4G to 5G networks and standard releases

CoE Training on Traffic engineering and advanced wireless network planning

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Objectives

Provide an overview of various technologies and standards of 4G and future 5G

Agenda

I. 4G and LTE networks

II. LTE Release 10 to 14

III. 5G

I. 4G and LTE networks

1. 4G motivations

Introduction

- Geneva, 18 January 2012 – Specifications for next-generation mobile technologies – *IMT-Advanced* – agreed at the ITU Radiocommunications Assembly in Geneva.
- ITU determined that "LTE-Advanced" and "WirelessMAN-Advanced" should be accorded the official designation of *IMT-Advanced*:
  - Wireless MAN-Advanced: Mobile WiMax 2, or IEEE 802. 16m;
  - 3GPP LTE Advanced: LTE Release 10, supporting both paired Frequency Division Duplex (FDD) and unpaired Time Division Duplex (TDD) spectrum.

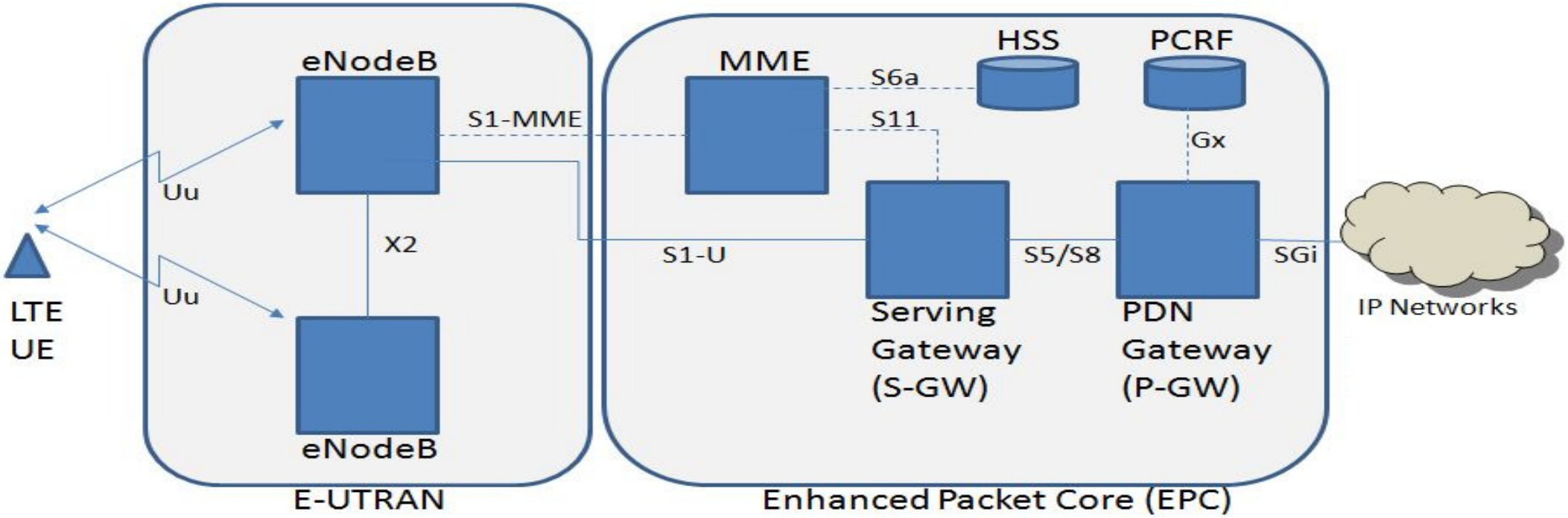
Needs for IMT-Advanced systems

- Need for **higher data rates** and greater spectral efficiency
- Need for a **Packet Switched only** optimized system
- Use of **licensed frequencies** to guarantee quality of services
- **Always-on experience** (reduce control plane latency significantly and reduce round trip delay)
- Need for **cheaper infrastructure**
- **Simplify architecture** of all network elements

Impact and requirements on LTE characteristics

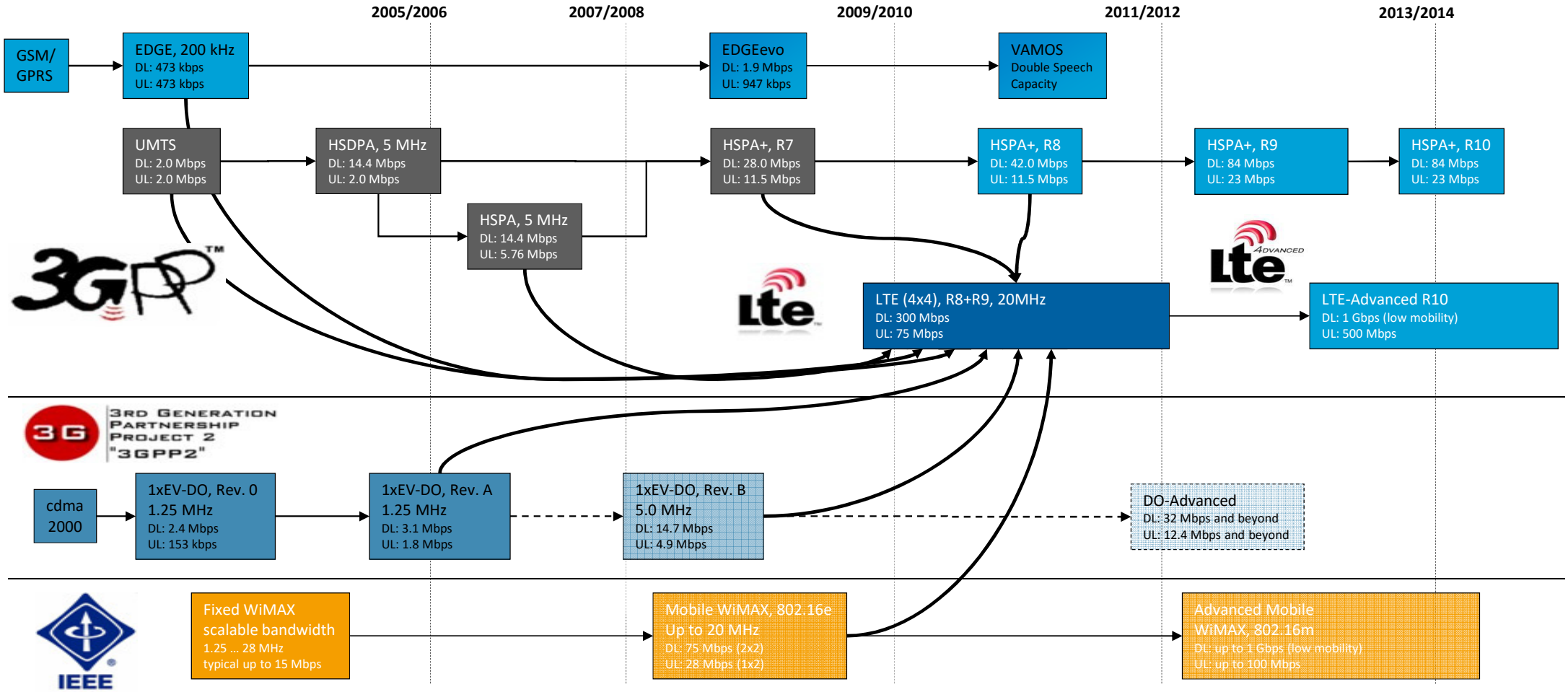
- Architecture (flat)
- Frequencies (flexibility)
- Bitrates (higher)
- Latencies (lower)
- Cooperation with other technologies (all 3GPP and non-3GPP)
- Network sharing (part or full)
- Full-IP (QoS issues, protocols integration, lower costs)
- OFDMA
- Broadcast services
- Intelligent radio schemes

