

# The Evolution of Wireless Networks for the Internet of Things

NSF Wireless Cities Workshop  
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# Slim Radio | Low cost & power for massive machine type communication

Mobile IoT for small, infrequent & low cost data transfer



### Power saving

- Longer sleeping cycles\*
- Less signaling for wakeup
- Power Save Mode
- eDRX

### Simplified modems

- Narrowband transmission
- Reduced transmit power
- Limited downlink transmission modes
- UE processing relaxations

### >10 years

Battery life with two AA batteries

### Very low device cost

### 4 x coverage

compared to current LTE

Repetition and power spectral density boosts

Improved indoor coverage

+15~20 dB coverage

### Standard availability

3GPP Rel-13

10,000 x

>10 Gbps

100 Mbps

<1 ms

10-100 x

ultra low

10 years

\* Extended Discontinuous Reception (DRX)

# IoT Wireless Connectivity

## Technology Choices



- Simple cheap devices
- Low energy consumption
- Massive number of devices
- Full coverage

### Internet of Things








- 3GPP RAN (Rel-12/13)
  - LTE evolution for MTC (LTE-M 1.4MHz)
  - LTE evolution for NB-IoT (200kHz)
- 3GPP GERAN (Rel-13)
  - Enhanced Coverage GPRS (EC-GPRS)

### licensed spectrum

- Short range
  - Bluetooth Low Energy
  - Wi-Fi, IEEE802.11ah
  - ZigBee
  - Z-wave
  - ...
- Long range
  - Sigfox
  - LoRa
  - Weightless
  - Ingenu
  - ...

### unlicensed spectrum

# IoT Technology Space

	SIGFOX	LoRa	Short-range	NB-IoT Rel. 13	LTE-M Rel. 13	EC-GSM Rel. 13	5G (targets)
							
Range MCL	<12km 160 dB	< 10km 157 dB	10cm to 200m	<15km 164 dB	< 10km 156 dB	< 15km 164 dB	<12km 160 dB
Spectrum Bandwidth	Unlicensed 900MHz 100Hz	Unlicensed 900MHz <500kHz	Unlicensed 2.4 GHz	Licensed IMT 200 kHz shared	Licensed IMT 1.4 MHz shared	Licensed 8-900MHz shared	Licensed IMT shared
Data rate	<100 bps	<10 kbps	<100s Mbps	<200 kbps	<1 Mbps	<70 kbps	<1 Mbps
Use case	Smart Grid/City/ Monitoring	Smart Grid / City/ Monitoring	Smart home/factory	Smart Grid/City/ Monitoring	Smart Grid / City / Monitor./ vehic.	Smart Grid / City / Monitor./ vehic.	Smart Grid / City / Monitor./ vehic.
Module cost	4.00\$ (2015) 2.64\$ (2020)	4.00\$ (2015) 2.64\$ (2020)	Not available	4\$ (2016) 2-3\$ (2020)	5.00\$ (2016) 3.30\$ (2020)	4.5\$ (2016) 2.97\$ (2020)	<\$2
Network cost, US example* (cost drivers)	\$10/year/km <sup>2</sup> >\$80M/year (HW+SW+Service)	\$10/year/km <sup>2</sup> >\$80M/year (HW+SW+Service)	Not available	\$1/year/km <sup>2</sup> <\$7M/year (SW upgrade)	\$1/year/km <sup>2</sup> <\$7M/year (SW upgrade)	\$1/year/km <sup>2</sup> <\$7M/year (SW upgrade)	Included in 5G deployment

## LTE for IoT

Wide area network coverage

Worldwide deployment, ubiquitous coverage, cell coverage comparable to GSM low data rates

Mature worldwide standards with large number vendors and operators, robust inter-operability

