

Agenda

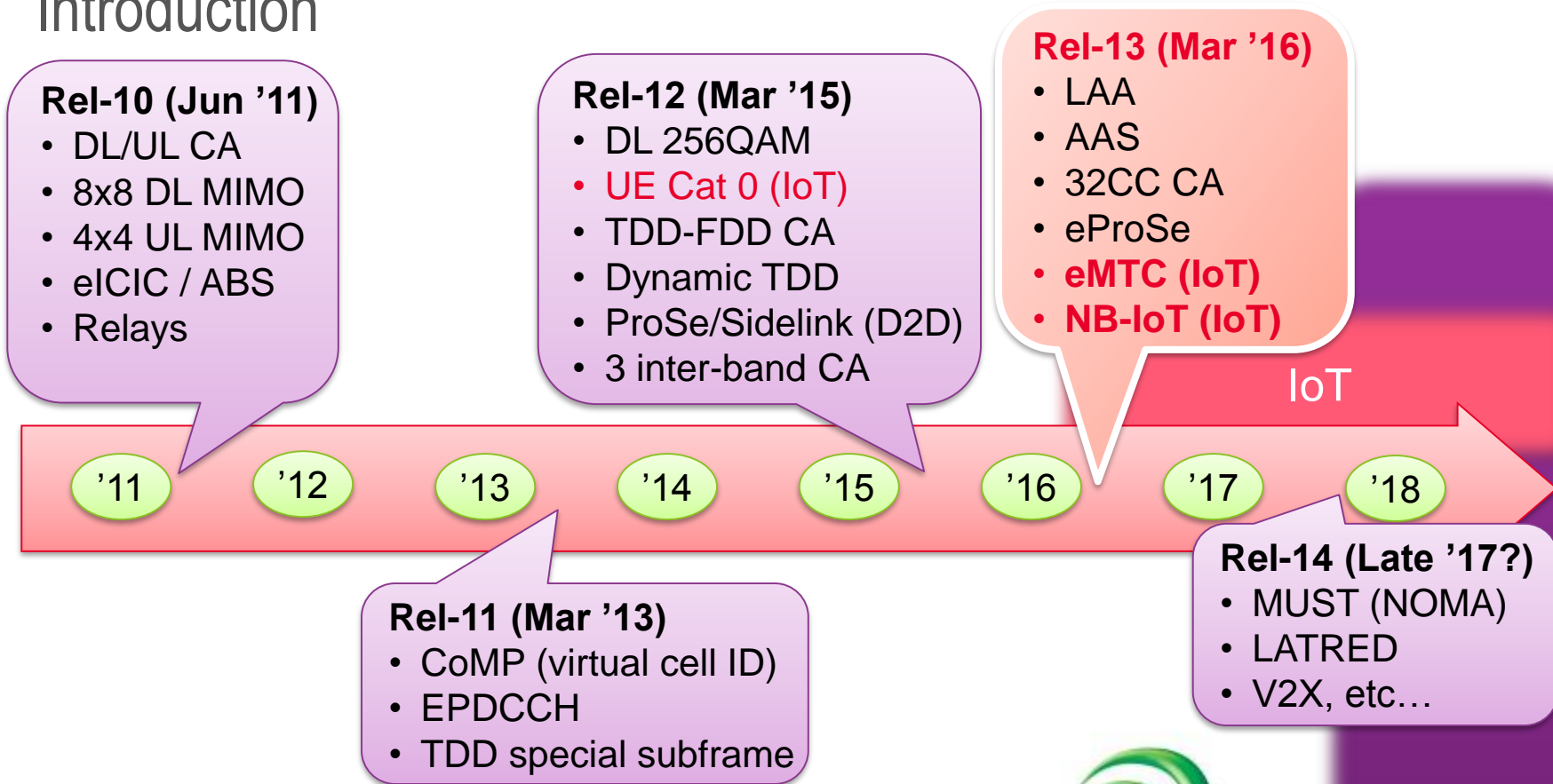
- Release 13 Overview
- LAA
- eMTC and NB-IOT
- E7515A UXM Platform
- E7515A UXM LTE/LTE-A
- Summary

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- **Release 13 Overview**
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3GPP LTE/LTE-Advanced Evolution...

Introduction



5G

Agenda

- Release 13 Overview
- **LAA**
- eMTC and NB-IOT
- E7515A UXM Platform
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Licensed-Assisted Access using LTE (LAA)

- The use of LTE in the ISM band by configuring standard Rel-12 has been called LTE-U. It is the most controversial use due to anticipated interference issues.
- The purpose of LAA is to modify LTE to better enable operators to offload traffic to LTE femtocells without requiring a WLAN network
- The initial focus is on the 5 GHz ISM band used for WLAN
- LTE is shown to be more efficient - but WLAN was there first
- Modifications to the LTE air interface will be proposed to make co-existence with WLAN more tolerable (e.g. Listen Before Talk – LBT)
- US regulations do not require LBT but Europe and Asia do
- LAA is likely to become the single biggest increase of cellular spectrum (up to 680 MHz in 5 GHz band) since the allocations given at WRC 07.
- If LAA is successful it may cause similar proposals to use 60 GHz for 5G

LAA Deployment scenarios

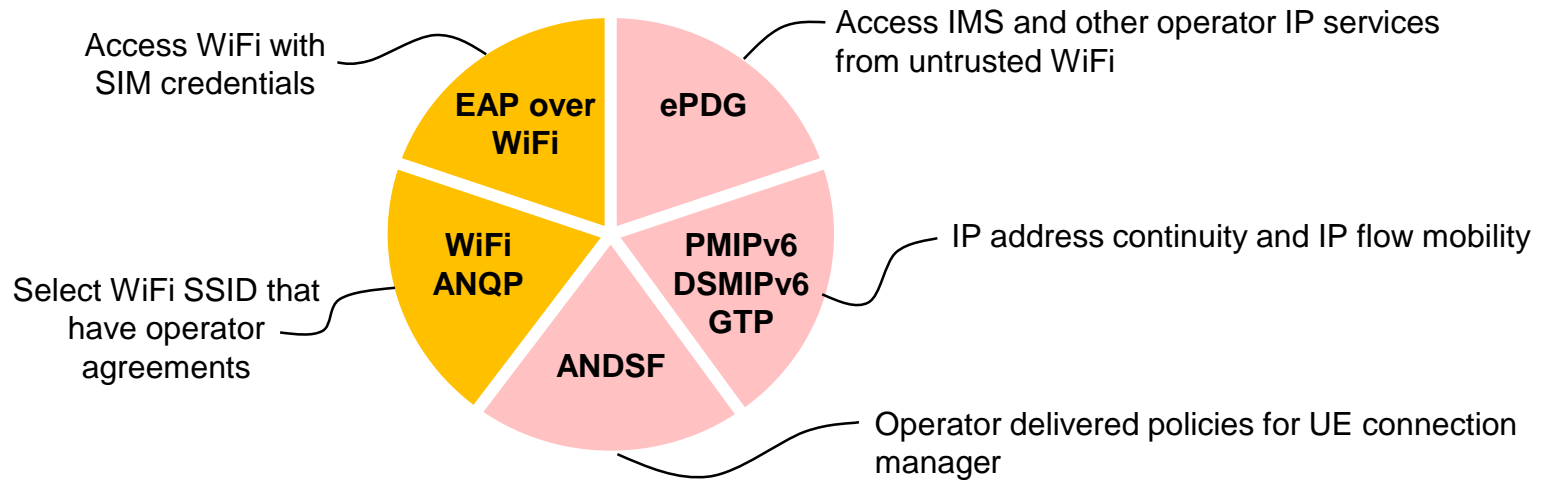
- Initial results show that, when augmented with the appropriate coexistence mechanisms to operate in unlicensed spectrum, e.g. Listen-Before-Talk, LTE can effectively coexist with WiFi and outperform it in terms of spectral efficiency

Deployment model	Mode of operation	
Co-located cells	Licensed-Assisted	Carrier Aggregation
Non co-located cells w/ ideal backhaul		Dual Connectivity
Non co-located cells w/out ideal backhaul		
Standalone cells	Standalone	

The alternative to LAA: Continued integration of cellular and Wi-Fi

802.11u/Hotspot 2.0 (Passpoint)

3GPP/I-WLAN



EAP – [Extensible Authentication Protocol](#)

ANQP – [Access network Query Protocol](#)

ePDG – [Evolved Packet Data Gateway](#)

PMIPv6 – [Proxy Mobil IP v6](#)

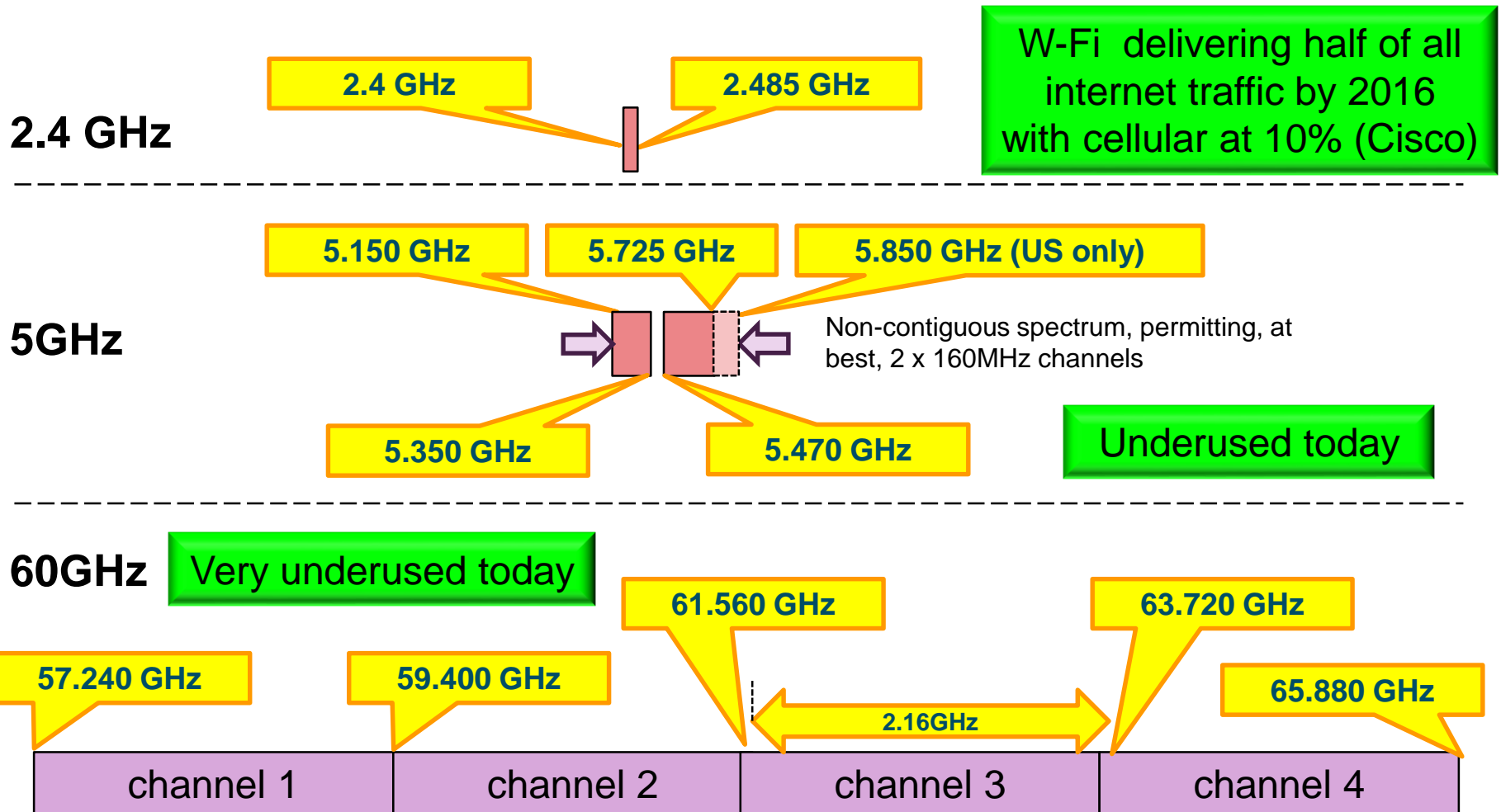
DSMIPv6 – [Dual Stack Mobility IP v6](#)

