Cellular IoT

Investor and analyst brief

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

Connectivity anywhere

Existing network
infrastructure

Security

Reliability and quality of service

The emergence of low power LTE

Cost/size/power

Higher

Lower

LTE Cat 1+

Low power LTE

(LTE-M, NB-IoT)

Lower throughput   Higher throughput
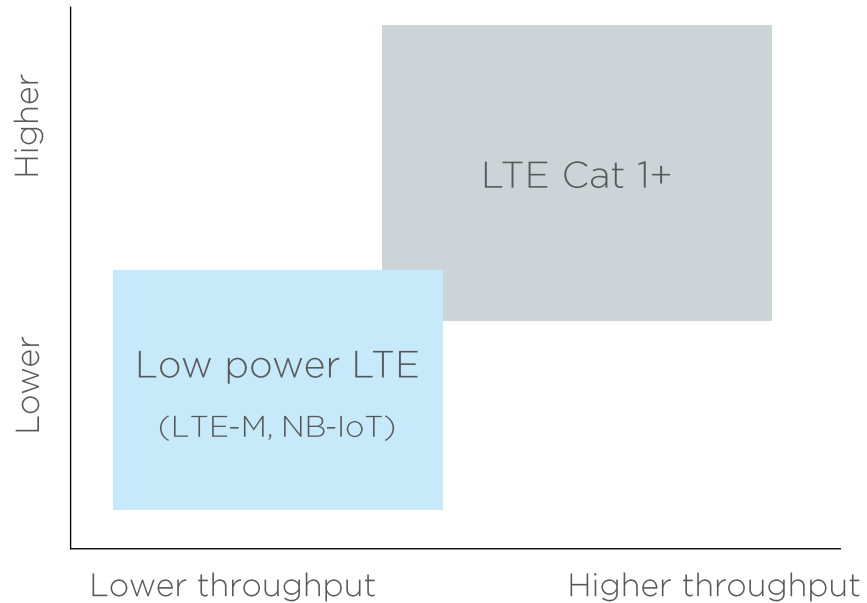
New low power LTE technologies

	LTE-M	NB-IoT	
Also known as	"LTE-MTC", "LTE Cat-M1"	"LTE Cat-M2","LTE Cat-NB1"	
Max throughput	~ 375kbps	~ 30/60kbps	
Range	Up to 4X	Up to 7X	
Mobility	Yes	Limited	
Frequency deployment	LTE In-band	LTE In-band, guard band and GSM re-purposing	
Deployment density	Up to 200,000 per cell		
Module price	Sub $10		
Module size	Suitable for wearables		
Power consumption	Up to 10 year of battery lifetime		

More than low power...

Broader coverage

Massive deployments

Smaller size

Lower cost

Rural areas

Deep indoor

Higher density
deployments

Space constrained
devices
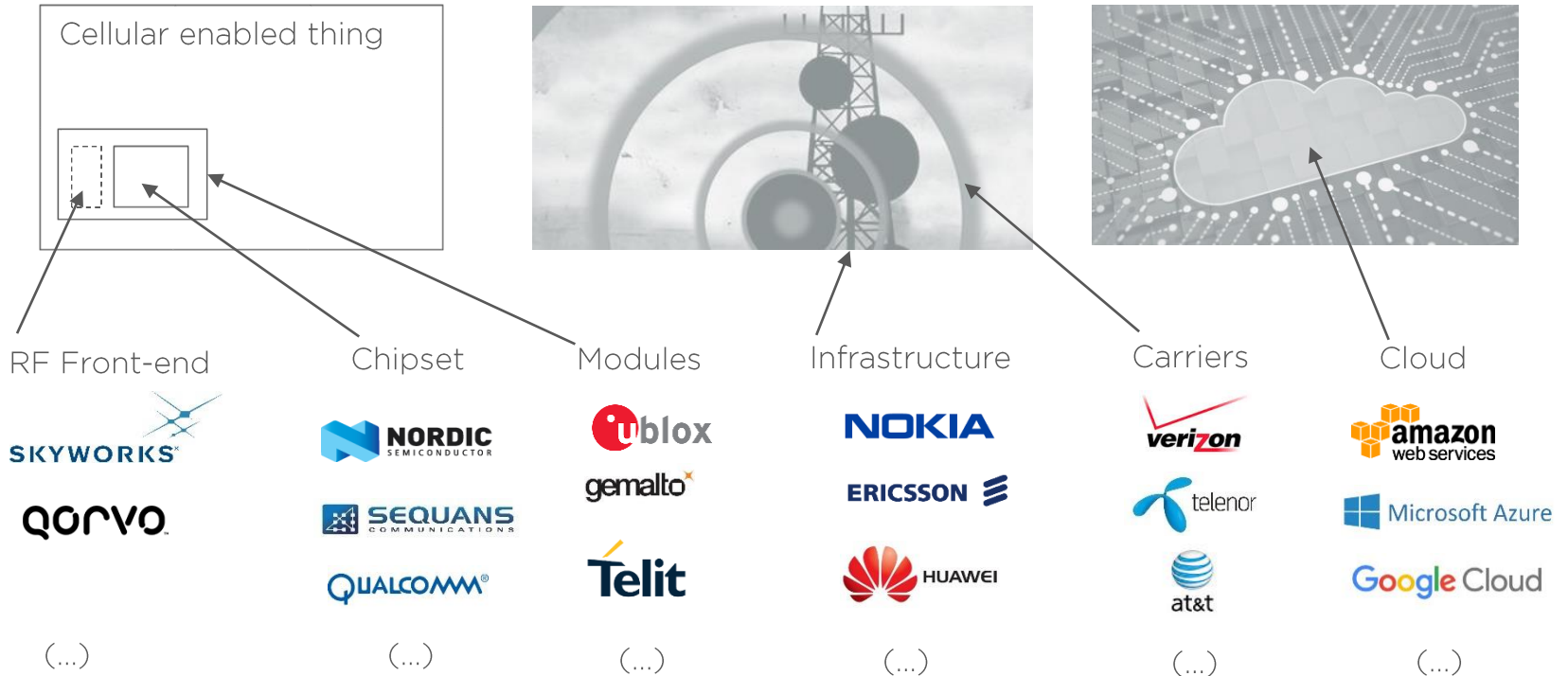
Module cost

Subscription cost

Low power LTE vs. unlicensed LPWNA

	Low power LTE (NB-IoT, LTE-M)	Unlicensed LPWAN (SigFox, LoRA…)
Open standard	Yes, 3GPP	No, proprietary
Frequency bands	Licensed	Unlicensed, sub 1-GHz ISM
Infrastructure	Existing LTE	New
Max throughput	Up to 375kbps	Up to 6kbps
Reliability and QoS	(+++)	(-)
Security	(+++)	(-)
Module cost	(-)	(+)
Power	(-)	(+)

Cellular IoT ecosystem and players

Cellular enabled thing

RF Front-end

Chipset

Modules

Infrastructure

Carriers

Cloud

(...) (...) (...) (...) (...) (...)

