IOT_1: Understanding IoT technologies

sensors, radios, clouds,...

OneTech Booster

Capsule Booster – 2022

Prof. Congduc Pham
http://www.univ-pau.fr/~cpham

European Commission | Horizon 2020 European Union funding for Research & Innovation

WAZIUP
IoT – from idea to reality
WAZIHUB

HUBiquitous
Paving for the next 10 years of innovation in IoT and AI

PRIMA PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

Intel-IrriS RESILINK
Advanced and disruptive IoT/AI technologies targeting the smallholder community for increased resilience

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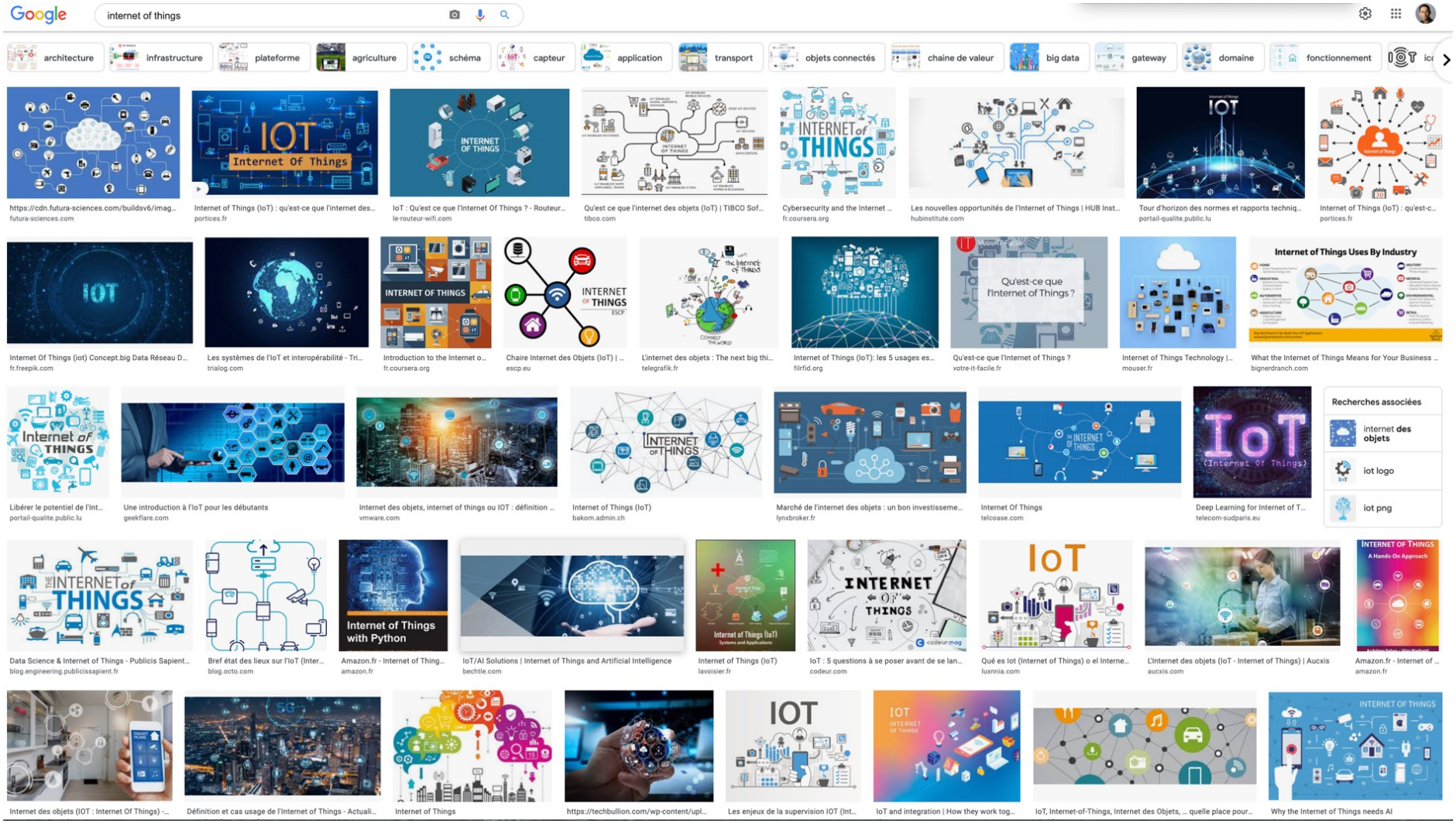
Googling for « Internet of Things »



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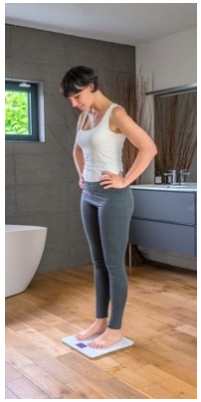
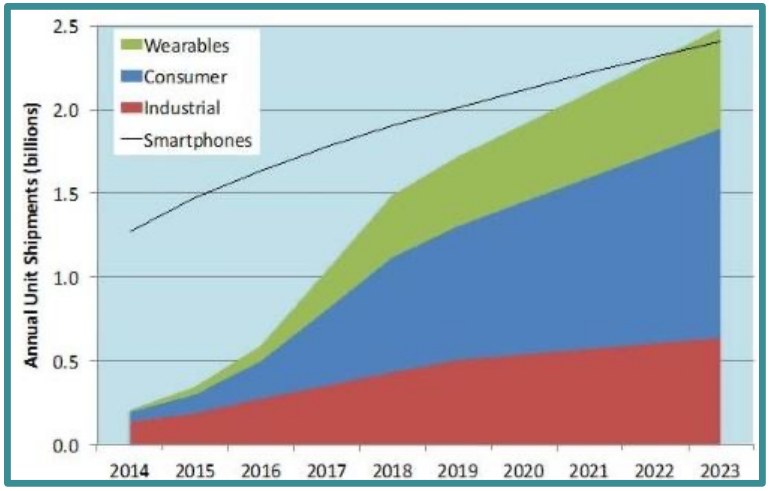
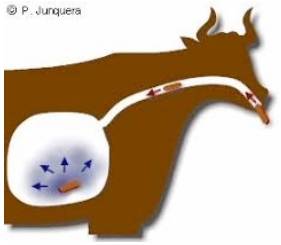
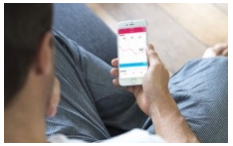
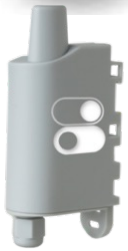
…shows communicating objects











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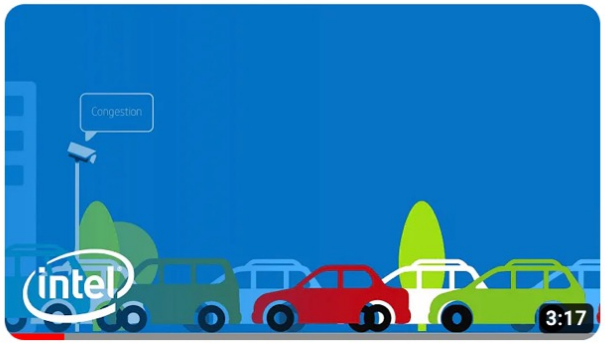
Also on YouTube: IoT teaser & tutorial videos



Intel IoT -- What Does The Internet of Things Mean?

591 k vues • il y a 8 ans

Intel

Fun, animated video answers: What does the Internet of Things mean? The Internet of Things (**IoT**) is an evolution of mobile, home ...

Intro | What is IoT | Transform our lives | Big picture | Example | Big Possibilities | Intelligent Traffic |... 9 chapitres

IOT Tutorial | IOT Tutorial For Beginners | IOT - Internet Of Things | IOT Course | Simplilearn

25 k vues • il y a 1 an

Simplilearn

This **IoT** tutorial video introduces you to **IoT** Technology and how it is revolutionizing the world today. Internet of things or **IoT** ...

Internet of Things (IoT) | What is IoT | How it Works | IoT Explained | Edureka

2,1 M de vues • il y a 4 ans

edureka!

Subscribe to our channel to get video updates. Hit the subscribe button above. #Edureka #EdurekaIoT #InternetOfThings ...

Sous-titres

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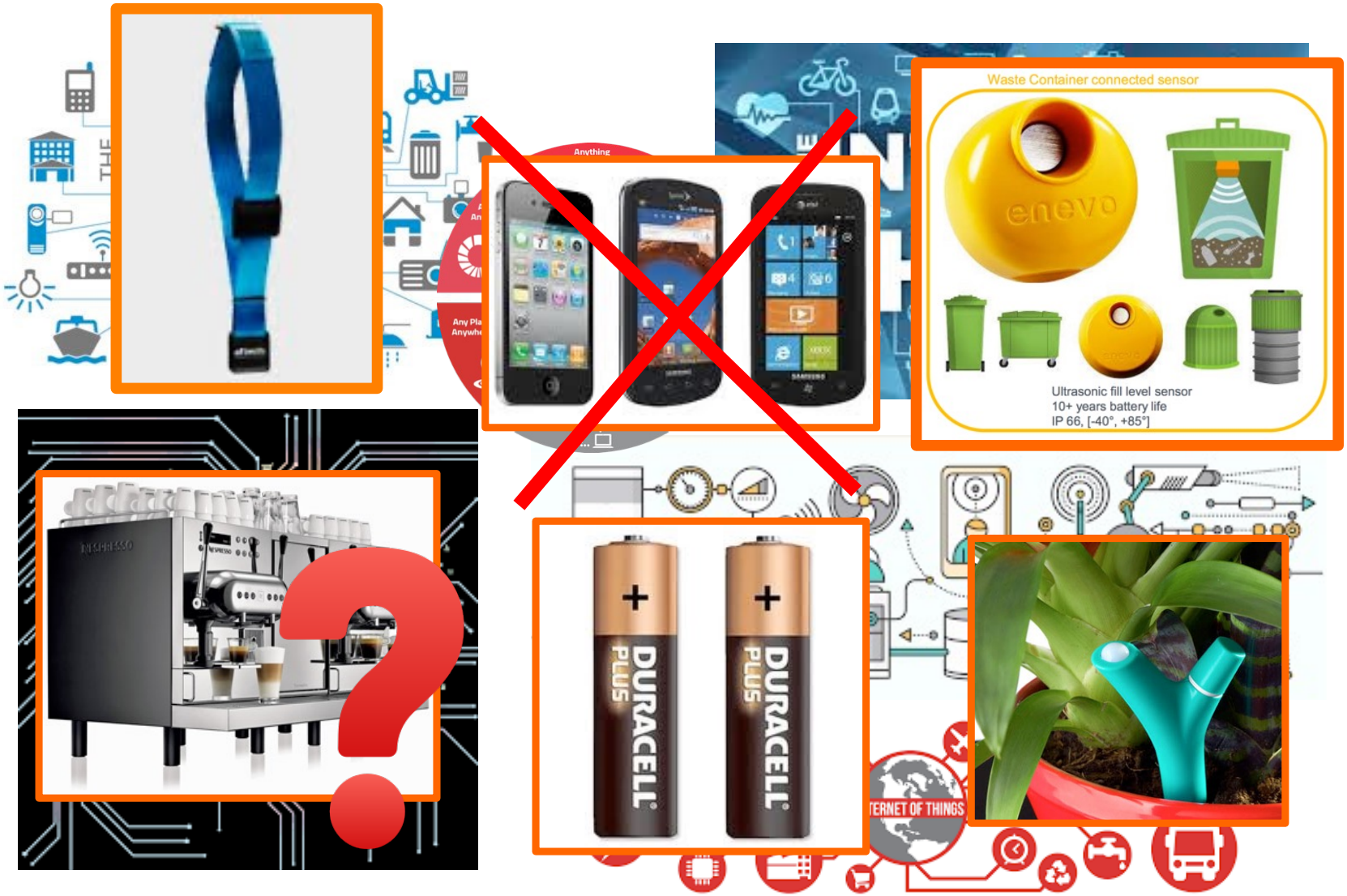
All communicating objects?



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IoT=interactions with physical world

Q: Interactions? How?

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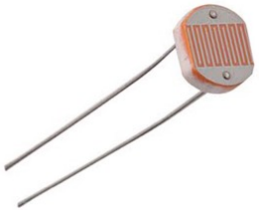
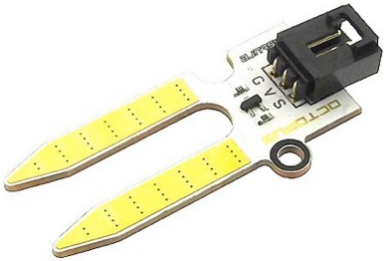
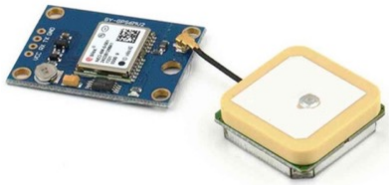
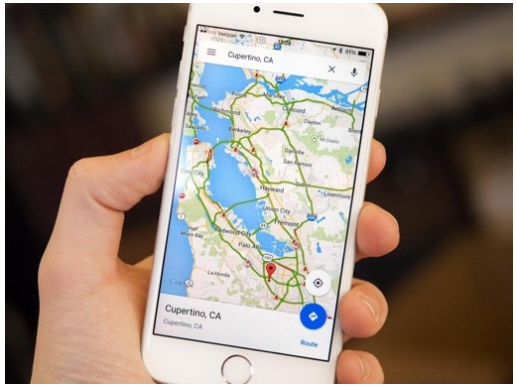
Interaction: Sensors









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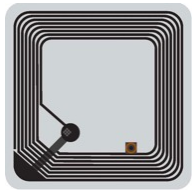
Interaction: RFID, NFC

- Radio-Frequency Identification (RFID)
- Near Field Contact (NFC)



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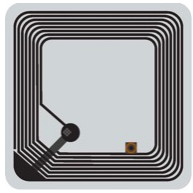
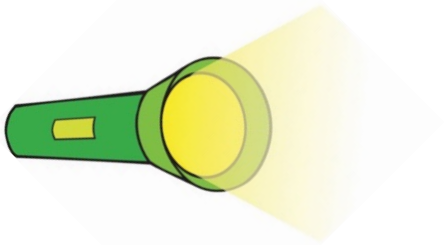
Interaction: RFID, NFC

- Radio-Frequency Identification (RFID)
- Near Field Contact (NFC)



Q: How RFID works without batteries?



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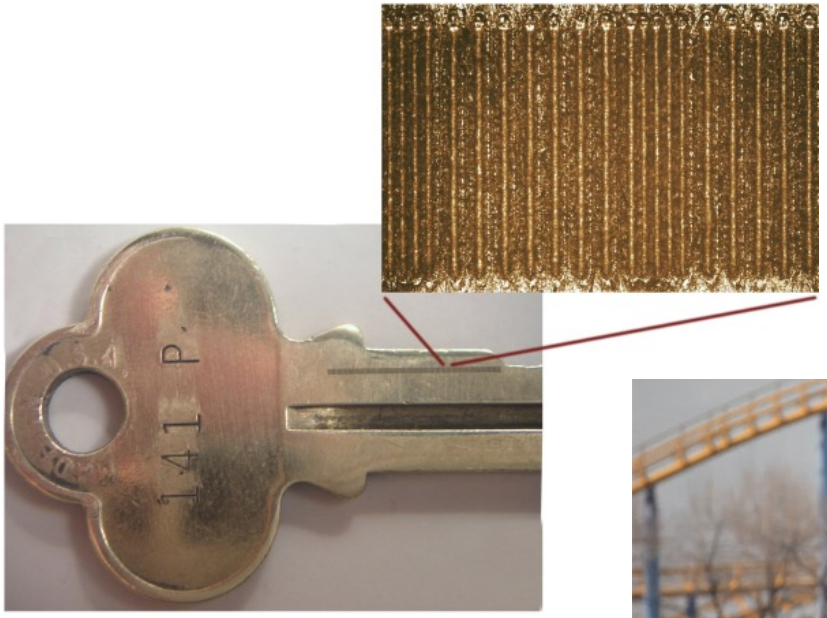
Interaction: always complex?



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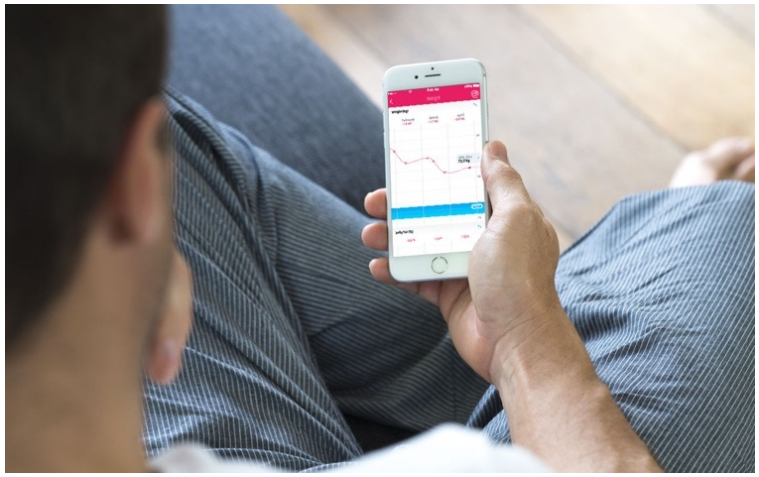
Home/consumer IoT products



Pictures from WiThing, https://www.withings.com/eu/fr/products/body

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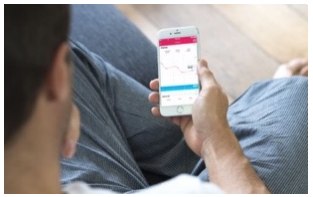
Local interaction is possible…



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…but IoT added-values come from interactions & linked data!

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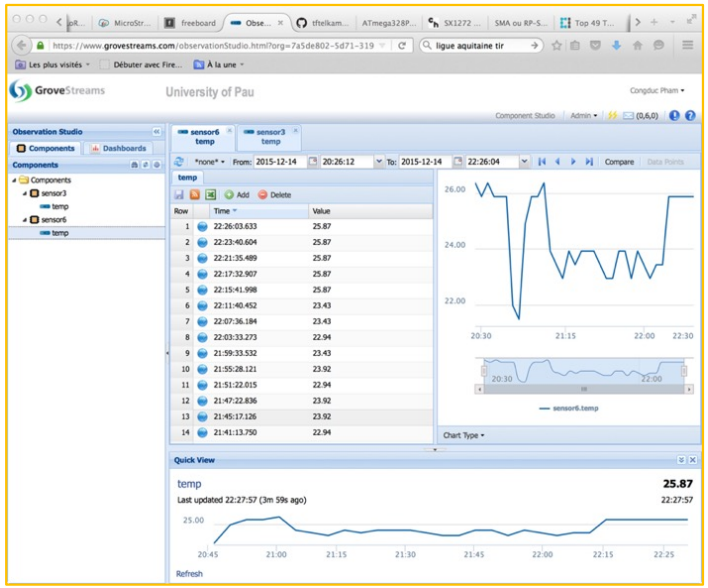
Clouds for IoT

VS



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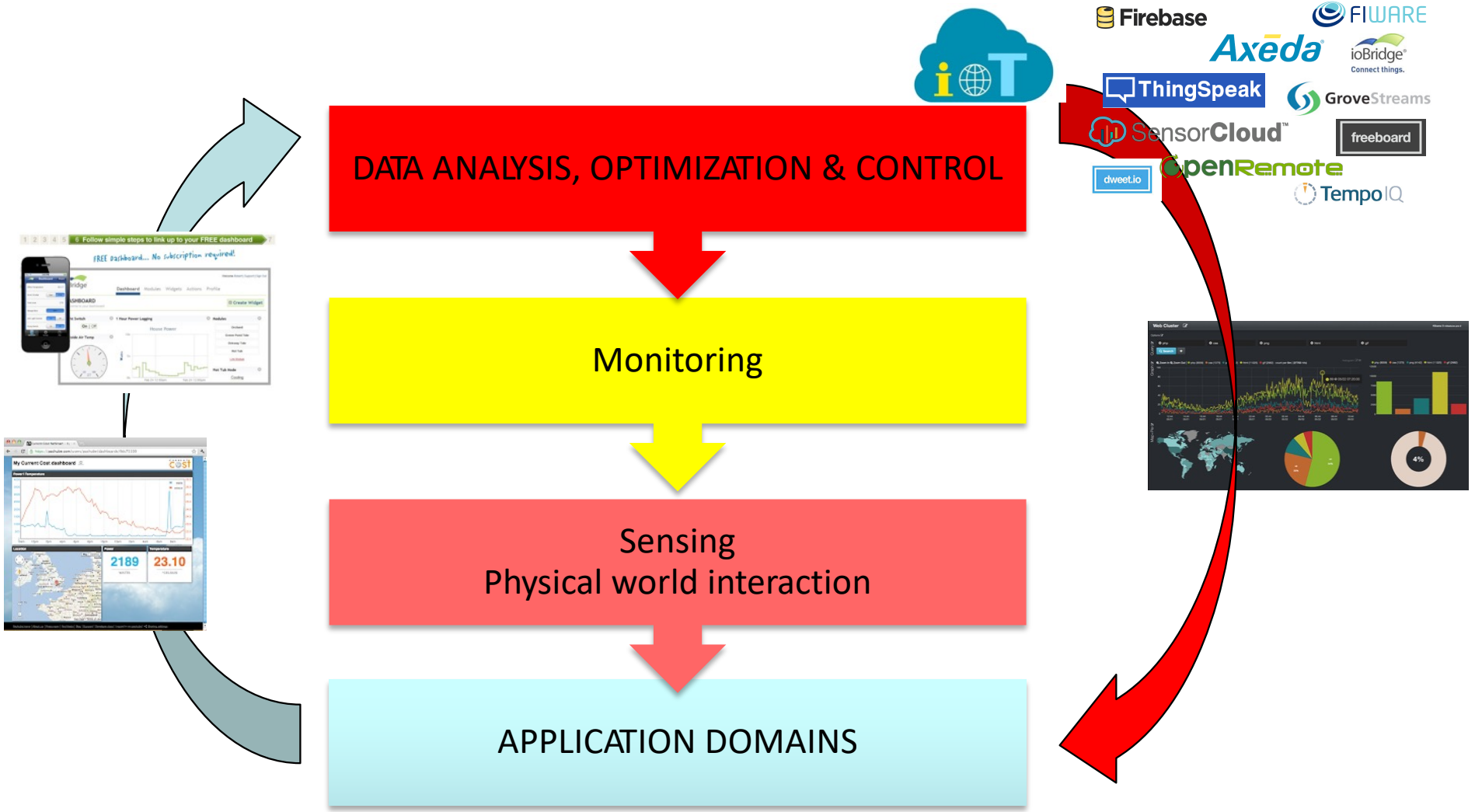
Sense, Monitor, Optimize & Control