LTE Architecture



2. Evolution 3G-4G

Wireless technology evolution path



Main wireless broadband systems

	HSPA	3GPP LTE	IEEE 802.16e[1]
Standardization body	3GPP	3GPP	IEEE
Deployment frequencies (GHz)	All 3G bands	All 3G bands, 2.6GHz	2.5, 3.5, 5.8 GHz
Bandwidth (MHz)	5	1.25, 2.5, 5, 10, 15, 20	5, 10, 20
Uplink scheme	CDMA	SC-FDMA	OFDMA
Downlink scheme	CDMA	OFDMA	OFDMA
Preferred duplex scheme	FDD	FDD	TDD, FDD
Peak DL data rate (Mbps) for 5MHz	13.6	25 (SISO)	18 (SISO)
Peak UL data rate (Mbps) for 5MHz	5.76	12.5 (SISO)	18 (SISO)
RAN latency (ms): RTT	<50	<10	30
Frequency reuse	1	FFR[2]	1 or 3

1 WiMAX mobile profile
2 Fractional Frequency Reuse

3. Evolution R9 – R10

What is 3GPP?

3GPP history and members

- Founded in December 1998

- 3GPP is a collaborative standardization activity between ETSI (Europe) and:
  - ARIB (Japan-radio)
  - TTC (Japan-network)
  - TTA (Republic of Korea)
  - CCSA (Peoples' Republic of China)
  - ATIS (North America)

- 3GPP should:
  - Have a significant presence in press and web based media,
  - Have a significant presence in telecoms conferences, workshops, webinars, …, on mobile telecommunications technology evolution
  - Be recognised by companies, engineers, students, …, involved in mobile telecommunications technology evolution

3GPP family standards evolution

4. Performance Objectives

Needs at the access level for LTE (Release 8)

- Radio interface bitrates: 100 Mbit/s DL and 50 Mbit/s UL.
- Data transmission delay: less than 5 ms between UE and the Access Gateway (AGW)
- Mobility: speeds between 120 and 350 km/h (or even up to 500 km/h depending on the frequency band)
- Co-existence and Interworking with 3G: HO between E-UTRAN and UTRAN should be achieved with less than 300 ms for real-time services and 500 ms for NRT services.
- Multicast support for multimedia applications.

Peak data rates DL and UL

Modulation coding		1.4 MHz	3.0 MHz	5.0 MHz	10 MHz	15 MHz	20 MHz
QPSK 1/2	Single stream	0.7	2.1	3.5	7.0	10.6	14.1
16QAM 1/2	Single stream	1.4	4.1	7.0	14.1	21.2	28.3
16QAM 3/4	Single stream	2.2	6.2	10.5	21.1	31.8	42.4
64QAM 3/4	Single stream	3.3	9.3	15.7	31.7	47.7	63.6
64QAM 4/4	Single stream	4.3	12.4	21.0	42.3	63.6	84.9
64QAM 3/4	2x2 MIMO	6.6	18.9	31.9	64.3	96.7	129.1
64QAM 1/1	2x2 MIMO	8.8	25.3	42.5	85.7	128.9	172.1
64QAM 1/1	4x4 MIMO	16.6	47.7	80.3	161.9	243.5	325.1

Modulation coding		1.4 MHz	3.0 MHz	5.0 MHz	10 MHz	15 MHz	20 MHz
QPSK 1/2	Single stream	0.7	2.0	3.5	7.1	10.8	14.3
16QAM 1/2	Single stream	1.4	4.0	6.9	14.1	21.6	28.5
16QAM 3/4	Single stream	2.2	6.0	10.4	21.2	32.4	42.8
16QAM 1/1	Single stream	2.9	8.1	13.8	28.2	43.2	57.0
64QAM 3/4	Single stream	3.2	9.1	15.6	31.8	48.6	64.2
64QAM 1/1	Single stream	4.3	12.1	20.7	42.3	64.8	85.5
64QAM 1/1	V-MIMO (cell)	8.6	24.2	41.5	84.7	129.6	171.1

5. Key features of LTE and LTE Advanced

Key Features of LTE (1)

- Multiple access scheme
  - Downlink: **OFDMA**
  - Uplink: **Single Carrier FDMA** (SC-FDMA)
- *Adaptive modulation and coding*
  - DL modulations: QPSK, 16QAM, and 64QAM
  - UL modulations: QPSK and 16QAM
  - Rel-6 Turbo code: Coding rate of 1/3, two 8-state constituent encoders, and a contention- free internal interleaver.
- **Bandwidth scalability** for efficient operation in differently sized allocated spectrum bands
- ***Single frequency network*** (SFN) operation to support MBMS

Key Features of LTE (2)

