NarrowBand-IoT:
Test Challenges and Solutions

Bai Ying

2017.12.08

Wireless Marketing Manager

KEYSIGHT
TECHNOLOGIES

Keysight History

1939–1998: HP

Start from electronic test and measurement

1999-2013: Agilent Technologies

Split from HP and became the world leading measurement company

Declared to split the electronic measurement business on Sep. 2013

2014: Keysight Technologies

Became an independent company on Nov. 2014

100% focus on electronic test and measurement

Agenda

Why NB-IoT
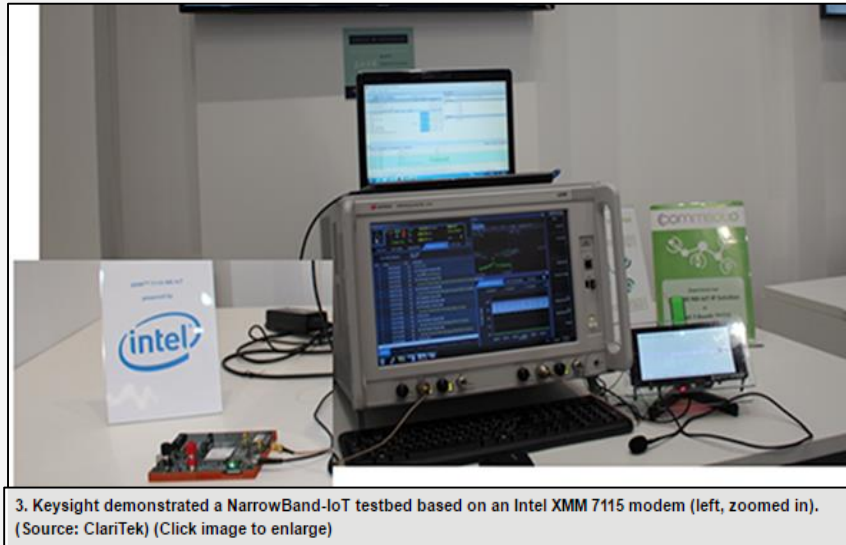
NB-IoT Test Challenges and Solutions

Summary

Agenda

Why NB-IoT

NB-IoT Test Challenges and Solutions

Summary

Cellular IoT gains momentum with NB-IoT

3. Keysight demonstrated a NarrowBand-IoT testbed based on an Intel XMM 7115 modem (left, zoomed in). (Source: ClariTek) (Click image to enlarge)

Vodafone reveals NB-IoT rollout plan
By Nick Wood, Total Telecom
Wednesday 19 October 2016
Dedicated IoT networks to go live in Germany, Ireland, Netherlands, Spain during first quarter of 2017.

Telefonica, Huawei, Kamstrup in first LatAm NB-IoT trial
Wednesday 15 February 2017 | 13:55 CET | News
Telefonica and Huawei have teamed up with smart metering products provider Kamstrup to launch what the partners describe as the first project using NarrowBand Internet of Things

Deutsche Telekom, Huawei activate NB-IoT network in Germany
Juan Pedro Tomás · October 13, 2016
Deutsche Telekom headquarters in Bonn, Germany. Image provided.
NB-IoT demo planned for Bonn

AT&T and Ericsson To Deliver Technologies That Boosts The Internet of Things
INNOVATION / Barcelona, Spain, Feb 22, 2016
Share

Ericsson to Deploy Cat-M and NB-IoT Software for AT&T's 4G LTE Network to Lower Power Consumption, Cost and Complexity

AT&T* is working with Ericsson (NASDAQ:ERIC) to deploy CAT-M and NB-IoT 3GPP standards-based technologies. This new software will support a new generation of Internet of Things (IoT) apps and improve device performance on the AT&T 4G LTE network.

Vodafone Spain expands NB-IoT network to six cities
Monday 27 February 2017 | 09:36 CET | News
Vodafone has confirmed that its NB-IoT (narrowband Internet of Things) network is now available in a total of six major Spanish cities. The operator launched the network in Madrid

