Wireless IoT Technologies and Applications
- Narrowband IoT Introduction

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Agenda

1. Market and Applications of Cellular Internet of Things (IoT)
2. Narrowband IoT (NB-IoT) technology
3. NB-IoT standardization in 3GPP
4. Summary
2.7 billion devices for IoT will be wirelessly connected via cellular network by 2022 according to several research companies’ forecast.
Which communication technology is the competitive candidate for long distance, low cost and highly reliable interconnection?
Communication technologies comparison

- Multiple Standards
- Power consumption largely dependent on transmission range and protocol

- Cellular communication can enable more applications of IoT.

https://community.freescale.com/community/the.embedded.beat/blog/2010/03/30/so-many.wireless.connectivities--won't-one-size-fit-all
Applications of cellular IoT (1)

Source: Huawei, NB-IoT white paper, 2015
Applications of cellular IoT (2)

- Water/gas/electricity metering
- Public lighting/water rush/smoke sensor monitor and control
- Modern agriculture:
  - Monitor the temperature and humidity of field
  - Monitor the health of forest/flower and etc.
  - Monitor the place and health of animal in the farm/water
- Vendor machine/POS machine
- Industry production control
- Electrical equipment control at home

In fact, 2G/3G communication technologies have already been used in interconnection of cellular IoT. However......
Issues of 2G/3G in cellular IoT applications

2G/3G is designed for human-to-human communications

- 2G: GPRS/EDGE and 3G: WCDMA/CDMA2000/TD-SCDMA
  
  ✓ High power
    - up to 31dBm output power
    - wideband communication
    - complex transceiver
      → replace battery regularly or use rechargeable battery

  ✓ Limited user capacity

  → unsuitable for mass cellular IoT deployment
2G/3G is designed for human-to-human communications

- **2G:** GPRS/EDGE and **3G:** WCDMA/CDMA2000/TD-SCDMA

  - **High cost**
    - e.g. very stringent out-of-band blocking
    - with SAW filter
      - unsuitable for mass cellular IoT deployment

  - **Limited coverage:**
    - repeaters required for deep coverage
Requirements for cellular IoT

- **Features of current cellular communication standards**
  - ✔ Supporting high data rate and high mobility
  - ✗ high power and high cost
  - ✗ wideband spectrum
  - ✗ dedicated infrastructure

- **However, most of cellular IoT applications require**
  - ✔ Supporting low data rate and low mobility
    - ✔ low power and low cost
    - ✔ not wideband spectrum
    - ✔ reused existing infrastructure

Therefore, new technology/standard is required for cellular IoT

**Narrowband IoT (NB-IoT)**
Coverage enhancement, low power and low cost are the key requirements of NB-IoT system.
Support 3 types of deployment

- **Standalone deployment**
  - re-farm GSM spectrum or use totally new spectrum

- **Guard band deployment**
  - deploy guard band of LTE spectrum

- **In band deployment**
  - deploy 1RB (180kHz) of LTE system
NB-IoT (3) – technical features

NB-IoT = cellular communication + narrowband communication

Narrowband: feature of GSM

OFDMA/SC-FDMA: feature of LTE

- **Multiple access/Modulation scheme**
  - **Uplink**: SC-FDMA (subcarrier spacing: 3.75kHz and 15kHz)
    - Single tone transmission: Pi/2-BPSK and Pi/4-QPSK
    - Multi tone transmission: QPSK
  - **Downlink**: OFDMA (subcarrier spacing: 15kHz) and QPSK

- **Duplex mode**
  - **Half duplex FDD**

- **UE maximum output power**
  - 23dBm
  - 20dBm
### NB-IoT (4) – technical features (cont’d)

