Internet of Things - IoT
System Design Challenges and Testing Solutions

Lothar Walther
Training Center
Rohde & Schwarz, Germany
“Everything that benefits from being connected will be connected”

Ericsson, 2010
Wearables
Smart Herd

MooMonitor+
Health & Fertility Monitoring

ROHDE & SCHWARZ

IoT - Italy - May 2017
Smart City
Low-power wide-area networks (LP-WAN) will enable applications which sense literally Everything Everywhere Anytime.
The **SIX L’s** characterizing LP-WANs, or
10 € devices capable of 10 km range with 10-year battery lifetime

<table>
<thead>
<tr>
<th><strong>Low Power</strong></th>
<th><strong>Low Cost</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery powered devices requiring 10+ years lifetime</td>
<td>Communication modules for 5 Euro and even less</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Long Range</strong></th>
<th><strong>Large Scale</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Covering large areas with low number of base stations</td>
<td>Several thousands of devices per gateway or base station</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Low Throughput</strong></th>
<th><strong>Low Responsiveness</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>From 100 bps to some few kbps; short message once per hour, day or week, ....</td>
<td>Relaxed requirements regarding responsiveness of a device</td>
</tr>
</tbody>
</table>
Outline

- The Internet of dogs, lights and doors
- Sigfox, LoRa and more
- LTE-A Pro: eMTC, NB-IoT
- What’s next on the way to 5G
LAN and PAN technology becoming more important

Bluetooth and especially BLE become important in the Smart Home market with features like Mesh.

Wi-Fi 802.11n/ac/ax stay relevant. Future of “Wi-Fi HaLow” and “White Wi-Fi” still unclear.

ZigBee ecosystem becomes stronger due to cooperation with enocean and Thread.
Example: Sigfox designed as LP-WAN sensor network

- Ultra Narrow Band Modulation (100 Hz / 600 Hz)
- Redundant uplink Transmission (2x repetitions)
- Pseudo–random frequency hopping (3 out of 320 ch.)
- Short messages
  - UL: 12 Byte
  - DL: 8 Byte
- No passive RX mode (RX window after TX)

Gateway

Backend Server

~2sec

~2sec

~2sec

12 Byte / max 140 per day* | 100 bps | (D)BPSK | < 14 dBm

8 Byte / max 4 per day* | 600 bps | 2GFSK / ±800 Hz | < 27 dBm

* ETSI regulation

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Another prominent example: LoRaWAN™

- Chirped Spread Spectrum (125/250/500 kHz)
- Multiple Gateways simultaneously receiving
- Pseudo–random frequency hopping (after each TX)
- Data Rate Adaption (spreading factor/ bandwidth)
- Different RX mode options (Class A/B/C)

* ETSI regulation
LP-WAN technologies in ISM/SRD bands shaking the market

<table>
<thead>
<tr>
<th>Technique</th>
<th>sigfox</th>
<th>LoRaWAN</th>
<th>ingenu</th>
<th>WEIGHTLESS-N</th>
<th>WEIGHTLESS-P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultra Narrow Band (UNB)</td>
<td>Ultra Narrow Band (UNB)</td>
<td>Chirp Spread Spectrum</td>
<td>DSSS RPMA</td>
<td>Ultra Narrow Band (UNB)</td>
<td>DSSS Narrow Band (NB)</td>
</tr>
<tr>
<td>Channel BW (UpLink)</td>
<td>ETSI: 100 Hz FCC: 600 Hz</td>
<td>125 kHz 250 kHz 500 kHz</td>
<td>1 MHz</td>
<td>200 Hz</td>
<td>6/7/8 MHz 12.5 kHz</td>
</tr>
<tr>
<td>Band</td>
<td>ISM/SRD &lt; 1 GHz</td>
<td>ISM/SRD &lt; 1 GHz</td>
<td>ISM/SRD 2.4 GHz</td>
<td>ISM/SRD &lt; 1 GHz</td>
<td>TV white space 470-790 MHz ISM/SRD &lt; 1 GHz</td>
</tr>
<tr>
<td>Driver</td>
<td>sigfox</td>
<td>SEMTECH</td>
<td>ingenu</td>
<td>nwave</td>
<td>neul</td>
</tr>
</tbody>
</table>
Typical RF parametric measurements to ensure desired performance as well as pre-conformance.

