KU LEUVEN

IoT on the road to the Sustainable Development Goals: Vehicle or bandit?

Liesbet Van der Perre

special thanks to DRAMCO/IoT team and Emma Fitzgerald

Defining 6G, summer school Linköping, Sweden, August 29th 2022

IoT defined, exemplary case, and the SDGs

Anatomy and operation of IoT nodes

(How) could 6G help?

IoT on the road to the SDGs: vehicle or bandit?

Internet of Things: sensor (actuator) data surfing on wireless waves, ‘measure for knowledge’

1

The **Things**, which are embedded with sensors and/or actuators

2

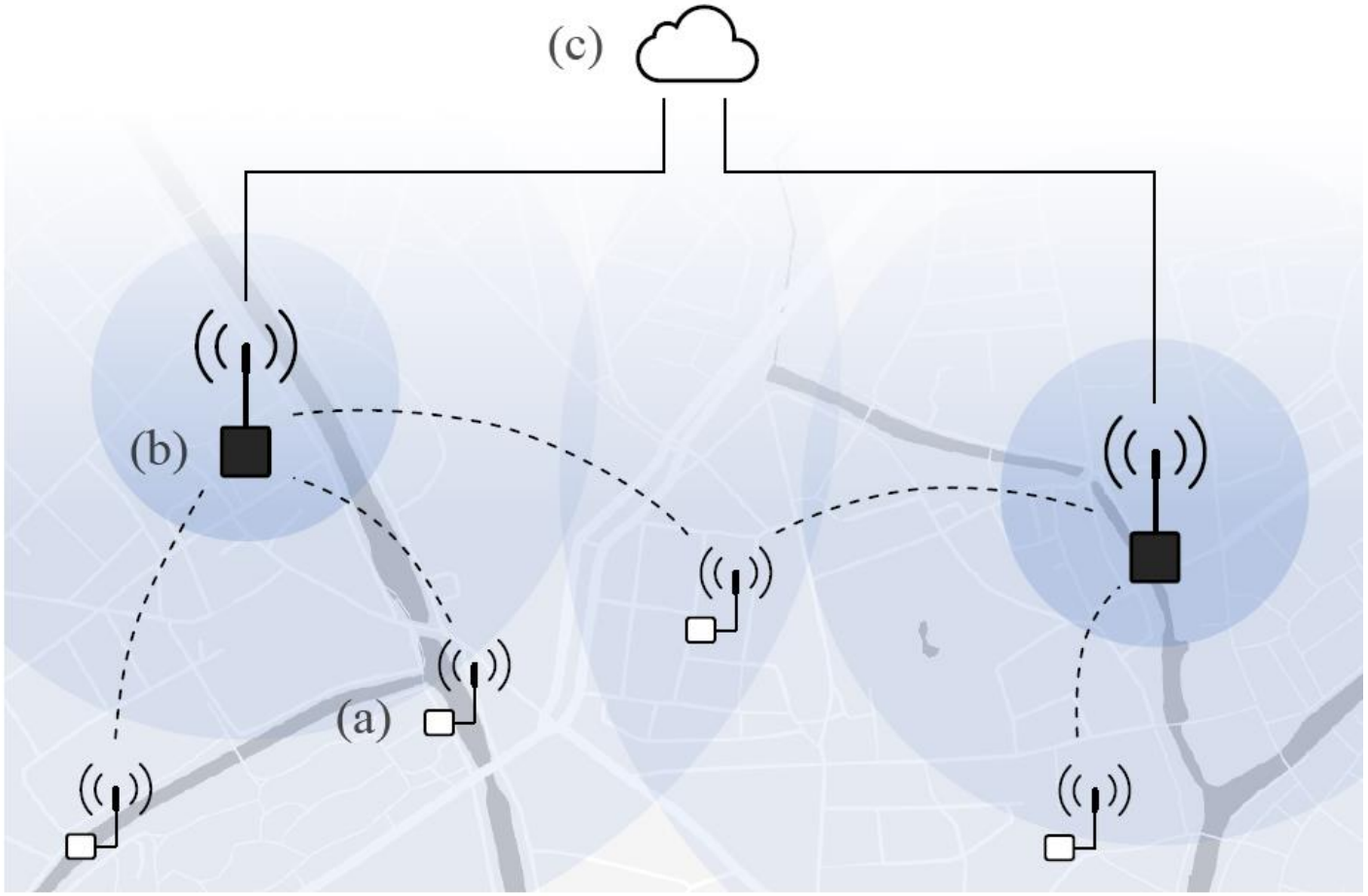
The **network** that connects them

3

The systems that **process** data to/from the Things

source: https://www.linkedin.com/pulse/internet-things-iot-dummies-rajat-kochhar

Connecting remote IoT nodes

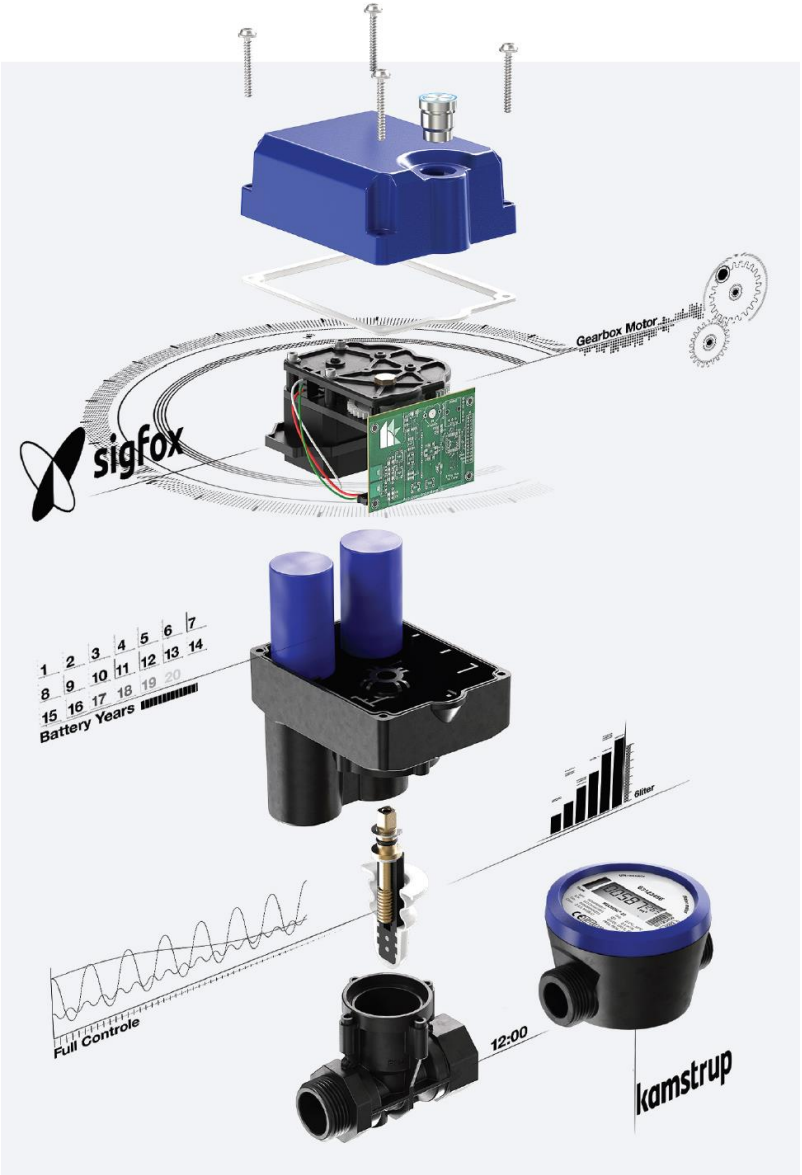


(**a**) connecting to one or more gateways or base stations

(**b**) interconnected gateways relay the information to server or cloud resources

(**c**) where data can be visualized and interpreted.

Example remote IoT node: smart water meter

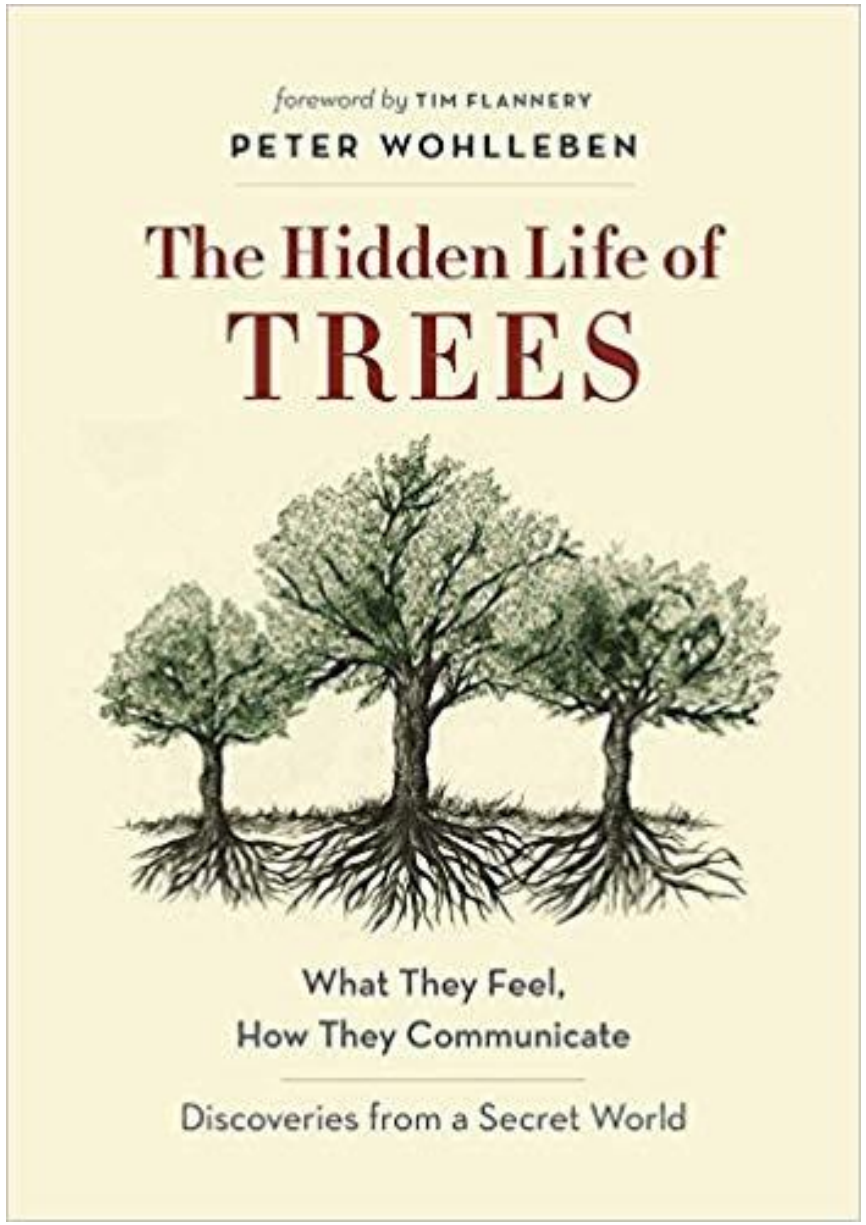


The smart meter **measures & sends data**

In the box:

- Sensor: little data, sporadic traffic
- Low power electronics
- Challenging wireless communications: up to kms range, basements, …
- Batteries to ensure > 10 years operation

KU LEUVEN



The ‘wood-wide web’

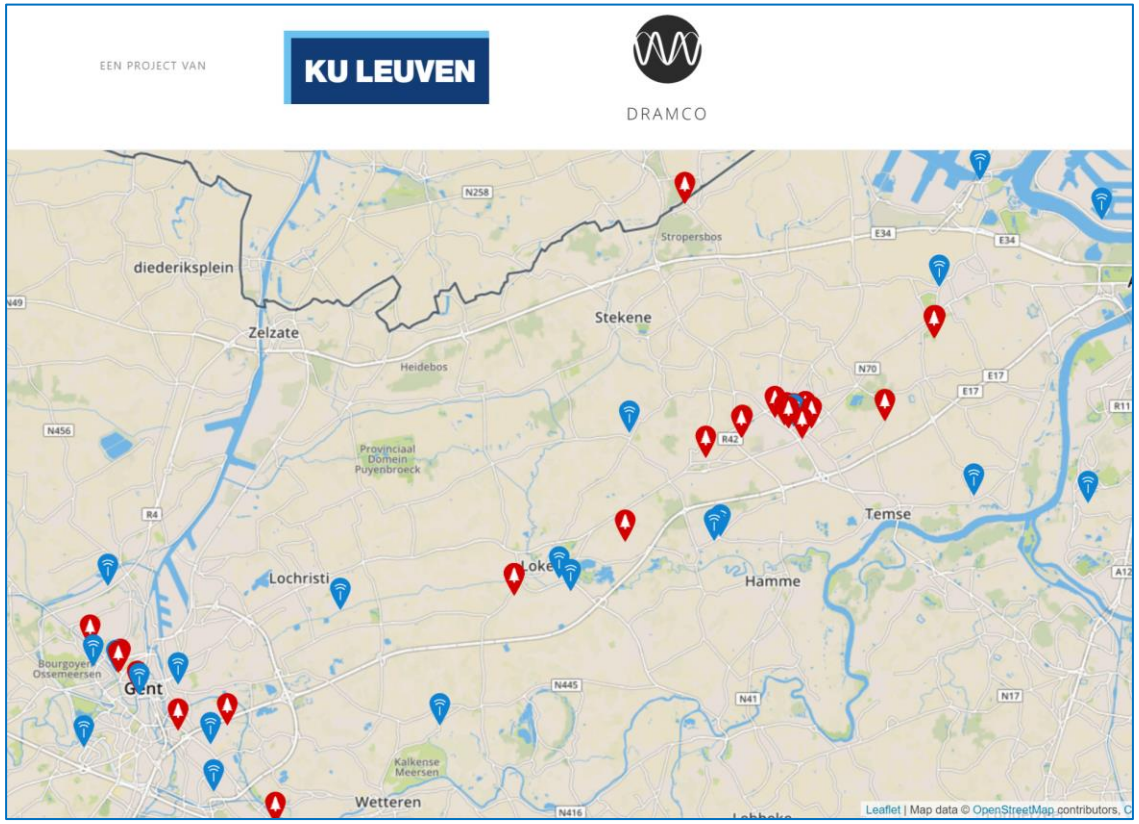
In the Internet-of-Things (IoT),

‘things’ mostly ‘talk’ about what they ‘sense’

and could ‘think’ about what they sense

Define 6G: connectivity-compute platform
enable ‘think before you talk’

IoTREE: monitoring and managing trees (stewards)



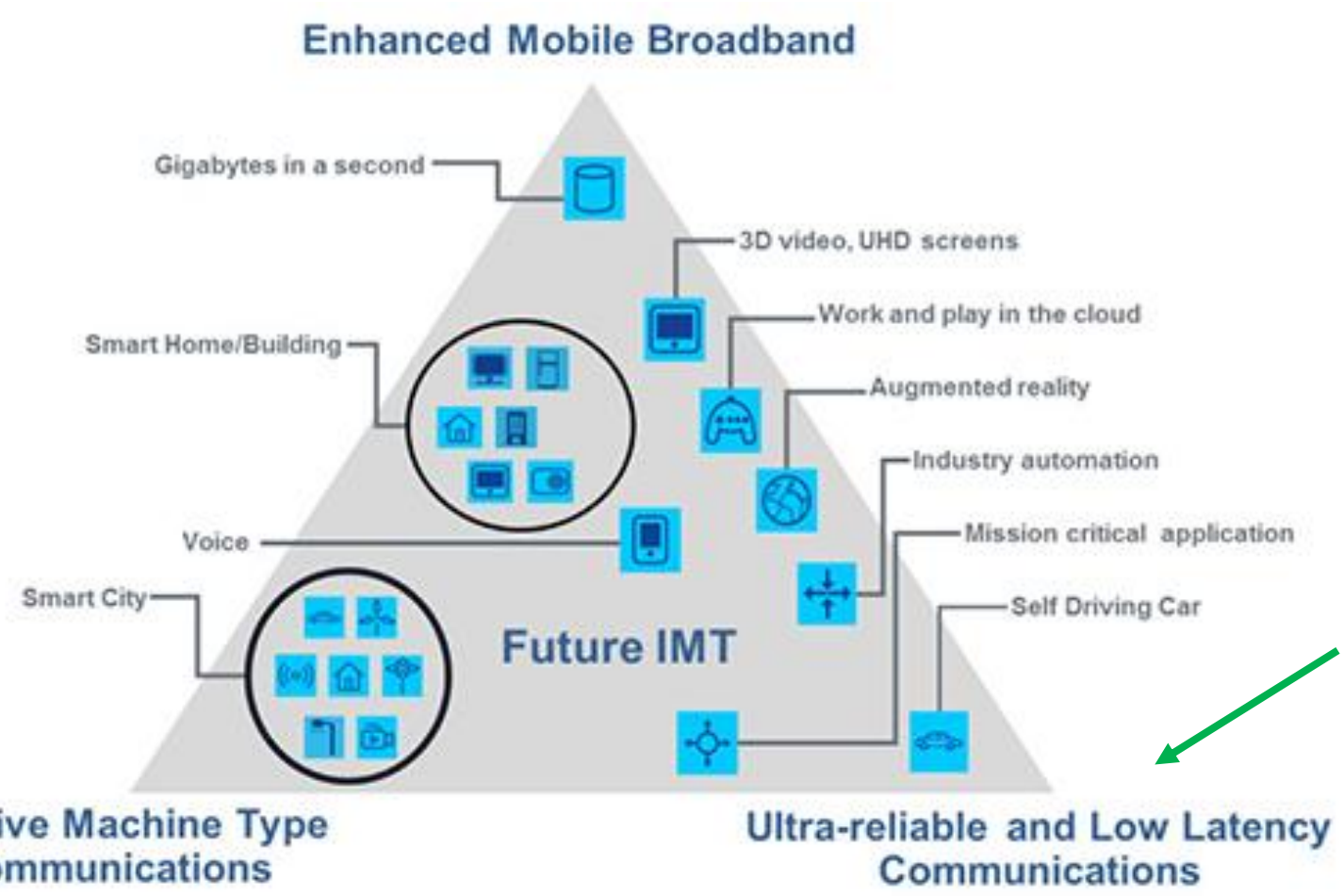
13 CLIMATE ACTION

3 GOOD HEALTH AND WELL-BEING

15 LIFE ON LAND

UN SDGs: Where to go (first) with IoT – and how?

5G to support IoT: good intentions



How?
When?

Supporting features in standard releases

© ITU: vision and requirements for 5G

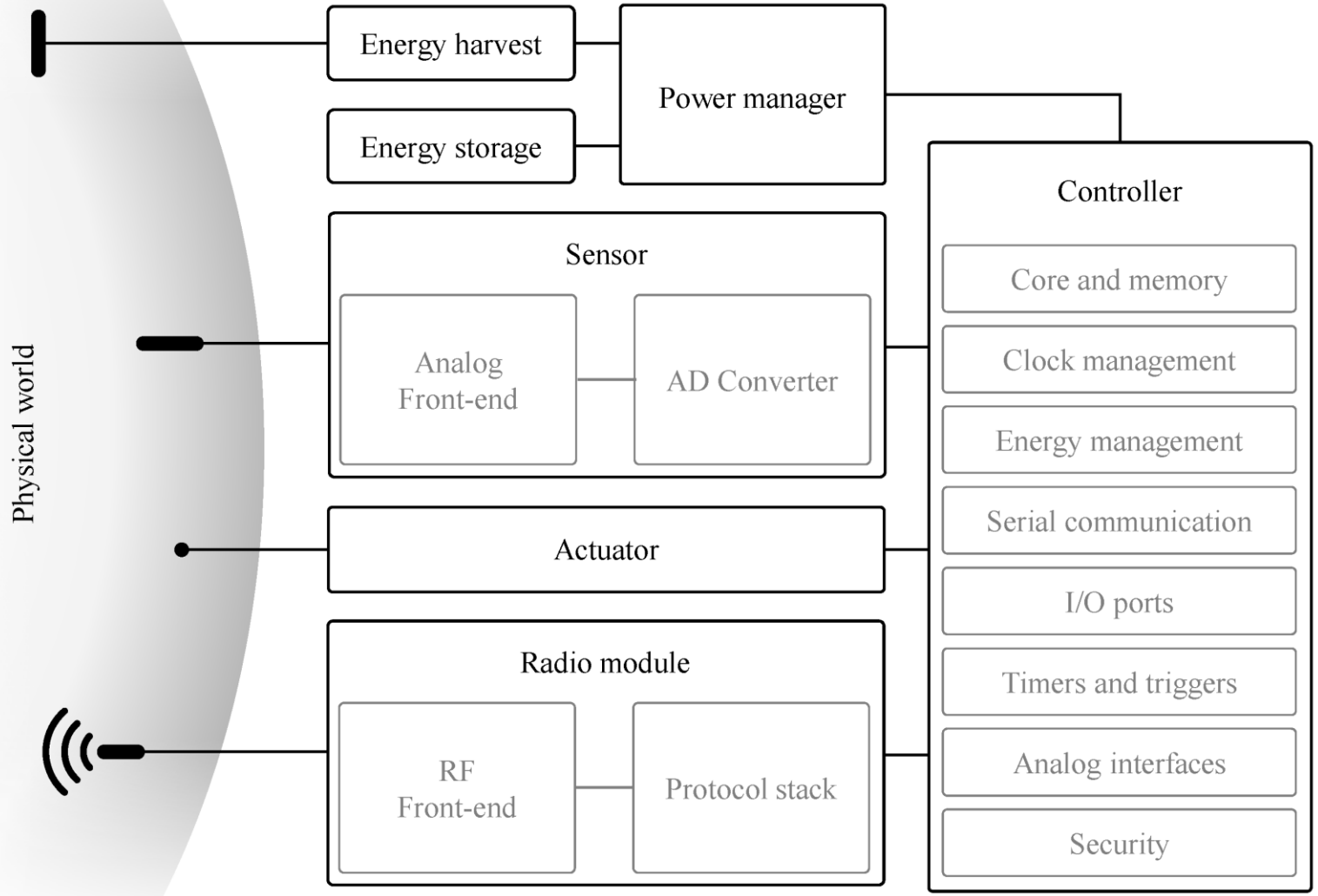
IoT defined, exemplary case, and the SDGs

Anatomy and operation of IoT nodes

(How) could 6G help?

