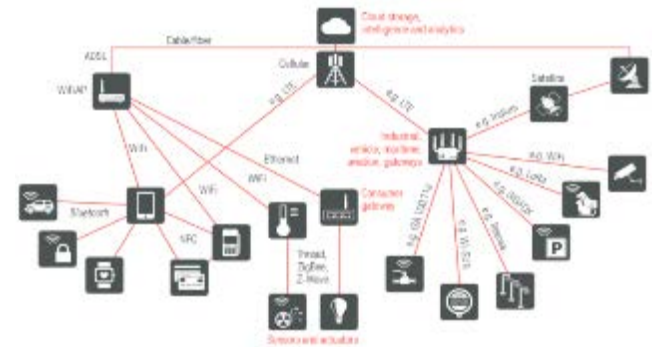


Philip Chang  
Keysight Technologies



# LPWAN & the Internet of Things

## Agenda

**I. IoT and LPWAN**

**II. 3GPP Cat M & NB-IoT**

**III. Test Challenge & Solution**

# IoT Market Predictions

**>30B Connected devices by 2020**

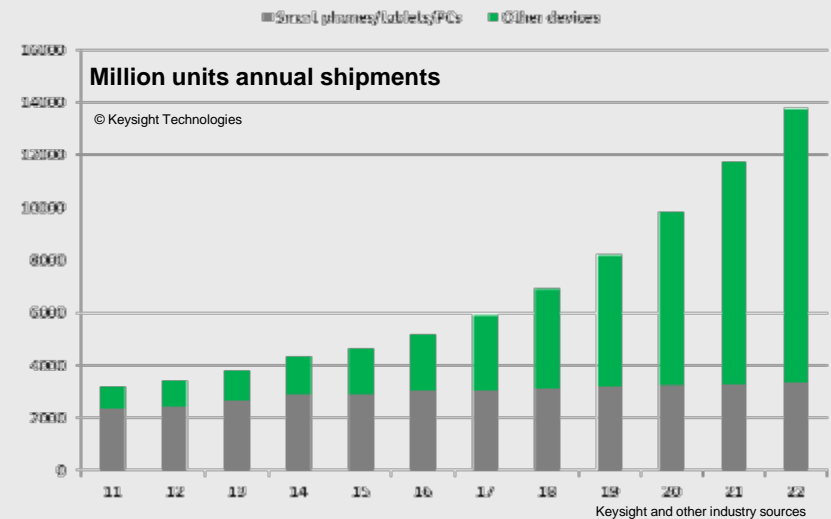
*ABI Research*

**50B devices will be connected by 2020**

*Cisco*

**95.5B connected devices by 2025**

*IHS Technology*

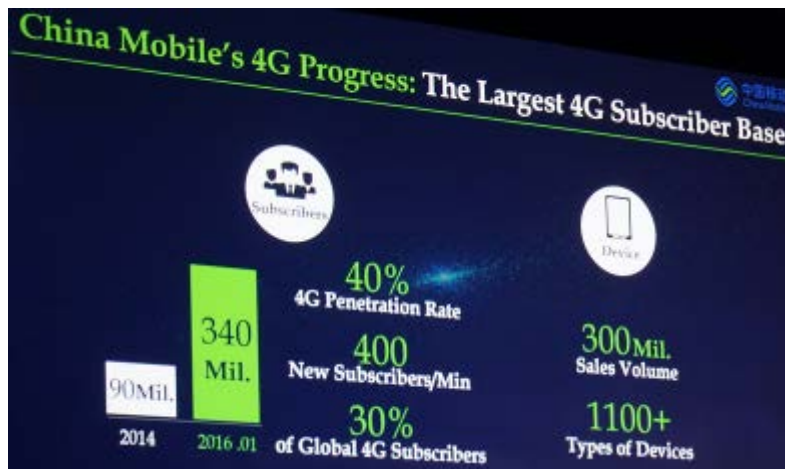


**“90% of all Samsung’s products will be IoT devices by 2017, and 100% by 2020”**

*BK Yoon Samsung Electronics President and CEO*

# GTI 2.0啟航 加速推動LTE應用服務與擴大LTE-A Pro發展資源為其重要的工作目標

**GTI 1.0** (2011年~2015年)



**GTI 2.0** (2016年~)



A1s

N2

A2

VoLTE  
RCS

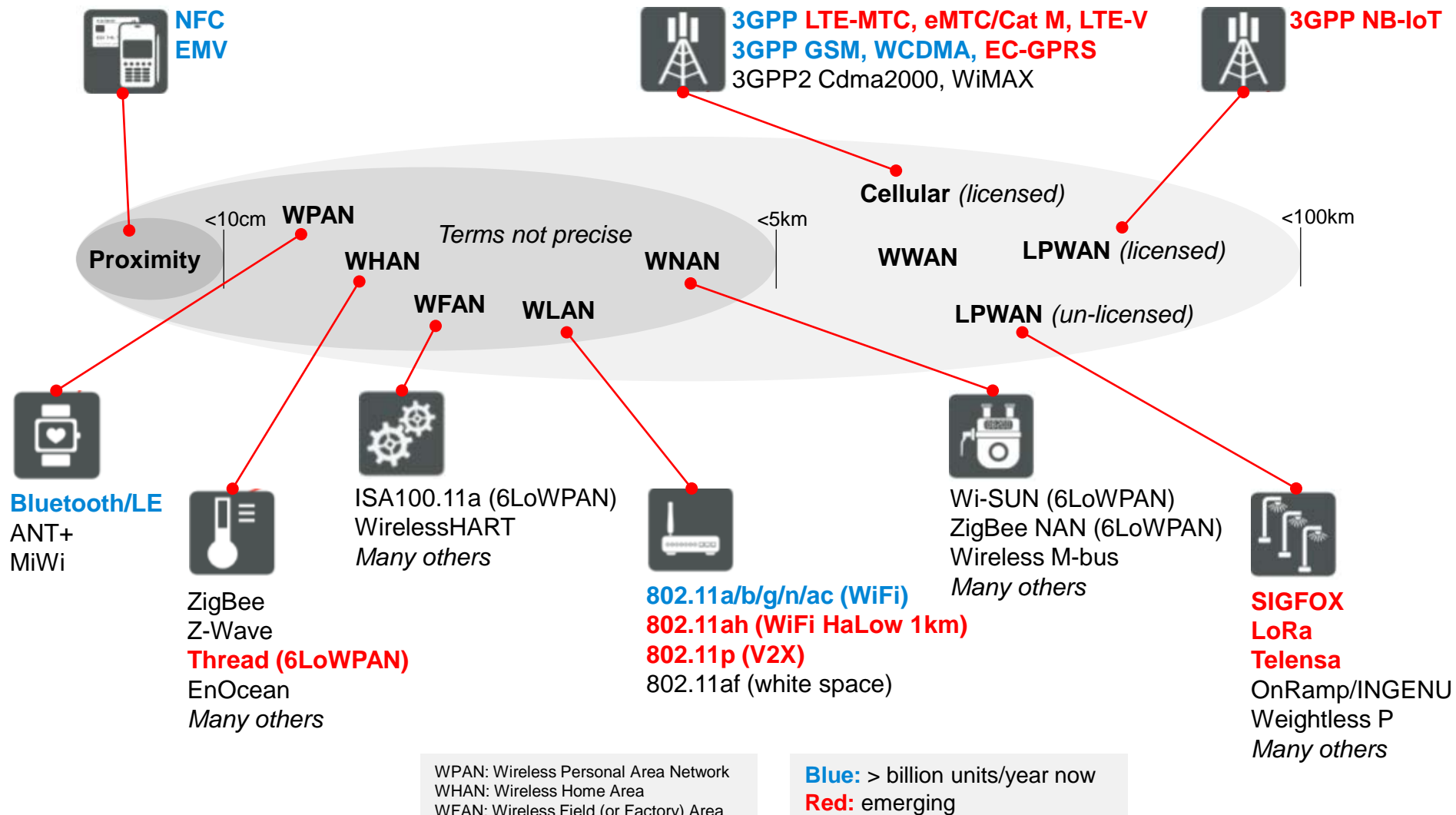


推動 TDD 4G  
Plus技術過渡到  
5G世代



推動NB-IoT  
於2017年實  
現商用化

# IoT Radios



# Low Power Wide Area (LPWA)

**Narrow band + Robust modulation =**

- 20dB better link budget than cellular
- 10 year battery life, Very low data rates

