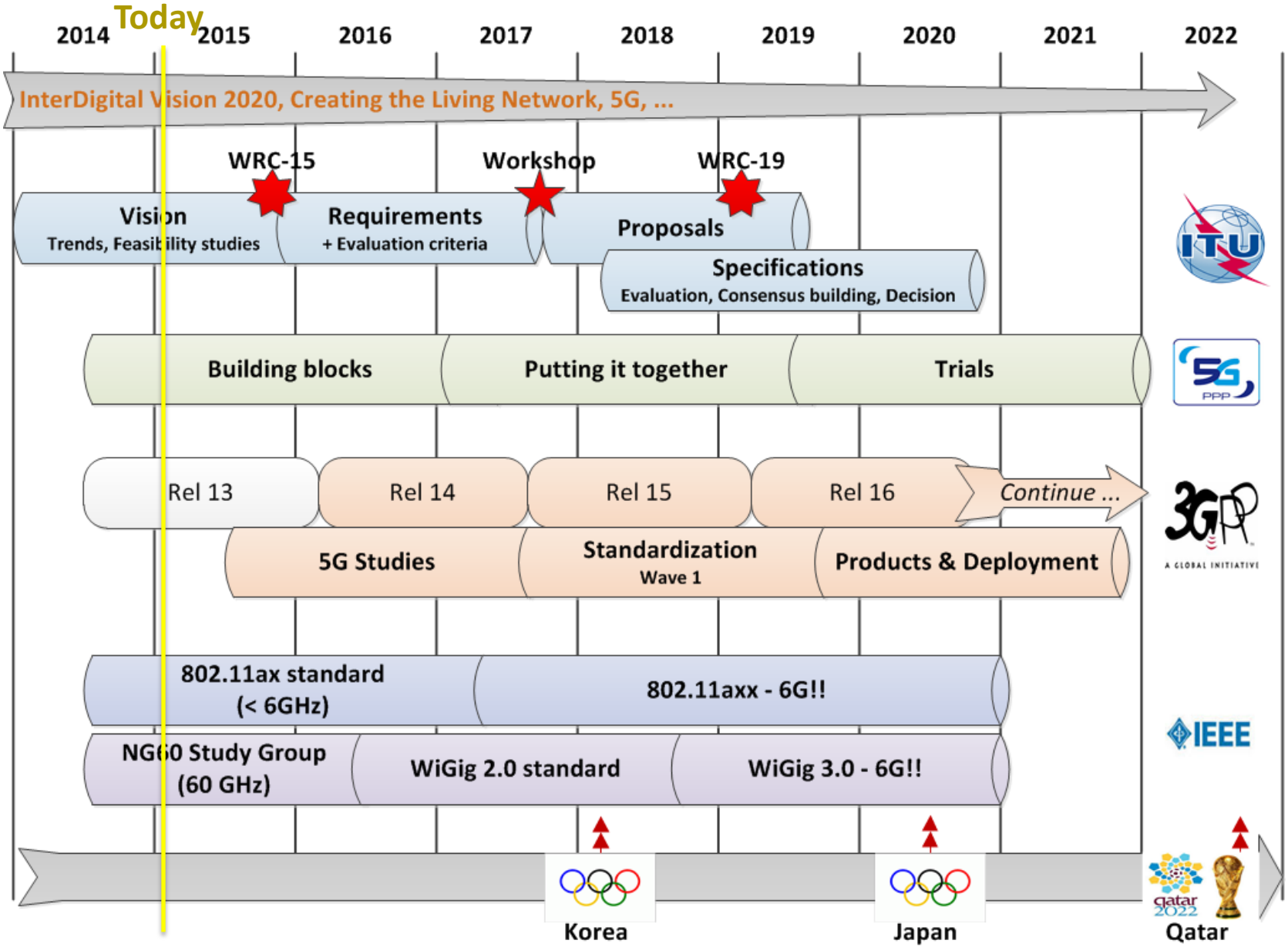
Flexible functional split (**virtualization / cloudification**)

Flexible **backhauling** and joint optimization with access

5G radio interface: a tale of two spectrum



5G radio interface: development timeline



Millimeter Wave

A new radio interface for 5G

mmWave: the bandwidth

Abundant Millimeter Wave Spectrum can provide **fiber-like capacity (multi-Gbps data rates)**

