LTE: Readiness for 5G & IoT

5th May 2016

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General Manager (Applications)

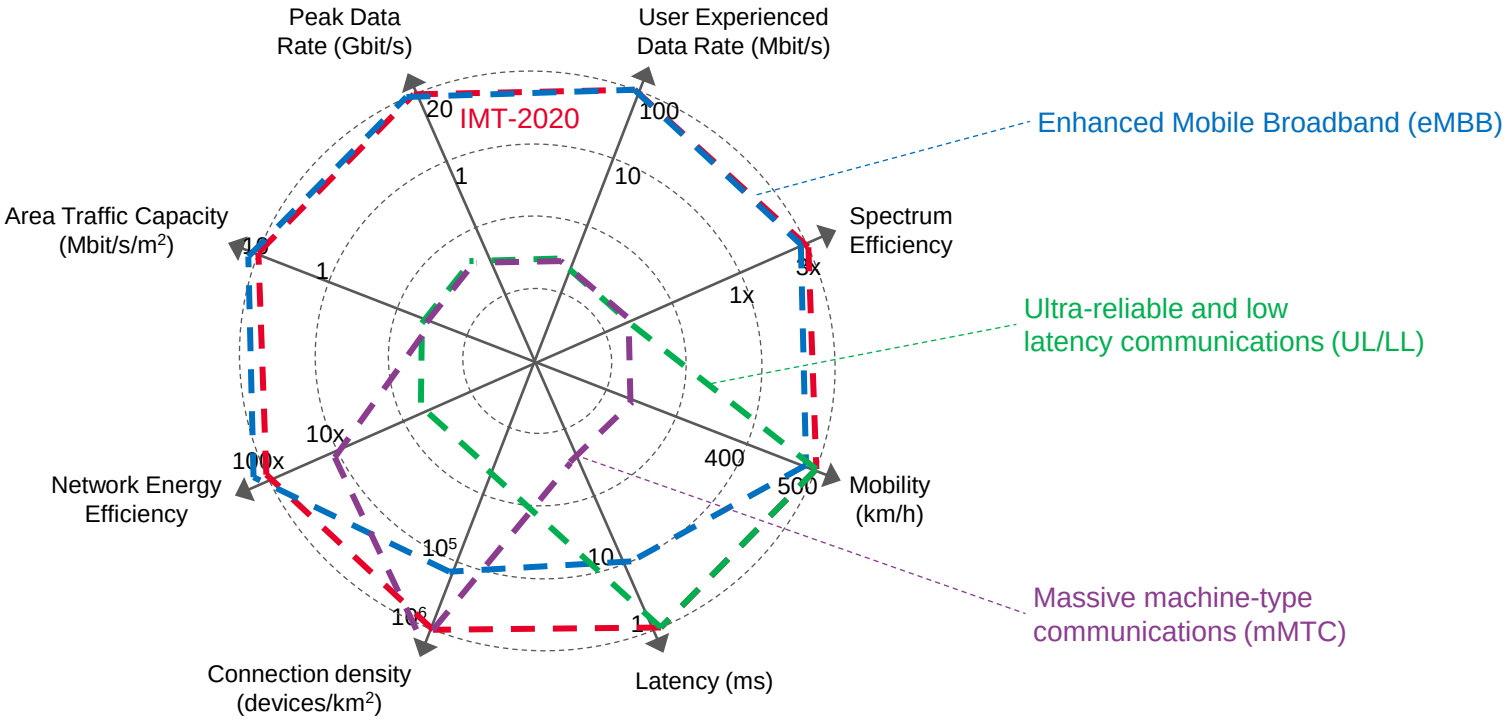
KEYSIGHT TECHNOLOGIES

Agenda

- **5G Update: 3GPP Perspective**
  - **Story continues…(we talked about this last year)**
- LTE Release 13: Exciting enablers
  - LTE in unlicensed spectrum: Marriage or Friendship!
  - MTC (IoT): New kid on the block asking for preferences
  - MIMO OTA

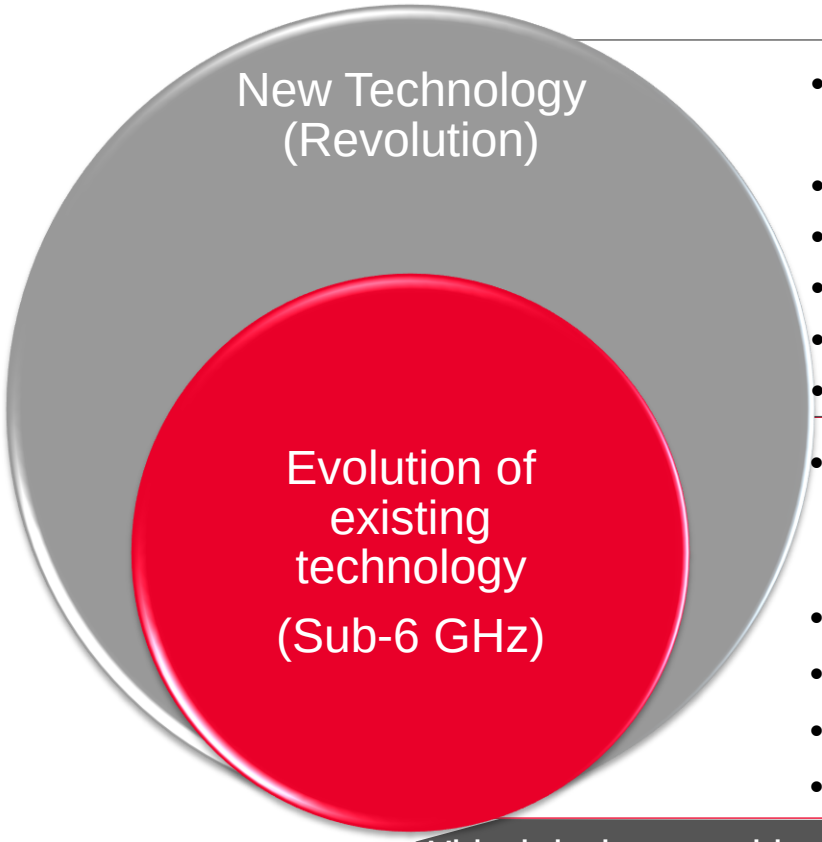
Proposed 5G Use Cases

5G capability perspectives from the ITU-R IMT-2020 vision



5G Enabling Technologies

Evolution of existing technology + Revolution of new technology



- Microwave and mmWave frequency bands (licensed and unlicensed)
- Wide bandwidth – up to 2 GHz or wider
- Massive MIMO - Number of BS antennas >> Number of UE's
- New waveforms and new radio access technology (RAT)
- In-band full duplex
- Software based network architecture: SDN and NFV

