Designing and deploying low-cost IoT: digital agriculture opportunity for smallholders

PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

Intel-IrriS

Presented on May 26th, 2021

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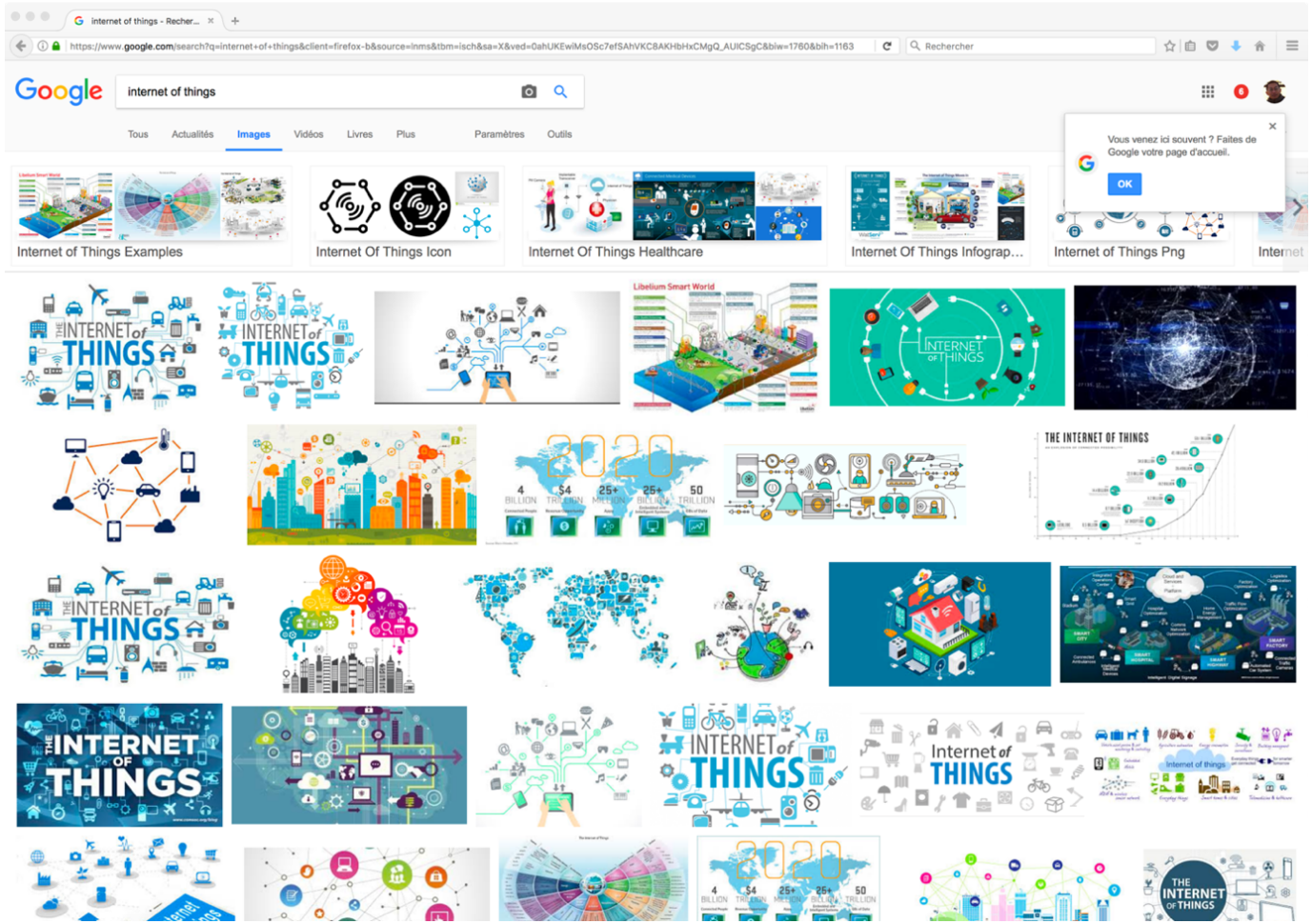
UNIVERSITÉ DE PAU ET DES PAYS DE L'ADOUR