## Typical applications

**Street lighting** (**Telensa** widely deployed)

**Parking** space occupancy sensors

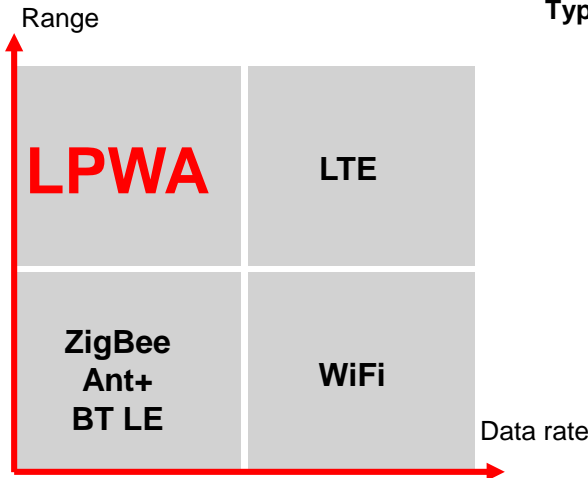
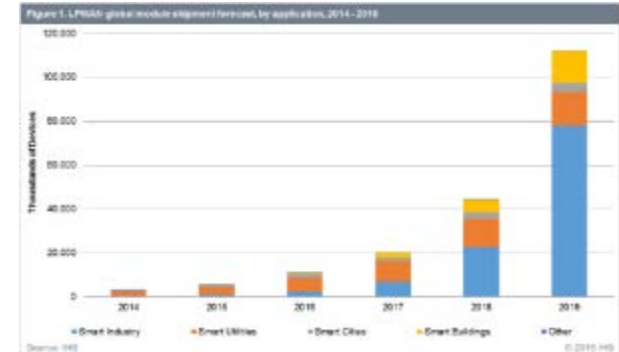
**Burglar alarm** back-up (cellular jammers widely available)

**Social housing** use cases (e.g. smoke alarm and energy credit policing **SIGFOX** in UK)

**Pet tracking**

**Garbage collection** bin fill level for pick up route optimization (**LoRa**)

**Agricultural sensors** **Forest fire detection**



## Coverage pools

## Region coverage

## Global coverage



Street lighting



Social housing monitoring



Fire detection

Parking sensor



Trash collection



Soil moisture

Pet tracker



Bag tracker



Bike tracker



Embedded asset status

Capital asset Meter



# Wide area networks

## Technology Trade-offs



### Pros:

- Long range
- **Long battery life (up to 20 years)**
- **Low cost**

### Cons:

- New standard
- Unlicensed band - interference
- **Can't run on existing cellular network** – needs a dedicated SIGFOX network
- Very low data rate - can only be used for IoT



### Pros:

- Long range
- **Long battery life (>10 years)**
- **Low cost**
- Uses **cellular network as backhaul**

### Cons:

- New standard
- Unlicensed band - interference
- Very low data rate – can only be used for IoT



### Pros:

- **Well established standards**
- Long range
- High data rate
- Very wide coverage
- Licensed band (except LTE-U)

### Cons:

- Not optimized for IoT
  - **Battery life**
  - **Cost**



# LPWAN & the Internet of Things

## Agenda

I. IoT and LPWAN

**II. 3GPP Cat M & NB-IoT**

III. Test Challenge & Solution



# 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

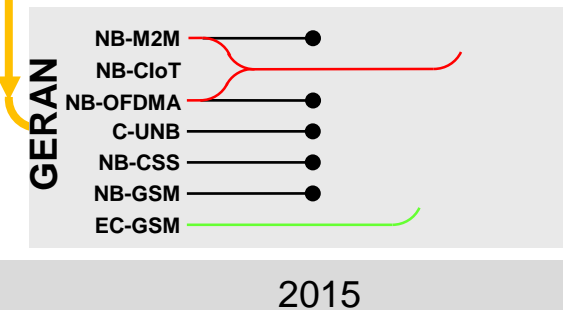
## GSMA Mobile IoT initiative backed by 21 MNOs:

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

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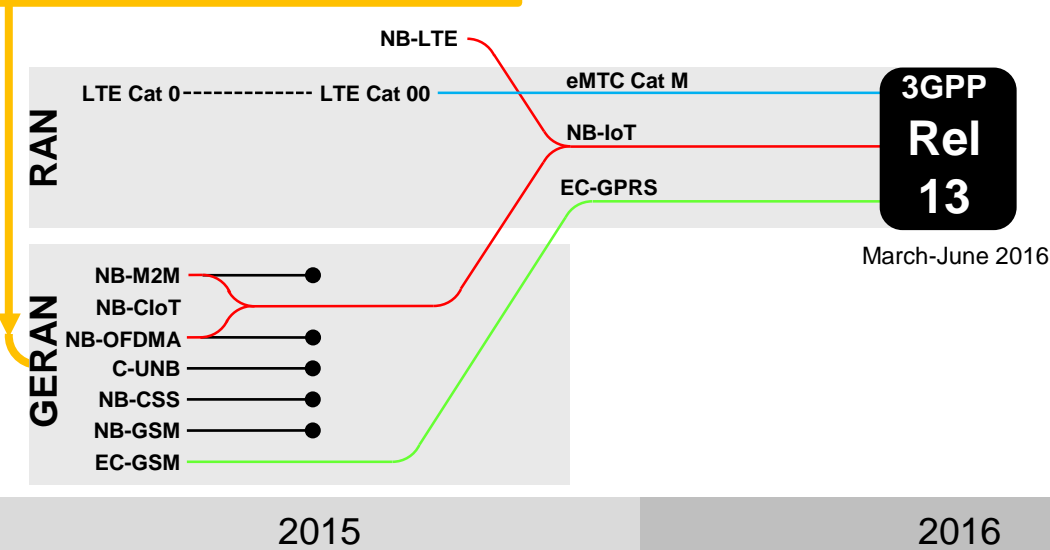
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3GPP spec dev