- Evolution of current cellular technologies – LTE-A/LTE-A Pro
  - Example: license assisted access (LAA); enhancement to machine type communication (MTC) or NB-IoT
- New waveforms and new radio access technology (RAT)
- New frequency bands below 6 GHz
- Ultra-dense networks – small cells and WLAN access points
- Evolution of RAN architecture (Advanced C-RAN)

With tight interworking between exiting technologies and the new technologies

5G Update: 3GPP Perspective

3GPP Release 13 & 14

– Study on channel model for frequency spectrum above 6 GHz

– The study item aims to develop a channel model to enable feasibility study and developing framework of using high frequency spectrum ranging from 6 GHz to 100 GHz. In order to achieve this, the study item should fulfil the following objectives.

- From RAN#69 (Sep 2015) to RAN#70 (Dec 2015), RAN identifies the status/expectation of existing information on high frequencies (e.g. spectrum allocation, scenarios of interest, measurements, etc.).
- From Q1 2016, RAN1 develops a channel model(s) for frequencies up to 100 GHz taking into account the outcome of RAN-level discussion and discussion in the ‘5G’ requirement study item.
- Consider the work done outside 3GPP as well as earlier 3GPP work, such as the 3GPP 3D-channel model, as a starting point for modelling of wireless channels of the high frequency spectrum for the identified scenarios.

Study on channel model for frequency spectrum above 6 GHz

- The main industry position is represented by R1-160704 which references a Globecom 2015 white paper proposing the continued use of stochastic modelling. It is supported by NTT DOCOMO, AT&T, CMCC, Ericsson, Huawei, HiSilicon, Intel, KT Corporation, Nokia, Qualcomm and Samsung.
- This enables continued use of existing stochastic modelling tools but will they work?
- The main alternative proposal is coming from Keysight (Anite) and that is to use a deterministic model augmented with local stochastic elements. Keysight papers are:
- R1-160487 METIS Map-Based Model
- R1-160823 5G Channel Model Requirements vs. Modelling Approaches
- R1-160824 An Implementation Based on Map–Based Model
- R1-160825 Map–based Hybrid Model Compared to geometric-based stochastic model
- R1-160826 Rays and Graphs
- The conclusion was that the stochastic model will be the default and further study will be made on the deterministic approach.

Study on Scenarios and Requirements for Next Generation Access Technologies

- An aspect worthy of early consideration is the testability of future of any future mmWave RAT.
- R4-160155 “On the testability of RF requirements for potential 5G devices” covers they key issues including the likely absence of connectors at mmWave frequencies and the need to characterize active antenna arrays
- There is much to learn from the previous OTA experiences with MIMO OTA and Active Antenna System that need to be used to ensure good choices in the future

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Evolution of Existing Technology: LTE in unlicensed spectrum

LTE-Advanced/LTE-Advanced Pro

LTE-U / LTE-LAA

- 5 GHz ISM Band

Data + Control
Licensed Anchor

Data only
Unlicensed (5 GHz)

Carrier Aggregation

LTE-Unlicensed (LTE-U): based on 3GPP Rel 10-12 and LTE-U Forum spec
LTE-License Assisted Access (LAA) part of 3GPP Rel-13

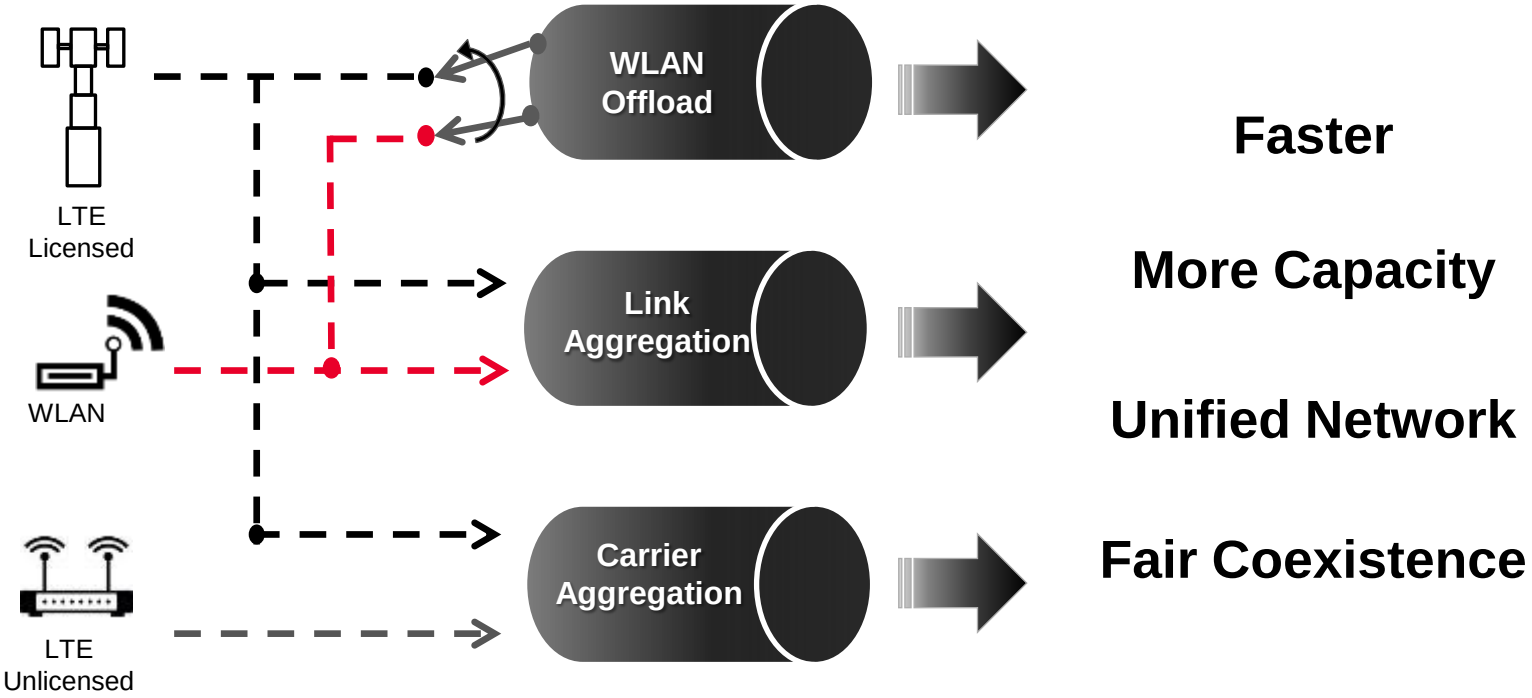
- Licensed spectrum remains top priority for operators
- LTE over unlicensed gives operators another option to offload traffic to unlicensed spectrum using LTE-U/LTE-LAA

