

IoT: Understanding the technologies and challenges of the Internet of Things

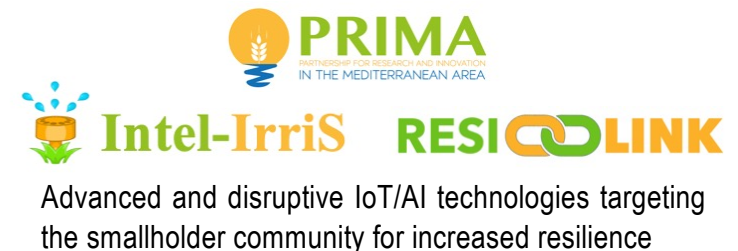


Capsule Booster – 2022

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



Horizon 2020
European Union funding
for Research & Innovation



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

Googling for « Internet of Things »

The image shows a Google search interface for the query "internet of things". At the top, the Google logo and search bar are visible. Below the search bar, there are several filters for refining the search, including "architecture", "infrastructure", "plateforme", "agriculture", "schéma", "capteur", "application", "transport", "objets connectés", "chaîne de valeur", "big data", "gateway", "domaine", "fonctionnement", and "IoT".

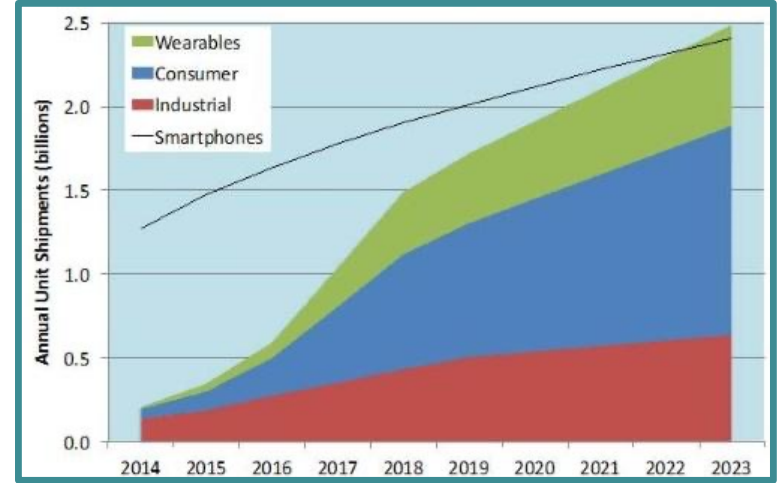
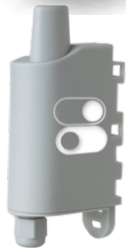
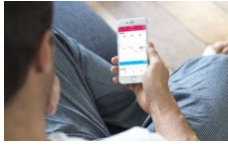
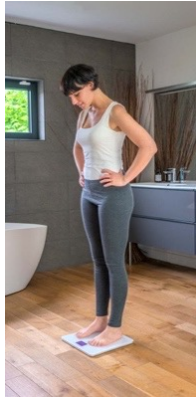
The main search results area displays a grid of image thumbnails, each with a small caption and URL. The thumbnails include various representations of IoT concepts, such as network diagrams, smart city scenes, and abstract digital art. Some thumbnails are more detailed, showing specific IoT applications or data visualizations.

On the right side of the search results, there is a "Recherches associées" (Related searches) section. It lists several related terms: "internet des objets", "iot logo", and "iot png".

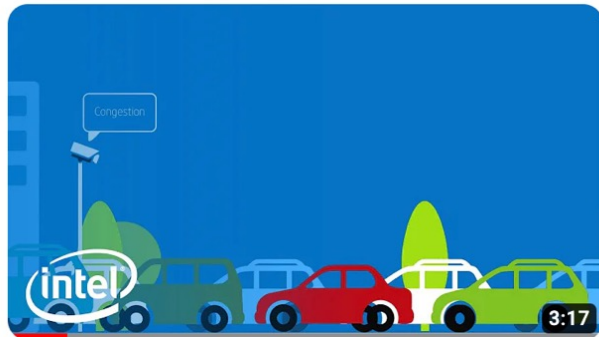
At the bottom of the page, there is a row of additional image thumbnails, each with a small caption and URL, continuing the visual exploration of IoT concepts.

...shows communicating objects

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http://



Also on YouTube: IoT teaser & tutorial videos



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

591 k vues • il y a 8 ans



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



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



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

Sous-titres

All communicating objects?



IoT=interactions with physical world

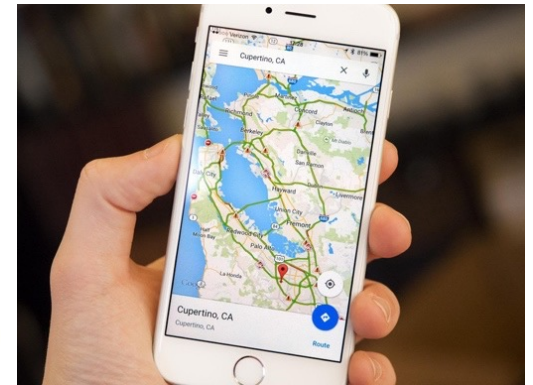
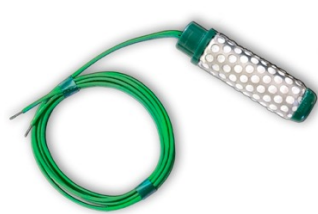


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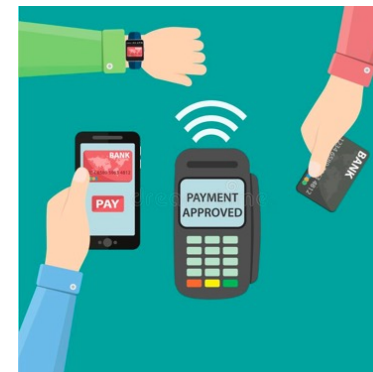
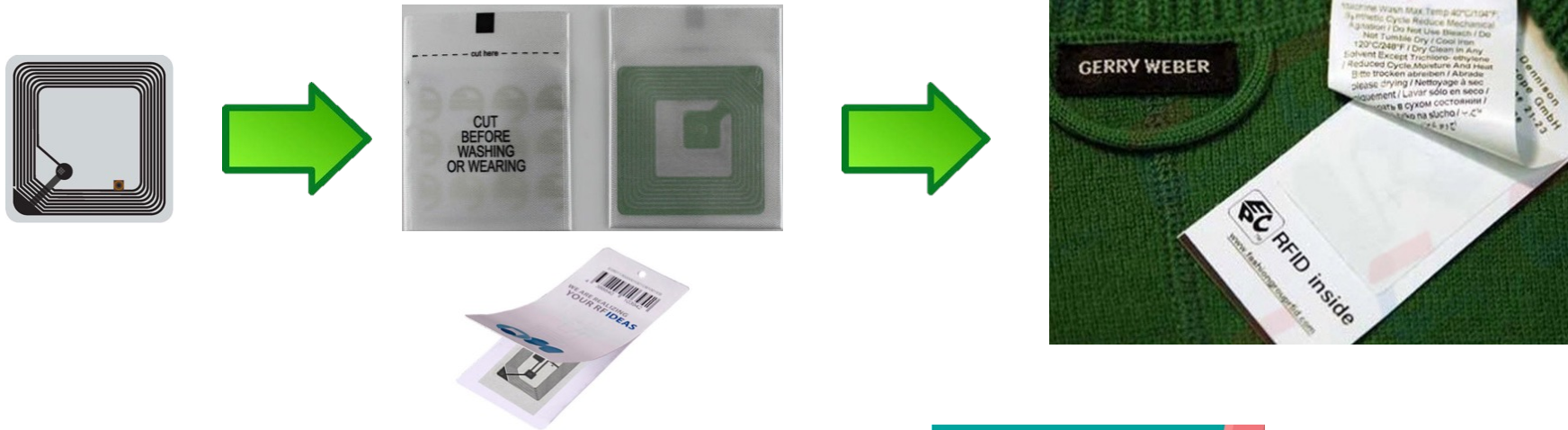
Q: Interactions? How?

Interaction: Sensors



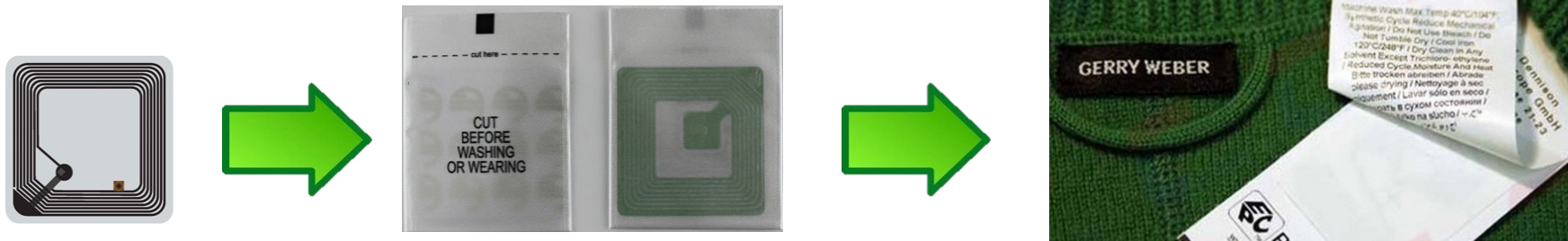
Interaction: RFID, NFC

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

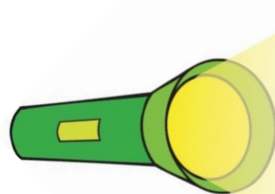


Interaction: RFID, NFC

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



Q: How RFID works without batteries?



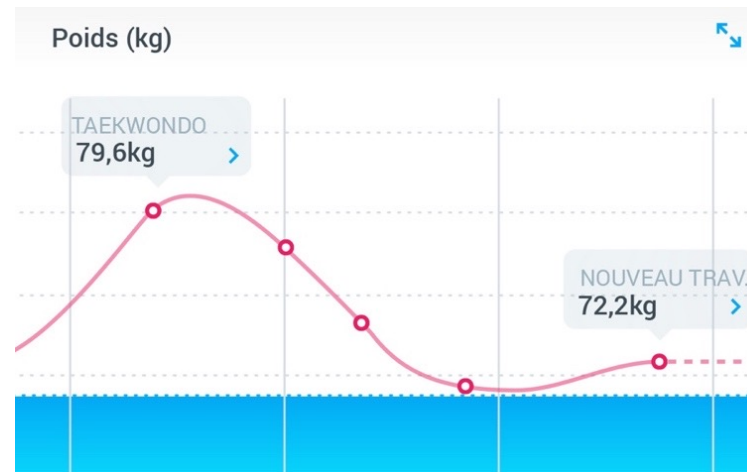
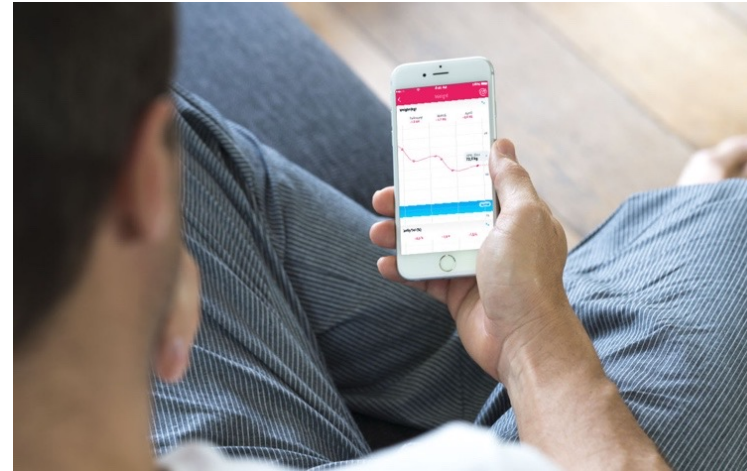
Interaction: always complex?



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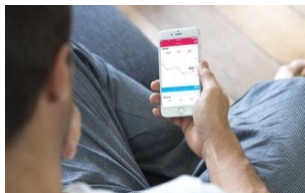


Home/consumer IoT products



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

Local interaction is possible...



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

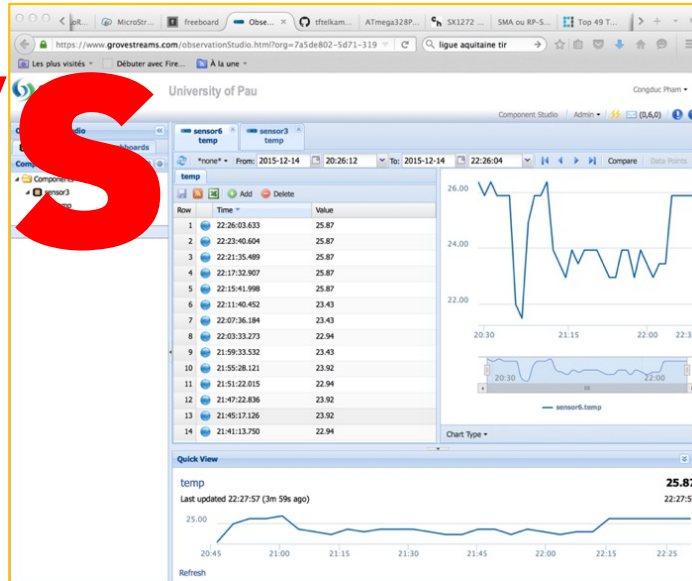
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Clouds for IoT