GTP – [GPRS Tunelling Protocol](#)

ANDSF – [Access network Discovery and Selection Function](#)



Industrial Scientific Medical (ISM) spectrum



LAA Functionalities

LTE functionality required:

- i. Listen-Before-Talk (LBT)
- ii. Frame structure type 3:
 - Discontinuous transmission with limited usage of channel
 - Use of incomplete subframes
 - Downlink only
 - No PBCH
 - Use of Band 46 (5.150 – 5.925 GHz)
- iii. Discovery Signals to enable RRM



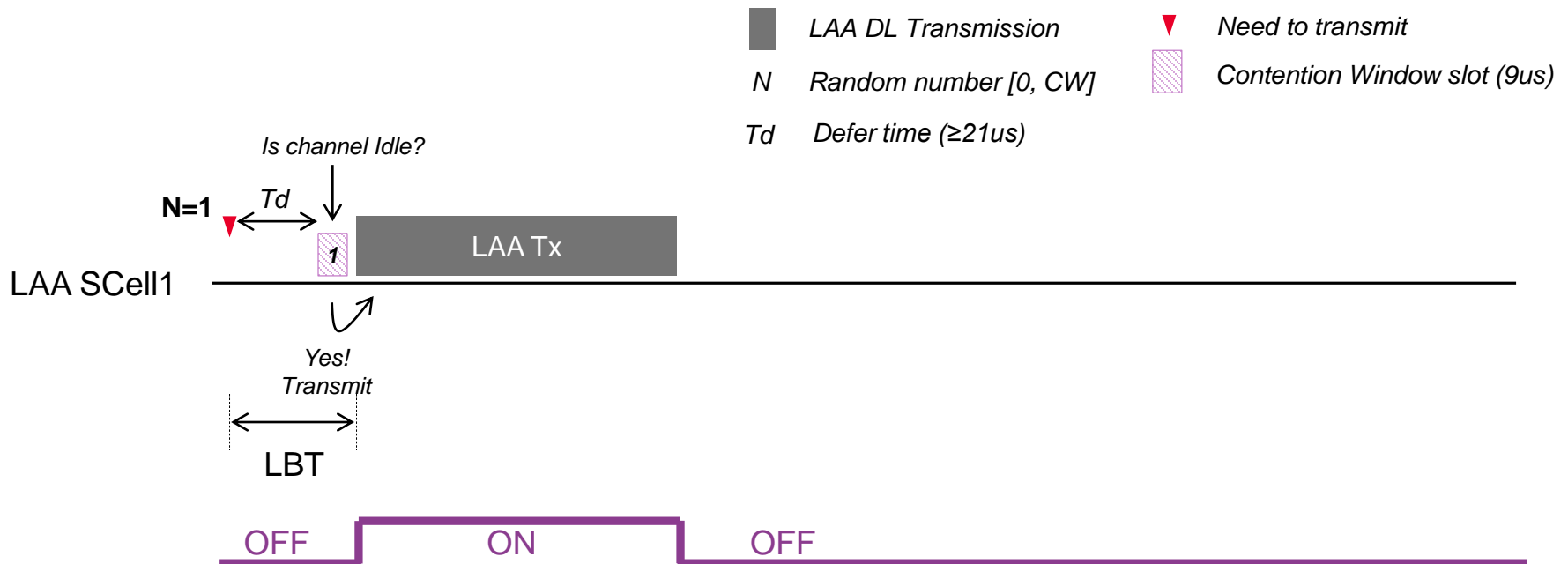
More information can be found in [TR 36.889](#)

“Feasibility Study on Licensed-Assisted Access to Unlicensed Spectrum”

LAA Functionalities: Listen-Before-Talk (LBT)

LBT (Listen-Before-Talk):

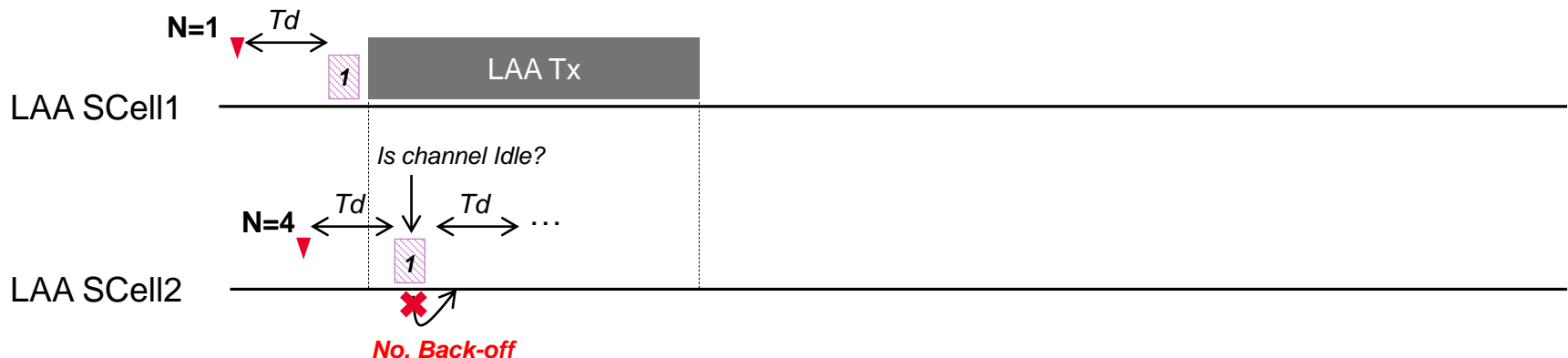
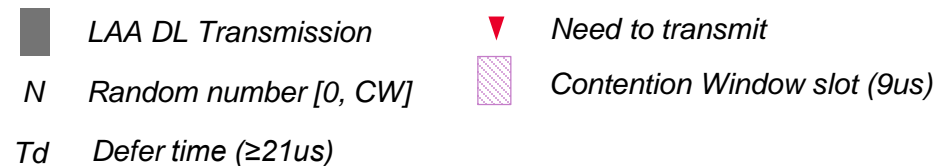
- **Is** a contention-based protocol that allows many users to use the same radio channel without pre-coordination
- **Relies** on eNB sensing the radio channel (CCA) before starts a transmission



LAA Functionalities: Listen-Before-Talk (LBT)

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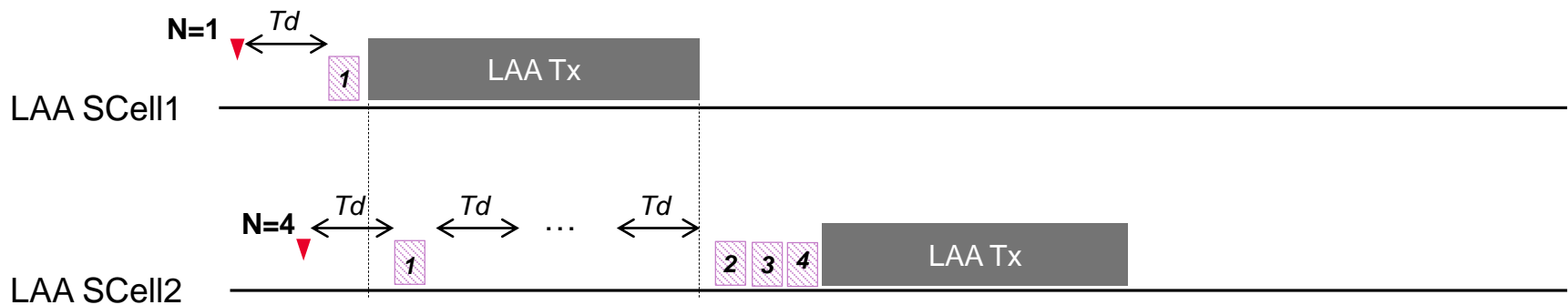
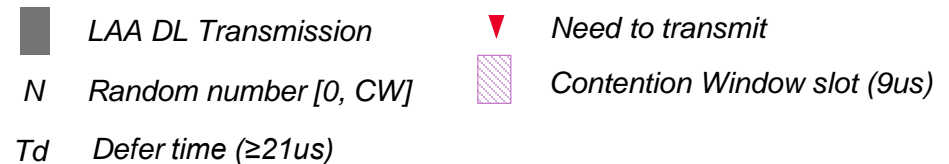
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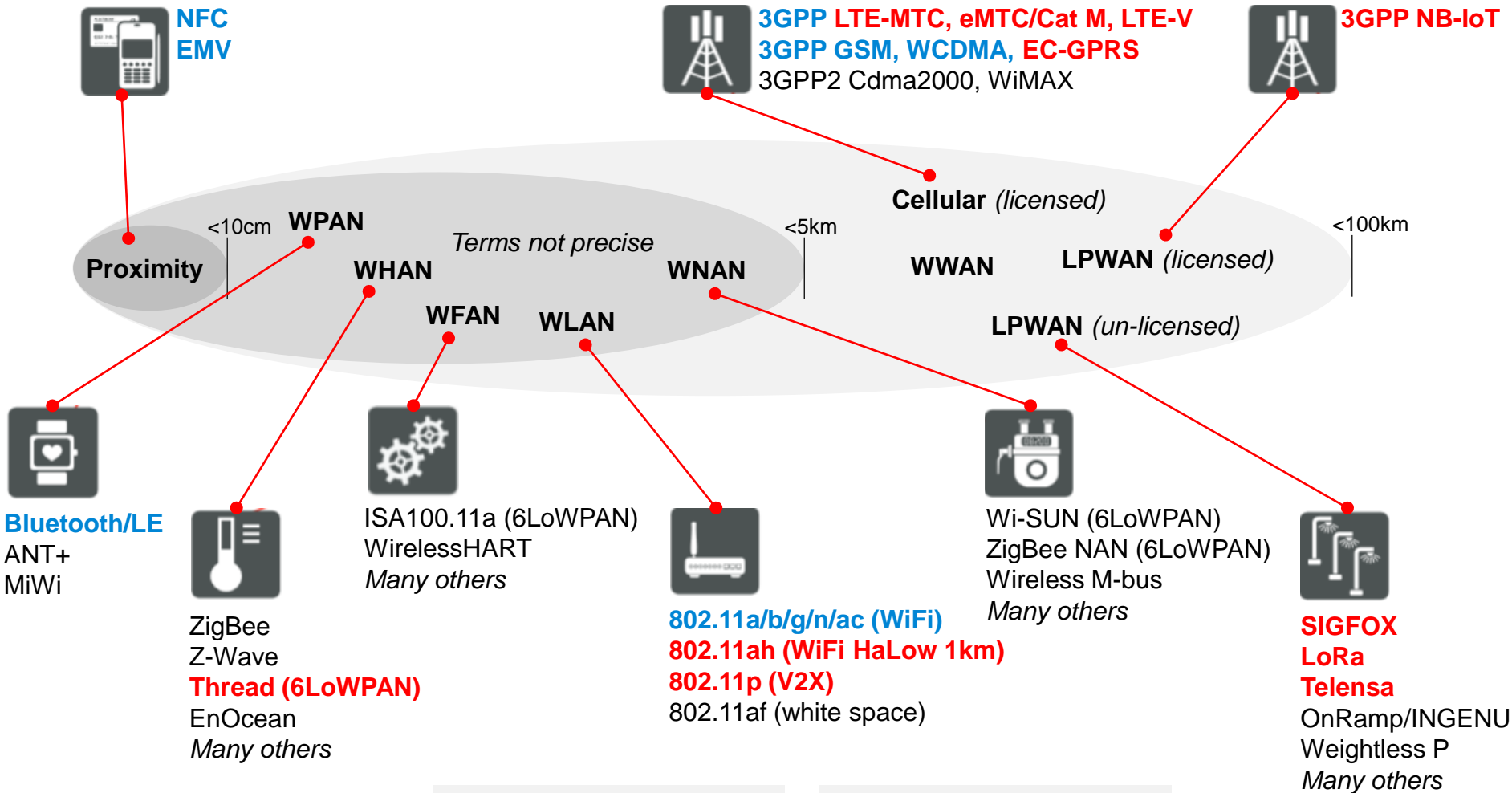
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IoT Radios