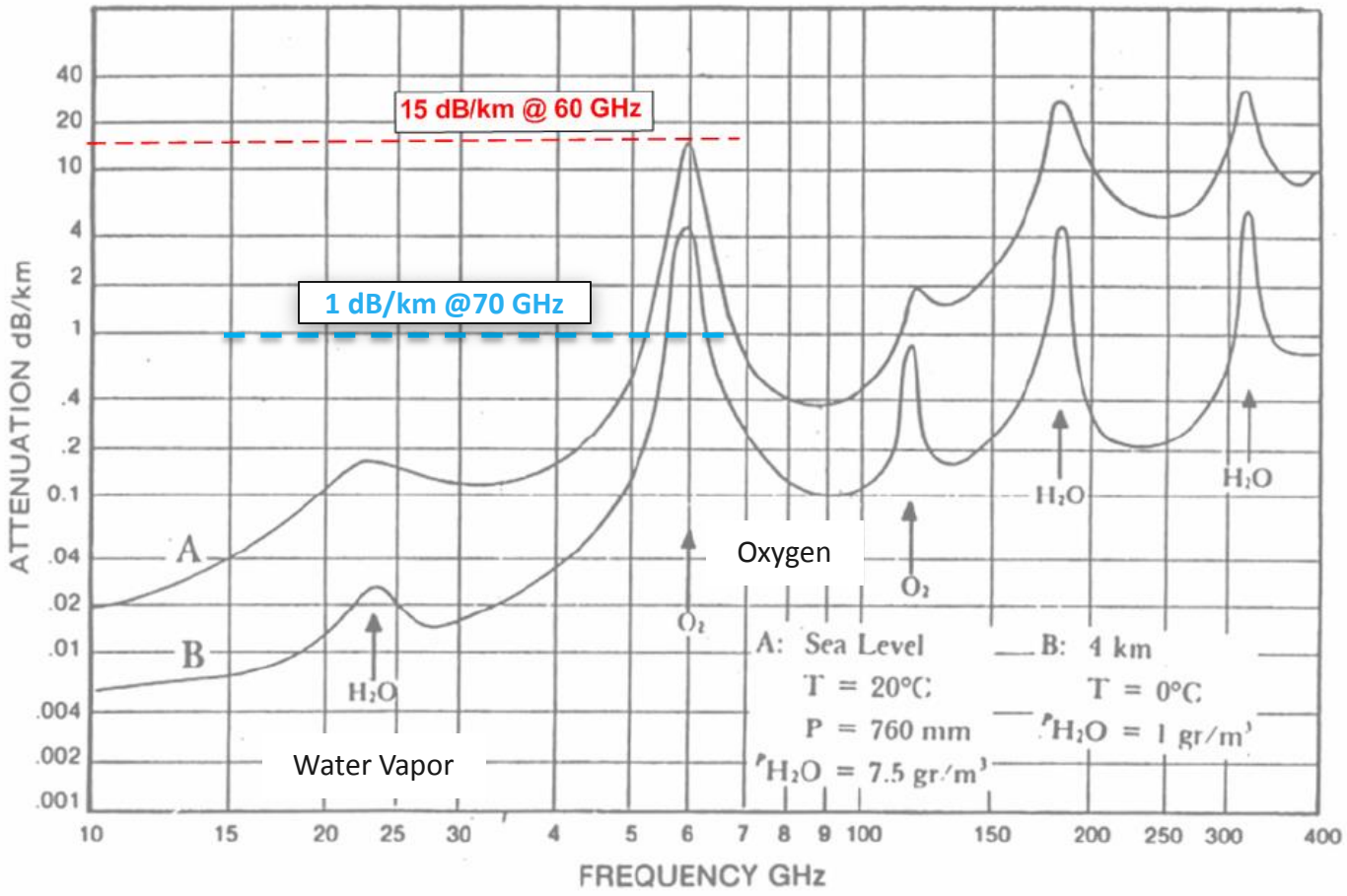
Band	Available Bandwidth (GHz)
LMDS (27.5-28.35 GHz, 29.1-29.25 GHz, and 31-31.3 GHz)	1.3
39 GHz Band (38.6-40 GHz)	1.4
37/42 GHz Bands (37.0-38.6 GHz and 42.0-42.5 GHz)	2.1
60 GHz Bands (57-64 GHz and 64-71 GHz)	14.0
70/80 GHz Bands (71-76 GHz, 81-86 GHz)	10.0
24 GHz Bands (24.25-24.45 GHz and 25.05-25.25 GHz)	0.4