Typical RX Measurement
• Receiver sensitivity
• Receiver blocking
• Adjacent channel selectivity
• Spurious response rejection
• …..

Typical TX Measurements
• Spectrum emission mask
• Power
• Frequency Error
• Error Vector Magnitude
• …..

RF Performance
Standard Conformance
Regulatory Conformance
Receiver sensitivity and Tx power are very critical

<table>
<thead>
<tr>
<th>Technology</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS</td>
<td>-140 dBm</td>
</tr>
<tr>
<td>LoRa</td>
<td>-110 dBm</td>
</tr>
<tr>
<td>NB-IoT</td>
<td>-100 dBm</td>
</tr>
<tr>
<td>Sigfox</td>
<td>-120 dBm</td>
</tr>
<tr>
<td>GSM</td>
<td>-130 dBm</td>
</tr>
<tr>
<td>enOcean</td>
<td>-150 dBm</td>
</tr>
<tr>
<td>802.11ah</td>
<td>-140 dBm</td>
</tr>
<tr>
<td>Z-wave</td>
<td>-160 dBm</td>
</tr>
<tr>
<td>802.15.4</td>
<td>-170 dBm</td>
</tr>
<tr>
<td>802.11ac</td>
<td>-180 dBm</td>
</tr>
<tr>
<td>Bluetooth</td>
<td>-190 dBm</td>
</tr>
</tbody>
</table>

Receiver sensitivity requirements of up to – 140 dBm
Example: Calibration and Verification of LoRaWAN Gateway

- RSSI calibration and verification
- Receiver sensitivity
- Tx calibration and verification
- Frequency tolerance
- GNSS sensitivity

Vector Signal Generator (e.g. R&S®SGT)

Vector Signal Analyzer (e.g. R&S®FPS)
Outline

- The Internet of dogs, lights and doors
- Sigfox, LoRa and more
- LTE-A Pro: eMTC, NB-IoT
- What's next on the way to 5G
Three LP-WAN technologies specified by 3GPP

- **Rel. 10**: NIMTC
- **Rel. 11**: SIMTC
- **Rel. 12**: LC-LTE/MTCe (CAT-0, PSM), eMTC (Cat-M1, eDRX, CE)
- **Rel. 13**: eMTC (1.4 MHz/half-duplex), NB-IoT (Cat-NB1, eDRX, CE)
- **Rel. 14**: 5G mMTC (positioning, mobility, multicast VoLTE support)

**NB-cIoT**

**NB-LTE**

**GERAN SI: CIoT**

**EC-GSM-IoT**

incl. eDRX
### 3GPP addresses the LP-WAN market as well

<table>
<thead>
<tr>
<th></th>
<th>LTE Cat M1</th>
<th>NB-IoT (Cat NB1)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Deployment</strong></td>
<td>In-band LTE</td>
<td>In-band LTE/Guard-band LTE Standalone</td>
</tr>
<tr>
<td><strong>Downlink</strong></td>
<td>OFDMA [15 kHz]</td>
<td>OFDMA [15 kHz]</td>
</tr>
<tr>
<td><strong>Uplink</strong></td>
<td>SC-FDMA [15 kHz]</td>
<td>Single tone [15/3.75 kHz]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Multi tone / SC-FDMA [15 kHz]</td>
</tr>
<tr>
<td><strong>Peak data rate</strong></td>
<td>DL: 1 Mbps, UL: 1 Mbps</td>
<td>DL: 250 kbps, UL: 20 kbps (ST)</td>
</tr>
<tr>
<td><strong>UE receiver BW</strong></td>
<td>1.4 MHz</td>
<td>200 kHz</td>
</tr>
<tr>
<td><strong>Duplex mode</strong></td>
<td>Full/Half-duplex, FDD/TDD</td>
<td>Half-duplex, FDD</td>
</tr>
<tr>
<td><strong>UE transmit power</strong></td>
<td>23 or 20 dBm</td>
<td>23 or 20 dBm</td>
</tr>
<tr>
<td><strong>Power saving</strong></td>
<td>PSM, eDRX</td>
<td>PSM, eDRX</td>
</tr>
<tr>
<td><strong>Voice support</strong></td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td><strong>Mobility (RRC_connected)</strong></td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>
eMTC / CAT-M1