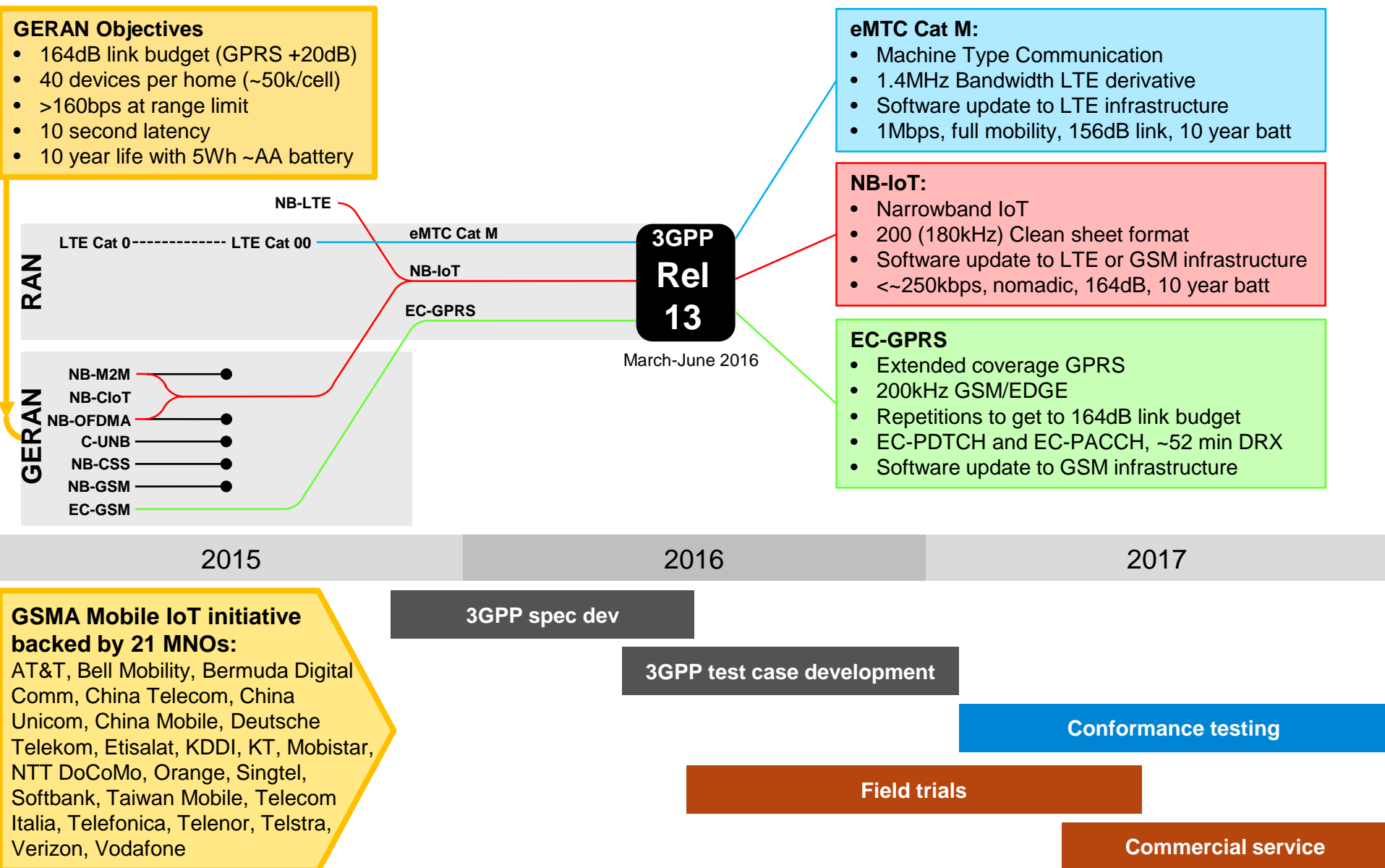
3GPP test case development

Conformance testing

Field trials

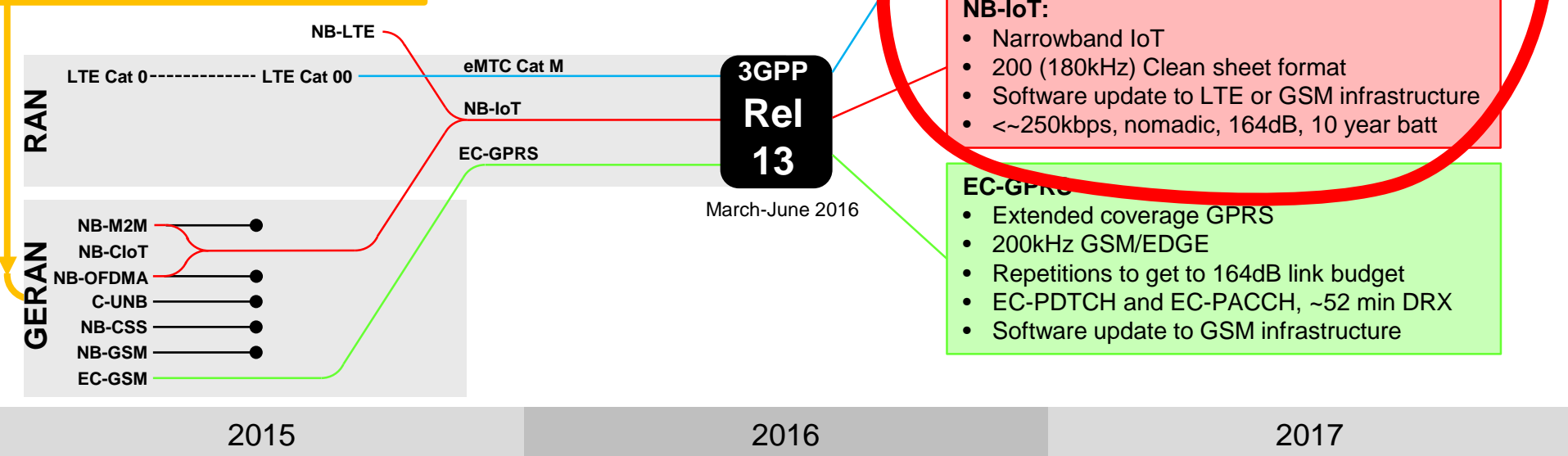
Commercial service

# 3GPP Release 13 Cellular IoT timelines

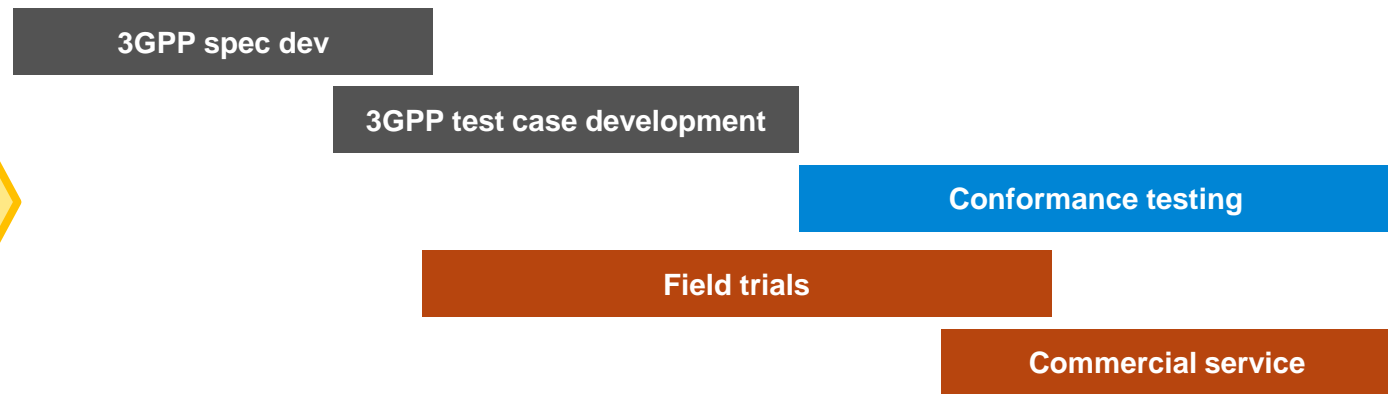


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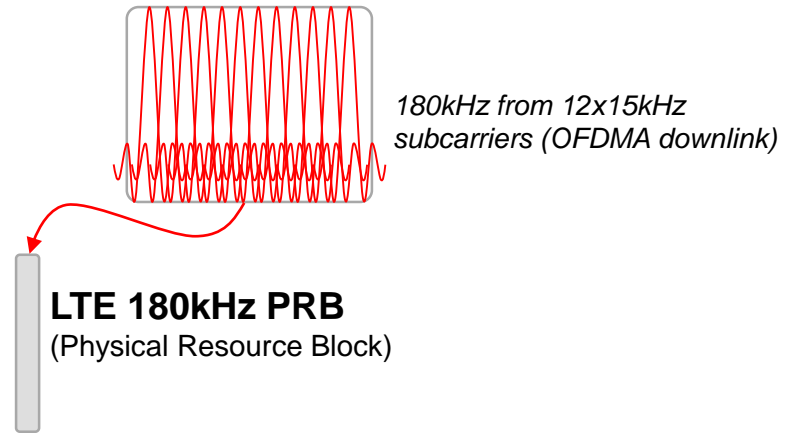


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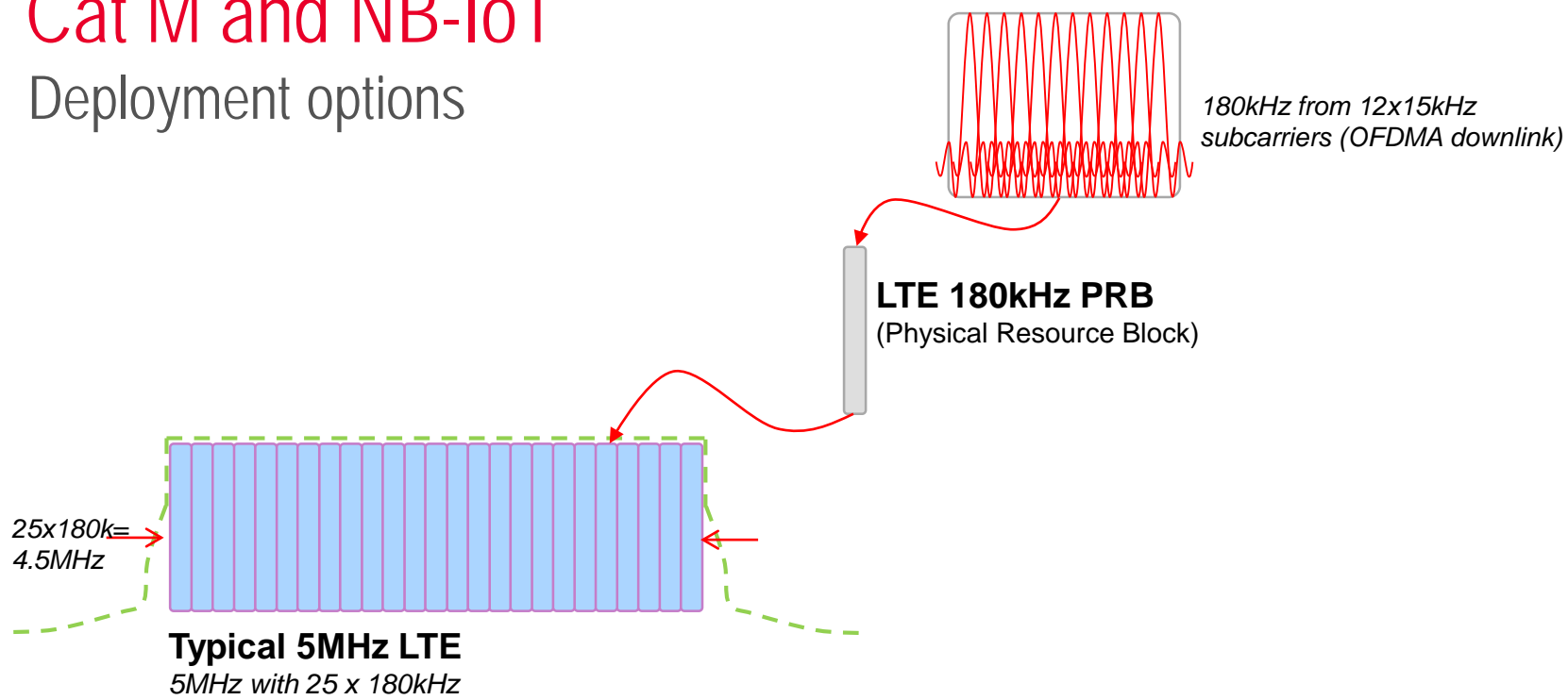
# Cat M and NB-IoT