WPAN: Wireless Personal Area Network
WHAN: Wireless Home Area
WFAN: Wireless Field (or Factory) Area
WLAN: Wireless Local Area
WNAN: Wireless Neighbourhood Area
WWAN: Wireless Wide Area
LPWAN: Low Power Wide Area Network

Blue: > billion units/year now
Red: emerging

Keysight
Measurement
Forum

Narrowband Internet of Things (IoT) - NB-IoT

- Terms used interchangeably by different vendors to mean the same thing
 - LTE-M = LTE-MTC = LTE Machine Type Communication
 - NB-CIoT = “NB-OFDMA/NB-M2M merged proposal”
 - NB-LTE = LTE-NB = Narrow Band LTE
- Other terms
 - NB-CIoT = Narrow Band Cellular IoT
 - NB-IoT = Narrow Band IoT
 - CIoT = collective term for all GERAN clean sheet proposals for cellular IoT
 - EC-GSM = Enhanced Coverage GSM
 - NB-GSM = Narrow Band GSM
 - C-UNB = Collaborative Ultra Narrow Band (version of SIGFOX)
 - NB-CSS = Narrow Band Chirp Spread Spectrum (version of LoRa)
 - LTE eMTC = LTE Cat 0 evolutions for R13 (Cat M (CAT 00?) 200 kbps)

Evolution of MTC/CIoT in 3GPP towards NB-IoT

CIoT GERAN Clean sheet proposals

- NB-M2M (Neul-Huawei, u-blox, Ericsson, Samsung)
- NB-OFDMA (Qualcomm)
- C-UNB (derivative of SIGFOX)
- NB-CSS (Semtech, derivative of LoRa)
- **NB-CIoT** (NB-M2M + NB-OFDMA) (Qualcomm, Neul-Huawei, u-blox others)

GSM Evolution proposals

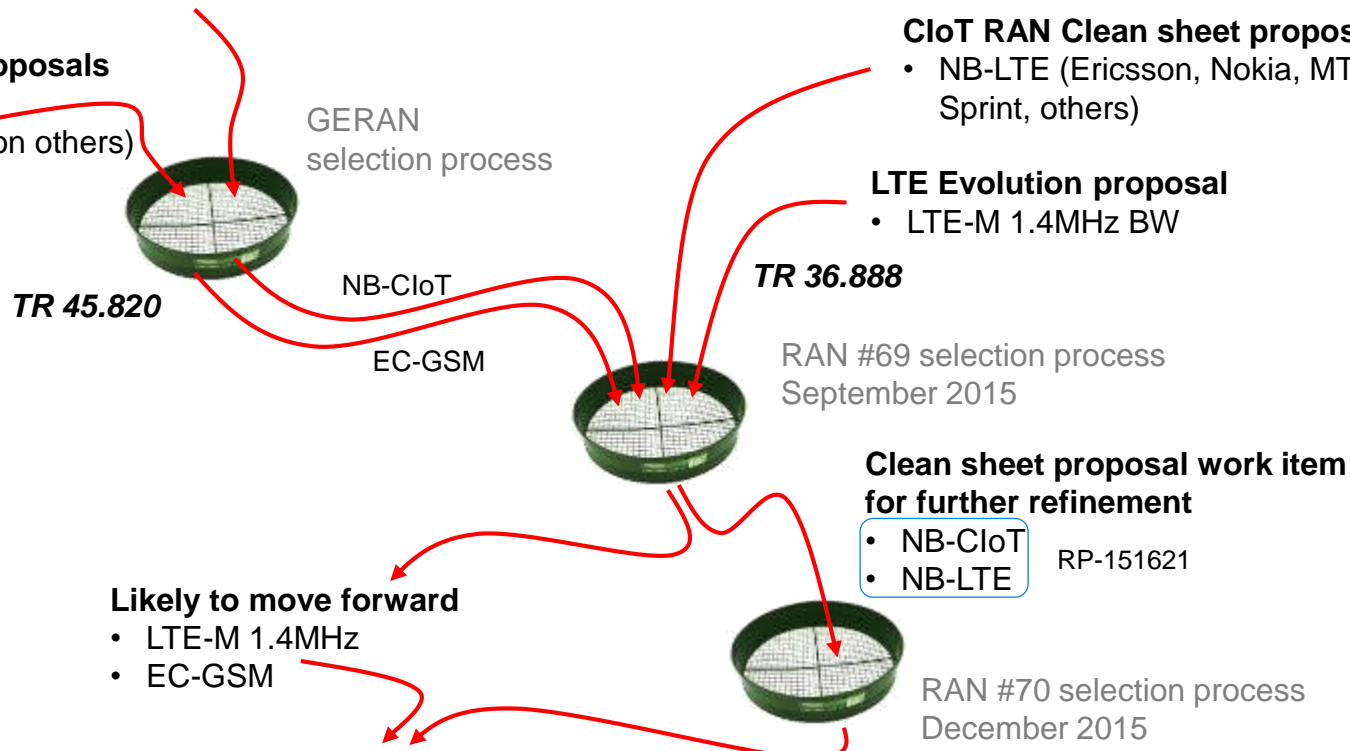
- NB-GSM
- **EC-GSM** (Ericsson others)

CIoT RAN Clean sheet proposal

- NB-LTE (Ericsson, Nokia, MTK, AT&T, Sprint, others)

LTE Evolution proposal

- LTE-M 1.4MHz BW



Likely to move forward

- LTE-M 1.4MHz
- EC-GSM

Output for R13 standardization

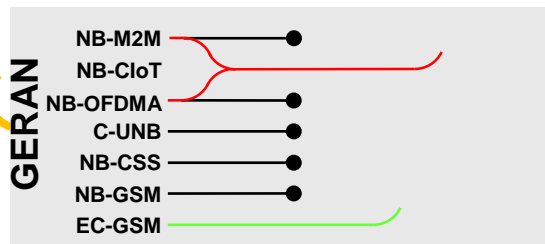
- LTE-M 1.4MHz
 - EC-GSM
- } Almost certain for Rel-13

- NB-CIoT
 - NB-LTE
- R13 spec June 2016, expect merged OFDMA DL and two separate UL TBC

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



2015

2016

2017

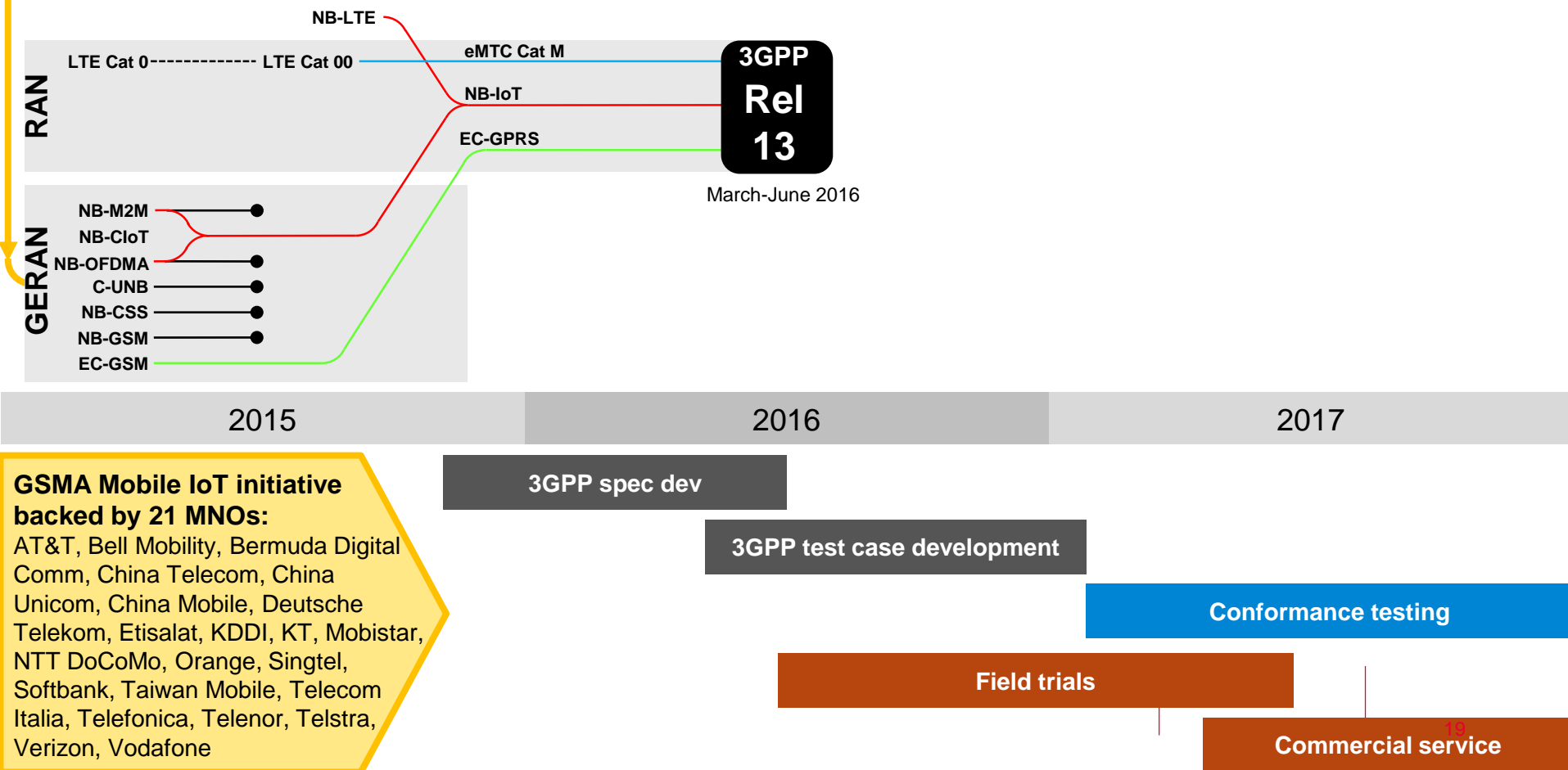
GSMA Mobile IoT initiative backed by 21 MNOs:

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

3GPP Release 13 Cellular IoT timelines

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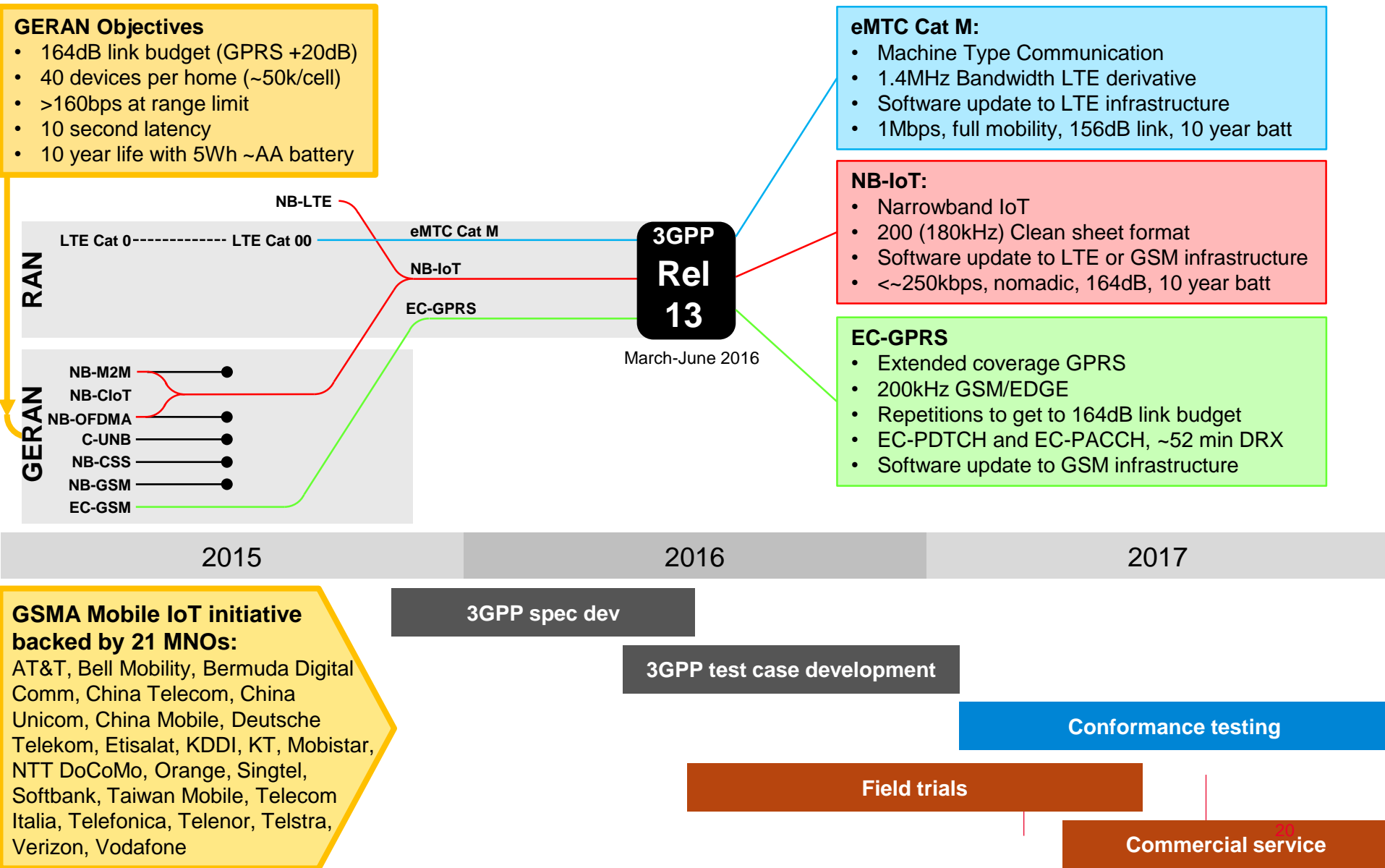
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3GPP Release 13 Cellular IoT timelines



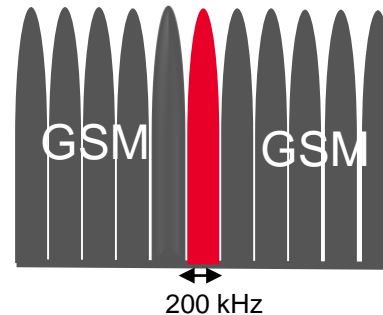
MTC/CIoT Physical Layer Parameters

	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 kbps, 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



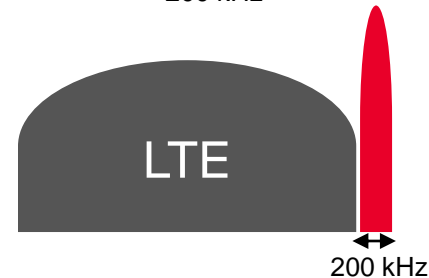
NB-IoT: Modes of Operation

- 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



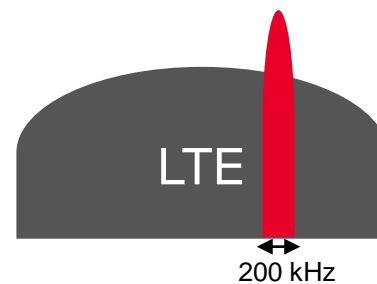
Stand-alone operation

- Utilizing dedicated spectrum. Example, re-farming GSM channels



Guard band operation

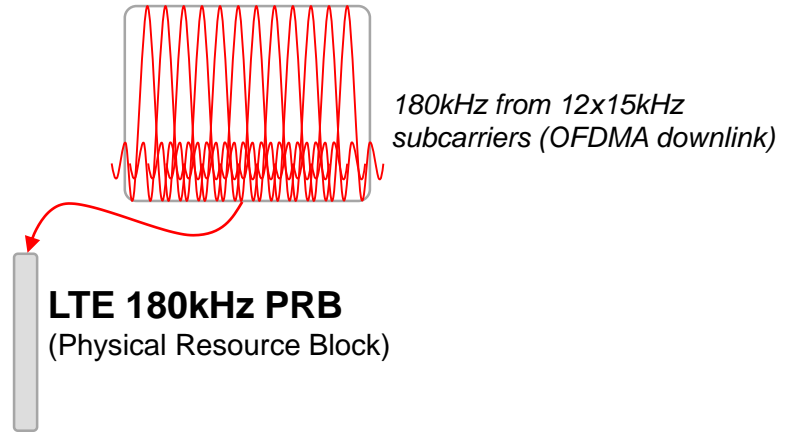
- Utilizing unused resource blocks within a LTE carrier's guard-band



In-band operation

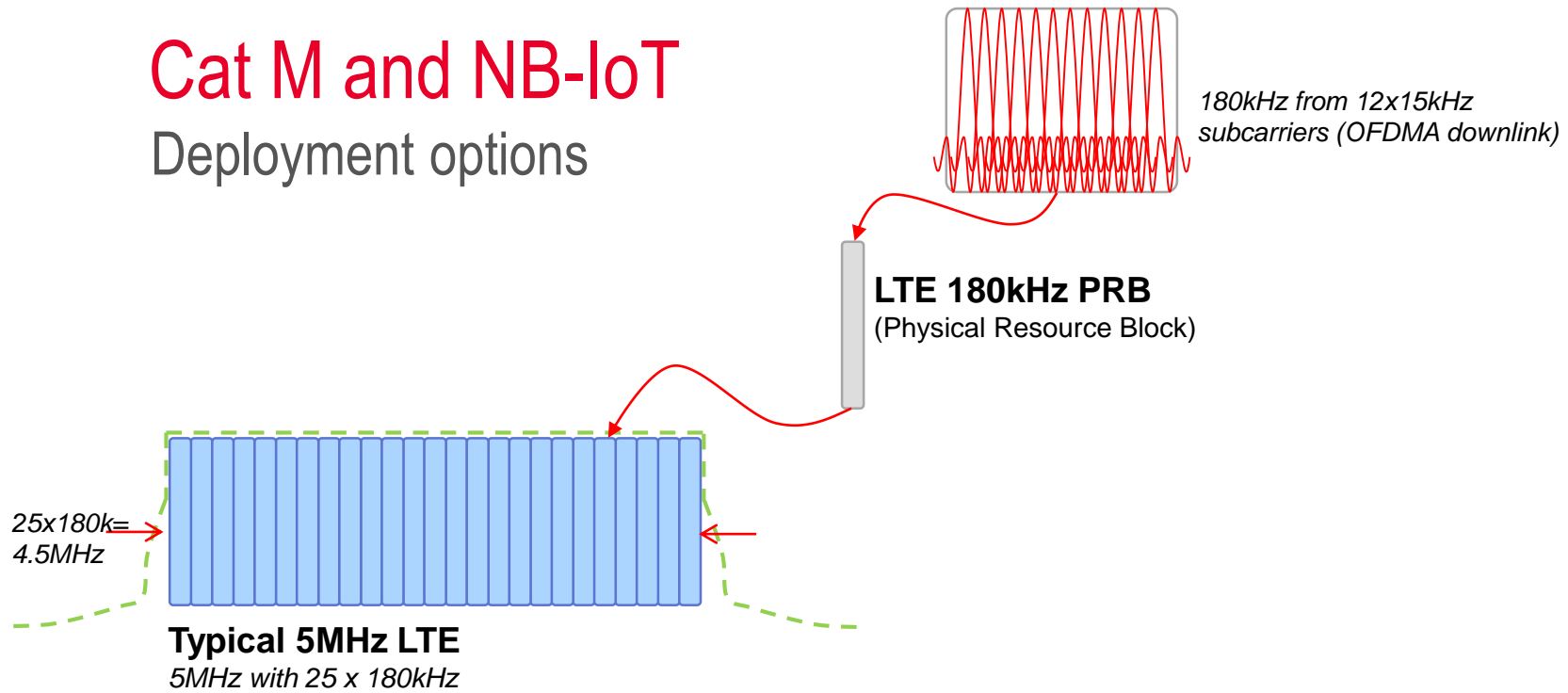
- Utilizing resource blocks within a normal LTE carrier

Cat M and NB-IoT Deployment options



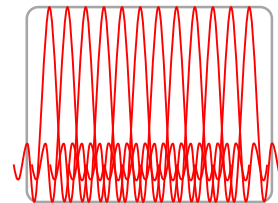
Cat M and NB-IoT

Deployment options

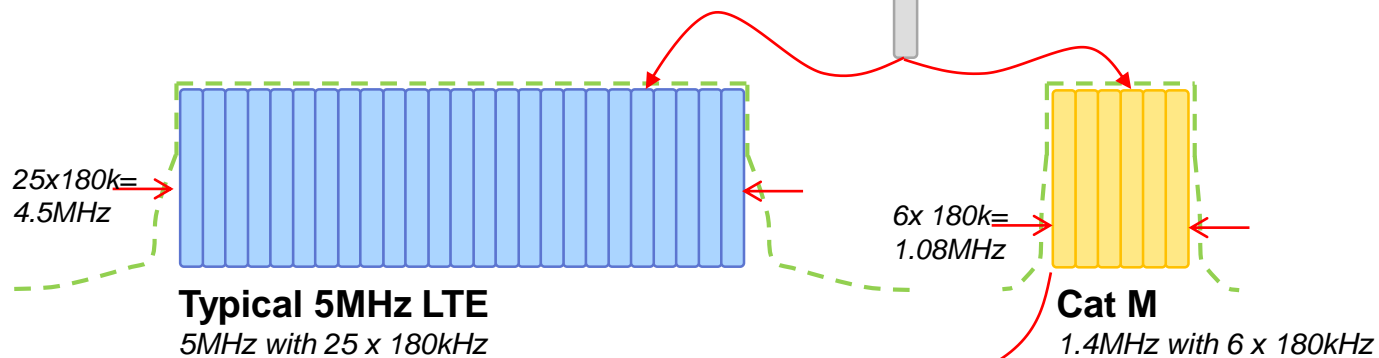


Cat M and NB-IoT

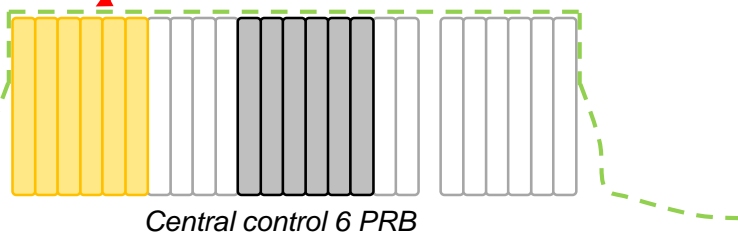
Deployment options



LTE 180kHz PRB
(Physical Resource Block)

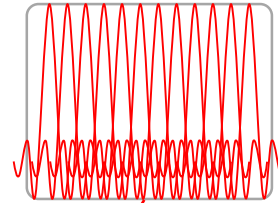


Cat M in-band with LTE

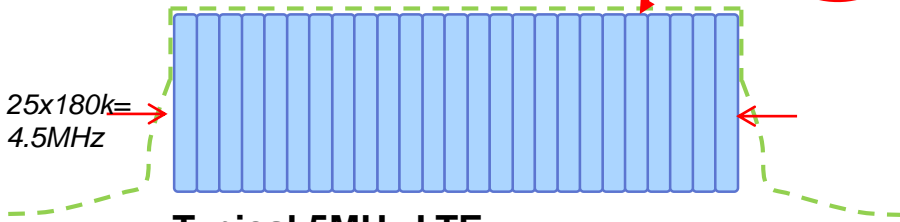


Cat M and NB-IoT

Deployment options



LTE 180kHz PRB
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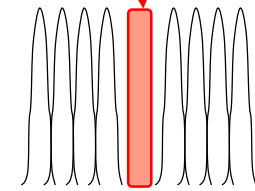
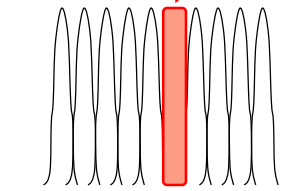
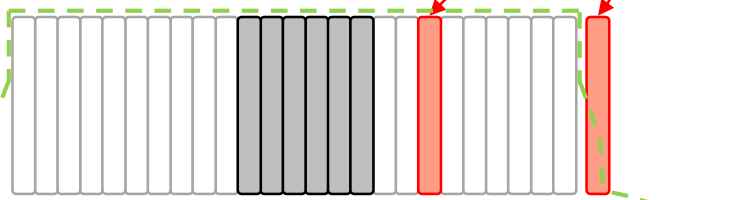