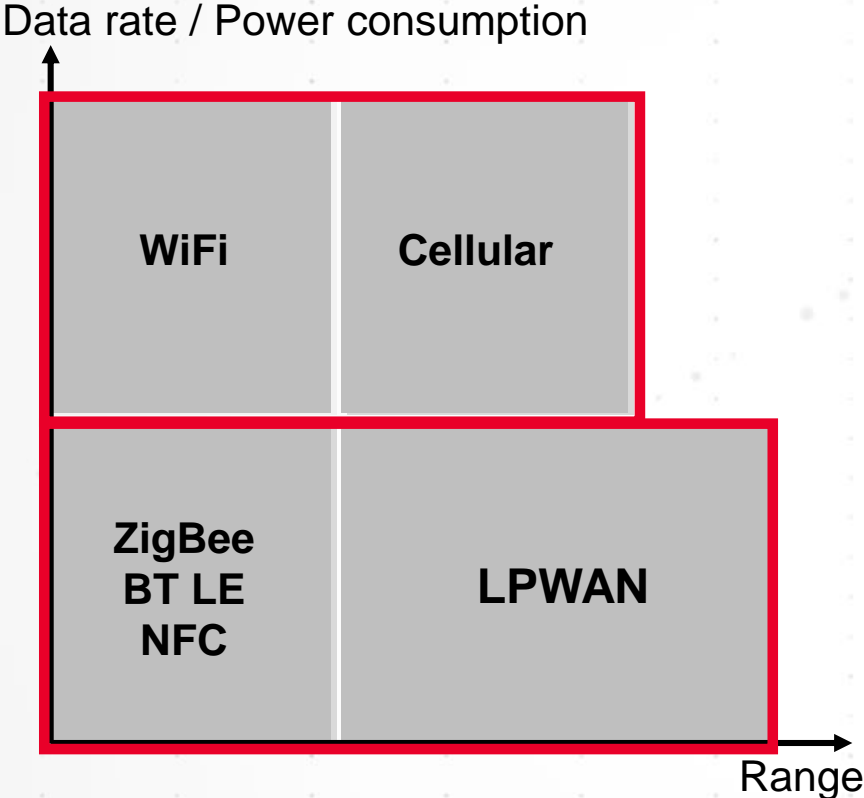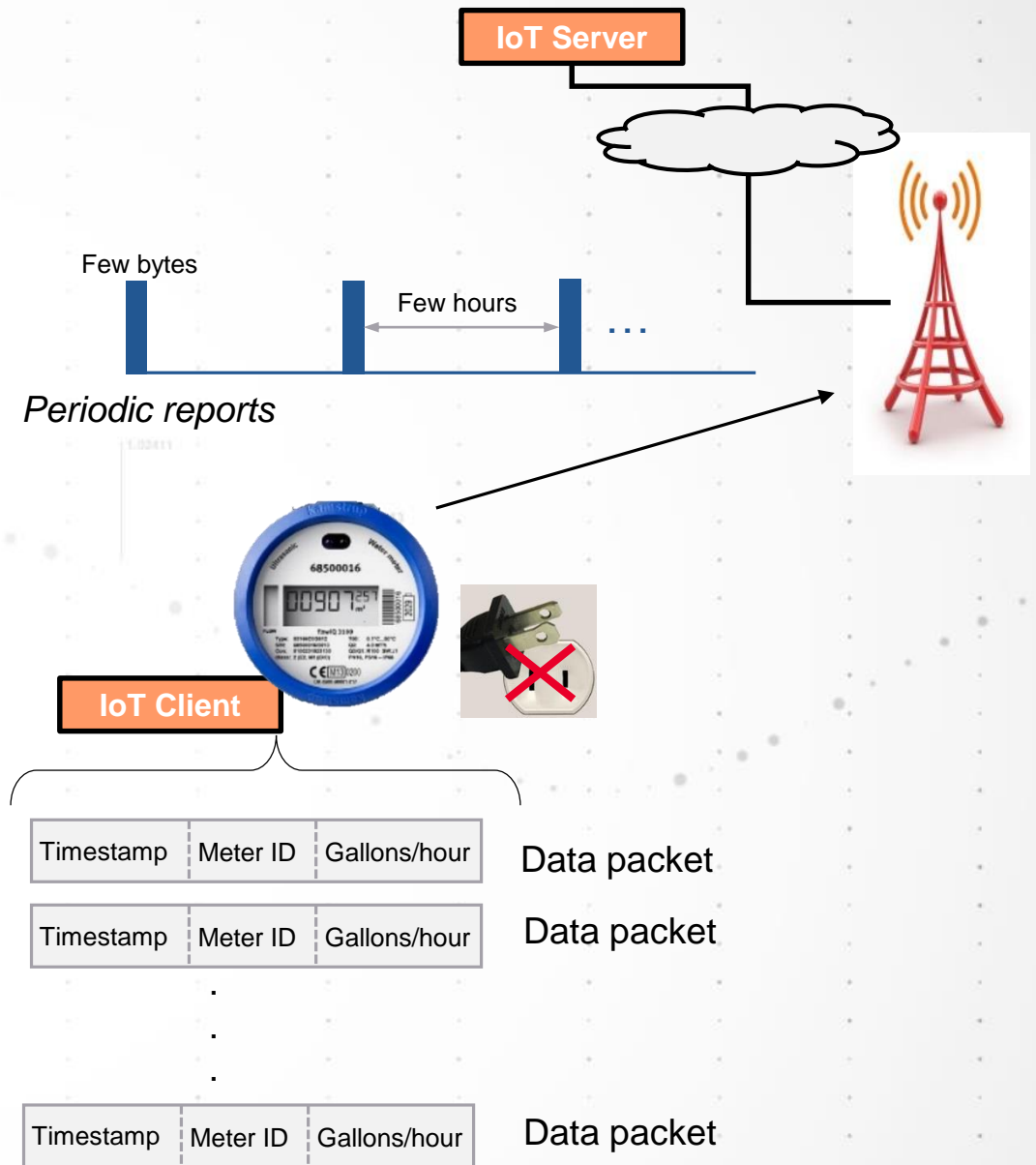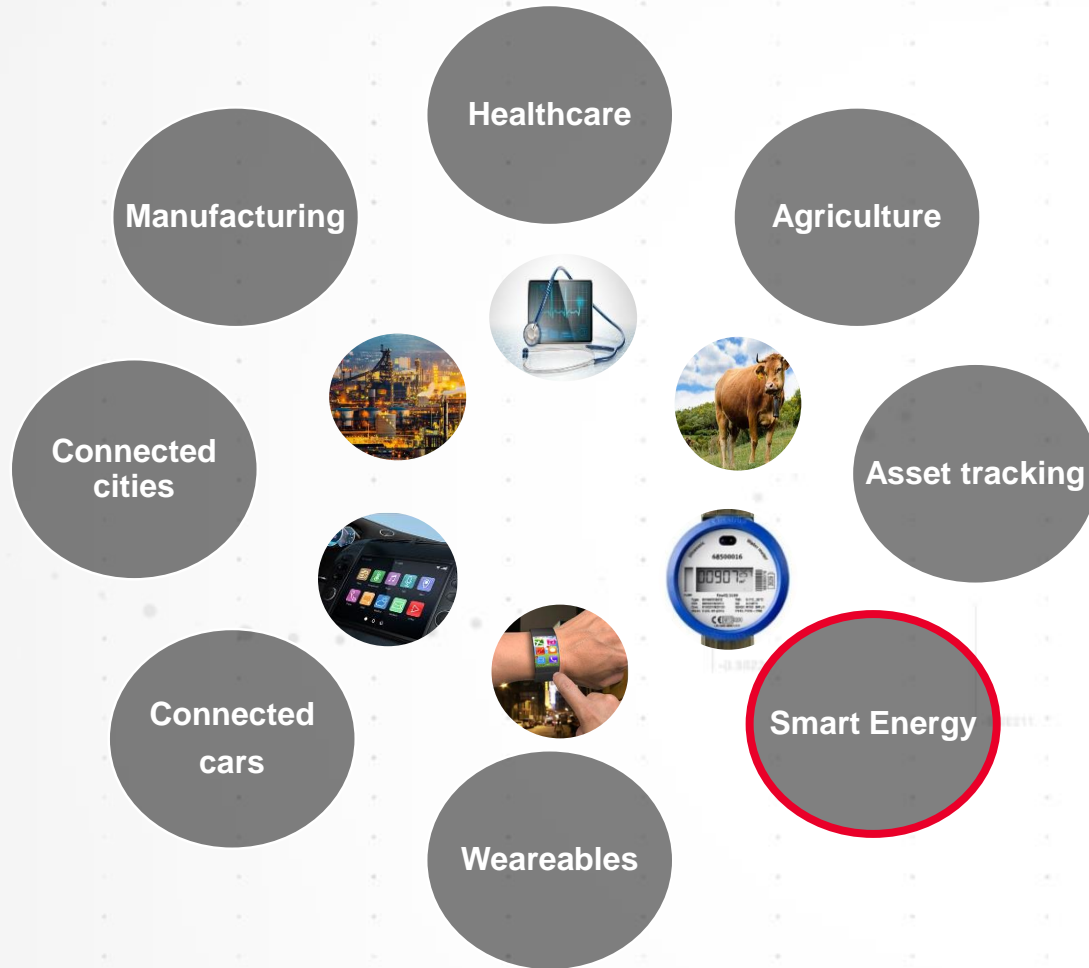Huawei and Oviphone tout "world's first NB-IoT watch"
17 OCT 2016
6   18   24