## Deployment options



# Cat M and NB-IoT

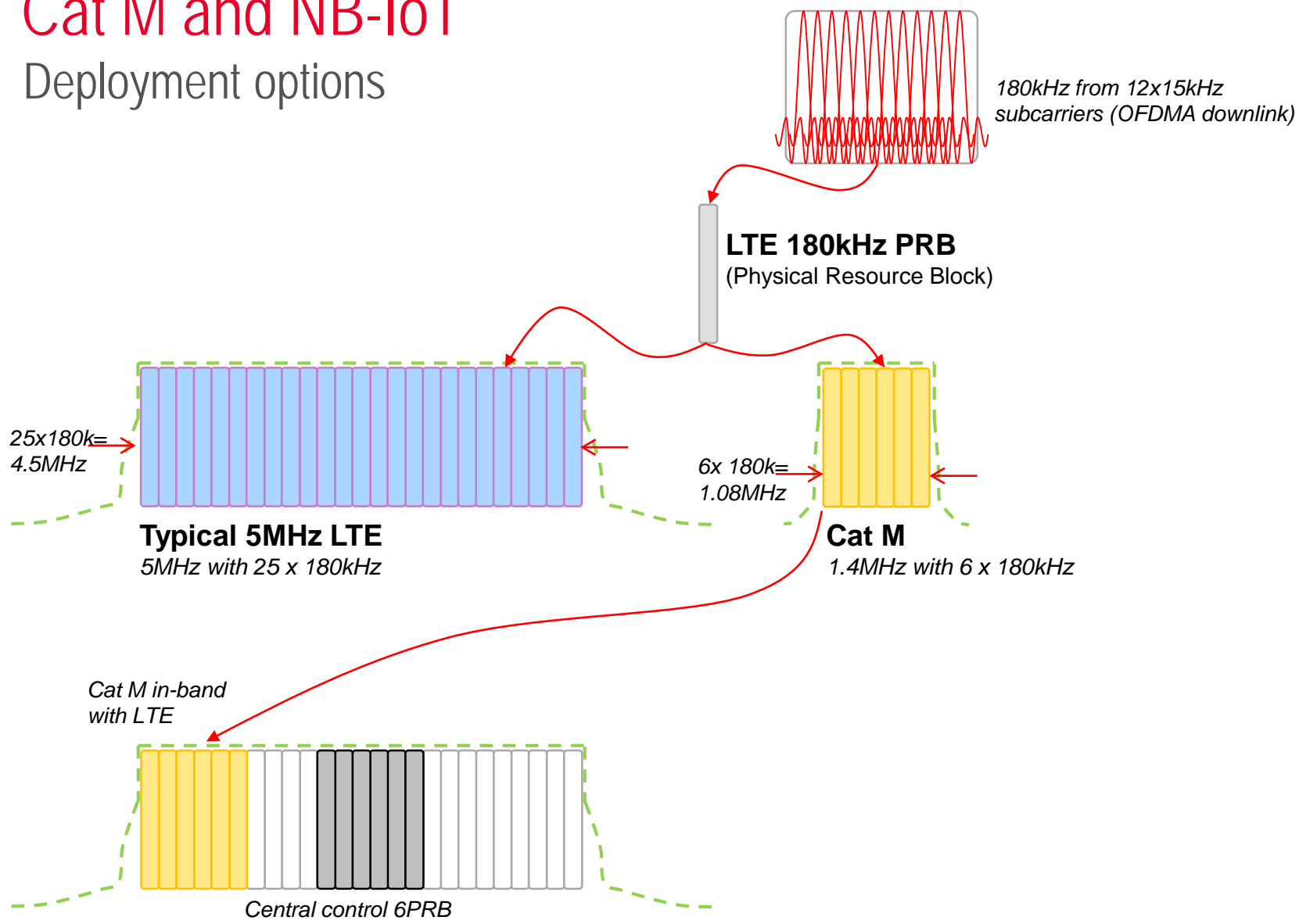
## Deployment options





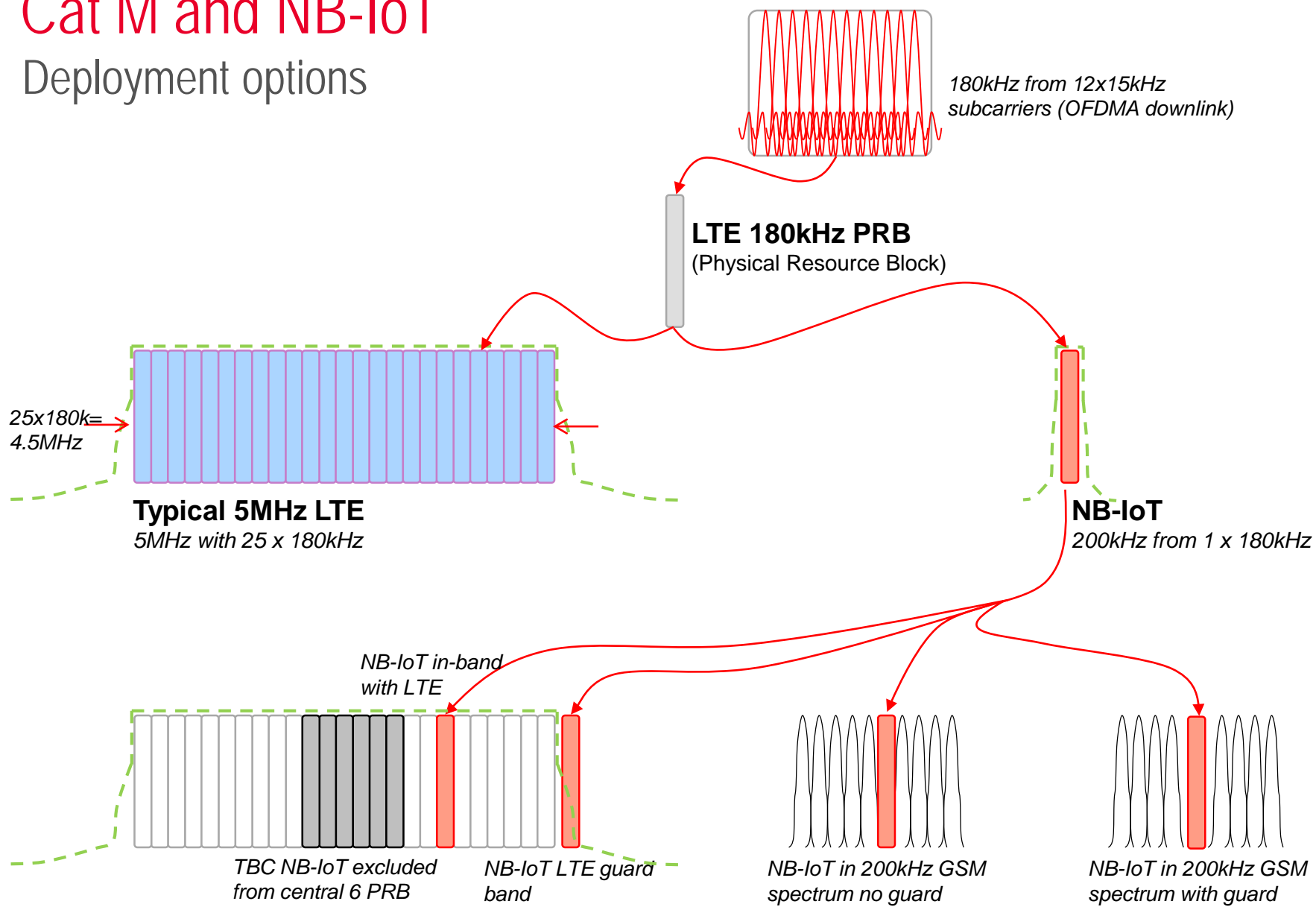
# Cat M and NB-IoT

## Deployment options



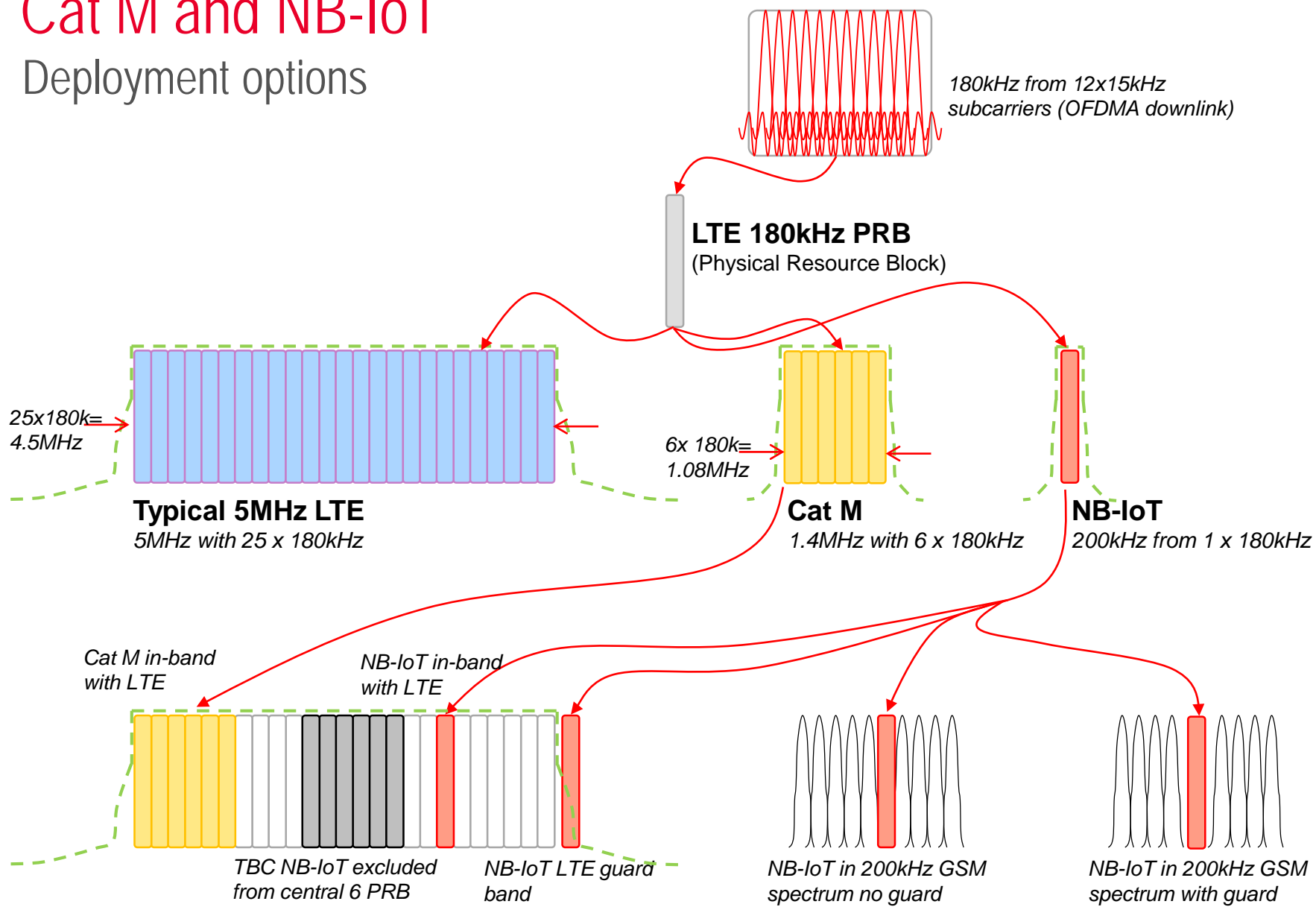
# Cat M and NB-IoT

## Deployment options



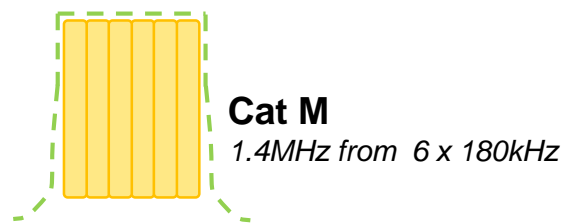
# Cat M and NB-IoT

## Deployment options



# Cat M

## 3GPP R13



### Close