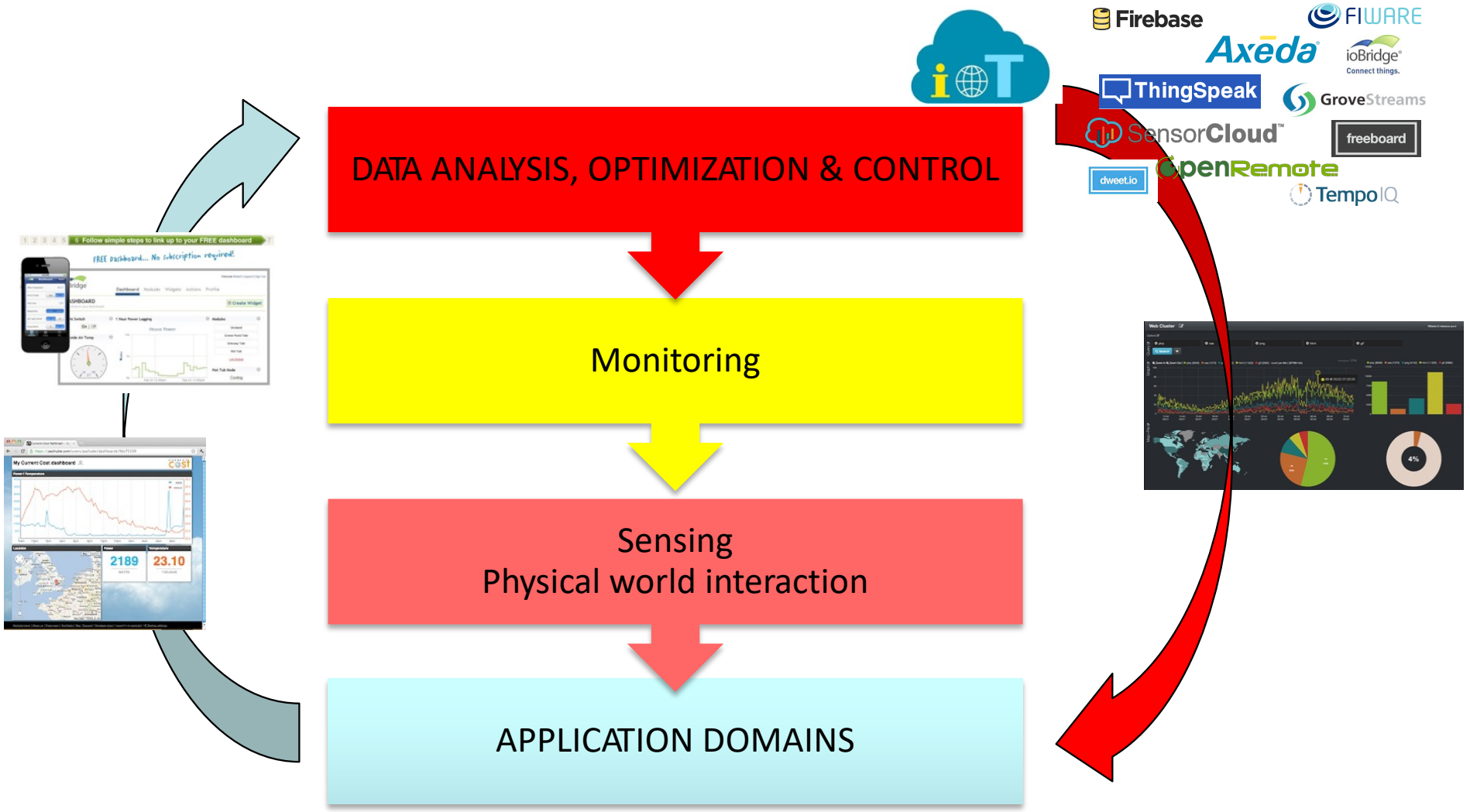


VS



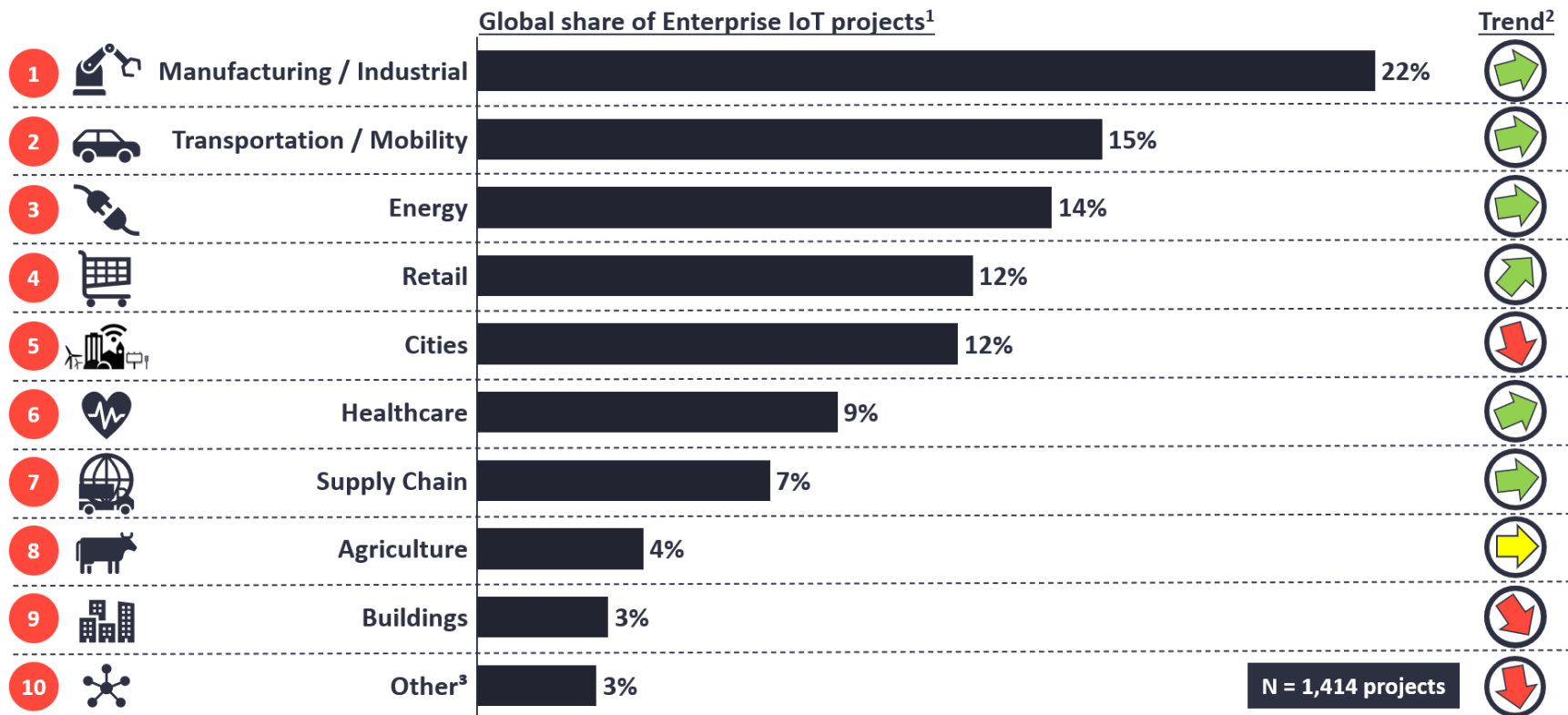
Sense, Monitor, Optimize & Control

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Top IoT applications, 2020

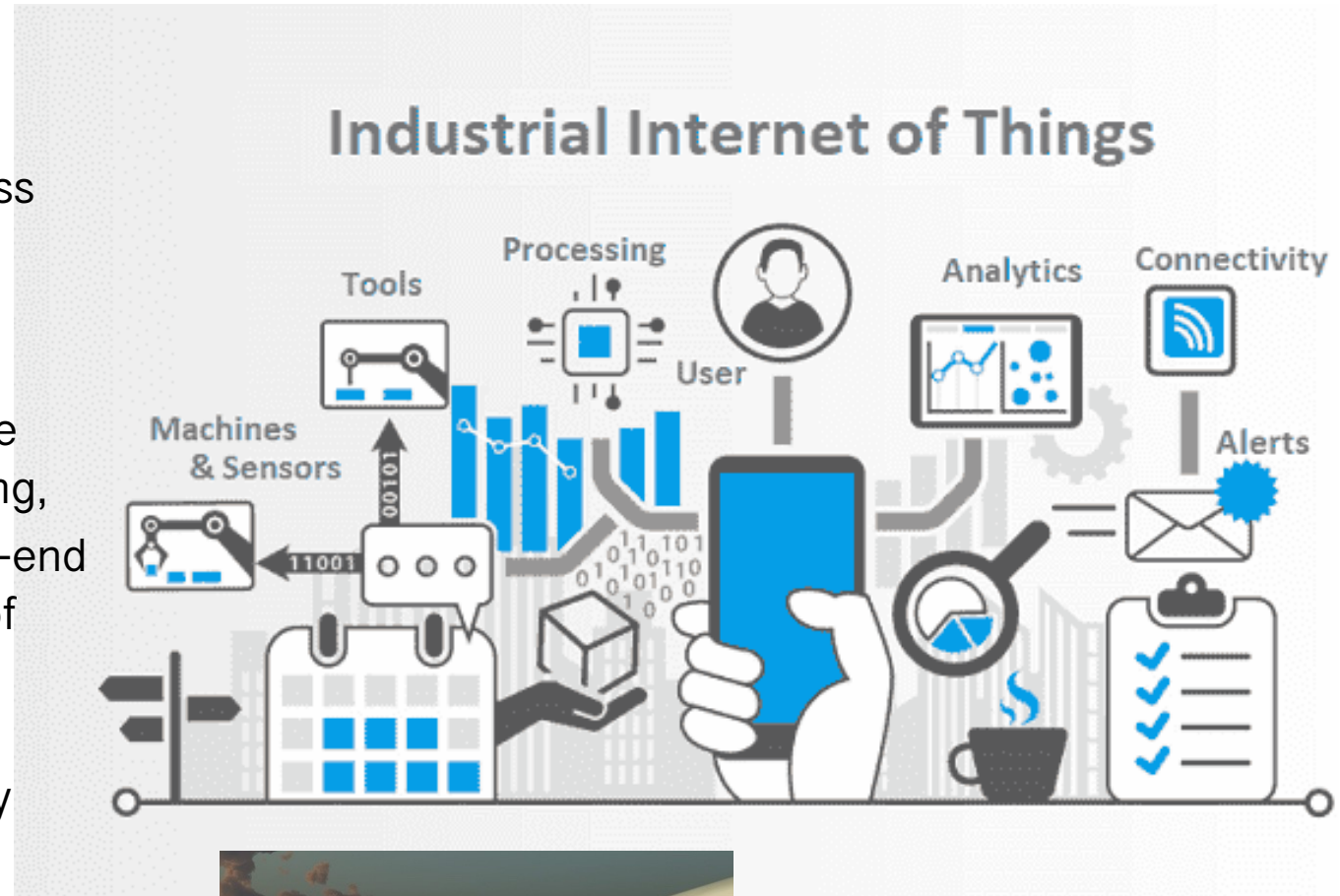
Top 10 IoT Application areas 2020



Note: 1. Based on 1,414 publically known IoT projects (not including consumer IoT projects eg smart home, wearables, etc.) 2. Trend based on relative comparison with % of projects in the 2018 IoT Analytics IoT project list e.g., a downward arrow means the relative share of all projects has declined, not the overall number of projects. 3. Other includes IoT projects from Enterprise & Finance sectors. **Source:** IoT Analytics Research - July 2020

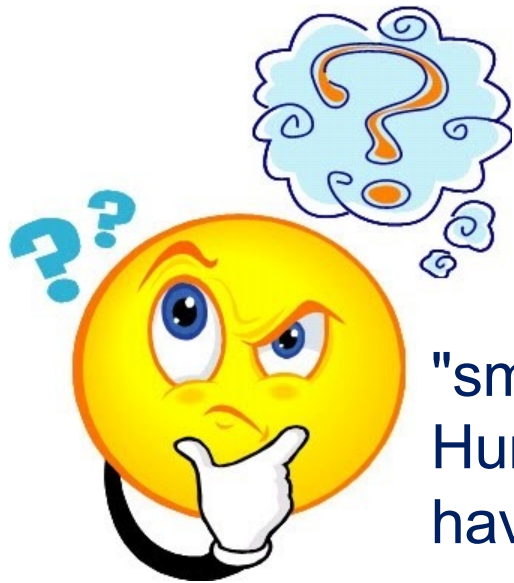
IoT in industry

- 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
- Infrastructure monitoring, Security & Safety



What is a good IoT solution?

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

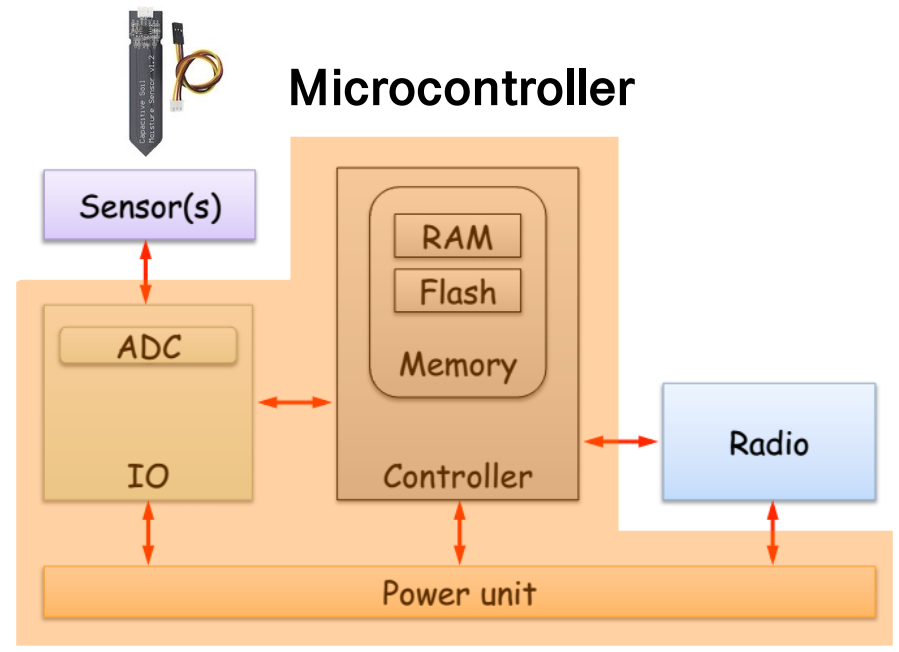
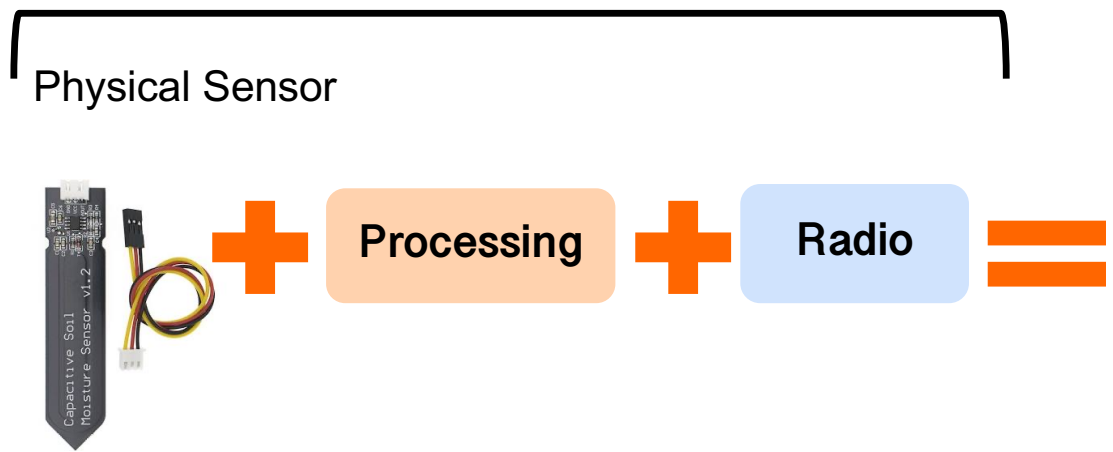


Typical IoT device

- IoT device can be viewed as a simple Embedded System



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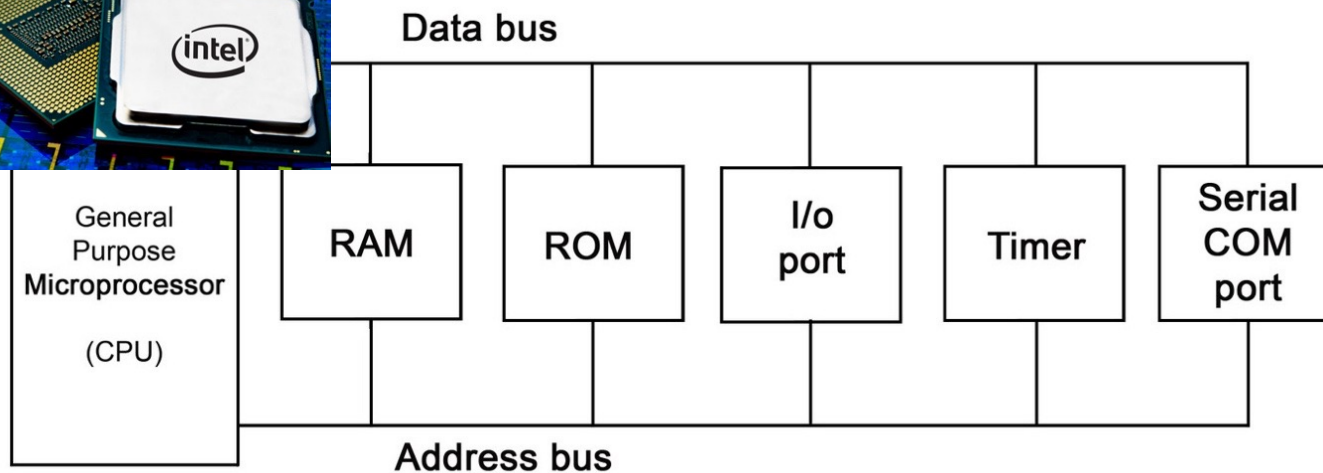
Q: uprocessor vs ucontroller?

Microprocessors & Microcontrollers

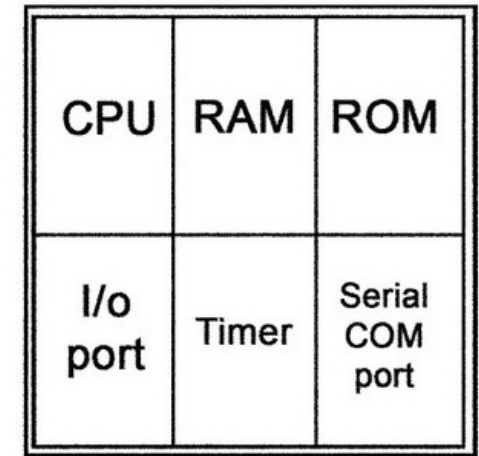
- A microprocessor unit (MPU) is a processor on one silicon chip
- A microcontroller unit (MCU) is a microprocessor with some added circuitry on one silicon chip
- Microcontrollers are used in embedded computing and **most IoT devices are based on microcontrollers**



Pham
tr/~cpham



VS



(Single chip)

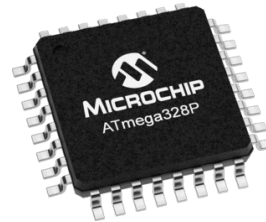
From "An Embedded System Overview" by Dr. Eng. Amr T. Abdel-Hamid

From μ controller to μ controller board

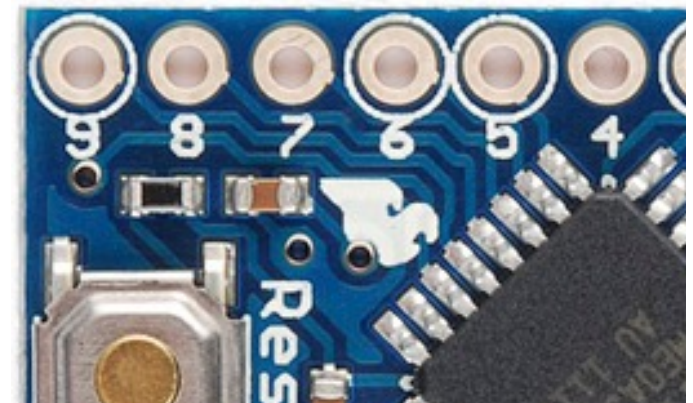
- ⦿ A μ controller can be standalone...

CPU	RAM	ROM
I/o port	Timer	Serial COM port

(Single chip)

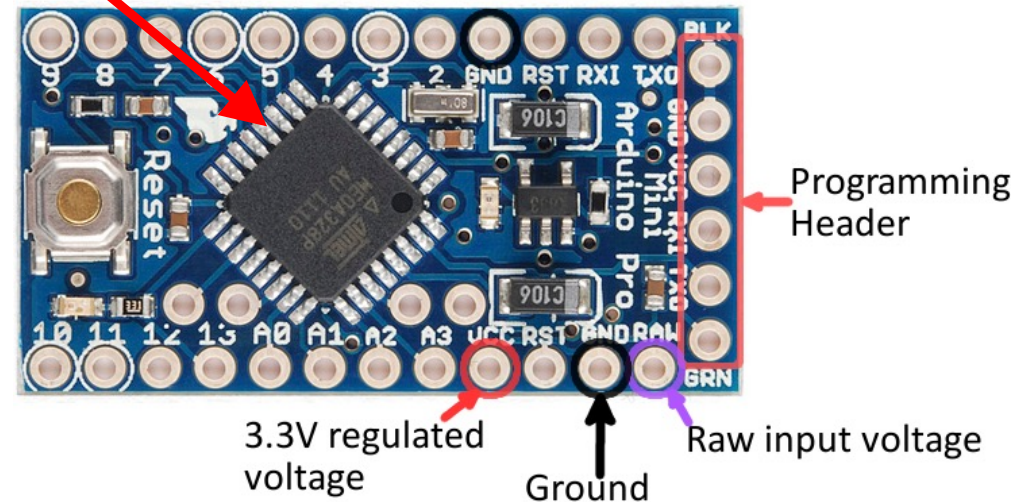


Many header pins are directly wire to microcontroller pins



- ⦿ But, it is usually mounted on a board with additional electronics parts

- ⦿ Leds, Voltage regulators
- ⦿ Easy access to pins
- ⦿ Reset button
- ⦿ Serial-USB interface



Arduino's success story starting in 2005



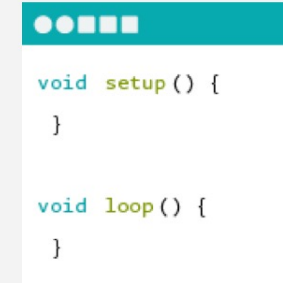
WHAT IS ARDUINO?

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



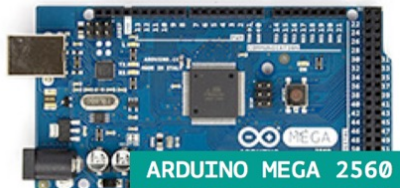
ARDUINO BOARD

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



ARDUINO SOFTWARE

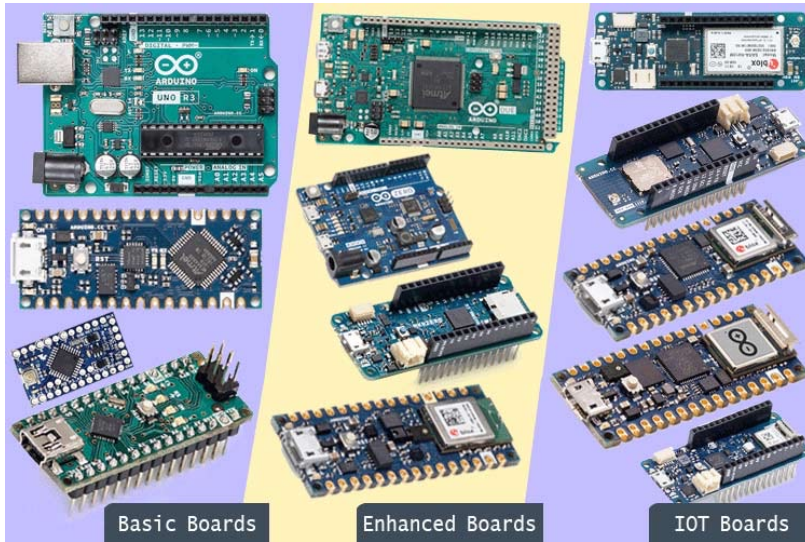
You can tell your Arduino what to do by writing code in the Arduino programming language and using the Arduino development environment.



17 years later: the incredibly large microcontroller board ecosystem!



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Basic Boards

Enhanced Boards

IOT Boards



LoPy

STM32 Nucleo-32



Teensy 3.2



LinkIt Smart7688 duo



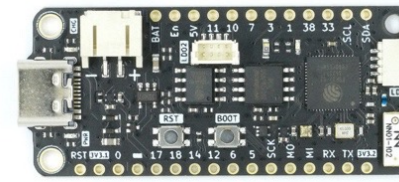
Adafruit Feather



uPesy ESP32



ePulse Feather Low Power ESP32



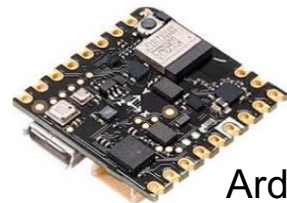
FeatherS3 - ESP32-S3



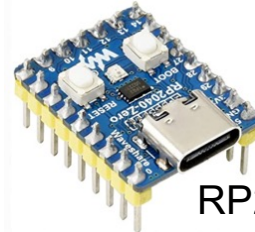
Heltec ESP32



XIAO SAMD21



Arduino Nicla Sense ME



RP2040 zero



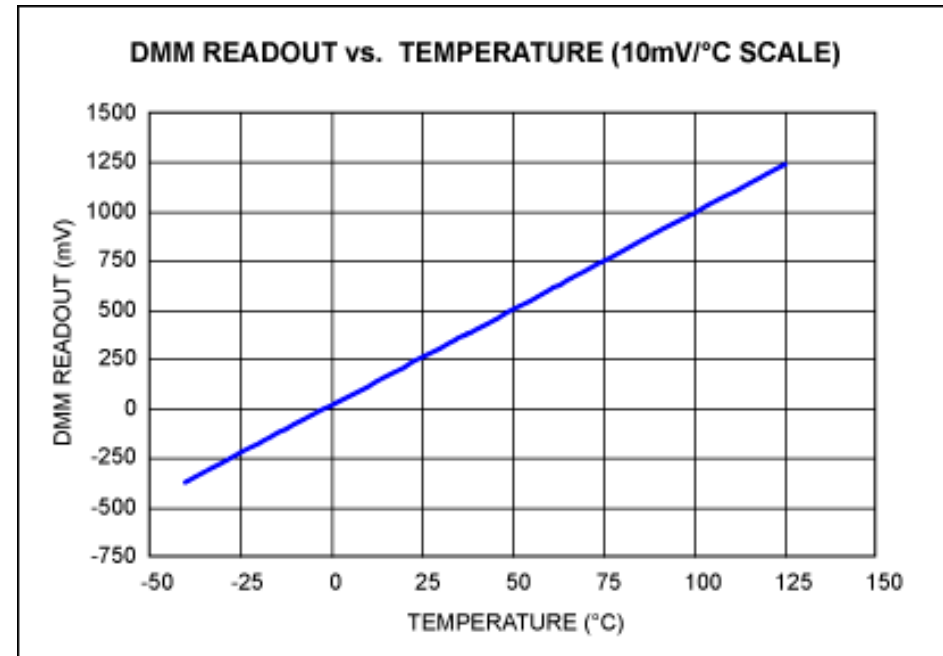
DFRobot Beetle



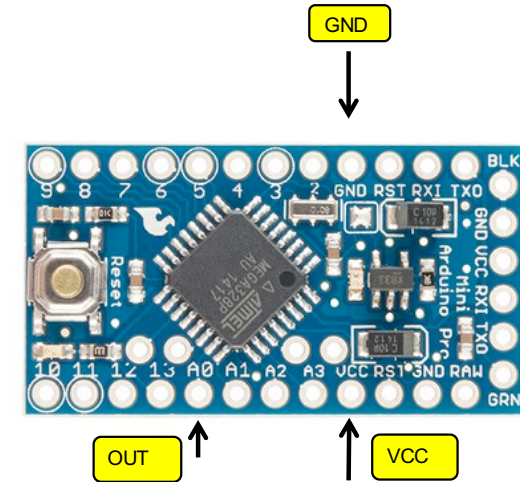
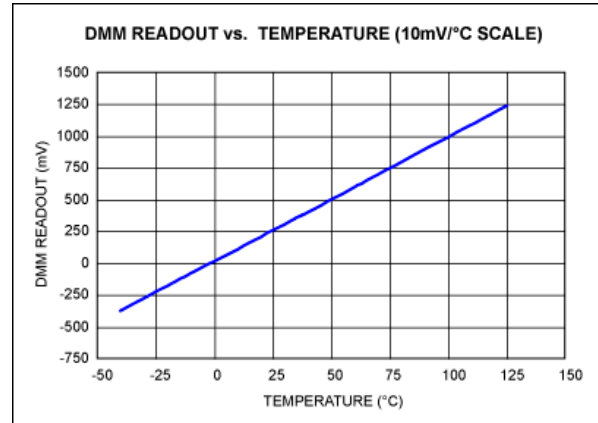
QT Py ESP32-C3

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,...



