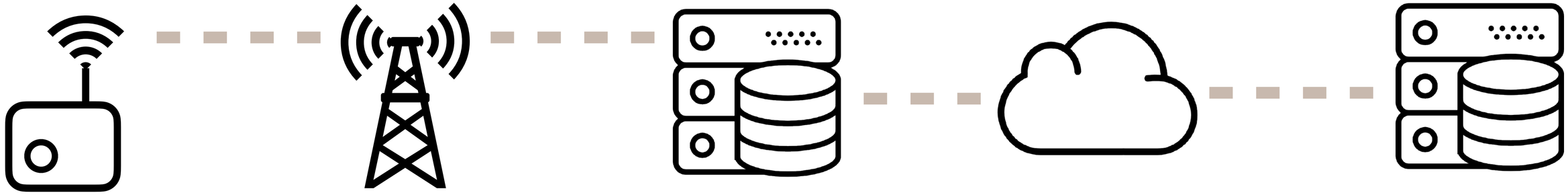
IOT TRAINING SESSION #2 | ISEP | © 2021-24 TG 

INTERNET OF THINGS

PREVIOUSLY

Introduction to IoT

IOT VALUE CHAIN



Connected Device

IoT Network

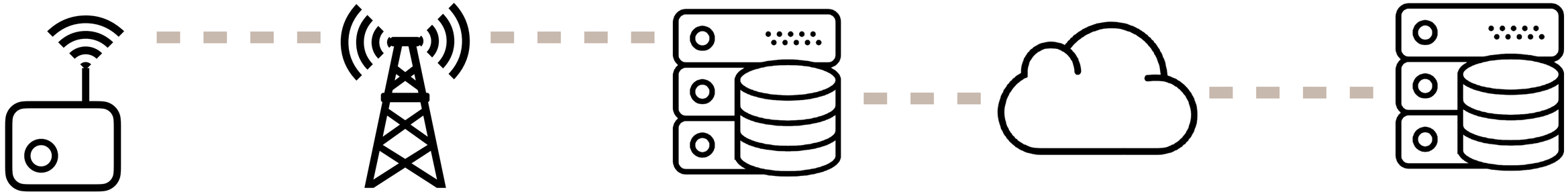
IoT Platform

Internet | VPN Connection

Business Application

IOT PLAYERS

Solutions Providers



Objects Makers

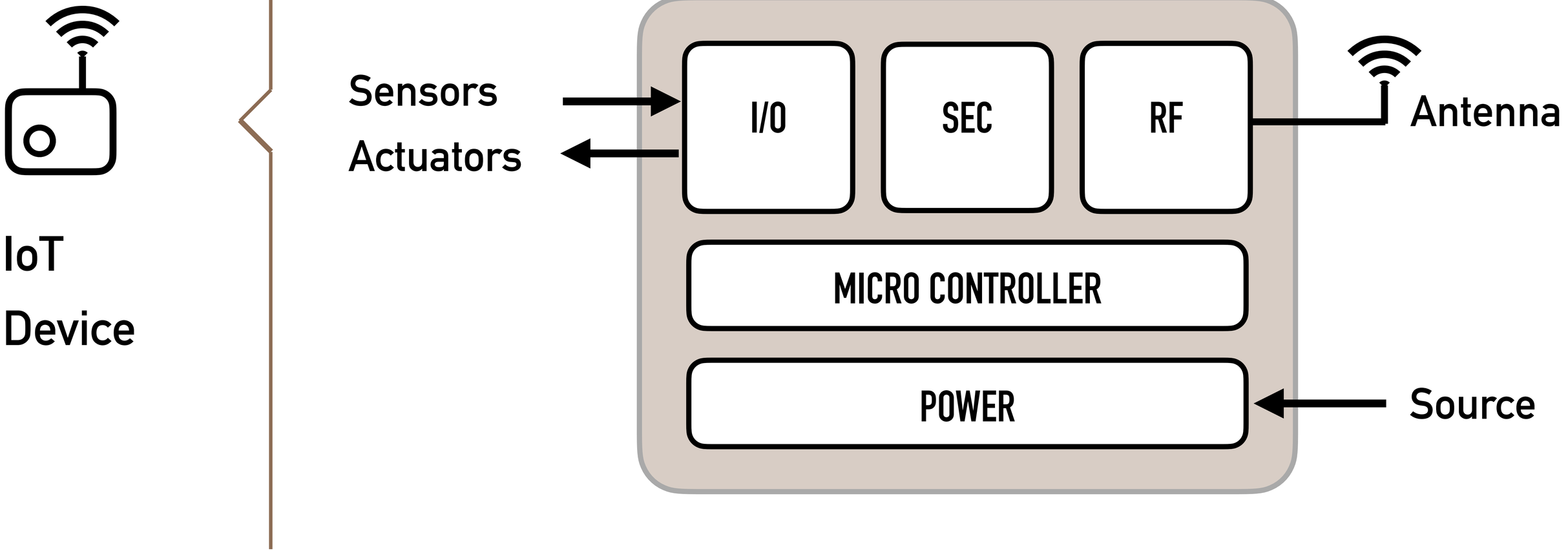
Operators

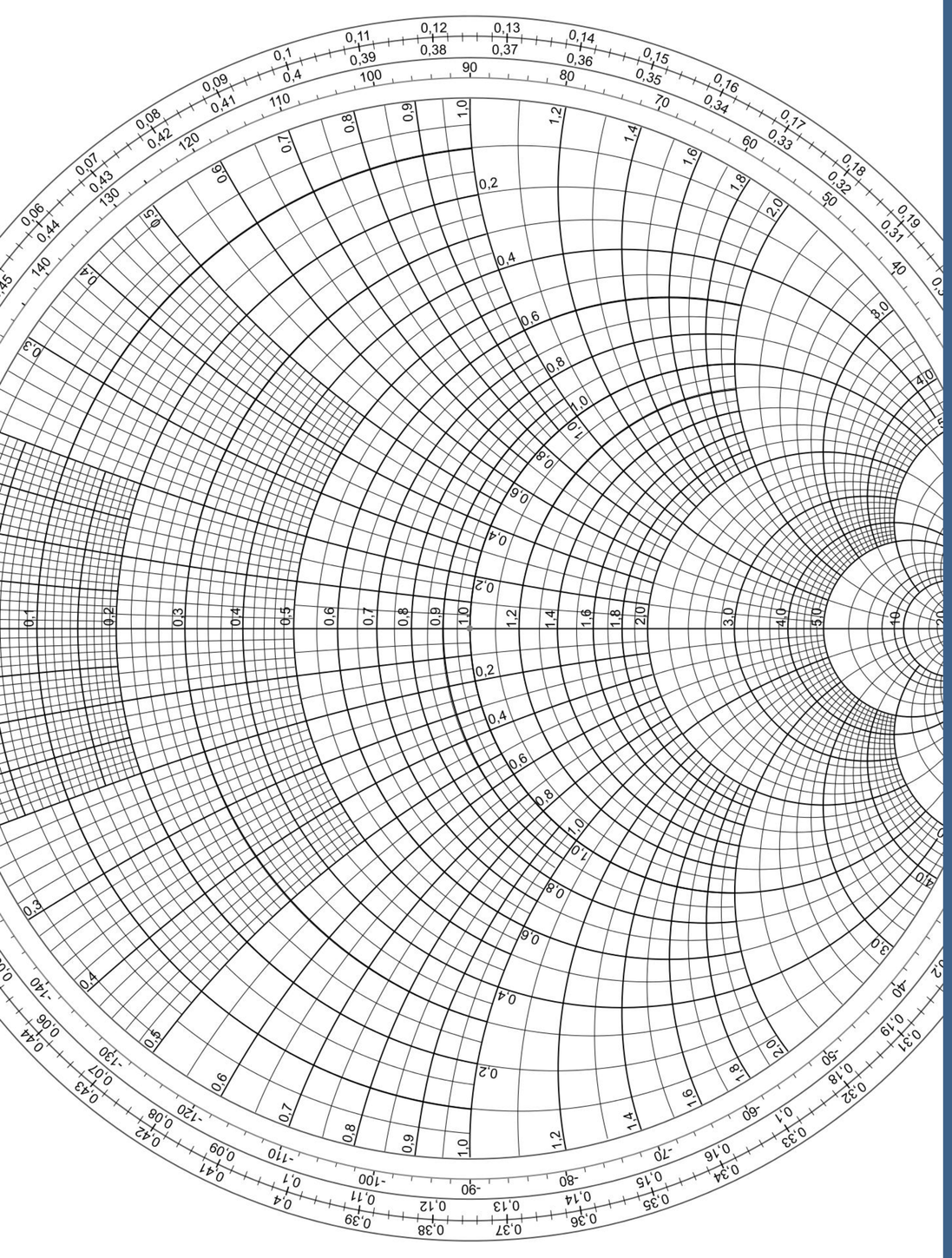
Cloud Providers

Apps Editors

Systems Integrators

IOT: PHYSICAL, SMART, CONNECTED DEVICES





IOT NETWORKS

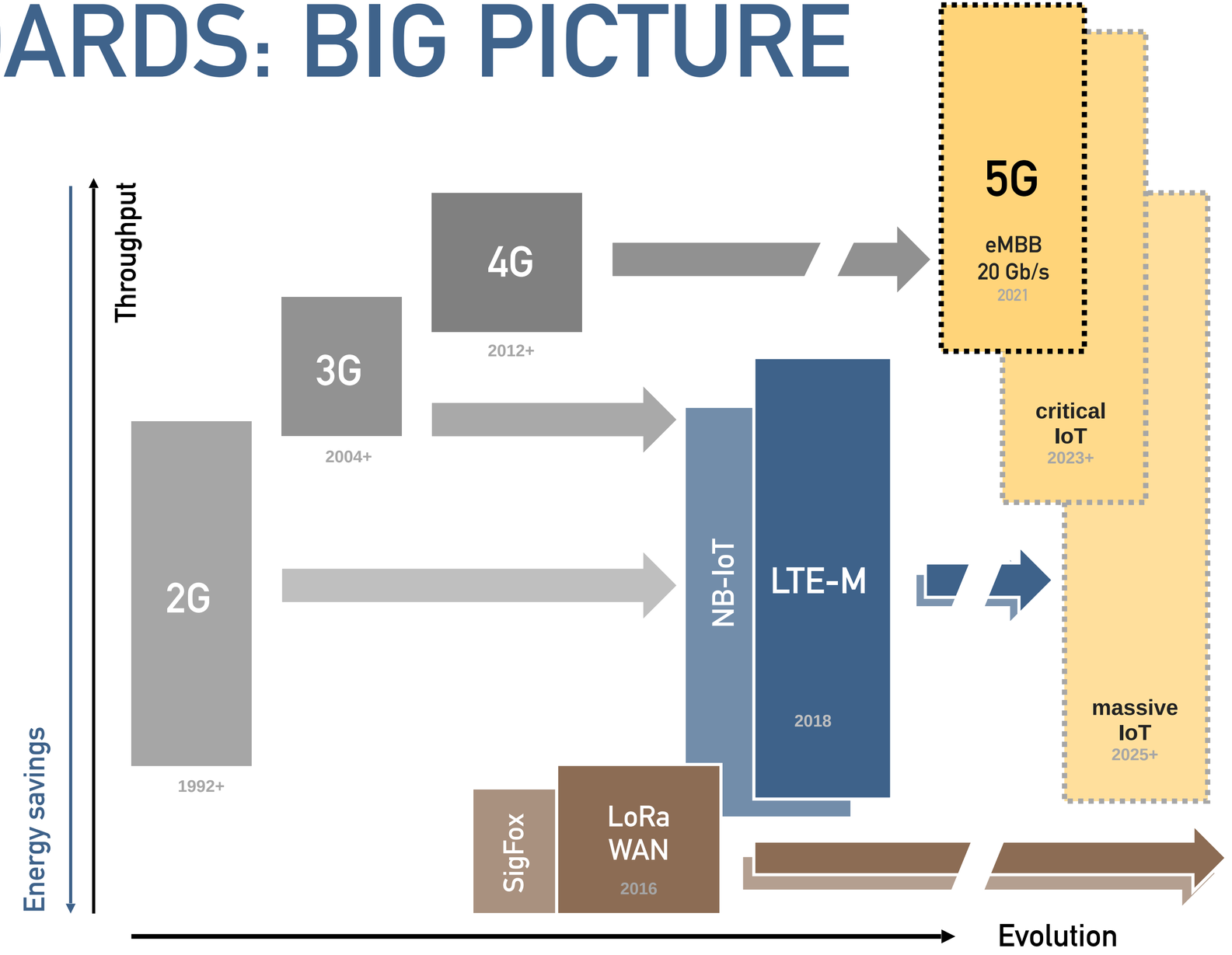
Wireless connectivity

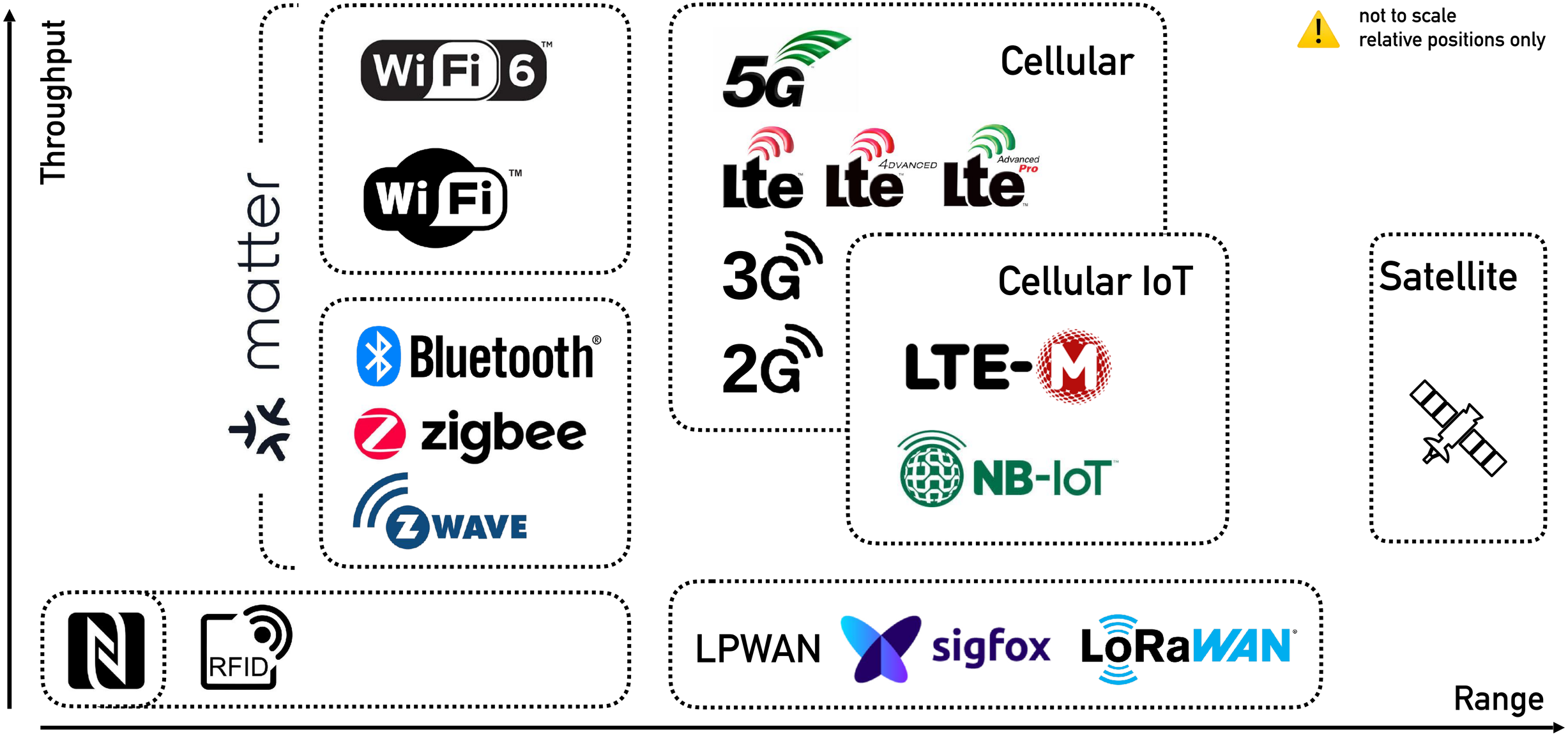
MOBILE STANDARDS: BIG PICTURE

Cellular

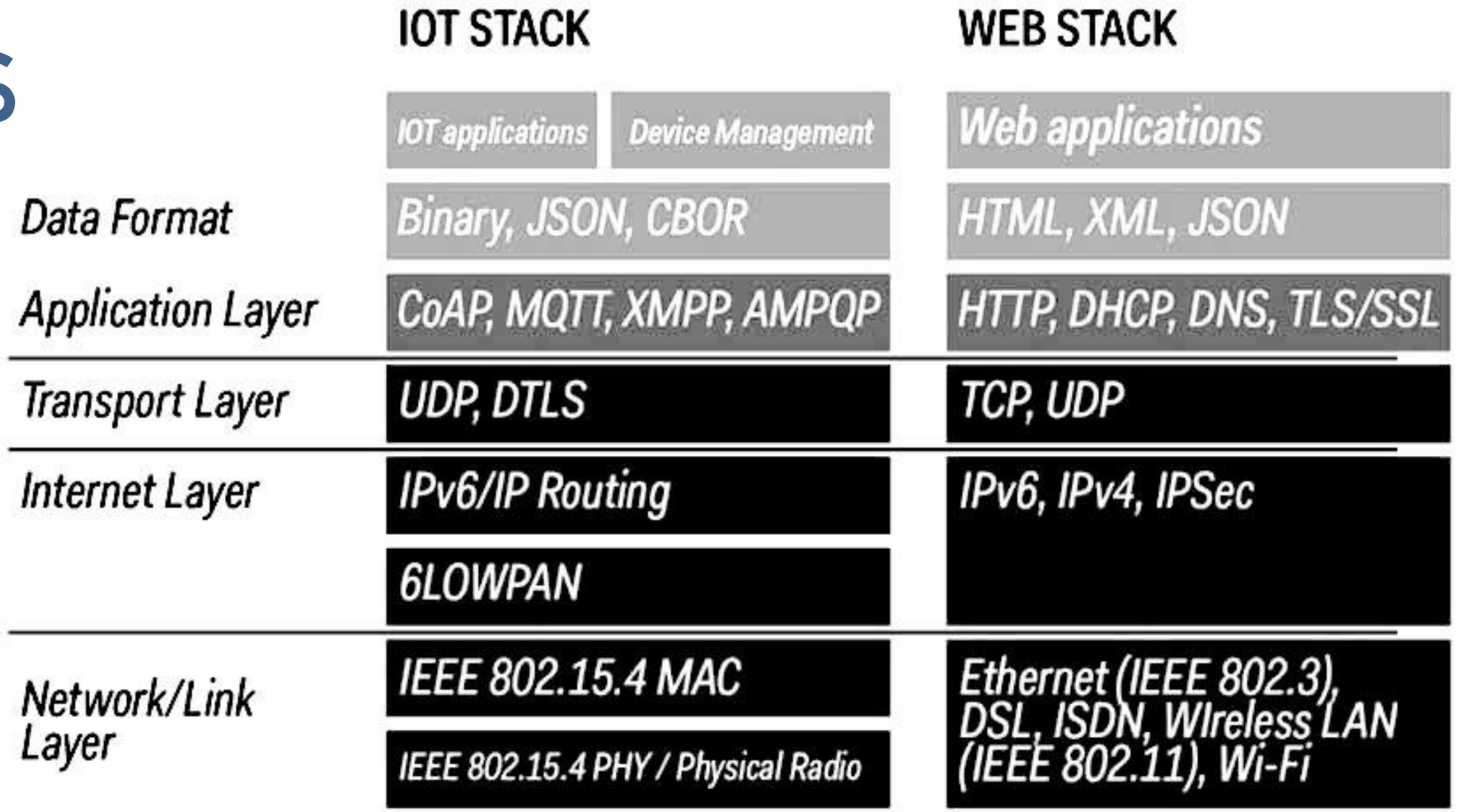
Cellular IoT

LPWAN / ISM bands



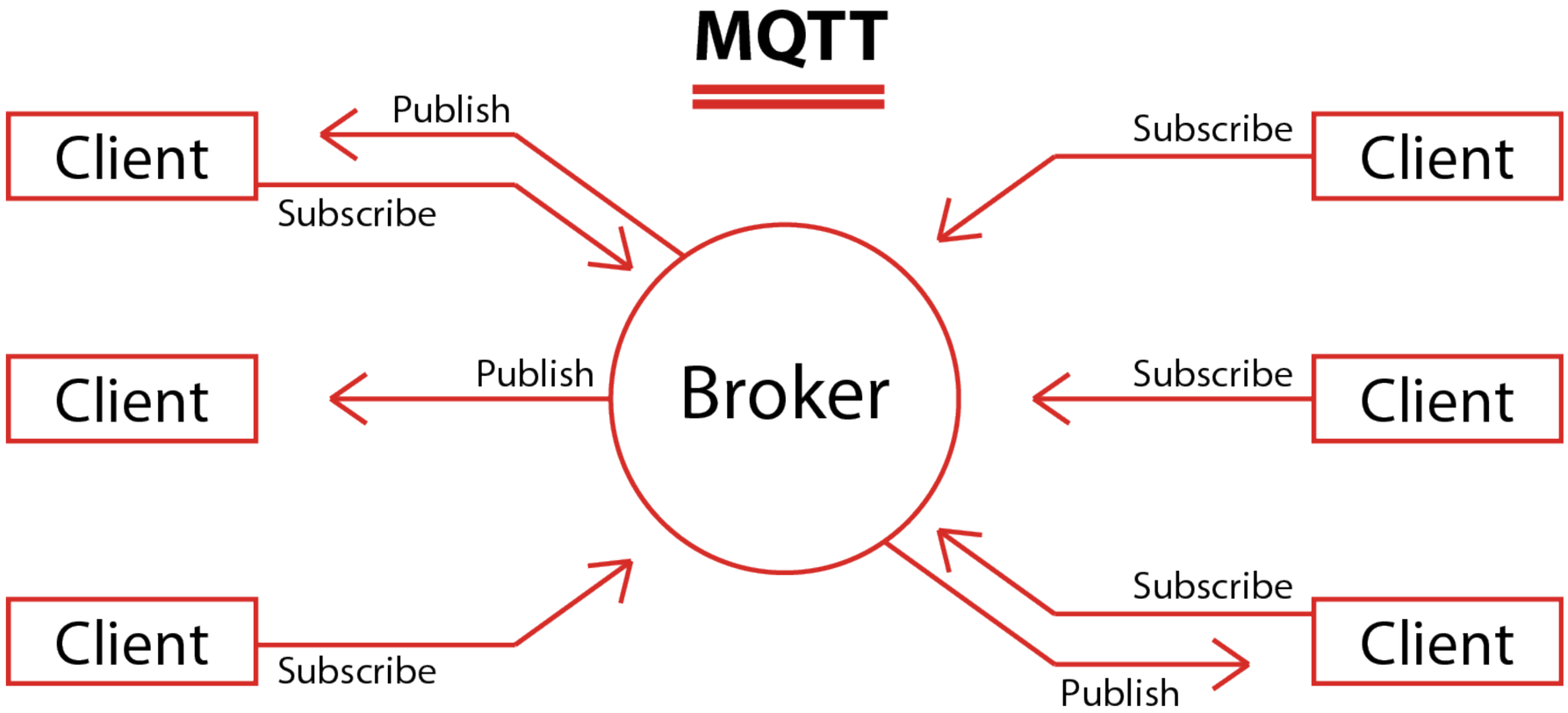

Throughput
matter
Wi Fi 6
Wi Fi
Bluetooth
zigbee
Z-WAVE
5G
Cellular
Lte
Lte Advanced
Lte Advanced Pro
3G
2G
Cellular IoT
LTE-M
NB-IoT
not to scale
relative positions only
Satellite
RFID
LPWAN
sigfox
LoRaWAN
Range

IOT VS. WEB STACKS



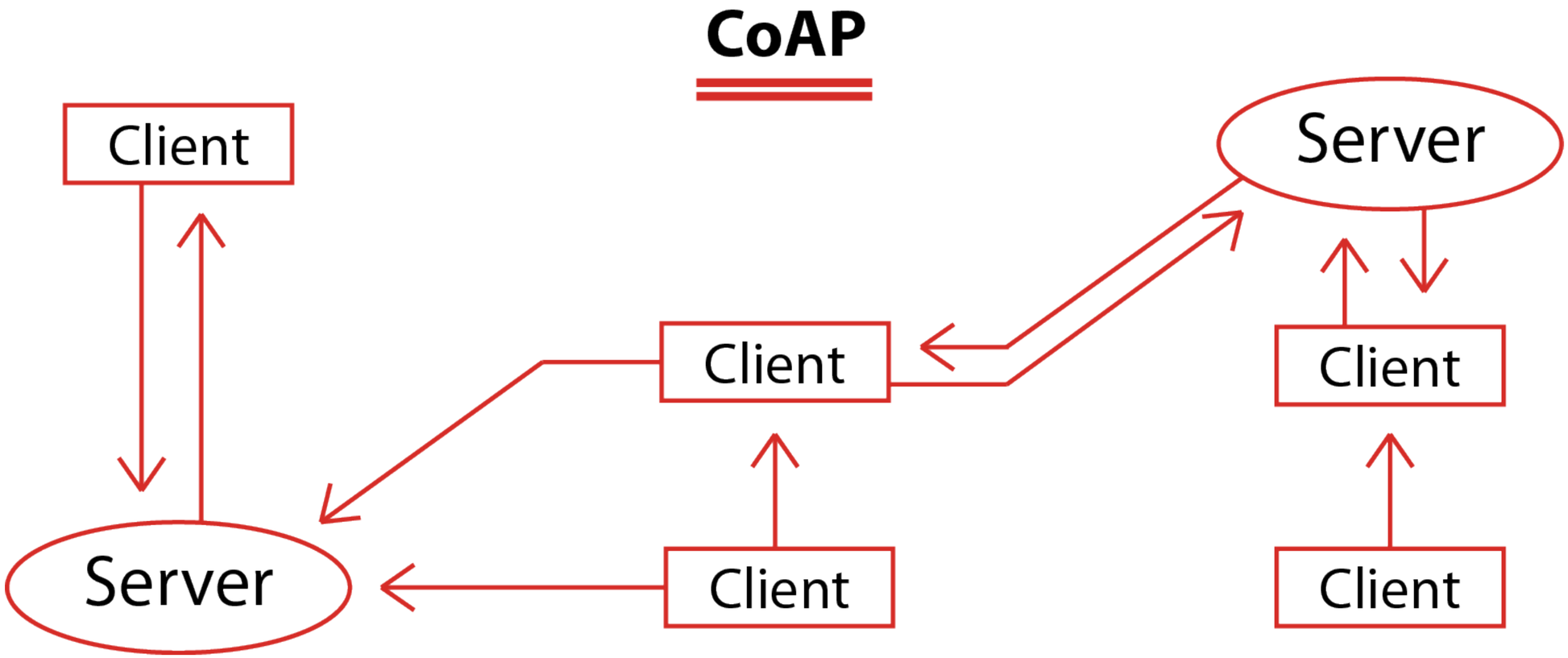
MQTT

Message Queue Telemetry Transport: publish-subscribe protocol that facilitates one-to-many communication mediated by brokers.
Clients can publish messages to a broker and/or subscribe to a broker to receive certain messages. Messages are organized by topics, which essentially are "labels" that act as a system for dispatching messages to subscribers.



COAP

Constrained Application Protocol: client-server protocol not yet standardized.
A client node can command another node by sending a CoAP packet.
The CoAP server will interpret it, extract the payload, and decide
what to do depending on its logic and acknowledge it or not.



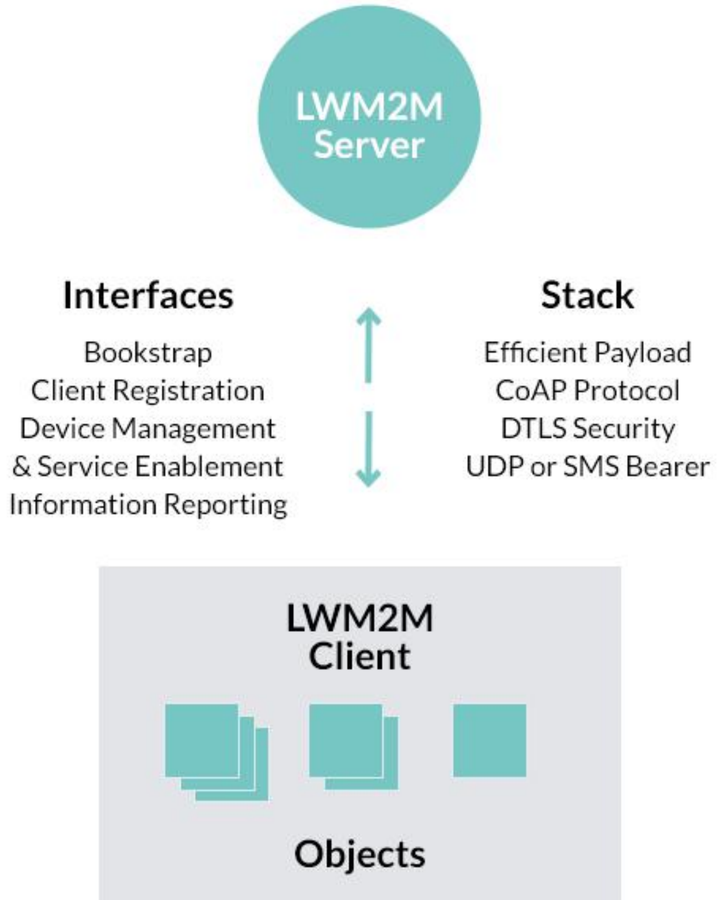
LWM2M

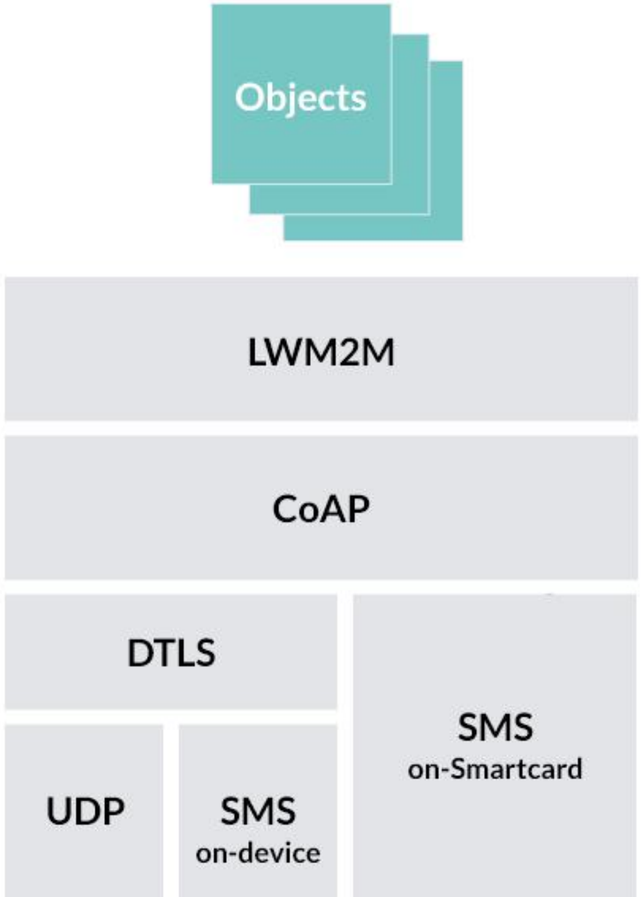
Application layer communication protocol

for IoT device management

an open standard from the

Open Mobile Alliance (OMA)



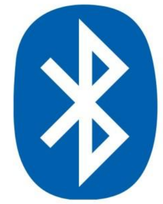


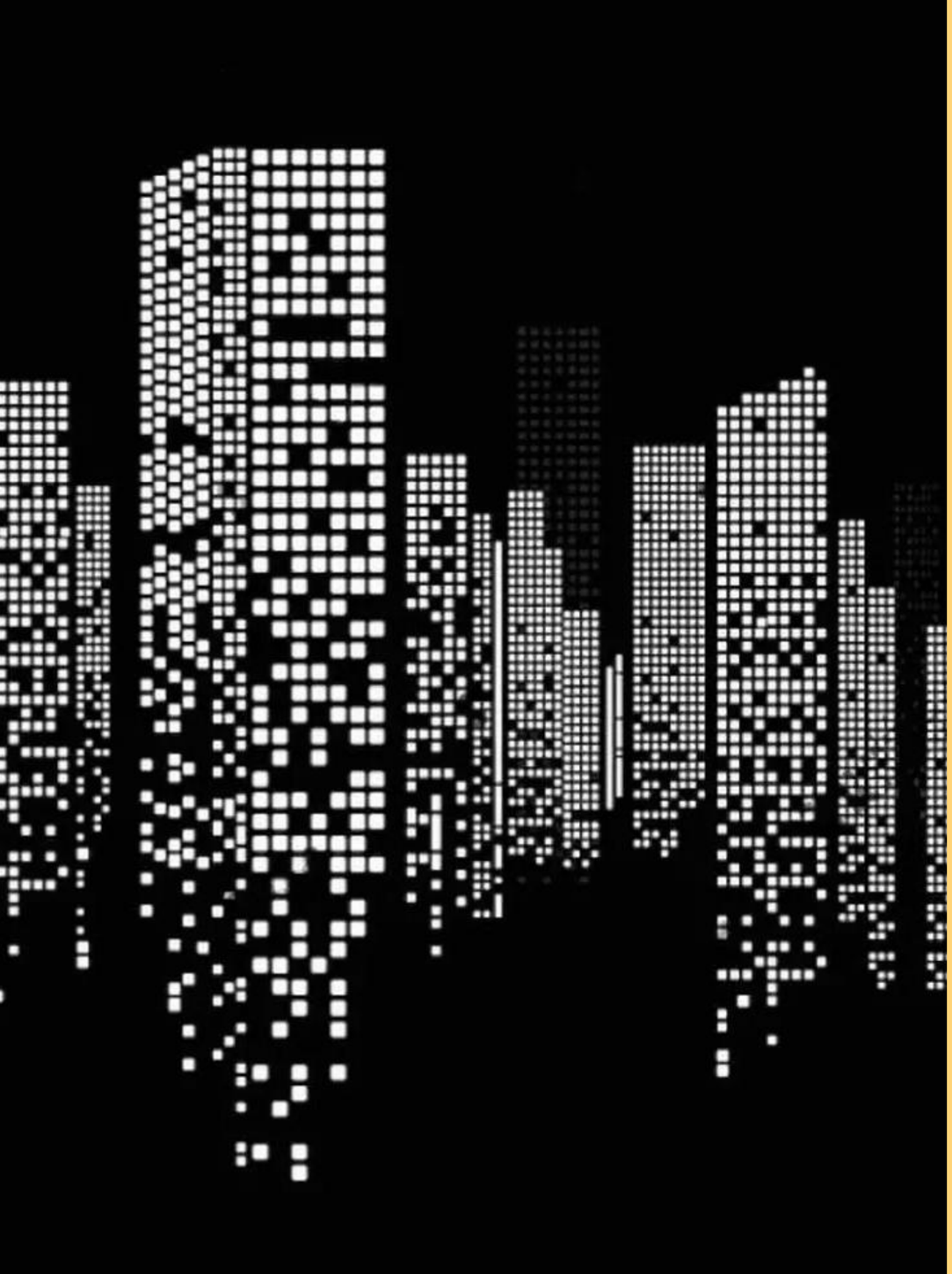
AGENDA

Session 2

AGENDA

Fundamentals: standards, networks, protocols





SMART BUILDING

vision

MAIN DRIVERS

SECURITY & SAFETY

COMFORT & HEALTH

ENERGY SAVING

Bosch Singapore Campus made smart with IoT

IOT: SUPPLY CHAIN

Logistics

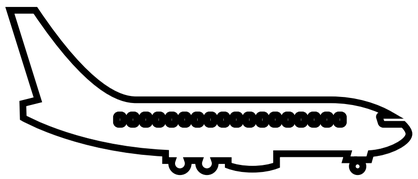
CLEAR IOT BENEFITS

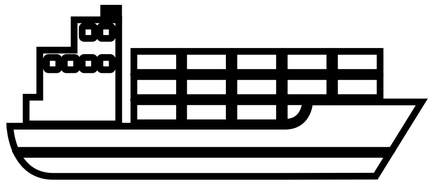
Better customer service, with realtime, reliable data

