Cellular IoT

Investor and analyst brief

Nordic Semiconductor ASA
November 28 2016
Oslo, Norway
Introduction
Svenn-Tore Larsen, CEO
Today is all about Cellular IoT

Low power LTE technology
  Fundamental concepts
  Shaping the future of IoT

The market opportunity
  Fundamental drivers
  Size and growth potential

Our strategic investment
  Product and market strategy
  Product development
Proven track record - 2 years into cellular IoT

Proprietary 2.4GHz

3 years to reach first revenue

Bluetooth

4 years to reach first revenue
Today’s speakers

Thomas Embla Bonnerud
Director of Strategy and IR
15 year+ with Nordic
Last 10 in Product Management
Product and market strategy

Svein-Egil Nielsen
Chief Technology Officer
Started in 2001
Responsible for R&D organization
Ex chairman of Bluetooth SIG

Juha Heikkilä
Head of Nordic Finland
> 20 years in cellular chipset development
Nokia, Renesas, Broadcom
Today’s agenda

#1 Technology and ecosystem
#2 Cellular IoT market
#3 Product and market strategy
#4 Product development
#5 Q&A
Technology and ecosystem
Thomas Embla Bonnerud
Cellular - a unique value proposition for IoT

Existing network infrastructure

Connectivity anywhere

Security

Reliability and quality of service
The emergence of low power LTE

Cost/size/power

<table>
<thead>
<tr>
<th>Higher throughput</th>
<th>Lower throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTE Cat 1+</td>
<td>Low power LTE</td>
</tr>
<tr>
<td>(LTE-M, NB-IoT)</td>
<td></td>
</tr>
</tbody>
</table>
# New low power LTE technologies

<table>
<thead>
<tr>
<th>LTE-M</th>
<th>NB-IoT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Also known as</strong></td>
<td>“LTE-MTC”, “LTE Cat-M1”</td>
</tr>
<tr>
<td><strong>Max throughput</strong></td>
<td>- 375kbps</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>Up to 4X</td>
</tr>
<tr>
<td><strong>Mobility</strong></td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Frequency deployment</strong></td>
<td>LTE In-band</td>
</tr>
<tr>
<td><strong>Deployment density</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Module price</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Module size</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Power consumption</strong></td>
<td></td>
</tr>
</tbody>
</table>
More than low power...

- Broader coverage
  - Rural areas
  - Deep indoor
- Massive deployments
- Smaller size
  - Higher density deployments
  - Space constrained devices
- Lower cost
  - Module cost
  - Subscription cost
## Low power LTE vs. unlicensed LPWNA

<table>
<thead>
<tr>
<th></th>
<th>Low power LTE (NB-IoT, LTE-M)</th>
<th>Unlicensed LPWAN (SigFox, LoRA...)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open standard</td>
<td>Yes, 3GPP</td>
<td>No, proprietary</td>
</tr>
<tr>
<td>Frequency bands</td>
<td>Licensed</td>
<td>Unlicensed, sub 1-GHz ISM</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>Existing LTE</td>
<td>New</td>
</tr>
<tr>
<td>Max throughput</td>
<td>Up to 375kbps</td>
<td>Up to 6kbps</td>
</tr>
<tr>
<td>Reliability and QoS</td>
<td>(+++)</td>
<td>(-)</td>
</tr>
<tr>
<td>Security</td>
<td>(+++)</td>
<td>(-)</td>
</tr>
<tr>
<td>Module cost</td>
<td>(-)</td>
<td>(+)</td>
</tr>
<tr>
<td>Power</td>
<td>(-)</td>
<td>(+)</td>
</tr>
</tbody>
</table>
Cellular IoT ecosystem and players

- Cellular enabled thing
- RF Front-end
- Chipset
- Modules
- Infrastructure
- Carriers
- Cloud

[Logos of various companies such as Skyworks, Nordic Semiconductor, Qorvo, Sequans, Qualcomm, Telit, Ericsson, Nokia, Huawei, AT&T, Telenor, and Google Cloud]
The importance of modules for IoT

Barriers for chipset integration

- Complexity of integration
- Tele-regulatory approvals
- Standard compliance
- Carrier certification
- Regional variants
Anatomy of a cellular module

LTE module for M2M

37x50x5.3mm, USD ~40 cost

- Chipset
  - Baseband Processor, Radio
- RF Front-end
  - PA, LNA, Switches, filters ++
- Memory
  - RAM, Flash
- Power Management IC (PMIC)

Source: IHS Technology Teardown Service, 2015
Region and carrier specific frequency bands