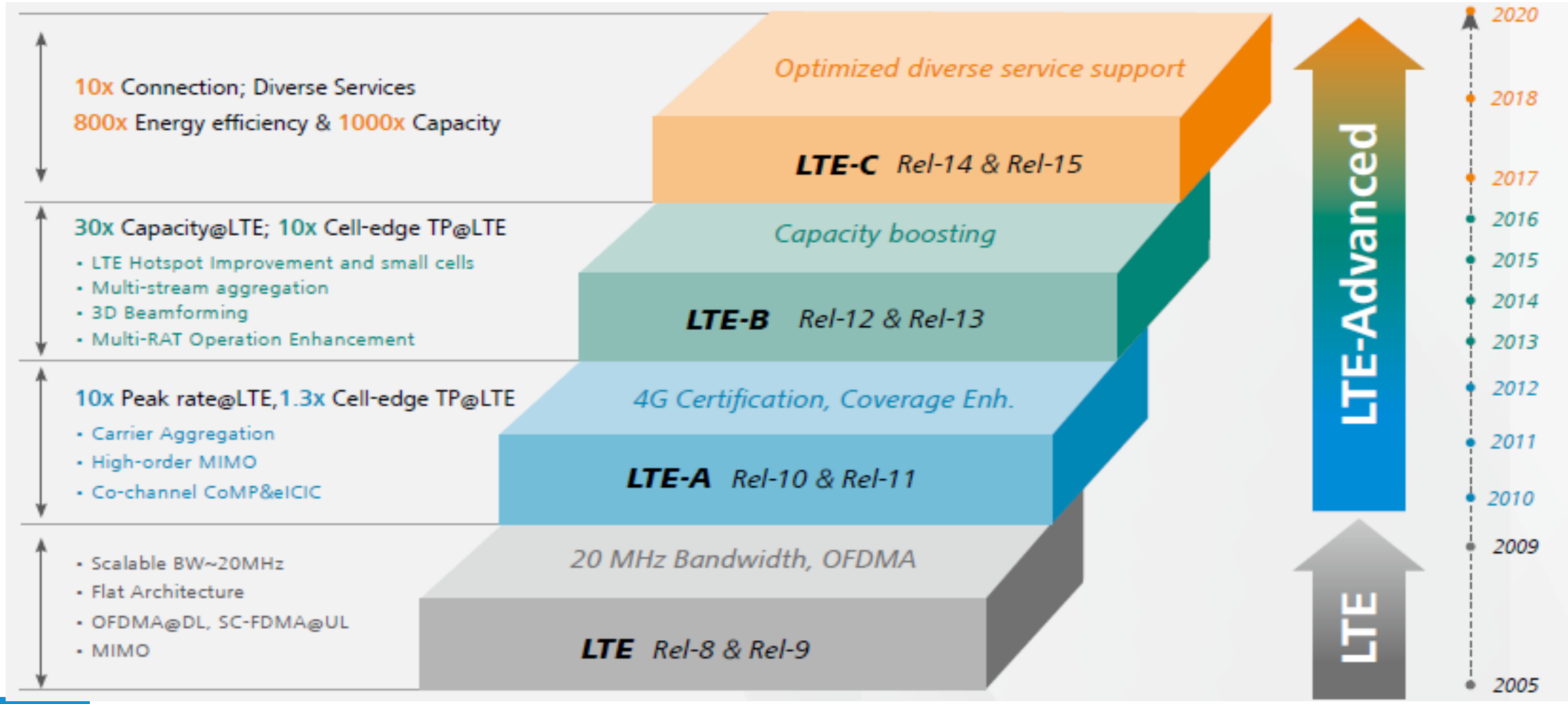
- **MIMO** technology for enhanced data rate and performance.
- **ARQ** at the RLC sublayer and **Hybrid ARQ** at the MAC sublayer.
- **Power control** and **link adaptation**
- **Interference coordination** between eNBs
- Support for both FDD and TDD
- **Channel dependent scheduling**
- **Reduced radio-access-network nodes** to reduce cost, protocol-related processing time & call set-up time

3GPP LTE objectives

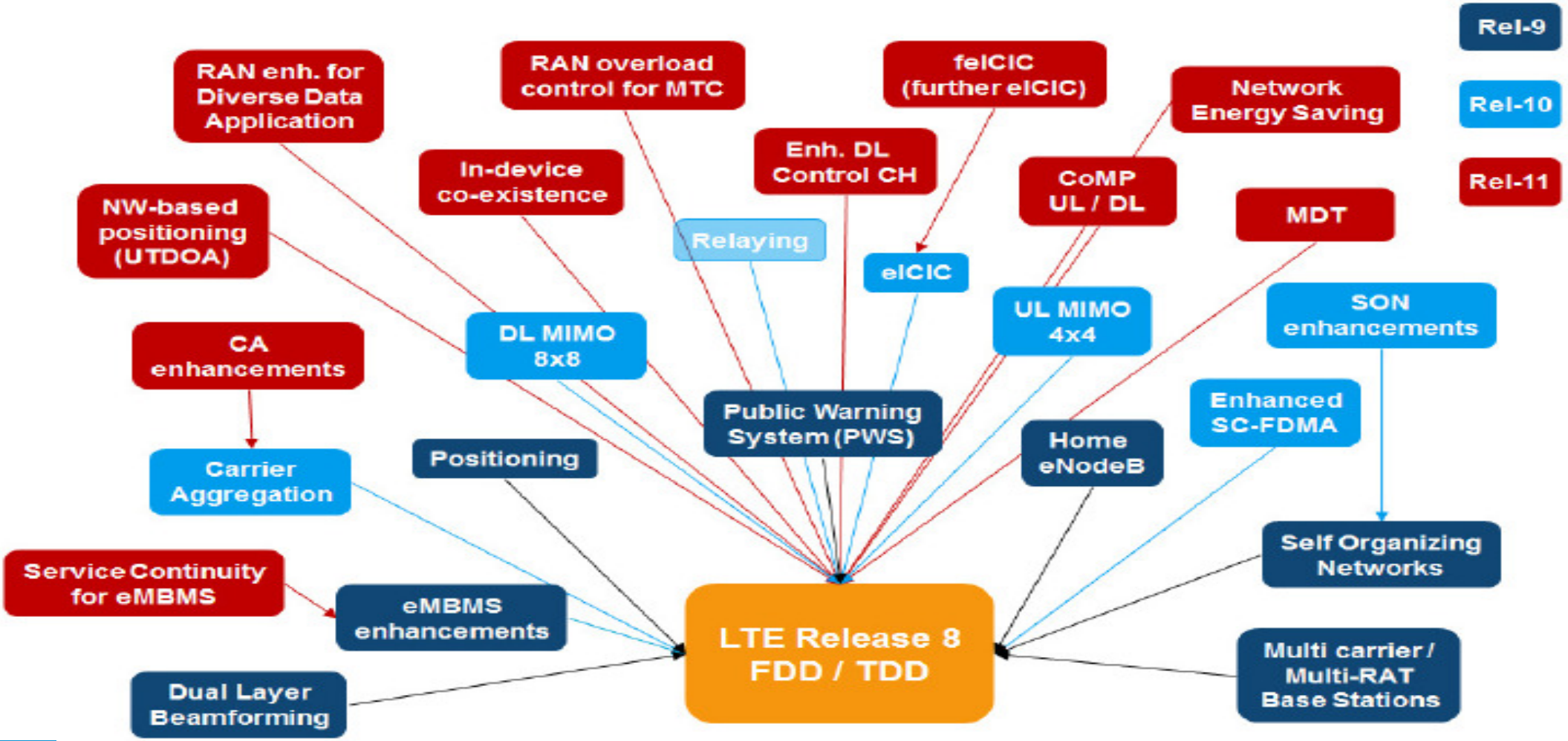
- Scalable bandwidth: 1.25, 2.5, 5, 10, (15), 20MHz
- Peak data rate (scaling linearly with the spectrum allocation)
  - DL (2 Rx @ UE): 100Mb/s for 20MHz spectrum allocation
  - UL (1 Tx @ UE): 50Mb/s for 20MHz spectrum allocation
- Spectrum efficiency
  - DL: 3-4 times HSDPA for MIMO (2,2)
  - UL: 2-3 times HSUPA for MIMO(1,2)
- > Reference Antenna configurations (typical achievable targets)
  - DL: 2Tx and 2 Rx
  - UL: 1 Tx and 2 Rx
- Latency
  - C-plane: < 50-100ms to establish U-plane
  - U-plane: << 10ms from UE to AGW
- Capacity
  - 200 users for 5MHz, 400 users in larger spectrum allocations (active state)
- Mobility
  - LTE is optimized for speeds 0-15km/h up to 350km/h