High network reliability

High performance

Robust features

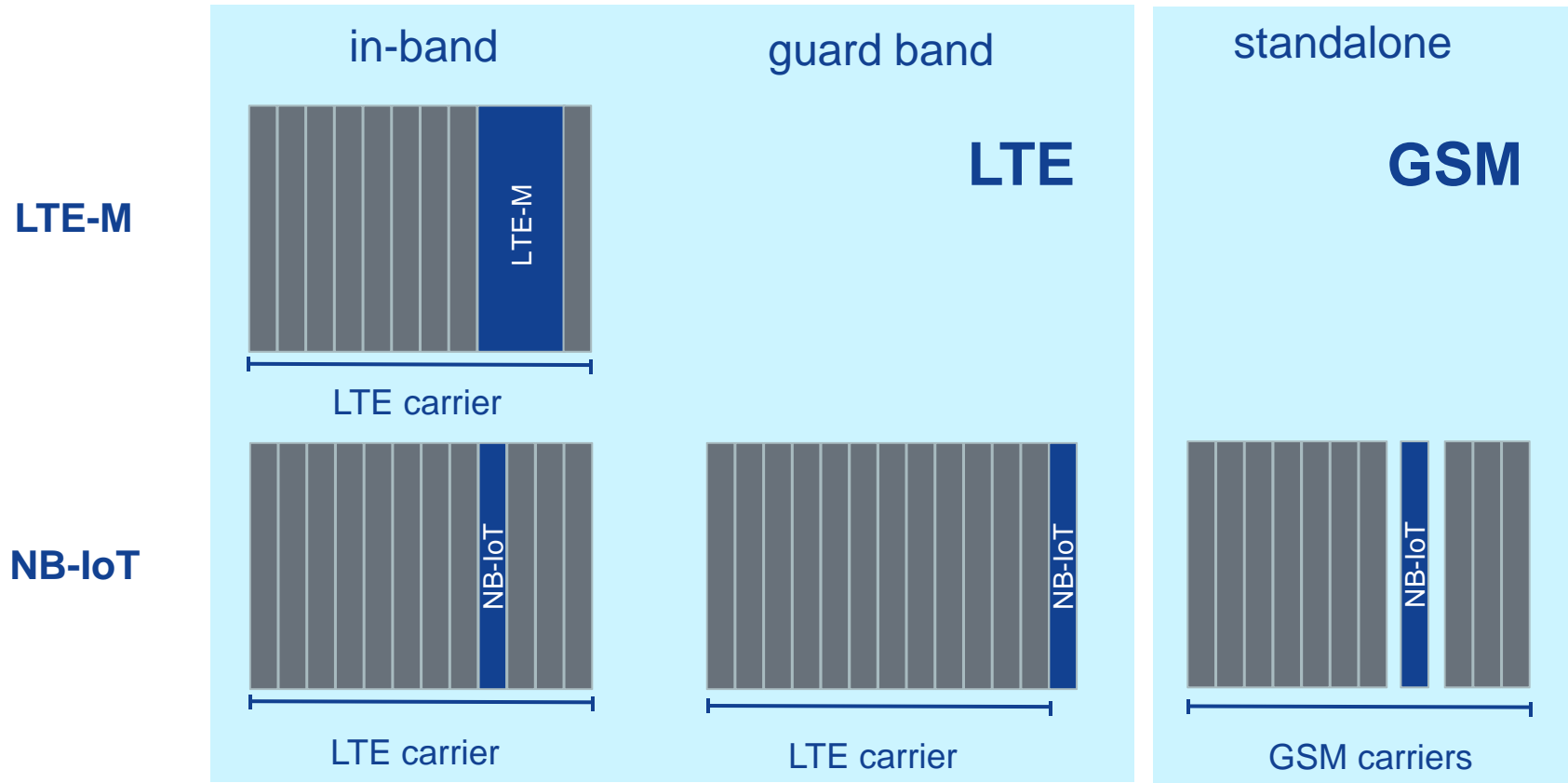
Security, policy and charging, managed QoS, etc