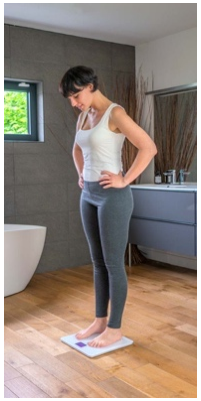
LIUPPA

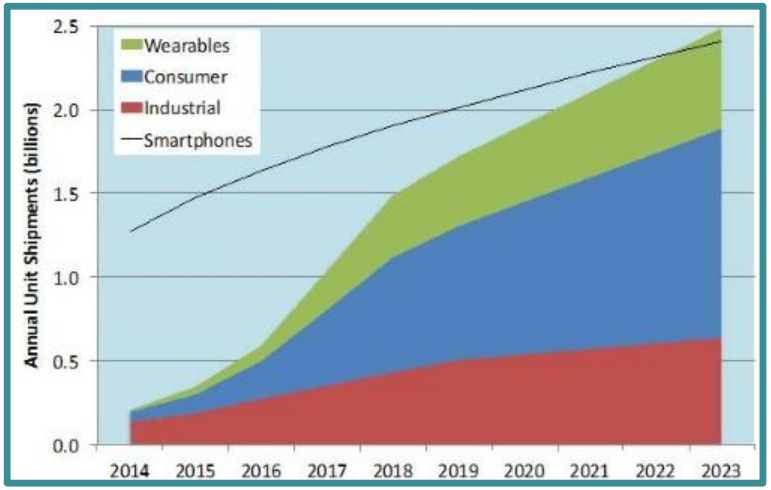
WAZIUP
IoT – from idea to reality
WAZIHUB

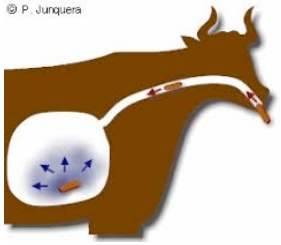
Googling for « Internet of Things »