Reducing safety stocks & avoiding out-of-stock

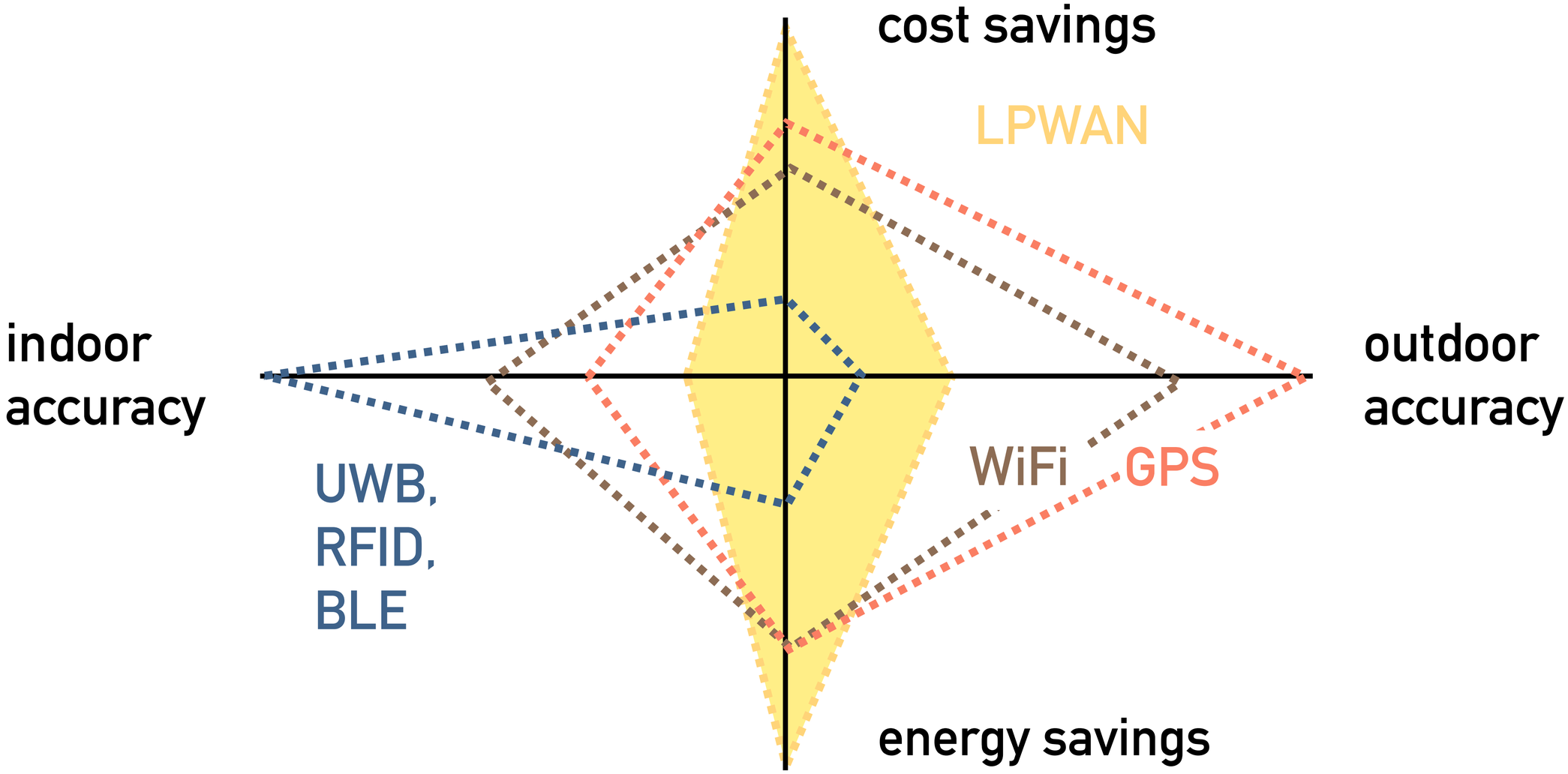
Decrease & better predict operating costs

Better manage multiple stakeholders





ASSET TRACKING: TECHNOLOGIES



SUPPLY CHAIN

WAREHOUSE

RTLS with UWB

Security & Safety

Operational efficiency

Optimal operations

TRACK & TRACE

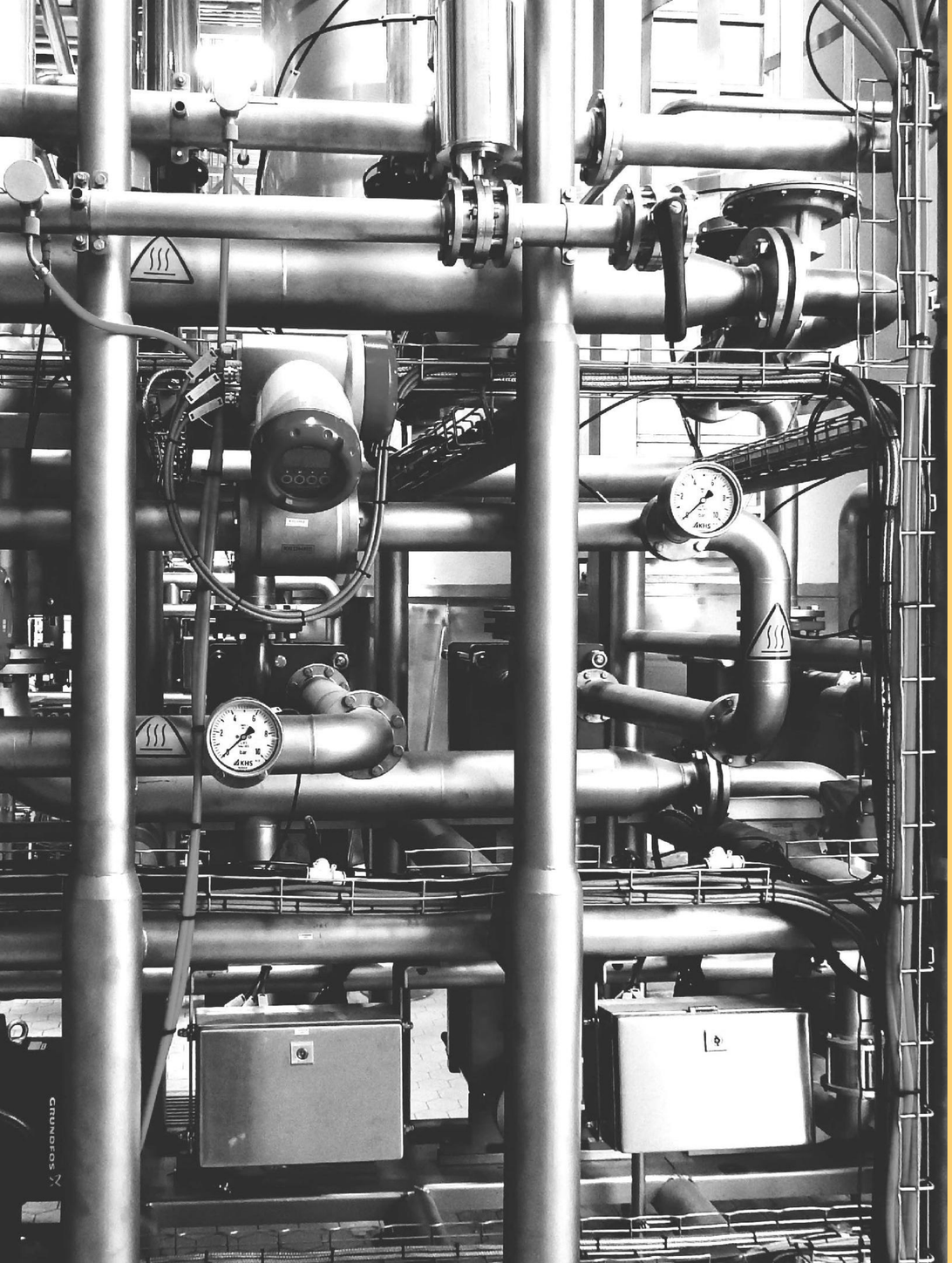
Asia-Pac's largest pallet pooling & returnable packaging provider:

LPWAN solution vs. RFID and previous 3G + GPS based experience

LOSCAM

thinxtra
Empowering Internet of Things

sigfox



IIOT: INDUSTRIAL IOT

Industry 4.0

INDUSTRY 4.0

“

IoT / industry 4.0 have so many benefits that it cannot be still a question...

it is like ERP in the 1990’s or PLM in the 2000’s or MES in the 2010’s:

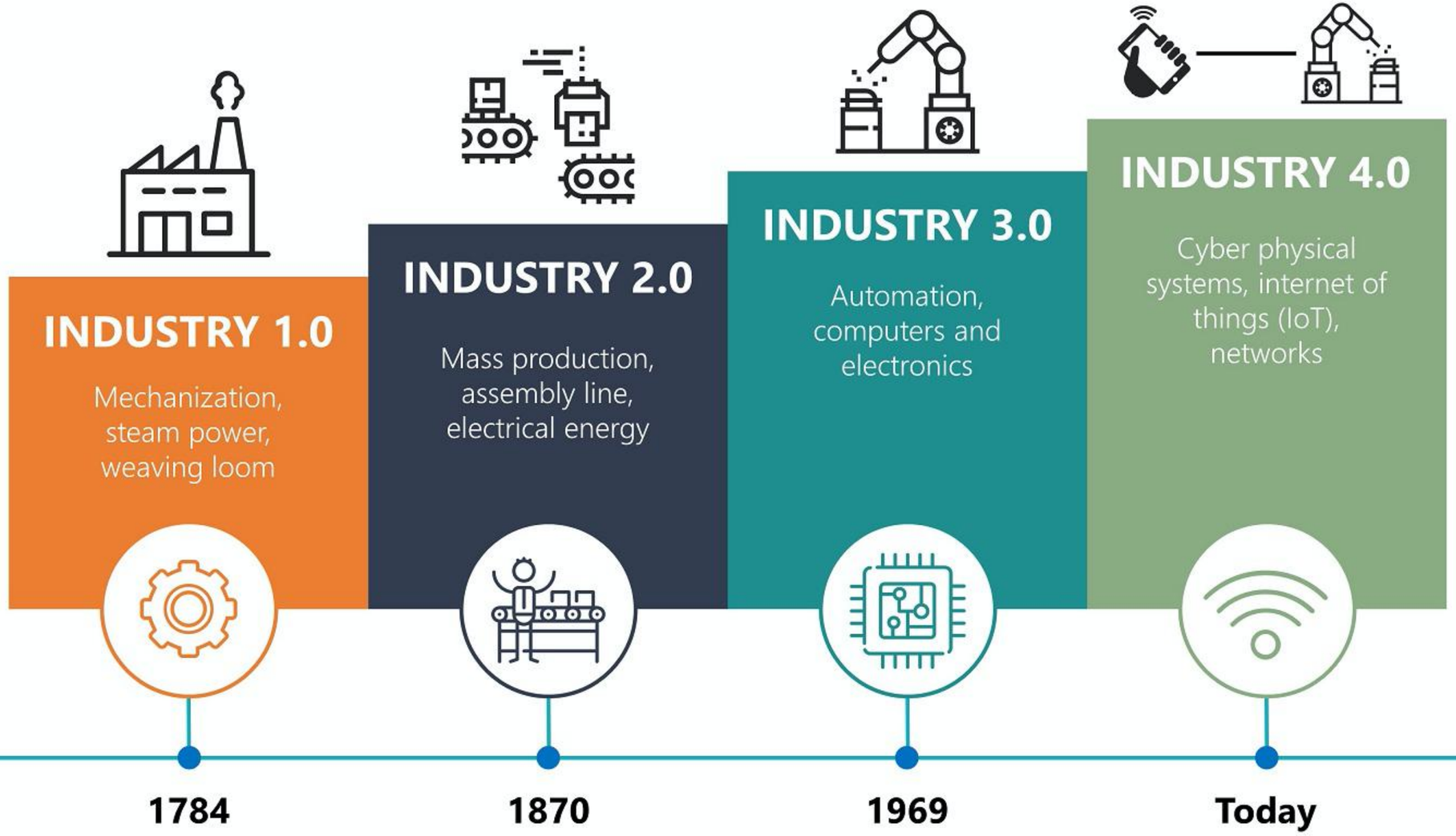
it is a question of time.

It took 30 years for ERP to be in all big 40 French companies

- Samir Djendoubi

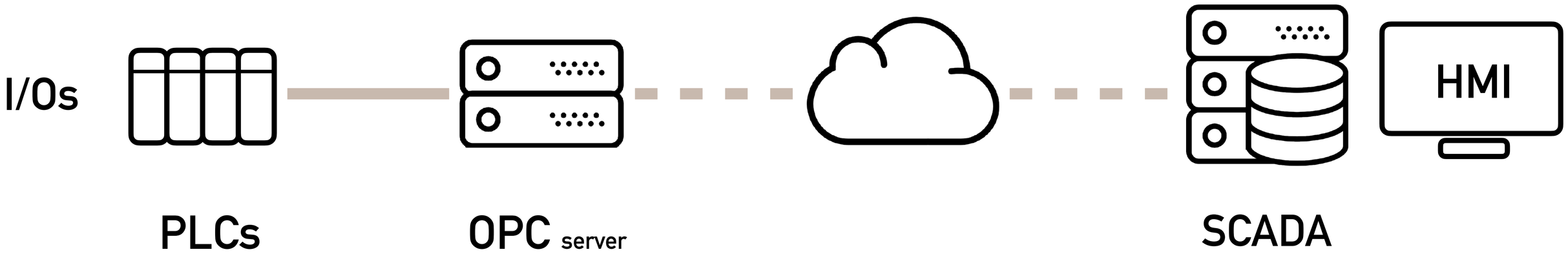
INDUSTRY 4.0

Fourth revolution

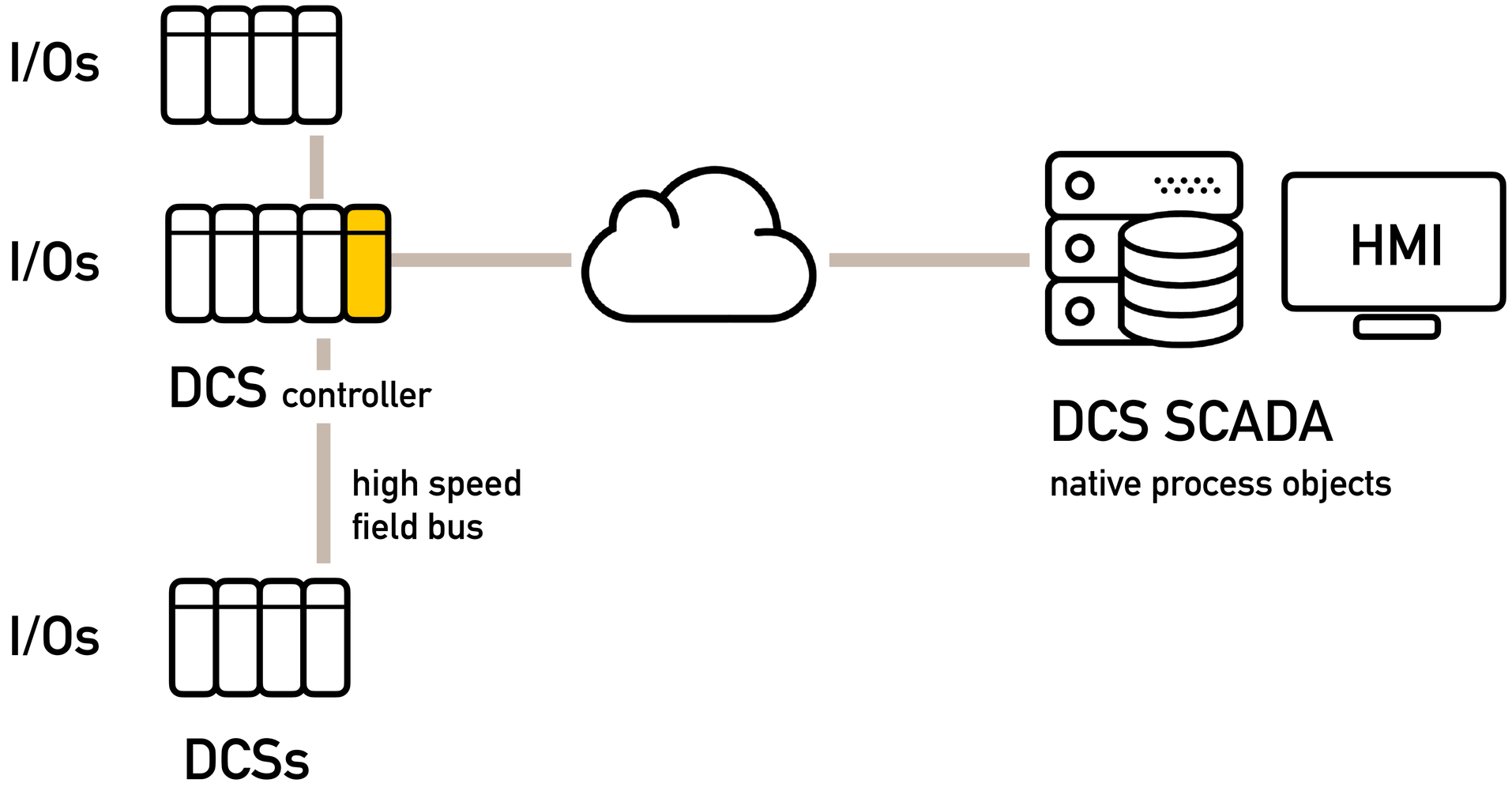


Credit: Enerco Energy Solutions LLP.

PLC > OPC > SCADA



DCS: DISTRIBUTED CONTROL SYSTEM



BOILER MONITORING

Predictive maintenance:

remaining lifetime of equipments,
intelligent diagnosis via ML
outage incident predictions

e.l.m. leblanc

BOSCH

Microsoft Azure
IoT Platform

orange™ Business Services

MINING

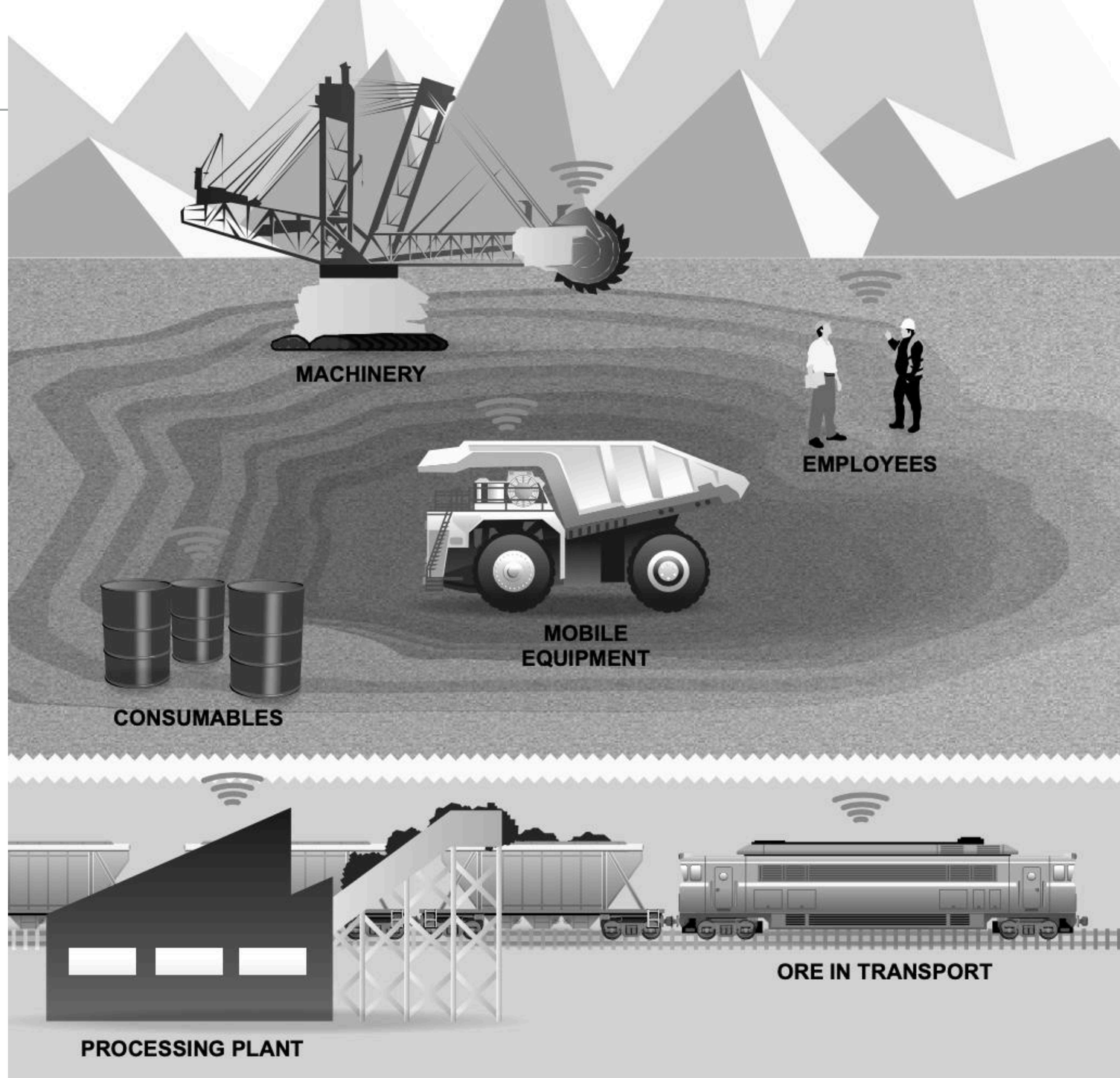
Condition-based maintenance

Operation management

Health & safety

IoT-enabled R&D

Presales enablement



Source: McKinsey

MINING

De Beers Marine's
diamond mining vessels

'zero harm' health & safety objectives in a heavy industrial environment

sensors & wearables to monitor crew proximity to machinery

DE BEERS MARINE

orange™ Business Services

INDUSTRIAL ASSET TRACKING

15,000+ trackers & 250+ antennas deployed at 2 Safran Aircraft Engines production sites in France

Centralizing data to improve Business processes

SAFRAN

orange™ Business Services

JET ENGINE MONITORING

Thousands of sensors in each of 4,500 Rolls-Royce engines in service.
500+GB of data per flight.

$250,000 savings / plane / year for a 1% reduction in fuel.

TANKS SCADA

DESARROLLO DE UNA SOLUCIÓN IOT INTEGRAL PARA LA MONITORIZACIÓN Y SUPERVISIÓN EN TIEMPO REAL DE LAS INSTALACIONES DE GAS

Más de **3.000** depósitos

1. Dispositivo IoT de telemedida

2. Conectividad red móvil IoT de Orange

LTE-M

3. Plataforma IoT Orange LiveObjects

4. Centro de Control . Integración con sistemas Redexis

Llevamos el gas a **hogares, edificios, oficinas, hospitales, hoteles, etc...**

Más y mayor calidad de la información

Datos en **tiempo real**

Automatización del proceso

Seguridad de suministro
+
Operación más eficiente
+
Mejora en la gestión

MEJOR CALIDAD DEL SERVICIO AL CLIENTE FINAL

Redexis | orange

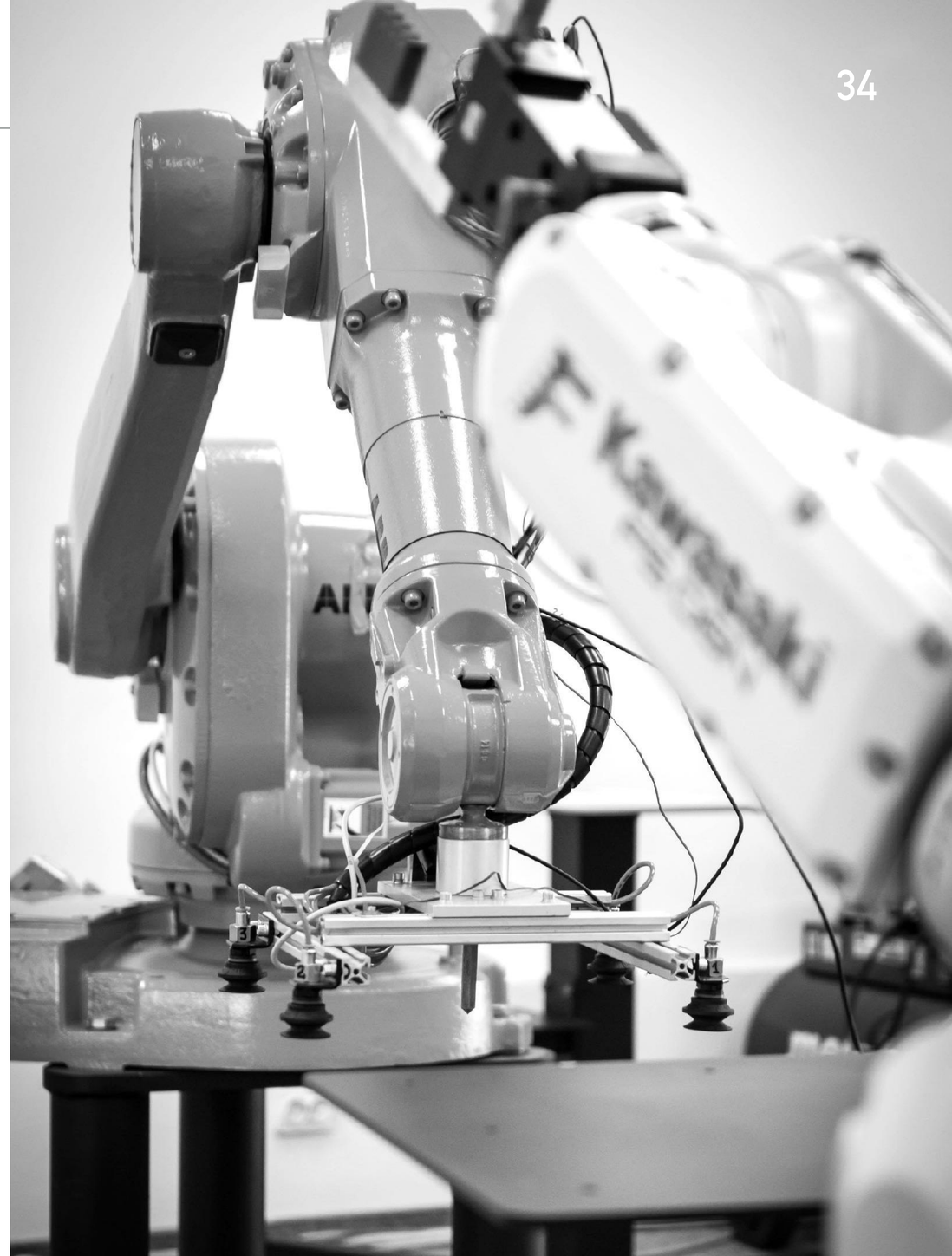
LTE-M

ROBOTICS

IoRT: Internet of Robotic Things

Europe has the highest robot density globally, with an average value of 114 units per 10,000 employees in the manufacturing industry alone.

Automated Guided Vehicles (AGVs) for supply chain warehouses.

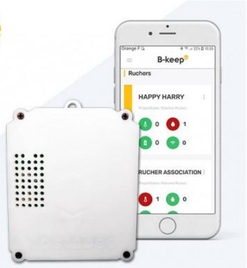


IOT: AGTECH

Smart Agriculture

BEEHIVES

B-keep



B-swarm

Beehives care / monitoring:
temperature, humidity, position,..

hostabee

LTE-M

LoRaWAN

orange™ Business Services

SILOS MONITORING

Time-of-Flight level monitoring for silos, waste, etc.

Contactless, wireless, battery-powered solution

GST GreenSysTech

LoRaWAN®

orange™ Business Services

STATIONS

Station and data logger for all climatic conditions

Powered by rechargeable battery and a solar panel

SMS alerts

Pessl INSTRUMENTS

Cellular data

1 wind speed

1 leaf wetness

1 rain gauge

1 water-meter (reed)

2 hygroclips (T°, H.)

AQUAPONICS

Plants + fish tanks monitoring

Dashboard + alerting

AtlasScientific™ Environmental Robotics

adeunis WIRELESS PRODUCTS & SOLUTIONS

MICROCHIP

AMP aquaculture & aquaponie

LoRaWAN®

orange™ Business Services

IOT: SMART METERING

Utilities: Gas • Water • Electricity

WATER UTILITIES

Leading utility company

Several million water meters in France in next few years

Control of the full value chain

birdz

LoRaWAN

orange™ Business Services

GAS METERING

Direct pulse counting

Alarm thresholds

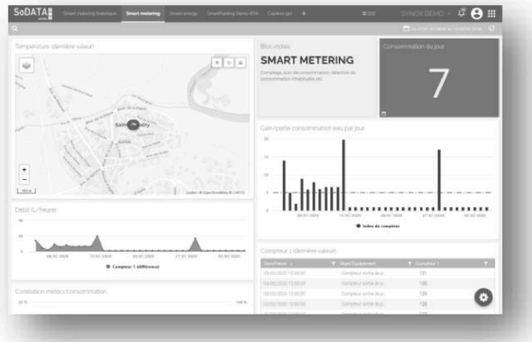
LPWAN or cellular connectivity

Télérelève des compteurs d'eau non connectés

SYNOX
Innovate together

Capteur

Réseau



Plateforme de visualisation

Les usages

- Télérelever des compteurs à intervalles réguliers
- Détecter les fuites, les fraudes et les vols
- Suivre la consommation en temps réel
- Gérer les pics de consommations
- Suivre les états de fonctionnement des compteurs
- Anticiper et optimiser les interventions techniques

Les fonctionnalités proposées

- Visualisation des compteurs d'eau sur une carte
- Paramétrage des alertes en fonction de seuils personnalisables
- Réception de notifications en cas de dépassement des seuils ou de consommation anormale
- Suivi des données en temps réel
- Historisation des données de consommation

Réalisez des économies

Améliorez la sécurité

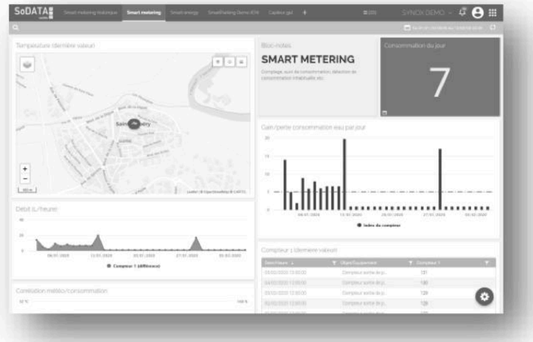
Contrôlez les dépenses en eau

Télérelève des compteurs d'eau connectés

SYNOX
Innovate together

Capteur

Réseau



Plateforme de visualisation

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- Historisation des données de consommation

Réalisez des économies

Améliorez la sécurité

Contrôlez les dépenses en eau

Détection d'intrusions dans un bâtiment

SYNOX Innovate together

Capteurs ouverture/fermeture

Capteur

Réseau

Plateforme de visualisation

Les usages

- Surveiller les infrastructures
- Déceler les intrusions ou les vols ; sur un site, chantier, bâtiment....
- Détecter l'ouverture ou la fermeture des portes, des fenêtres, des armoires fortes ou même des chambres froides
- Détecter la présence par la chaleur corporelle

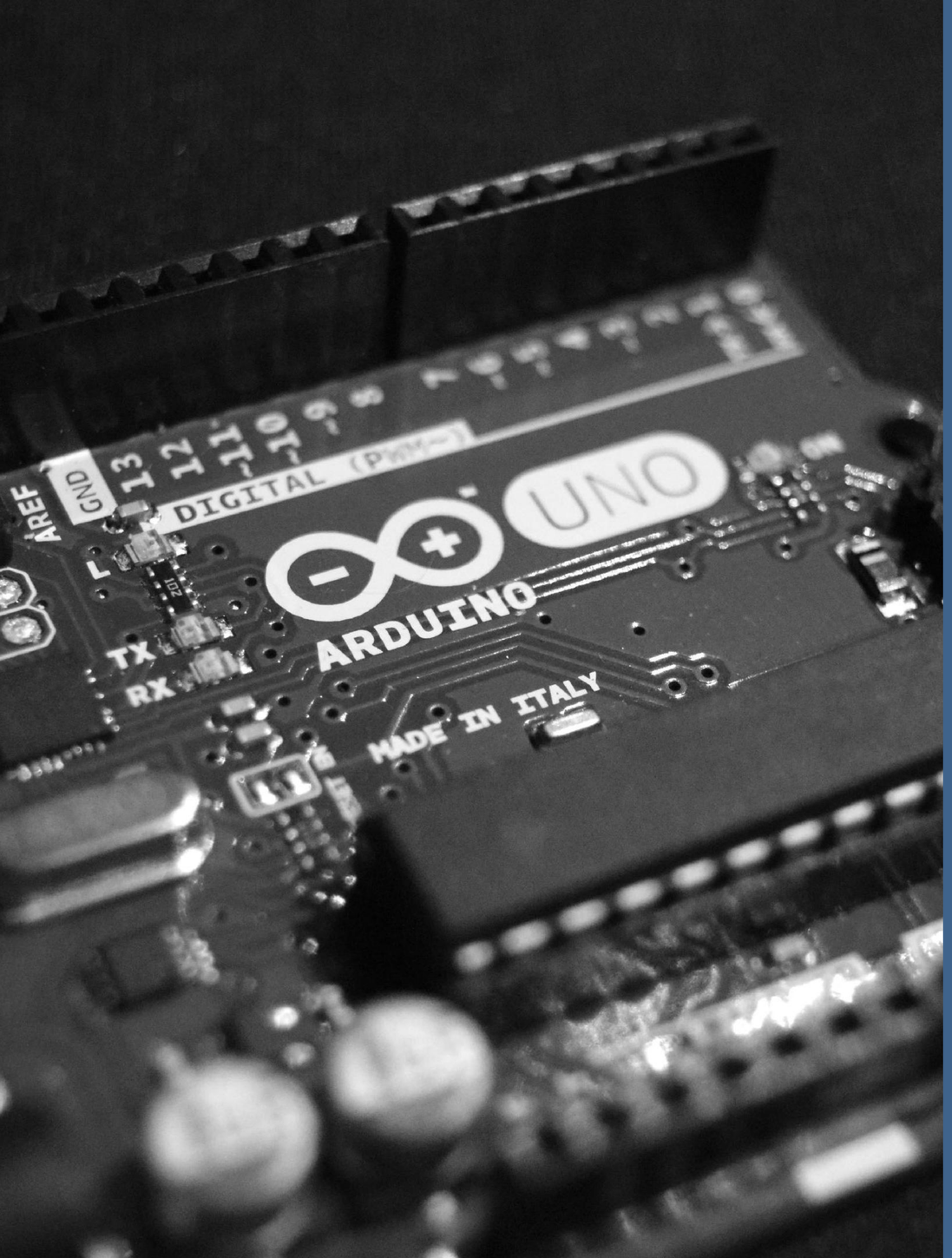
Les fonctionnalités proposées

- Visualisation des infrastructures sur une carte
- Paramétrage des alertes en fonction de seuils personnalisables
- Réception de notifications en cas d'intrusion
- Comptage du nombre de changements d'états
- Activation ou redémarrage des équipements à distance
- Suivi des données en temps réel
- Historisation des données