Typical 5MHz LTE
5MHz with 25 x 180kHz



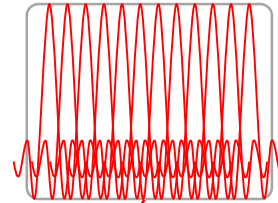
Cat M in-band with LTE

NB-IoT in-band with LTE

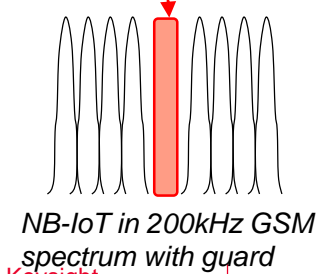
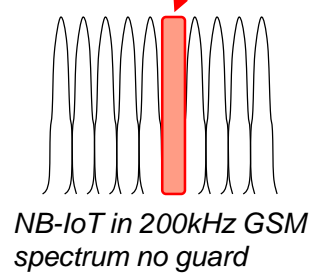
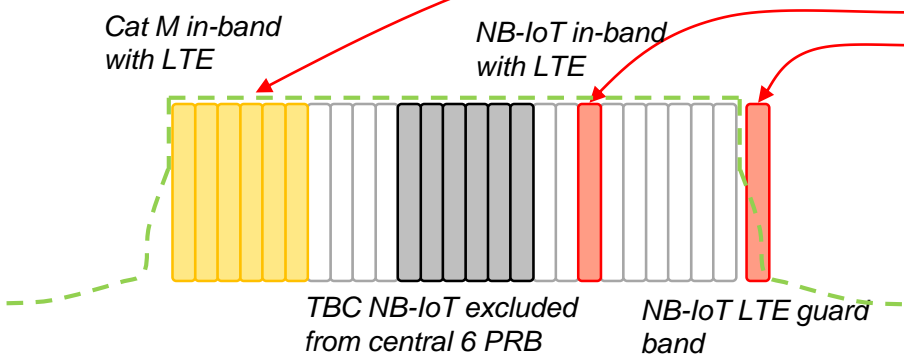
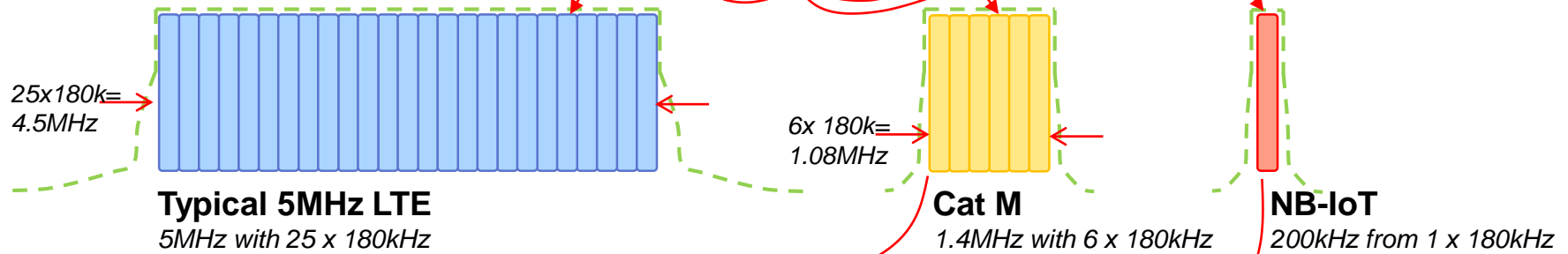


Cat M and NB-IoT

Deployment options

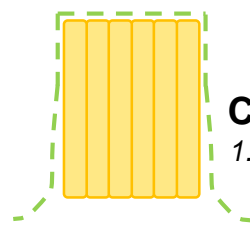


LTE 180kHz PRB
(Physical Resource Block)



Cat M

3GPP R13



Cat M
1.4MHz from 6 x 180kHz

Close to standard LTE including full mobility

~ 15dB Coverage enhancements over standard LTE

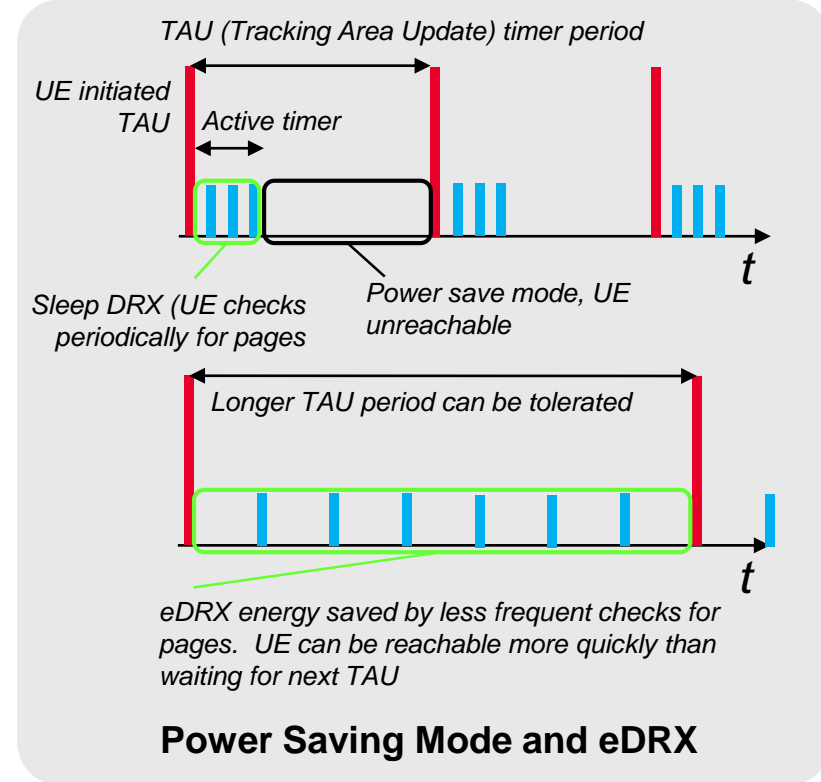
- Frequency hopping
- PSD (Power Spectral Density) boosting
- TTI bundling or repetition (redundant transmission)
- Multi-subframe channel estimation

Power and complexity savings

- Fewer supported transmission modes
- Reduced max Tx power (20dBm power class)
- Reduced measurement reports
- PSM (R12 Power Saving Mode) & eDRX (R13 extended Discontinuous Reception)
- C-eDRX (Connected mode eDRX 5.12 and 10.24 second cycles)
- I-eDRX (Idle mode eDRX ~44 minute cycles)

Deployable in any 6PRB group e.g. of a 20MHz channel

- New M-PDCCH similar to EPDCCH (Physical Dedicated Control Channel)
- UE uses 6 central PRBs for synchronization & PRACH then re-tunes to another 6PRB frequency range for follow-on control messages
- No support for PDCCH, PCFICH, PHICH



NB-IoT

3GPP R13



Clean-sheet design though leverages significantly from LTE Cat M but with nomadic mobility only

- Coverage enhancements (~23dB improvement over standard LTE)
- Downlink leveraged from 1 LTE PRB
- Uplink: LTE-like 15kHz subcarrier multi-tone SC-FDMA, single tone 15kHz FDMA or 3.75kHz FDMA
- R13 standardization focussing on FDD, TDD could be added later

Power and complexity savings

- RLC-Transparent Mode and simplified RLC-Ack' Mode only (TBC no RLC-Unack' Mode)
- Downlink TBCC (tail biting convolutional code) – easier to decode than LTE turbo-codes
- Half-duplex only
- Control plane (CP) data transmission (inside RRC/NAS messages) as a lower overhead alternative to full DRB IP user plane (UP) data transmission
- C-eDRX (Connected mode eDRX 5.12 and 10.24 second cycles)
- I-eDRX (Idle mode eDRX ~3 hour cycles)

New NB channels

Downlink:

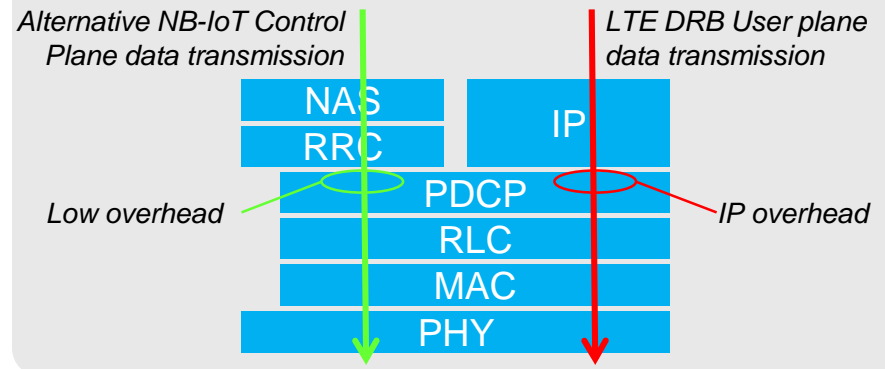
- **NPBCH** (physical broadcast channel)
- **NPDSCH** (physical downlink shared channel)
- **NPDCCH** (physical downlink control channel),
- **NRS** (Narrowband Reference Signal)
- **NPSS/SSS** (primary and secondary synchronization channels)

Uplink:

- **NPUSCH** (Narrowband Physical Uplink Shared CHannel),
- **NPRACH** (Narrowband Physical Random Access CHannel),
- **DMRS** (demodulation reference signal)



Control plane and user plane data transmission



Licensed and unlicensed examples

	SIGFOX	LoRaWAN	NB-IoT	Cat M	EC-GPRS
Release	Now	Now	H2 2016	H2 2016	H2 2016
Link budget	~162dB	~157dB	~164dB	~156dB	~164dB
Battery life	>10 years	>10 years	>10 years	>10 years	>10 years
Spectrum	un & lightly-license bands e.g. 868, 915 MHz	un & lightly-license bands e.g. 169, 433, 470, 868, 915 MHz	GSM & LTE Licensed bands	LTE Licensed bands	GSM Licensed bands
Rates and modulation	Uplink: 100bps BPSK 100 Hz BW Downlink: 500bps GFSK 600Hz BW	GFSK, CSS (Chirp Spread Spectrum) ~0.3 to 50kbps 125kHz BW	Up to ~250kbps Uplink /4-QPSK, rotated $\pi/2$ BPSK, 8PSK, opt 16QAM Downlink BSK-16QAM 180kHz BW	1Mbps QPSK, 16 or 64QAM 1.4MHz BW	~10 to ~240kbps GMSK, opt 8PSK, 200kHz BW
Silicon	Multi-vendor	Semtech (2 nd vendor announced)	Multi-vendor	Multi-vendor	TBC
Protocol	SIGFOX	Semtech (2 nd vendor announced)	3GPP Multi-vendor	3GPP Multi-vendor	3GPP Multi-vendor
Certification	SIGFOX	LoRa Alliance	GCF/PTCRB TBC	GCF/PTCRB TBC	GCF/PTCRB TBC

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The path to the future

Dramatic change from LTE/LTE-A to LTE-A Pro



The Trend:

- **Operators are seeking higher speed up to 1Gbps and beyond**
 - Retain end users, improve data experiences
 - Increase average revenue per end user
- **3GPP standards to compete in IoT market**
 - From infrastructure to devices
 - Sensors into smartphones and “ALL Things”