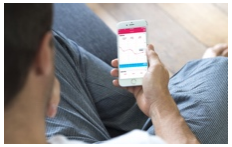


…shows communicating objects

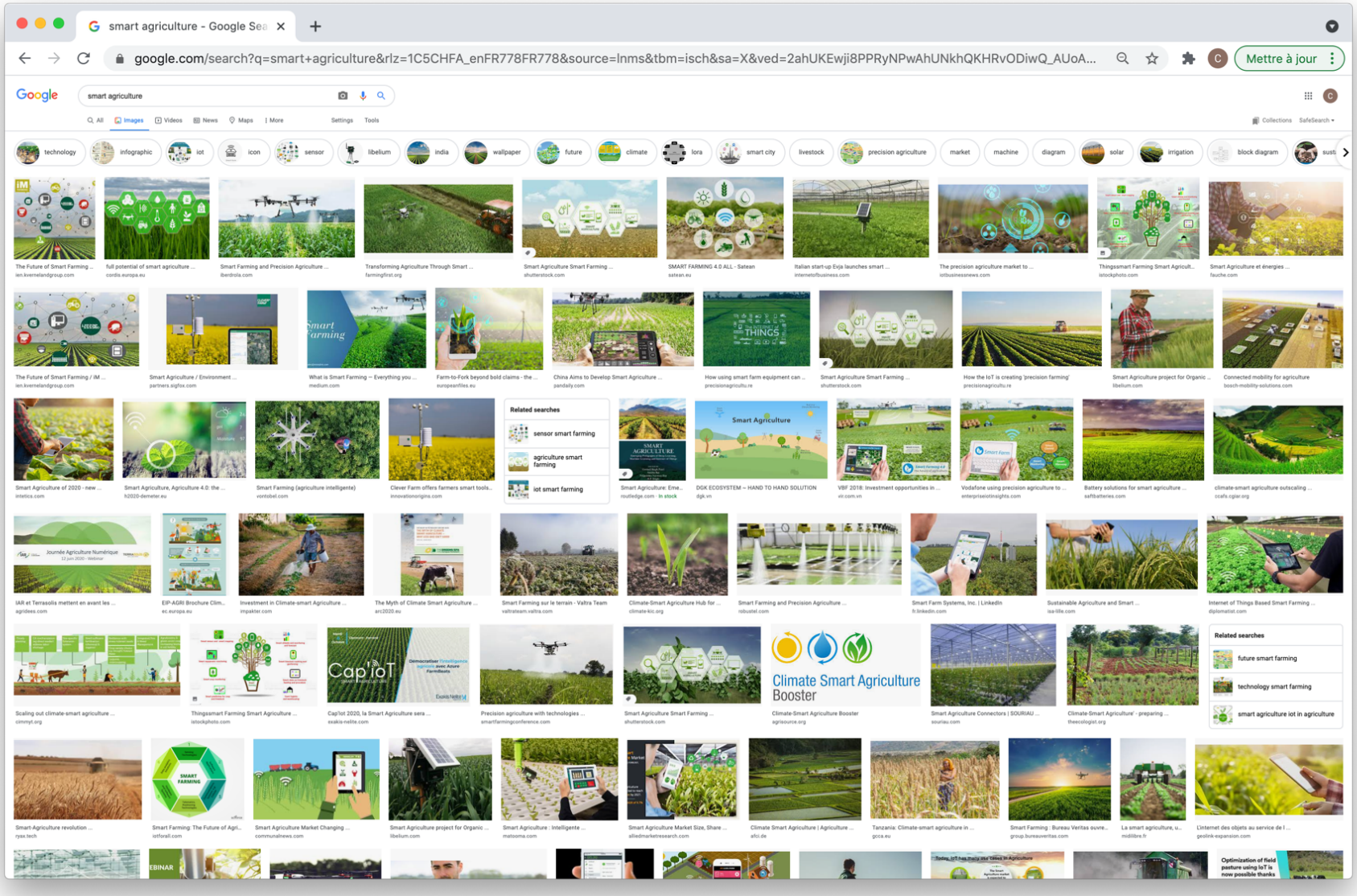




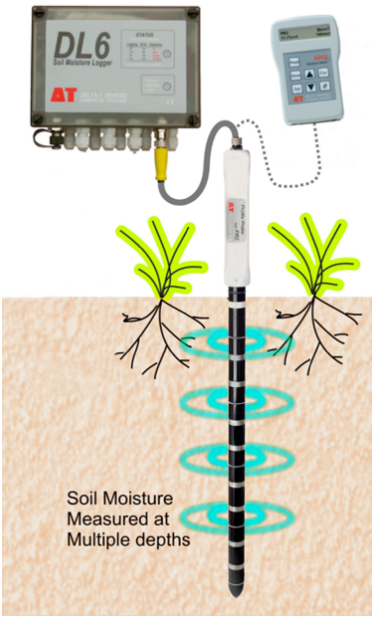




Googling for "Smart Agriculture"



Smart Agriculture, a mature technology



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 OpenRemote dweet.io TempoIQ