II. Releases 10 to 13 main features

LTE Evolutions



LTE releases evolutions



LTE to LTE-M

3GPP Releases	8 (Cat.4)	8 (Cat. 1)	12 (Cat.0) LTE-M	13 (Cat. 1,4 MHz) LTE-M
Downlink peak rate (Mbps)	150	10	**1**	**1**
Uplink peak rate (Mbps)	50	5	**1**	**1**
Number of antennas (MIMO)	2	2	**1**	**1**
Duplex Mode	Full	Full	**Half**	**Half**
UE receive bandwidth (MHz)	**20**	**20**	**20**	**1.4**
UE Transmit power (dBm)	**23**	**23**	**23**	**20**

Release 12

- New category of UE ("Cat-0"): **lower complexity** and low cost devices
- **Half duplex FDD** operation allowed
- **Single receiver**
- Lower data rate requirement (Max: 1 Mbps)

Release 13

- Reduced receive bandwidth to 1.4 MHz
- **Lower device power** class of 20 dBm
- 15dB additional link budget: **better coverage**
- More **energy efficient** because of its extended discontinuous repetition cycle (eDRX)

Release 12 new network features

eMTC

Objectives

- Long battery life: ***~10 years*** of operation with 5 Watt Hour battery
- Low device cost: comparable to that of GPRS/GSM devices
- Extended coverage: ***>155.7 dB*** maximum coupling loss (MCL)
- Variable rates: ***~10 kbps to 1 Mbps*** depending on coverage needs

Deployment

- Can be deployed in any ***LTE spectrum***
- Coexist with other LTE services within ***the same bandwidth***
- Support ***FDD, TDD*** and ***half duplex (HD) modes***
- Reuse ***existing LTE base stations*** with ***software update***

