Wireless IoT Technologies and Applications
- Narrowband IoT Introduction

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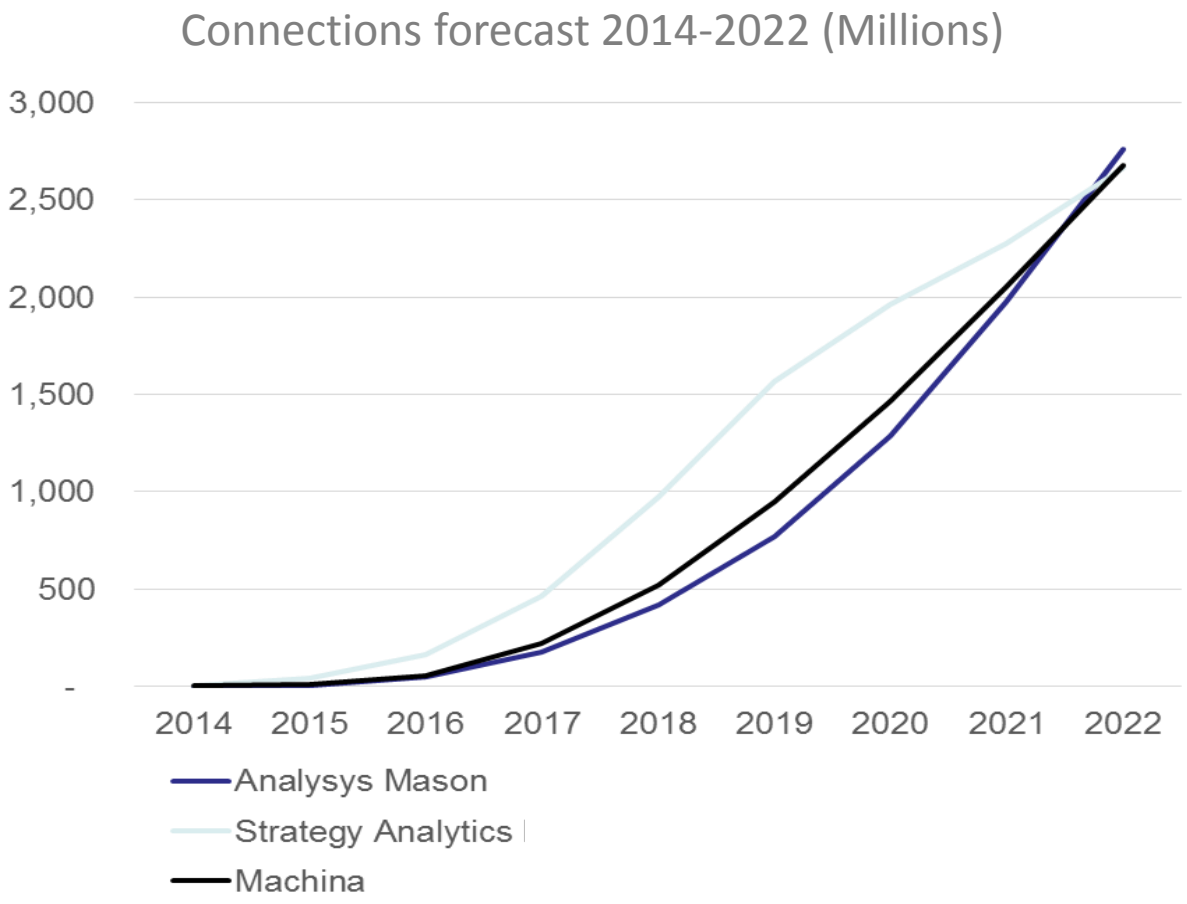
May, 2016