- eMTC
  - Cat-M1, eDRX, CE
  - 1.4 MHz/half-duplex

- NB-LTE
  - NB-cIoT

- Rel. 10
  - NIMTC

- Rel. 11
  - SIMTC

- Rel. 12
  - eMTC

- Rel. 13
  - 1

- Rel. 14
  - 2

- mMTC

- IoT - Italy - May 2017
Further LTE Physical Layer Enhancements for MTC (eMTC)

Quick facts

- RAN1 Work item (follow-up to Rel-12 MTC)
- Started September 2014
- Completed March 2016
- **Main** topics of the Work Item

**Low complexity**
- 1.4 MHz bandwidth
- Reduced max. Tx power
- Reduced number of transmission modes

**LTE coverage improvement**
- (15dB for FDD) by
  - Repetition of PHY channels
  - Skipping of channels

"not extending coverage for given data rate, but coverage is extended by reducing the data rate"

- **Low-cost UEs (LC)**
- **BL**: Bandwidth reduced low complexity
- “BL UEs”

- **BL UEs also support CE**

- **UEs operating in coverage enhancement**
- “UEs in CE”

- **CE can also be used by “regular” R13 UEs**
## eMTC Properties - Overview

<table>
<thead>
<tr>
<th>UE Cat. M1</th>
<th>Coverage Enhancement - Repetition-</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.4 MHz bandwidth (tunable)</td>
<td>PBCH / MIB</td>
</tr>
<tr>
<td>No legacy PCFICH, PDCCH, PHICH</td>
<td>MPDCCH</td>
</tr>
<tr>
<td>SIB1-BR</td>
<td>Cross-subframe scheduled PDSCH</td>
</tr>
<tr>
<td>New power class (20 dBm) and CE operation optional</td>
<td>PUCCH</td>
</tr>
<tr>
<td>CEMode A (and CEModeB)</td>
<td>PUSCH</td>
</tr>
<tr>
<td>Only TM1/2/6 for CRS + TM9 for DM-RS based demodulation</td>
<td>PRACH multiple attempts and repetition levels</td>
</tr>
</tbody>
</table>
Narrowbands (eMTC; Cat-M1) inside the LTE carrier

- Frequency retuning (e.g. after cell search) to multiple narrowbands to support scalable resource allocation
- Frequency hopping between narrowbands for coverage enhancement
- Guard Period for retuning: 2 OFDM Symbols (created by UE)
- TDD: same set of narrowbands for UL and DL

- 3, 5, 15 MHz carrier
- 10, 20 MHz carrier

NB #N
6 PRB/1.4 MHz

NB #N/2
6 PRB/1.4 MHz

NB #N/2+1
6 PRB/1.4 MHz

NB #1
6 PRB/1.4 MHz

Remaining PRBs

N=2/4/12

N=16/8

NB index
## CE Modes A and B → PDSCH / PUSCH repetition

### pd(u)sch-maxNumRepetitionCEmodeA

<table>
<thead>
<tr>
<th>Value</th>
<th>Repetition Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not configured</td>
<td>{1,2,4,8}</td>
</tr>
<tr>
<td>16</td>
<td>{1,4,8,16}</td>
</tr>
<tr>
<td>32</td>
<td>{1,4,16,32}</td>
</tr>
</tbody>
</table>

