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The Next Wave in Wireless

The Dawn of 5G

QUALCOMM®

WInnComm
25 March 2015

Mobile has made a leap every ~10 years

1G

Analog voice

AMPS, NMT, TACS

1980s

2G

Digital voice

D-AMPS, GSM, IS-95 (CDMA)

1990s

3G

Mobile broadband

WCDMA/HSPA+, CDMA2000/EV-DO

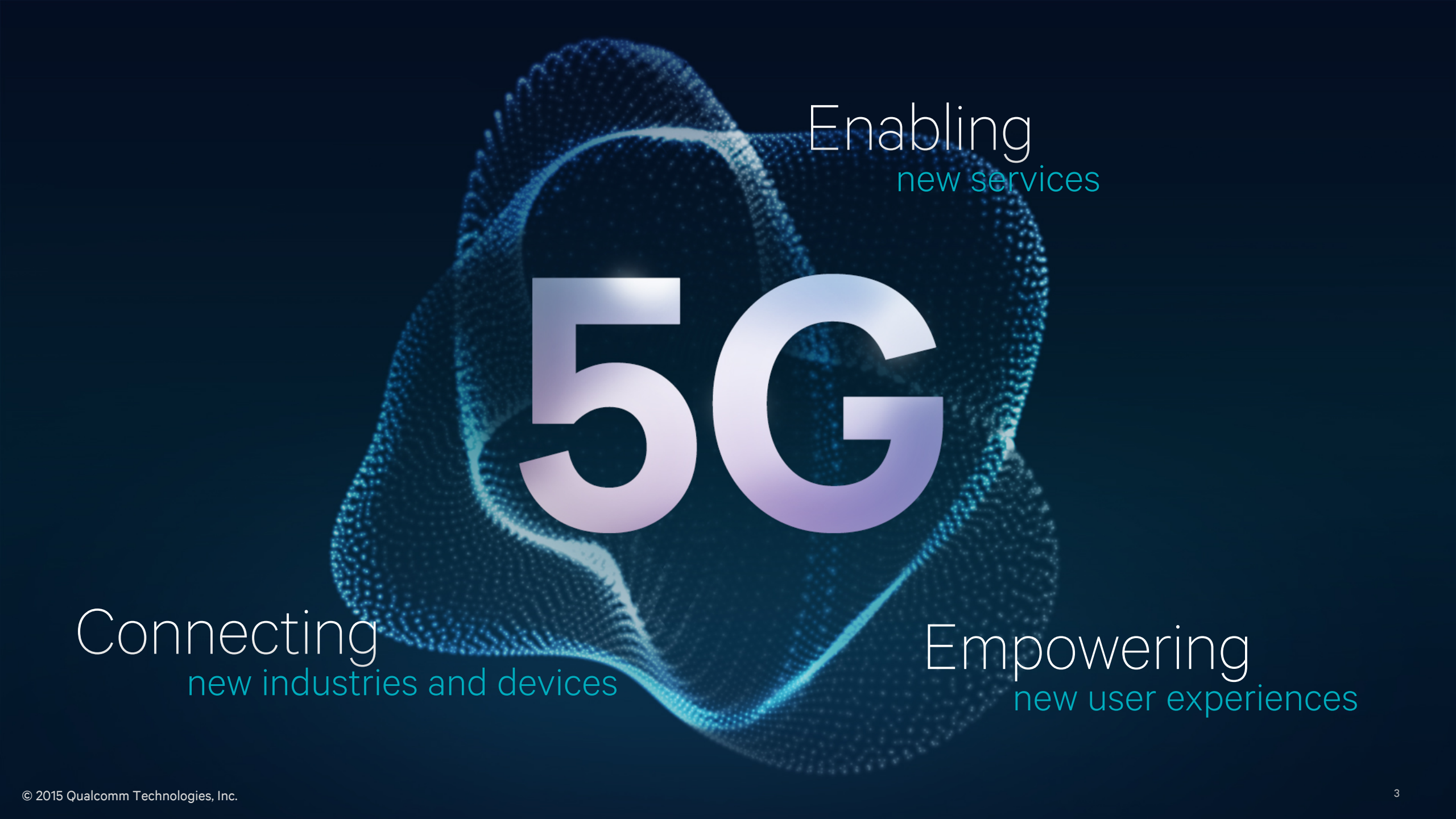
2000s

4G

Faster and better MBB

LTE, LTE Advanced

2010s

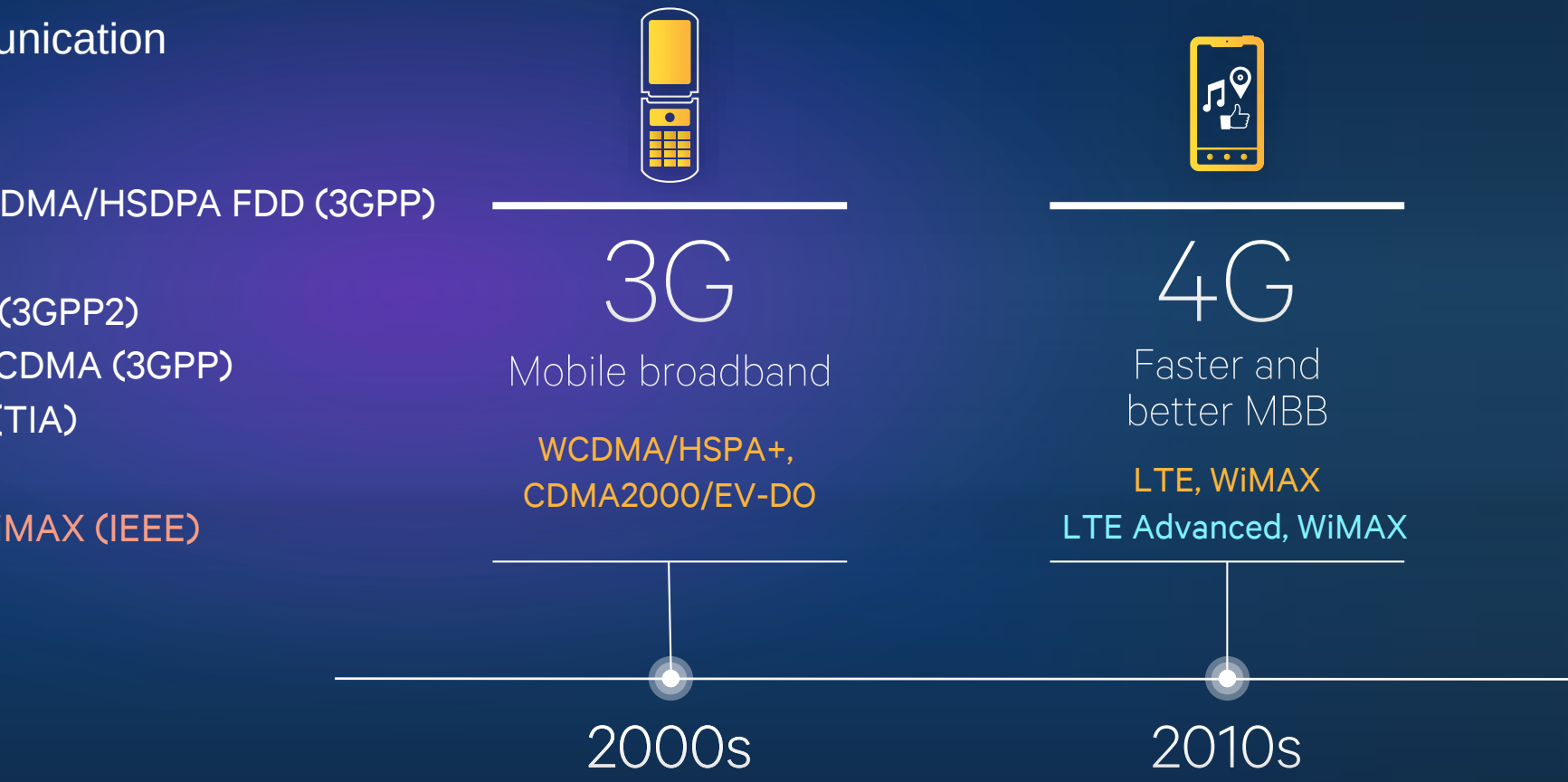


Potpourri of Organizations Involved with 5G

