IoT Planning (LoRAWAN and NB-IoT cases)

FACE-TO-FACE Training Course on
”TECHNICAL ASPECTS OF WIRELESS SOLUTIONS FOR THE INTERNET OF THINGS (IoT)”

Sami TABBANE
30 September -03 October 2019
Bangkok, Thailand
Objectives

Present the parameters and methodology for planning an IoT network, starting from the expected services to be proposed.
1. Network capacity dimensioning
### Dimensioning Steps and Process

1. **Traffic Modeling**
   - Models selection
   - Parameters setting

2. **Bandwidth dimensioning**
   - Models application
   - Aggregated capacity
   - Number of network elements

3. **Dimensioning and Planning Integrated Process**
   - Simulation of coverage and capacity
   - Revision of the initial assumption

4. **Network capacity dimensioning**
   - Output:
     - Network design
     - Gateways parameters
Dimensioning Phases

- Traffic Dimensioning

- Equipment dimensioning
  - Dimensioning Traffic
    - Signaling Traffic
    - Data Traffic

  Services and end devices demands
  → Number of gateways required
Dimensioning Phases

- **Dimensioning preliminary phases**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Parameters/Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial parameters configuration</td>
<td>- Number of end devices, N</td>
</tr>
<tr>
<td></td>
<td>- Number of end devices type 1</td>
</tr>
<tr>
<td></td>
<td>- …</td>
</tr>
<tr>
<td></td>
<td>- Number of end devices type k</td>
</tr>
<tr>
<td>End devices profiles configuration</td>
<td>- Packets sizes</td>
</tr>
<tr>
<td></td>
<td>- Packet arrival rates</td>
</tr>
<tr>
<td>Traffic at Busy hour</td>
<td>- Traffic percentage in DL/UL</td>
</tr>
<tr>
<td>Signaling Traffic</td>
<td>- Control DL</td>
</tr>
<tr>
<td></td>
<td>- ACK</td>
</tr>
<tr>
<td></td>
<td>- …</td>
</tr>
</tbody>
</table>
Traffic dimensioning at BH

- **Initial parameters (Number of end devices of each type)**

  \[
  N_1 = N_A \cdot P_1 \\
  N_2 = N_A \cdot P_2 \\
  \vdots \\
  N_k = N_A \cdot P_k
  \]

  Where:
  - \( N_i \): Number of end devices of type \( i \)
  - \( N_A \): Total end devices number
  - \( P_i \): Type \( i \) end devices percentage
Traffic dimensioning at BH

- End devices profile at Busy hour

Accesses of end devices to the network are for:
- Measurements reporting,
- Alarms,
- Control,
- ...

Traffic at busy hour:

\[ \rho_{BH-DL/UL}^S = \left( T_{session} N_{session} \right) \]

Where

- \( \rho_{BH-DL/UL}^S \): Traffic volume in UL/ DL at Busy hour
- \( T_{session} \): Data volume transmitted per exchange (i.e., session)
- \( N_{session} \): Number of exchanges at BH

Service characteristics:
- Activity rate per end device,
- Packets sizes.
Traffic dimensioning at BH

Traffic on the DL:

$$\rho^{S}_{BH-DL} = (\rho^{S}_{BH-DL/UL}) \cdot \rho_{DL}$$

Where:

- $$\rho^{S}_{BH-DL/U}$$: Traffic volume at Busy hour
- $$\rho^{S}_{BH-DL}$$: Traffic volume on the DL
- $$\rho_{DL}$$: Percentage of DL traffic
Traffic dimensioning at BH

- Traffic at BH

  ➔ Type $i$ end devices total traffic at BH

  \[ \rho_{i\, DL/UL} = \rho_{i\, BH-DL/UL} \times N_i \]

  $\rho_{i\, DL/UL}$: type $i$ end devices total traffic at Busy hour

  ➔ Type $i$ end devices throughput at BH

  \[ TH_{i\, BH-DL/UL} = \left( \rho_{i\, DL/UL} \right) / 3600 \]
2. Dimensioning Use Case
Load assessment

The capacity of the planned network must comply with the requirements of the terms of traffic to be handled.

