Understanding Internet-of-Thing technologies

DISRUPTIVE INTERNET OF THINGS APPLICATIONS IN AFRICA

Total Booster Learning Capsule – May 25th, 2021

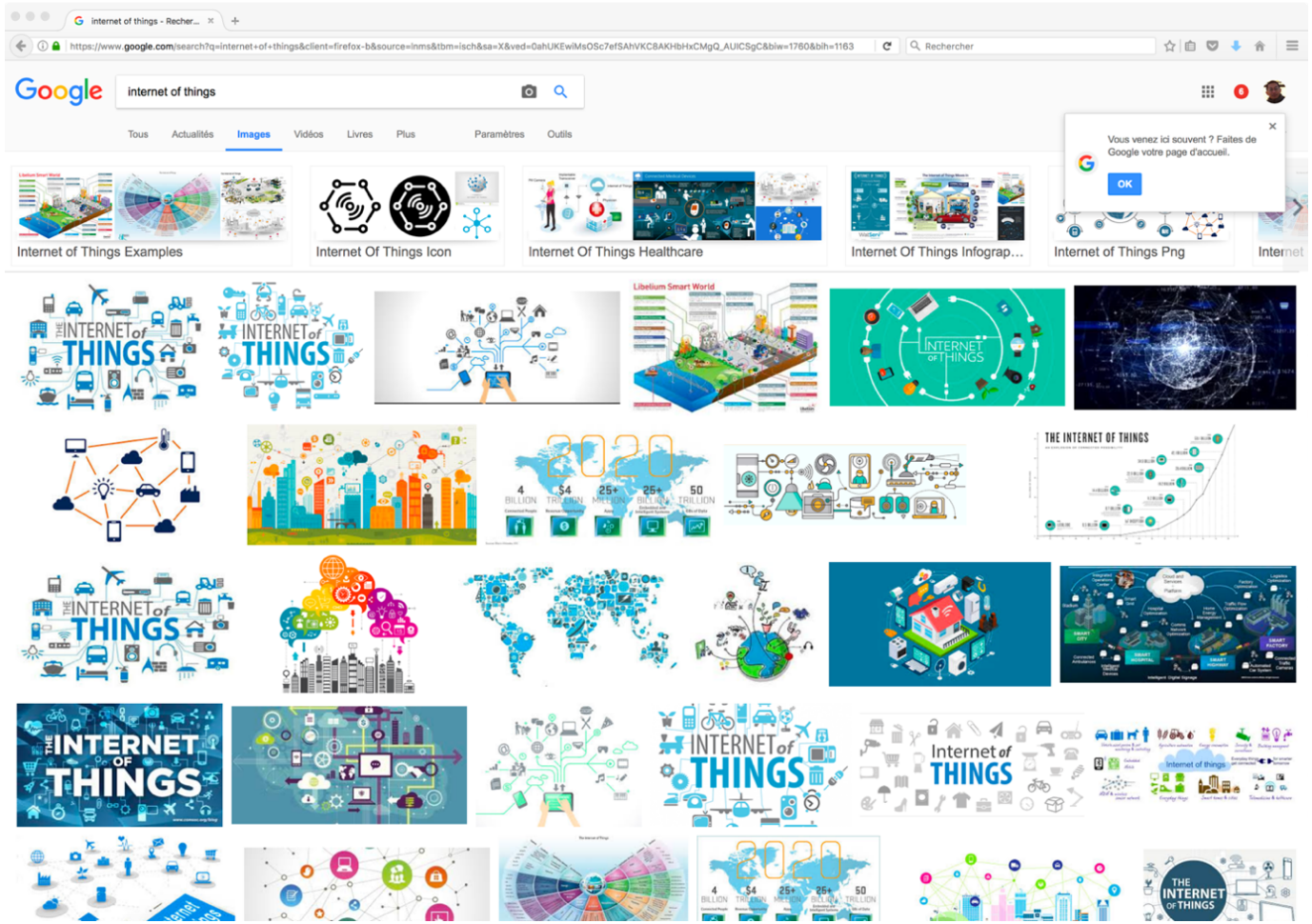
Prof. Congduc Pham
http://www.univ-pau.fr/~cpham
Université de Pau, France

UNIVERSITÉ DE PAU ET DES PAYS DE L'ADOUR

HORIZON 2020

WAZIUP
IoT – from idea to reality
WAZIHUB

Googling for « Internet of Things »



Q: What is IoT for you?

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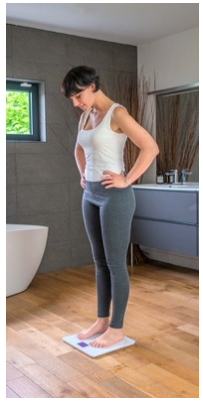
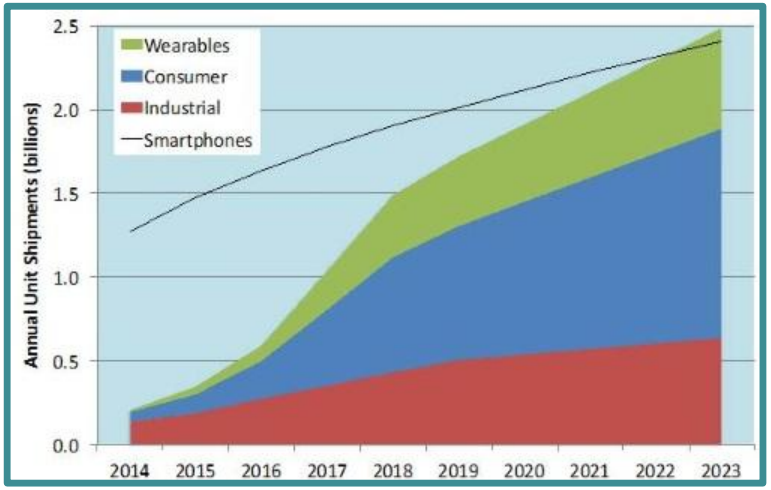
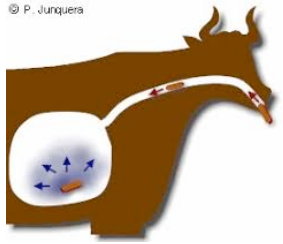
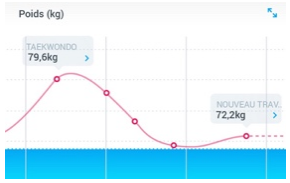
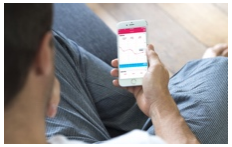
...shows communicating objects



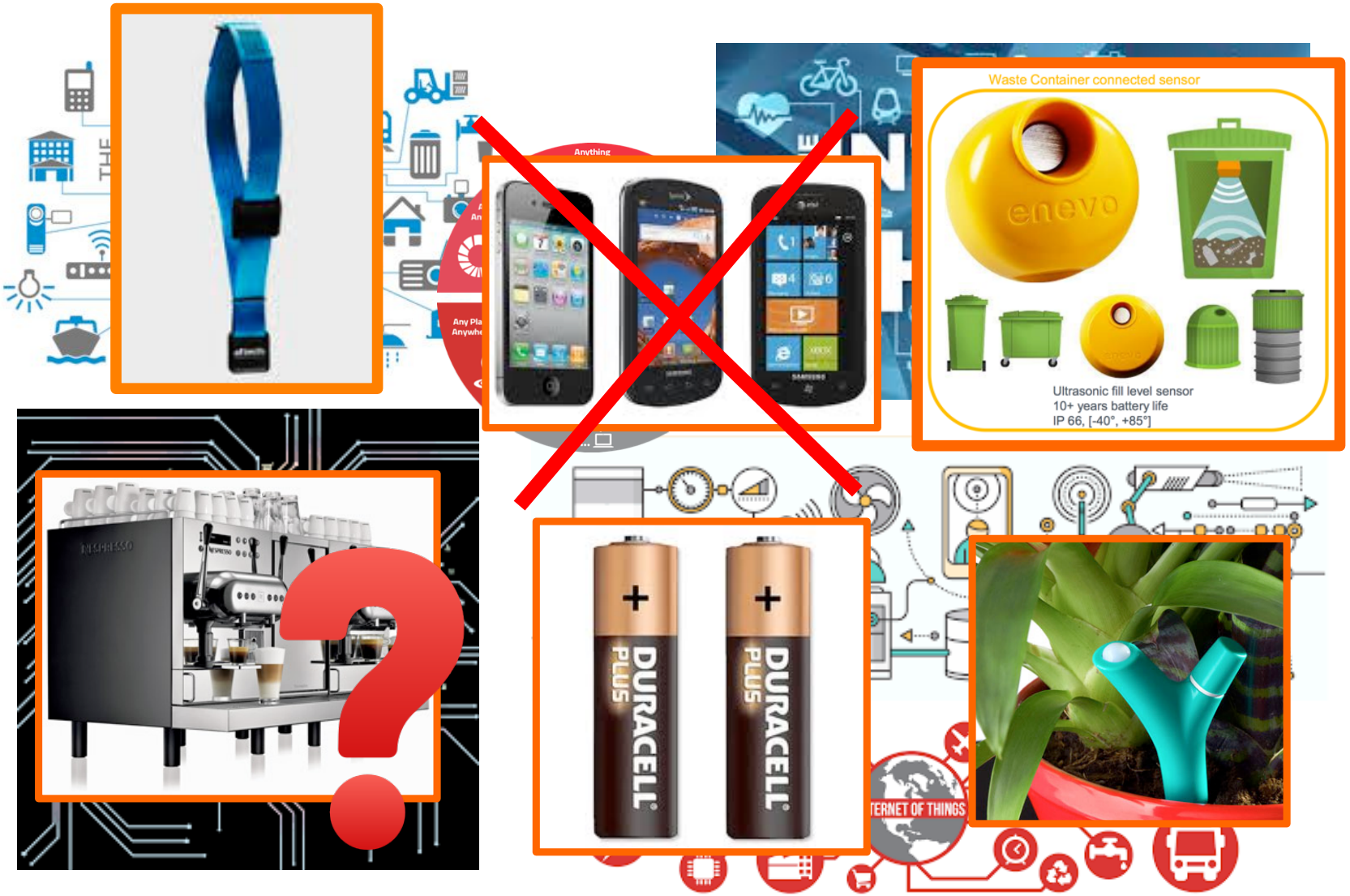








All communicating objects?



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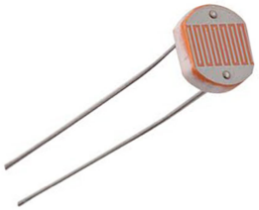
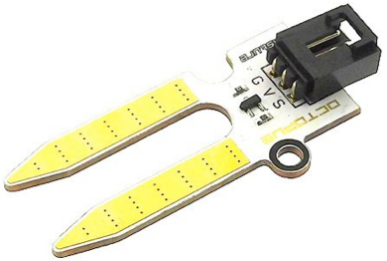
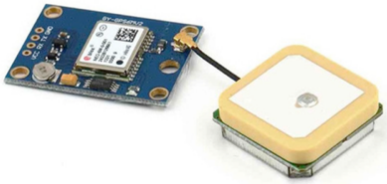
IoT=interactions with physical world

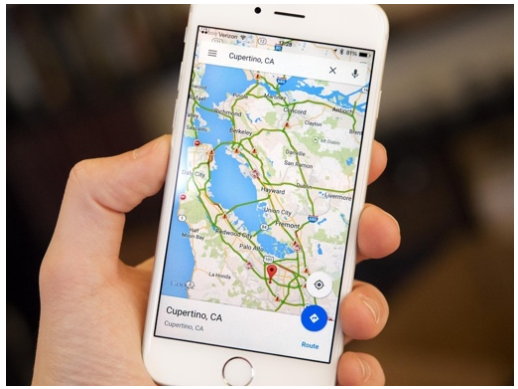
Q: Interactions? How?

Sensing the physical world



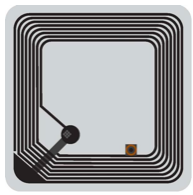






RFID, NFC, active, passive?

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



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RFID, NFC, active, passive?

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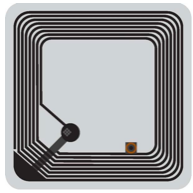
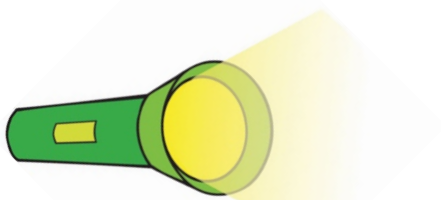
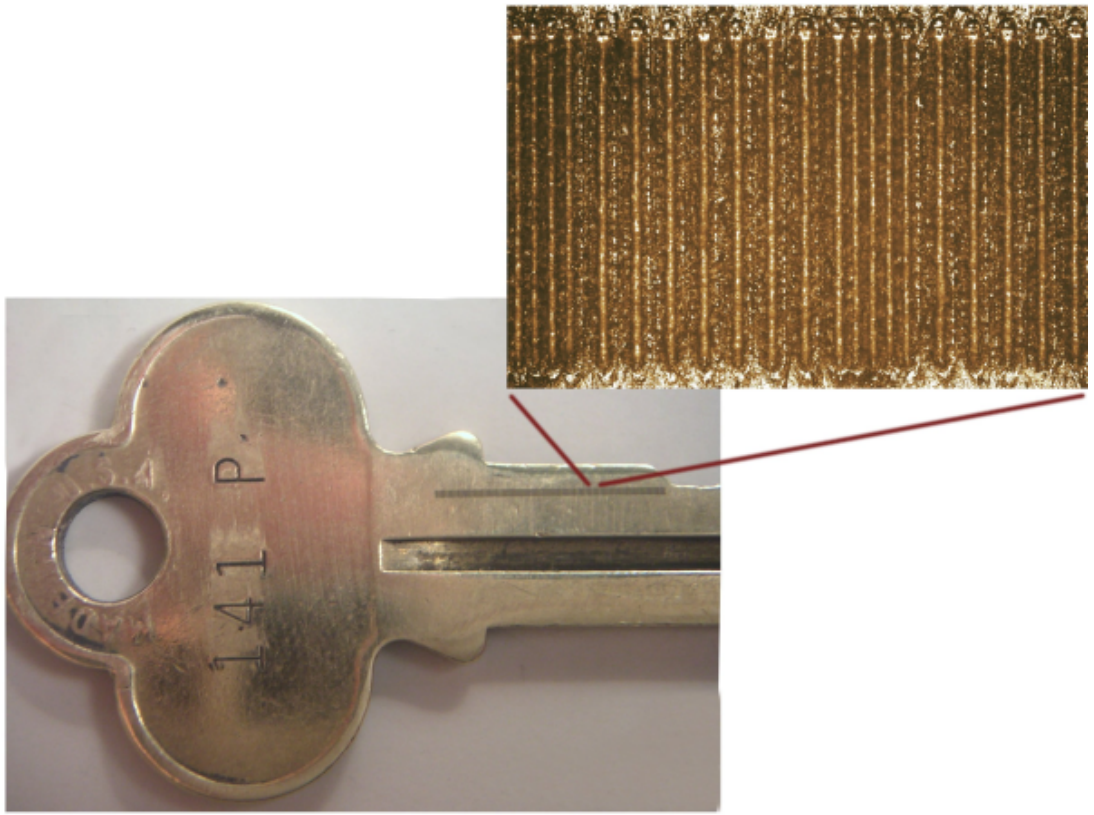


Q: How RFID works?

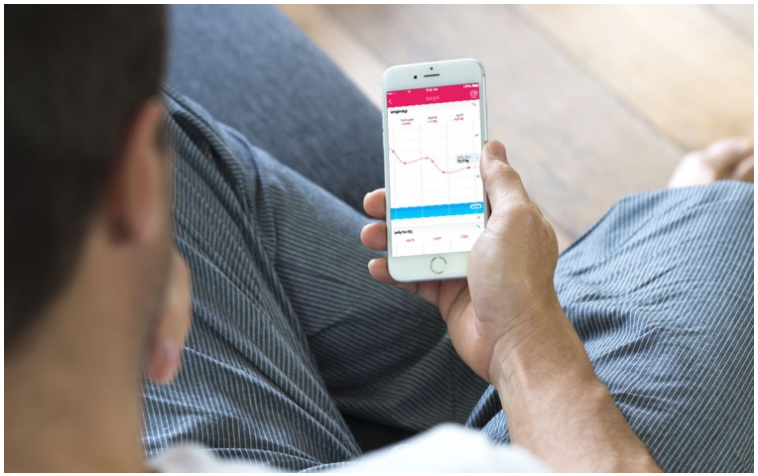
hint

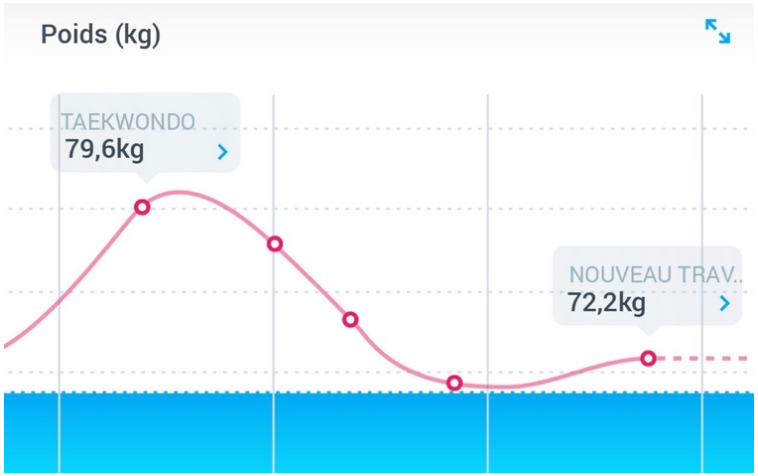


Need sophisticated communication?



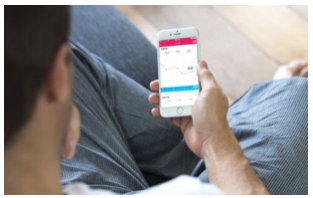
Home/consumer IoT products





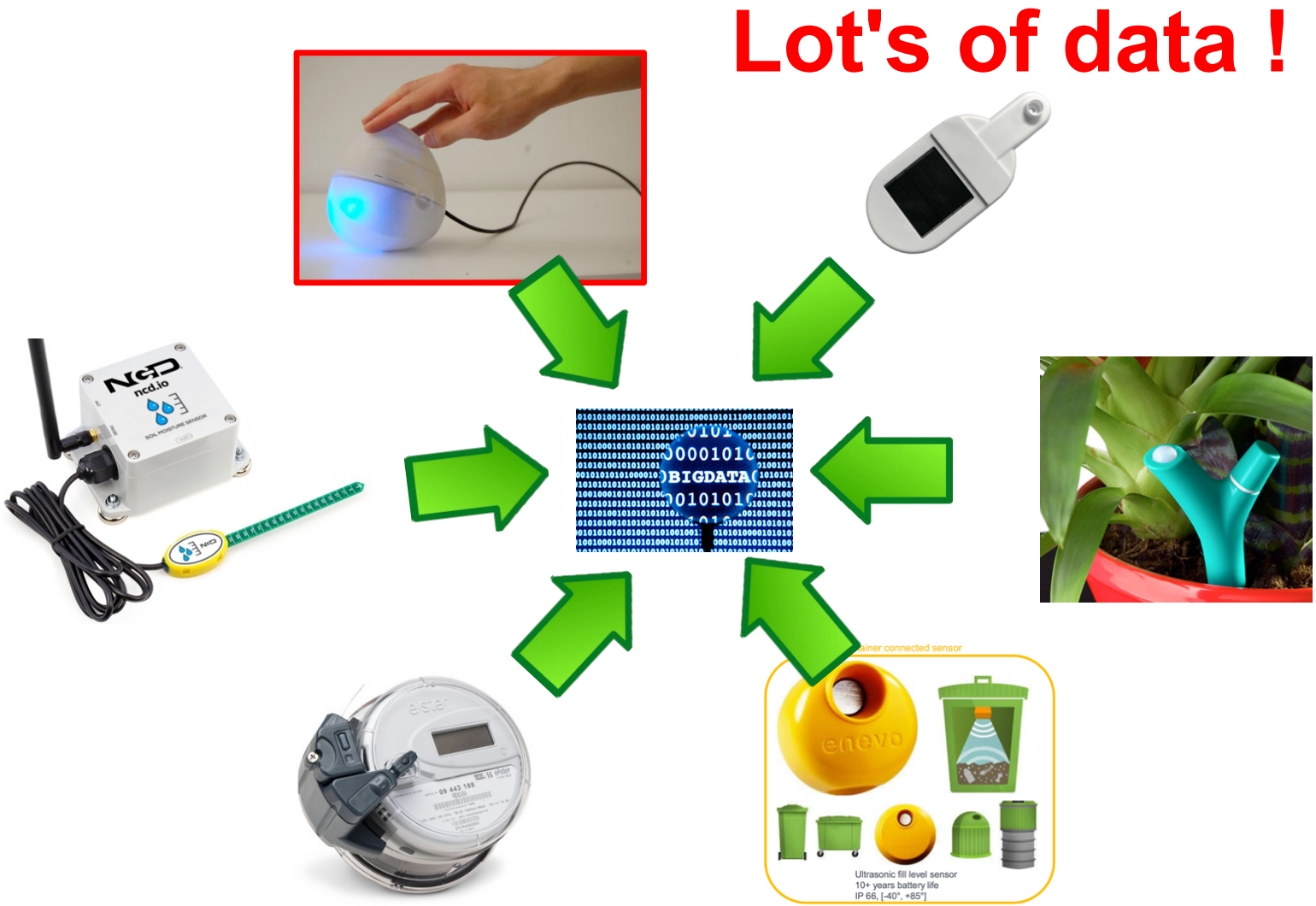
Pictures from WiThing, https://www.withings.com/eu/fr/products/body

Local interaction is possible…

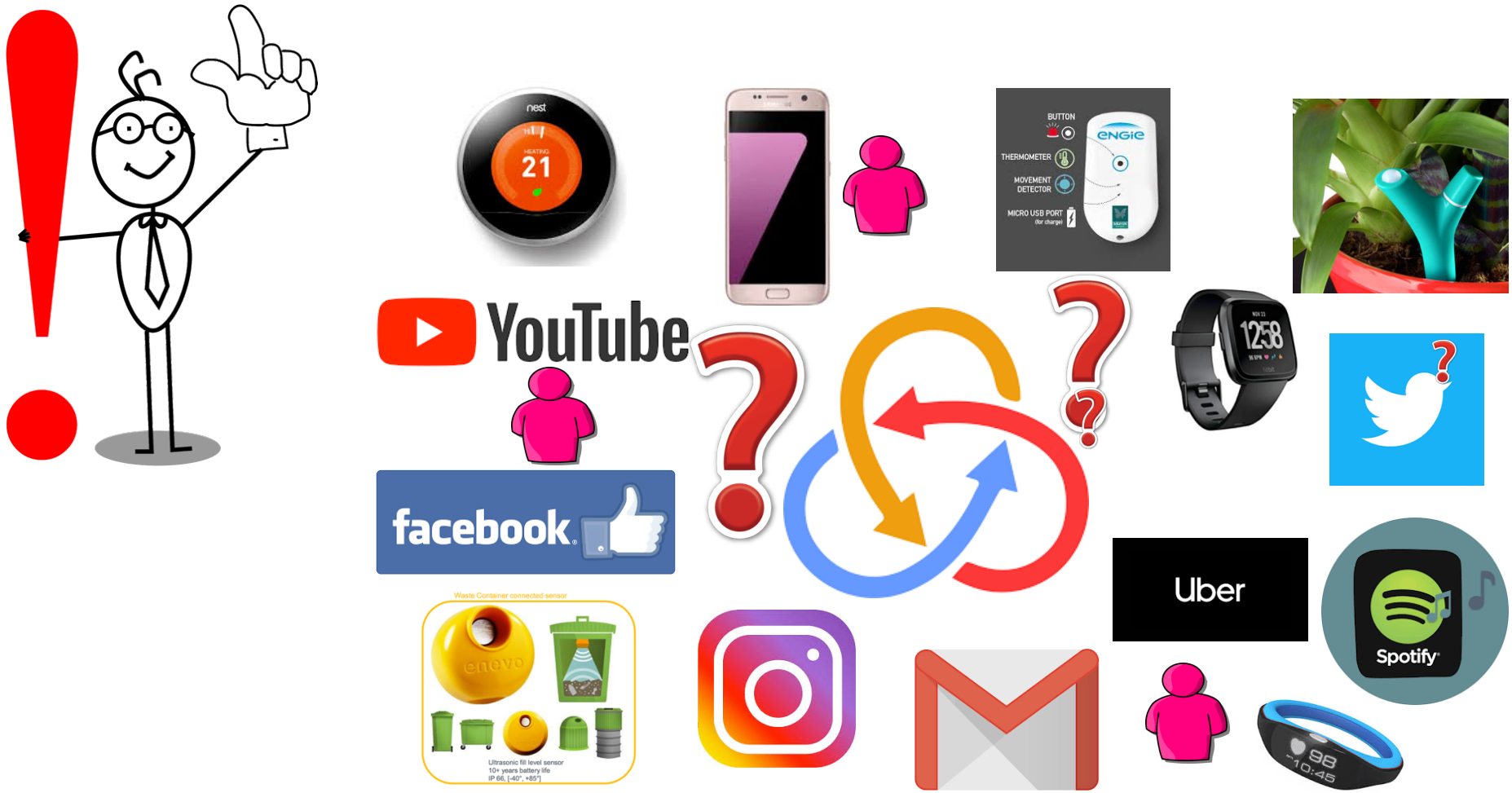


Q: Where is the real power of data?

