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Wireless Technologies for IoT

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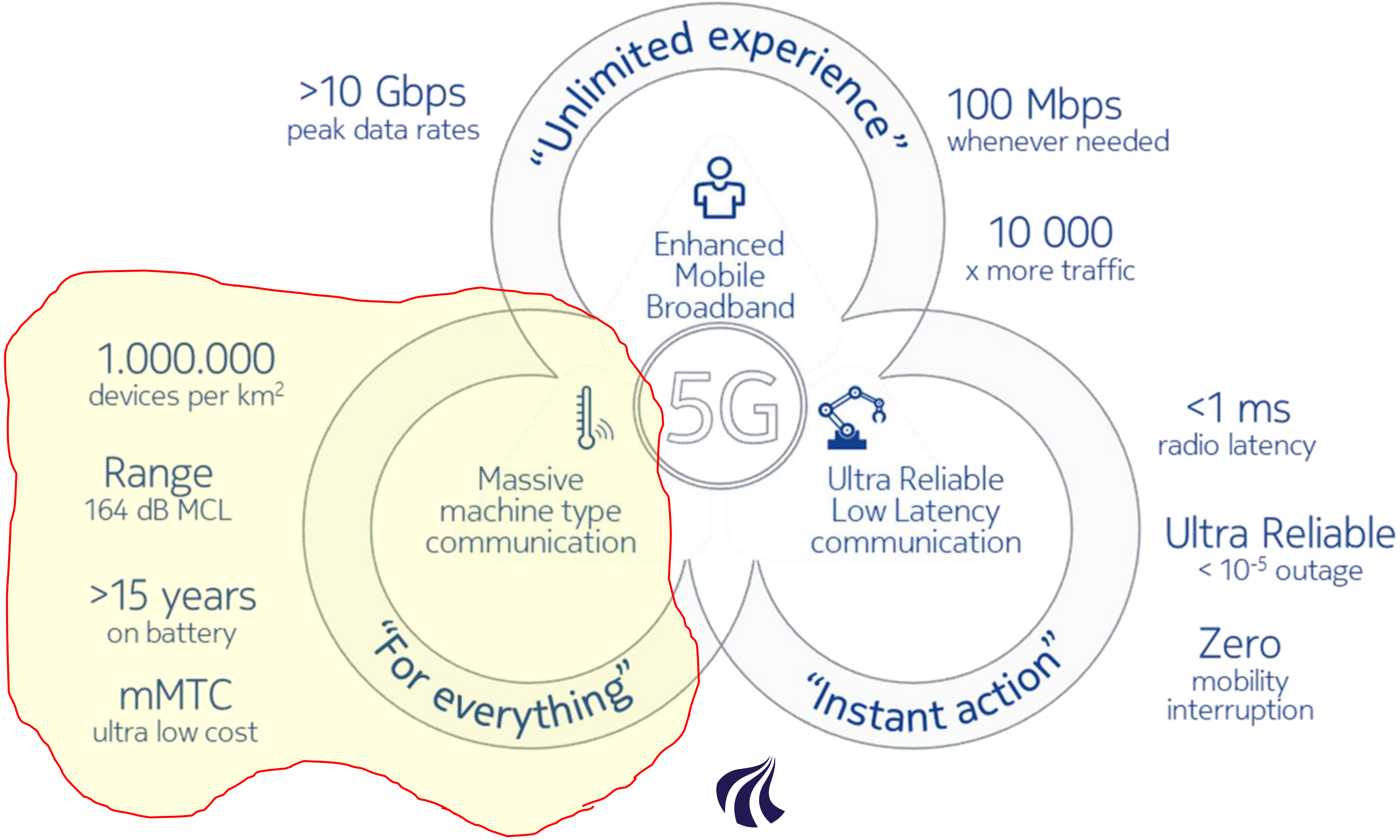
Outline of the SESAM Webinar

- Introduction
- Overview of Wireless Technologies for IoT
- Details on Sigfox, LoRa and LTE NB-IoT
- How to choose the appropriate LPWAN technology?
- Practical Examples for LoraWan and Sigfox
- Concluding Remarks

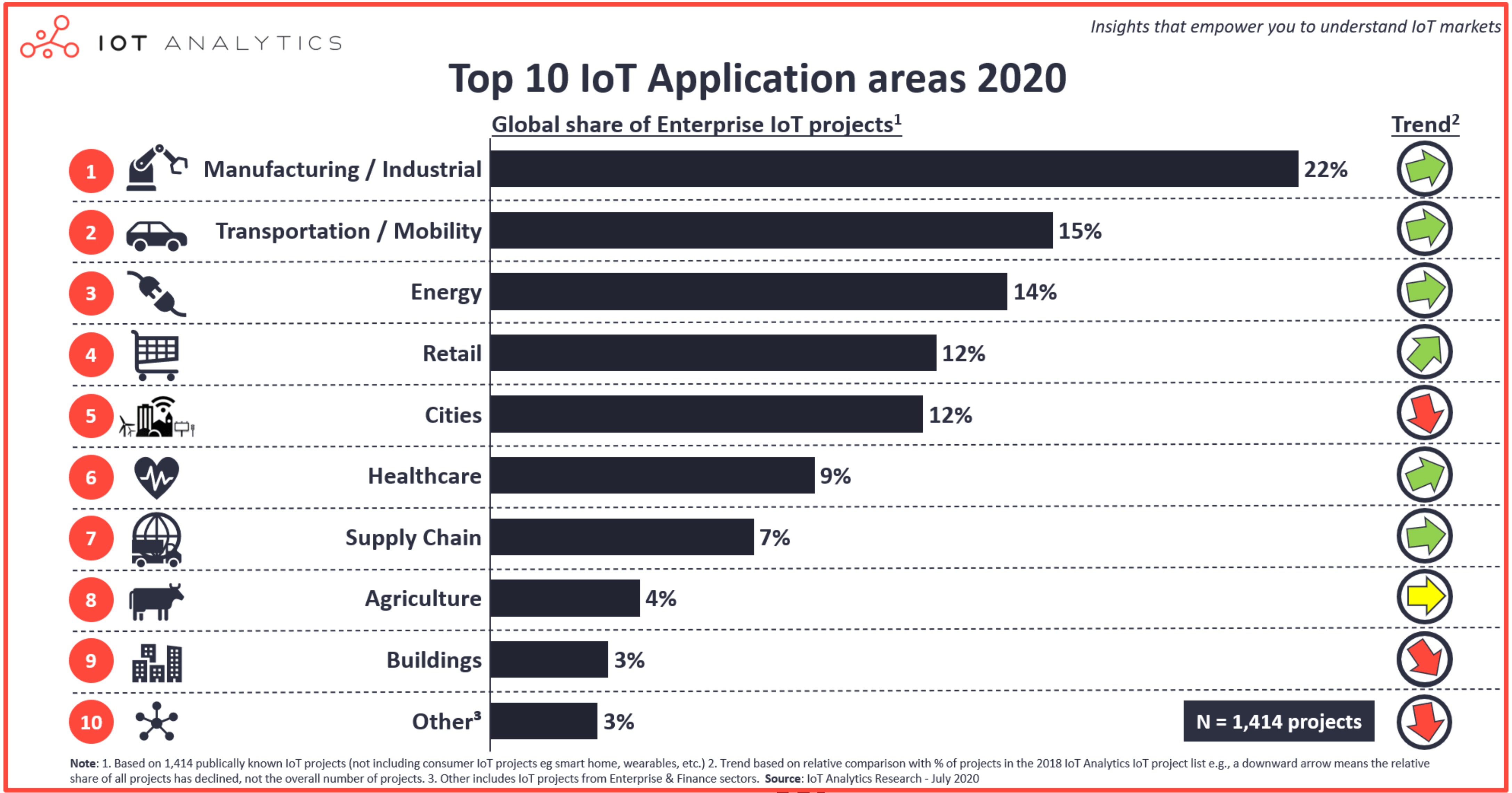
Introduction – New wireless use cases



Introduction – Areas of Applicability

Endless possibilities!

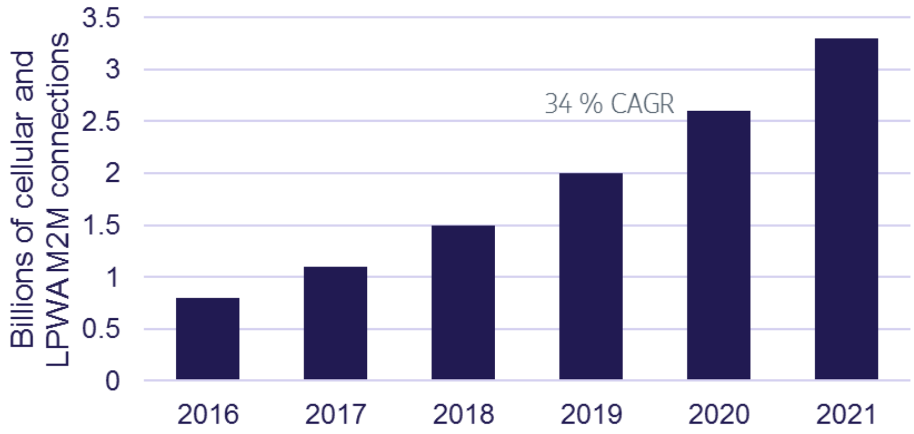
Introduction – International Trends



Source: IoT Analytics 2020

Introduction – Wireless IoT

- The number of IoT devices is increasing year by year.
- Everybody & everything connected, data collection, data exchange, analysis…
- It will never happen if it's not wireless
- Multiple Low Power Wide Area standards operating in licensed and unlicensed spectrum
- But why now?



Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2016–2021, white paper 2017, figure 16.