C114   2016-5-27 15:43
China Unicom starts NB-IoT networking trials in China, plans to push NB-IoT deployment in 2017

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Diverse IoT Applications

Data rate / Power consumption

WiFi	Cellular
ZigBee BT LE NFC	LPWAN

Range

Healthcare

Manufacturing

Agriculture

Connected cities

Asset tracking

Connected cars

Smart Energy

Weareables

LPWA Technology Challenges

Manufacturing

Healthcare

Agriculture

Connected cities

Asset tracking

Connected cars

Smart Energy

Weareables

IoT Server

Few bytes

Few hours

...

Periodic reports

IoT Client

Timestamp	Meter ID	Gallons/hour	Data packet
Timestamp	Meter ID	Gallons/hour	Data packet
.			
.			
.			
Timestamp	Meter ID	Gallons/hour	Data packet

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The solution is in the Network Operators

Solutions Today

- Infrastructure investment
- Soft standardization
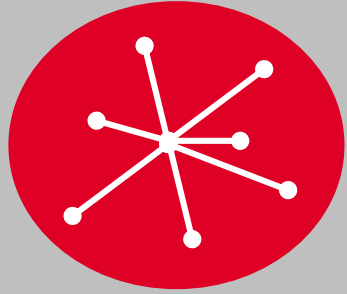- Range limitations
- Limited battery life
- Cellular as backhaul

Cellular LPWA

- Reuse of Cellular infrastructure
- Strong standardization
- Improved coverage
- Mobility, Roaming
- Security, Authentication

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3GPP Release 13 Narrowband IoT: Design Goals

NB-IoT

High Density

- 10s k devices/cell
- Data rates of 10s of kbps
- Low frequency of connections

Low Cost

- Modules < $5
- No fancy features
- Reliable, stable

Superior Battery Life

- Up to 10+ years
- Enhanced sleep modes

Extreme Coverage

- +20 dB compared to GPRS
- Areas of difficult access or remote

Upgrade

- To existing RAN infrastructure
- Global technology standard (3GPP)