Release 13 and beyond



**MTC
enhancements**



**MIMO
enhancements**



**Public safety
D2D**



**Un-licensed spectrum
Wifi coexistence**

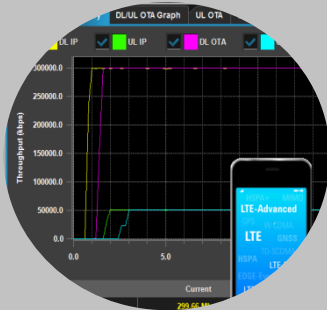


**More
Carrier Aggregation**

Make a Clear Call

Assess design readiness with greater confidence

Gain New Insights for LTE-A Pro



- Sustained 1Gbps* data
- Flexible emulation
- Trusted RF test

Be Ready for 4G and Beyond



- Future-ready platform
- Integrated fading/MIMO
- Versatile touch screen

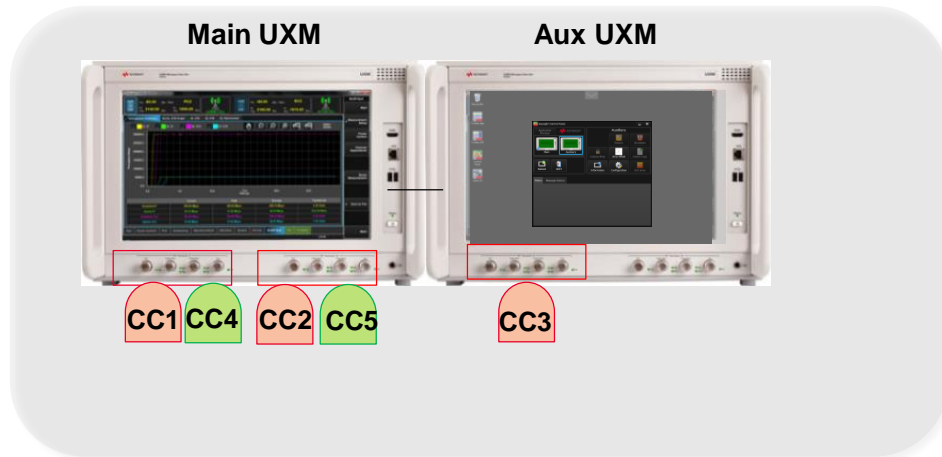
Make a Seamless Transition



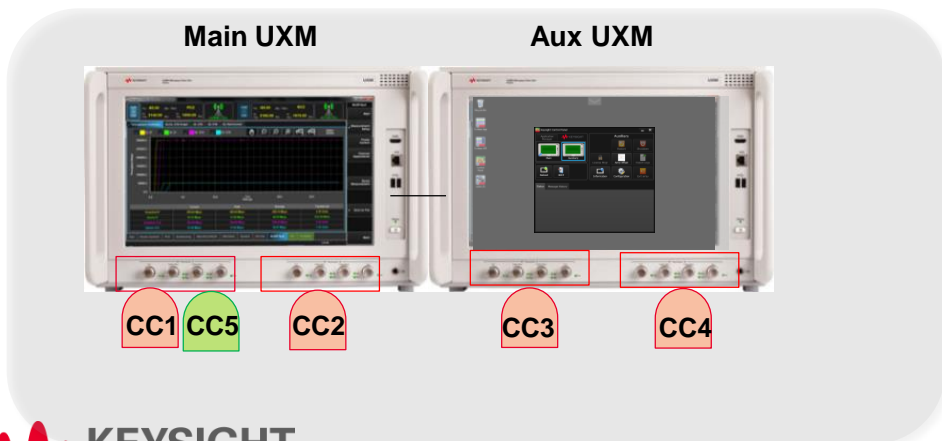
- 2G/3G/4G Multi-format
- Compatible SCPI
- Investment protection

LTE-Advanced Carrier Aggregation

World's first solution to support 5CC



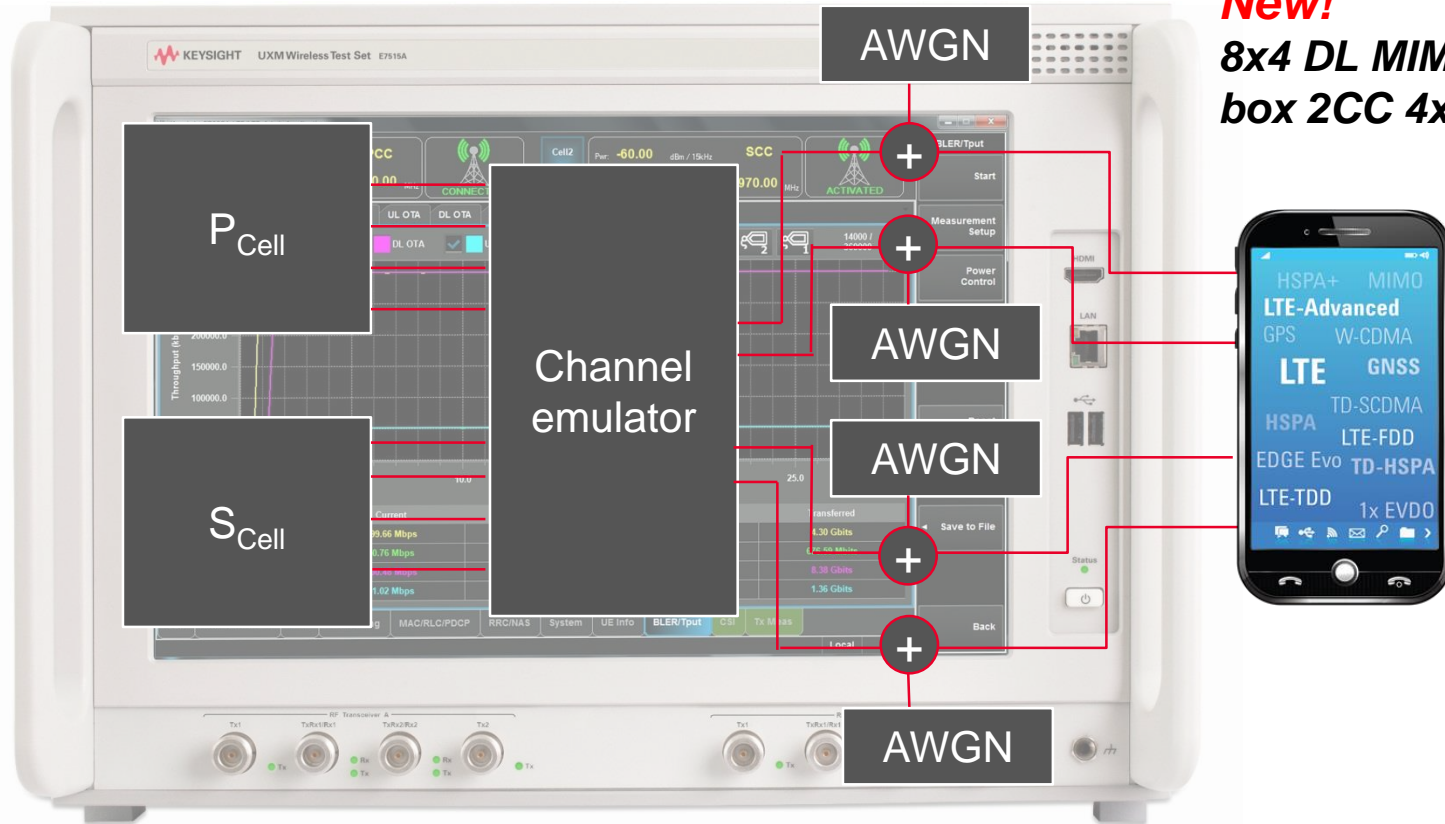
- A 3-TRX UXM array support up to 2 floating cells(CC4 and CC5)
- DL frequency offset between these two CCs hosted on each TRX is within 80MHz
- CC4 and CC5 can be hosted on any of the TRXs



- A 4-TRX UXM array support up to one floating cell(CC5)
- DL frequency offset between these two CCs hosted on each TRX is within 80MHz
- CC5 can be hosted on any of the TRXs

Assess Chipset and UE Performance

Emulate network and channel to fully assess your design



New!
8x4 DL MIMO and one-box 2CC 4x4 DL MIMO

Example Test Setup: LTE-A with 2CC, 4x4 DL MIMO, fading, AWGN
Offset frequency for Cell 1/Cell 2 within 80MHz
Fading support Bypass and static MIMO only

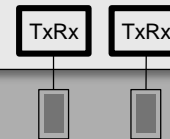
Dual Device Test

2-phone parallel RF test, end-to-end VoLTE/data connections, dual-SIM

- 2-phone parallel RF test is included in the base test applications.
- E7515A-D01 Dual IP Device Test license enables two IP connections on a single UXM.
 - Applications:
 - End-to-end VoLTE or end-to-end IP data connections
 - Dual-SIM testing (LTE+2G/3G)
 - Presence of –D01 doubles the TA licenses on that UXM
(base TAs and feature options)

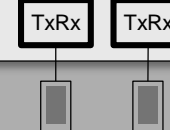
Parallel LTE RF Test

E7530A-1FP-xDD
-504/6, -C01, -L01



E2E VoLTE*

E7530A-1FP-xDD
E7515A-D01
-504/6, -C01, -L01



LTE + 2G/3G Dual-SIM*

E7530A-1FP-xDD
E752xA-1FP
E7515A-D01
-504/6, -C01, -L01



Agenda

- Release 13 Overview
- LAA
- eMTC and NB-IOT
- E7515A UXM Platform
- **E7515A UXM LTE/LTE-A**
- Summary

What's New in UXM Release 1.4

LTE/LTE-A LA and TA

3CC + 256 QAM 587.5 Mbps DL

Ensure device performance at max data rates

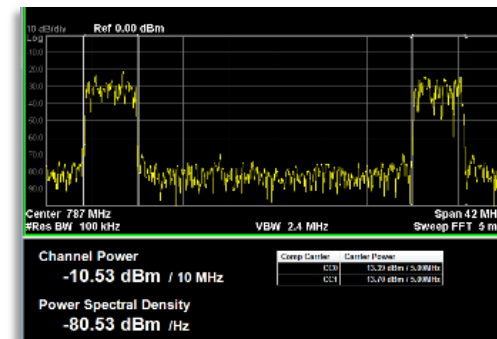
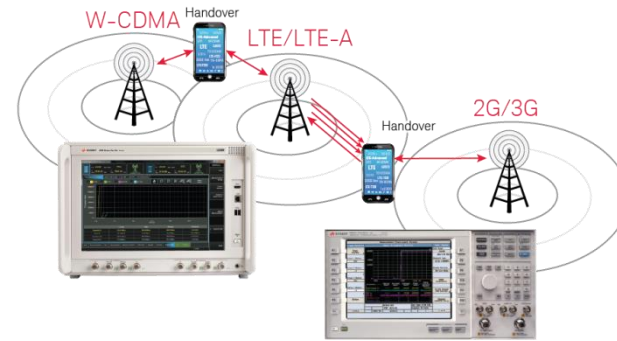
- FDD 4CC DL (*cat 11/12: 600Mbps/100Mbps*)
- TDD 3CC/4CC DL (*cat 9-12: up to 526Mbps/61Mbps*)
- 256 QAM DL (*3CC FDD 587Mbps, 3CC TDD 503Mbps*)
- FDD-TDD mixed CA
- LTE-U

Go deeper in functional test

- LTE / W-CDMA interRAT handovers and mobility in one UXM
- 2CC, 3CC, and 4-cell handovers
- Time-aligned multi-format logging
- Cat 0 (M2M)

Achieve greater confidence in RF performance

- Inter-band UL CA Tx measurements
- 6.3.5.2 Power Ctrl Relative Power Tolerance



What's New in UXM Release 1.5

LTE/LTE-A Test Application

Ensure device performance at max data rates

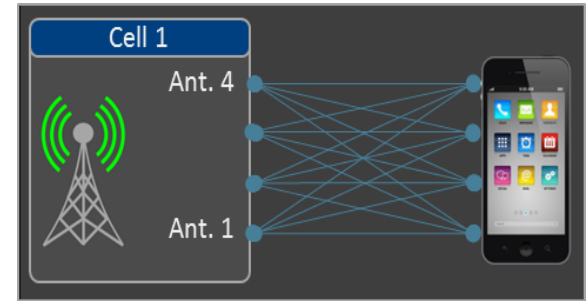
- FDD/TDD 4x4 DL MIMO
 - 1CC 4x4 DL MIMO with 1 UXM
 - 2CC CA 4x4 DL MIMO with 2 UXMs
- Full IP data rate cyphering up to 600/50Mbps