… but IoT usually means cloud data



IoT added-values come from interactions and linked data!



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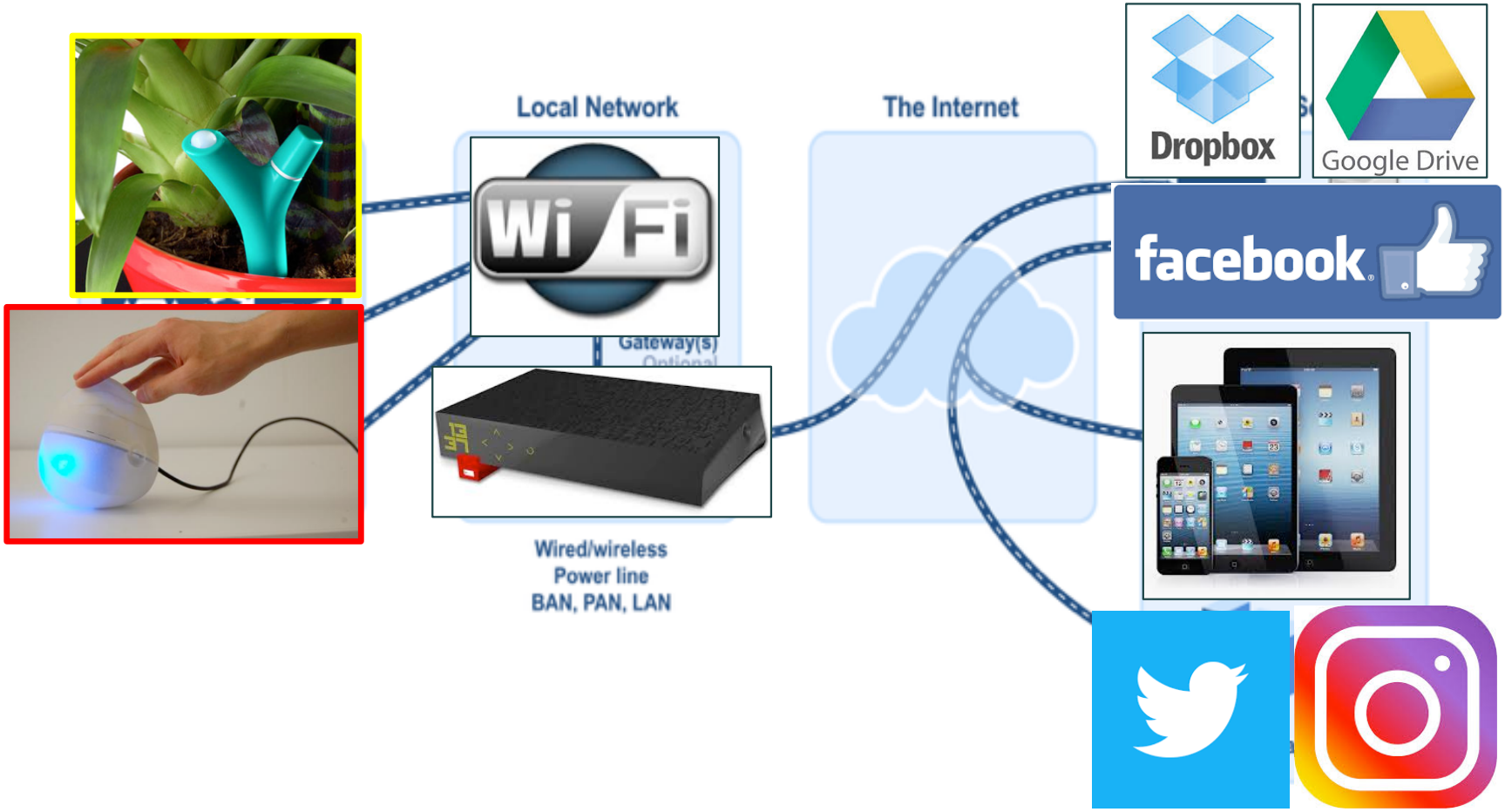
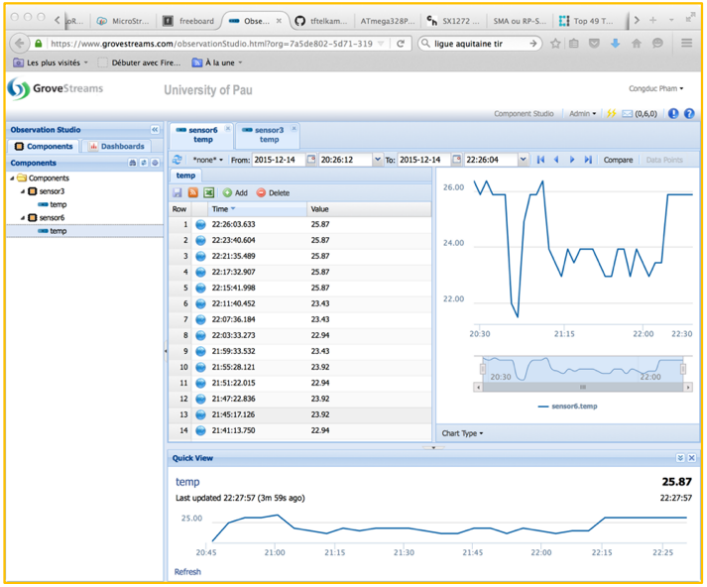
General public IoT architecture



Pictures from ArchitectCorner

IoT cloud and visualization tools

Firebase
FIWARE
Axēda
ioBridge
Connect things.
ThingSpeak
GroveStreams
SensorCloud™
freeboard
dweet.io
OpenRemote
TempoIQ



Sense, Monitor, Optimize & Control

DATA ANALYSIS, OPTIMIZATION & CONTROL

MONITORING

SENSING PHYSICAL WORLD INTERACTION

APPLICATION DOMAINS

Firebase

FIWARE

Axēda

ioBridge Connect things.

ThingSpeak

GroveStreams

SensorCloud

freeboard

dweet.io

OpenRemote

TempoIQ

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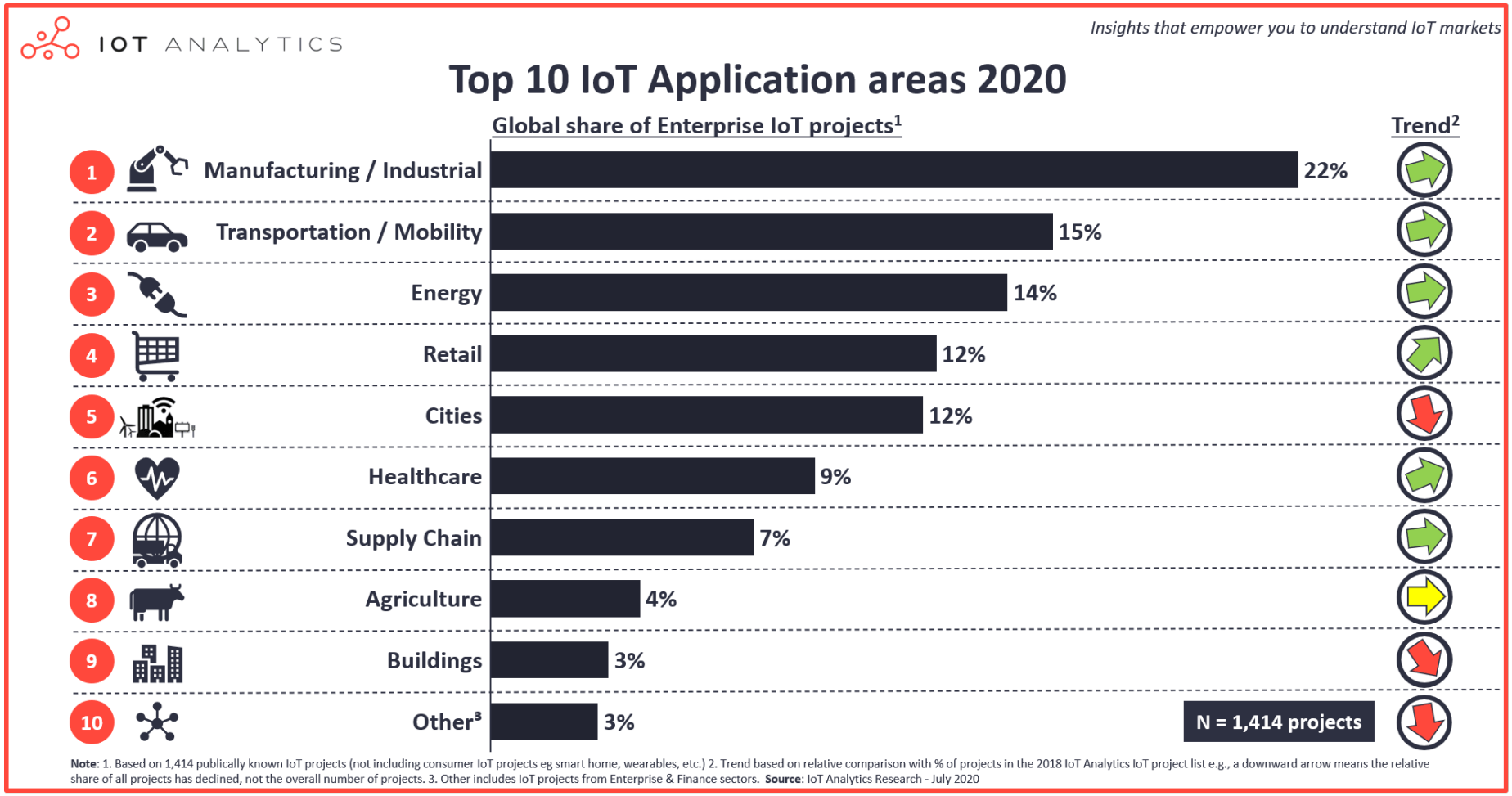
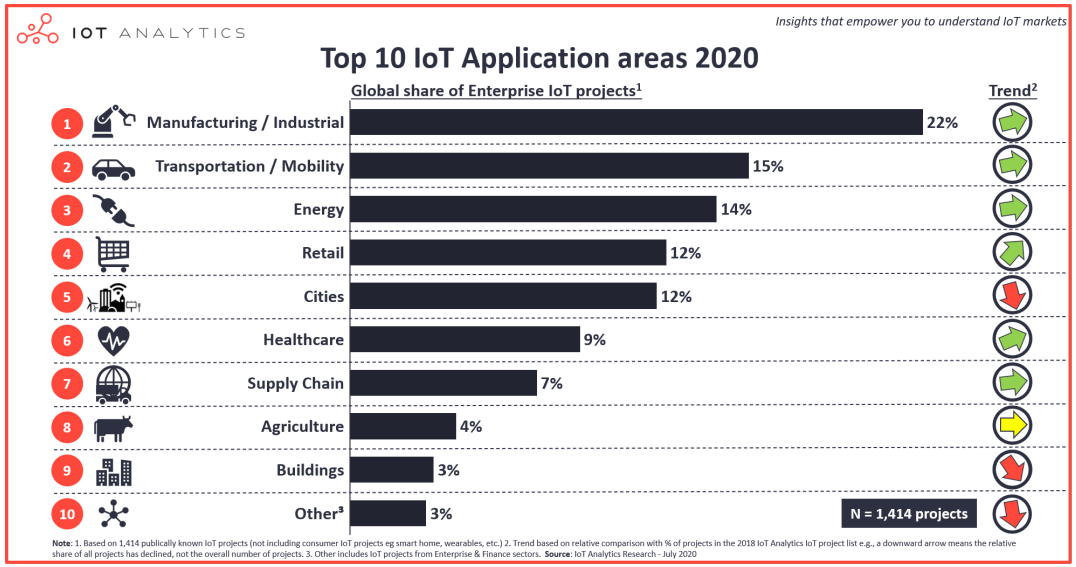
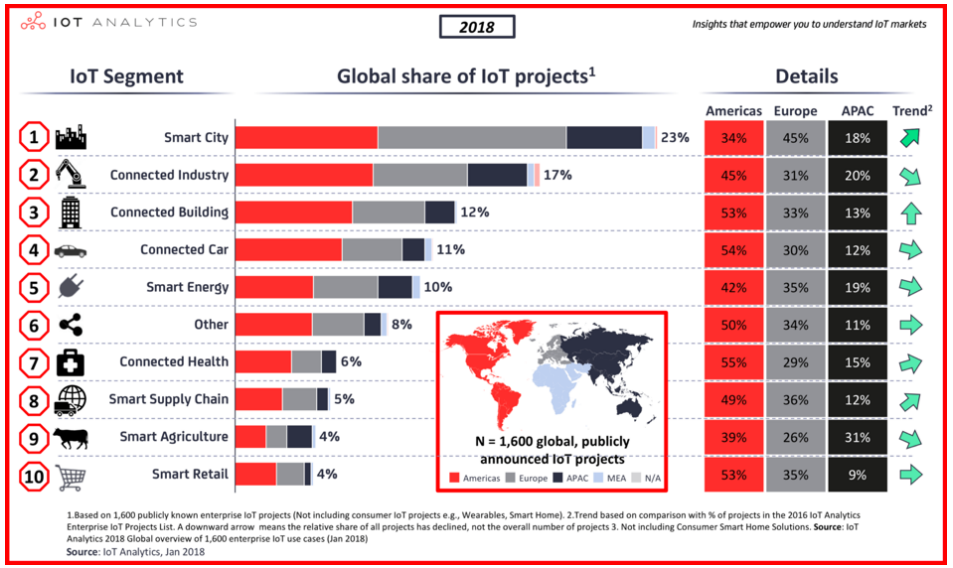
Top IoT applications, 2020



IoT: 2020 vs 2018

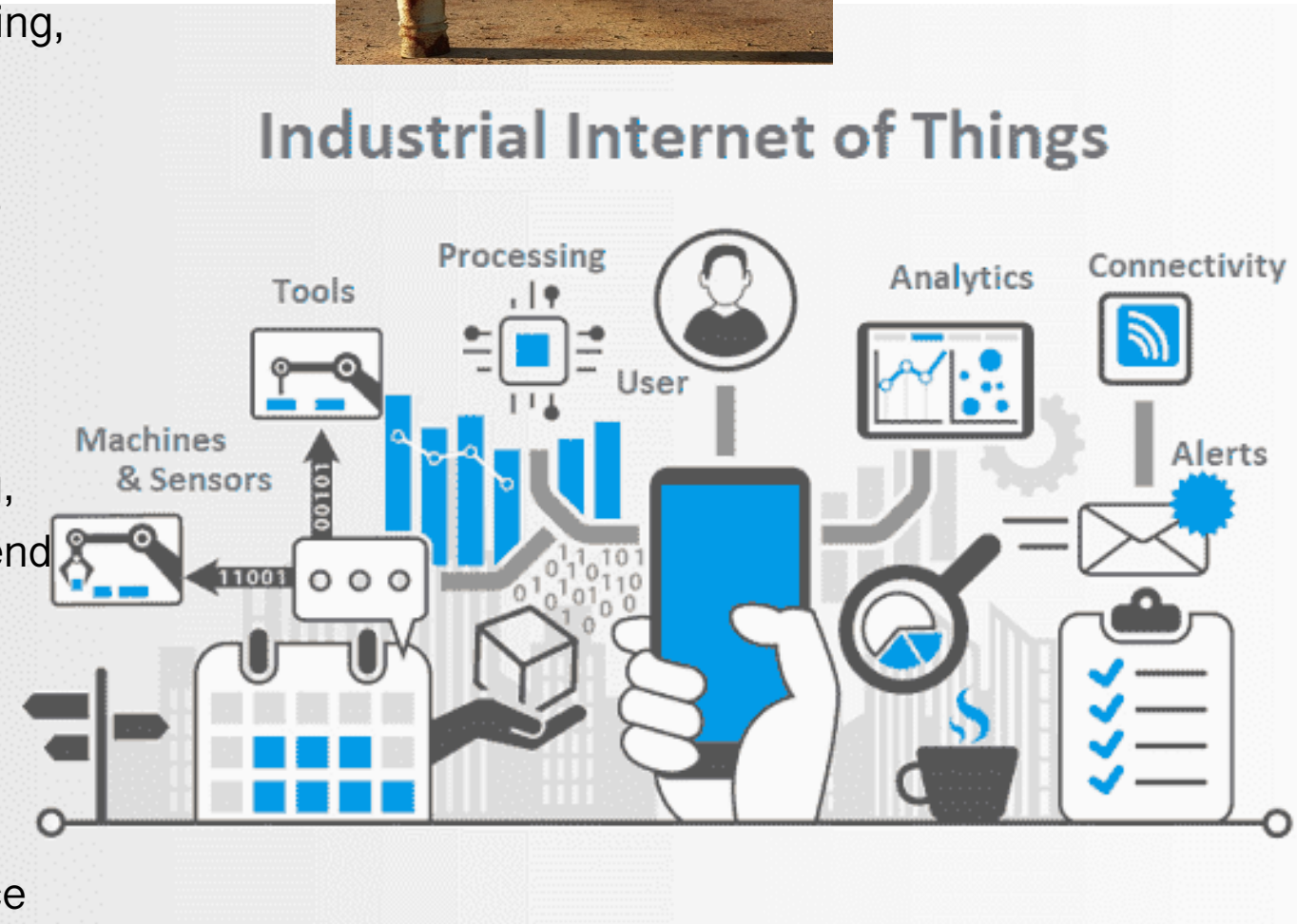




Q: Where are the differences?

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



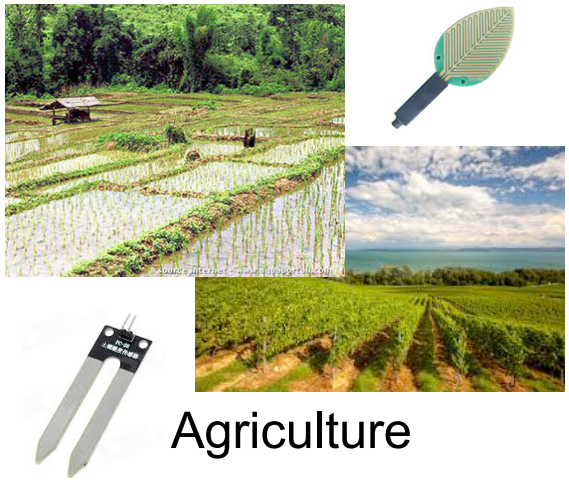
IoT for development!