- Industry attention for exclusive licensing
- Need to deal with incumbents (e.g. FSS)

- Industry attention on 60 GHz upper part & E-band
- All options on the table for spectrum licensing
- Global harmonization possible

mmWave: the range

~ 20 dB free space path loss attenuation compared to below < 6 GHz + additional gaseous (Water Vapor / Oxygen) attenuation → **Inherently short range →**
Enables X factor of densification



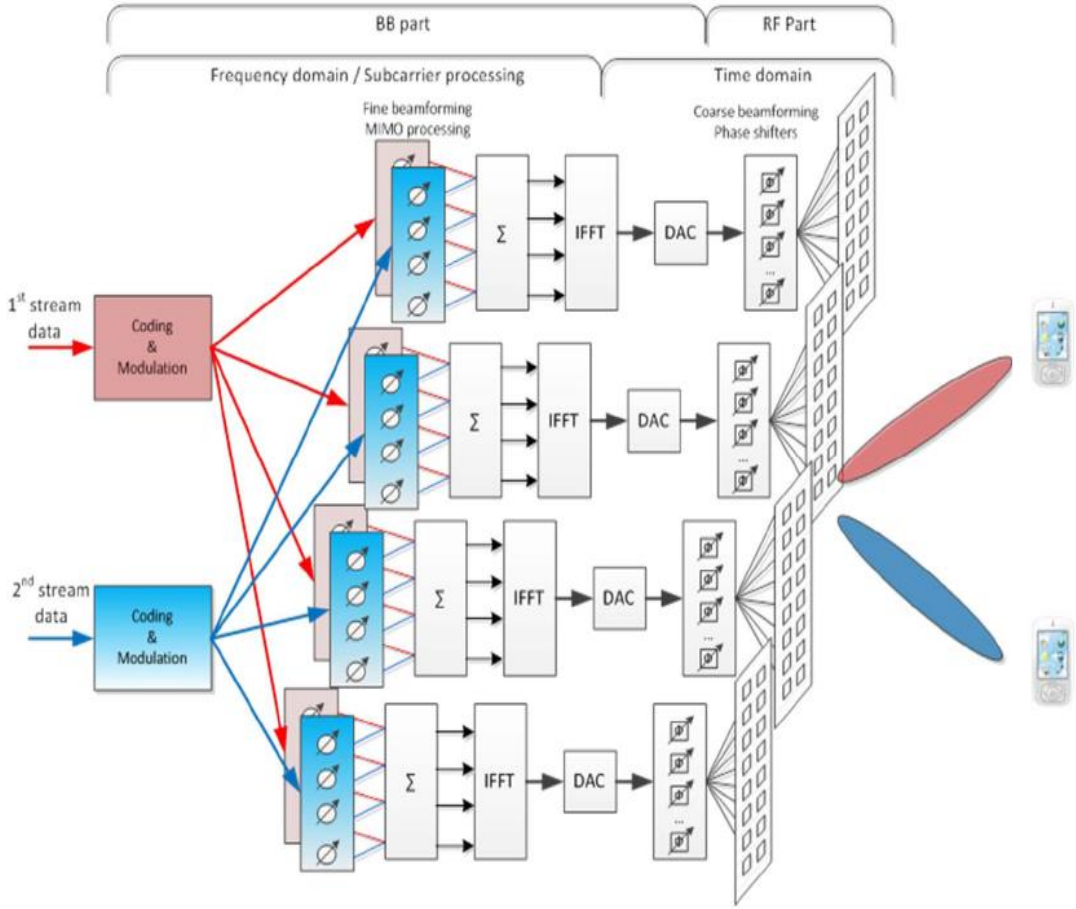
Few Kilometers in outdoor LOS

Target in 5G
→ 100-200m outdoor
→ 10-50m indoor

Few meters in indoor NLOS

mmWave: the beam

2-3 degrees beam width → array of antennas for wide angular coverage & multiple simultaneous beams/links @low interference → **Enables high multiplexing gain**