### pd(u)sch-maxNumRepetitionCEmodeB

<table>
<thead>
<tr>
<th>Value</th>
<th>Repetition Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not configured</td>
<td>{4,8,16,32,64,128,256,512}</td>
</tr>
<tr>
<td>192</td>
<td>{1,4,8,16,32,64,128,192}</td>
</tr>
<tr>
<td>256</td>
<td>{4,8,16,32,64,128,192,256}</td>
</tr>
<tr>
<td>384</td>
<td>{4,16,32,64,128,192,256,384}</td>
</tr>
<tr>
<td>512</td>
<td>{4,16,64,128,192,256,384,512}</td>
</tr>
<tr>
<td>768</td>
<td>{8,32,128,192,256,384,512,768}</td>
</tr>
<tr>
<td>1024</td>
<td>{4,8,16,64,128,256,512,1024}</td>
</tr>
<tr>
<td>1536</td>
<td>{4,16,64,256,512,768,1024,1536}</td>
</tr>
<tr>
<td>2048</td>
<td>{4,16,64,128,256,512,1024,2048}</td>
</tr>
</tbody>
</table>

---

**SIB2 → cell specific**

**DCI → UE specific**
eMTC: Downlink

Downlink Physical channels
- MPDCCH
- PBCH
- PDSCH

Downlink Logical channels
- DL-SCH
- PCCH
- BCCH
- PCH
- BCH
- DTCH
- BR-BCCH

Physical Channel | Modulation Scheme
-----------------|---------------------
P BCH             | QPSK                
MPDCCH           | QPSK                
PDSCH            | QPSK/16QAM          

Signals
- PSS
- SSS
- CRS
- DMRS

no change, use legacy
System Information - MIB

-- ASN1START

MasterInformationBlock ::= SEQUENCE {
    dl-Bandwidth ENUMERATED {
        n6, n15, n25, n50, n75, n100},
    phich-Config PHICH-Config,
    systemFrameNumber BIT STRING (SIZE (8)),
    schedulingInfoSIB1-BR-r13 INTEGER (0..31),
    spare BIT STRING (SIZE (5))
}

-- ASN1STOP

Scheduling of SIBs without Control Channel
LTE CAT-M1 – 1.4 MHz DL channel support
MPDCCH - Frequency Hopping

Based on absolute subframe number counted from the first subframe in SFN=0

System Bandwidth

interval-DLHoppingConfigCommon, here: 2

mpdcch-pdsch-HoppingOffset-r13, here: 2

→ equal spacing between 4 NB

here: mpdcch-pdsch-HoppingNB-r13 = 4

NB 7
NB 6
NB 5
NB 4
NB 3
NB 2
NB 1

time (subframes)
PDSCH Cross Subframe scheduling

delay allows to decode MPDCCH without buffering

channels

MPDCCH

PDSCH

start of MPDCCH

DCI subframe repetition number

n

n+k_i

fixed to 2 subframes

time in subframes
eMTC: Uplink

### Physical Channel
- **PUSCH**
  - UL-SCH
  - **Modulation Scheme**: QPSK / 16-QAM → CEModeA
  - QPSK → CEModeB
- **PUCCH**
  - UCI
  - **Modulation Scheme**: depends on format
- **PRACH**
  - RACH
  - **Modulation Scheme**: N/A

### Signal
- **DMRS**
- **SRS**
- no changes
PUSCH - Frequency Hopping

Similar to MPDCCH/PDSCH-hopping, but only between 2 narrowbands

Based on absolute subframe number counted from the first subframe in SFN=0

interval-ULHoppingConfigCommon, here: 2

Based on: pusch-HoppingOffset-v1310

NB 2 → from DCI UL grant

NB 3

NB 4
eMTC: Uplink Transmission Gaps

UL transmission period X < 256ms

UL transmission gap Y < 10ms

PUSCH

PSS/SSS/
PBCH/CRS

UE tunes to DL during UL transmission gaps in order to keep frequency synchronised (for long UL transmissions)
NB-IoT / CAT-NB1

