Measuring the performance of Narrowband-IoT (NB-IoT)

Ahmed Elmokashfi, Foivos Michelinakis and Anas Al-selwi
IoT applications have diverse requirements

- **Shorter to medium battery life**
  - Medium coverage
  - Some mobility
  - Latency in order of seconds

- **Battery life 5-10 years**
  - Ubiquitous outdoor coverage
  - Some mobility
  - Medium to high reliability
  - Latency < 10 seconds

- **Battery life 10-15 years**
  - Outdoor and deep indoors (+20dB)
  - Stationary
  - Medium to high reliability
  - Latency 10 to 60 seconds

- **Mains powered**
  - Outdoor and indoors
  - Stationary
  - Low to high reliability
  - Latency < 30 seconds
Mobile-IoT must be scalable, energy efficient and ubiquitous

- Long battery life
- Low device cost
- Low deployment cost

- Extended coverage
- Support for many devices
- User security, control & service API
3GPP Release 13 standardized two solutions for current and future IoT

<table>
<thead>
<tr>
<th></th>
<th>NB-IoT LTE Cat. NB</th>
<th>eMTC LTE Cat. M1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Deployment</strong></td>
<td>In-Band LTE, guard-band LTE and standalone</td>
<td>In-Band LTE</td>
</tr>
<tr>
<td><strong>Bandwidth</strong></td>
<td>180 KHz</td>
<td>1.08 MHz</td>
</tr>
<tr>
<td><strong>Peak data rate</strong></td>
<td>~150 kbps</td>
<td>1 Mbps</td>
</tr>
<tr>
<td><strong>Latency</strong></td>
<td>1.6s-10 s</td>
<td>10-15 ms</td>
</tr>
<tr>
<td><strong>Max UE tx 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>Duplex</strong></td>
<td>Half</td>
<td>Full/Half</td>
</tr>
<tr>
<td><strong>Complexity relative to LTE</strong></td>
<td>10%</td>
<td>20-25%</td>
</tr>
</tbody>
</table>
NB-IoT is now deployed in several countries
NB-IoT has two mechanisms to help devices conserving power

**Power Saving Mode (PSM)**

Power Saving Mode (PSM) is designed to help IoT devices conserve battery power and potentially achieve a 10-year battery life. Whilst it has always been possible for a device’s application to turn its radio module off to conserve battery power, the device would subsequently have to reattach to the network when the radio module was turned back on. The reattach procedure consumes a small amount of energy, but the cumulative energy consumption of reattaches can become significant over the lifetime of a device. Therefore, battery life could be extended if this procedure could be avoided.

When a device initiates PSM with the network, it provides two preferred timers (T3324 and T3412); PSM time is the difference between these timers (T3412 - T3324). The network may accept these values or set different ones. The network then retains state information and the device remains registered with the network. If a device awakes and sends data before the expiration of the time interval it agreed with the network, a reattach procedure is not required.

For example, for a monitoring application, the radio module in a device might be configured by an application to enable PSM, negotiate a 24-hour time interval with the network and...
NB-IoT enhances coverage by using transmission repetitions

- 2x repetitions translates into 3dB coverage gain
- 2x repetitions results in 0.5x speed and 2x latency
Early measurements of NB-IoT commercial deployments

- 2 mobile operators + 2 NB-IoT modules
- UDP ping every minute with packet sizes in the range 20 to 512 bytes
Measurements traffic pattern

- Connecting & sending
- Active paging
- Idle paging
- PSM
Clear differences in energy consumption between operators and devices

These differences can reduce battery lifetime by 6 years (assuming that we are using a CR2032 battery with 235mAh capacity and 1 activity period per day)
The differences are also evident when the coverage is poor.
The two operators configure power management differently.
The two operators configure power management differently.
RTTs are mostly below 10 seconds but are characterized by wide variability.
Achieving a similar delay may correspond to different energy consumption levels.
RTT variability can partially be attributed to differences in coverage.
What is my target battery lifetime?

What is corresponding max RTT?

How likely I get RTTs higher than max?

Battery lifetime (years) vs. RTT (sec)

Fraction of packets with RTT > x vs. RTT (sec)
There is a need for new metrics for describing NB-IoT reliability and performance

Several questions remain unanswered
- Can we generate realistic traffic patterns?
- Understand how transport protocols perform over NB-IoT e.g. COAP, MQTT

NB-IoT large parameter space makes interpreting measurements difficult
- Power management timers
- Repetitions