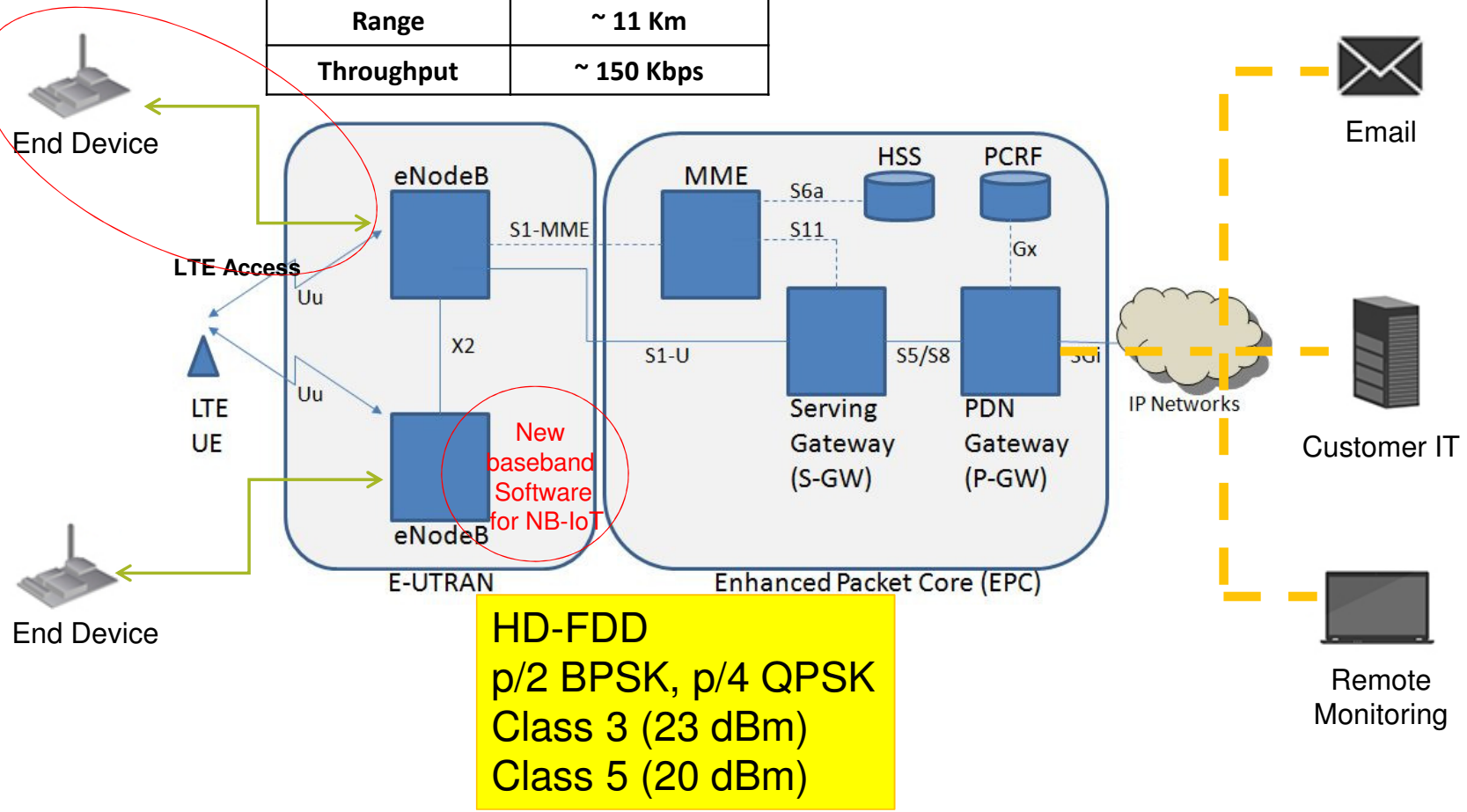
Main PHY/RF features

- Narrowband operation with ***1.08 MHz bandwidth***
- ***Frequency hopping***
- ***TTI bundling/repetition*** to achieve large coverage enhancements
- ***New UE power class of 20 dBm.***

Release 13 new radio features

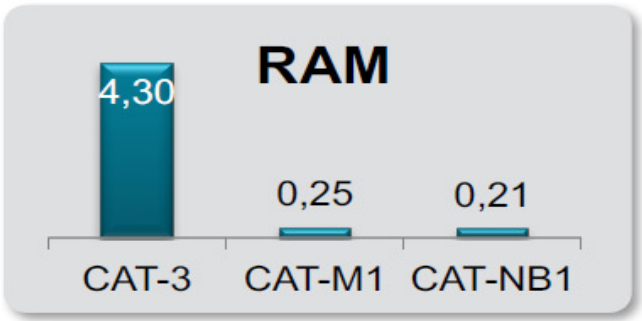
NB-IoT Architecture

Frequency Band	Ultra Narrow Band
Range	~ 11 Km
Throughput	~ 150 Kbps



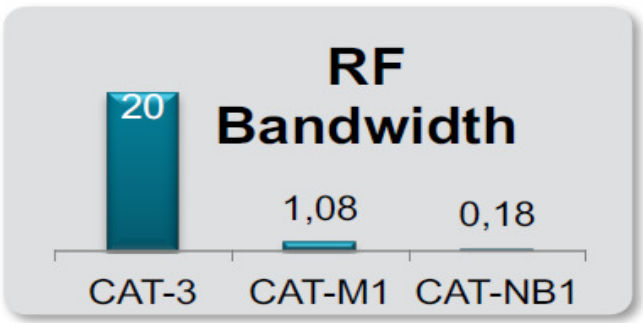
HD-FDD
p/2 BPSK, p/4 QPSK
Class 3 (23 dBm)
Class 5 (20 dBm)

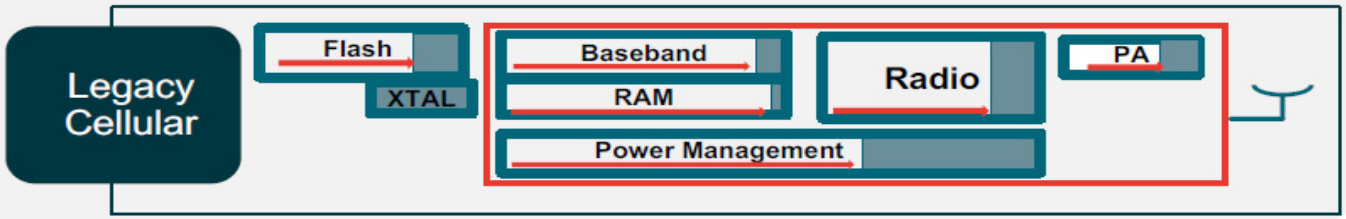
LTE Cat-M1 cost reduction



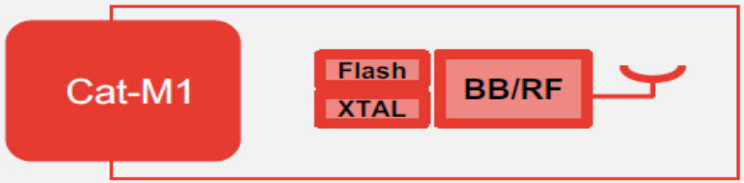
Reduce Complexity:

- Half Duplex
- Single receiver
- Lower Memory
- Lower bandwidth
- Simpler processing
- Lower PA



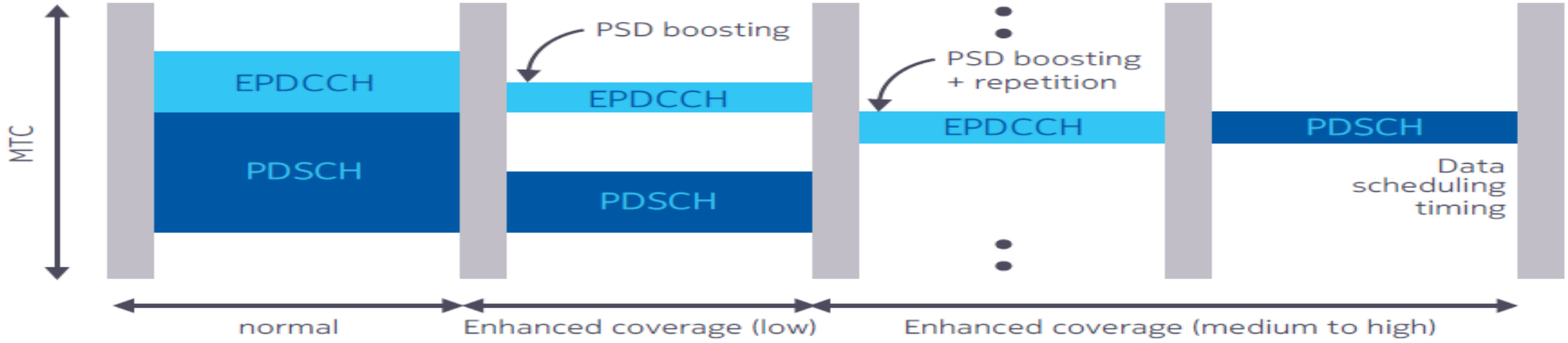


Integration



Full coverage for IoT

- In LTE-M 1.4 MHz and NB LTE-M 200 kHz: basic LTE design is used with modifications for support of coverage enhancements: **Elimination of LTE DL control channels** including PDCCH, PCFICH and PHICH. Only the EPDCCH is supported.
- In enhanced coverage mode, **PSD** (*Power Spectral Density*) **boosting** and **repetition** are used to reach devices in poor coverage.
- Coverage increased by operating in 200 kHz or 1.4 MHz (/20 MHz): 20 dB and 11.5 dB improvement.
- LTE-M allows output power reduction by 3 dB for lower implementation cost.
- Control and data signals can be repeated to reach the required coverage enhancements