Digitalizing the physical world!



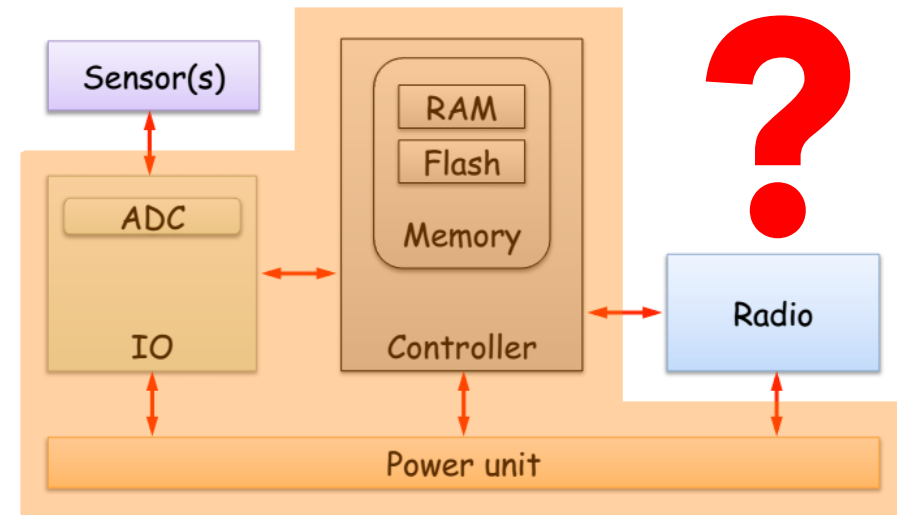
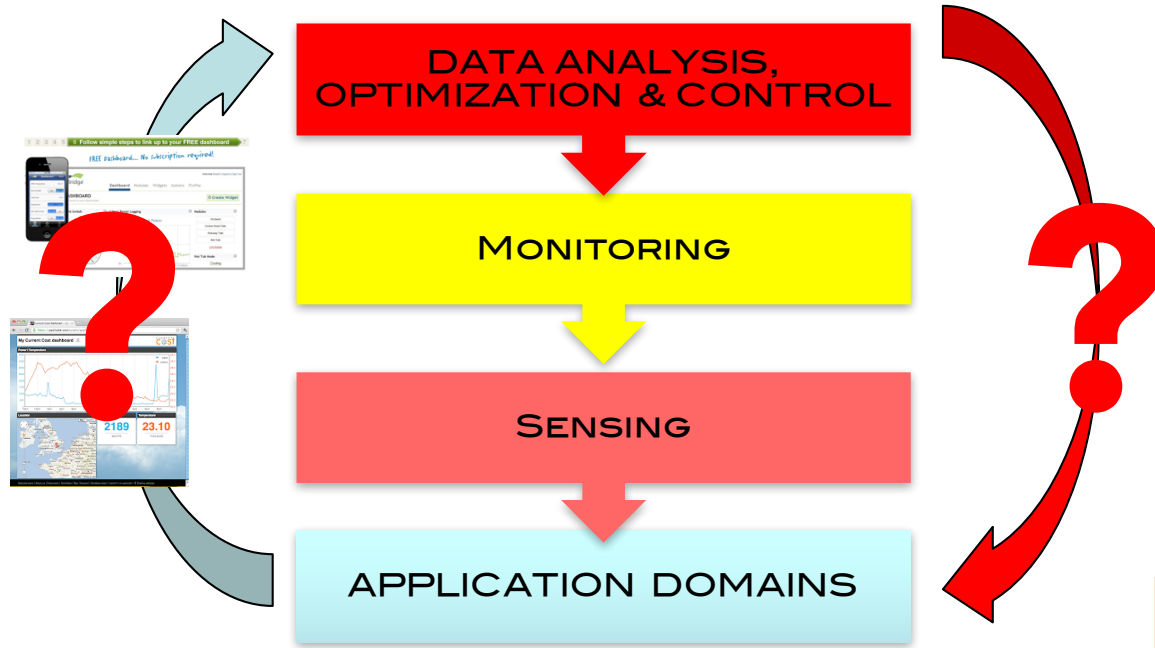
Microcontrollers have Analog/Digital (A/D) converter to map a voltage to a numerical value, in a linear way, For instance **0 for 0V** and **1023 for 3300mV**

3300mV/1024=3.22mV is the granularity of the measure

Reading a digital value of 100 means $100 \times 3.22\text{mV} = 322\text{mV}$

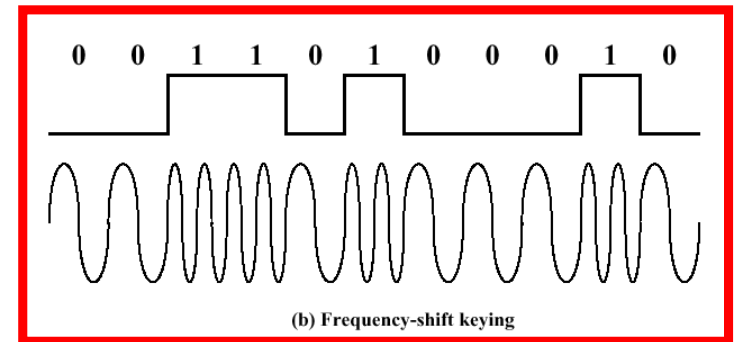
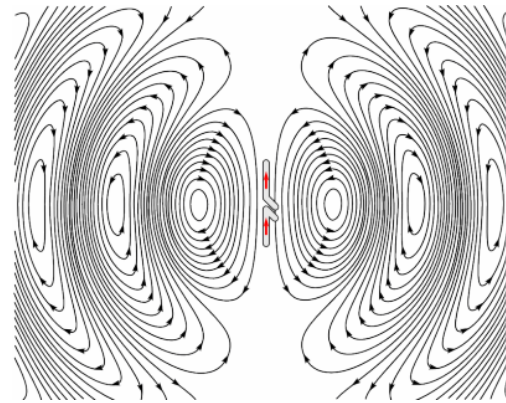
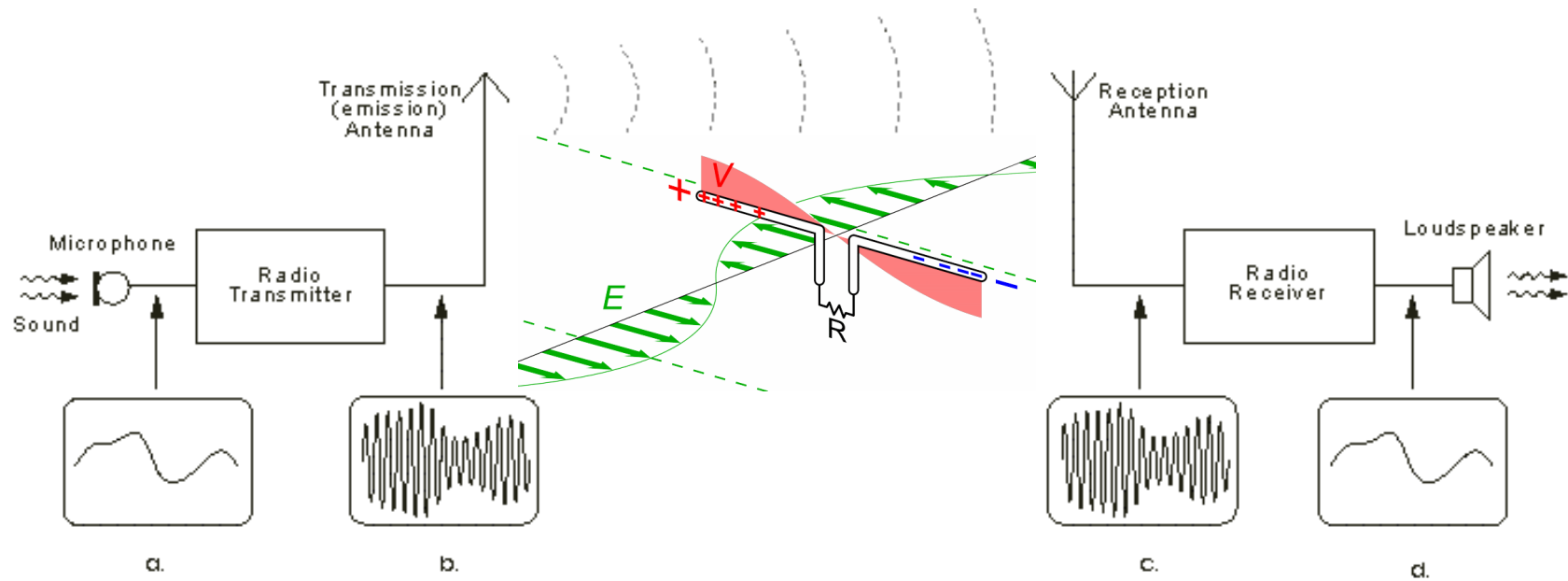
If the sensor output is 10mV/1°C then the physical temperature is $322\text{mV}/10\text{mV} = 32.2^\circ\text{C}$

How to collect data?



Microcontroller

Wireless (radio) transmission basics



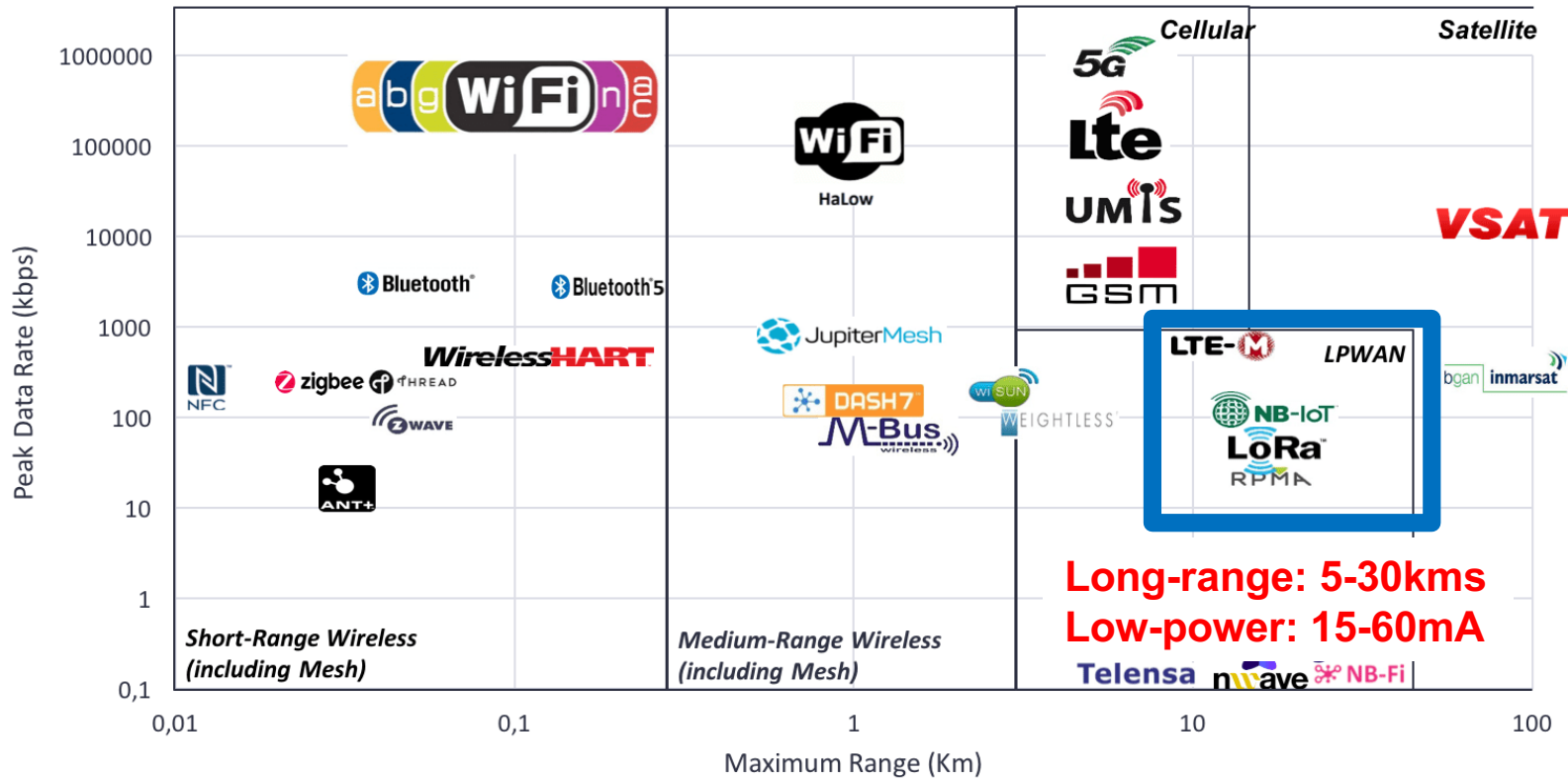
Q: Can we have Gbps in wireless? 30

Low-power & long-range radios

Comparison Wireless technologies

Peak Data Rate vs Maximum Range

Energy-Range dilemma



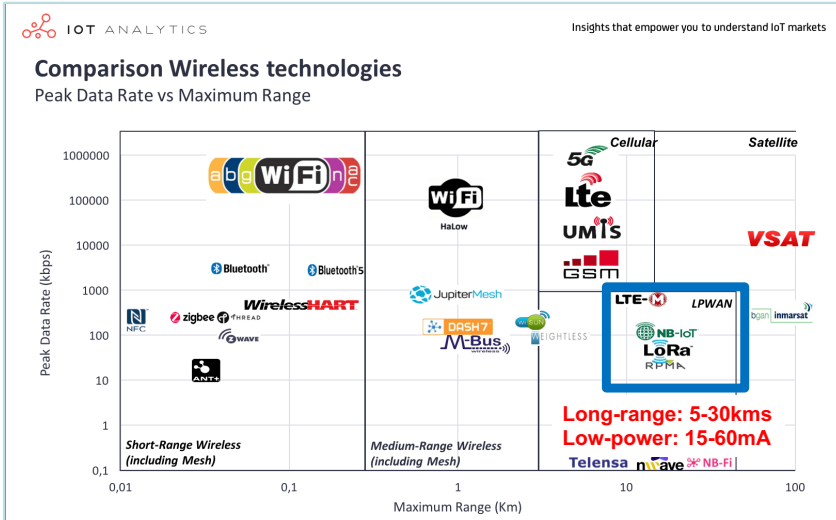
Long-range: 5-30kms
Low-power: 15-60mA

Very low throughput!

Energy



Energy consumption comparison



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

IC Pham



2500mA

TX power: 500mA. Mean consumption: $(8s \times 500 + 3592s \times 0.005) / 3600 = 1.11mA$

$2500 / 1.11 = 2252h = 93 \text{ days} = 3 \text{ months}$ 😞

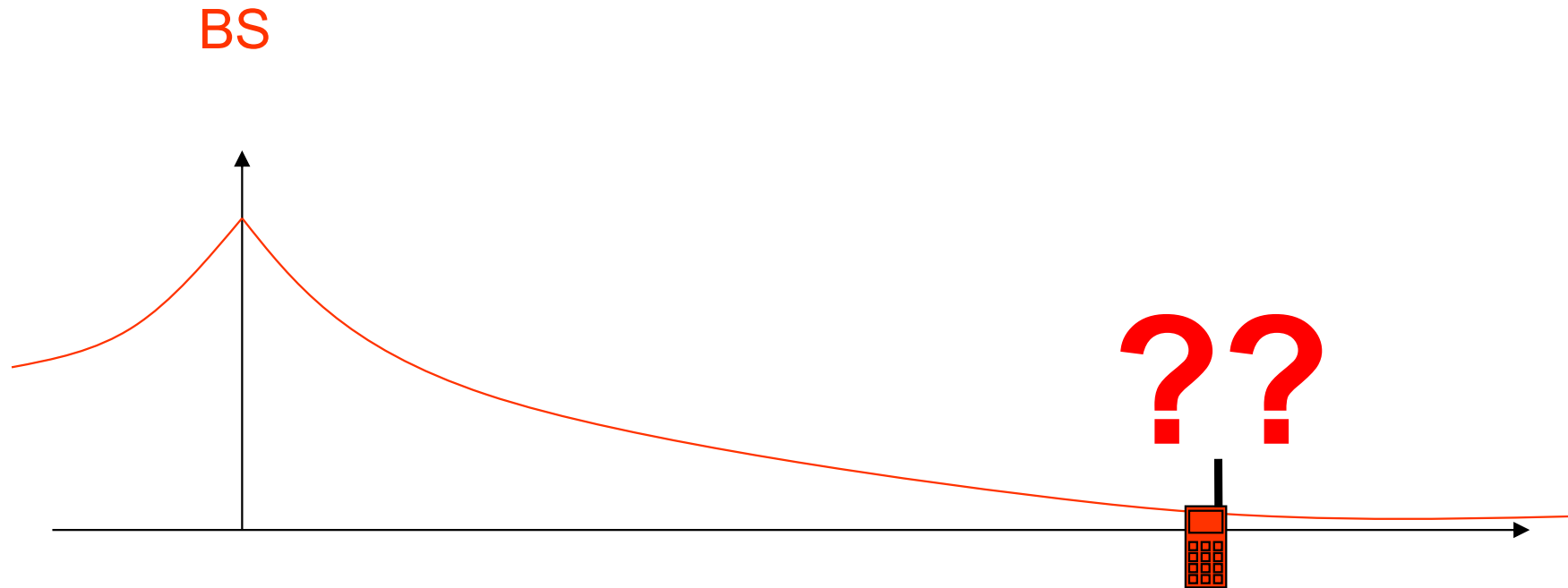
In most cellular networks, the device is still maintaining communication with BS even if it is inactive

TX power: 40mA. Mean consumption: $(2s \times 40 + 3598s \times 0.005) / 3600 = 0.027mA$

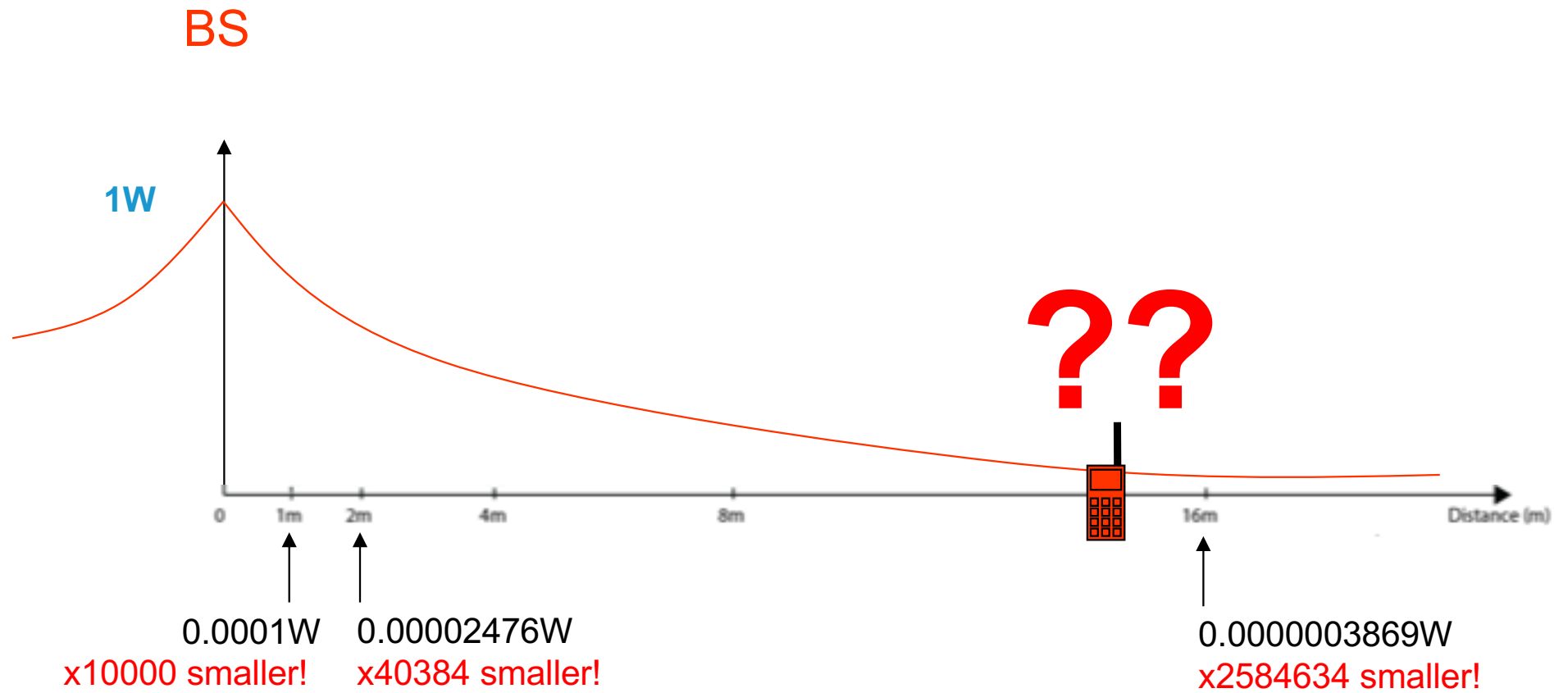
$2500 / 0.027 = 92592h = 3858 \text{ days} = 10 \text{ y.}$ 😊

LPWAN does not need to maintain connection if not in used

1st challenge: signal attenuation



Attenuation is very high!