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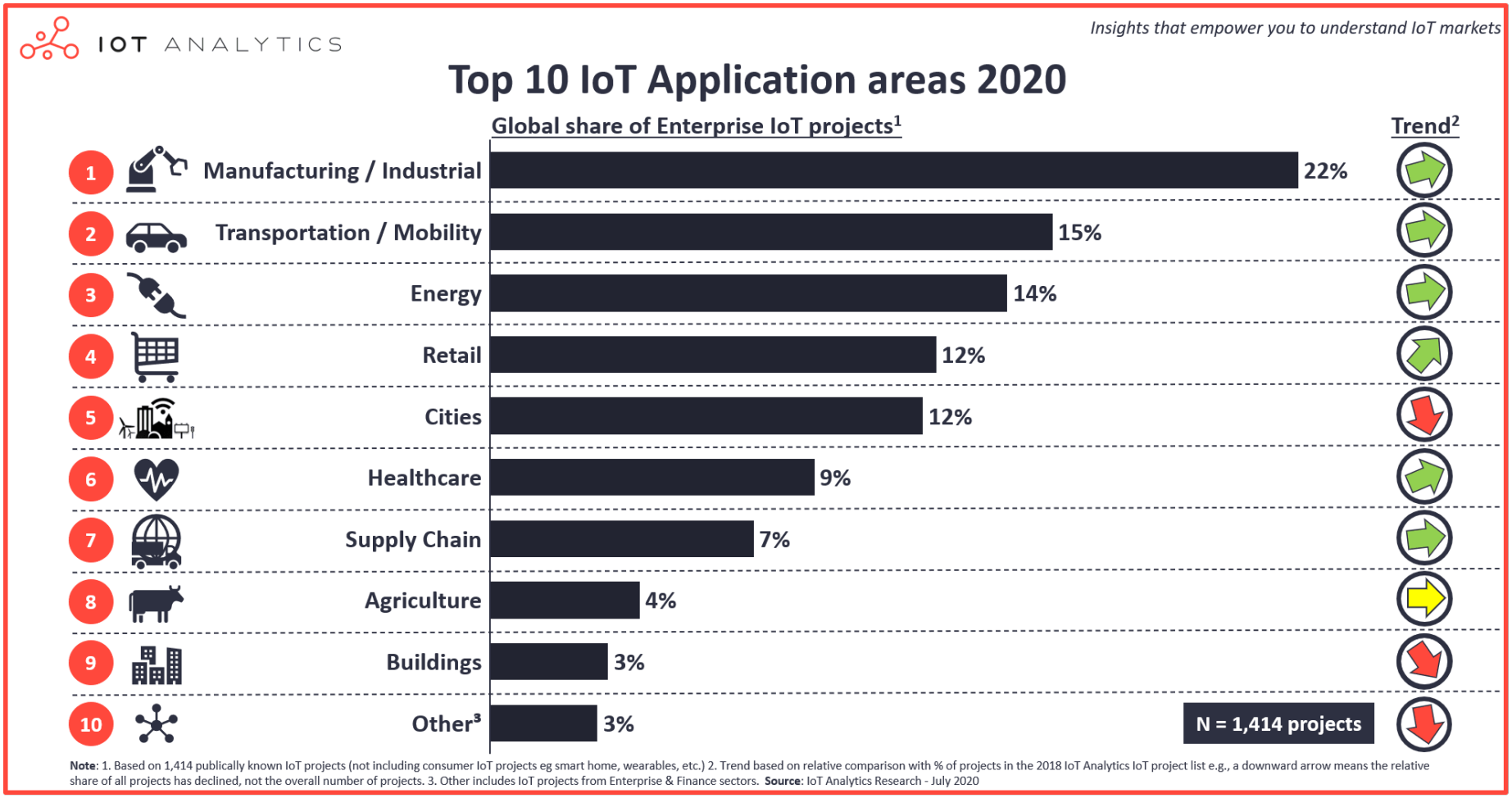
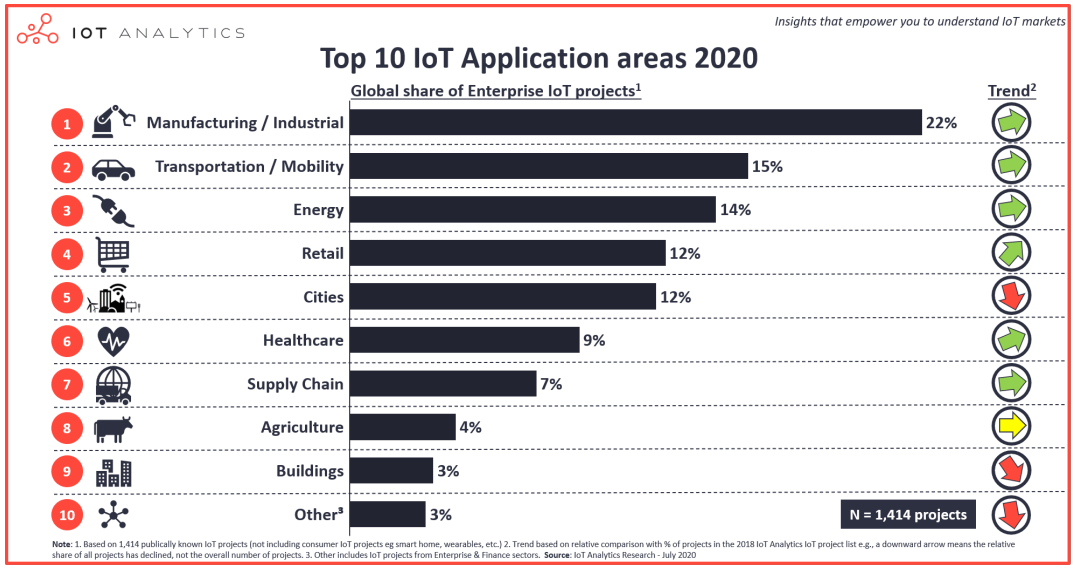
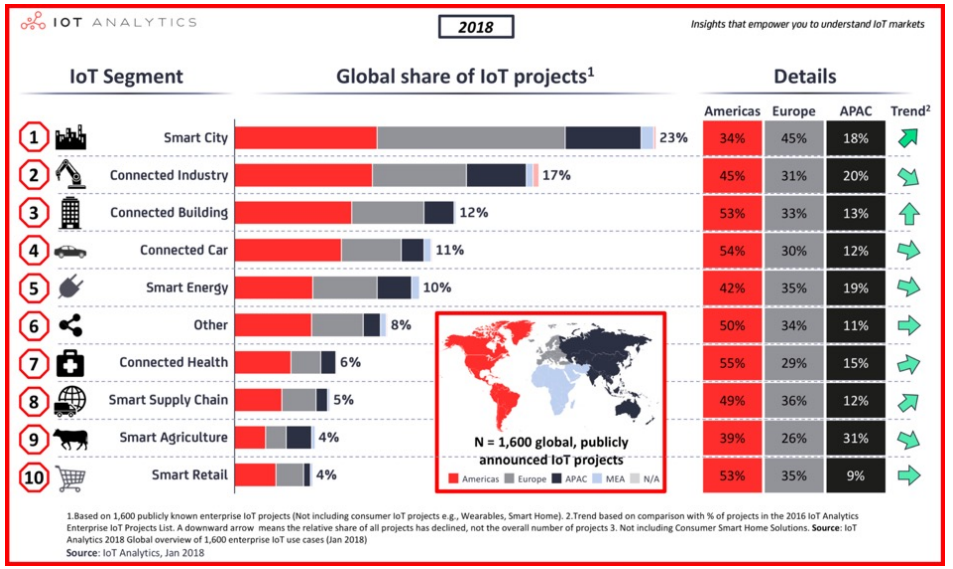
Top IoT applications, 2020



IoT: 2020 vs 2018





Q: What happen to Smart City?

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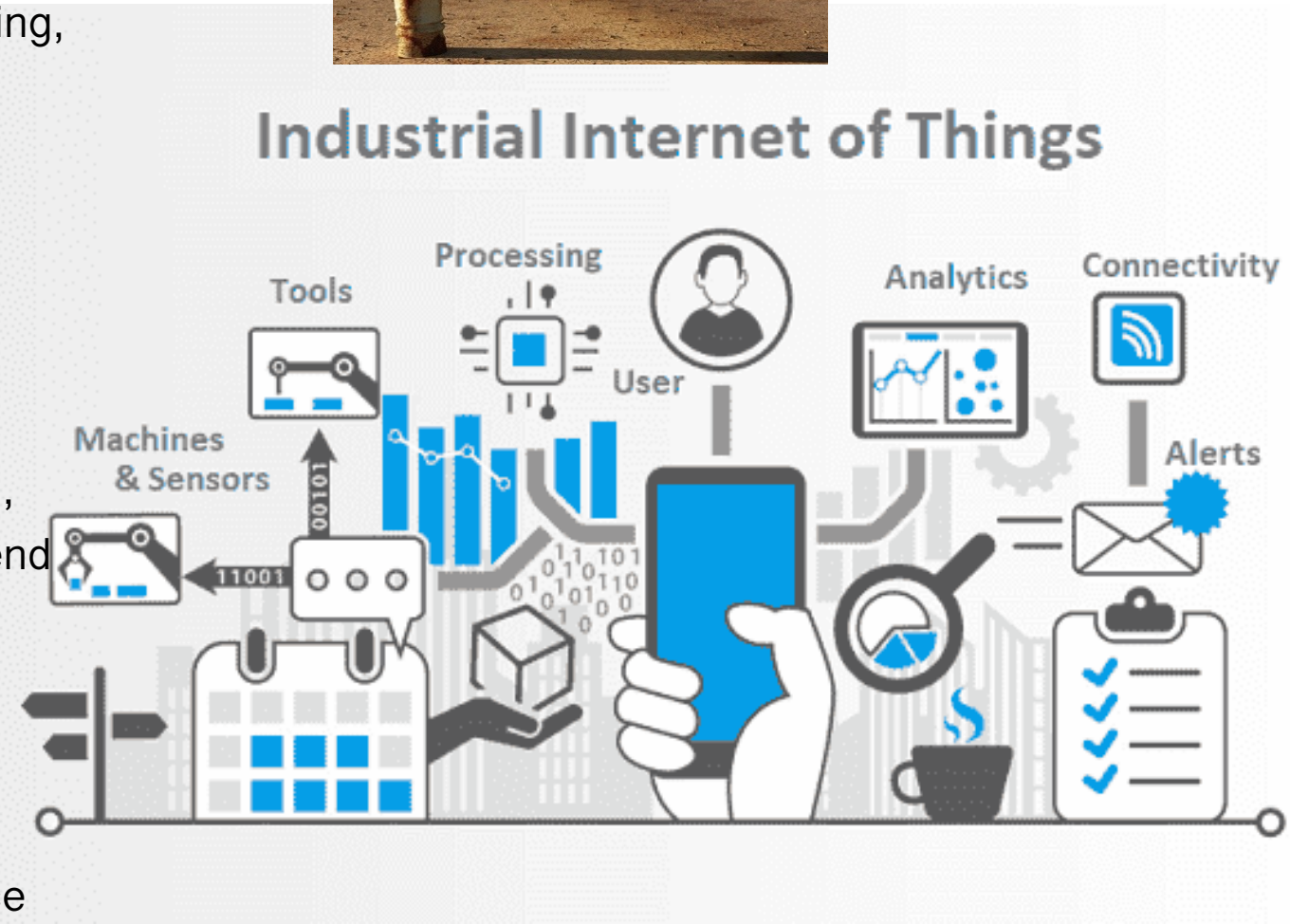
IoT in industry

- Infrastructure monitoring, Security & Safety
- Continuous process improvement, Process automation, Process optimization
- Smart logistics management, remote management, tracking,
- Connectivity to back-end system, integration of smart tools, Interoperability
- Data analysis, Supply Chain Optimization, Predictive maintenance



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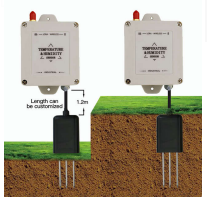
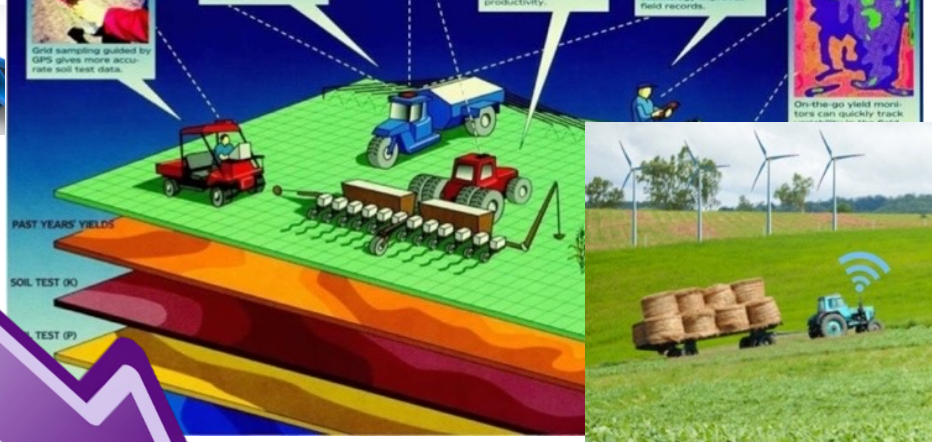
IoT for Smart Agriculture









Soil Monitoring

Connected Agriculture

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Is IoT the solution for your problem?

Q: How get real-time position of all city buses?

A: Install a GPS + 4G electronic box in each bus to turn the bus into a connected bus!

Q: Is it cost-effective?

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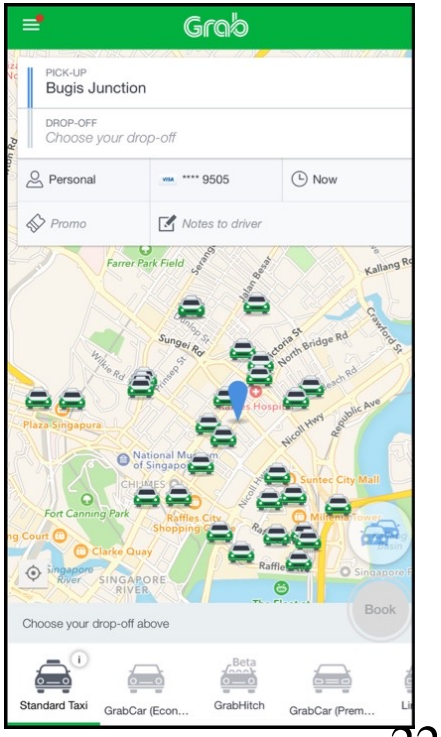
Is IoT the solution for your problem?

Q: How get real-time position of all city buses?

"GPS + 4G"
Hum, looks like a smartphone…



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Is IoT the solution for your problem?

Q: How to enable municipal street sweepers to report illegal dumping, leaking pipes and emergencies?

I know! I know !

A: Give them a smartphone and they can use it for reporting!

Q: Is it efficient?

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Is IoT the solution for your problem?

Q: How to enable municipal street sweepers to report illegal dumping, leaking pipes and emergencies?

"smartphone"
Hum, they only have 2 hands…

ITU Telecom World 2018
Phathwa Senene at MTN booth

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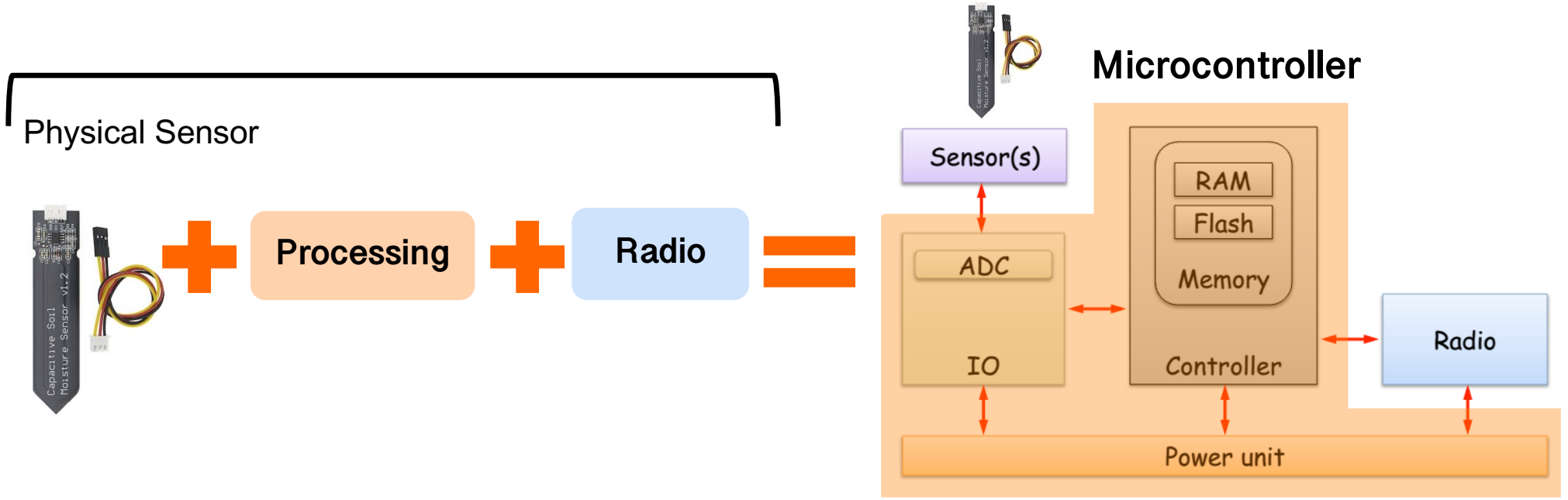
IOT

TECHNOLOGY ?

CONCEPT ?

Typical IoT device

- IoT device can be viewed as a simple Embedded System



Q: uprocessor vs ucontroller?

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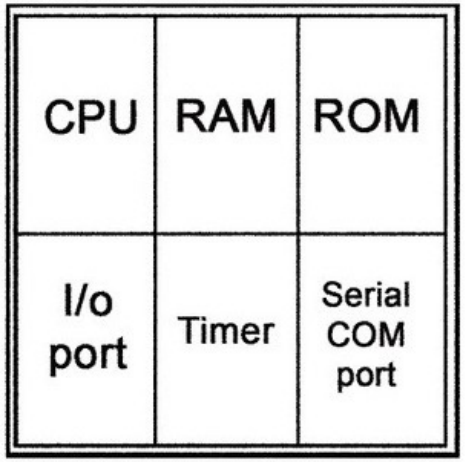
Microprocessors & Microcontrollers

- A microprocessor unit (MPU) is a processor on one silicon chip
- A microcontroller unit (MCU) is a microprocessor with some added circuitry on one silicon chip
- Microcontrollers are used in embedded computing and most IoT devices are based on microcontrollers

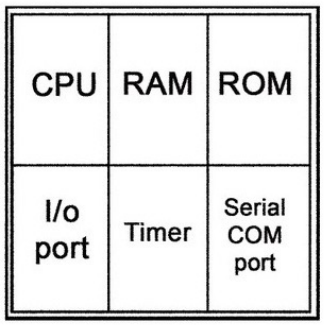
VS



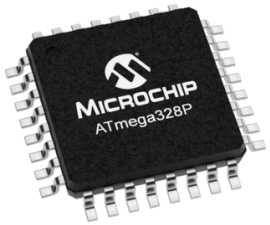
From "An Embedded System Overview" by Dr. Eng. Amr T. Abdel-Hamid

From µcontroller to µcontroller board

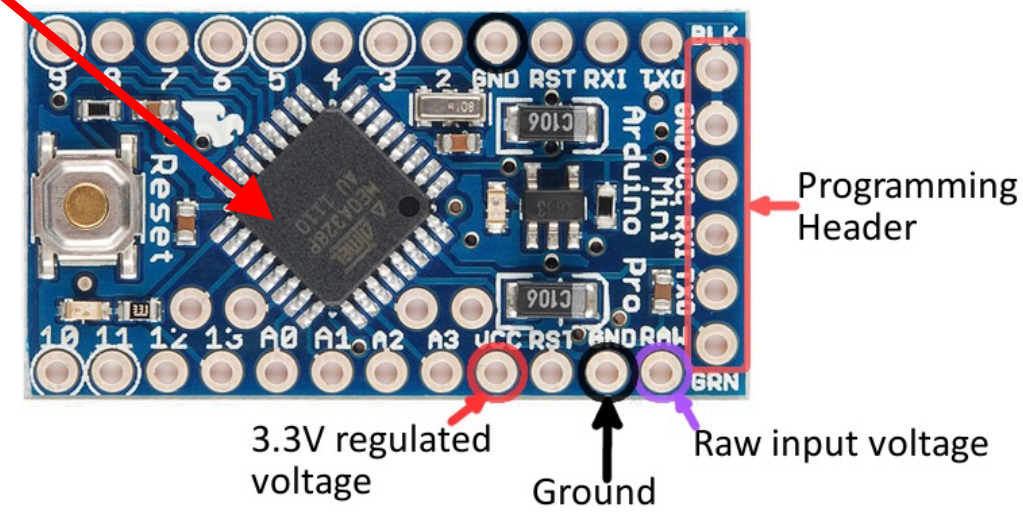
- A µcontroller can be standalone…



(Single chip)



- But, it is usually mounted on a board with additional electronics parts
  - Leds, Voltage regulators
  - Easy access to pins
  - Reset button
  - Serial-USB interface



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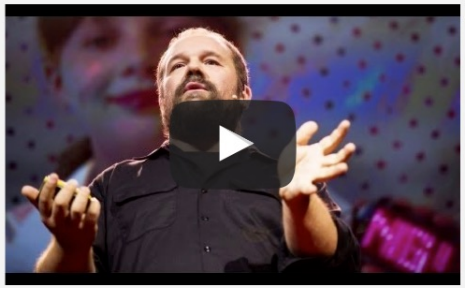
Arduino's success story starting in 2005



WHAT IS ARDUINO?