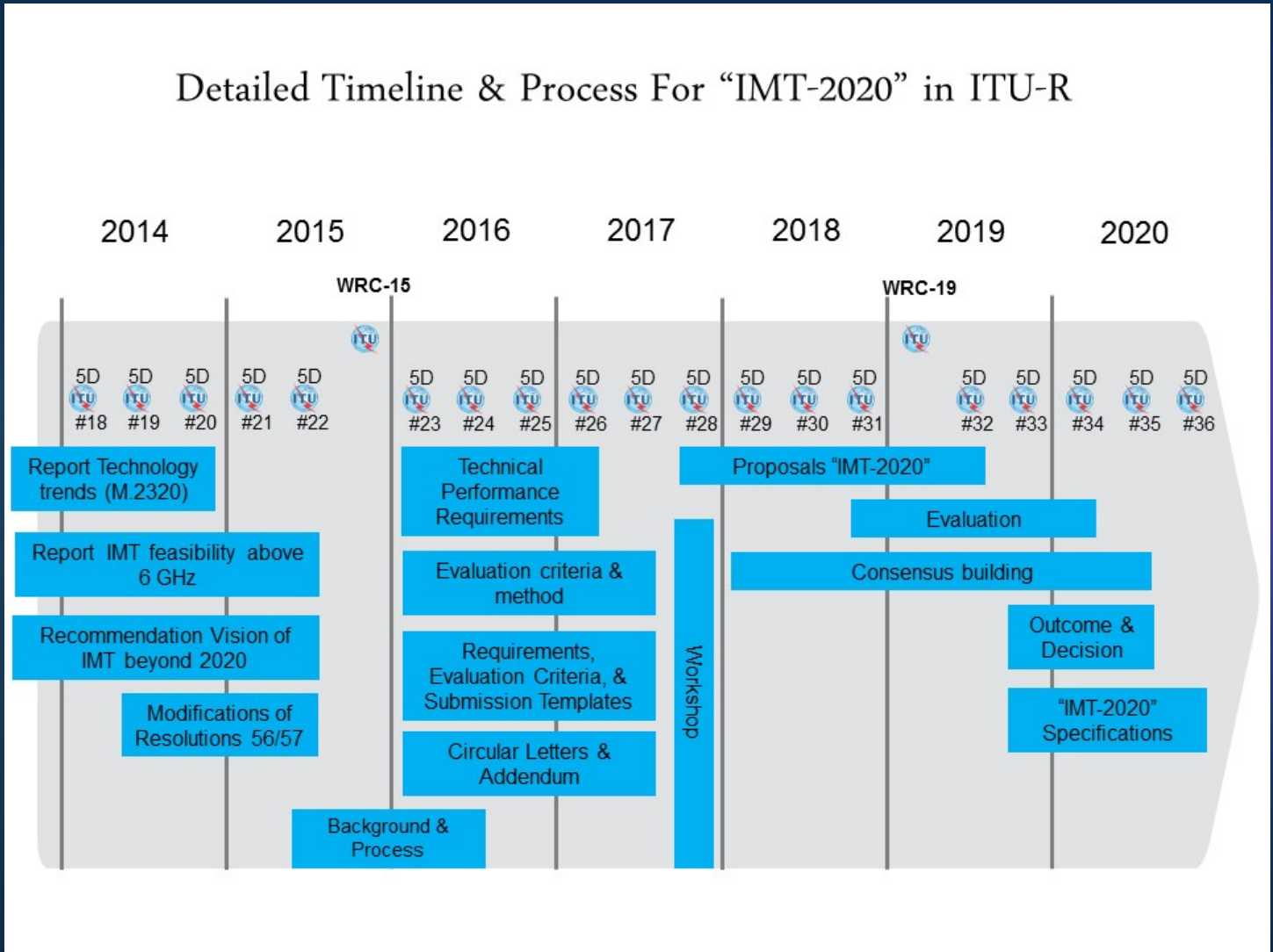
Mobile has made a leap every ~10 years

IMT - International Mobile Telecommunication

- IMT-2000
  - CDMA Direct Spread – UMTS/WCDMA/HSDPA FDD (3GPP)
    LTE Release 8/E-UTRA
  - CDMA Multi-Carrier – cdma2000 (3GPP2)
  - CDMA TDD – UMTS TDD & TD-SCDMA (3GPP)
  - TDMA Single-Carrier – UWC-136 (TIA)
  - FDMA/TDMA – DECT (ETSI)
  - OFDMA TDD WMAN – 802.16e/WiMAX (IEEE)
- IMT-Advanced
  - LTE Release 10 (3GPP)
  - WiMAX 802.16m (IEEE)

