LTE Evolution for Cellular IoT
Ericsson & NSN
# LTE Evolution for Cellular IoT

## Overview and Introduction

- White Paper on M2M is geared towards low cost M2M applications
- Utility (electricity/gas/water) metering can be seen as a typical example
- We refer to this as “Cellular Internet of Things” or “Cellular IoT”

## Requirements

- Wide support for operator frequency bands with different system bandwidths
- M2M services can be operated on stand-alone carrier or multiplexed with other services
- Battery life >10 years with 2 AA batteries
- Support large number of M2M devices
- Additional 20 dB coverage
- Very low device cost

## Solutions

- Rel-12 introduces important improvements for M2M
  - Lower device cost, longer battery life
- Further improvements for M2M are envisioned in Rel-13
  - Enhanced coverage, even lower device cost, even longer battery life

## Network Deployment

- Wide support for operator frequency bands with different system bandwidths
- M2M services can be operated on stand-alone carrier or multiplexed with other services
- Battery life >10 years with 2 AA batteries
- Support large number of M2M devices
- Additional 20 dB coverage
- Very low device cost
Low device cost

- Rel-12 introduces a new low complexity UE category (“Cat-0”)
- Further device complexity reduction can be achieved in Rel-13 (cf. TR 36.888)
  - Reduced UE receive bandwidth to 1.4 MHz allows for substantial complexity reduction
  - The UE will still be able to operate in all existing LTE system bandwidths up to 20 MHz
  - A lower UE power class will allow integration of power amplifier in single chip solution

<table>
<thead>
<tr>
<th></th>
<th>Rel-8 Cat-4</th>
<th>Rel-8 Cat-1</th>
<th>Rel-12 Cat-0</th>
<th>Rel-13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downlink peak rate</td>
<td>150 Mbps</td>
<td>10 Mbps</td>
<td>1 Mbps</td>
<td>~200 kbps</td>
</tr>
<tr>
<td>Uplink peak rate</td>
<td>50 Mbps</td>
<td>5 Mbps</td>
<td>1 Mbps</td>
<td>~200 kbps</td>
</tr>
<tr>
<td>Max number of downlink spatial layers</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Number of UE RF receiver chains</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Duplex mode</td>
<td>Full duplex</td>
<td>Full duplex</td>
<td>Half duplex (opt)</td>
<td>Half duplex (opt)</td>
</tr>
<tr>
<td>UE receive bandwidth</td>
<td>20 MHz</td>
<td>20 MHz</td>
<td>20 MHz</td>
<td>1.4 MHz</td>
</tr>
<tr>
<td>Maximum UE transmit power</td>
<td>23 dBm</td>
<td>23 dBm</td>
<td>23 dBm</td>
<td>~20 dBm</td>
</tr>
<tr>
<td>Modem complexity relative to Cat-1</td>
<td>125%</td>
<td>100%</td>
<td>50%</td>
<td>25%</td>
</tr>
</tbody>
</table>

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Long battery life

• Rel-12 introduces a UE power saving mode (PSM) for improved battery life
  - UE performs periodic tracking area update (TAU) after which it stays reachable for paging during a configurable Active timer before it goes to sleep (not reachable)
  - More than 10 years battery lifetime with 2 AA batteries can be achieved for delay-tolerant traffic if the TAU cycle is 10 minutes
• Further battery life improvements for other cases may be considered in Rel-13

<p>| Estimated battery lifetime in months for different TAU cycles and transaction cycles |
|----------------------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|</p>
<table>
<thead>
<tr>
<th>Trans.</th>
<th>TAU cycle</th>
<th>2.56 s (Rel-8)</th>
<th>10.24 s</th>
<th>1 min</th>
<th>10 min</th>
<th>1 h</th>
<th>2 h</th>
<th>1 day</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 min</td>
<td></td>
<td>3.7</td>
<td>4.5</td>
<td>4.9</td>
<td>4.9</td>
<td>4.9</td>
<td>4.9</td>
<td>4.9</td>
</tr>
<tr>
<td>1 hour</td>
<td></td>
<td>8.1</td>
<td>13.8</td>
<td>17.0</td>
<td>17.8</td>
<td>17.9</td>
<td>17.9</td>
<td>17.9</td>
</tr>
<tr>
<td>1 day</td>
<td></td>
<td>13.2</td>
<td>39.1</td>
<td>84.9</td>
<td>108.0</td>
<td>110.8</td>
<td>111.1</td>
<td>111.3</td>
</tr>
<tr>
<td>1 week</td>
<td></td>
<td>13.5</td>
<td>42.0</td>
<td>99.4</td>
<td>132.1</td>
<td>136.2</td>
<td>136.6</td>
<td>137.0</td>
</tr>
<tr>
<td>1 month</td>
<td></td>
<td>13.6</td>
<td>42.3</td>
<td>101.6</td>
<td>135.9</td>
<td>140.2</td>
<td>140.7</td>
<td>141.1</td>
</tr>
<tr>
<td>1 year</td>
<td></td>
<td>13.6</td>
<td>42.5</td>
<td>102.3</td>
<td>137.1</td>
<td>141.4</td>
<td>141.9</td>
<td>142.3</td>
</tr>
</tbody>
</table>
Enhanced coverage