to standard LTE including full mobility

#### ~ 15dB Coverage enhancements over standard LTE

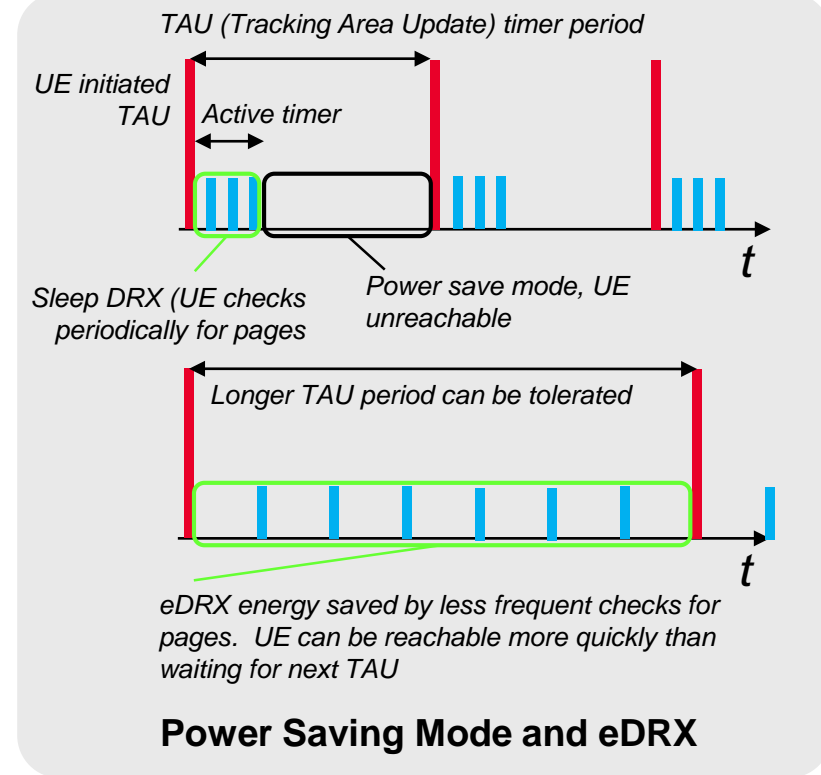
- Frequency hopping
- PSD (Power Spectral Density) boosting
- TTI bundling or repetition (redundant transmission)
- Multi-subframe channel estimation

### 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

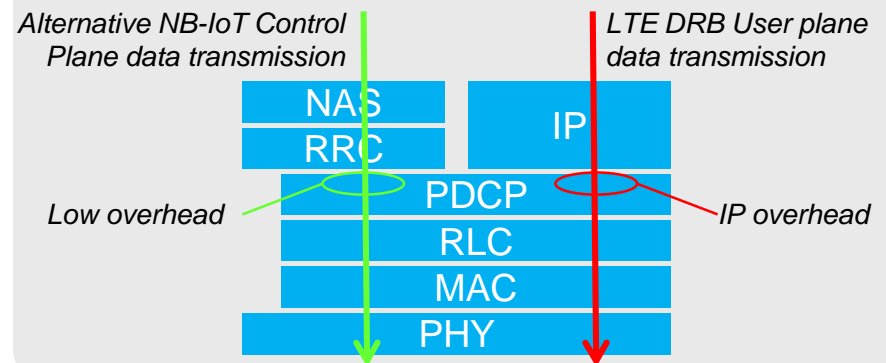
#### Downlink:

- **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




# 3GPP Cellular IoT summary

|                                   | 3GPP Rel 12        | 3GPP Rel 13        |                        |  |
|-----------------------------------|--------------------|--------------------|------------------------|--|
|                                   | MTC Cat 0          | eMTC Cat M*        | EC-GPRS                | NB-IoT*  |
| <b>Heritage</b>                   | LTE                | LTE                | GSM                    | Clean-slate  |
| <b>Bandwidth (downlink)</b>       | 20 MHz             | 1.4 MHz            | 200 kHz                | 180kHz (12 by 15kHz)   |
| <b>Bandwidth (uplink)</b>         | 20 MHz             | 1.4 MHz            | 200 kHz                | Single-tone (180kHz by 3.75kHz or 15kHz) or multi-tone (180kHz by 15kHz)                     |
| <b>Multiple access (downlink)</b> | OFDMA              | OFDMA              | TDMA                   | OFDMA  |
| <b>Multiple access (uplink)</b>   | SC-FDMA            | SC-FDMA            | TDMA                   | Single-tone FDMA or multi-tone SC-FDMA   |
| <b>Modulation (downlink)</b>      | QPSK, 16QAM, 64QAM | QPSK, 16QAM, 64QAM | GMSK, optional 8PSK    | BPSK, QPSK, optional 16QAM   |
| <b>Modulation (uplink)</b>        | QPSK, 16QAM        | QPSK, 16QAM        | GMSK, optional 8PSK    | TBC $\pi/4$ -QPSK, rotated $\pi/2$ -BPSK, 8PSK optional 16QAM                                |
| <b>Peak data rate</b>             | 1 Mbps             | 1 Mbps             | 10 kbps to 240kbps TBC | DL up to 250kbps TBC, UL single tone up to 20 to 64kbps TBC, UL multi-tone up to 250kbps TBC |
| <b>Coverage (link budget)</b>     | ~141dB             | ~156dB             | ~164dB                 | ~164dB   |
| <b>Mobility</b>                   | Full               | Full               | Full                   | Nomadic  |

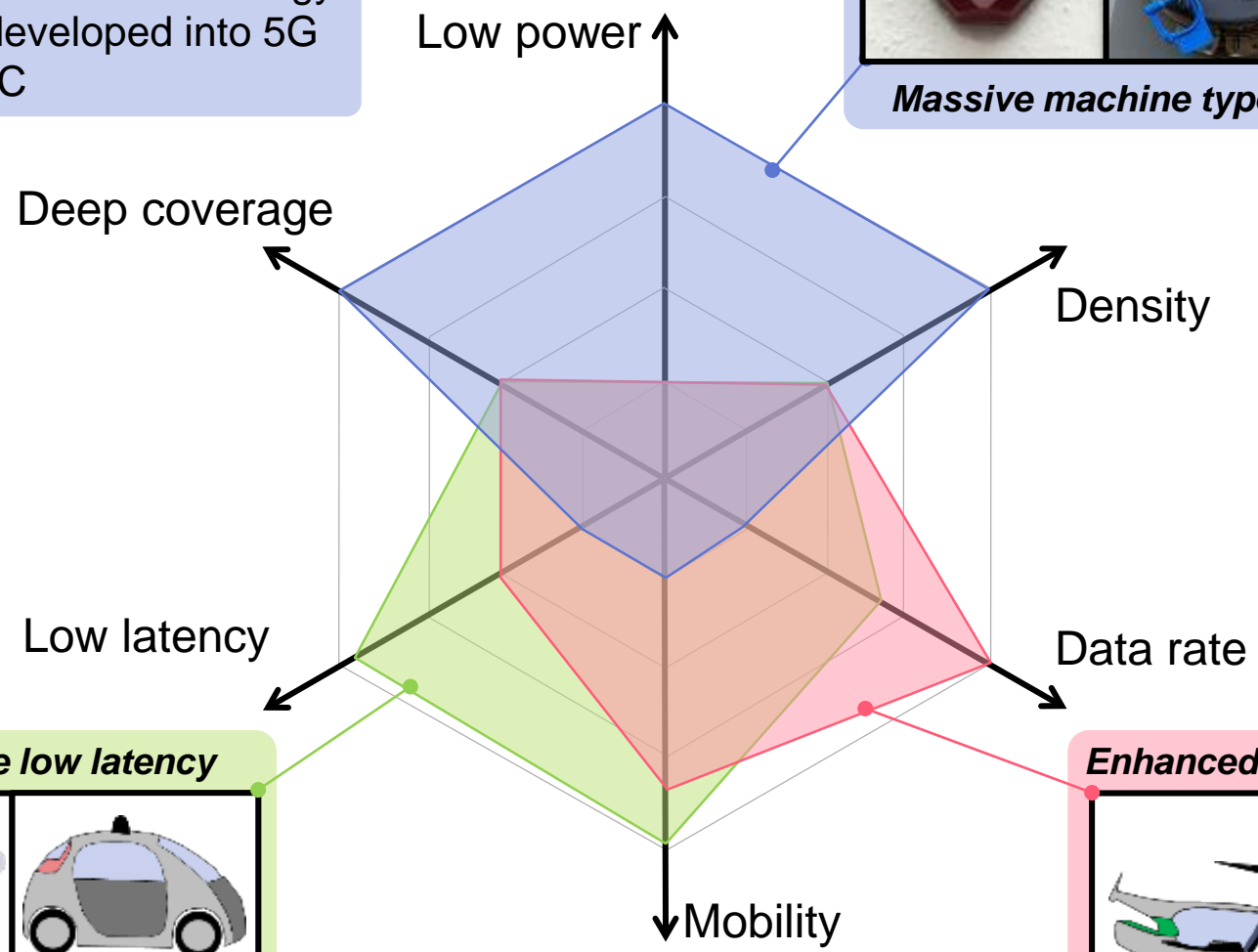
Note \* Cat M also currently referred to as Cat M1, NB-IoT also referred to as Cat M2. Details for NB-IoT are subject to change as 3GPP drafting continues

# NB-IoT 5G context


NB-IoT is a pre-5G technology likely to be developed into 5G massive MTC




**Massive machine type communications**



**Ultra reliable low latency**




Drones




Vehicles

**Enhanced mobile broadband**



VR & AR



Smartphones



# Licensed and unlicensed examples

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

# LPWAN & the Internet of Things

## Agenda

I. IoT and LPWAN

II. 3GPP Cat M & NB-IoT

**III. Test Challenge & Solution**

# IoT Verification Challenges

## Power consumption

Lifetime SLA, software update drain

Operator settings, IoT protocol selection

Unhandled software and network exceptions

## Radio frequency design

Achieving deep in-building coverage

3<sup>rd</sup> party enclosure/antenna effects

Multi-radio interference/inter-mod

## Stability/longevity

Long time between re-boot, unattended recovery

Authentication, security, secure boot

Remote software update

## Acceptance/production

Certification & regulation test e.g. GCF/PTCRB

Operator acceptance, interop lab and field test

System integrator acceptance

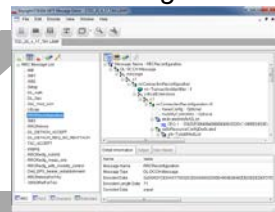
# Example applications

## Power consumption

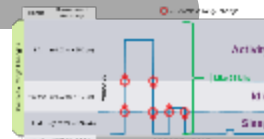


UXM

UXM message editor



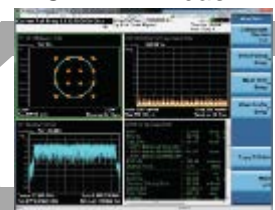
Source Measurement Unit



## Radio frequency design



UXM RF Meas'



GP RF test tools



## Stability/longevity



UXM built-in app server



Test Automation Platform (TAP)



