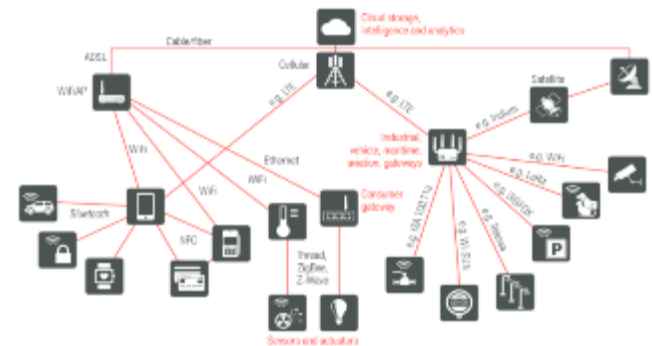


Low Power Wide Area Networks, NB-IoT and the Internet of Things

Philip Chang
Keysight Technologies

Oct. 2016



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

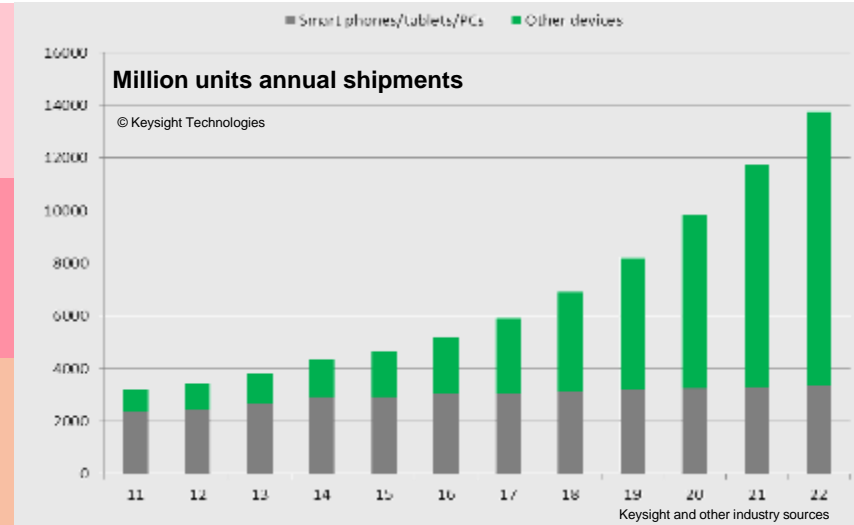
ABI Research

50B devices will be connected by 2020

Cisco

95.5B connected devices by 2025

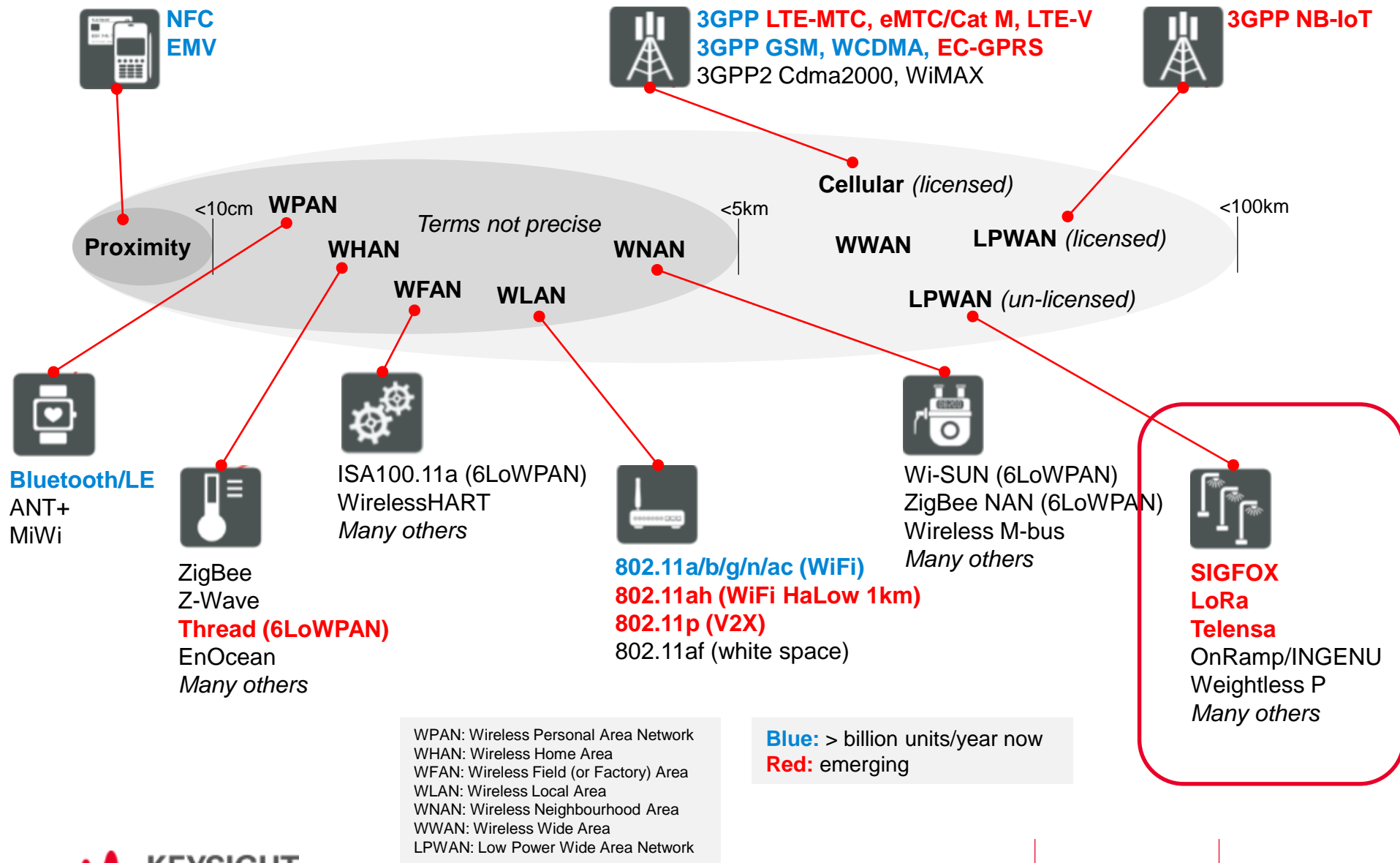
IHS Technology



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

BK Yoon Samsung Electronics President and CEO

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

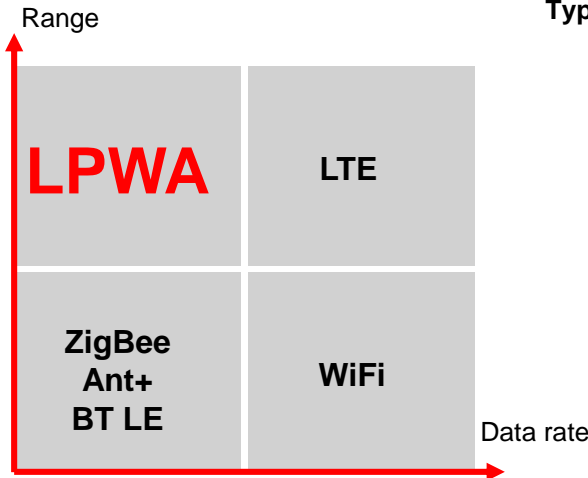
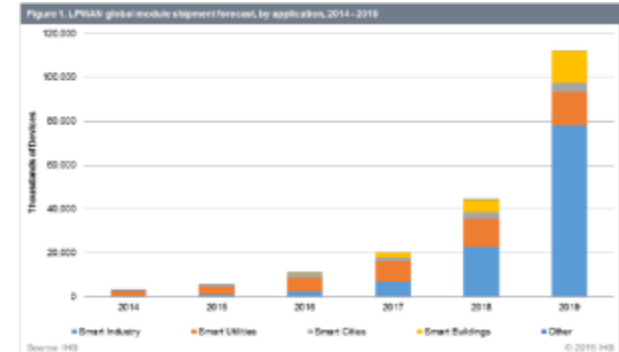
Burglar alarm back-up (cellular jammers widely available)