**Supporting bands:** Band 1, 3, 5, 8, 12, 13, 17, 19, 20, 26, 28

<table>
<thead>
<tr>
<th>NB-IoT Operating Band</th>
<th>Uplink (UL) operating band BS receive UE transmit</th>
<th>Downlink (DL) operating band BS transmit UE receive</th>
<th>Duplex Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$F_{UL_low}$ – $F_{UL_high}$</td>
<td>$F_{DL_low}$ – $F_{DL_high}$</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1920 MHz – 1980 MHz</td>
<td>2110 MHz – 2170 MHz</td>
<td>HD-FDD</td>
</tr>
<tr>
<td>3</td>
<td>1710 MHz – 1785 MHz</td>
<td>1805 MHz – 1880 MHz</td>
<td>HD-FDD</td>
</tr>
<tr>
<td>5</td>
<td>824 MHz – 849 MHz</td>
<td>869 MHz – 894 MHz</td>
<td>HD-FDD</td>
</tr>
<tr>
<td>8</td>
<td>880 MHz – 915 MHz</td>
<td>925 MHz – 960 MHz</td>
<td>HD-FDD</td>
</tr>
<tr>
<td>12</td>
<td>699 MHz – 716 MHz</td>
<td>729 MHz – 746 MHz</td>
<td>HD-FDD</td>
</tr>
<tr>
<td>13</td>
<td>777 MHz – 787 MHz</td>
<td>746 MHz – 756 MHz</td>
<td>HD-FDD</td>
</tr>
<tr>
<td>17</td>
<td>704 MHz – 716 MHz</td>
<td>734 MHz – 746 MHz</td>
<td>HD-FDD</td>
</tr>
<tr>
<td>19</td>
<td>830 MHz – 845 MHz</td>
<td>875 MHz – 890 MHz</td>
<td>HD-FDD</td>
</tr>
<tr>
<td>20</td>
<td>832 MHz – 862 MHz</td>
<td>791 MHz – 821 MHz</td>
<td>HD-FDD</td>
</tr>
<tr>
<td>26</td>
<td>814 MHz – 849 MHz</td>
<td>859 MHz – 894 MHz</td>
<td>HD-FDD</td>
</tr>
<tr>
<td>28</td>
<td>703 MHz – 748 MHz</td>
<td>758 MHz – 803 MHz</td>
<td>HD-FDD</td>
</tr>
</tbody>
</table>
Coverage enhancement, low power and low cost are the key requirements of NB-IoT system.
NB-IoT (5) – coverage enhancement

➢ Narrow band: (compared with wideband)

✓ Pros

→ less integrated noise
→ better SNR
→ better sensitivity
→ more coverage

✓ Cons

→ very accurate clock source
Repetition

- Pros
  - 3dB sensitivity improvement by 2X repetition

- Cons
  - longer transmission time
NB-IoT (1) – application requirements

- Coverage Enhancement
  - 20dB better than GSM

- Low Power Consumption
  - 10 years battery life

- Low Cost
  - Terminal cost < $5

Coverage enhancement, low power and low cost are the key requirements of NB-IoT system.
NB-IoT (6) – low power

- **Uplink modulation scheme**
  - SC-FDMA
    - propose several methods to decrease Peak-to-Average Power Ratio (PAPR)
  - Single tone is especially suitable for low PAPR (<0.5dB)
    - non-linear power amplifier (PA)

- **Narrowband communication**
  - Relatively simple transceiver architecture
Coverage enhancement, low power and low cost are the key requirements of NB-IoT system.

- Coverage Enhancement: 20dB better
- Low Power Consumption: 10 years battery life
- Low Cost: Terminal cost < $5
NB-IoT (7) – low cost

- **Uplink modulation scheme**
  - Compared with conventional LTE
    - lower PAPR
    - integrated PA and RF switch
  - Relaxed out-of-band blocking requirement in standard
    - facilitate realizing SAW-less transceiver architecture
  - Digital Controlled Crystal Oscillator (DCXO) instead of Temperature Compensated Crystal Oscillator (VC-TCXO)

- **Narrowband communication**
  - Relatively simple transceiver architecture
## Comparison with competitive technologies

<table>
<thead>
<tr>
<th></th>
<th>Coverage (dB)</th>
<th>Indoor</th>
<th>Module cost</th>
<th>Battery life</th>
<th>Infrastructure cost</th>
<th>Security</th>
<th>Global ecosystem</th>
<th>Spectrum</th>
<th>Time to market</th>
<th>Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC-GSM</td>
<td>179 &lt;sup&gt;Note1&lt;/sup&gt;</td>
<td>✓</td>
<td>2×</td>
<td>Low</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>2.4MHz</td>
<td>1~2 years</td>
<td>✓</td>
</tr>
<tr>
<td>Low cost LTE MTC</td>
<td>155 &lt;sup&gt;Note1&lt;/sup&gt;</td>
<td>×</td>
<td>&gt;3×</td>
<td>Low</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>20MHz</td>
<td>2~3 years</td>
<td>✓</td>
</tr>
<tr>
<td>(R12)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>eMTC (R13)</td>
<td>170 &lt;sup&gt;Note1&lt;/sup&gt;</td>
<td>✓</td>
<td>&gt;2×</td>
<td>Low</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>1.4MHz</td>
<td>3~5 years</td>
<td>✓</td>
</tr>
<tr>
<td>SigFox</td>
<td>162 &lt;sup&gt;Note2&lt;/sup&gt;</td>
<td>×</td>
<td>X</td>
<td>Overlay</td>
<td>×</td>
<td>×</td>
<td>?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LoRa</td>
<td>174 &lt;sup&gt;Note2&lt;/sup&gt;</td>
<td>✓</td>
<td>X</td>
<td>Overlay</td>
<td>×</td>
<td>×</td>
<td>?</td>
<td>✓</td>
<td></td>
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</tr>
<tr>
<td>NB-IoT</td>
<td>179</td>
<td>✓</td>
<td>X</td>
<td>Low</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>200kHz</td>
<td>1~2 years</td>
<td>✓</td>
</tr>
</tbody>
</table>