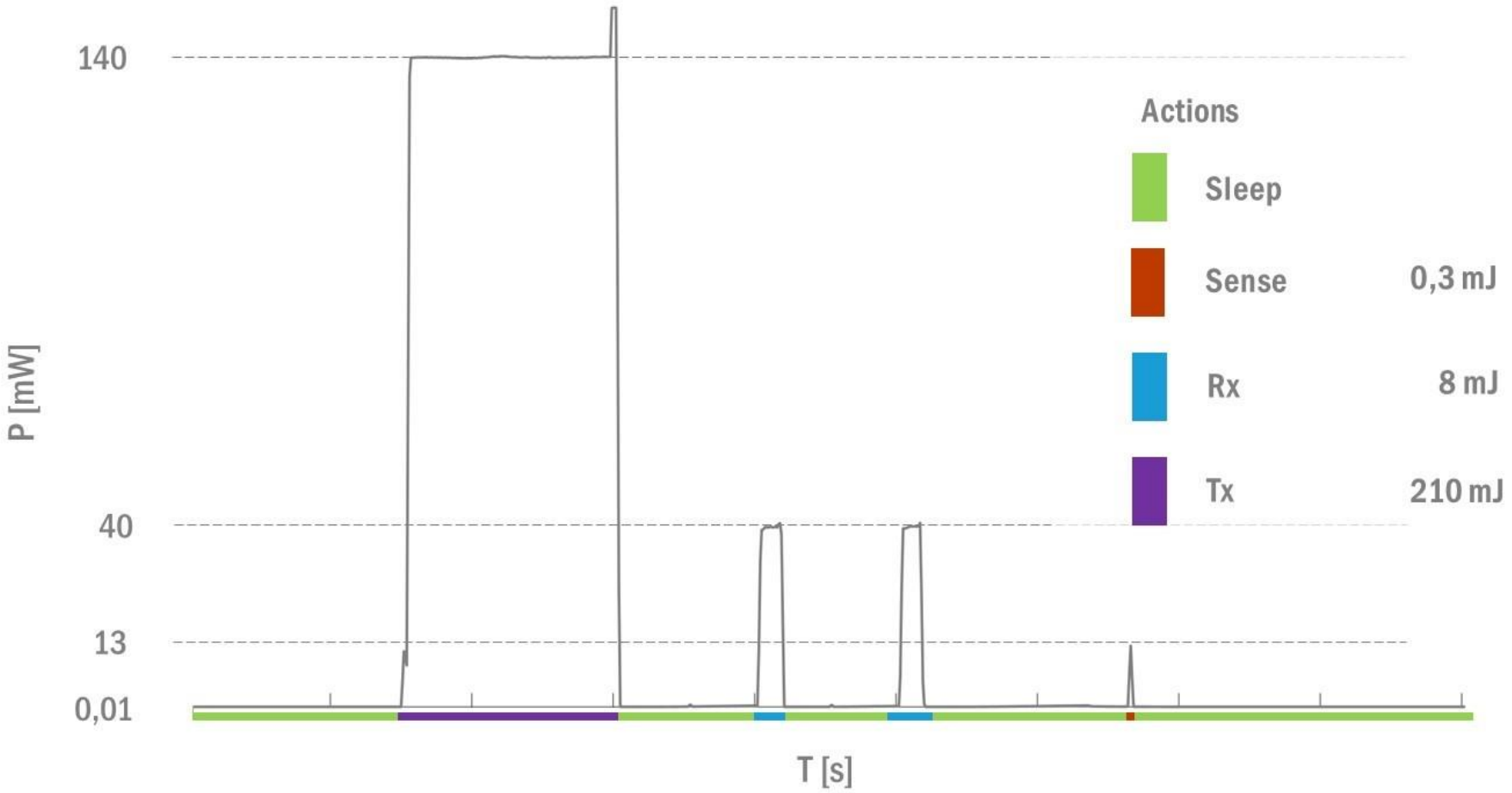
IoT on the road to the SDGs: vehicle or bandit?

Anatomy of an IoT node



Sensors on bridges communicate to update their health

batteries eventually drain out



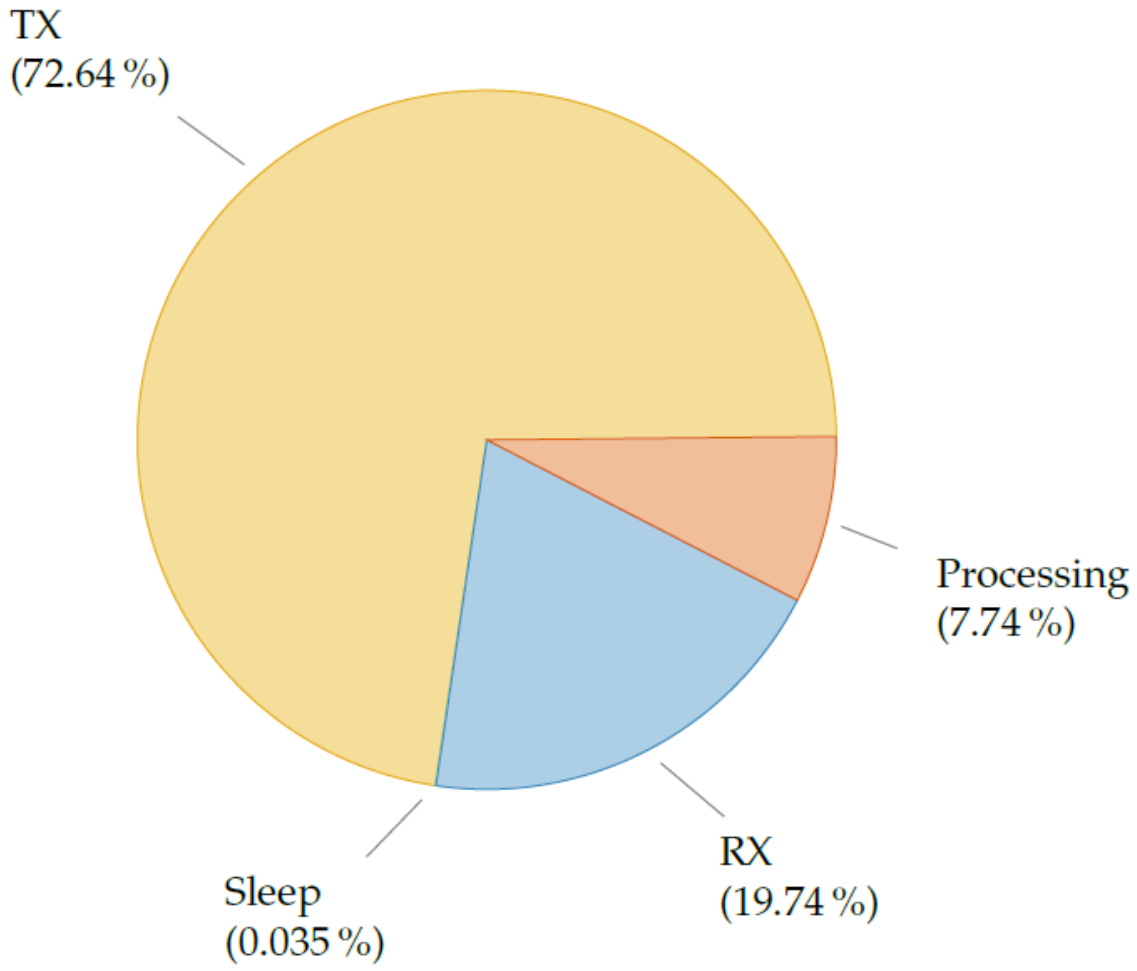
~1V, ~150mAh

Transmit message 6/h?

Transmit message 2/day?

1/week + on demand?