The evolution of NB-IoT standardization

Sept 2015

NB-IoT Study Item

June 2016

Rel-13 Standard

1st Trials

March 2017

Rel-14 Standard

1st Deployments

Low Cost

Low Power

Extreme Coverage

High Density

Higher data rates

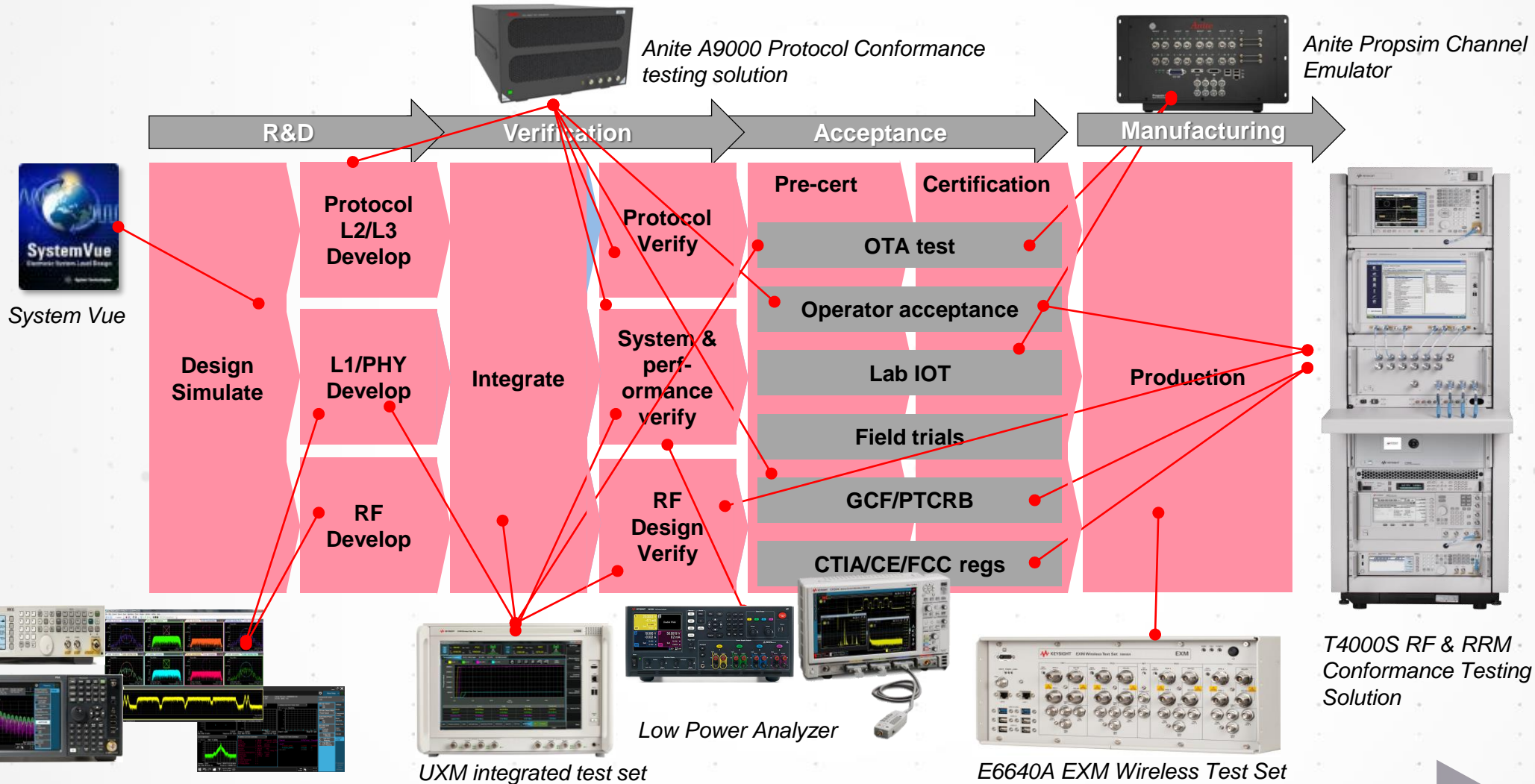*Enhanced mobility*

Positioning

Further power reduction

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Agenda

Why NB-IoT

NB-IoT Test Challenges and Solutions

Summary

NB-IoT Test Solutions Across the Lifecycle

Anite A9000 Protocol Conformance testing solution

Anite Propsim Channel Emulator

R&D → **Verification** → **Acceptance** → **Manufacturing**

System Vue

				Pre-cert	Certification	
Design Simulate	Protocol L2/L3 Develop	Integrate	Protocol Verify			Production
	L1/PHY Develop		System & perf-ormance verify	OTA test		
				Operator acceptance		
	RF Develop		RF Design Verify	Lab IOT		
				Field trials		
				GCF/PTCRB		
				CTIA/CE/FCC regs		

Low Power Analyzer

UXM integrated test set

E6640A EXM Wireless Test Set

T4000S RF & RRM Conformance Testing Solution

Speed, performance and results you can trust… Across the whole NB-IoT device lifecycle

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12

3GPP Release 13 Narrowband IoT: Design Goals

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Extreme Coverage

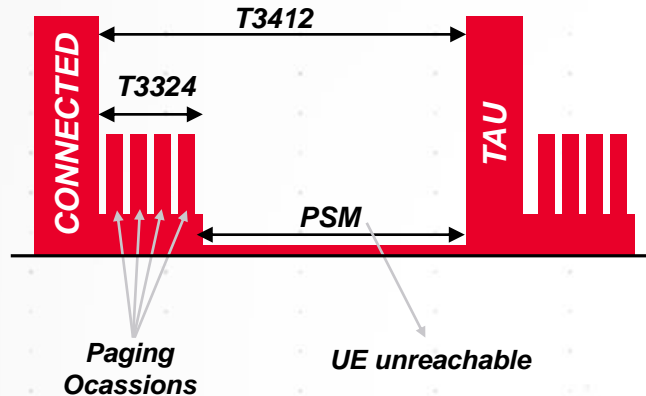- +20 dB compared to GPRS
- Areas of difficult access or remote

Upgrade
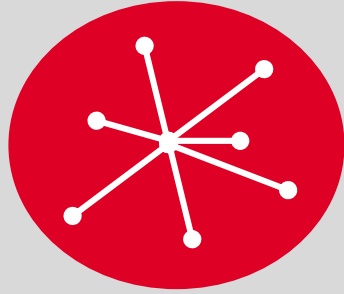
- To existing RAN infrastructure
- Global technology standard (3GPP)

NB-IoT Power Saving Mode and eDRX

Rel-12 Power Saving Mode (PSM)

Paging Ocassions

UE unreachable

- T3324 determines for how long the UE will monitor paging beforing entering in PSM

- While in PSM, UE is not reachable by the Network and all circuitry is turned off

- UE exits PSM when T3412 expires (TAU) or with a Mobile Originated transfer

Rel-13 Enhanced DRX (eDRX)

CONNECTED eDRX

Before   *UE monitoring control channel*   *Rel-13*

2.56s   *9.22s*
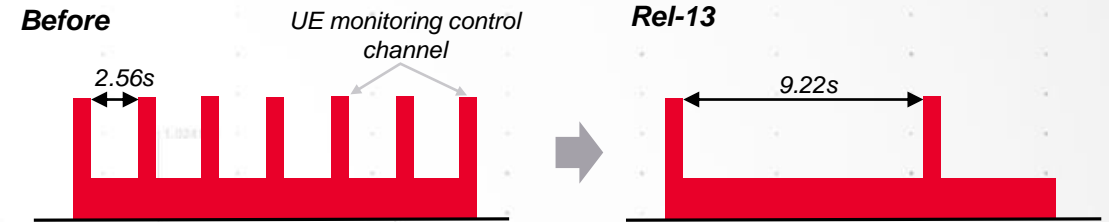
- DRX cycles extended from 2.56 seconds:
  - To 9.22 seconds in NB-IoT

IDLE eDRX

Paging Time Window

- New Paging Time Window which allows longer paging cycles:
  - 3 hours in NB-IoT

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NB-IoT Design Challenge - Power Consumption & Efficiency

Challenge #1: Setting the device in different operating modes realistically

- Different modes including IDLE, CONNECTED, PSM and eDRX

- Impact of very consuming activities like Repetitions, data transmissions or OTA updates

Challenge #2: Accurately measure sleep modes in presence of large spikes

- Wide dynamic range: sub-μA to 100 mA

- Single view logging providing complete analysis

Challenge #3: Characterize battery run-down including aging effect

- Being able to measure current and voltage simulatenously with enough accuracy

- Emulation of series resistance of the power supply

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NB-IoT Design Challenge - Power Consumption & Efficiency

***Characterize critical scenarios before deploying:***

- Efficiency of power saving modes (PSM, eDRX)

- Transitions between states (connected, idle, sleep)

- Data transfer (uplink, downlink, bi-directional)

