LTE Summit 2015

Mapping the Path to 5G: A Cellular Perspective

Alain Mourad, InterDigital Europe
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What I will be Talking about Today

- A Little Background on InterDigital

- Summary of InterDigital 5G Vision

- The Path(s) to 5G from a Cellular Perspective
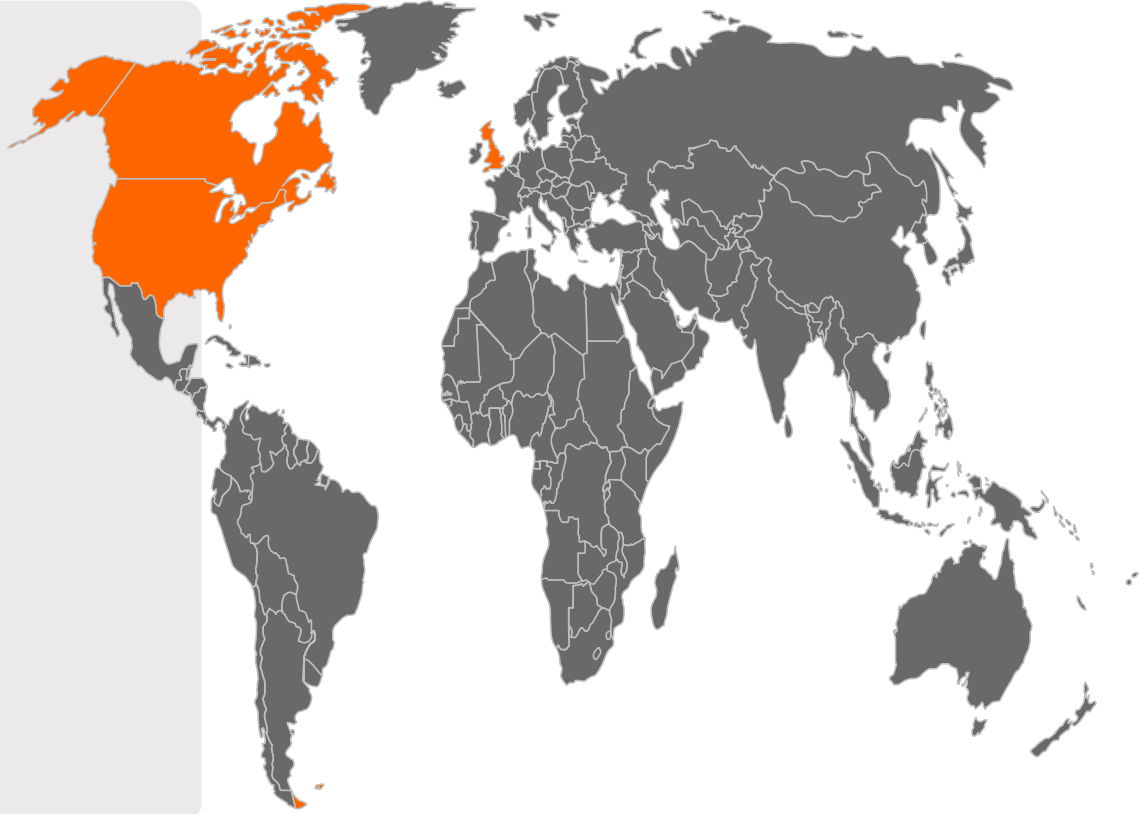
- One of our H2020 5G Projects

InterDigital Snapshot: Invention, Collaboration, Innovation

Four decades of leading technology discovery and innovation

Widely known for wireless standards but today we are really quite diverse

Diverse R&D activities in radio, backhaul, video, with **main focus on 5G and IoE**

Recently launched two new startup companies: WOT.io and Xcellair

InterDigital Europe – Open for Business July 2013

- Central mission is to drive technology collaboration & partnership initiatives across the European stage

- Happy to call London and "Tech City" our home affording us easy access to anywhere in Europe

- We play in Horizon 2020, 5GPPP, Innovate UK and are always looking to create new projects and alliances

- Already seeing some good results with **Four Wins** in EU competition (e.g. H2020) so far

- Also driving a integrated transport initiative, "oneTRANSPORT" in the area of the IoT

So where is our wireless industry today?