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

Trash collection



Soil moisture

Pet tracker



Bag tracker

Bike tracker



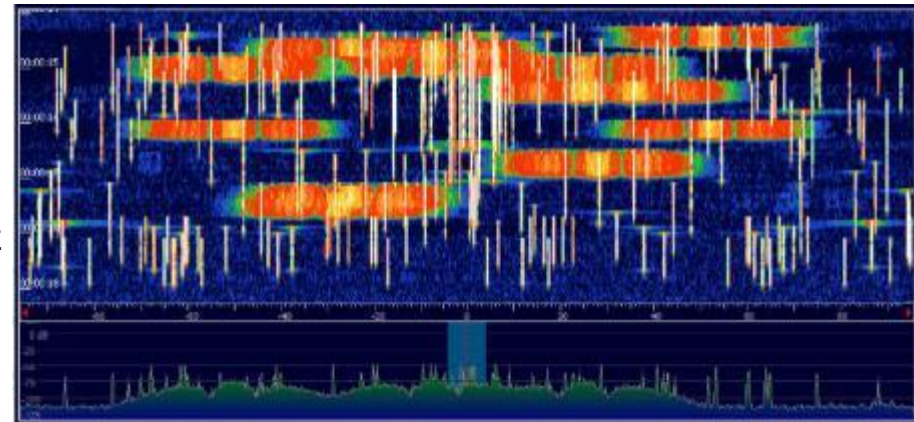
Embedded asset status

Capital asset Meter

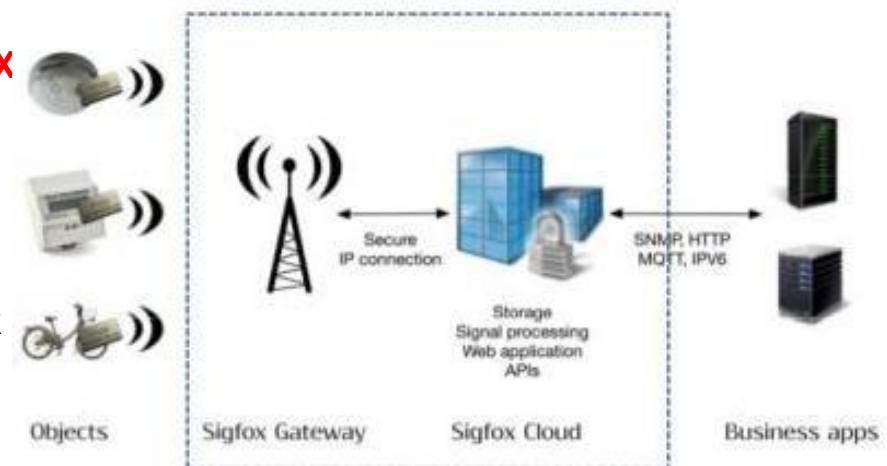


IoT Key Enabling Technologies

- **SIGFOX** is a startup in **France** building a **low cost network** dedicated for IoT.
- Uses **unlicensed spectrum** – mostly sub-GHz band and patented **ultra narrow band (UNB)** communication
 - **Ultra low throughput** - ~100 bps
 - Device send **0 and 140 messages/day**, each message is up to **12 bytes**
 - **Low power**: Up to **20 years** of battery life
 - **Long range** – up to **30 miles** in rural area and **2-6 miles** in urban area
- Devices require a SIGFOX modem and **SIGFOX network**
- **Target applications**: smart meter, pet tracking, smoke detector, agriculture etc...
- **Networks deployed** in **France**, Netherlands, Russia and Spain; Launching 902 MHz network in San Francisco

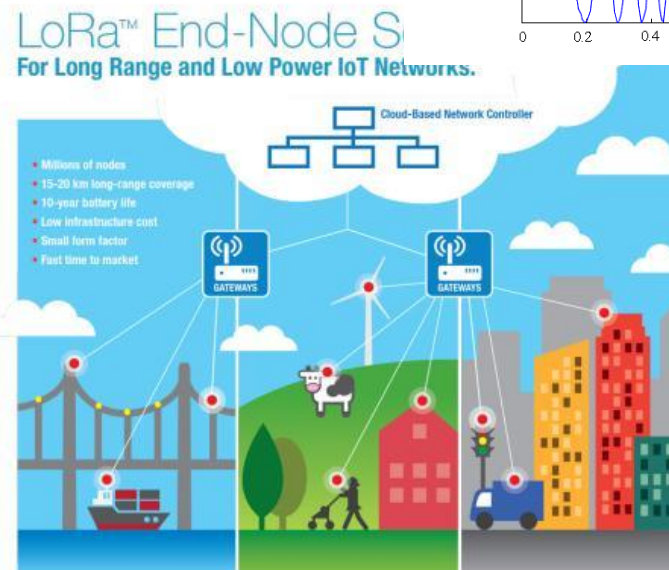
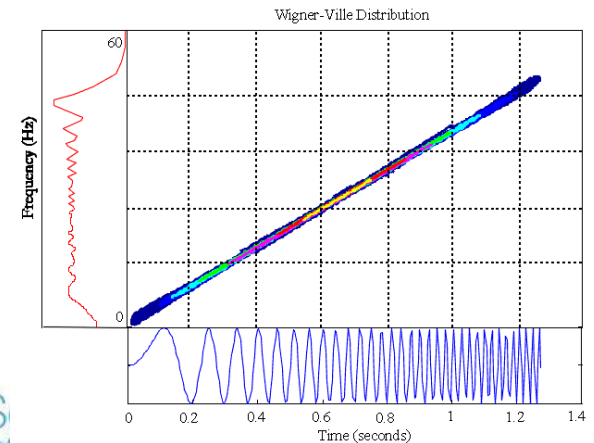