Améliorez la sécurité des sites

Soyez alerté en temps réel

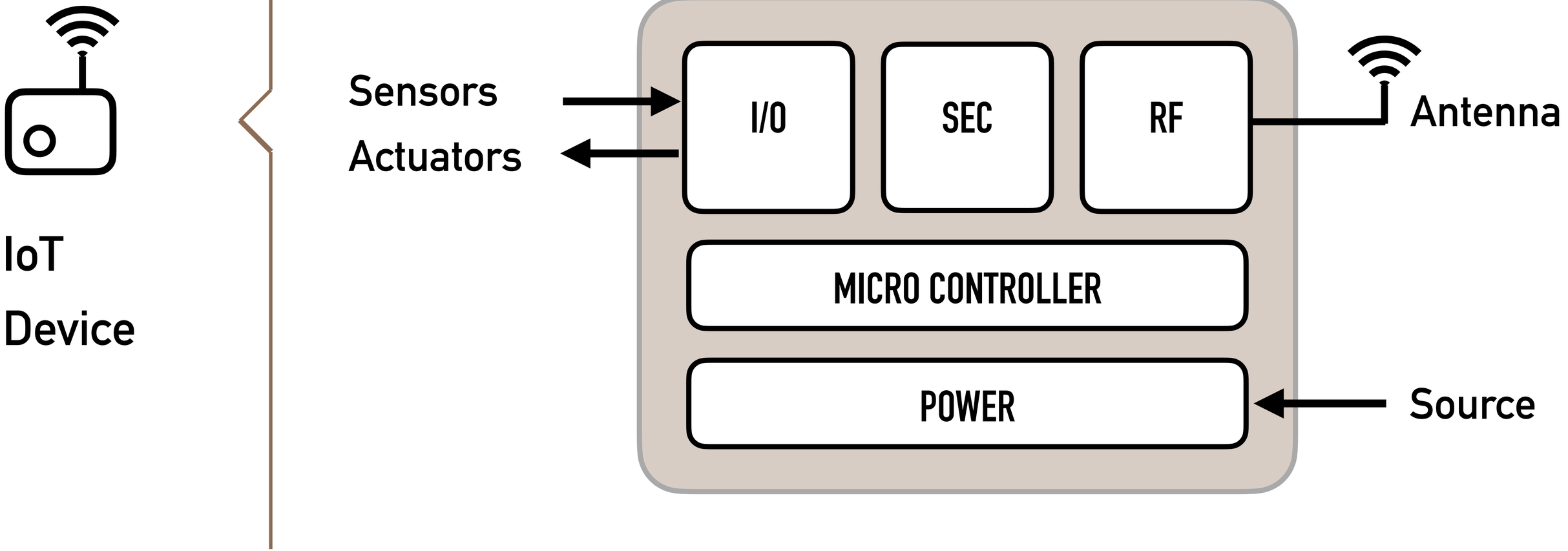
Anticipez les situations à risques



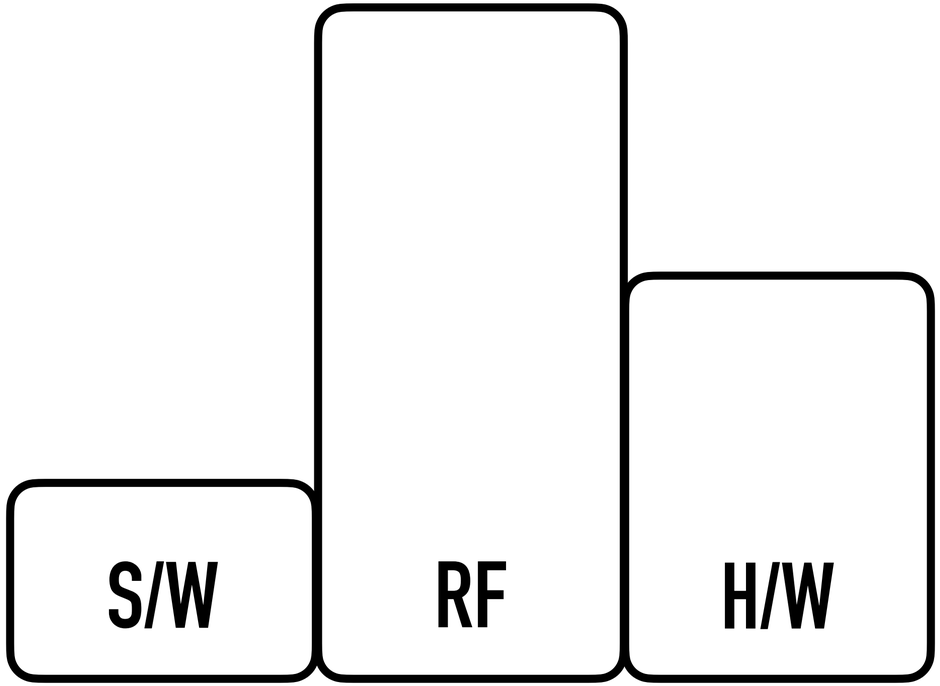
EMBEDDED DEVICES

Hardware is hard

IOT: ANATOMY OF EMBEDDED H/W



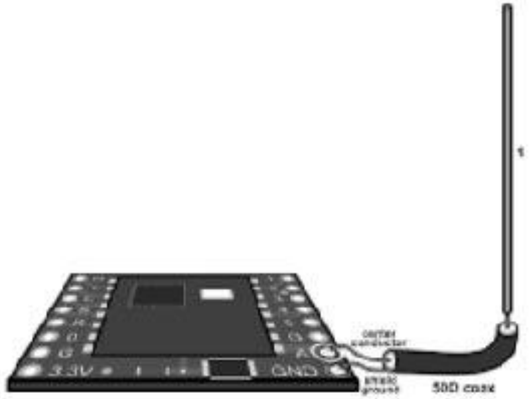
IOT: LEVELS OF DIFFICULTY



IOT: ANTENNAS

PCB

Wire



Chip

Whip

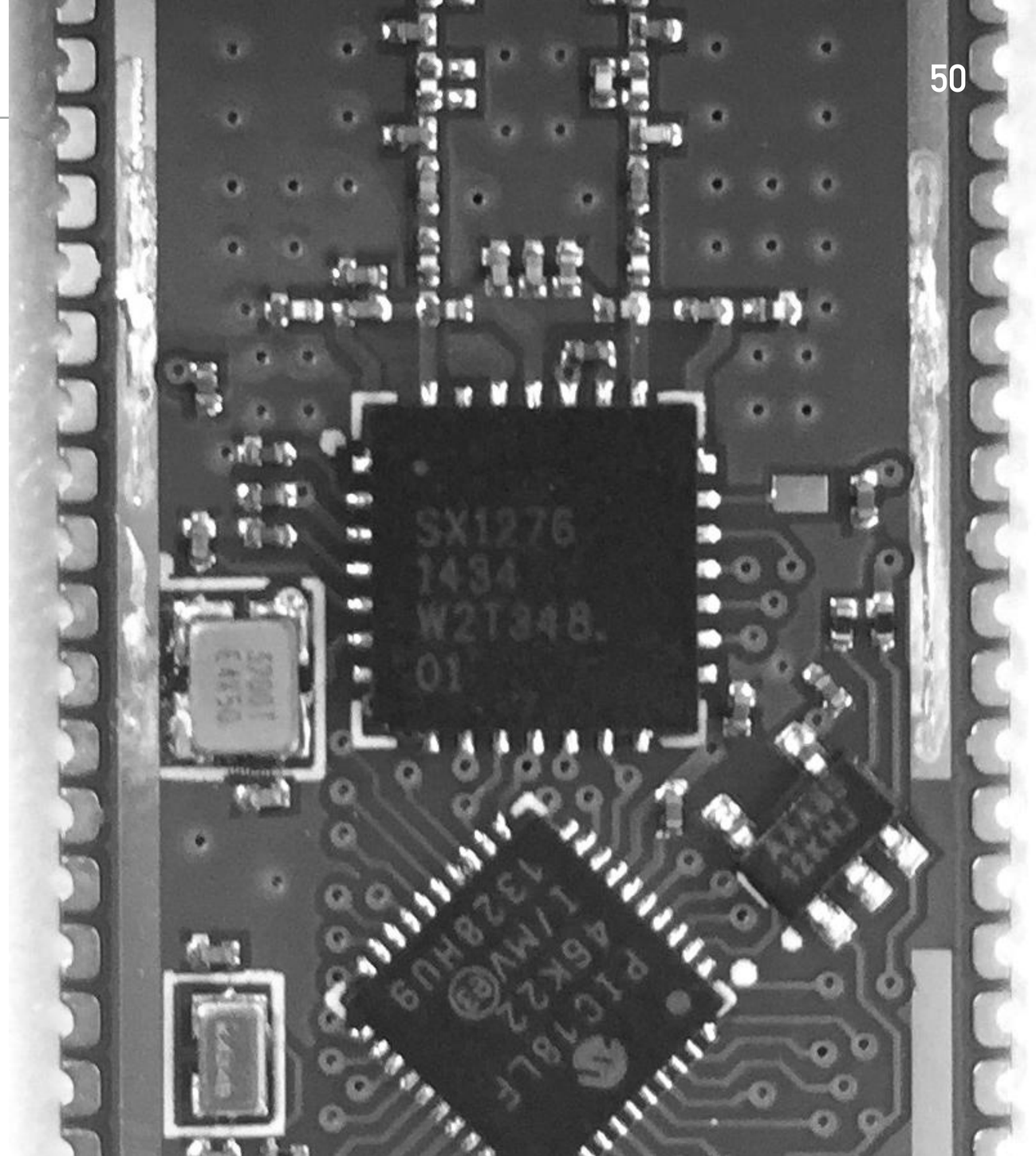
CHIPS … MODULES

Chips

SiP: System in Package

SoC: System on Chip

Modules

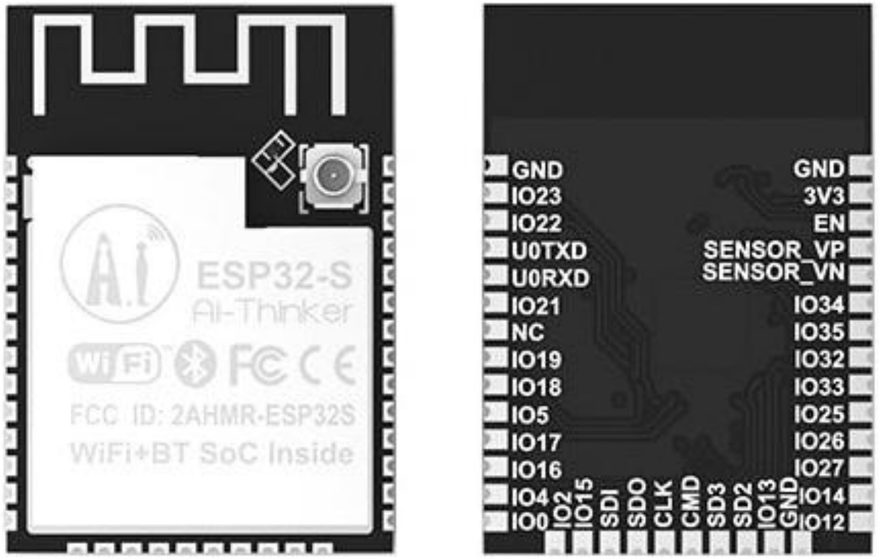


ESP32 SOC

Entry-level SoC by Expressif

32 bit Extensa microcontroller

WiFi and Bluetooth



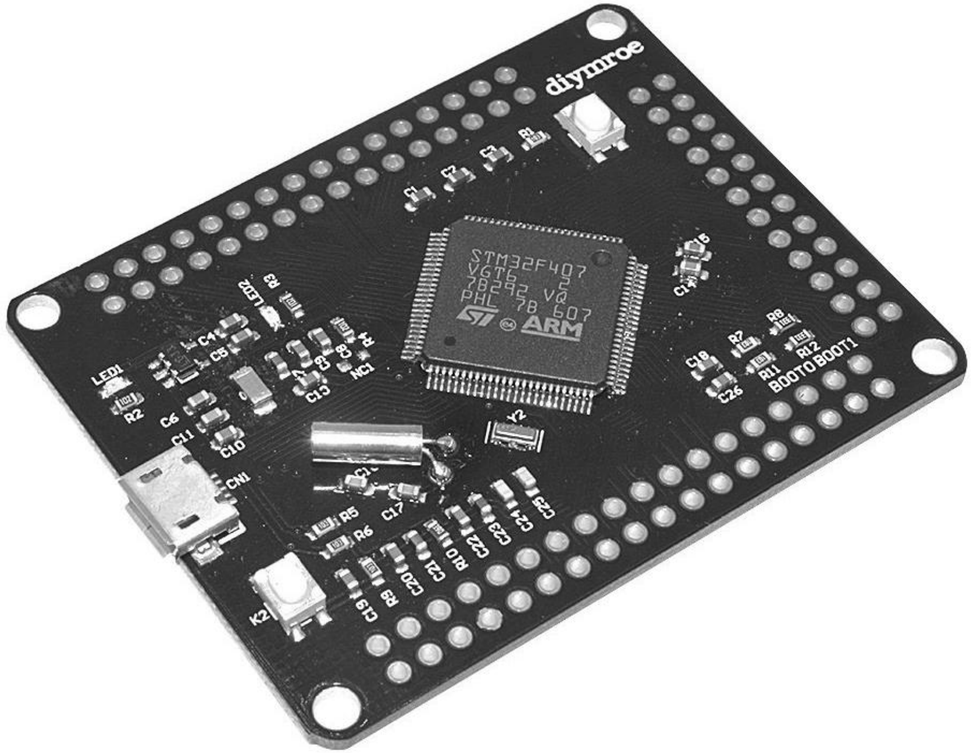
STM32 ARM CORTEX

Powerful M3-M4 processors

Low cost

Low power

Multiple S/W libraries



RASPBERRY PI

Comprehensive platform

Very capable, Linux OS

Fast CPU, lots of memory

Extension slot & I/Os

High power > 250 mAh

Great for tests, not for embedded production

ARDUINO

Open source hardware, multiple add-ons

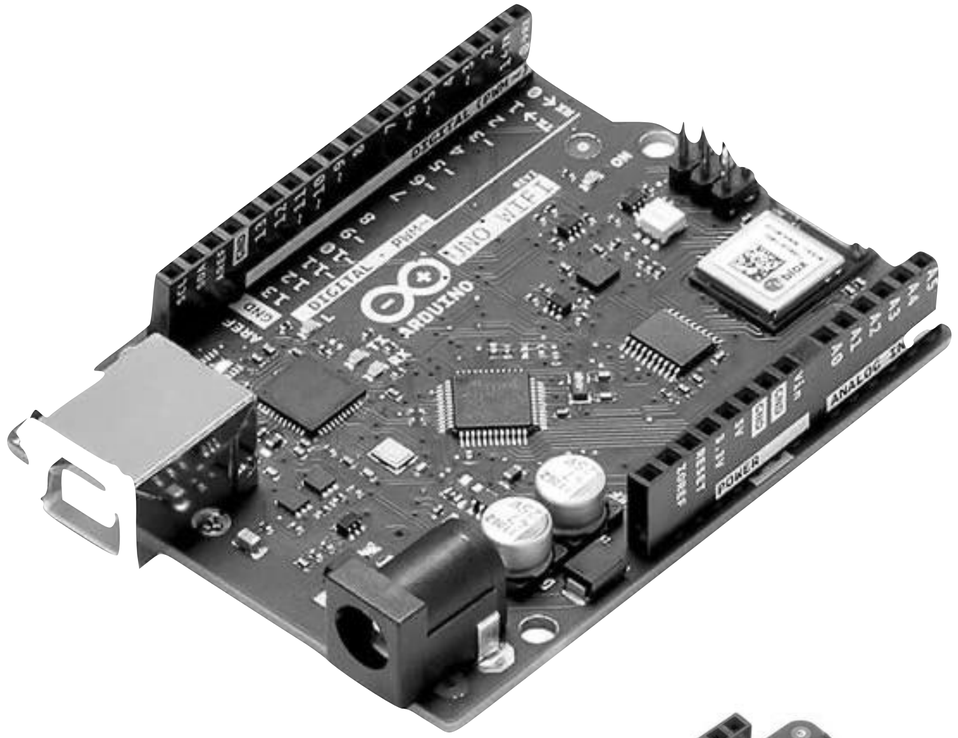
Easy coding, multiple libraries

Cost effective

Small form factor

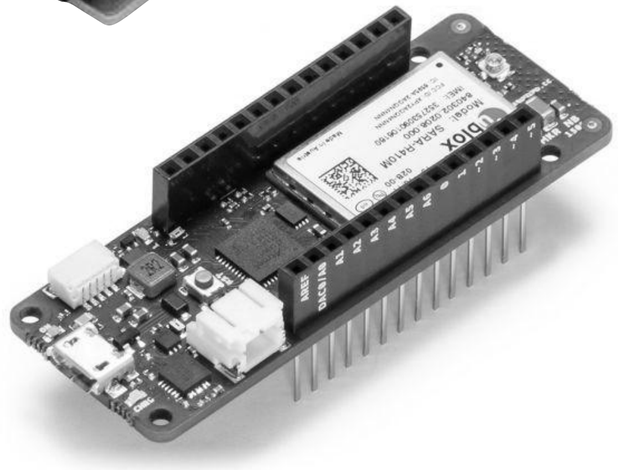
Energy efficiency: low power
Up to 1 year with 3 AA batteries

GPIO, analog & digital I/Os



Ideal for IoT:

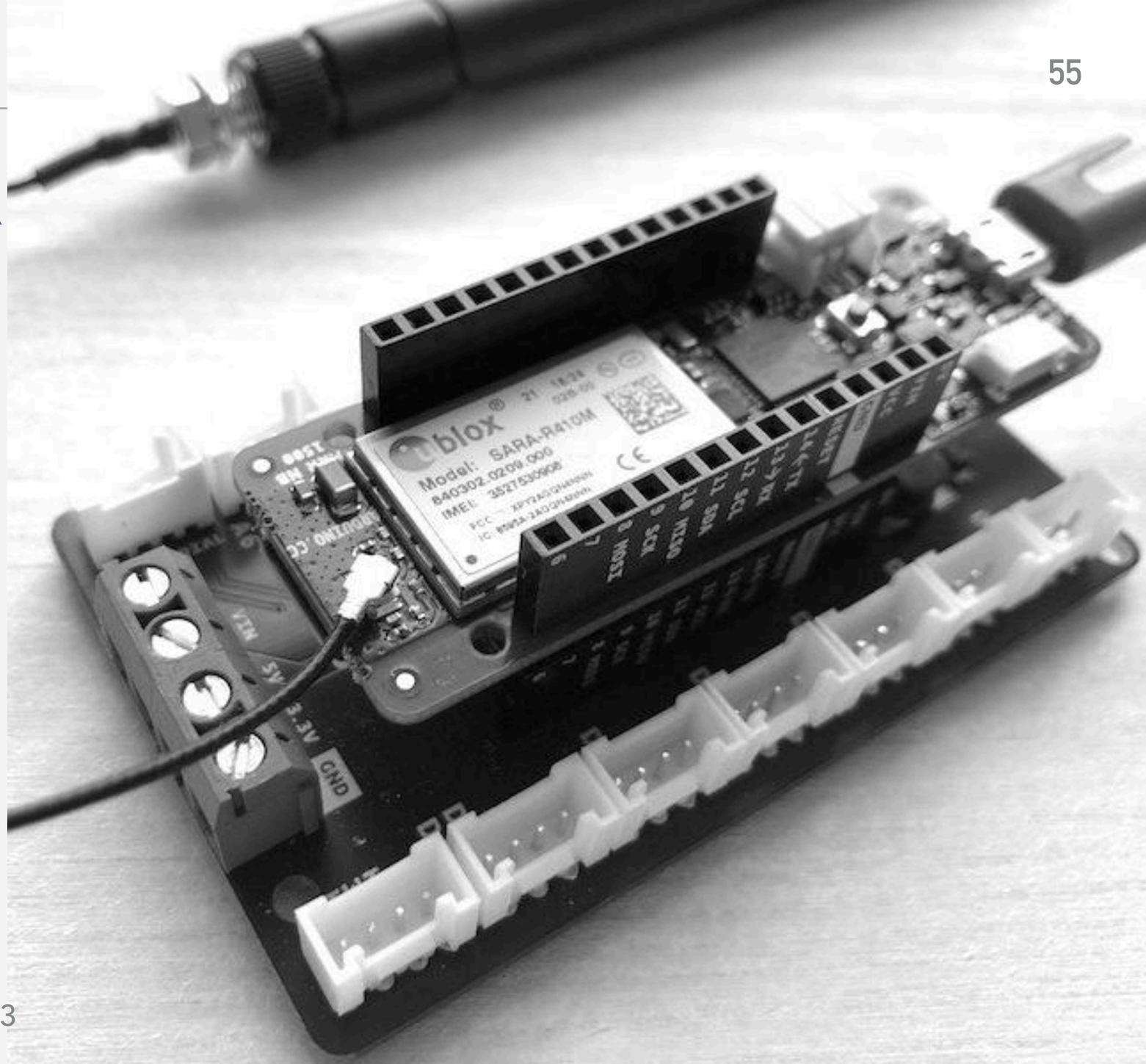
MKR Series
Cortex M0 MCU



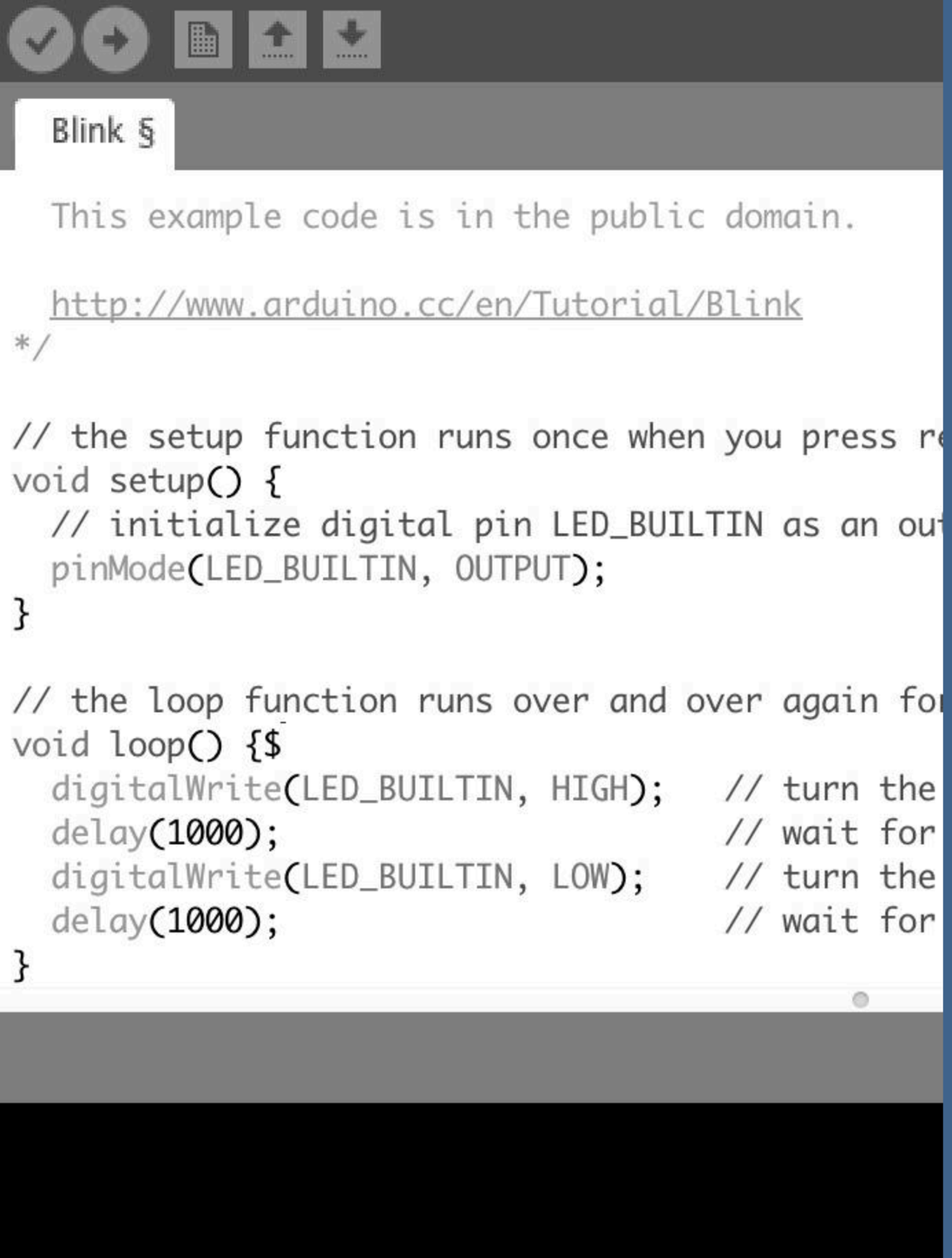
ARDUINO MKR ON CARRIER

plugged on MKR connector carrier

for Grove modules by Seeed Studio



https://store.arduino.cc/arduino-mkr-nb-1500-1413



EMBEDDED SOFTWARE

Frugal coding

ARDUINO LIVE DEMO

Analog input

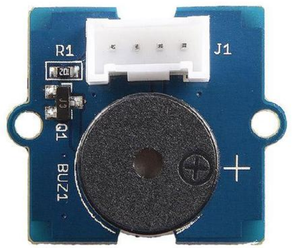
Light sensor
v.1.1

light_sensor_monitoring

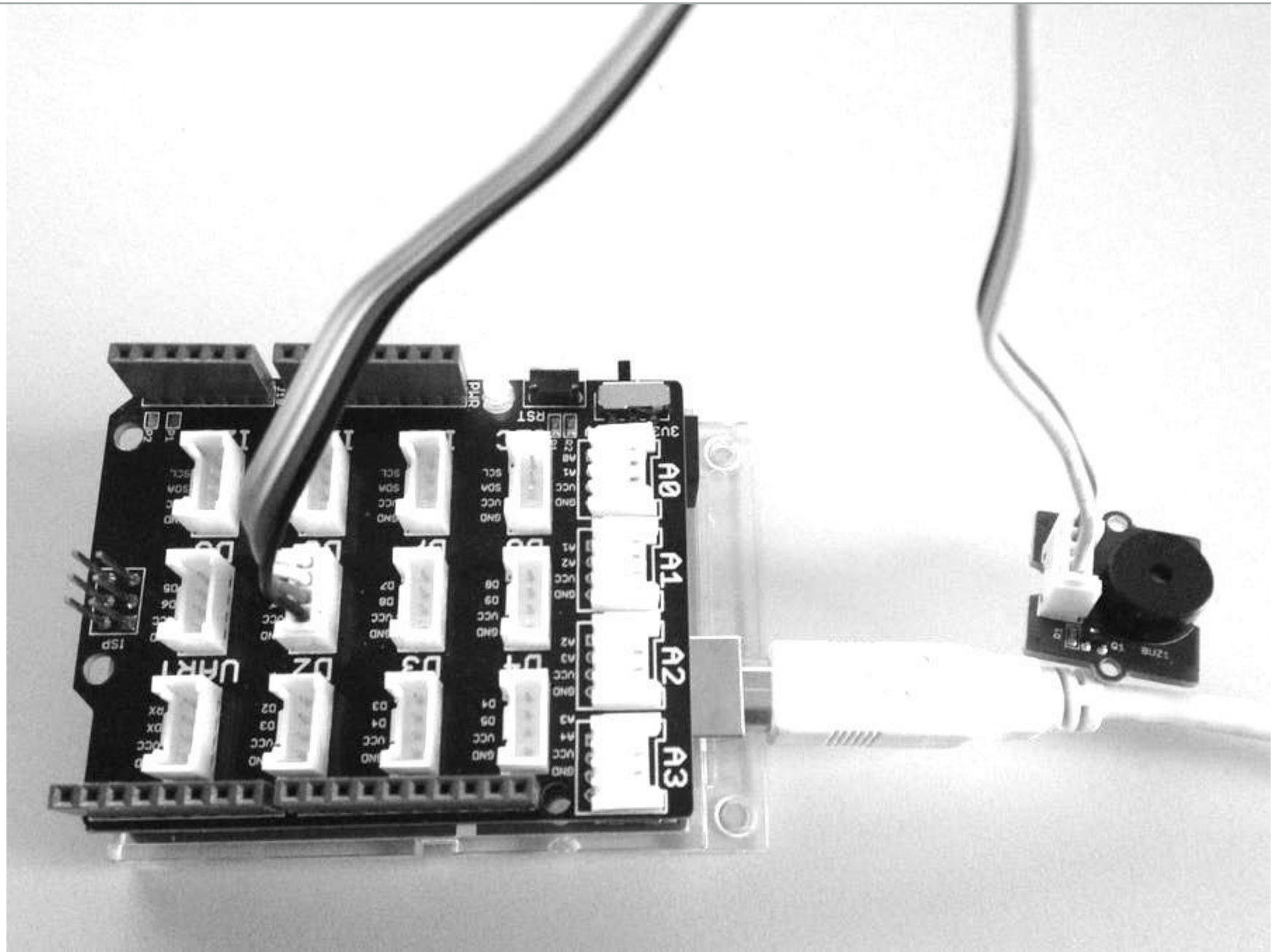
```
/*
 *  Grove - Light Sensor monitoring demo
*/
#include <math.h>

#define LIGHT_SENSOR A0          // Grove - Light Sensor is connected to A0 of Arduino
float Rsensor;                   // Resistance of sensor in K

void setup()
{
    Serial.begin(38400);           // Start the Serial connection
    pinMode(LED_BUILTIN, OUTPUT);
}

void loop()
{
    int sensorValue = analogRead(LIGHT_SENSOR);
    Rsensor = (float)(1023-sensorValue)*10/sensorValue;

    Serial.println(Rsensor);  //show the ligth intensity on the serial monitor;

    digitalWrite(LED_BUILTIN, (Rsensor > 500));

    delay(50);
}
```

ARDUINO
LIVE DEMO

Digital output

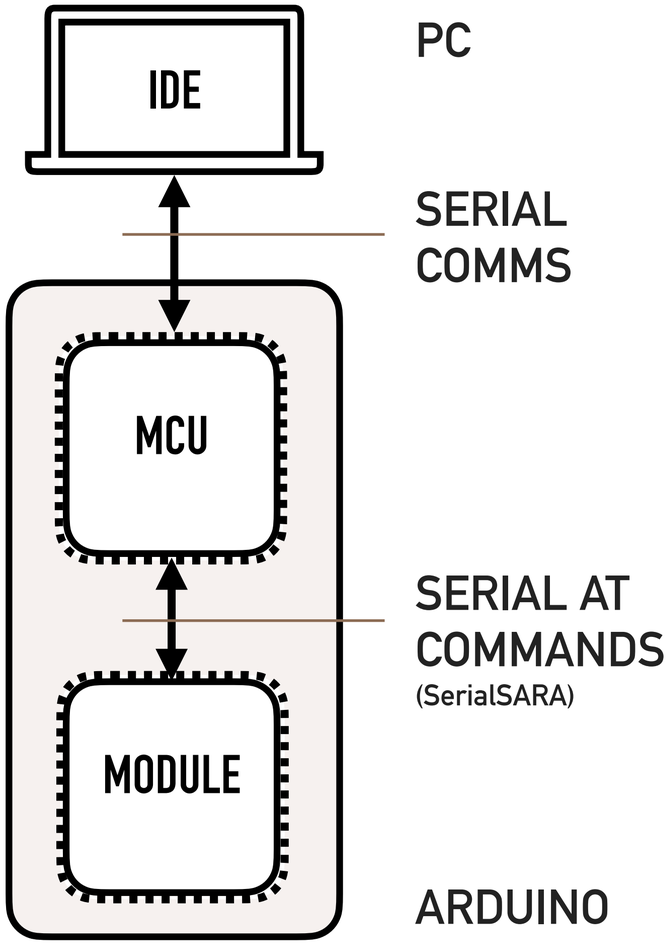


Buzzer



ARDUINO

USING AT COMMANDS

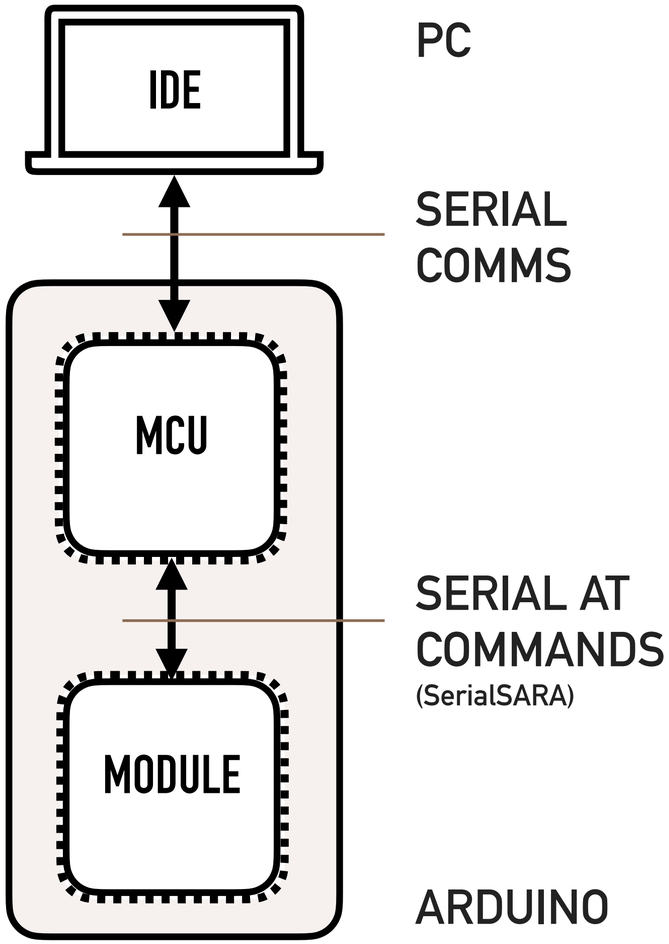



```
void setup() {
  pinMode(SARA_RESETN, OUTPUT);
  digitalWrite(SARA_RESETN, HIGH);
  delay(100);
  digitalWrite(SARA_RESETN, LOW);

  Serial.begin(115200);
  SerialSARA.begin(115200);
}

void loop() {
  if (Serial.available()) {
    SerialSARA.write(Serial.read());
  }

  if (SerialSARA.available()) {
    Serial.write(SerialSARA.read());
  }
}
```

https://www.thingforward.io/techblog/2018-11-14-a-first-look-at-arduinos-mkr1500-for-lte-narrowband-lte-m-connectivity.html