Arduino is an open-source electronics platform based on easy-to-use hardware and software. It's intended for anyone making interactive projects.

ARDUINO BOARD

Arduino senses the environment by receiving inputs from many sensors, and affects its surroundings by controlling lights, motors, and other actuators.

```
void setup() {
 }

void loop() {
 }
```

ARDUINO SOFTWARE

You can tell your Arduino what to do by writing code in the Arduino programming language and using the Arduino development environment.

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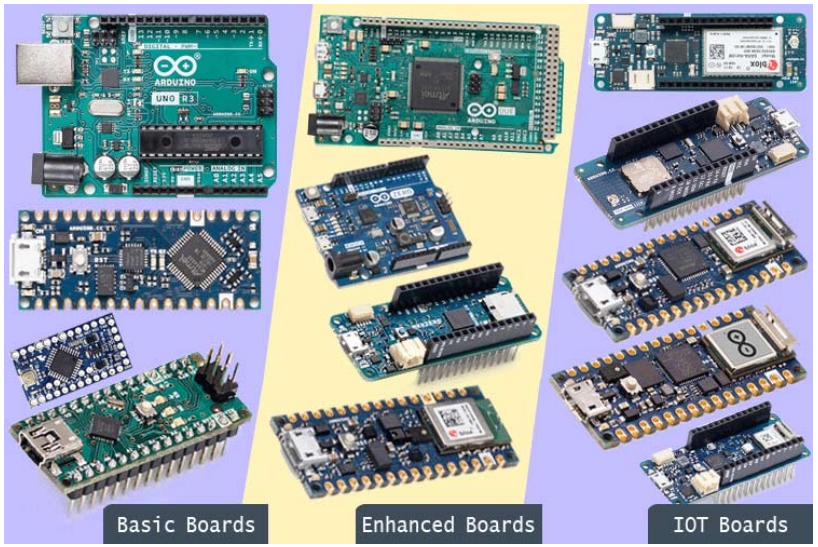
17 years later: the incredibly large microcontroller board ecosystem!



STM32 Nucleo-32

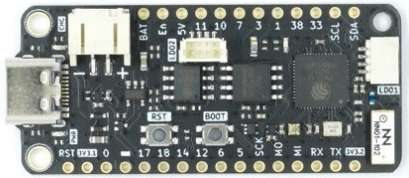
Teensy 3.2

LinkIt
Smart7688 duo

Adafruit Feather

uPesy ESP32

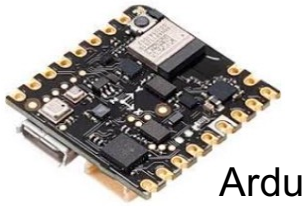
ePulse Feather Low Power ESP32



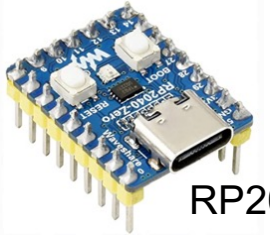
FeatherS3 – ESP32-S3

Heltec ESP32

XIAO SAMD21



Arduino Nicla
Sense ME



RP2040
zero

DFRobot
Beetle

QT Py ESP32-C3

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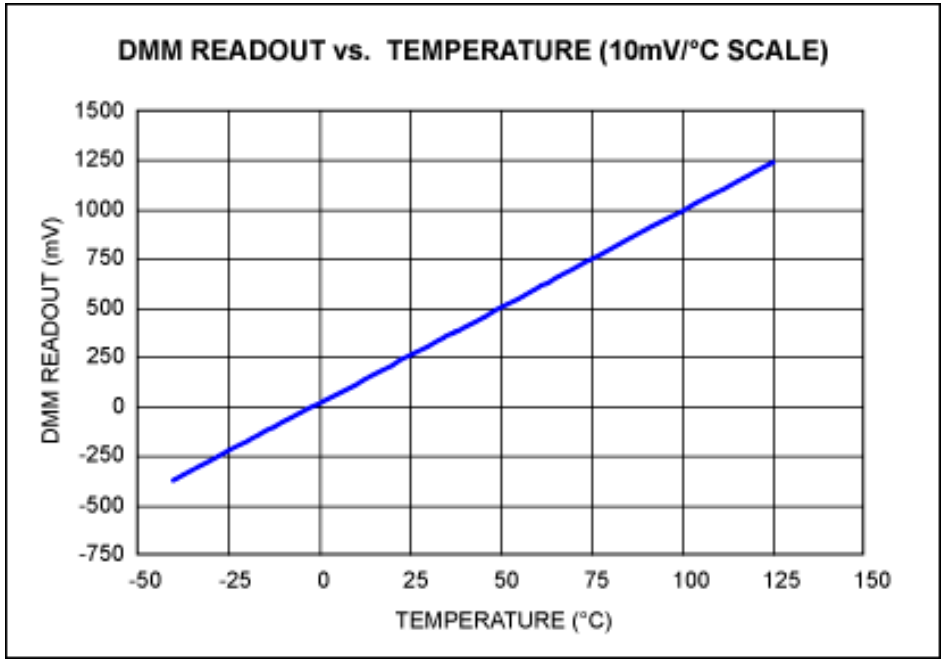
Interacting with the real world?

- Taking the simple analog sensors example
- Analog sensors provides a voltage output that varies according to a physical parameter, e.g. temperature, humidity, luminosity,…



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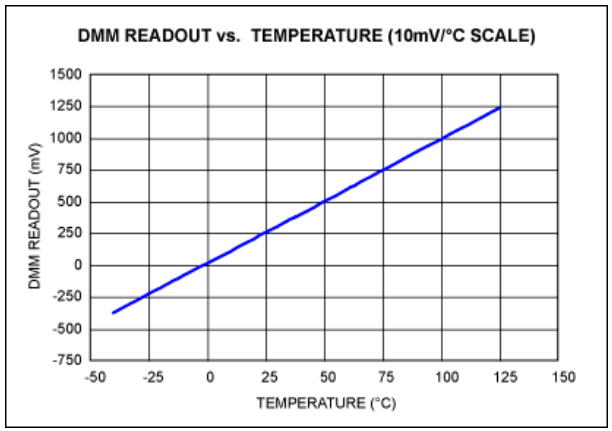
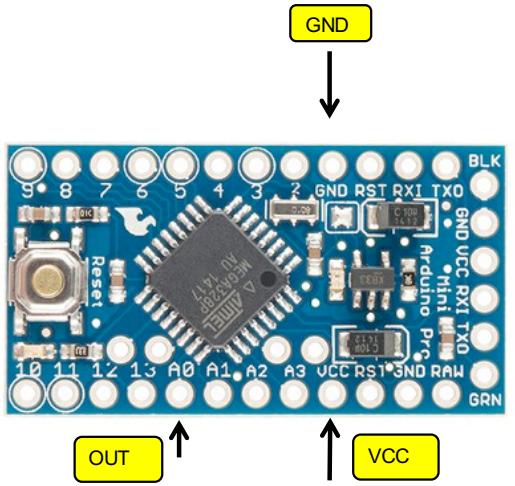
Digitalizing the physical world!





Microcontrollers have Analog/Digital (A/D) converter to map a voltage to a numerical value. **A/D with 10-bit resolution give numerical values in [0, 2^{10}-1] = [0, 1023]**

Vcc usually refers to the operating voltage of a given microcontroller. Vcc is typically 3.3V.

If 0=0V and 1023=3300mV then **3300mV/1024=3.22mV is the granularity of the measure**

Reading a digital value of 100 means 100*3.22mV=322mV

If the sensor output is 10mV/1°C then the physical temperature is 322mV/10mV=32.2°C

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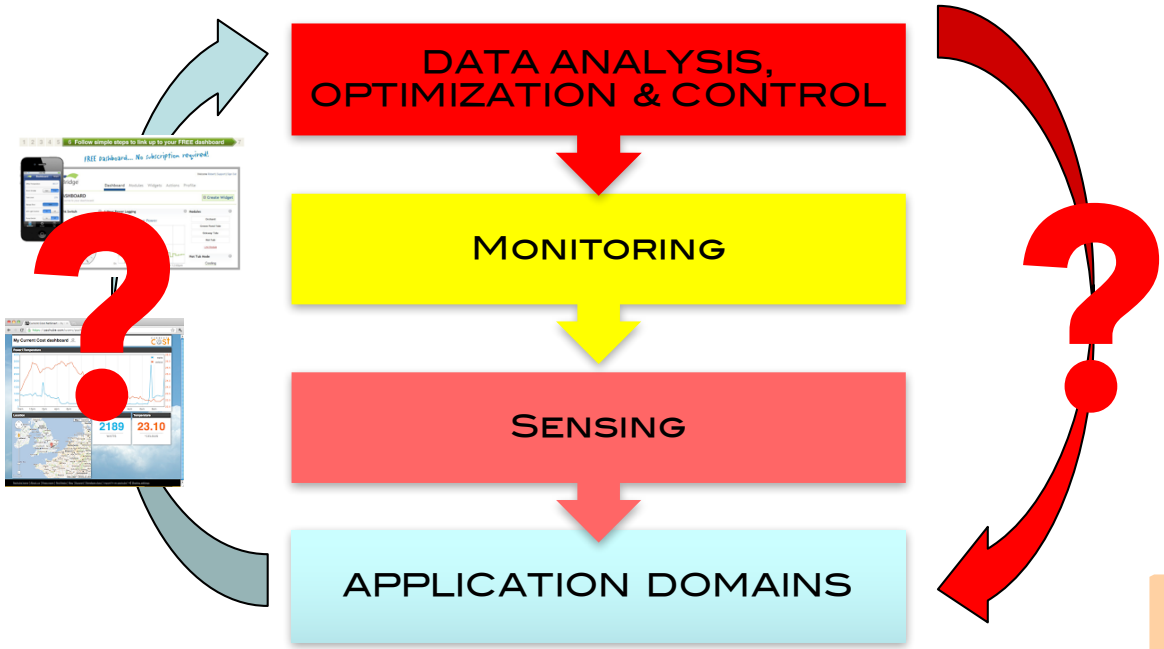
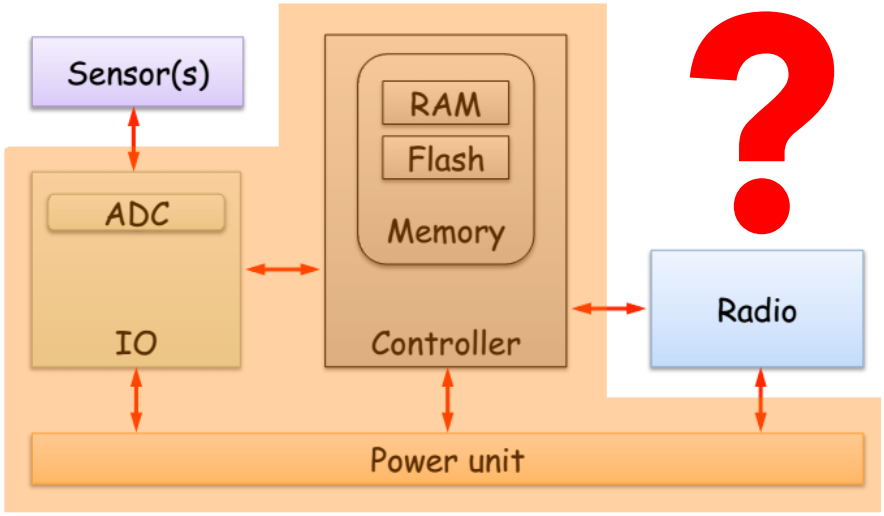
How to collect data?





Microcontroller

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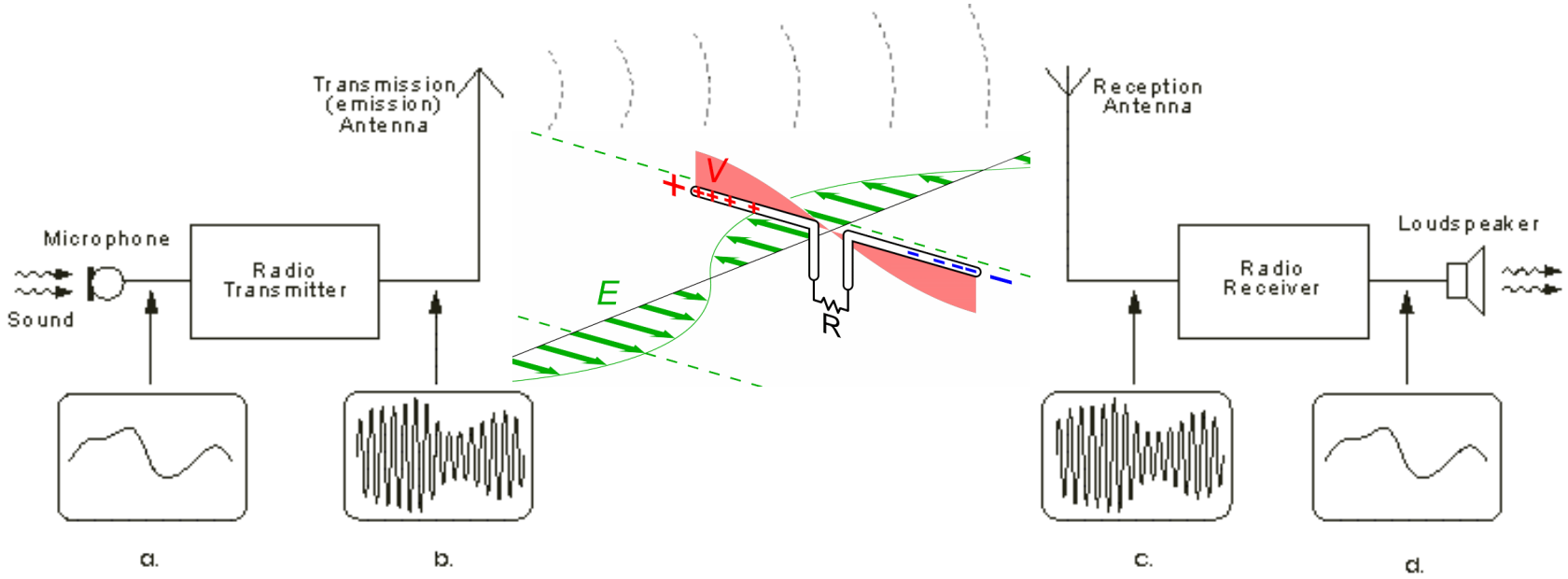
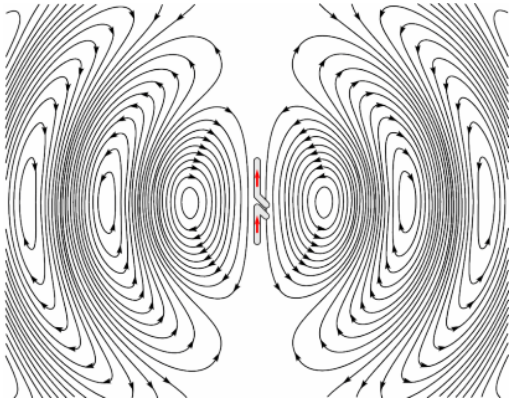
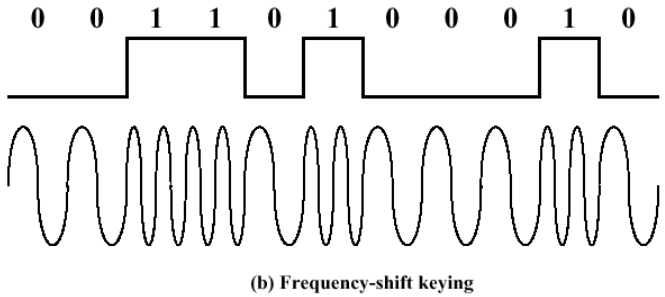
Wireless (radio) transmission basics





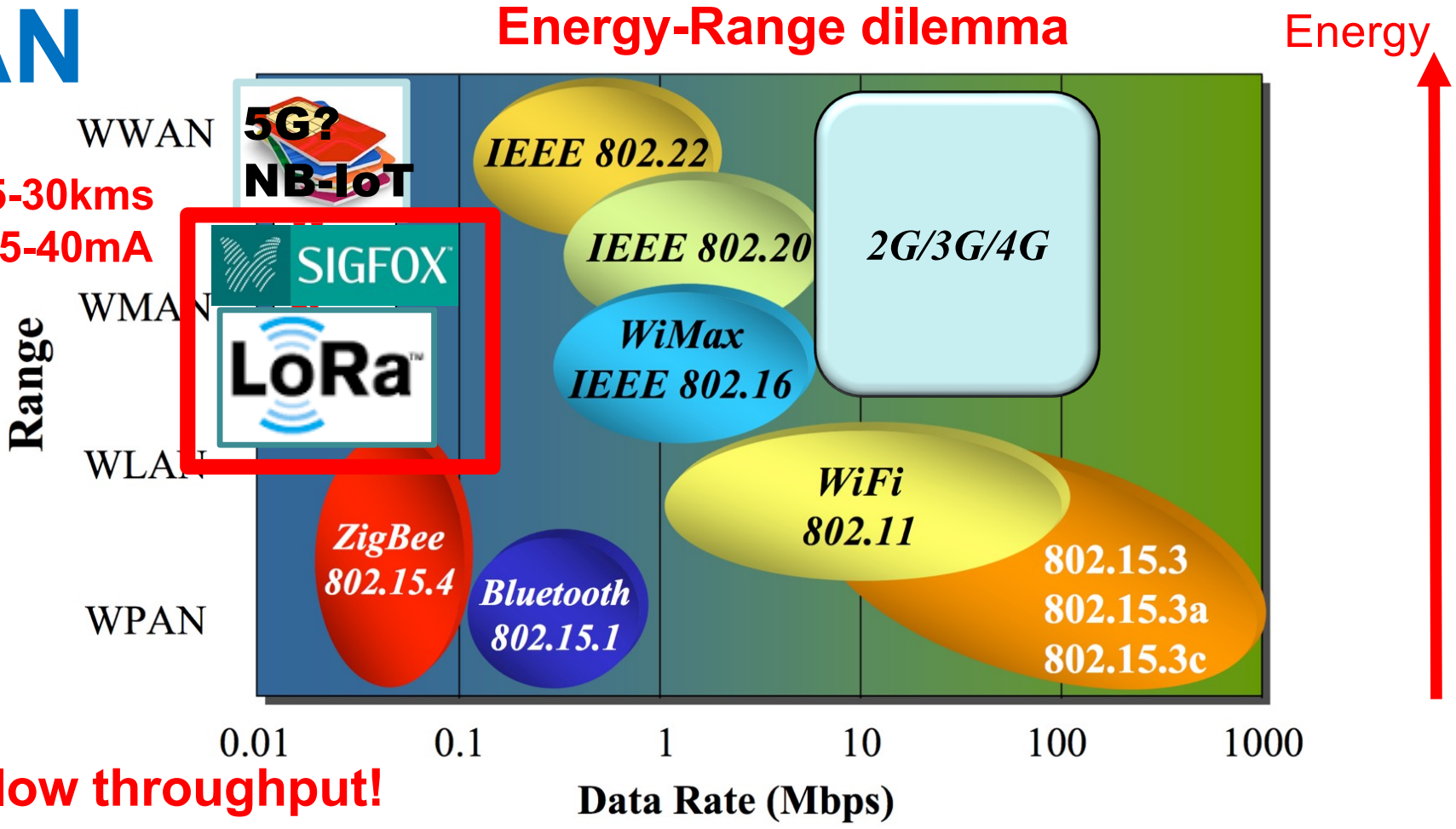


Q: Can we have Gbps in wireless?