For **1 million people**

We can predict **7 million devices**

Possible distribution in the different areas according to the number of people and the penetration

<table>
<thead>
<tr>
<th>End devices</th>
<th>Urban area (60 %)</th>
<th>Suburban area (30 %)</th>
<th>Rural area (10 %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 million</td>
<td>4.2 million</td>
<td>2.1 million</td>
<td>0.7 million</td>
</tr>
</tbody>
</table>
Service and End Device Modeling

Modeling of:
- End devices (type, technology used, ...)
- Sensors
- Other connected things

Fleet Management: The end device can send a packet in the network every 30 second to track a vehicle.

Logistic: an end device can send a packet in the network every 5 min to report his occupation state.

Water meter: can send a packet once a day to inform the water consumption.

Modeling the services
Traffic Modeling

Several parameters to consider depending on the technology

<table>
<thead>
<tr>
<th>Packet size</th>
<th><strong>Preamble</strong></th>
<th><strong>Payload</strong></th>
<th><strong>CRC</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Change according the services

More channels ➔ More simultaneous connections

Gateway Capacity

Gateway capacity (packets/day, maximum throughput, ...)

Determine the time on Air ➔ Packets inter-arrival time
Use case

Assumptions

- Big City
- Public LoRaWAN Network Dimensioning
- Number of devices increase every year
- Total Bandwidth: **1 MHz**

- LoRa SX1301 Chipset
- Bandwidth: 125 KHz
- 8 channels
- Central Frequency: 868 MHz
- CRC enabled
- Low data rate optimization enabled
## Use case
### Traffic Modeling

<table>
<thead>
<tr>
<th>Services</th>
<th>Packet transmission frequency (per hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor</td>
<td>1</td>
</tr>
<tr>
<td>Metering</td>
<td>0,04</td>
</tr>
<tr>
<td>Alarm</td>
<td>1/365/24</td>
</tr>
<tr>
<td>Tracking Logistic</td>
<td>2</td>
</tr>
<tr>
<td>Vehicle Tracking</td>
<td>6</td>
</tr>
<tr>
<td>Traffic Control</td>
<td>60</td>
</tr>
<tr>
<td>Agriculture</td>
<td>1</td>
</tr>
<tr>
<td>Wearables</td>
<td>2</td>
</tr>
<tr>
<td>Home Automation</td>
<td>0,50</td>
</tr>
</tbody>
</table>
Profiles of traffic

IoT Traffic Characterisation

- Periodic
- Event-Based
- Mixed-Mode

System Status
- e.g. 10-600 bytes

Observation/Actuation Message
- e.g. 10-600 bytes
Lora Gateway **Capacity**: given in terms of **number of packets per day**.

### LoRa Packet
(maximum size: 256 bytes)

<table>
<thead>
<tr>
<th>Payload Size (byte)</th>
<th>Spreading Factor</th>
<th>Symbol Rate</th>
<th>Programmed Preamble (Symbol)</th>
<th>Preamble Duration (ms)</th>
<th>Coding Rate</th>
<th>Number of payload Symbol</th>
<th>Payload Duration (ms)</th>
<th>Duration of packet (ms)</th>
<th>Single Gateway with 8 channels Capacity (Packets per day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>7</td>
<td>0.98</td>
<td>6</td>
<td>10</td>
<td>2</td>
<td>32</td>
<td>32</td>
<td>43</td>
<td>1 997 041</td>
</tr>
<tr>
<td>10</td>
<td>8</td>
<td>0.49</td>
<td>6</td>
<td>20</td>
<td>1</td>
<td>23</td>
<td>47</td>
<td>68</td>
<td>1 268 797</td>
</tr>
<tr>
<td>5</td>
<td>9</td>
<td>0.24</td>
<td>6</td>
<td>41</td>
<td>2</td>
<td>14</td>
<td>57</td>
<td>99</td>
<td>869 845</td>
</tr>
<tr>
<td>15</td>
<td>10</td>
<td>0.12</td>
<td>6</td>
<td>83</td>
<td>4</td>
<td>40</td>
<td>327</td>
<td>411</td>
<td>209 888</td>
</tr>
<tr>
<td>15</td>
<td>11</td>
<td>0.06</td>
<td>6</td>
<td>167</td>
<td>1</td>
<td>23</td>
<td>376</td>
<td>544</td>
<td>158 600</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
<td>0.98</td>
<td>6</td>
<td>10</td>
<td>4</td>
<td>40</td>
<td>40</td>
<td>51</td>
<td>1 679 104</td>
</tr>
<tr>
<td>15</td>
<td>8</td>
<td>0.49</td>
<td>6</td>
<td>20</td>
<td>1</td>
<td>33</td>
<td>67</td>
<td>88</td>
<td>975 434</td>
</tr>
<tr>
<td>12</td>
<td>9</td>
<td>0.24</td>
<td>6</td>
<td>41</td>
<td>3</td>
<td>29</td>
<td>118</td>
<td>160</td>
<td>537 420</td>
</tr>
<tr>
<td>12</td>
<td>10</td>
<td>0.12</td>
<td>6</td>
<td>83</td>
<td>1</td>
<td>23</td>
<td>188</td>
<td>272</td>
<td>317 199</td>
</tr>
</tbody>
</table>
### Many different M2M applications with different characteristics