Representative case: power consumption in remote IoT node

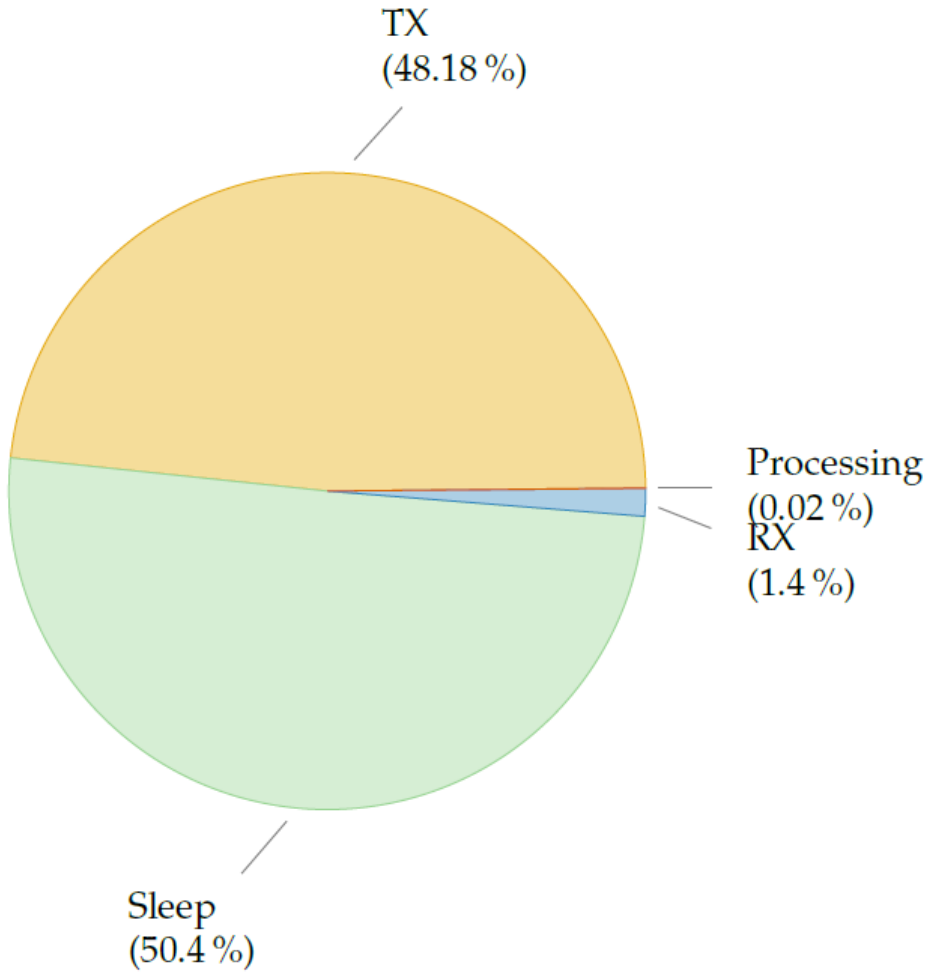


Listen very carefully

Sleep as much as possible

KU LEUVEN

Representative case: energy consumption remote IoT node



Think before you talk

Sleep quietly

KU LEUVEN

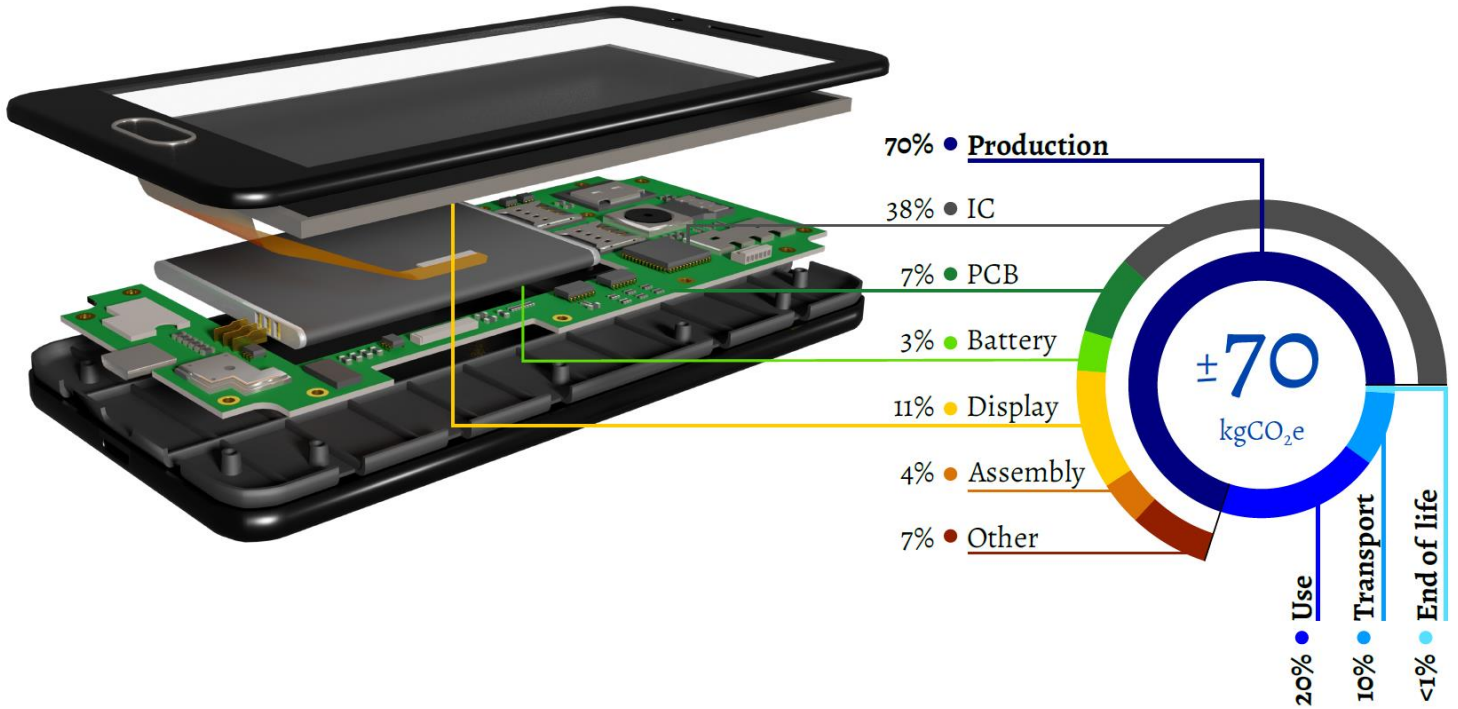
Challenges in IoT node: Power and Energy!

- Power consumption will heat your system
- Energy consumption will drain your battery

Requires meticulous engineering:

1. In design: selecting appropriate technologies
2. In operation: efficient strategies

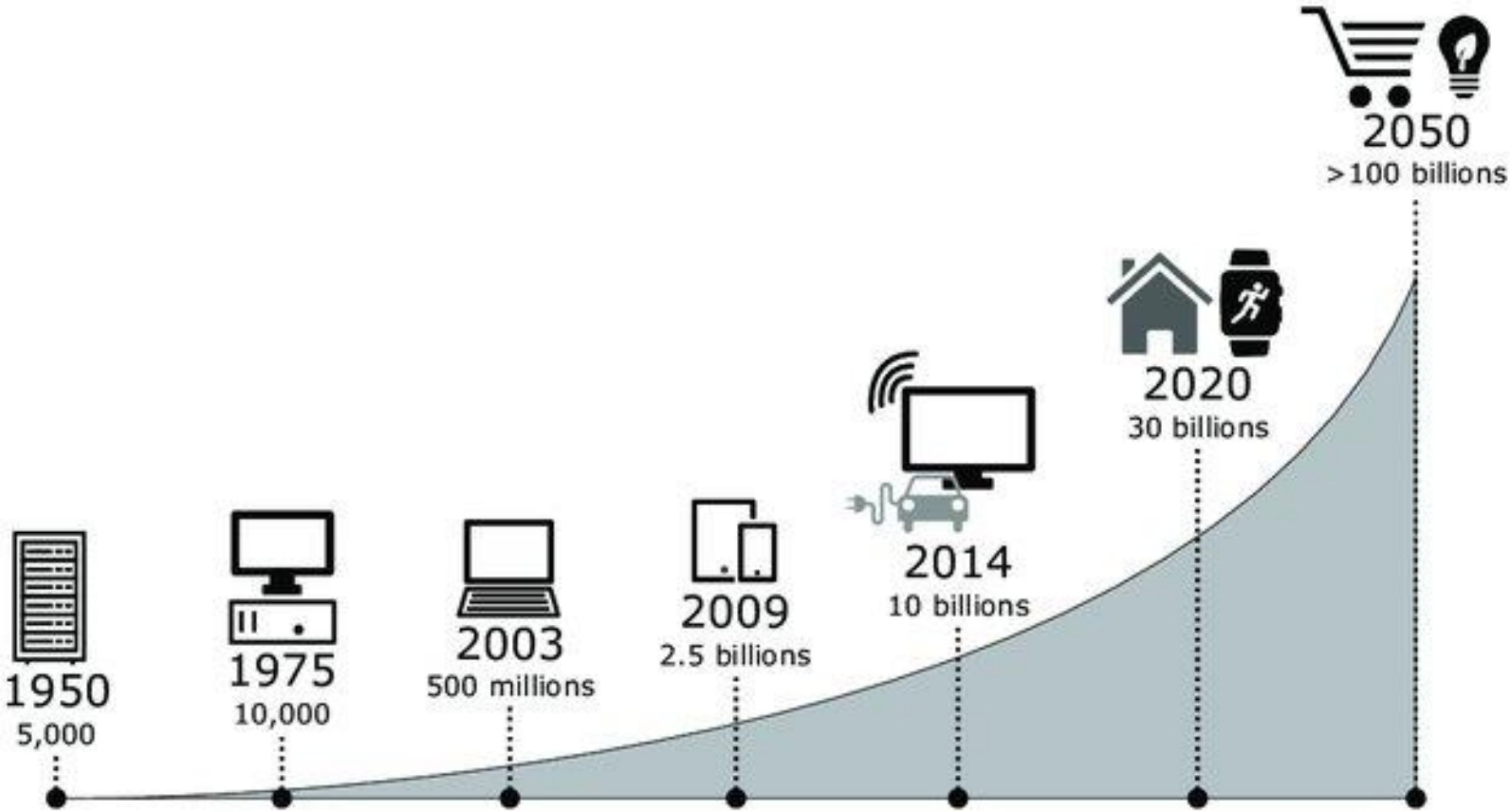
Carbon footprint of electronics: higher than operating consumption



T. Pirson and D. Bol, “Assessing the embodied carbon footprint of IoT edge devices with a bottom-up life-cycle approach,” *Journal of Cleaner Production*, vol. 322, p. 128966, 2021