Attenuation in a very simple formula!

- ⦿ For an ideal antenna (theoretic)

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

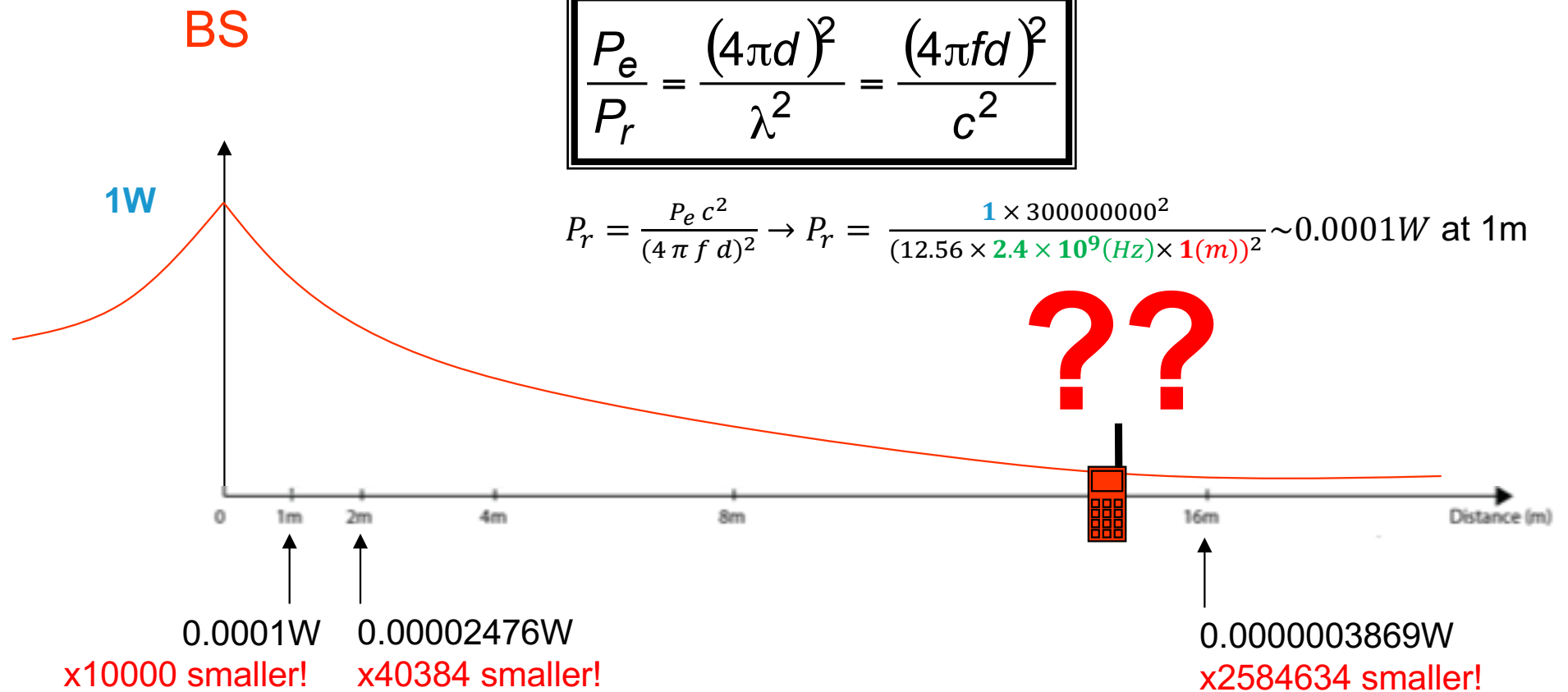
- P_e = transmitted power
- P_r = received power
- P_e / P_r is high when P_r is small → high attenuation
- d = distance between antennas
- c = light speed in space $3 \cdot 10^8$ m/s
- λ = wave length of the signal = c/f
- Higher frequencies f means higher attenuation!

Attenuation, values in watts

- Free Space Path Loss model

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

$$P_r = \frac{P_e c^2}{(4\pi f d)^2} \rightarrow P_r = \frac{1 \times 300000000^2}{(12.56 \times 2.4 \times 10^9 \text{ (Hz)} \times 1 \text{ (m)})^2} \sim 0.0001 \text{ W at } 1 \text{ m}$$



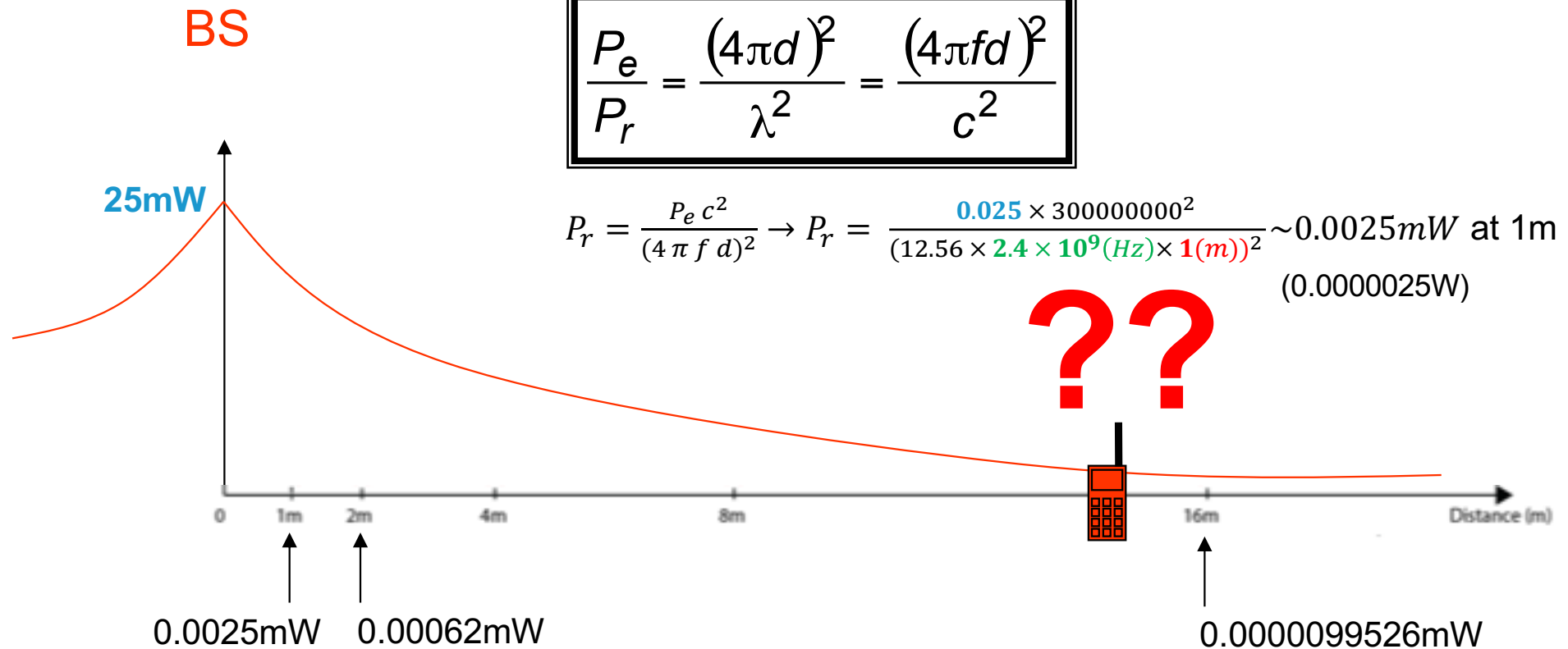
1W is a still lot, IoT uses milliwatts!

Free Space Path Loss model

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

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

(0.0000025W)

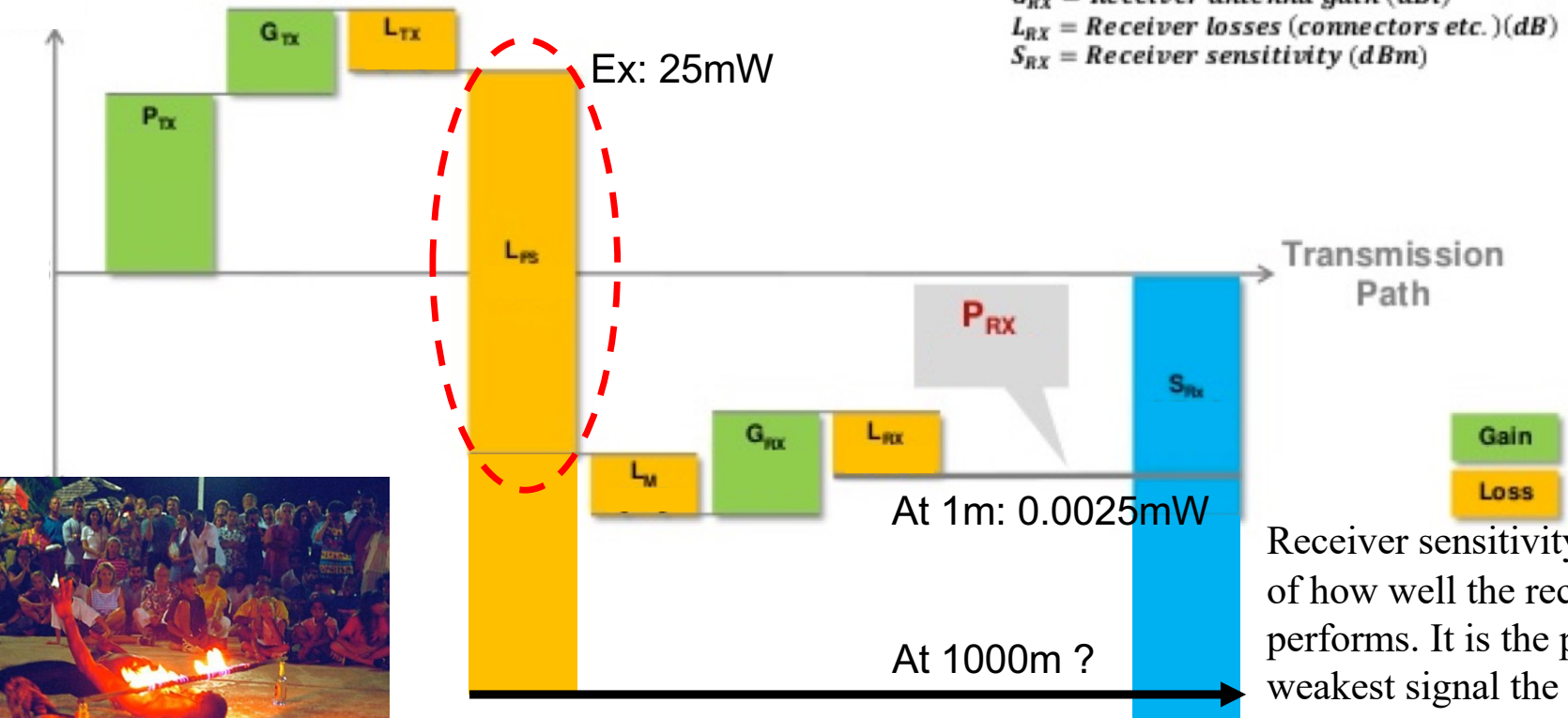


Link budget in wireless system – (simplified)

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

- 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

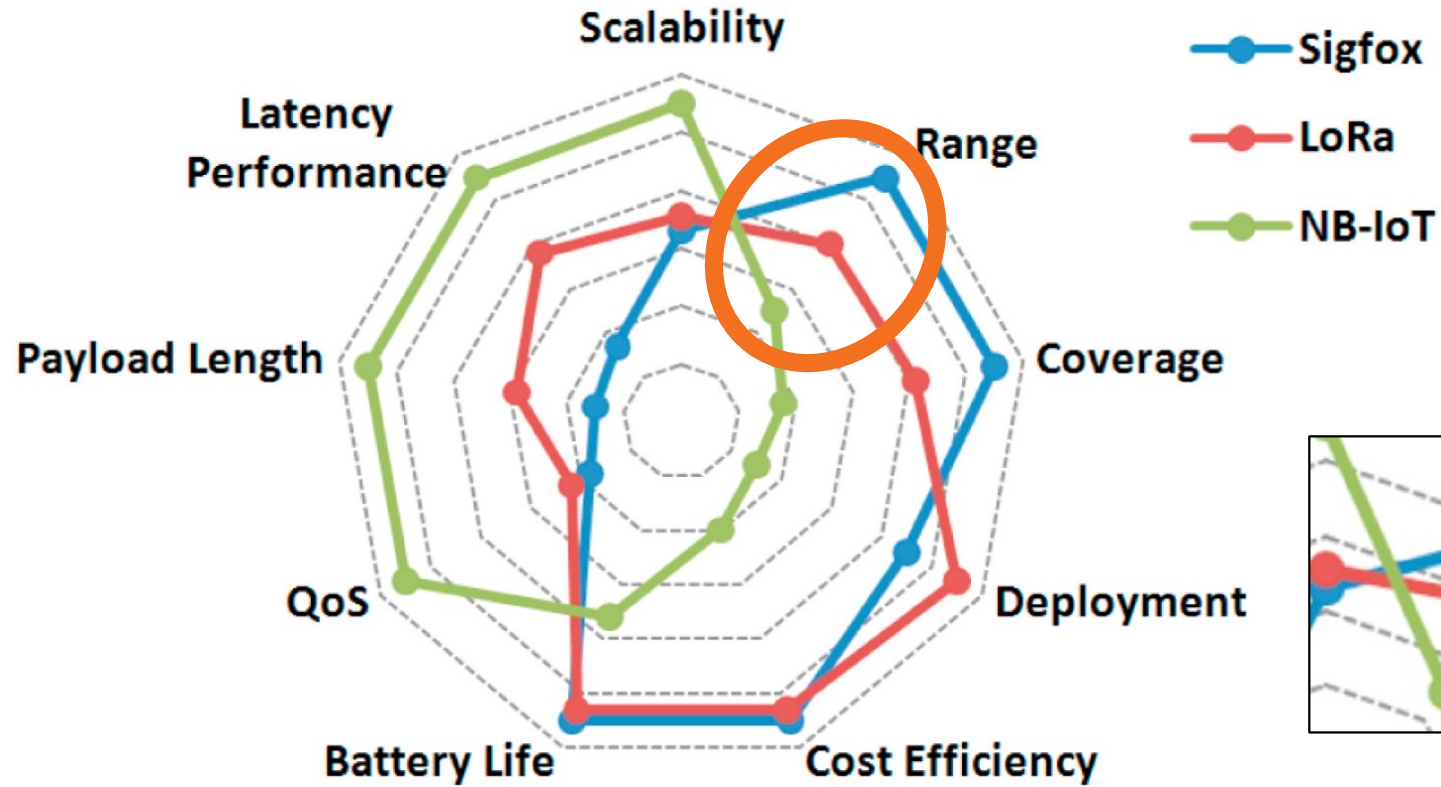


Receiver sensitivity is a measure of how well the receiver performs. It is the power of the weakest signal the receiver can detect

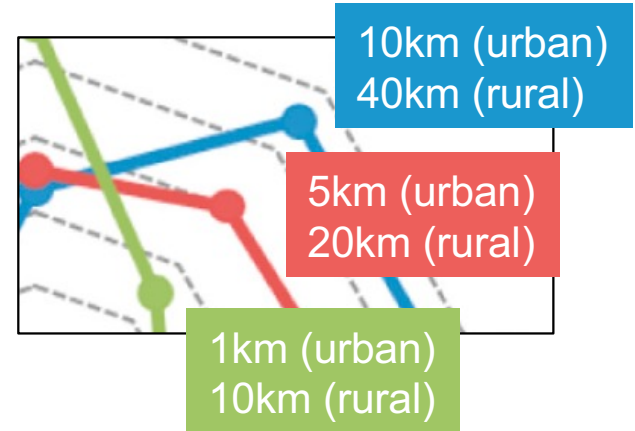
How low can you go?



LPWAN expected range?



Bluetooth: about 20m
 WiFi: about 300m-500m
 3G/4G: about 2km-4km



How can we increase range?

- ⦿ Increase TX power and/or improve RX sensitivity



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!)**

I'm not fluent in idiot
could you please speak



more slowly?

hello

hello

hello

How can we increase range?



I'm not fluent in idiot
could you please speak



more slowly?

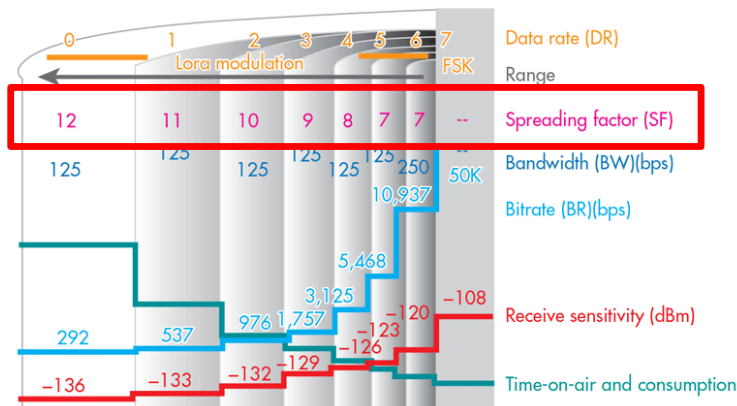
- ⦿ Increase TX power and/or improve RX sensitivity
- ⦿ Generally, RX sensitivity (~robustness) can be increased when transmitting (much) slower (like speaking slower!)



- ⦿ 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

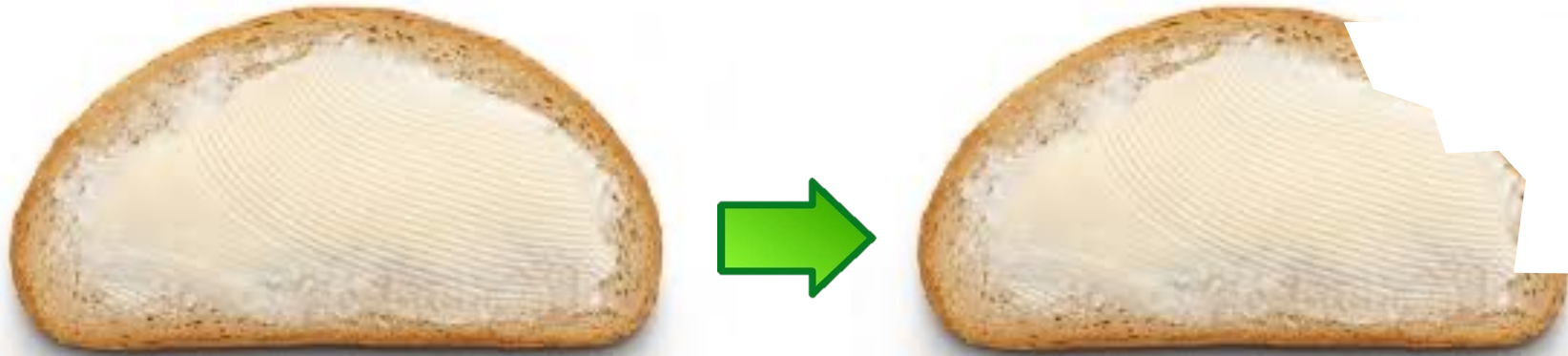
⦿ The price to pay for LPWAN

- ⦿ 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!