Cost
Decreasing sensor and device costs

Power
Improved efficiencies

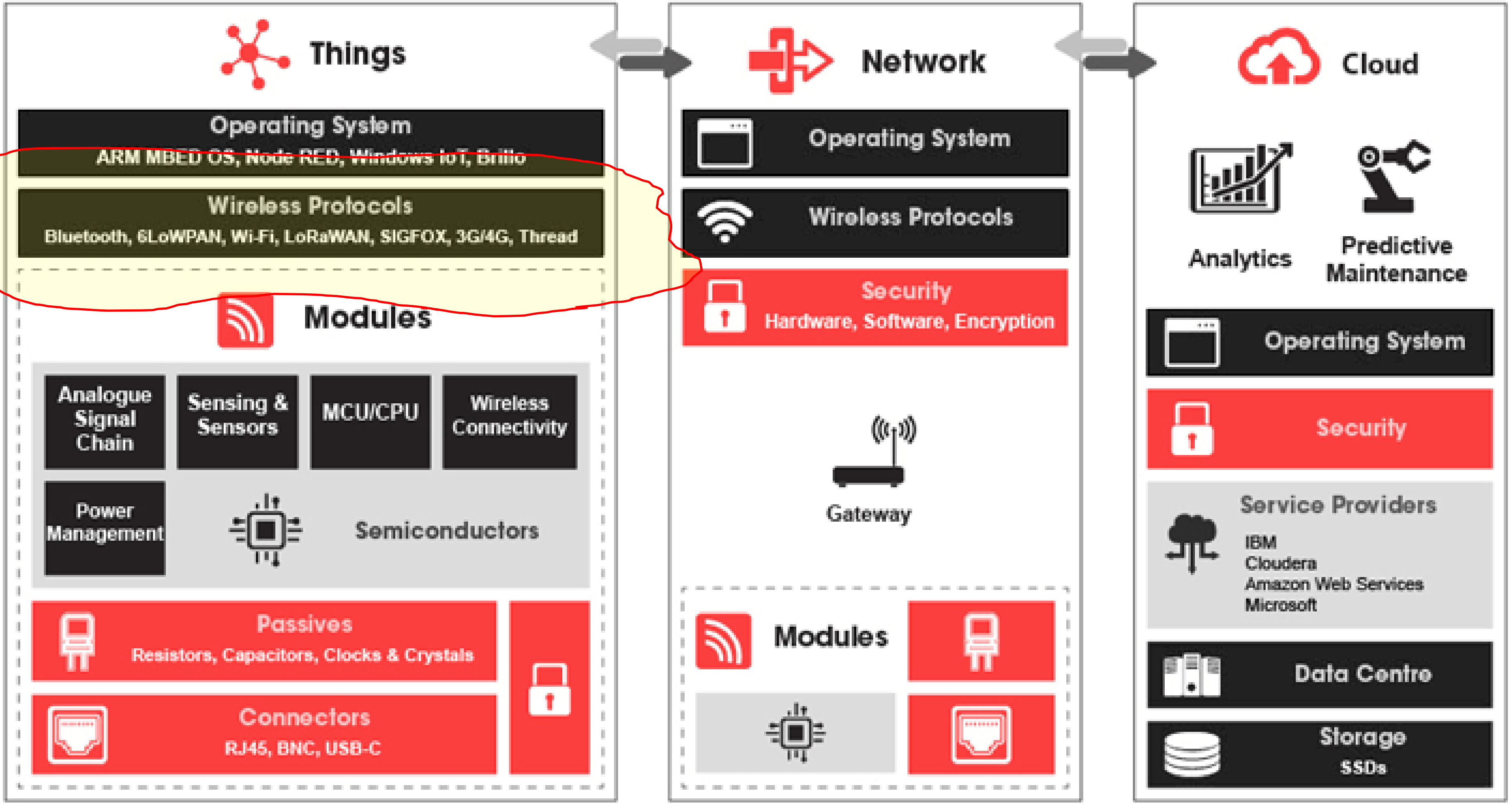
Cloud
Rise of cloud, SaaS, IaaS, PaaS

Wireless
Increasing coverage

Mobility
Ubiquity of mobile devices and apps

Big Data/Analytics
New capabilities to gain insight from data

Introduction – Typical IoT Architecture



Source: rs online

40+ example providers

Source: IoT Analytics 2020

How do we bring data from sensors to the cloud?

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Overview of the main LPWAN Technologies

Technology	LoRa™		sigfox		NB-IoT™		GSM™	
	UL	DL	UL	DL	UL	DL	UL	DL
Frequency Spectrum [MHz]	863-870 (5 channels)		868.1-868.3	869.425 -869.625	832-862	791-821	890-915	935-960
Spectrum regulation	ISM, unlicensed		ISM, unlicensed		Licensed		Licensed	
Max payload @ MCL [bytes]	51	51	12	8	128	85	22	22
Supporting Remote software update	Limited by duty cycle, multicast available		Limited by duty cycle and payload size		Possible using multicast		Possible, no multicast	
Transmit power [dBm]	14	14	14	27	23	37	33	37
Maximum Coupling Loss [dB]	154	152	158	161	164	169	144	152
Range in urban [km]	5.6		7.3		10.8		2.9	
Mode of operation	Self-owned or/and Subscription incl. cloud service		Subscription incl. cloud service		Mobile Network Operator			

Other LPWAN technologies:

WEIGHTLESS™ LTE-M MULTEFIRE™

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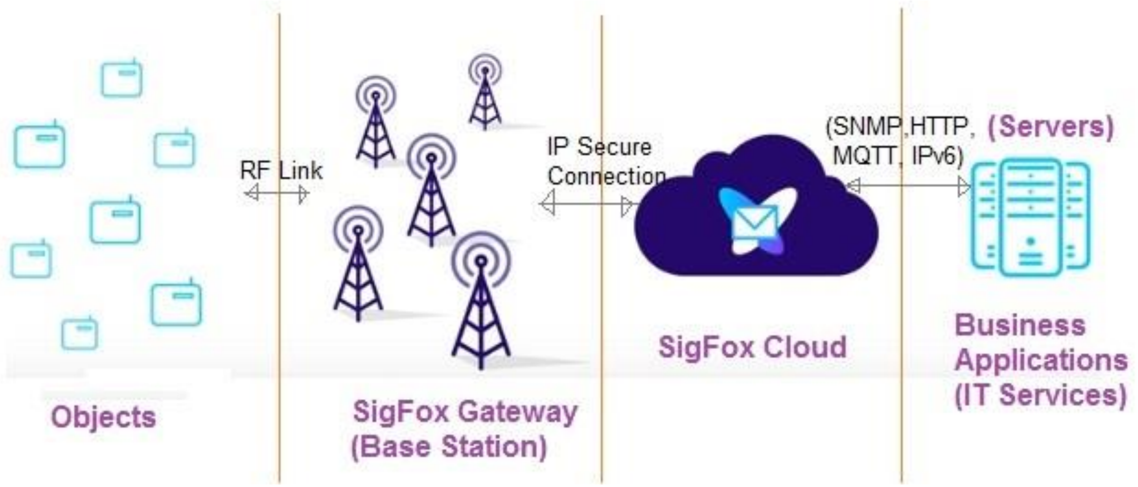
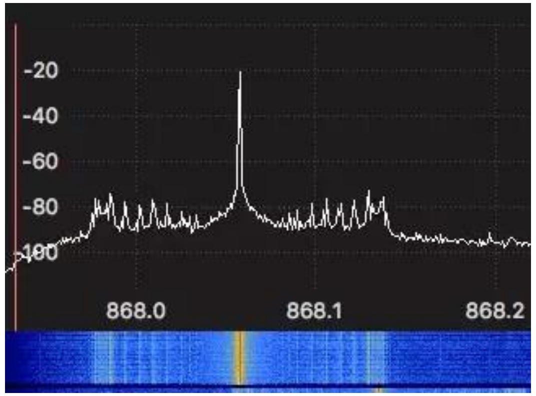
Sigfox in a nutshell



- ❖ Ultra narrowband (UNB)
- ❖ 100 Hz BW
- ❖ D-BPSK modulation
- ❖ Low data rate: 100 bps
- ❖ Lightweight protocol: 12 bytes of data (26 bytes in total) in UL
- ❖ Max 140 UL messages per day*
- ❖ Only 4 DL messages in DL and limited to 8 bytes of payload
- ❖ Star network architecture
- ❖ Devices are not attached to a specific base station
- ❖ On-air time: 2 s per message/repetition.
- ❖ 3 message repetitions at different carrier frequencies to deal with interference and collisions



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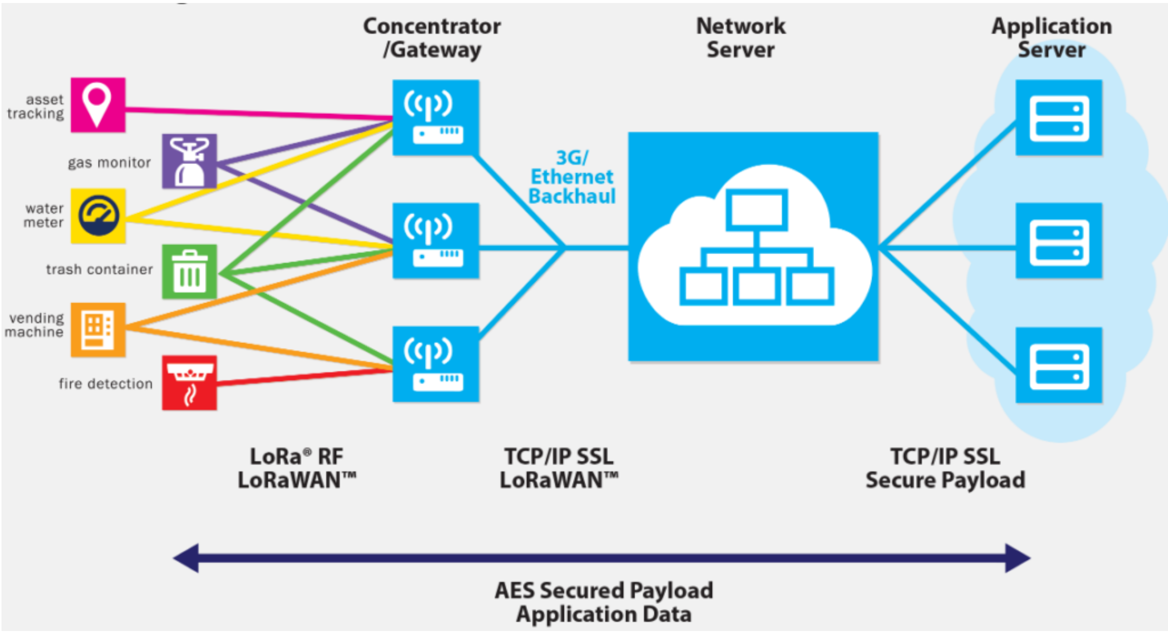
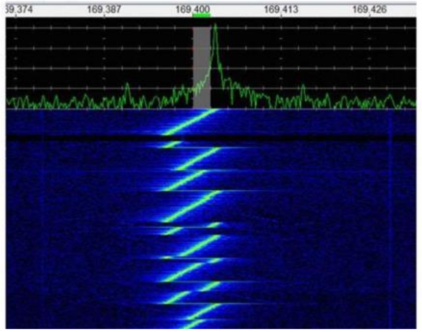
LoRa in a nutshell