ARDUINO

USING AT COMMANDS



300 page manual
of AT commands

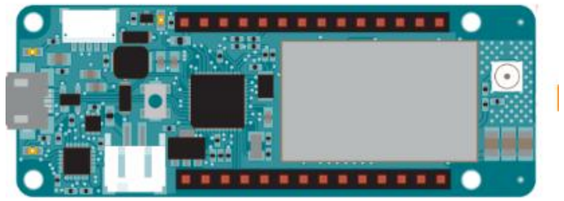
COMMAND LINE:

```
AT
OK
AT+CGMI
u-blox
OK
AT+CGMM
SARA-R410M-02B
OK
AT+CFUN=1
OK
AT+CFUN?
+CFUN: 1
OK
```

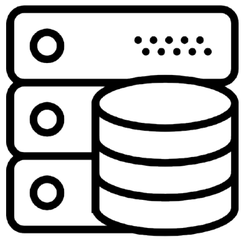
https://www.u-blox.com/sites/default/files/SARA-R4_ATCommands_%28UBX-17003787%29.pdf

ARDUINO

USING LIBRARIES

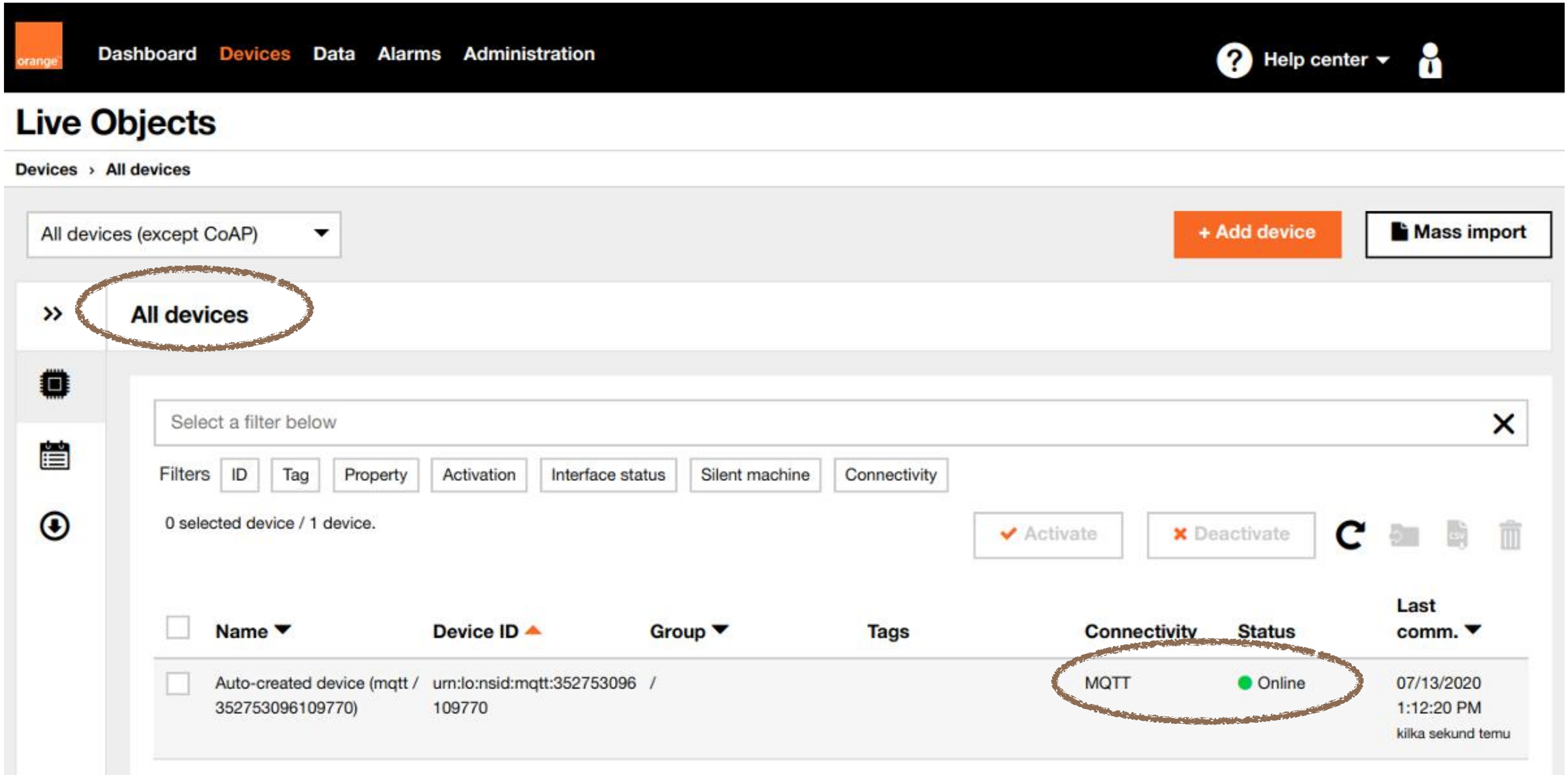


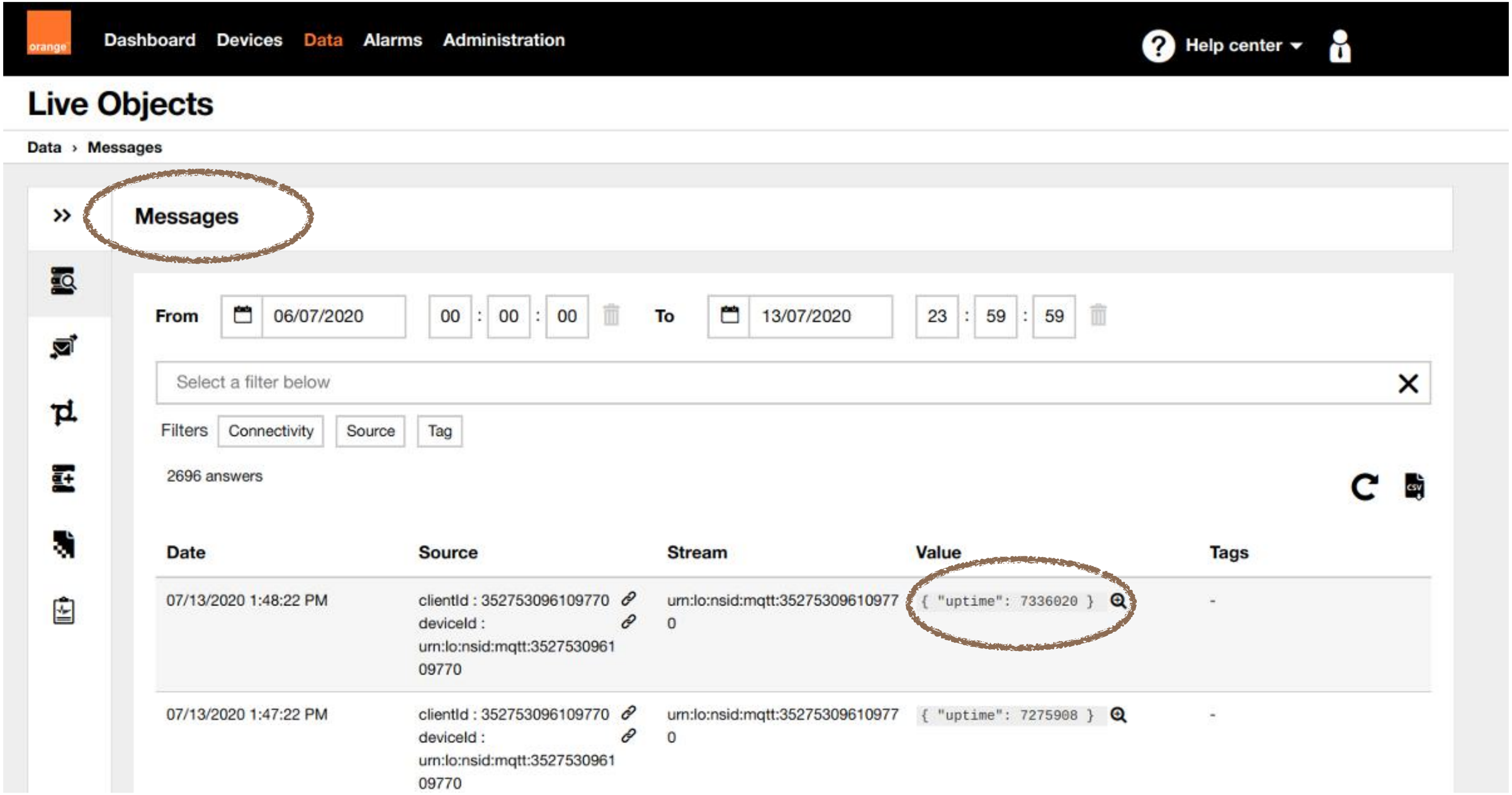
MKRWAN 1300



```ino
#include "LiveObjects.h"

uint32_t messageRate = 5000;        // current data message rate in ms
unsigned long uptime;               // device uptime to be sent as data
unsigned long lastMessageTime = 0; // time when last data message was sent

void setup() {

  Serial.begin(115200);
  Serial.print("\nLive Objects for Arduino MKR boards, revision ");
  Serial.println(SW_REVISION);

  lo.begin(MQTT, TLS, true);
  lo.connect(); // connects to the network + Live Objects
}

void loop() {

  if (millis() - lastMessageTime > messageRate) { // every messageRate ms

    uptime = millis();
    lo.addToPayload("uptime", uptime);
    lo.sendData();  // send the data to Live Objects
    lastMessageTime = millis();
  }
  lo.loop();    // listen what Live Objects can send
}
```

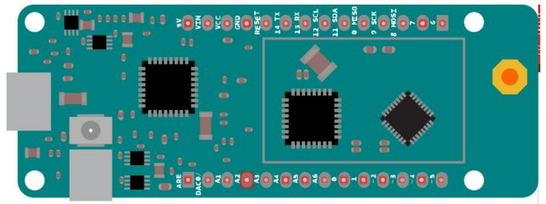
GitHub


orange
Dashboard
Devices
Data
Alarms
Administration
Help center
Live Objects
Devices › All devices
All devices (except CoAP)
+ Add device
Mass import
All devices
Select a filter below
Filters
ID
Tag
Property
Activation
Interface status
Silent machine
Connectivity
0 selected device / 1 device.
Activate
Deactivate
Name
Device ID
Group
Tags
Connectivity
Status
Last comm.
Auto-created device (mqtt / 352753096109770)
urn:lo:nsid:mqtt:352753096109770
/
MQTT
Online
07/13/2020 1:12:20 PM
kilka sekund temu

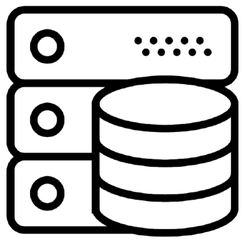

orange
Dashboard
Devices
Data
Alarms
Administration
Help center
Live Objects
Data › Messages
Messages
From
06/07/2020
00 : 00 : 00
To
13/07/2020
23 : 59 : 59
Select a filter below
Filters
Connectivity
Source
Tag
2696 answers
Date
Source
Stream
Value
Tags
07/13/2020 1:48:22 PM
clientId : 352753096109770
deviceId : urn:lo:nsid:mqtt:352753096109770
urn:lo:nsid:mqtt:35275309610977 0
{ "uptime": 7336020 }
-
07/13/2020 1:47:22 PM
clientId : 352753096109770
deviceId : urn:lo:nsid:mqtt:352753096109770
urn:lo:nsid:mqtt:35275309610977 0
{ "uptime": 7275908 }
-

ARDUINO

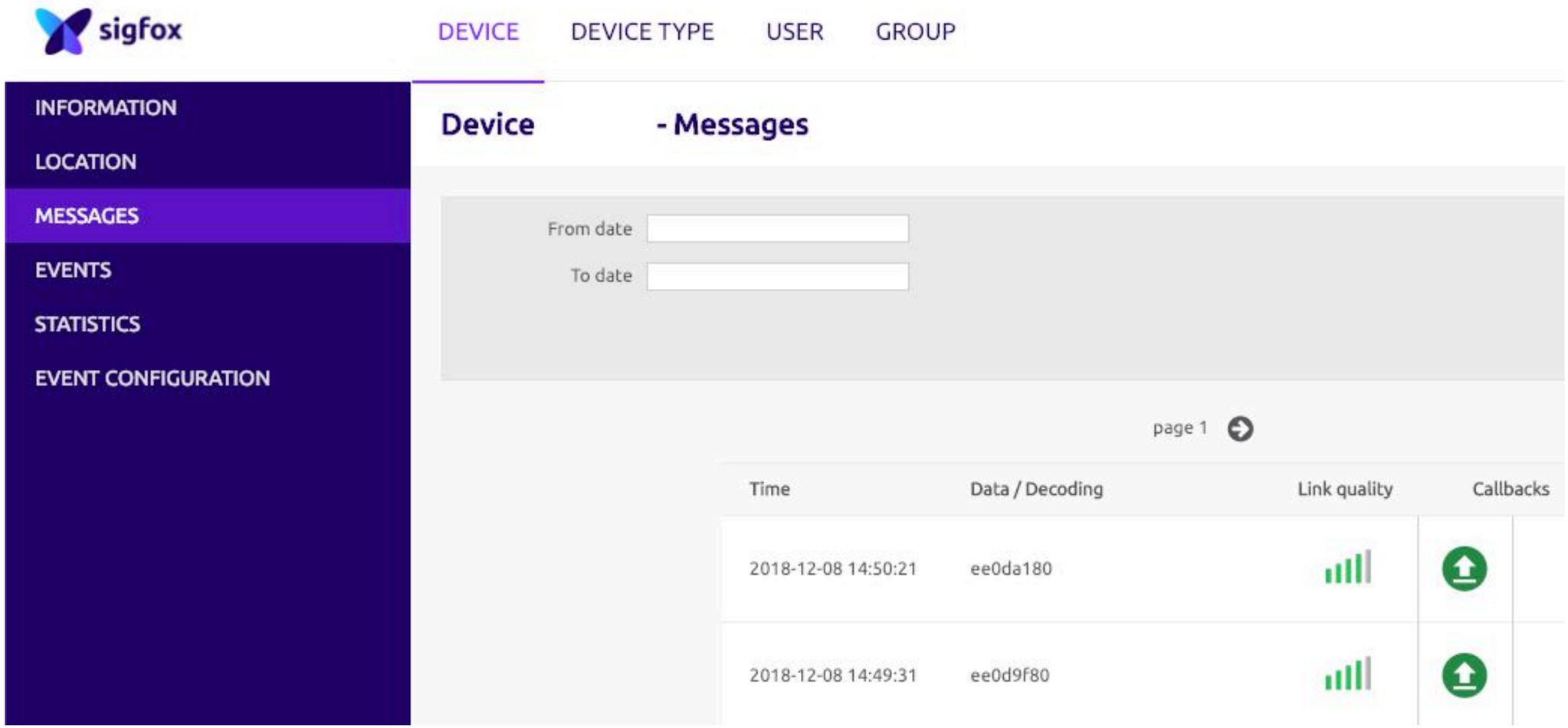
USING LIBRARIES



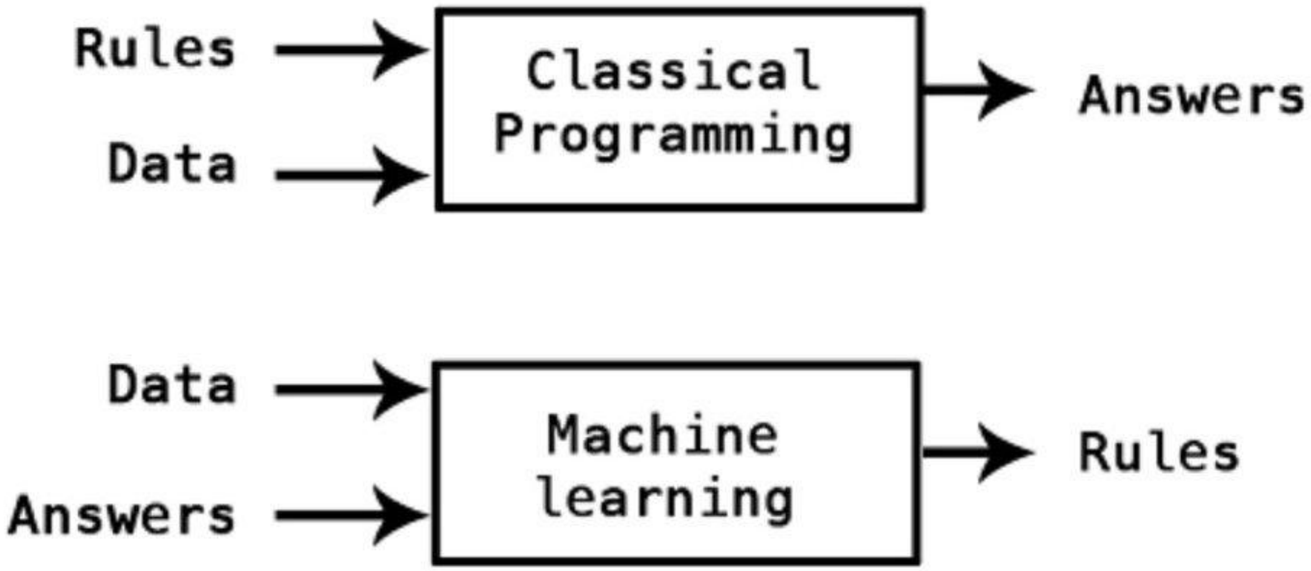
MKRFOX



```
#include <SigFox.h>
#include <ArduinoLowPower.h>

volatile int alarm_source = 0;

void setup() {

  if (!SigFox.begin()) {
    reboot();
  }
  SigFox.end(); // Send module to standby until we need to send a message

  // attach pin 0 and 1 to a switch and enable the interrupt on voltage falling event
  pinMode(0, INPUT_PULLUP);
  LowPower.attachInterruptWakeup(0, alarmEvent1, FALLING);
  pinMode(1, INPUT_PULLUP);
  LowPower.attachInterruptWakeup(1, alarmEvent2, FALLING);
}

void loop()
{
  LowPower.sleep(); // Sleep until an event is recognized

  SigFox.begin();

  delay(100);

  // 3 bytes (ALM) + 4 bytes (ID) + 1 byte (source) < 12 bytes
  String to_be_sent = "ALM" + SigFox.ID() +  String(alarm_source);

  SigFox.beginPacket();
  SigFox.print(to_be_sent);
  int ret = SigFox.endPacket();

  SigFox.end(); // shut down module, back to standby
}

void alarmEvent1() {
  alarm_source = 1;
}
```


sigfox
DEVICE
DEVICE TYPE
USER
GROUP
INFORMATION
LOCATION
MESSAGES
EVENTS
STATISTICS
EVENT CONFIGURATION
Device - Messages
From date
To date
page 1
Time
Data / Decoding
Link quality
Callbacks
2018-12-08 14:50:21
ee0da180
2018-12-08 14:49:31
ee0d9f80

AIOT = AI + IOT


Rules
Data
Classical Programming
Answers
Data
Answers
Machine learning
Rules


OBJECT
OBJECT
PERSON
PERS
PERSON
PERSON

CARTESIAM

AI/MACHINE LEARNING

MICROCHIP DESIGN PARTNER

Embedded Machine-Learning Software

Microchip‘s AI partner to simplify AI design

for ARM® Cortex® M based 32-Bit MCUs

Powers the Eolane BOB device

NanoEdge AI studio

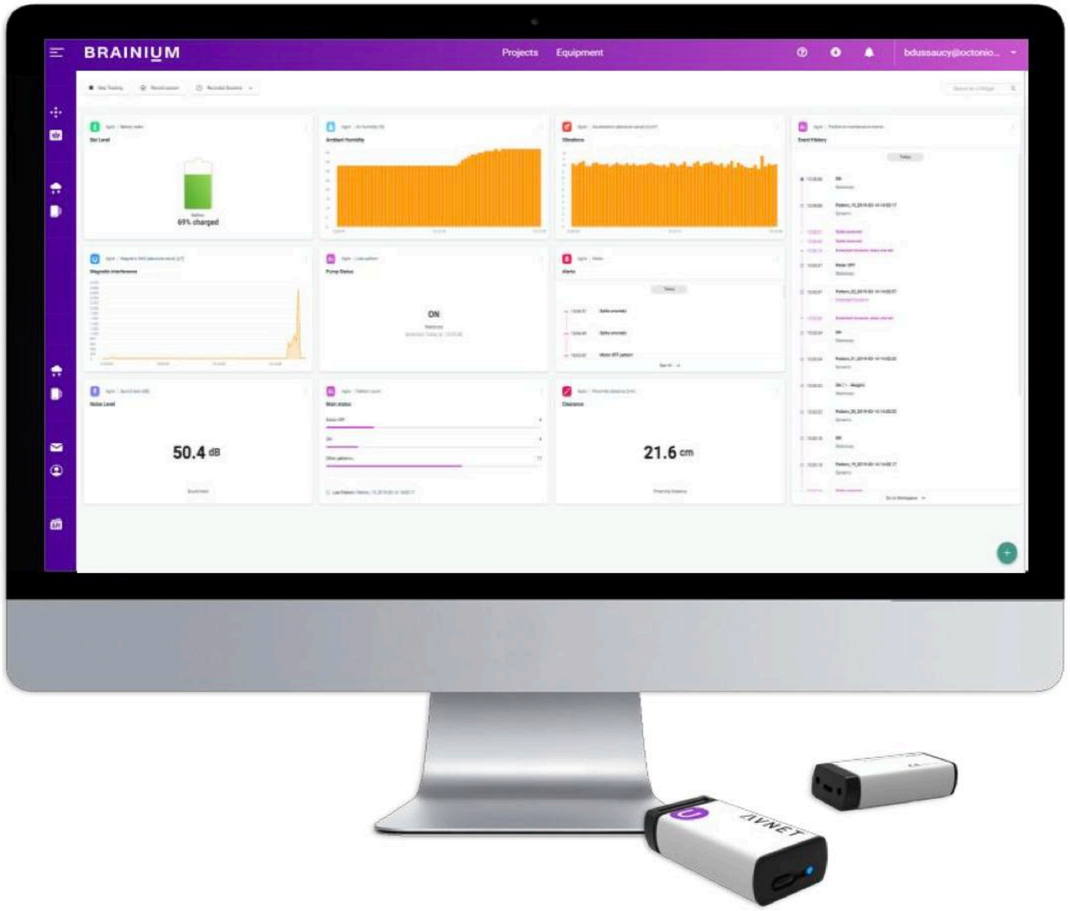
BRAINIUM

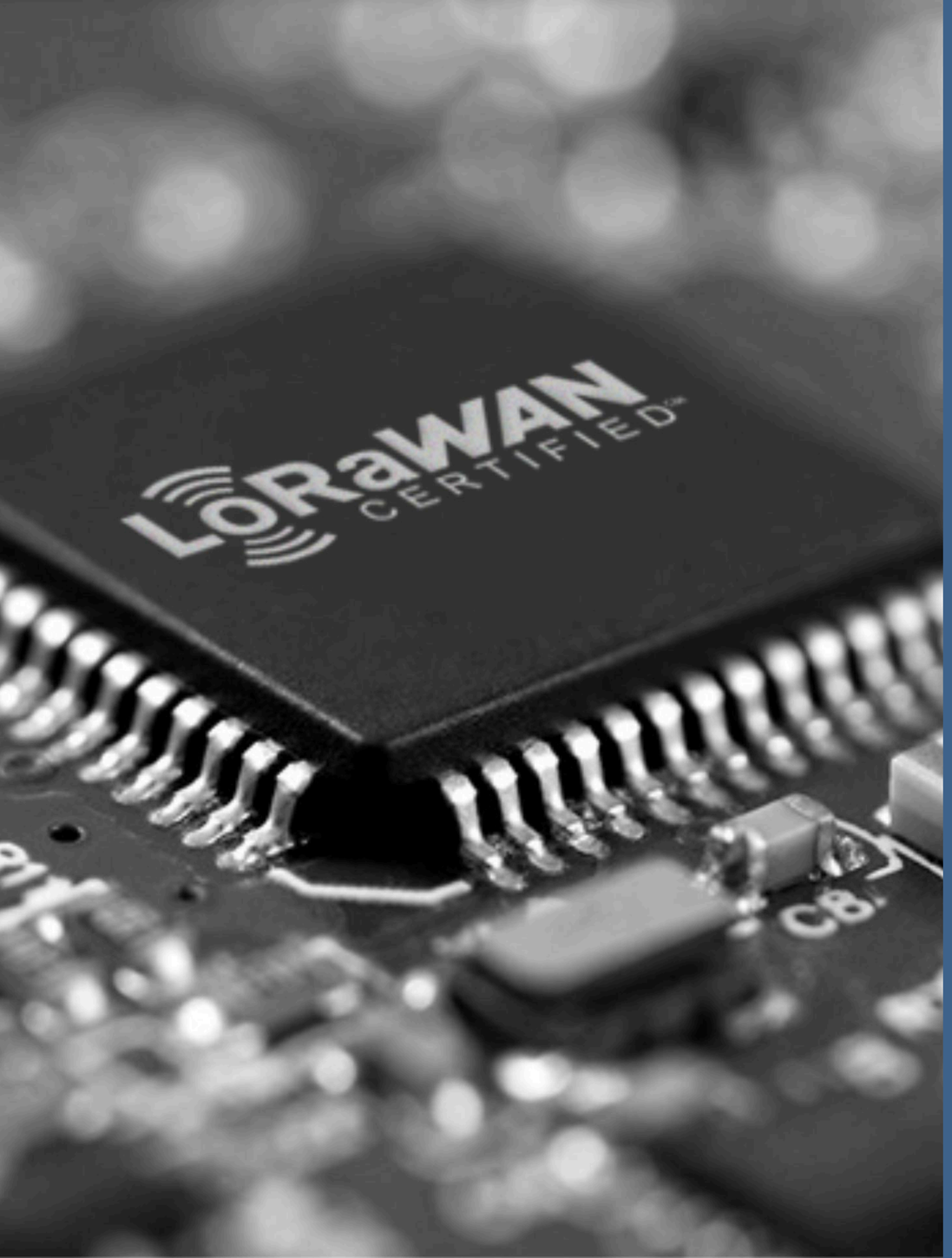
End-to-End IoT solution to deliver AI and Security at the Edge

AI Studio: motion and vibration analysis with zero coding approach

life.augmented AVNET Octonion

PREDICTIVE MAINTENANCE





LPWAN IN DEPTH

Fasten your seat belt :–)

dBm

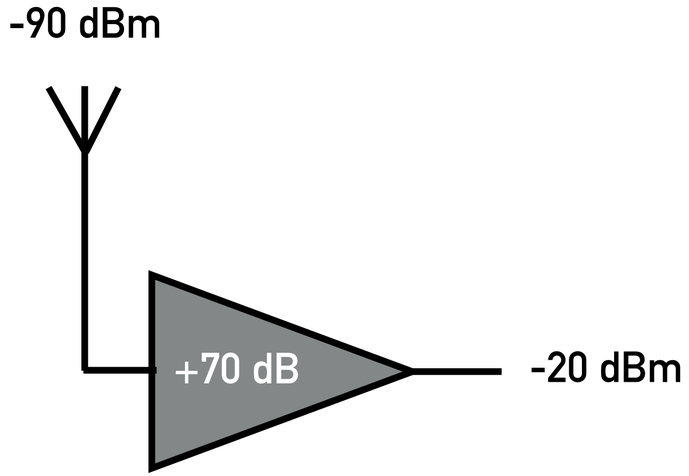
dBm (decibel milliwatts): amount of power that an antenna or amplifier is able to produce, or how much signal is present at a site.

dBm : unité de puissance en décibels (dB) par rapport à une valeur de référence de 1 mW, pour les réseaux radio, micro-ondes et fibre optique, par exemple.

$$Power\ (dBm) = 10.log_{10}\left(\frac{Power\ (Watt)}{0{,}001}\right)$$

dB

A decibel (dB) reading signifies the amount of increase or decrease in a signal. dB is a dimension-less measure of relative power, as a difference between two dBm figures.



dB

$$Power\ ratio\ (dB) = 10.log_{10}\left(\frac{P_R}{P_T}\right)$$

P_R : Power on the Receiver

P_T : Power on the Transmitter

10 dB : multiplication by 10

-10 dB : division by 10

3 dB : multiplication by 2

-3 dB : division by 2

dBm for 3G/4G

Different readings
as 3G and 4G have
different wavelengths

-70 dBm	excellent for 3G
-90 dBm	excellent for 4G
-110 dBm	‘dead zone’ for 3G ‘poor signal’ for 4G
-120 dBm	‘dead zone’ for 4G

LoRaWAN RSSI

Received Signal Strength Indication

RSSI

Indication de l'intensité du signal reçu

-30 dBm signal is strong

-70 dBm

.

-90 dBm .

.

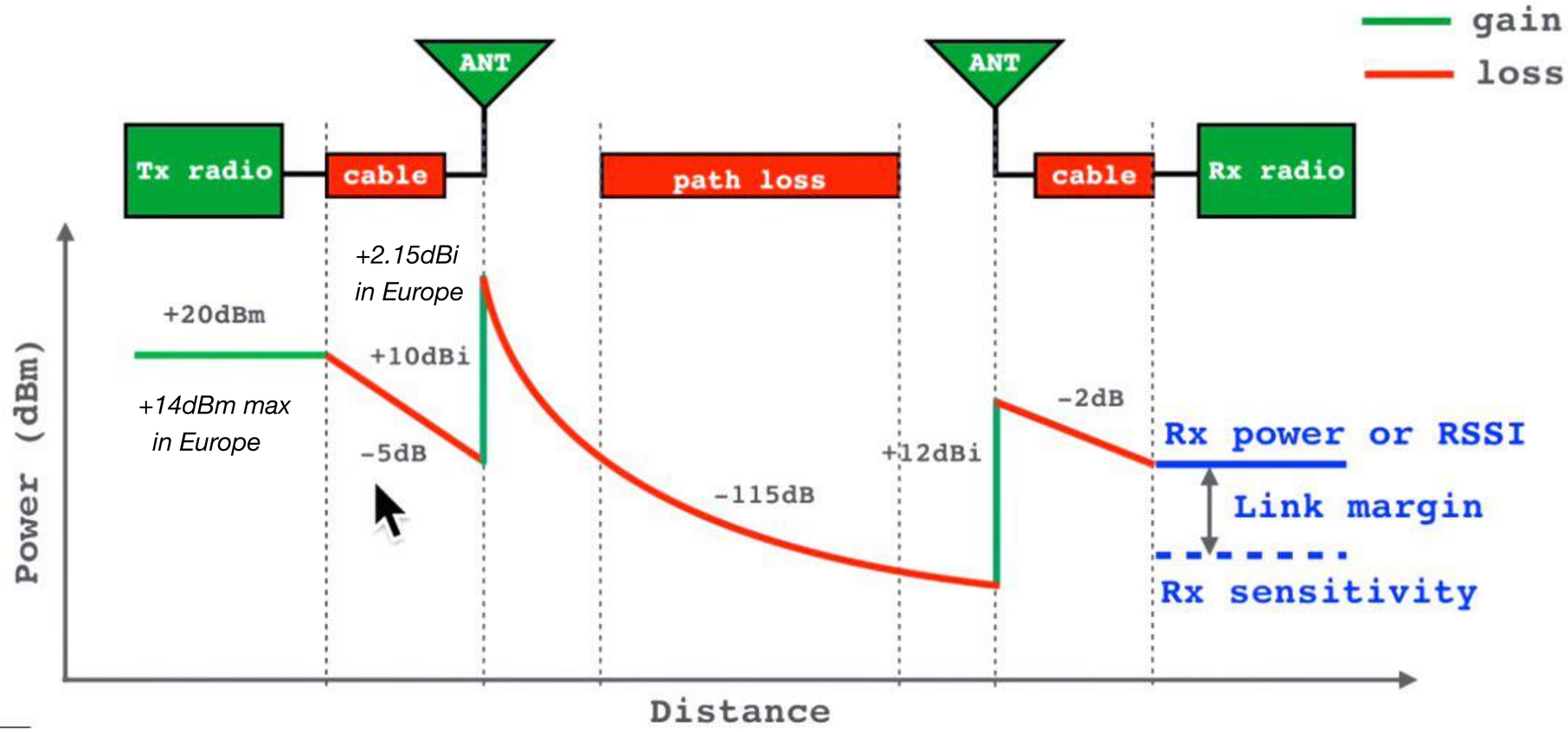
-110 dBm

-120 dBm signal is weak

LoRaWAN LINK BUDGET (bilan de liaison)

Sum of all of the gains and losses from the transmitter, through the medium to the receiver:

Received power (dBm) = transmitted power (dBm) + gains (dB) – losses (dB)



LoRaWAN - FREE SPACE LOSS

$$L(fs)\ \text{in dB} = 32.45 + 20 \bullet \log(d) + 20 \bullet \log(f)$$

868 MHz in Europe

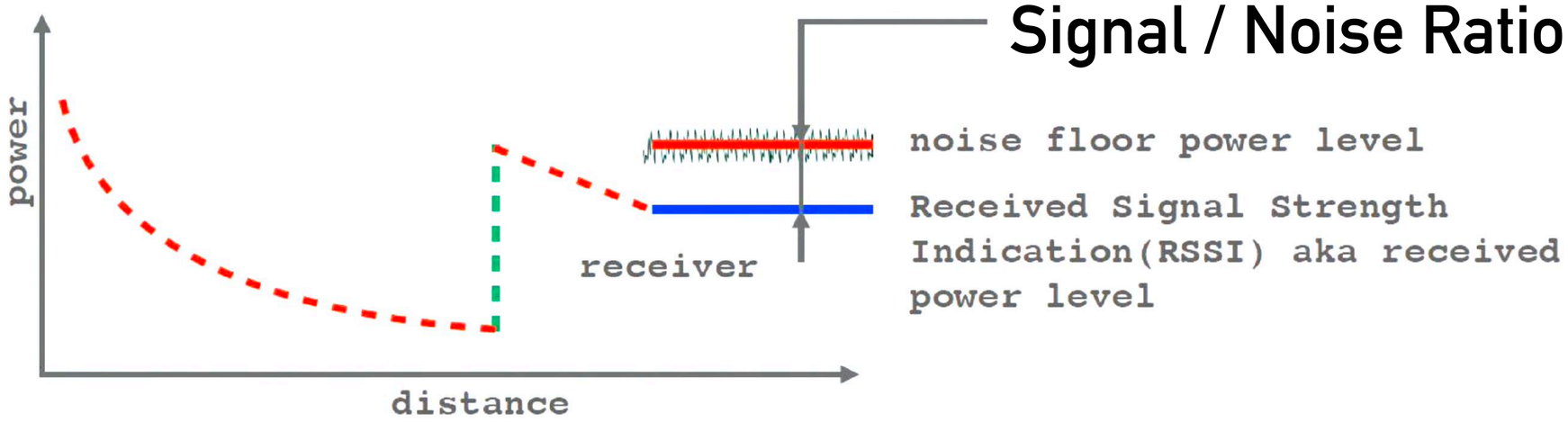
D = 10 m $L(fs) = 32.45 + 20 \bullet \log(0.01) + 20 \bullet \log(868) = 51$ dB

D = 1 km $L(fs) = 32.45 + 20 \bullet \log(1.00) + 20 \bullet \log(868) = 91$ dB

LoRaWAN - STRUCTURAL ATTENUATION

Material	Attenuation (dB)
glass (13mm)	2
Wood (76mm)	2,8
Brick (178mm)	5
stone wall (406mm)	17
concrete (203mm)	23
reinforced concrete (89mm)	27
stone wall (610mm)	28

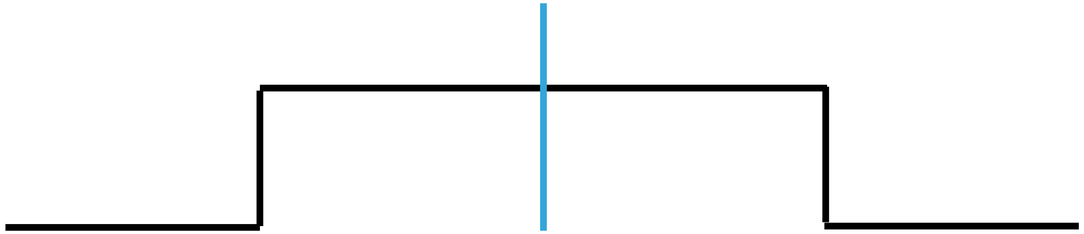
LoRaWAN SNR & SENSITIVITY



Transmitter	Receiver	
Spreading Factor	Sensitivity	Minimum SNR
7	-123 dBm	7.5 dB
8	-126 dBm	10 dB
9	-129 dBm	12.5 dB
10	-132 dBm	15 dB
11	-134.5 dBm	17.5 dB
12	-137 dBm	20 dB

LORAWAN SPECTRUM

On considère une émission sur la fréquence centrale 868.1 MHz avec une Bande Passante de 125 kHz.