*dashboard SDGs Belgium

The problem can get worse than a disrupted service



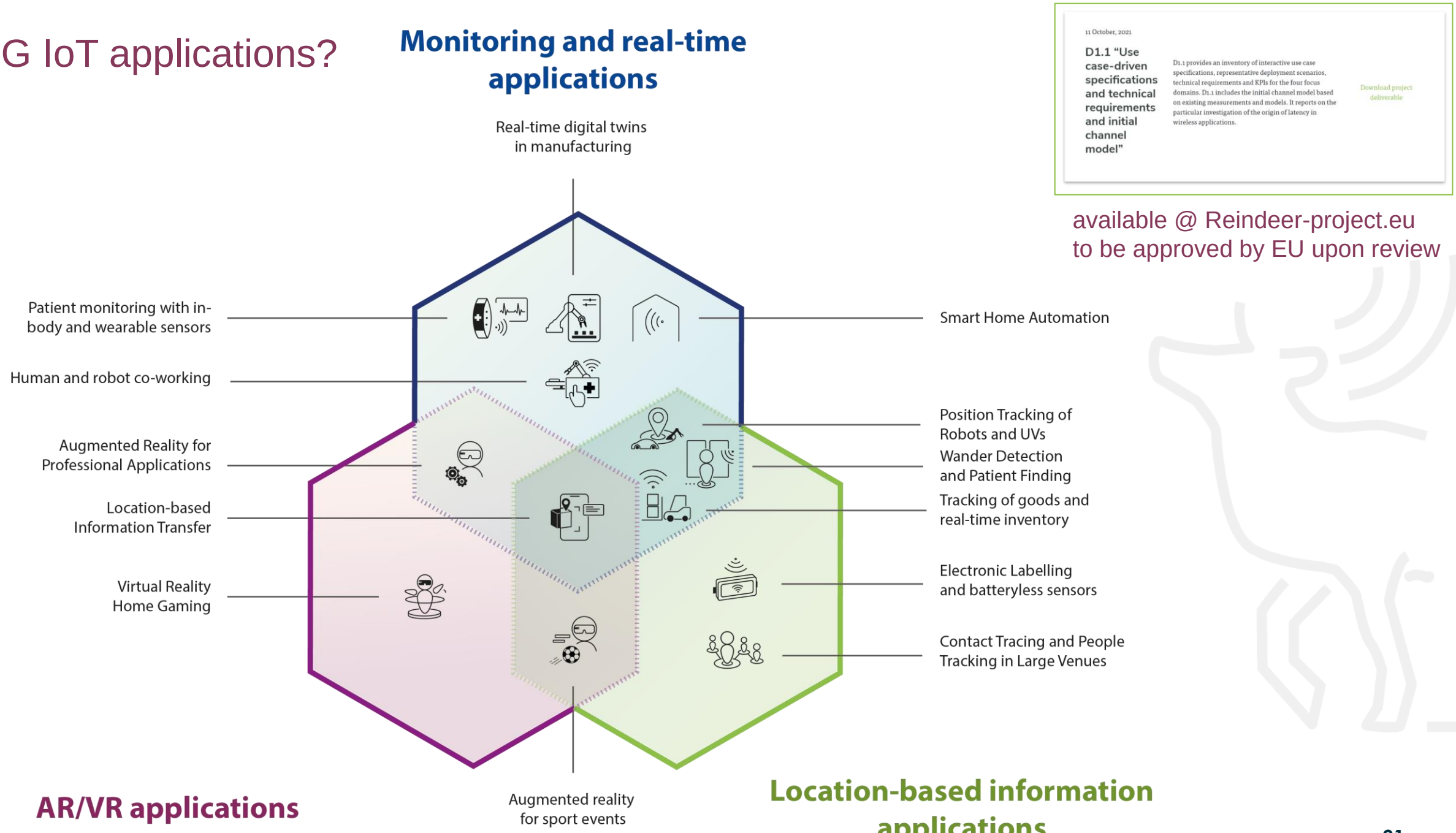
IoT defined, exemplary case and the SDGs

Anatomy and operation of IoT nodes

(How) could 6G help?

IoT on the road to the SDGs: vehicle or bandit?

6G IoT applications?



11 October, 2021

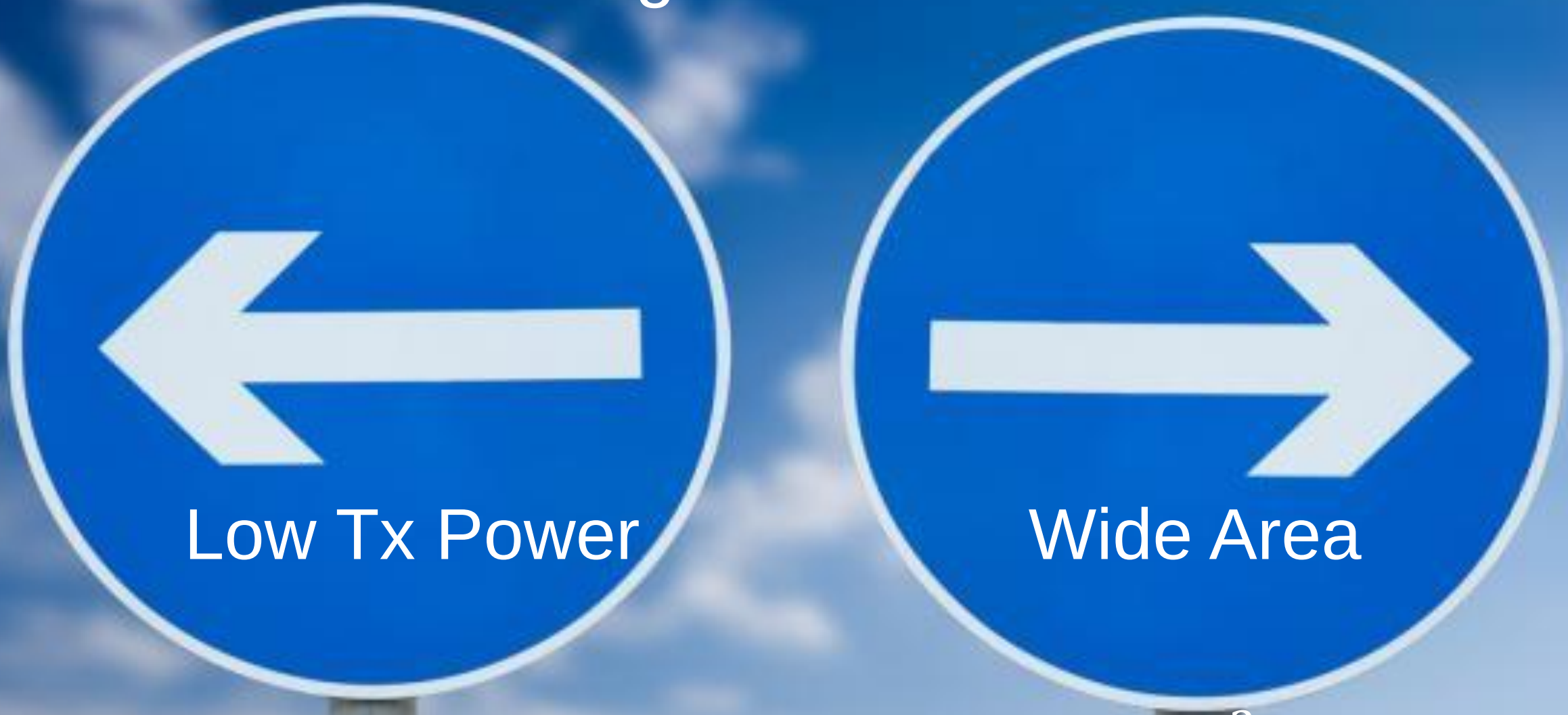
D1.1 "Use case-driven specifications and technical requirements and initial channel model"

D1.1 provides an inventory of interactive use case specifications, representative deployment scenarios, technical requirements and KPIs for the four focus domains. D1.1 includes the initial channel model based on existing measurements and models. It reports on the particular investigation of the origin of latency in wireless applications.

Download project deliverable

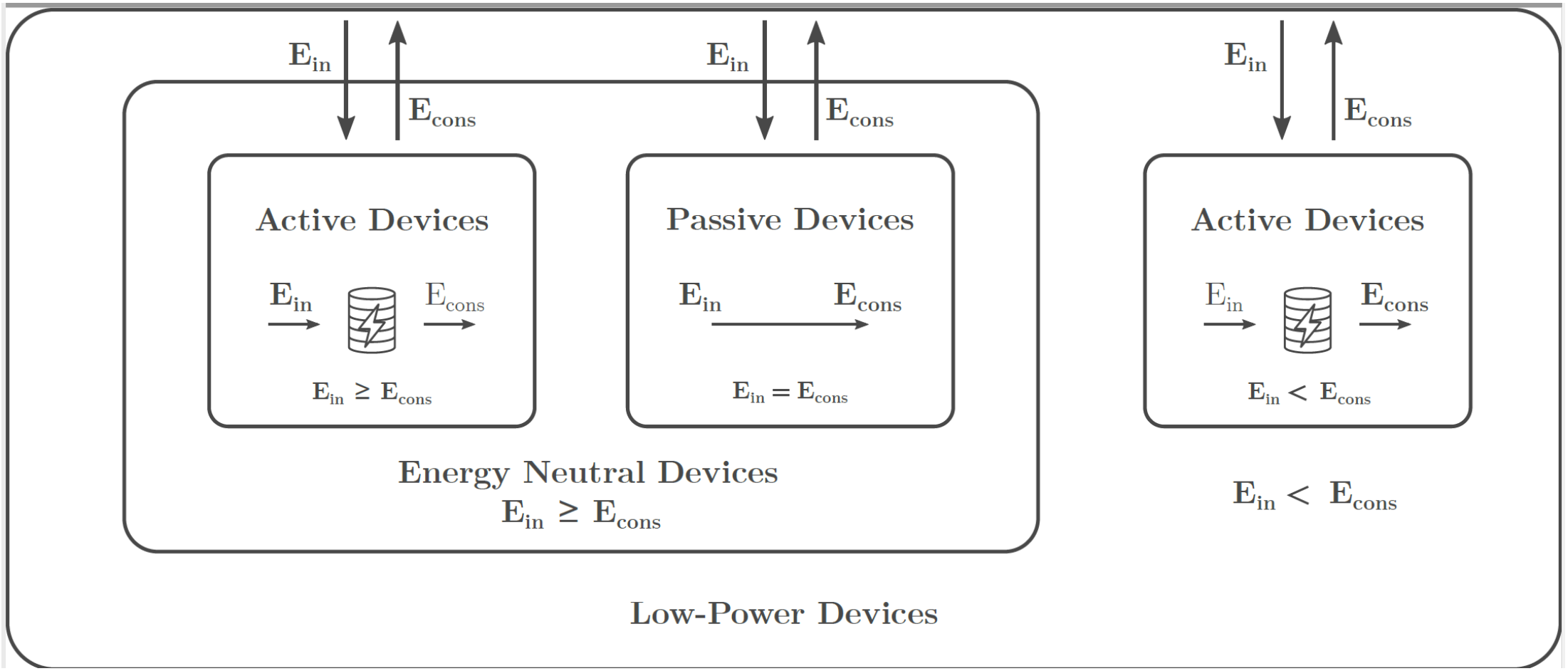
available @ Reindeer-project.eu
to be approved by EU upon review

Defining 6G for remote IoT



$$Power_{Receive} = Power_{Transmit} \cdot \frac{\lambda^2}{(4\pi.distance)^{2+}}$$

Defining 6G for energy-neutral devices



IoT connectivity at long range: to license or not to license?

To pay or not to pay?