Go deeper in functional test

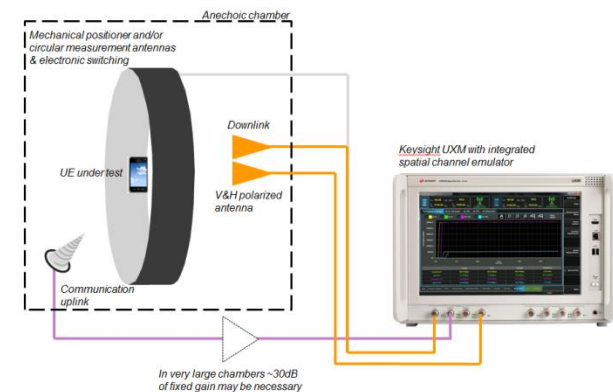
- Transmission Mode 9
 - CSI RS port selection
 - Layer/codeword number selection
 - Beamforming model selection

Achieve greater confidence in RF performance

- Suitable for use in OTA test (SISO & MIMO)
- Integrated fader now supports spatial channel models (SCME UMi, UMa)
- Special features to enable RTS MIMO OTA



LTE FDD 4x4 MIMO+ TM9 1CC + 64QAM DL ~224.8Mbps (theoretical)



In very large chambers ~30dB of fixed gain may be necessary

What's New in UXM Release 1.6

LTE/LTE-A Test Application

Ensure device performance at max data rates

- Beyond 1Gbps E2E data throughput
 - 5CC in 4 bands within 2 UXMs
 - 4CC in 2 bands with 1 UXM
 - Higher order MIMO (8x4 and 8x2 DL)

Go deeper in functional test

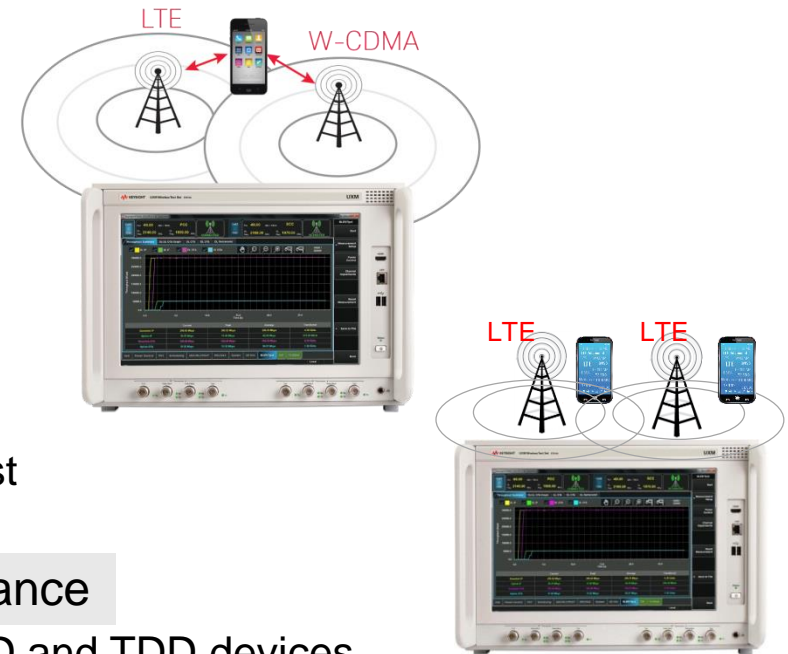
- WLAN Offload/WLAN Calling
- E2E VoLTE calls with 2x UEs in one UXM
- Integrated IMS and dedicated bearers
- More mobility
 - W-CDMA to LTE PS handover
 - LTE to TD-SCDMA PS handover and CSFB
 - LTE to GSM CSFB and SRVCC
- New battery saving in DRX for battery drain test
- DRX, CSI settings change while call is up

Achieve greater confidence in RF performance

- Dual device/parallel testing of multi-format FDD and TDD devices
- Integrated CW interferer



1.6Gbps data throughput with LTE-A 4CC CA with 4x4 DL MIMO from simulated UE



The path beyond 1Gbps

E7515A UXM Wireless Test Set



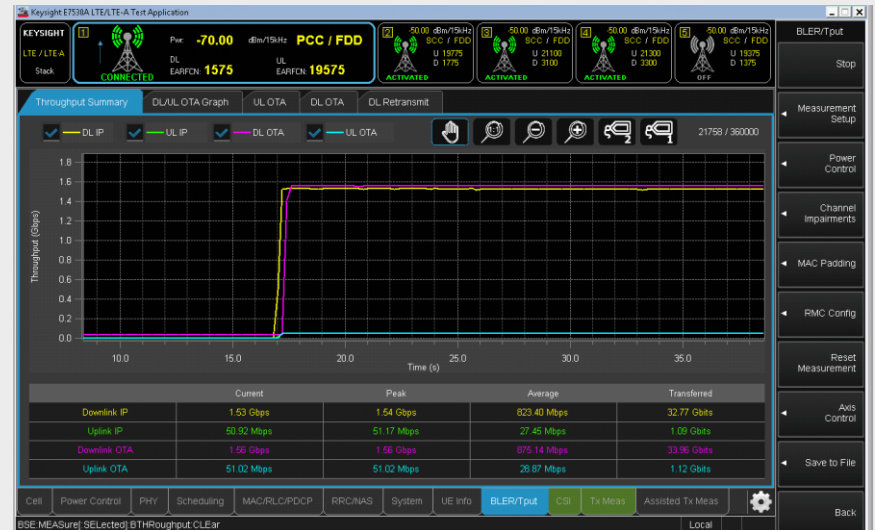
A validated solution

- **Industry Leadership:** Joint validation and commercialization
- Mobile Industry Milestone: **1Gbps IP Data Throughput**
- Qualcomm Snapdragon X16 LTE modem
- 4x4 MIMO w/ Carrier Aggregation & 256QAM Downlink



Future-ready capabilities

- **1.6Gbps** IP data throughput with LTE-A 4CC CA and 4x4 DL MIMO (with simulated uplink)
- World's first benchtop solution capable to support **5CC**



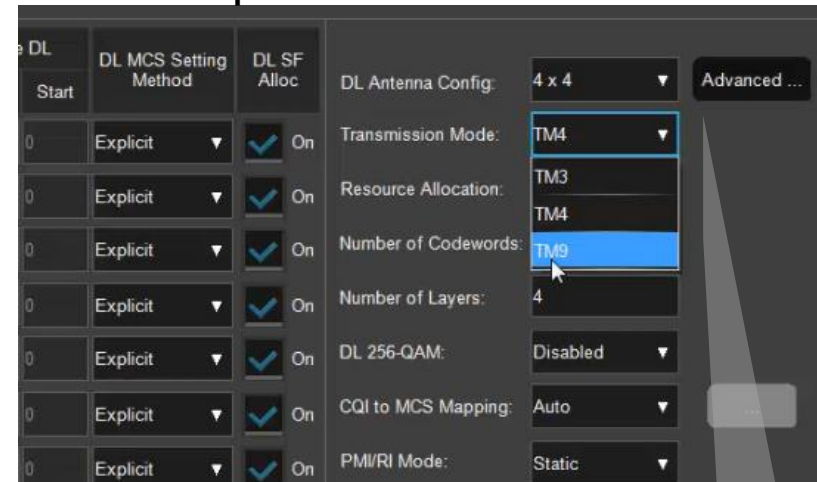
End-to-End IP Data Throughput – with Transmission Mode

Ensure realistic data performance

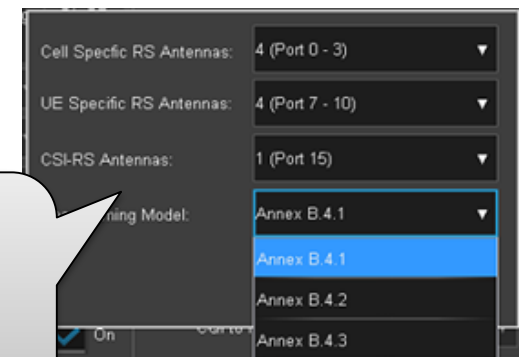
Set up channel conditions including MIMO, Transmission Mode, MCS all in one UI

- Spec supports up-to 8 layers (8x8)
- UXM supports 8x2/ 8x4 (*new at 1.6 release*)
- Includes UE specific RS supporting 8 layers for beamforming (4 supported in the UXM)
 - Supports both SU and MU-MIMO (UXM supports SU only)
 - CDM is used to separate MU-MIMO reference signals
- Includes CSI reference signals
- New DCI format – format 2C
- Closed loop PMI (*new at 1.6 release*)
- Codebook Subset Restriction controls (*new at 1.6 release*)
- Change TM “on fly”, while UE connected

Up to 8x4 DL MIMO and TM9



Advanced



“Advanced” button gives:

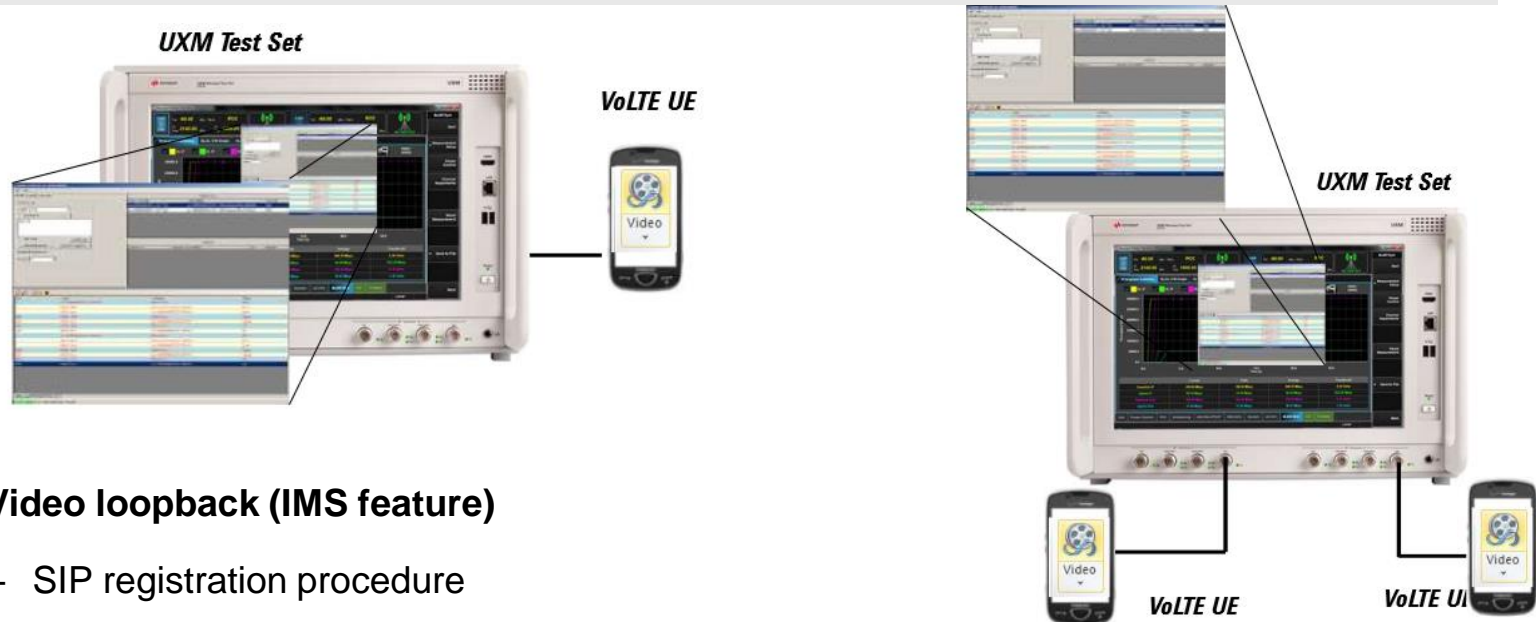
Selectable 3GPP 36.521 Annex B.4 Beamforming models