Electronically steerable phased array antennas to enable dynamic (re)configuration for guaranteed link reliability (in particular in mobile scenarios)

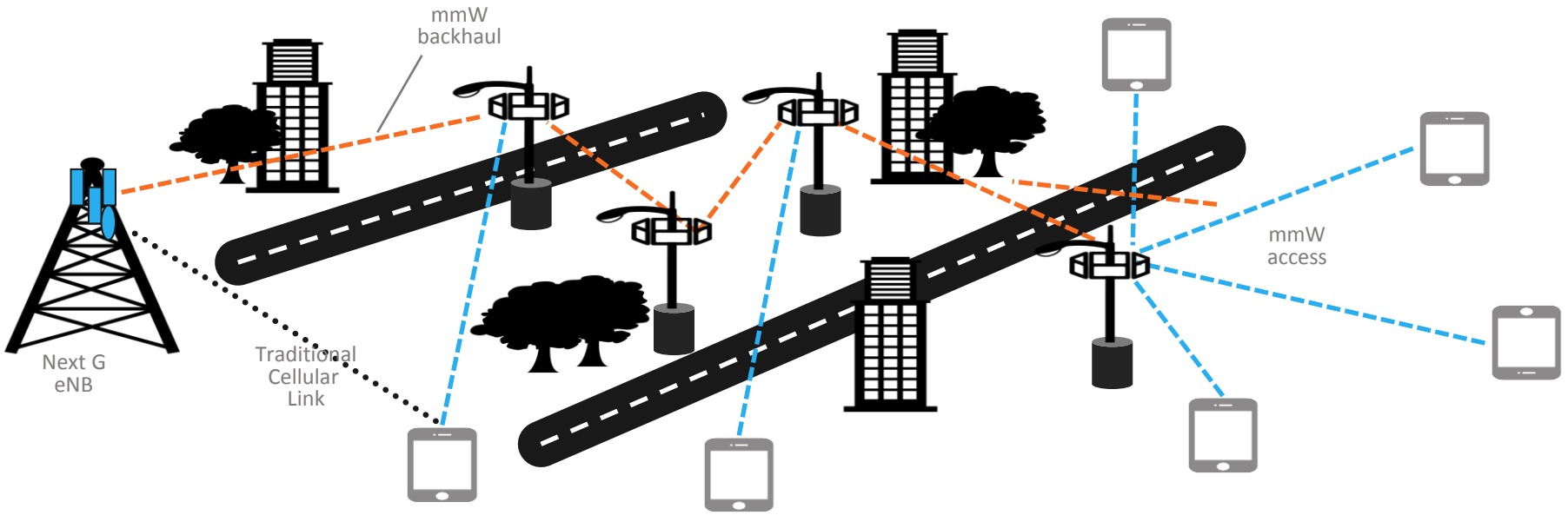
Small form factor (thanks to small antenna aperture and short inter-antenna distance) enabling the support of large number of antennas at the TX and RX

mmWave: the capacity

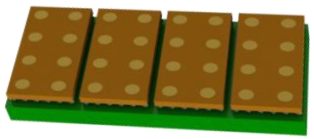
(20 x 10 x 5) = 1000x capacity increase

Wide contiguous bandwidth	**X 20**	Throughput gain
Short range and narrow beams	**X 10**	Densification gain
Multiple simultaneous links in the same band	**X 5**	Multiplexing gain