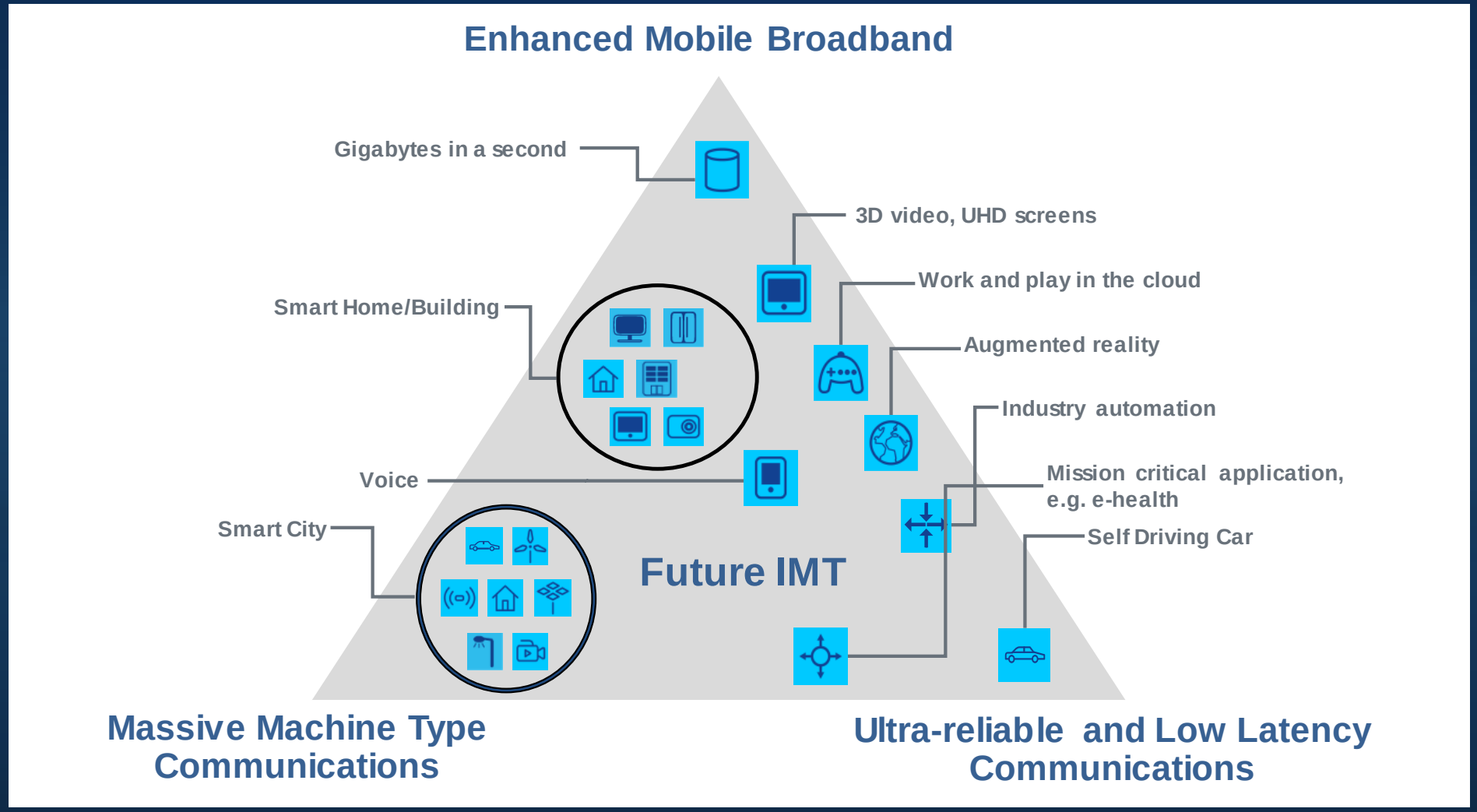


IMT-2020 – The ITU Vision

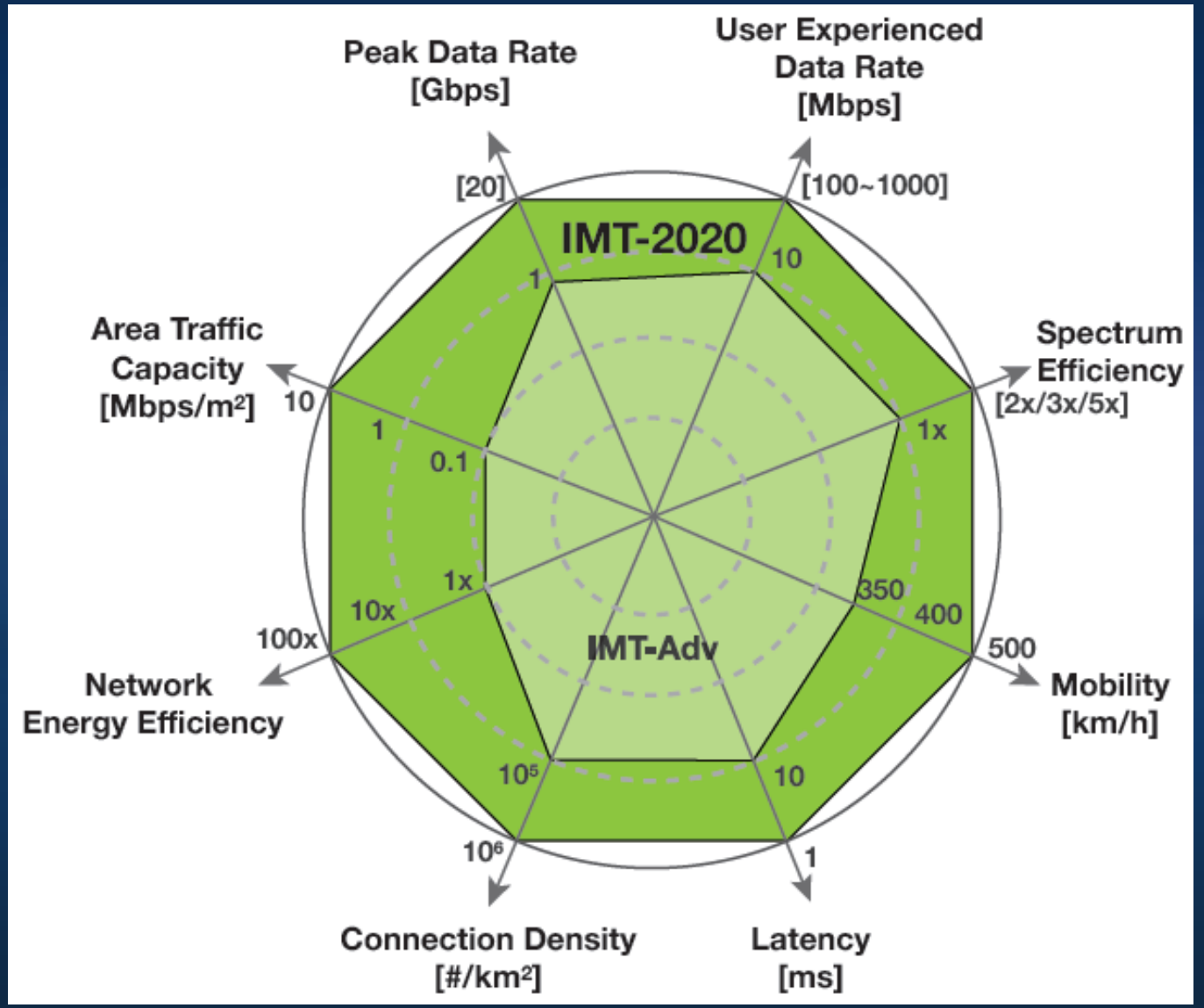


- M.2290 - M.[IMT.2020.ESTIMATE] – *"Future spectrum requirements estimate for terrestrial IMT"* – December 2013
- M.2320 - M.[IMT.FUTURE TECHNOLOGY TRENDS] - *Future technology trends of terrestrial IMT systems* – October 2014
- M.[IMT.ABOVE 6 GHz] - *The technical feasibility of IMT in the bands above 6 GHz* –WP 5D targets finalization in June 2015
- M.[IMT.Vision] – *Framework and overall objectives of the future development of IMT for 2020 and beyond* –WP 5D targets finalization in June 2015
- M.[IMT.BEYOND2020.TRAFFIC] – *IMT Traffic estimates beyond the year 2020* –WP 5D targets finalization in June 2015
- M.[IMT.ARCH] - *Architecture and Topology of IMT Networks* –WP 5D targets finalization in June 2015

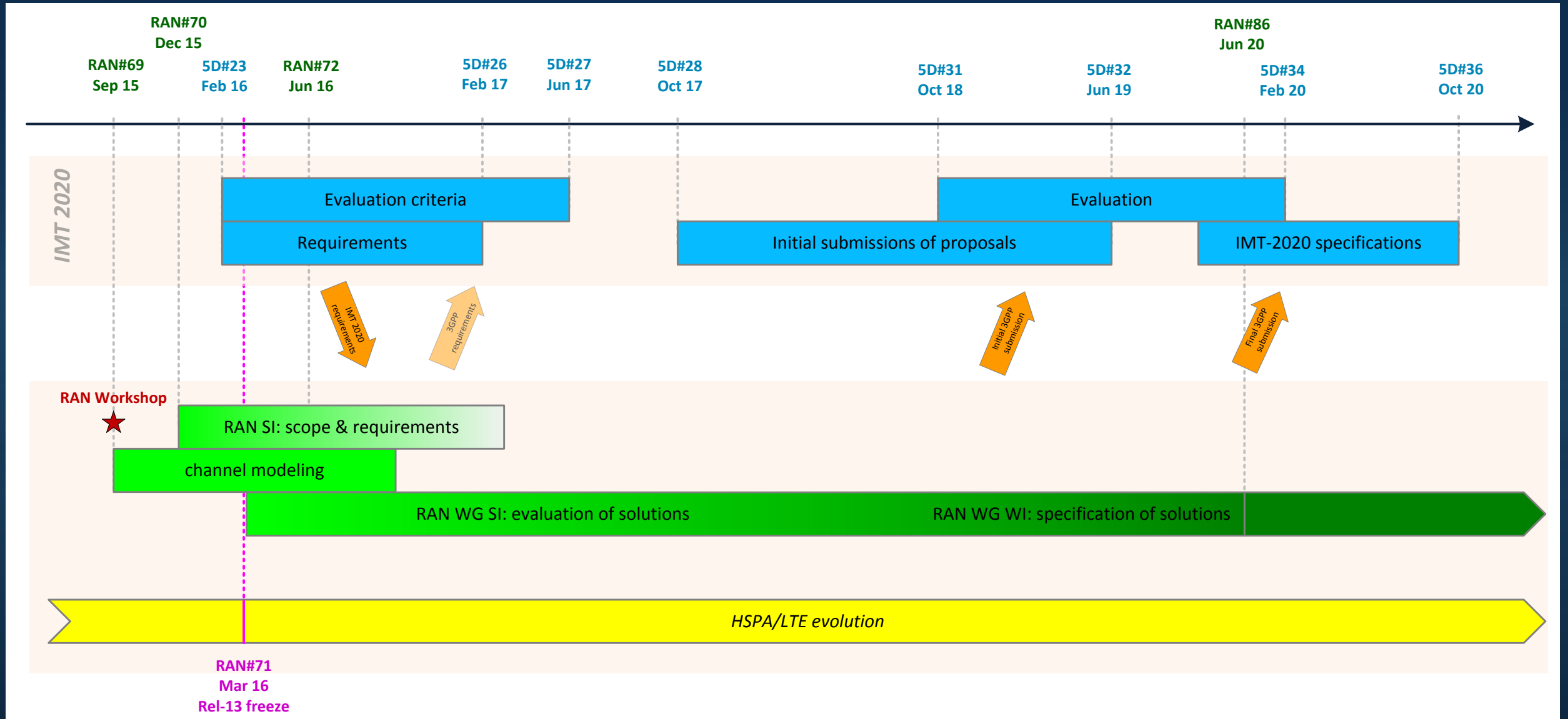
The WP 5D View in M.[IMT.Vision]