Topology

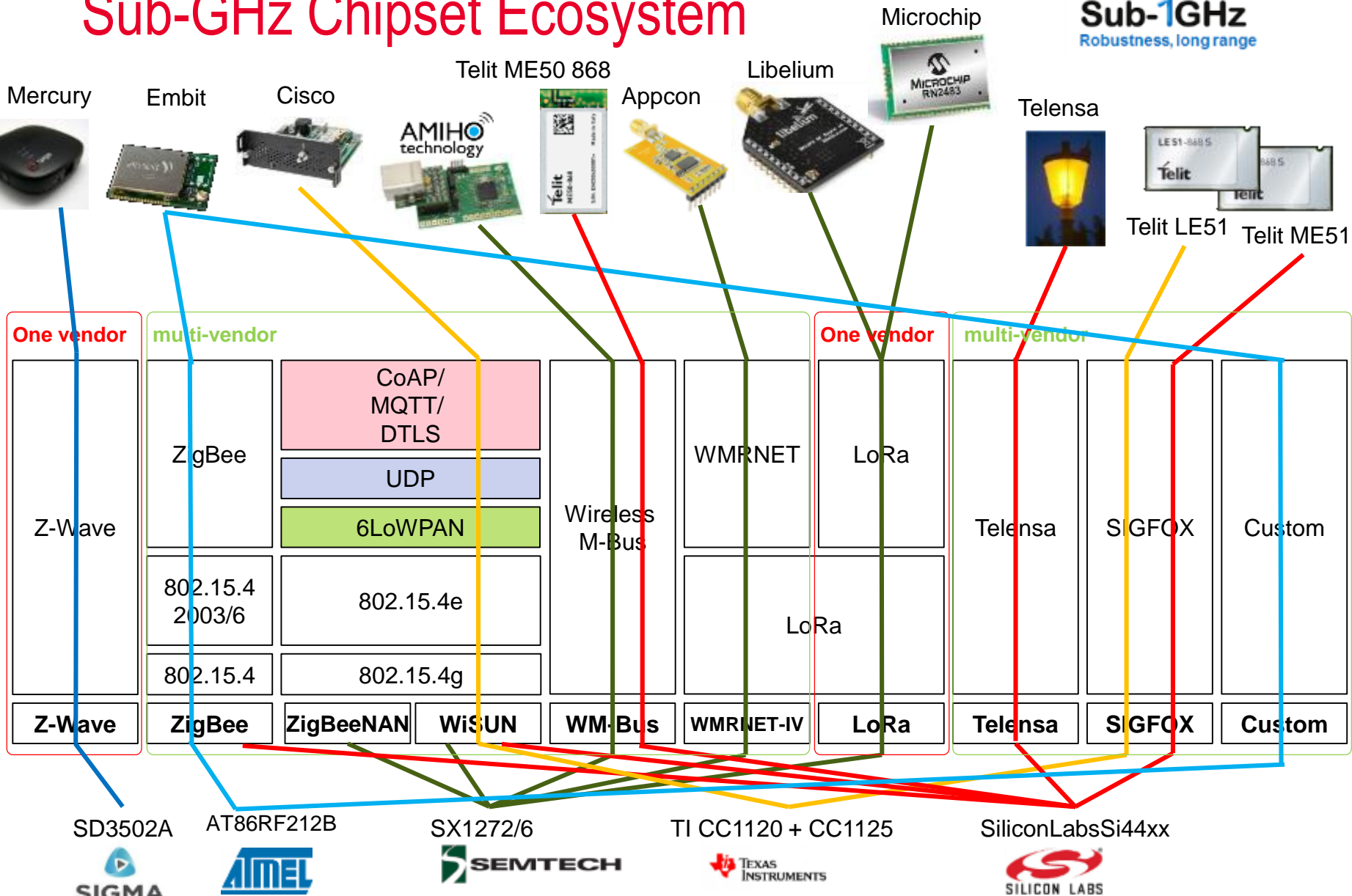


LoRa Alliance

- **LoRa** : **Long Range** M2M communications used for applications like **IoT**, using very low power levels. LoRa Alliance is an open, non-profit association.
- **Members** of the LoRa Alliance include Actility, **Cisco**, Eolane, **IBM**, Kerlink, IMST, MultiTech, Sagemcom, **Semtech**, and **Microchip** Technology.
- **Frequency bands**: sub-1GHz ISM bands:
 - **868 MHz** for Europe
 - **915 MHz** for North America
 - **433 MHz** band for Asia
- **Key Features**
 - **Low Cost**: simple modulation
 - **Low power**: Long of **ten yrs**
 - **Long range**: ~**15 - 20 km**



Sub-GHz Chipset Ecosystem



Also: Axsemi, Freescale, Analog Devices, etc...



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

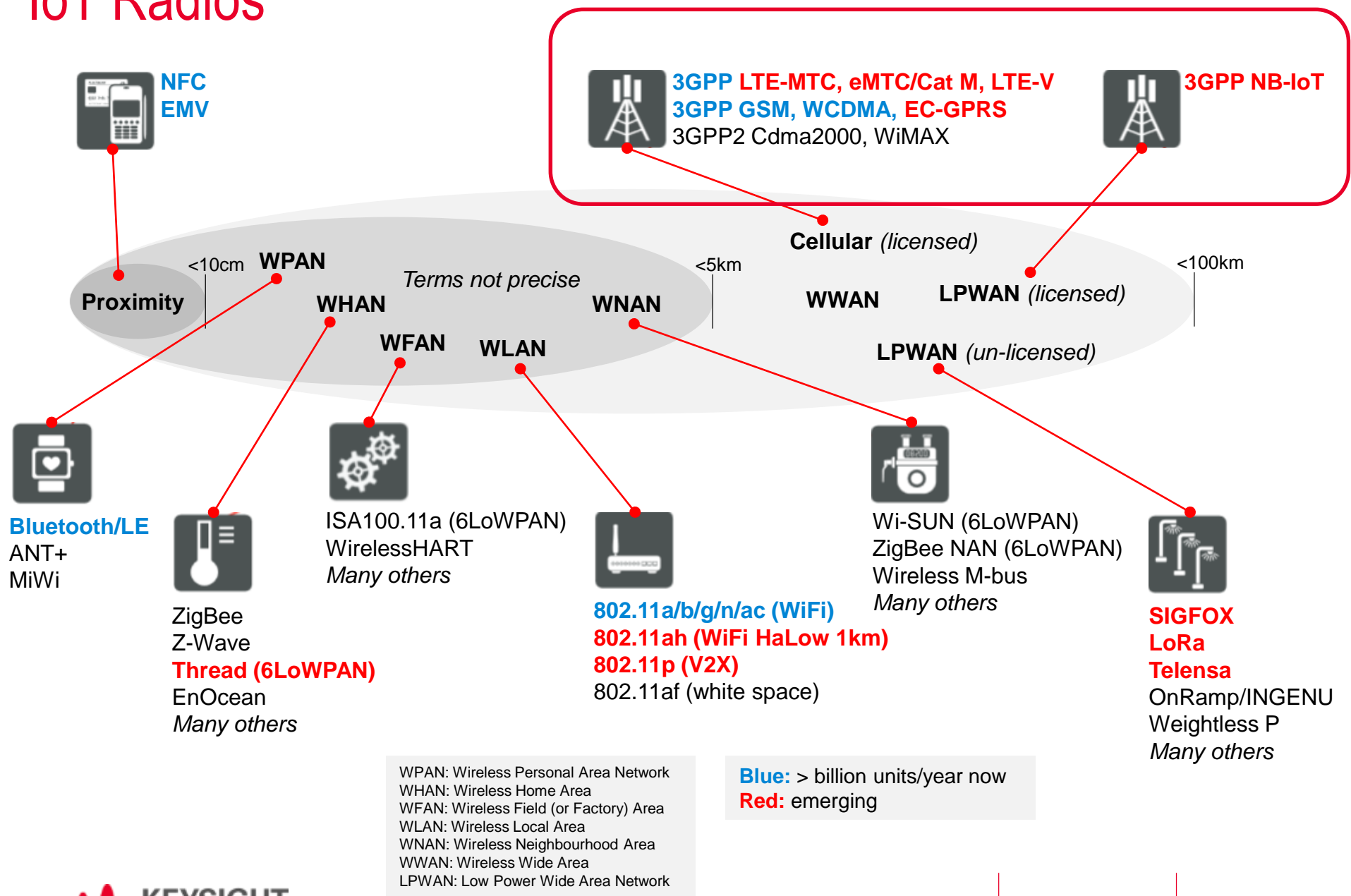
Agenda

I. IoT and LPWAN

II. 3GPP Cat M & NB-IoT

III. Test Challenge & Solution

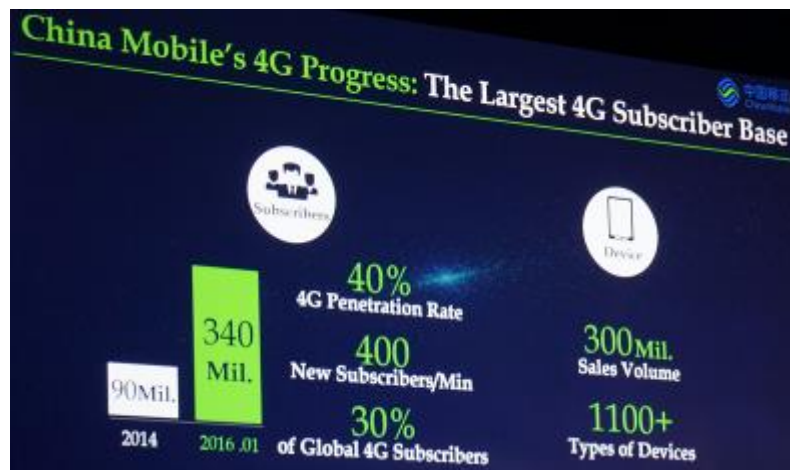
IoT Radios



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~)



推動NB-IoT
於2017年實現商用化

LTE MTC (Machine-Type Communications)

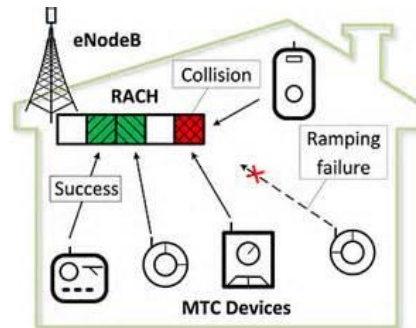
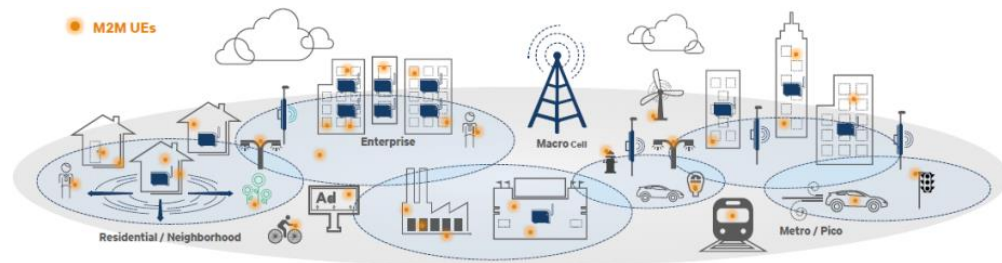
Features