The importance of modules for IoT

Barriers for chipset integration

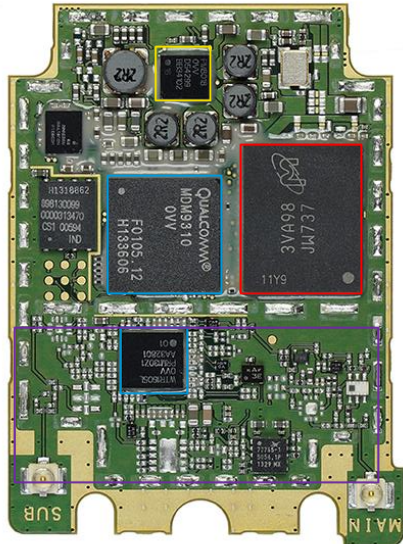Complexity of integration

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

2,4,12,13,17...

...

1,3,8,20...

...

- 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
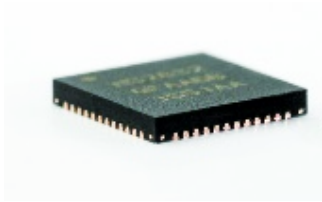
Chipset

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

17

Device band support

4G data modem

Modern smartphone

1-3 bands

Limited to a carrier and region

Lower complexity and cost

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
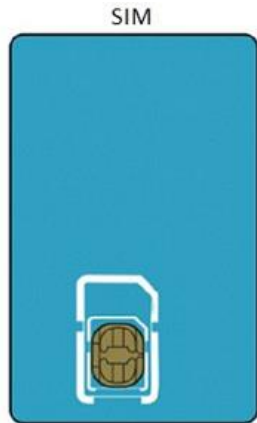
eSIM is key for IoT

SIM card not practical for IoT application

eSIM is chip

Over-the-air provisioning

Remotely manage subscription

SIM

Mini-SIM

Micro-SIM

Nano-SIM

E-SIM

Low power LTE standardization

LTE-M

NB-IoT

Standardization body

GSM, UMTS and LTE

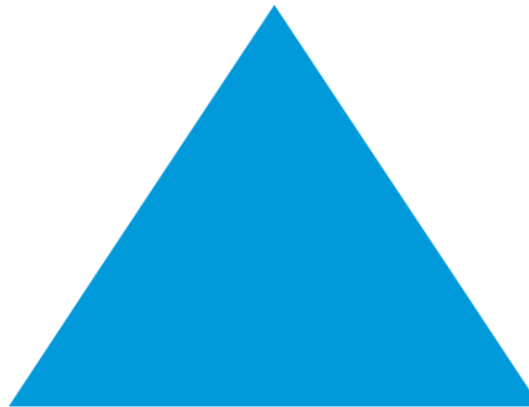Part of Release 13

Completed

Part of Release 13

Completed

Certification complexity

Standard compliance

3GPP requirements

Tele-regulatory

Regional variations,

FCC, ETSI, Telec etc.

Cost & effort

Region/carrier specific products

Carrier specific certification

Additional and more stringent requirements

Varies between carriers
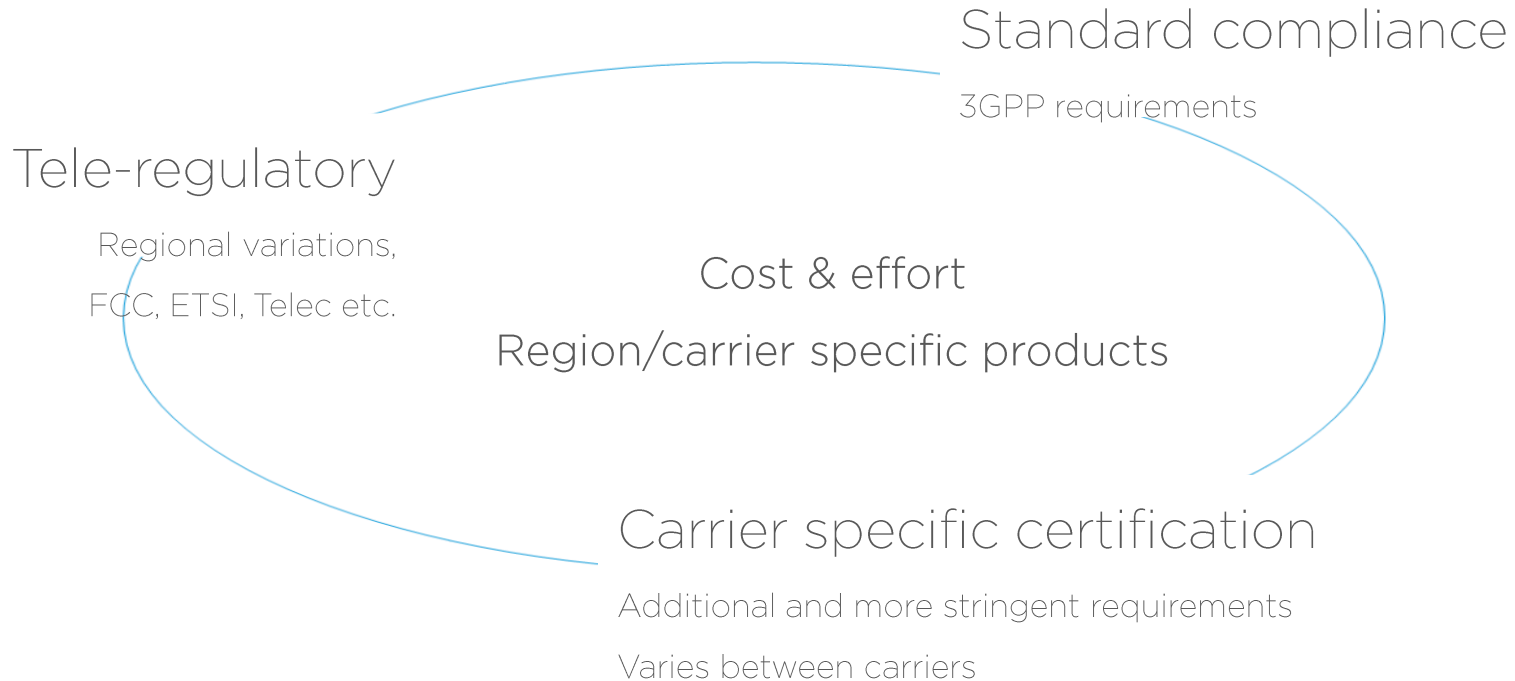
Evolution path to 5G