Carrier Aggregation	• Up to 32 CCs including LAA operation • TDD-FDD joint operation
Dual Connectivity	• Simultaneous connection to macro & small cell
Full-Dimension MIMO (FD-MIMO)	• Simultaneously supports elevation and azimuth Beamforming • High order MIMO with up to 64 antenna ports at eNB
Narrow Band IoT (NB-IoT)	• New narrowband radio technology to address the requirements of the Internet of Things (IoT) (Rel. 13)
Vehicle to Vehicle (V2V) communication	• Support for V2V services based on LTE sidelink (Rel. 14)

LTE in unlicensed spectrum

It's happening in multiple ways…

– 3GPP has focused in two areas to help Operators offload traffic in the unlicensed spectrum:
  - WLAN via LTE/WLAN Interworking (via offload or aggregation)
  - LTE over unlicensed spectrum



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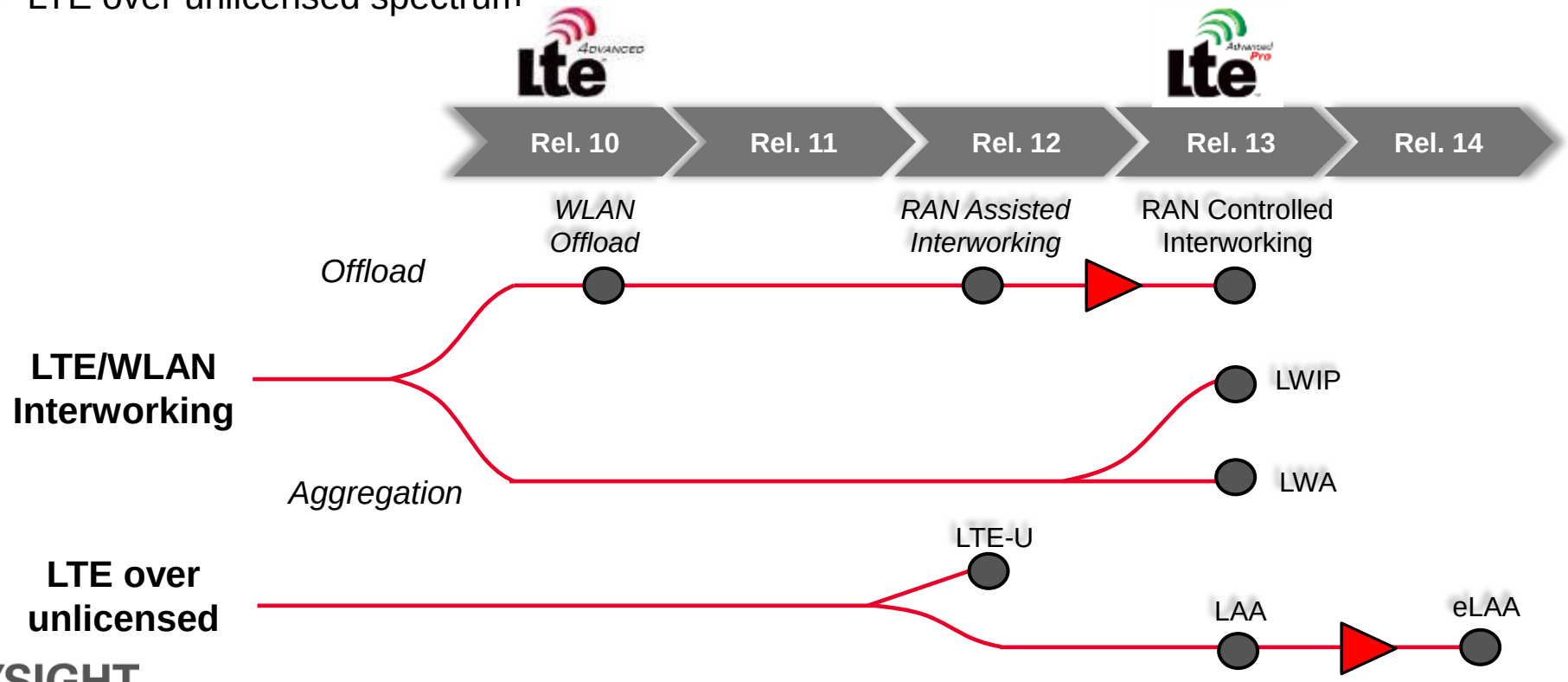

LTE in unlicensed spectrum: Summary

Offload & Aggregation (LTE-WLAN and LTE only)

Unified Network (LTE – WLAN) ⟷ **Single RAT (LTE)**

	RALWI	RCLWI	LWA	LWIP	LTE-U	LAA
Complete name	RAN Asissted LTE-WLAN Interworking	RAN Controlled LTE-WLAN Interworking	LTE WLAN Aggregation	LTE WLAN Integration with IP Tunneling	LTE Unlicensed	License Assisted Access
3GPP Release	12	13	13	13	12*	13
Infrastructure	EPC + legacy WLAN	EPC + legacy WLAN	EPC + WLAN	EPC + legacy WLAN	EPC	EPC
WLAN relation	Offload	Offload	Aggregation	Aggregation	co-existence	co-existence
Co-existence	CSMA	CSMA	CSMA	CSMA	CSAT	LBT
Aggregation layer	IP	IP	PDCP	IP	MAC	MAC
DL and/or UL	DL and UL	DL and UL	DL only	DL (and UL)	DL only	DL only