– Power saving:

- **Enhanced Power Save Mode (PSM):** More efficiently turn on/off modem; optimized for scheduled applications
- **Extended Discontinuous Reception (DRX):** Longer sleep cycles optimized for delay-tolerant
- **Connectionless Random Access Channel (RACH)**
- Less frequent **Tracking Area Updates (TAUs)** and measurements

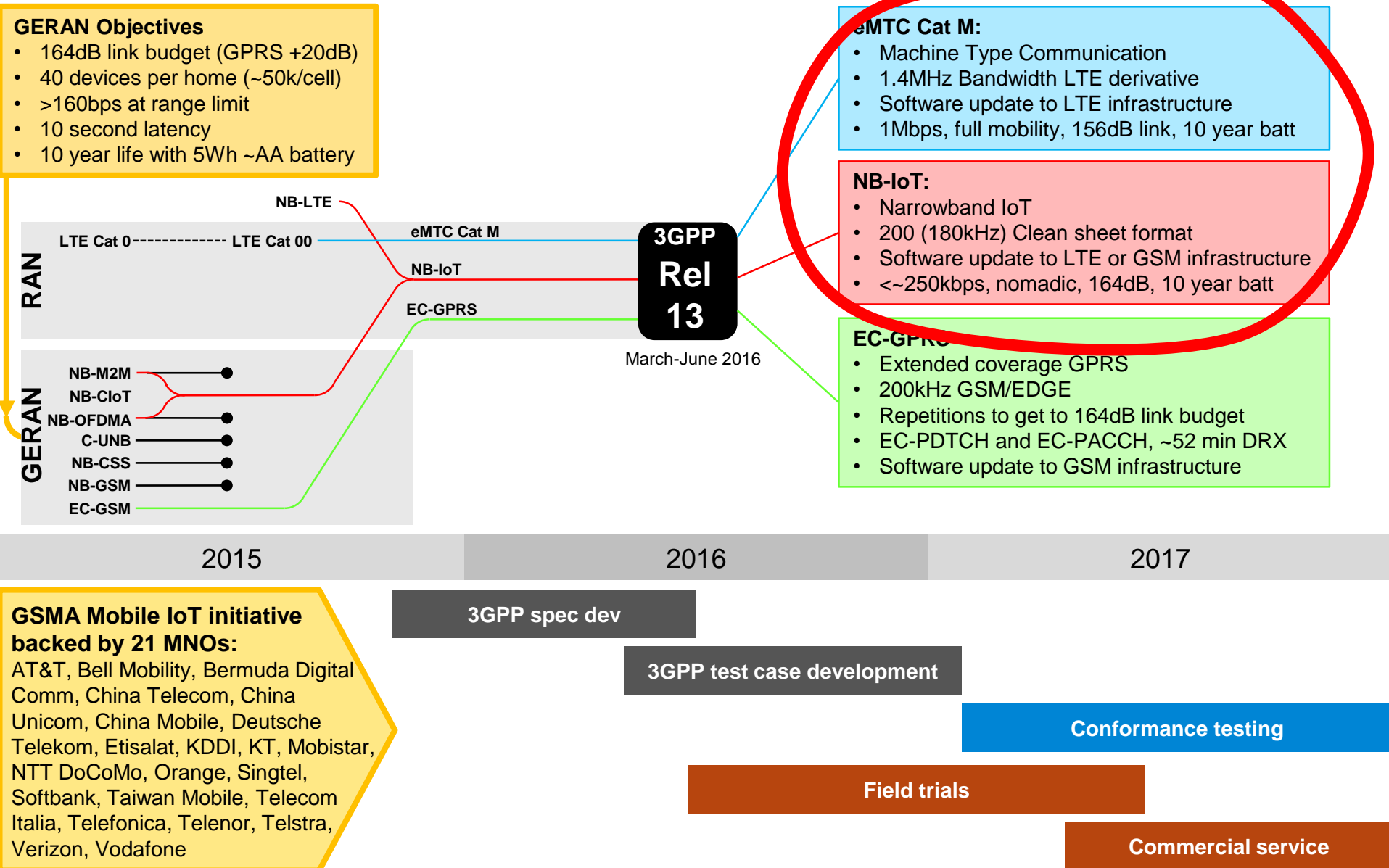
– Reduces device cost:

- **Narrowband (~1 MHz)**
- **Reduced Data Rate (<2 Mbps)**
- **Single receive antenna**
- **Half Duplex Operation**