mmWave: the network

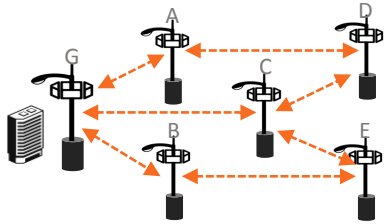


mmW Phase Array Radio and Antenna

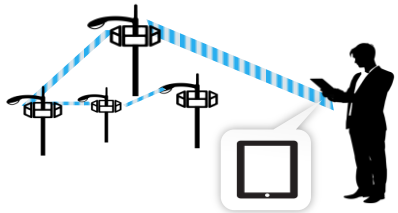


Wireless Mesh Backhaul

MWC 2015



5G Access



Earliest Commercialization Timeline

2016

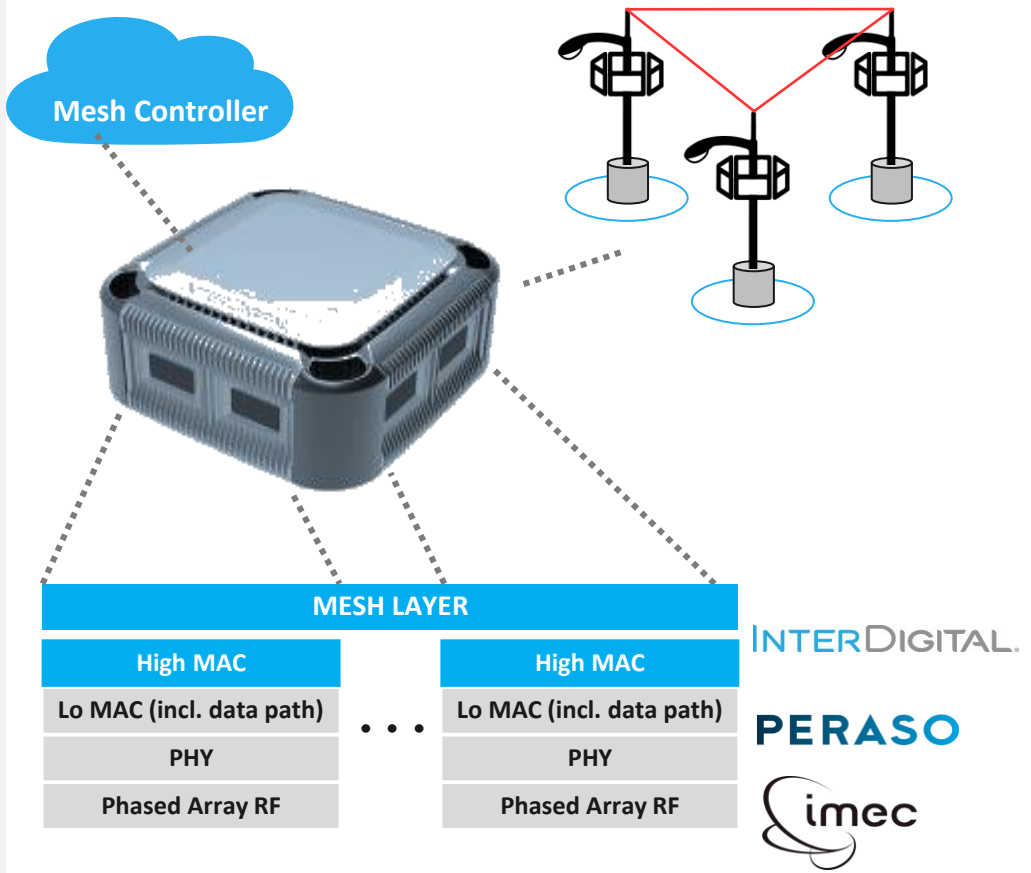
2020

Full mmH Architecture 2023

mmWave: the backhaul

InterDigital has high data rate (>1 Gbps), mesh backhaul solution that provides a self-healing, plug-n-play, low cost solution

- **System-oriented approach to develop future small cell platform**
  - Wireless backhaul is an enabler
  - Extend to cloud based management, edge caching and other services
- **Low Cost & High Capacity**
  - Leverage high volume WiGig baseband
  - Phased Array steerability reduces installation cost
  - > 1 Gbps over 150m+
- **Scalable system for outdoor small cell deployment**
  - New sites can be added without having to re-align antenna pointing at old sites
  - 1Gbps per channel links provide ample near term capacity, with future expansion to all four 2GHz unlicensed channels