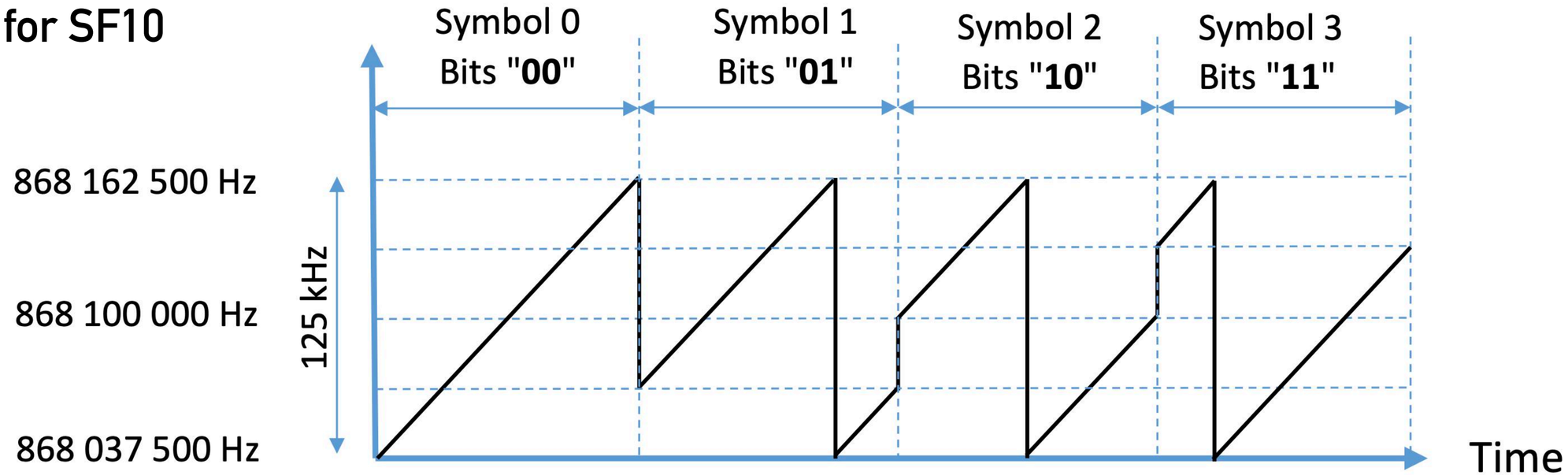
Fréquences de début : 868 100 000 – 125 000/2 Hz
et de fin : 868 100 000 + 125 000/2 Hz
du symbole (chirp)

LORAWAN SF & CHIRP

Number of bits transmitted in a symbol to transmit = Spreading Factor (SF)

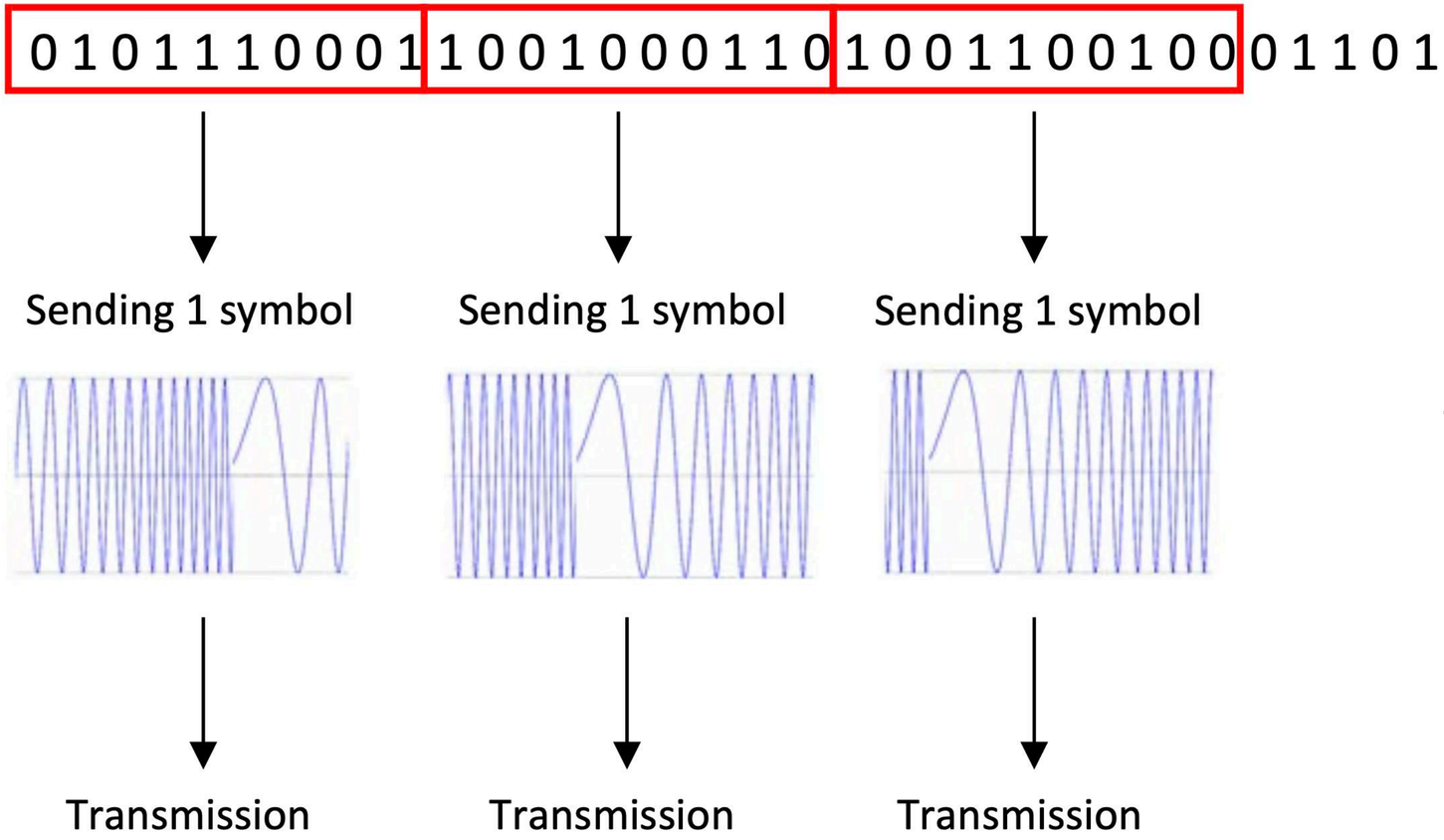
During emission, the bits are grouped together in packets of **SF** bits. Then each packet is represented by a particular symbol among 2^{SF} possible forms. Between symbols, the only difference is that they all starts from a specific frequency which represent the packet of bits.

Spectrogram for SF10



LORAWAN SF & CHIRP

To transmit the binary 01011100011001001101 at SF10, we group bits in packets of 10:



There are 1024 different symbols to encode the 1024 possible binary combinations (2^{10}).

LORAWAN DATA RATES & PAYLOADS

$$Bit\ Rate\ (bit/s) = SF.\frac{Bandwidth}{2^{SF}}$$

← 125 kHz in Europe

Data Rate	Spreading Factor	Bandwidth	Max Frame Payload (Number N)
DR 0	SF12	125 KHz	51 bytes
DR 1	SF11	125 KHz	51 bytes
DR 2	SF10	125 KHz	51 bytes
DR 3	SF9	125 KHz	115 bytes
DR 4	SF8	125 KHz	242 bytes
DR 5	SF7	125 KHz	242 bytes
DR 6	SF7	250 KHz	242 bytes

← North America

LORAWAN DATA RATES & PAYLOADS

$$Bit\ Rate\ (bit/s) = SF.\frac{Bandwidth}{2^{SF}}$$

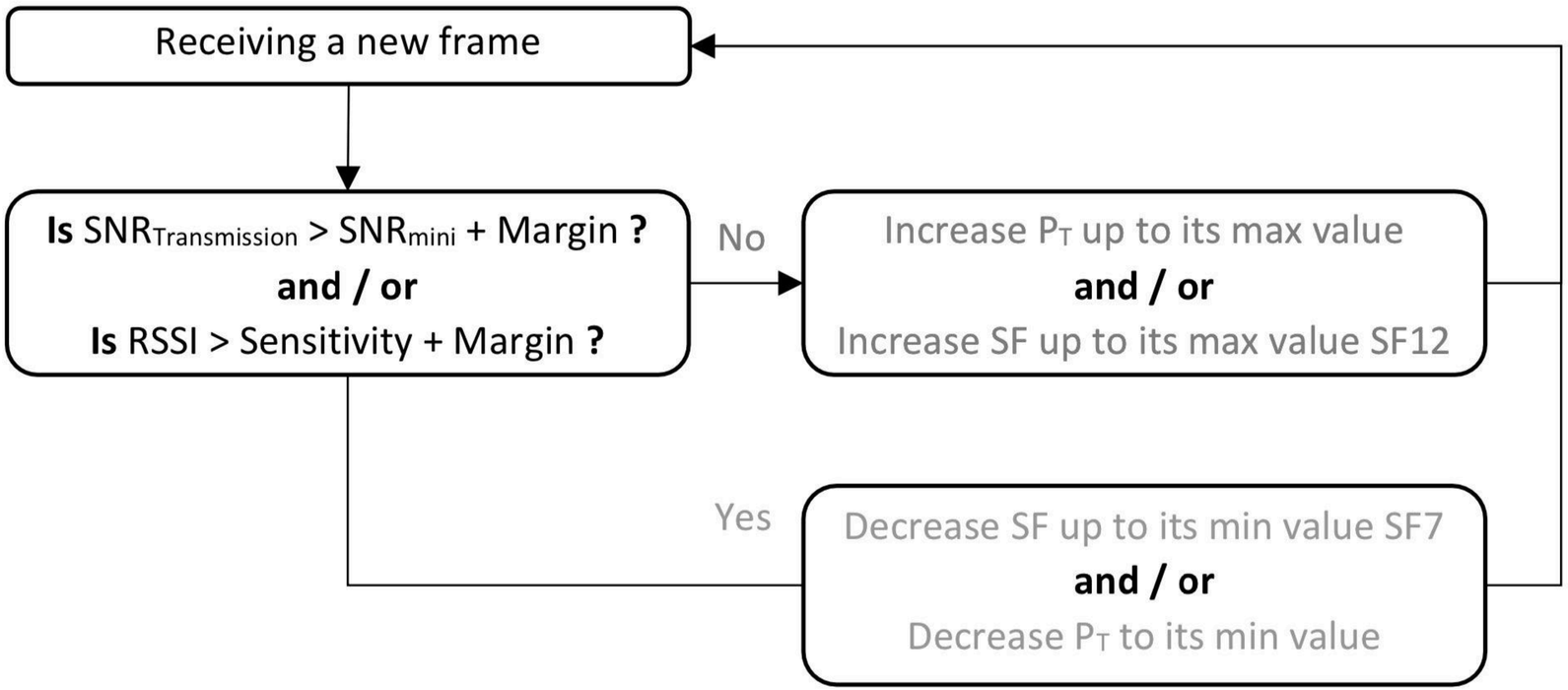
← 125 kHz in Europe

For SF7 Bit Rate = 6,836 bps

For SF12 Bit Rate = 366 bps only, but coverage is maximised

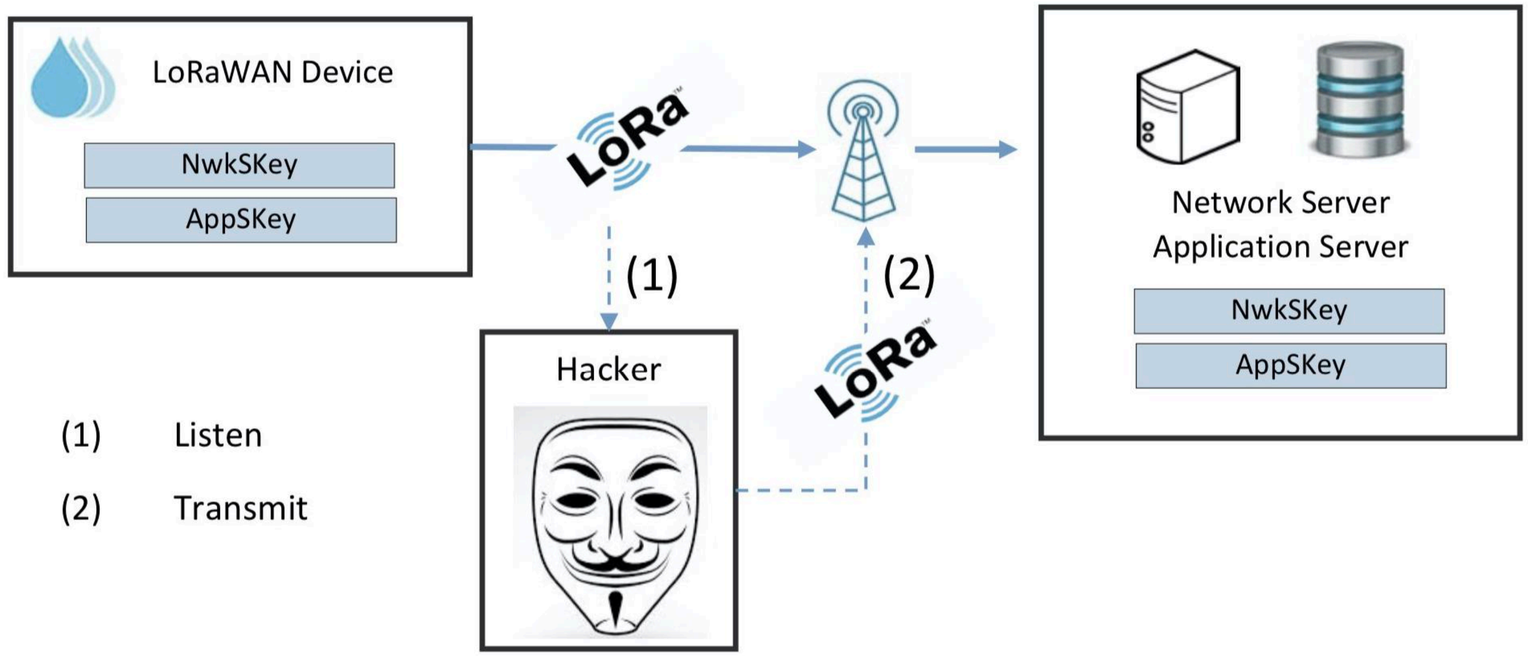
LoRaWAN ADR

Auto adaptative trade-off between QoS and Autonomy



LORAWAN / SECURITY

Typical replay attack:



Typical goal: credit N times an account with repeated payload

Vulnerability fixed: LoRaWAN now implements frame counters

LORAWAN / FURTHER READINGS

« This book is a tremendous resource for anyone interested in LoRaWAN technology. You will simply discover why LoRaWAN is the premier leading solution for large scale LPWAN deployments. Many thanks to the Savoie Mont Blanc University team on behalf of the LoRa Alliance. »

”

- Ms Donna Moore, CEO and Chairwoman of the LoRa Alliance

https://www.univ-smb.fr/lorawan/livre-gratuit/

LTE-M

LTE-CatM

LTE-M ESSENTIALS

LTE evolution for M2M / IoT

Cellular IoT: Cat-M1 at 800 MHz

Lower energy consumption

Mobility: handover

Roaming between operators

Standardized and 5G ready

LTE-M ESSENTIALS - CONTD

Half-Duplex mode (TX then RX)

375 kb/s max / UpLink (UL)

300 kb/s max / DownLink (DL)

Latency: 100–150 ms

LTE-M LAUNCH IN FRANCE- END 2018

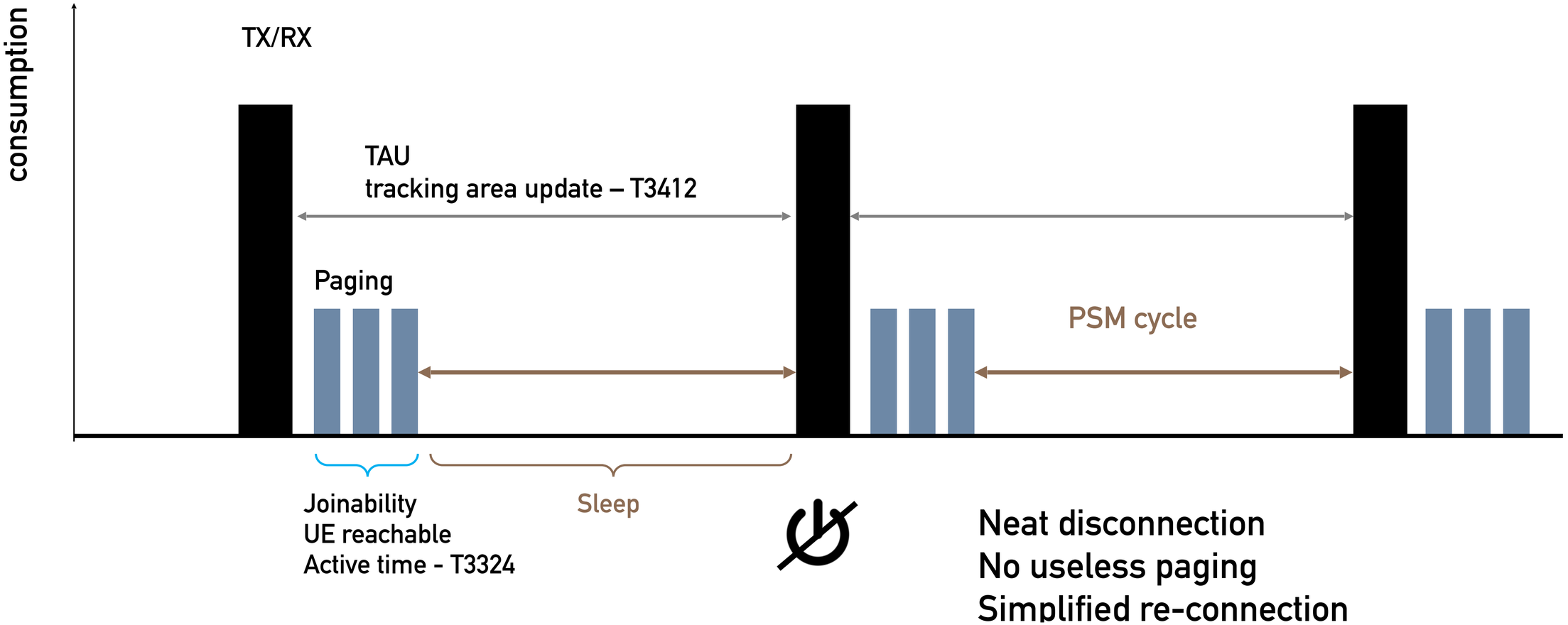
Security, control

Monitoring

Smart tracking

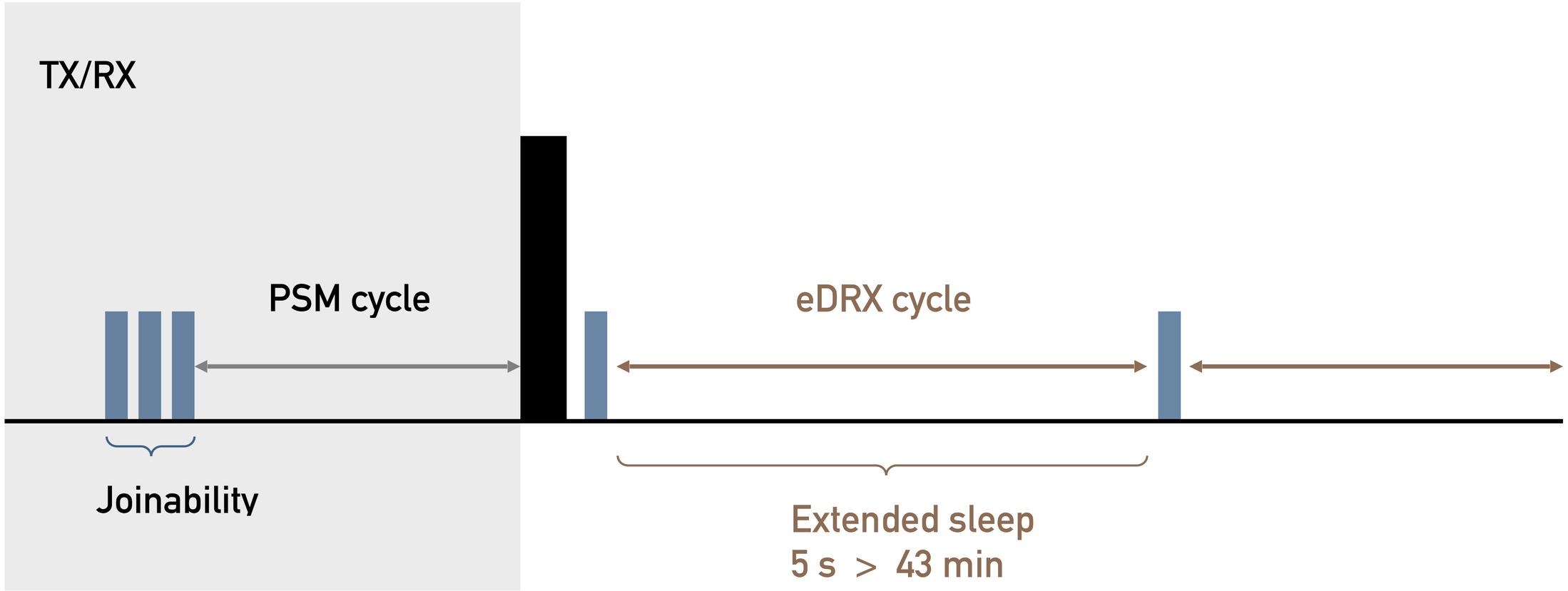
LTE-M Challenge
16 teams, 11 use-cases

PSM: POWER SAVING MODE



Neat disconnection
No useless paging
Simplified re-connection

EDRX: EXTENDED DISCONTINUOUS RECEPTION

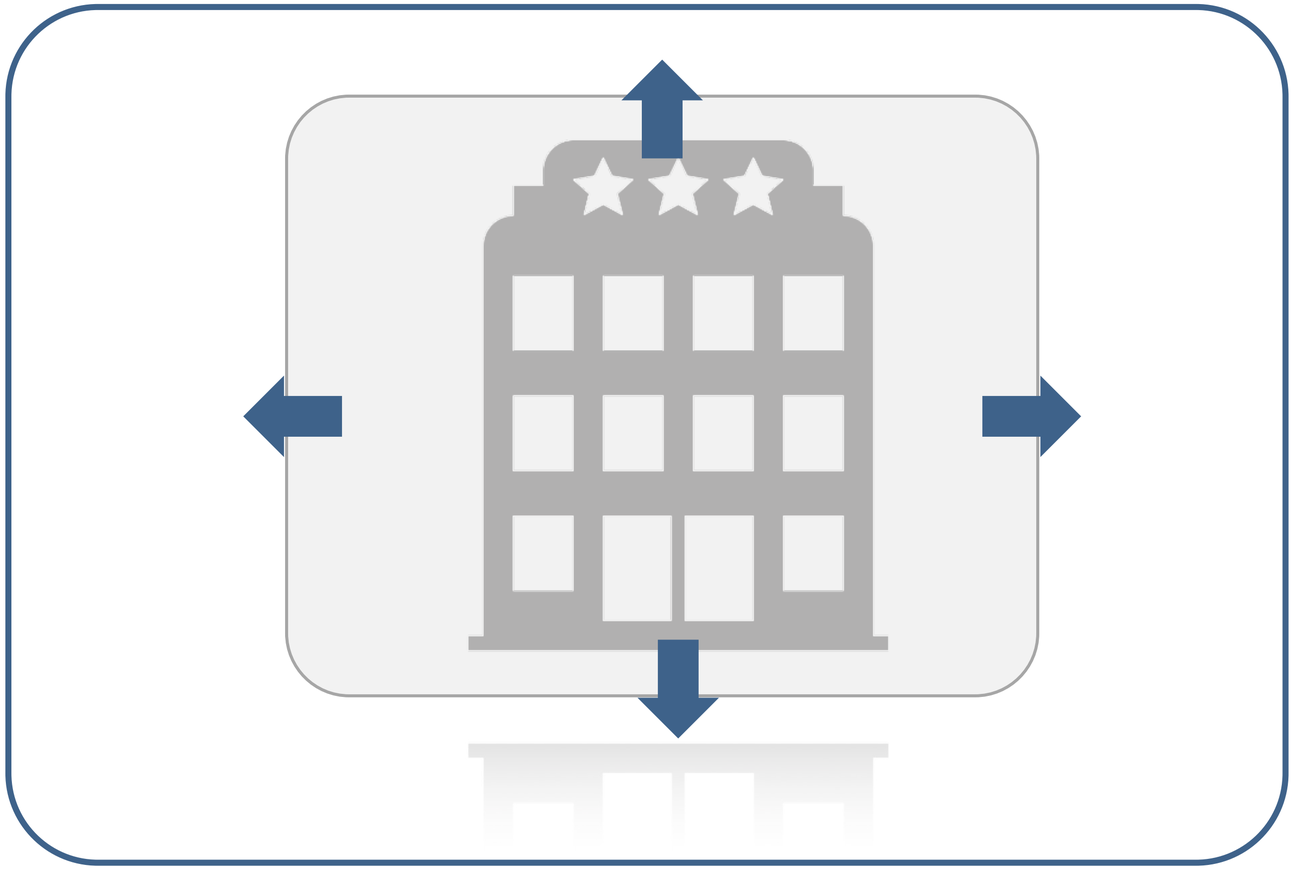


EC: EXTENDED COVERAGE

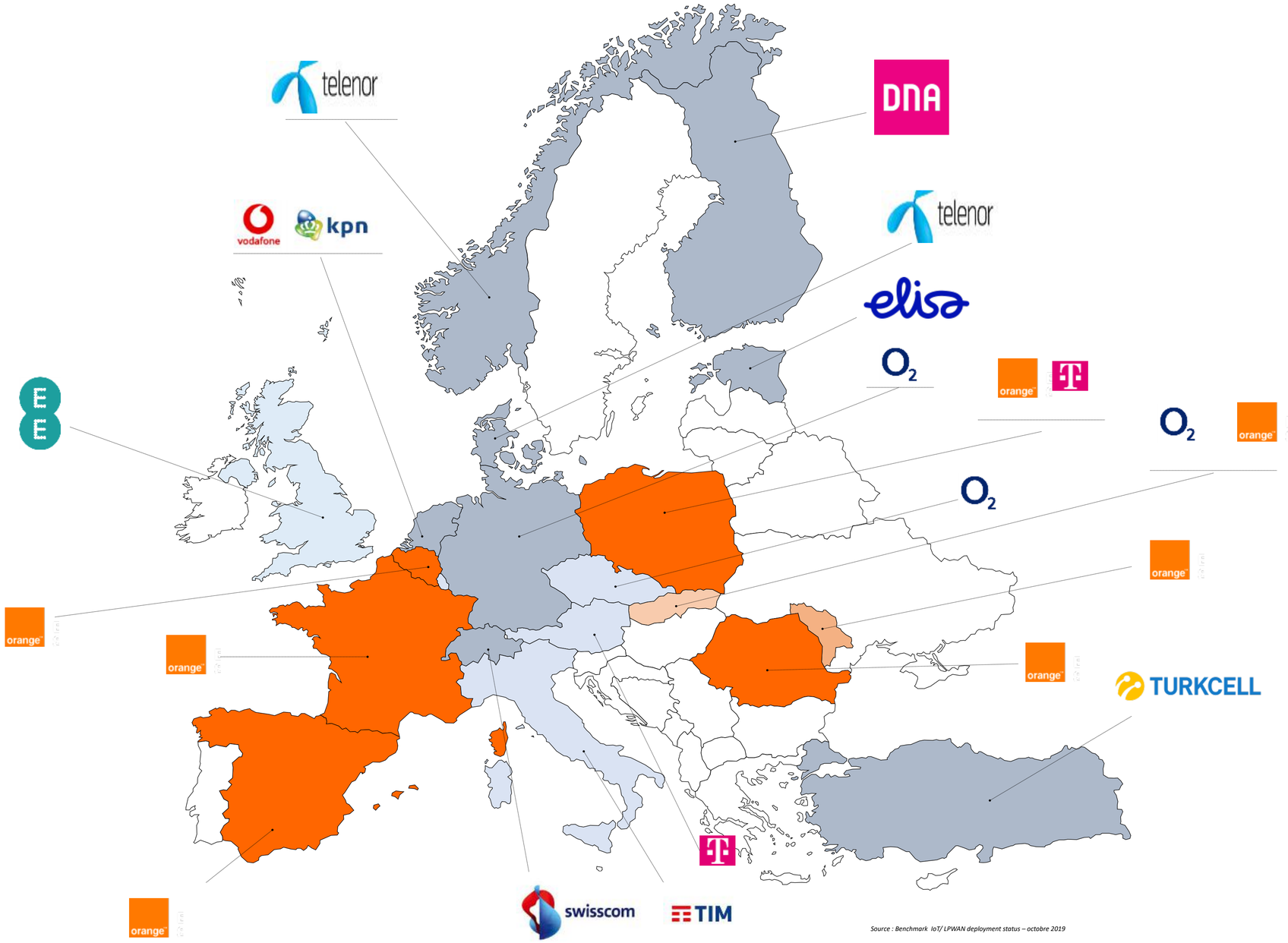
+8 dBm gain

Repetition mechanism

Latency impact

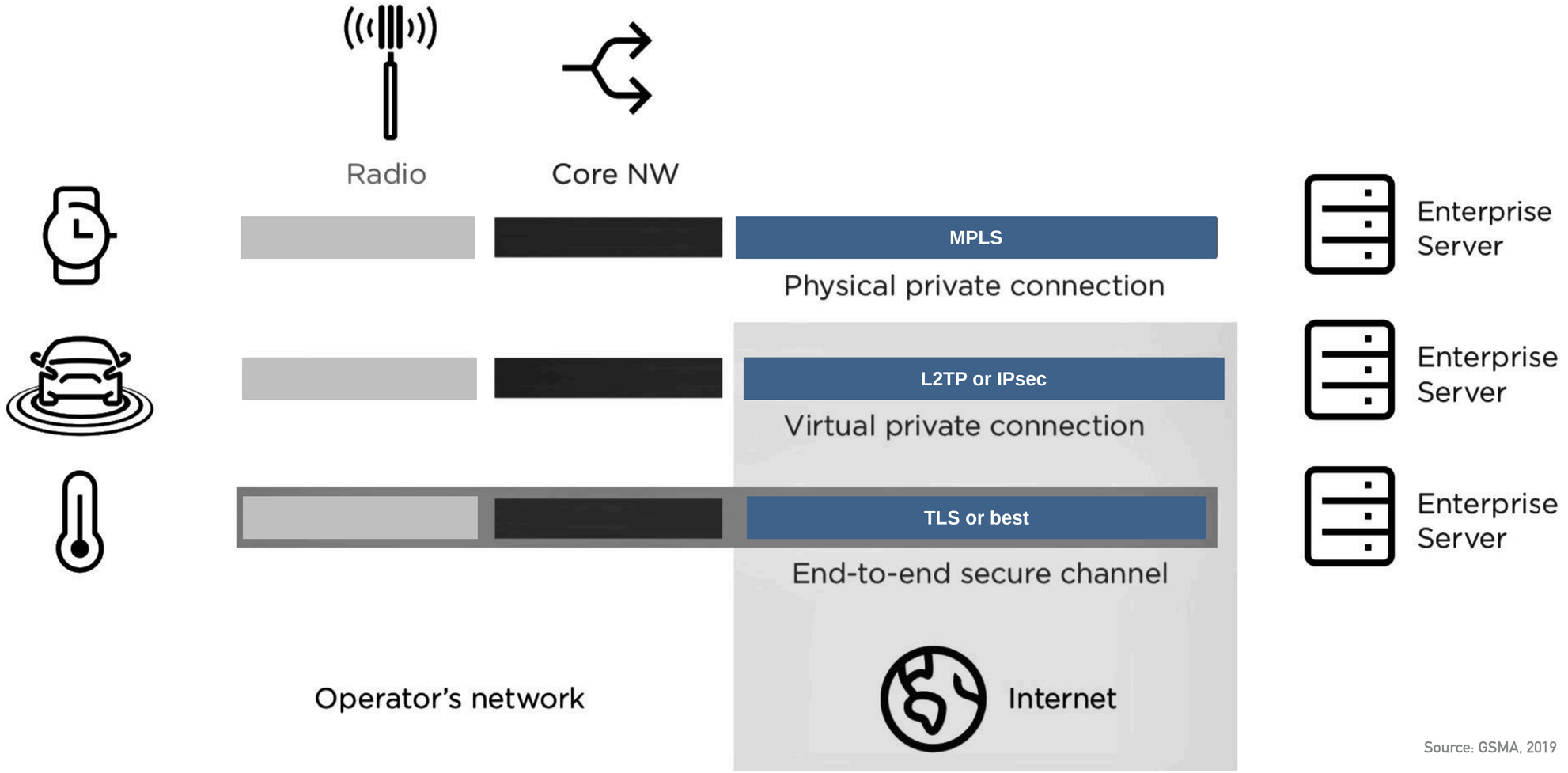


ROAMING



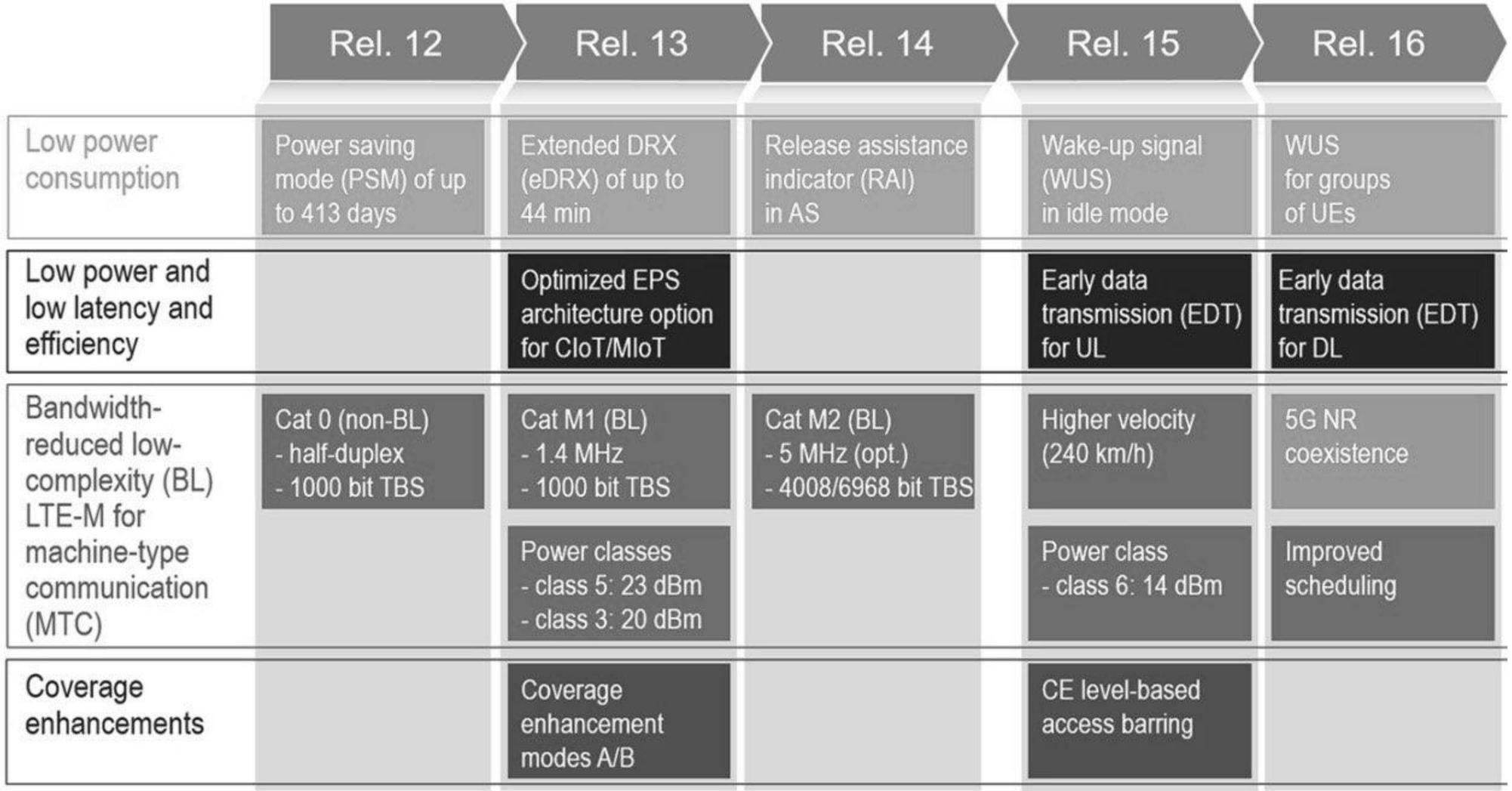
Orange	Others	
		Tests/deployments in progress
		Launched