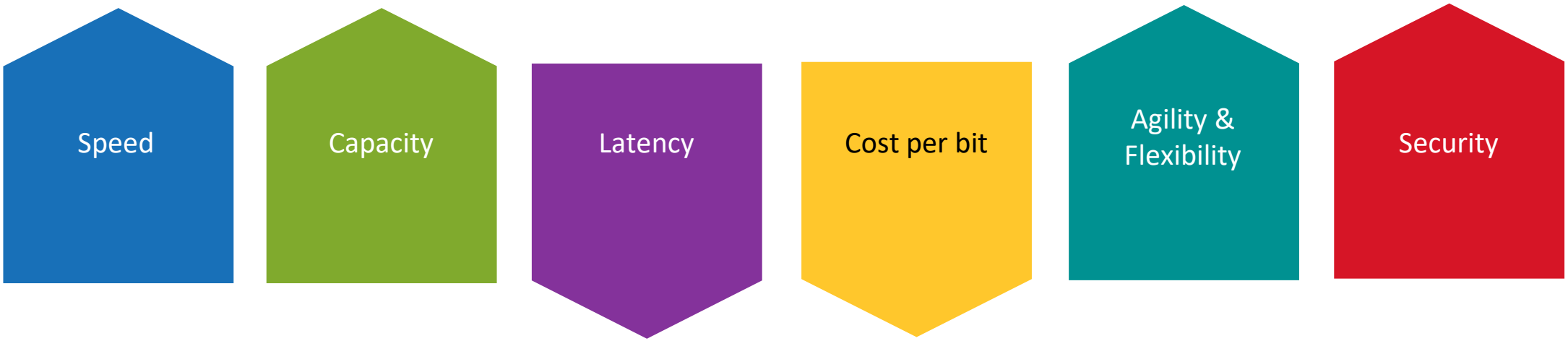


Agenda

III. 5G

5G Objectives

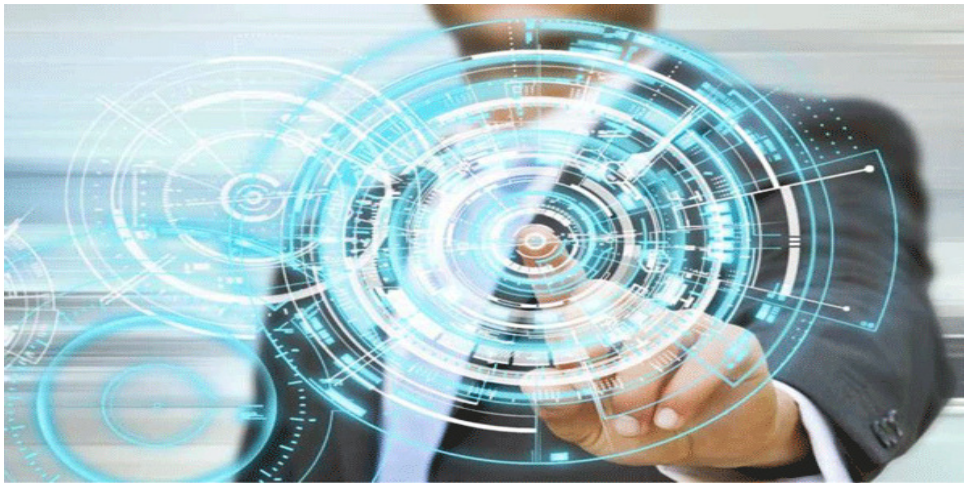
Context: the evolving demands on the network



"Maybe along with the three legs that 5G stands on (**massive Machine Type Communication** (MTC), **enhanced Mobile Broadband** (eMBB), and **Ultra Reliable Communication** (URC)) we need to add a fourth leg of **ultra low cost broadband** (ULCBB)."