- ❖ Chirp spread spectrum (CSS)
- ❖ BW: 125, 250 or 500 kHz
- ❖ Adaptive bit rate based on SF and CR
- ❖ SF: 5 (higher data rate), 7, 10, 12 (more robust)
- ❖ CR: 4/5, 4/6, 4/7, 4/8 (serves as FEC)
- ❖ On-air time: depends on BW, SF, CR (50ms to >2sec)
- ❖ LoRaWAN defines a full protocol and netwotk architecture on top of the LoRa physical layer modulation (at least 13 bytes overhead)
- ❖ Device classes:
  - ❑ A (the device open a DL receive window right after an UL transmission)
  - ❑ B (the device can schedule specific DL windows)
  - ❑ C (the device is almost constantly listening for DL transmissions) -> more power comsumption.



Spectrum Access for 868 MHz ISM bands

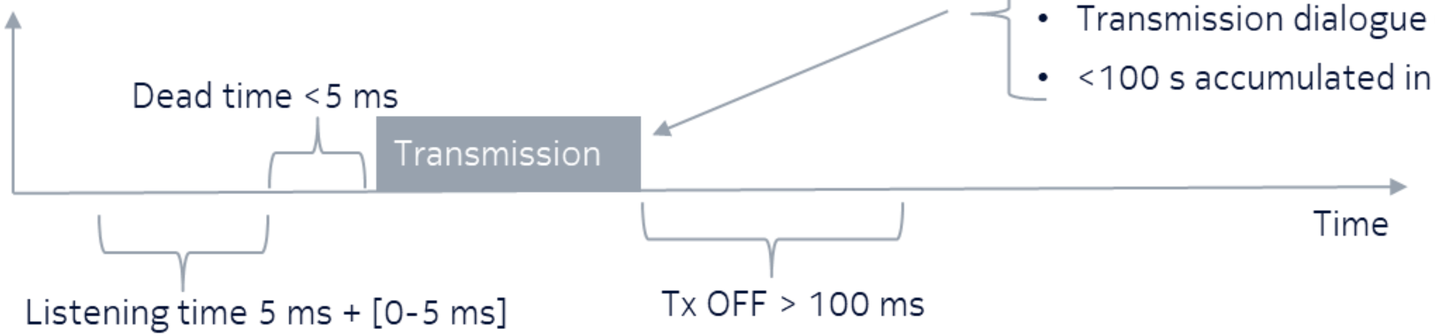
Duty cycle definition

$$\frac{\text{Active time}}{\text{1 hour}} < \text{DC requirement}$$

Used by Sigfox and LoRa

According to ETSI 300 220-1

Listen before talk definition



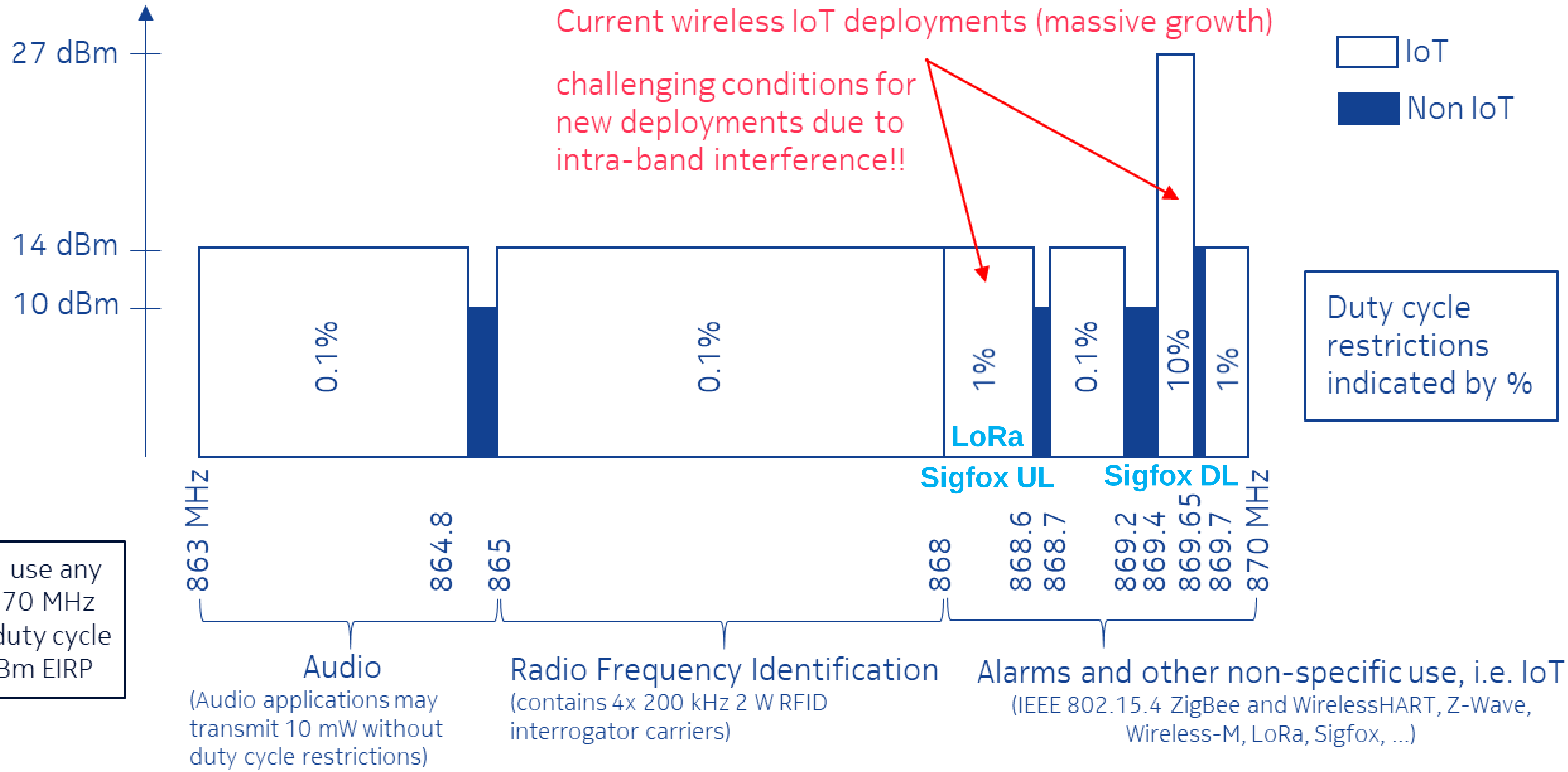
- Single transmission <1 s
- Transmission dialogue (incl. ACKs) <4 s
- <100 s accumulated in 1 hour (2.78 %) in a 200 kHz spectrum

Adaptive Frequency Agility: Ability to change carrier frequency dynamically

Used by WiFi

868 MHz ISM Band Regulation (Europe)

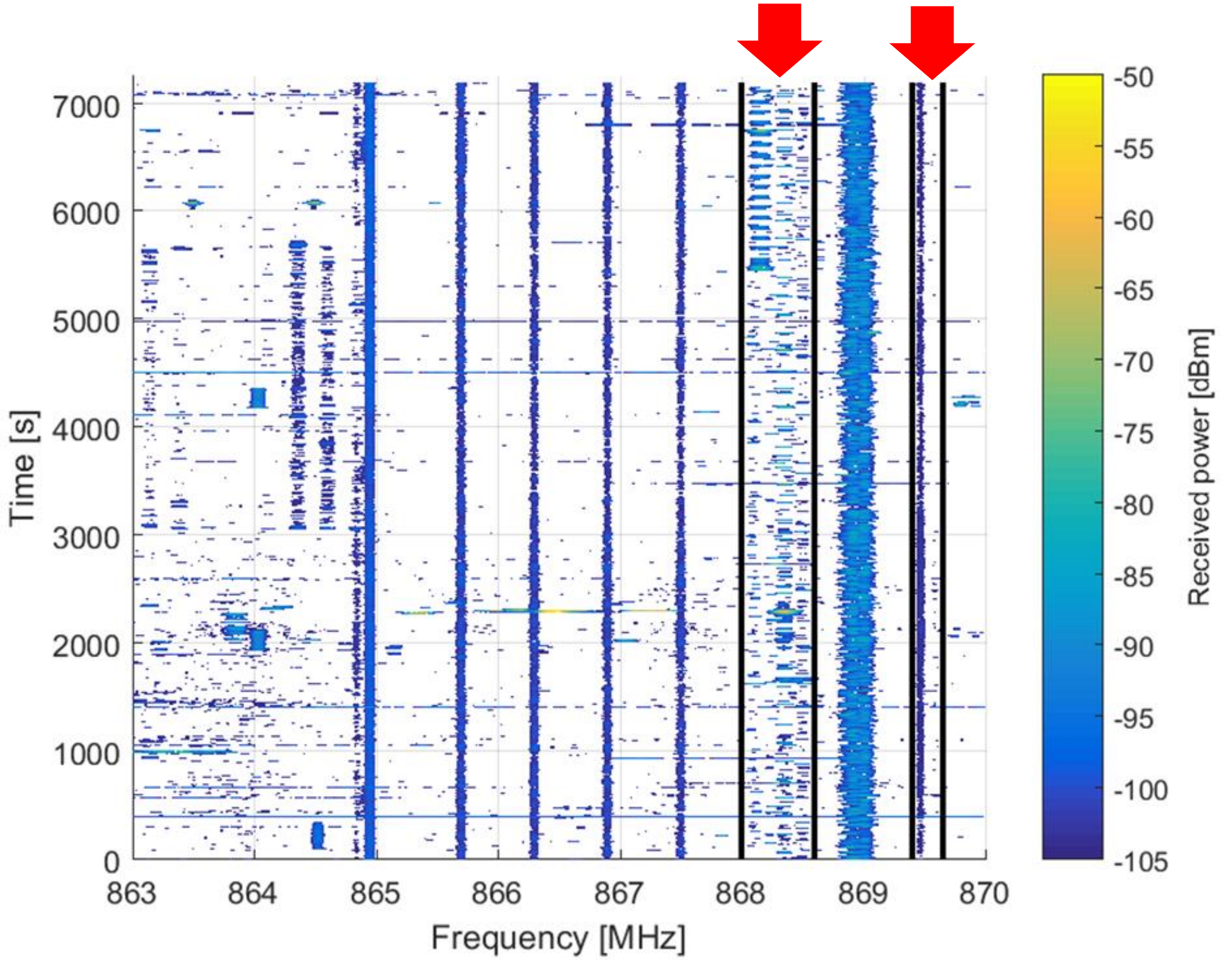
ISM band use according to the ERC Rec. 70-03 on the use of Short Range Devices