Irrigation

Livestock farming

Fish farming & aquaculture

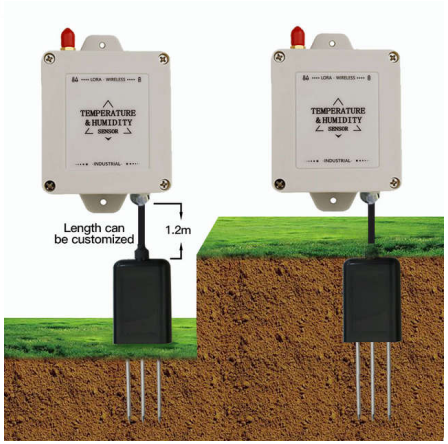
Logistic, Storage,
Asset Tracking

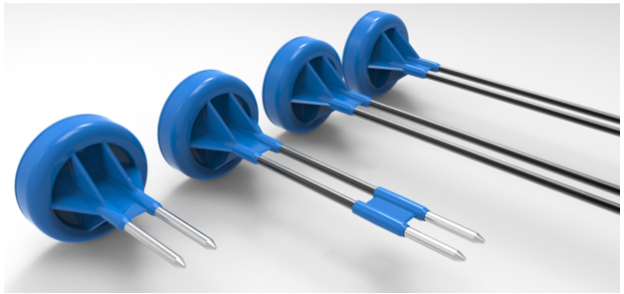


Agriculture

Fresh water

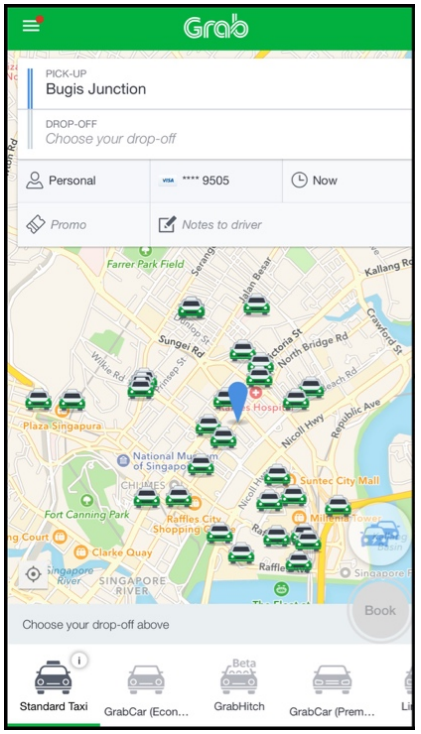
e.g. Smart Agriculture





Is IoT the solution for your problem?

Q: How would you implement a real-time positioning system of city buses?



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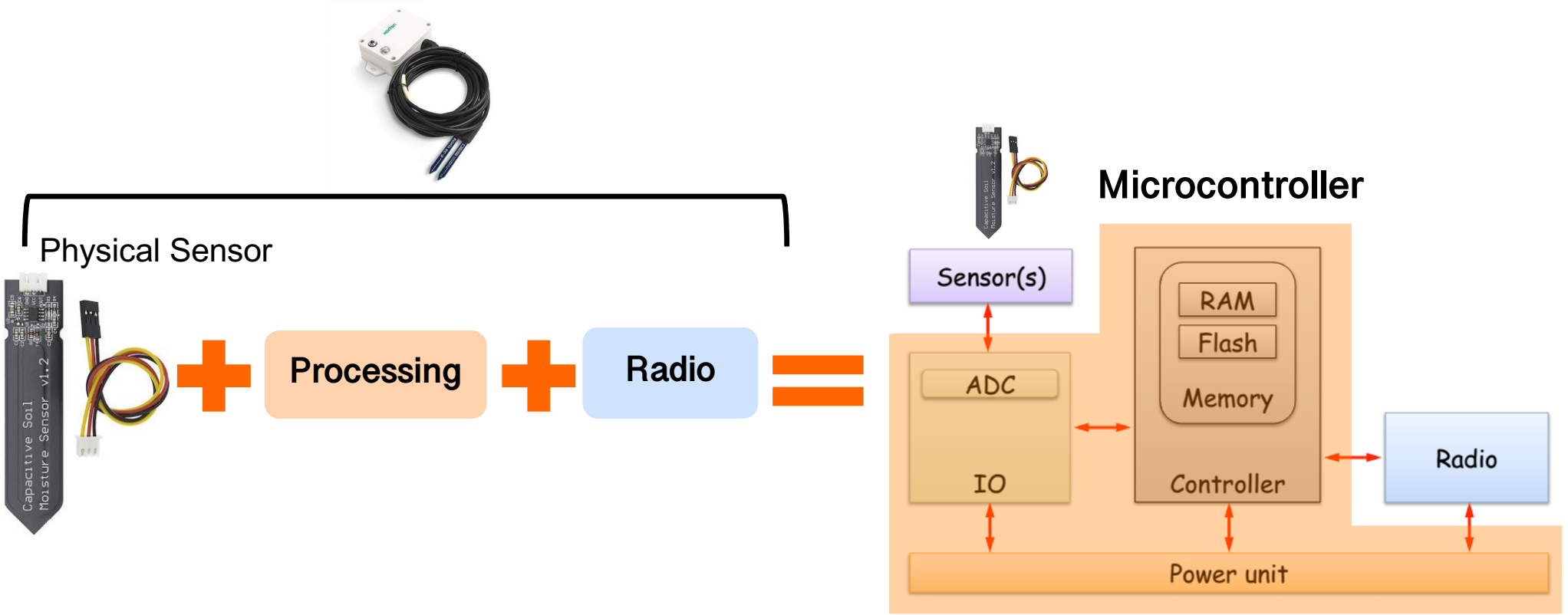
Is IoT the solution for your problem?

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

ITU Telecom World 2018
Phathwa Senene at MTN booth

Typical IoT device

- IoT device can be viewed as a simple Embedded System

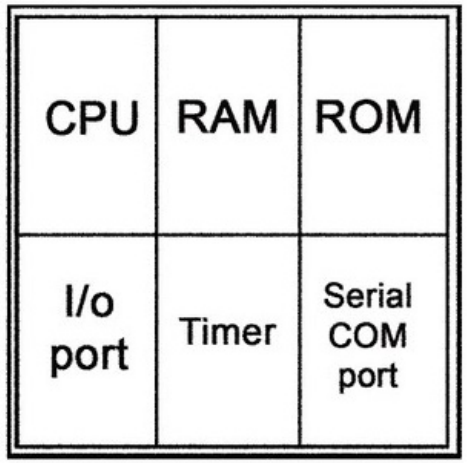


Q: uprocessor vs ucontroller?

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

VS

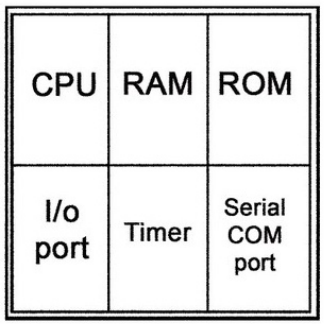


(Single chip)

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

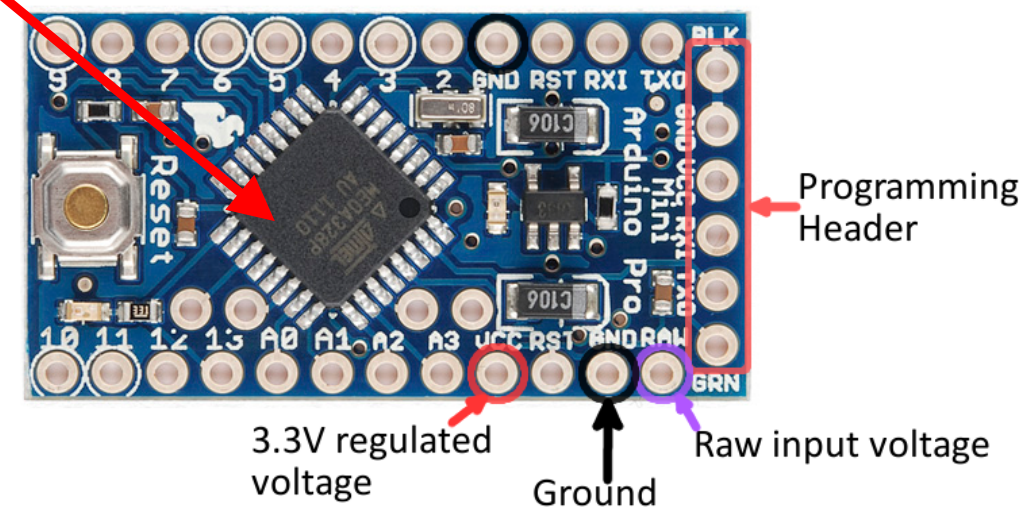
From µcontroller to µcontroller board

- A µcontroller can be standalone…



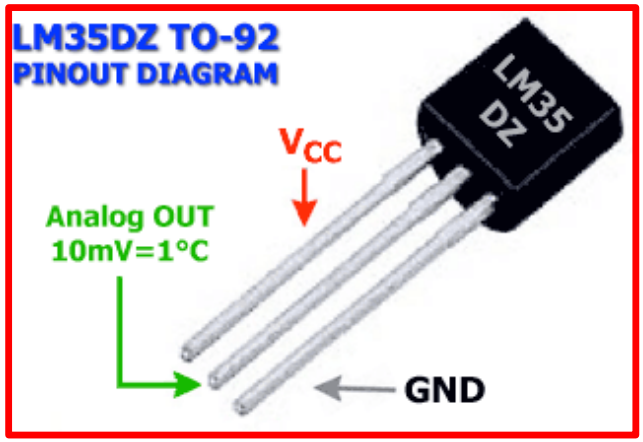
(Single chip)

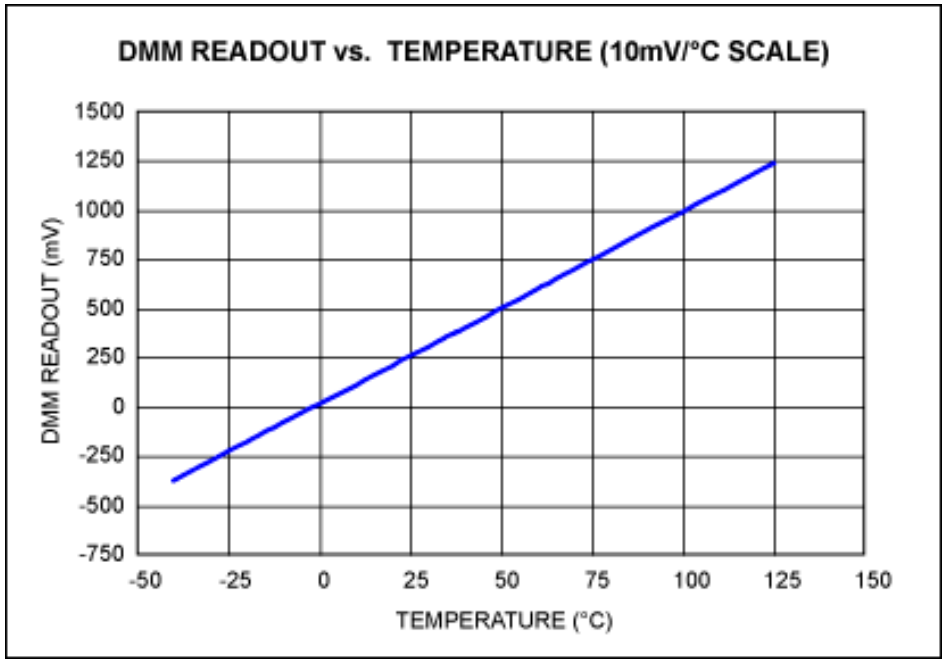
- But, it is usually mounted on a board with additional electronics parts
  - Leds, Voltage regulators
  - Easy access to pins
  - Reset button
  - Serial-USB interface



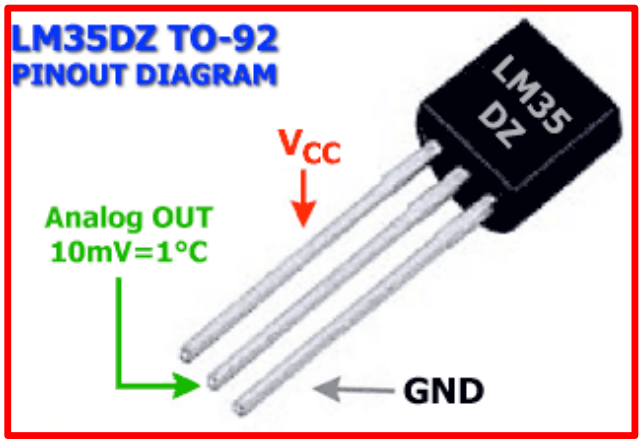
Understanding simple analog sensor

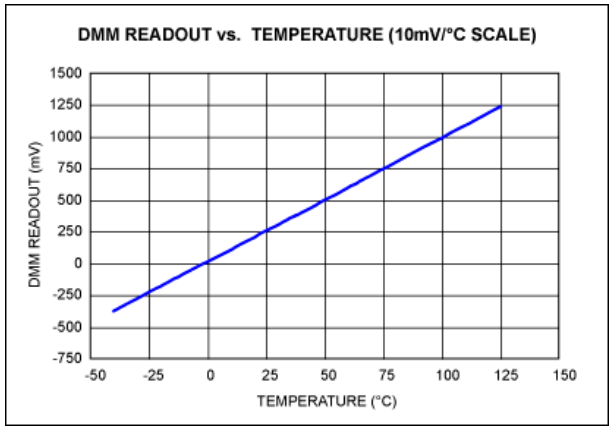
- Analog sensors provides a voltage output that varies according to a physical parameter, e.g. temperature, humidity, luminosity,...

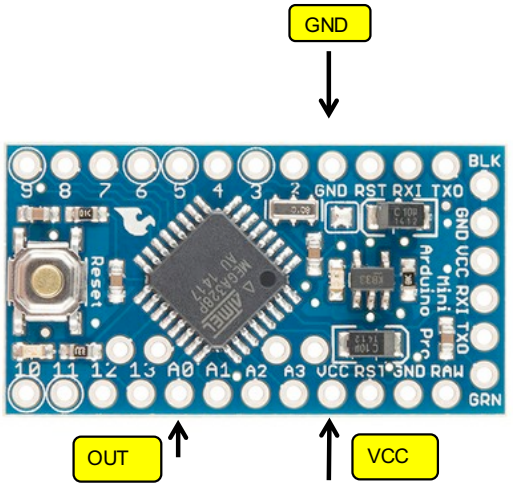




Digitalizing the real world!







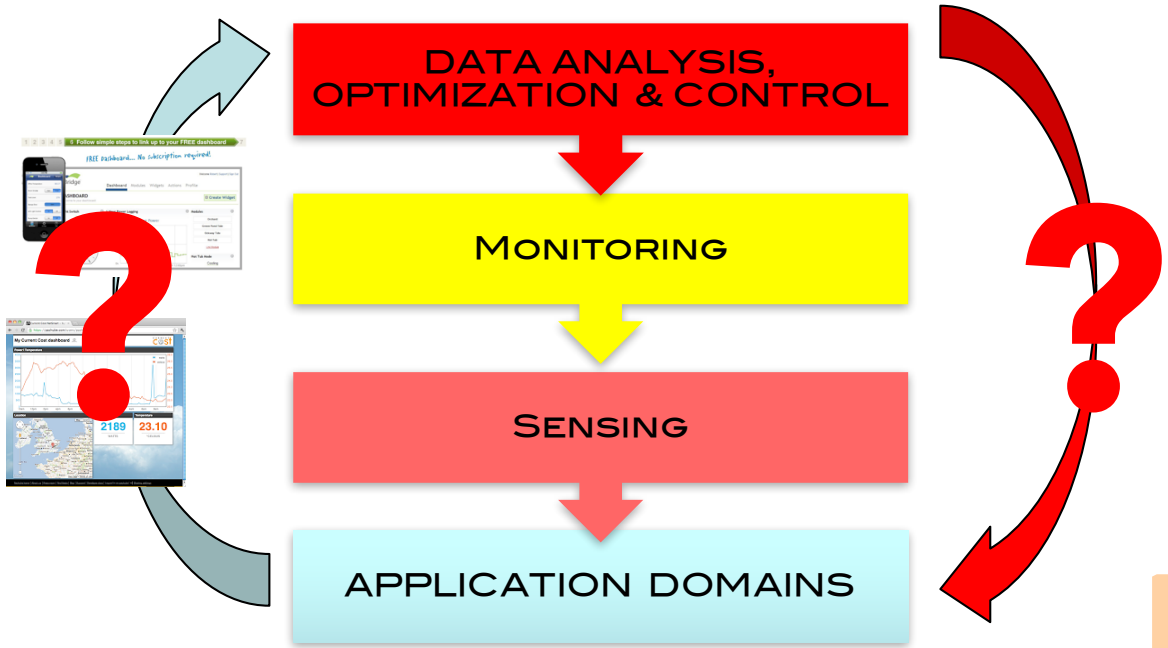
Vcc is typically 3.3V. Microcontrollers have Analog/Digital (A/D) converter to map a voltage to a numerical value. **A/D with 10-bit resolution give values in [0, 2^{10}-1] = [0, 1023]**

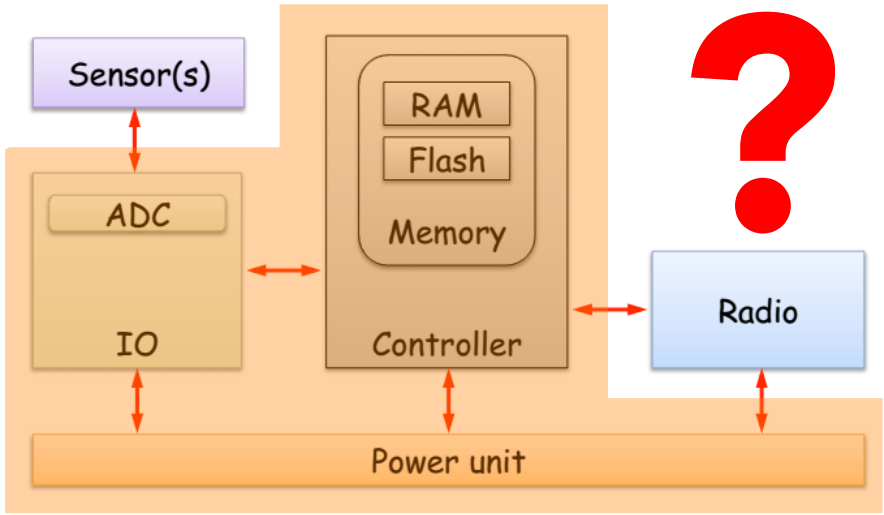
If 0=0V and 1023=3300mV then **3300mV/1024=3.22mV is the granularity of the measure**

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

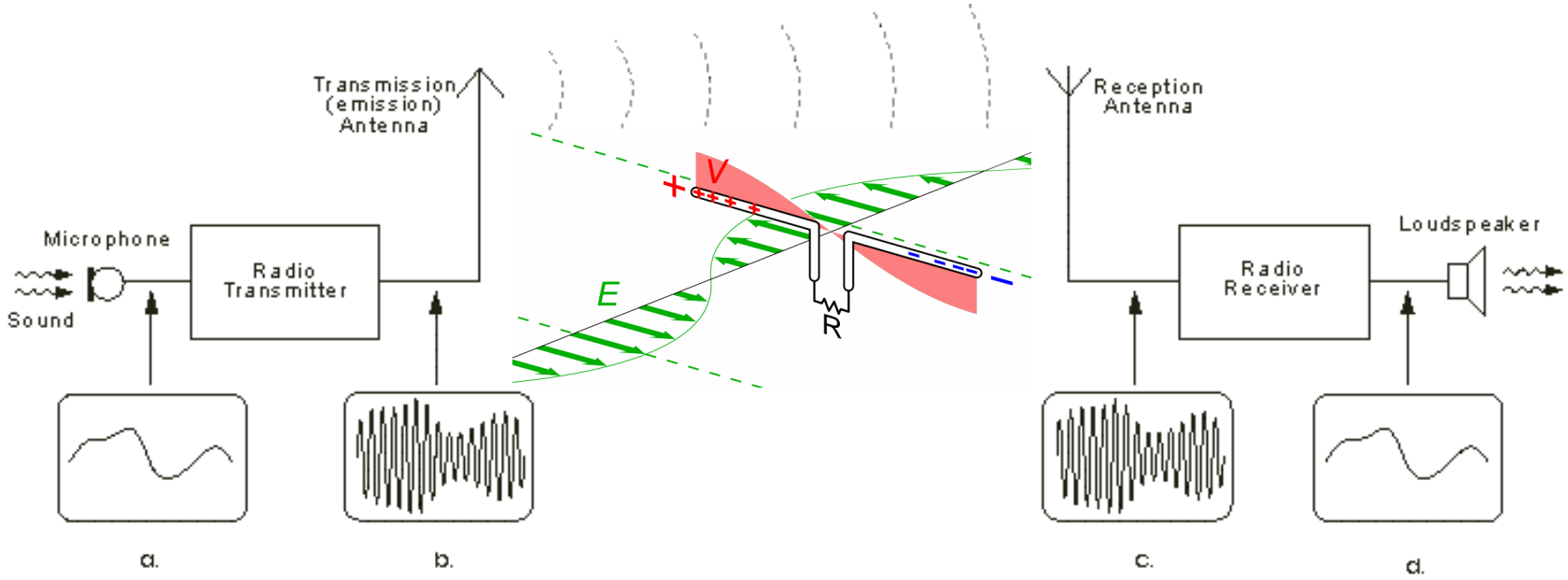
How to collect data?

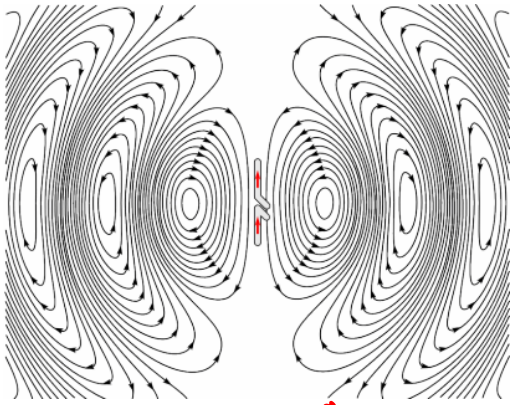


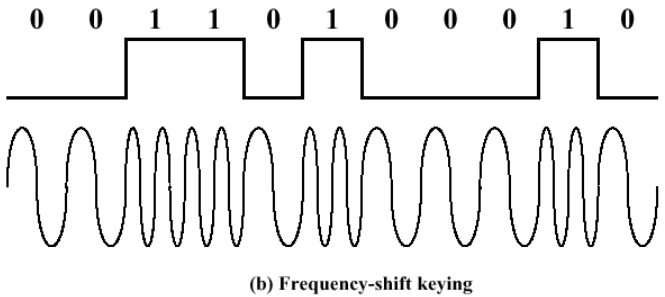


Microcontroller

Wireless (radio) transmission basics







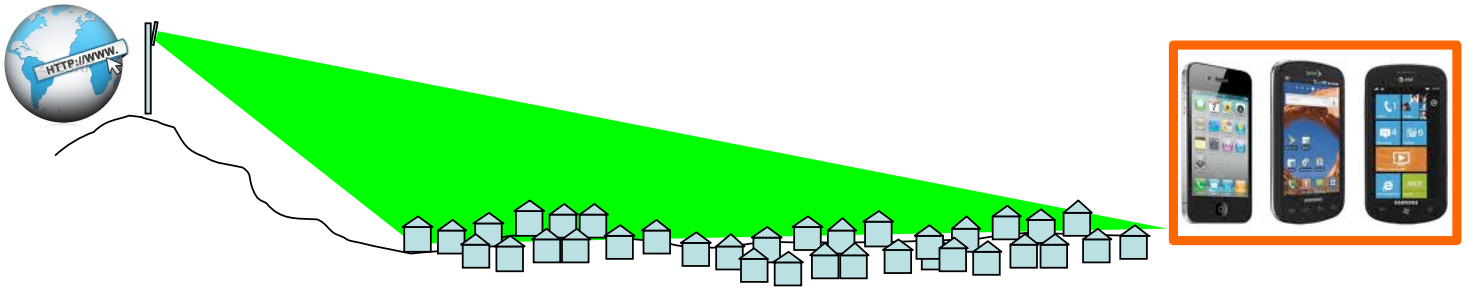
Q: Can we have Gbps in wireless?