Alan Gatherer, Editor in Chief, ComSoc Technology News

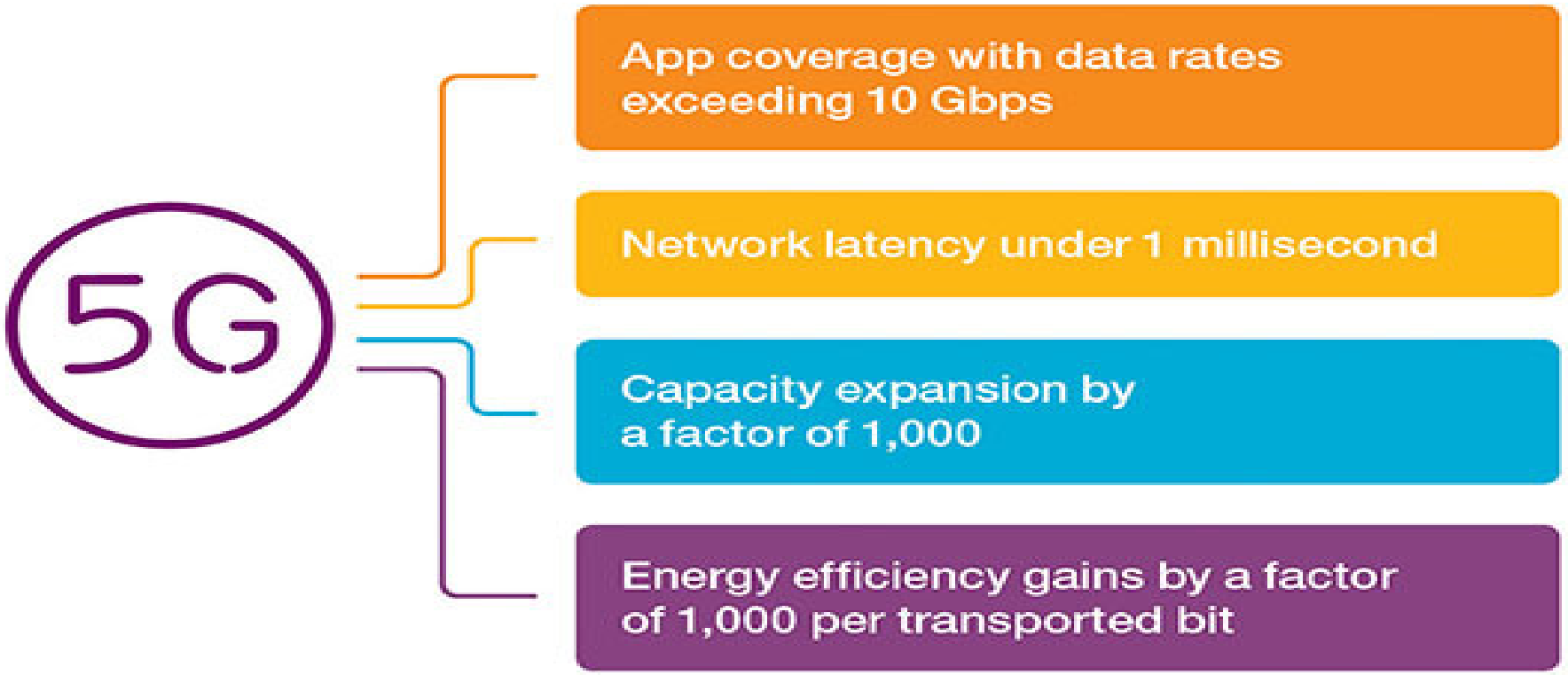
1 ms latency and tactile internet



- IEEE defines the **tactile internet** as dealing with processes or objects in perceived real time.
- Allows ***catch a falling object remotely***, ***control a connected car*** at an intersection.

- Will be used in areas such as automation, education, entertainment, gaming, farming, health care, industrial transportation, …
- Enables humans to control robots remotely in real time.