Note: devices can use any part of the 863-870 MHz band with 0.1 % duty cycle (or LBT) and 14 dBm EIRP

The challenge of using ISM bands

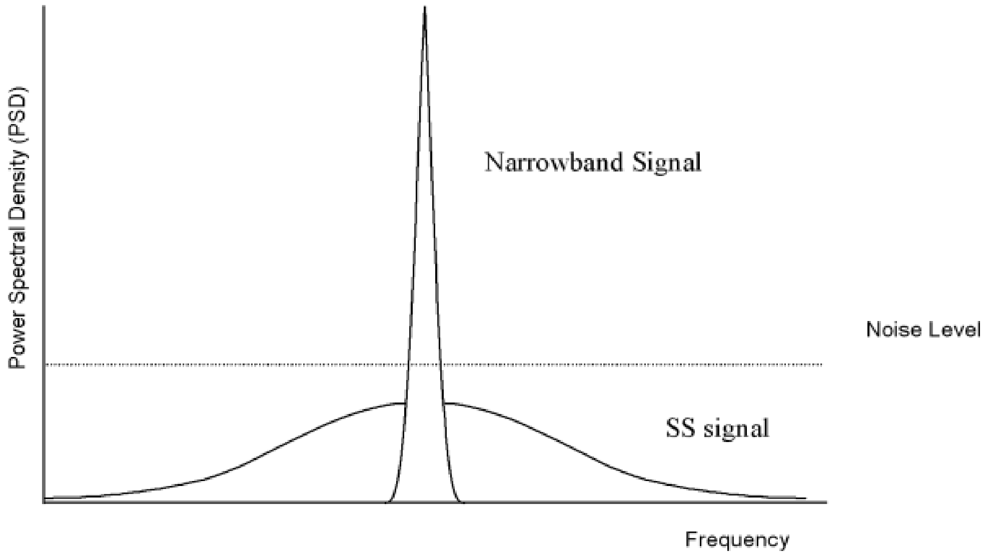
- ❖ There are more technologies than Sigfox and LoRa utilizing the 868 MHz ISM spectrum.
- ❖ As the number of IoT deployment increases, interference levels increase as well.
- ❖ Challenging situations? More spectrum may be needed.

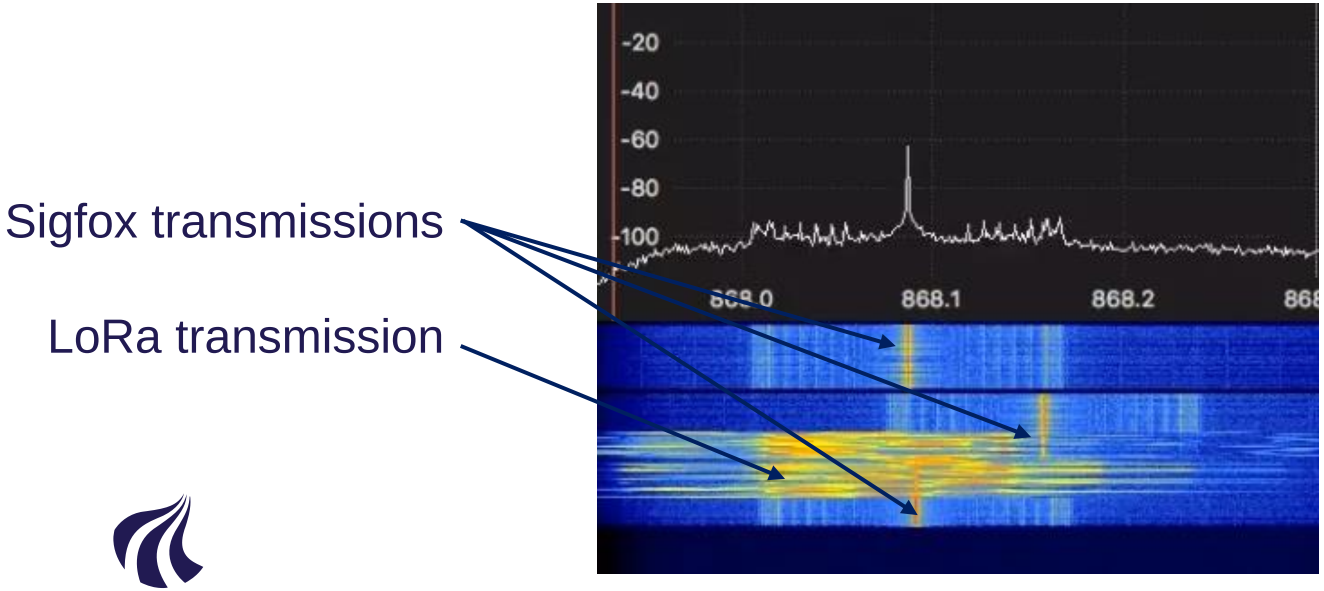


2 h measurements at hospital complex, 2016

Sigfox vs LoRa over the 868 MHz spectrum

- Sigfox and LoRa operate over the same ISM band -> potential interference!
- Sigfox combats interference by spatial diversity (the message can be received by multiple gateways) and frequency diversity (the message is repeated 3 times over random different channels).
- LoRa with its spread spectrum, spans the different message bits over a large a bandwidth, achieving protection against interference and environmental noise. With higer SF, the on-air time is longer, providing robustness in time domain.





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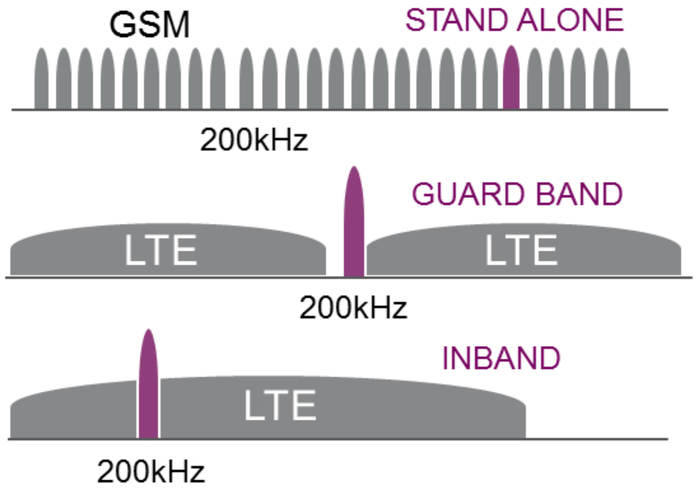
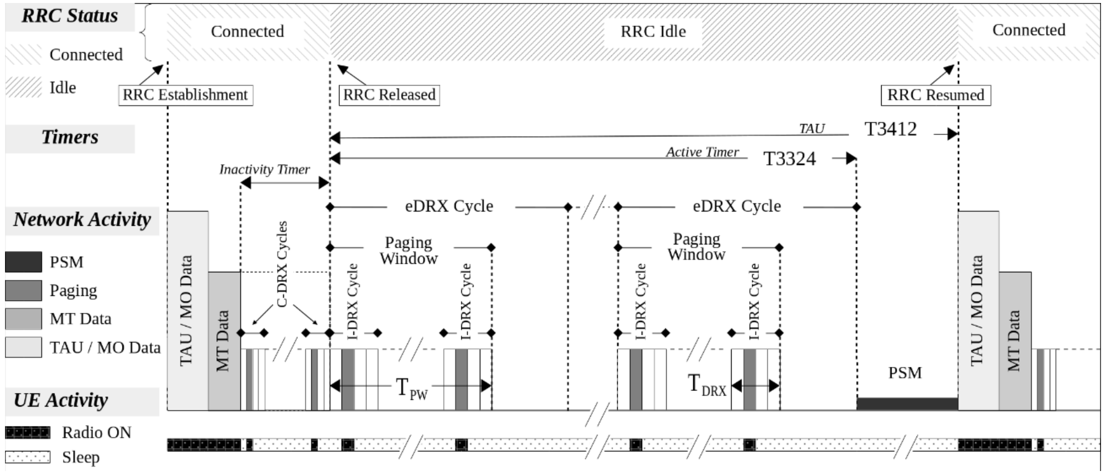
LTE NB-IoT in a nutshell