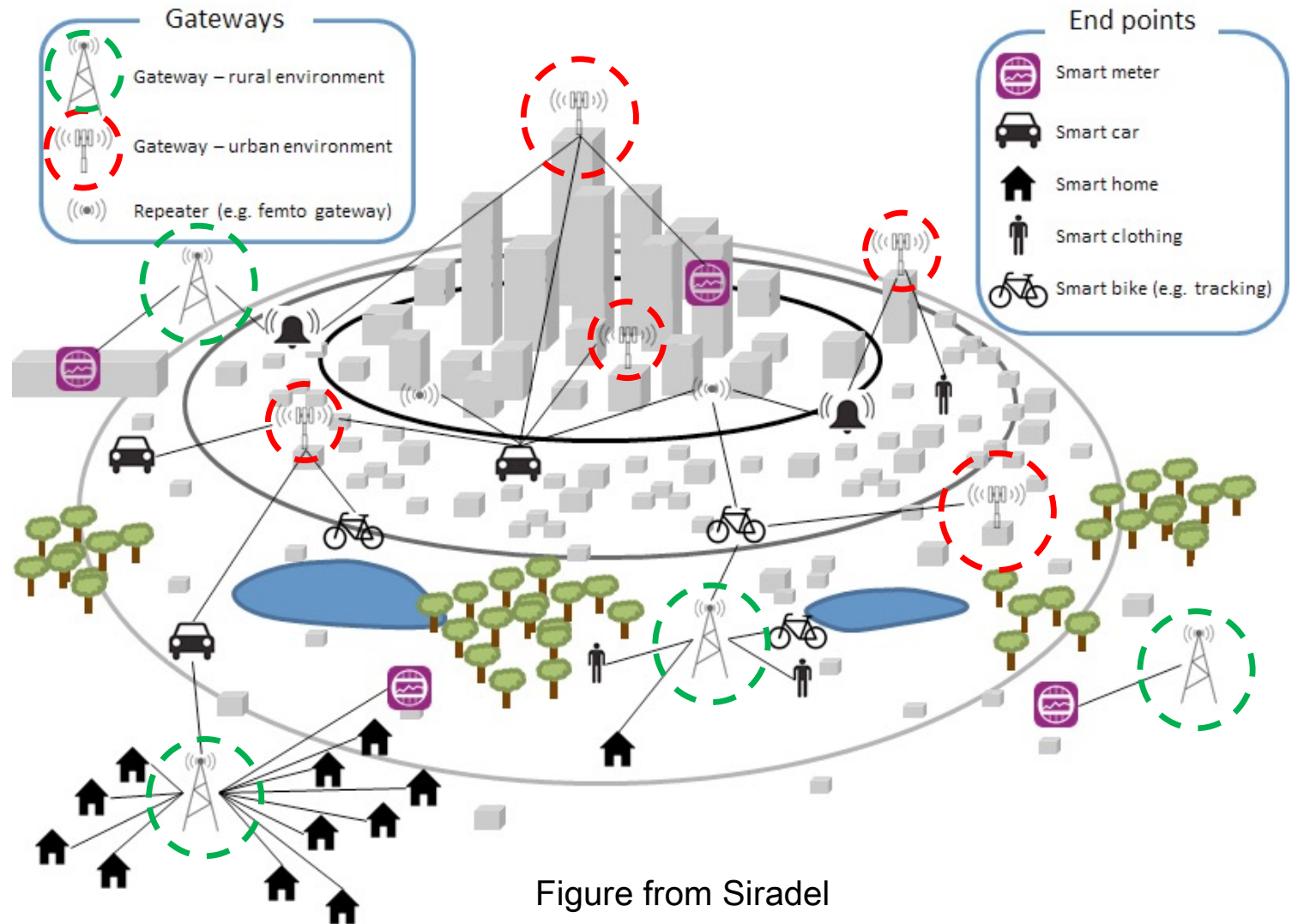
The buttered toast example



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

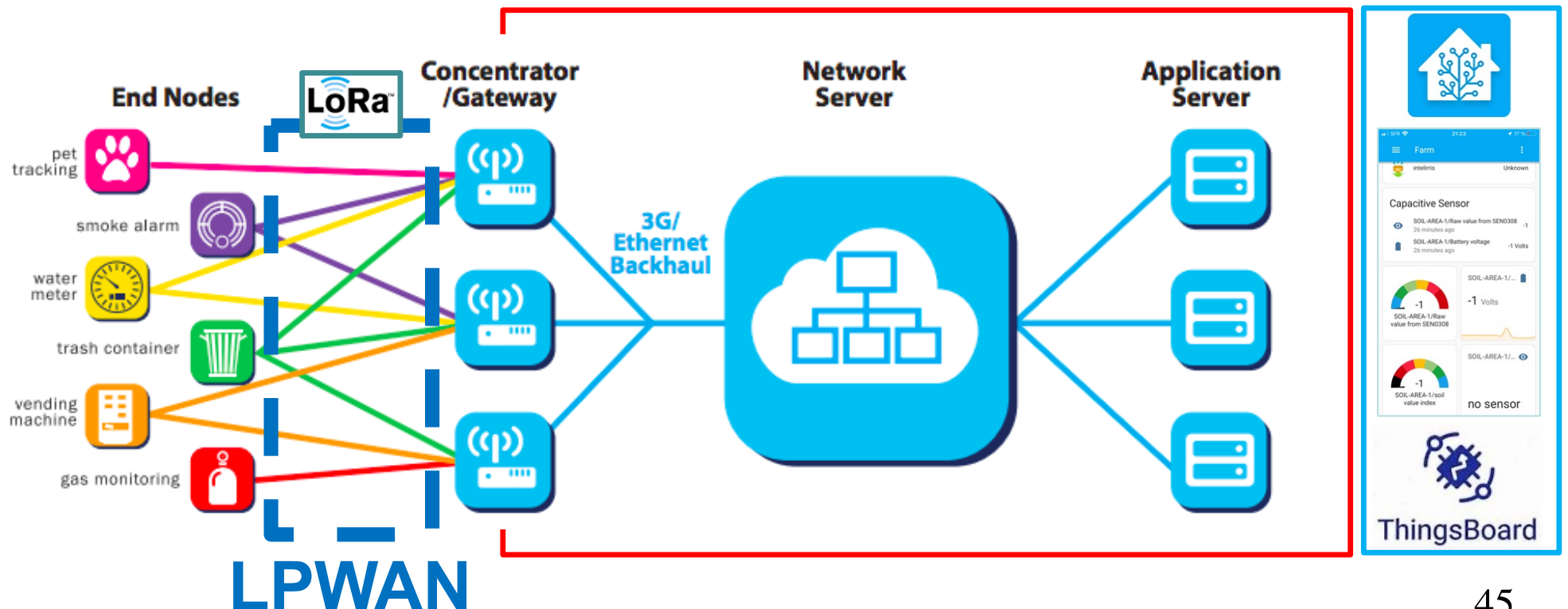
LPWAN=star topology, gateway centric

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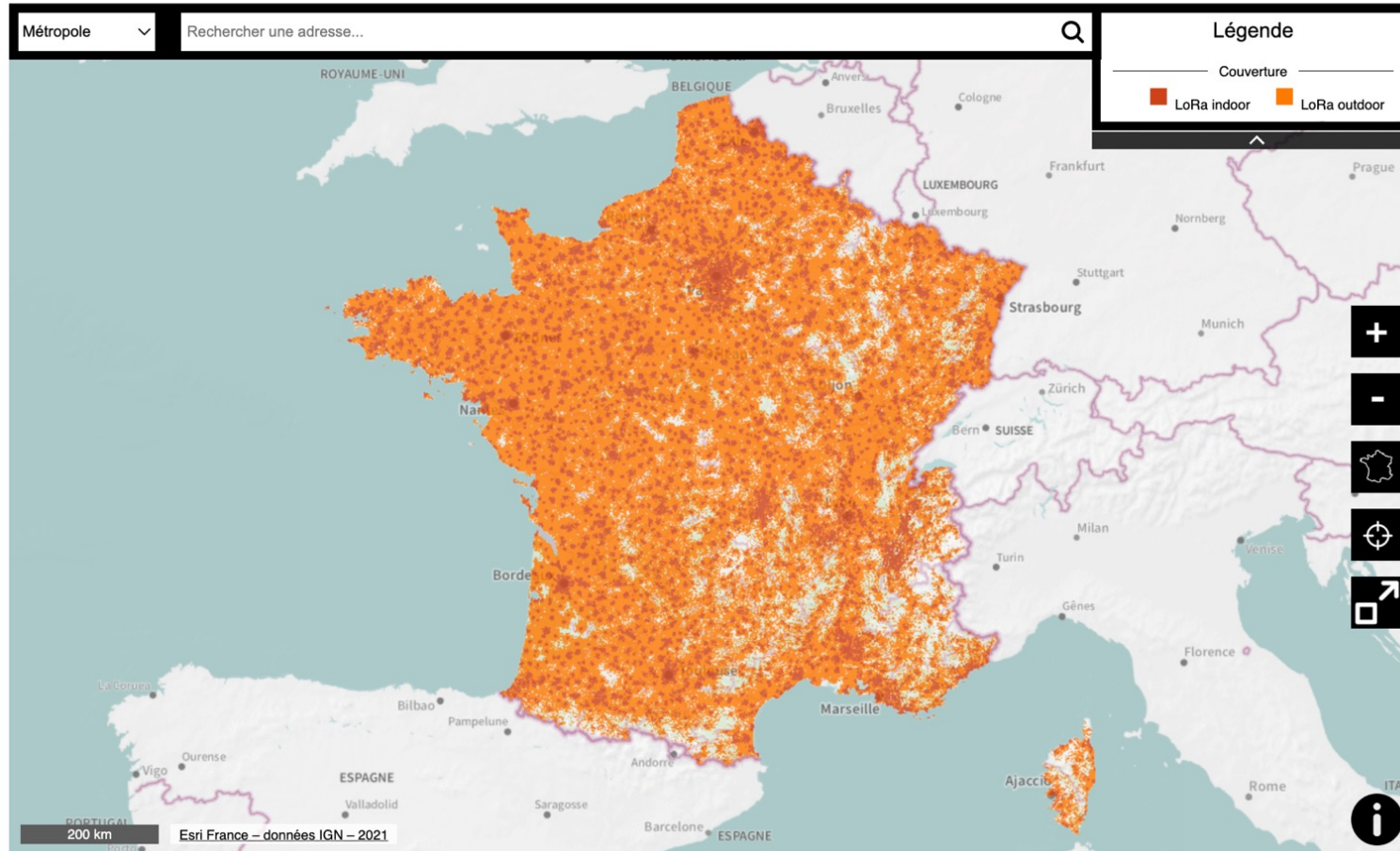
IoT networks architecture

- Most of IoT networks are organized with Network & Application servers
- Below, an example with LoRaWAN IoT networks



LoRaWAN in France

Couverture LoRa® Orange

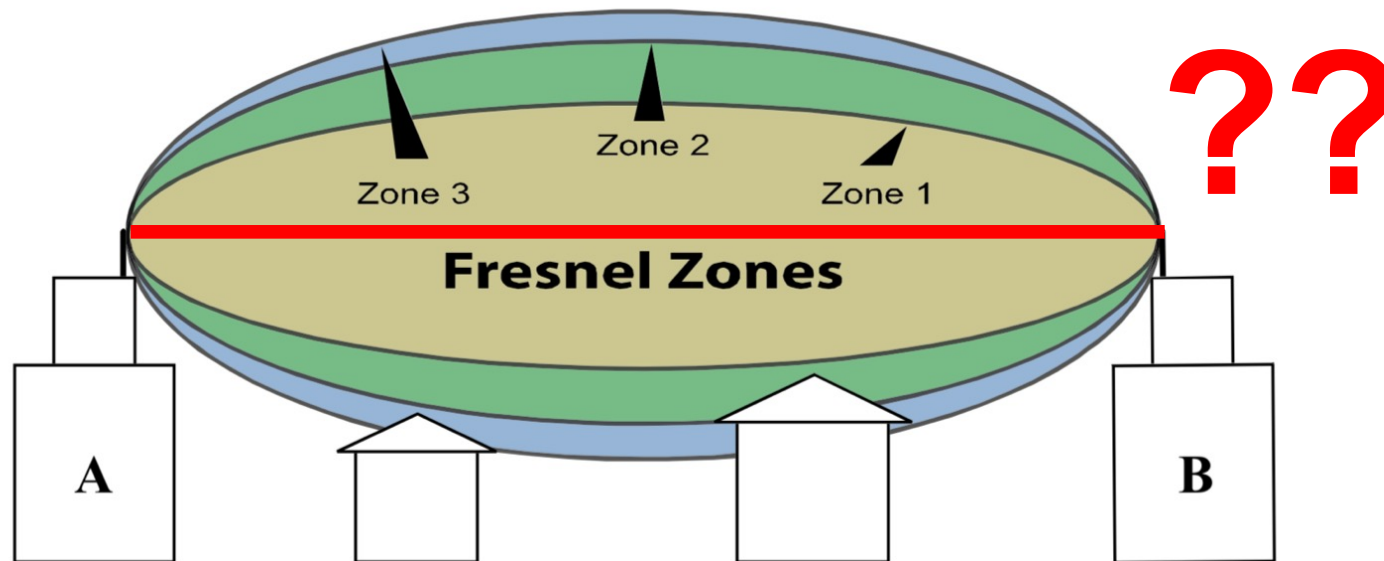


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<https://www.orange-business.com/fr/reseau-iot>

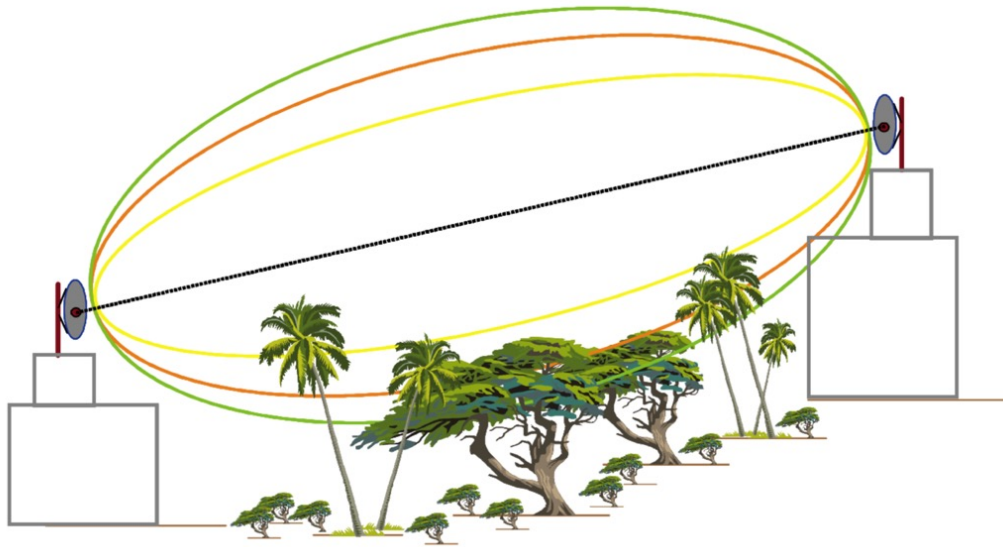
Line-of-Sight & Fresnel zone

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



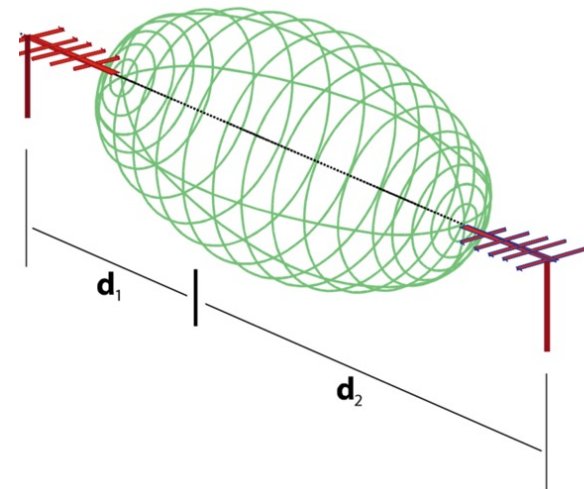
Clearing the Fresnel zone? Raise antennas!

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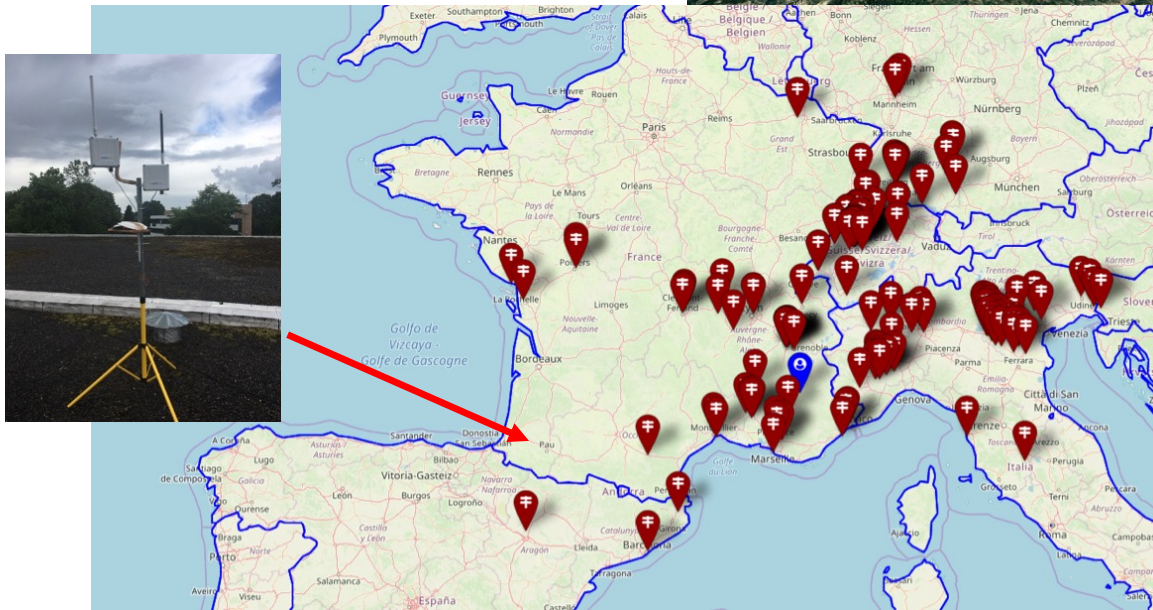
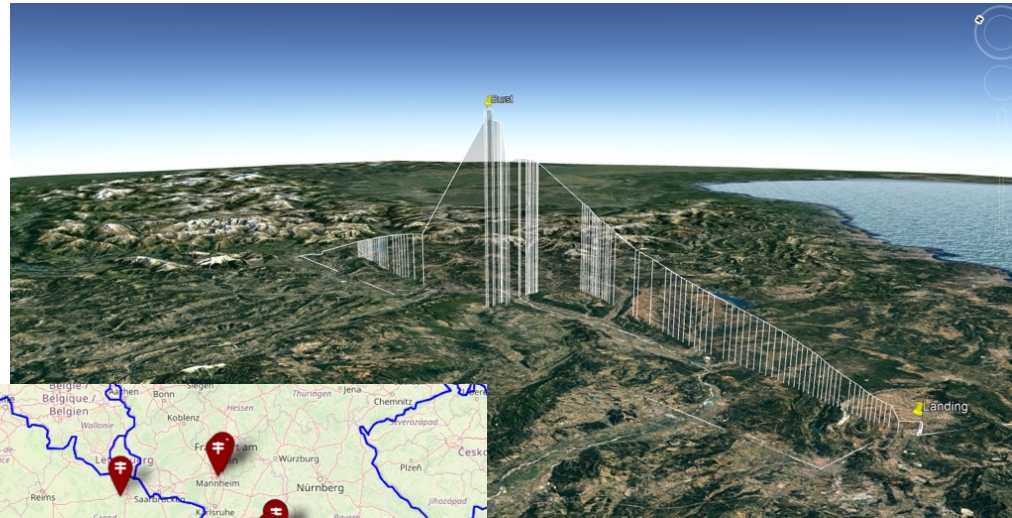
$$r_n = \sqrt{\frac{d_1 d_2}{d_1 + d_2}}$$