<table>
<thead>
<tr>
<th>Example Applications</th>
<th>Data volume</th>
<th>Quality of Service</th>
<th>Amount of signalling</th>
<th>Time sensitivity</th>
<th>Mobility</th>
<th>Server initiated communication</th>
<th>only Packet switched</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart energy meters</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Road charging</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>yes</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>eCall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Remote maintenance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Fleet management</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Photo frames</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Asset tracking</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Mobile payments</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>yes</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Media synchronisation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Surveillance cameras</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Health monitoring</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

- There is not one type of M2M application with one set of requirements
- Operators should be able to differentiate their M2M portfolio

Source: www.itu.int/md/T09-SG11-120611-TD-GEN-0844/en
Use case

First Year

Gateway **Capacity: 1 500 000 packets per day**

<table>
<thead>
<tr>
<th>Services</th>
<th>Packet transmission frequency (at BH)</th>
<th>End devices Number</th>
<th>Number of packets per day for one device</th>
<th>Burstiness Margin</th>
<th>Security Margin</th>
<th>Number of packets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor</td>
<td>1</td>
<td>200</td>
<td>24</td>
<td>20%</td>
<td>10%</td>
<td>152 064</td>
</tr>
<tr>
<td>Metering</td>
<td>0,04</td>
<td>100,00</td>
<td>1</td>
<td>20%</td>
<td>10%</td>
<td>132</td>
</tr>
<tr>
<td>Alarm</td>
<td>0,00</td>
<td>100,00</td>
<td>1</td>
<td>20%</td>
<td>10%</td>
<td>132</td>
</tr>
<tr>
<td>Tracking Logistic</td>
<td>2</td>
<td>100</td>
<td>48</td>
<td>20%</td>
<td>10%</td>
<td>304 128</td>
</tr>
<tr>
<td>Vehicle Tracking</td>
<td>6</td>
<td>70</td>
<td>144</td>
<td>20%</td>
<td>10%</td>
<td>1 916 007</td>
</tr>
<tr>
<td>Traffic Control</td>
<td>10</td>
<td>150</td>
<td>240</td>
<td>20%</td>
<td>10%</td>
<td>11 404 800</td>
</tr>
<tr>
<td>Agriculture</td>
<td>1</td>
<td>200,00</td>
<td>24</td>
<td>20%</td>
<td>10%</td>
<td>152 064</td>
</tr>
<tr>
<td>Wearables</td>
<td>0,5</td>
<td>1000,00</td>
<td>12</td>
<td>20%</td>
<td>10%</td>
<td>190 080</td>
</tr>
<tr>
<td>Home Automation</td>
<td>0,5</td>
<td>300</td>
<td>12</td>
<td>20%</td>
<td>10%</td>
<td>57 024</td>
</tr>
<tr>
<td><strong>Total Packets per day</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>14 176 431</strong></td>
</tr>
</tbody>
</table>