The real limitation in wireless

Moisture/
Temperature of
storage areas

10-15kms

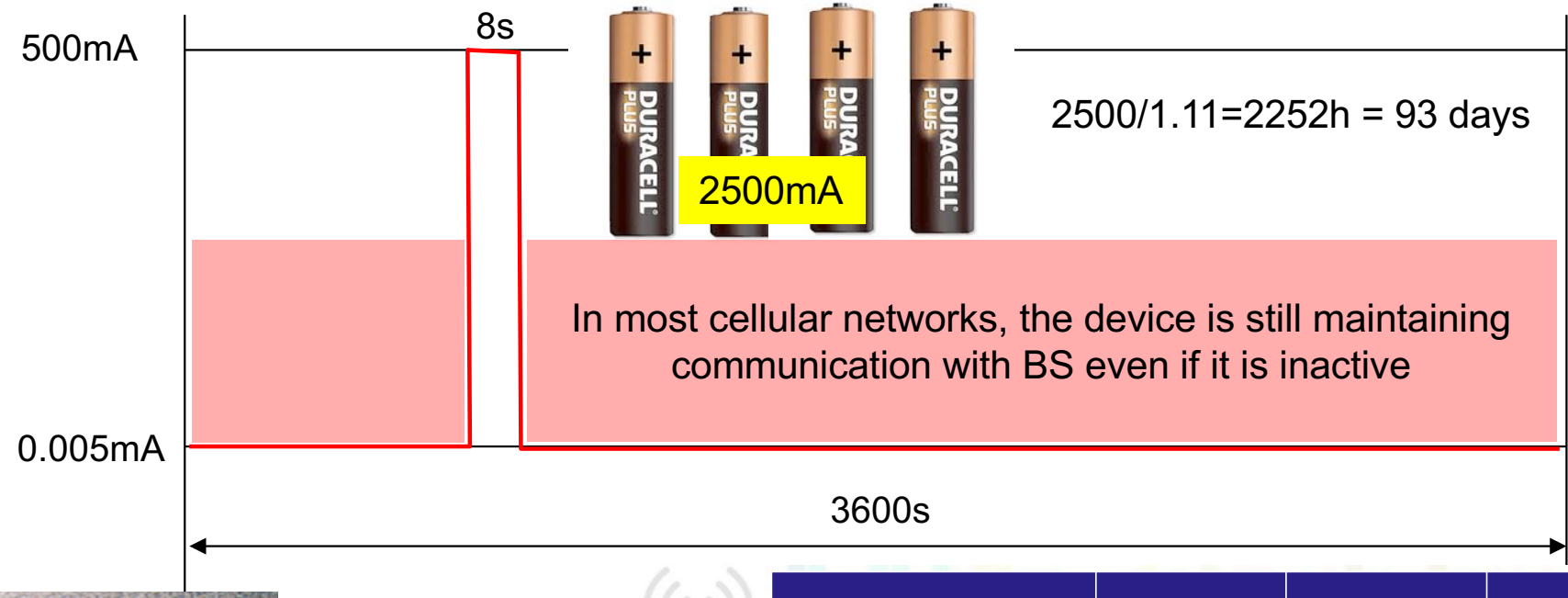
GSM GPRS

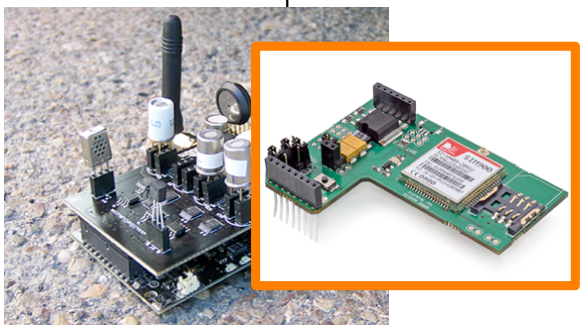


Technology	2G	3G	LAN
Range (I=Indoor, O=Outdoor)	N/A	N/A	O: 300m I: 30m
Tx current consumption	200-500mA	500-1000mA	100-300mA
Standby current	2.3mA	3.5mA	NC

Energy consideration

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





2G/3G/4G

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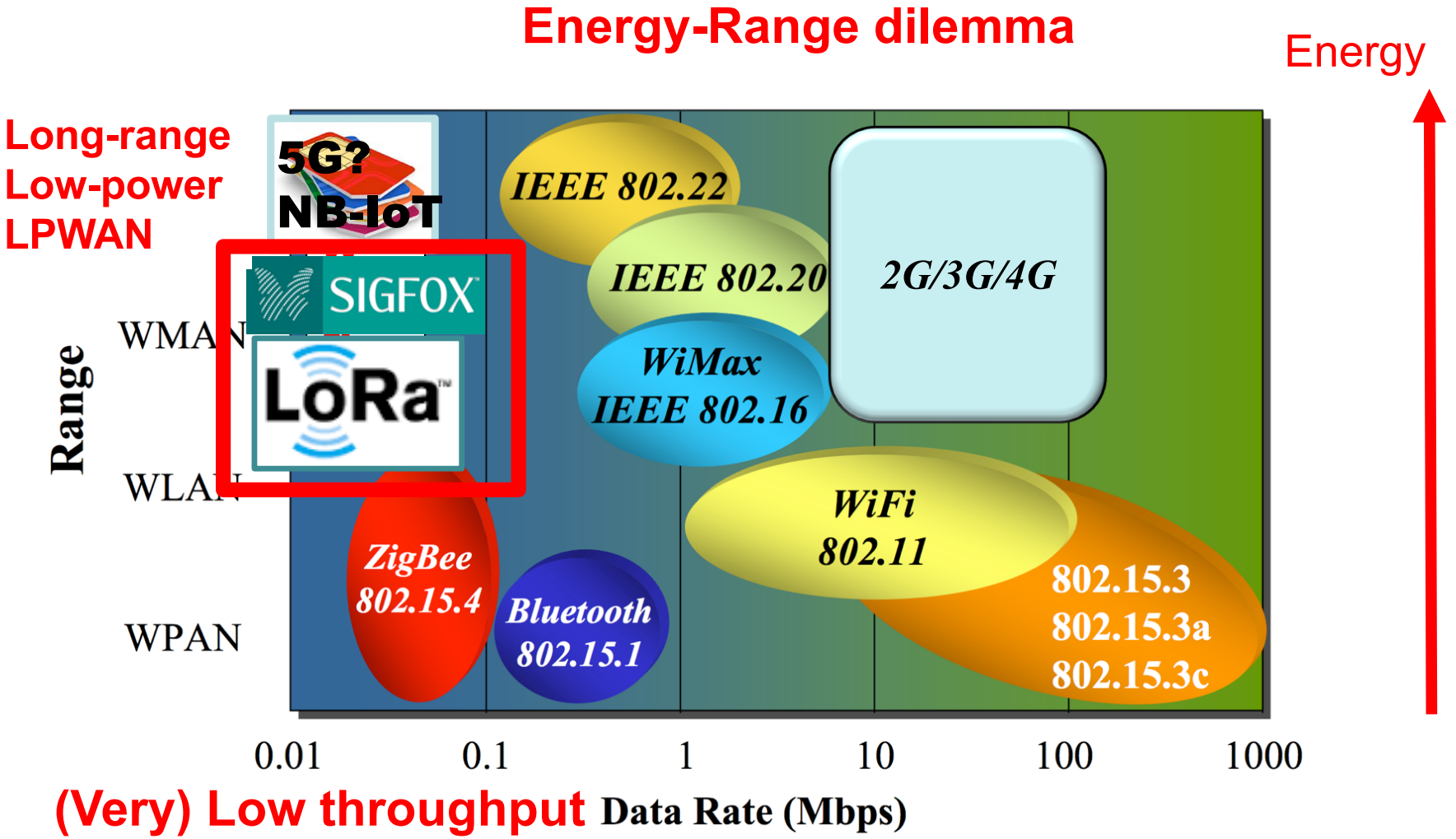
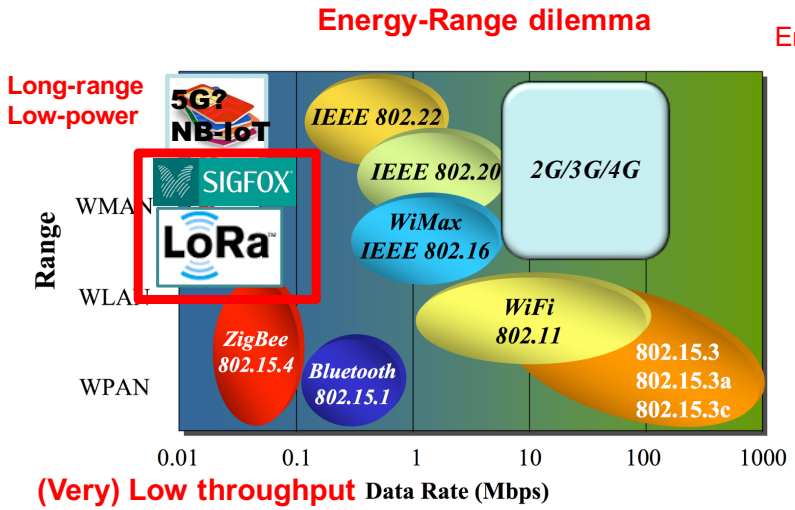
Low-power & long-range radios

Energy-Range dilemma



Energy consumption comparaison



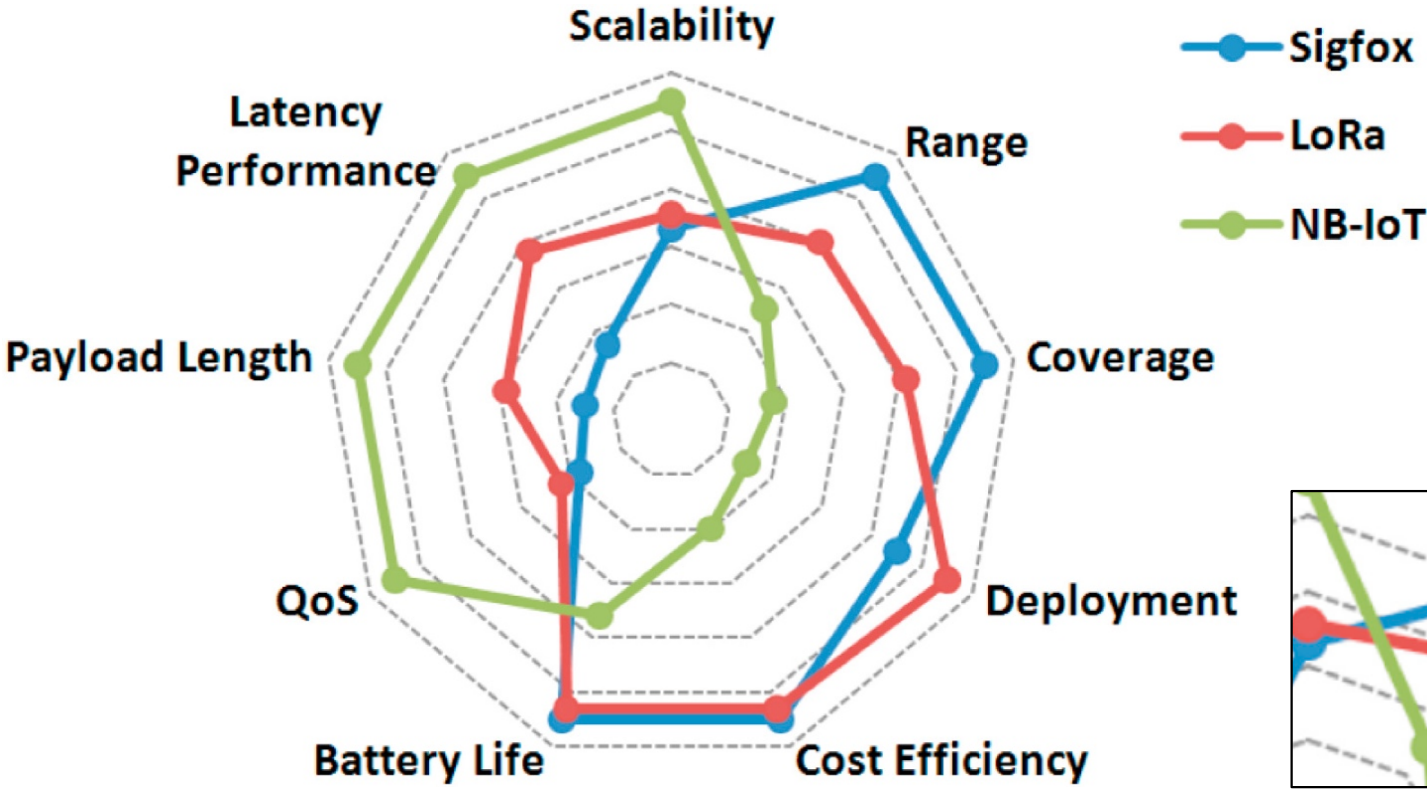
Energy

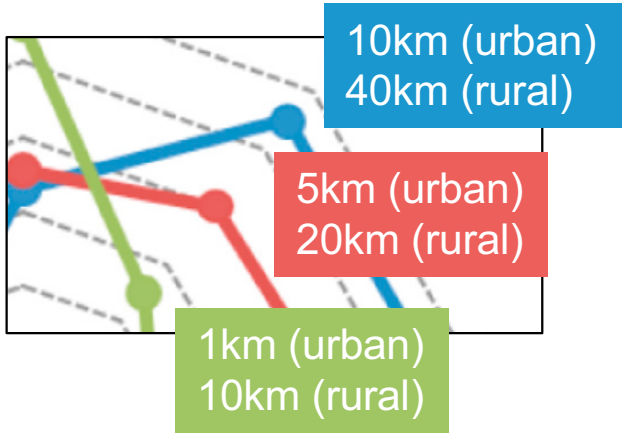
2G	3G	LAN	ZigBee	Lo Power WAN
N/A	N/A	O: 300m I: 30m	O: 90m I: 30m	Same as 2G/3G
200-500mA	500-1000mA	100-300mA	18mA	18mA-40mA
2.3mA	3.5mA	NC	0.003mA	0.001mA

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

2500/0.027=92592h = 3858 days = 10 years

LPWAN Expected range?





Attenuation in general

- 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

Attenuation in practice

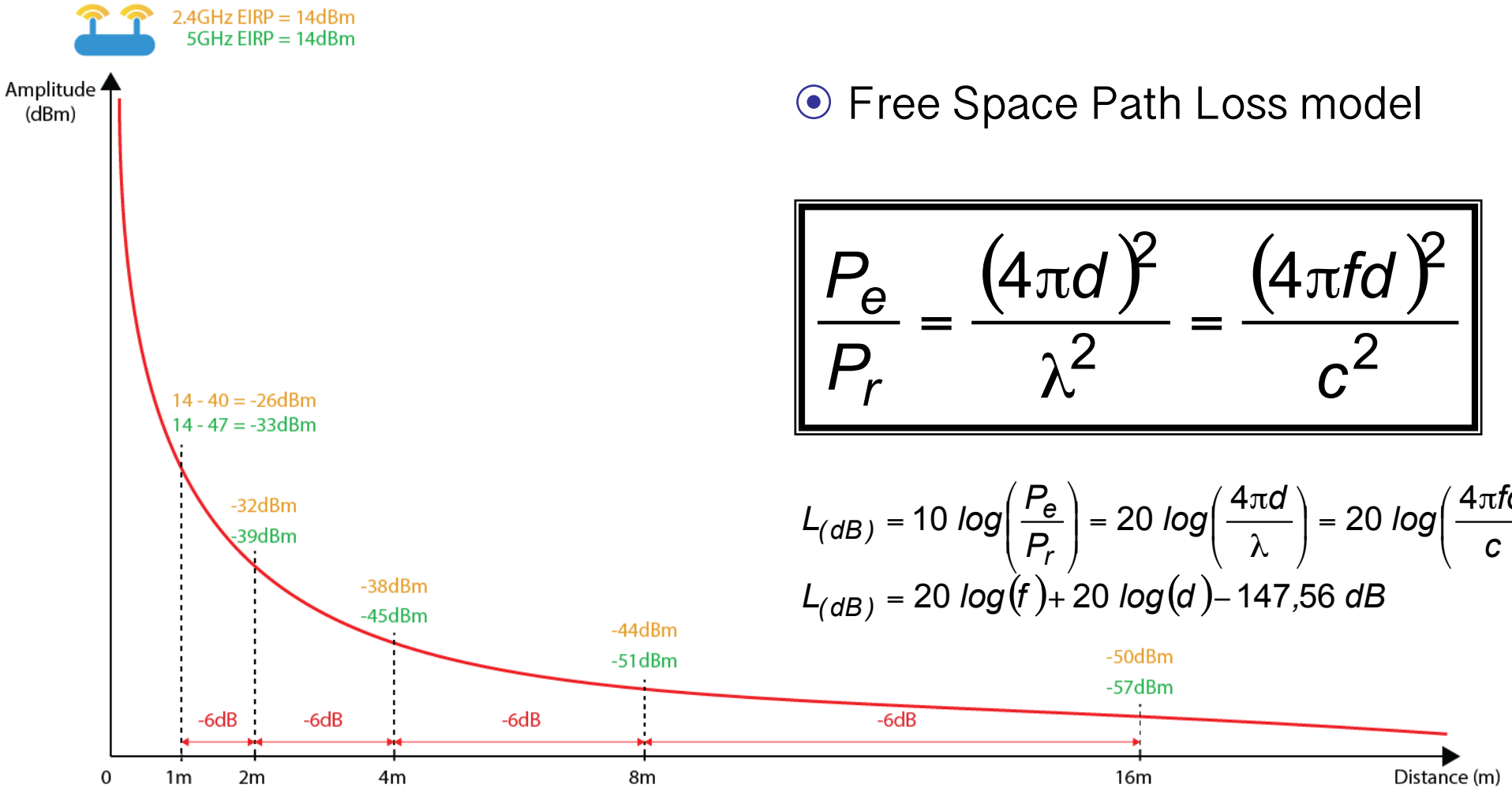
- For an ideal antenna (theoretic)

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

- P_e = transmitted power
- P_r = received power
- d = distance between antennas
- c = light speed in space 3.10^8 m/s
- λ= wave length of the signal=c/f

37

Attenuation in image



- Free Space Path Loss model

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

$$L_{(dB)} = 10\ log\left(\frac{P_e}{P_r}\right) = 20\ log\left(\frac{4\pi d}{\lambda}\right) = 20\ log\left(\frac{4\pi f d}{c}\right)$$

$$L_{(dB)} = 20\ log(f) + 20\ log(d) - 147{,}56\ dB$$

Q: who know what is dB?

Link budget in wireless system

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

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)

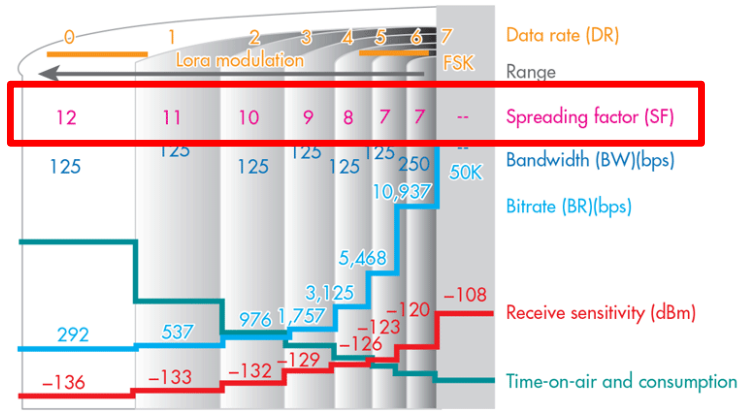
Adapted from Peter R. Egli, INDIGOO.COM

$$L_{(dB)} = 20\,log(f) + 20\,log(d) - 147{,}56\,dB$$

Receiver sensitivity is a measure of how well the receiver performs and is defined as the power of the weakest signal the receiver can detect

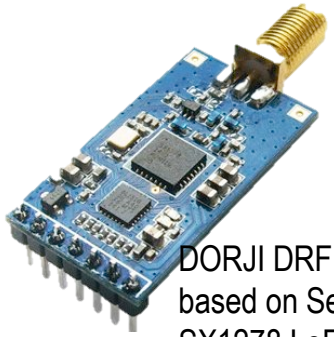
How can we increase range?

- 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)

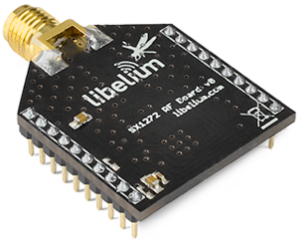


- WiFi 802.11n: 450 000 000 bps (450Mbps)
- WiFi 802.11g: 54 000 000 bps (54Mbps)
- Bluetooth3&4: 25 000 000 bps (25Mbps)
- Bluetooth BLE: 2 000 000 bps (2Mbps)
- 3G/4G : 20Mbps-200Mbps
- LoRa : 200bps-37500bps (0.0002-0.0375Mbps)
- 3G/LoRa ratio: 20,000,000bps/200bps=100000!