We have come a long way but have really only just begun...

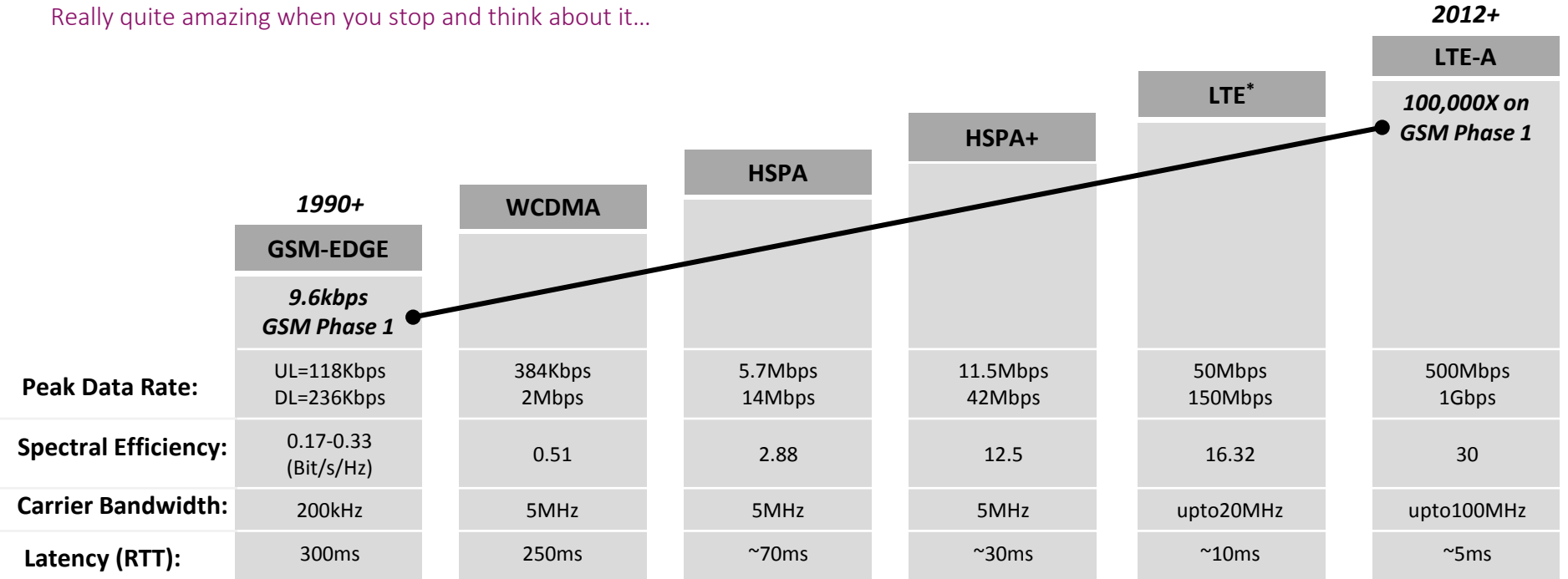# CONNECTIVITY View - And in the Beginning there was 9.6kbps!

2G Narrowband Era   ● IMT-2000   **3G** Broadband Era (for the few)   ● IMT-A   **4G** ...and for the masses

Really quite amazing when you stop and think about it...

2012+

LTE-A

100,000X on GSM Phase 1

LTE*

HSPA+

HSPA

WCDMA

1990+

GSM-EDGE

9.6kbps GSM Phase 1

	GSM-EDGE	WCDMA	HSPA	HSPA+	LTE*	LTE-A
Peak Data Rate:	UL=118Kbps DL=236Kbps	384Kbps 2Mbps	5.7Mbps 14Mbps	11.5Mbps 42Mbps	50Mbps 150Mbps	500Mbps 1Gbps
Spectral Efficiency:	0.17-0.33 (Bit/s/Hz)	0.51	2.88	12.5	16.32	30
Carrier Bandwidth:	200kHz	5MHz	5MHz	5MHz	upto20MHz	upto100MHz
Latency (RTT):	300ms	250ms	~70ms	~30ms	~10ms	~5ms

*LTE Category 4

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SERVICES View: And in 5G it will be all about EVERYTHING!
-In 5G the Everything is Information and Information will be Everything-

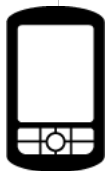Wave 1 (About one THING) | Wave 2 (A Few more THINGS) | 5G: ~~The Internet of~~ EVERYTHING

Glory days of GSM

IMS promises

Walled garden worries!