Source: Huawei, The Way to The Connected Planet, 2015

➤ **NB-IoT is more competitive and has broader market prospects.**
### Project Co-ordination Group (PCG)

<table>
<thead>
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<th>TSG GERAN</th>
<th>TSG RAN</th>
<th>TSG SA</th>
<th>TSG CT</th>
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<td>GSM EDGE</td>
<td>Radio Access Network</td>
<td>Service &amp; Systems Aspects</td>
<td>Core Network &amp; Terminals</td>
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<tr>
<td>Radio Access Network</td>
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<td>GERAN WG1</td>
<td>RAN WG1</td>
<td>SA WG1</td>
<td>CT WG1</td>
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<tr>
<td>Radio Aspects</td>
<td>Radio Layer 1 spec</td>
<td>Services</td>
<td>MM/CC/SM (lu)</td>
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<td>GERAN WG2</td>
<td>RAN WG2</td>
<td>SA WG2</td>
<td>CT WG3</td>
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<tr>
<td>Protocol Aspects</td>
<td>Radio Layer 2 spec</td>
<td>Architecture</td>
<td>Interworking with external networks</td>
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<td>GERAN WG3</td>
<td>RAN WG3</td>
<td>SA WG3</td>
<td>CT WG4</td>
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<td>Terminal Testing</td>
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<td>Security</td>
<td>MAP/GTP/BCH/SS</td>
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<td>UTRAN O&amp;M requirements</td>
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<td>RAN WG4</td>
<td>Radio Performance</td>
<td>SA WG4</td>
<td>CT WG6</td>
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<td>Protocol aspects</td>
<td>Protocol aspects</td>
<td>Codec</td>
<td>Smart Card Application Aspects</td>
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<td>RAN WG5</td>
<td>Mobile Terminal</td>
<td>SA WG5</td>
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<td>Conformance Testing</td>
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<tr>
<td>RAN WG6</td>
<td>Legacy RAN radio and</td>
<td>SA WG6</td>
<td>Mission-critical applications</td>
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<tr>
<td>protocol</td>
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</table>
Several technologies were studied in 3GPP GERAN TSG firstly, and technical report was finalized in GERAN#67 meeting held in Yinchuan in August, 2015;

NB-IoT Work Item was initiated in RAN#69 plenary meeting held in Phoenix in September, 2015;

RAN1#82-BIS meeting and RAN4#76-BIS meeting were held in Sweden and France respectively in October, 2015, and big difference existed between two candidate technical solutions;

In RAN#70 plenary meeting held in Spain in December 2015, consensus was achieved and fundamental technical solution was agreed; NB-IoT standardization progresses rapidly;
NB-IoT standardization progress (cont’d)

- RAN1-4 Ad hoc meetings for NB-IoT were held in Budapest in January 2016;
- RAN1-4 meetings were held in Malta in February 2016, and more agreements were achieved;
- RAN#71 plenary meeting were held in Sweden in March 2016, Release13 was approved in this meeting;
- RAN1#84-BIS RAN4#78-BIS were held in South Korea and Mexico respectively in April 2016.
NB-IoT standardization outlook

- RAN1-4 meetings will be held in Nanjing in May 2016;
- RAN#72 plenary meeting will be held in South Korea in June 2016, and NB-IoT technical specification is expected to be finalized in this meeting.
Internet of things (IoT) is one of important strategic industries in the world;

Rapid development of IoT industry calls for new cellular communication technology dedicated for IoT LPWA applications;

NB-IoT is a new developing cellular communication technology with features of enhanced coverage, low cost and low power;

NB-IoT is being standardized in 3GPP. NB-IoT standard is expected to be finalized in June, 2016.
Thank you!

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www.astri.org