- Repetitions performance for different Coverage levels

- Negative testing (IoT server down, no coverage, etc…)
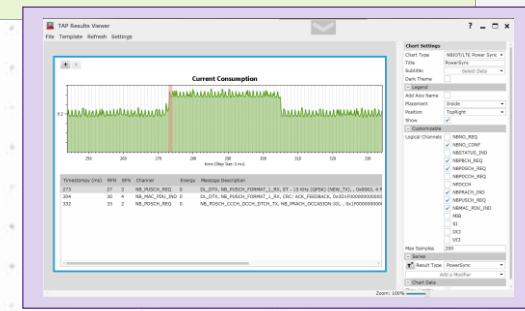
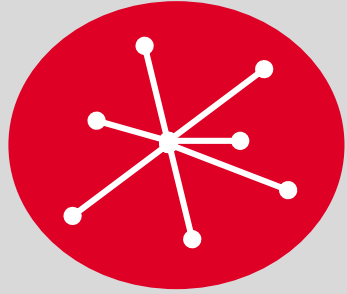- Software updates when in the field
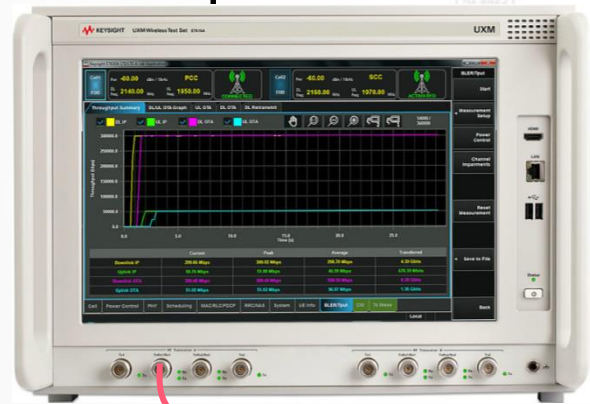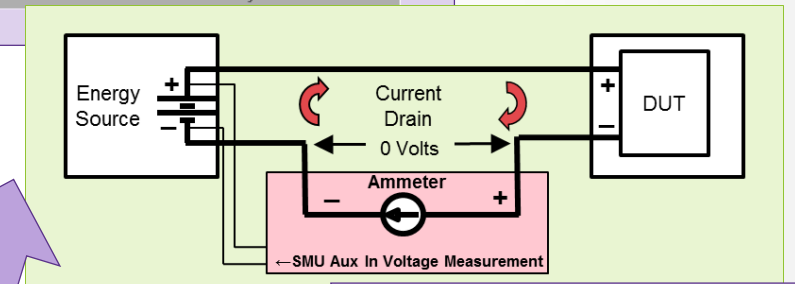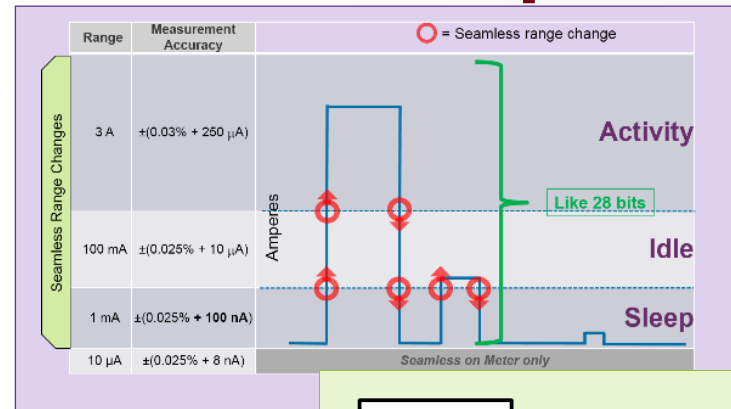
UXM Wireless Test Set

N6705B with Source Measurement Unit
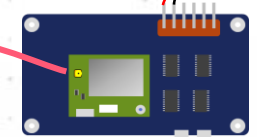
Device under test

3GPP Release 13 Narrowband IoT: Design Goals

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Upgrade

- To existing RAN infrastructure
- Global technology standard (3GPP)

NB-IoT: Extreme Coverage

Remote location

Basements and sewerages

Hidden Installation

Industrial Environments

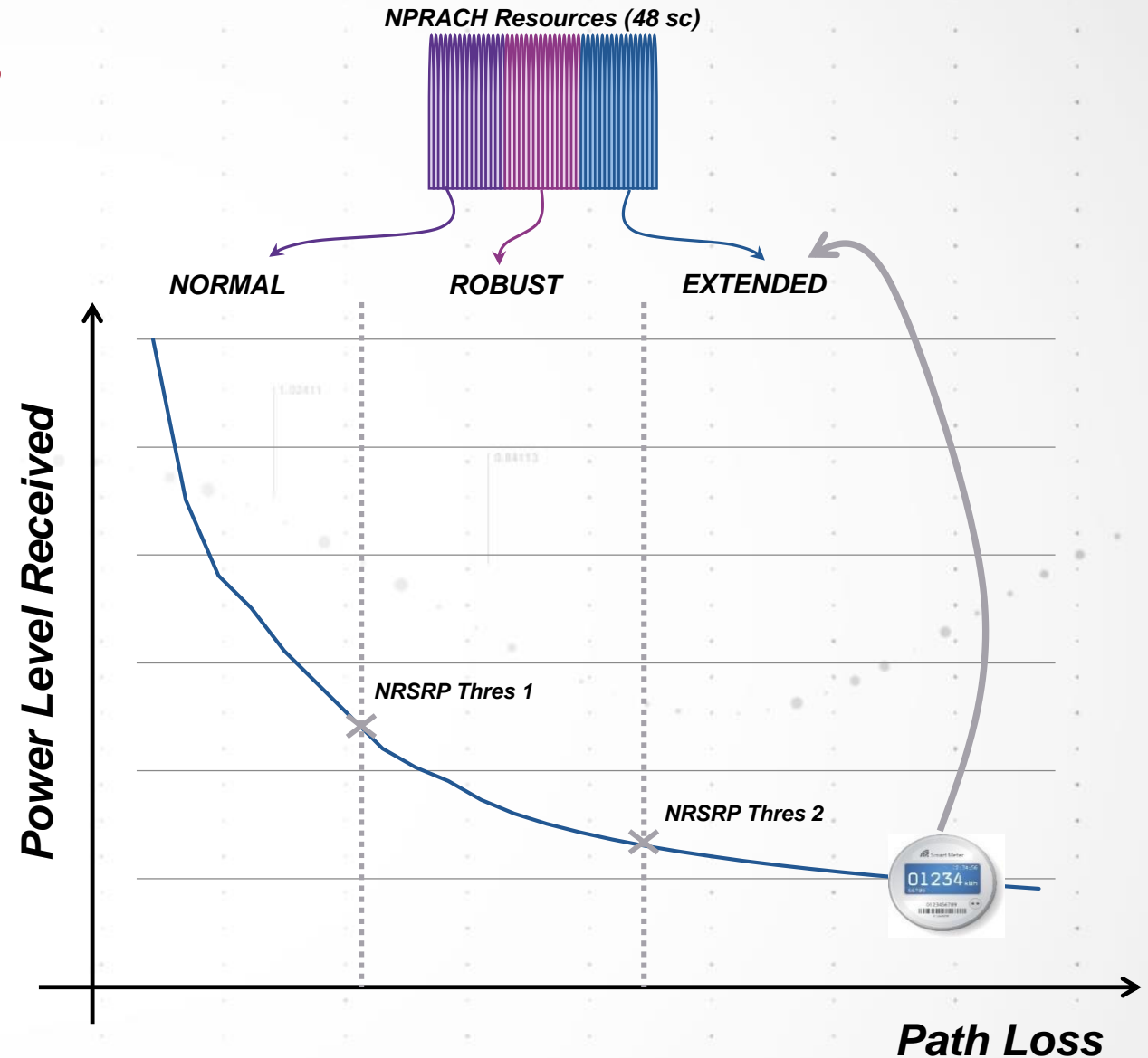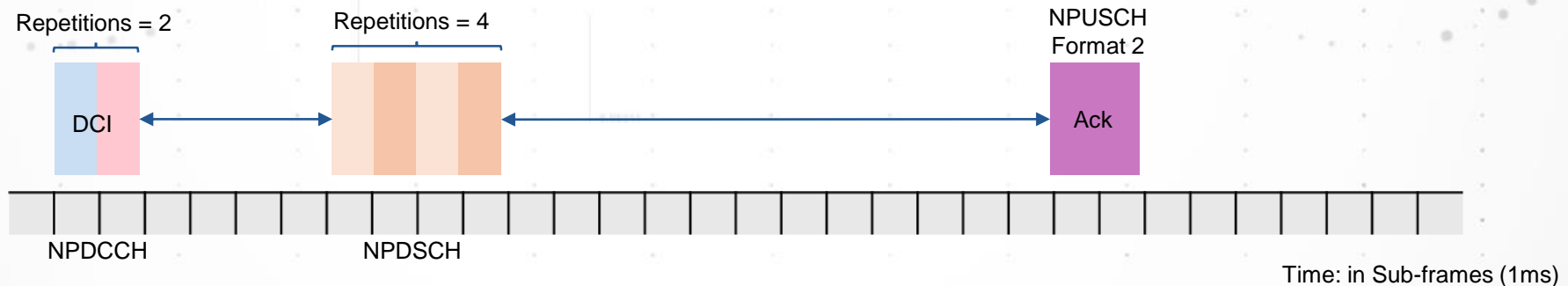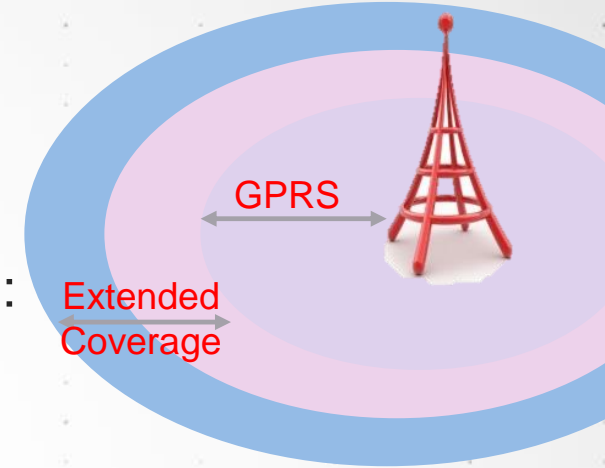| Characterization	Performance	OTA
- Extreme Sensitivity - Sync under low SNR - Transmitted Signal - Blocking and Intermodulation	- Propagation conditions - Slow fading profiles - Different operation modes and antenna configurations	- Wall, metallic structures - 3rd party enclosure and antenna effects