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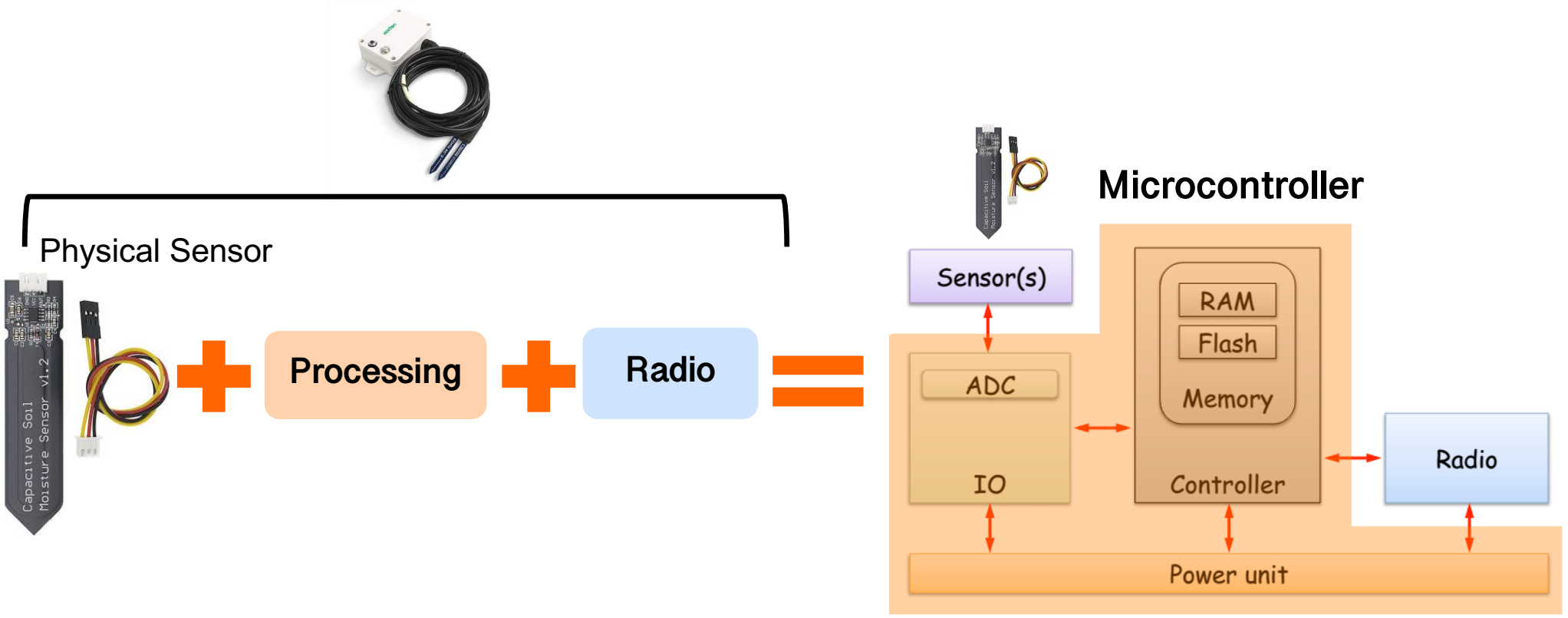
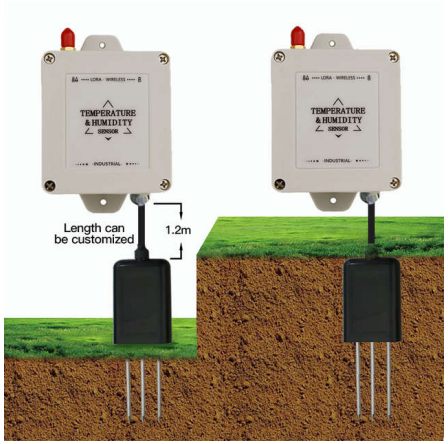
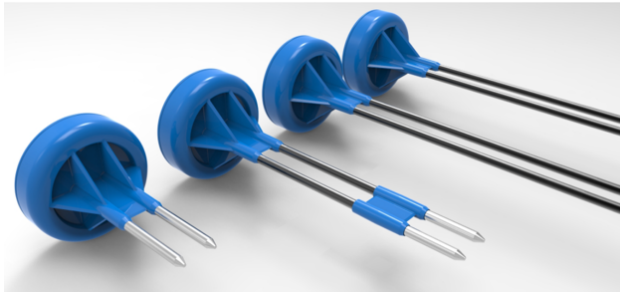
IoT device

- IoT device can be viewed as a simple Embedded System



Smart Agriculture Sensors





Smallholders & Smart Agriculture?

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

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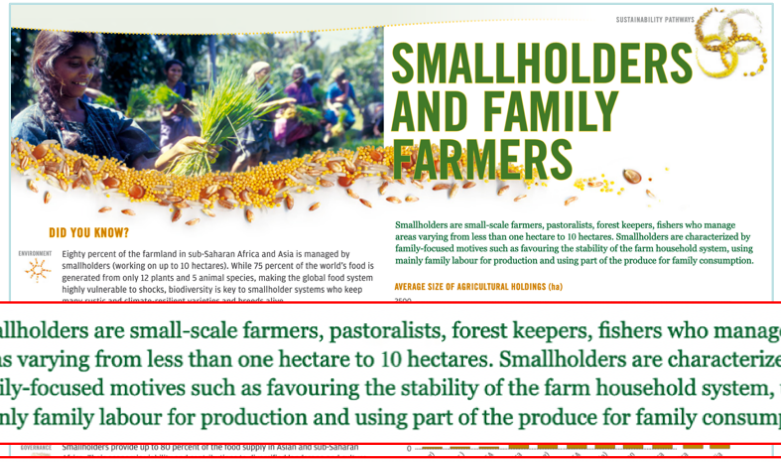
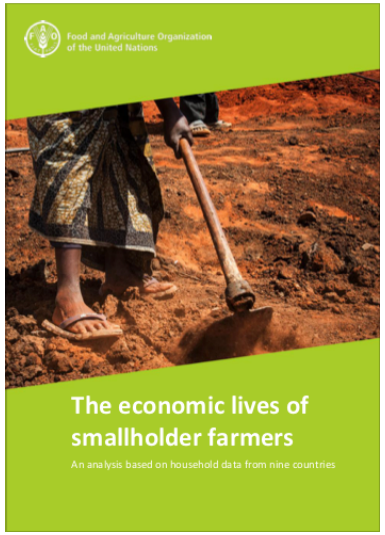
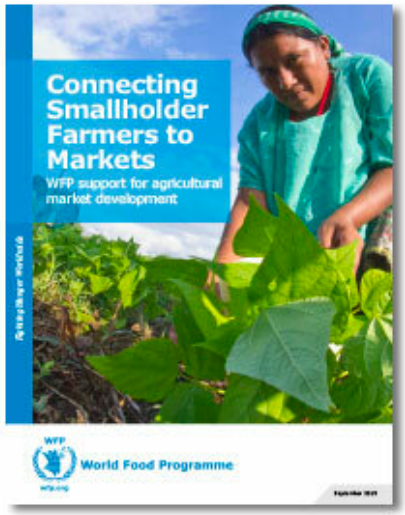
Smallholders: the next decade challenge!