LoRa modules with Semtech's SX127x



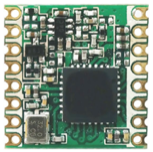
DORJI DRF1278DM is based on Semtech SX1278 LoRa 433MHz



Libelium LoRa is based on Semtech SX1272 LoRa 863-870 MHz for Europe

inAir9 based on SX1276

Froggy Factory LoRa module (Arduino)

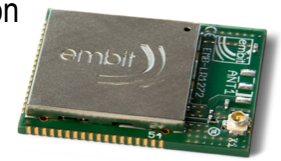


HopeRF RFM series

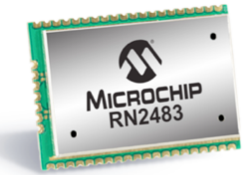
HopeRF HM-TRLR-D

LinkLabs Symphony module

IMST IM880A-L is based on Semtech SX1272 LoRa 863-870 MHz for Europe



Embit LoRa



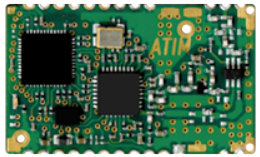
Microship RN2483

Adeunis ARF8030AA- Lo868

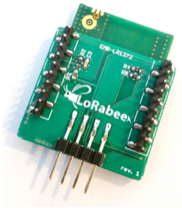
habSupplies

Multi-Tech MultiConnect mDot

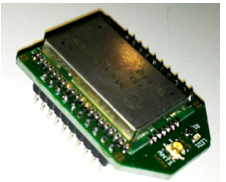
AMIHO AM093



ARM-Nano N8 LoRa module from ATIM



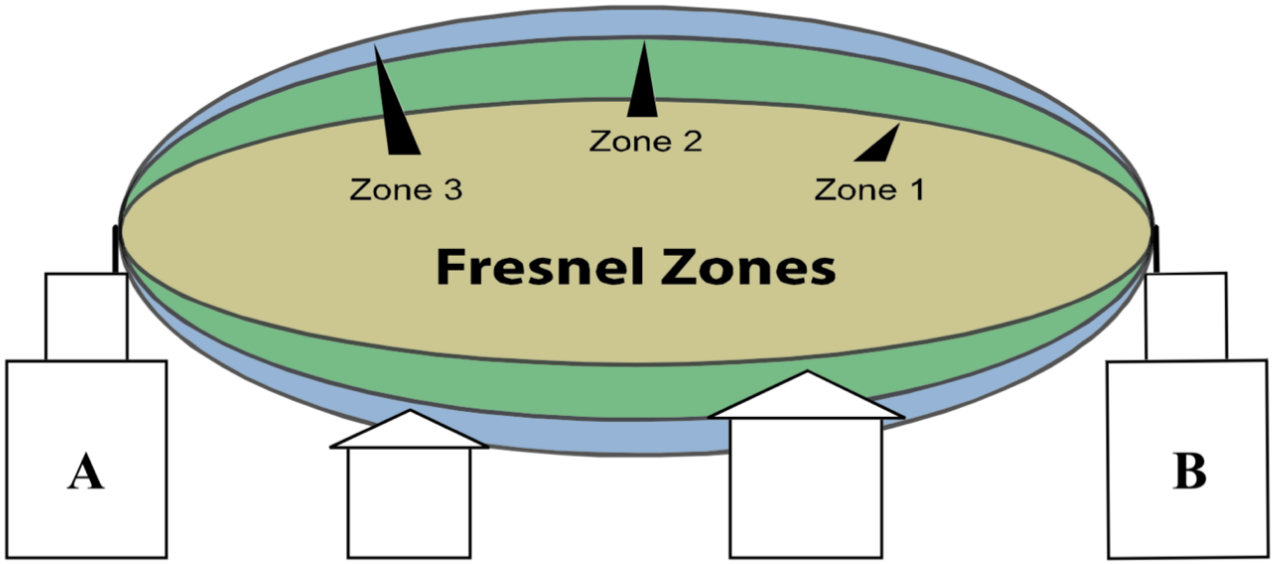
SODAQ LoRaBee Embit



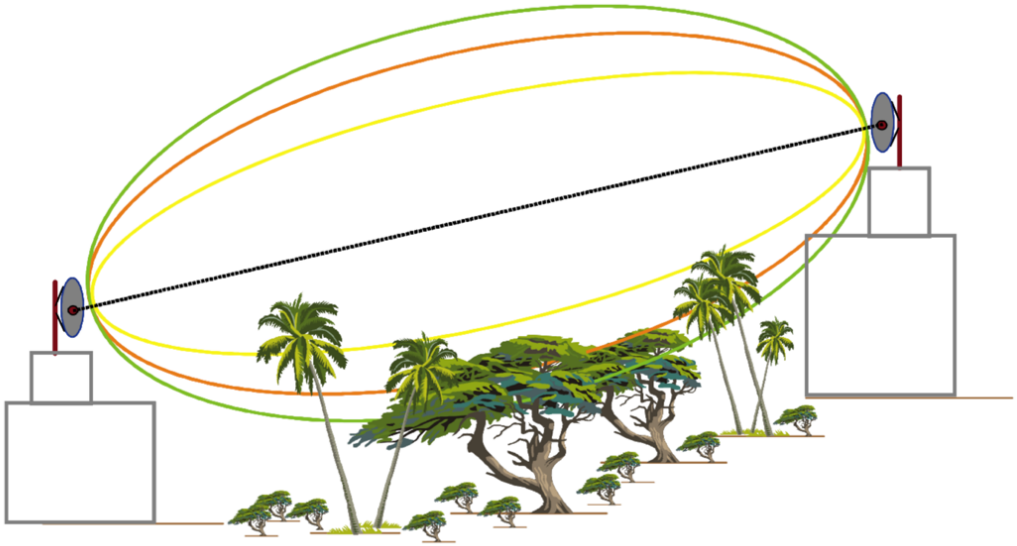
SODAQ LoRaBee RN2483

Line-of-Sight & Fresnel zone

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

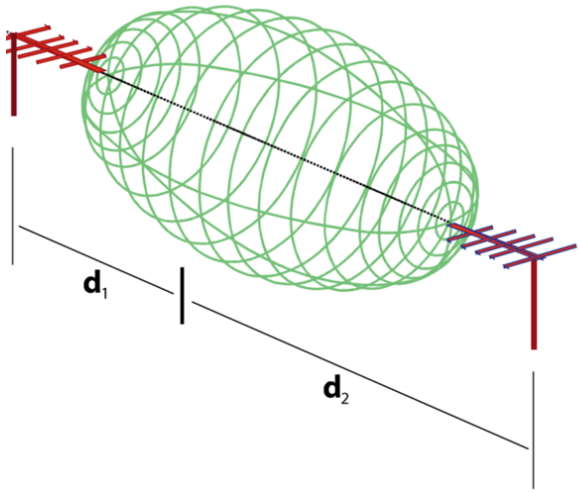


Clearing the Fresnel zone? Raise antennas!



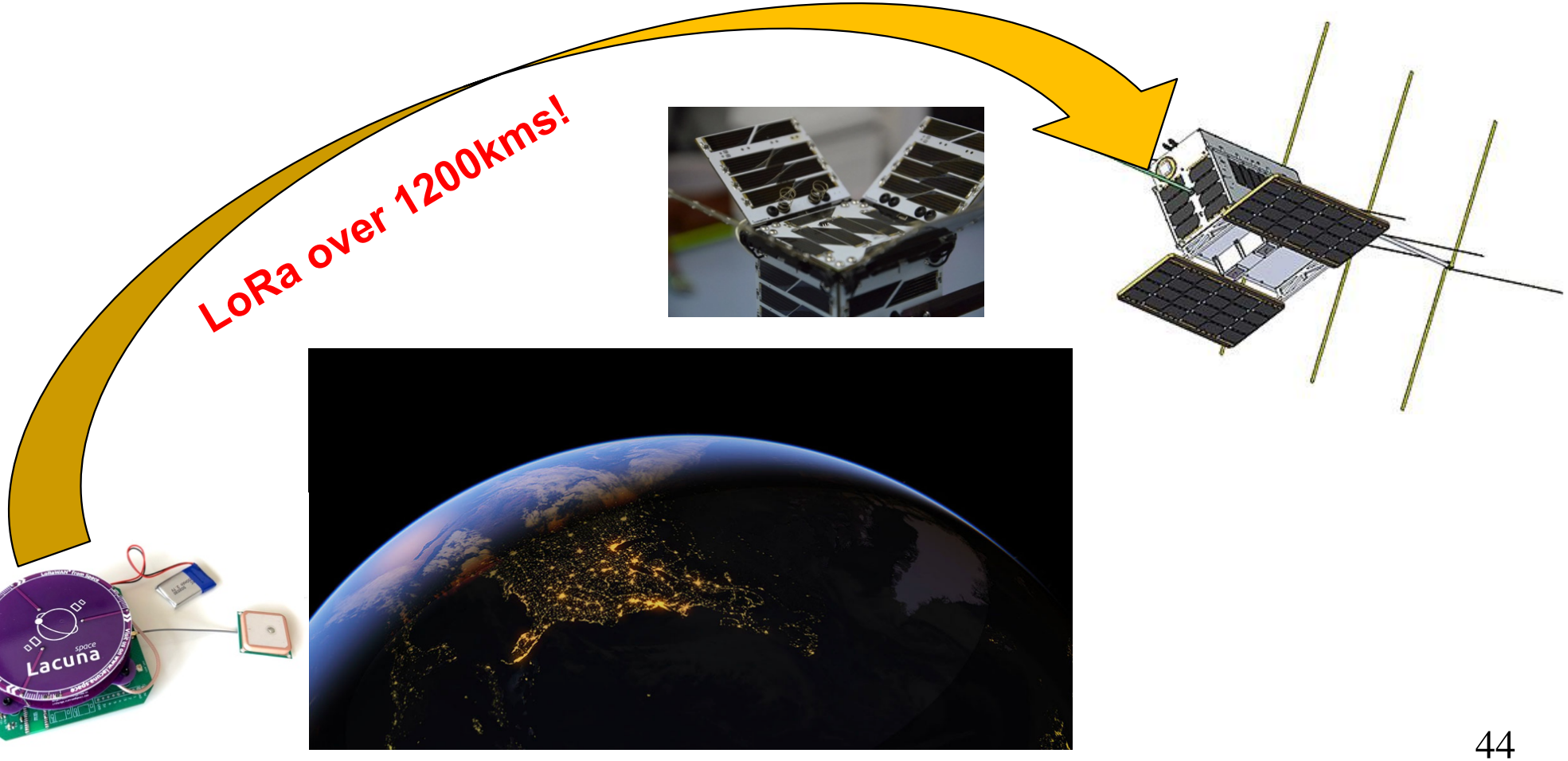
$$r_n = \sqrt{\frac{\quad}{d_1 + d_2}}$$

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)



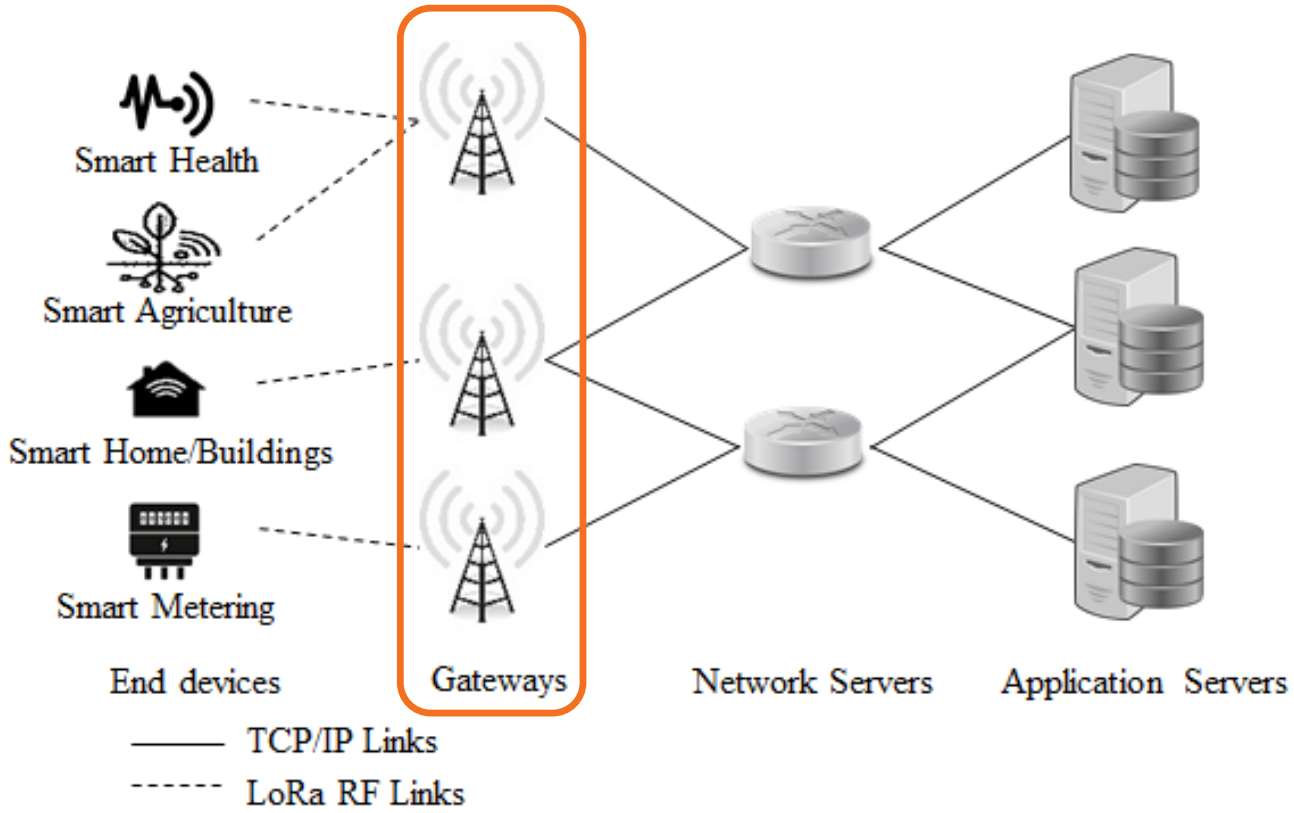
Clearing the Fresnel zone? Let's use satellite!

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

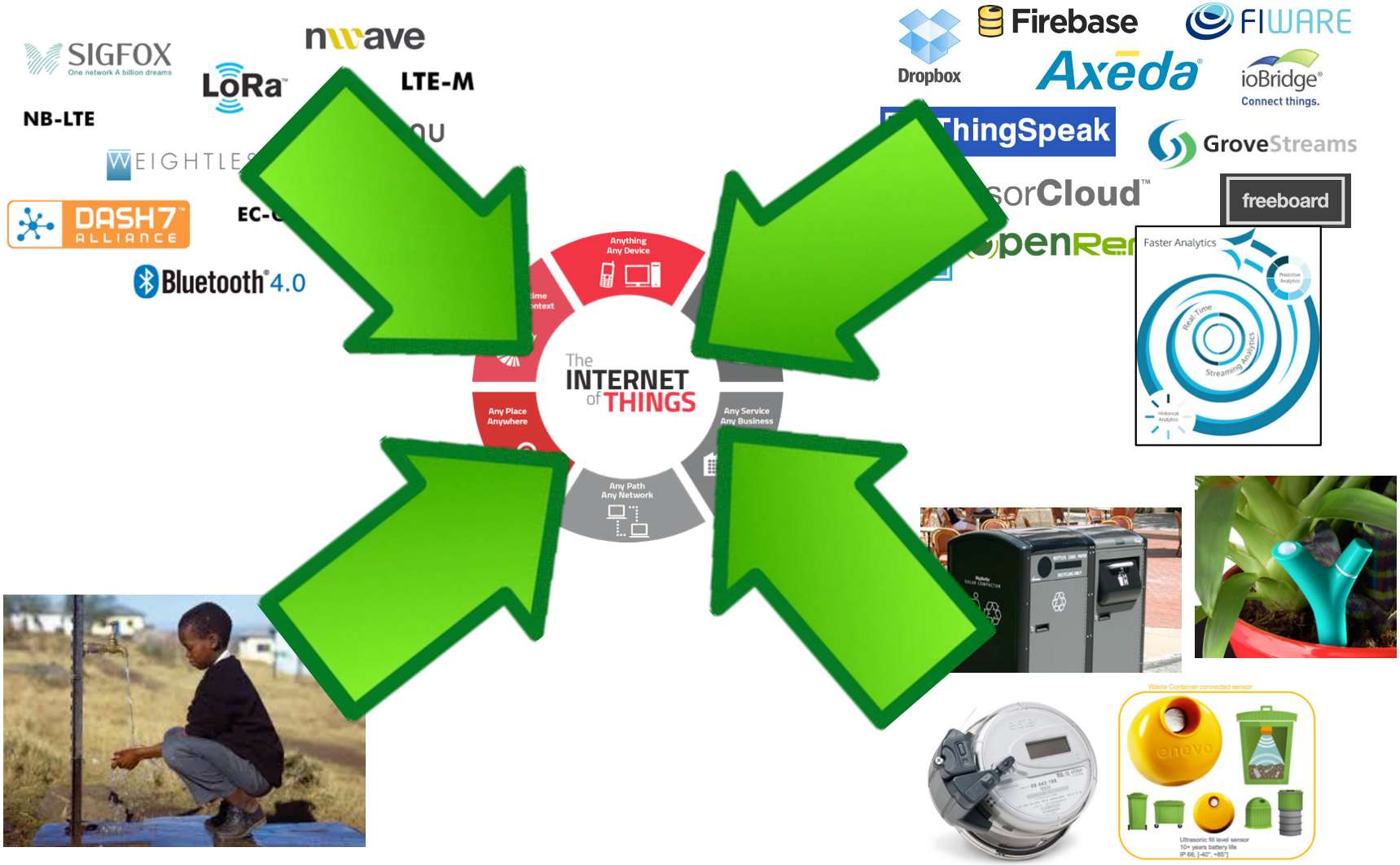


General LPWAN IoT architecture

- LPWAN architecture is gateway-centric
  - IoT gateways are connected to Internet
  - They forward data from IoT device to Internet Servers



IoT becomes reality!



A reality for everybody?

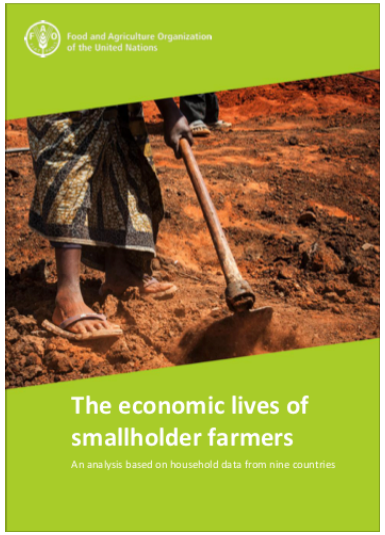
IoT in developing countries?

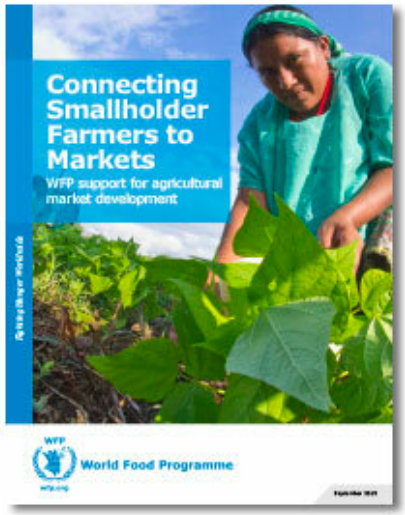
Too expensive
Too integrated
Highly specialized
Difficult to customize
Difficult to upgrade

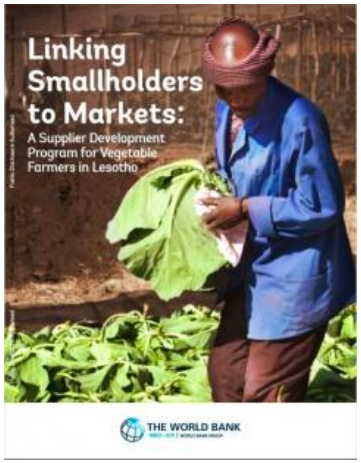
Smallholders: the next decade challenge!

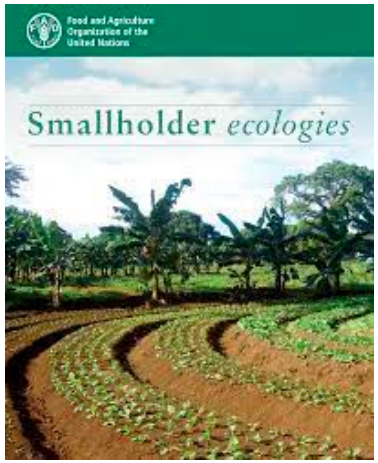
Smallholders are small-scale farmers, pastoralists, forest keepers, fishers who manage areas varying from less than one hectare to 10 hectares. Smallholders are characterized by family-focused motives such as favouring the stability of the farm household system, using mainly family labour for production and using part of the produce for family consumption.

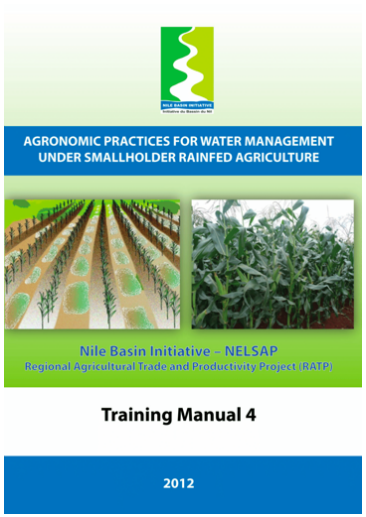
Eighty percent of the farmland in sub-Saharan Africa and Asia is managed by smallholders (working on up to 10 hectares). While 75 percent of the world's food is generated from only 12 plants and 5 animal species, making the global food system highly vulnerable to shocks, biodiversity is key to smallholder systems who keep many rustic and climate-resilient varieties and breeds alive.





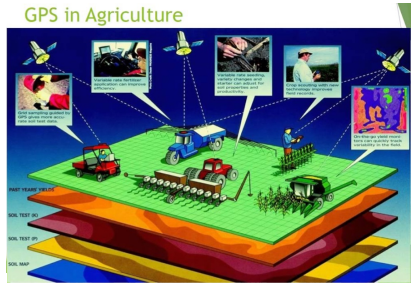


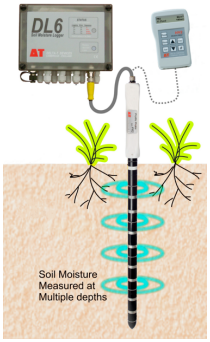




Adapting technological solutions

Many commercial systems are not adapted for developing countries, rural areas, smallholders



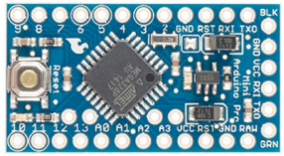


Low-cost IoT!