- Rel. 10: NB-IoT
- Rel. 11: NB-IoT
- Rel. 12: NB-IoT
- Rel. 13: NB-IoT
- Rel. 14: NB-IoT

- EcGSM-IoT incl. eDRX
- mMTC
- eMTC
- Cat-M1, eDRX, CE

- 1.4 MHz/half-duplex
- 200 kHz

Positioning, mobility, multicast VoLTE support
## NB-IoT Design Objectives

<table>
<thead>
<tr>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved indoor coverage: extended coverage of 20 dB</td>
</tr>
<tr>
<td>Support of massive number of low throughput devices (e.g. 40 MTC devices per household) → 52547 devices per cell (“standard”) sector</td>
</tr>
<tr>
<td>Reduced complexity</td>
</tr>
<tr>
<td>Things that cost less than a 2G device</td>
</tr>
<tr>
<td>Improved power efficiency: more than 10 years battery life time (@200bytes per day)</td>
</tr>
<tr>
<td>Relaxed delay characteristics: ~10 sec.</td>
</tr>
</tbody>
</table>
NB-IoT Architecture

Requirements:
Following architecture requirements shall be supported:
- minimize system signalling load especially over Radio interface
- appropriate security to EPS system
- improve battery life
- support delivery of IP data
- support delivery of non-IP data
- support of SMS

General Architecture not changed

X2: no handover, but resume to other eNB
NB-IoT Architecture: Optimized to support transfer of small data

Minimize signaling load over the radio interface

Control Plane CIoT EPS optimization:
Data Exchange on RRC level by adding data to ConnectionSetup or in UL ConnectionSetupComplete message or using Information Transfer messages.
- non-IP messages to/from SCEF and
- IP messages to/from SGW/PGW

User Plane CIoT EPS optimization
Data Exchange (IP and Non-IP data) using the user data plane via radio bearers
**NB-IoT: Physical Operations**

UE RF **Bandwidth will be 180 kHz** for both downlink and uplink. (1 PRB)

- **Downlink**
  - OFDMA with 15kHz subcarrier spacing

- **Uplink**
  - multi-tone transmissions
    - SC-FDMA based
    - 15 kHz subcarrier spacing ➔ optional
  - single tone transmissions
    - 3.75 kHz or 15 kHz subcarrier spacing ➔ mandatory

Only **FDD in half-duplex mode** TypeB, **no TDD** (in Rel. 13)
NB-IoT: Physical Operations

**‘Stand-alone operation’**
- e.g. refarm existing GSM carriers

**‘Guard operation’**
- in guard-band of LTE carrier
  - capacity of LTE Carrier unchanged

**‘In-band operation’**
- use RB of a regular LTE carrier.
  - Flexible assignments of resources between LTE and NB-IoT.

- CRS of the LTE cell may be used by the NB-IoT UE
NB-IoT: Downlink

<table>
<thead>
<tr>
<th>Physical Channel</th>
<th>Modulation Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPBCH</td>
<td>QPSK</td>
</tr>
<tr>
<td>NPDCCH</td>
<td>QPSK</td>
</tr>
<tr>
<td>NPDSCH</td>
<td>QPSK</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Signals</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NPSSS</td>
<td>only one sequence !</td>
</tr>
<tr>
<td>NSSSS</td>
<td>504 sequences (NB-PCID)</td>
</tr>
<tr>
<td>NRS</td>
<td>1 or 2 ports</td>
</tr>
</tbody>
</table>
### NB-IoT: Uplink