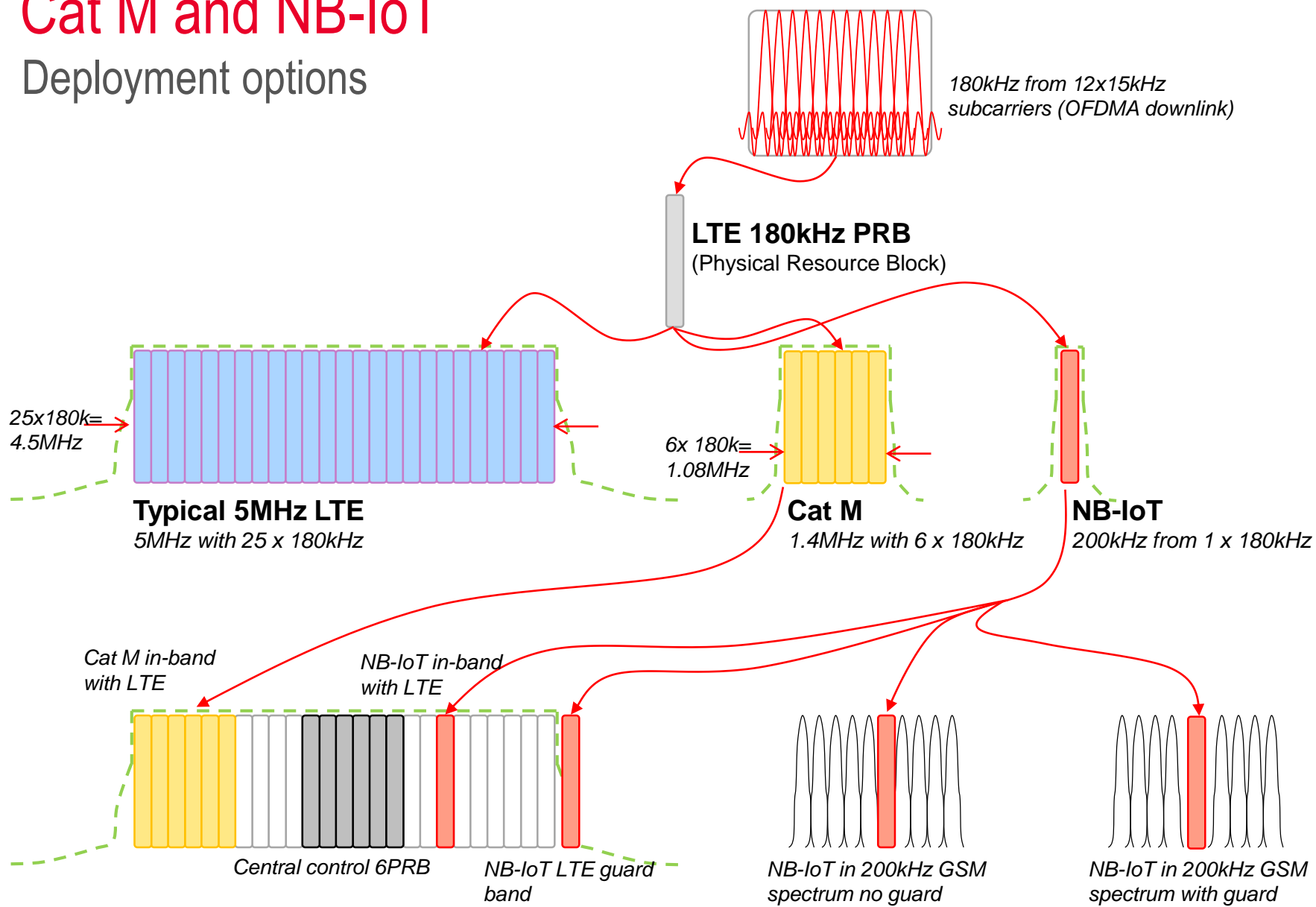
Data refer from Qualcomm

3GPP Release 13 Cellular IoT timelines



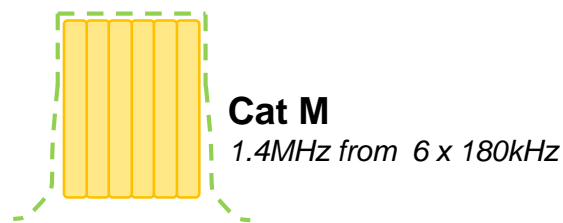
Cat M and NB-IoT

Deployment options



Cat M

3GPP R13



Close to standard LTE including full mobility

~ 15dB Coverage enhancements over standard LTE

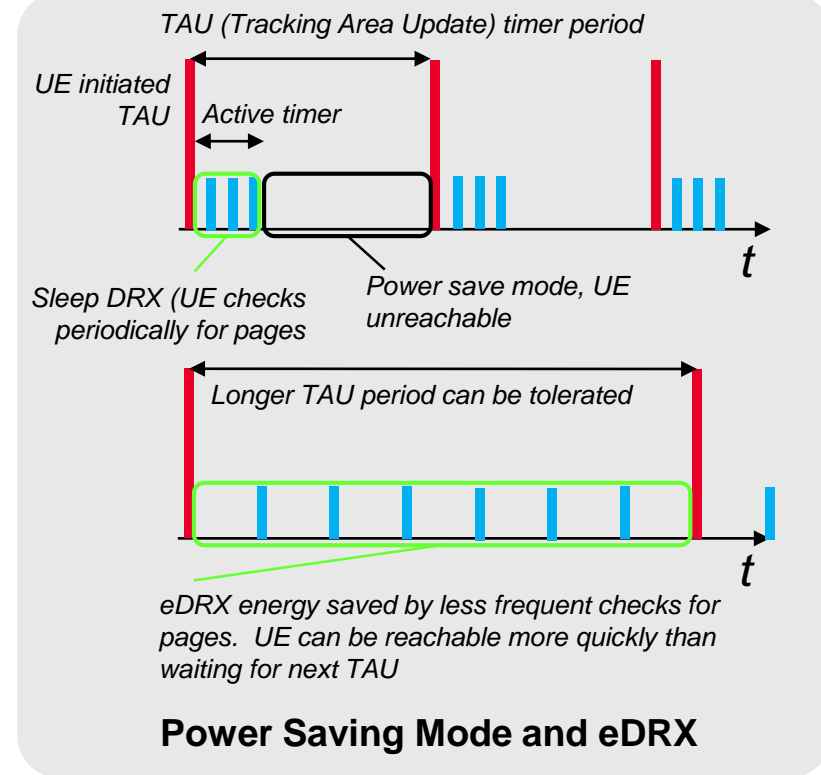
- Frequency hopping
- PSD (Power Spectral Density) boosting
- TTI bundling or repetition (redundant transmission)
- Multi-subframe channel estimation

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)

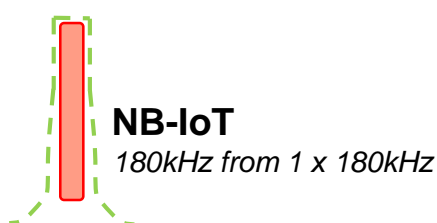
Deployable in any 6PRB group e.g. of a 20MHz channel

- 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

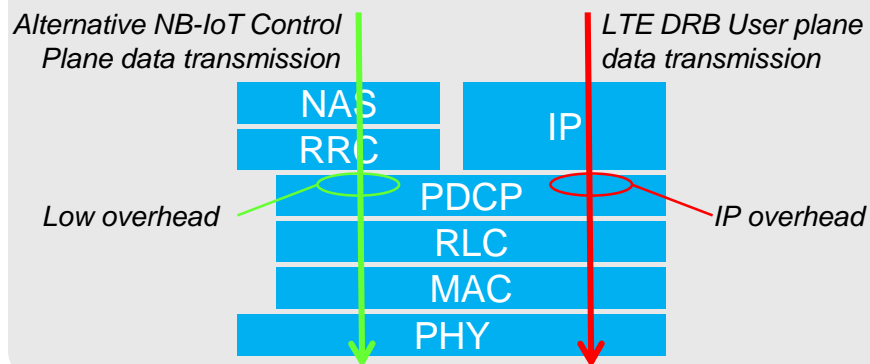
Downlink:

- **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



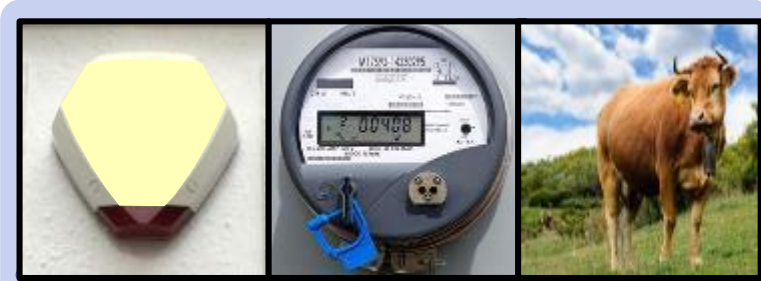
3GPP Cellular IoT summary

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

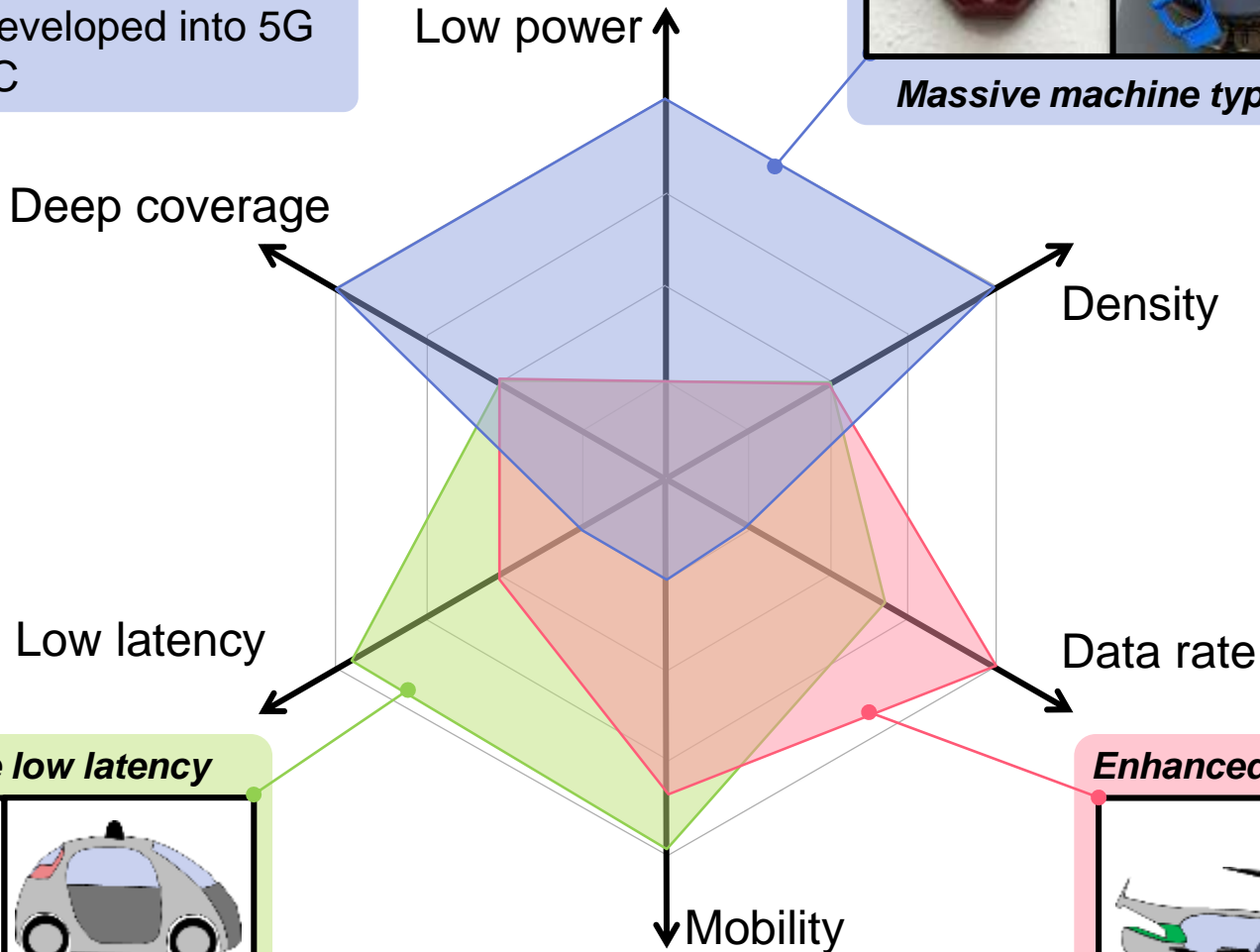
Note * Cat M also currently referred to as Cat M1, NB-IoT also referred to as Cat M2. Details for NB-IoT are subject to change as 3GPP drafting continues