Antenna test systems

## Acceptance/production



T4000S RCT/RRM operator RF

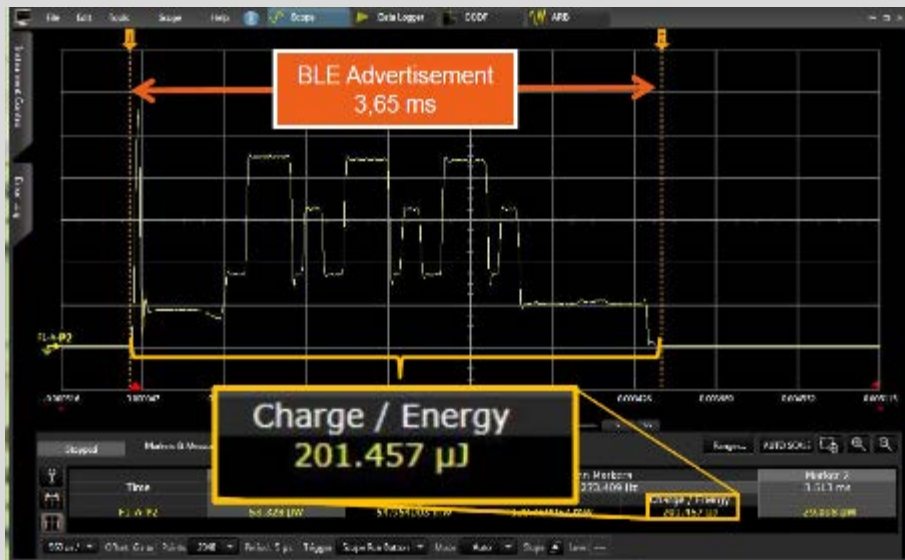
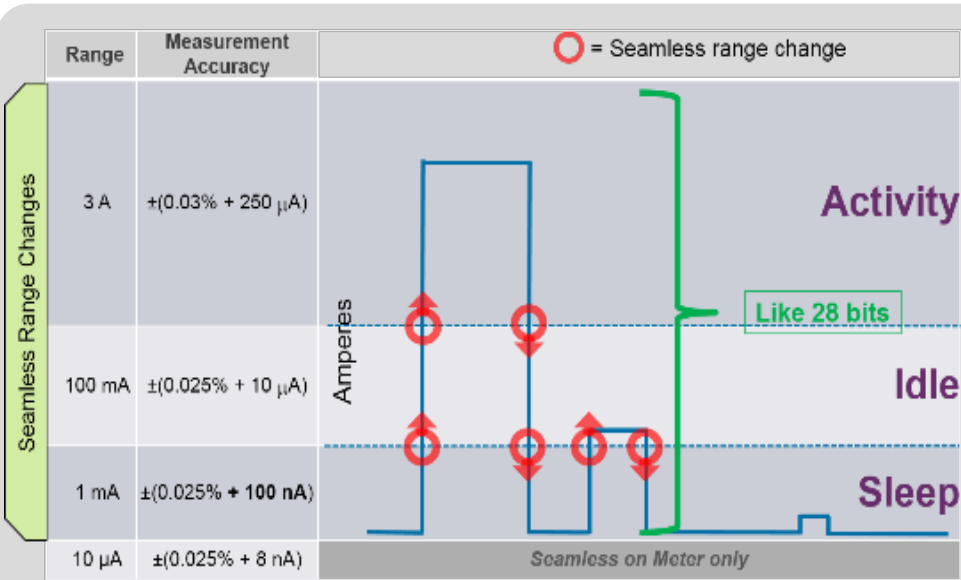


Anite protocol and operator test

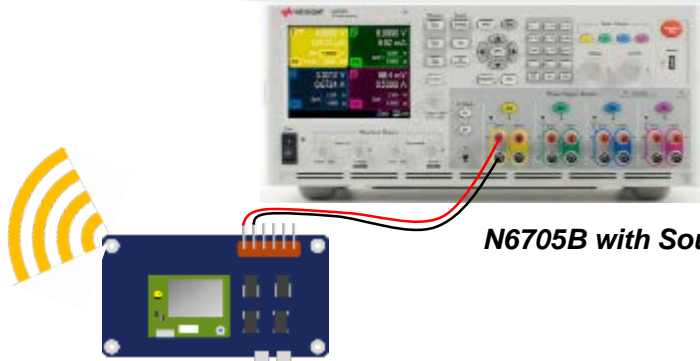


EXM high volume mfg

# Power consumption analysis



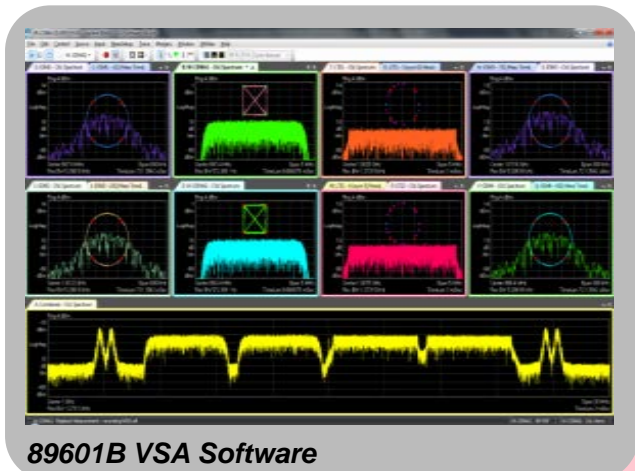
Golden device



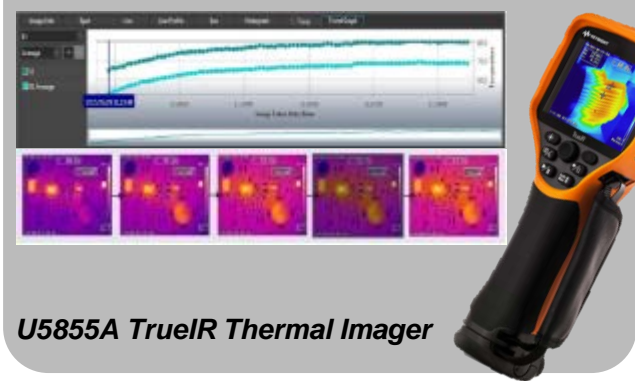
Device under test

N6705B with Source Measurement Unit

# Probing for insight



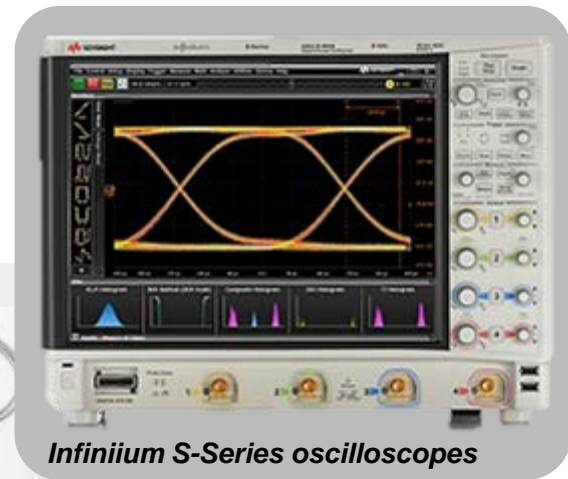
**N9010B EXA Signal Analyzer,  
Multi-touch, 10 Hz to 44 GHz**



**U5855A TrueIR Thermal Imager**



**N2820A 3 MHz/50uA High  
Sensitivity AC/DC Current Probe**



**Infiniium S-Series oscilloscopes**



**N6705B with Source Measurement Unit**



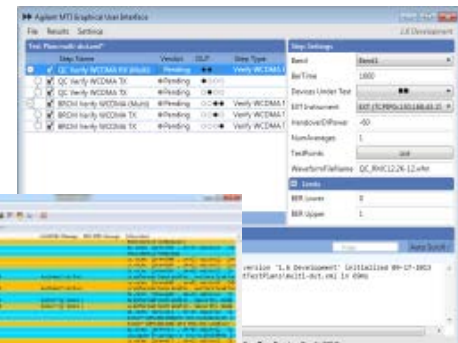
**Device under test**



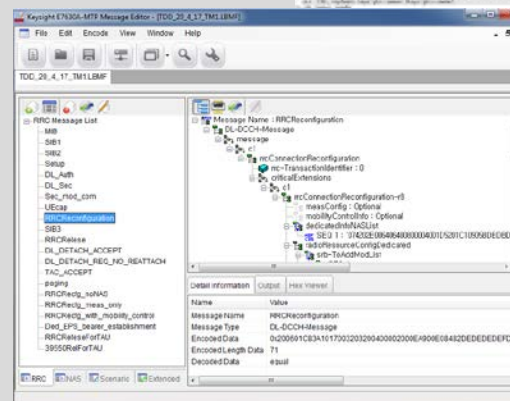
# Base station and network emulation

## Keysight UXM Wireless Test Set

- 300MHz to 6GHz Multi-format base station emulation
- Built-in server PC to host cloud & remote end-point apps
- End to end IP connection to internet
- IMS support
- Tx and Rx measurements
- Built-in channel emulator (fader)