<table>
<thead>
<tr>
<th>Physical Channel</th>
<th>Transport Channel</th>
<th>$N_{sc}^{UL}$</th>
<th>Modulation Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPUSCH Format 1</td>
<td>UL-SCH</td>
<td>1</td>
<td>$\pi/2$ BPSK, $\pi/4$ QPSK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;1</td>
<td>QPSK</td>
</tr>
<tr>
<td>NPUSCH Format 2</td>
<td>UCI</td>
<td>1</td>
<td>BPSK</td>
</tr>
<tr>
<td>NPRACH</td>
<td>RACH</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Signal</th>
<th>Constellation</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMRS</td>
<td>matching PUSCH modulation</td>
</tr>
</tbody>
</table>
**NB-IoT: NPUSCH**

<table>
<thead>
<tr>
<th>Subcarrier spacing</th>
<th>Symbol duration</th>
<th>N</th>
<th>(N_{\text{sc}}^{\text{UL}})</th>
<th>(T_{\text{slot}})</th>
<th>(T_{\text{slot}})</th>
<th>slots per radio frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Delta f = 3.75\ kHz)</td>
<td>266,6(\mu)s</td>
<td>8192</td>
<td>48</td>
<td>61440 (T_s)</td>
<td>2,0ms</td>
<td>5</td>
</tr>
<tr>
<td>(\Delta f = 15\ kHz)</td>
<td>66,6(\mu)s</td>
<td>2048</td>
<td>12</td>
<td>15360 (T_s)</td>
<td>0,5ms</td>
<td>20</td>
</tr>
</tbody>
</table>

\[\Delta f = 3.75\ kHz \quad T_s \sim 32\text{ns}\]

\[\text{CP}=256T_s\]

8192\(T_s\) 2304\(T_s\)

1 slot = 2ms
**NB-IoT: NPUSCH**

Resource units are used to describe the mapping of the NPUSCH to resource elements. NPUSCH can be mapped to one or more than one resource unit.

\[
RU = N_{UL_{symb}} \times N_{UL_{slots}} \times N_{UL_{symb}} x N_{sc}^{RU} \text{ consecutive subcarriers}
\]

<table>
<thead>
<tr>
<th>NPUSCH format</th>
<th>usage</th>
<th>$\Delta f$</th>
<th>$N_{sc}$</th>
<th>$N_{UL_{symb}}$</th>
<th>$T_{slot}$ [ms]</th>
<th>$T_{RU}$ [ms]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>UL-SCH</td>
<td>3.75 kHz</td>
<td>1</td>
<td>16</td>
<td>2</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15 kHz</td>
<td>1</td>
<td>16</td>
<td>0,5</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>8</td>
<td>0,5</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td>4</td>
<td>0,5</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>12</td>
<td>2</td>
<td>0,5</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>UCI</td>
<td>3.75 kHz</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15 kHz</td>
<td>1</td>
<td>4</td>
<td>0,5</td>
<td>2</td>
</tr>
</tbody>
</table>
Extended DRX in idle (I-eDRX) and connected (C-eDRX) mode

For devices with infrequently uplink data transmission, energy consumption can be reduced significantly by longer cycles for discontinuous reception (DRX).
Power Saving Mode (PSM)

PSM Mode: UE remains registered with the network and there is no need to re-attach or re-establish PDN connections – saves power, but UE isn’t reachable in PSM Mode
LTE Cat-0 and Power Saving Mode Testing with R&S®CMW500

Cat-0 device testing like any LTE device:
- IE in SIB1 “category0Allowed”
- Half-duplex by TTI based scheduling

Test of Power Saving Mode:
- support of related timer (T3324)
- device in PSM mode not reachable
eMTC / LTE Cat-M1 Testing with R&S®CMW500

Cat-M1 device testing like any LTE device

Configuration of:
- Repetitions
- Coverage Enhancement levels
- Hopping
eMTC / NB-IoT support – Signal Generation with R&S®SMW200A
Narrow Band IoT measurement application with R&S®VSE

- Operates with RTO, FPS, FSW and FSV/FSVA
- UL and DL measurements
- Demodulation measurements (EVM)
- Spectral measurements (ACLR, SEM)
NB-IoT/eMTC Test application with R&S signal generators
From High-End to Low-cost solutions

BS Receiver Test

Module / Device Test

Component Test

R&S®SMW

R&S®SGT

R&S®SGT

R&S®FPS

DUT

DUT

Uplink

Downlink
Analyzing/optimizing Power Consumption in e2e environment

- App Server
- e.g. LTE Cat-M1
- IPv6 (e.g. MQTT)
- Network Emulation, IP Traffic Analysis, etc.