Low-power & long-range radios

LPWAN

Long-range: 5-30kms
Low-power: 15-40mA



Very low throughput!

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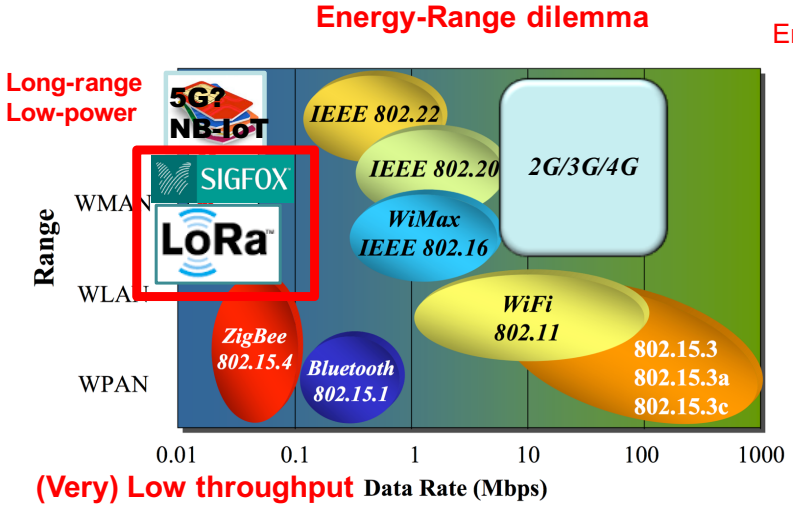
Energy consumption comparison



Energy

2G	3G	LAN	ZigBee	Lo Power WAN
N/A	N/A	O: 300m I: 30m	O: 90m I: 30m	Same as 2G/3G
200-500mA	500-1000mA	100-300mA	18mA	18mA-40mA
2.3mA	3.5mA	NC	0.003mA	0.001mA

2500mA

TX power: 500mA. Mean consumption: (8sx500+3592sx0.005)/3600=1.11mA

2500/1.11=2252h = 93 days = 3 months ☹

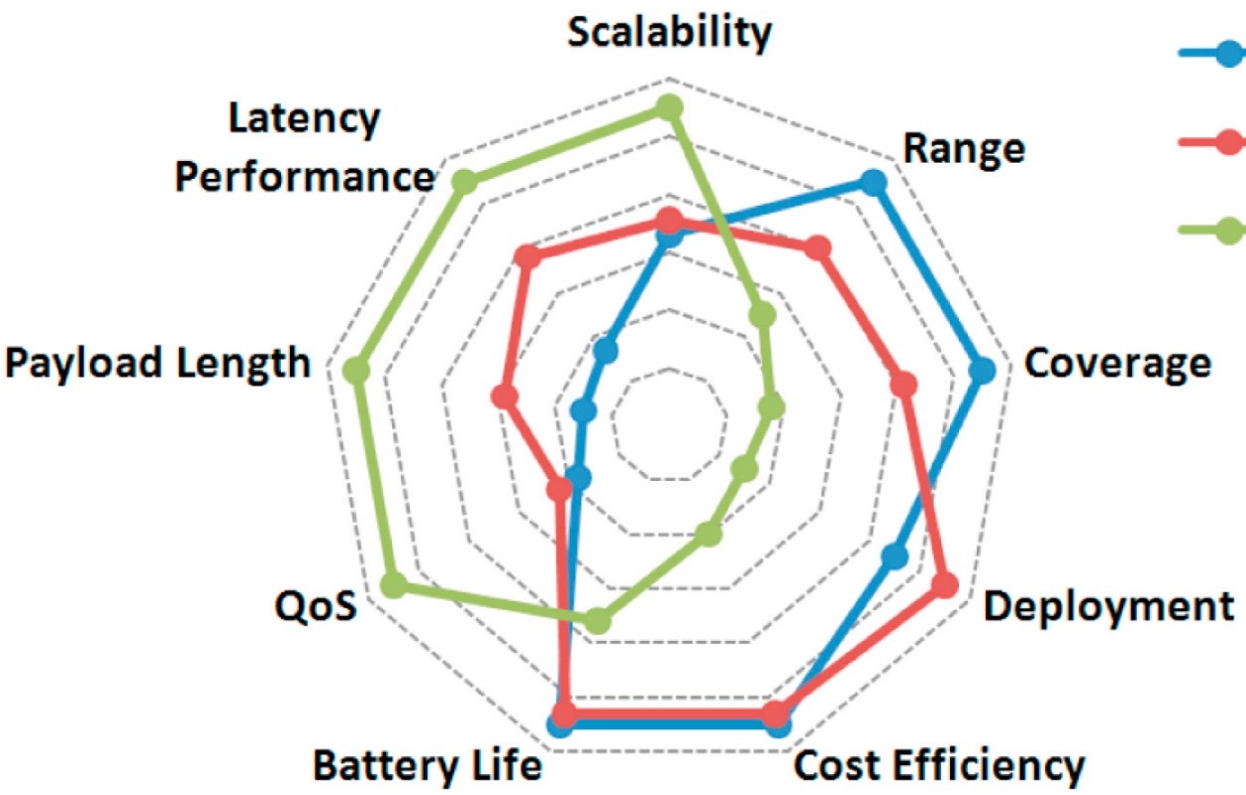
In most cellular networks, the device is still maintaining communication with BS even if it is inactive

TX power: 40mA. Mean consumption: (2sx40+3598sx0.005)/3600=0.027mA

2500/0.027=92592h = 3858 days = 10 y. ☺

LPWAN does not need to maintain connection if not in used

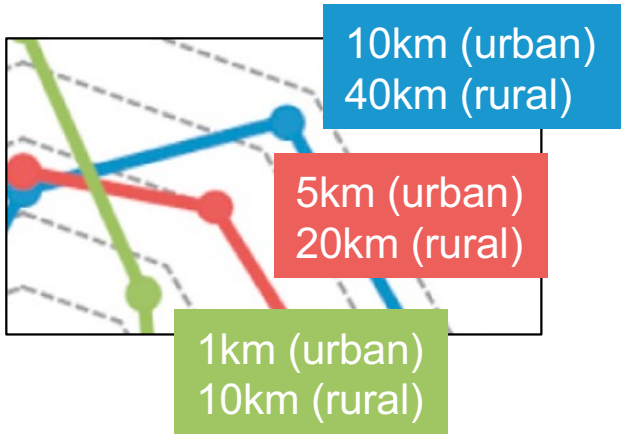
LPWAN expected range?



Bluetooth: about 20m

WiFi: about 300m-500m

3G/4G: about 2km-4km



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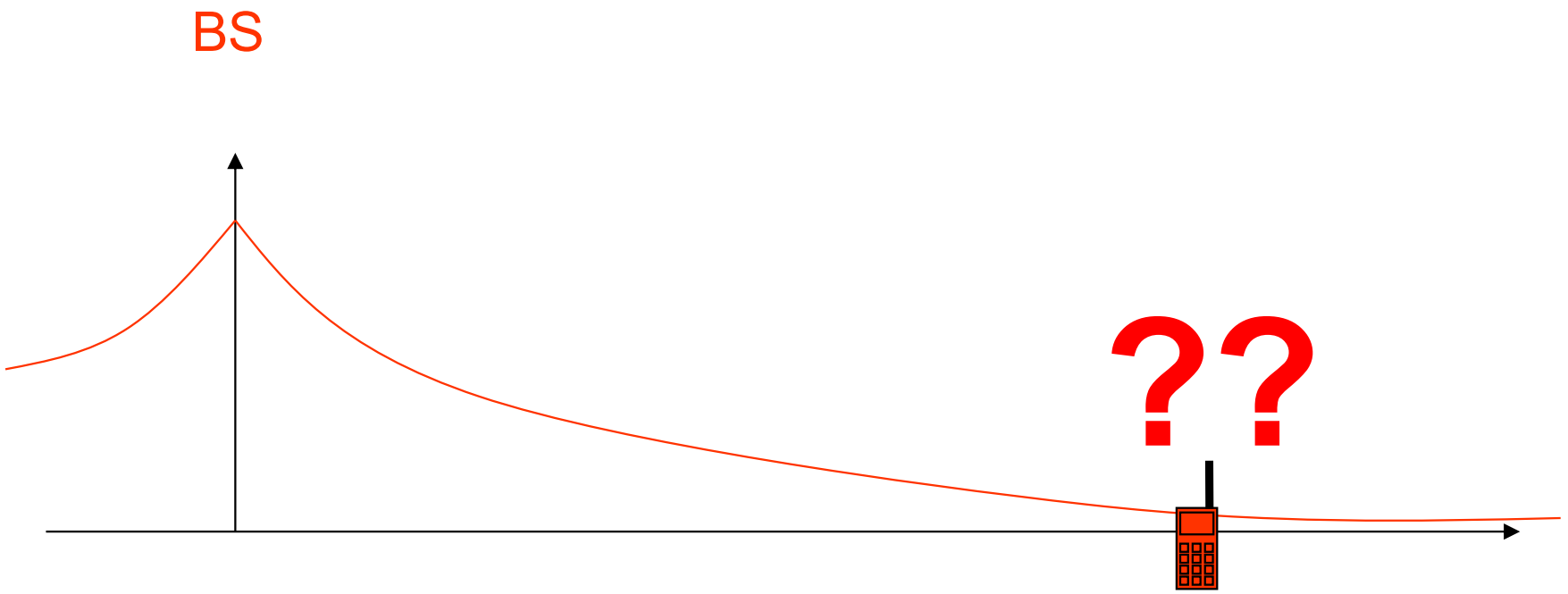
1st challenge: signal attenuation



Attenuation limits the range!

- Depends mainly on distance

$$P_r = P_e d^{-\alpha}$$

- with :
  - P_e = transmitted power
  - P_r = received power
  - d = distance between antennas
  - α from 2 to 4

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Attenuation in practice

- For an ideal antenna (theoretic)

$$\frac{P_e}{P_r} = \frac{(4\pi d)^2}{\lambda^2} = \frac{(4\pi f d)^2}{c^2}$$

- P_e = transmitted power
- P_r = received power
- P_e / P_r is high when P_r is small → high attenuation
- d = distance between antennas
- c = light speed in space 3.10^8 m/s
- λ= wave length of the signal=c/f
- Higher frequencies f means higher attenuation!

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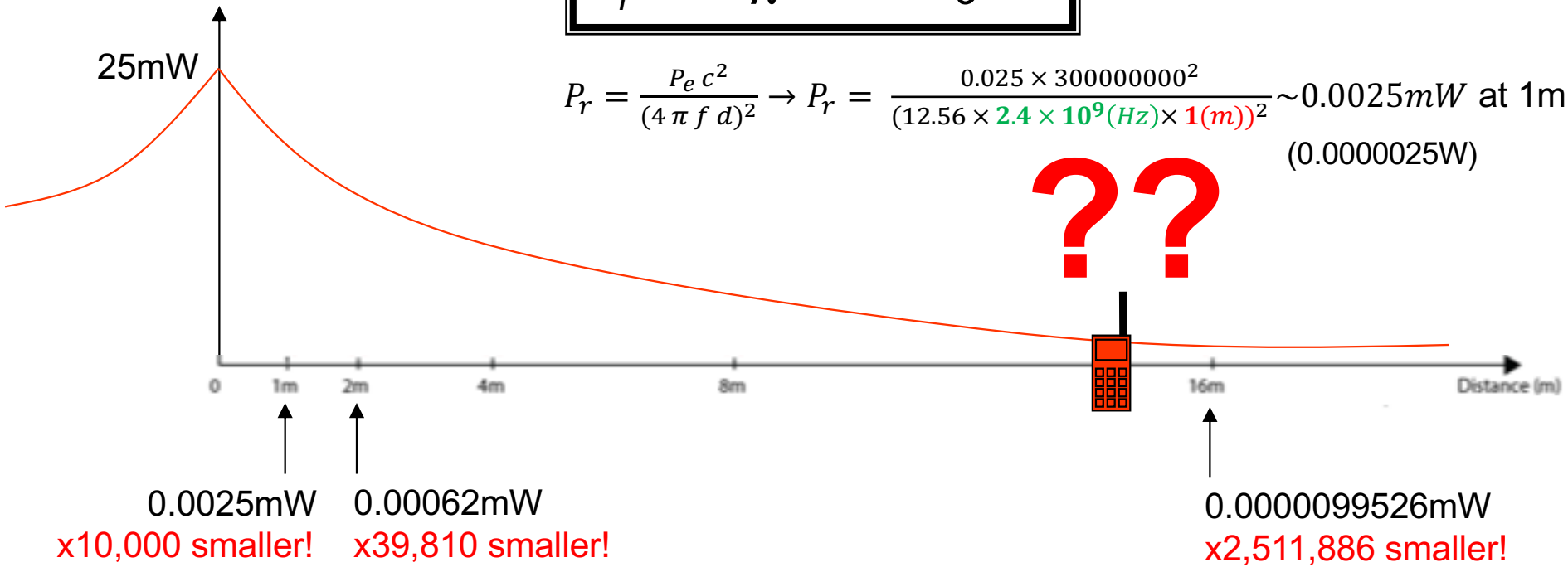
Attenuation, values in watts

- Free Space Path Loss model

$$\frac{P_e}{P_r} = \frac{(4\pi d)^2}{\lambda^2} = \frac{(4\pi f d)^2}{c^2}$$

$$P_r = \frac{P_e\, c^2}{(4\,\pi\, f\, d)^2} \rightarrow P_r = \frac{0.025 \times 300000000^2}{(12.56 \times \mathbf{2.4} \times \mathbf{10^9}(Hz) \times \mathbf{1}(m))^2} \sim 0.0025mW \text{ at 1m}$$

(0.0000025W)

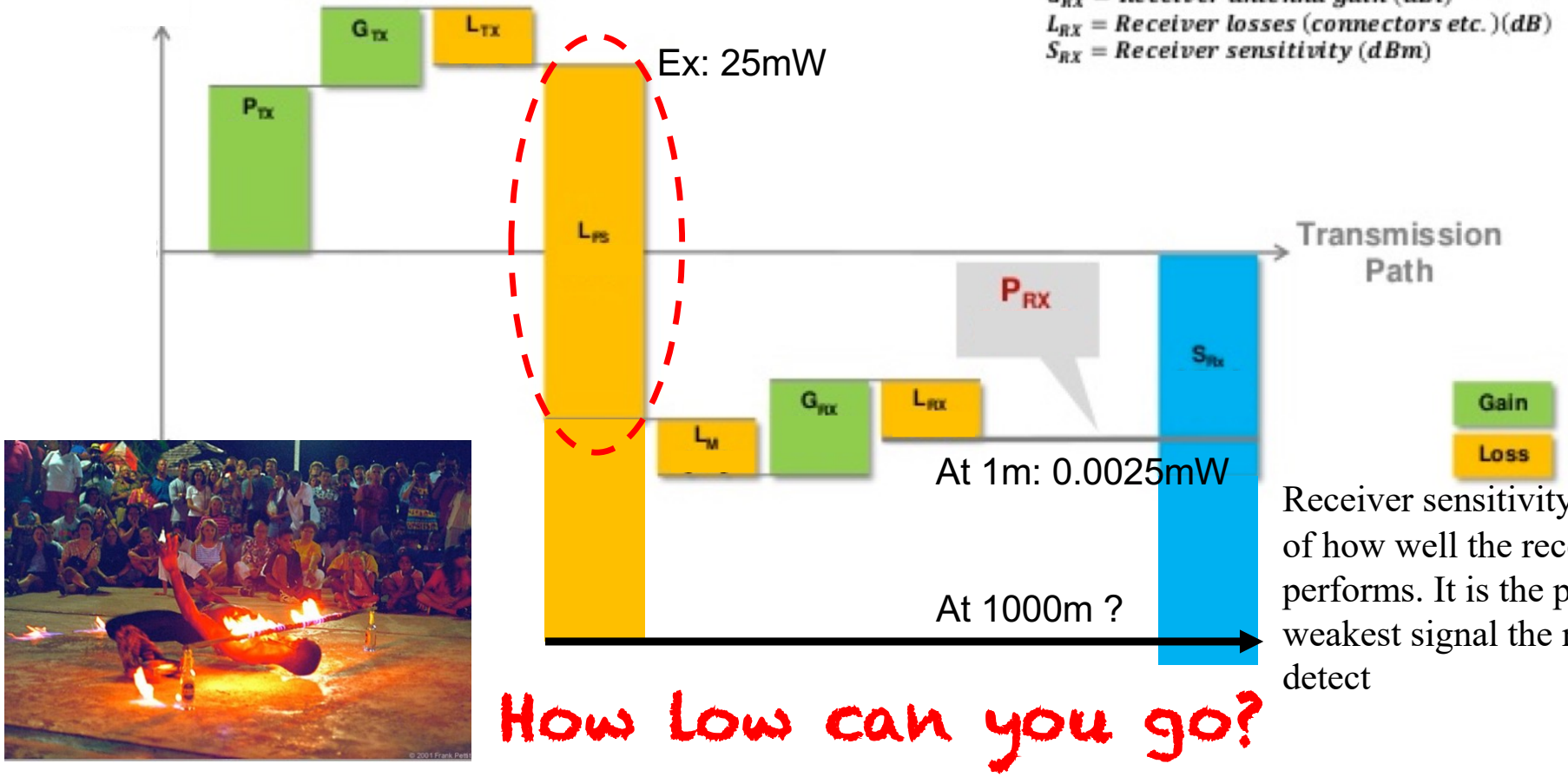


Link budget in wireless system – (simplified)

$$P_{RX} = P_{TX} + G_{TX} - L_{TX} - L_{FS} - L_M + G_{RX} - L_{RX}$$

P_{RX} = Received power (dBm)
P_{TX} = Sender output power (dBm)
G_{TX} = Sender antenna gain (dBi)
L_{TX} = Sender losses (connectors etc.)(dB)
L_{FS} = Free space loss (dB)
L_M = Misc. losses (multipath etc.)(dB)
G_{RX} = Receiver antenna gain (dBi)
L_{RX} = Receiver losses (connectors etc.)(dB)
S_{RX} = Receiver sensitivity (dBm)

Adapted from Peter R. Egli, INDIGOO.COM



Receiver sensitivity is a measure of how well the receiver performs. It is the power of the weakest signal the receiver can detect

Attenuation, in decibel (dB)

- Since attenuation is high, received power P_r is very small compared to transmitted power P_t : from 25mW to 0.0025mW
- **Decibel uses logarithmic scale** to express attenuation in a more "simple" way: $P_t/P_r = 10^{dB/10}$
- An attenuation of 40dB means $P_t/P_r = 10^{40/10} = 10{,}000$
- To simplify even more it would be great to easily add or substract transmitted power with attenuation= 25mW – 40dB?
- We need to also **express transmitted power in logarithmic scale**. We use dBm to express power relatively to 1mW
- $P(mW) = 10^{dBm/10}$
- A transmit power of 14dBm means $P_t = 10^{14/10} \sim 25mW$
- Now, we can do 14dBm-40dB=-26dBm → $P_r = 10^{-26/10} = 0.0025mW$

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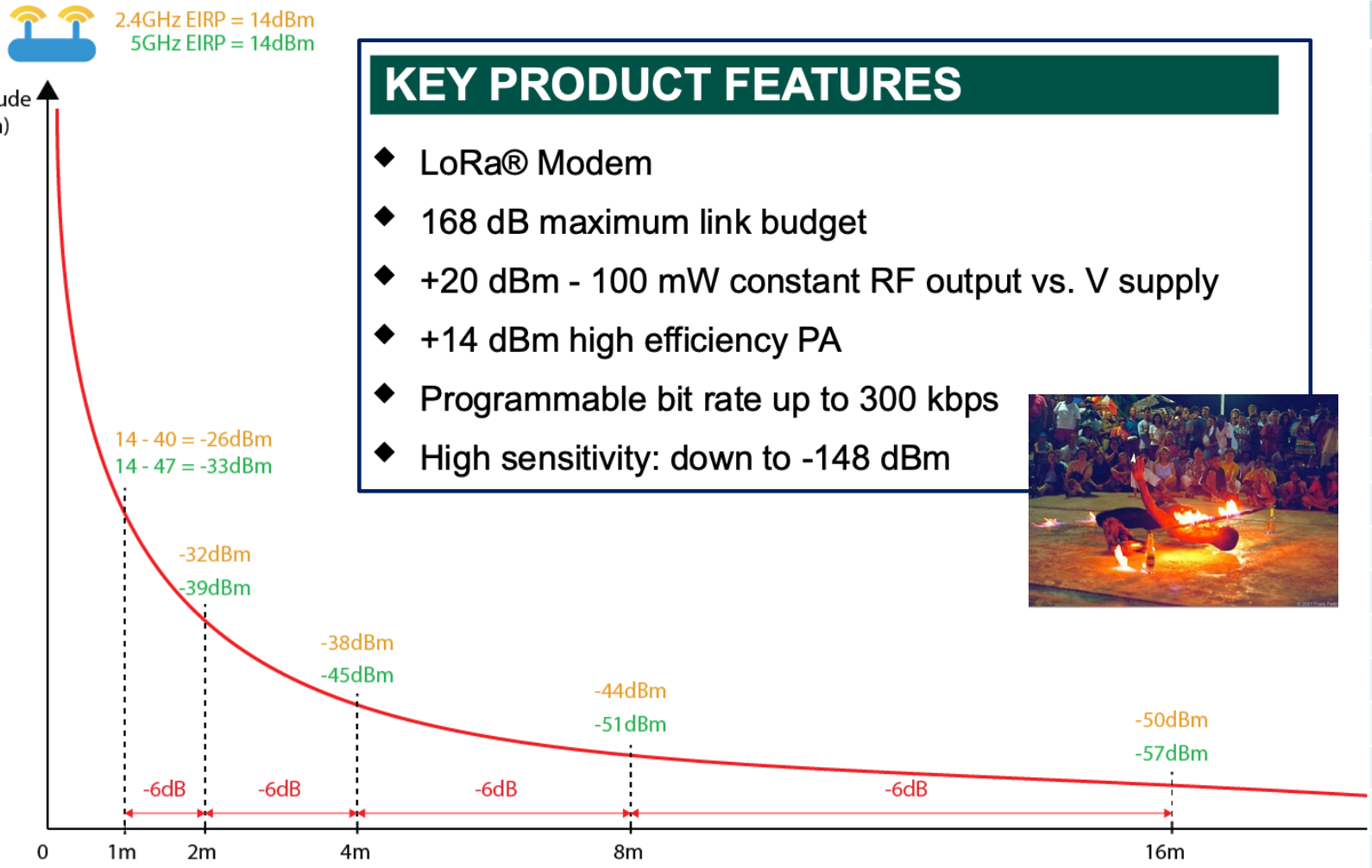
Attenuation and how far can we go?