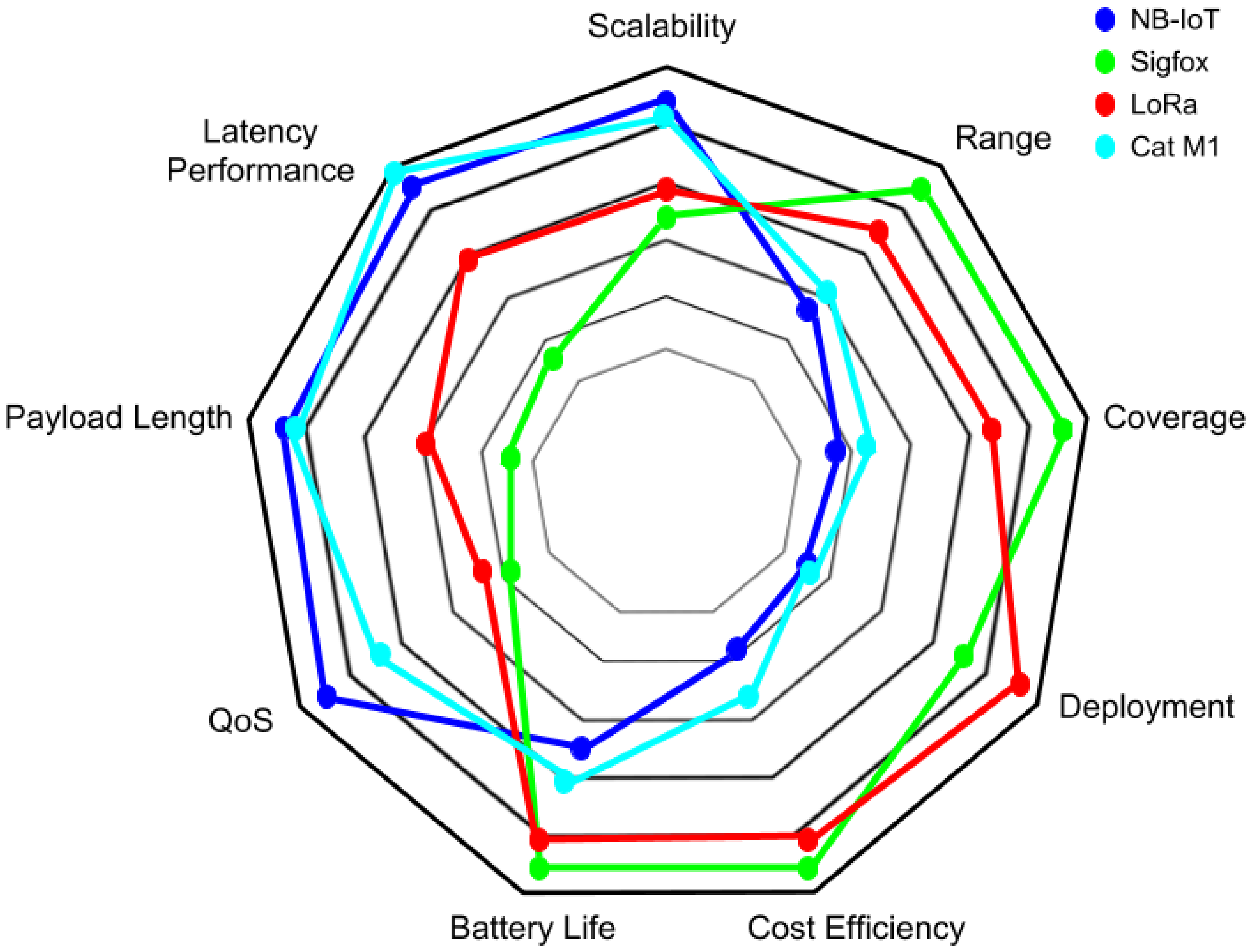


- ❖ Deployment options: standalone, guardband, inband
- ❖ Half-duplex FDD, 180 kHz BW
- ❖ UL: SC-FDMA
  - ❑ single-tone, QPSK modulation, up to 20 kbps
  - ❑ multi-tone (3, 6 or 12 SC), π/2-BPSK, π/4-QPSK modulation, up to 64 kbps
- ❖ DL: OFDMA, 12 SC, QPSK modulation, up to 50 kbps
- ❖ Frequency bands: 800, 900, 1900, 2100 MHz
- ❖ Repetitions can be enabled
- ❖ Celullar features:
  - ❑ HARQ, UL power control, power saving, eDRX



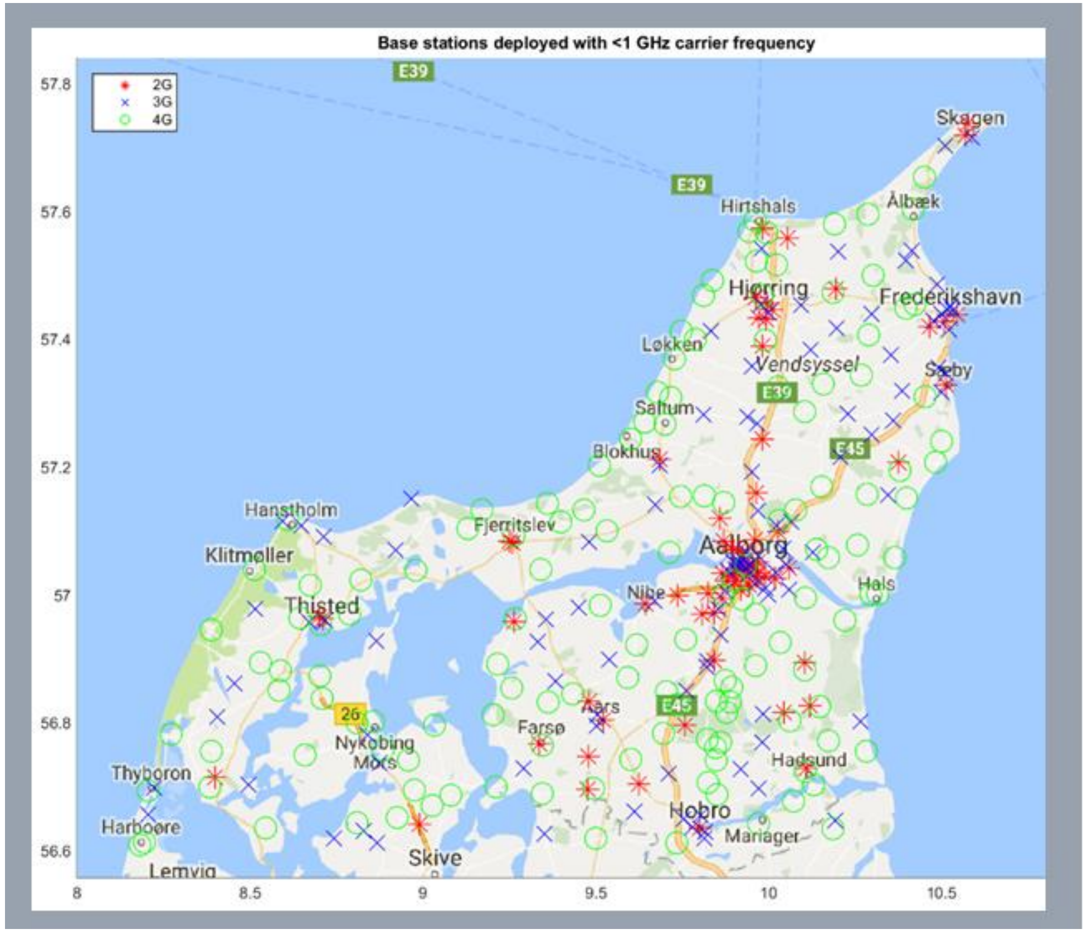
Comparison between LPWAN technologies

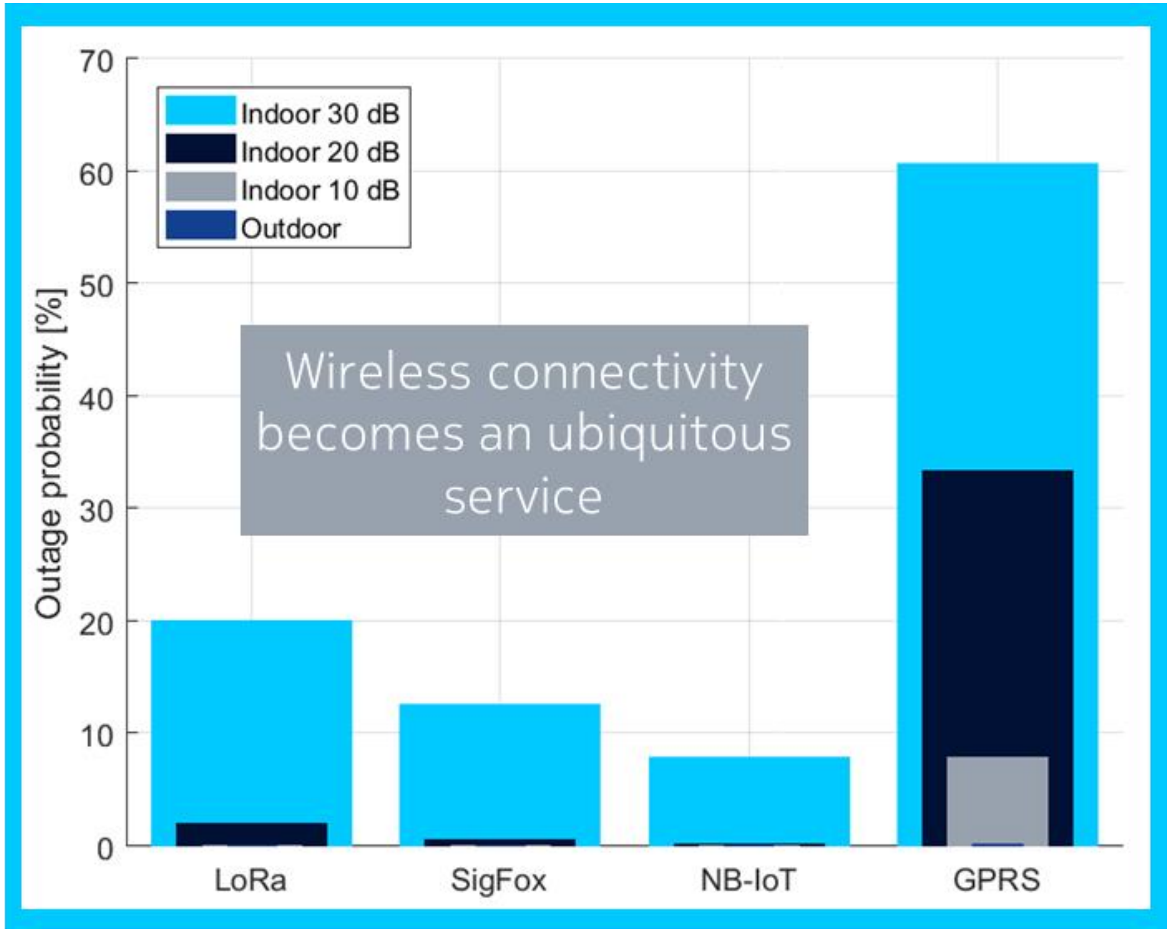
❖ Note: this diagram might change depending on who is the author (i.e. Depending on which technology they are trying to sell :D)