Device/App under Test

- R&S®CMW500
- R&S®RT-ZVC04

APP Server

R&S®CMWrun
NB IoT – Mobile Network Testing Challenges

Coverage / Pathloss measurements in all basements of a city?

Tuning of coverage models used in network planning tools

Validation of co-existence with existing networks, i.e. LTE and GSM

NB IoT Network Scanners by Rohde&Schwarz

e.g. R&S®TSMA
Outline

The Internet of dogs, lights and doors
Sigfox, LoRa and more
LTE-A Pro: eMTC, NB-IoT
What’s next on the way to 5G
Rel. 14: feMTC e.g. for wearables like smart watches

New UE Category: CAT-M2

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>M2</td>
<td>4008</td>
<td>4008</td>
<td>100000</td>
<td>5 MHz in CE A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.4 MHz in CE B</td>
</tr>
<tr>
<td>M1</td>
<td>1000 or 2984</td>
<td>20000 or 40000</td>
<td></td>
<td>1.4 MHz</td>
</tr>
</tbody>
</table>

If UE indicates: ce-pusch-nb-maxTbs-r14 (in CE Mode A)
Rel. 14: feMTC e.g. for wearables like smart watches

Positioning
E-CID: RSRP / RSRQ measurements
E-CID: Rx-Tx time difference
Observed Time Difference Of Arrival (OTDOA)

Multicast for FW update and group messages
Extended Rel. 13 Single-cell Point-to-Multipoint (SC-PTM)

Mobility and service continuity enhancements
Standard support for inter-frequency measurements

VoLTE
VoLTE for half-duplex communication

Higher Data Rate for audio/voice streaming
For example by HARQ-ACK bundling, 10 HARQ processes or larger maximum TBS
Rel. 14: eNB-IoT Enhancements e.g. for tracking applications

New UE Category: CAT-NB2

<table>
<thead>
<tr>
<th>CAT</th>
<th>TBS DL [bits]</th>
<th>TBS UL [bits]</th>
<th>Buffer [bytes]</th>
</tr>
</thead>
<tbody>
<tr>
<td>NB2</td>
<td>2536</td>
<td>2536</td>
<td>8000</td>
</tr>
<tr>
<td>NB1</td>
<td>680</td>
<td>1000</td>
<td>4000</td>
</tr>
</tbody>
</table>

New Power Class: 14dBm

Multi-PRB (non-anchor PRB enhancements)
NPRACH and paging on a non-anchor NB-IoT PRB

Coverage Enhancement Authorization
not all networks (PLMN) allow UE to use Coverage Enhancement Feature.
(Appplies also to LTE UE)
Rel. 14: eNB-IoT - Optional Features

- **Positioning**
  E-CID / OTDOA, capability / assistance data transfer via LPP
  (N)RSRP / (N)RSRQ / Rx-Tx time difference / (N)RSTD measurements in idle mode only

- **Multicast for FW update and group messages**
  Extended Rel. 13 Single-cell Point-to-Multipoint (SC-PTM)

- **Mobility and service continuity enhancements**
  Connected Mode Mobility via RRC re-establishment

- **2 HARQ Processes**
  Support part of UE capability information, enabled via RRC signaling

- **Release Assistance (rai)**
  Support part of UE capability information, indicated by UE via BSR=0
Your Partner in testing the Internet of Things

Thanks for your attention.