Ride of the OTT

A new status quo

Seamless Integration of Verticals (Healthcare, Energy, Transport, etc.)

The living experience

The video experience

Integrated telephony applications

Rise of the mobile internet

Boiler Plate Alert! Defining Requirements For Everything is Tough

4G purposed mainly for VIDEO... **IMT-2020** **5G** video ++ ● IoE ● TACTILE internet ● mission critical

	LTE	LTE-A	<1millisecond latency (when needed!)	10-50Gbps peak data rates (when needed!)	90% Energy reduction per service
Peak Data Rate:	50Mbps 150Mbps	500Mbps 1Gbps	100-500MHz Carrier Bandwidth	Higher Density: Millions of connections per km²	Higher Traffic Volume: 1-10 Tbps per km²
Spectral Efficiency:	16.32	30			
Carrier Bandwidth:	upto20MHz	upto100MHz	Rapid Service Creation (from days to minutes)	Sustainable Total Cost of Owner for all players	User Definable Security & Privacy
Latency (RTT):	~10ms	~5ms			

*Key requirements harmonized & agreed in ITU-R WP5D

5G Socio-Economic Study: Refining the Challenge of EVERYTHING
- An EU Commission Funded & Supported Study -

- Develop a better understanding of the potential economic impact of 5G networks in vertical markets

- Identify the relative potential of each use for social and economic benefits in the European context

- Fully informed by and consistent with the 5GPPP initiatives while offering fresh and independent perspective

- Open Stakeholder hearings on 22 Sep and workshop on 19 October – **Please Join in!**

- Follow on Linkedin: http://linkd.in/1Kra7n4

So what can we "confidently" say about 5G as of today

- 5G will certainly be the most diverse generation in history with perhaps the most challenging set of requirements of any "G"

- on the **5G air interface**: There will be "at least" three "RATs" *or modes*: Two below 6GHz (coverage & IoE) & one above (capacity)

- on the **5G network**: It will be built on the base of programmability and SDN/NFV will provide the cornerstones for its essential fabric

- on the **5G system**: It will be as much about the *fog* as it will be about the *cloud* and where the line falls between will define 5G

- on the **5G bottomline**: Not to be lost and perhaps above all else 5G will be about **FLEXIBILITY** and **SIMPLIFICATION**

ITU Regulation: Setting the Stage for 5G

WRC 2015

WRC 2019

Identifying Additional Spectrum for 5G

- Additional spectrum expected to be identified for IMT at WRC in 2015
- More than 500 MHz of additional spectrum could be identified for IMT **below 6 GHz**
  - Low band (<1 GHz) for macro coverage
  - Mid-to-high band (1-3 GHz) for macro/micro coverage
  - High band (3-6 GHz) for micro/pico/hotspots

Spectrum outlook for 2020 and beyond:

- Potential Agenda Item for spectrum **above 6 GHz** to be considered at WRC 2019
- Additional Spectrum below 6 GHz could be also considered

Identifying Capabilities for 5G

- The mobile community is working towards defining objectives for IMT-2020
- Key capabilities **have been identified and** may continue to evolve in the future

User experienced data rate	Peak data rate	Mobility	Latency	Connection density	Energy efficiency	Spectrum efficiency	Are Traffic Capacity
[100 Mbit/s – 1 Gbit/s]	[20 Gbit/s]	500km/h	1ms (radio interface)	10^6 per km^2	100 times IMT-Advanced	[2,3,5 times IMT-Advanced]	10 Mbps/m2

Emerging 5G RAT Story: Holistic View (Licensed/Unlicensed)