© Qualcomm

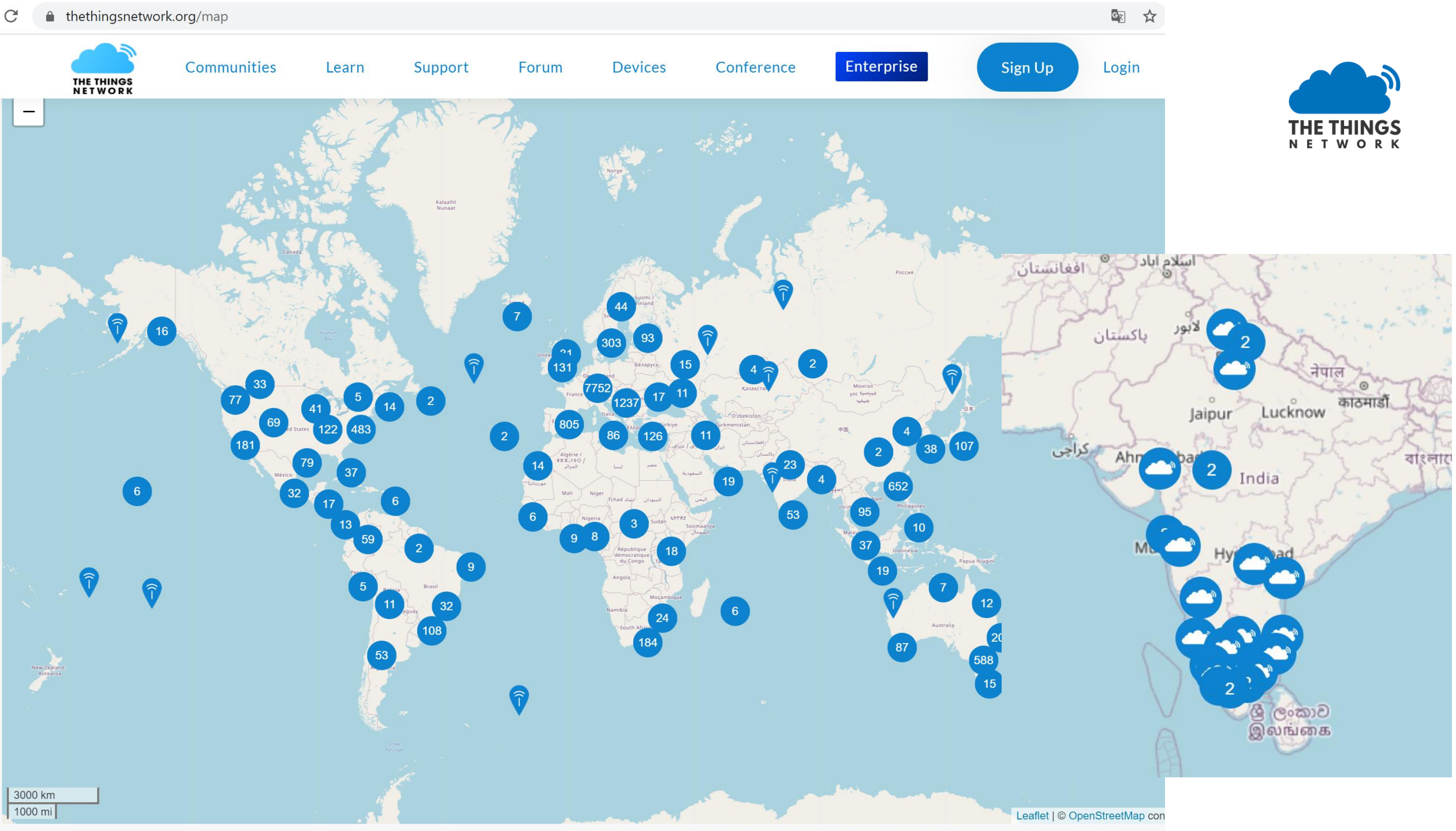
Exclusive use & managed services -> Quality of Service?

LoRaWAN: Different Deployment Strategies

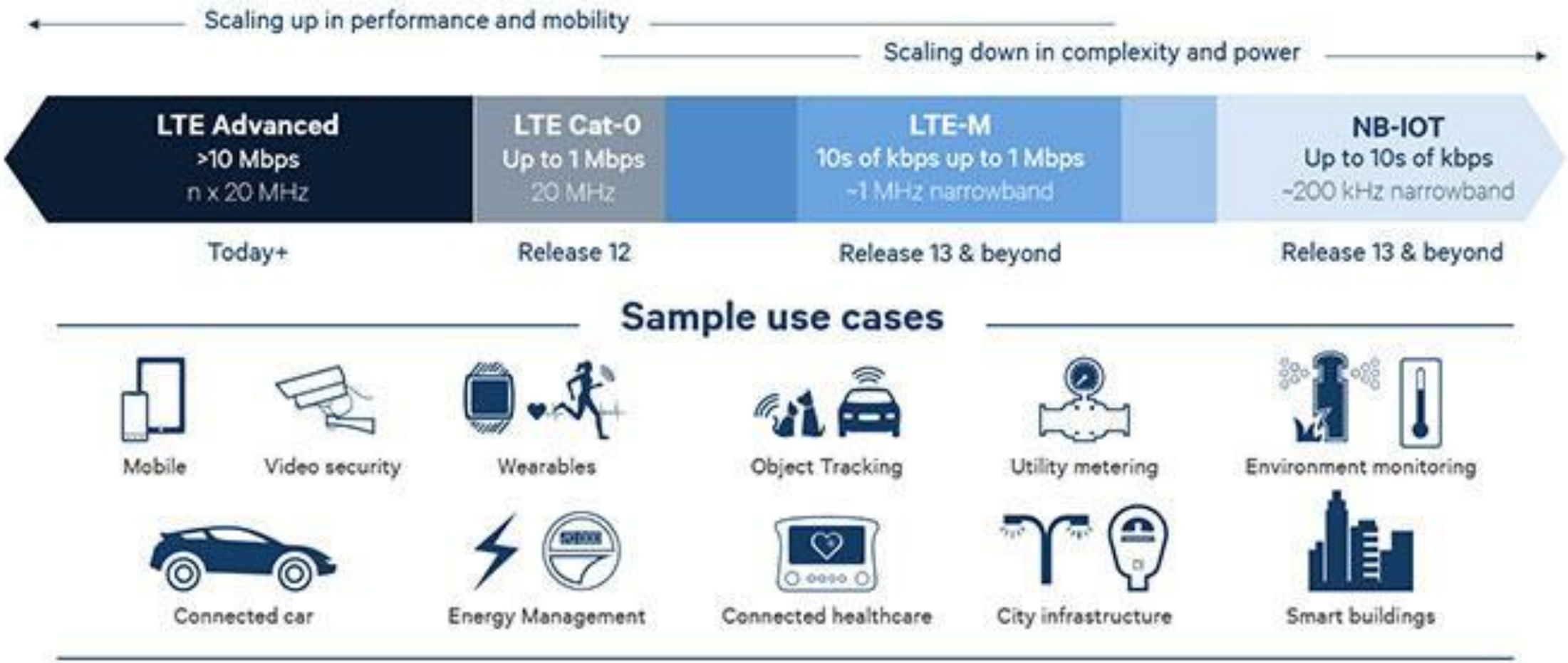
Private Networks

Commercial Networks

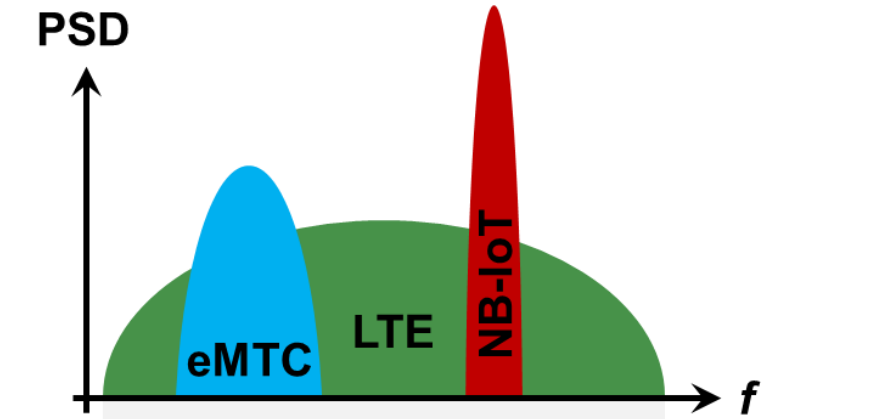
Crowdsourced Networks


thethingsnetwork.org/map
THE THINGS NETWORK
Communities
Learn
Support
Forum
Devices
Conference
Enterprise
Sign Up
Login
THE THINGS NETWORK
3000 km
1000 mi
Leaflet | © OpenStreetMap con
India
Jaipur
Lucknow
काठमाडौं
नेपाल
پاکستان
افغانستان
اسلام آباد
لاہور
کراچی
இலங்கை

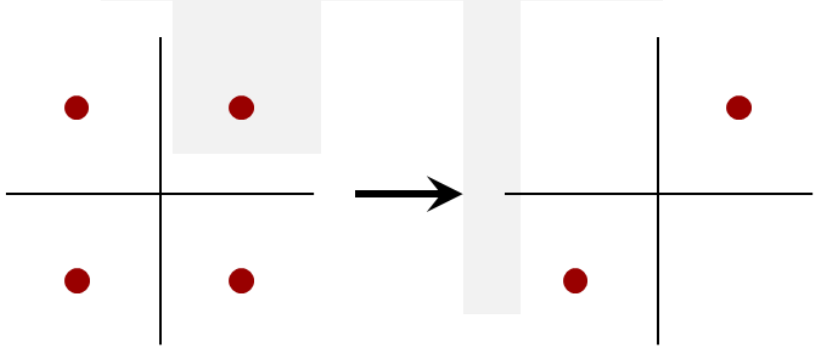
Cellular technologies for IoT: 3GPP standards are key



Coverage: NB-IoT designed to improve



PSD boost in bandwidth as small as 3.75 kHz



Low-PAPR $\pi/2$-BPSK modulation
(and $\pi/4$-QPSK in NB-IoT)