## Cellular IoT Solution Space

### 3GPP Radio Solution

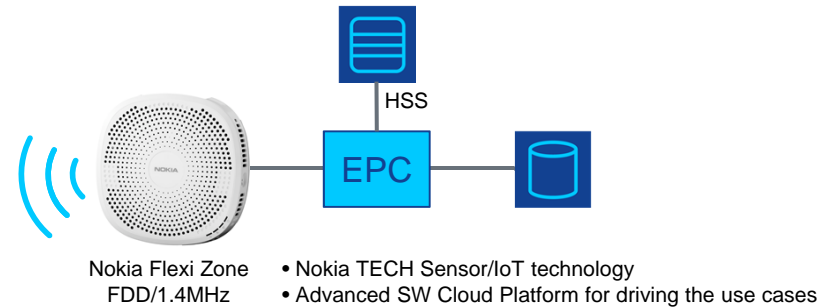
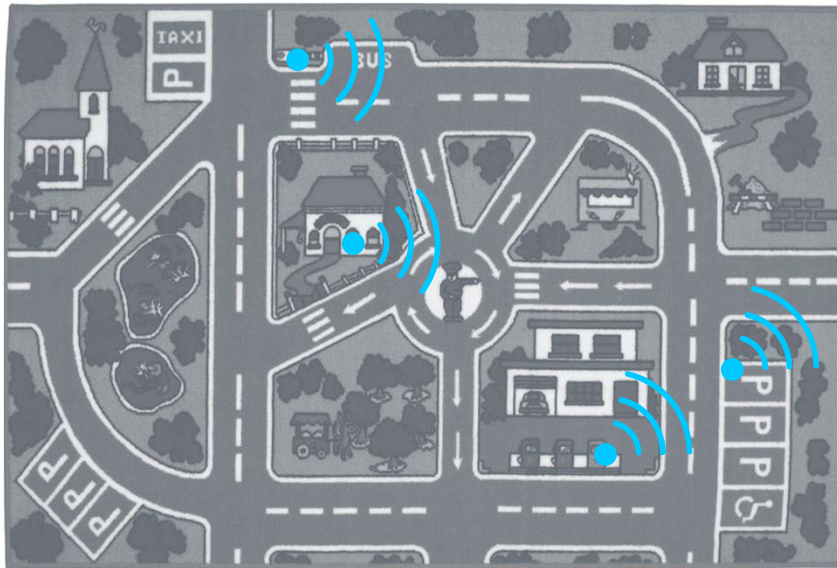
Targets	LTE-M (1.4 MHz)	NB-IoT (200 kHz)	EC-GSM (200 kHz)
Improved coverage including indoor	156 dB MCL (+15 dB improvement)	164 dB MCL (+20 dB improvement)	164 dB MCL (+20 dB improvement)
Massive MTC capacity	>52K UEs/cell/180 kHz	>52K UEs/cell/180 kHz	>52K UEs/cell/180 kHz
Data rate	< 1 Mbps	< 200 kbps	< 70 kbps
Improved power efficiency - battery life	>10 years	>10 years	>10 years
Latency	<10 secs	<10 secs	<10 secs
Low cost module	5.00\$ (2016), 3.30\$ (2020)	4\$ (2016), 2-3\$ (2020)	4.5\$ (2016), 2.97\$ (2020)
Deployment scenarios	In-band	Stand-alone, in-band, guard-band	Stand-alone

# IoT Deployment Options



# LTE-M Demonstration Setup

## Overview



At MWC, we demonstrated several type of sensors using mock up models placed on a small scale city. City model was modeled with the flat rug approx. 1 x 2 m in size displaying street, parking area and associated building on top of which we placed our sensors and street lamps.



## N-way-partnering: Nokia and KT opened IoT<sup>2</sup> lab in Korea in June 2015



Dedicated space for customers/partners for testing their IoT equipment / systems

Connected



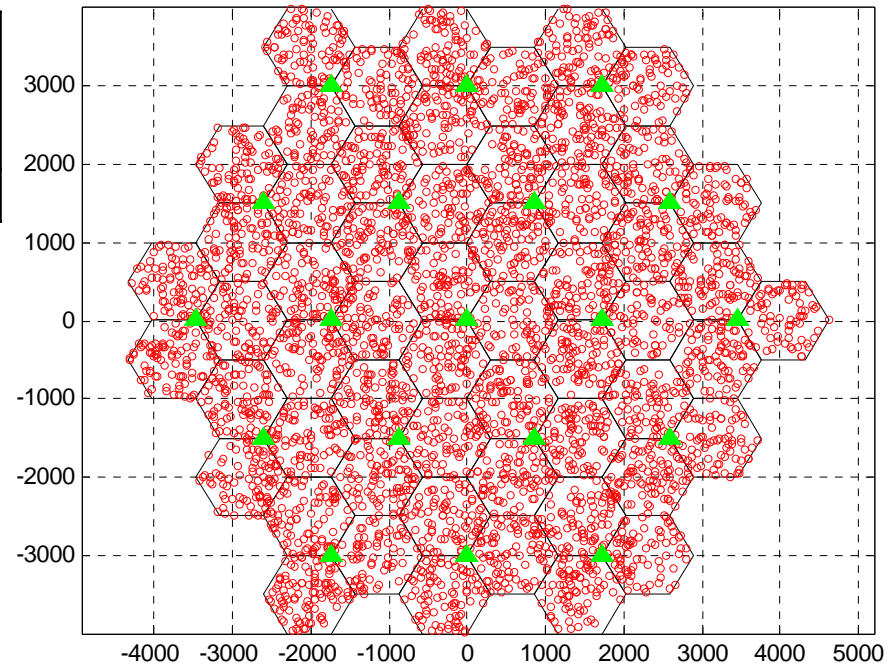
Nokia lab including LTE RAN (both FDD & TDD), EPC, IMS, etc for any kind of network infrastructure related testing. Plan to expand to have Radio Cloud, 5G as well.