KEY PRODUCT FEATURES

- LoRa® Modem
- 168 dB maximum link budget
- +20 dBm - 100 mW constant RF output vs. V supply
- +14 dBm high efficiency PA
- Programmable bit rate up to 300 kbps
- High sensitivity: down to -148 dBm

-26	1
-32	2
-38	4
-44	8
-50	16
-56	32
-62	64
-68	128
-74	256
-80	512
-86	1024
-92	2048
-98	4096
-104	8192
-110	16384
-116	32768
-122	65536
-128	131072
-134	262144
-140	524288
-146	1048576
-152	2097152

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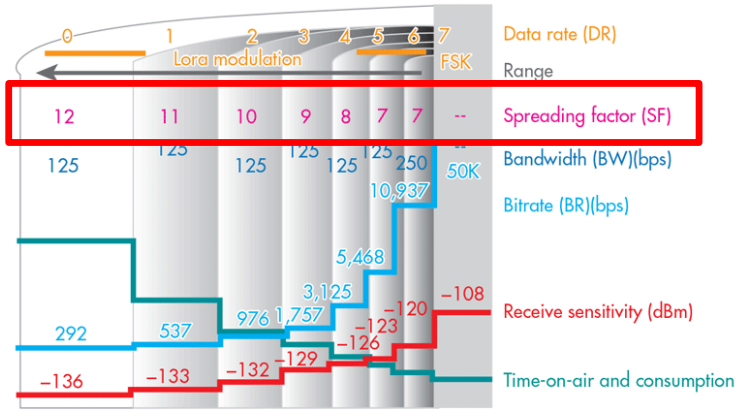
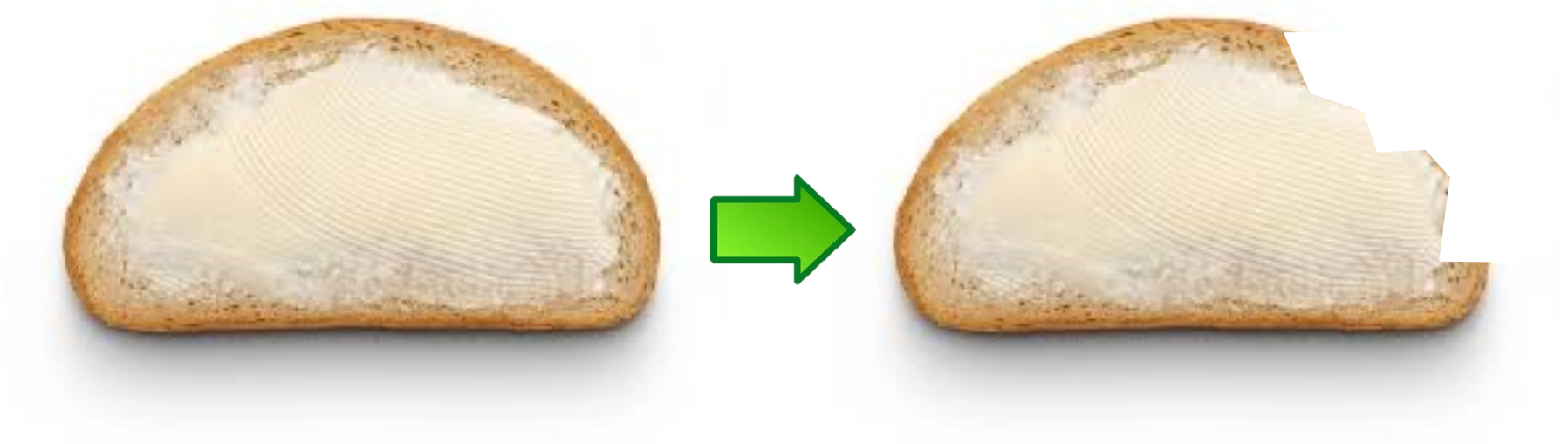
How can we increase range?

- Increase TX power and/or improve RX sensitivity
- Generally, RX sensitivity (~robustness) can be increased when transmitting (much) slower (like speaking slower!)
- LoRa uses spread spectrum approach to increase RX sensitivity
  - Spreading Factor defines how many chips will be used to code a symbol. More chip/symbol=longer transmission time ➠ more robustness
- **The price to pay for LPWAN**
  - LoRa has very low throughput: 200bps-37500bps (0.2-37.5kbps)



- WiFi 802.11n: 450 000 000 bps (450Mbps)
- WiFi 802.11g: 54 000 000 bps (54Mbps)
- Bluetooth3&4: 25 000 000 bps (25Mbps)
- Bluetooth BLE: 2 000 000 bps (2Mbps)
- 3G/4G : 20Mbps-200Mbps
- LoRa: 200bps-37500bps (0.0002-0.0375Mbps)
- 3G/LoRa ratio: 20,000,000bps/200bps=100000!

The buttered toast example



- Assuming you could get back ALL your butter, how much butter did you loose?
- This is the idea behind "spread spectrum" techniques: the more you "spread", the more it is robust to interferences

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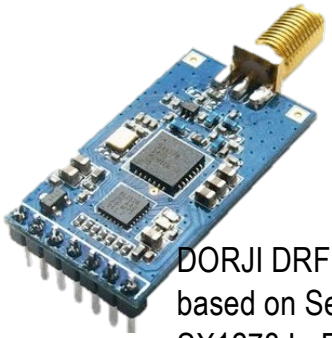
LoRa modules with Semtech's SX12xx



DORJI DRF1278DM is based on Semtech SX1278 LoRa 433MHz

EBYTE E22

RAK Wireless 3172

inAir9 based on SX1276

Froggy Factory LoRa module (Arduino)

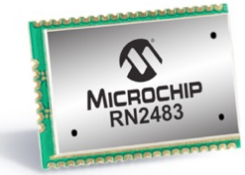
HopeRF RFM series

HopeRF HM-TRLR-D

LinkLabs Symphony module

Microship WLR089

Embit LoRa



LoRa™ Long-Range Sub-GHz Module (Part # RN2483)

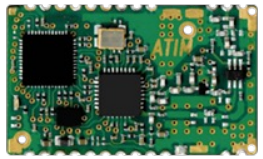
Microship RN2483

habSupplies

Adeunis ARF8030AA- Lo868

Multi-Tech MultiConnect mDot

AMIHO AM093



ARM-Nano N8 LoRa module from ATIM

SODAQ LoRaBee Embit

SODAQ LoRaBee RN2483

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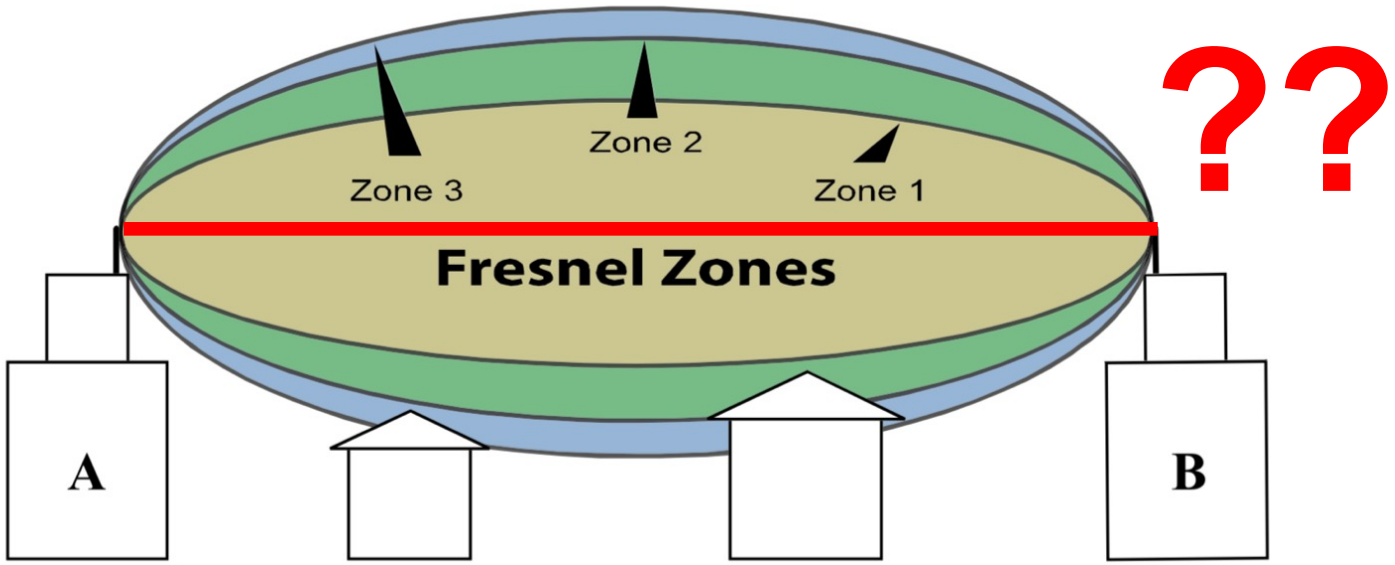
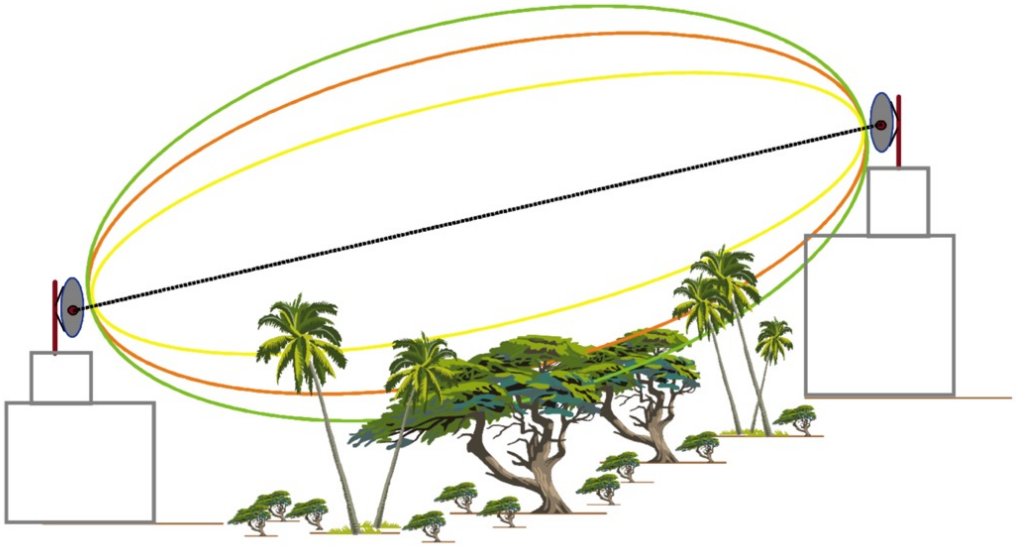
Line-of-Sight & Fresnel zone

- LoS means clear Fresnel zone
- Football (american) shape
- Acceptable = 60% of zone 1 + 3m

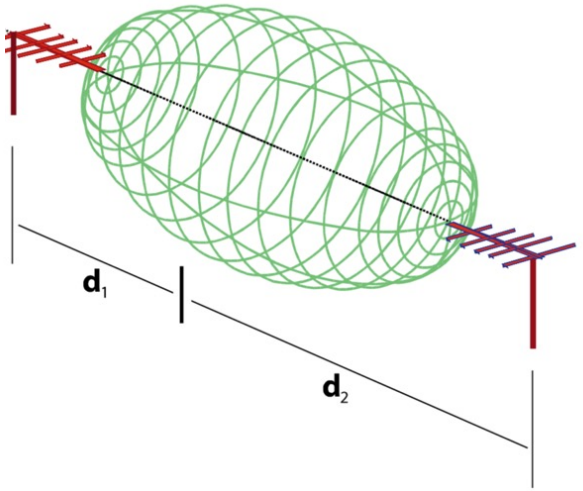


Clearing the Fresnel zone? Raise antennas!



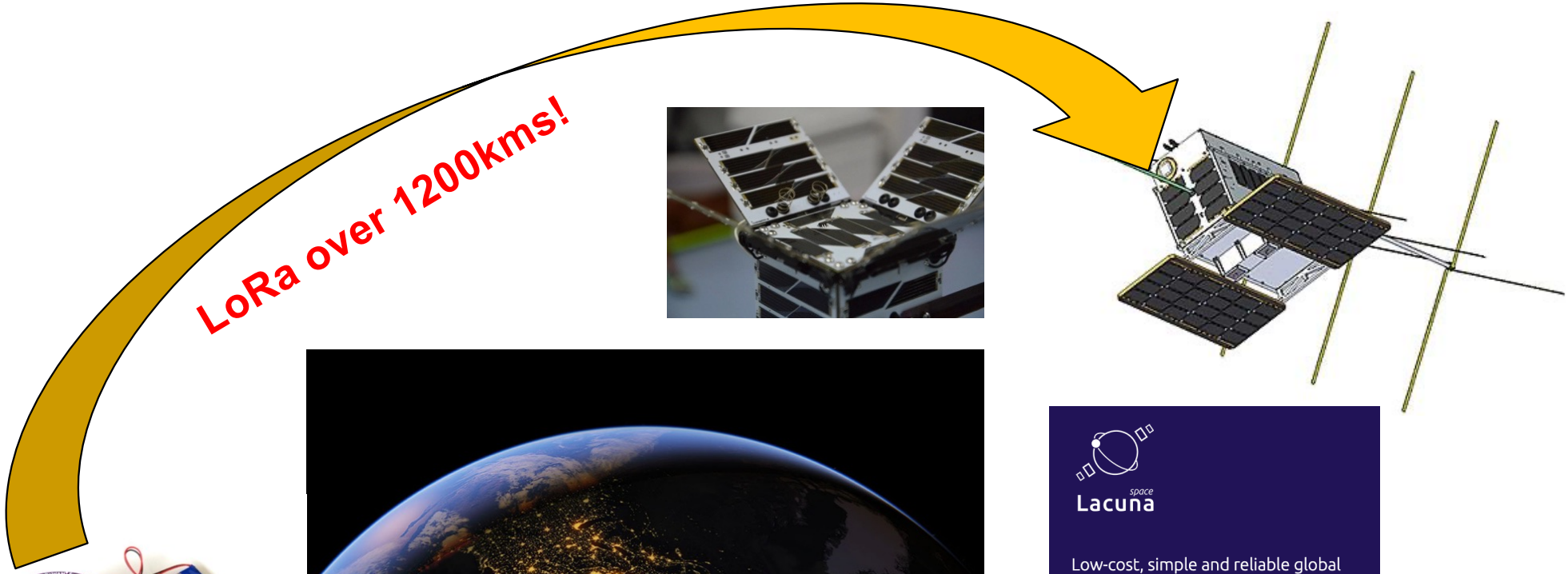
$$r_n = \sqrt{\frac{n\lambda d_1 d_2}{d_1 + d_2}}$$

Range Distance	900 MHz Modems Required Fresnel Zone Diameter	2.4 GHz Modems Required Fresnel Zone Diameter
1000 ft. (300 m)	16 ft. (5 m)	11 ft. (3.4 m)
1 Mile (1.6 km)	32 ft. (10 m)	21 ft. (6.4 m)
5 Miles (8 km)	68 ft. (21 m)	43 ft. (13 m)
10 Miles (16 km)	95 ft. (29 m)	59 ft. (18 m)



Clearing the Fresnel zone? Let's use satellite!

- Low-orbit, low-cost; compact satellite for global coverage



https://lacuna.space/first-successful-lacunasat-launch-in-2021/

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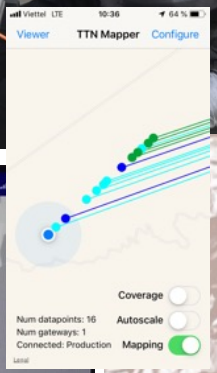
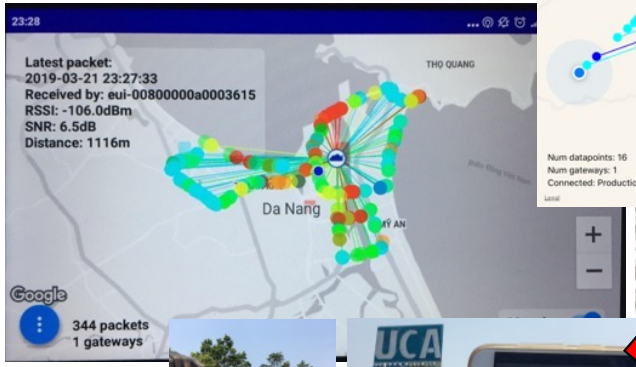
Coverage test by Fabien Ferrero on March 21-22, 2019

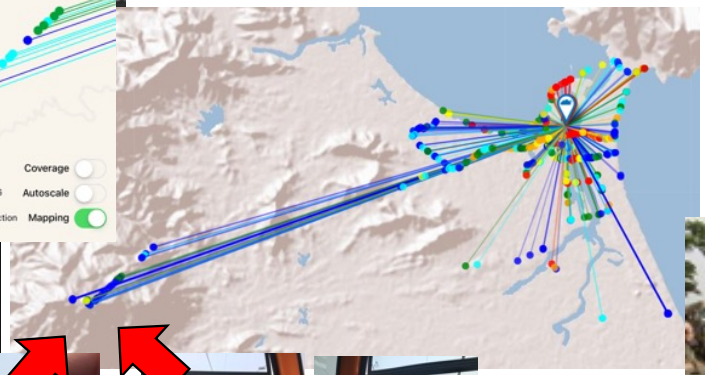
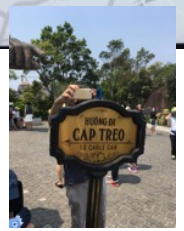
- LoRaWAN gateway on top of Danang's DSP building by Fabien, U. Danang and DSP team. Almost 26kms! Congrats Fabien!