• It is feasible to increase the maximum coupling loss from ~140 dB to ~160 dB to achieve 20 dB coverage enhancement
  - The targeted link budget improvement for each individual physical channel will range between 12 dB and 20 dB (cf. 3GPP TR 36.888 V12.0.0 Section 9.2)

• Techniques:
  - The targeted coverage enhancement for some physical control channels can be achieved through relaxation of acquisition time requirements (SCH, PBCH)
  - For other physical control channels, robust quality with the targeted coverage is achieved through repetition (PDCCH/EPDCCH, PUCCH, PRACH)
  - For the physical data channels, subframe bundling and HARQ retransmissions will achieve sufficient coverage for low-end M2M data services (PDSCH, PUSCH)
  - Alternative means of transmission for some higher layer messages that are currently handled as cell common transmissions (SIB, RAR, Paging) should be considered
## Enhanced coverage
### Link budget

<table>
<thead>
<tr>
<th>Physical channel name</th>
<th>PUCCH</th>
<th>PRACH</th>
<th>PUSCH</th>
<th>PDSCH</th>
<th>SCH</th>
<th>PBCH</th>
<th>PDCCH</th>
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</thead>
<tbody>
<tr>
<td><strong>Transmitter</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max Tx power (dBm)</td>
<td>23</td>
<td>23</td>
<td>23</td>
<td>46</td>
<td>46</td>
<td>46</td>
<td>46</td>
</tr>
<tr>
<td>(1) Actual Tx power (dBm)</td>
<td>23</td>
<td>23</td>
<td>23</td>
<td>46</td>
<td>46</td>
<td>46</td>
<td>46</td>
</tr>
<tr>
<td><strong>Receiver</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Thermal noise density (dBm/Hz)</td>
<td>-174</td>
<td>-174</td>
<td>-174</td>
<td>-174</td>
<td>-174</td>
<td>-174</td>
<td>-174</td>
</tr>
<tr>
<td>(3) Receiver noise figure (dB)</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>(4) Interference margin (dB)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>(5) Occupied channel bandwidth (Hz)</td>
<td>180000</td>
<td>1080000</td>
<td>360000</td>
<td>180000</td>
<td>1080000</td>
<td>1080000</td>
<td>1080000</td>
</tr>
<tr>
<td><strong>Effective noise power</strong></td>
<td>= (2) + (3) + (4) + 10 log((5)) (dBm)</td>
<td>-116.4</td>
<td>-108.7</td>
<td>-113.4</td>
<td>-112.4</td>
<td>-104.7</td>
<td>-104.7</td>
</tr>
<tr>
<td>(7) Required SINR (dB)</td>
<td>-7.8</td>
<td>-10</td>
<td>-4.3</td>
<td>0</td>
<td>-3.8</td>
<td>-3.5</td>
<td>-0.7</td>
</tr>
<tr>
<td>(8) Coverage enhancement technique</td>
<td>Repetition and/or PSD boosting</td>
<td>12.8</td>
<td>14.7</td>
<td>19.3</td>
<td>2.6</td>
<td>6.5</td>
<td>6.8</td>
</tr>
<tr>
<td>13.8</td>
<td>19.3</td>
<td>20.3</td>
<td>2.6</td>
<td>6.5</td>
<td>6.8</td>
<td>9.6</td>
<td></td>
</tr>
<tr>
<td>Frequency hopping</td>
<td>4.6</td>
<td>1.0</td>
<td>6.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple decoding attempts</td>
<td>3.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(9) Receiver sensitivity</td>
<td>= (6) + (7) - (8) (dBm)</td>
<td>-138.0</td>
<td>-138.0</td>
<td>-138.0</td>
<td>-115.0</td>
<td>-115.0</td>
<td>-115.0</td>
</tr>
<tr>
<td>(10) MCL</td>
<td>= (1) - (9) (dB)</td>
<td>161.0</td>
<td>161.0</td>
<td>161.0</td>
<td>161.0</td>
<td>161.0</td>
<td>161.0</td>
</tr>
</tbody>
</table>
High capacity