**Number of Gateways: 10**
**Use case**

**Second Year**

Gateway **Capacity: 1 500 000 packets per day**

<table>
<thead>
<tr>
<th>Services</th>
<th>Packet transmission frequency (at BH)</th>
<th>End device Number</th>
<th>Number of packets per day for one device</th>
<th>Burstiness Margin</th>
<th>Security Margin</th>
<th>Number of packet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor</td>
<td>1</td>
<td>400</td>
<td>24</td>
<td>20%</td>
<td>10%</td>
<td>304 128</td>
</tr>
<tr>
<td>Metering</td>
<td>0,04</td>
<td>200</td>
<td>1</td>
<td>20%</td>
<td>10%</td>
<td>264</td>
</tr>
<tr>
<td>Alarm</td>
<td>0,00</td>
<td>200</td>
<td>1</td>
<td>20%</td>
<td>10%</td>
<td>264</td>
</tr>
<tr>
<td>Tracking Logistic</td>
<td>2</td>
<td>200</td>
<td>48</td>
<td>20%</td>
<td>10%</td>
<td>608 256</td>
</tr>
<tr>
<td>Vehicle Tracking</td>
<td>6</td>
<td>140</td>
<td>144</td>
<td>20%</td>
<td>10%</td>
<td>3 832 013</td>
</tr>
<tr>
<td>Traffic Control</td>
<td>10</td>
<td>300</td>
<td>240</td>
<td>20%</td>
<td>10%</td>
<td>22 809 600</td>
</tr>
<tr>
<td>Agriculture</td>
<td>1</td>
<td>400</td>
<td>24</td>
<td>20%</td>
<td>10%</td>
<td>304 128</td>
</tr>
<tr>
<td>Wearables</td>
<td>0,5</td>
<td>2000</td>
<td>12</td>
<td>20%</td>
<td>10%</td>
<td>380 160</td>
</tr>
<tr>
<td>Home Automation</td>
<td>0,5</td>
<td>600</td>
<td>12</td>
<td>20%</td>
<td>10%</td>
<td>114 048</td>
</tr>
</tbody>
</table>

Total Packets per day: 28 352 861

**Number of Gateways: 19**
# Use case

## Third Year

<table>
<thead>
<tr>
<th>Services</th>
<th>Packet transmission frequency (at BH)</th>
<th>End device Number</th>
<th>Number of packets per day for one device</th>
<th>Burstiness Margin</th>
<th>Security Margin</th>
<th>Number of packets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor</td>
<td>1</td>
<td>800</td>
<td>24</td>
<td>20%</td>
<td>10%</td>
<td>608 256</td>
</tr>
<tr>
<td>Metering</td>
<td>0.04</td>
<td>400</td>
<td>1</td>
<td>20%</td>
<td>10%</td>
<td>528</td>
</tr>
<tr>
<td>Alarm</td>
<td>0.00</td>
<td>400</td>
<td>1</td>
<td>20%</td>
<td>10%</td>
<td>528</td>
</tr>
<tr>
<td>Tracking Logistic</td>
<td>2</td>
<td>400</td>
<td>48</td>
<td>20%</td>
<td>10%</td>
<td>1 216 512</td>
</tr>
<tr>
<td>Vehicle Tracking</td>
<td>6</td>
<td>300</td>
<td>144</td>
<td>20%</td>
<td>10%</td>
<td>8 211 456</td>
</tr>
<tr>
<td>Traffic Control</td>
<td>10</td>
<td>600</td>
<td>240</td>
<td>20%</td>
<td>10%</td>
<td>45 619 200</td>
</tr>
<tr>
<td>Agriculture</td>
<td>1</td>
<td>800</td>
<td>24</td>
<td>20%</td>
<td>10%</td>
<td>608 256</td>
</tr>
<tr>
<td>Wearables</td>
<td>0.5</td>
<td>3000</td>
<td>12</td>
<td>20%</td>
<td>10%</td>
<td>570 240</td>
</tr>
<tr>
<td>Home Automation</td>
<td>0.5</td>
<td>1200</td>
<td>12</td>
<td>20%</td>
<td>10%</td>
<td>228 096</td>
</tr>
</tbody>
</table>

Total Packets per day: **57 063 072**

Number of Gateways: **39**
3. Network planning
Wireless Network Planning Process

- Pre-planning
  - Collect area parameters
  - End devices information
  - Traffic models

- Dimensioning:
  - Requirements and Coverage strategy, Capacity and quality

- Coverage planning
  - Coverage and capacity constraints
  - Minimize used resources

- Network design
  - Number of sites/gateways
  - Traffic rate
  - Signaling

- Parameters tuning

- Optimization
  - Performance analysis in terms of quality and interference

Output:
- Equipment capacities
- Number of network elements

Output:
- Number of sites/gateways
- Traffic rate
- Signaling
1. Pre-planning of radio network: Initial Site Selection

Determine:
- Theoretical location of sites
- Implementation parameters (antenna type / azimuth / tilt / altitude / feeder type / length )
- Gateway parameters (as transmission power, transmission periodicity, ...)