Higher Power Spectral Density (PSD), more robust modulation

NB-IoT can hence operate in lower SNIR Signal-to-Noise and Interference regime

Power consumption: >3x higher than LORA
Energy: packet-size dependent

TABLE VII. CURRENT CONSUMPTION ASSUMPTIONS

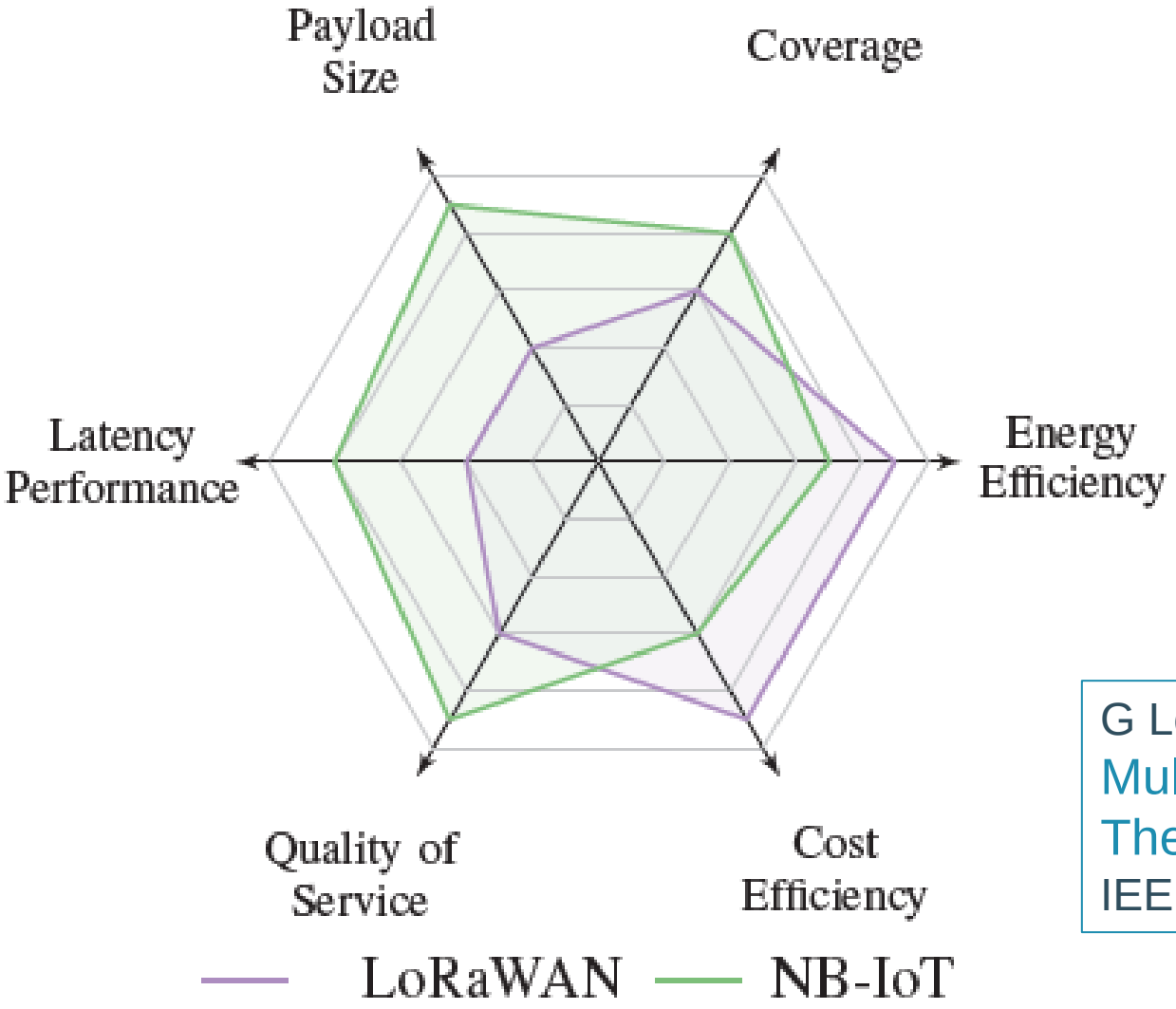
	Power [mW]
Battery power during Tx (assuming 44% PA efficiency)	543
Battery power for Rx	90
Battery power when Idle but not in PSS	2.4
Battery power in Power Save State (PSS)	0.015

NB-IoT System for M2M Communication

Rapeepat Ratasuk, Benny Vejlgaard, Nitin Mangalvedhe, and Amitava Ghosh
Mobile Radio Research Lab, Nokia Bell Labs

+ seldom mentioned:
Impact on network infrastructure consumption

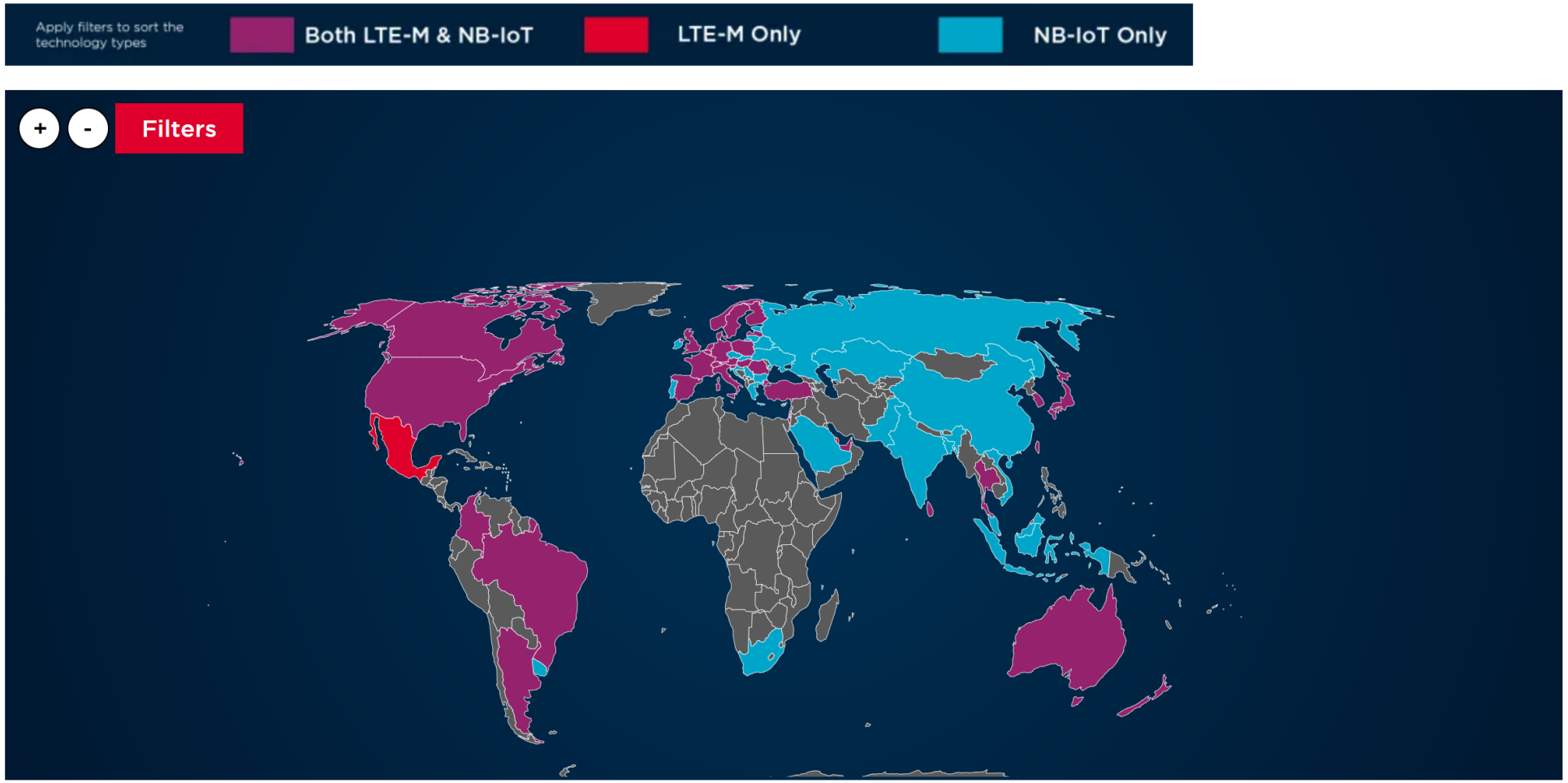
How do LPWAN performances compare? LoRaWAN vs NB-IoT



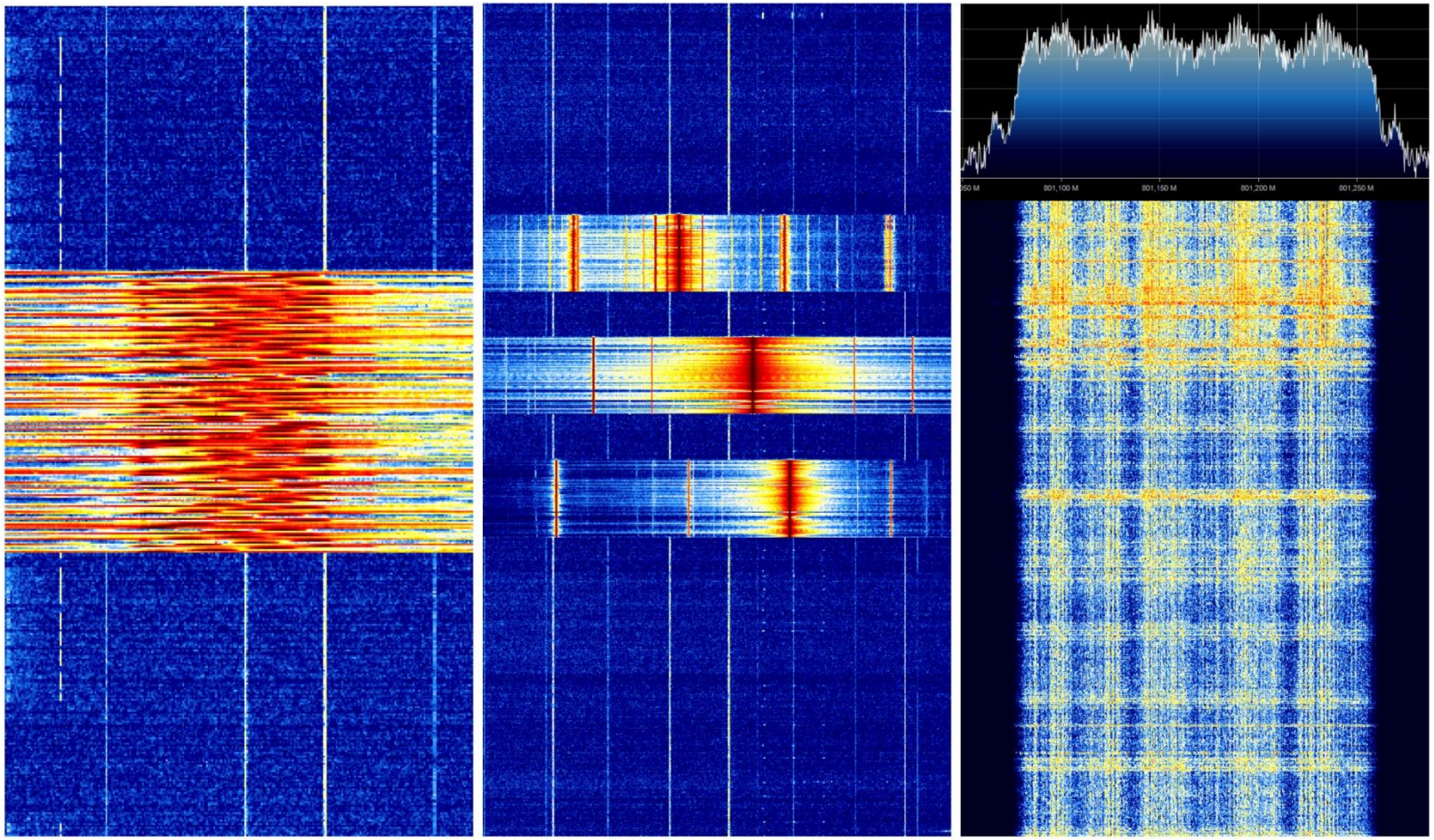
G Leenders et Al. (Dramco team)
Multi-RAT for IoT:
The Potential in Combining LoRaWAN and NB-IoT
IEEE communications Magazine, Dec. 2021

Mobile IoT Deployment Map

This map illustrates the Mobile IoT commercial launches to-date. For a summary list of launches, please visit **Mobile IoT Commercial Launches**. Select the country and scroll down for details.