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

Market forecast of cellular IoT

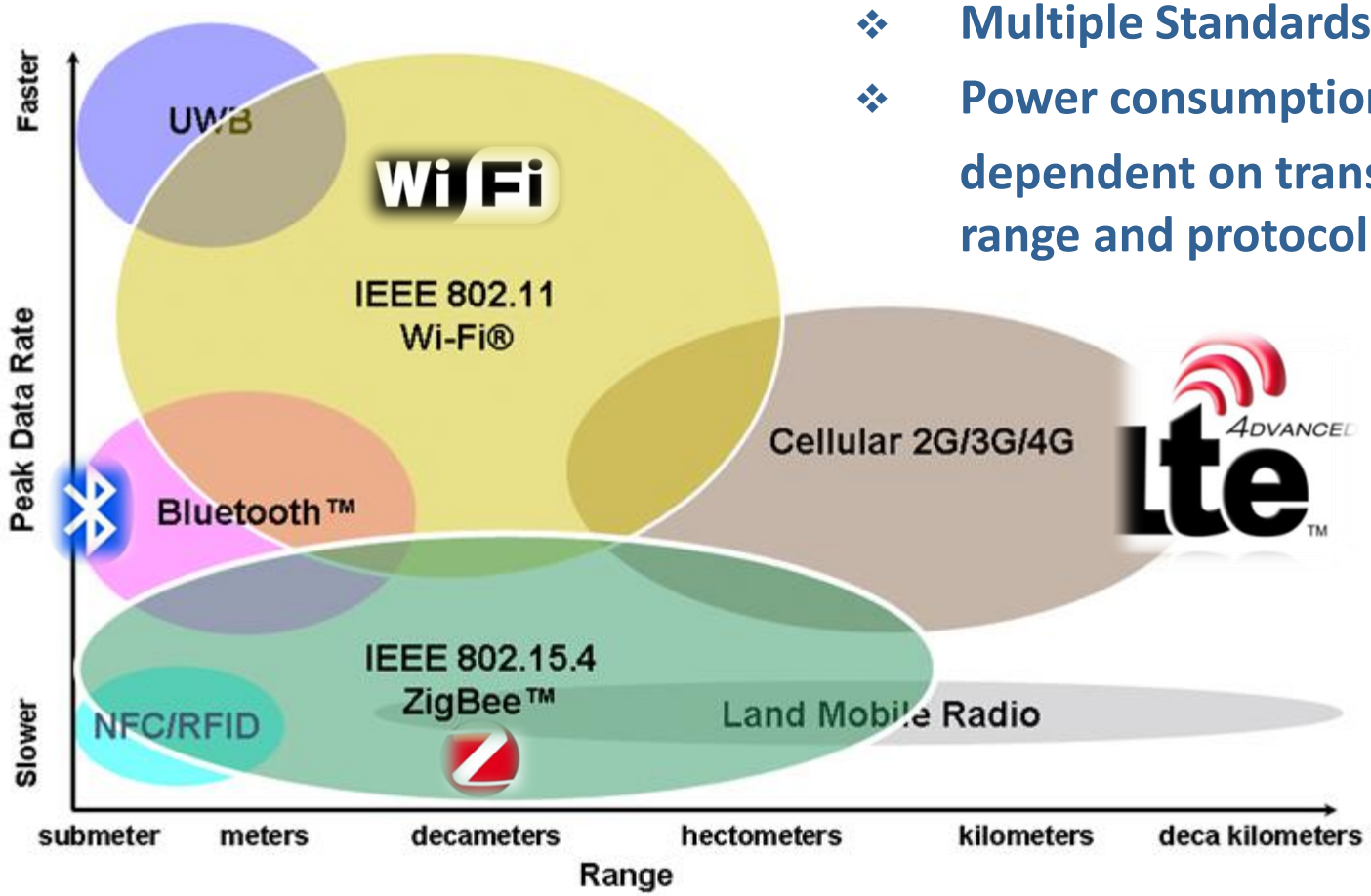


- **2.7 billion devices for IoT will be wirelessly connected via cellular network by 2022 according to several research companies' forecast.**

Interconnection – one key aspect of IoT

- **Which communication technology is the competitive candidate for long distance, low cost and highly reliable interconnection?**