ABOUT »
TECHNOLOGIES »
COMMUNITY
NEWS & EVENT »
DOWNLOADS
DEV KIT
FAQ
CONTACT
HORIZON 2020
AFFORDABLE
TECHNOLOGIES
TO EMPOWER
RURAL ECONOMIES

Low-cost microcontroller boards

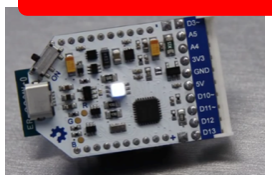
Arduino Pro Mini



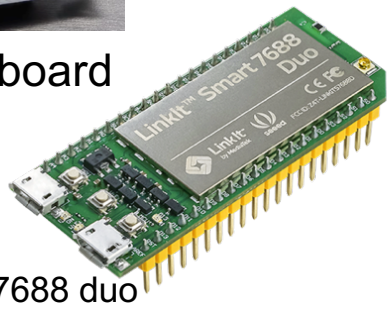
LoPy

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/



Theairboard

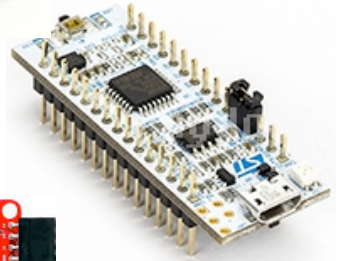


LinkIt Smart7688 duo

Expressif ESP32

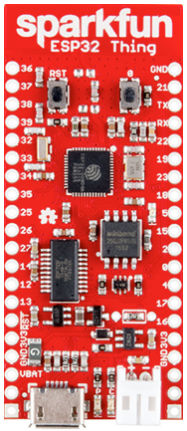
Teensy 3.2

STM32 Nucleo-32



Heltec ESP32 + OLED

Adafruit Feather



Sparkfun ESP32 Thing

Tessel

SodaqOnev2

Tinyduino

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.

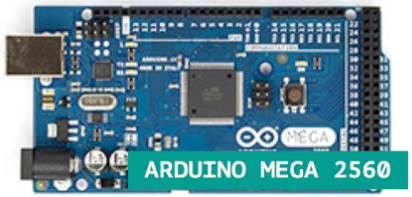
ARDUINO BOARD

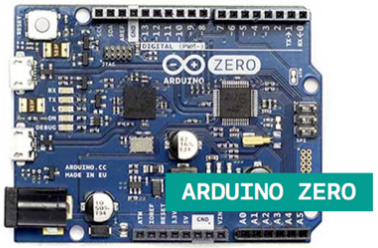
Arduino senses the environment by receiving inputs from many sensors, and affects its surroundings by controlling lights, motors, and other actuators.

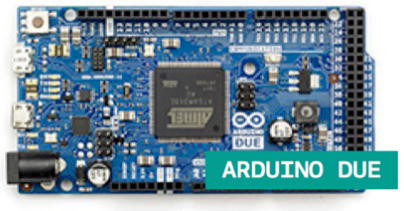
```
void setup() {
 }

void loop() {
 }
```

ARDUINO SOFTWARE

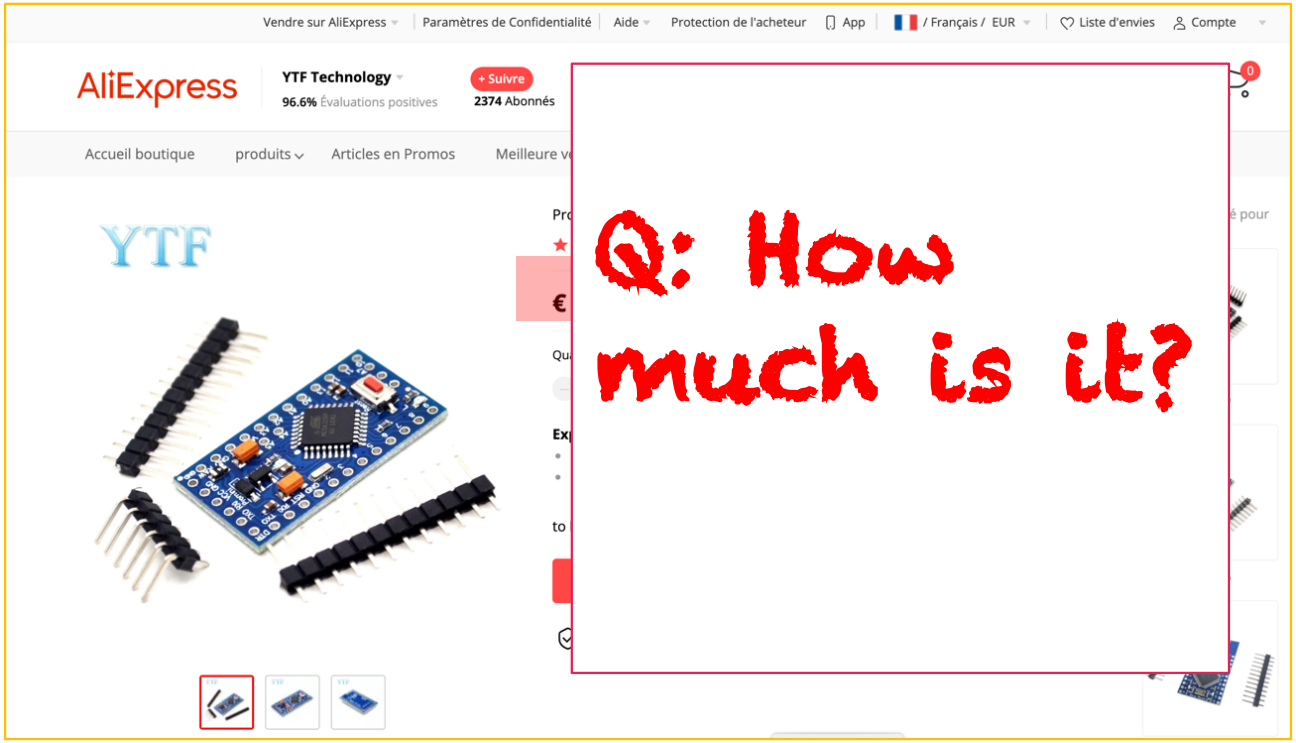
You can tell your Arduino what to do by writing code in the Arduino programming language and using the Arduino development environment.





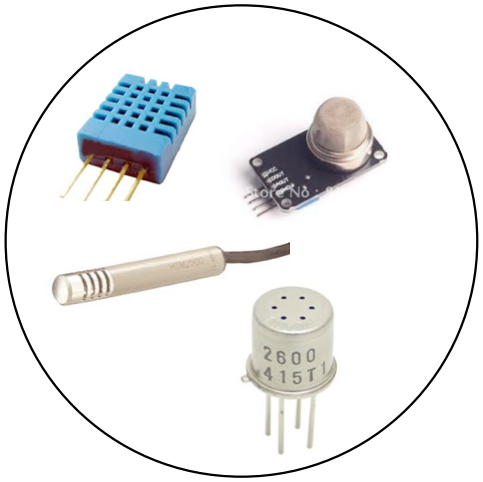


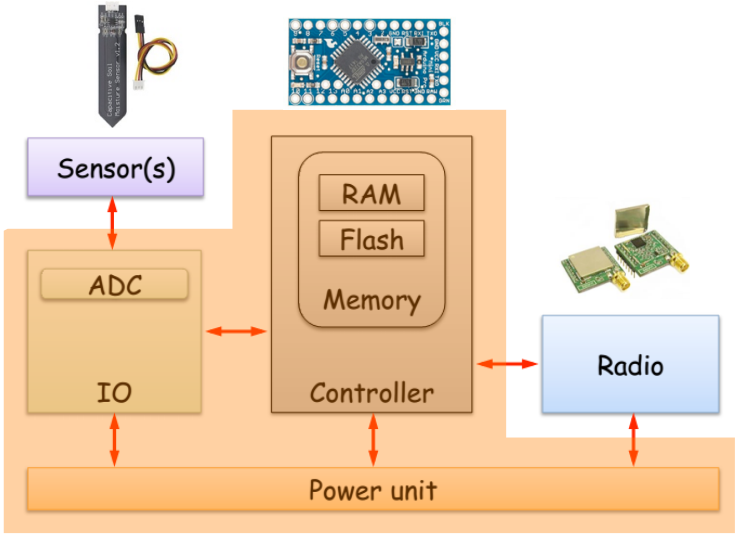
Why go for Arduino?

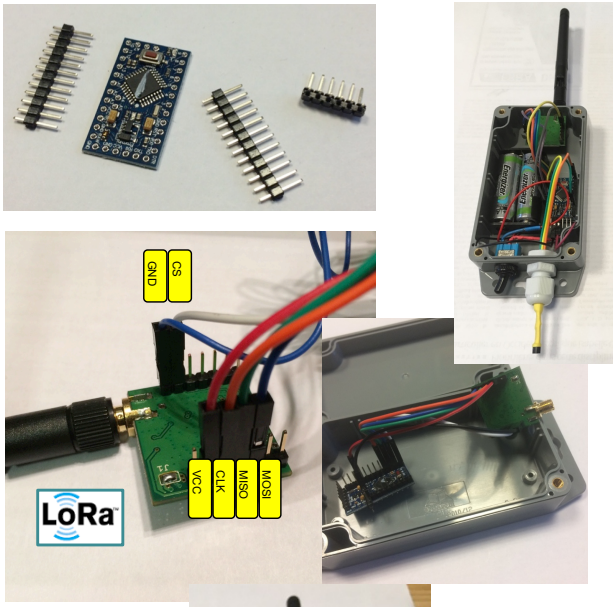


- Cheap, open, and easy to use/program
- **Huge developer communities**
- Hardware is not the main important issue
- Hardware is nothing without software libraries!

Do-It-Yourself IoT

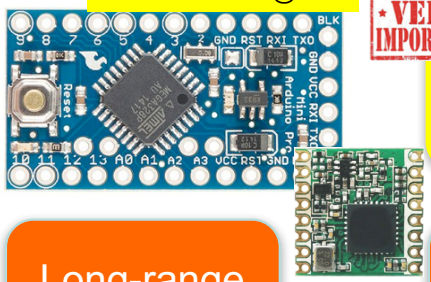






Physical sensor mgmt

Arduino Pro Mini @3.3V



VERY IMPORTANT

Activity duty-cycle, low power

VERY IMPORTANT

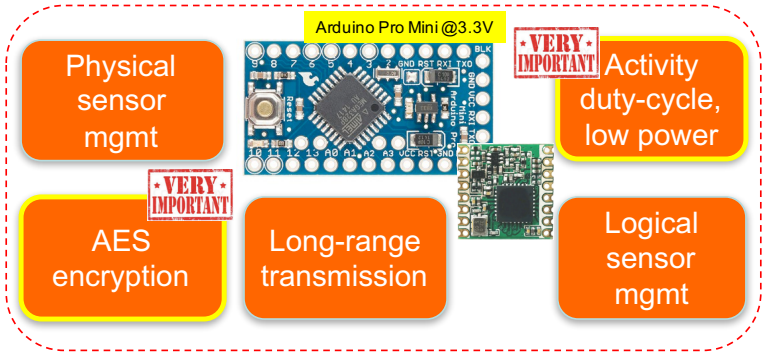
AES encryption

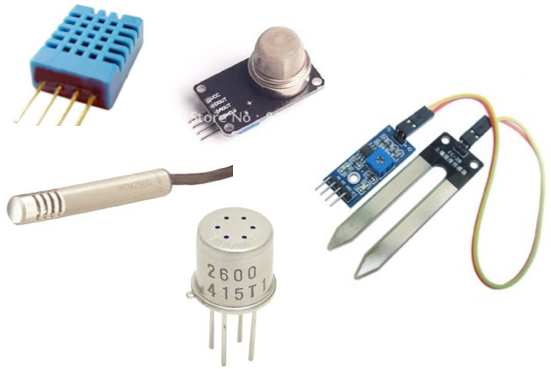
Long-range transmission

Logical sensor mgmt

Generic IoT v.s. highly specialized

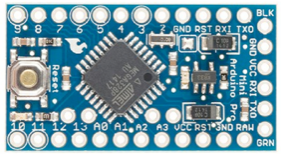
- Build low-cost, low-power, generic IoT platform
- Methodology for low-cost platform design
- Technology transfers to user communities, economic actors, stakeholders,...





A simple temperature sensor example

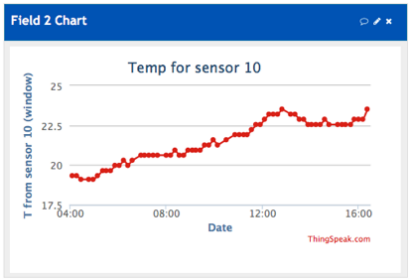
Arduino Pro Mini @3.3V



Modtronix inAir9

TMP36

Wakes-up every 10min, take a measure (temp) and send to gateway

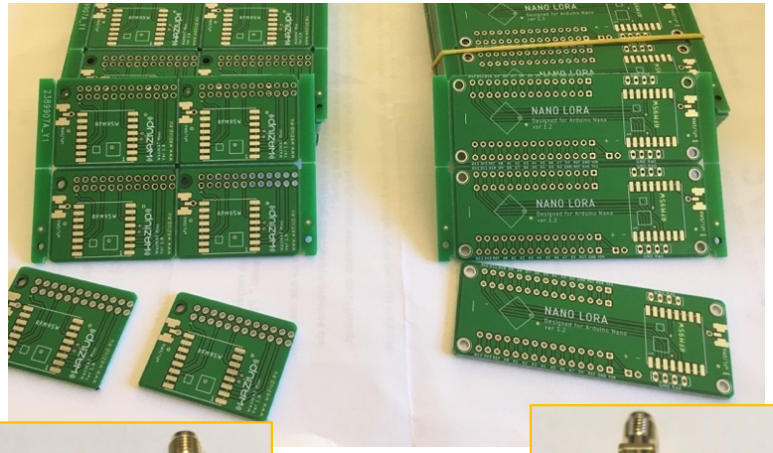


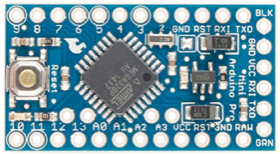
5µA in deep sleep mode, about 40mA when active and sending

More than 1 year with 1 measure/10min

Can run several years with 1 measure/1h

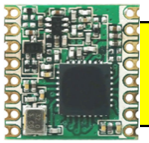
Simple PCBs ease the DIY approach



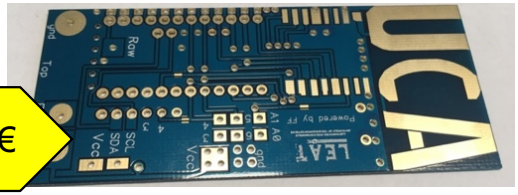


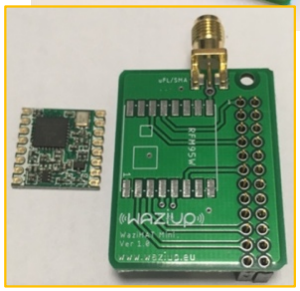
1.5€

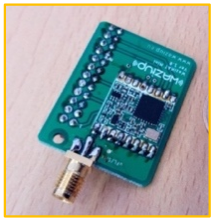
https://github.com/FabienFerrero/UCA_Board

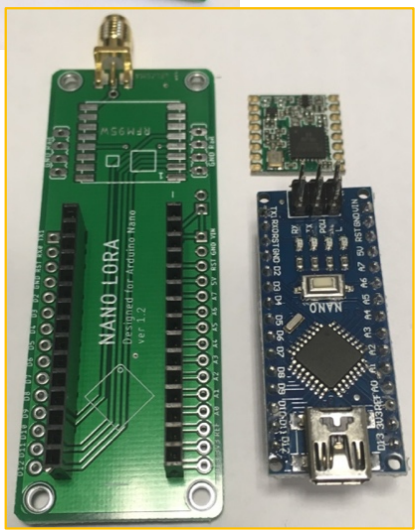


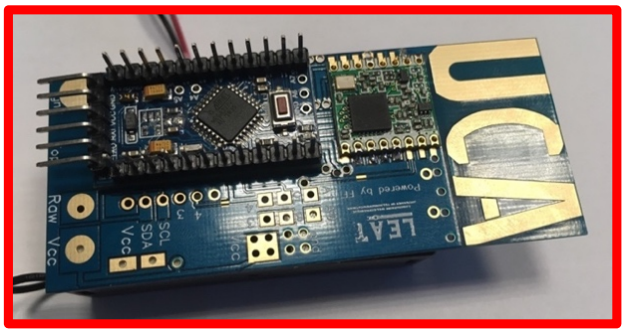
5€

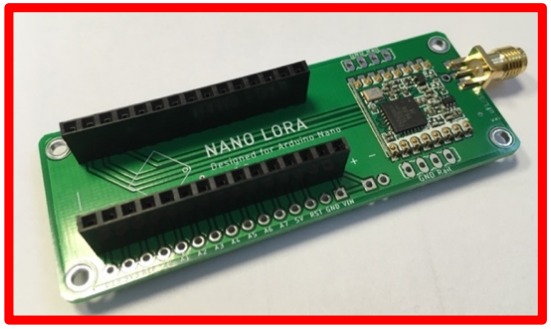












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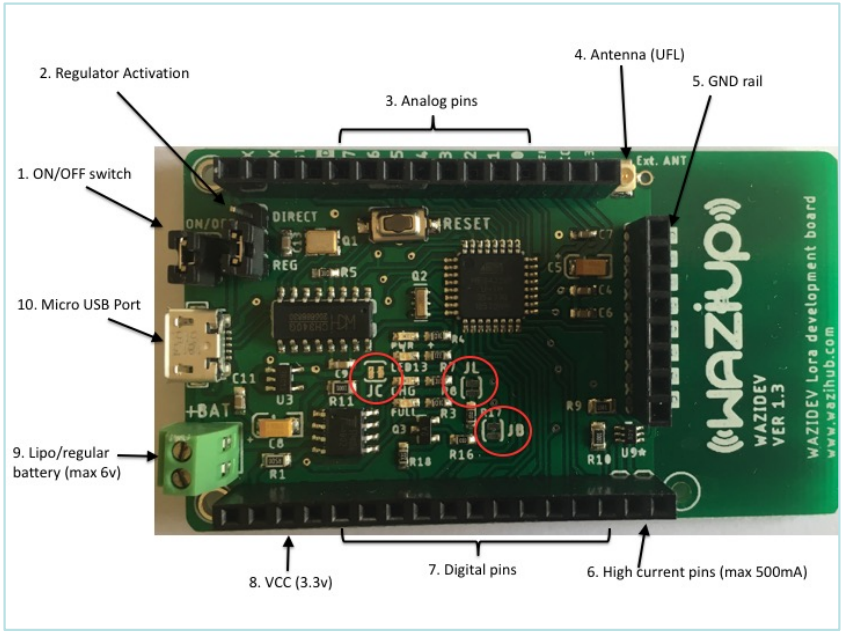
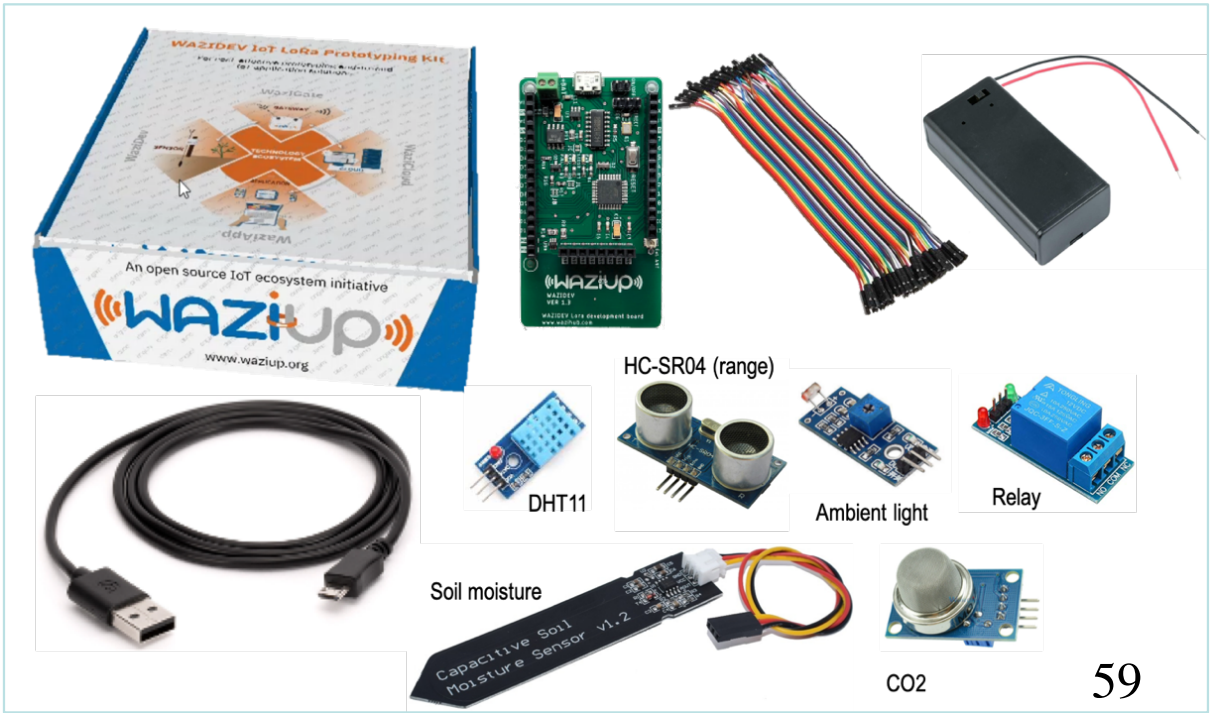
WaziDev kit: IoT in-a-box!