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)



Coverage test by Fabien Ferrero on June 11th, 2019

⦿ High Altitude Balloon



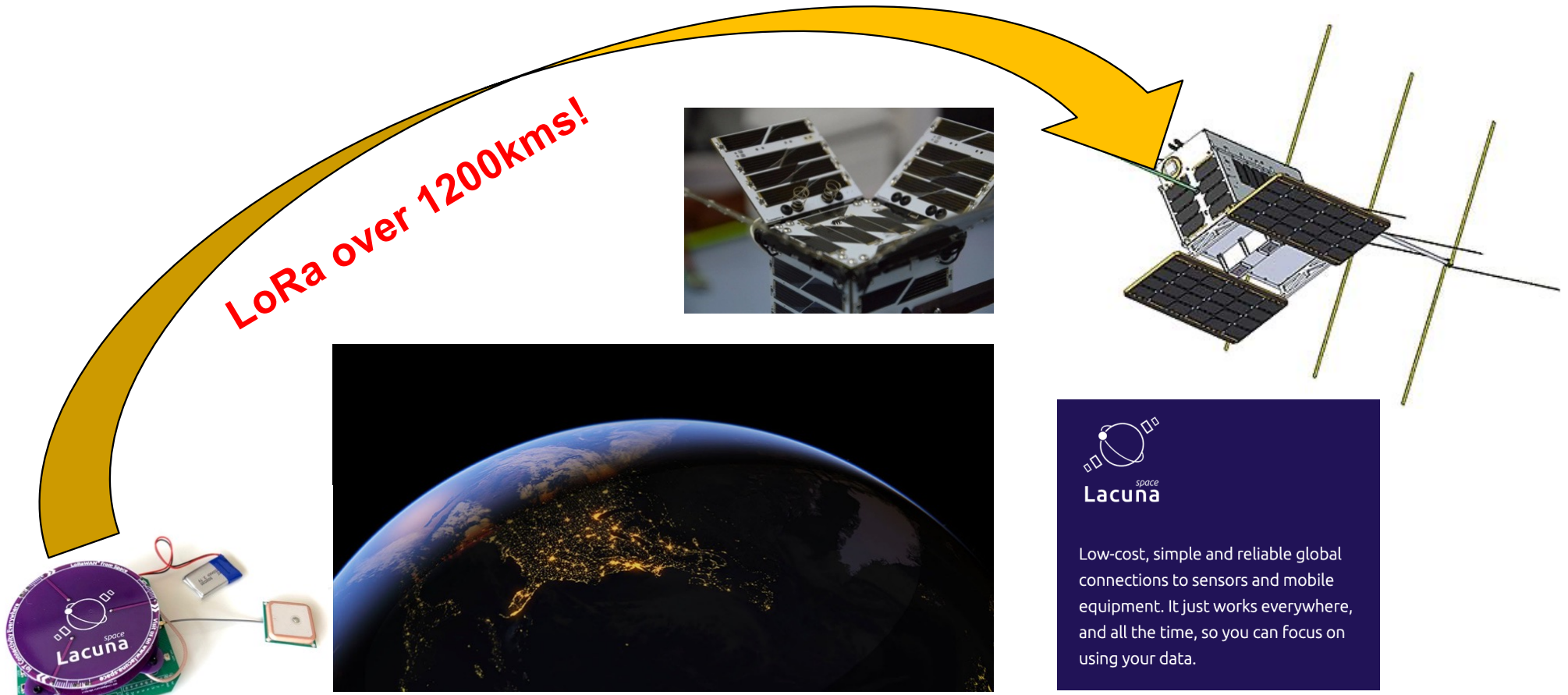
- ⦿ 31kms high
- ⦿ Reception at 642km (Udine, Italy)!
- ⦿ Current record at 702km with balloon at 38kms

https://github.com/FabienFerrero/HAB_Relay_STM32Contest

Clearing the Fresnel zone? Let's use satellite!

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

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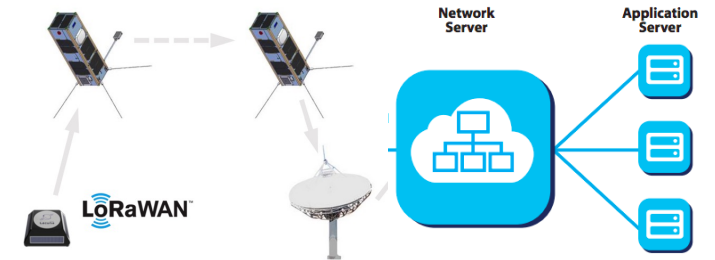


Lacuna
space

Low-cost, simple and reliable global connections to sensors and mobile equipment. It just works everywhere, and all the time, so you can focus on using your data.

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

Satellite LPWAN principle



- ① Battery powered devices direct to satellite – no gateway required
- ② Satellites in low earth orbit collect and store received messages
- ③ Messages are relayed to ground station when satellite goes overhead
- ④ Data relayed to The Lacuna Network for distribution
- ⑤ Distributed to Lacuna Space customers or other operators as appropriate

Use ISM bands : 868 or 920MHz

Satellite LPWAN unlocks a wide range of new applications!

- ⦿ Environmental / healthcare, health security applications



- ⦿ Deploying IoT in developing countries



- ⦿ Expected prices can be as low as \$3/year/device!



**2023, billions of IoT devices
are deployed worldwide!**

IoT added-values come from interactions and linked data...

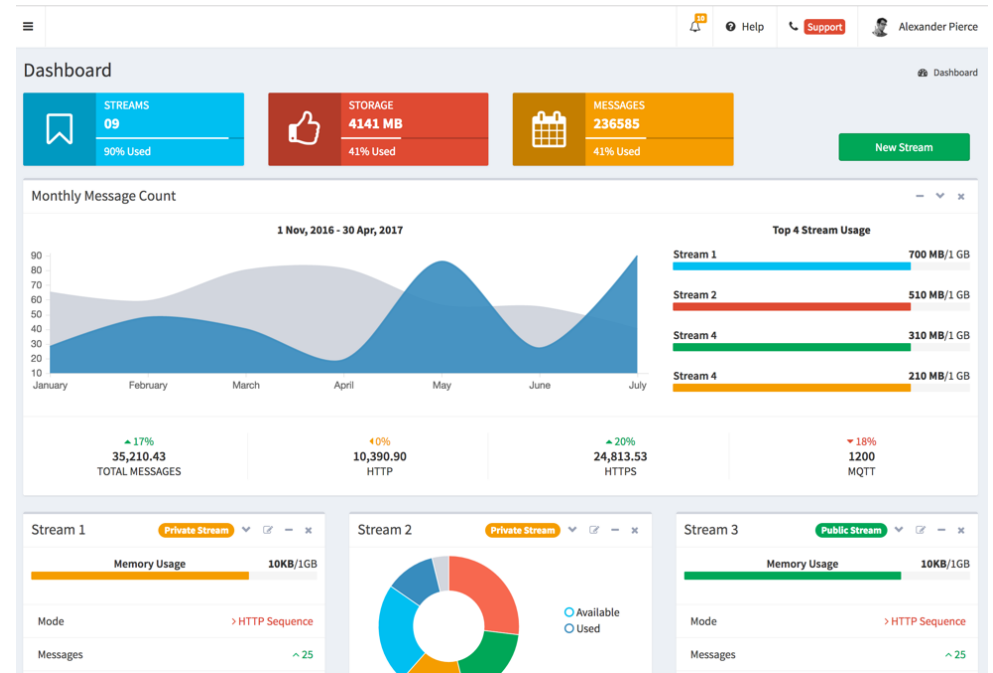
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A central collage of IoT-related icons and logos. At the top left is a Nest smart thermostat showing 21 degrees. Next to it is a smartphone and a pink person icon. To the right is an ENGIE smart meter with labels for 'BUTTON', 'THERMOMETER', 'MOVEMENT DETECTOR', and 'MICRO USB PORT (for charge)'. Further right is a potted plant with a blue Y-shaped sensor. Below these are the YouTube logo, a pink person icon, and the Facebook logo. In the center is a large graphic of three interlocking arrows (red, yellow, blue) with question marks. To the right of this are a smartwatch showing 12:38, the Twitter logo with a question mark, the Uber logo, and the Spotify logo. At the bottom left is an 'enovo' waste container sensor with text: 'Waste Container connected sensor', 'Ultrasonic ti level sensor', '10+ years battery life', 'IP 66, (-40° - +85°)'. To its right are the Instagram logo, an envelope icon, a pink person icon, and a smart ring showing 98 and 10:45.

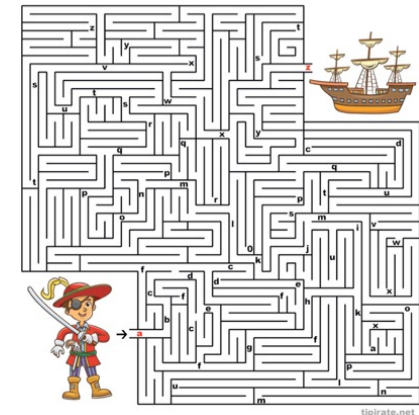
... to integrate multiple data sources!

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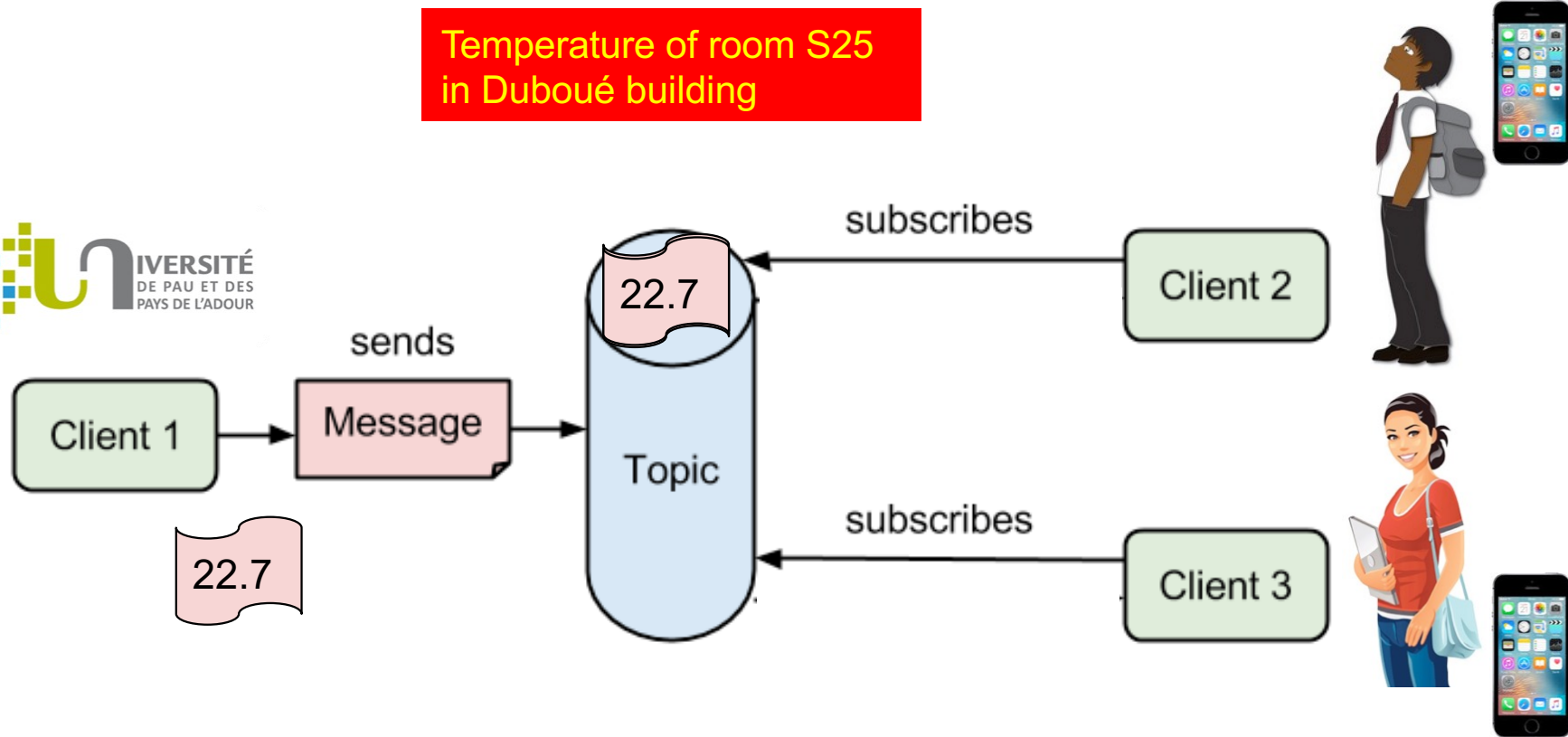
Integrating, ok, but how? From where?

- ⦿ Sensors' data can eventually be accessed with traditional methods such as web URL
- ⦿ But web based (HTTP) protocols are not lightweight! They have been designed for computers, not IoT!
- ⦿ IoT calls for a more "automatized" and "simplistic" approach
- ⦿ Automatized → when IoT data changes, users want to get immediate notifications
- ⦿ Notification-based is nowadays very common: smartphones, news, social media, ...



From "search for info" to "get the info"

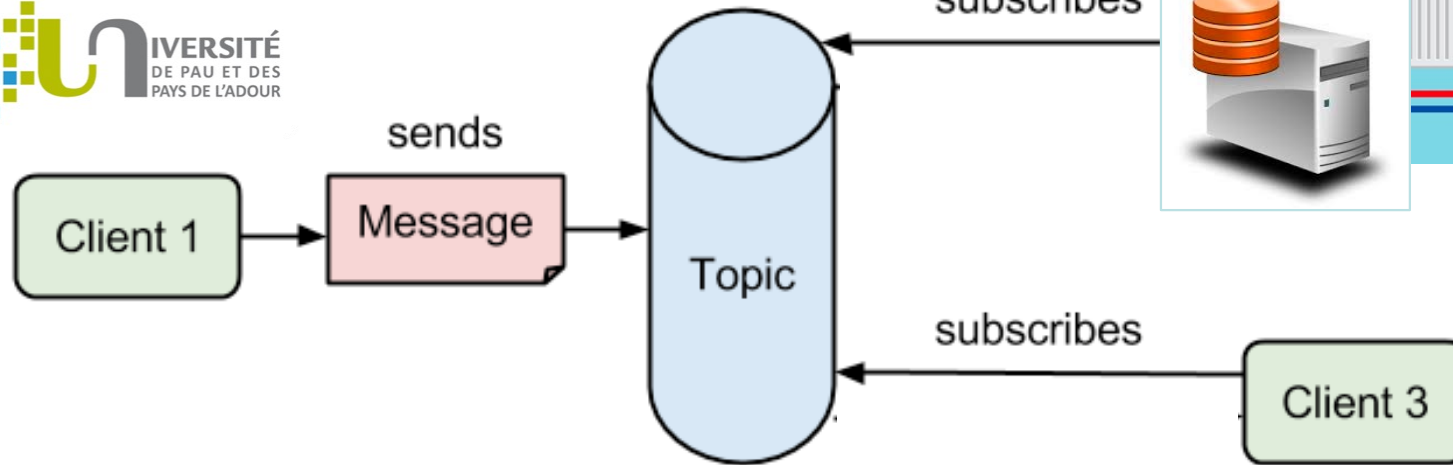
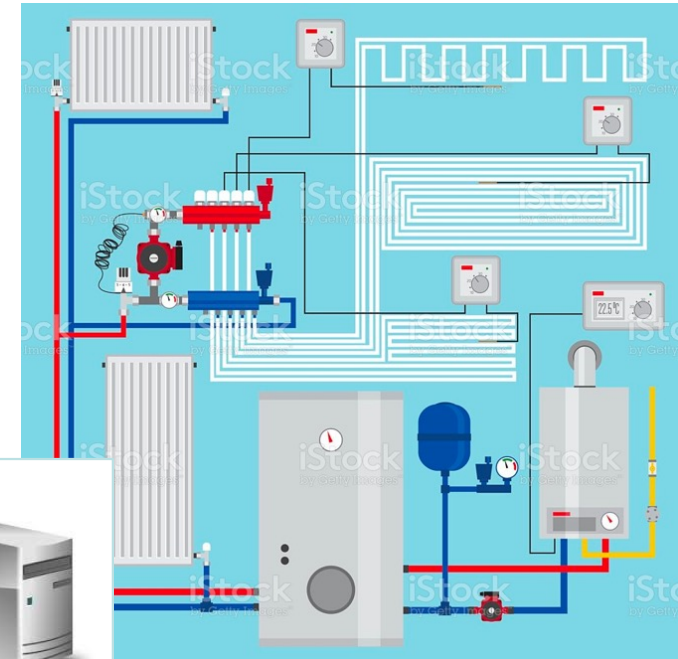
- Use the PUBLISH/SUBSCRIBE model



Automatization made simpler

- Use the PUBLISH/SUBSCRIBE model

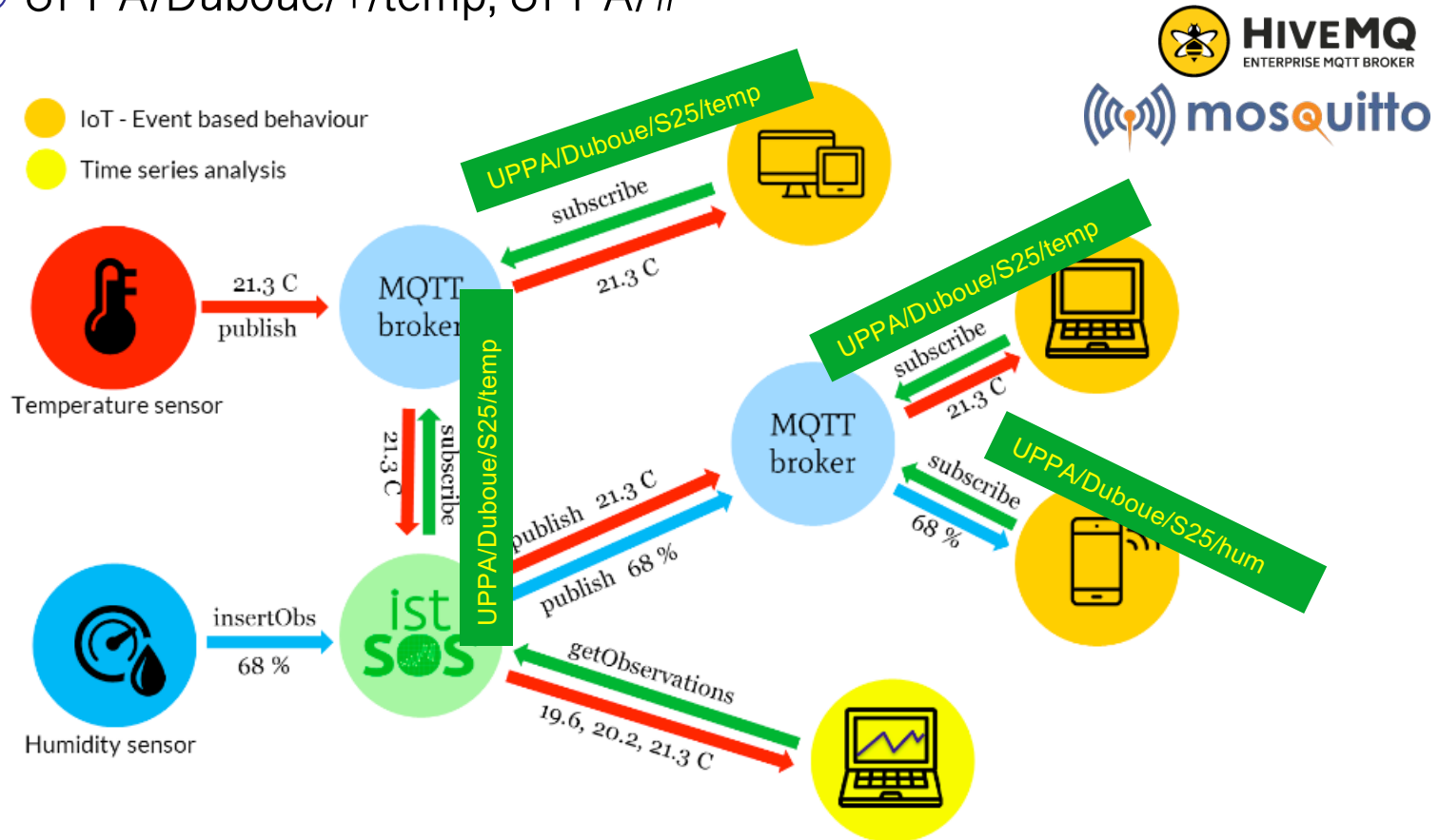
Temperature of room S25
in Duboué building



MQTT

Message Queue Telemetry Transport

- ⦿ Use broker nodes to manage topics
 - ⦿ UPPA/Duboue/S25/temp, UPPA/Duboue/S25/hum
 - ⦿ UPPA/Duboue/+/temp, UPPA/#



MQTT+smartphone=



Editors' Choice

MQTT Dash (IoT, Smart Home)

Routix software Communication ★★★★★ 1,584

PEGI 3

This app is compatible with all of your devices.