Source: Ubidots 2019

Wireless IoT coverage Simulation





Evaluation of LoRa/Sigfox/NB-IoT coverage under the same deployment conditions: one gateway per 4G mast of a Danish operator

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IoT device battery life

❖ Extended coverage entails:

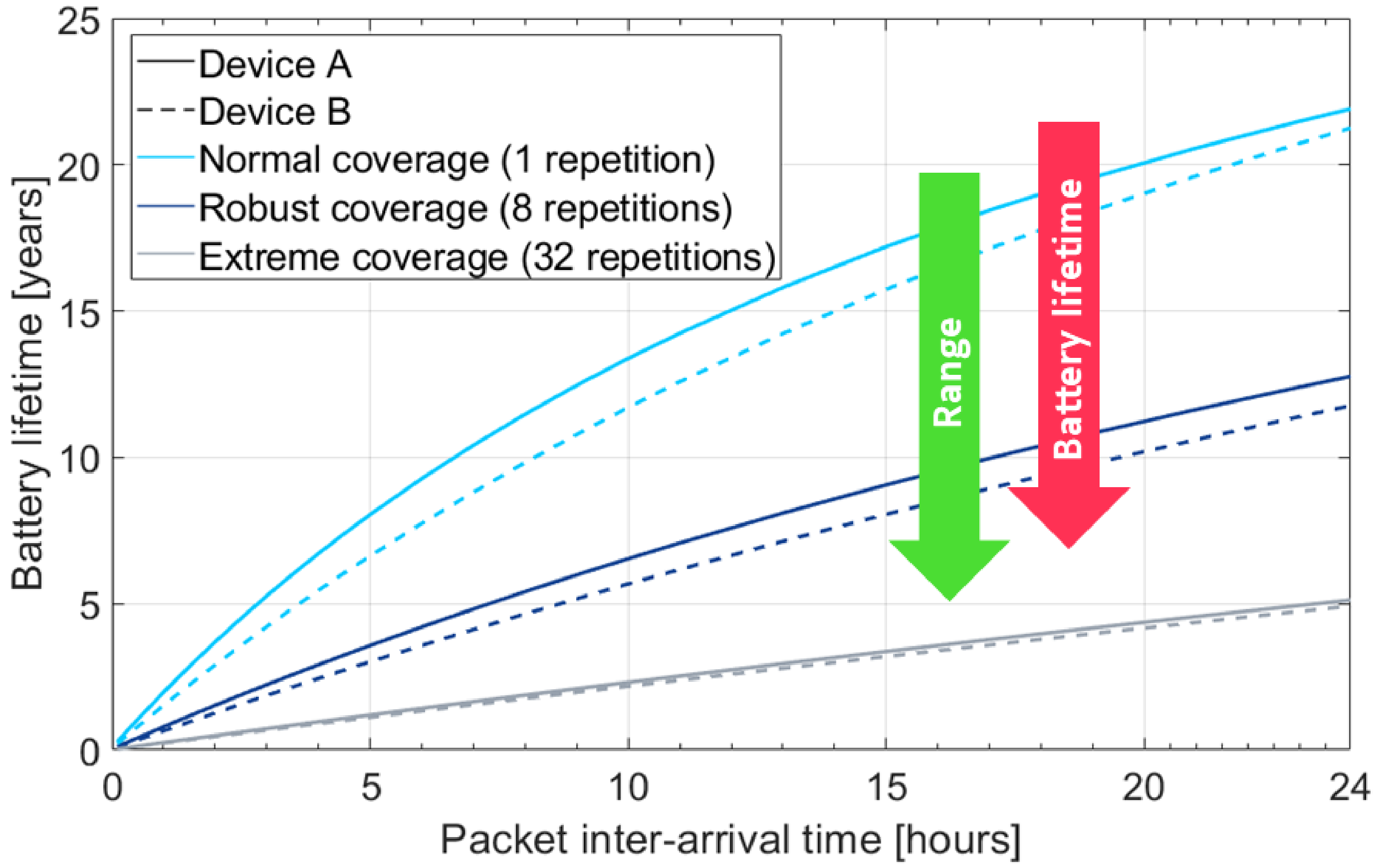
❑ higher transmit power

❑ longer transmissions (except Sigfox)

❖ This results in:

❑ Shorter battery lifetime

❑ Lower network capacity



Estimated NB-IoT battery lifetime using real measurements

How to choose the correct technology?

- There is no universal solution for a given use case, unfortunately ☺

- Main considerations:
  - How much data and how often do you need to transmit? In both uplink and downlink.
  - QoS: Can you live with some eventual packet losses?
  - Is latency critical? How much?
  - How much area do you need to cover? Global/local coverage?
  - Do you want to deploy your own system? Are you willing to buy connectivity from an IoT operator?
  - Is battery life of the end device important?
  - Is total cost an issue?
  - …

Do not forget to think about the long term!

- What if your IoT system becomes successful?

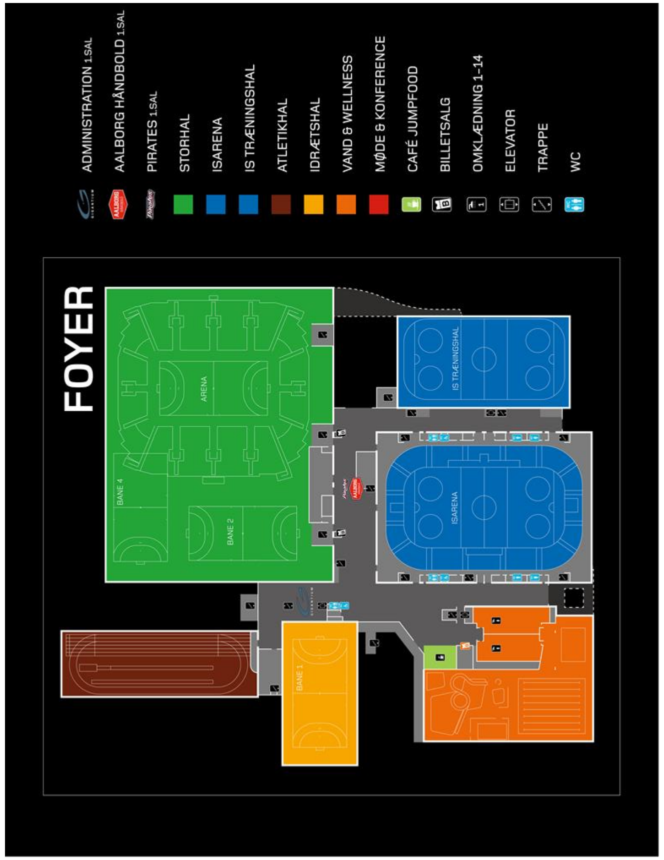
- You may need to scale the system.

- It is always a very good idea to have that in mind from the very beginning. Otherwise, you may need to make a huge investment to patch or change technology.

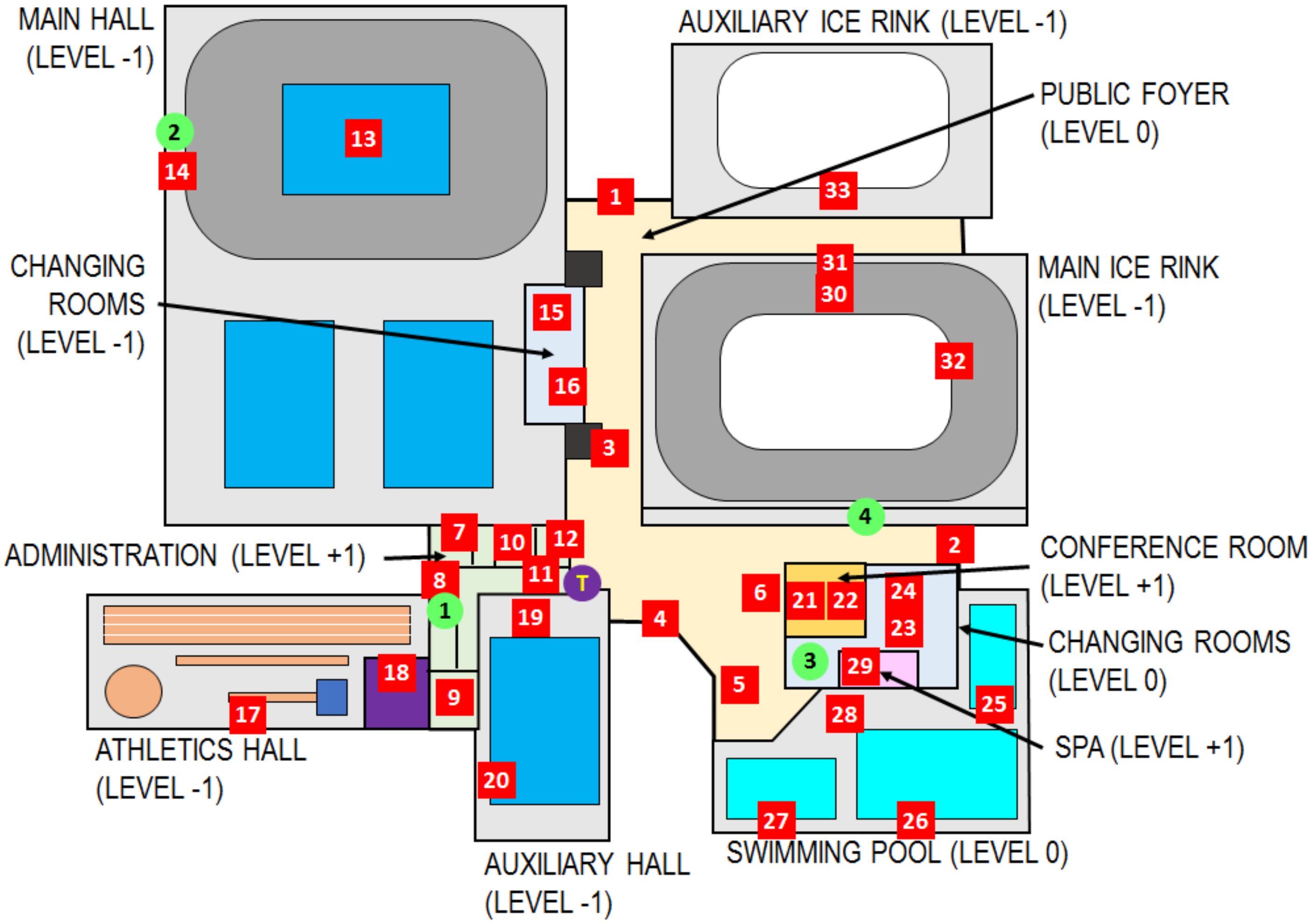
- This should be considered not only from the physical deployment perspective, but also from the protocol implementation side.