- WaziDev
  - ATMega328P, 8MHz, 3.3v
  - FTDI chip
  - RFM95W LoRa module
  - Integrated antenna



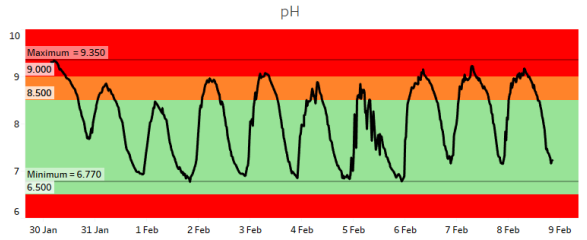
- Included
  - LiPo battery regulator accepting solar panel input
  - Battery level monitor
  - 2 high-current control pin
  - GND rail

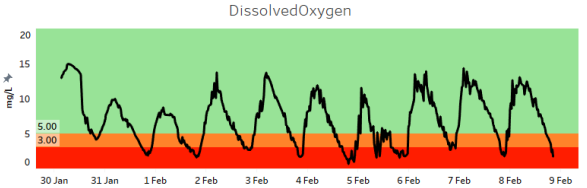
Generic IoT v.s. highly specialized

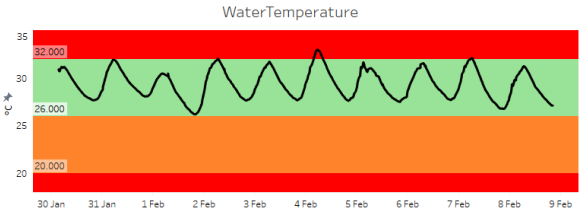
The MVP approach in WAZIUP

IoT platform design

Low-cost buoy for fish farming MVP

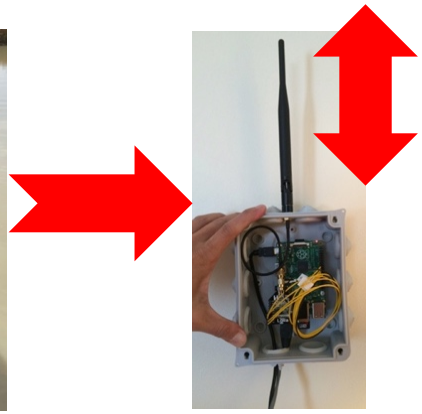


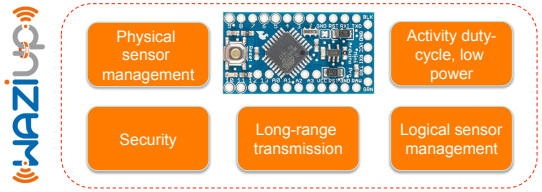




Physical sensor reading

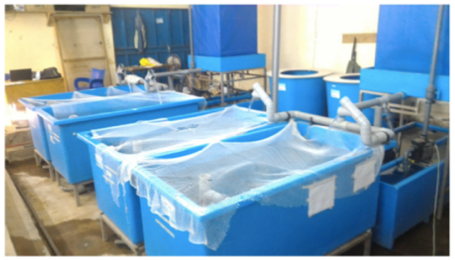
Credit: EGM

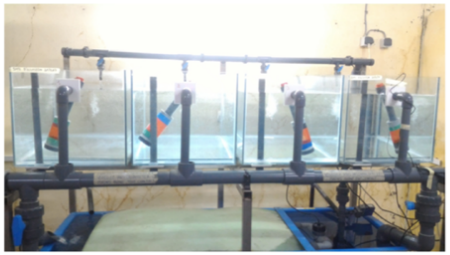




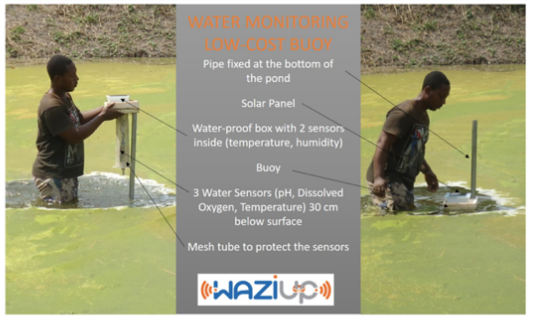
Hatchery experiment, Burkina Faso

- 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

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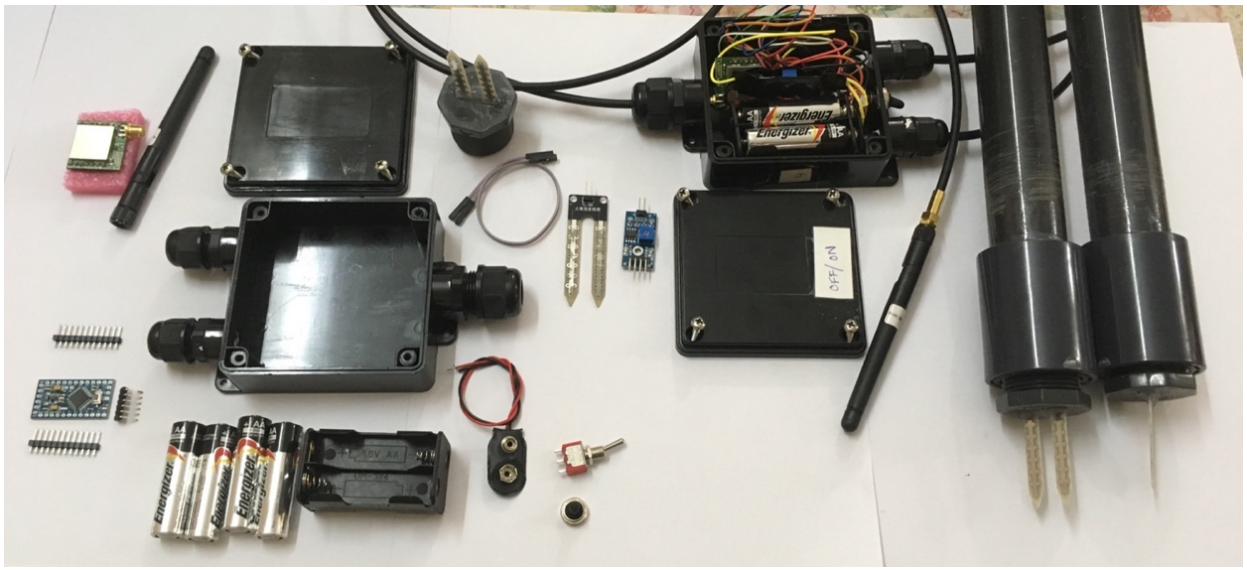
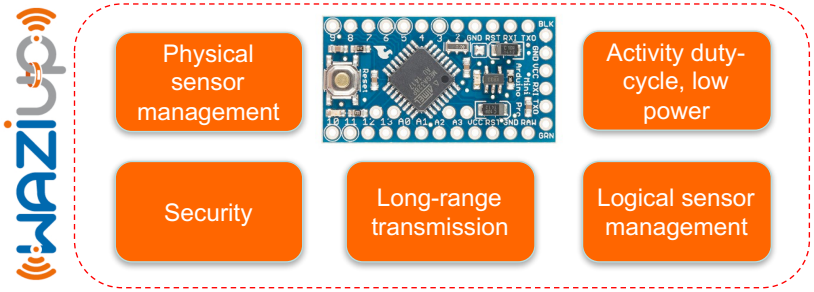
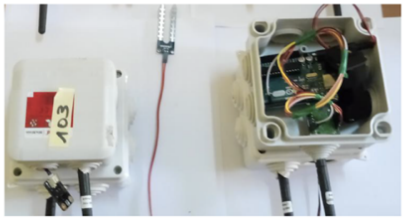
Soil humidity sensors for agri MVP





UBG farm, Senegal

Soil humidity sensor for agriculture



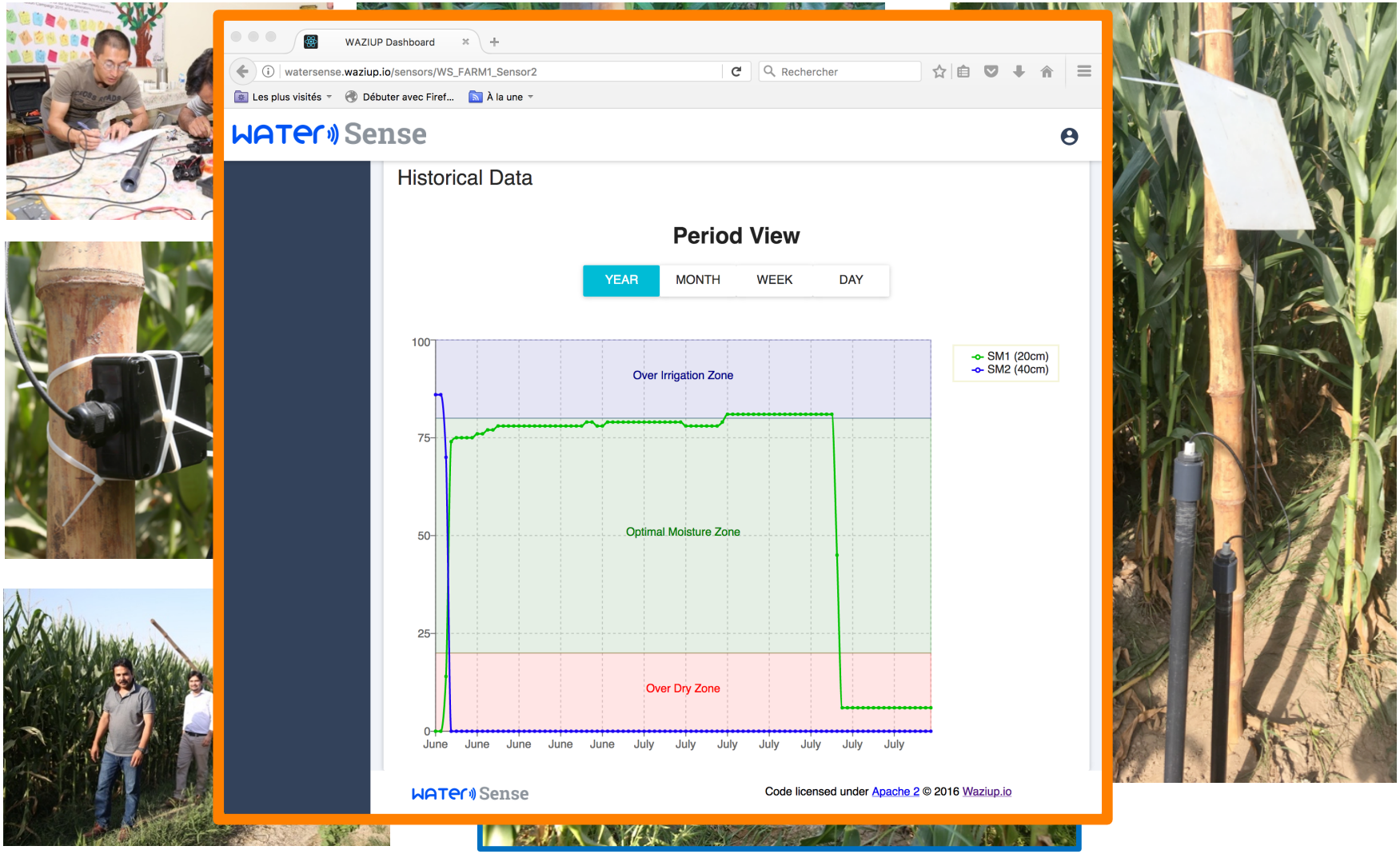
Monitoring soil moisture and other parameters to provide insightful recommendations and notifications to farmers, and advisors


Nasso site, Burkina Faso

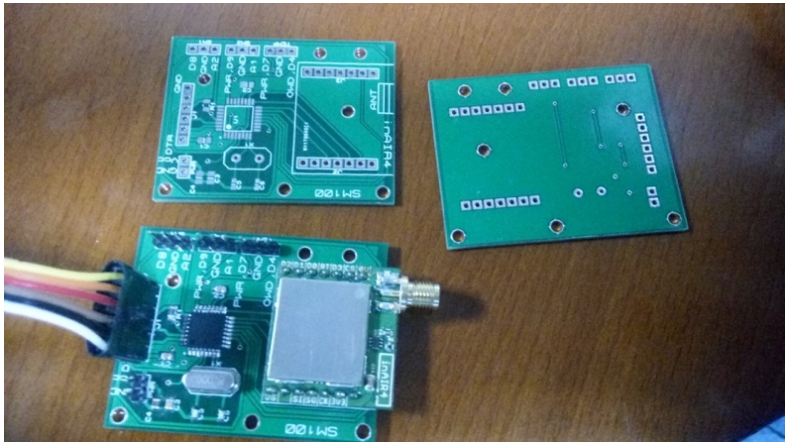
Urbannatic gardens, Togo

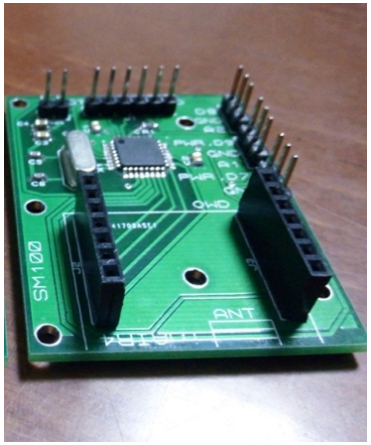

Deployment for Nestlé's WaterSense

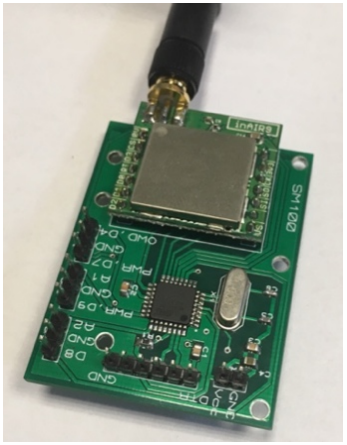
Deployment for Nestlé's WaterSense

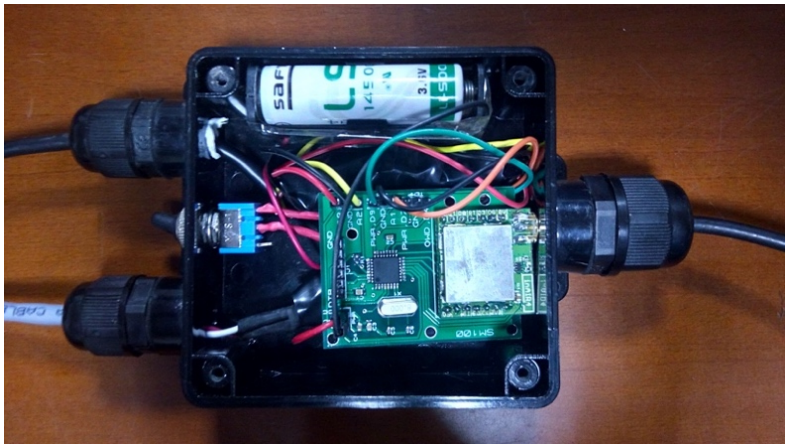


Local integration, technology transfer





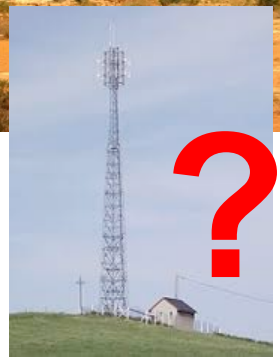




Deployment in rural areas no Internet ☹

- deploying IoT in very isolated areas...
- ... where internet and electricity are not stable!

Q: What can we do?



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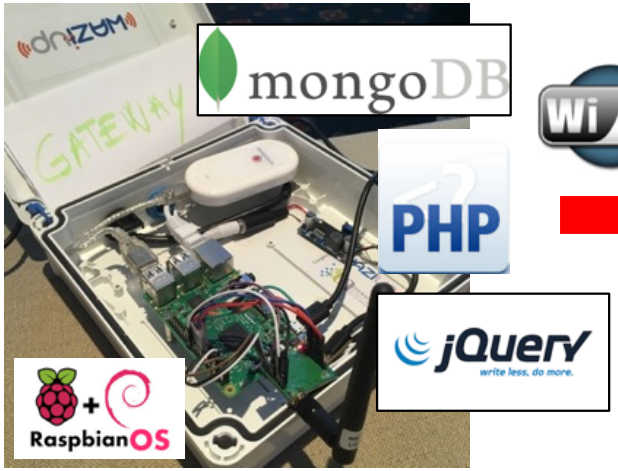
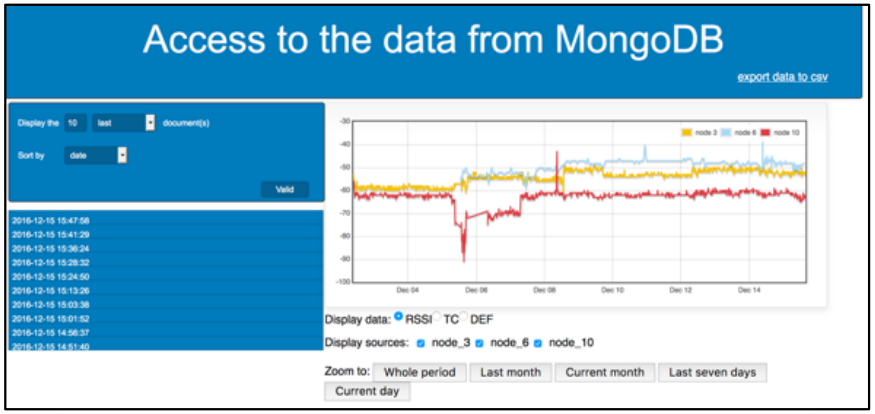
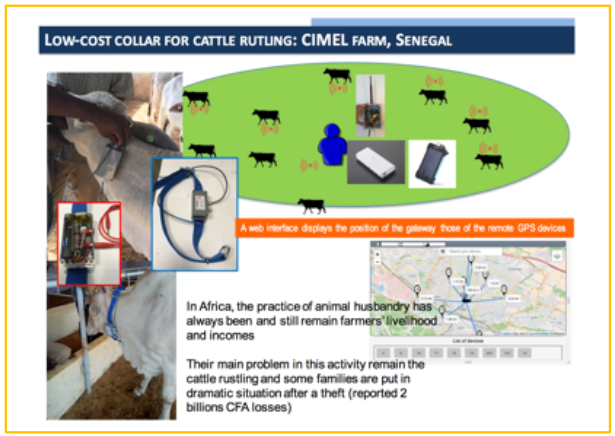
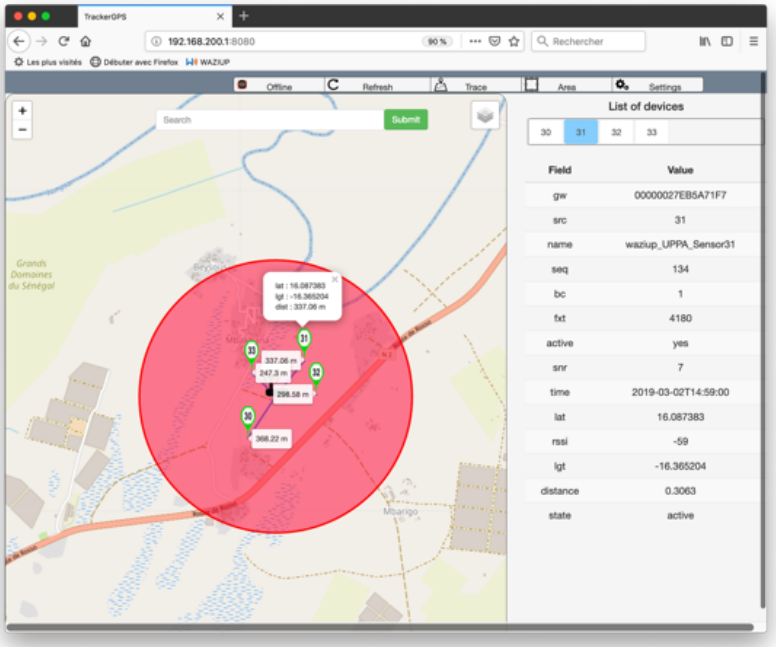
Deploying IoT in Africa

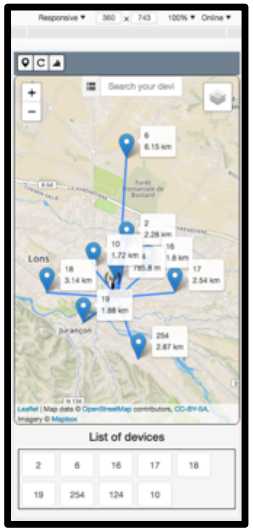
Autonomous gateway – no Internet – Edge IoT











Link to a short demo video of the collar web interface: https://youtu.be/meFDav1SLPI

Making IoT happening!