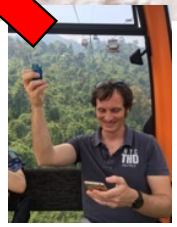








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LPWAN=star topology, gateway centric

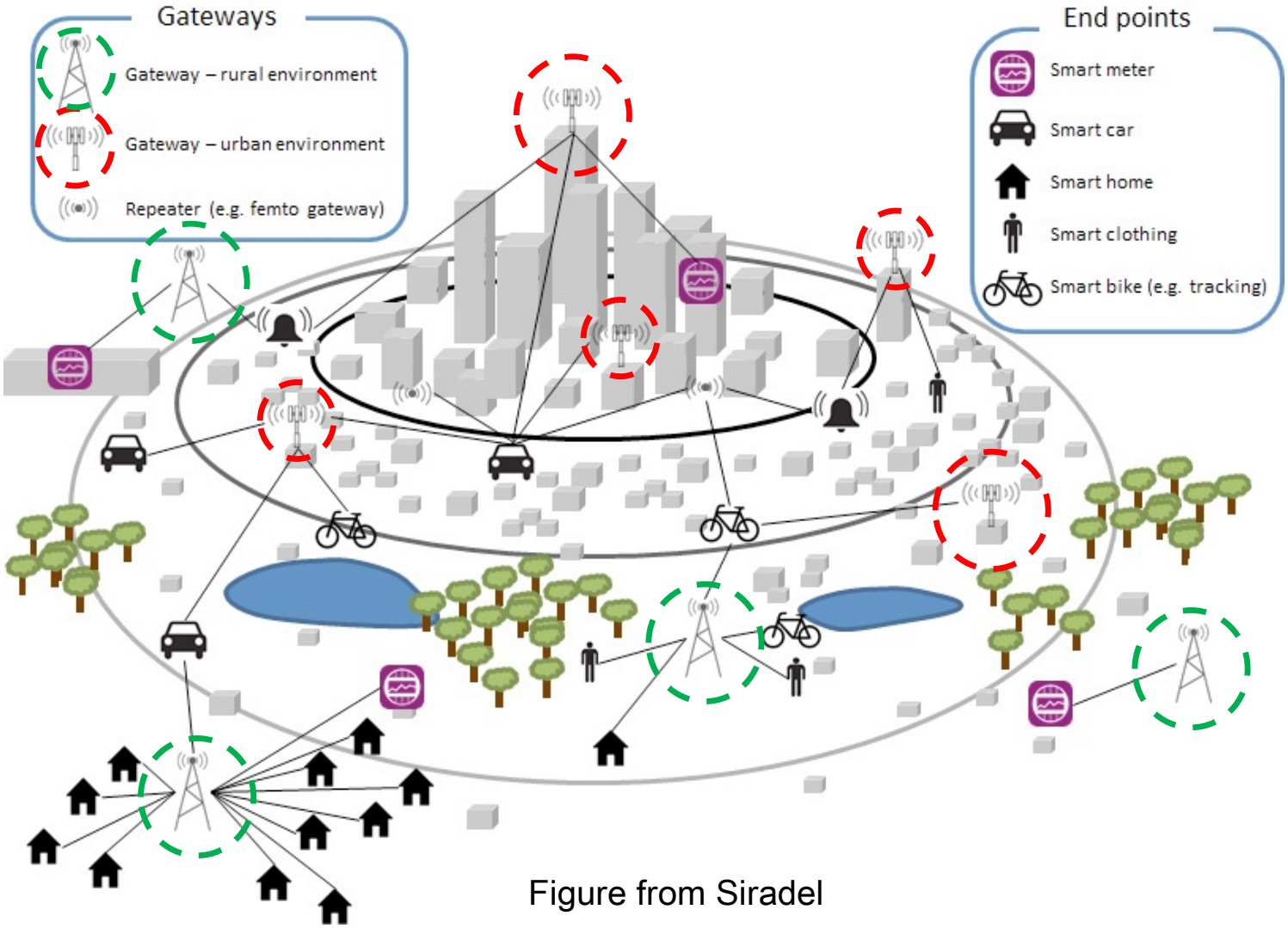

Figure from Siradel

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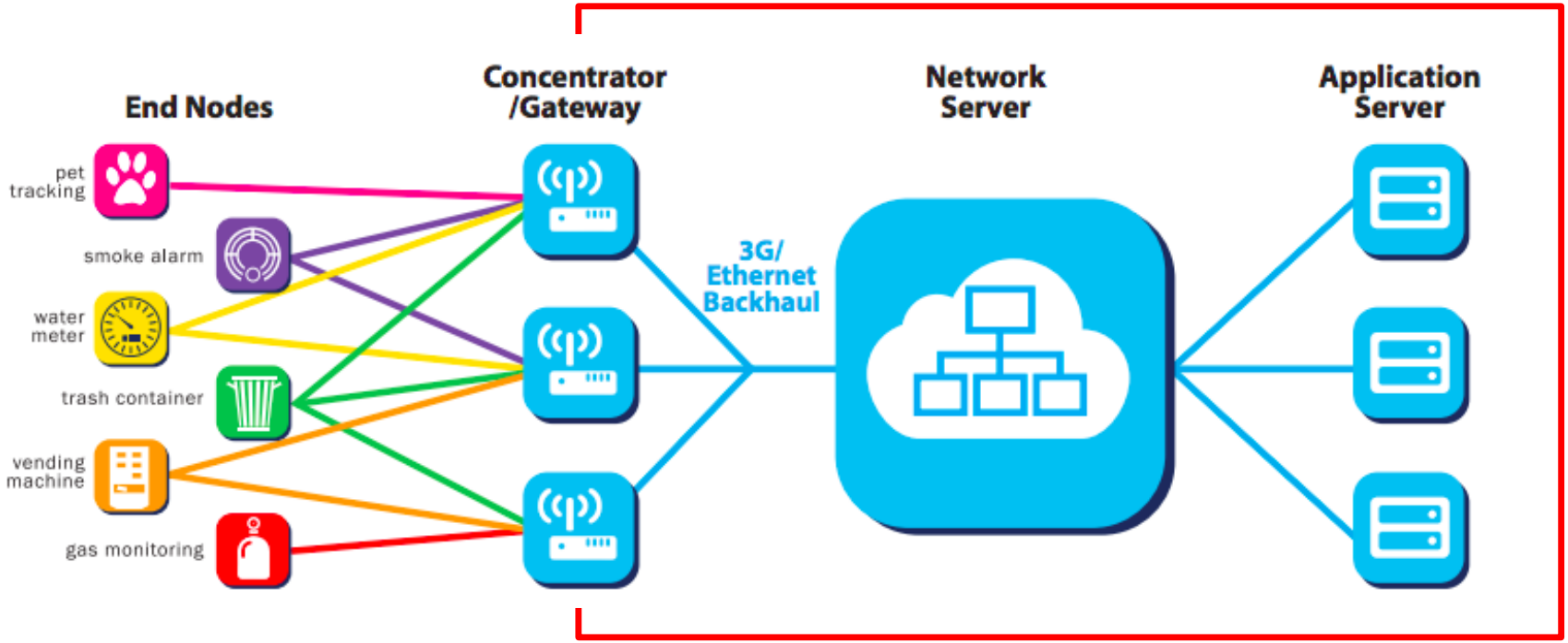
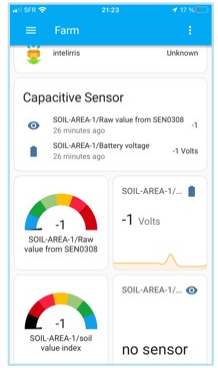
LoRaWAN IoT networks

- LoRaWAN specifications/protocols run on top of LoRa physical networks. It is defined and managed by the LoRa Alliance
- Make possible to run large-scale, public LoRa networks





ThingsBoard

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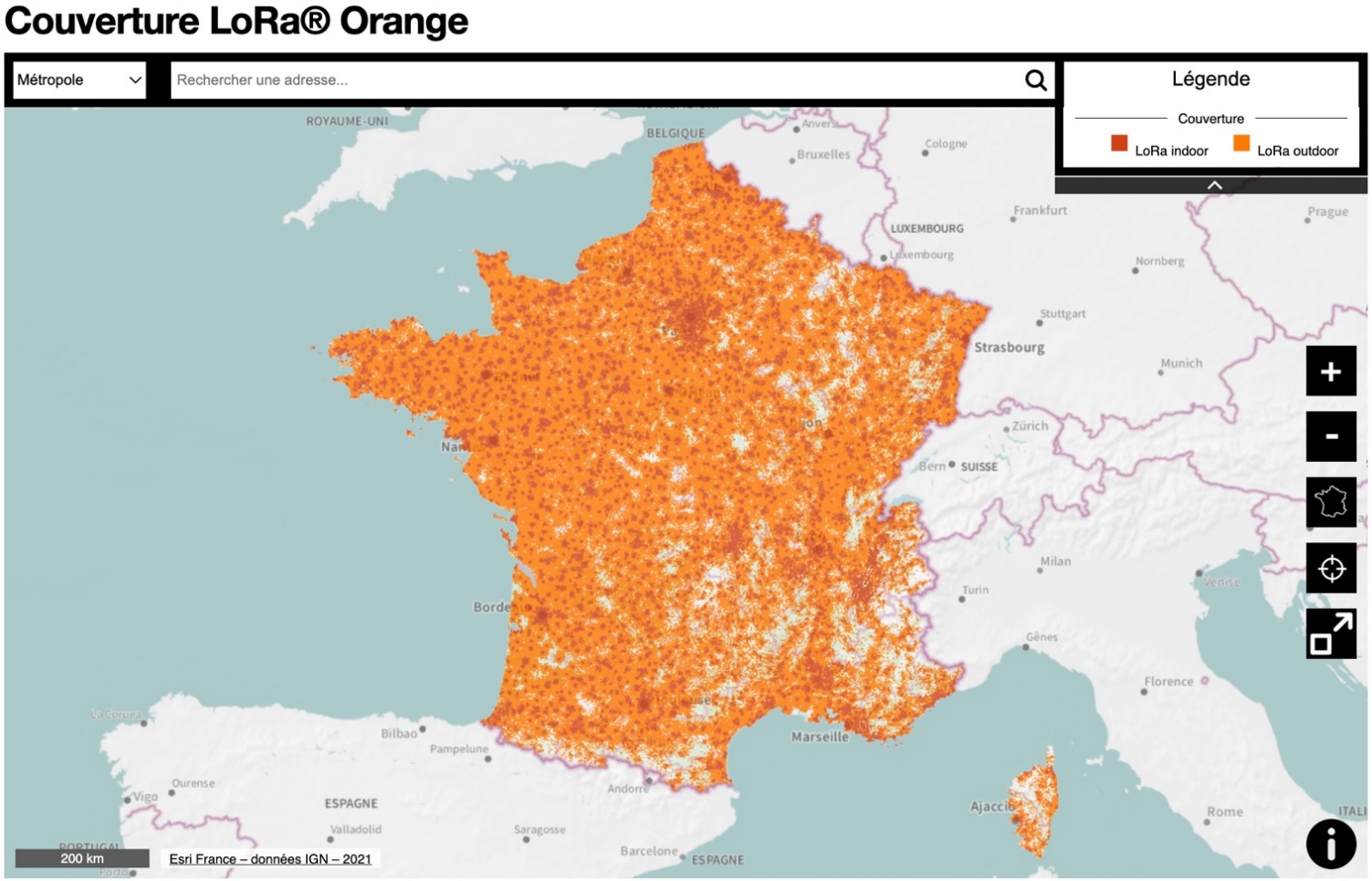
LoRaWAN in France



https://www.orange-business.com/fr/reseau-iot

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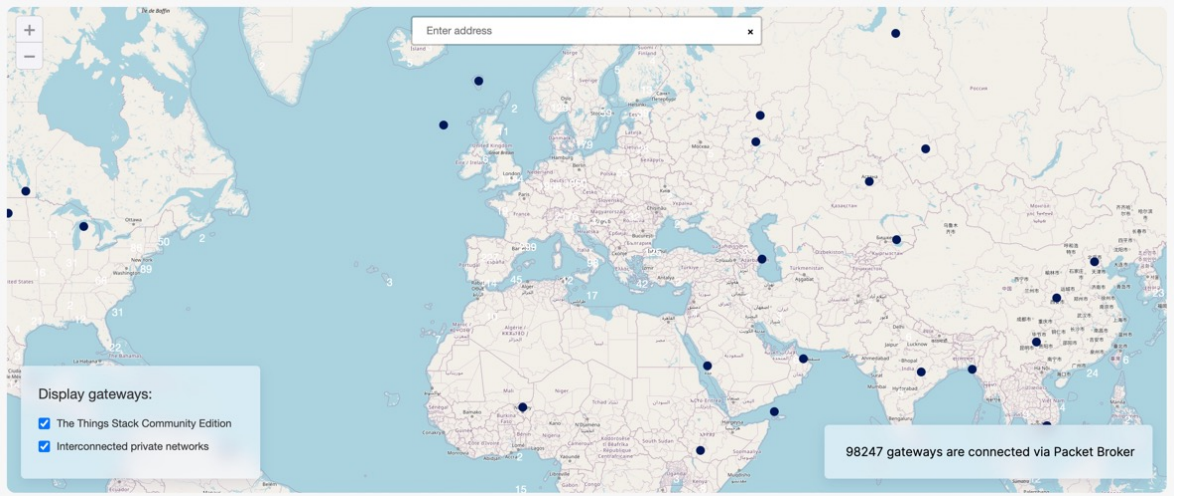
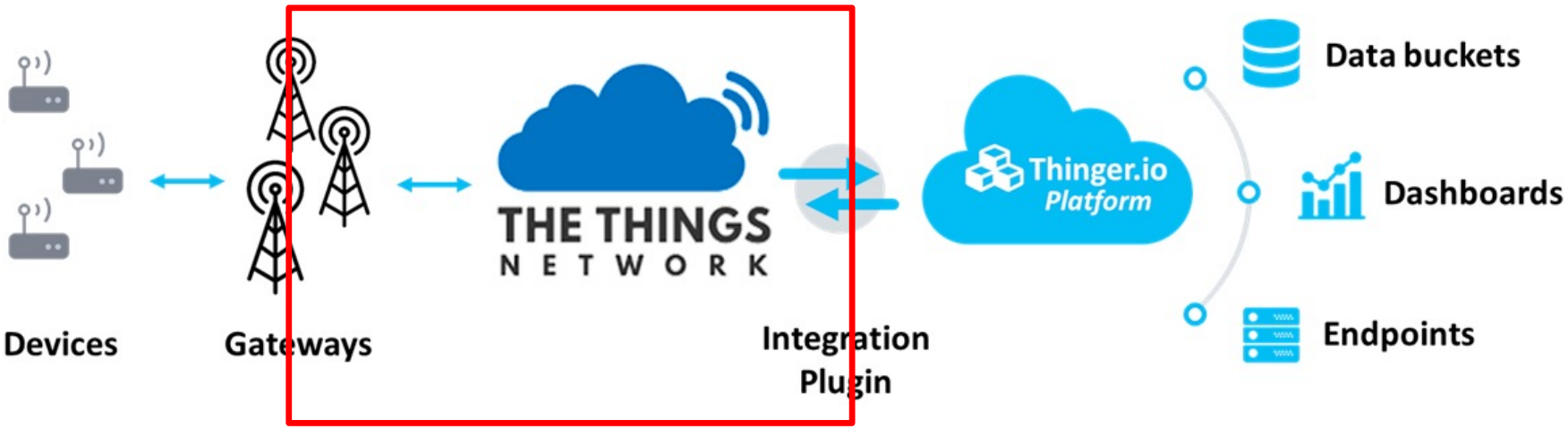
TheThingNetwork network

- Community-based, more than 98000 gw





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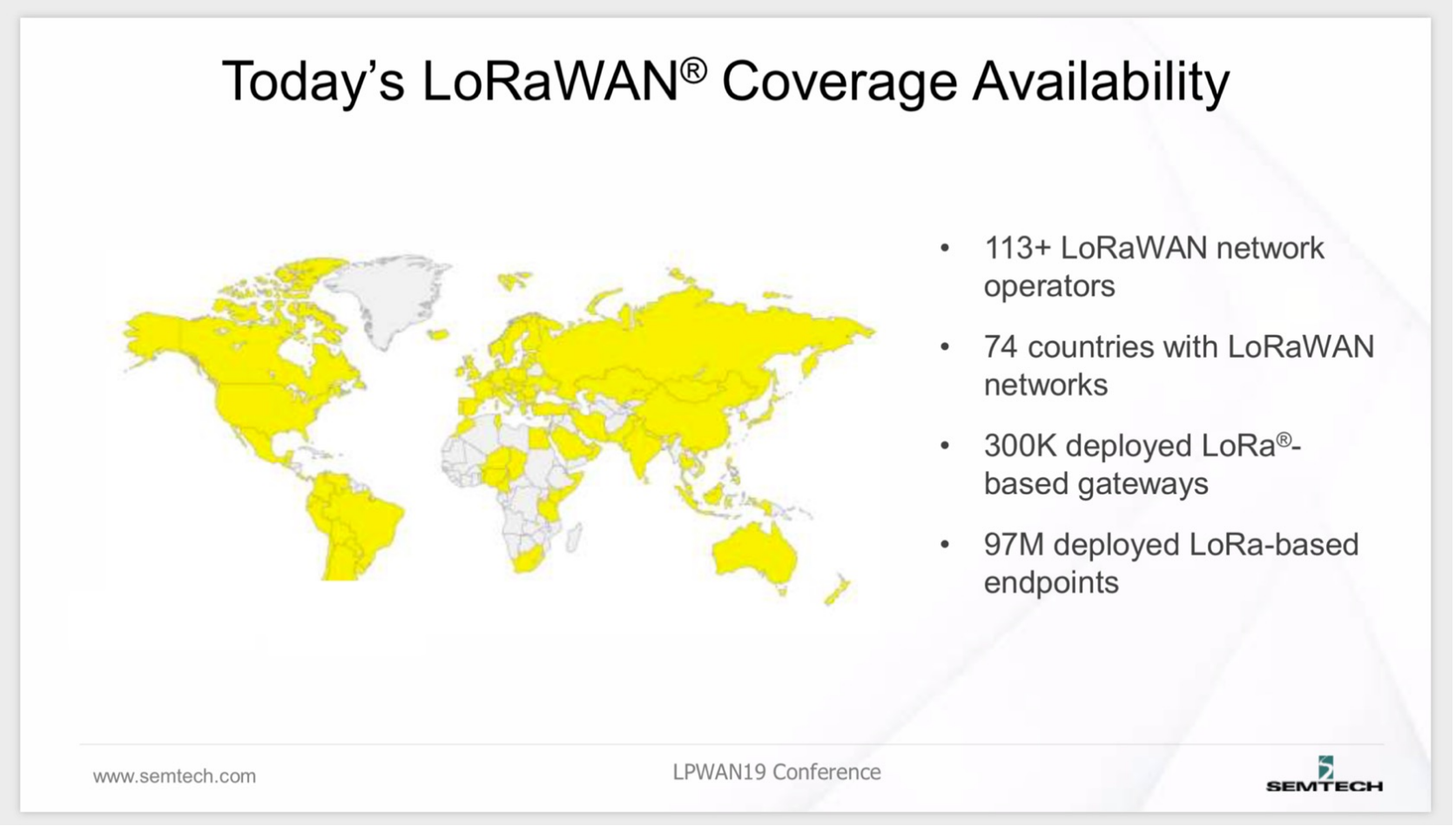
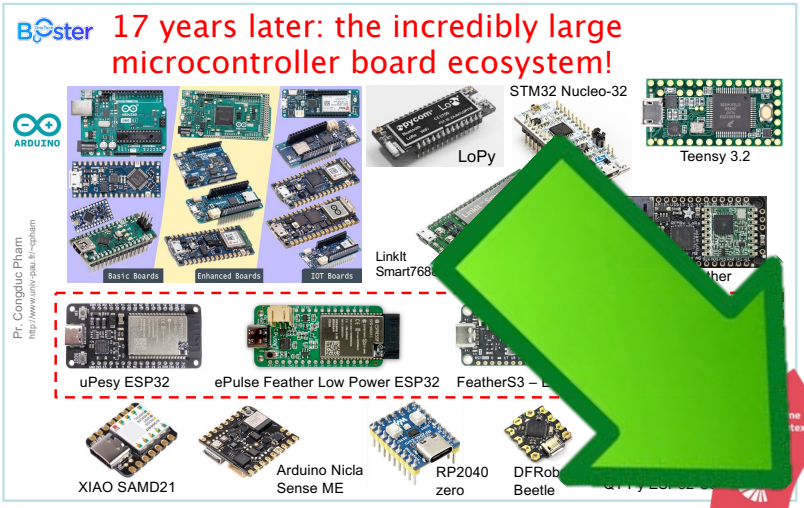
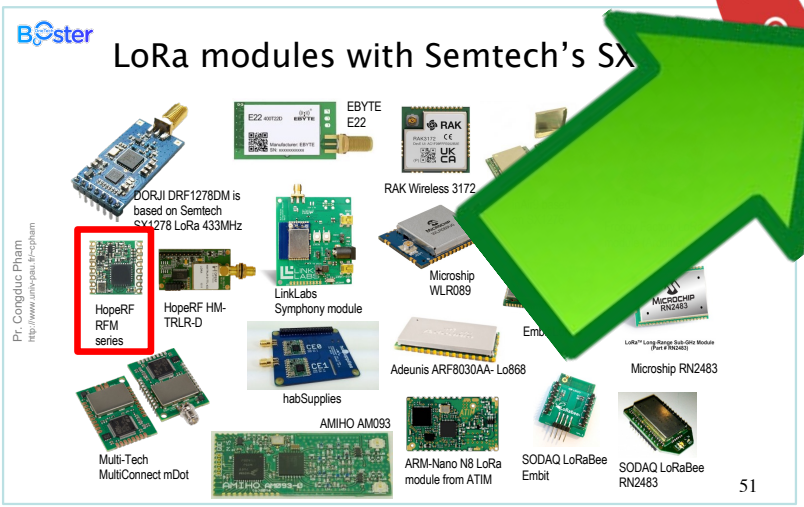
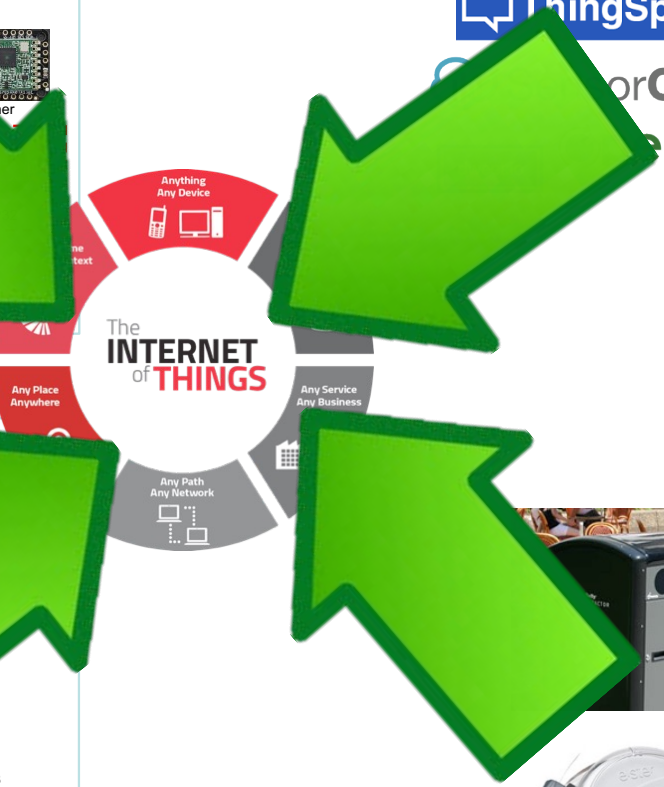
LoRaWAN coverage from Semtech



IoT becomes reality!