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

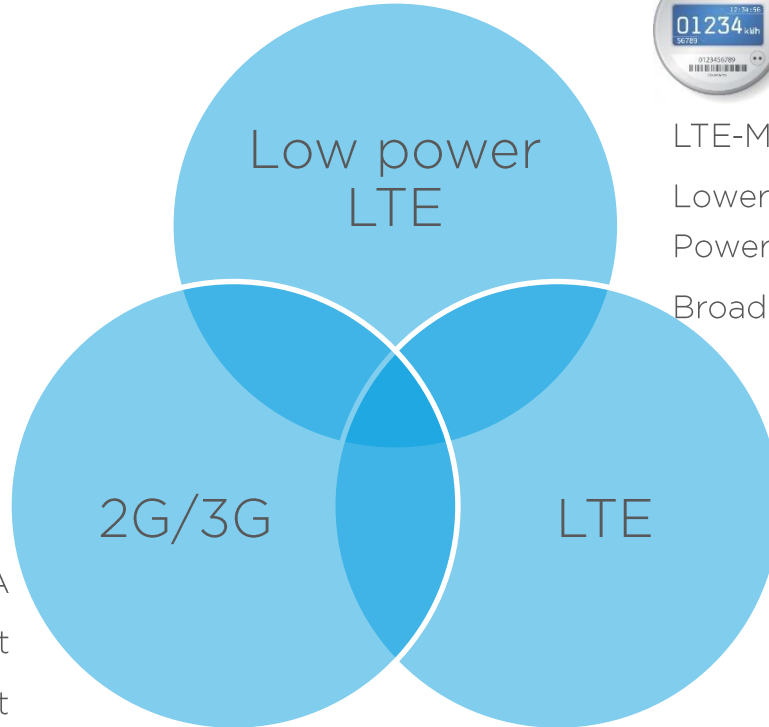### Complements Bluetooth market

Different type of applications

A few overlaps

(*Source: Ericsson Mobility Report 2015)

Split between technologies

Low power
LTE

2G/3G

LTE

LTE-M, NB-IoT

Lower throughput -

Power, size, coverage, cost

Broad range of applications

GSM, UMTS, CDMA

Maturity, coverage and cost

Network to be phased out

LTE Cat 1+

Future proof, high throughput

High throughput applications

Low power connectivity redefined
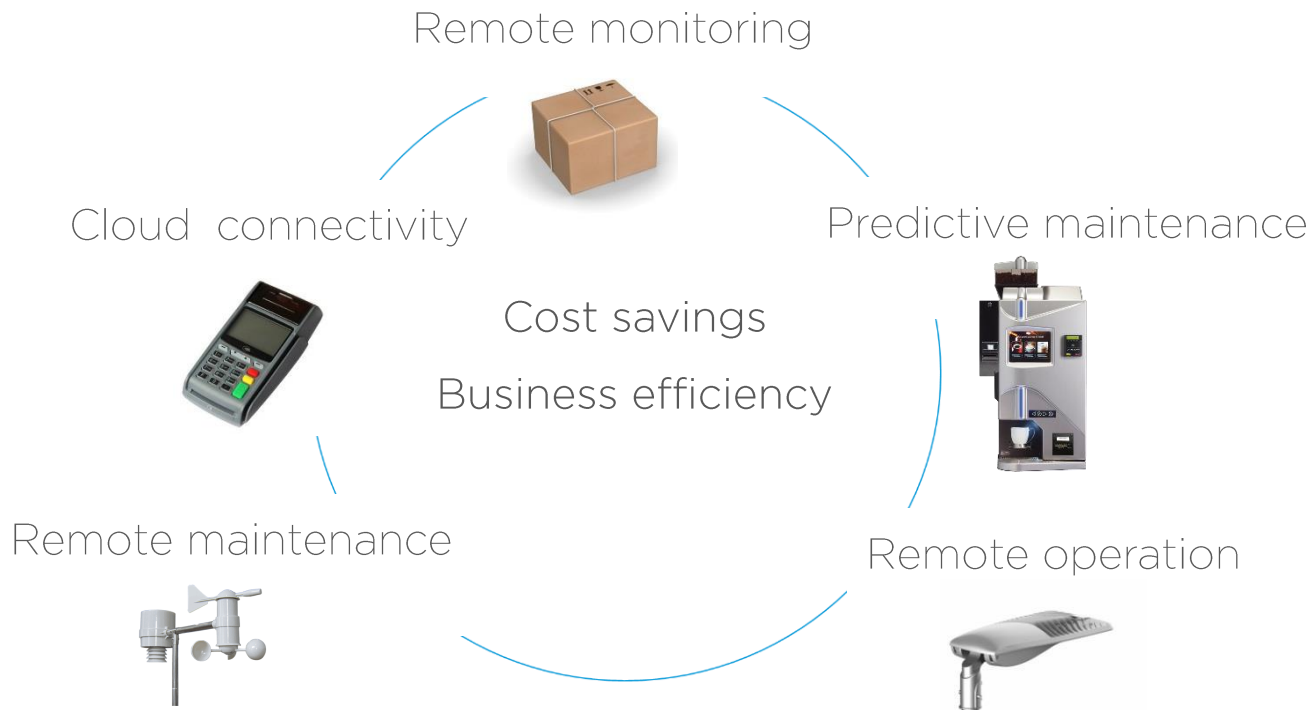
No local
area network