NB-IoT: Coverage Levels

- Up to 3 different Coverage Levels signaled via SIB2-NB (Normal, Robust, Extreme)

- The coverage level selected determines the NPRACH resources to use:
  - Subset of subcarriers, PRACH Repetitions, Max number of attempts, etc…

- UE derives the Coverage Level based on NRSRP measured
  - NPRACH resources to be used are determined by the Coverage Level

NPRACH Resources (48 sc)

NORMAL   **ROBUST**   **EXTENDED**

Power Level Received

NRSRP Thres 1

NRSRP Thres 2

Path Loss

NB-IoT: Repetitions

- Technique consisting on repeating the same transmission several times:

  - Achieve extra coverage (up to 20 dB compared to GPRS)

  - Each Repetition is self-decodable

  - Scrambling code is changed for each transmission to help combination

  - Repetitions are ACK-ed just once

- For NB-IoT all channels can use Repetitions to extend coverage

GPRS

Extended Coverage

Repetitions = 2

Repetitions = 4

NPUSCH Format 2

DCI

Ack

NPDCCH

NPDSCH

Time: in Sub-frames (1ms)

Example: *Repetitions used in NB-IoT in NPDCCH and NPDSCH channels*

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NB-IoT: Extreme Coverage – Test Challenges

Challenge #1: Receiver Sensitivity without and with Repetitions

- Below -120 dBm requires very accurate signal generation
- Soft-combination delivers expected gain in the receiver
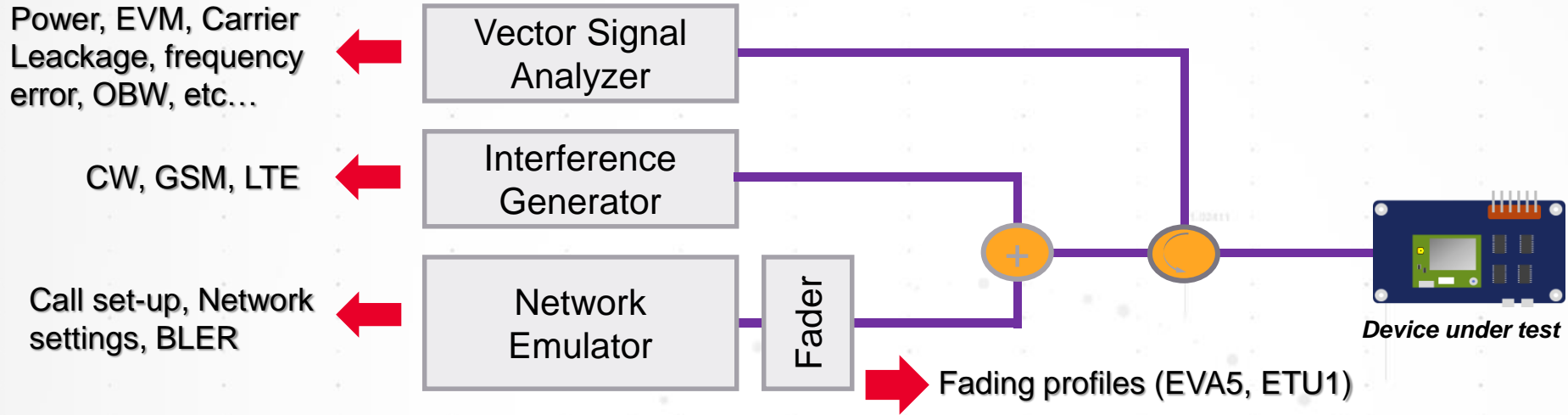- NRSRP and NRSRQ properly measured and reported to higher layers