IoT for everybody?

Too expensive
Too integrated
Highly specialized
Difficult to customize
Difficult to upgrade

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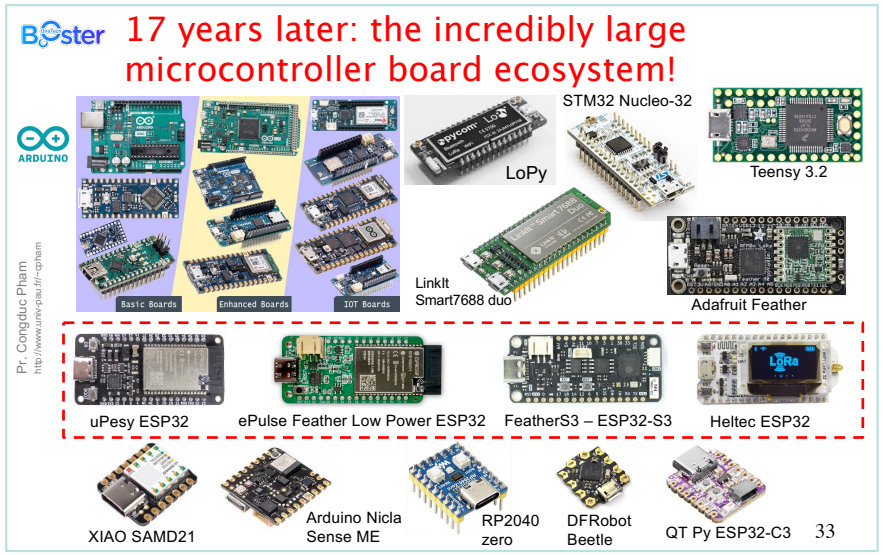
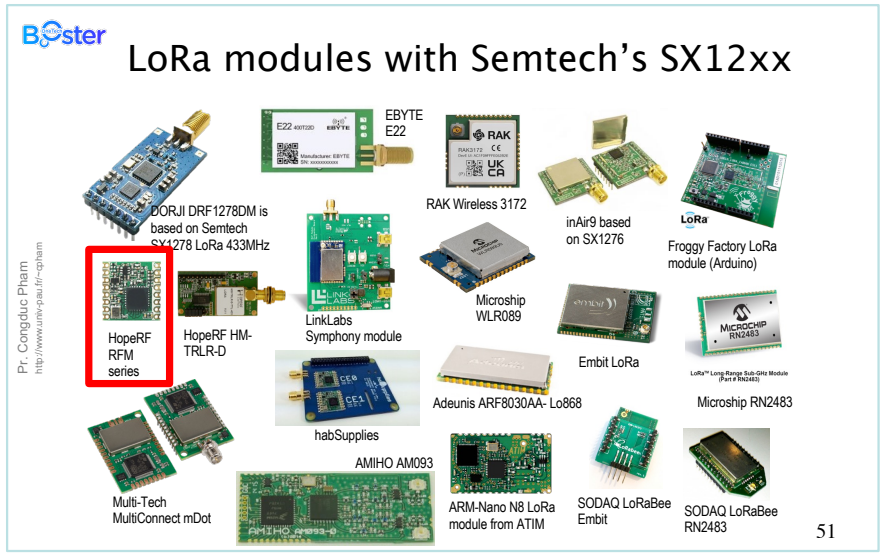
Convergence of technologies





Too expensive
Too integrated
Highly specialized
Difficult to customize
Difficult to upgrade

Do-It-Yourself (DIY) IoT
Off-the-shelves parts
Generic platform
Open-source
Modular design

: Low-cost IoT since 2016!

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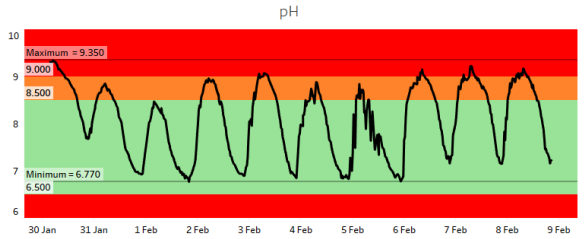
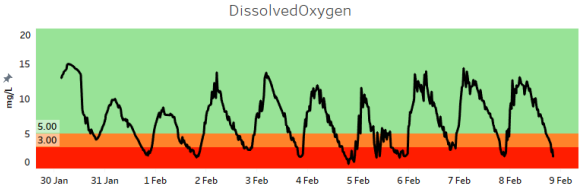
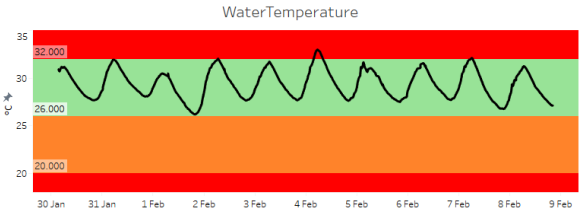
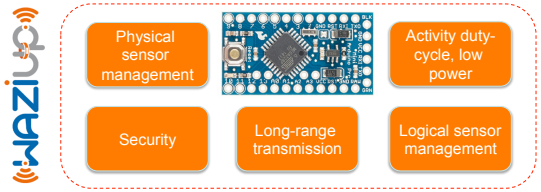
Low-cost buoy for fish farming MVP



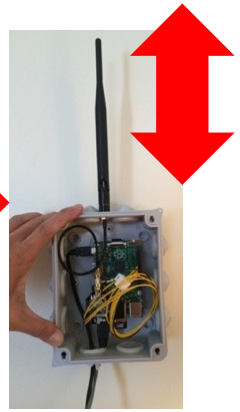




Physical sensor reading



Credit: EGM



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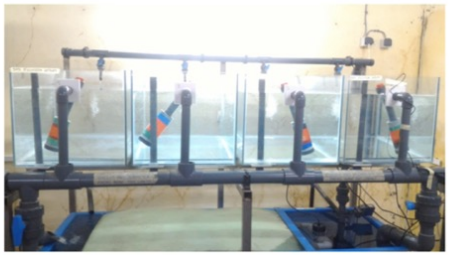
Hatchery experiment, Burkina Faso

- Laboratory named Laboratoire d'Études des Ressources Naturelles et des Sciences de l'Environnement (LERNSE)
- NAZI BONI University in a small village of Bobo-Dioulasso city
- Sensors are placed in a hatchery and the box is placed outside of the building



Low-cost buoy for fish farming

In Sub-Saharian Africa, the volume of natural captured fish doesn't meet half of the population demand

Increasing production of aquaculture will help reduce the quantity of imported fishes in Africa

The aim is to monitor in real-time different parameters to control water quality and prevent some diseases that could affect fish in order to improve the quality and quantity of the production

Kumah farm, Ghana

- The Kwame Nkrumah University of Science and Technology (KNUST)
- Located on the campus of the Kwame Nkrumah University of Science and Technology in Kumasi, Ghana.
- The farm comprises 30 constructed fish ponds, a farm house, a recirculating aquaculture system (RAS) laboratory and store houses.

Sanar farm, Senegal

- Farm located at less than 2 km from UGB.
- One pond is dedicated for the Waziup application : 50x25m, average depth of 0.5 meters, populated by 4000 individuals of saltwater tilapia.
- The basin is irrigated via a water supply system fed by a river in proximity.
- The water in the pond is changed every 10 days

Collar for Cattle Rustling MVP

A web interface displays the position of the gateway those of the remote GPS devices

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PRIMA PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

Intel-IrriS June 2021 – May 2024

Intelligent Irrigation System for Low-cost Autonomous Water Control in Small-scale Agriculture

AUA: Agricultural University of Athens — Greece

ENSA-Safi: National School of Applied Sciences – Safi — Morocco

INRA: National Institute of Agronomic Research — Morocco

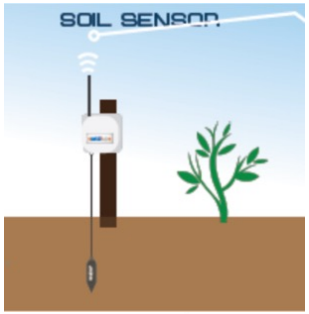
IRD: Institute for Research & Development — France

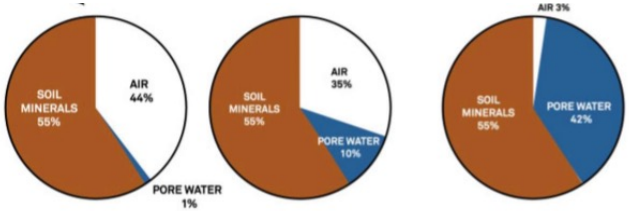
UMAB: University A. Benbadis — Algeria

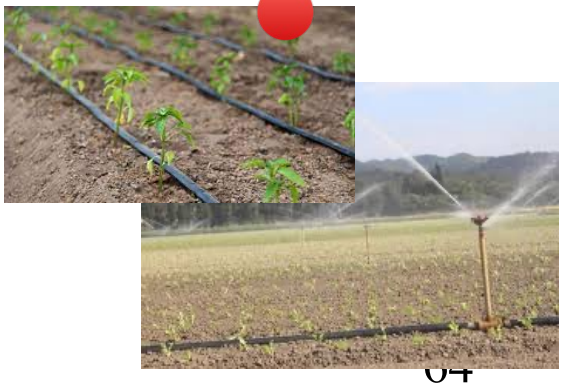
UORAN1: University of Oran 1 — Algeria

UPPA: University of Pau & Adour Country — coordinator — France

WAZIUP eV: WAZIUP association — Germany







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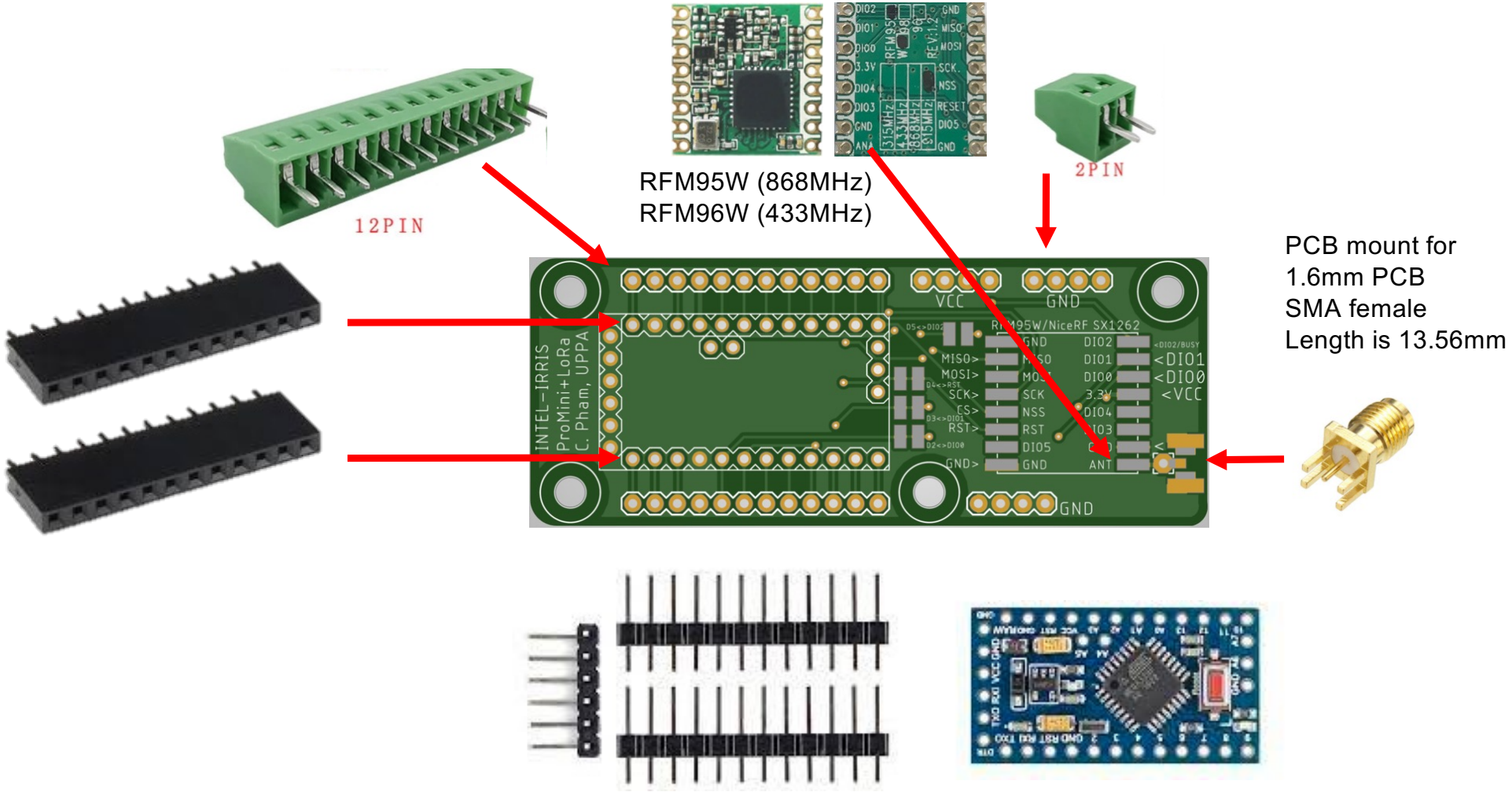
INTEL-IRRIS starter-kit

- "Intelligent Irrigation in-the-box", "plug-&-sense", fully autonomous
- From idea to reality!

< 90€

Soil sensor: electronic parts

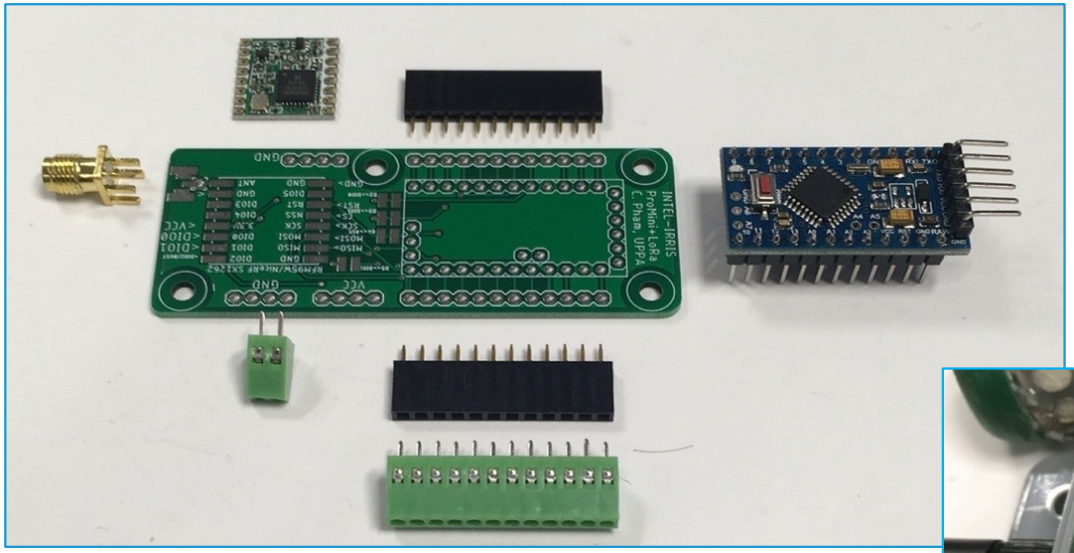
starter-kit version

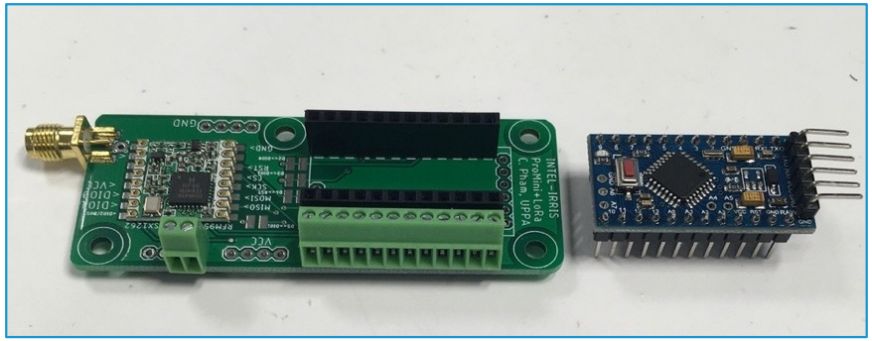


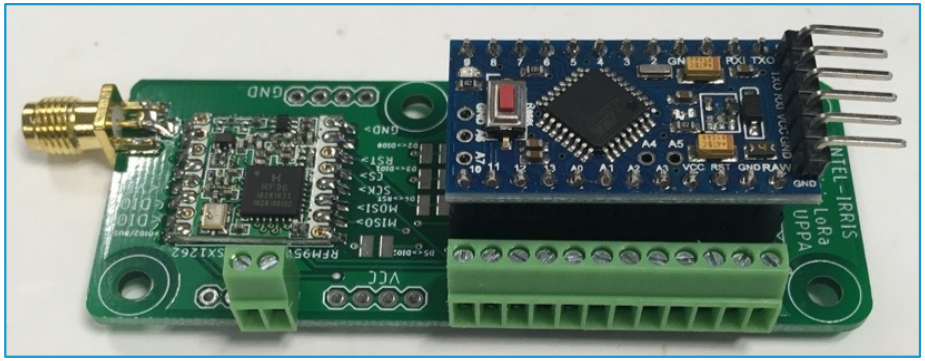
Arduino ProMini 3.3V 8MHz

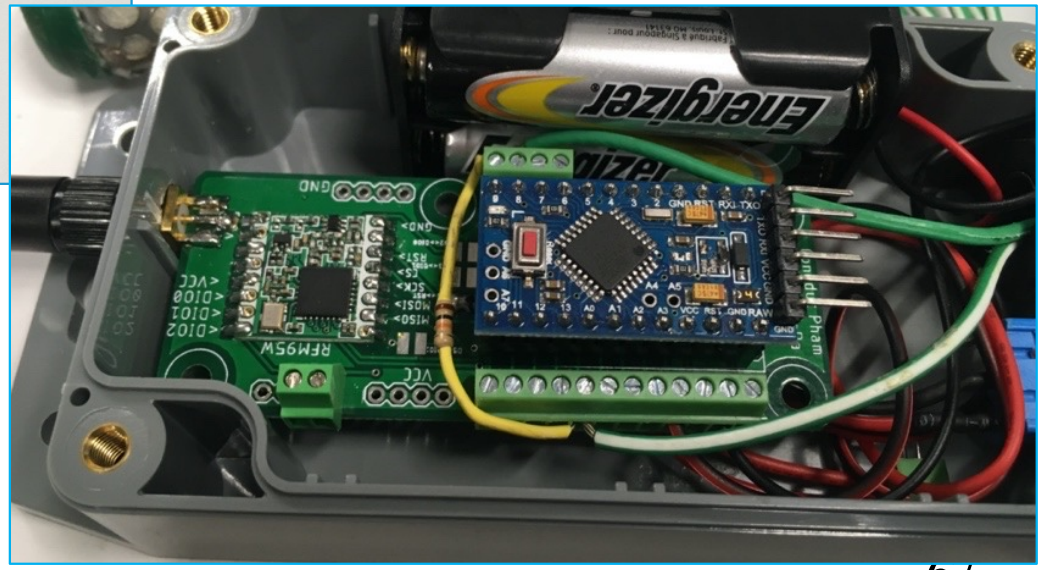
Simple & Modular design

- Simple integration on PCB of off-the-shelves components





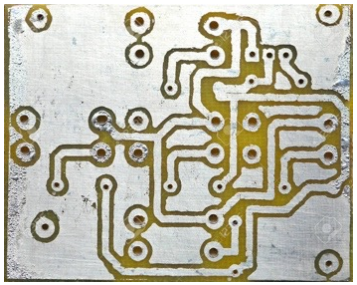




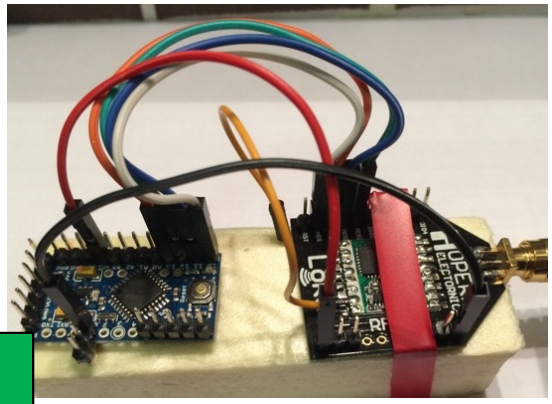
What is a PCB?