1. Based on the network dimensioning and site information.
2. An analysis is made to check whether the coverage of the system meets the requirements ⇒ the height and tilt of the antenna and the GTWs number are adjusted to optimize the coverage.
3. The system capacity is analyzed to check whether it meets the requirement.
2. Pre-planning of radio network: Prediction

- Predict coverage results such as best serving cell, overlapping area ...
- Carry out detailed adjustments (such as gateway number, gateway configuration, antenna parameters) after analyzing the coverage prediction results
- Obtain proper site location and parameters that should satisfy coverage requirements
Planning overview

3. **Cell planning of radio network: Site survey**

- Select backup location for site if theoretical location is not available

- Take into account:
  - Radio propagation factor: situation / height / surrounding /
  - Implementation factor: space / antenna installation / transmission / power supply
3. Cell planning of radio network: Simulation

- Generate certain quantity of network instantaneous state (snapshots)
- By iteration
- Determinate gateway load, connection status and rejected reason for each end device

⇒ understand network performance
Radio Planning

PRE-PLANNING

- Choice of the area
- Choice of antennas
- Choice of equipment (GW and sensor)
- Choice of propagation model
- Frequencies choice
### Coverage Planning

- **Hnode = 0.3m**
- **HNodeB = 30m**
- **Dense urban**
- **Lora & Sigfox**
  - Frequency = 868 MHz
- **RPMA** frequency = 2.4 GHz
- **LTE-M** frequency = 1.8 GHz

<table>
<thead>
<tr>
<th>Technologies</th>
<th>Parameters</th>
<th>LORA</th>
<th>RPMA</th>
<th>SIGFOX</th>
<th>LTE_M</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DL</td>
<td>UL</td>
<td>DL</td>
<td>UL</td>
</tr>
<tr>
<td>TX power (dBm)</td>
<td>TXp</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>23</td>
</tr>
<tr>
<td>TX Cable loss (dB)</td>
<td>TXl</td>
<td>-3</td>
<td>-1</td>
<td>-3</td>
<td>-1</td>
</tr>
<tr>
<td>TX Antenna gain, dBi</td>
<td>TXg</td>
<td>9</td>
<td>0</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>TX subtotal (dB)</td>
<td>TXs</td>
<td>26</td>
<td>19</td>
<td>26</td>
<td>22</td>
</tr>
<tr>
<td>RX Sensitivity (dBm)</td>
<td>RXs</td>
<td>-137</td>
<td>-142</td>
<td>-133</td>
<td>-142</td>
</tr>
<tr>
<td>RX Environment noise (dB)</td>
<td>RXn</td>
<td>0</td>
<td>-10</td>
<td>0</td>
<td>-10</td>
</tr>
<tr>
<td>RX Antenna gain diversity (dBi)</td>
<td>RXgd</td>
<td>0</td>
<td>10</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>RX SubTotal (dBm)</td>
<td>RXs</td>
<td>137</td>
<td>142</td>
<td>141</td>
<td>142</td>
</tr>
<tr>
<td>Total (dBm)</td>
<td>Tot=TXs+RXs</td>
<td>163</td>
<td>161</td>
<td>167</td>
<td>164</td>
</tr>
<tr>
<td>Maximum allowable pathloss</td>
<td>Min(TotDL, TotUL)</td>
<td>161</td>
<td>164</td>
<td>159</td>
<td>148</td>
</tr>
<tr>
<td>Range (Km)</td>
<td></td>
<td>3.5</td>
<td>2</td>
<td>3.2</td>
<td>2.8</td>
</tr>
<tr>
<td>Sectorization</td>
<td></td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>

Using COST Hata model as propagation model.
4. Dimensioning and Planning Integrated Process
Dimensioning Steps and Process

Traffic Modeling
- Models selection
- Parameters setting

Bandwidth dimensioning
- Models application
  Output:
  - Aggregated capacity
  - Number of network elements

Dimensioning and Planning Integrated Process
- Simulation of coverage and capacity
- Revision of the initial assumption

Output:
- Network design
- Gateways parameters

Network capacity dimensioning
Relation between coverage and bitrate

2D simulation (flat environment)