NB-IoT 5G context

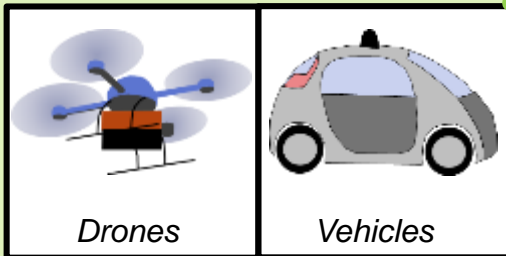
NB-IoT is a pre-5G technology likely to be developed into 5G massive MTC



Massive machine type communications



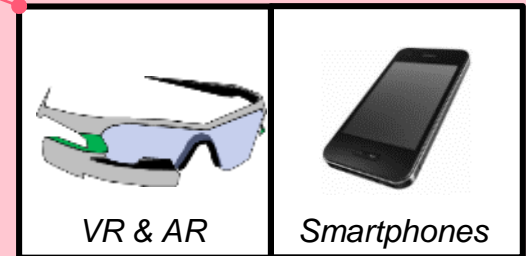
Ultra reliable low latency



Drones

Vehicles

Enhanced mobile broadband



VR & AR

Smartphones

Licensed and unlicensed examples

	SIGFOX	LoRaWAN	NB-IoT	Cat M	EC-GPRS
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 100Hz BW Downlink: 500bps GFSK 600Hz BW	GFSK, CSS (Chirp Spread Spectrum) ~0.3 to 50kbps 125kHz BW	Up to ~250kbps Uplink $\pi/4$ -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

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

3rd 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

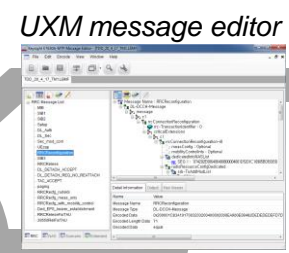
System integrator acceptance

Example applications

Power consumption



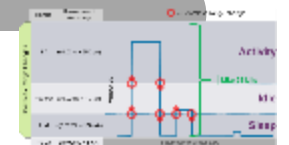
UXM



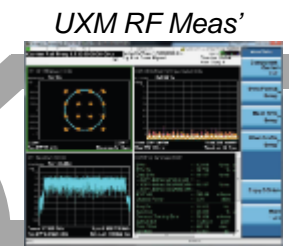
UXM message editor



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

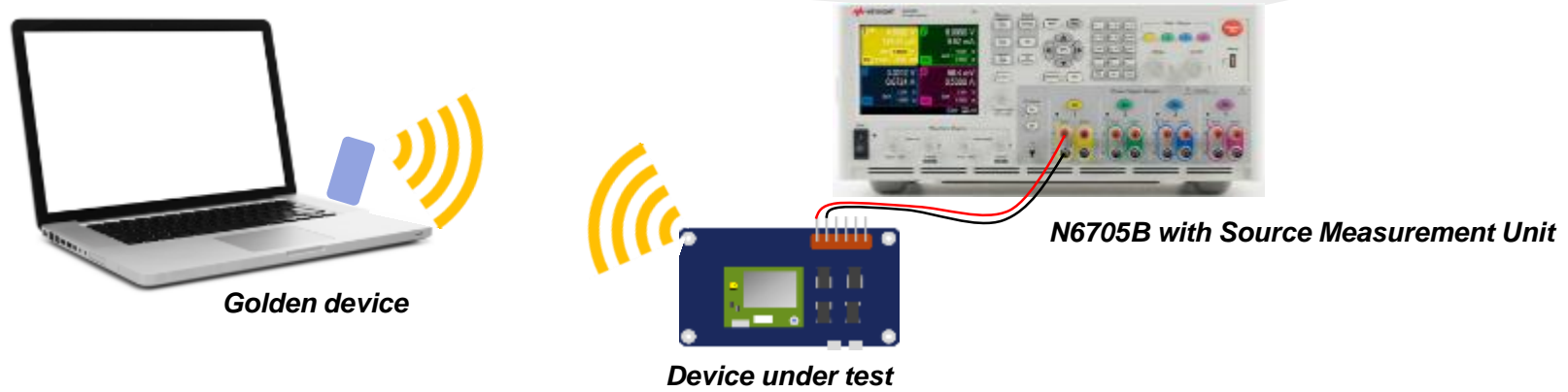
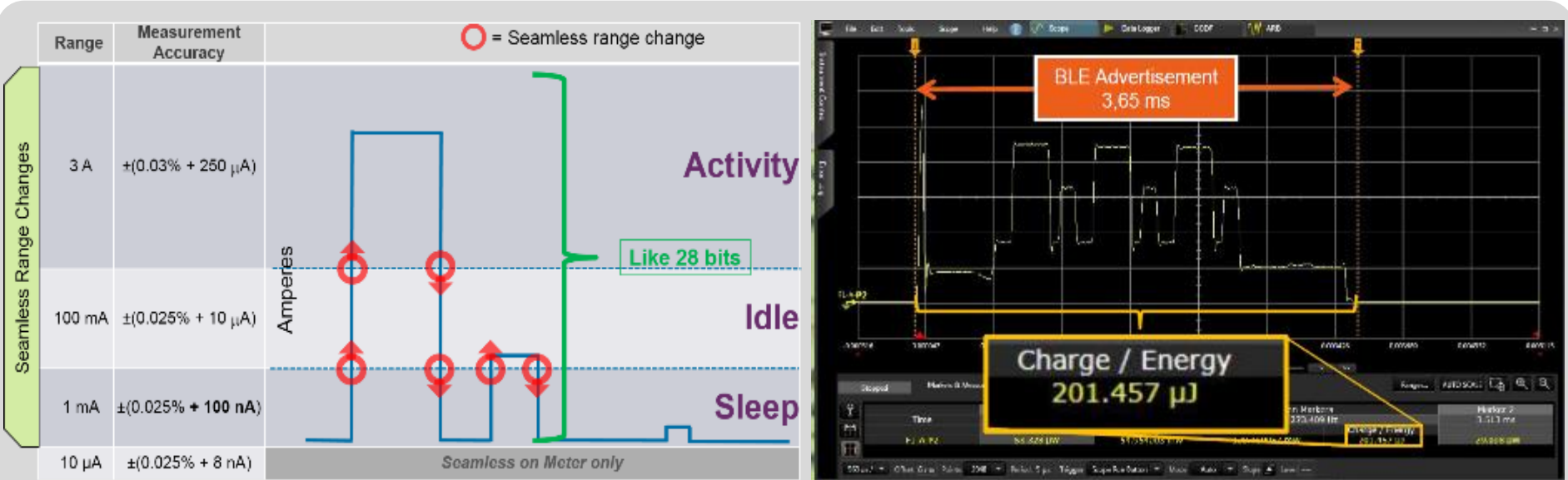