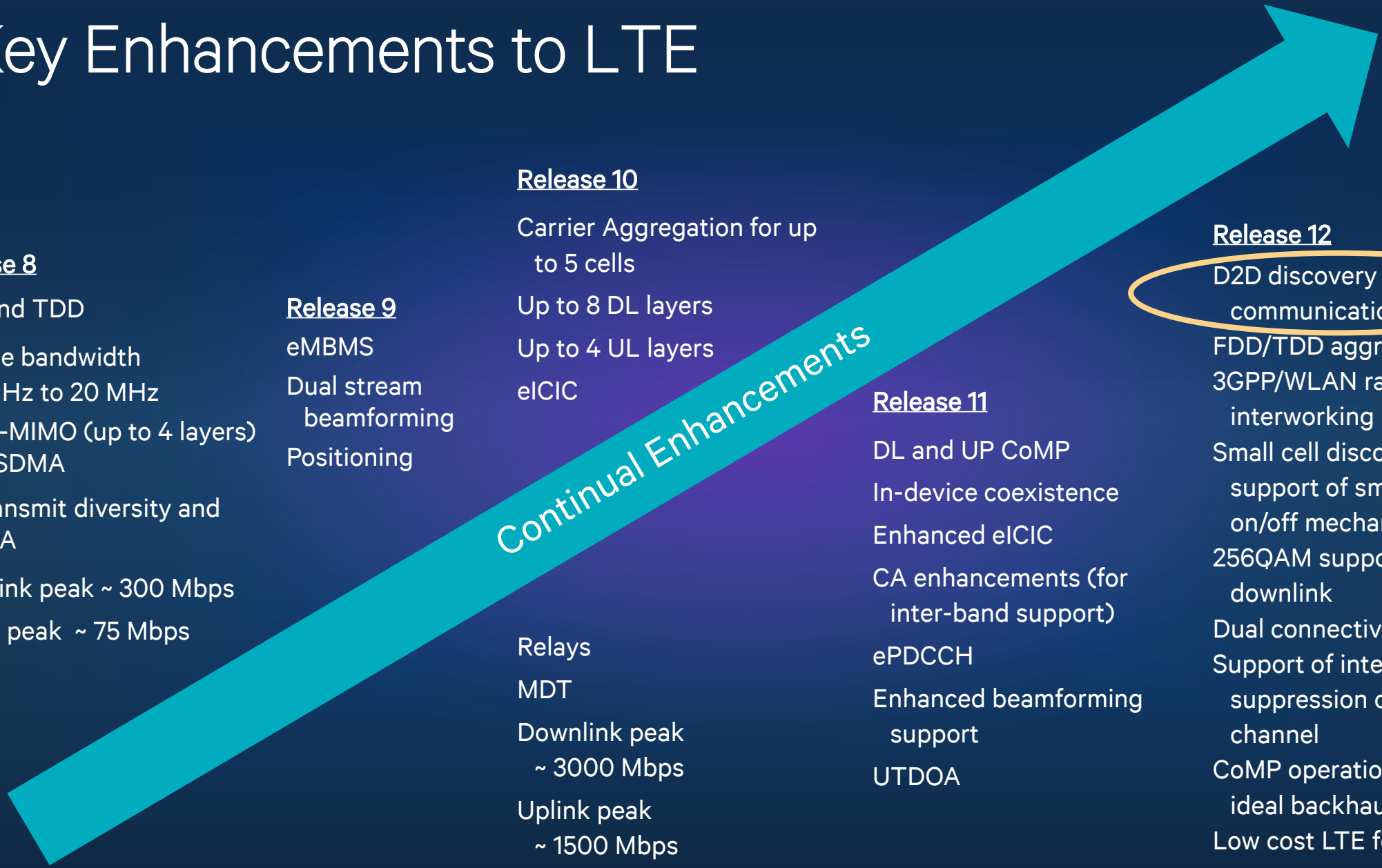
The WP 5D View in M.[IMT.Vision]



5G Timeline: 3GPP



Key Enhancements to LTE



Release 8

FDD and TDD

Flexible bandwidth 1.4 MHz to 20 MHz

DL SU-MIMO (up to 4 layers) and SDMA

UL Transmit diversity and SDMA

Downlink peak ~ 300 Mbps

Uplink peak ~ 75 Mbps

Release 9

eMBMS

Dual stream beamforming

Positioning

Release 10

Carrier Aggregation for up to 5 cells

Up to 8 DL layers

Up to 4 UL layers

eICIC

Relays

MDT

Downlink peak ~ 3000 Mbps

Uplink peak ~ 1500 Mbps

Release 11

DL and UP CoMP

In-device coexistence

Enhanced eICIC

CA enhancements (for inter-band support)

ePDCCH

Enhanced beamforming support

UTDOA

Release 12

D2D discovery and communication (ProSe)

FDD/TDD aggregation

3GPP/WLAN radio-level interworking

Small cell discovery and support of small cell on/off mechanisms

256QAM support in downlink

Dual connectivity

Support of interference suppression on the data channel

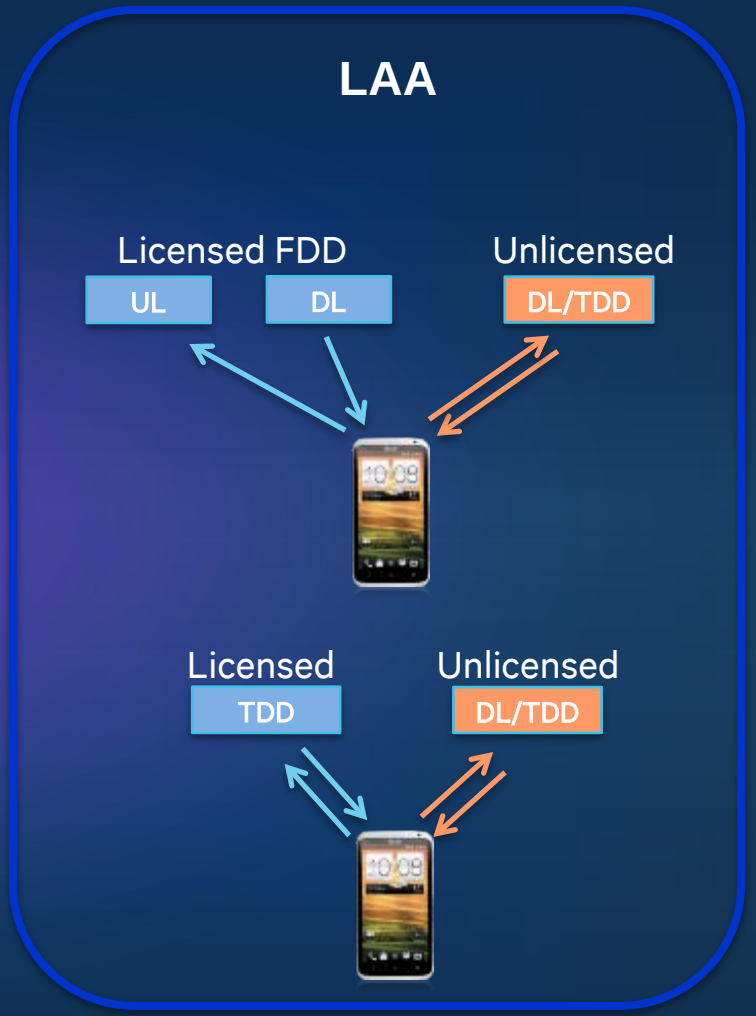
CoMP operation w/ non-ideal backhaul

Low cost LTE for MTC

Release 13

LTE Release 13

- LAA (License Assisted Access)
- LTE-Wifi Aggregation
- Further enhancements for MTC (low cost / range / power)
- Enhancements for D2D and DC operation
- 3D/FD MIMO
- Indoor positioning
- Single-cell Multi-Point
- Latency reduction*
- Non-orthogonal Multiple Access*