- 44 LTE frequency bands
- Low Bands (Sub 1GHz)
- Mid Bands (2GHz)
- High Bands (>2GHz)
- Lower frequency longer range
- Country specific bands
- Operator specific bands
Band support for chipset and modules

Chipset

Transceiver support for multi-band
Cost and complexity impact

Module

RF-front-end support for multi-band
Significant cost and complexity impact
Typically 2 – 5 bands
Device band support

4G data modem

1-3 bands
Limited to a carrier and region
Lower complexity and cost

Modern smartphone

25+ bands
Worldwide roaming
Higher complexity and cost
SIM and subscription

SIM is needed for network access

- Unique information / process for network identification
- Specialized secure microcontroller and memory

eSIM is key for IoT

- SIM card not practical for IoT application
- eSIM is chip
- Over-the-air provisioning
- Remotely manage subscription
Low power LTE standardization

3GPP

A GLOBAL INITIATIVE

Standardization body
GSM, UMTS and LTE

LTE-M
Part of Release 13
Completed

NB-IoT
Part of Release 13
Completed
Certification complexity

Tele-regulatory
- Regional variations, FCC, ETSI, Telec etc.

Standard compliance
- 3GPP requirements

Cost & effort
- Region/carrier specific products

Carrier specific certification
- Additional and more stringent requirements
  - Varies between carriers
Evolution path to 5G

Ultra high throughput
Higher frequency (>26GHz)

Massive IoT
Evolution of LTE-M and NB-IOT

Ultra reliable IoT
Zero outage, low latency
Cellular IoT market
Cellular IoT market opportunity

Existing and fast growing market
Excludes phones, tablets and PCs
- 400M connection in 2015
  27% CAGR*

Low power LTE a key driver
Continued growth → 2022
Diversification of the market

Complements Bluetooth market
Different type of applications
A few overlaps

(*Source: Ericsson Mobility Report 2015)
Split between technologies

Low power LTE
- LTE-M, NB-IoT
- Lower throughput
- Power, size, coverage, cost
- Broad range of applications

2G/3G
- GSM, UMTS, CDMA
- Maturity, coverage and cost
- Network to be phased out

LTE
- LTE Cat 1+
- Future proof, high throughput
- High throughput applications
Low power connectivity redefined

No local area network
Existing infrastructure

Mobility & roaming
Ubiquitous connectivity

Independence from local area network
Security and reliability
Ease of use
Key use cases in cellular IoT

- Remote monitoring
- Cloud connectivity
- Cost savings
- Business efficiency
- Predictive maintenance
- Remote maintenance
- Remote operation
A diversified market opportunity

Low power LTE market

2017 - 2021

Home

City

Industry

Healthcare

Buildings

Transport

Logistics

Utilities

Consumer

Enterprise and retail

Agriculture & environment
Product-as-a-service unlocking consumer

Cellular subscription part of the service

Services built on top of connectivity
Cloud, big data, machine learning
Per “use” and/or recurring
Low power LTE coverage is key enabler

Massive worldwide LTE coverage

- LTE Cat 3+
- January 2016: 480 networks, 157 countries
- Drivers: throughput and spectrum efficiency

Low power LTE status and projection

- Upgrade of existing LTE infrastructure
- Rapid deployment
- Test deployments in 2016
- LTE-M in US, NB-IoT in Europe and Asia
- First commercial services 2017
- Broad coverage for both technologies 2018→
Market sizing: public research

Ericsson Mobility Report
(2015)

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2021</th>
<th>CAGR 2015–2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellular IoT</td>
<td>0.4</td>
<td>1.5</td>
<td>27%</td>
</tr>
<tr>
<td>Non-cellular IoT</td>
<td>4.2</td>
<td>14.2</td>
<td>22%</td>
</tr>
<tr>
<td>PC/laptop/tablet</td>
<td>1.7</td>
<td>1.8</td>
<td>1%</td>
</tr>
<tr>
<td>Mobile phones</td>
<td>7.1</td>
<td>8.6</td>
<td>3%</td>
</tr>
<tr>
<td>Fixed phones</td>
<td>1.3</td>
<td>1.4</td>
<td>0%</td>
</tr>
</tbody>
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GSMA
(2015)

<table>
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</thead>
<tbody>
<tr>
<td>Connections (million)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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- Higher potential target
  - 2015-17 CAGR 40%
  - 2016-20 CAGR 48%
- Stimulated growth
  - 2015-17 CAGR 33%
  - 2016-20 CAGR 40%
- Current trajectory
  - 2015-20 CAGR 25%
Modelling unit shipments for low power LTE