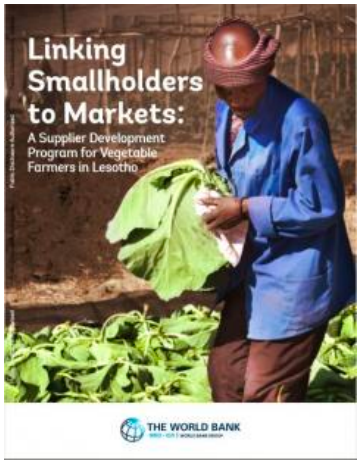


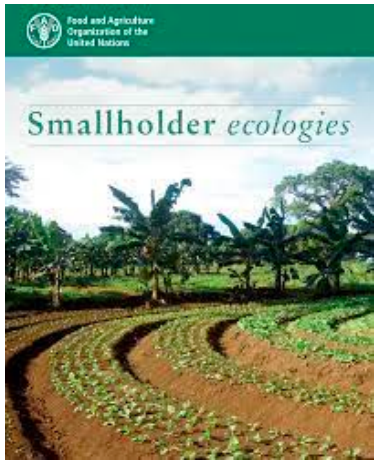


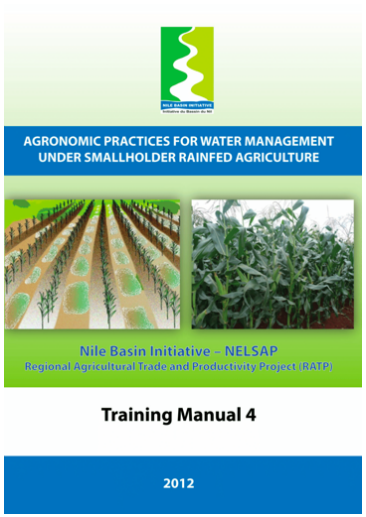


Smallholders are small-scale farmers, pastoralists, forest keepers, fishers who manage areas varying from less than one hectare to 10 hectares. Smallholders are characterized by family-focused motives such as favouring the stability of the farm household system, using mainly family labour for production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

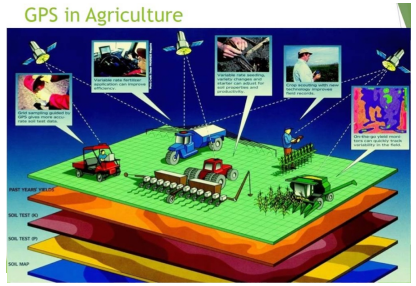


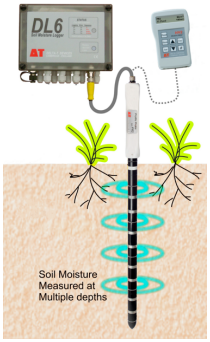




Smart Agriculture for Smallholder?