LTE-WLAN Offload | **LTE-WLAN Aggregation** | **LTE Carrier Aggregation**

*Not a 3GPP feature

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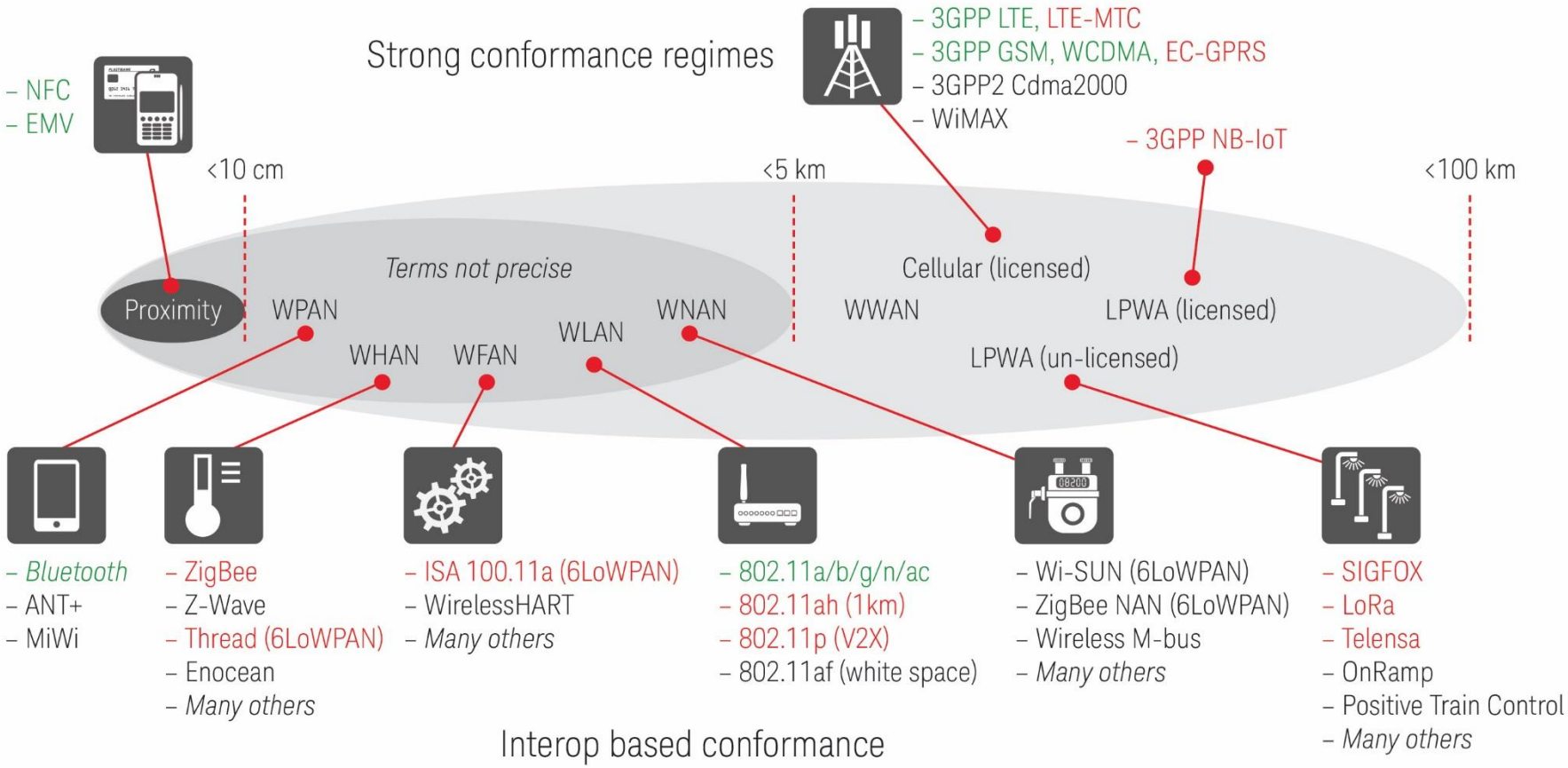
IoT Radio Technologies



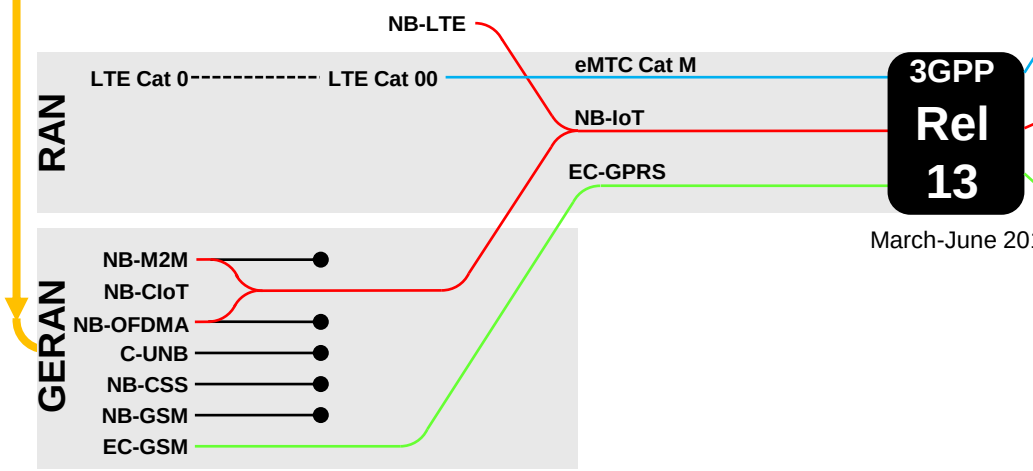
■ : > Billion units/year now
■ : Emerging

WPAN: Wireless Personal Area Network
WHAN: Wireless Home Area Network
WFAN: Wireless Field (or Factory) Area Network
WLAN: Wireless Local Area Network

WNAN: Wireless Neighborhood Area Network
WWAN: Wireless Wide Area Network
LPWA: Low Power Wide Area

3GPP Release 13 Cellular IoT timelines

GERAN Objectives
- 164dB link budget (GPRS +20dB)
- 40 devices per home (~50k/cell)
- >160bps at range limit
- 10 second latency
- 10 year life with 5Wh ~AA battery