<table>
<thead>
<tr>
<th>Spreading Factor</th>
<th>Symbols/second</th>
<th>Bitrate</th>
<th>TOA (10 bytes, ms)</th>
<th>SNR limit (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF 7</td>
<td>976</td>
<td>5469</td>
<td>56</td>
<td>-7,5</td>
</tr>
<tr>
<td>SF 8</td>
<td>488</td>
<td>3125</td>
<td>103</td>
<td>-10</td>
</tr>
<tr>
<td>SF 9</td>
<td>244</td>
<td>1758</td>
<td>205</td>
<td>-12,5</td>
</tr>
<tr>
<td>SF 10</td>
<td>122</td>
<td>977</td>
<td>371</td>
<td>-15</td>
</tr>
<tr>
<td>SF 11</td>
<td>61</td>
<td>537</td>
<td>741</td>
<td>-17,5</td>
</tr>
<tr>
<td>SF 12</td>
<td>30</td>
<td>293</td>
<td>1483</td>
<td>-20</td>
</tr>
</tbody>
</table>
Distribution of the SF in the cell

Gateway

SF 12  SF 10  SF 7

Sub #1  Sub #2  Sub #3

...Sub #N
## Impact on the cell capacity

<table>
<thead>
<tr>
<th>SNR</th>
<th>SF</th>
<th>Bitrate (b/s)</th>
<th>% of the cell</th>
<th>% of the population in this area</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>-20dB</td>
<td>LoRa SF12</td>
<td>293</td>
<td>15%</td>
<td>10%</td>
<td>29</td>
</tr>
<tr>
<td>-17.5dB</td>
<td>LoRa SF11</td>
<td>537</td>
<td>15%</td>
<td>10%</td>
<td>53</td>
</tr>
<tr>
<td>-15dB</td>
<td>LoRa SF10</td>
<td>977</td>
<td>10%</td>
<td>20%</td>
<td>195</td>
</tr>
<tr>
<td>-12.5dB</td>
<td>LoRa SF9</td>
<td>1758</td>
<td>10%</td>
<td>20%</td>
<td>351</td>
</tr>
<tr>
<td>-10dB</td>
<td>LoRa SF8</td>
<td>3125</td>
<td>20%</td>
<td>25%</td>
<td>781</td>
</tr>
<tr>
<td>-7.5dB</td>
<td>LoRa SF7</td>
<td>5469</td>
<td>30%</td>
<td>15%</td>
<td>820</td>
</tr>
</tbody>
</table>

**Cell capacity (bit/sec)** 2231
Dimensioning process

**Step 1**: initial configuration (dimensioning and planning)

Traffic and mobility model
- End devices classes
- Services QoS characteristics
- Services contention ratios
- Transmission and protocols overheads

Radio planning
- Radio interface characteristics
- Coverage and interference requirements
- End devices geographic distribution
- Allocated spectrum

Aggregate required capacity (Mb/s)

Theoretical cell available bandwidth

Initial number of required GTWs

GTW available bandwidth (Mb/s)
Dimensioning process

Step 2: final configuration

- Cell available bandwidth (Mb/s)
- Aggregate required capacity (Mb/s)
- Coverage and interference characteristics
- Radio interface characteristics
- New radio planning: optimization

Final number of required cells and gateway configuration
Inputs

- End devices types,
- Service usage/end devices class,
- Contention ratios/end devices class,
- End devices geographic distribution,
- Services packet sizes,
- Services and protocols overheads.
F. Case studies

IoT planning with Mentum Planet
Use cases

• **Introduction to Planet**
  
  • Use case 1: LoRa network planning in Tunis area
  
  • Use case 2: Patavina Technologies network in Italy
IoT Planning

• Create demand forecasts and determine best technology options
• Dimension and simulate LPWA networks
• Optimize deployment of IoT technologies
**New IoT capabilities.** Support for IoT technologies SIGFOX and LoRa is delivered through an optional module. Network analyses (best server, signal strength, SIGFOX diversity levels, Uplink LoRa, best available modulation based on spreading factors) are all available.

**MapInfo geographic information system.** Operators planning their network and related demand forecasts are trying to solve an RF geospatial problem. Planet is includes a leading geographic information system — MapInfo Professional™ — native to the application.

**An open platform.** Planet offers multiple means to integrate 3rd-party solutions or key systems through application programming interfaces (APIs).
**Different Steps**

**Project Setup**
- Network Settings: Frequency, bands, ...
- Site Editor: Propagation, antenna, PA Power, ...
- IoT Device Editor: PA Power, Noise Figure, ...