<table>
<thead>
<tr>
<th>Connections</th>
<th>Replacement</th>
<th>Low power LTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>→ Unit shipments</td>
<td>rate (%)</td>
<td>share (%)</td>
</tr>
<tr>
<td>Change in number of connections</td>
<td>Replacement of 2G/3G General replacement</td>
<td>vs. 2G/3G and LTE Cat 1+</td>
</tr>
</tbody>
</table>
Example model: units shipment 2016 - 2021

Cellular IoT device shipment (MU)

<table>
<thead>
<tr>
<th>Year</th>
<th>High speed</th>
<th>Low power</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>108</td>
<td>0</td>
</tr>
<tr>
<td>2017</td>
<td>149</td>
<td>2</td>
</tr>
<tr>
<td>2018</td>
<td>181</td>
<td>10</td>
</tr>
<tr>
<td>2019</td>
<td>182</td>
<td>61</td>
</tr>
<tr>
<td>2020</td>
<td>169</td>
<td>138</td>
</tr>
<tr>
<td>2021</td>
<td>141</td>
<td>250</td>
</tr>
</tbody>
</table>

Dataset and assumptions
- Ericsson Mobility Report 2015
- 400M connected devices in 2015, mainly 2G/3G
- 27% CAGR

Replacement rate
- % of total number of connection
- 2% per year 2017 - 2021: total of 110MU

Low power LTE share
- Bluetooth Smart: from 0 to 250MU in 5 years
- May be to optimistic, may be to pessimistic
- Just an example!
Projected chipset ASP 2017 - 2021

$10

Chipset price range

$3

‘Baseline’

- Transceiver + Baseband Processor
- Single mode NB-IoT or LTE-M
- Single low band support
- Price erosion → 2021

‘Value add’

- Application Processor
- Memory (Flash/RAM)
- Power Management
- Multimode LTE-M/NB-IoT
- Multi-band support
- Simplified RF front-end
- Size, power and performance
- Advanced connectivity features
Projected module ASP 2017 - 2021

$20

Module price range

$5

‘Baseline’

- ‘Thin modem’, low cost LGA
- Single mode NB-IoT or LTE-M
- Single low band support
- Price erosion→ 2021

‘Value add’

- Multi-band, high performance RF front-end
- Higher value chipset
- On-board sensors, including GPS
- On-board application processor
- On-board eSIM
- Temperature range
- Automotive qualification
- Miniaturization
Modelling market value for chipsets

ASP ≠ lowest price
Volume distribution over the price range
Distribution of customer size

Range of price points
Market / application depend
Market dependent

There will be a “value play”
Example model: market value 2016 - 2021

Low power LTE chipsets (MUSD)

Dataset and assumptions:
- Unit per year model earlier slide (Ericsson Mobility Report)
- Low power LTE only
- Flat $5 ASP
- Value add integration offsets price erosion
- May be to optimistic, may be to pessimistic
Other market enablers/drivers

Subscription
- cost / model

Support for
eSIM
- Over the air provisioning

Adoption in
consumer
- Shorter design cycles
  Drive early volume ramp

Cost of ownership
Product and market strategy
Birdseye view – strategic rationale

Technology shift
- High throughput →
  power, size, coverage and cost

Market shift
- Specialized →
  broad diversified market

Right expertise
- Nordic low power DNA
- Broad market model
- Cellular expertise in Finland
Technology strategy

Low power LTE only
LTE-M and NB-IoT

LTE-M first
Early US deployments
Broader range of applications

Multi-mode LTE-M / NB-IoT chipset
Incremental approach to a bigger market
Why not unlicensed LPWAN?

1. Proprietary – not open standards
2. Limited freedom to play and differentiate
3. Less attractive market opportunity
The chipset – a different approach

Architected and optimized for LTE-M and NB-IoT

High level of integration

NB-IoT support enabled with firmware update

Power
Size
Performance
Features
Solution cost

nRF91xx
Off-the-shelf and broad market solution

Complete and easy to use solution

Strategic partnerships
Hardware, software and tools

Lowering barriers of adoption

Enable innovation
Drive market growth

Leverage existing community & ecosystem

Forum and Developer Zone
3’rd party tools and solutions
Focused and incremental go-to-market

Regions
Regional tailored offerings
Carrier certifications and partnerships

Customers and verticals
High volume and growth potential
Strong competitive edge

Software
New features and performance improvements,
Meeting focus customer requirements
Lead customer momentum