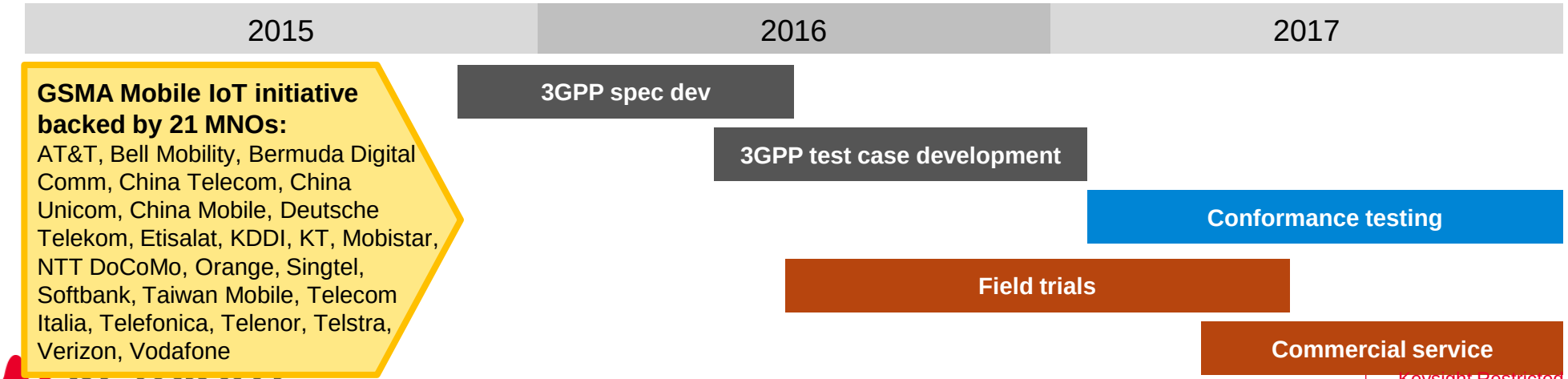
3GPP Rel 13

March-June 2016

eMTC Cat M:
- Machine Type Communication
- 1.4MHz Bandwidth LTE derivative
- Software update to LTE infrastructure
- 1Mbps, full mobility, 156dB link, 10 year batt

NB-IoT:
- Narrowband IoT
- 200 (180kHz) Clean sheet format
- Software update to LTE or GSM infrastructure
- <~250kbps, nomadic, 164dB, 10 year batt

EC-GPRS
- Extended coverage GPRS
- 200kHz GSM/EDGE
- Repetitions to get to 164dB link budget
- EC-PDTCH and EC-PACCH, ~52 min DRX
- Software update to GSM infrastructure



GSMA Mobile IoT initiative backed by 21 MNOs:
AT&T, Bell Mobility, Bermuda Digital Comm, China Telecom, China Unicom, China Mobile, Deutsche Telekom, Etisalat, KDDI, KT, Mobistar, NTT DoCoMo, Orange, Singtel, Softbank, Taiwan Mobile, Telecom Italia, Telefonica, Telenor, Telstra, Verizon, Vodafone

Cellular Internet of Things (CIoT)

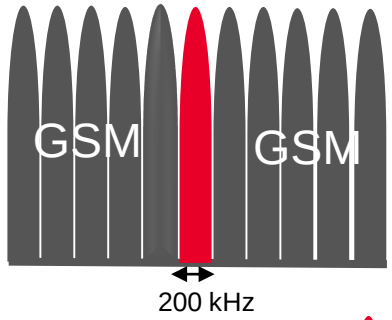
Some new technologies and some enhancements over existing ones

	LTE-MTC		EC-GSM (EC-GPRS)	NB-IoT (Cat M2)	
	Cat 0	Cat M (M1)		Single tone mode	Multi-tone mode
	3GPP Rel 12	3GPP Rel 13	3GPP Rel 13	3GPP Rel 13	3GPP Rel 13
Technology	Based on LTE	Based on LTE	GSM extension	Clean-slate	Clean-slate
DL Bandwidth	20 MHz	1.4 MHz	200 kHz	180 kHz (12 by 15 kHz)	
UL Bandwidth	20 MHz	1.4 MHz	200 kHz	180 kHz (by 3.75kHz or 15kHz)	180 kHz (by 15 kHz)
Multiple access DL	OFDMA	OFDMA	TDMA	OFDMA	
Multiple access UL	SC-FDMA	SC-FDMA	TDMA	FDMA	SC-FDMA
Modulation DL	QPSK, 16QAM, 64QAM	QPSK, 16QAM, 64QAM	GMSK	BPSK, QPSK, optional 16QAM	
Modulation UL	QPSK, 16QAM	QPSK, 16QAM	GMSK	BPSK, QPSK, 8PSK	BPSK, QPSK, optional 16QAM
Peak data rate	1 Mbps	1 Mbps	10 kbps	DL 128 kbps, UL 48 kbps TBC	DL 128 kbs, UL 64 kbps TBC
Coverage	~141dB link budget	~156 dB link budget	~164 dB link budget	~164 dB link budget	~164 dB link budget
Mobility	Full	Full	Full	Nomadic	Nomadic

NB-IoT

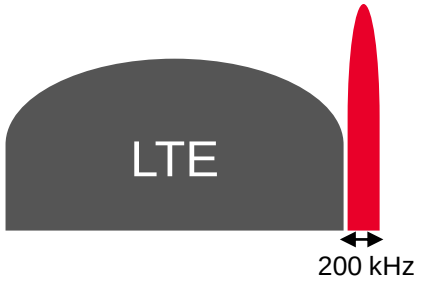
Modes of Operation

- NB-IoT is 200 kHz wide, self-contained carrier with three modes of operation:
  - stand-alone; guard band; and in-band
- **Downlink transmission:**
  - OFDMA with 180 kHz RF BW
  - 15 kHz subcarrier spacing
- **Uplink single tone transmission**:
  - FDMA with 180 kHz RF BW
  - 3.75 kHz and 15 kHz subcarrier spacing
- **Uplink multi-tone transmission**:
  - SC-FDMA with 180 kHz RF BW
  - 15 kHz subcarrier spacing



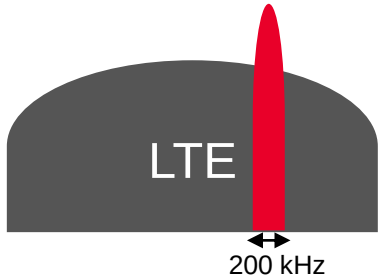
Stand-alone operation

Utilizing dedicated spectrum. Example, re-farming GSM channels



Guard band operation

Utilizing unused resource blocks within a LTE carrier's guard-band



In-band operation

Utilizing resource blocks within a normal LTE carrier

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MIMO OTA

Why the buzz?