Mobility
& roaming

Independence from
local area network

Existing infrastructure

Ubiquitous
connectivity

Security and reliability
Ease of use

Key use cases in cellular IoT

Remote monitoring

Cloud connectivity

Predictive maintenance

Cost savings

Business efficiency

Remote maintenance

Remote operation

A diversified market opportunity

Low power LTE market

2017 - 2021

Logistics

Buildings

Utilities

Home

City

Transport

Consumer

Industry

Healthcare

Enterprise and retail

Agriculture & environment

Product-as-a-service unlocking consumer
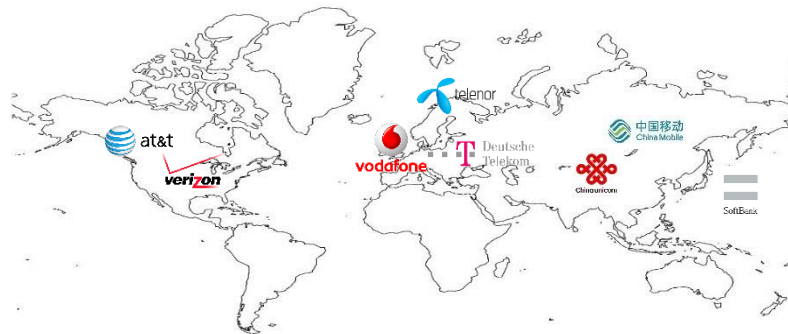
Cellular subscription part of the service

Services built on top of connectivity

Cloud, big data, machine learning

Per "use" and/or recurring

Low power LTE coverage is key enabler
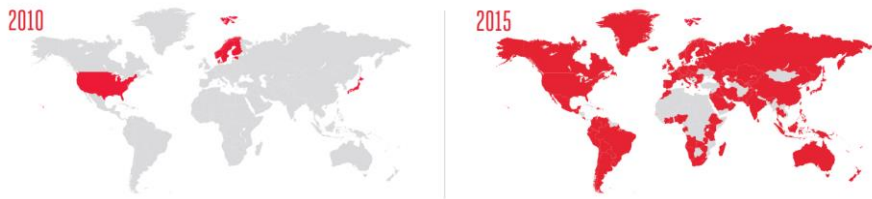
Massive worldwide LTE coverage

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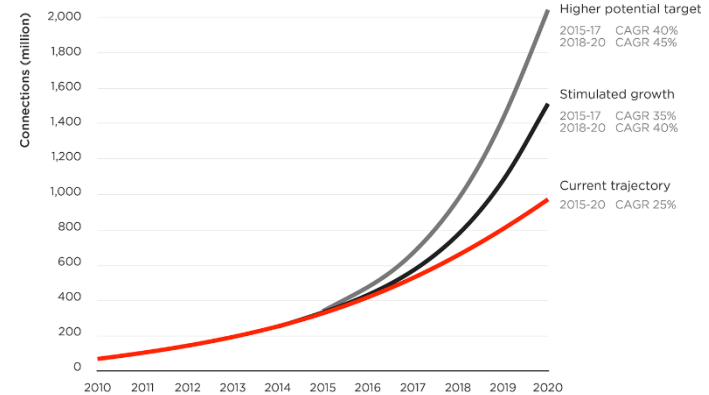
Low power LTE status and projection

- 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 →

30

Market sizing: public research

Ericsson Mobility Report (2015)

GSMA (2015)

Modelling unit shipments for low power LTE

Connections

→ Unit shipments

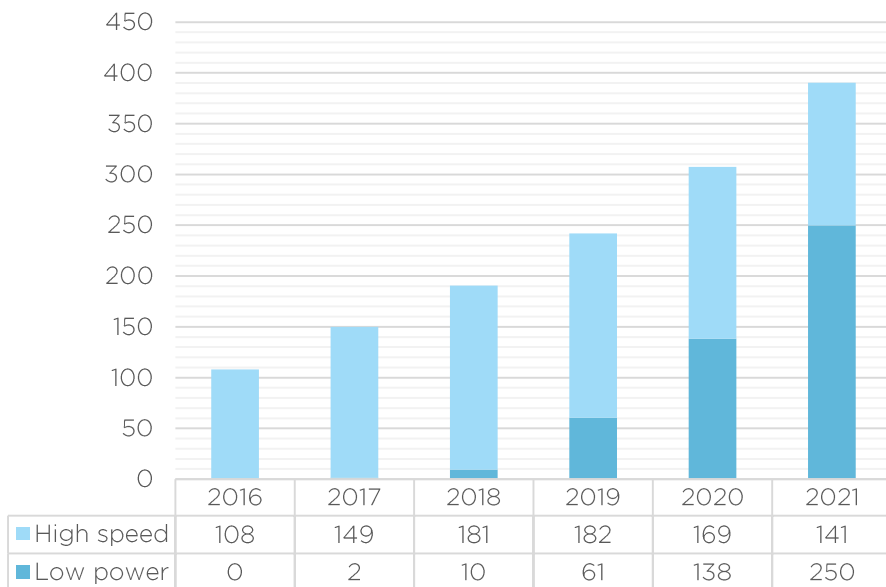Change in number of
connections

Replacement

rate (%)

Replacement of 2G/3G

General replacement

Low power LTE

share (%)

vs.
2G/3G and LTE Cat 1+

Example model: units shipment 2016 - 2021

Cellular IoT device shipment (MU)

	2016	2017	2018	2019	2020	2021
High speed	108	149	181	182	169	141
Low power	0	2	10	61	138	250

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
There will be a "value play"