LPWAN technologies: (very) similar goals, quite different transmission approach



(a) LoRaWAN (125 kHz) (b) Sigfox (100 Hz) (c) NB-IoT (180 kHz)

What is on the 6G innovation wish list for IoT with a tiny footprint*?

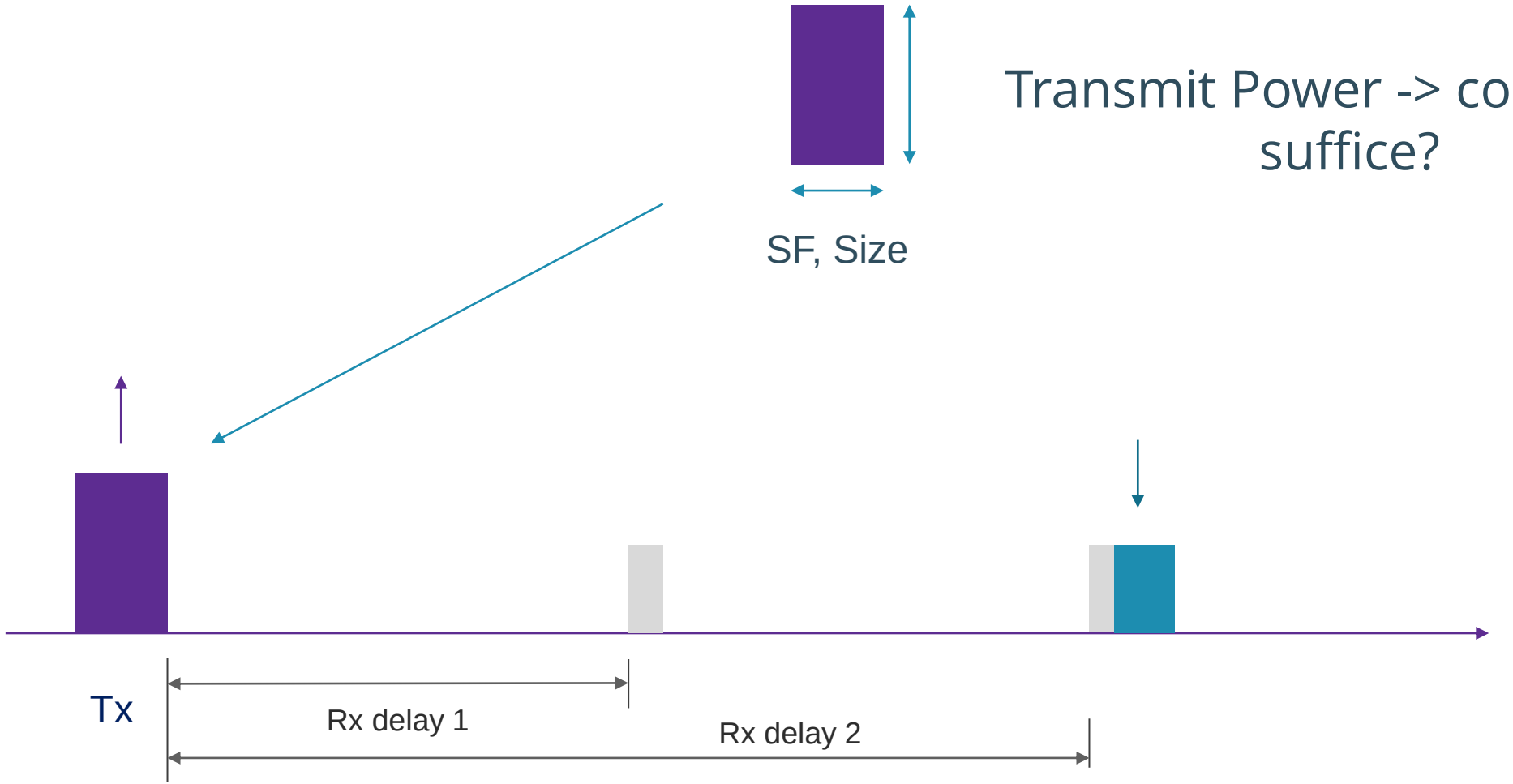
1. Access schemes and networks enabling low power Tx and deep sleep

2. Protocols for efficient control plane for (very) sporadic traffic of a massive number of devices

3. For energy-neutral (potentially battery-less) devices: proximity of the access infrastructure (distributed architectures) and large array gain

*For zero-ecological footprint electronics, contact the marketing department, or implement 100% sleep time

To increase energy efficiency: Address the big spender



Transmit Power -> could less suffice?

Reception with large arrays (massive MIMO) to listen very carefully – reduce IoT node transmit power

R&D and experiments focused on operation in unlicensed 868MHz band
Movie including link to open data: https://dramco.be/iot/

IoT defined, exemplary case and the SDGs

Anatomy and operation of IoT nodes

(How) could 6G help?

IoT on the road to the SDGs: vehicle or bandit?

Self-impact IoT technology introduction

- Carbon footprint devices
- Clean water usage in productions
- Material usage devices
- Toxics left behind
- Increased power consumption in the network

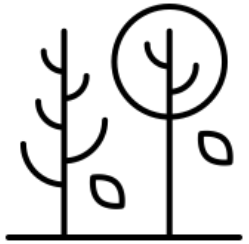
< ?

Impact through applications

- Vehicle opportunities: many e.g. carbon footprint reduction could be >> larger than self-impact
- Bandit treats: diverse

IoT versus the SDGs: the technology can be a vehicle

IoT can help to address ‘hard’ problems in ‘soft‘ themes: connecting for a sustainable future



Use case bike sharing system: eases access and improves tracking of bikes

NB-IoT connectivity

Contactless sensing

IOASE: zones and periods of silence in cities, schools

Noise nuisance monitoring to raise awareness and support control

Student-team project: monitoring @ sea

IoT Sensors Reveal New Ways for Manufacturers to Cut Energy Usage

Removing inefficiencies on the factory floor and in the supply chain can cut costs

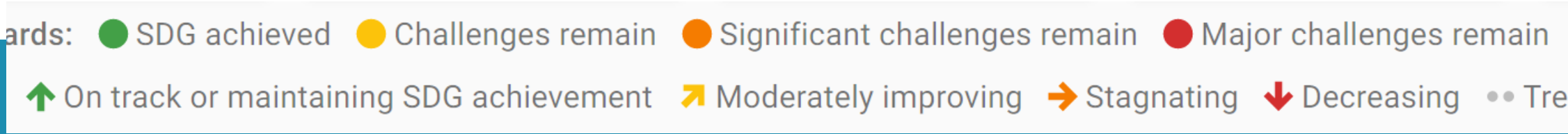
By **Stacey Higginbotham**

The next big effort to reduce carbon emissions and hold the line on climate change will be enabled by the Internet of Things. Companies can rethink their costs of operations, taking into account the energy used, with a combination of more granular data from cheap sensors and faster, more in-depth analytics from cheap computing.

At Schneider Electric's factory in Lexington, Ky., workers make electric

IEEE spectrum, Sept. 2018

*dashboard SDGs western country



IoT versus the SDGs: warning for the bandit

Caricature by Italian artist Giacomo Cardelli

Moreau, N.; Pirson, T.; Le Brun, G.; Delhaye, T.; Sandu, G.; Paris, A.; Bol, D.; Raskin, J.-P. **Could Unsustainable Electronics Support Sustainability?** *Sustainability* **2021**, *13*, 6541.

‘Digital Divide’: today, we do not reach people equally

“Digital literacy has become a source of (gender) inequality and vulnerability, which increased in the COVID-19 crisis. The EU has recently laid out in its strategy “Shaping Europe’s digital future” that technology should ‘work for people’. Digital solutions should be inclusive and promote technology adoption.”

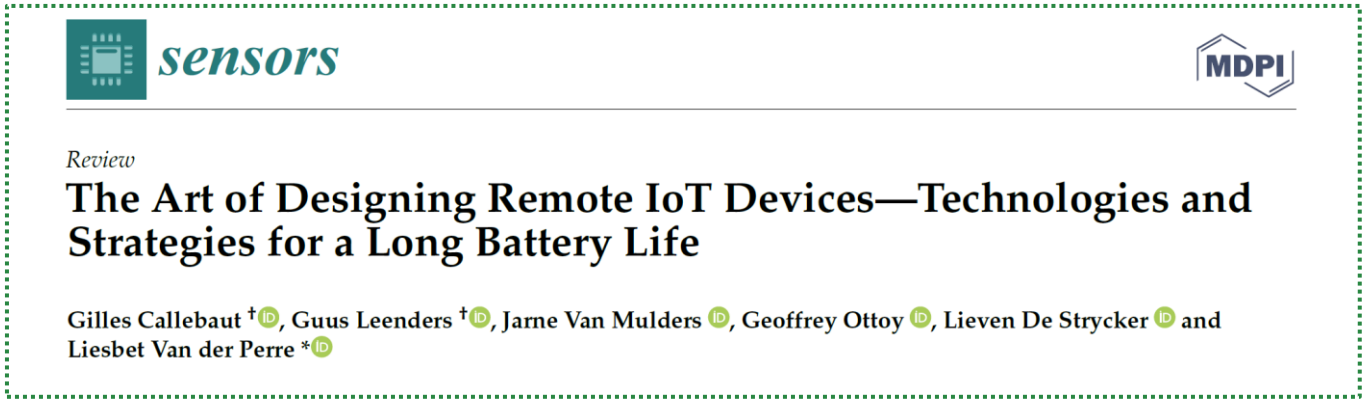
Vehicle or bandit?

‘Design is freedom of choice’

Prof. Jan Rabaey, UC Berkeley

IoT technology and 6G innovation needed

Circular IoT: adopt design-for-reuse strategies



sensors

MDPI

Review

The Art of Designing Remote IoT Devices—Technologies and Strategies for a Long Battery Life

Gilles Callebaut †, Guus Leenders †, Jarne Van Mulders, Geoffrey Ottoy, Lieven De Strycker and Liesbet Van der Perre *

KU LEUVEN