- MIMO OTA performance testing is used to assess the end user's experience accessing data services on a mobile device.
- All critical parts of the mobile device design – including the antennas, RF front end, baseband processing – are thoroughly and simultaneously tested in real-life conditions.
- Measurements:
  - Transmitter performance: Total Radiated Power (TRP)
  - Receiver performance: Total Isotropic Sensitivity (TIS)
- MIMO OTA antenna test function (ATF) for LTE defined two new UE measurements:
  - RSAP – Reference Signal Antenna Power
    - The incident downlink power seen by the UE on each antenna
  - RSARP – Reference Signal Antenna Relative Phase
    - The observed phase difference between the antennas

MIMO OTA

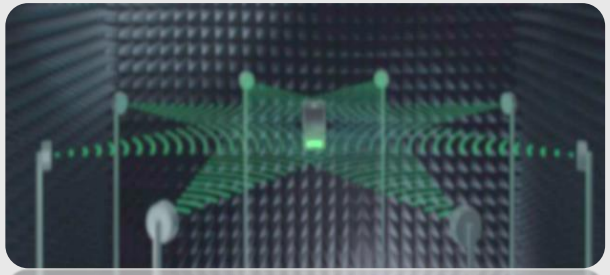
Test Methods

– Anechoic Chamber Methods
  - Multi-probe method
  - Two stage method

– Reverberation Chamber Method
  - Reverberation chamber with channel emulator

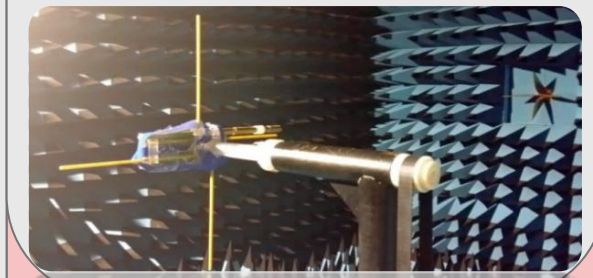
MPAC
(Multi-Probe Anechoic Chamber)

- Method approved by CTIA for lab use for TM2 & TM3
- Works with Anite PropSIM Channel Emulator



RTS
(Radiated Two-Stage)

- Leverages existing chambers
- UXM incorporates chamber channel inversion matrix



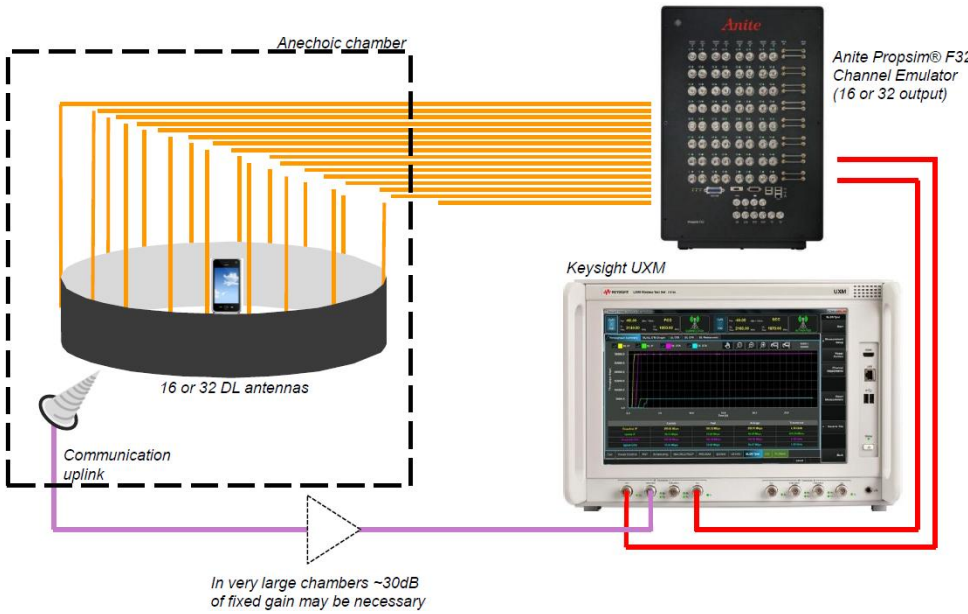
RC / RC+CE
(Reverb Chamber + Channel Emulation)

- Method approved by CTIA for lab use for TM2
- Uses metallic stirrers (Rayleigh fading) in reverb chamber

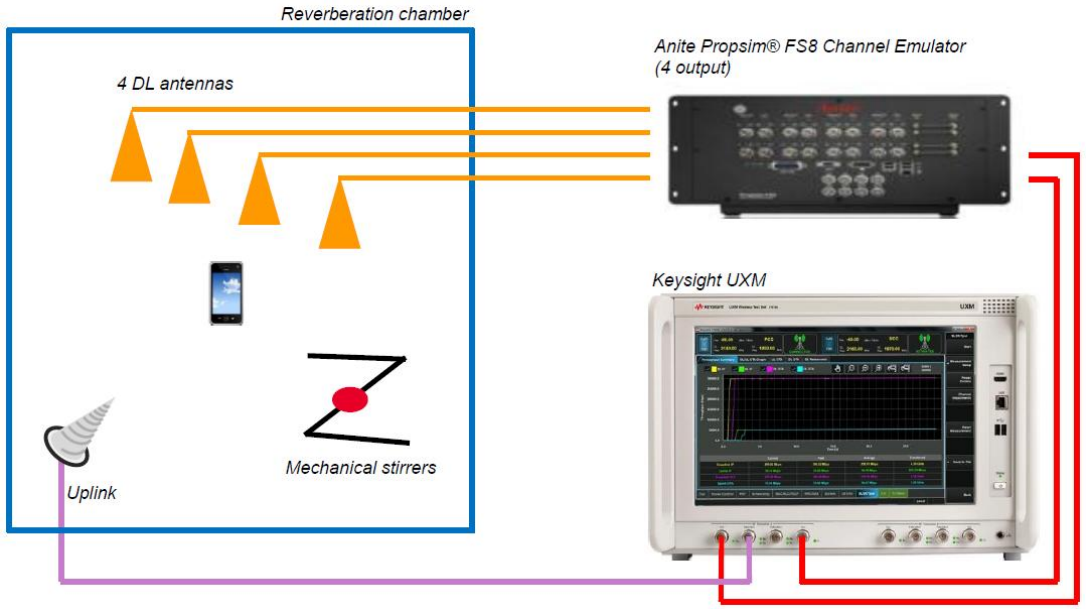
Cost effective using UXM's internal channel emulator

Test setup examples

Multi-Probe Anechoic Chamber (MPAC) & RC + CE MIMO OTA system



Multi-probe MIMO OTA system



2x4 MIMO 1*CC using external RF Fading

Finally, Keysight Solution for Wireless Ecosystem

System Vue & ADS

Anite A9000 protocol development, conformance and operator acceptance

Anite Propsim channel emulator

Design Simulate

Protocol L2/L3 Develop

L1/PHY Develop

RF Develop

Integrate

Protocol Verify

System & perf-ormance verify

RF Design Verify

Pre-cert

Certification

OTA test

Operator acceptance

Lab IOT

Field trials

GCF/PTCRB

CTIA/CE/FCC regs

T4000S RCT & RRM systems

Pilot production

Volume production ramp

VSA/VSG/scopes

UXM Device Design and Verification Solutions

Battery drain analyser

EXM Fast, multiport production solution

Thank you.