Market / application depend

Market dependent

Example model: market value 2016 - 2021

Low power LTE chipsets (MUSD)
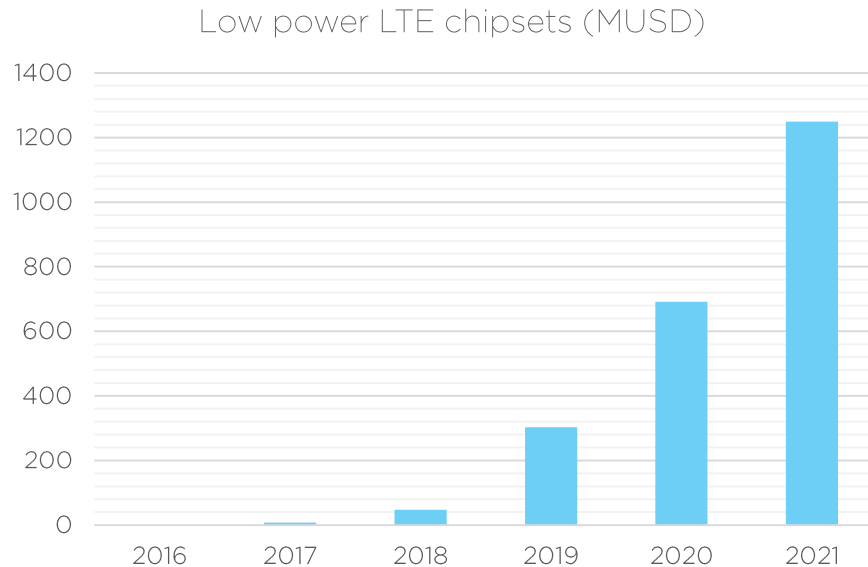
Dataset and assumptions

- Unit per year model earlier slide (Ericsson Mobility Report)
- Low power LTE only
- Flat $5 ASP
- Value add integration offsets price erosion
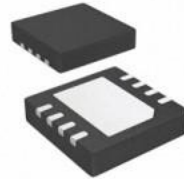- May be to optimistic, may be to pessimistic

Other market enablers/drivers

Subscription

cost / model

Cost of ownership

Support for

eSIM

Over the air provisioning

Adoption in

consumer

Shorter design cycles

Drive early volume ramp

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?