Anite protocol and operator test



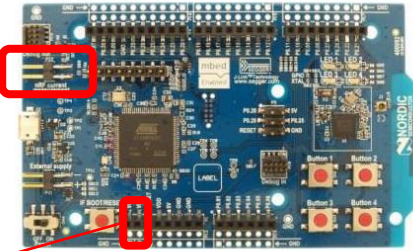
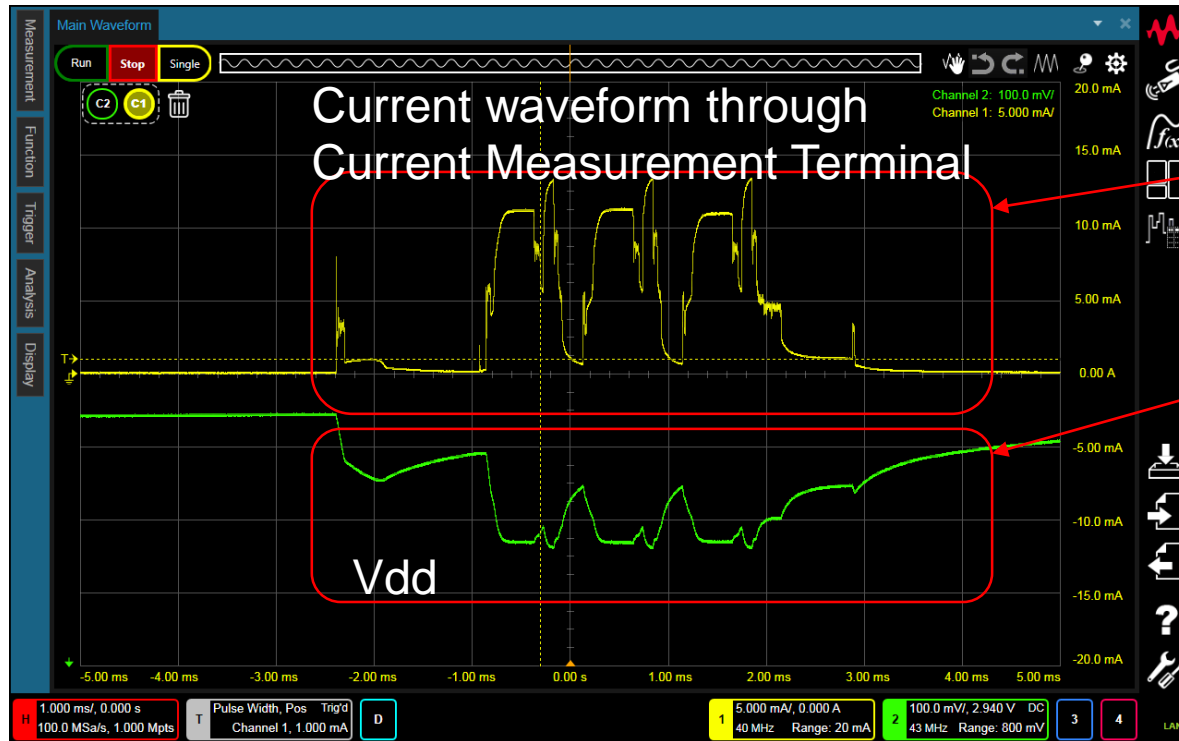
EXM high volume mfg

Power consumption analysis

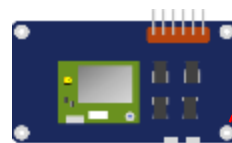


Power consumption analysis

CX3300 Current Waveform Analyzer

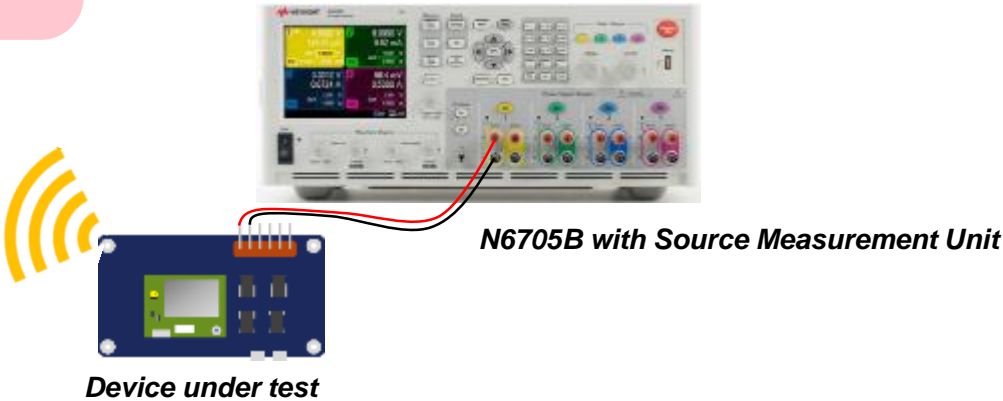
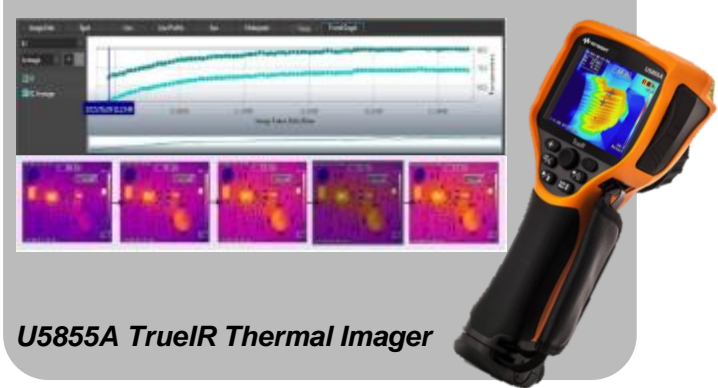
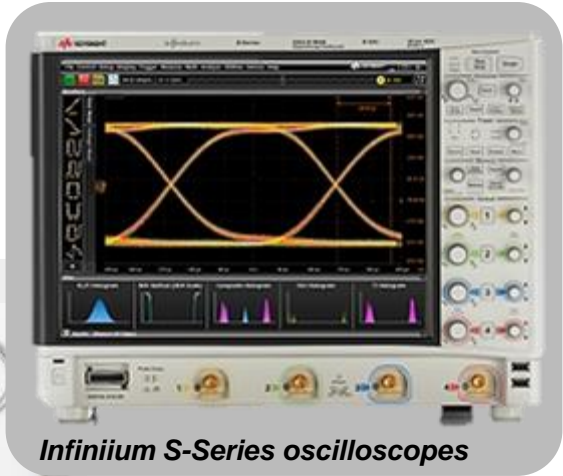
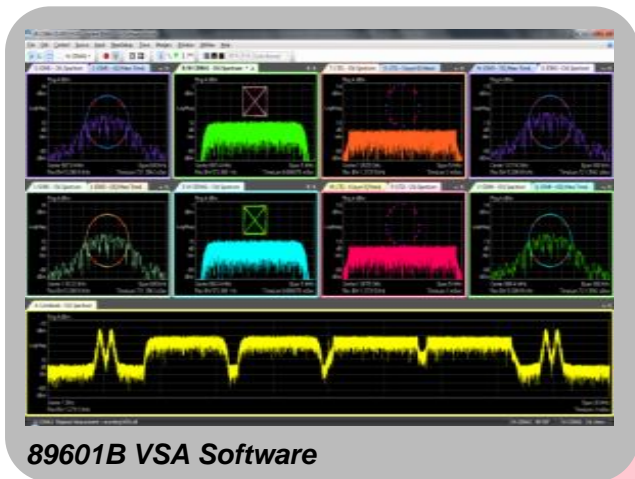


nRF51DK



Device under test

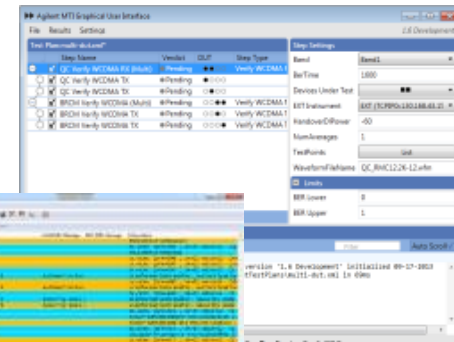
Probing for insight



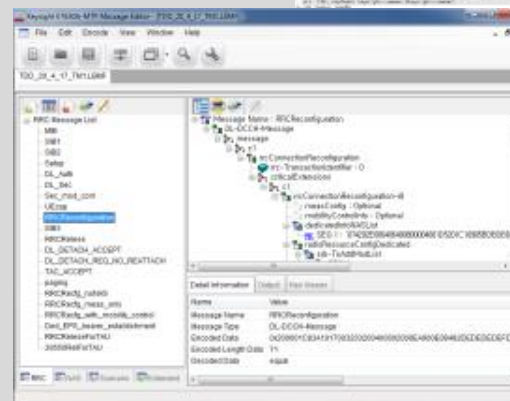
Base station and network emulation

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)