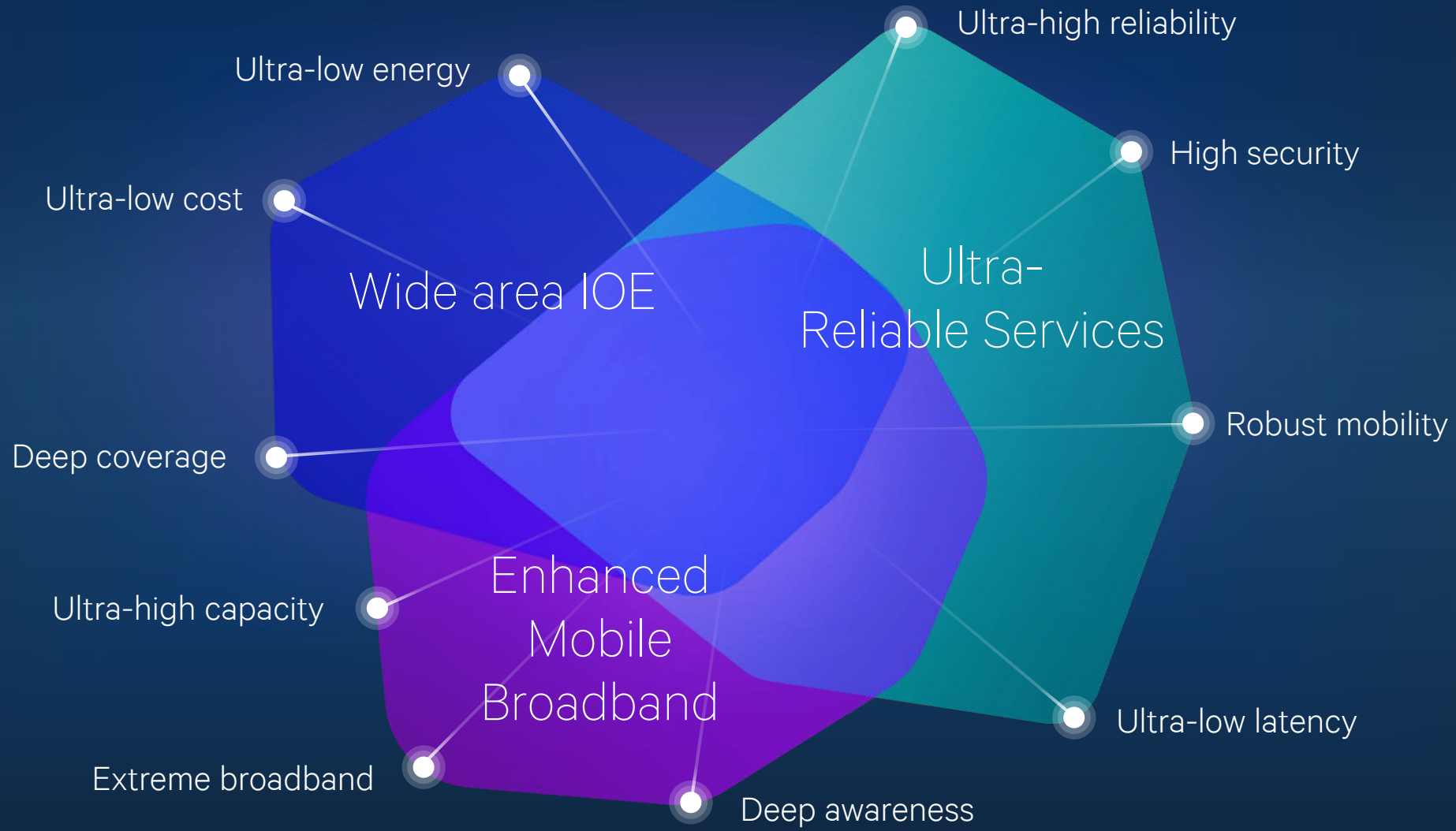
** Studies targeting normative work in Rel-14*

Technology enablers for improved system designs

Technology	Air Interface Impact
Improved RF/antenna capabilities	New mmWave bands, and Massive MIMO with new PHY/MAC design across bands
Improved radio processing	Faster narrow/wide bandwidth switching and TDD switching
Improved baseband processing	Lower latency and faster turn around, new PHY/MAC algorithms
Virtualized Network Elements	Dynamically move processing between cloud and edge

- Drive fundamental improvements in user experience, coverage, and cost efficiency
  - Deliver high quality of experience and new services across topologies and cell sizes
  - New designs below 6 GHz and above 6 GHz including mmWave

Extreme variation of requirements



Can we predict the world in 2025?

To maximize the opportunity, we need a user-centric approach—around human, thing, machine

Communication	>	Also to control and discover
Best effort data	>	Also ultra reliable and aware services
Device as end-points	>	Also new ways of connecting everything

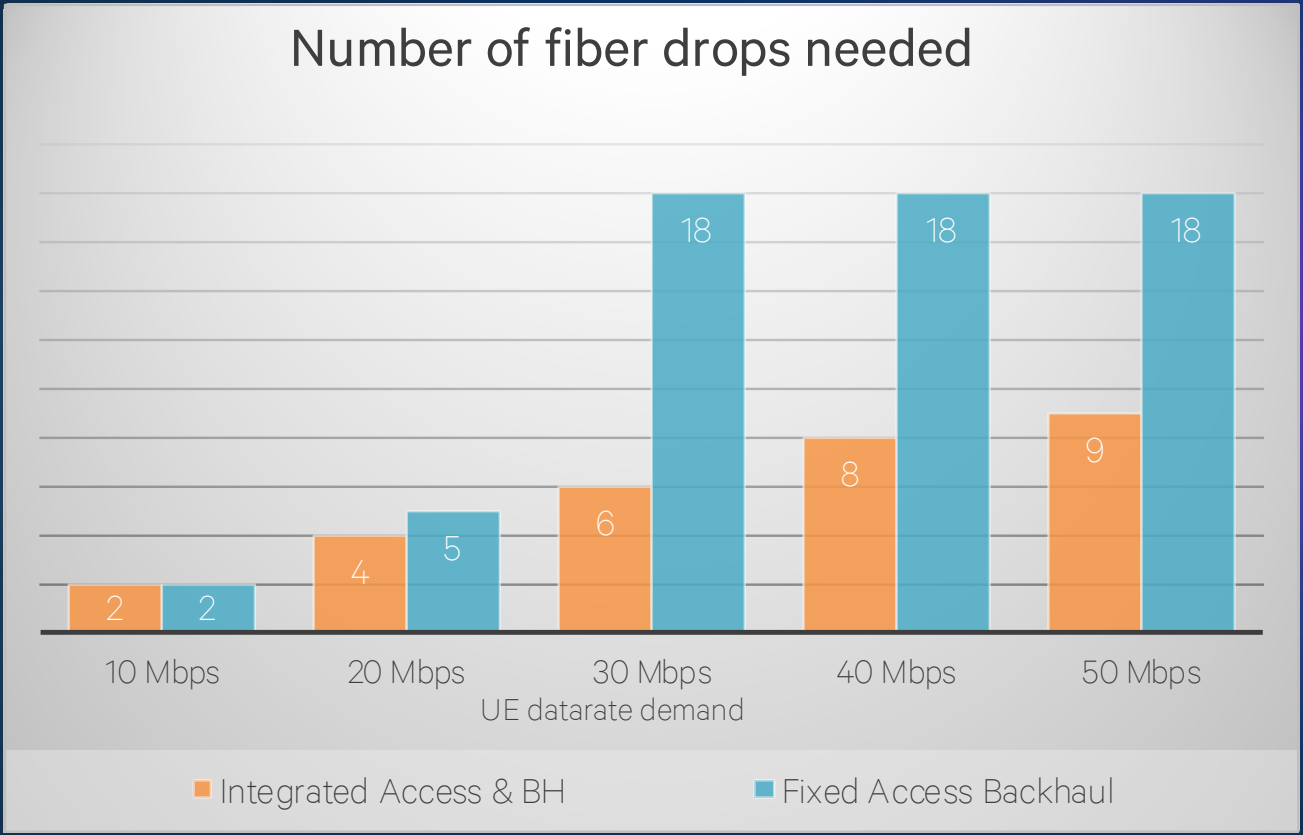
5G Unified Air Interface (UAI)

Multiple techniques under a common framework to support diverse requirements & spectrum types

Extreme Range of Application Requirements

Diverse Spectrum Types

Integrated access & backhaul techniques reduce network deployment cost



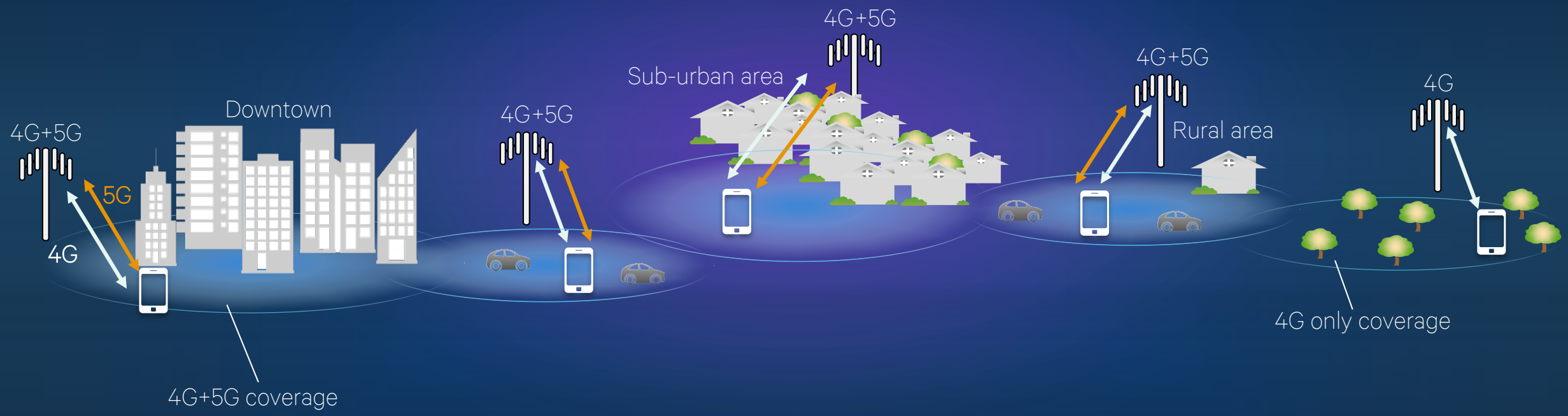
Integrated access and backhaul techniques are more adaptive and less expensive