SIGFOX One network A billion dreams

#1 Proprietary – not open standards

LoRa™

#2 Limited freedom to play and differentiate

RPMA

WEIGHTLESS™

#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

nRF91xx

Power

Size

Performance

Features

Solution cost

Off-the-shelf and broad market solution

Complete and easy to
use solution

Lowering barriers
of adoption

Leverage existing
community & ecosystem

Strategic partnerships

Hardware, software and tools

Enable innovation

Drive market growth

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

Strong interest

Competitiveness of our solution

Working with Nordic

Collaboration on requirements

Matching our early offering to their requirements

Target sampling and launch
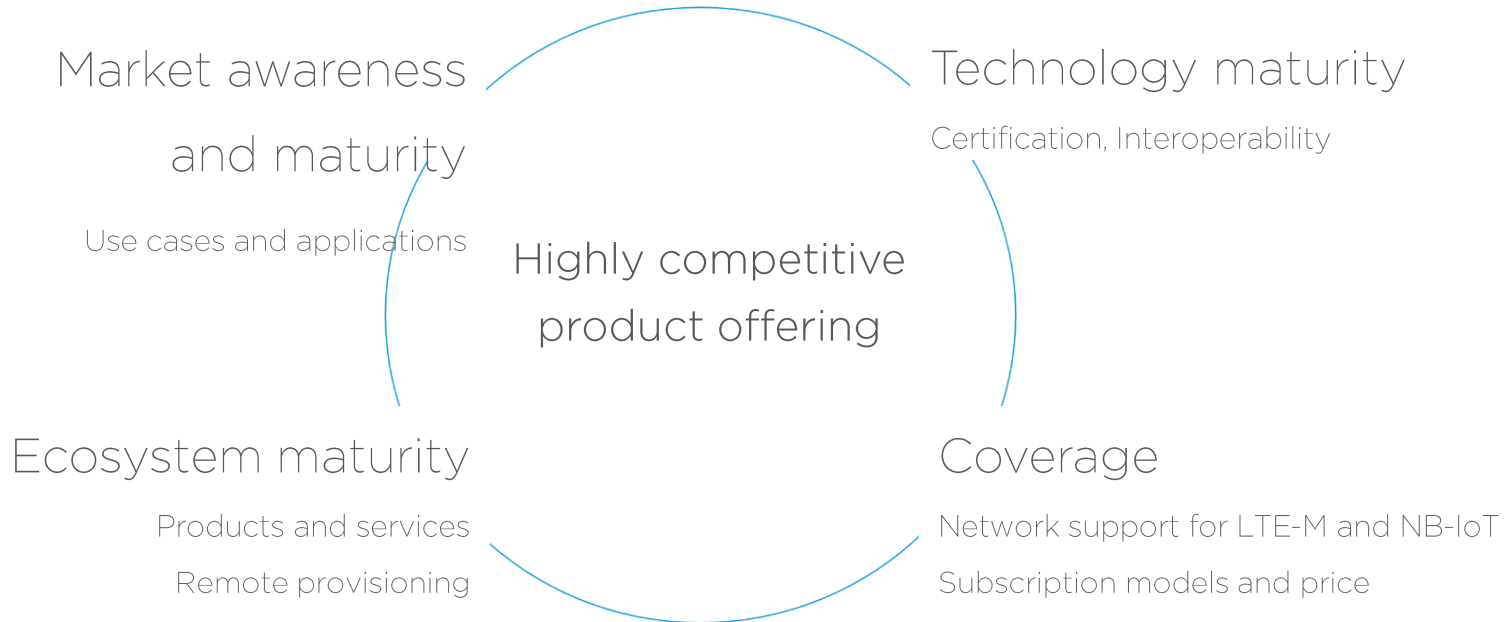
Second half

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

Highly competitive
product offering

Ecosystem maturity

Products and services

Remote provisioning

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

51
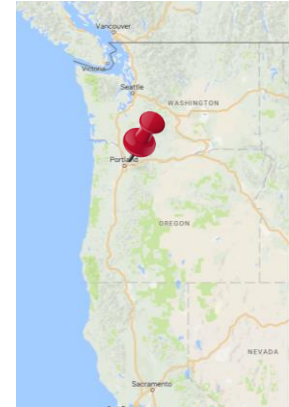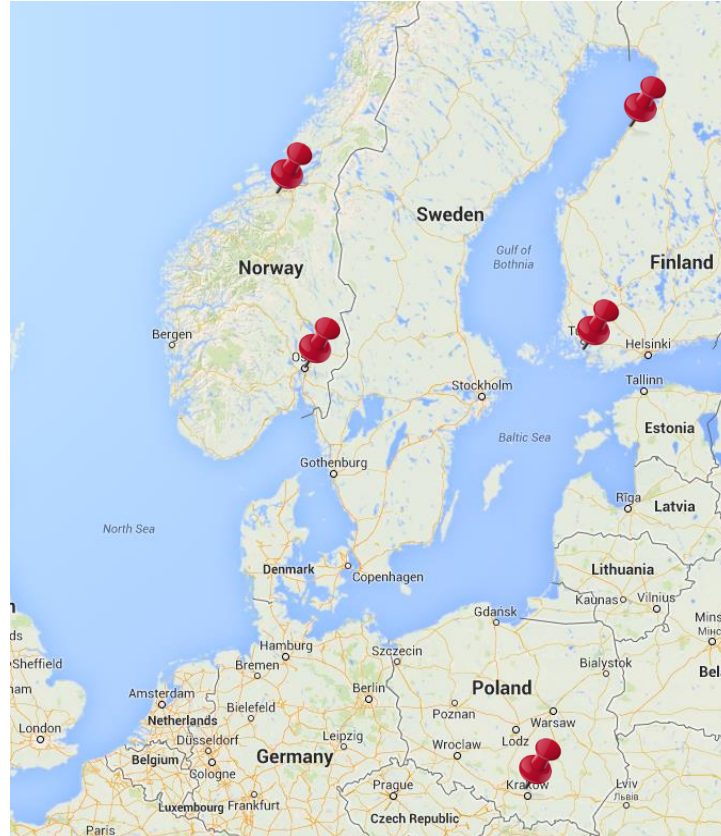
World class IC design capability

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
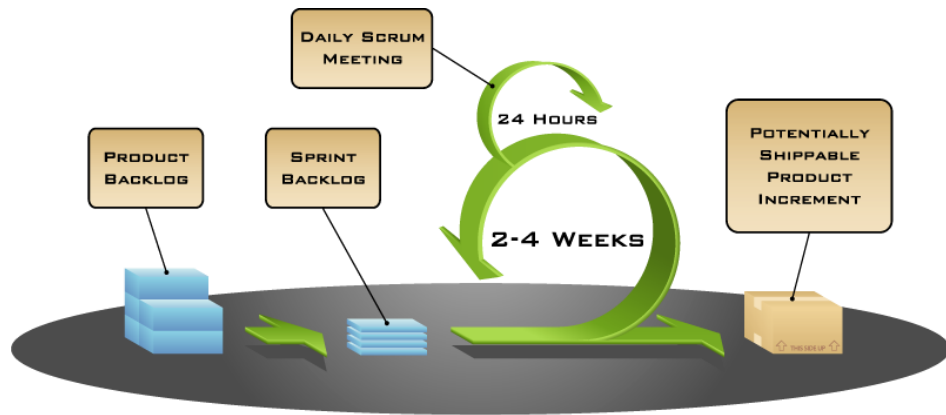- Source IP when a commodity freeing up R&D resources to focus on customer
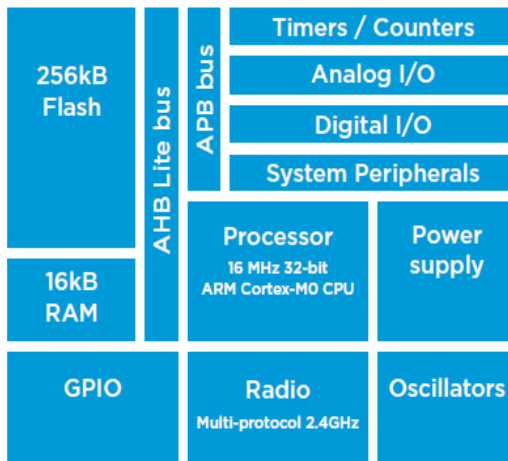
Large software teams in place

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

- …

DAILY SCRUM MEETING

PRODUCT BACKLOG

SPRINT BACKLOG

24 HOURS

2-4 WEEKS

POTENTIALLY SHIPPABLE PRODUCT INCREMENT

COPYRIGHT © 2005, MOUNTAIN GOAT SOFTWARE

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 customer 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

UUTISET > NEWS

News 23.7.2014 14:27 | updated 23.7.2014 14:27

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.

Recommend 45 people recommend this. Be the first of your friends.

Image: Kirsi Karppinen / Yle

The fate of Oulu as an IT hub hangs in the balance after another company announced hundreds of job losses in the sector. Broadcom, a US wireless modem firm that runs a research hub in the city, is to cease operations in the connectivity chip field after failing to find a buyer for the unit.

The closure means 600 people in Finland will lose their jobs, with some 430 of those based in Oulu making 'baseband' chips for mobile devices.

The northern city has been hit hard by changes in the technology sector, with some 500 people informed just last week that their jobs at Microsoft's research and development centre will go when the centre shuts down.

DATA CENTRE   SOFTWARE   SECURITY   TRANSFORMATION   DEVOPS   BUSINESS   PERSONAL TECH   SCIENCE

Data Centre > Networks

Ericsson follows Broadcom to modem Mordor

Swedes ring off

22 Sep 2014 at 13:36, Simon Rockman   0

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-2013, ST-Ericsson was dissolved – with the modem business moving to Ericsson. The closure of the joint venture led to the loss of 1,600 jobs.

THE WALL STREET JOURNAL.

Home   World   U.S.   Politics   Economy   Business   Tech   Markets   Opinion   Arts   Life   Real Esta

EUROPEAN BUSINESS NEWS

Microsoft Layoffs Hit Finland Staff Hard

Country's Startup Culture Is Building as Rovi, Others Pick Up High-Tech Workers

Finnish politicians issued statements on Thursday calling on Microsoft to show social responsibility and offer retraining and generous severance packages to the people it is dismissing. AGENCE FRANCE-PRESSE/GETTY IMAGES

By JUHANA ROSSI   0 COMMENTS
July 17, 2014 3:14 p.m. ET

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

14:17:40:47
DAYS   HOURS   MINUTES   SECONDS
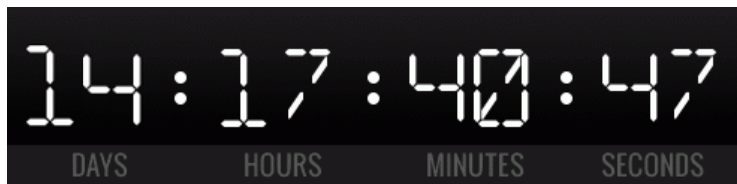
Clear success criteria for establishing a presence in Finland