Technology evolution + **New spectrum** + **New capabilities** = **The Paths to 5G (All 5G!)**
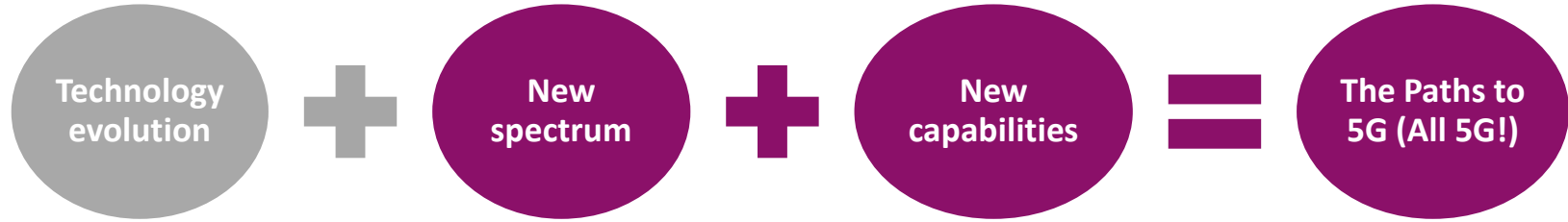
Backwards Compatible Evolution below 6 GHz

Non-Backwards Compatible in Additional Spectrum below 6 GHz (WRC15)

New Spectrum above 6GHz (WRC19)

2,3,4G applications

More Mobile Broadband! Limited M2M/IoT, Coverage

Enhancements to LTE

D2D, M2M, V2X, 3D-MIMO, Multi-connectivity, LAA, WLAN fine integration

IEEE 802.11 ax (<6GHz)
IEEE 802.11 ah (<1GHz)

NEW 5G Applications

More Mobile Broadband! IoE (<u>massive</u> connections), Mission-critical, Tactile (<u>low latency</u>),

New flexible RAT design

Flexible waveform, duplexing, non-orthogonal multiplexing, aggregation, Light MAC, etc.