- Fewer fiber drop points needed compared to fixed backhaul for a given backhaul demand
- Higher trunking efficiency results in better user experience
- Dynamically adjusts to changes in fiber drop locations & number

*Assumptions: 28 GHz band, 1GHz b/w, 18 base-stations; 200m ISD; 600 devices, uniform distribution

Phased 5G rollout leveraging 4G coverage

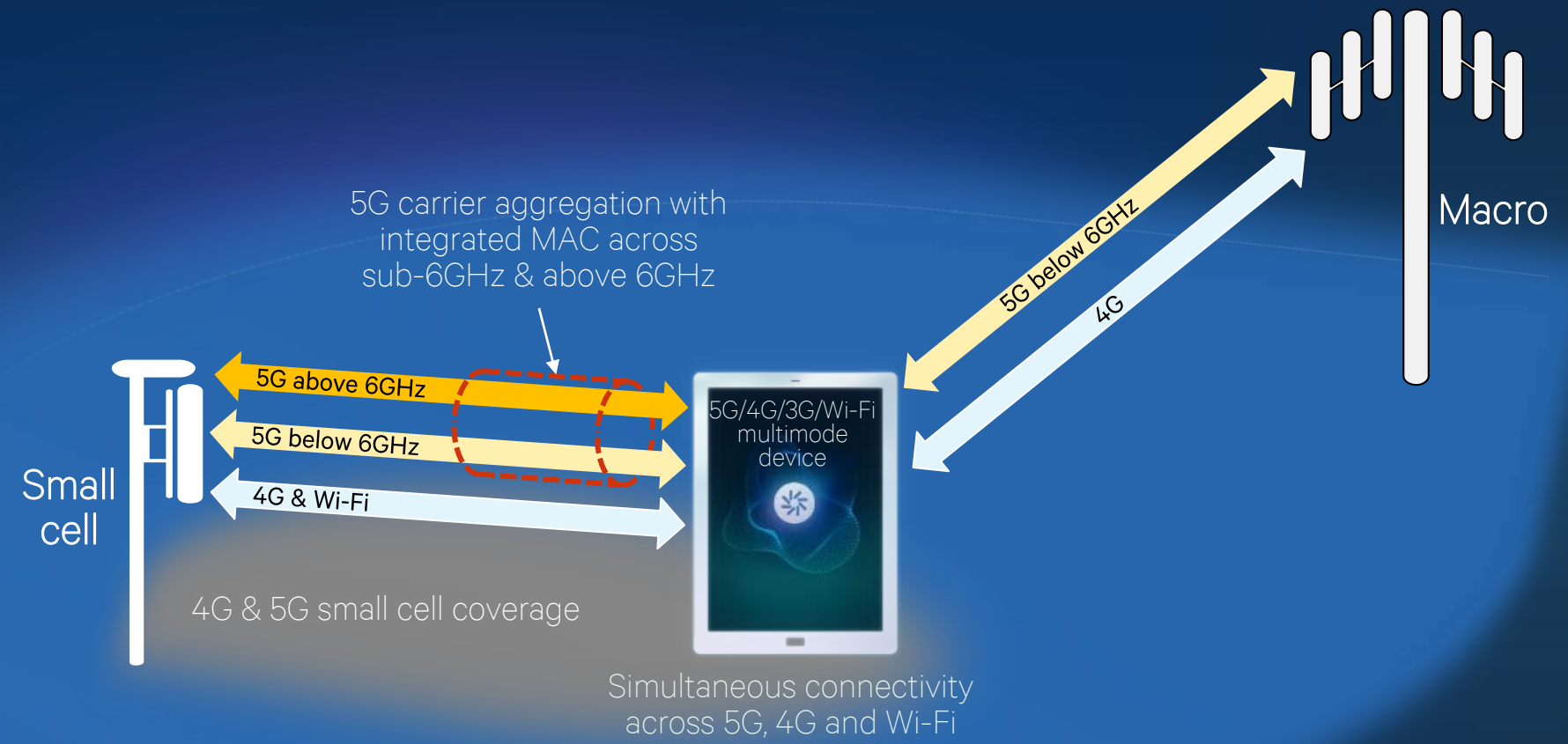
4G+5G multi-connectivity ensures coverage and seamless mobility



Phased 5G rollout

Multi connectivity across bands & technologies

Leverage 4G investments and enable phased 5G rollout



5G deployment scenarios:

- Deploy below 6GHz
- Deploy above & below 6GHz when available

5G addresses evolving mobile broadband requirements

Key requirements

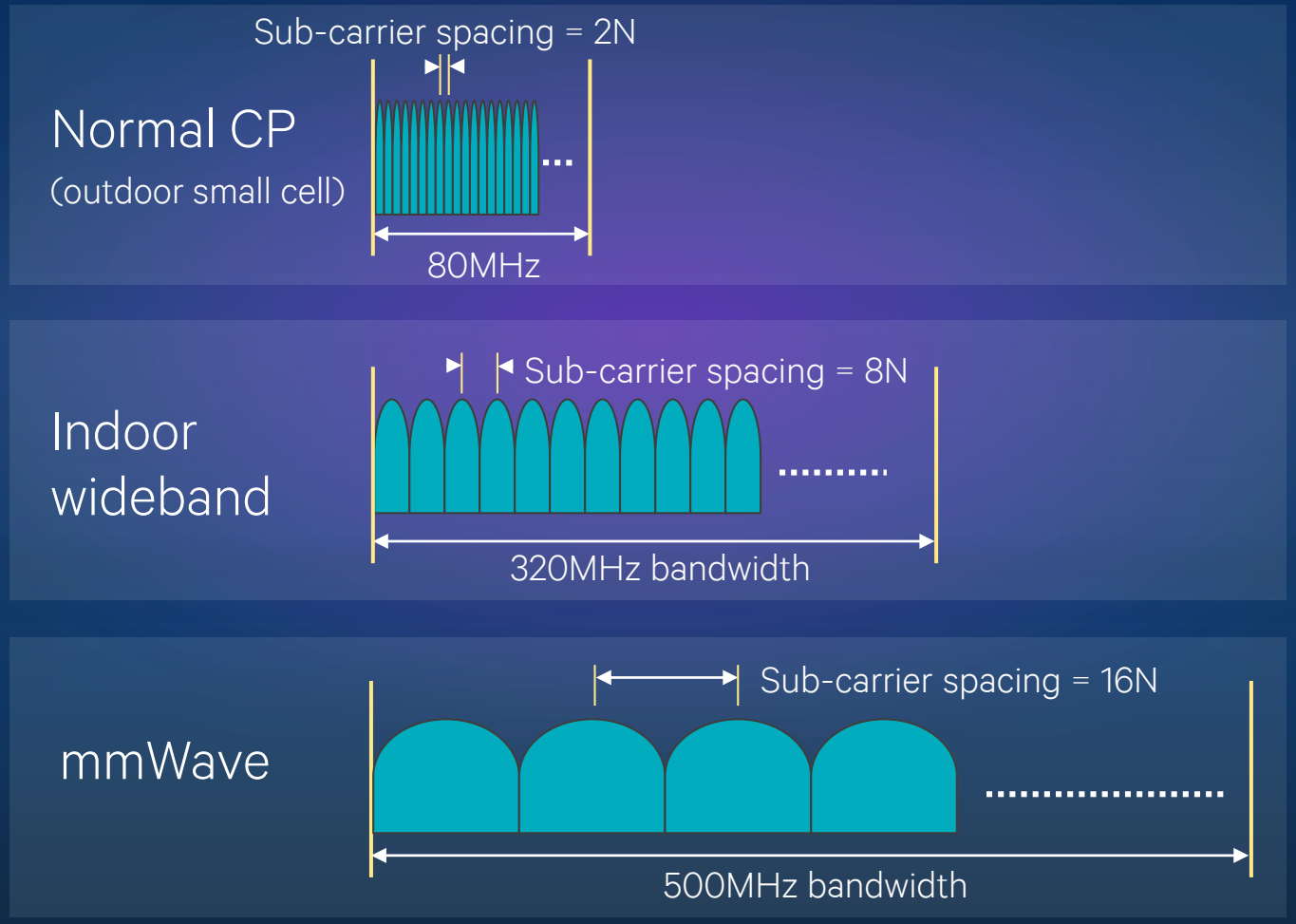
- Extreme peak rates
- Uniform user experience
- Ultra-high network capacity
- Improved cost & energy efficiency