- 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

Nordic Semiconductor Finland – Oulu Office

Juha Heikkilä
Head of Finland

HR/Finance/Admin
Sonja Kusmin

Radio
Systems
Yrjö
Kaipainen

SW
Vesa
Pellikka

RF
Olli Närhi

Digital BB
Pekka
Kotila

Project Management
Heikki Päivike

Highly capable organization quickly built

```
              ┌─────────────┐
              │   Finland   │
              │    Head     │
              └──────┬──────┘
                     │
          ┌──────────┤
   ┌──────┴──────┐   │
   │    Staff    │   │
   │  Functions  │   │
   └─────────────┘   │
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Radio Systems	Software	RF/Analog	Digital/BB
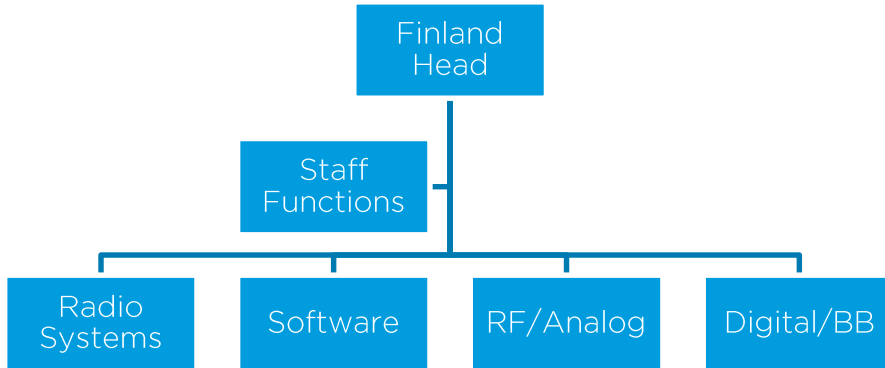
- Managment team rapidly built
- Have recruited the whole cellular modem competence in house
- Resourcing optimized for cellular low power and low cost IoT develoment

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

62

Highly relevant experience

Radio Systems personell with Nokia-Renesas-Broadcom background

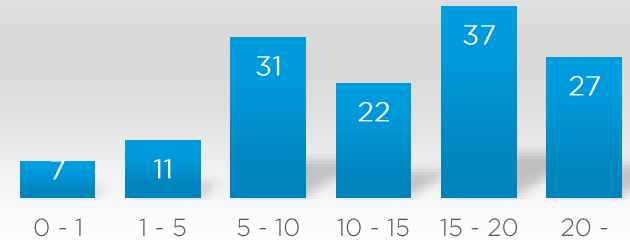- Design from very first cellular systems up to highest category LTE modems

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

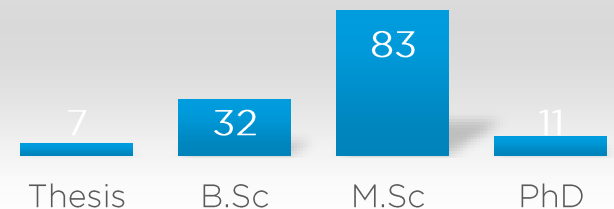Firmware and protocol SW personnel with Nokia-Renesas-Broadcom and Nokia-ST-Ericsson-Ericsson background

- Multi-billion cellular product volume experience

R&D Finland Cellular Experience in Years

0 - 1	1 - 5	5 - 10	10 - 15	15 - 20	20 -
7	11	31	22	37	27

R&D Finland Education

Thesis	B.Sc	M.Sc	PhD
7	32	83	11

63

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
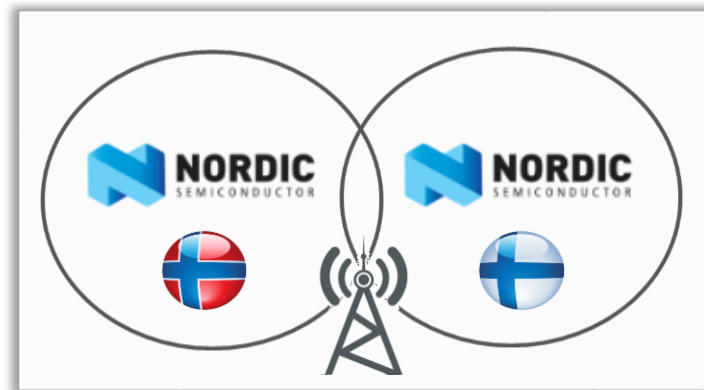
Scaling on existing Nordic Semiconductor infrastructure