Selected verticals
Logistics, consumer, utilities

Collaboration on requirements
Matching our early offering to their requirements

Strong interest
Competitiveness of our solution
Working with Nordic
Target sampling and launch

Second half

2017

Limited sampling
- Lead customers only
- Pre-production hardware and software

2018

General sampling
- Public launch
- Pre-production hardware and software
2017 – 2018 market entry

Market awareness and maturity
Use cases and applications

Technology maturity
Certification, Interoperability

Ecosystem maturity
Products and services
Remote provisioning

Highly competitive product offering

Coverage
Network support for LTE-M and NB-IoT
Subscription models and price
Aligning production with lead customers

9 – 18+ months design-in time
Evaluation – development – certifications – production
Production ramp linked to sampling schedule

2018
Volume ramp with lead customers
Dependent on sampling schedule and design-in time

2019
Lead customers in volume production
Volume ramp with general customers
Product development
Svein-Egil Nielsen
Juha Heikkilä
Nordic has six R&D locations

- **Trondheim**
  - 230 Engineers
  - RF/Analog, Digital design, Test, Firmware

- **Oslo**
  - 35 Engineers
  - RF/Analog, Digital Design, Firmware

- **Krakow**
  - 25 Engineers
  - Firmware

- **Oulu/Turku**
  - 130 Engineers
  - RF/Analog, Digital/Mixed-Signal, Test, Firmware

- **Portland, OR**
  - IOT Labs
  - 3 persons
World class IC design capability

Leading edge Radio’s

- Fully designed in house
- Stability and yield in production
- Leading edge performance
  - Basic Rate Bluetooth radio typically uses 25 to 35mA
  - Nordic 51 radio similar Basic Rate performance uses as low as 9mA

Highly configurable digital platform architecture

- Able to turn on/off each and every block to minimise current
- Co-operation with ARM so have leading micro-controller options for all products
- Flash process allowing flexibility and optimization by customers
- Source IP when a commodity freeing up R&D resources to focus on customer
Large software teams in place

Software is a key enabler for silicon sales

How does software add value?

- Making complex hardware simple to use
- Adding reliability
- Adding security
- Adding higher-level functionality
- Over-the-Air Device Firmware Upgrade
- Application-specific functions
- Enabling multi-role / multi-link / multi-protocol
- ...

Overall: enabling customers to concentrate on their contribution, not on Nordic’s hardware or software
We are building sustainable competitive edge with R&D

Tight collaboration with marketing, sales and customers to ensure we make the right products

Highly educated and experienced staff
- low attrition rate
- selective recruiting

Large portfolio of in-house IP that are leveraged in new products, patent portfolio

Top of the line design tools

Collaboration with leading partners
- TSMC, ARM, CEVA

Active participant in standards organizations to shape tomorrow’s specifications
- Bluetooth Sig, ETSI, 3GPP, NCF Forum, IEEE, Rezence, ++

Focus and agility
Committed to customer focused development

Nordic Semiconductor’s R&D Department have a customer focused approach committed to providing off-the-shelf solutions to thousands of customers but at the same time be able to develop targeted solution to key application segments and supporting key customers with their special needs. With our flexible IC and software architecture, robust solutions, willingness to support customers, whatever it takes attitude, we will provide the ultimate peace of mind for any engineer and company working with our products.
Fall of 2014 large layoffs in Finland

Broadcom to stop making phone chips—600 jobs to go in Finland

The wireless modem maker Broadcom is to shut down its connectivity chip operations with the loss of 600 jobs in Finland. Some 430 of them will go in Oulu, which is already reeling from the announcement last week that Microsoft will close a research facility there.

Ericsson follows Broadcom to modem Mordor

Swedes ring off

Ericsson, once the major manufacturer of modems, is planning to leave the business. The move will see 1,000 redundancies and 500 people moving to other Ericsson projects, such as small cells.