Installed

Maxime Carrier

Instant.solutions

Webcam

Outside humidity 11%

Garage door

Water level

MQTT Dash

Home

My MQTT broker

Mom's house

Servers' health

My lab

MQTT Dash

This metric is intended for state displaying and switching (e.g. light on/off). Payload expected to be string.

Name

The door

Topic (sub)

door/lock

Topic (pub) - keep empty if the same as sub

Payload and icons

On 1 Off 0

Other settings

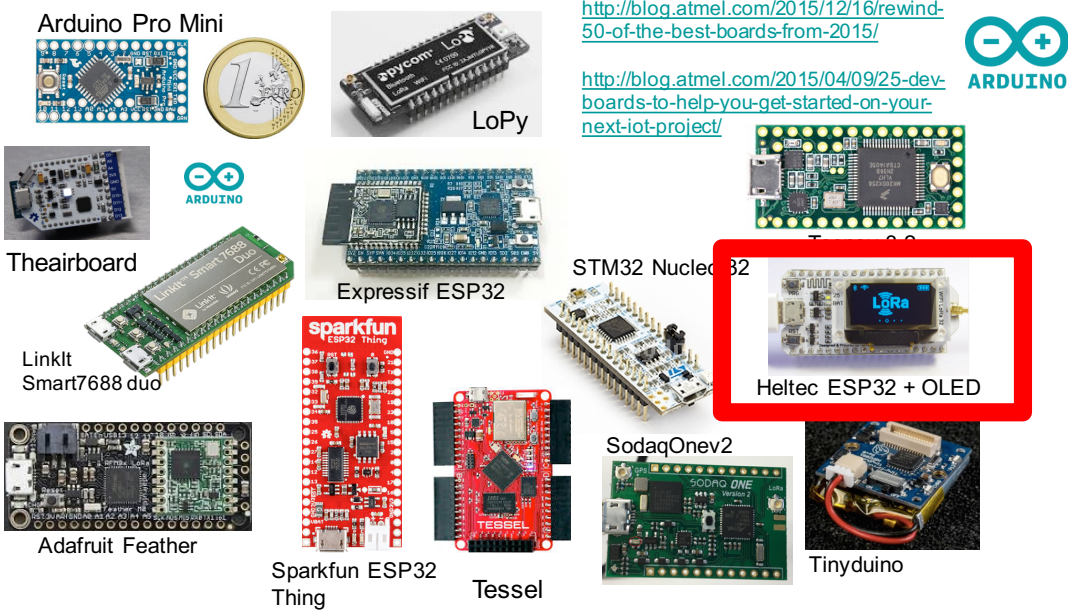
0x0(0) 0x0(1) 0x0(2)

Retained

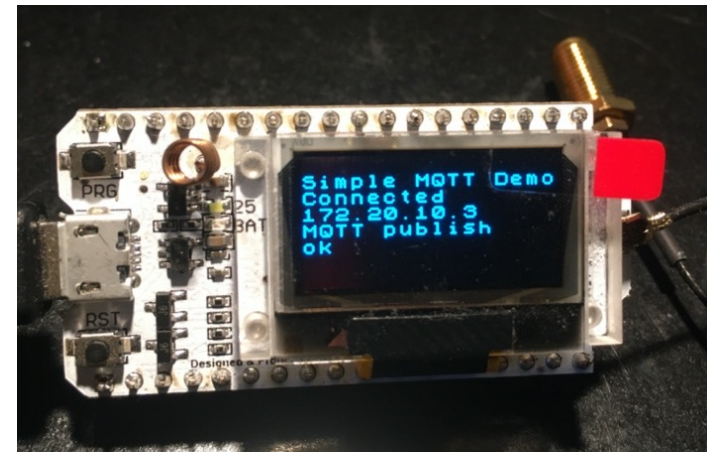
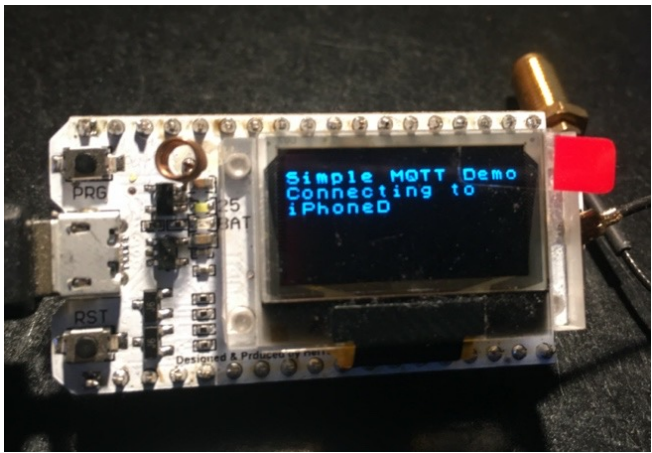
- ☐ Towards open data
 - ☐ UPPA/ROOMS/#
 - ☐ UPPA/CONGRESS/#
 - ☐ PAU/WEATHER/#

MQTT is very lightweight

- ⦿ MQTT can run on small IoT devices
- ⦿ Heltec WiFi ESP32
 - ⦿ Device connects to WiFi network
 - ⦿ Then will publish data to MQTT topic



<http://blog.atmel.com/2015/12/16/rewind-50-of-the-best-boards-from-2015/>
<http://blog.atmel.com/2015/04/09/25-dev-boards-to-help-you-get-started-on-your-next-iot-project/>



Ex: Mosquitto MQTT broker

DEMO



- ⦿ Eclipse Mosquitto is an open-source MQTT broker
- ⦿ MQTT test broker: `test.mosquitto.org`
- ⦿ IoT device will publish to topic `UPPA/Duboue/S25/temp`
- ⦿ On a computer, use `mosquitto_sub` to subscribe
 - ⦿ `mosquitto_sub -v -h test.mosquitto.org -t UPPA/Duboue/#`
 - ⦿ `-v` \Rightarrow to display information in detailed mode
 - ⦿ `-h` \Rightarrow the MQTT broker: `-h test.mosquitto.org`
 - ⦿ `-t` \Rightarrow the MQTT topic: `-t UPPA/Duboue/#`

Ex: HiveMQ broker on websocket

🕒 <https://www.hivemq.com/demos/websocket-client/>

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MQTT Websocket Client

Non sécurisé | hivemq.com/demos/websocket-client/

Applications | Liste de lecture

HIVEMQ Websockets Client Showcase

Connection connected

Publish

Topic: booster_pau/test QoS: 0 Retain:

Message: hello from booster Pau

Subscriptions

Add New Topic Subscription

MQTT Websocket Client

Non sécurisé | hivemq.com/demos/websocket-client/

Applications | Liste de lecture

HIVEMQ Websockets Client Showcase

Connection connected

Publish

Topic: testtopic/1 QoS: 0 Retain:

Message:

Subscriptions

Add New Topic Subscription

Qos: 2 booster_pau/test

Messages

2021-11-25 08:55:20 Topic: booster_pau/test Qos: 0
hello from booster Pau

DEMO

MQTT in real IoT deployment

Sensor part

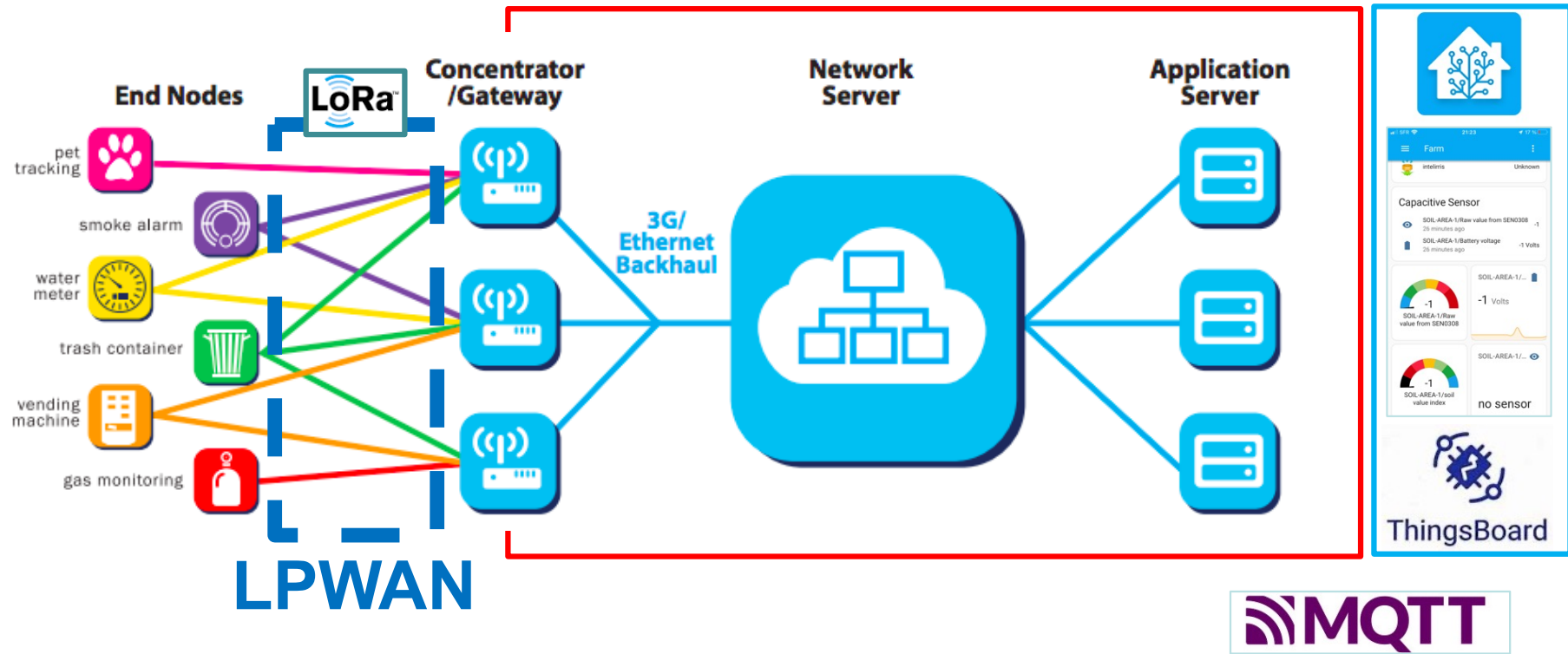


- Simple IoT devices have no WiFi
- Use Low-Power, Long Range radios, e.g. LoRa
- Send to IoT gateway

Control part – IoT gateway



Integration from IoT clouds

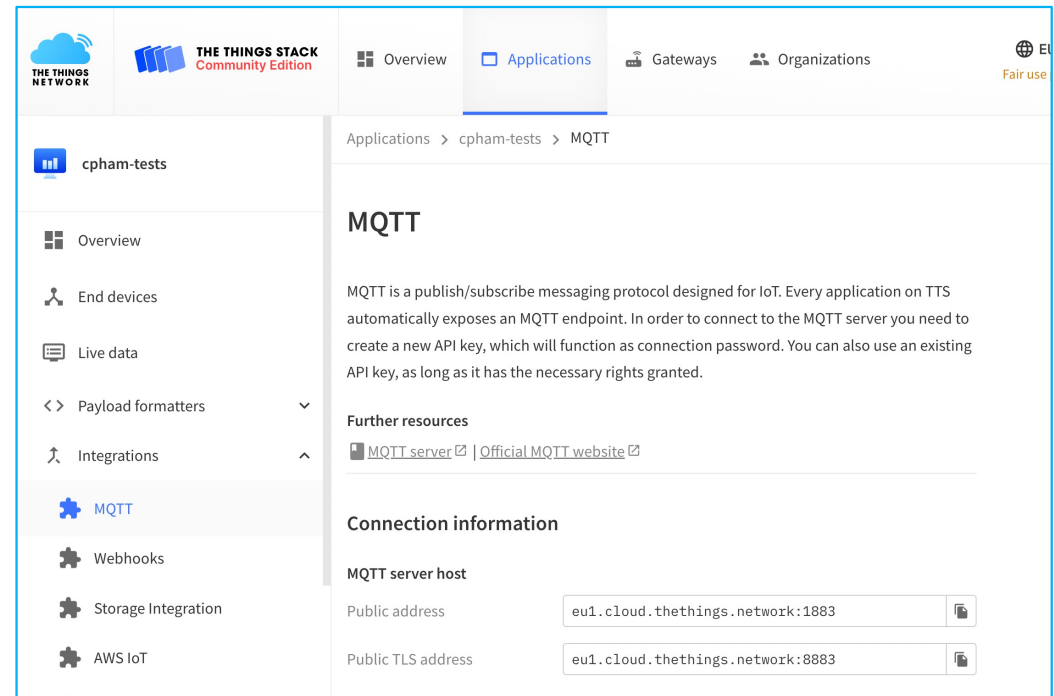
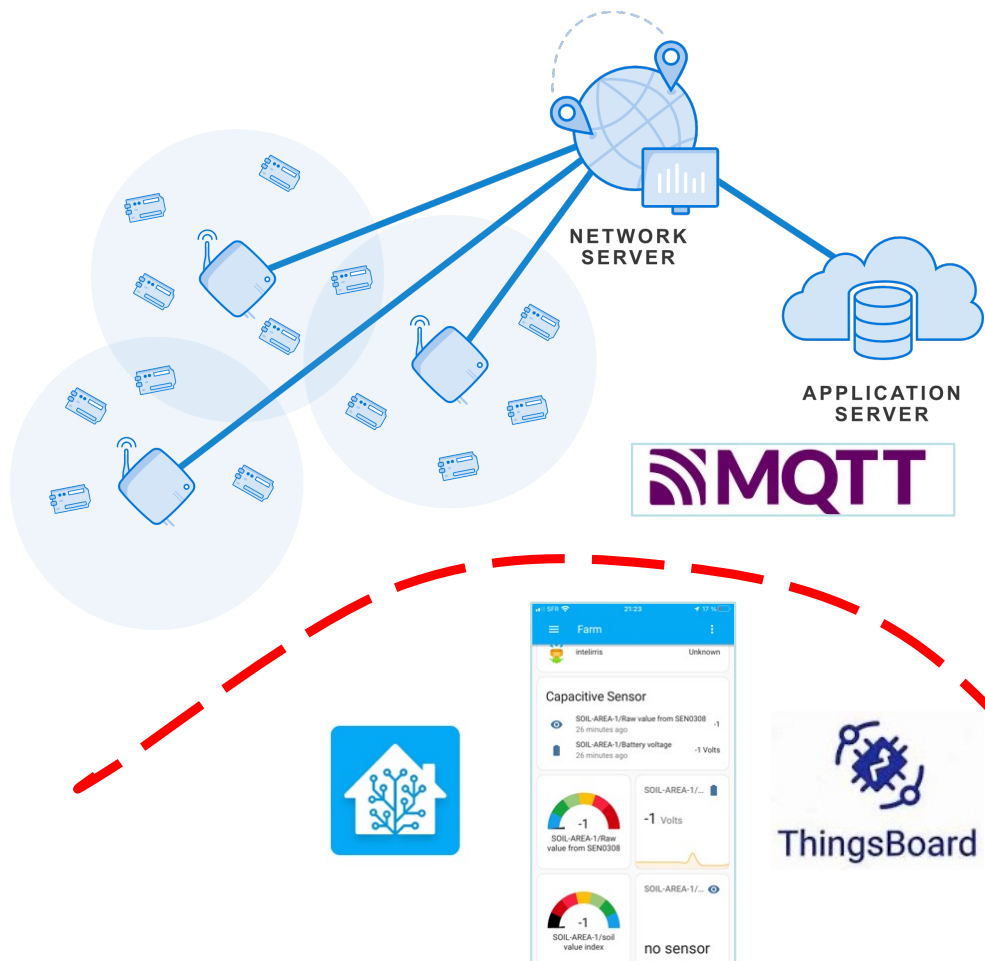


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<http://www.univ-pau.fr/~cpham>

Ex: TheThingNetwork

⦿ TTN is a well-known LoRa IoT Network Provider

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



MQTT implementing social media

- It is very easy to implement a social media app using MQTT

- WhatsApp-like example

- Define MQTT topic per phone number

- Alice: myWhatsApp/0655667788

- Bob: myWhatsApp/0611223344

- To receive/send message

- Alice publishes to myWhatsApp/0611223344

- Bob publishes to myWhatsApp/0655667788

- Both subscribe to their own topic

- To create a group

- Alice creates a group showcase-iot

- myWhatsApp/0655667788/showcase-iot

- To join(publish) on(to) the group

- Subscribe(publish) to myWhatsApp/0655667788/showcase-iot



0655667788



Alice

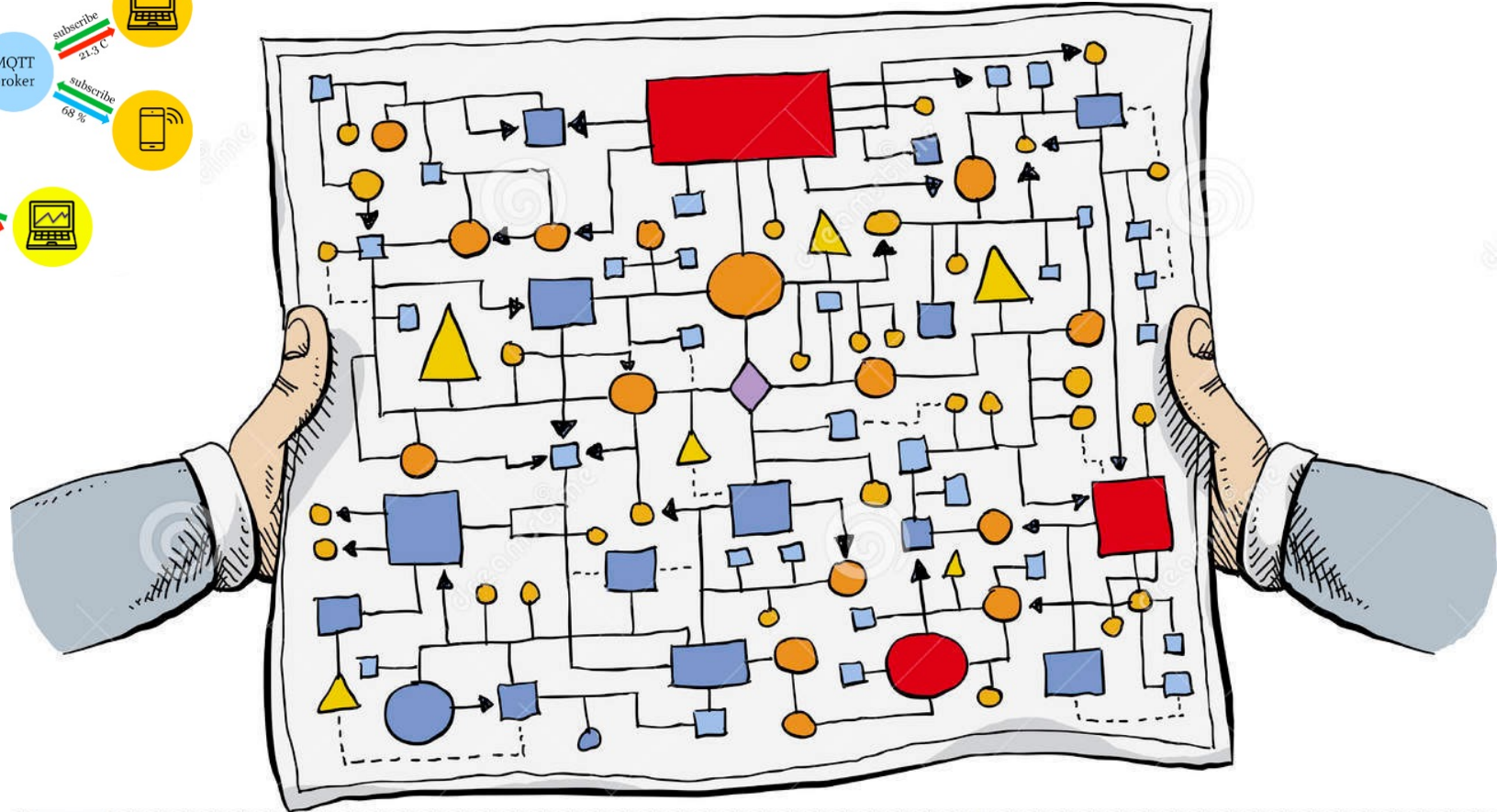
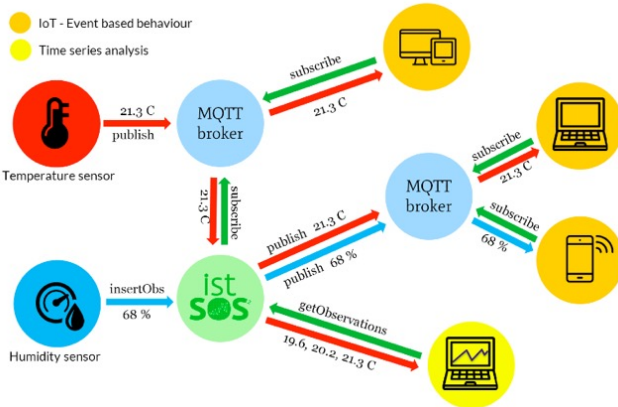


0611223344



Bob

Creating complex data flows?