Innovative IoT technologies

"IoT for All" paradigm

IoT infrastructures and use cases

Knowledge dissemination & training

Users/Developers engagement

Innovative solutions adapted to local needs

Exploitation plan and innovation hubs

Communication & community building

Sustainable & long-term innovation

Community building for sustainable innovation

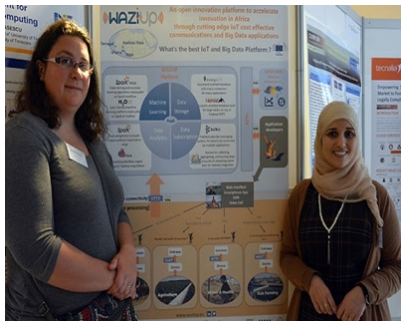
International Events
+ 20 organized & attended

Launch event (Ghana, iSpace)

Launch event (Senegal, CTIC Dakar)

Workshop at the European Conference on Networks & Cmmunications (Greece, CNET)

IoTWeek2016 (Belgrade, EGM)



IoTBigData2016 (Italy, EGM)

IoTCareConference (Budapest, CNET)

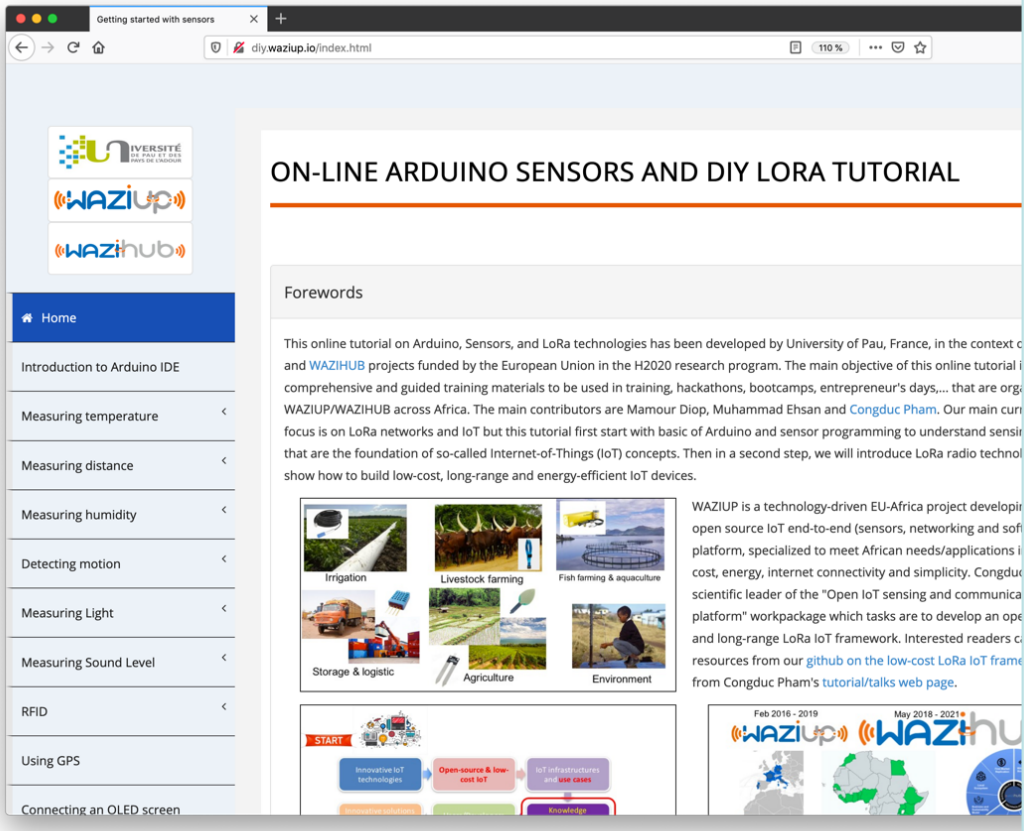
WAZIUP Workshop on IoT (Togo, L'Africaine d'Architecture)

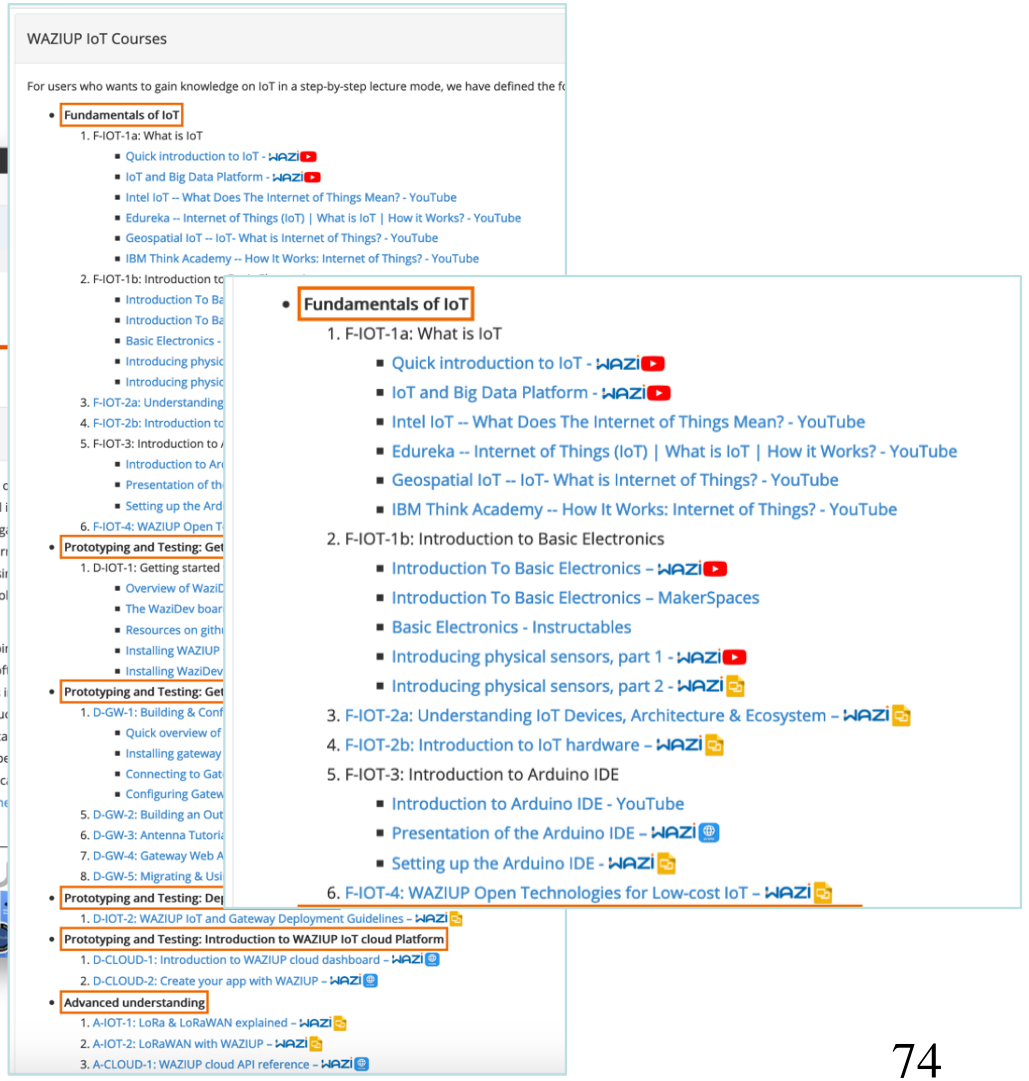
Credit: C. Vavasseur, CTIC Dakar

Workshop at the RESSACS 2016 (France, UPPA)

WAZIUP Online Course

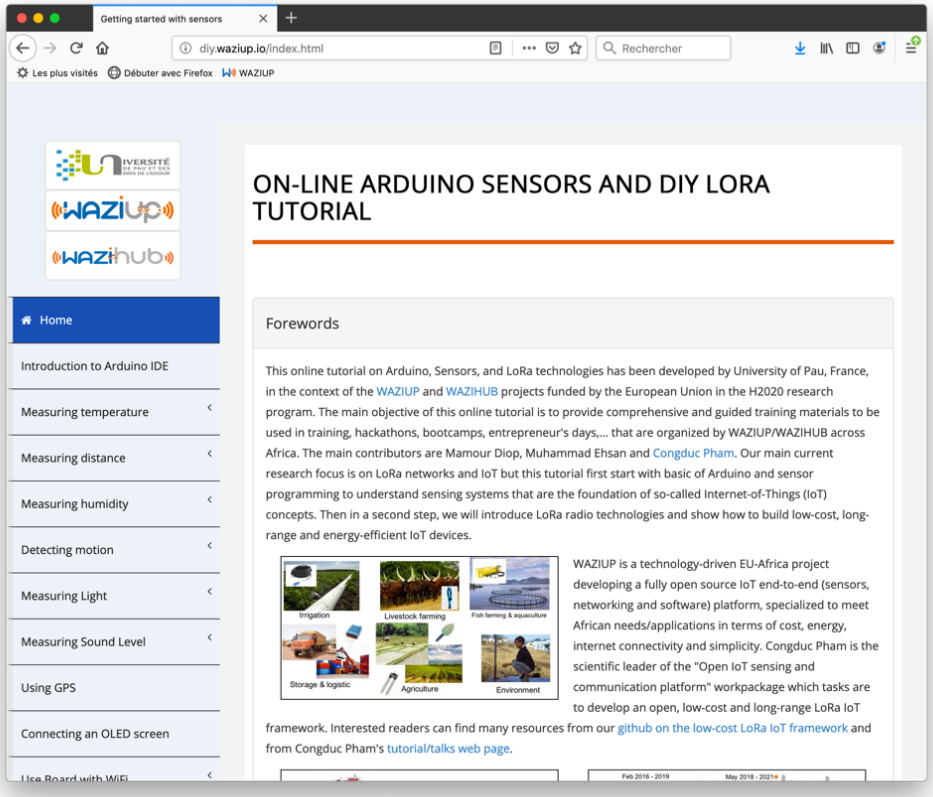
- http://diy.waziup.io





Training & hackathons

- Technical training sessions
- Hackathons, ...



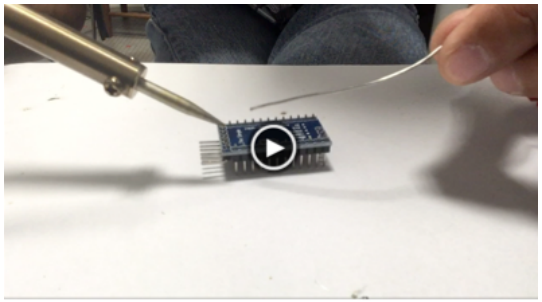
Online Arduino & IoT step-by-step tutorial
https://diy.waziup.io

Tutorials/resources

https://github.com/CongducPham/tutorials

YouTube videos

Low-cost LoRa IoT device



+94000 views

May2021

https://www.youtube.com/watch?v=YsKbJeeav_M

Low-cost LoRa IoT gateway

+22000 views

May2021

https://www.youtube.com/watch?v=mj8ItKA14PY

Extreme low-power LoRa IoT

+9000 views

May2021

https://www.youtube.com/watch?v=2_VQpcCwdd8

Setting up a gateway in 5mins

+4600 views

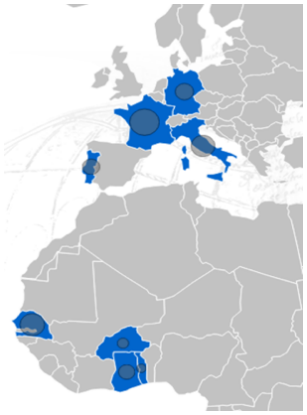
May2021

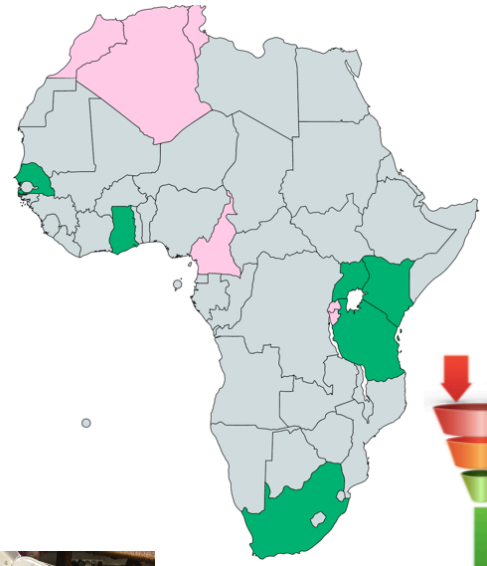
https://www.youtube.com/watch?v=CJbUFXLpSok

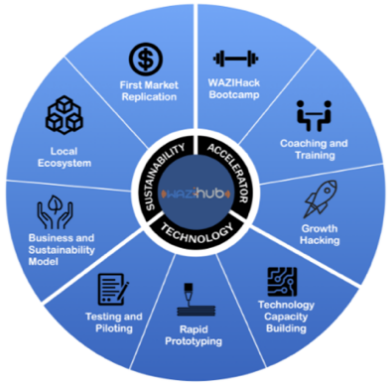
Scaling-up!

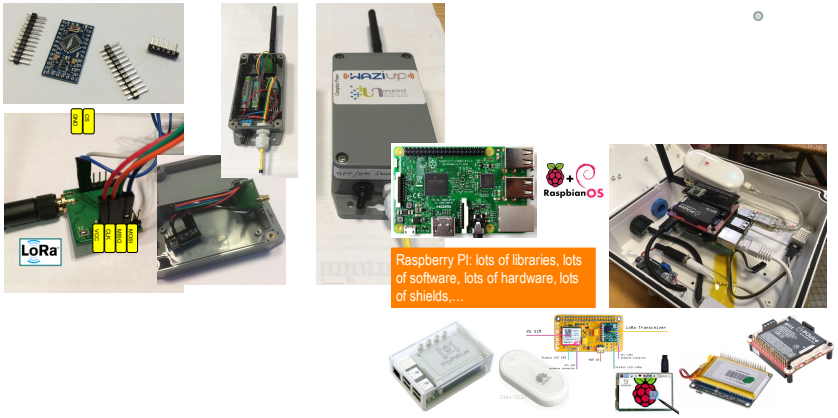
Feb 2016 - 2019

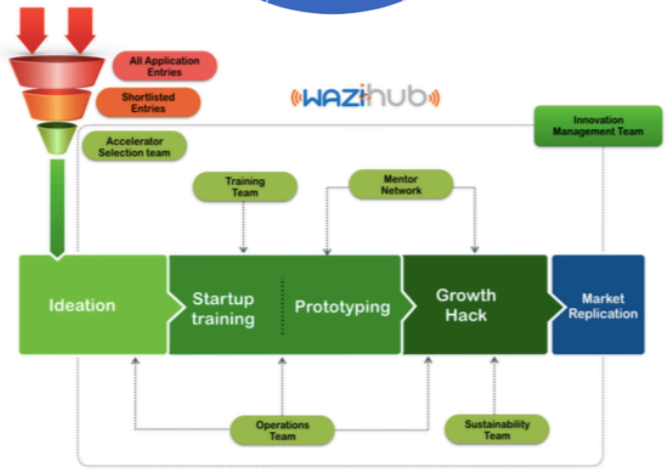
May 2018 – July 2021











Emergence of an ecosystem!

AFRICA INNOVATION EUROPE PARTNERSHIP

ITU

SMART INCUBATOR

AfriLabs

ZiNDi
www.zindi.africa

DIHNET.EU
Europe's Network of Digital Innovation Hubs

ADNE
AFRICAN DIASPORA NETWORK EUROPE

AI4EU
Advancing Europe through collaboration in AI

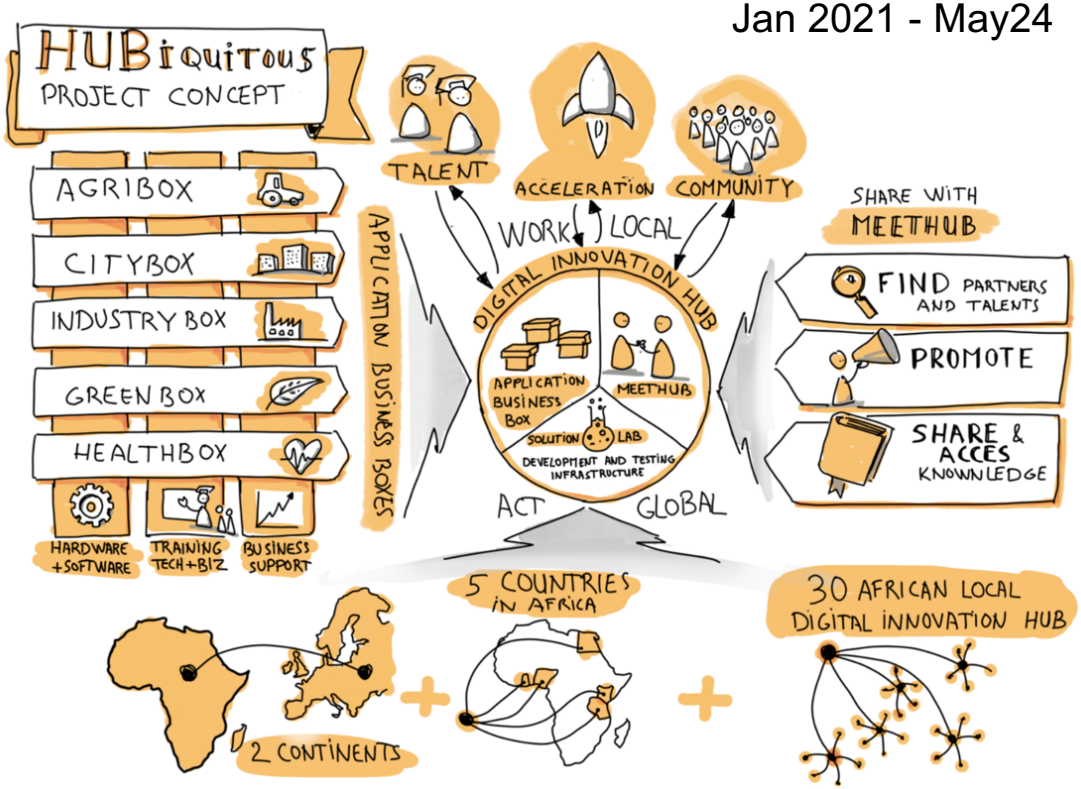
SOFT LANDING

Beyonds state-of-the-art!

HUBiquitous

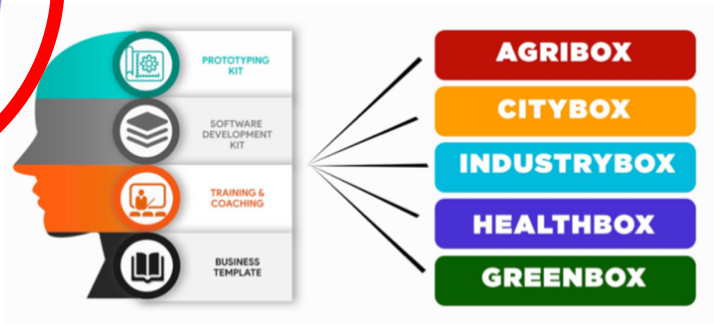
Jan 2021 - May24

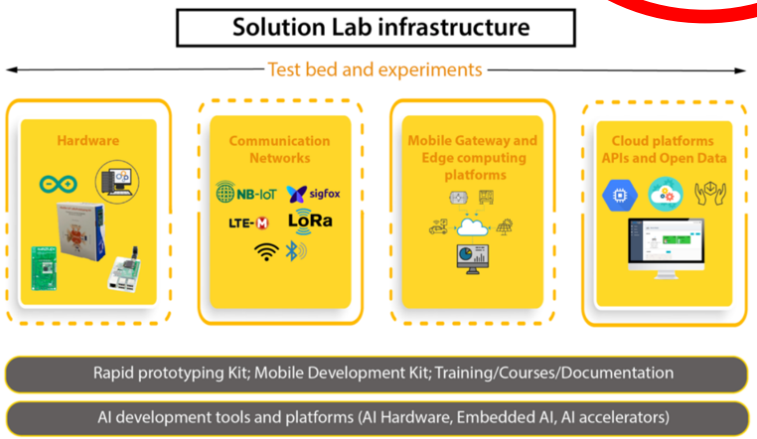
Widen the scope of technologies to prepare for the next 10 years of innovation in IoT, AI & BigData



3 Innovation Enablers

Create vertical solutions with go-to-market objectives

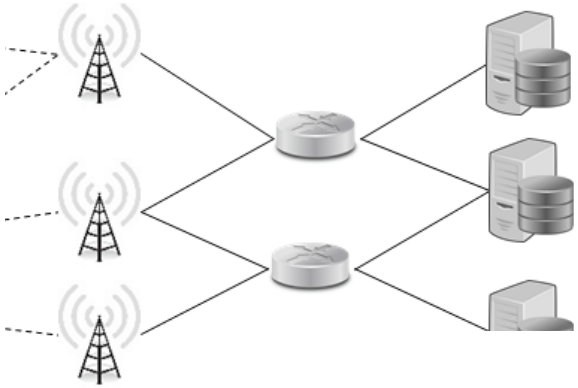




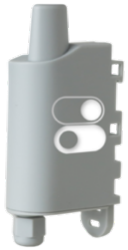
Create synergies amongs innovation actors, DIHs, stakeholders,…

Make disruptive technologies accessible to entrepreneurs!

Now what?



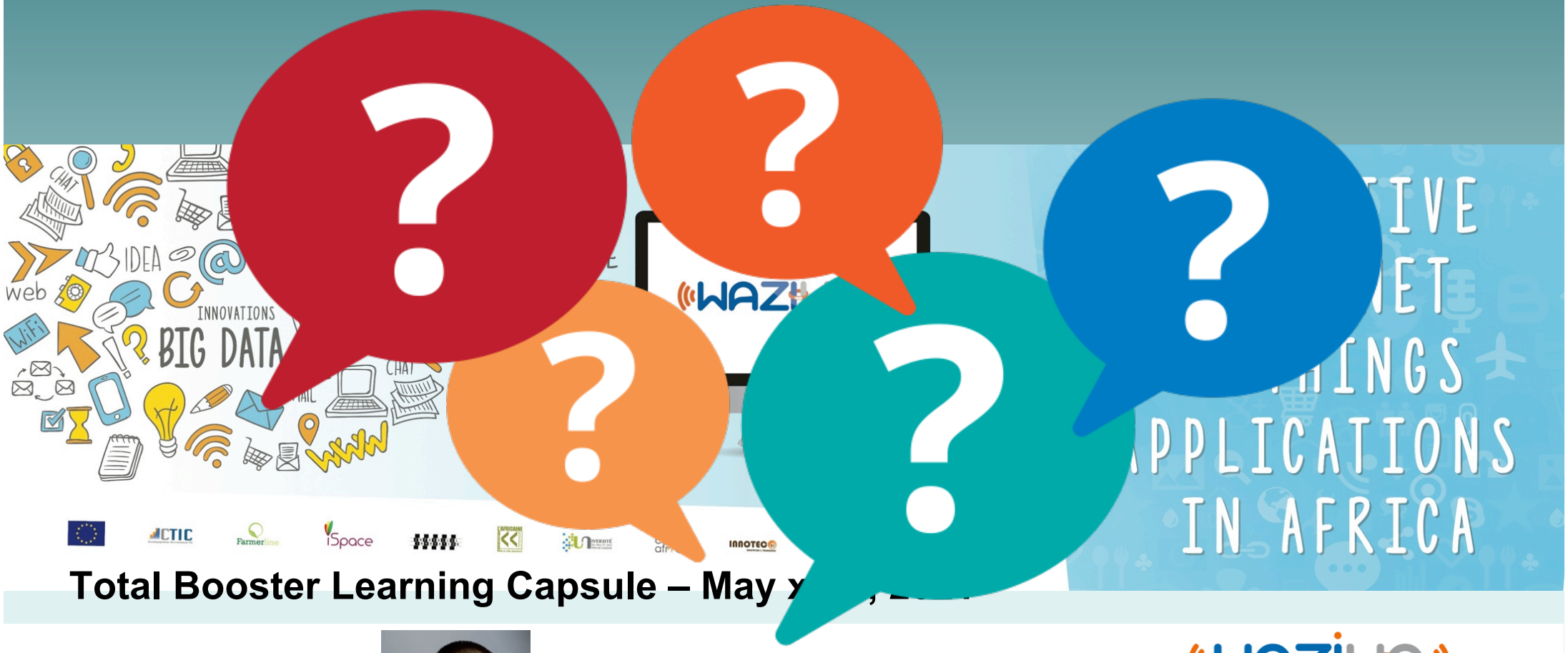
Gateways



Conclusions

- Internet-of-Things provides the unique feature to make things "talk" to us: localisation, surrounding environmental conditions, particular events, ...
- It has huge potential in industrial applications but has also unique capabilities in helping humanity to reach more sustainable development
- Next gen sensors such as cameras, spectrometers, hyperspectral cameras,... will provide possibilities to further optimize a number of complex processes
- LIUPPA works for more than 8 years to develop & deploy low-cost IoT in Africa with 4 EU H2020/PRIMA projects

Undestanding Internet-of-Thing technologies



Total Booster Learning Capsule – May x

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Université de Pau, France

IVERSITÉ DE PAU ET DES PAYS DE L'ADOUR

HORIZON 2020

WAZIup
IoT – from idea to reality
WAZIhub