The Evolution of Wireless Networks for the Internet of Things

NSF Wireless Cities Workshop
Presenter: Phil Fleming
Mobile Networks Senior Technology Advisor
Nokia Networks
Arlington Hts., IL
Slim Radio | **Low cost & power for massive machine type communication**

Mobile IoT for small, infrequent & low cost data transfer

**Power saving**
- Longer sleeping cycles*
- Less signaling for wakeup
- Power Save Mode
- eDRX

**Simplified modems**
- Narrowband transmission
- Reduced transmit power
- Limited downlink transmission modes
- UE processing relaxations

**4 x coverage**
- Compared to current LTE
- Repetition and power spectral density boosts
- Improved indoor coverage
- +15~20 dB coverage

**Standard availability**
- 3GPP
- Rel-13

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* Extended Discontinuous Reception (DRX)

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IoT Wireless Connectivity
Technology Choices

- Simple cheap devices
- Low energy consumption
- Massive number of devices
- Full coverage

Internet of Things

- 3GPP RAN (Rel-12/13)
  - LTE evolution for MTC (LTE-M 1.4MHz)
  - LTE evolution for NB-IoT (200kHz)

- 3GPP GERAN (Rel-13)
  - Enhanced Coverage GPRS (EC-GPRS)

- Short range
  - Bluetooth Low Energy
  - Wi-Fi, IEEE802.11ah
  - ZigBee
  - Z-wave
  - ...

- Long range
  - Sigfox
  - LoRa
  - Weightless
  - Ingenu
  - ...

licensed spectrum

unlicensed spectrum
## IoT Technology Space

<table>
<thead>
<tr>
<th></th>
<th>SIGFOX</th>
<th>LoRa</th>
<th>Short-range</th>
<th>NB-IoT Rel. 13</th>
<th>LTE-M Rel. 13</th>
<th>EC-GSM Rel. 13</th>
<th>5G (targets)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Range</strong></td>
<td>&lt;12km</td>
<td>&lt;10km</td>
<td>10cm to 200m</td>
<td>&lt;15km 164 dB</td>
<td>&lt;10km 156 dB</td>
<td>&lt;15km 164 dB</td>
<td>&lt;12km 160 dB</td>
</tr>
<tr>
<td><strong>Spectrum</strong></td>
<td>Unlicensed 900MHz 100Hz</td>
<td>Unlicensed 900MHz &lt;500kHz</td>
<td>Unlicensed 2.4 GHz</td>
<td>Licensed IMT 200 kHz shared</td>
<td>Licensed IMT 1.4 MHz shared</td>
<td>Licensed 8-900MHz shared</td>
<td>Licensed IMT shared</td>
</tr>
<tr>
<td><strong>Bandwidth</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Data rate</strong></td>
<td>&lt;100 bps</td>
<td>&lt;10 kbps</td>
<td>&lt;100s Mbps</td>
<td>&lt;200 kbps</td>
<td>&lt;1 Mbps</td>
<td>&lt;70 kbps</td>
<td>&lt;1 Mbps</td>
</tr>
<tr>
<td><strong>Use case</strong></td>
<td>Smart Grid/City/ Monitoring</td>
<td>Smart Grid / City/ Monitoring</td>
<td>Smart home/factory</td>
<td>Smart Grid/City/ Monitoring</td>
<td>Smart Grid / City / Monitor./ vehic.</td>
<td>Smart Grid / City / Monitor./ vehic.</td>
<td>Smart Grid / City / Monitor./ vehic.</td>
</tr>
<tr>
<td><strong>Network cost, US example</strong> (cost drivers)</td>
<td>$10/year/km² &gt;$80M/year (HW+SW+Service)</td>
<td>$10/year/km² &gt;$80M/year (HW+SW+Service)</td>
<td>Not available</td>
<td>$1/year/km² &lt;$7M/year (SW upgrade)</td>
<td>$1/year/km² &lt;$7M/year (SW upgrade)</td>
<td>$1/year/km² &lt;$7M/year (SW upgrade)</td>
<td>Included in 5G deployment</td>
</tr>
</tbody>
</table>
## LTE for IoT