- Assumptions for capacity estimation
  - Daily uplink report of 100 bytes, not sensitive to latency (model based on TR 36.888)
  - Ideal scheduling is assumed but all overheads from message header, RRC connection set-up and release have been included
  - Other assumptions: 1732 m inter-site distance, 900 MHz band, 10 MHz system bandwidth, eNB antenna gain 14 dBi, UE antenna gain -4 dBi, penetration loss from TR 36.888, antenna pattern from TR 36.814

| Number of user data messages per day per cell per 180 kHz spectrum allocation |
|-------------------------------------------------|-------------------------------------------------|
| **Case 3a:** 1.2 km/h UE velocity, 20 dB additional penetration loss | **Case 3b:** 30 km/h UE velocity, 10 dB additional penetration loss |
| > 5 million | > 5 million |
Timeline

- **Rel-12**
  - Work Item
  - Implementation
  - Commercial Deployment

- **Rel-13**
  - Work Item
  - Implementation
  - Commercial Deployment

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Sub-GHz frequency bands (bands below 1 GHz) are attractive from coverage point of view
- In many deployment scenarios, introducing LTE in a sub-GHz band is straightforward with an LTE system bandwidth between 1.4 MHz and 20 MHz
- But in some scenarios, it may be challenging to find at least 1.4 MHz of available spectrum in order to deploy LTE for e.g. M2M
- In scenarios where only a very narrow spectrum allocation is available, a more narrow LTE system bandwidth than 1.4 MHz would appear to be desirable

The following slides outline a potential solution for narrowband LTE deployment within a 200-kHz spectrum allocation intended for M2M services
- Given enough industry support, this new LTE system bandwidth can be standardized
Narrowband deployment
200 kHz system bandwidth - downlink solution

• An LTE system bandwidth of 200 kHz can be realized by restricting the downlink transmission to a single 180-kHz LTE physical resource block (PRB)
  - The minimum system bandwidth now corresponds to a single PRB of 180 kHz instead of 6 PRBs
  - Use TDM between downlink channels (SCH, PBCH, PDCCH, PDSCH)
  - Time expansion principle applies to some downlink channels (PBCH, PDCCH, PDSCH)
  - Need to design new synchronization signals (SCH)
In uplink, allocate resources on 15-kHz subcarrier level

- The purpose is to be able to multiplex more than one user simultaneously in uplink
  - This may be considered also for other narrow system bandwidths than 200 kHz, e.g. 1.4 MHz
  - This is not needed in downlink since downlink is not power limited to the same extent as uplink
- Vary number of repetitions and subcarriers depending on coverage situation
- Use TDM between uplink channels (PRACH, PUCCH, PUSCH)
- Need to design new random access preamble signals (PRACH)
Narrowband deployment
200 kHz system bandwidth - co-existence with GSM

- Two deployment options:
  - Without guard bands, one LTE channel replaces one GSM channel
  - With 100-kHz guard bands, one LTE channel replaces two GSM channels
- No or minor impact on the performance of adjacent GSM carriers
Summary

• LTE evolution is able to provide an efficient solution for Cellular IoT
  - Natural evolution of existing networks in existing or additional spectrum
  - M2M traffic can co-exist on the same carrier as other traffic if desired
• Rel-12 improvements for M2M
  - 50% modem complexity reduction compared to Cat-1 UE
  - 10+ years battery lifetime for downlink delay-tolerant traffic
• Envisioned Rel-13 improvements for M2M
  - 75% modem complexity reduction compared to Cat-1 UE
  - Main cost reduction comes from reducing the UE receive bandwidth to 1.4 MHz
  - 10+ years battery lifetime for cases not targeted by Rel-12
  - 15-20 dB coverage enhancement
• Narrowband deployment
  - Introduction of a narrower LTE system bandwidth (e.g. 200 kHz) can be considered
    but requires substantial additional efforts compared to the improvements listed above