mmWave: the access

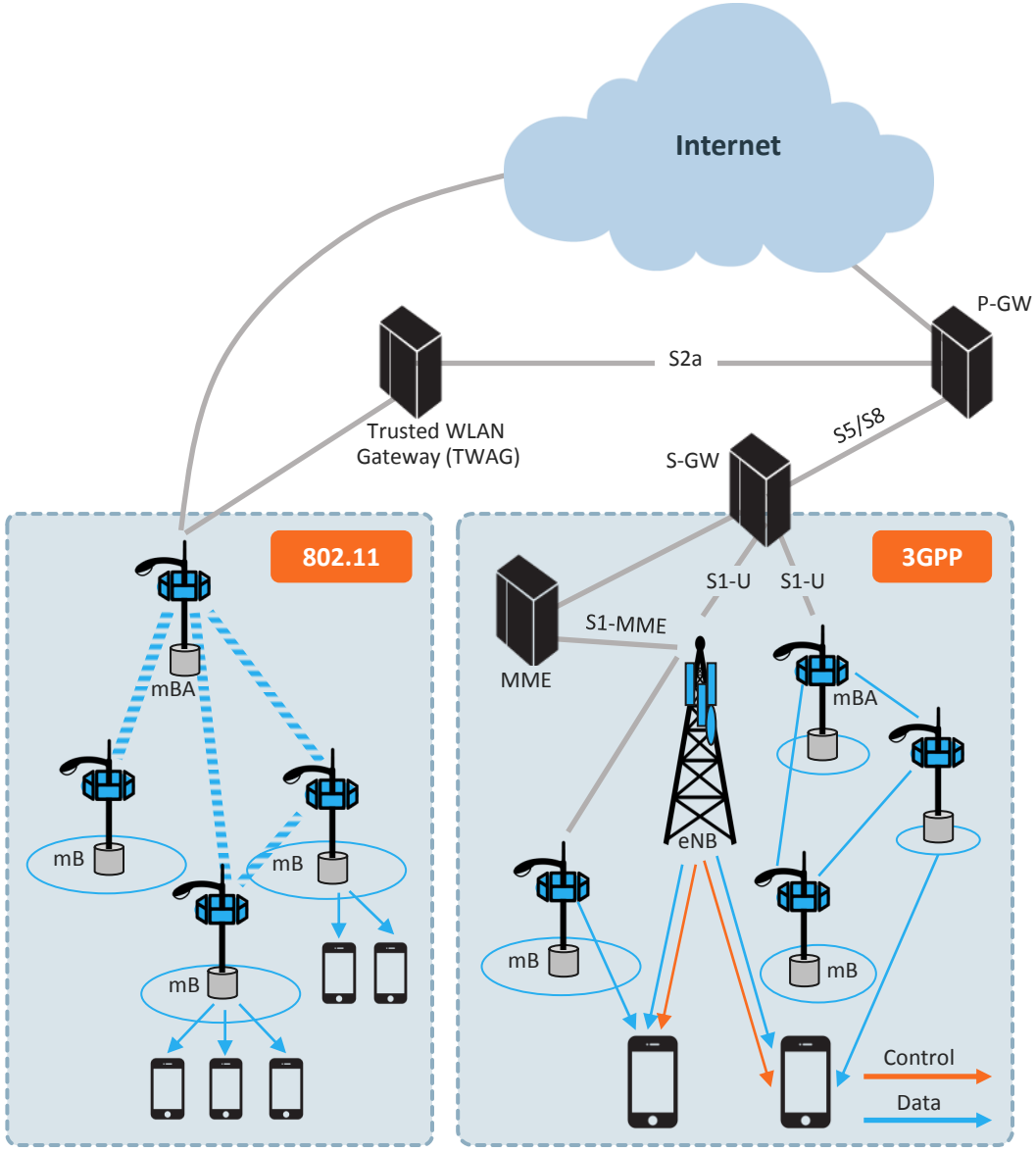
Options for Network Integration

3GPP

- mB underlay integrated with RAN architecture, with no Core Network impact
- Tight interworking at lower-layers between new mmWave RAT and evolved LTE RAN
- Control plane functions provided by eNB and data capacity provided by local mB
- mB joint access and backhaul design