Selectable port numbers

IMS/VoLTE

Go deeper in functional test

VoLTE - Voice/Video Loopback Test Solution



Video loopback (IMS feature)

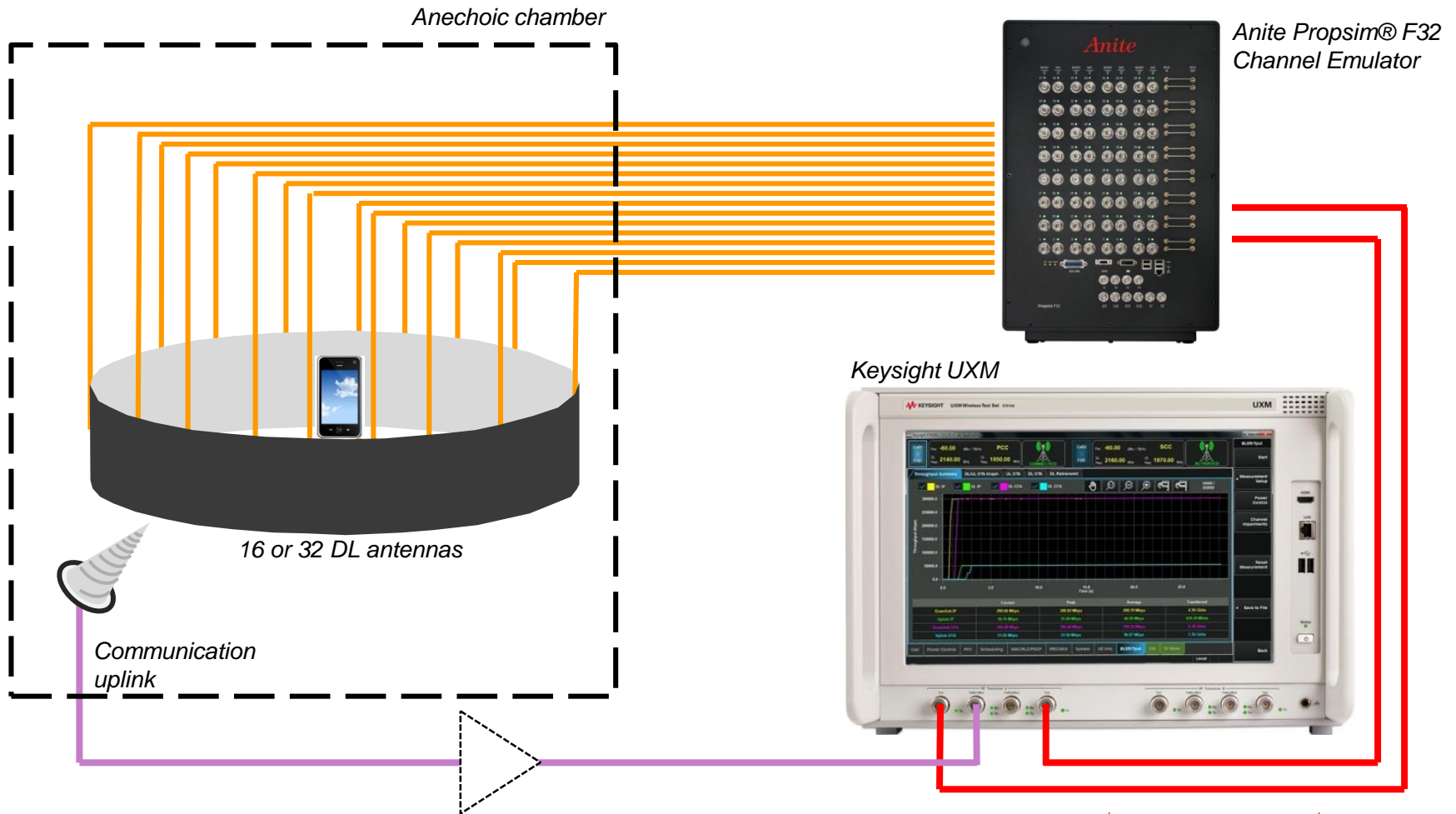
- SIP registration procedure
- Negative registration processes
- Test call set up
- Soft client must enable loopback
- Not a quality measurement

E2E two-phone VoLTE test

- UE to UE interaction
- Test with reference/commercial phones
- Two UEs with different SIMs(Identities) if registered on same IMS server

MIMO OTA test with UXM

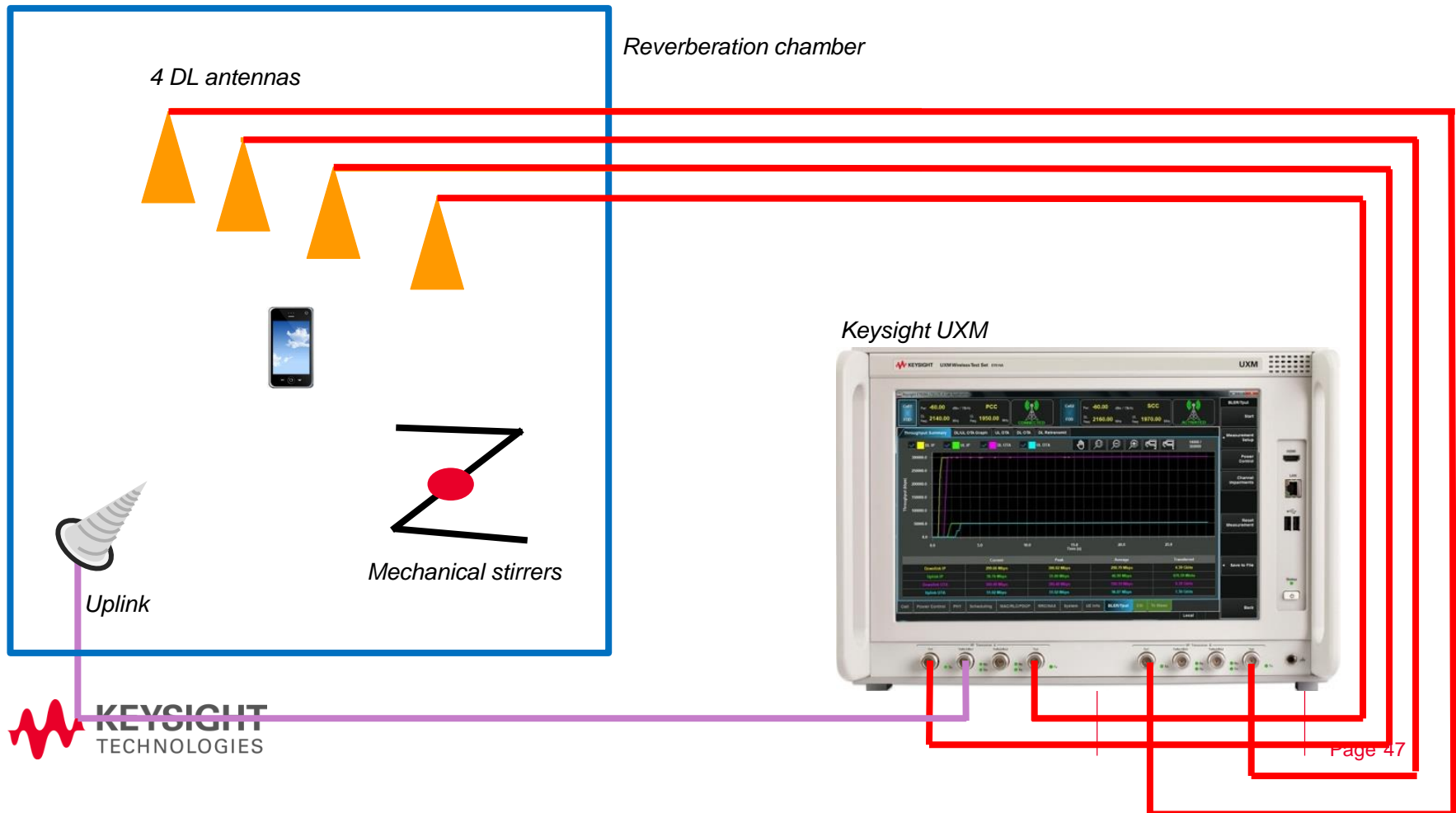
Typical multi-probe MIMO OTA system



MIMO OTA test with UXM

Typical RC + CE MIMO OTA system

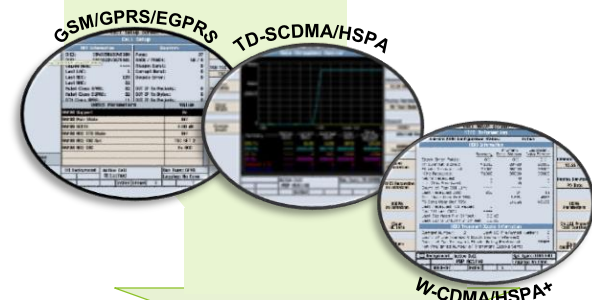
2x2 or 4x4 MIMO 1*CC using internal RF Fading



E7515A UXM Wireless Test Set

Release 1.6: Now with 2G and 3G

- Leveraging the industry-standard 8960 (E5515C/E)
- Experience the 8960's reliable performance over a broad range of capabilities...
 - RF test with Keysight's X-Series (UE Tx) and familiar 8960 measurements (UE Rx)
 - Advanced data throughput test
 - Functional and RF test with signaling including voice and data
- ...with the power of the UXM platform:
 - Integrated fading and noise
 - LTE/2G/3G mobility and dual device testing in one box
 - 15" touch-screen color display
- Add GSM, TD-SCDMA and W-CDMA to your existing UXM with a simple software upgrade
 - Get credit for your 8960 software investment with an equivalent seat license (ESL) on the UXM



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- **Summary**

E7515A UXM... Make a Clear Call

Assess design readiness with greater confidence

Cell Emulation

- 4CC in one box, 5CC in two boxes
- 8x4 DL MIMO, 256QAM
- Transmission mode
- Downlink channel power
- Internal fading



Use Model Flexibility

- Modern touch UI
- Full remote desktop support
- LAN-based programming interface



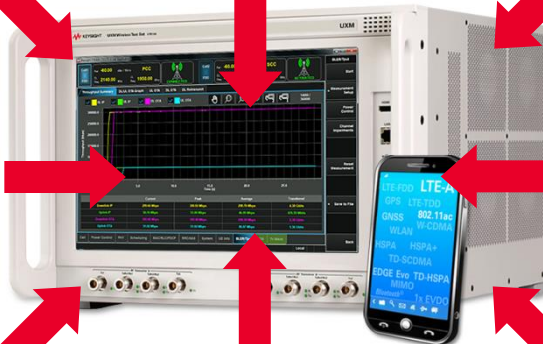
Functional Test

- Robust E2E IP
- Handover testing
- Battery life testing
- Message Editor scenario creation + Wireshark protocol logger



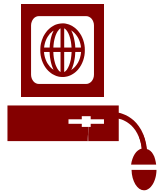
UL RF Measurements

- Trusted X-Series Measurements
- Test per the specification or explore beyond
- UL CA measurement support



Integrated Applications Server PC

- IP Throughput
- VoLTE/ IMS testing support
- ftp



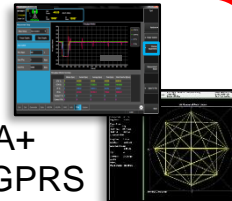
DL Rx Measurements

- BLER/Tput/CSI Testing
- Closed loop CQI
- Complete scheduling flexibility



Multi-format

- LTE, LTE-A
- W-CDMA/HSPA+
- GSM/GPRS/EGPRS
- TD-SCDMA/HSPA



CA & Multi-Cell Support

- FDD/TDD for 3CC/4CC/5CC
- Up to CAT16
- LTE-U
- 5 cells for intraRAT/interRAT handover/mobility and FeICIC



Q and A Session