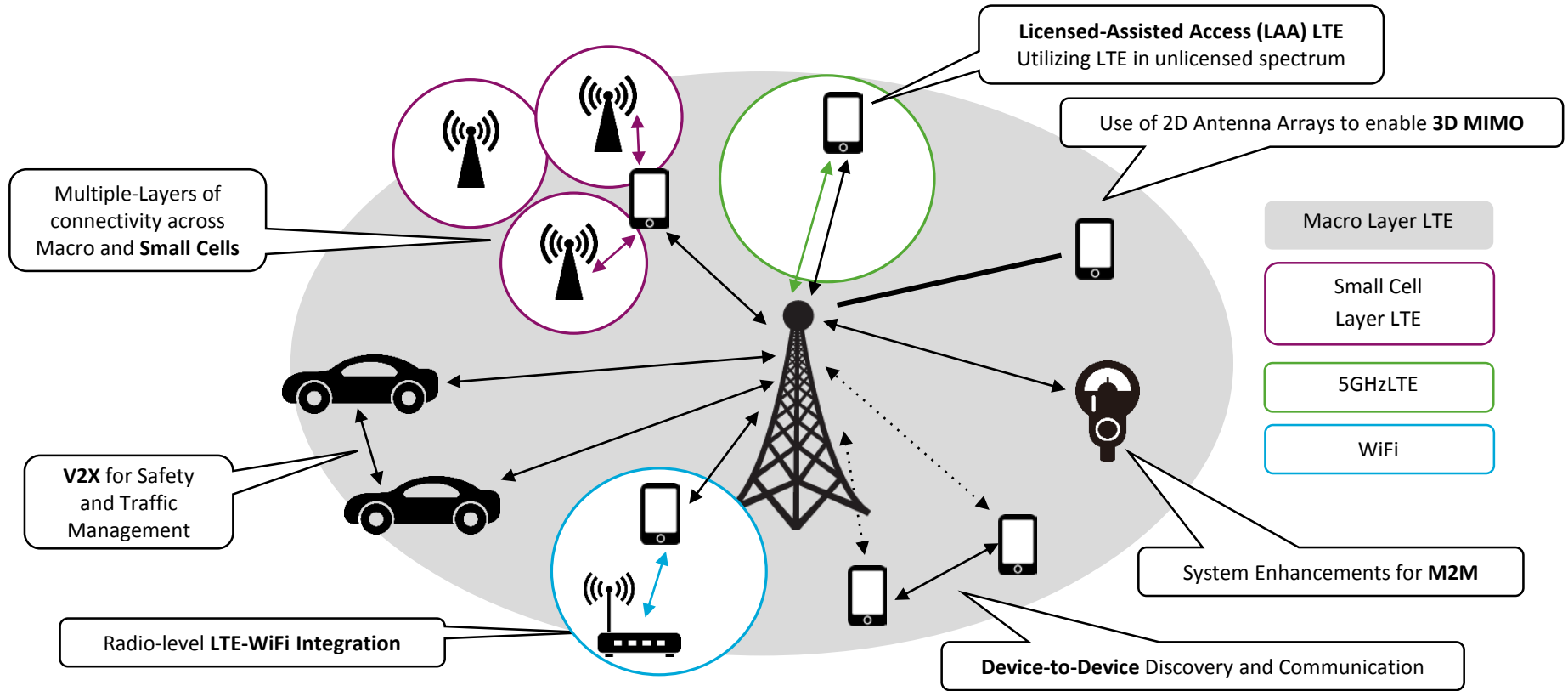
NEW 5G Applications

Ultra Dense (<u>ultra high capacity</u>); Indoor/Outdoor 5G Experience (<u>low latency</u>)

Clean slate RAT design

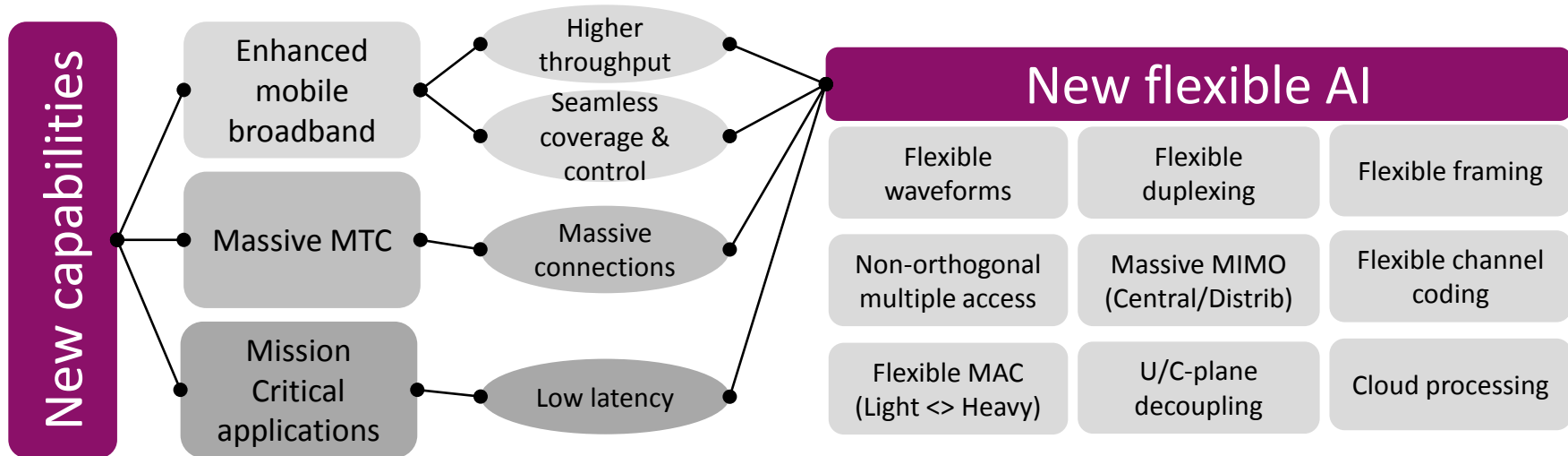Large bandwidth, new waveform, new multiple access, advanced beamforming, etc.

IEEE 802.11ay (6OGHz)

1st Path: Backwards Compatible Evolution (< 6 GHz)

Licensed-Assisted Access (LAA) LTE
Utilizing LTE in unlicensed spectrum

Use of 2D Antenna Arrays to enable **3D MIMO**

Multiple-Layers of connectivity across Macro and **Small Cells**

V2X for Safety and Traffic Management

Radio-level **LTE-WiFi Integration**

System Enhancements for **M2M**

Device-to-Device Discovery and Communication

Macro Layer LTE

Small Cell Layer LTE

5GHzLTE

WiFi

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2nd path – Non-backwards compatible in additional spectrum below 6 GHz