Communication technologies comparison

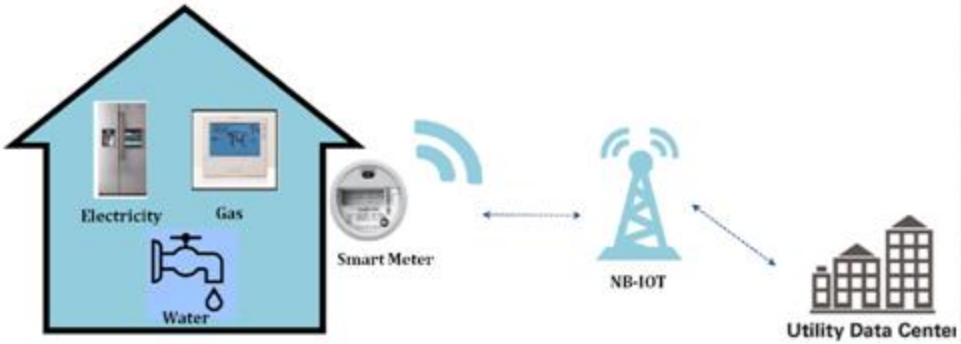


- Multiple Standards
- Power consumption largely dependent on transmission range and protocol

https://community.freescale.com/community/the-embedded-beat/blog/2010/03/30/so-many-wireless-connectivities--wont-one-size-fit-all

- **Cellular communication can enable more applications of IoT.**

Applications of cellular IoT (1)



Smart metering

Alarm & Event Detectors

Moden Agriculture

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

Issues of 2G/3G in cellular IoT applications(cont'd)

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 date 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)

NB-IoT (1) – application requirements

Coverage Enhancement

20dB better

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 (2) – deployment requirements

- **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

NB-IOT Operating Band	Uplink (UL) operating band BS receive UE transmit	Downlink (DL) operating band BS transmit UE receive	Duplex Mode
	F_{UL_low} – F_{UL_high}	F_{DL_low} – F_{DL_high}	
1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	HD-FDD
3	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	HD-FDD
5	824 MHz – 849 MHz	869 MHz – 894MHz	HD-FDD
8	880 MHz – 915 MHz	925 MHz – 960 MHz	HD-FDD
12	699 MHz – 716 MHz	729 MHz – 746 MHz	HD-FDD
13	777 MHz – 787 MHz	746 MHz – 756 MHz	HD-FDD
17	704 MHz – 716 MHz	734 MHz – 746 MHz	HD-FDD
19	830 MHz – 845 MHz	875 MHz – 890 MHz	HD-FDD
20	832 MHz – 862 MHz	791 MHz – 821 MHz	HD-FDD
26	814 MHz – 849 MHz	859 MHz – 894 MHz	HD-FDD
28	703 MHz – 748 MHz	758 MHz – 803 MHz	HD-FDD

NB-IoT (1) – application requirements

Coverage Enhancement

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

Coverage Enhancement

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

NB-IoT (5) – coverage enhancement (cont'd)

- **Repetition**
  - ✓ Pros
    - → 3dB sensitivity improvement by 2X repetition
  - ✓ Cons
    - → longer transmission time

NB-IoT (1) – application requirements

Coverage Enhancentment

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.

Low Power Consumption

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

NB-IoT (1) – application requirements

Coverage Enhancement

20dB better

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.

Low Cost

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

	Coverage(dB)	Indoor	Module cost	Battery life	Infrastructure cost	Security	Global ecosystem	Spectrum	Time to market	Regulation
EC-GSM	179 *Note1*	✓	2X	◕	Low	✓	✓	2.4MHz	1~2 years	✓
Low cost LTE MTC (R12)	155 *Note1*	✗	>3X	◑	Low	✓	✓	20MHz	2~3 years	✓
eMTC (R13)	170 *Note1*	✓	>2X	◑	Low	✓	✓	1.4MHz	3~5 years	✓
SigFox	162 *Note2*	✗	X	●	Overlay	✗	✗	?	✓	✗
LoRa	174 *Note2*	✓	X	●	Overlay	✗	✗	?	✓	✗
NB-IoT	179	✓	X	●	Low	✓	✓	200kHz	1~2 years	✓