- 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
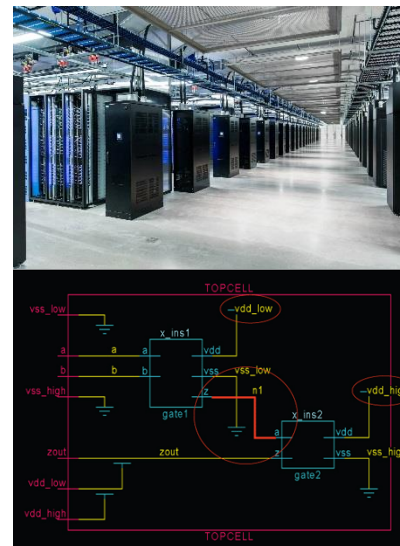
Technology purchasing, licensing and outsourcing vital to development success

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

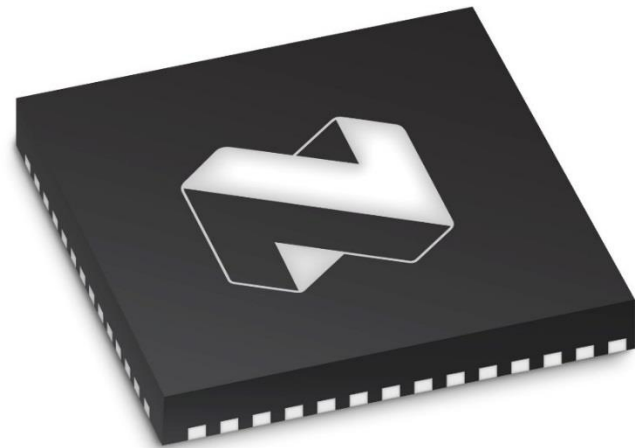# Iterated IC development process

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
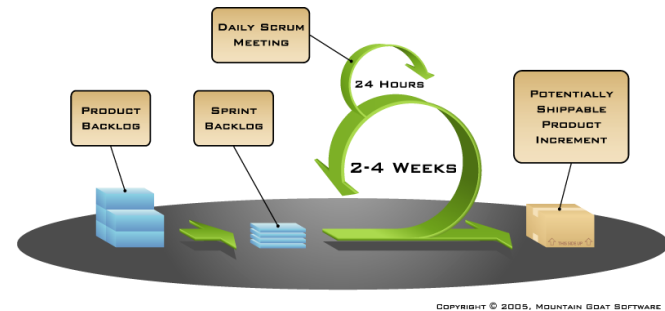
Software releases through iterative process

- Initial and subsequent alpha level software
- Beta software releases
- Production SW releases

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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

Product Integration and Testing

Production

RF Tranceiver dev.

IC Prototypes

IC Production

Modem BB dev.

LTE Protocol SW Development

Alpha-level releases

Production software

Test development

Lab testing

Field Testing

Interoperability Testing

Pre-Certification

Certification

Certification

Certification

Customer sampling
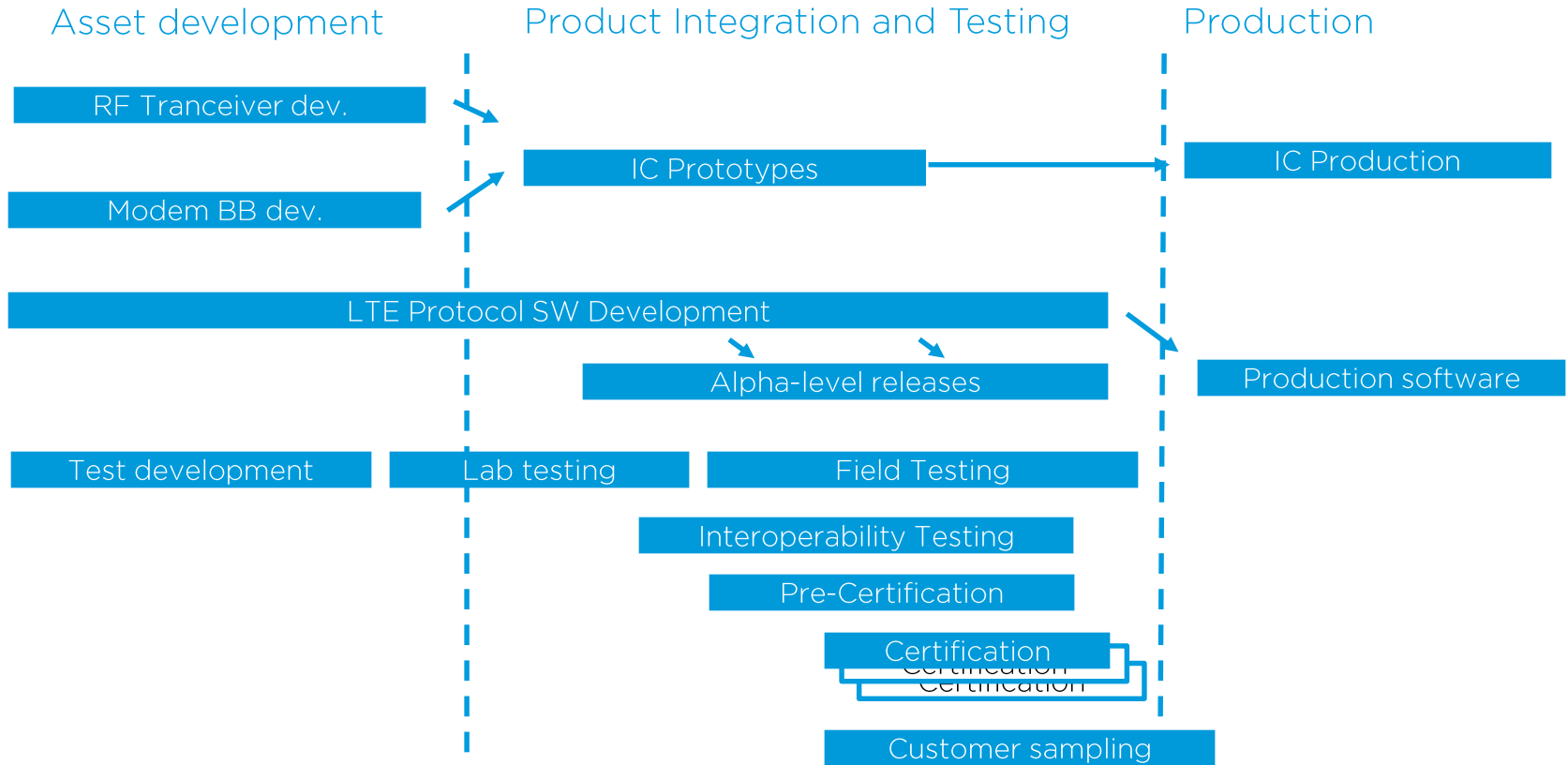
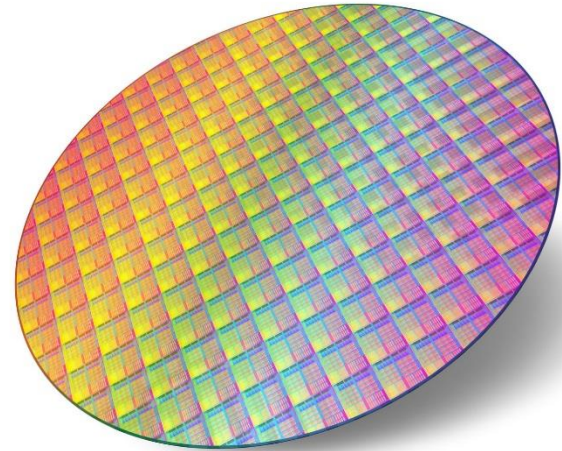# Significant development progress

Multiple succesfull tapeouts

- Two RF chips
- Full prototype Baseband Chip

Software development in good shape

- 1.5 million lines of code

Partnerships in place

- Technology
- Infrastrucuture 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	The market opportunity	Our strategic investment
Fundamental concepts	Fundamental drivers	Product and market strategy
Shaping the future of IoT	Size and growth potential	Product development

Q&A

Cellular IoT

Investor and analyst brief

Nordic Semiconductor ASA

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Oslo, Norway

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