**Propagation Modeling**
- Geographical Data support (Elevation, clutter, height, buildings, forest, polygons, ...)
- Intelligent antenna management and modeling

**Network Analyses**
- Signal Strength, best available modulation, ...
- Data analytics and statistics
- Scheduling and automating
- Antenna’s property
- Radiation pattern
- HBA
- Tilt
- Azimuth, ...
Network Analysis

- IoT-specific simulation engine with downlink and uplink analysis
  - DL/UL best server
  - DL/UL received signal strength
  - DL/UL S/(N+I)
  - DL/UL coverage (Including diversity requirement)
  - Number of servers
  - Nth Best Server
  - LoRa Uplink capacity
- Multi-threaded
Use cases

- Introduction to Planet
- Use case 1: LoRa network planning in Tunis area
- Use case 2: Patavina Technologies network in Italy
Use case 1

Area choice

13 LoRa Gateways for simulation

1 227.3 Km²
Use case 1

Downlink Best Server

[Map showing various sites labeled Site_1, Site_2, Site_3, etc., with different colors representing different signal strengths.

Legend:
- Site_1_1
- Site_1_2
- Site_1_3
- Site_10_1
- Site_10_2
- Site_10_3
- Site_11_1
- Site_11_2
- Site_11_3
- Site_12_1
- Site_12_2
- Site_12_3
- Site_13_1
- Site_13_2
- Site_13_3
- Site_2_1
- Site_2_2
- Site_2_3
- Site_3_1
- Site_3_2
- Site_3_3]
Use case 1

Downlink Signal Strength
Use case 1

Downlink Signal Strength

Percentage Sub Area

Covered Area (km²)
Uplink Signal Strength

- More important to consider
- IoT devices send more packets to gateway than they receive
- LoRa End Devices Transmit Power: **14 dBm to 20 dBm**

**Two use cases**

<table>
<thead>
<tr>
<th>14 dBm</th>
<th>20 dBm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Better battery economy for end devices</td>
<td>Better for end devices on the grid</td>
</tr>
</tbody>
</table>
Use case 1

Uplink Signal Strength

End Device Power: 20 dBm
End Device Power: 14 dBm

Legend:
-70 to -60
-90 to -70
-100 to -90
-120 to -100
-140 to -120
-160 to -140
Use case 1

Uplink Signal Strength

End Device Power: 20 dBm

End Device Power: 14 dBm
Use case 1

Comparison of Areas covered percentage

Uplink Signal Strength

-200 ~ -120
-120 ~ -100
-100 ~ -90
-90 ~ -80
-80 ~ -70
-70 ~ -50

Ranges 20 dbm
Ranges 14 dBm
Lora Spreading Factor use per area

Use case 1

End Device Power: 20 dBm

End Device Power: 14 dBm
Use case 1

Lora Spreading Factor use per area

End Device Power: 20 dBm

End Device Power: 14 dBm
Use case 1

Lora Spreading Factor use per area

Comparison of SF use per device transmit Power

LoRa SF = 6
LoRa SF = 7
LoRa SF = 8
LoRa SF = 9
LoRa SF = 10
LoRa SF = 11
LoRa SF = 12

14dBm
20dBm
Total Number of sites calculation

Distribute End Nodes per area according the different services

Calculate possible number of packets to be send in every area simultaneously

Calculate the number of gateways according the capacity of one gateway

Final Numbers of Gateways = Maximum {

Number of Gateways (coverage),
Number of Gateways (capacity) }

KPN deployment plans for LoRa in the Netherlands, showing planned coverage for the end of May 2016 (left) and end of June 2016 (right).
Use cases

• Introduction to Planet
• Use case 1: LoRa network planning in Tunis area
• Use case 2: Patavina Technologies network in Italy
Use case 2

- Private Network by Patavina Technologies in Italy
- Building with 19 floors
- LoRaWAN Network
- Goal:
  - Reduce the cost related to heating, ventilation and air conditioning
  - Temperature and Humidity control

Installation

- Single gateway on ninth floor
- 32 nodes All over the building
- All nodes successfully covered

- Open places
- Stress test (elevators, ...)
Use case 2

- Coverage analysis by Patavina Technologies in Italy
- Padova, Italy
- LoRaWAN Network
- Goal:
  - Assess “worst case” coverage (Harsh propagation conditions)
  - Conservative estimate number of gateways to cover the whole city
Use case 2

Results

Single gateway
Max radius: 2 Km
Nominal Radius: 1.2 Km

Padova system cell overage

- 30 gateways
- 200,000 inhabitants ➔ 7,000 per gateway
- Adequate for most smart city applications
Thank You