**Test automation**



**Wireshark logging**

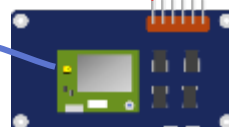
**Protocol message editor**



**UXM Wireless Test Set**



**N6705B with Source Measurement Unit**



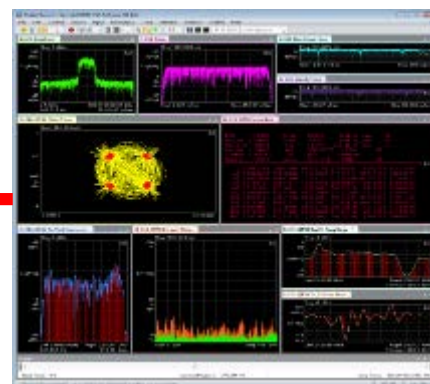
**Device under test**



# RF Design verification



**Signal Studio & waveform creator**



**89601B Flexible VSA**

**Replay and edit captured waveforms**

**X-series measurement applications**

**Matlab**

**Rx test**

**Tx test**

**M9420A VXT PXIe Vector Transceiver**

## M9420A VXT PXIe Vector Transceiver

- 60MHz to 6GHz
- 160MHz channel bandwidth

### Complement with:

- Vector Network analysers
- Microwave sources and analyzers
- Power supplies
- Software, fixtures, systems, services

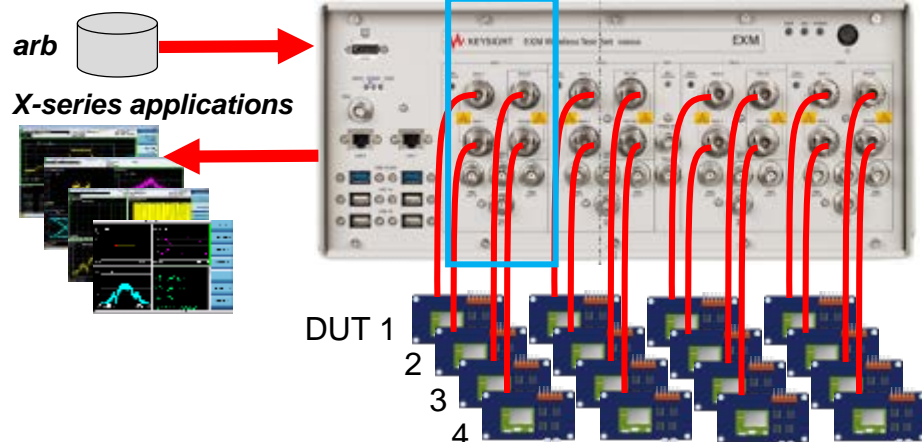
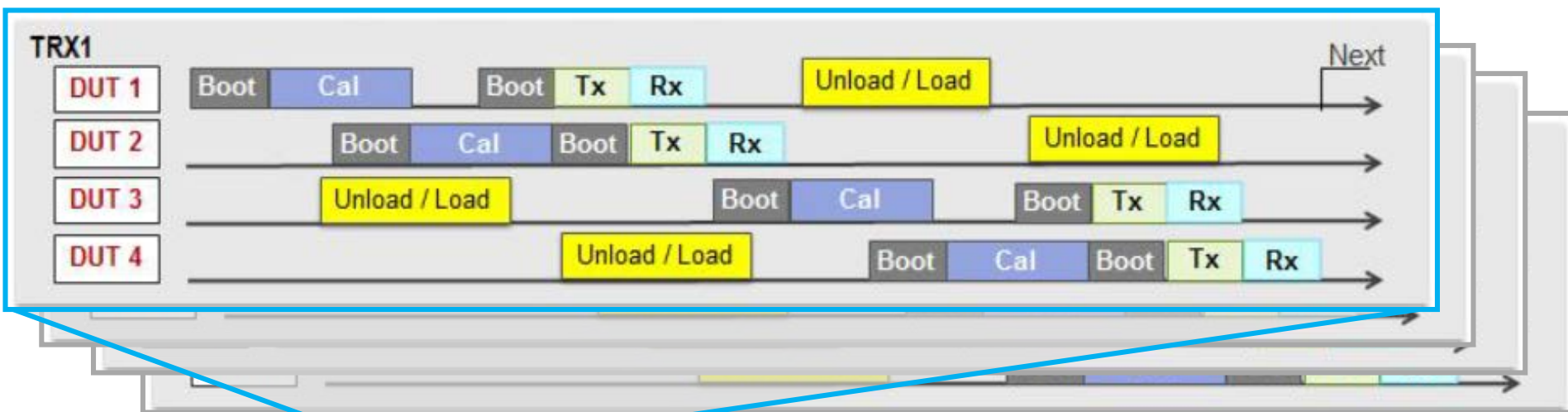
**Device under test**

## Broadest format coverage

- LTE-A, GSM, WCDMA, cdma2000
- eMTC Cat M and NB-IoT TBC
- GNSS
- 802.11a/b/g/n/ac/p/j/ah/af
- 802.15.4 (Zigbee, Thread/ 6LoWPAN)
- Bluetooth/BLE, Z-Wave, ANT+
- Wireless M-Bus, LoRa, SIGFOX & many others



# Production ramp



## E6640A EXM Wireless Test Set

- High speed sequencer
- Overlap/parallel Ping-Pong and pipelined testing
- Scalable and upgradeable from 1 to 4 TRX
- Port switching, robust N-connectors
- Broadest format coverage with arb files and X-Apps
- Systems, software, consulting and services

# Keysight Technologies



Modelling tools

Network Analyzers



Anite



Propsim channel emulator

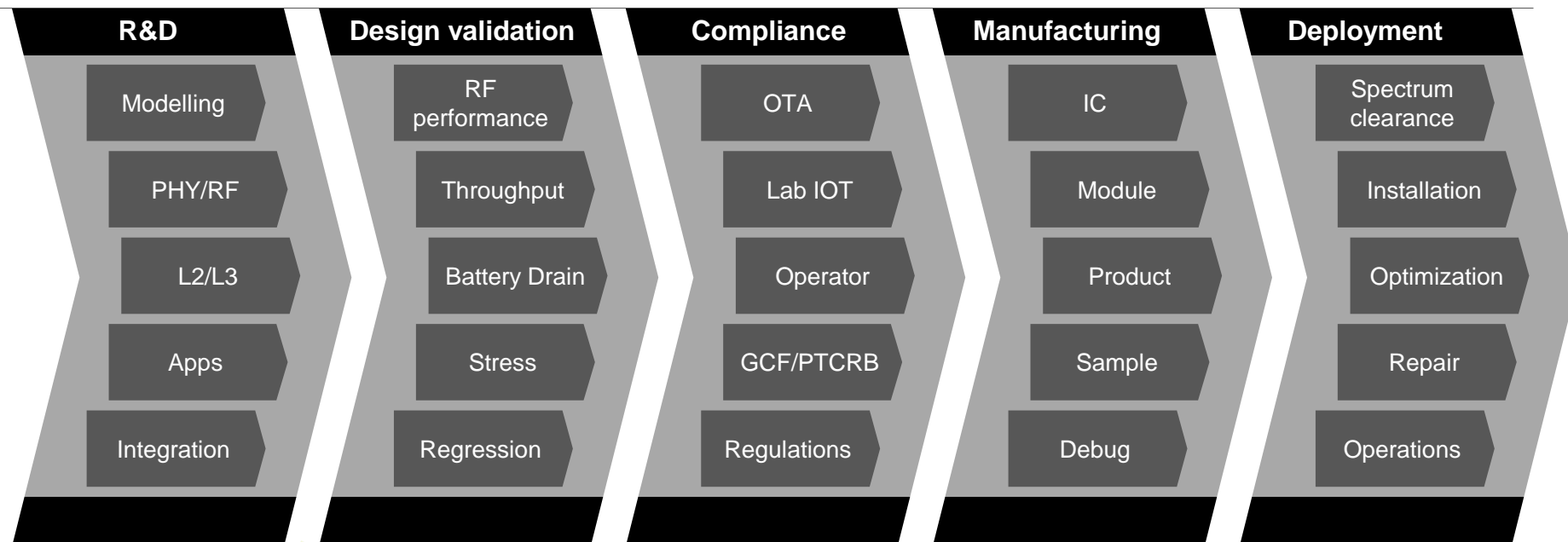


i3070 test systems

FieldFox



A9000 protocol conformance test



VSA/VSG



Thermal test



UXM Wireless Test Set

RF & RRM conformance

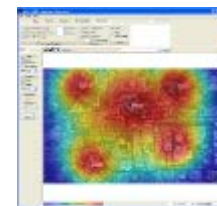


Source measurement units



EXM Wireless Test Set

Oscilloscopes



Spectrum regulation and network optimization tools

# Thank You !!!

## Questions and Answers