Solutions

- Scalable numerology and TTI to support various spectrum and QoS requirements
- Massive MIMO to achieve high capacity, better coverage, and low network power consumption
- Self-contained TDD subframe to enable massive MIMO and other deployment scenarios
- Device centric MAC to reduce network energy consumption & improve mobility management

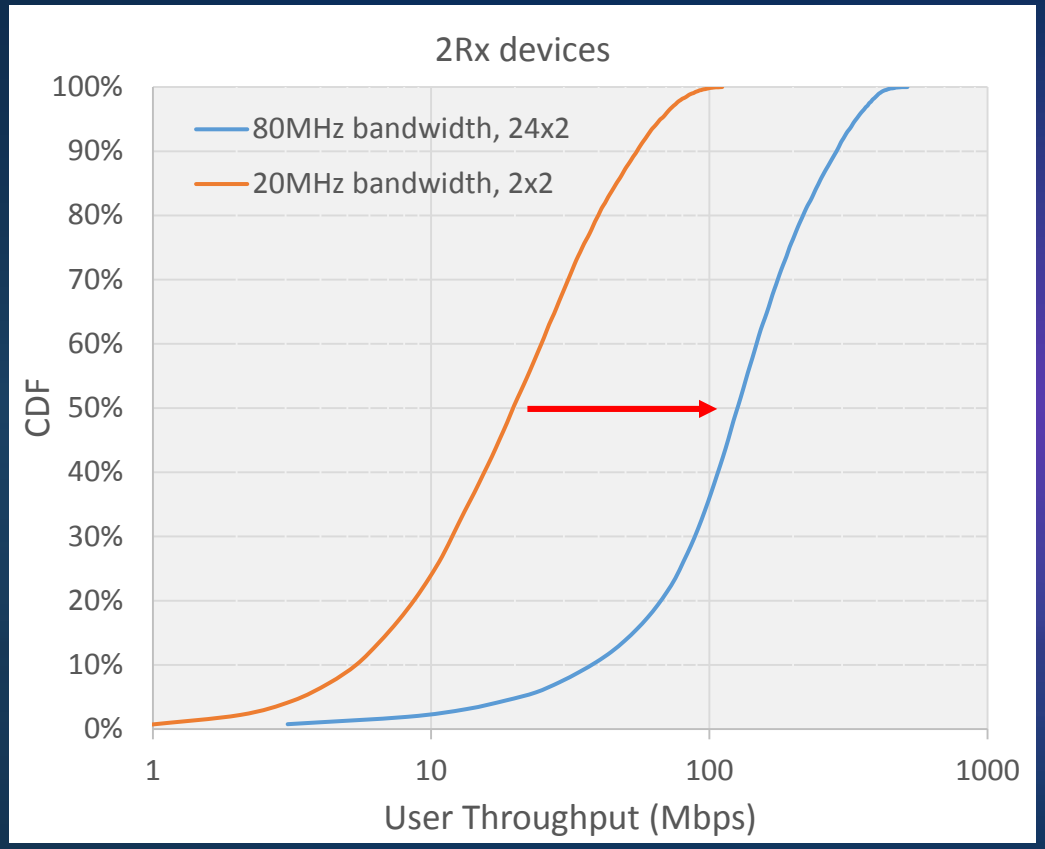
5G extreme bandwidth

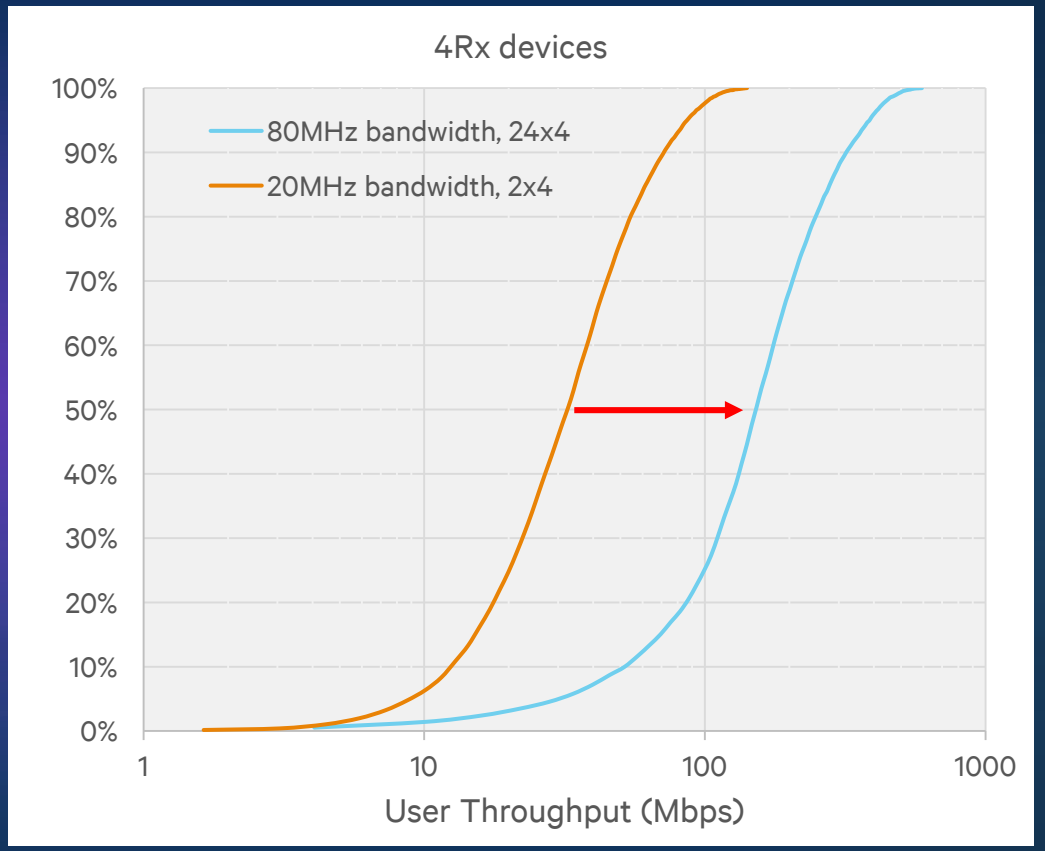
Scalable Numerology



Note: not drawn to scale

Coverage layer improvements (1.7km intra-site distance) with 4GHz massive MIMO & new SF – low mobility





- Gains of 4 GHz Massive MIMO with 80MHz compared to 2GHz with 2Tx DL over 20 MHz
- Leverage same cell tower locations and same transmit power as legacy systems (no new cell planning)
- Cell-edge user @ 1km cell radius still able to scale up throughput with bandwidth (for ~80 Mbps)

Assumptions: 46 dBm Tx power

mmWave enables 5G Extreme Mobile Broadband

Opportunities

- Availability of large bandwidth from 100s of MHz up to 9 GHz
- Extreme data-rates (e.g. up 10 Gbps)
- Dense spatial reuse can enable extreme network capacity
- Beamforming to overcome poorer propagation
- Flexible deployment with integrated backhaul (200m – 500m) and access (100m- 150m)

Challenges

- Higher path-loss at mmWave frequencies, susceptibility to blockage
- Robust beam search & tracking
- System design with directional transmissions
- Device cost and RF challenges at mmW

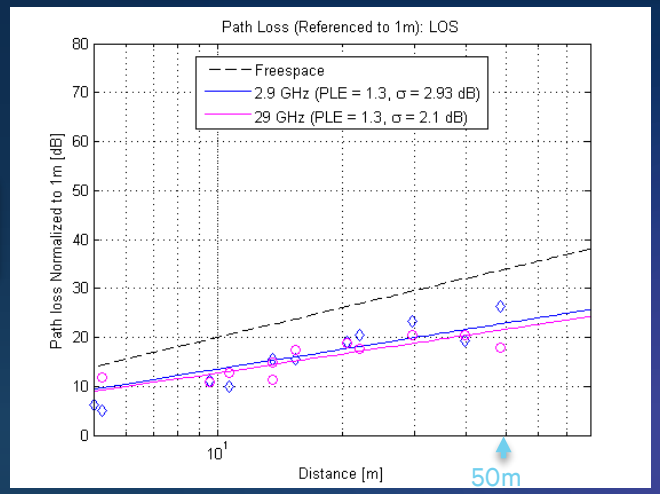
Solutions

- Tight integration with 5Gsub6 increases robustness
- Smart beam search & tracking algorithms
- Antenna management & reconstructive beam forming algorithms
- Coordinated scheduling for proximal user interference management
- Phase noise mitigation in RF components for cheaper devices