Challenge #2: Performance characterization using low cost components

- Synchronization when poor Signal to Noise Ratio due to low cost crystal oscillator
- Impact of the transmitted signal due to removal of PAPR reduction circuitry

Challenge #3: Nomadic devices with slow mobility

- SISO and Transmit Diversity
- Complex test set-ups including multiple antennas, AWGN and Fading

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NB-IoT: Extreme Coverage

Power, EVM, Carrier Leackage, frequency error, OBW, etc…

← Vector Signal Analyzer

CW, GSM, LTE

← Interference Generator

Call set-up, Network settings, BLER

← Network Emulator

Fader

+

Device under test

→ Fading profiles (EVA5, ETU1)

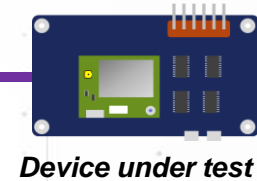| Characaterization	Performance	OTA
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Agenda

Why NB-IoT

NB-IoT Test Challenges and Solutions

Summary

Keysight Selected by China Mobile for Conformance Testing System

Keysight Technologies Selected by China Mobile Terminals for Cellular-IoT RF, RRM Conformance Testing

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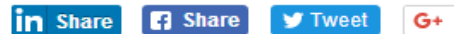
Collaboration enables chipset, module and device makers to optimize their designs and verify RF and RRM performance to China Mobile's Cellular-IoT test plan

Highlights:

- Keysight's integrated cellular-IoT RF and RRM conformance solution enables developers to optimize cellular-IoT designs

- Keysight's cellular-IoT test solution, using the E7515A UXM an all-in-one test platform supports China Mobile Terminals' NB-IoT and eMTC RF and RRM conformance test needs

SANTA ROSA, Calif., Aug. 25, 2017

Keysight Technologies, Inc. (NYSE: KEYS) today announced that its cellular-IoT RF/RRM test solution was selected by China Mobile Terminals to be used for Cellular-IoT (C-IoT) chipset and module certification. Based on the E7515A UXM wireless test set, Keysight is the only all-in-one test platform vendor to support China Mobile's C-IoT RF and RRM conformance test.

C-IoT is a cellular radio technology designed for the internet of things (IoT) for 3GPP. C-IoT, including narrowband-IoT (NB-IoT) and enhanced machine-type communication (eMTC), enables telecom operators to run IoT services on existing commercial networks to support diverse IoT application scenarios. Many telecom operators, such as China Mobile, have announced its C-IoT network launch plans in recent months.

Keysight and China Mobile Terminals are collaborating on C-IoT test plans to ensure the C-IoT chipset, module and device RF and RRM performance to GCF conformance test needs.

"Engineers can use Keysight's UXM industry-leading wireless test set to evaluate RF and RRM measurements with NB-IoT and eMTC devices to ensure standards compliance," said Garrett Lees, senior director, Keysight's Operator and Test Lab Business. "Working with key industry leaders and telecom operators, such as China Mobile, has allowed us to offer a complete solution that covers cellular IoT design, verification, interoperability and carrier acceptance test."

More information about Keysight's UXM wireless test set is available at www.keysight.com/find/UXM. High resolution images are available at www.keysight.com/find/UXM-images. Videos demonstrating the UXM's versatile capabilities are available on YouTube. Contact Keysight at www.keysight.com/find/contactus for E7515A UXM pricing and delivery information.

About Keysight Technologies

Keysight Technologies Selected by China Mobile Research Institute for Mobile Internet of Things Test System

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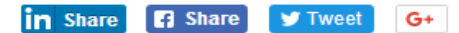
Evaluates power consumption, RF and positioning performance of internet of things (IoT) products—supports research verification of new IoT technologies and devices

Highlights:

- Keysight's cellular IoT test system verifies power consumption, RF and positioning performance of IoT devices—allowing companies to verify and improve the performance of their mobile IoT products and devices

- Keysight's cellular IoT test system, using the E7515A UXM an all-in-one test platform, supports China Mobile Research Institute's study of IoT testing solutions and the verification of its new technologies

SANTA ROSA, Calif., Sept. 20, 2017

Keysight Technologies, Inc. (NYSE: KEYS) today announced that its mobile internet of things (IoT) test system was selected by China Mobile Research Institute (CMRI). Based on the E7515A UXM wireless test set, Keysight helps CMRI study the power consumption, RF, and positioning performance, and verification, of new IoT technologies, devices and products.

The mobile IoT module bridges the mobile IoT chipset and device, fulfills the specific requirements of IoT fragmentation applications, and helps with the quick deployment of new products. While the IoT module plays a key role in ensuring the quality of IoT applications, a standard testing platform and method is indispensable to ensure the key performance of the IoT module's power consumption, RF and positioning capabilities. Lower power consumption means longer usage time and lower deployment and maintenance cost; superior RF performance means a more reliable network connection and greater stability; and precise positioning performance means the system is suitable for different application scenarios within the mobile environment.

"Keysight's cellular IoT testing solution is the leading solution in the IoT industry and supports narrow-band IoT as well as enhanced machine type communication within the same platform," said Garrett Lees, senior director, Keysight's Operator and Test Lab Business. "Engineers can use this IoT test solution to verify a device's power consumption, RF and positioning performance, while tracking their R&D progress and enhancing the overall competitiveness of their products."

More information about Keysight's UXM wireless test set is available at www.keysight.com/find/UXM. High resolution images are available at www.keysight.com/find/UXM-images. Videos demonstrating the UXM's versatile capabilities are available on YouTube. Contact Keysight at www.keysight.com/find/contactus for E7515A UXM pricing and delivery information.

About Keysight Technologies

T4010S Conformance Test System-Key Features

Configuration suitable for NB-IoT and LTE up to 2CC, 3CC/4CC requires a second UXM

Dual feed antenna UE' s support

Complete 3GPP RF test case coverage for RF and RRM according to GCF and PTCRB requirements-TP 195

From LTE Rel-8 to 4CC supported today and ready for 5CC

Full test system automation

Scalable solution from one box to full system

Pre-conformance and Design Verification tool

UE automation capabilities allowing unattended operation of the test system

Extensive test coverage for major US operators acceptance test plans: AT&T, Verizon, T-Mobile and Sprint.