In February 2009, Ericsson entered into a joint venture with ST-Microelectronics — itself a merger of SGS-Thomson and NXP — in a bid to take on Qualcomm. In mid-2015, ST-Ericsson was dissolved — with the modern business moving to Ericsson. The closure of the joint venture led to the loss of 1,600 jobs.
We travelled to Oulu to recruit and investigate opportunities
Saw a great opportunity, action needed fast

- We knew it is difficult to build a large competent and experienced team in Norway quickly
- Competencies found in Finland was a great match to our ambitious
- Could build a sizeable organization quickly
- Cultural and Geographical fit
- Needed decision quickly
Clear success criteria for establishing a presence in Finland

- Strong management team.
- Recruit efficiently and find great talent. Get up to speed fast with experience people
- License key IP to secure schedule and performance of product
- Solid integration with other parts of organization -
  - “Not: them and us”
  - “It’s about the culture”
- Leverage existing investments in IP and process and platform
- Scale on existing Nordic infrastructure
Radio Systems
Yrjö Kaipainen

SW
Vesa Pellikka

RF
Olli Närhi

Digital BB
Pekka Kotila

Project Management
Heikki Päivike

HR/Finance/Admin
Sonja Kusmin

Juha Heikkilä
Head of Finland

Heikki Päivike
Highly capable organization quickly built

- Management team rapidly built
- Have recruited the whole cellular modem competence in house
- Resourcing optimized for cellular low power and low cost IoT development

65 employees in place by start 7 January 2015, now 135 employees
Highly relevant experience

Radio Systems personell with Nokia-Renesas-Broadcom background

- Design from very first cellular systems up to highest category LTE modems

Power management, RF and Digital IC and SOC design personell with Nokia-Renesas-Broadcom and Nokia-ST Ericsson-Ericsson backround

- Multi-billion IC/SOC volume experience

Firmware and protocol SW personnel with Nokia-Renesas-Broadcom and Nokia-ST-Ericsson-Ericsson background

- Multi-billion cellular product volume experience
Products developed with cross-functional teams in Finland and Norway

R&D Finland tightly integrated with teams in Norway

- 80% development in Finland: Cellular technology
- 20% in Norway: Low power technology SOC integration
- Cross fertilization of best in class knowledge
- Scale on specialized skills in each office
- Ensure reuse of building blocks
- Common culture, sharing
Scaling on existing Nordic Semiconductor infrastructure

- Leveraging existing technology platforms
- Internal design processes, Quality systems
- Reuse of technology and design blocks from current Nordic projects
- Shared CAD tools
- Shared resources for verification
- Common datacenter
- Existing suppliers such as; TSMC, ASE, AMKOR
Technology purchasing, licensing and outsourcing vital to development success

Licensed and acquired HW and SW building blocks to speed up development and reduce risk

- Microcontrollers, DSP, memory,
- RF modules
- Software
- OS’s

Selective outsourcing of key elements to key partners
Extensive laboratory setup built

- Pre-silicon modelling environments (IC emulation and FPGA) in place
- RF and Power measurement capability with high level of automatization
- Automated protocol testing capability
- RF Shielded champers
Iterated IC development process

Special function test chips
  › Analog/RF

Full system prototypes for SW development
  › Debugging/verification, certification/ carrier interoperability
  › Early customer sampling

Mass-production chips
  › Fixing bugs and issues from prototype chips
  › Possibly add additional functionality as needed
Software development ongoing

Software development for Cellular IOT products
- Firmware and RF SW
- L1 and L2/L3 protocols
- Communication protocols
- Test and verification SW
- Interoperability and field testing + certification

Multiple tools and platforms
- Emulators
- FPGA platforms
- Prototype Chips

Software releases through iterative process
- Initial and subsequent alpha level software
- Beta software releases
- Production SW releases
Partners in place for interoperability testing and certification

Collaboration with main infrastructure vendors in place

- Requirements alignment: technical details, feature roadmap and schedules
- Interoperability testing (lab and field testing)

Carrier collaboration with selected carriers in place

- Requirements alignment: features and schedules, certification processes
- Pre-certification testing planned to selected carrier labs
Overall development flow

Asset development
- RF Transceiver dev.
- Modem BB dev.

LTE Protocol SW Development

Product Integration and Testing
- IC Prototypes
- Alpha-level releases

Field Testing
- Interoperability Testing
- Pre-Certification
- Certification
- Certification

Production
- IC Production
- Production software

Test development
- Lab testing

Customer sampling
Significant development progress

Multiple successful tapeouts
- Two RF chips
- Full prototype Baseband Chip

Software development in good shape
- 1.5 million lines of code

Partnerships in place
- Technology
- Infrastructure vendors
- Carriers

Note: Image is not the new Nordic Cellular IOT Chip it is an older Nordic chip used for illustrative purposes
Summary and Q&A
Today is all about Cellular IoT

Low power LTE technology
- Fundamental concepts
- Shaping the future of IoT

The market opportunity
- Fundamental drivers
- Size and growth potential

Our strategic investment
- Product and market strategy
- Product development
Cellular IoT

Investor and analyst brief

Nordic Semiconductor ASA
November 28 2016
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