- This is a lab to do **Inter-operability Test (IoT) on Internet of Things (IoT) → IoT<sup>2</sup>**
- 3GPP Rel-8 **Cat-1**, Rel-12 **Cat-0**, Rel-13 **Cat-M1** have been tested
- One of next steps can be **NB-IoT** test/demo/PoC with Korean industry (3GPP progress dependent)

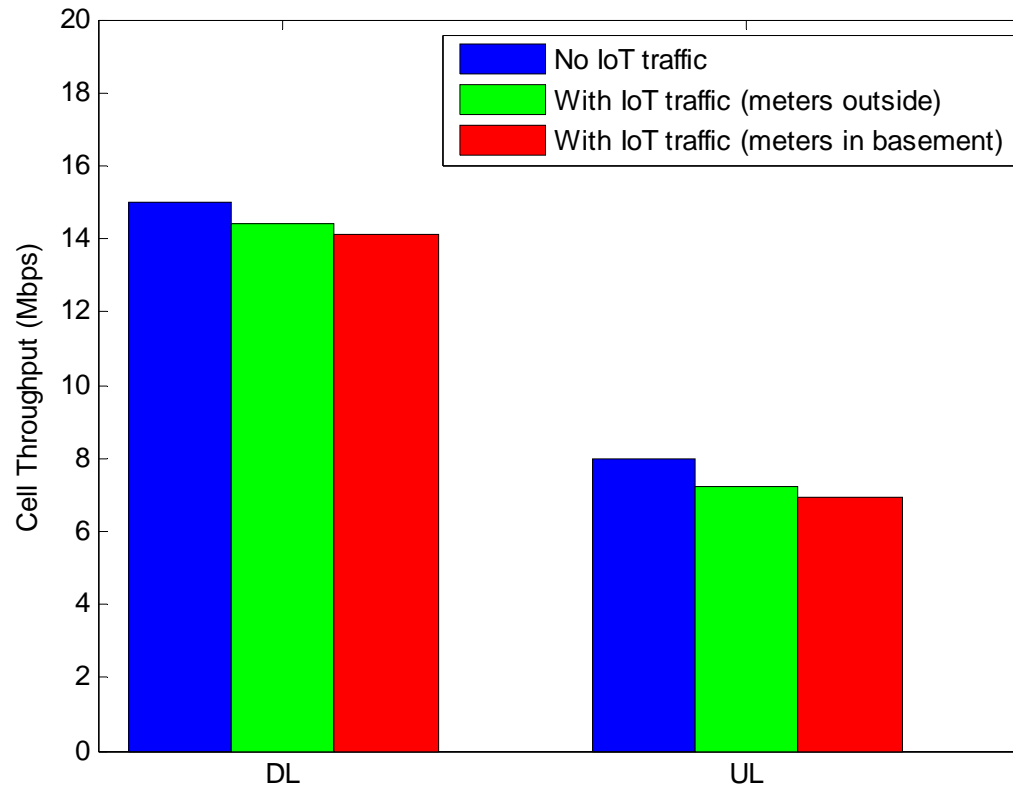
## Capacity Analysis

Case	Household Density per Sq km	Inter-site Distance (ISD) (m)	Number of devices within a household
Urban	1517	1732 m	40

- Traffic model is machine reporting (80%) and network command (20%)
- In stand-alone deployment, at least 71k devices/cell/200 kHz can be supported



## Impact to Data Traffic



- Suburban macrocell (1732m ISD)
- IoT traffic is a mixture of smart meters, home security systems, and sensors
- Small impact from IoT traffic to data traffic.

**NOKIA**