Support of Regulatory for Europe RF EN 301 908-13

Easy to use test project management environment for streamlined testing execution and results analysis

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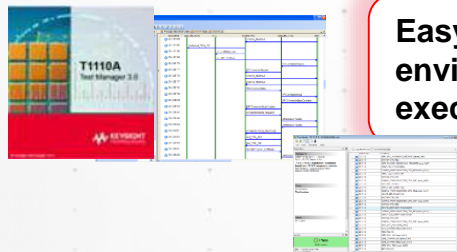
NB-IoT requirements in Regulatory next version 13.1.1

Keysight collaborates in NB-IoT regulatory definition

NB-IoT Candiates	
4.2.2.4	Transmitter output power for category NB1
4.2.3.5	Transmitter spectrum emission mask for category NB1
4.2.4.5	Transmitter spurious emissions for category NB1
4.2.5.4	Transmitter minimum output power for category NB1
4.2.6.3	Receiver Adjacent Channel Selectivity (ACS) for category NB1
4.2.7.3	Receiver Blocking Characteristics for category NB1
4.2.8.3	Receiver Spurious Response for category NB1
4.2.9.3	Receiver Intermodulation Characteristics for category NB1
4.2.11.5	Transmitter adjacent channel leakage power ratio for category NB1
4.2.12.2	Receiver Reference Sensitivity Level for category NB1

➢ Keysight actively collaborates in the update of next regulatory version. Specifically, Keysigh is in charge on NB-IoT requirements for regulatory.

➢ This is the list of requirements added in the early draft of v13.1.1. Note that only Rx/Tx requirements are considered in regulatory.

➢ European bands for NB-IoT: Bands 1, 3, 8, 20, 28.

NB-IoT is becoming a reality

❖ **NB-IoT addresses LPWA use cases re-using existing cellular infrastructure**

- A completely new technology that will continue developing in further 3GPP Releases

- Narrowband technologies will continue to serve the MTC use case with 5G NR

❖ **NB-IoT networks are becoming a reality…**

- Multiple Operators trials now in EU and Asia; planning to deploy services during 2H 2017

- Strong interest from other Operators worldwide

❖ **Covering new use cases means facing new challenges**

- Extended coverage, low power consumption, stability, etc…

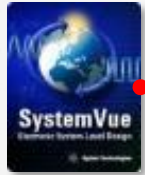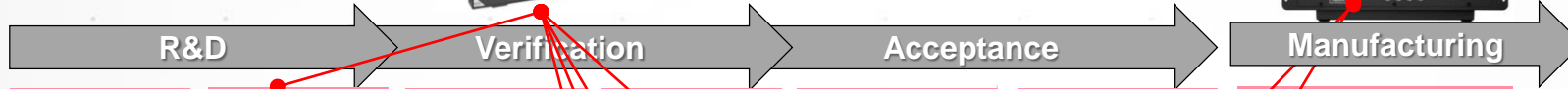- Operators' Acceptance including 3GPP conformance test and certification

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NB-IoT Test Solutions Across the Lifecycle

Anite A9000 Protocol Conformance testing solution

Anite Propsim Channel Emulator

R&D → Verification → Acceptance → Manufacturing

System Vue

Protocol L2/L3 Develop

Protocol Verify

Pre-cert | Certification

OTA test

Operator acceptance

Design Simulate

L1/PHY Develop

Integrate

System & performance verify

Lab IOT

Production

Field trials

RF Develop

RF Design Verify

GCF/PTCRB

CTIA/CE/FCC regs
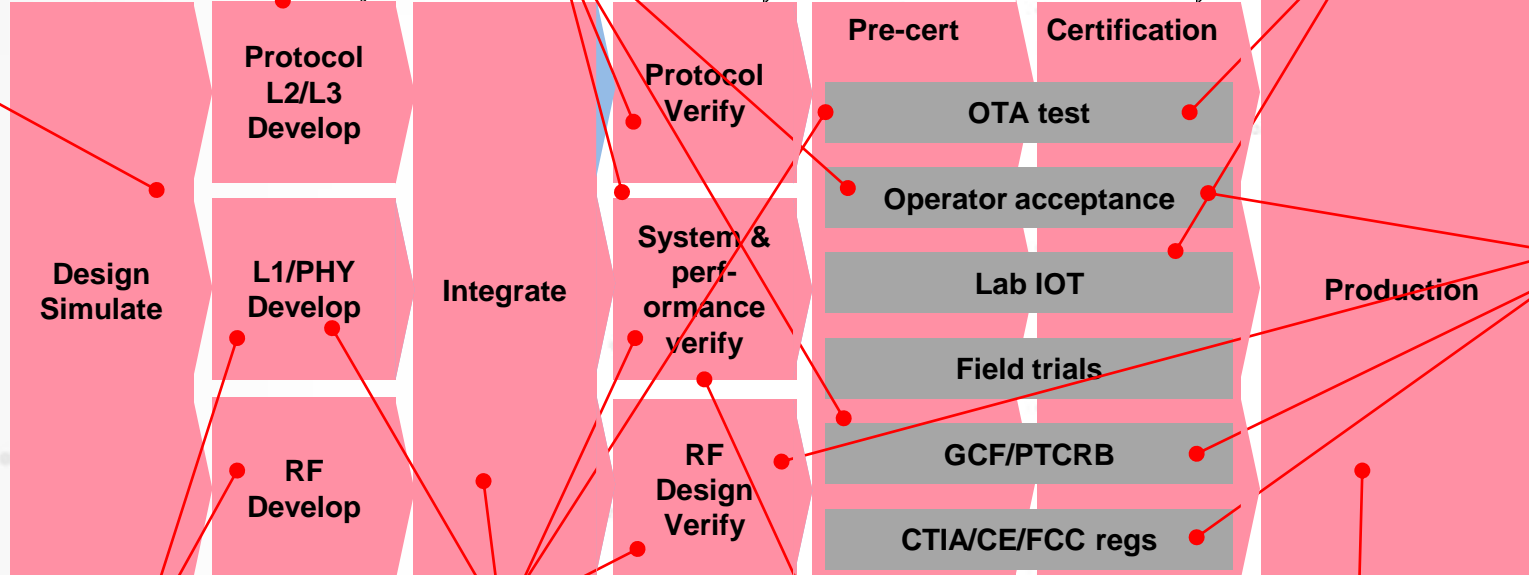
T4000S RF & RRM Conformance Testing Solution

Low Power Analyzer

UXM integrated test set

E6640A EXM Wireless Test Set

Speed, performance and results you can trust… Across the whole NB-IoT device lifecycle

The Key to Success in Technology

THANK YOU!

HARDWARE + SOFTWARE + PEOPLE = INSIGHTS