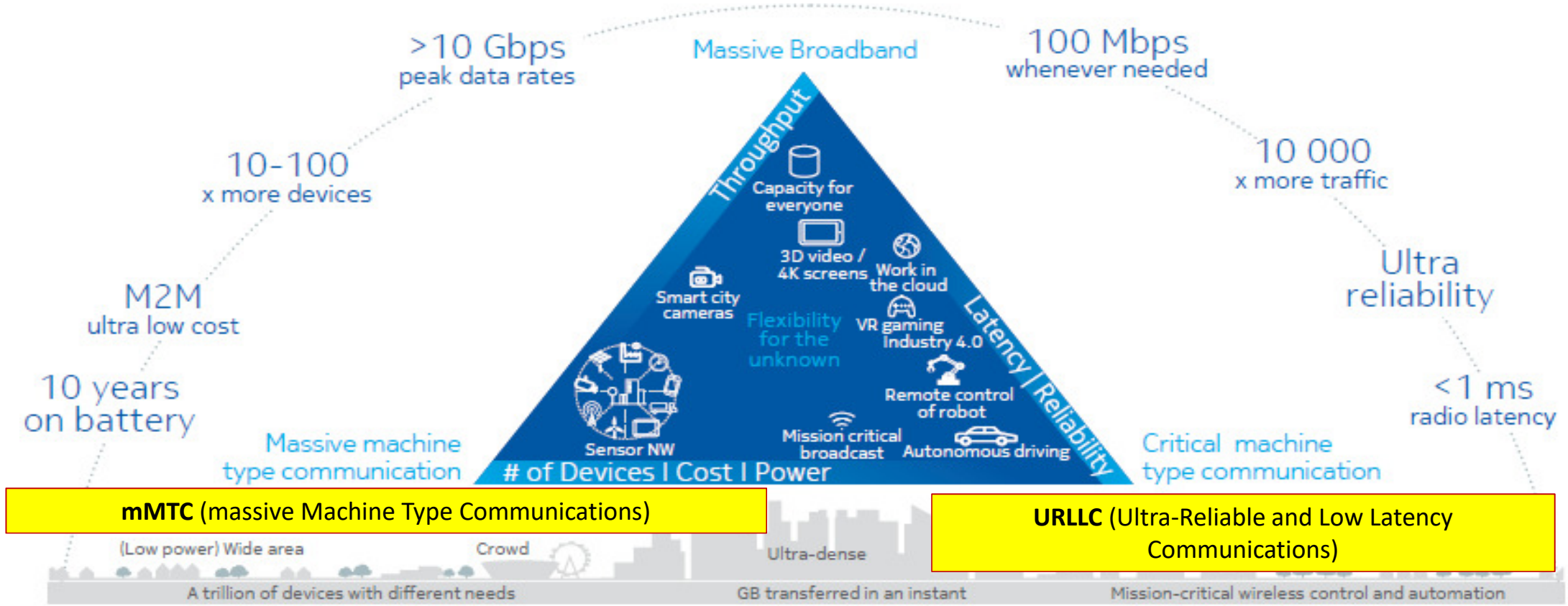
5G Main Objectives



Optimize the bit/s/Hz/m^2/Joule/$

5G three pillars

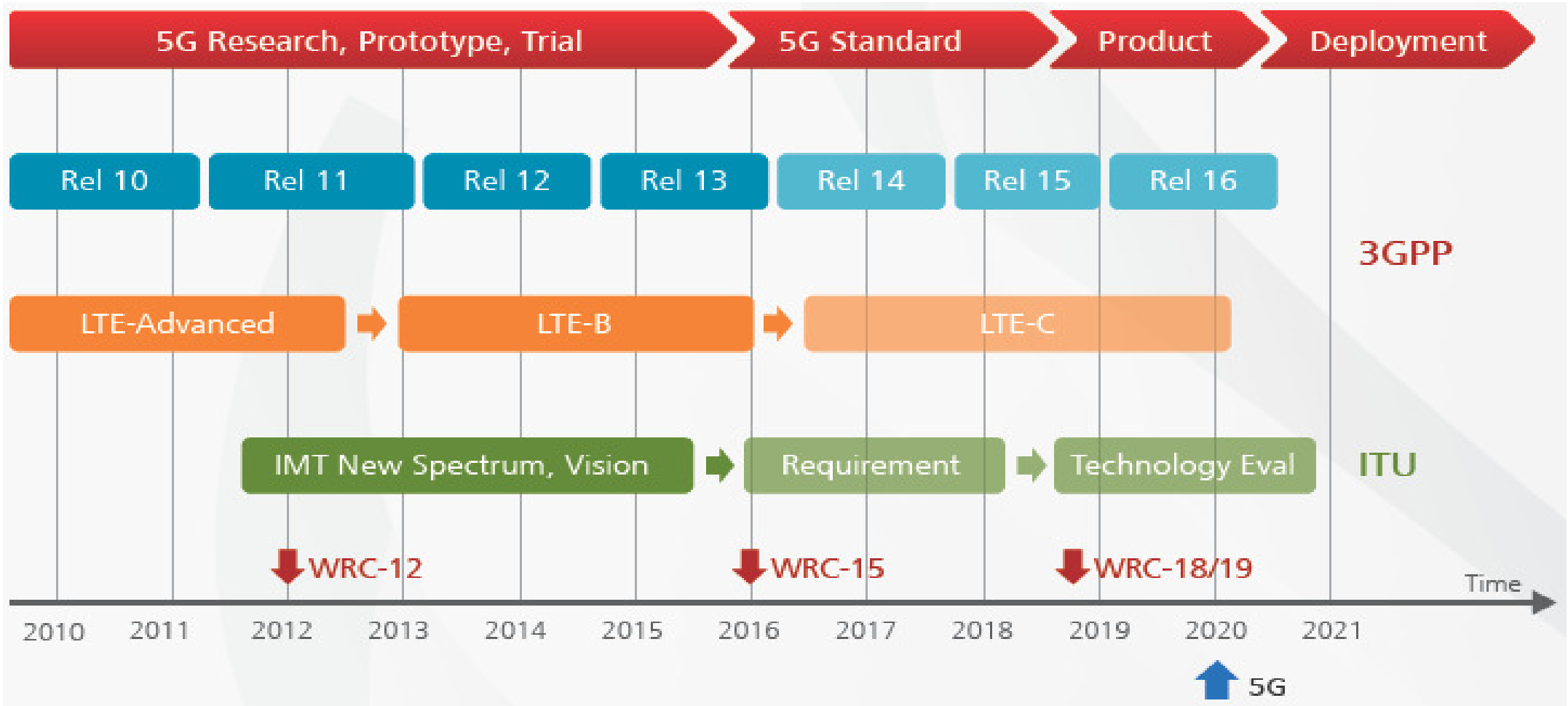
eMBB (enhanced Mobile BroadBand)



mMTC (massive Machine Type Communications)

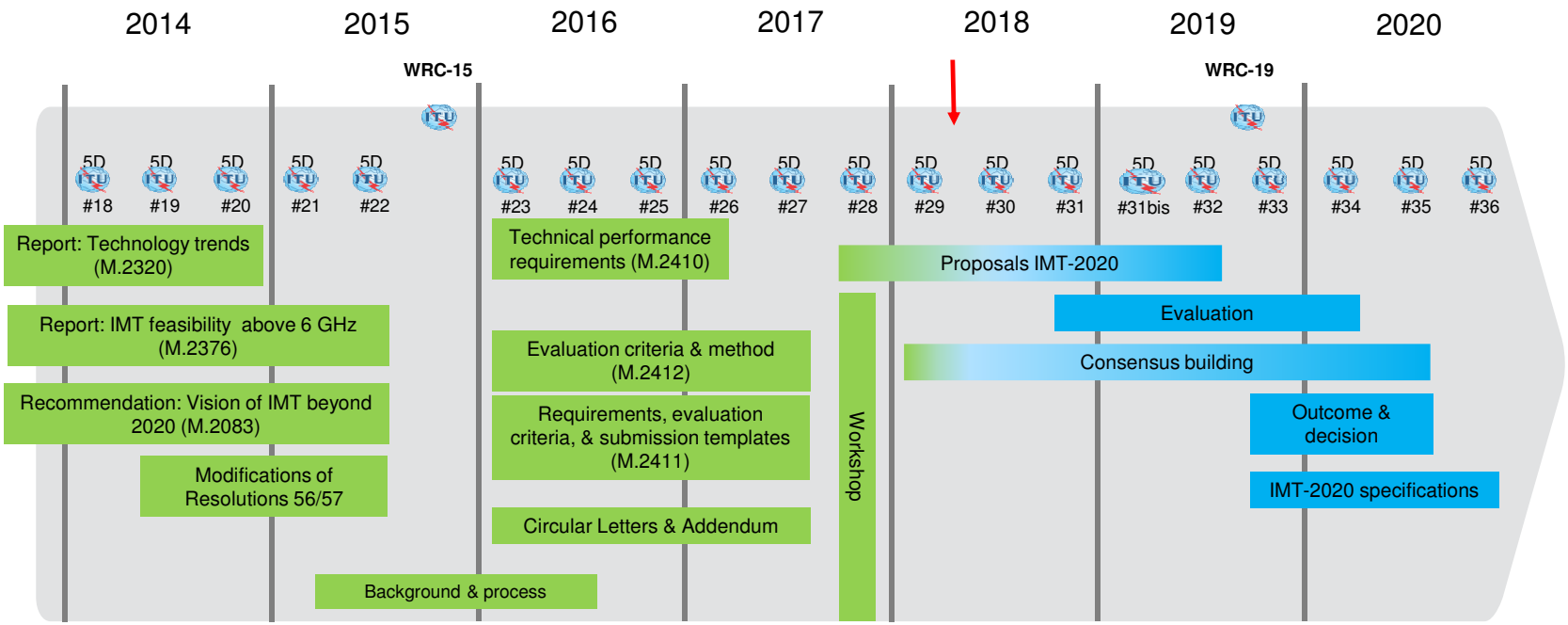
URLLC (Ultra-Reliable and Low Latency Communications)

5G Roadmap


5G Research, Prototype, Trial
5G Standard
Product
Deployment
Rel 10
Rel 11
Rel 12
Rel 13
Rel 14
Rel 15
Rel 16
3GPP
LTE-Advanced
LTE-B
LTE-C
IMT New Spectrum, Vision
Requirement
Technology Eval
ITU
WRC-12
WRC-15
WRC-18/19
Time
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
5G

ITU-R WP5D

ITU-R WP 5D timeline for IMT-2020
Detailed specifications for the terrestrial radio interfaces



- Initial technology submission: Meeting 32 (**June 2019**)
- Detailed specification submission: Meeting 36 (**October 2020**)

Quiz – 3GPP Standards evolution

1. What are the main motivations for introducing 4G?
2. What are the main motivations for introducing 5G?
3. What are the three pillars of 5G?
4. What is the main disruptive parameter in 5G?
5. Which 3GPP release introduces 5G services?

Thank You