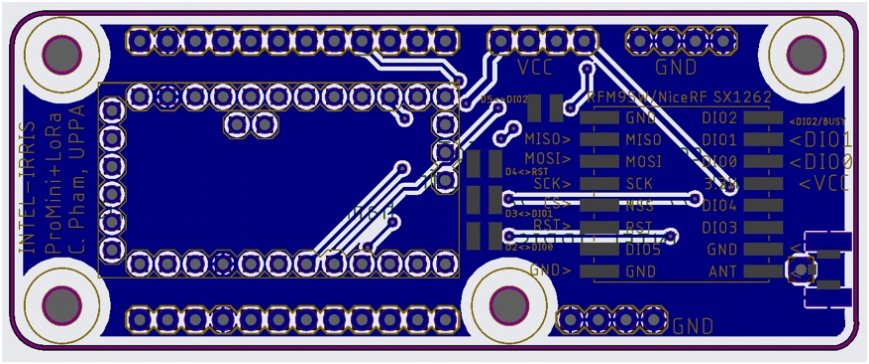
- PCB=Printed Circuit Board
- Copper paths replace Dupont wires

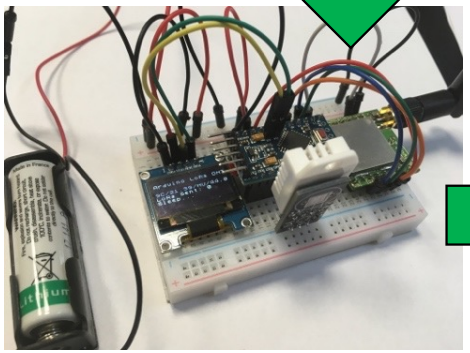
Raw PCB copper board

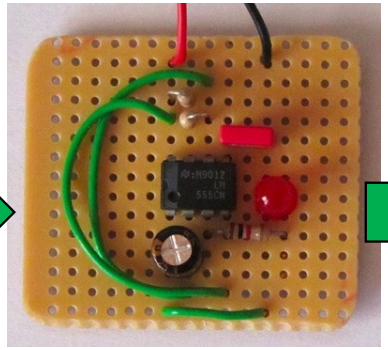


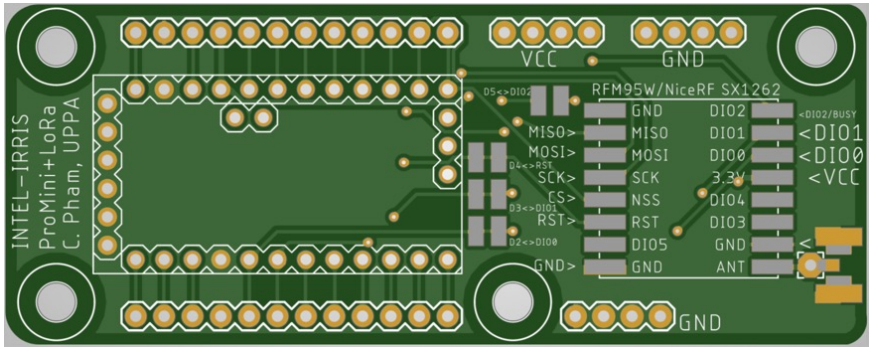
Removing copper to create wire path











Breadboard

Stripboard

A generic sensor platform

- Low-cost: < 20€
- Off-the-shelves composants
- Easily duplicated
- Assembling by local partners
- Can connect several sensors
- Can be adapted by local partners
- Can be improved by local entrepreneurs
- Can increase capacity-building for local innovation

Final integration – DIY

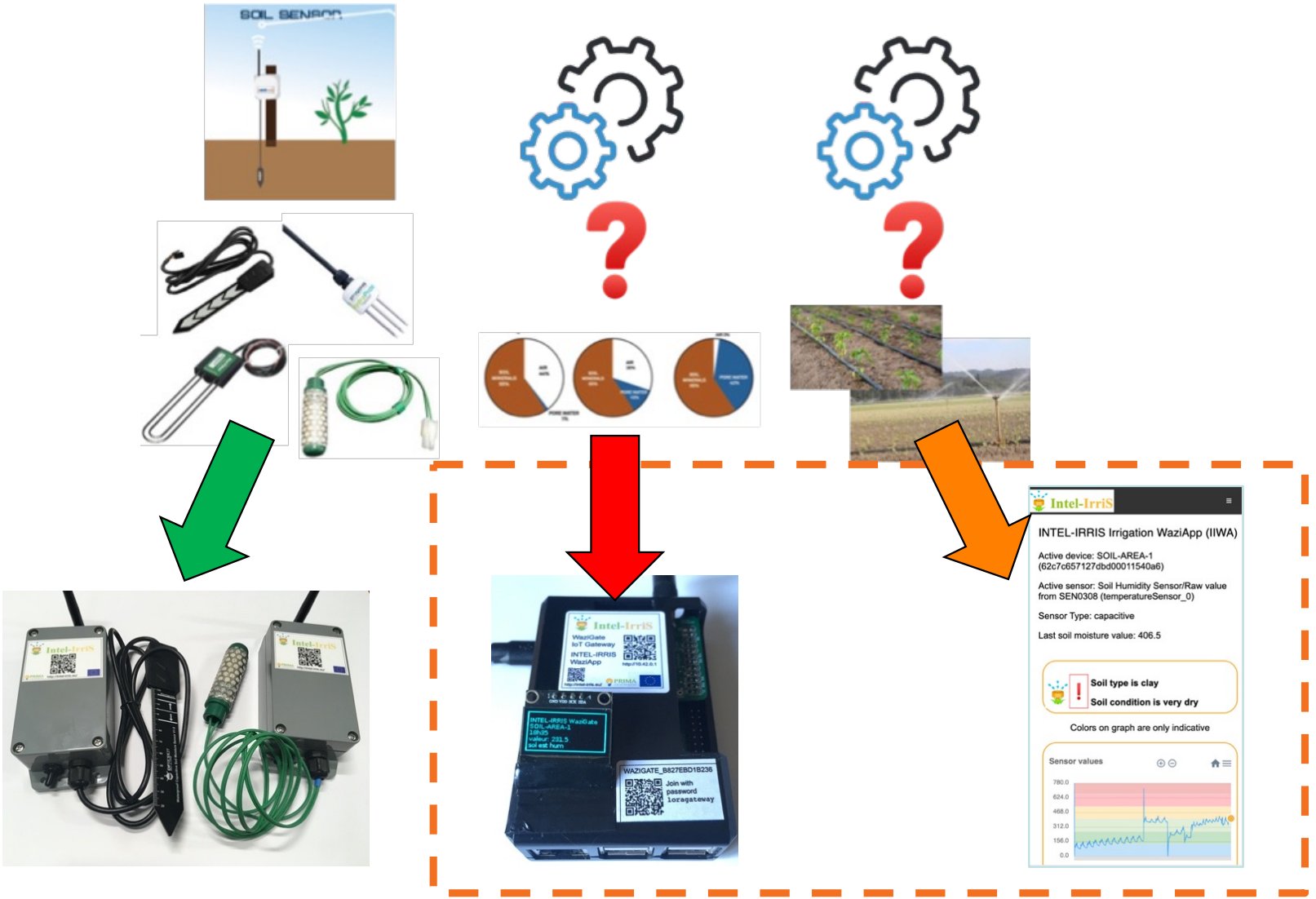
Low-cost soil moisture device

SEN0308
capacitive sensor

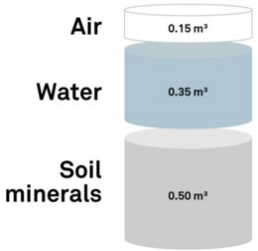
Watermark WM200
Water tension sensor

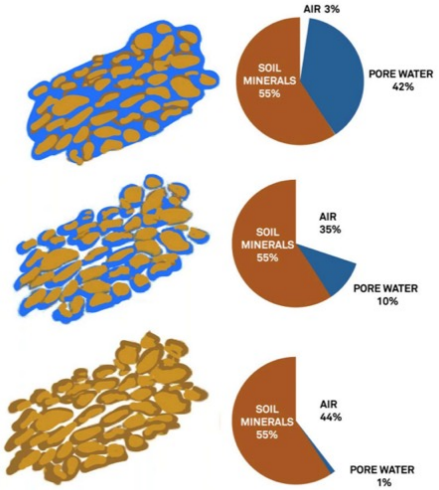
A soil temperature sensor can be added

INTEL-IRRIS intelligence part



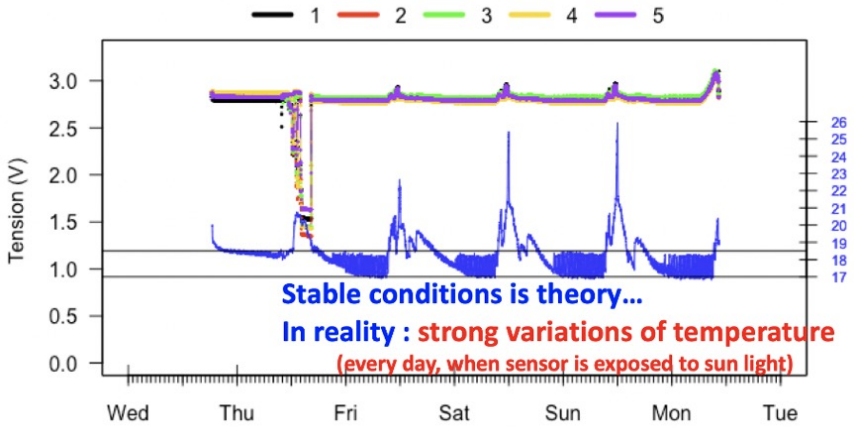
Capacitive sensor





From METER group

- Capacitive soil moisture sensors usually measure volumetric water content
- Soil density & soil texture are important parameters

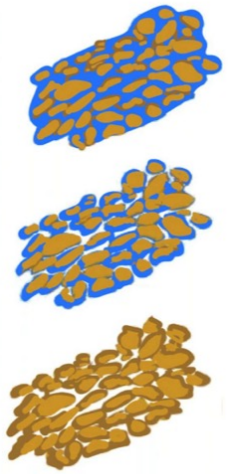


Impact of temperature ?

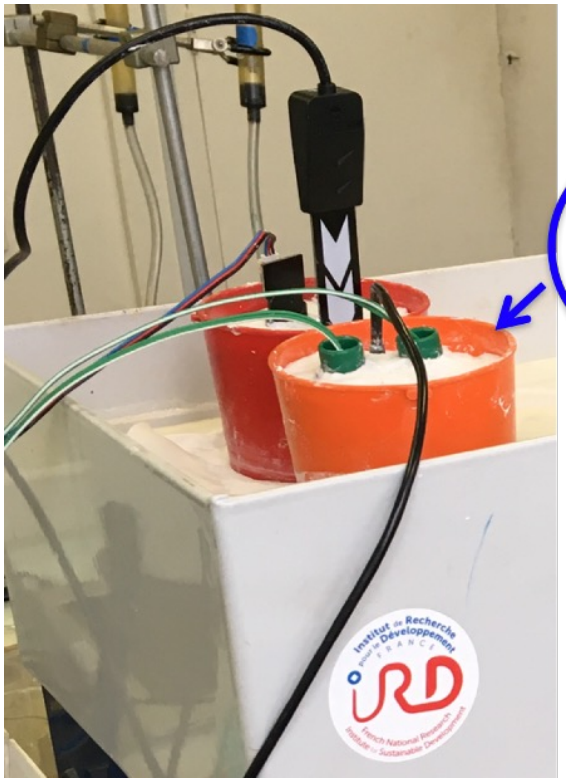
IRD in conducting extentise test on the accucary and the stability of the low-cost SEN0308 capacitive sensor

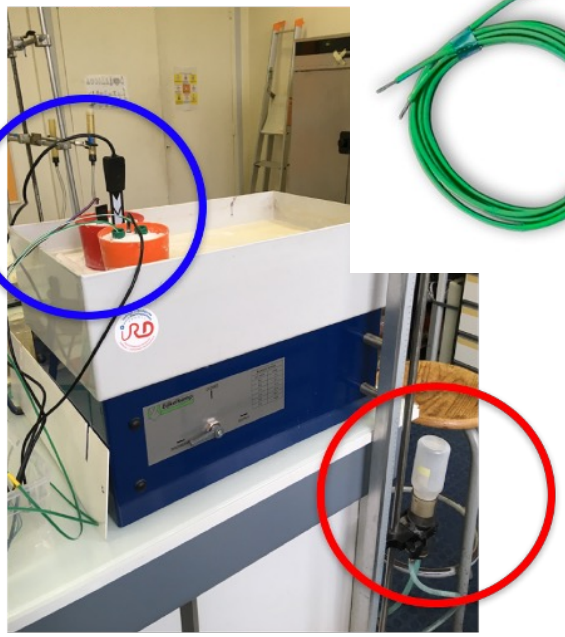
Water tension sensor

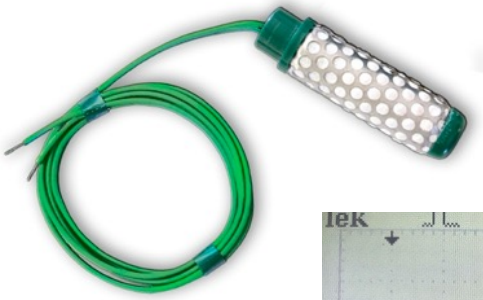
- Water tension sensor measures the amount of force required to extract water from soil's pores

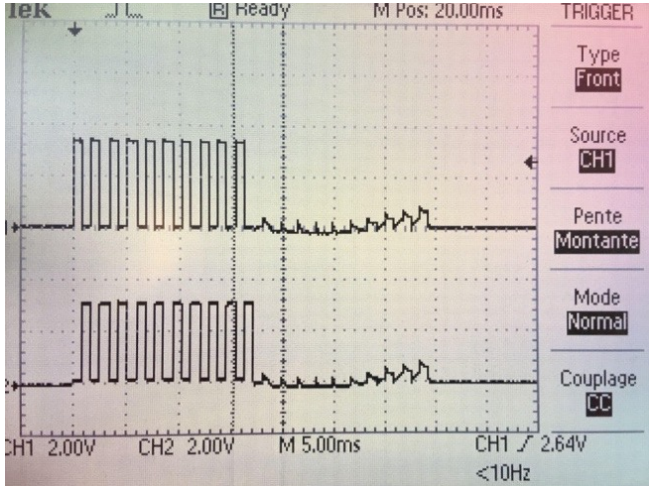


From METER group





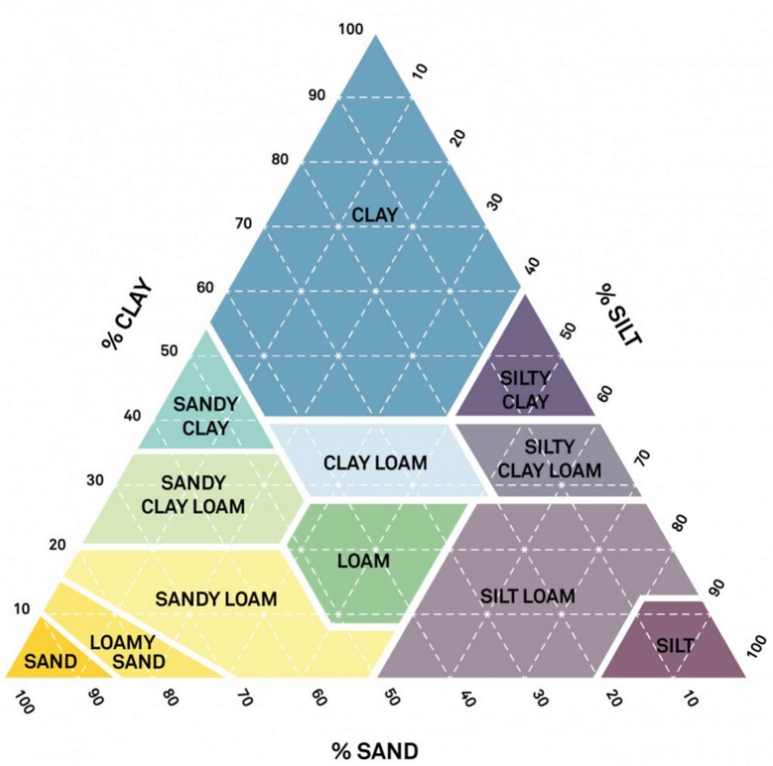


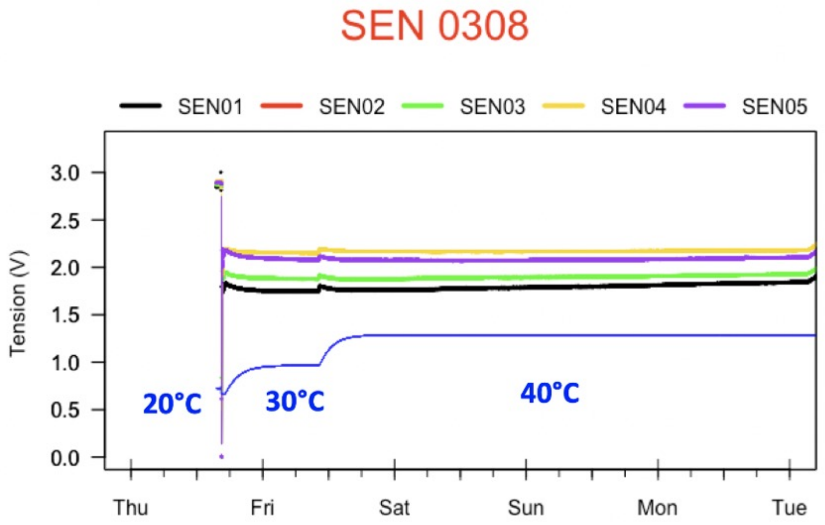


IRD in conducting extensive tests on the stability & suitability of microcontroller-based usage of the Watermark water tension sensor

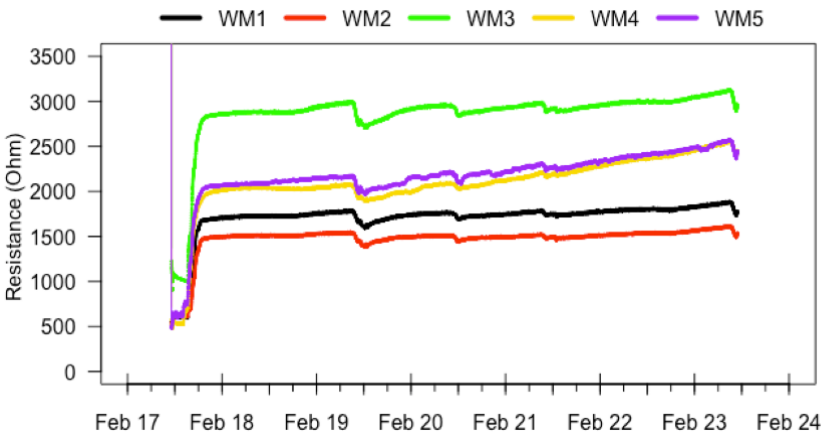
Calibration

- Soil-specific calibration
- Impact of external "noise"



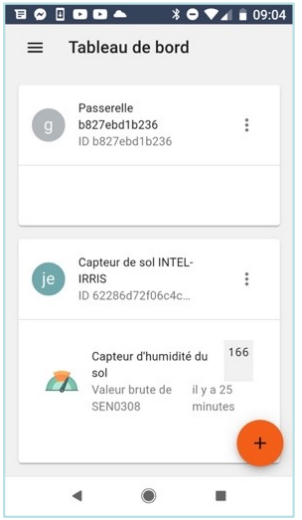


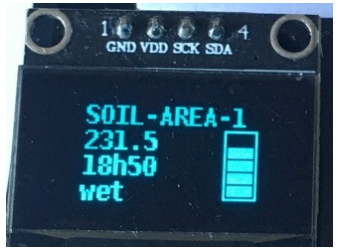
Ambient air emperature has low impact, except...

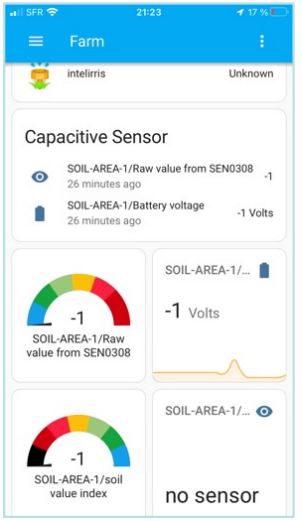


Adapt the solution to end-user

- "Intelligent Irrigation in-the-box"
- User interface is critical for smallholders
- Visual components for summarizing important parameters
- Translation when possible







Conclusions

- Internet-of-Things provides the unique feature to make things "talk" to us: localisation, surrounding environmental conditions, particular events, …
- Next gen sensors such as cameras,
  spectrometers, hyperspectral cameras,…
  will provide possibilities to further optimize a number of complex processes

Now what?

IOT_2: Unleash the power of IoT data !

So, IoT: Technology or Concept?

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http://www.univ-pau.fr/~cpham

IOT_2: Unleash the power of IoT data

protocols, analysis, artificial intelligence, machine learning,...

OneTech Booster

Capsule Booster – 2022

Prof. Congduc Pham

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UNIVERSITÉ DE PAU ET DES PAYS DE L'ADOUR — LIUPPA

European Commission | Horizon 2020 European Union funding for Research & Innovation

WAZIUP

IoT – from idea to reality

WAZIHUB

HUBiquitous

Paving for the next 10 years of innovation in IoT and AI

PRIMA PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

Intel-IrriS

RESILINK

Advanced and disruptive IoT/AI technologies targeting the smallholder community for increased resilience