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





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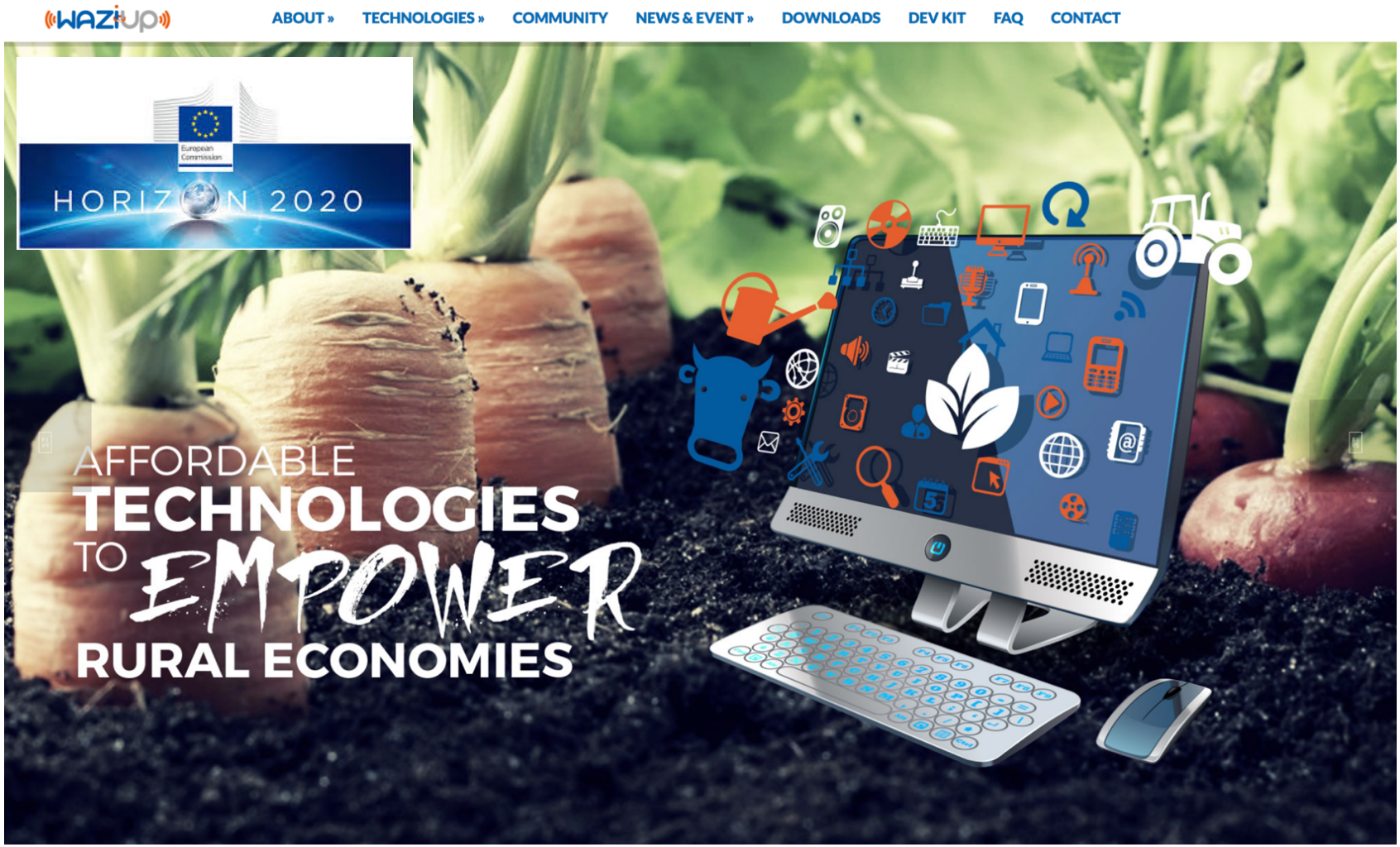
Low-cost IoT!