SECURITY



Source: GSMA, 2019

PERSPECTIVES



NB-IOT

NarrowBand IoT

INBAND VS. STANDALONE

3GPP cellular technology standard introduced in Release 13

"in-band" within a standard LTE carrier or

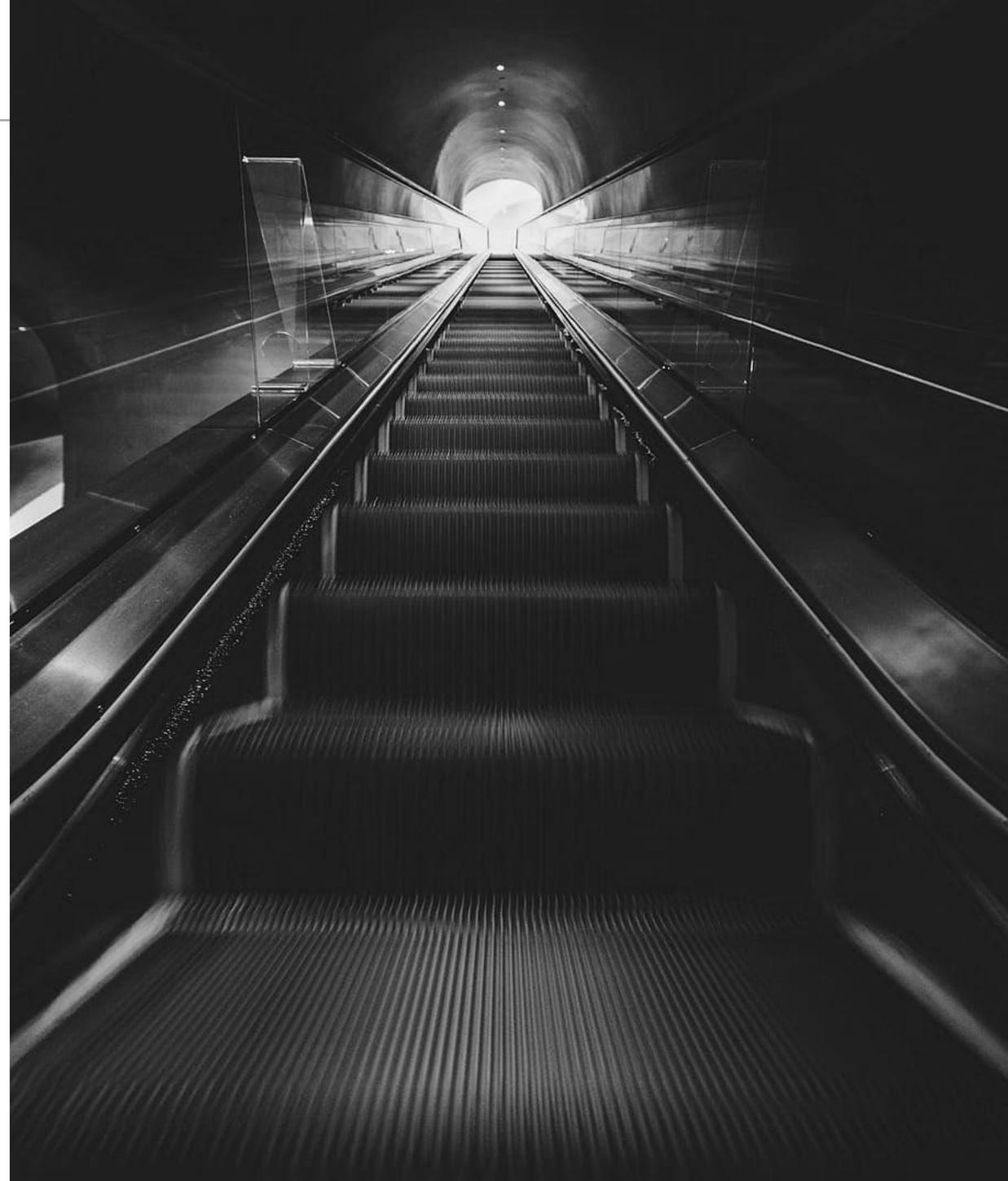
"standalone" for deployments in dedicated spectrum.

DEEP INDOOR

Deep-indoor coverage:
key NB-IoT differentiator

Up to 20+dB for underground and enclosed spaces

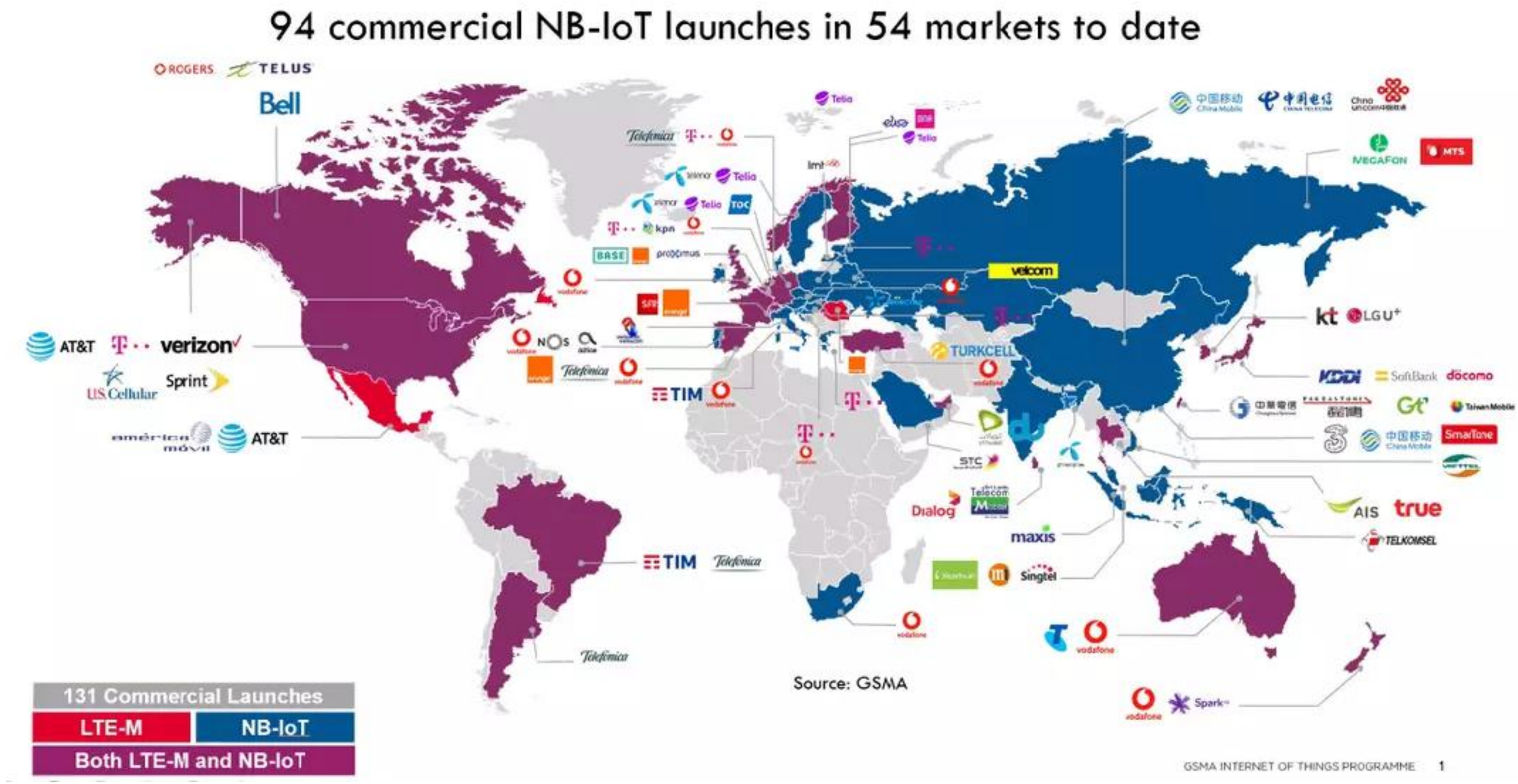
DSSS modulation technology vs. LTE-M spread technology



LTE-M VS. NB-IOT

	LTE-M		NB-IoT	
	LTE CAT M1 (since Rel. 13)	**LTE CAT M2 (since Rel. 14)**	**LTE CAT NB1 (since Rel. 13)**	**LTE CAT NB2 (since Rel. 14)**
Deployment	in-band LTE		in-band LTE, guard band LTE, standalone	
Downlink OFDMA subcarriers	72 (i.e. 6 resource blocks)	288 (i.e. 24 resource blocks)	12 (i.e. 1 resource block)	
Downlink subcarrier spacing	15 kHz		15 kHz	
Uplink SC-FDMA subcarriers	72 (i.e. 6 resource blocks)	288 (i.e. 24 resource blocks)	single-tone (1 subcarrier at 15 kHz/ 3.75 kHz subcarrier spacing); multi-tone (3, 6 or 12 subcarriers at 15 kHz subcarrier spacing)	
Uplink subcarrier spacing	15 kHz		15 kHz/3.75 kHz	
Peak rate	DL: 1 Mbps UL: 1 Mbps	DL: 4 Mbps UL: 6 Mbps	DL: 27 kbps UL: 60 kbps	DL: 79 kbps UL: 106 kbps
Duplex mode	full/half-duplex FDD/TDD		half-duplex FDD	
UE receiver bandwidth	1.4 MHz	5 MHz	200 kHz	
UE TX power	23/20 dBm		23/20 dBm	23/20/14 dBm
Power saving	PSM, eDRX		PSM, eDRX	
Antenna(s)	1 RX/TX		1 RX/TX	

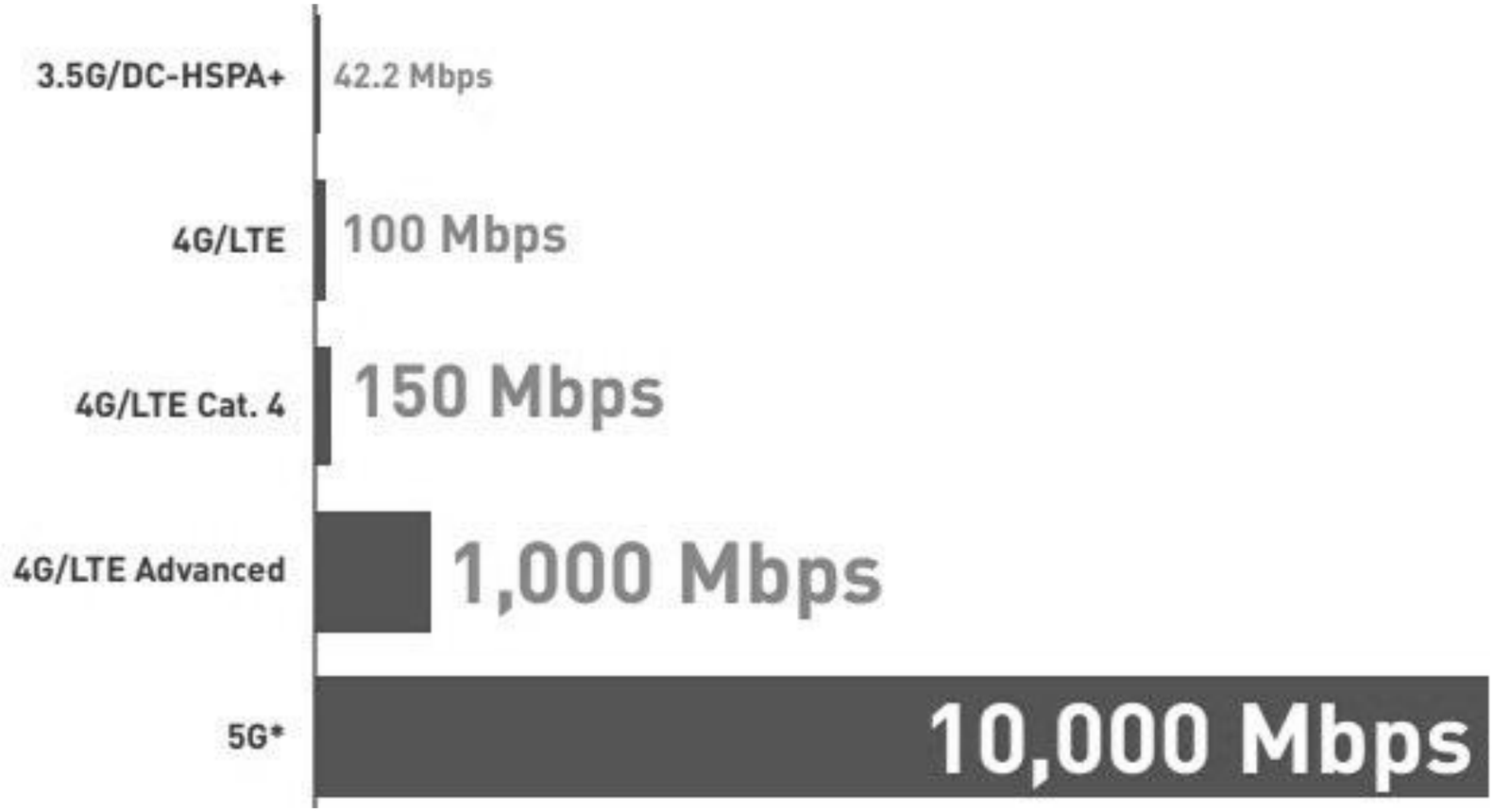
LTE-M VS. NB-IOT



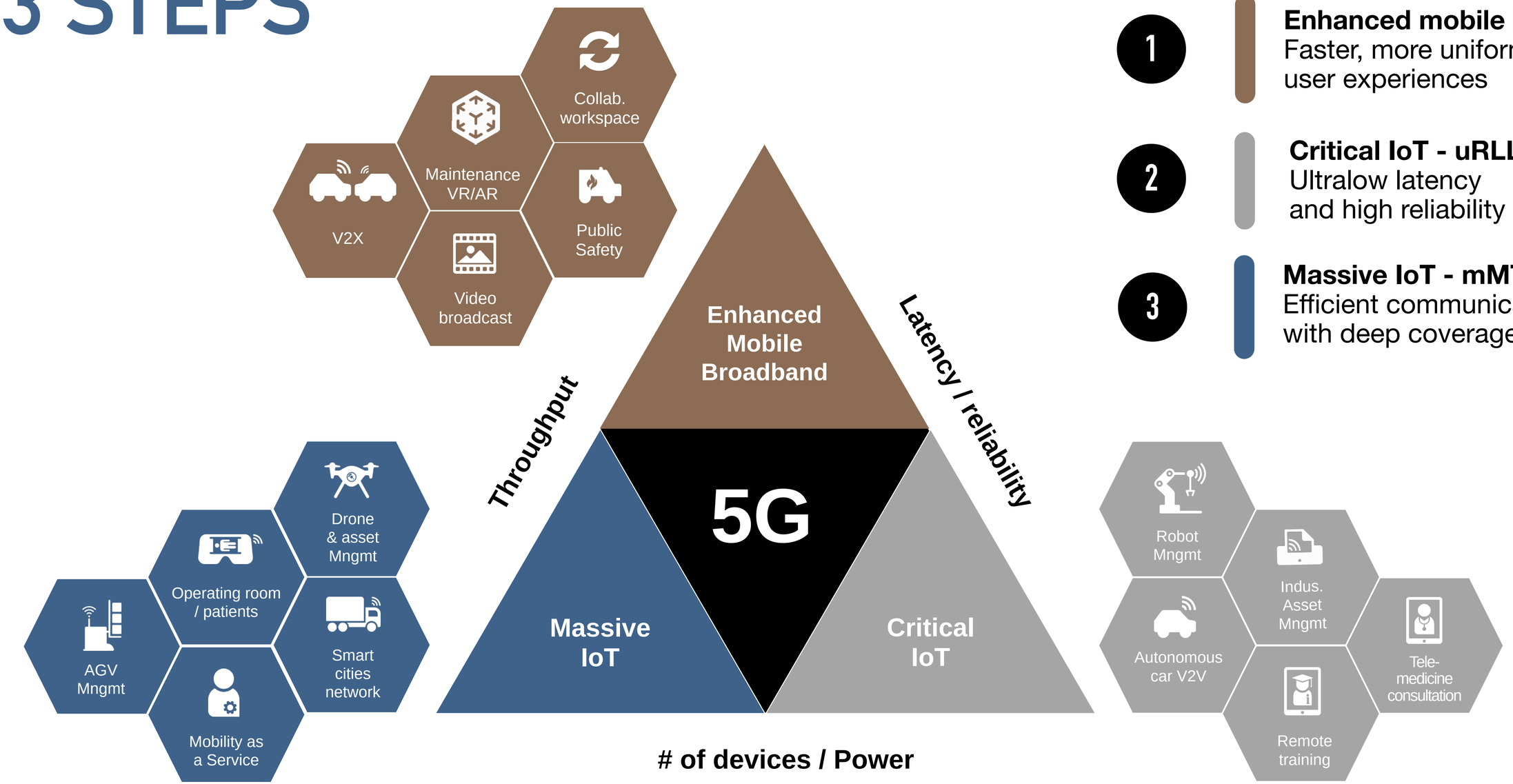
5G

the promise

HOW FAST CAN 5G BE?



3 STEPS

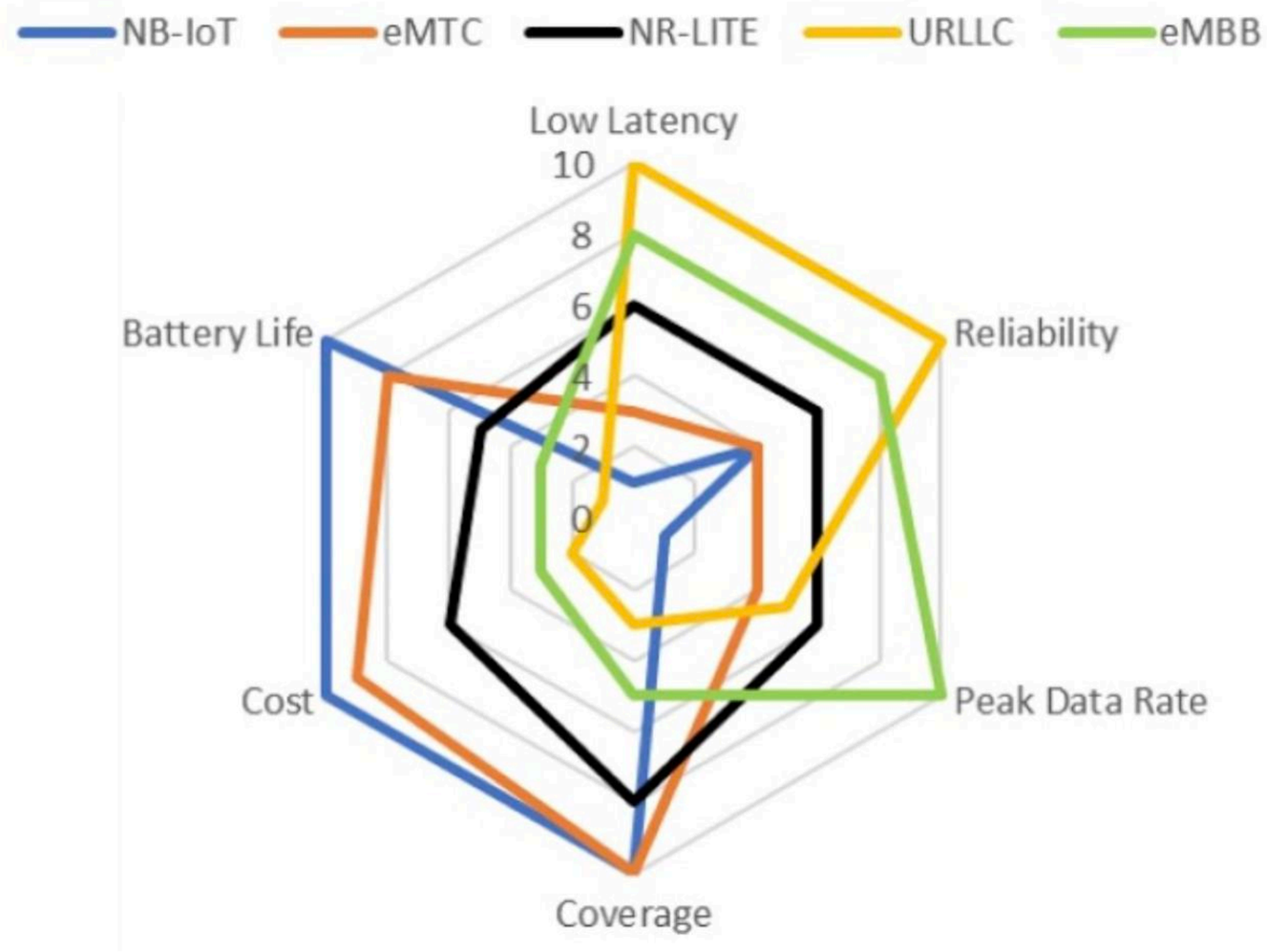


1 **Enhanced mobile broadband**
Faster, more uniform user experiences

2 **Critical IoT - uRLLC**
Ultralow latency and high reliability

3 **Massive IoT - mMTC**
Efficient communications with deep coverage

TRADE-OFF



eMBB - enhanced Mobile Broadband

uRLLC - ultra Reliable Low Latency Communications critical IoT

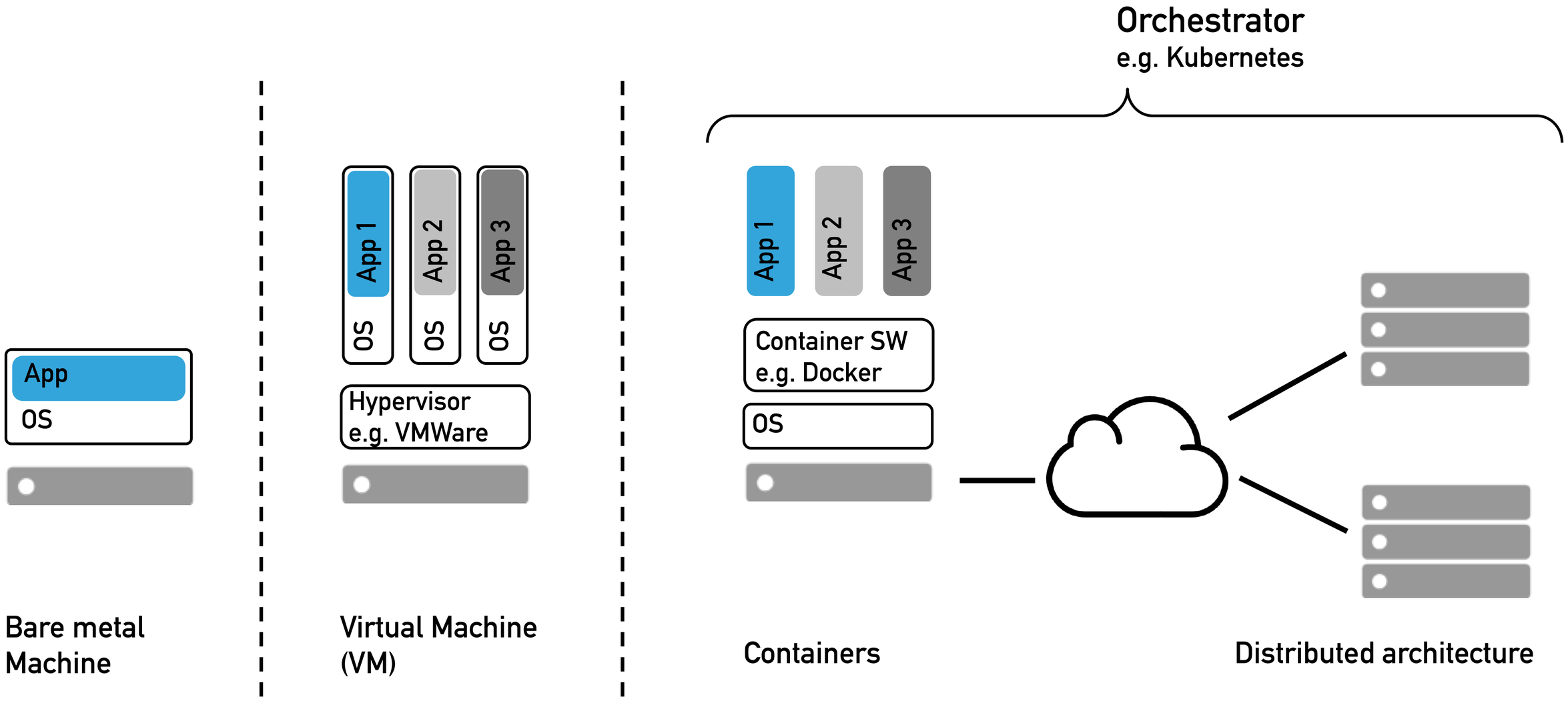
mMTC - massive Machine Type Communications massive IoT

RedCap - aka NR Lite - Reduced Capacity

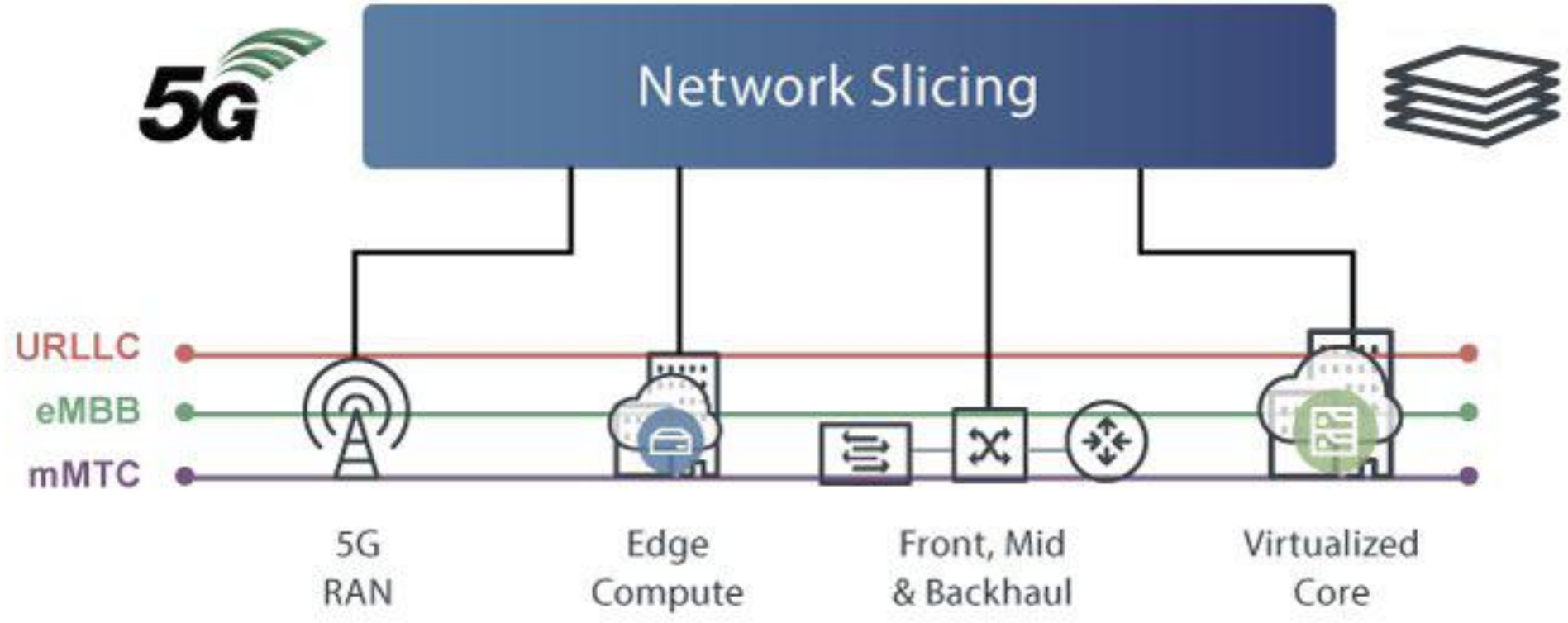
WHAT IS 5G?

Evolution	+	Révolution
Coverage		Active antennas
Deployment		New frequencies
Devices		Edge computing
Standards		New network core
		Slicing, etc.