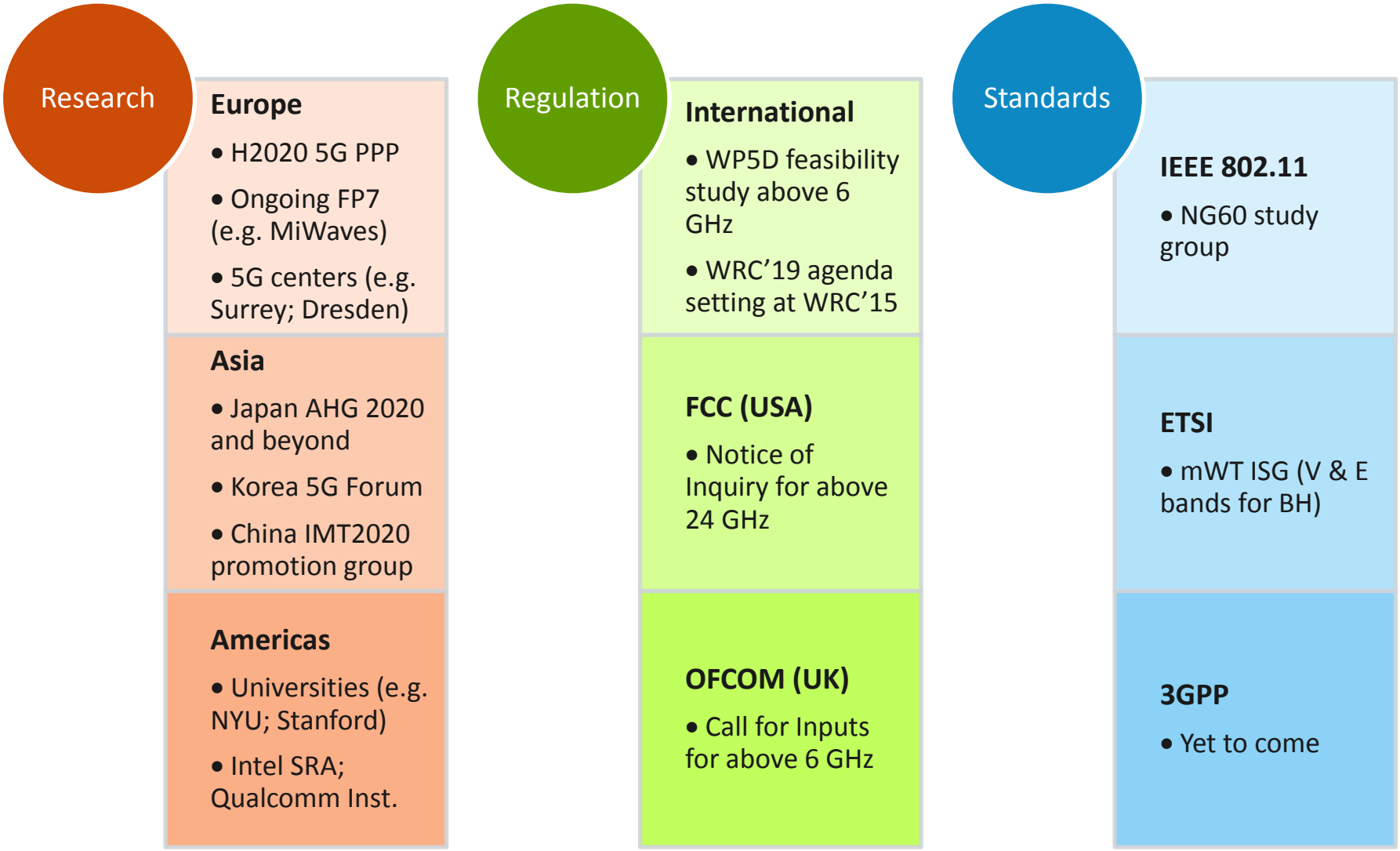
802.11 (Wi-Fi)

- Interfaces with Core Network using standards based WLAN/3GPP interworking
- Mesh extension of existing mmWave MAC/PHY
- Shared mB equipment for backhaul and access
- Multi-band (2.4/5/60 GHz) support for enhanced coverage



mB = Millimeter Wave Base station; **mBA** = mB Aggregator

mmWave: ongoing development efforts



Few Takeaways

Few Takeaways

- 5G radio interface will need to respond to very challenging and diverse requirements, and is therefore expected to include **2 or more complementary technologies (< and > 6 GHz).**
- 5G mmW spectrum will include **more than one band** (e.g. LMDS, V, E bands) with both **licensed and unlicensed** regimes.
- 5G mmW technologies will cover both segments of the small cell network, namely the **backhaul and access.**
- There is still room for lot of innovations in particular for the **mobile access** and its **joint optimization with the backhaul.**

Come and see our mmW backhaul demo at MWC'15 (stand 7A721)