LoraWan Practical Examples

- Case 1:
  - The indoor climate monitoring system in a 33.000 m2 multi-arena needs to be replaced.
  - Right now, each of the 6 arenas and the different office/management areas have their own (and very expensive) independent systems; based on cabled buses which wires the sensors to its centralized control machine.
  - The systems from the different arenas are not compatibles with each other, so one solution could be to integrate the 5 different systems by writing the approapiate software drivers.
  - If we do that, we would still be limited if we want to add some new sensors in the future... so we see potential benefits in designing and deploying a new wireless IoT system instead.



Final Deployment – SN and GW Locations



Sensor Nodes (SN) - RTX4301

SENSOR	MEASUREMENT SPECIFICATIONS
HUMIDITY	0-100% rel. humidity (±3% accuracy)
PRESSURE	300-1100 hPa (±0.2 Pa = 1.7cm)
TEMPERATURE	-40°C - 125°C (± 0.3 °C)
PIR MOTION	Distance: 12m Detection area: 40° horizontal, 105° vertical
AIR QUALITY	eCO2 Levels: 400ppm - 8192ppm TVOC levels: 0 – 1187 ppb
UV (UV-A & UV-B) AND AMBIENT LIGHT	UV Index: ~0.5 - ~6.8 Ambient light: 0-1000 Meter LUX
ACCELERATION	Linear acceleration full scale of ±2g/±4g/±8/±16 g
GYRO	Angular rate of ±245/±500/±2000 dps.
MAGNETOMETER	Magnetic field full scale of ±4/±8/±12/±16 gauss
SOUND PRESSURE SENSOR	Dynamic range: 40dBA – 105dBA

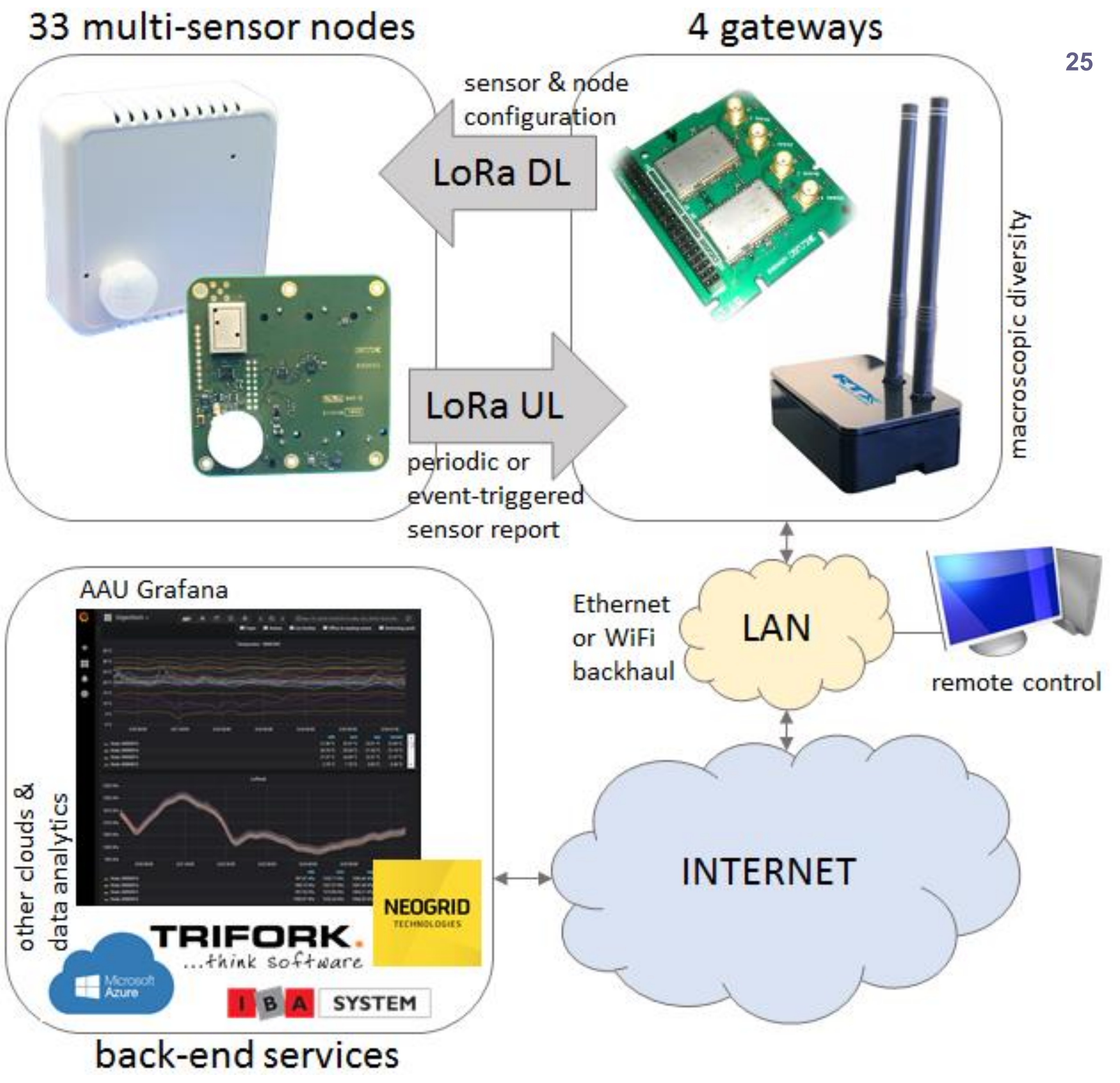
Gateways (GW) - RTX4302

SUBJECT	SPECIFICATIONS
DIMENSIONS	H: 3cm, W: 5cm, L: 8cm
OPERATION TEMP.	0° to +50°
WIRELESS RADIOS	Up to 4 Semtech SX1276 radios supporting +1000 of nodes
SUPPORTED WIRELESS TECHNOLOGIES	LoRa, Proprietary Sub-Ghz FSK modulation
LINUX VERSIONS	Raspbian Jessie
CLOUD SUPPORT	Open Linux platform enables option to connect to any cloud service.

System Configuration

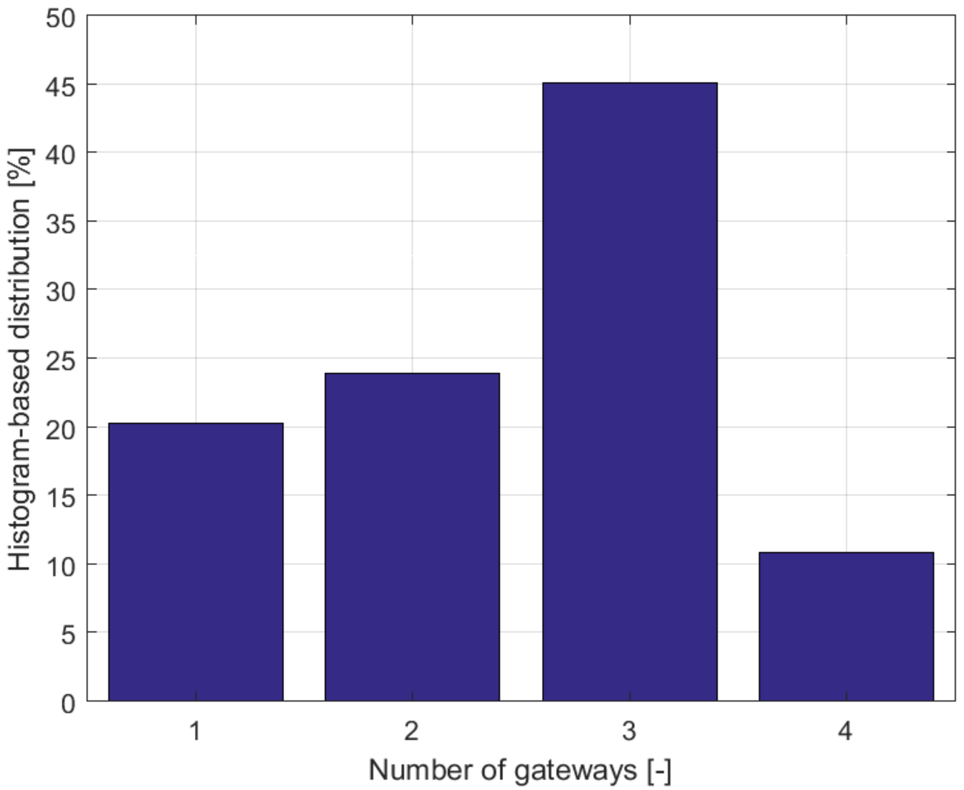
This was one the very first end-to-end wireless IoT pilot networks ever deployed.