5G VIRTUALIZATION



5G SLICING


5G
Network Slicing
URLLC
eMBB
mMTC
5G
RAN
Edge
Compute
Front, Mid
& Backhaul
Virtualized
Core

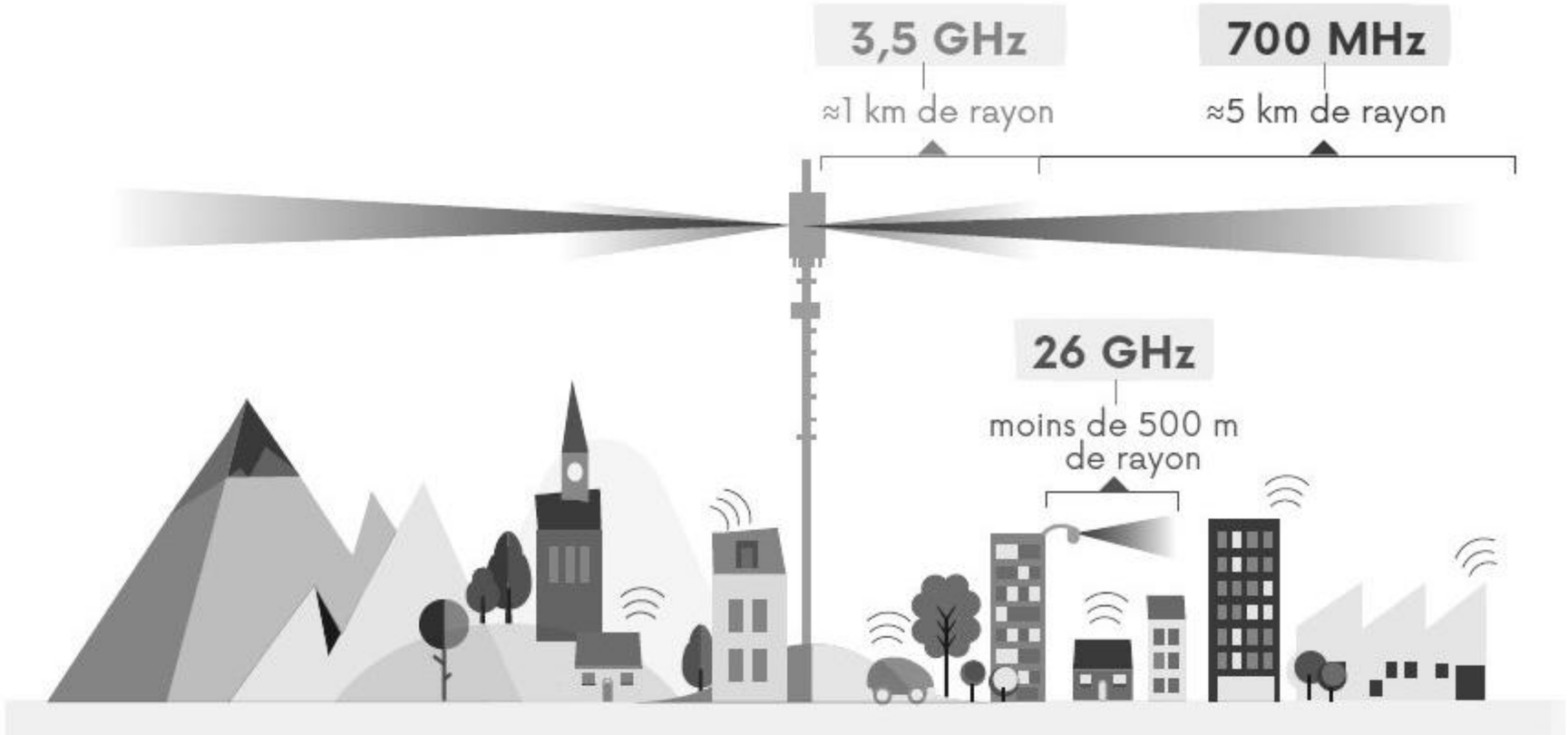
MAIN FREQUENCY BANDS (FRANCE)

Source : Arcep _ 2020

700 MHz

3.5 GHz

26 GHz



FREQUENCY TRADE-OFF

4G like throughputs

700 MHz
FDD Frequency-division duplexing

Indoor	Range	Throughput
++	++	--

Bandwidth: 20 MHz

Deployed in 2020

4G < throughputs

3.4-3.8 GHz
TDD Time-division duplexing

Indoor	Range	Throughput
-	-	+

Bandwidth: 100 MHz

Fiber-like throughputs

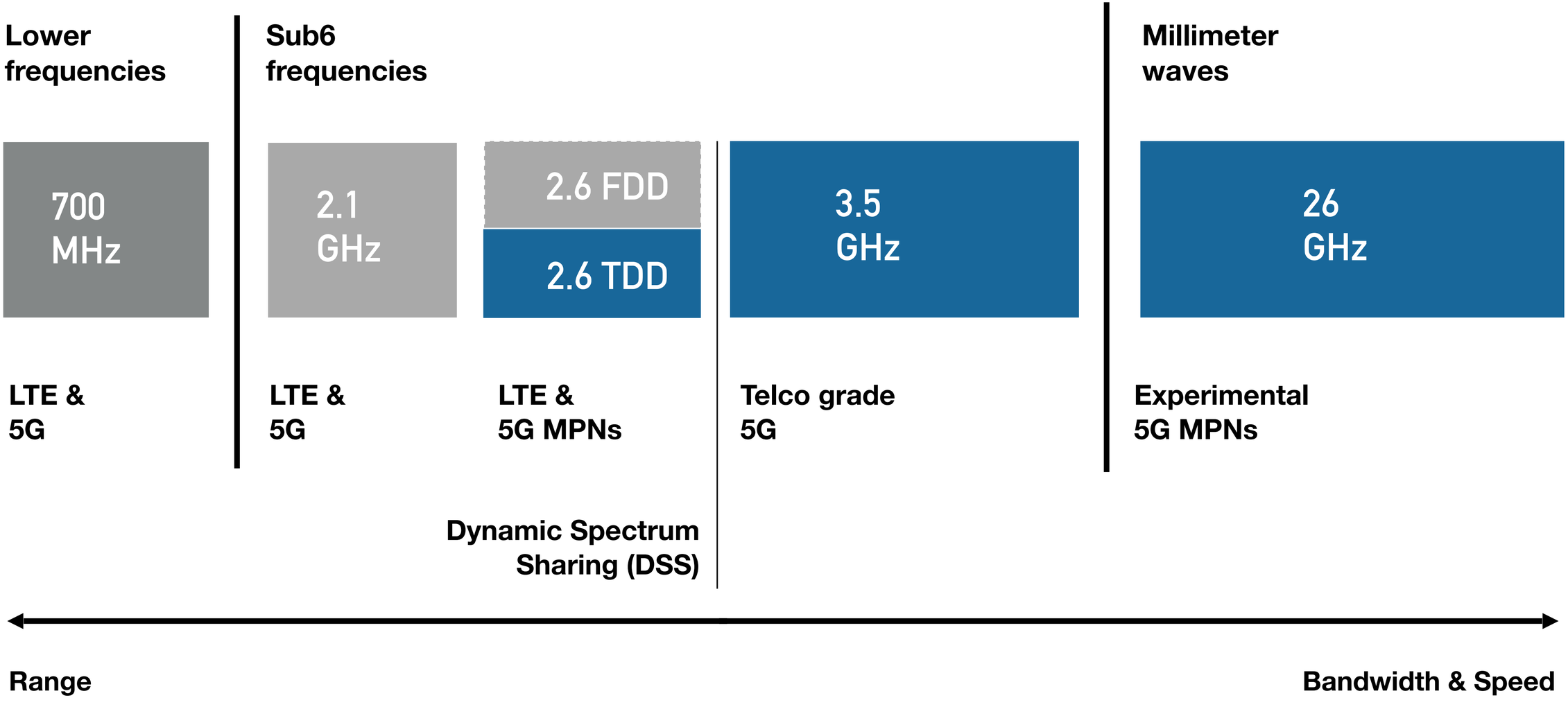
26 (24-27) GHz
TDD Time-division duplexing

Indoor	Range	Throughput
--	--	+++

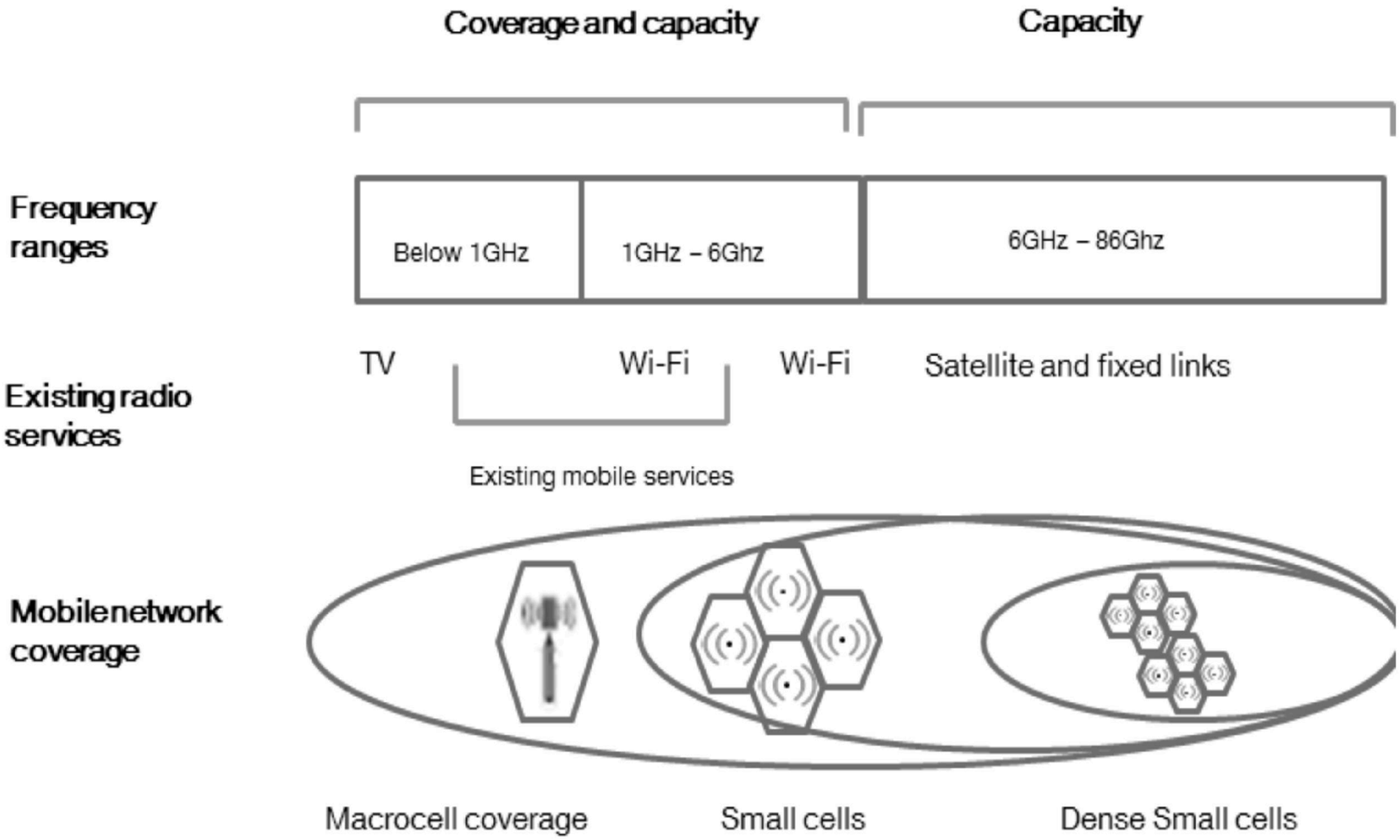
Bandwidth: 400 MHz

Trials - e.g. mobile hotspots & FWA

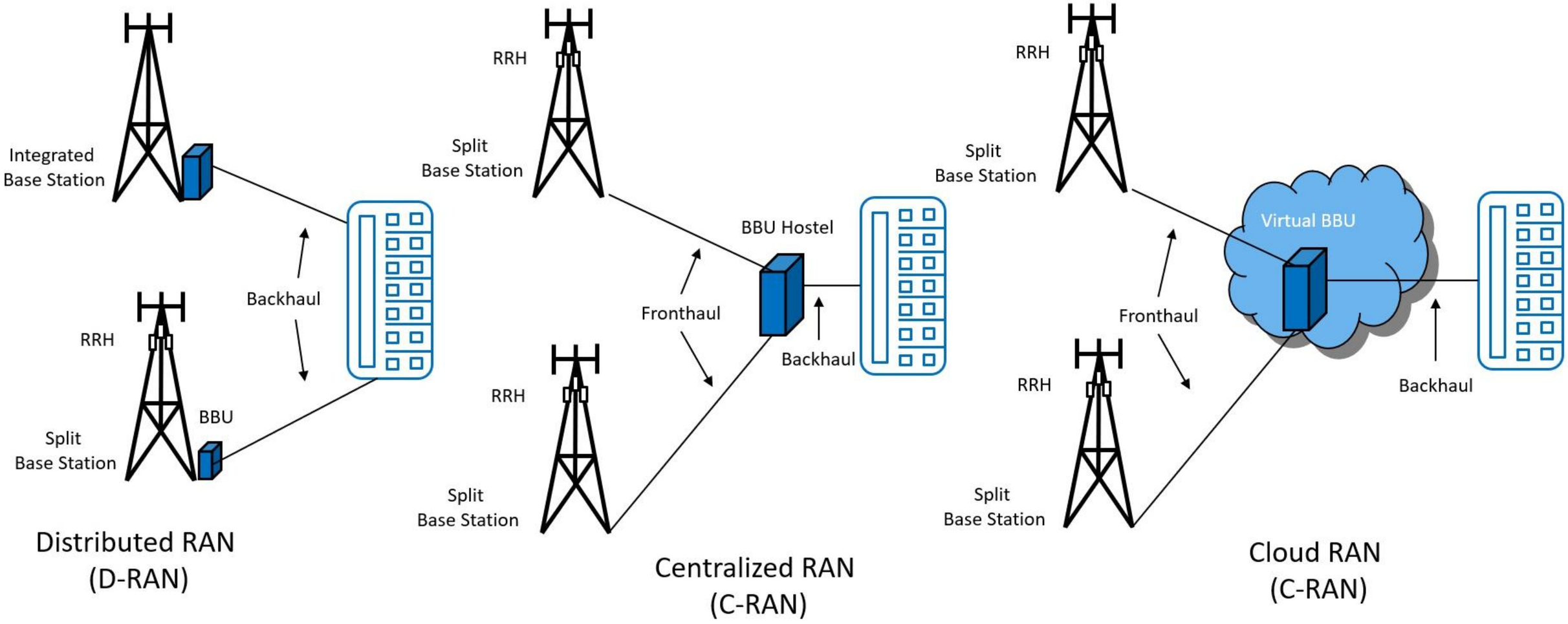
FREQUENCIES (FRANCE)



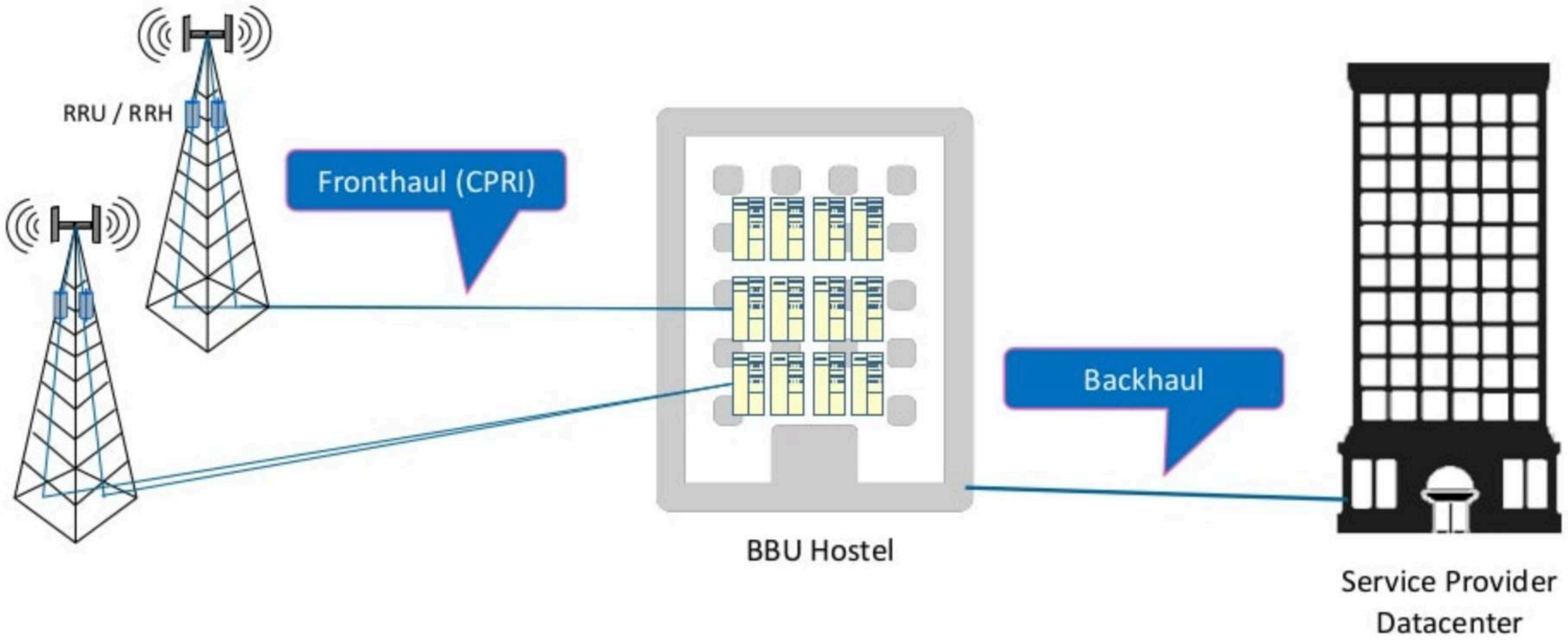
CELLS


Coverage and capacity
Capacity
Frequency ranges
Below 1GHz
1GHz – 6Ghz
6GHz – 86Ghz
Existing radio services
TV
Wi-Fi
Wi-Fi
Satellite and fixed links
Existing mobile services
Mobile network coverage
Macrocell coverage
Small cells
Dense Small cells

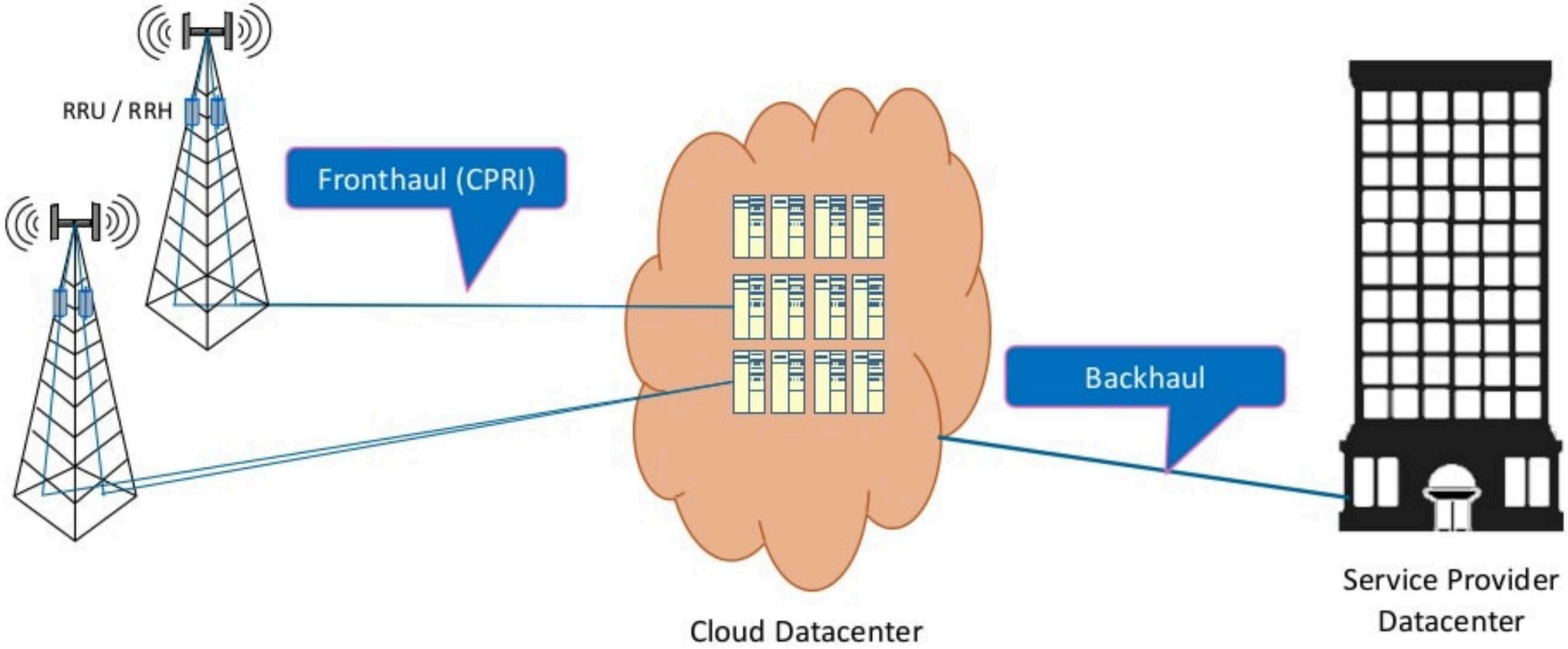
DEPLOYMENT OPTIONS



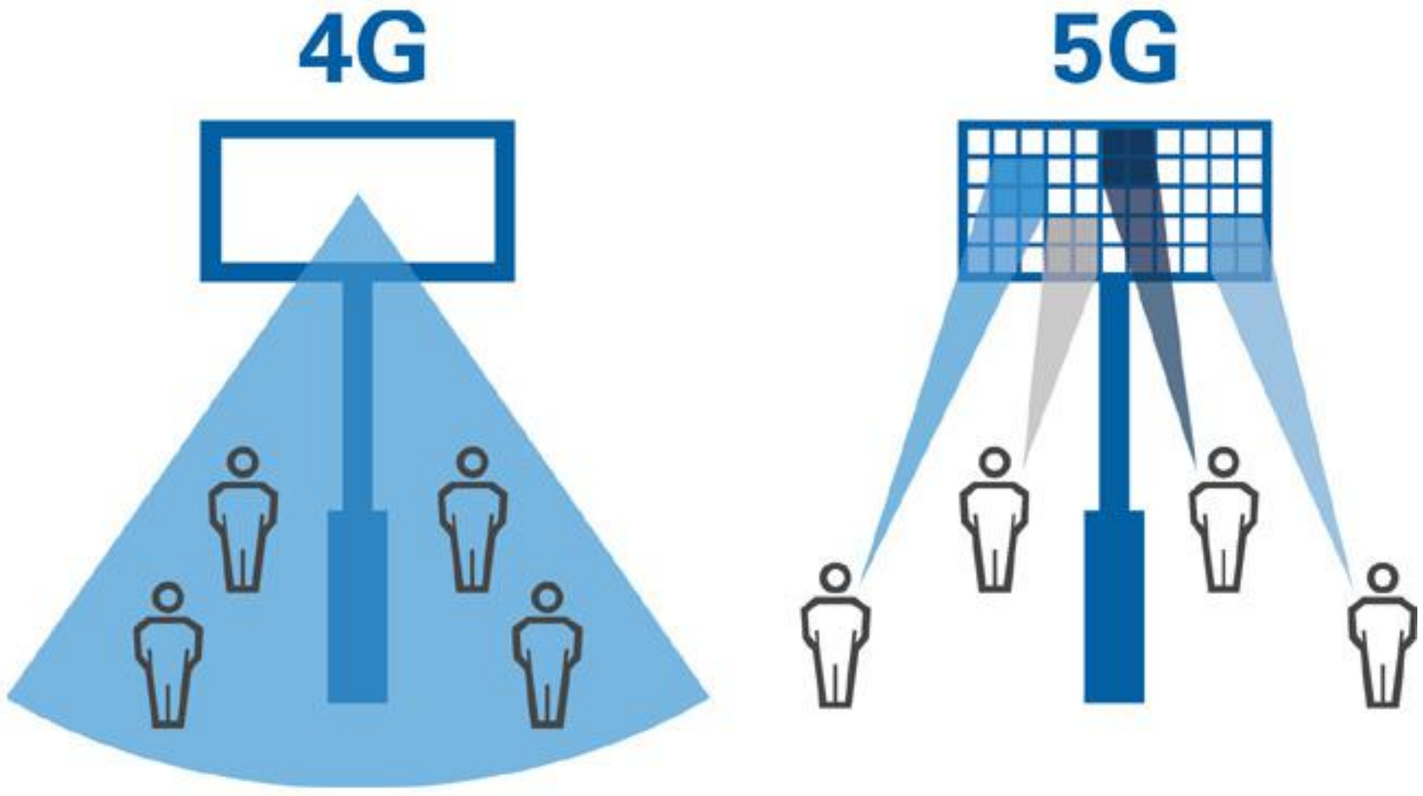
DEPLOYMENT / CENTRALIZED RAN



DEPLOYMENT / CLOUD RAN



ANTENNAS

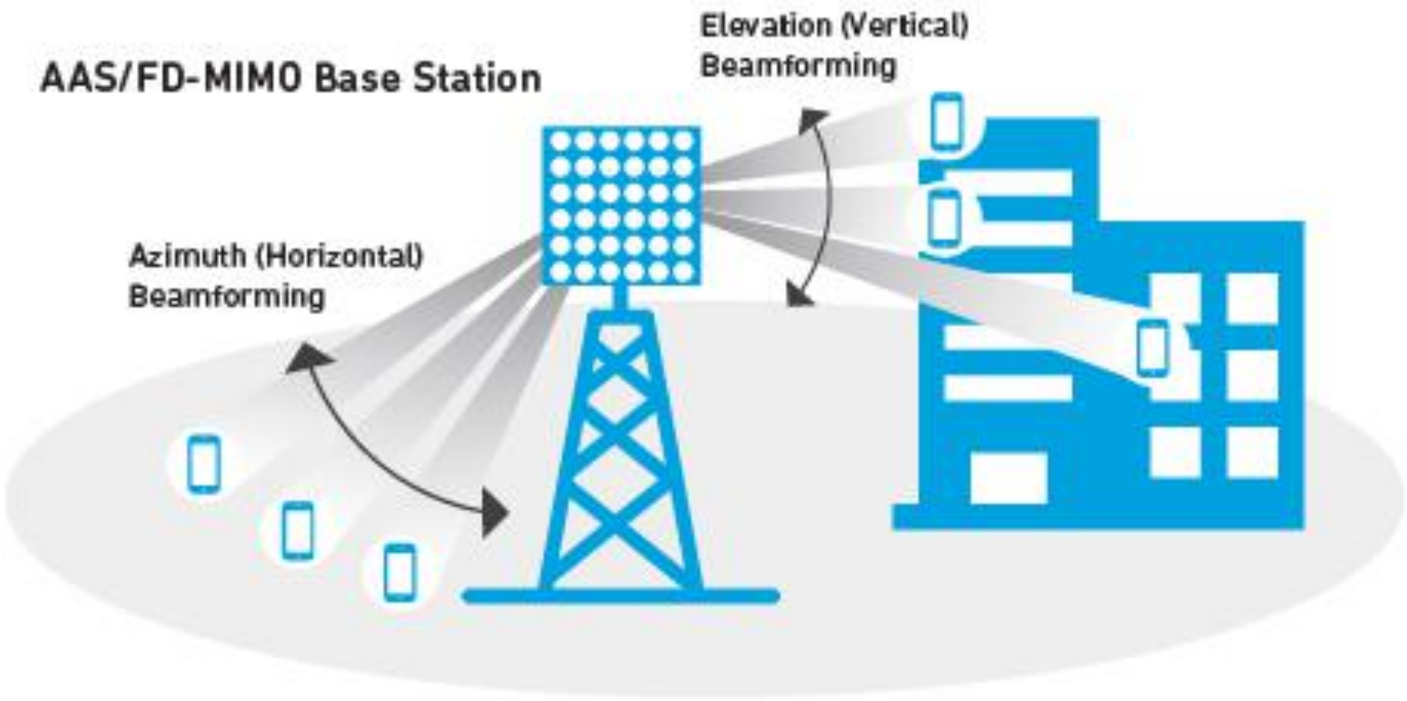


MU-MIMO CAPABILITIES
WITH ACTIVE ANTENNA ARRAYS

MU-MIMO: MultiUser MIMO (Multiple-Input Multiple-Output)

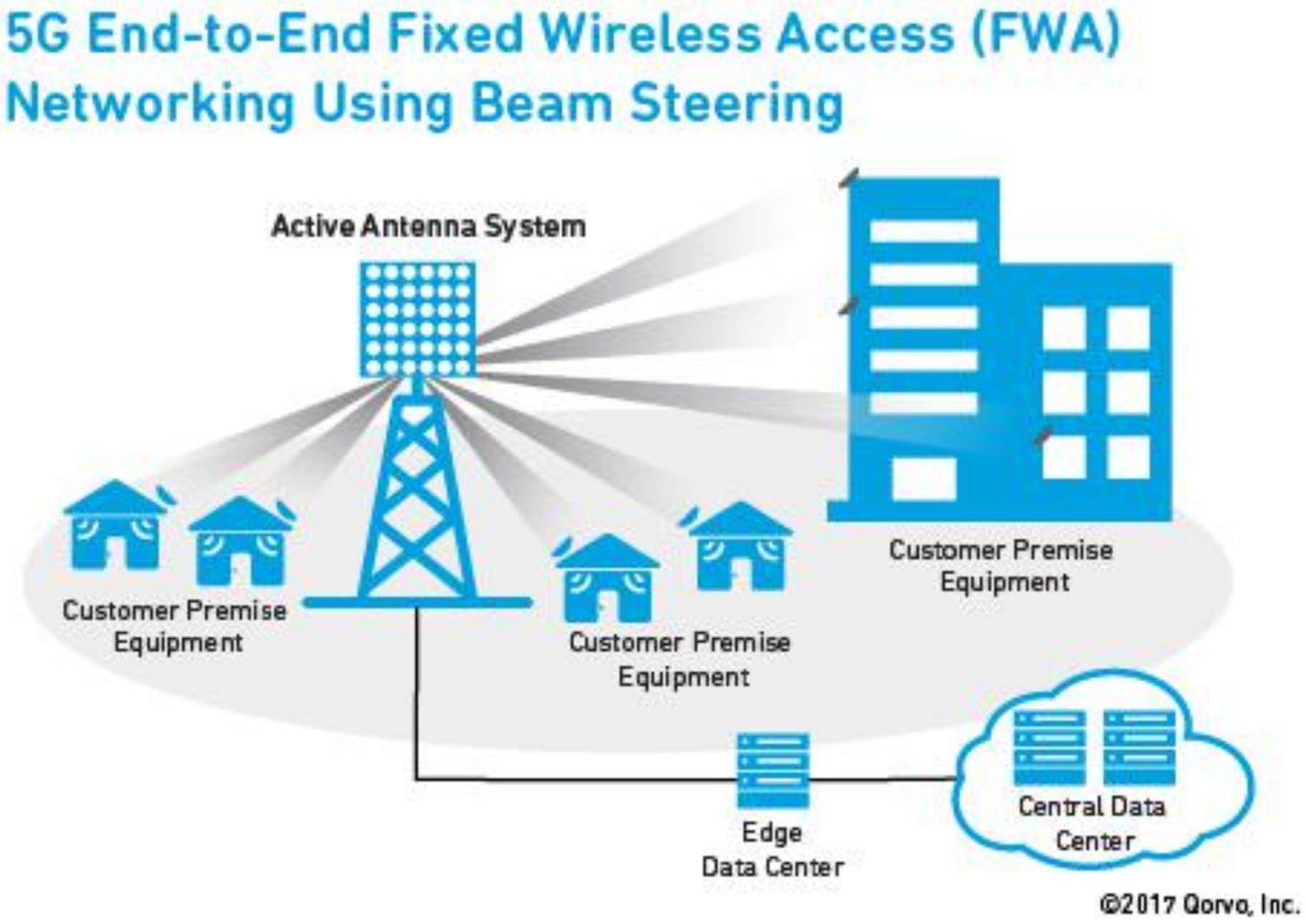
BEAM FORMING

Antenna Beam Forming



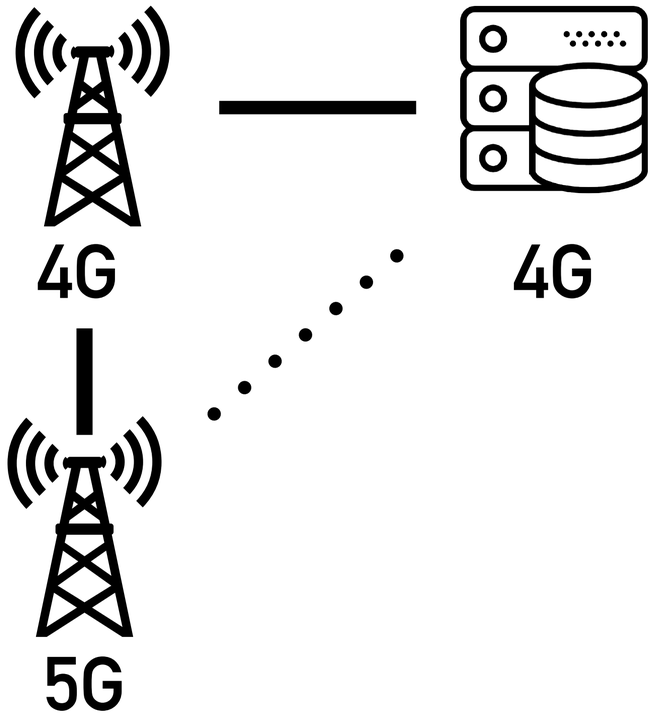
©2017 Qorvo, Inc.

FIXED WIRELESS ACCESS (FWA)

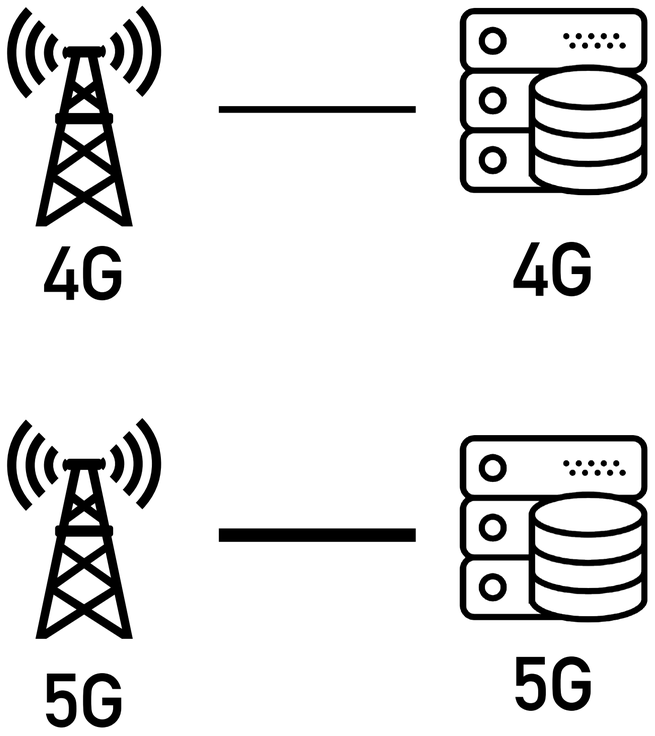


NSA & SA 5G

Non standalone



Standalone



PATHS TO 5G

4G LPWA → **5G LPWA**

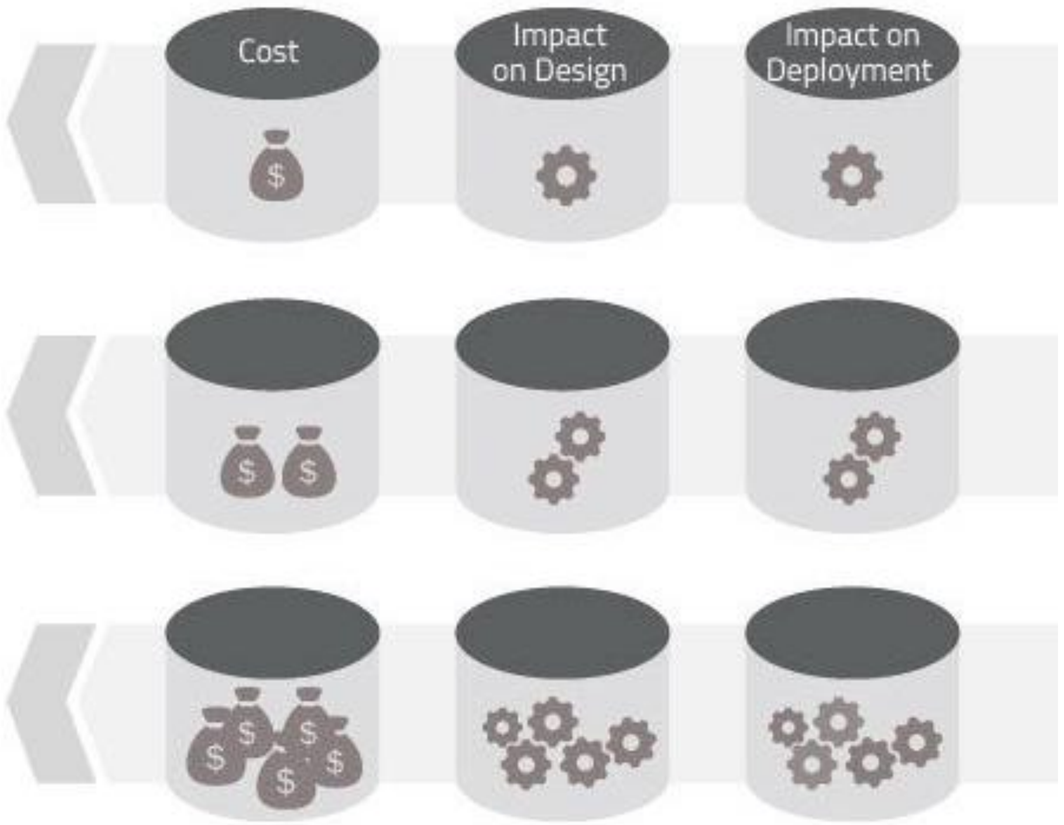
Advancing your design from 4G LPWA to 5G LPWA is a simple firmware upgrade with no hardware change.