- Flexible design that can customize the technology blocks to optimize the performance for different applications/KPIs

New capabilities

- Enhanced mobile broadband
  - Higher throughput
  - Seamless coverage & control
- Massive MTC
  - Massive connections
- Mission Critical applications
  - Low latency

New flexible AI

Flexible waveforms	Flexible duplexing	Flexible framing
Non-orthogonal multiple access	Massive MIMO (Central/Distrib)	Flexible channel coding
Flexible MAC (Light <> Heavy)	U/C-plane decoupling	Cloud processing

15

3rd path – New Spectrum above 6 GHz

- Clean-slate AI design geared towards fiber-like experience for indoor and outdoor small cells
  - New Waveforms (tailored for large bandwidth at cm/mm -W)
  - Advanced beamforming (tailored to very narrow beams)
  - Advanced channel coding (tailored to Gbps link throuhputs)
  - Advanced MAC schemes (tailored to fast discovery, and low latency recovery from blockage and failure)
  - Flexible architecture for integration with below 6 GHz AIs and for joint optimization with the backhaul/fronthaul
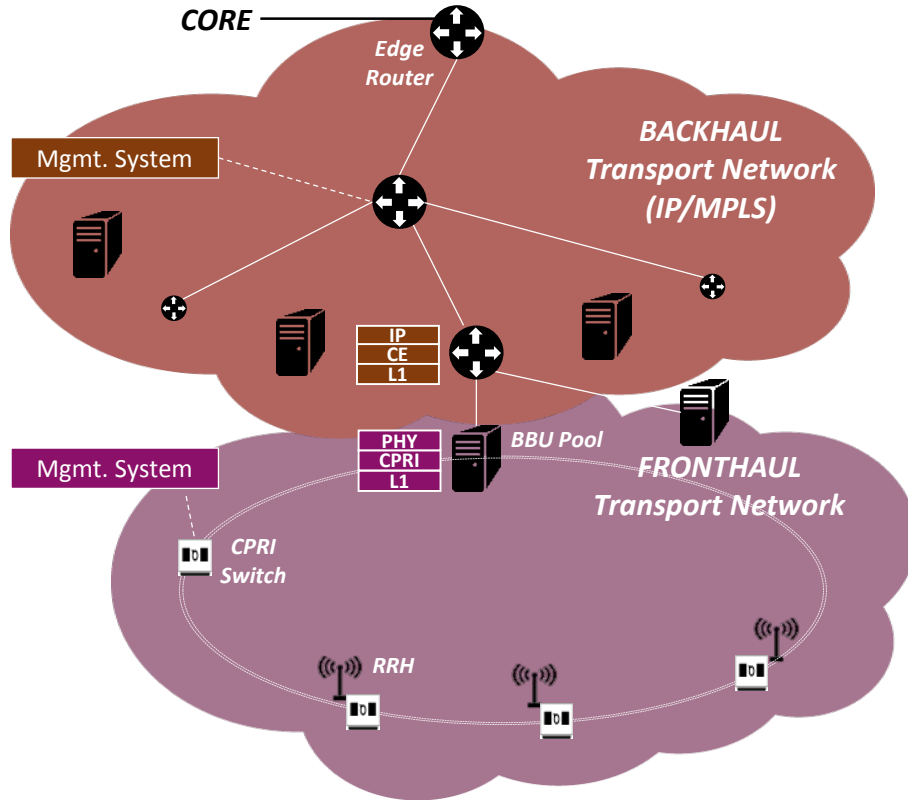
One of our EU H2020 5G projects