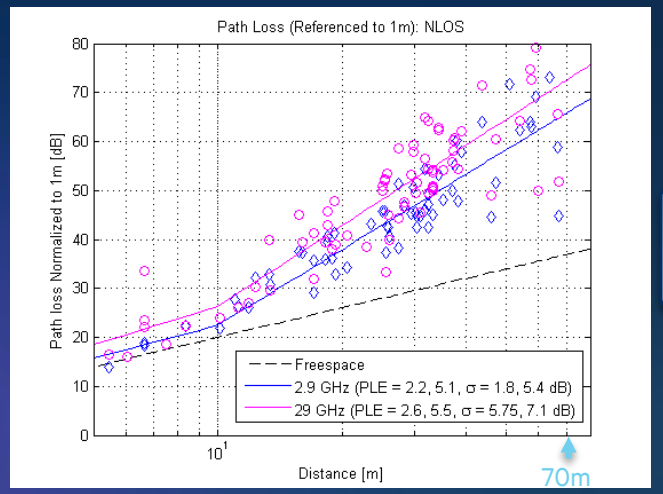
Indoor Measurements: Modern Office Building

Path Loss (2.9 and 29 GHz)

LOS



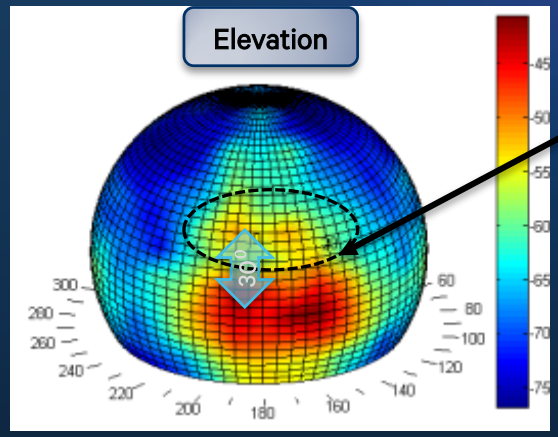
Path loss characteristics in a dense multi-wall environment:
LOS: 29 GHz better than 2.9 GHz
NLOS: 29 GHz not significantly worse than 2.9 GHz
→ *Coverage looks promising*



NLOS

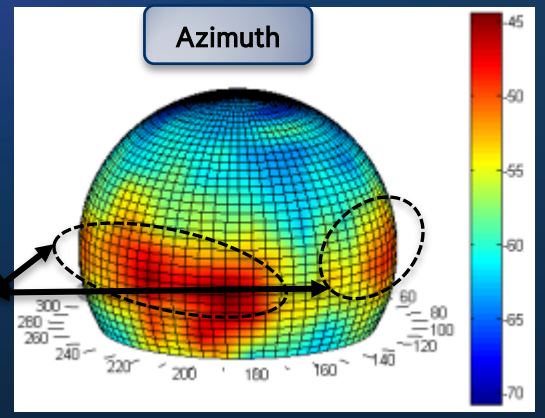
Actual PL = [reference loss at 1m for a given frequency] + [normalized PL as shown]

Angular Spread/Diversity (29 GHz)



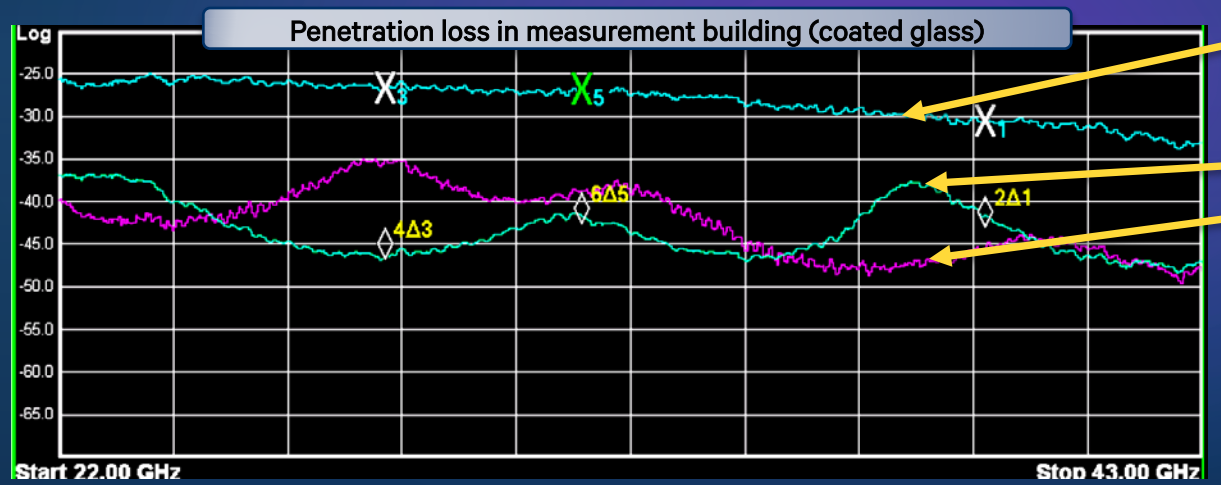
Numerous resolvable paths in elevation
→ *Suggests a 3-D channel model*

Significant path diversity in azimuth
→ *Ability to withstand blockage events*



Outdoor to Indoor Penetration: Measured Material Losses

- Modern office building exteriors are a combination of complex wall structures and coated glass
- Wall structures are a mixture of concrete (and/or rock slab), metal and aluminum clad insulation
  → *High penetration loss*
- Penetration loss of coated glass in measurement building is ~15 dB with angle of incidence and frequency dependency due to glass geometry
  - Measured loss for a range of sample materials was between 10-40 dB for coated glass and 1-2 dB for clear glass



Reference measurement

Measured Loss
- 45^0 angle of incidence
- Normal angle of incidence

Penetration Loss = Reference-Measured Loss

Overall level of penetration is highly dependent on the construction type (type of glass, concrete, etc…) and building design (locations and quantity of windows, adjacent foliage, etc…)

mmW deployment scenarios

Stand alone mmW access

Collocated mmW + 5Gsub6 access

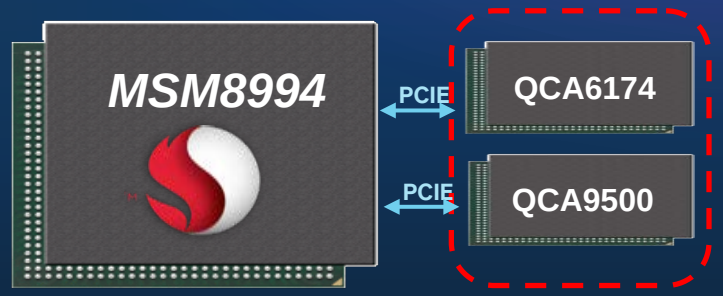
Non-collocated mmW + 5Gsub6 access

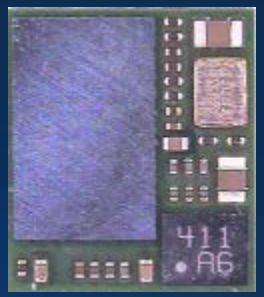
mmW integrated access & backhaul relay

5Gsub6 mmW

802.11ad 60 GHz Solutions

- 802.11ad supports channel BW of 2 GHz providing 7 Gbps link rates (spec)
- Qualcomm was first to market with 802.11ad (60 GHz) solutions, beginning in 2013 with wireless docking
- RF modules can pack 32 radios and antennas in a small package enabling directivity (up to 30 dBi)
  - MuRata and SEMCO supply integrated RF modules with antennas
- 802.11ad chipset included in Snapdragon 810 reference platform





Mobile .11ad Baseband

Mobile .11ad Radio Module

Snapdragon 810 reference platform with 802.11ad

5G will take us to new heights

Aware, uniform fiber-like broadband everywhere

Mission critical services like remote surgery

Connecting everything from simple sensors to complex robots

Important Dates

Technical Program

- Workshop Proposal
  ~~15~~ February 2015
- Tutorial Proposal
  15 March 2015
- Symposia Papers
  1 April 2015

Industry (IF&E) Program

- Panel Proposal
  20 April 2015
- Tutorial Proposal
  20 April 2015
- Workshop Proposal
  8 June 2015
- Demo Proposal
  6 July 2015

Thank you

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