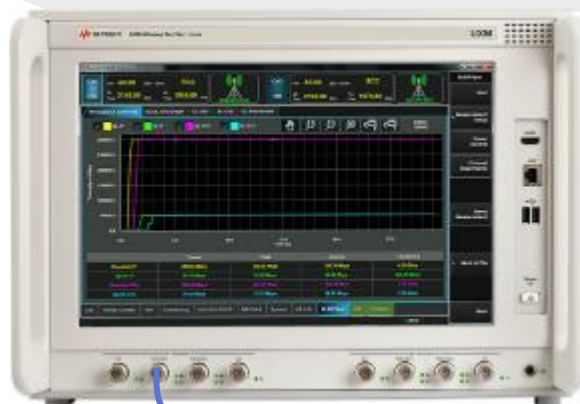


Test automation



Wireshark logging

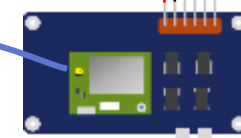
Protocol message editor



UXM Wireless Test Set



N6705B with Source Measurement Unit

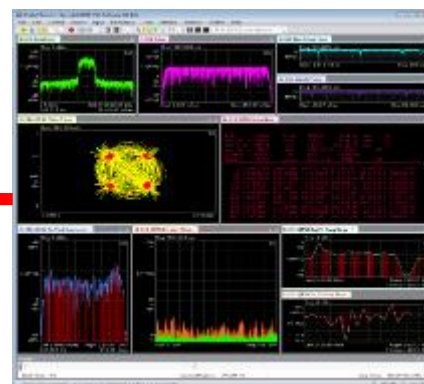


Device under test

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

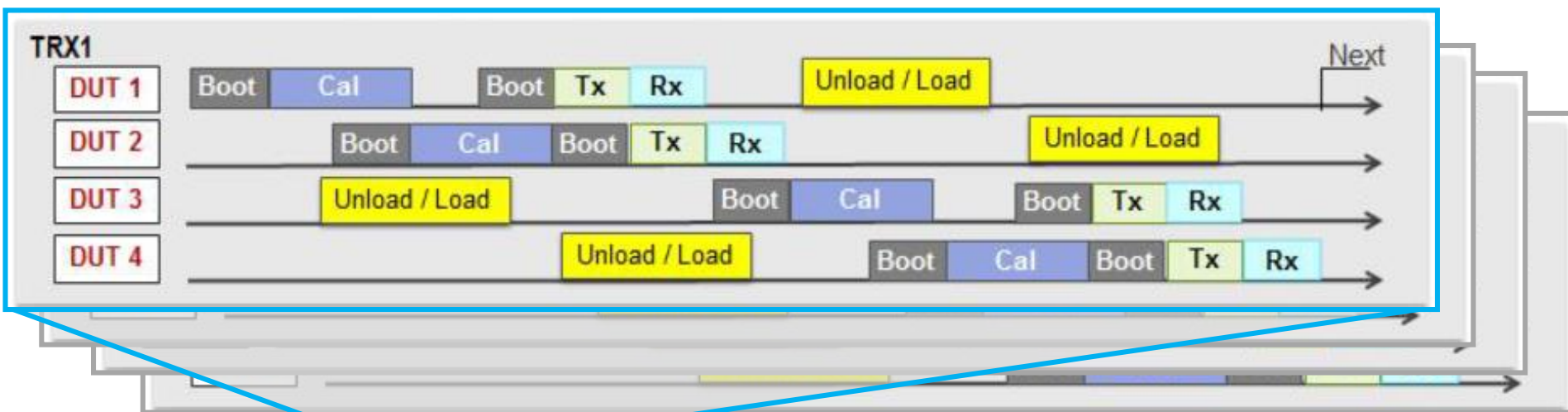
Device under test

Broadest format coverage

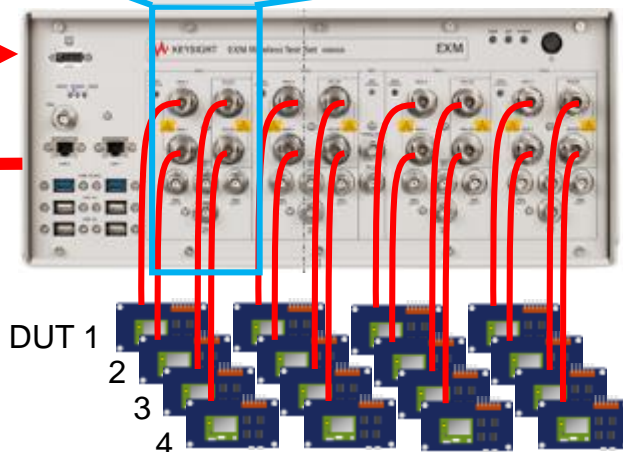
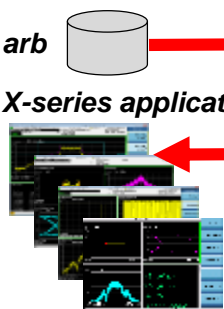
- LTE-A, GSM, WCDMA, cdma2000
- eMTC Cat M and NB-IoT TBC
- GNSS
- 802.11a/b/g/n/ac/p/j/ah/af
- 802.15.4 (Zigbee, Thread/ 6LoWPAN)
- Bluetooth/BLE, Z-Wave, ANT+
- Wireless M-Bus, LoRa, SIGFOX & many others



Production ramp



arb
X-series applications



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

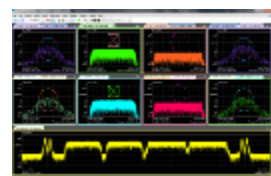
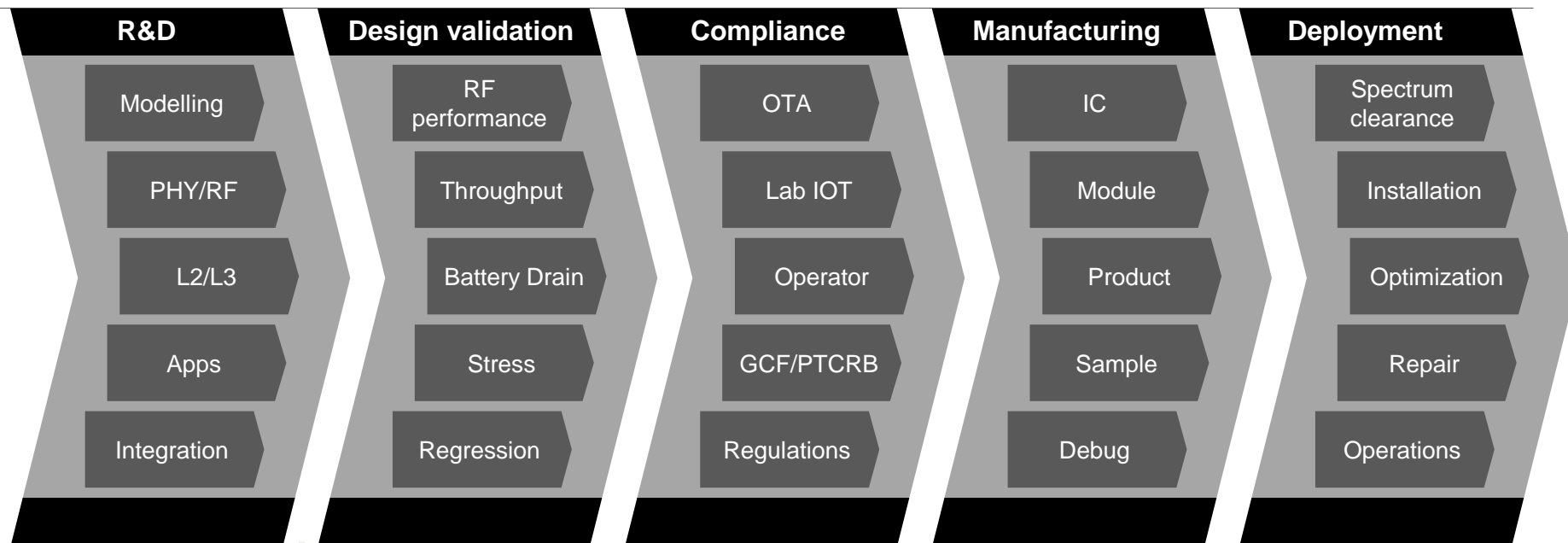


i3070 test systems

FieldFox



A9000 protocol conformance test



VSA/VSG



Thermal test



UXM Wireless Test Set

RF & RRM conformance

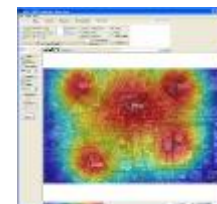


Source measurement units



EXM Wireless Test Set

Oscilloscopes



Spectrum regulation and network optimization tools

Thank You !!!

Questions and Answers