Unlocking Measurement Insights for 75 Years

For Study

LTE in the Unlicensed Spectrum

The constant growing demand for higher data rates in mobile devices is causing network Operators to think on innovative paths to help cope with the mobile capacity crunch and, the active use of unlicensed spectrum has become a key enabler.

With more than half of the wireless internet traffic, WLAN is undoubtedly the leading technology for delivering ubiquitous wireless connectivity. Historically WLAN and cellular have been viewed as competing technologies with separate standards bodies and solutions; however, thinking is being challenged with recognition that, with inter-working, the two technologies can be use used to complement each other and improve the overall performance of the network.

On the other hand, WLAN is also one of multiple technologies that make use of the ISM band. The lack of any licensing requirement makes this part of the spectrum very attractive to Operators and therefore it's been a major driver in the standardization bodies lately which are working towards ensuring LTE can be deployed in the unlicensed spectrum.

This is happening in multiple ways…

- LTE and WLAN inter-working defines a framework to enable a seamless and smart traffic offload between the two technologies. In the 3GPP Release 13, RAN-controlled LTE-WLAN Interworking (RCLWI) takes RAN assisted WLAN Offload (Release 12) to a new level by increasing the offload control by the 3GPP network.
- LTE-WLAN link aggregation (i.e. Release 13 LWA and LWIP) goes beyond the offload and allows the simultaneous combination of both technologies to opportunistically boost data rates.
- LTE in the unlicensed spectrum (i.e. LTE-U, LAA) takes advantage of the LTE-A feature, carrier aggregation, to enable the use of LTE in the underutilized 5GHz ISM band. To ensure co-existence with other technologies, new mechanisms like LBT (Listen-Before-Talk) or carrier sensing have been defined by the 3GPP.

WLAN Offload: Use Case

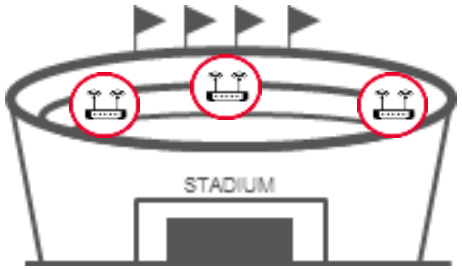
– Delivery of mobile cellular traffic over WLAN to reduce congestion of the cellular network by taking advantage of:
  - Most of mobile devices usually have a built-in WLAN function
  - Readily available WLAN networks

– LTE – WLAN Inter-working standardization is needed to improve QoE:

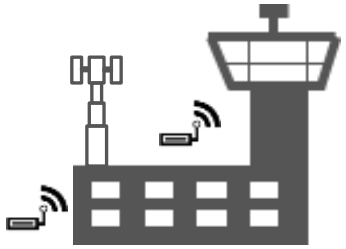
1. **WLAN Calling offload** ***(3GPP Network access through WLAN)***
   - Receive and place calls, SMS through IMS in areas with poor cellular coverage
2. **Smart Offload** ***(Network selection)***
   - Select LTE or WLAN based on environment, network conditions and per-service
3. **Seamless Offload** ***(Session mobility)***
   - Higher quality transitions when entering/exiting LTE or WLAN coverage

LTE WLAN User Plane Aggregation: Use Case

- Enable link aggregation of LTE and WLAN to increase throughput
  - Reliable LTE used as control and mobility anchor to secure QoE
  - WLAN (using unlicensed spectrum) is opportunistically used to increase data rates
- Operators can use deployed WLAN network as standalone for legacy devices but also to increase data rates in new devices
- The benefits can be realized in:
  - **Co-located** (e.g. a small-cell that integrates both LTE and WLAN)
  - **Non-co-located** (e.g. agreement to use a partner's WLAN network)



Co-located
Integrated LTE / WLAN small-cells

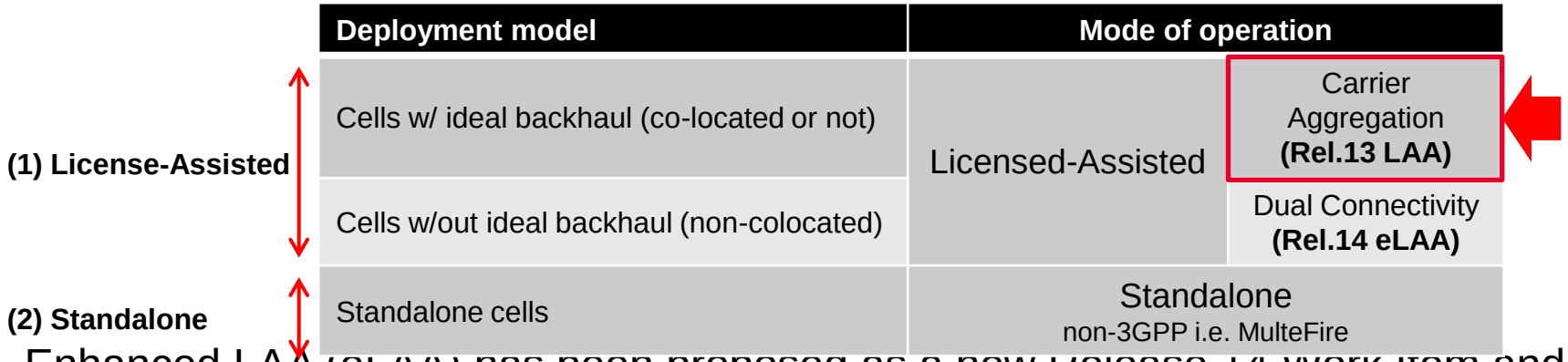


Non-co-located
Cellular network partering with WLAN operator

LTE over Unlicensed: Licensed Assisted Access

– Opportunistic use of LTE in the Unlicensed Spectrum represents an important complement to meet traffic demand and help boost data rates