4G LTE → **5G Sub-6**

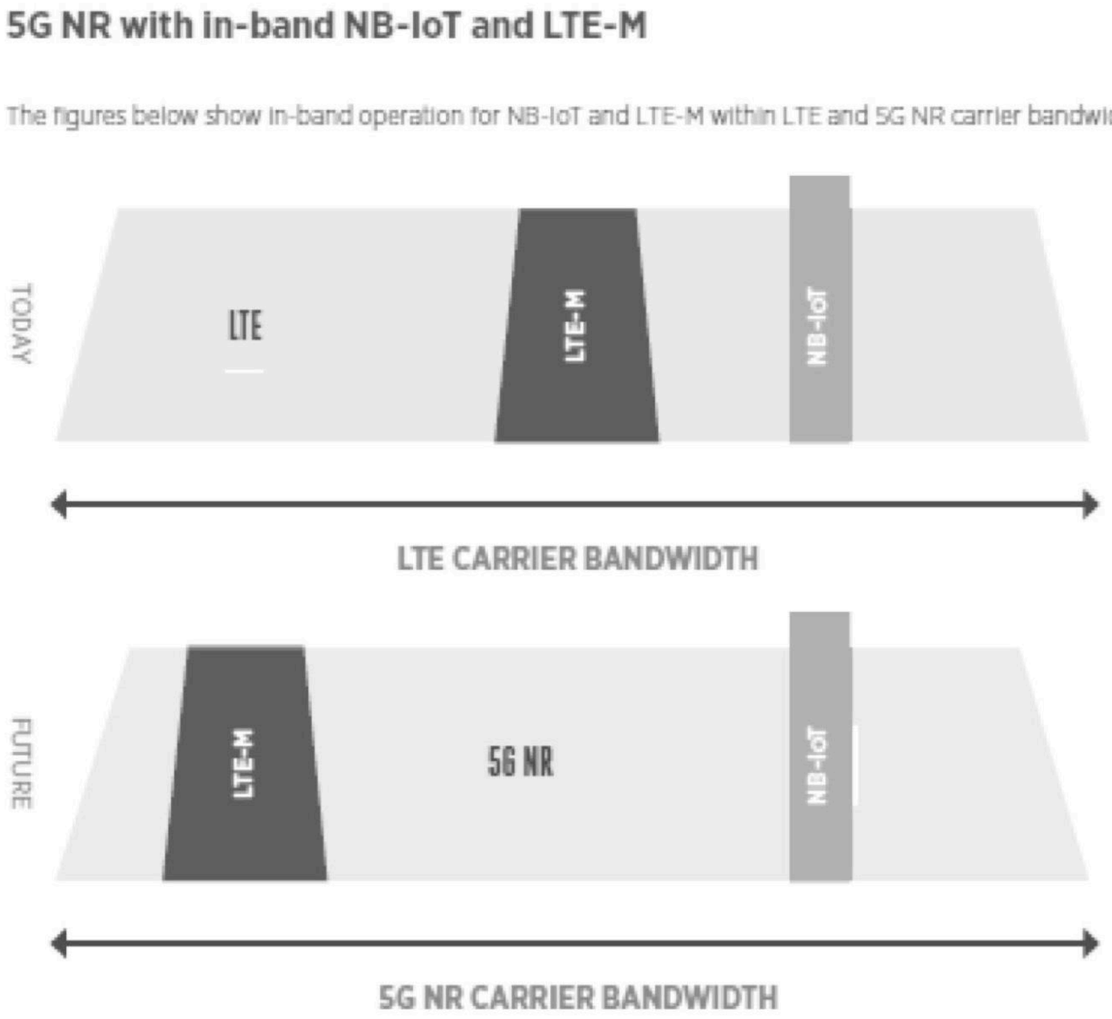
Going from LTE to 5G Sub-6 requires a new radio and potential improvements in product design.

4G LTE / 5G Sub-6 → **5G mmWave**

Upgrading from LTE or 5G Sub-6 to 5G mmWave will require a major product redesign.



PATHS FROM LTE-M & NB-IOT

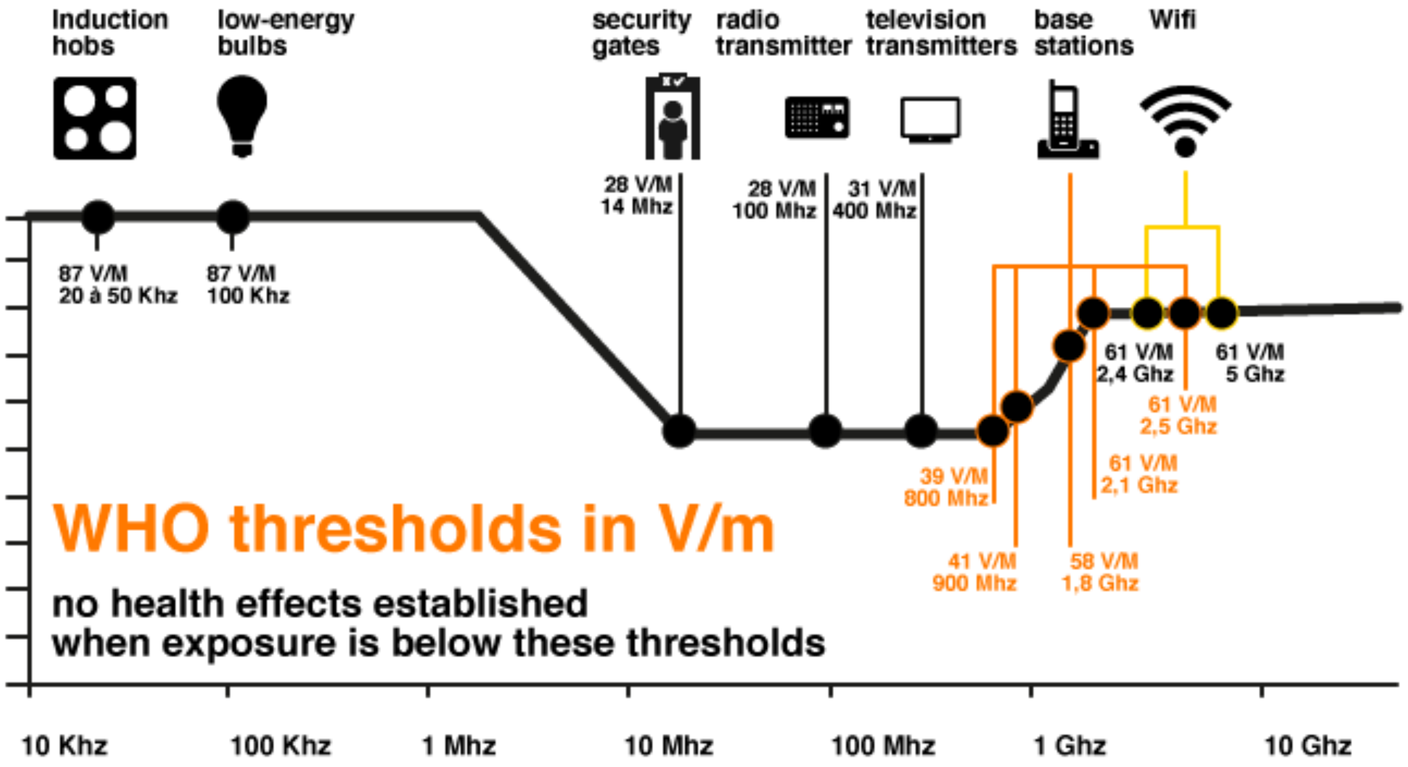


Current deployments of LTE-M and NB-IoT:
L800 / L1800 bands in Europe

3GPP has specified co-existence scenarios
between LTE-M / NB-IoT and 5G NR
in the same band

source: GSMA

5G & HEALTH



The World Health Organisation (WHO) recommendations cover exposure limits from 0 to 300 GHz.

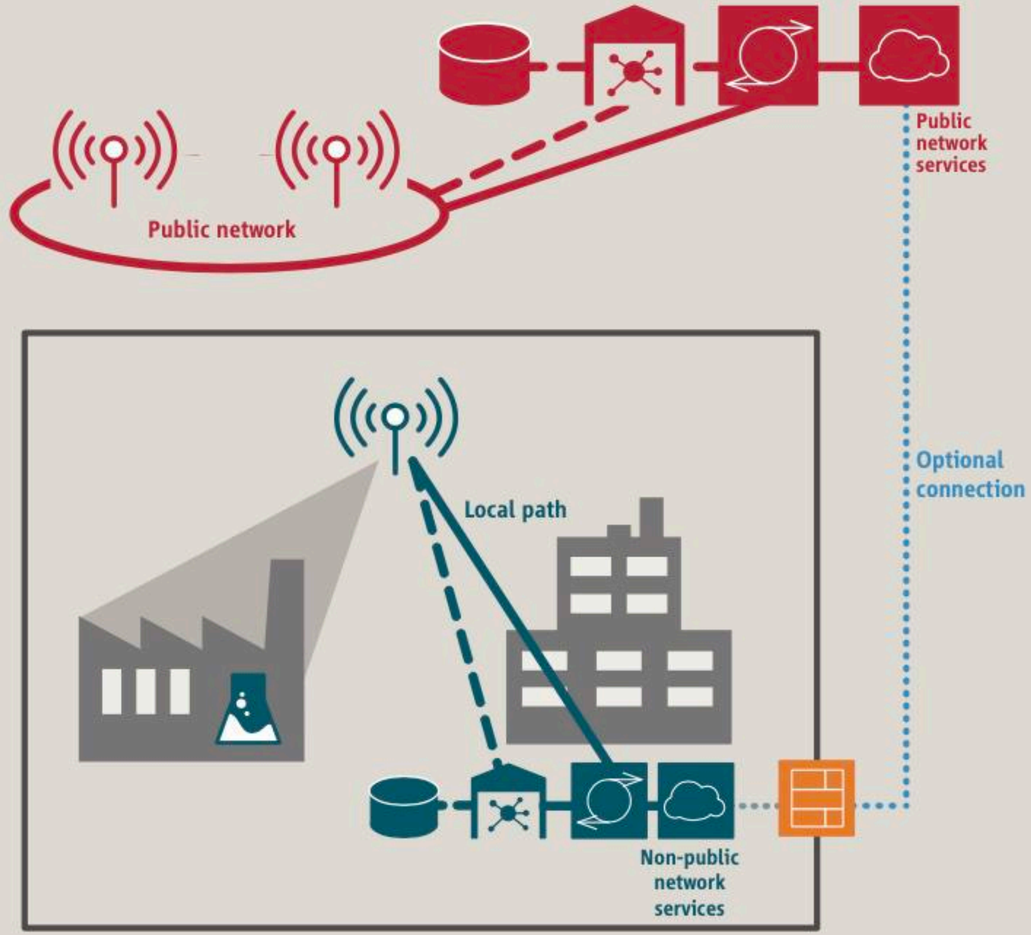
WHO has concluded that exposure linked to wireless networks and their use does not cause adverse health effects if this exposure is below recommended limits.

For 5G, the threshold is 39 V/m at 700 MHz and 61 V/m at 3.5 GHz and 26 GHz

https://radio-waves.orange.com/en/radio-networks-and-antennas/5g/your-questions-about-5g-and-health/

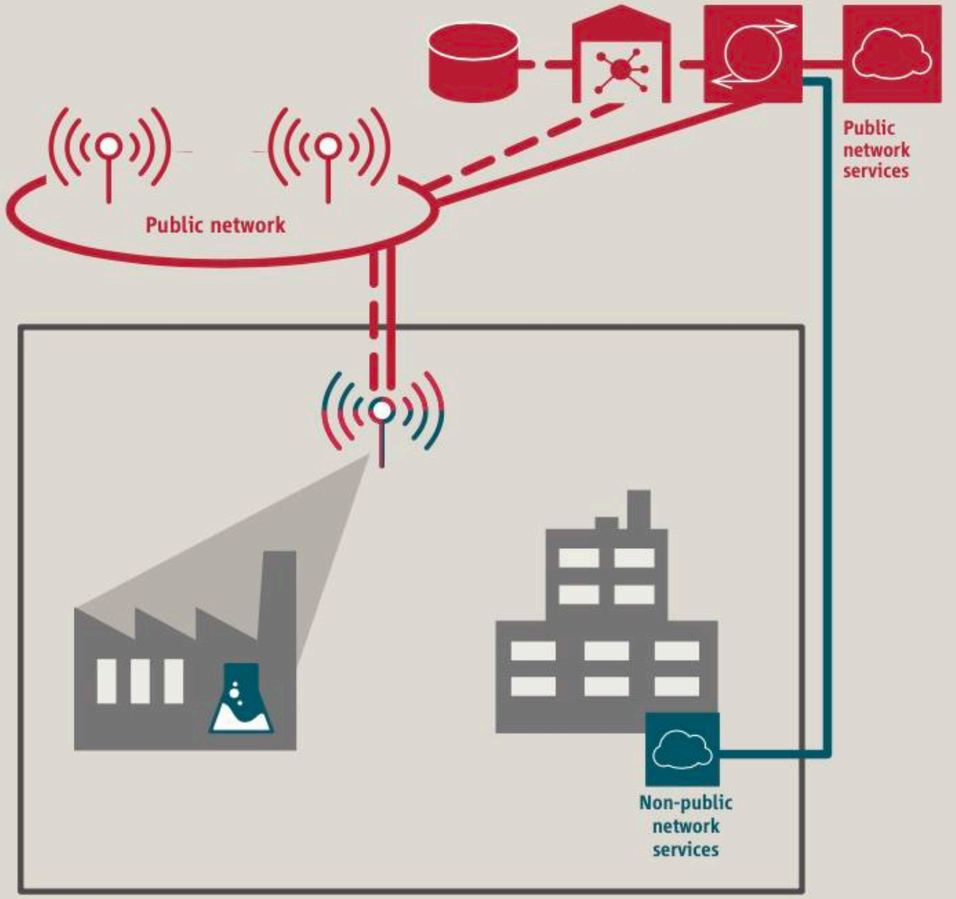
PRIVATE 5G NETWORKS

Fig. 1: Deployment as isolated network



Source: 5G-ACIA

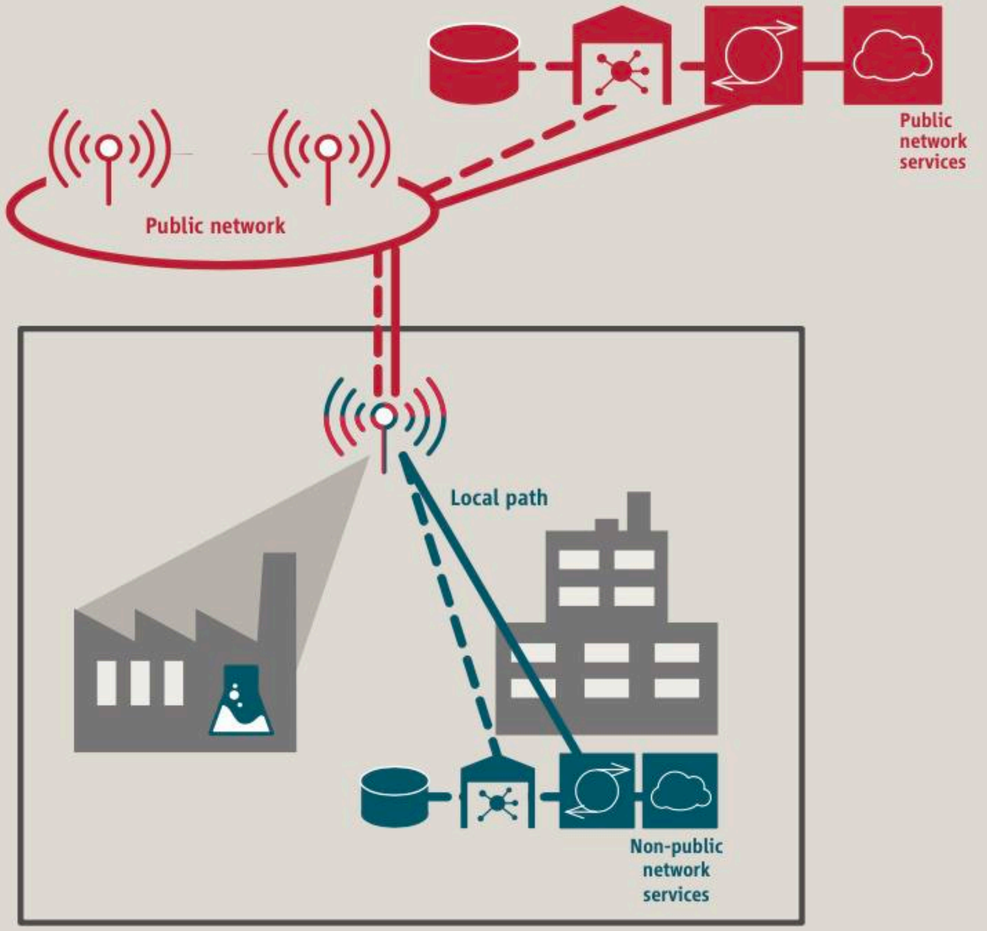
Fig. 4: NPN deployed in public network



Source: 5G-ACIA

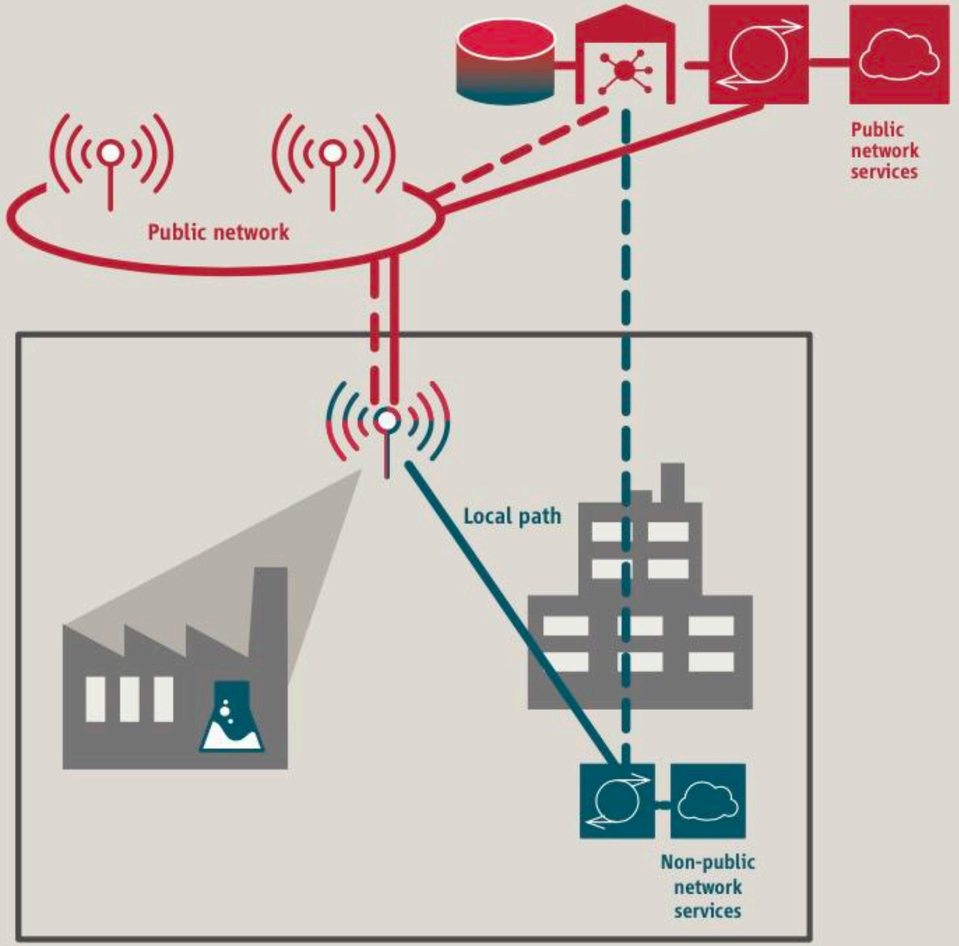
PRIVATE 5G NETWORKS

Fig. 2: Deployment with shared RAN



Source: 5G-ACIA

Fig. 3: Deployment with shared RAN and control plane



Source: 5G-ACIA

5G

use cases

5G FOR STADIUMS

VR

360° cameras

Mixed audio sources

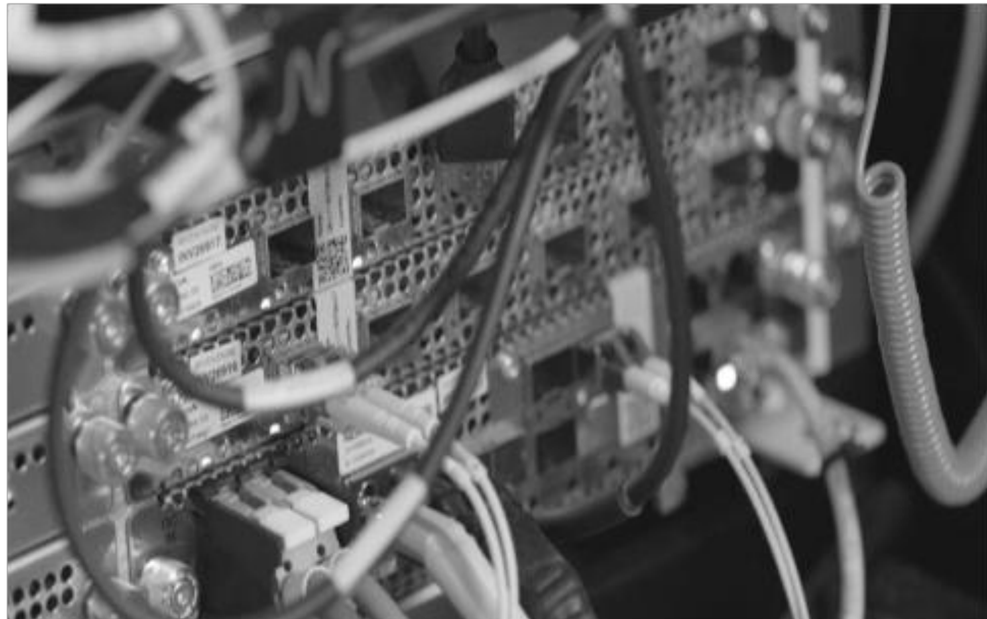
Live streaming

5G FOR STATIONS

26GHz experimentation

Ultra fast downloads

Better experience for travellers



5G FOR BUILDINGS

Building automation with pervasive sensors & actuators

Digital twins with huge data transfers in real time

Better quality control in construction sites

Multimedia, collaborative, multi-site meetings

Videoprotection, enhanced security

Etc.

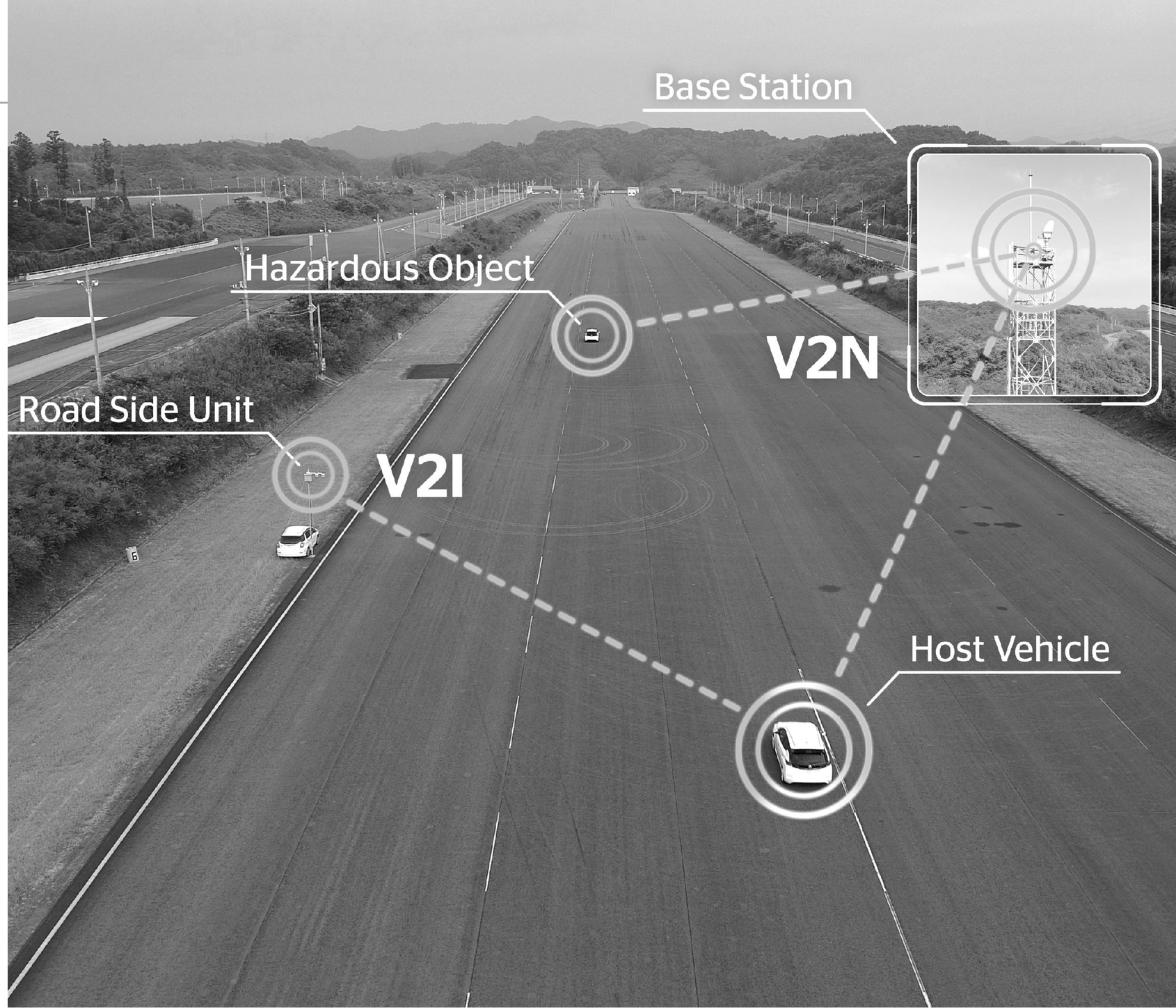
5G FOR VEHICLES

V2X -to-Everything

V2V -to-Vehicle

V2I -to-Infrastructure

Autonomous, connected cars

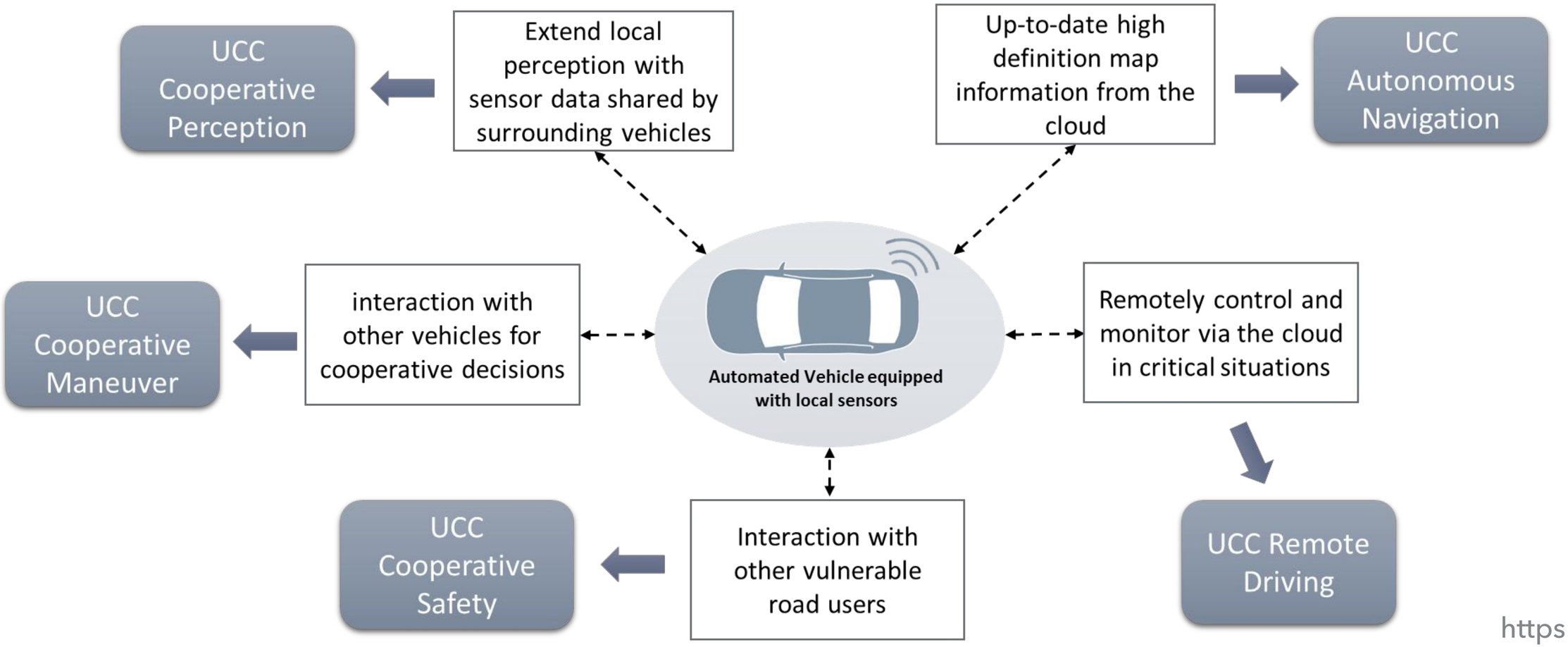


5GCAR

5G Communication Automotive Research and innovation Consortium led by Ericsson:

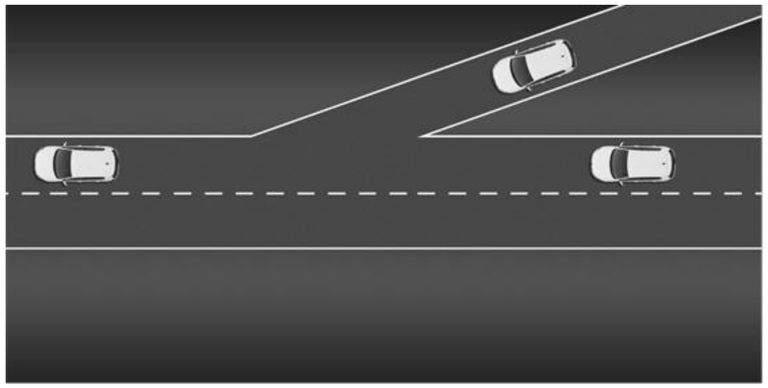
https://5gcar.eu

5GCAR

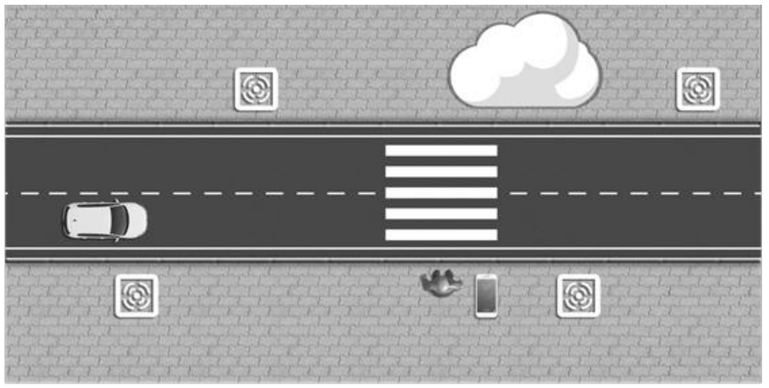


https://5gcar.eu

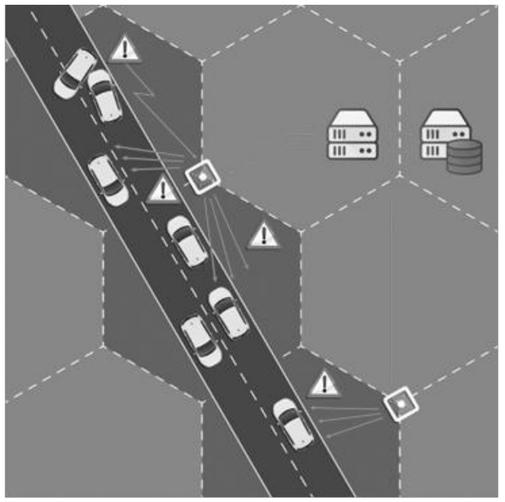
5GCAR



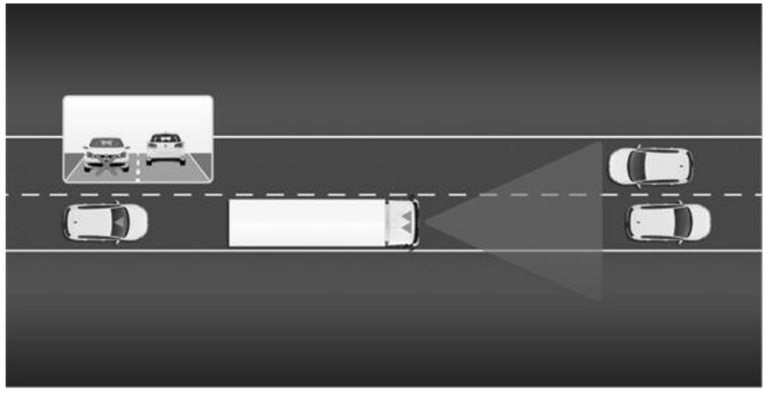
Lane merge



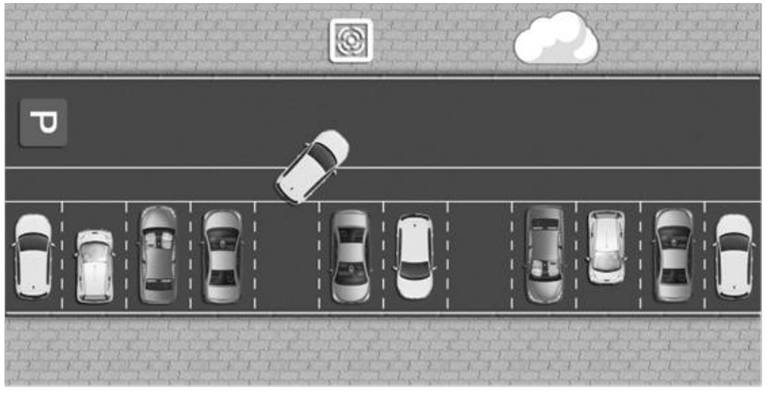
Network assisted vulnerable pedestrian protection



High definition local map acquisition



See-through



Remote driving for automated parking

https://youtu.be/bSlf2kNczMw

https://5gcar.eu

IMMERSIVE VR

Immersive Virtual Reality

Training / Gaming

TELESURGERY

All about:

- highest speed
- lowest latency
- highest QoS

PORT OF ANTWERP

5G / Industry 4.0 campus

Connected tugboats:
real time broadcasting of
mobile radar HD images

Smart Field Operators
security and safety

Port of Antwerp

5G

FACTORY OF THE FUTURE

symbiose

Smart Automation flagship

5G tests for wireless AVGs

Ambient connectivity

Electronics LACROIX

5G

AVGs: Automated Guided Vehicles

ADVANCED MAINTENANCE

5G Trial at Vaudreuil factory, FR

Augmented technicians w/ AR

Telepresence robots

Ambient connectivity

Low latency

GLOSSARY

IoT

6LOWPAN	Communication protocol which compresses IPv6 packages
Actuator	Transforms electrical signal sinto different forms of energy - see sensor
ADR	Adaptive Data Rate - to optimize LoRaWAN SF
API	Application Programming Interface
BLE	Bluetooth Low Energy
COAP	Constrained Application Protocol
DCS	Distributed Control System
Edge	Where the action is, near data source
eMBB	5G's enhanced Mobile Broadband
EnOcean	Energy harvesting wireless technology
ERP	Enterprise Resources Planning
GSM	Global System for Mobile communications
I2C	Inter Integrated Circuits protocol
IaaS	Infrastructure as a Service
IoT	Internet Of Things
IP	Internet Protocol - See TCP and UDP
IPv6	Version 6 of IP - allowing fixed addresses for all devices
LoRaWAN	Long Range Wide Area Network
LTE-M	Long Term Evolution : 4G
LTE-M	Long Term Evolution / Cat M1
M2M	Machine to Machine - part of IoT legacy
MES	Manufacturing Execution System
ML	Machine Learning
mMTC	5G's massive Machine Type Communications
MQTT	Message Queuing Telemetry Transport

NB-IoT	Narrow Band IoT
NFC	Near Field Communication
PaaS	Platform as a Service
PAN	Personal Area Network
PLC	Programmable Logic Controller
PoE	Power over Ethernet
QoS	Quality of Service
RFID	Radio Frequency Identification
RSSI	Received Signal Strength Indication
SCADA	Supervisory Control and Data Acquisition
SaaS	Software as a Service
Sensor	Determine physical characteristic and transform them in electrical signals
SF	Spreading Factor for LoRaWAN - SF7 (highest speed) to S12 (best coverage)
SLA	Service Level Agreement
SNR	Signal over Noise Ratio
TCP	Transmission Control Protocol / IP - connected mode
UDP	User Datagram Protocol / IP - non connected mode
UMTS	3G
URLLC	5G's Ultra Reliable Low Latency Communications