5G PPP Xhaul

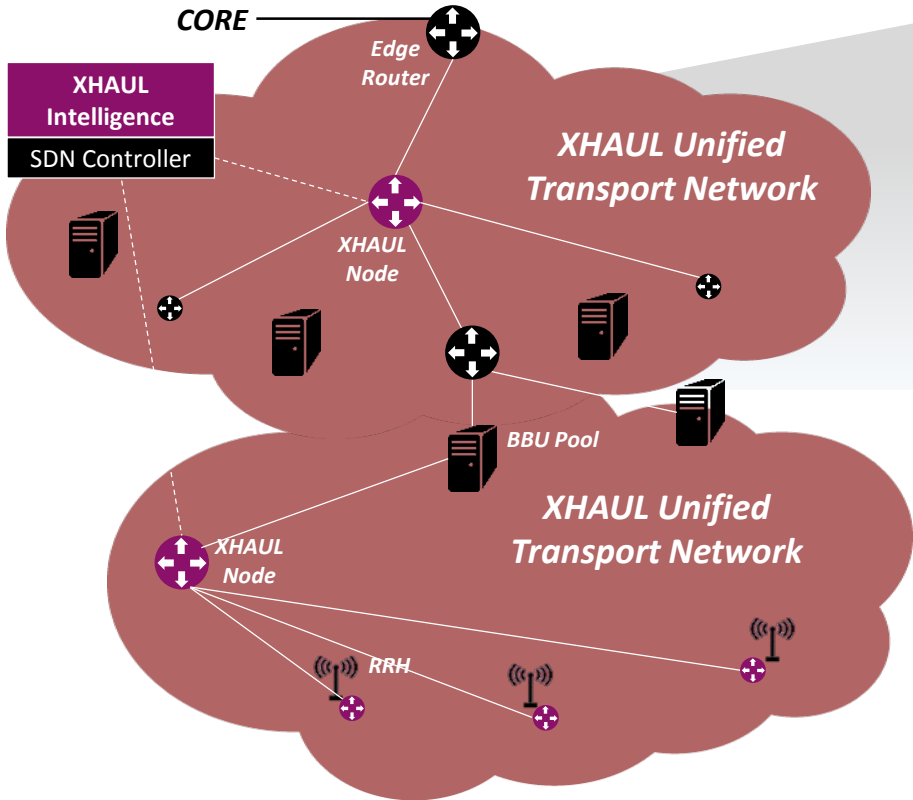# XHAUL: A SIMPLIFYING Twist on Backhaul and Fronthaul

CORE

Edge Router

Mgmt. System

BACKHAUL Transport Network (IP/MPLS)

IP
CE
L1

PHY
CPRI
L1

BBU Pool

Mgmt. System

FRONTHAUL Transport Network

CPRI Switch

RRH

Backhaul and Fronthaul Systems have evolved on quite different trajectories

- A wide array of L1-L3 technologies are deployed in todays FH and BH systems
- Carrier Ethernet preferred on Backhaul
- CPRI approach common in Fronthaul
- Independent management systems

XHAUL aim is unification of Backhaul and Fronthaul in common SDN fabric

- Unprecedented 5G "Everything" needs will demand a new level of dynamism
- Demo in Berlin planned + standards

XHAUL: An Ambitious SDN Approach for BH & FH Unification

CORE

Edge Router

XHAUL Intelligence

SDN Controller

XHAUL Unified Transport Network

XHAUL Node

BBU Pool

XHAUL Unified Transport Network

XHAUL Node

RRH

IP			PHY/BB		
Carrier Ethernet			CPRI/OBSAI		
XHAUL Common Abstraction Layer					
Radio over Fiber	Passive Optical Network	Wave Division MUX	Micro Wave Link	mmW Link	Free Space Optics

XHAUL Node (e.g. a 5G Base Station)

Key Challenges Being Addressed in XHAUL

- Explore novel SDN-based control architectures to support flexible functional splits for dynamic KPI optimization
- Develop common abstractions on southbound i/f (including unified framing) across disparate tech to enable a seamless SDN integration.
- Deliver a suite of enabling applications for fluid management of unified and virtualized XHAUL resources
- Special focus on flexible sharing/multi-tenancy support

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We will be bringing our EDGEHAUL™ solution to Berlin Trial

- Low-cost, high capacity, scalable design for today's small cell backhaul and future 5G architectures
  - Leverage high volume WiGig baseband
  - 60GHz Phased Array with electronic beam steering reduces installation cost and provides interference management

- Gbps throughput over 200-300m range suitable for dense urban small cell deployments

- Mesh connectivity enables an adaptable network around interference and congestion

- High capacity, low-latency inter-cell connectivity ideal for 5G advanced RAN architectures
  - RAN Virtualization
  - Edge Intelligence

MWC 2015

Thank you!

Alain Mourad
InterDigital Europe, Ltd.
64 Great Eastern Street
London, EC2A 3QR
+44 7920 798685
Alain.Mourad@InterDigital.com

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