<table>
<thead>
<tr>
<th>Wide area network coverage</th>
<th>Mature worldwide standards with large number vendors and operators, robust inter-operability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worldwide deployment, ubiquitous coverage, cell coverage comparable to GSM low data rates</td>
<td></td>
</tr>
<tr>
<td>High network reliability</td>
<td>Robust features</td>
</tr>
<tr>
<td>High performance</td>
<td>Security, policy and charging, managed QoS, etc</td>
</tr>
</tbody>
</table>
# Cellular IoT Solution Space

## 3GPP Radio Solution

<table>
<thead>
<tr>
<th>Targets</th>
<th>LTE-M (1.4 MHz)</th>
<th>NB-IoT (200 kHz)</th>
<th>EC-GSM (200 kHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved coverage including indoor</td>
<td>156 dB MCL (+15 dB improvement)</td>
<td>164 dB MCL (+20 dB improvement)</td>
<td>164 dB MCL (+20 dB improvement)</td>
</tr>
<tr>
<td>Massive MTC capacity</td>
<td>&gt;52K UEs/cell/180 kHz</td>
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<td>&gt;52K UEs/cell/180 kHz</td>
</tr>
<tr>
<td>Data rate</td>
<td>&lt; 1 Mbps</td>
<td>&lt; 200 kbps</td>
<td>&lt; 70 kbps</td>
</tr>
<tr>
<td>Improved power efficiency - battery life</td>
<td>&gt;10 years</td>
<td>&gt;10 years</td>
<td>&gt;10 years</td>
</tr>
<tr>
<td>Latency</td>
<td>&lt;10 secs</td>
<td>&lt;10 secs</td>
<td>&lt;10 secs</td>
</tr>
<tr>
<td>Deployment scenarios</td>
<td>In-band</td>
<td>Stand-alone, in-band, guard-band</td>
<td>Stand-alone</td>
</tr>
</tbody>
</table>

*MCL - minimal coupling loss*
IoT Deployment Options

 LTE-M

 in-band

 guard band

 LTE

 standalone

 GSM

 LTE carrier

 NB-IoT

 LTE-M

 LTE carrier

 NB-IoT

 LTE carrier

 NB-IoT

 GSM carriers
LTE-M Demonstration Setup
Overview

At MWC, we demonstrated several types of sensors using mockup models placed on a small scale city. City model was modeled with the flat rug approx. 1 x 2 m in size displaying street, parking area, and associated building on top of which we placed our sensors and street lamps.
N-way-partnering: Nokia and KT opened IoT² lab in Korea in June 2015

• This is a lab to do **Inter-operability Test (IoT)** on **Internet of Things (IoT)** ➔ IoT²
• 3GPP Rel-8 **Cat-1**, Rel-12 **Cat-0**, Rel-13 **Cat-M1** have been tested
• One of next steps can be **NB-IoT** test/demo/PoC with Korean industry (3GPP progress dependent)

Dedicated space for customers/partners for testing their IoT equipment / systems

Nokia lab including LTE RAN (both FDD & TDD), EPC, IMS, etc for any kind of network infrastructure related testing. Plan to expand to have Radio Cloud, 5G as well.
**Capacity Analysis**

<table>
<thead>
<tr>
<th>Case</th>
<th>Household Density per Sq km</th>
<th>Inter-site Distance (ISD) (m)</th>
<th>Number of devices within a household</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>1517</td>
<td>1732 m</td>
<td>40</td>
</tr>
</tbody>
</table>

- Traffic model is machine reporting (80%) and network command (20%)
- In stand-alone deployment, at least 71k devices/cell/200 kHz can be supported
Impact to Data Traffic

- Suburban macrocell (1732m ISD)
- IoT traffic is a mixture of smart meters, home security systems, and sensors
- Small impact from IoT traffic to data traffic.