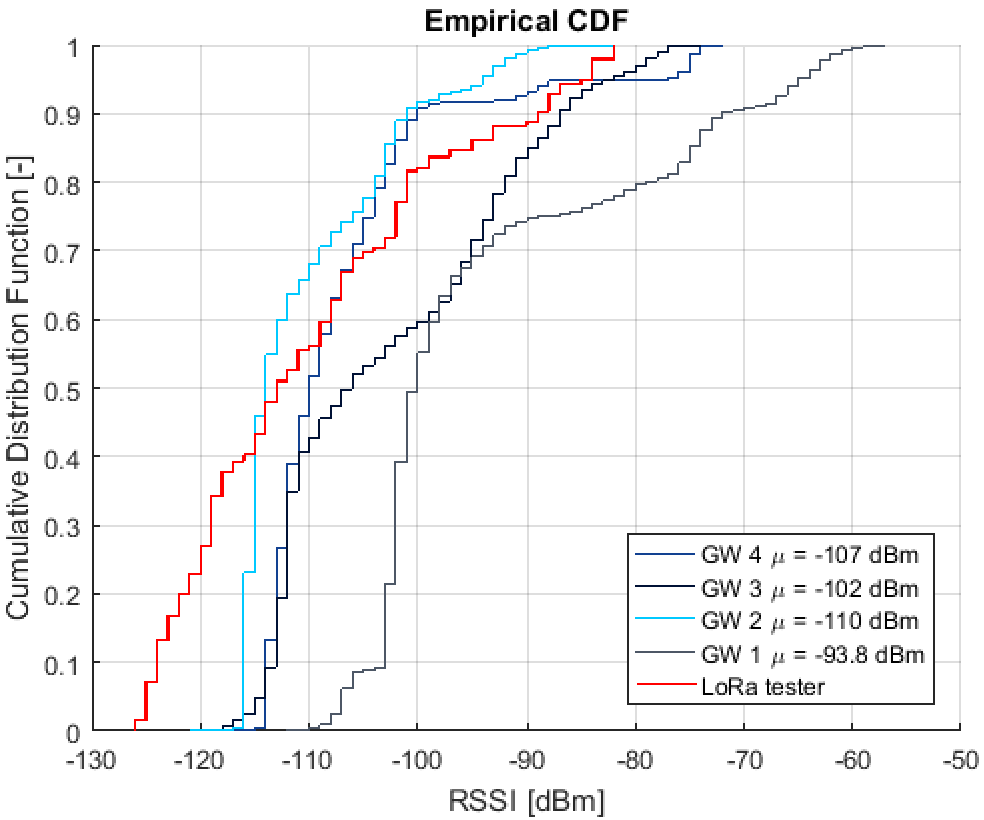
- 4 gateways (macroscopic diversity)
- 33 multi-sensors
    - 5 active sensors (payload 45 bytes)
        - Temperature
        - Pressure
        - Humidity
        - CO2
- Battery-operated nodes (3xAA) -> ~2 months life
- All 33 nodes paired to the 4 GWs (reliability)
- 310 s (~5 min) intervals between readings
- Random activation time
- SF10, CR 4/5, BW 125 kHz
- LoRa air time 520 ms -> 0.17% (<1% DC)



Final Deployment – Macro Diversity Analysis

One week of data in March 2018, 55000+ packets





Most of packets are received by at least 3 GWs
Packet Error Rate ~ 1%

High RSSI (as a consequence of macrodiversity)
Time/clutter-variant dynamics included in the statistics

Backend Monitoring and Data Analytics

NEOGRID TECHNOLOGIES

IBA SYSTEM

TRIFORK. ...think software

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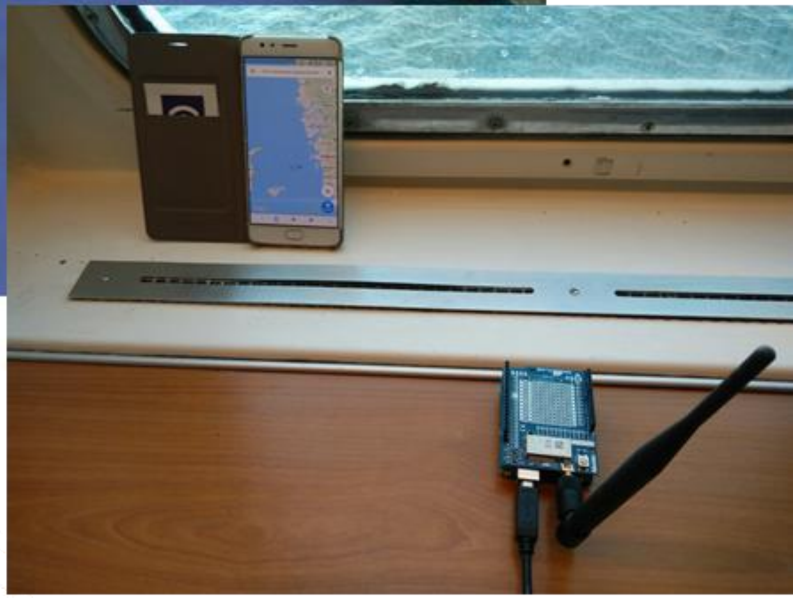
Sigfox Practical Example

❖ Case 2:

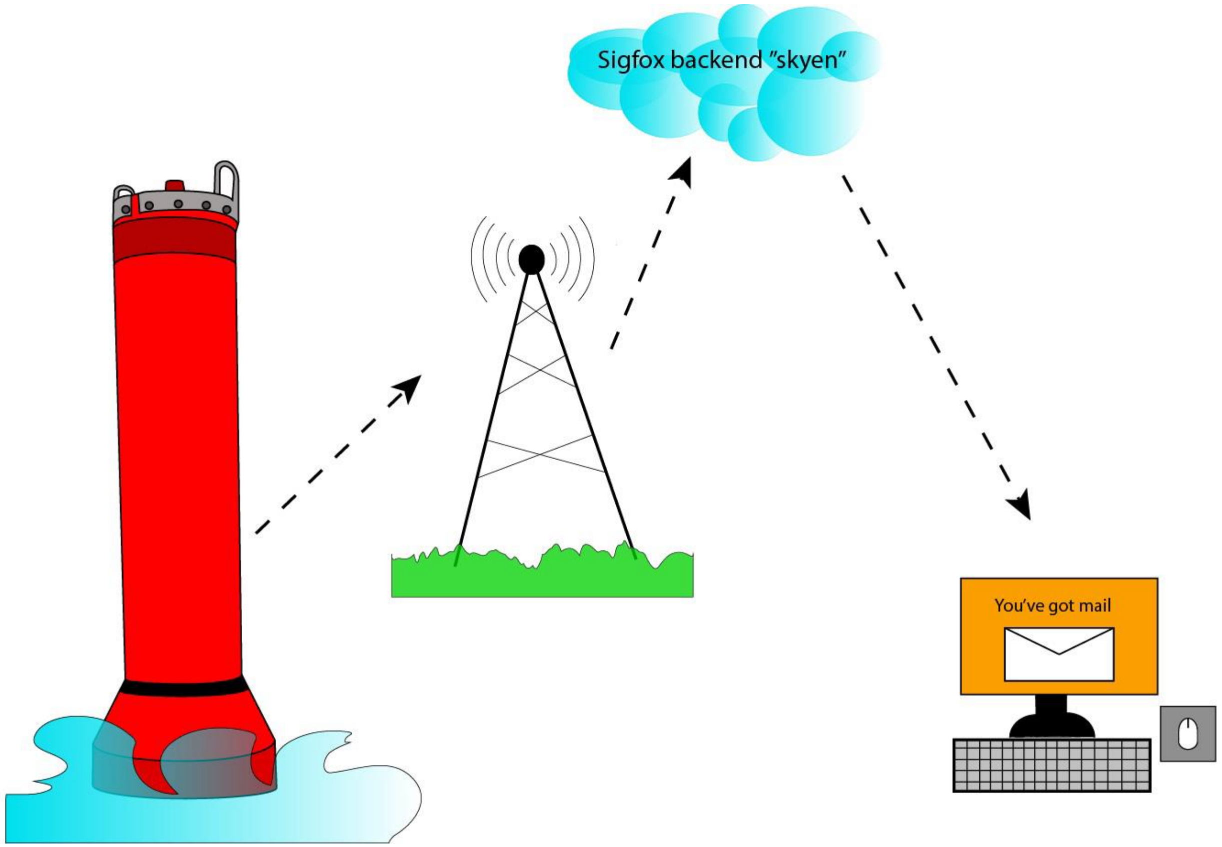
- ❑ Every year, a number of accidents happen to the bouys that signal the entrance to the Limfjorden. Bouys can move out from their static positions if there is a problem with their anchorage wires.
- ❑ Aalborg havn perform periodic trips to check the status of the buoys (anchorage, battery level), but they would like to have either an alert or monitoring system that informs them in case of a problem with a buoy.

In-sea Sigfox coverage



- First signal detected ~35 km from Frederikshavn: -142 dBm
- Close-to-land signal: -105 dBm
- Up to 3 BS detected close to land

Example: Sea Buoy tracking using Sigfox



Bouy tracking prototype:
FiPy from Pycom + buoy battery monitor circuit

Main design target: should not consume much energy from the buoy.

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Concluding Remarks

- An overview of the main wireless IoT LPWAN technologies (LoRa, Sigfox and LTE NB-IoT) has been presented.

- These technologies have been designed with very similar targets: low power consumption and wide area coverage, operate at very similar low frequencies; but they are based on different physical layers and present different modes of operation ones from the others.

- The same problem can have multiple solutions. A particular use case can be coped by different wireless IoT technologies, and thus it is important to consider very carefully all possible aspects during the system design:
  - Data size, repetitions, energy consumption, reliability, QoS, ISM/licensed spectrum, scalability, software upgrades…

Thanks for your attention!

Questions

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