– 3GPP has analyzed different modes of Operations depending on scenarios:

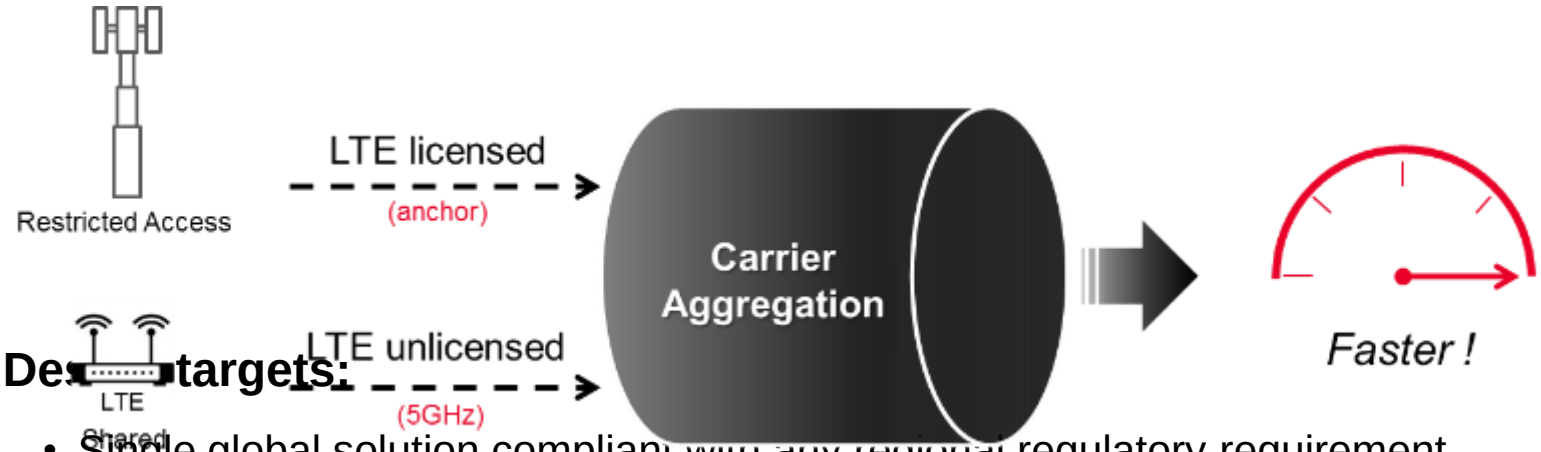


– Enhanced LAA (eLAA) has been proposed as a new Release 14 work item and will specify LAA support for Uplink and Dual Connectivity in the LAA SCell

– Standalone operation within unlicensed spectrum is not planned yet by 3GPP

LAA Overview and Design Targets

– Based on **Carrier Aggregation** with the Primary Cell being deployed in any Licensed Band to ensure highest reliability and a set of SCells in unlicensed spectrum to boost data rates.

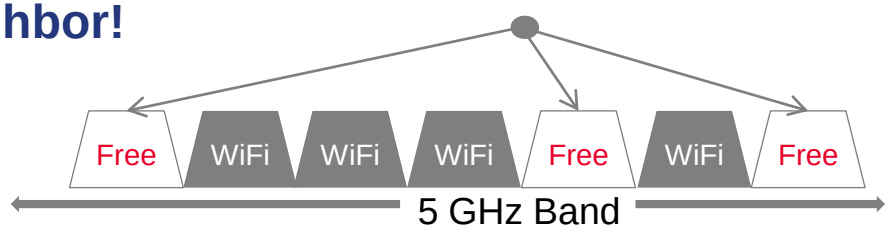


– **Design targets:**
  - Single global solution compliant with any regional regulatory requirement
  - Effective and fair co-existence with WLAN
  - Effective and fair co-existence with others Operators' LAA deployments

Evolution of Existing Technology: Sub-6 GHz

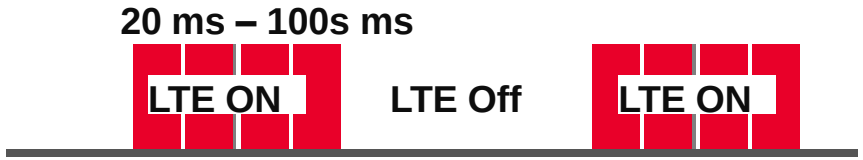
LTE-U / LTE-LAA: How does it work?

1) Be a good neighbor!



2) If no free carriers exist: fair sharing

LTE-U



- **No Change to 3GPP Standard**
- Adaptive duty cycle based on channel utilization
- **Can be deployed now:**
  - **US, Korea, China, India**

LTE-LAA (3GPP Rel-13)

- Based on 3GPP R13 (completion ~H1 2016)
- Listen before talk (LBT) - Sense channel every 20 us (clear channel assessment)
- Dynamic frequency selection (DFS) for radar avoidance
- **Minor changes to physical layer**
  - 1 ms – 10 ms transmissions
  - Add discovery signals / beacon signals
  - HARQ modified for asynchronous operation
- **Required for deployment in:**
  - **Europe, Japan**

Source: Qualcomm

Release 13
Spectrum – new FDD bands

- As many as six new band may get added in Rel-13.
- So far three have been specified – band numbering has restarted at 65

Band	Uplink MHz		Downlink MHz		Width	Duplex	Gap
65	1920	2010	2110	2200	90	190	100
66	1710	1780	2110	2200	70	400	330
67	DNA		738	758	20	-	-

- Band 67 is the third supplemental downlink (SDL) band to be added
- SDL is used for downlink-only carrier aggregation to improve data rates

Release 13
Spectrum – new TDD bands

– Two new TDD bands have been defined.

Band	Uplink MHz		Downlink MHz		Width
45	1447	1467	1447	1467	20
46	5150	5925	5150	5925	775

– Band 45 is for TD-LTE in China

– Band 46 was introduced as part of the LAA work and is the 5 GHz ISM band.

Return to Rel-13

Relevant Links

- http://www.3gpp.org/DynaReport/36-series.htm
- http://www.3gpp.org/release-13
- http://www.3gpp.org/news-events/3gpp-news/1628-rel13
- http://www.3gpp.org/release-14
- http://www.3gpp.org/news-events/3gpp-news/1768-ran_rel14
- http://the-mobile-network.com/2016/03/3gpp-announces-ran-work-programme-for-r14/