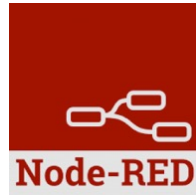
...without programming?



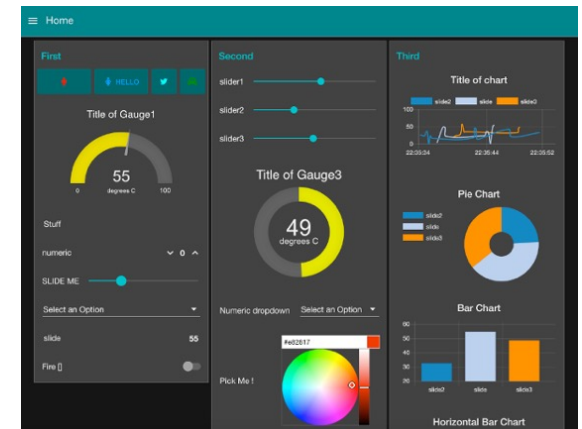
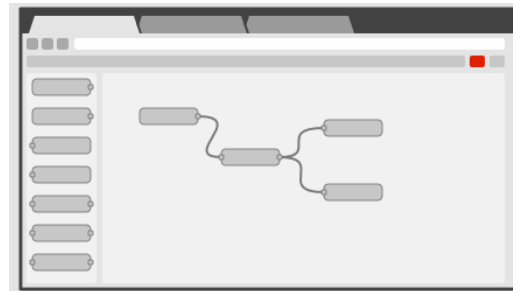
- End-users are not necessarily computer science experts nor high-skilled programmers



Node-RED

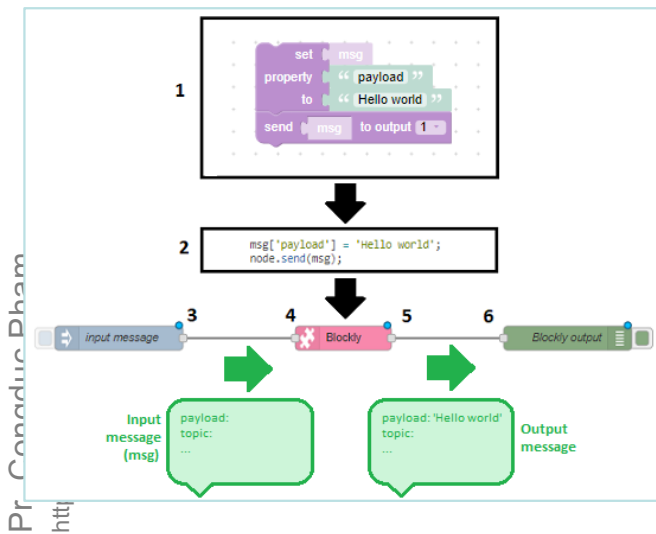


- Use graphical tools to build data processing flows, allowing intuitive connection from IoT data producers to IoT data consumers
- Node-RED is a programming tool for wiring together hardware devices, APIs and online services, e.g. clouds of various types
- provides a browser-based flow editor to wire together flows with a wide range of nodes



Node-RED blocks

Increasing number of Node-RED blocks



Nodes represent reusable pieces of code and logic. Node-RED comes with a core set of useful nodes, but there are a growing number of additional nodes available to install from both the Node-RED project as well as the wider community or you

Nodes

input

- inject
- catch
- status
- mqtt
- http
- websocket
- serial
- tcp
- mqtt
- ibmiot

output

- debug
- mqtt
- http response
- websocket
- serial
- tcp
- udp
- mqtt
- twilio
- ibmpush
- ibmiot
- OpenWhisk

function

- function
- template
- delay
- trigger
- comment
- http request
- switch
- change
- range
- csv
- html
- json
- xml
- rbe
- tcp request
- OpenWhisk

social

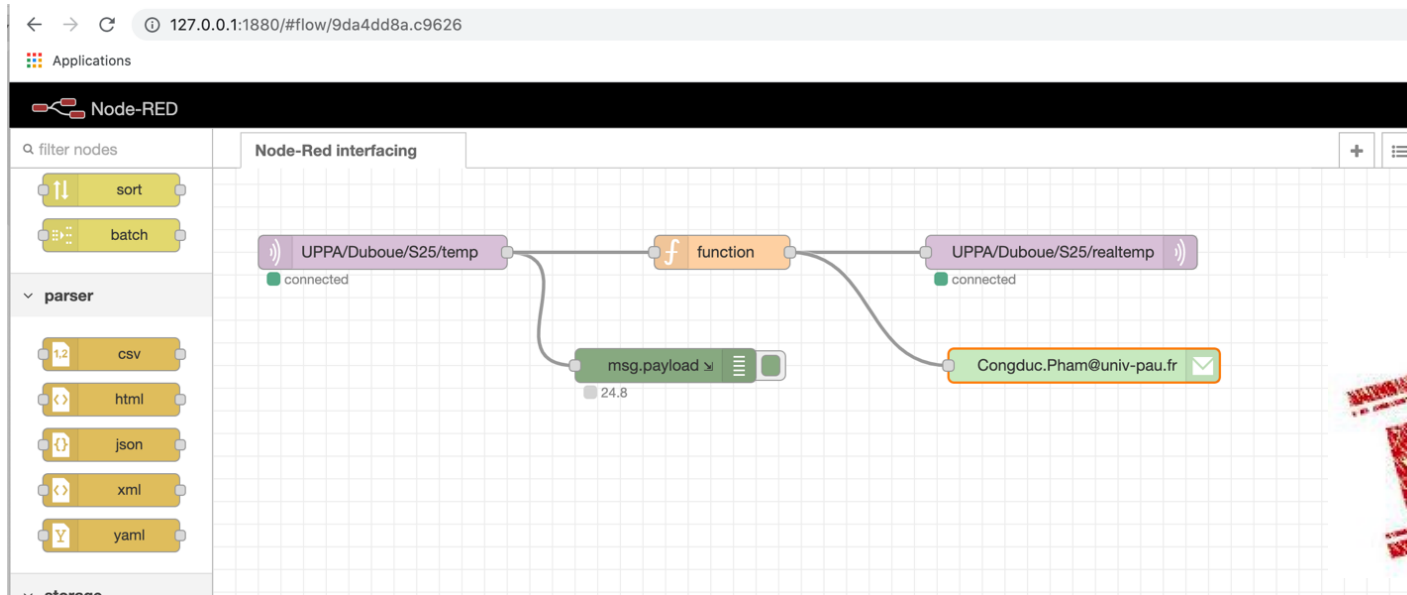
- e mail
- twitter
- e mail
- twitter

storage

- mongodb
- ibm hdfs
- ibm hdfs
- cloudant
- sqldb
- dashDB
- mongodb
- cloudant
- sqldb
- dashDB

Simple MQTT Node-RED flow

- ⦿ MQTT in-broker: `test.mosquitto.org`
- ⦿ **"MQTT in"** node listens on `UPPA/Duboue/S25/temp`
- ⦿ "Function" node to correct temperature by -1.8°C
- ⦿ MQTT out-broker: `broker.hivemq.com`
- ⦿ **"MQTT out"** node publishes on `UPPA/Duboue/S25/realtemp`
- ⦿ "Mail" node sends corrected temp to `Congduc.Pham@univ-pau.fr`



DEMO

Simple MQTT Node-RED flow

The image shows a Node-RED interface on the left and a Hivemq Websocket Client interface on the right. The Node-RED interface includes a sidebar with nodes like 'sort', 'batch', 'parser' (with 'csv', 'html', 'json', 'xml', 'yaml' options), and 'storage'. The main workspace shows a flow with a 'mqtt' node connected to a 'publish' node. The Hivemq interface shows a 'connected' status, a 'Publish' section with 'testtopic/1' as the topic, and a 'Subscriptions' section with two active subscriptions: 'booster_pau/test' and 'UPPA/Duboue/S25...'. The 'Messages' section displays a list of received messages:

Timestamp	Topic	Message	QoS
2021-11-25 09:18:14	UPPA/Duboue/S25/realtemp	20.7	0
2021-11-25 09:18:11	booster_pau/test	hello from booster Pau	0
2021-11-25 09:18:04	UPPA/Duboue/S25/realtemp	20.7	0
2021-11-25 09:17:57	UPPA/Duboue/S25/realtemp	20.7	0

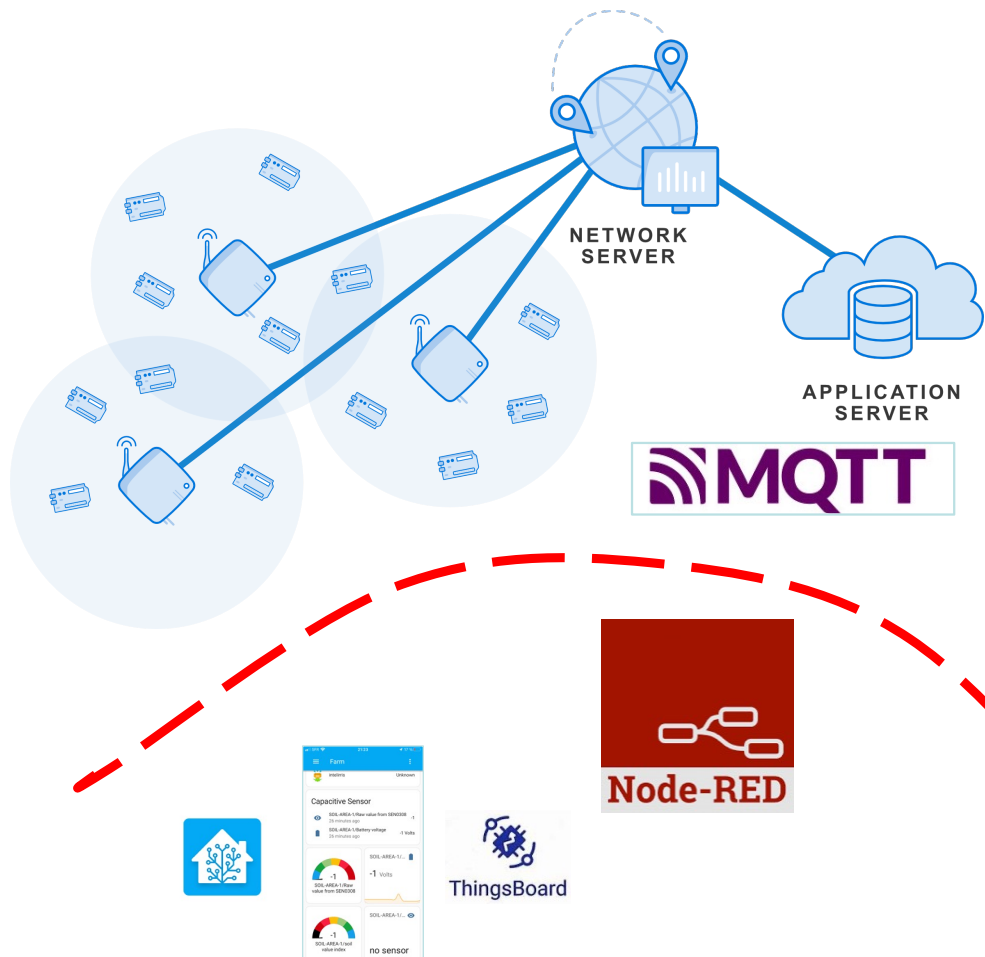
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<http://www.univ-pau.fr/~cpham>



TheThingNetwork + Node-Red

- TTN is a well-known LoRa IoT Network Provider

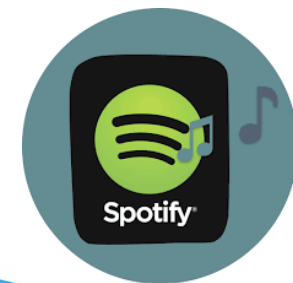
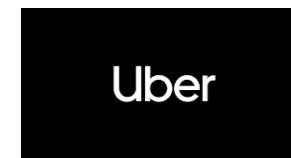
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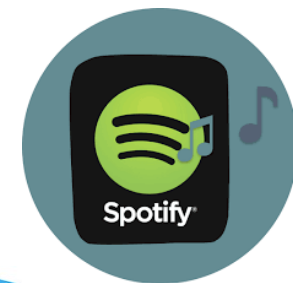
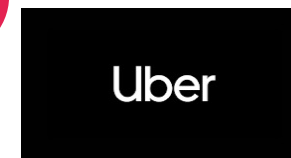
The screenshot shows the **THE THINGS STACK Community Edition** interface. The navigation menu includes Overview, Applications, Gateways, and Organizations. The current page is **Applications > cpham-tests > MQTT**. The page content includes:

- MQTT** section: A description stating that MQTT is a publish/subscribe messaging protocol designed for IoT. It notes that every application on TTS automatically exposes an MQTT endpoint and that users need to create a new API key to connect to the MQTT server.
- Further resources**: Links to [MQTT server](#) and [Official MQTT website](#).
- Connection information**:
 - MQTT server host**:
 - Public address:
 - Public TLS address:

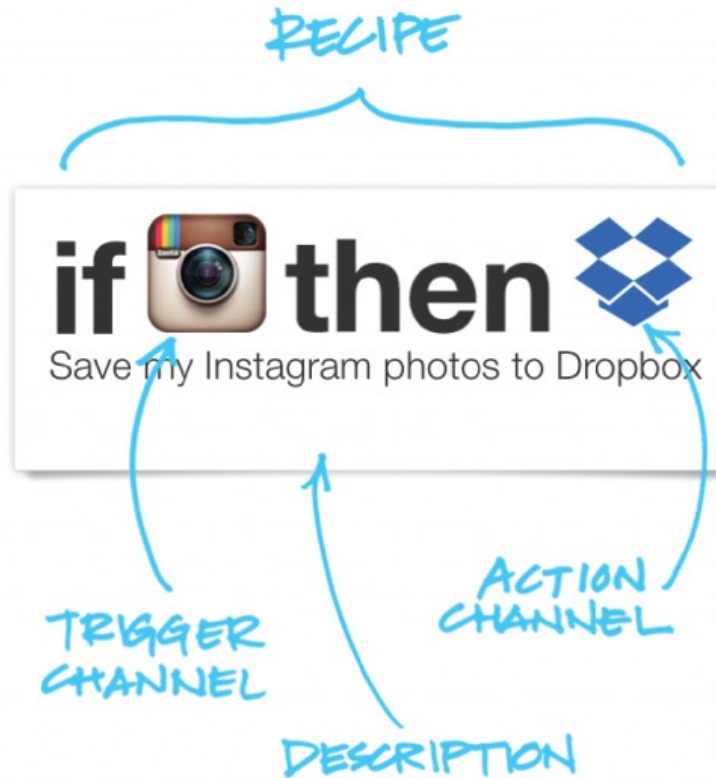
Generalizing interactions?



Adding interactions?



IF THIS THEN THAT applets



Some example Recipes

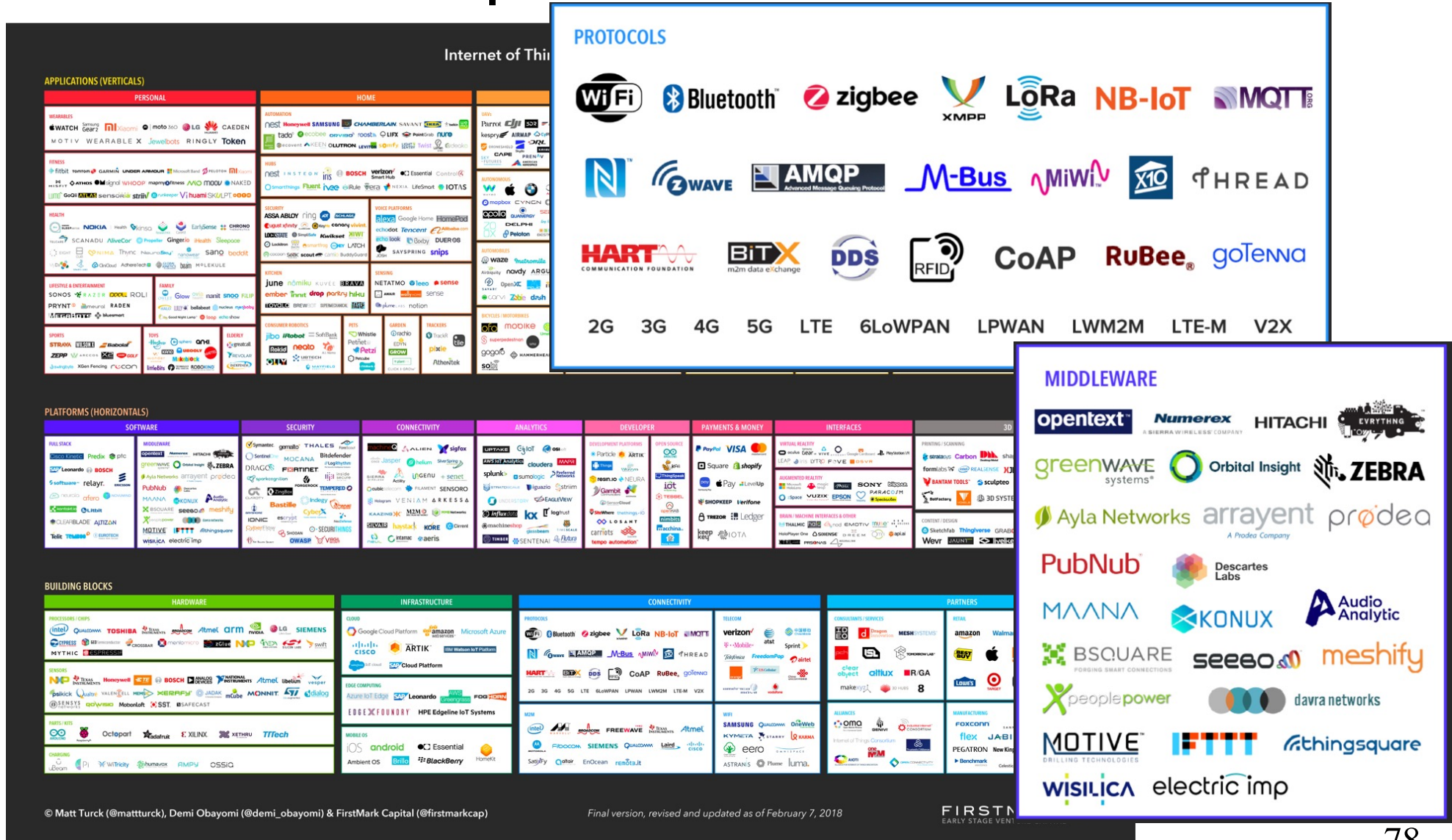
if  **then** 
Nearly home? Direct message the person who should know

if  **then** 
Email your new iPhone photos to yourself

if  **then** 
Backup your contacts to a Google Spreadsheet

IoT landscape

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



© Matt Turck (@mattturck), Demi Obayomi (@demi_obayomi) & FirstMark Capital (@firstmarkcap)

Final version, revised and updated as of February 7, 2018

FIRST MARK EARLY STAGE VENTURE

IoT: Understanding the technologies and challenges of the Internet of Things

Booster

OneTech



Capsule Booster – 2022

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



Horizon 2020
European Union funding
for Research & Innovation