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

- **NB-IoT is more competitive and has broader market prospects.**

3GPP technical specification groups (TSG)

Project Co-ordination Group (PCG)

TSG GERAN GSM EDGE Radio Access Network	TSG RAN Radio Access Network	TSG SA Service & Systems Aspects	TSG CT Core Network & Terminals
GERAN WG1 Radio Aspects	RAN WG1 Radio Layer 1 spec	SA WG1 Services	CT WG1 MM/CC/SM (Iu)
GERAN WG2 Protocol Aspects	RAN WG2 Radio Layer 2 spec Radio Layer 3 RR spec	SA WG2 Architecture	CT WG3 Interworking with external networks
GERAN WG3 Terminal Testing	RAN WG3 Iub spec, Iur spec, Iu spec UTRAN O&M requirements	SA WG3 Security	CT WG4 MAP/GTP/BCH/SS
	RAN WG4 Radio Performance Protocol aspects	SA WG4 Codec	CT WG6 Smart Card Application Aspects
	RAN WG5 Mobile Terminal Conformance Testing	SA WG5 Telecom Management	
	RAN WG6 Legacy RAN radio and protocol	SA WG6 Mission-critical applications	

NB-IoT standardization progress

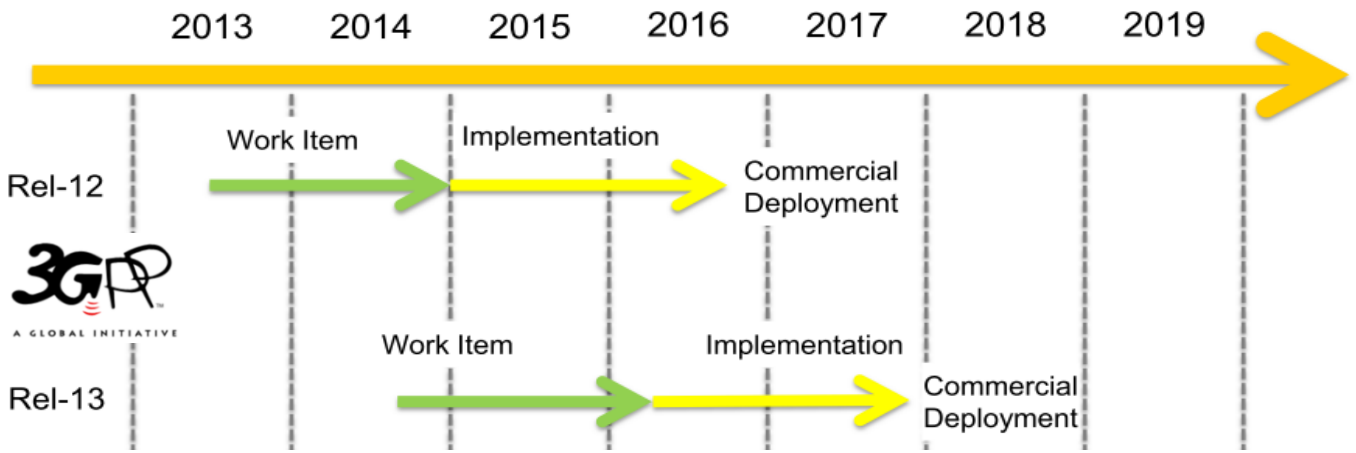
- Several technologies were studied in 3GPP GERAN TSG firstly, and technical report was finalized in GERAN#67 meeting held in Yinchuan in August, 2015;
- NB-IoT Work Item was initiated in RAN#69 plenary meeting held in Phoenix in September, 2015;
- RAN1#82-BIS meeting and RAN4#76-BIS meeting were held 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.



Summary

- 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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