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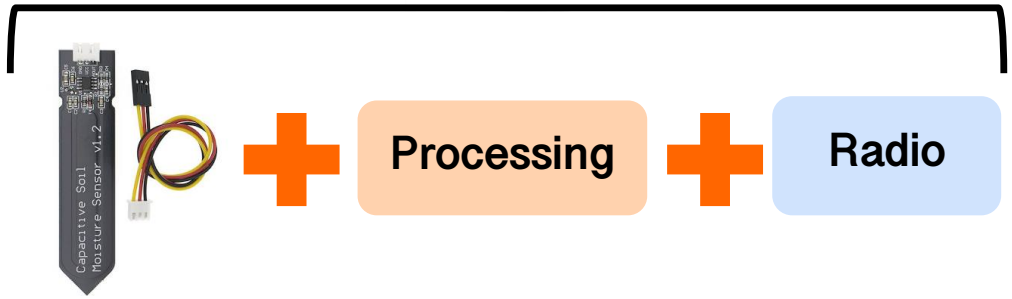
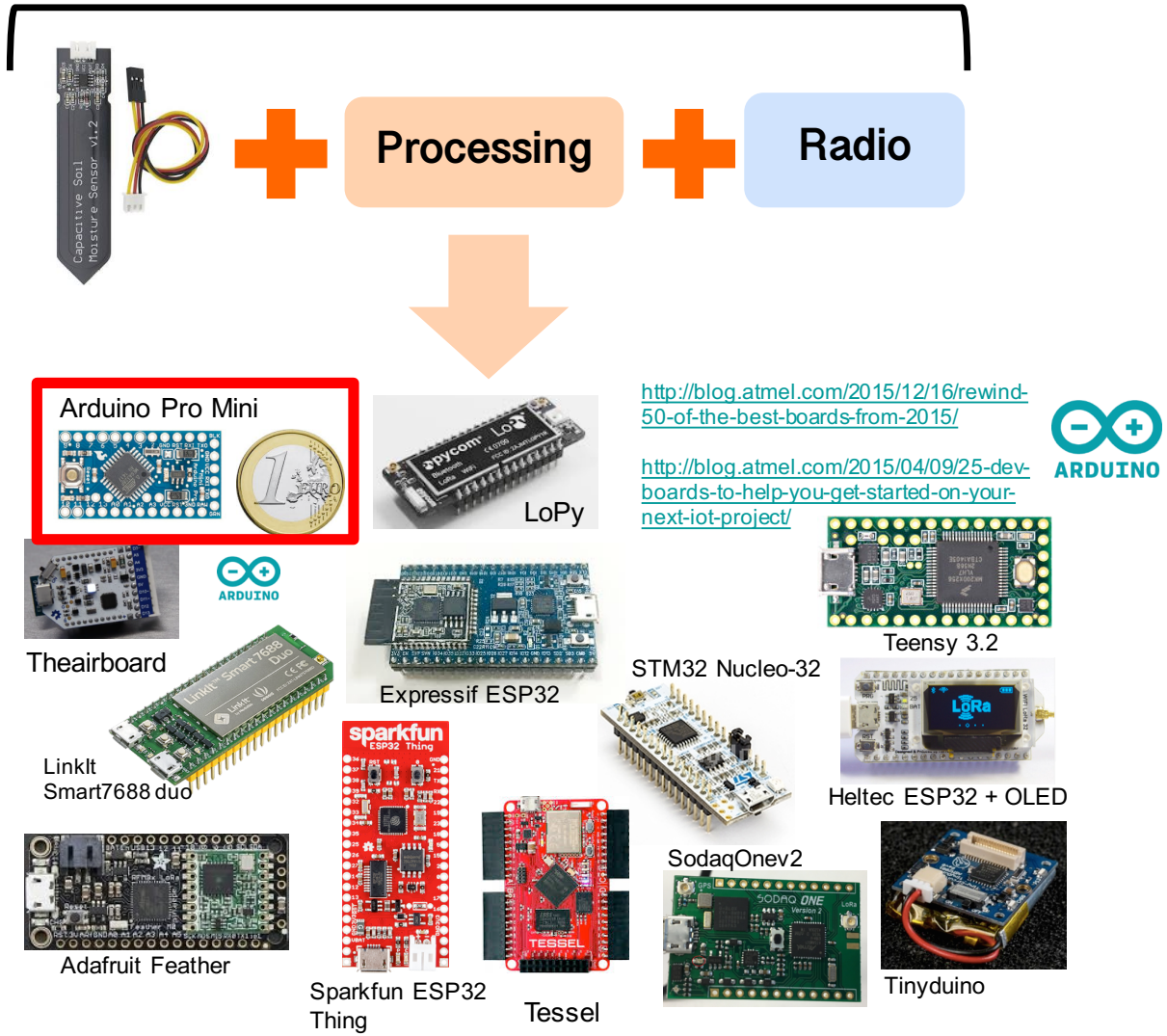
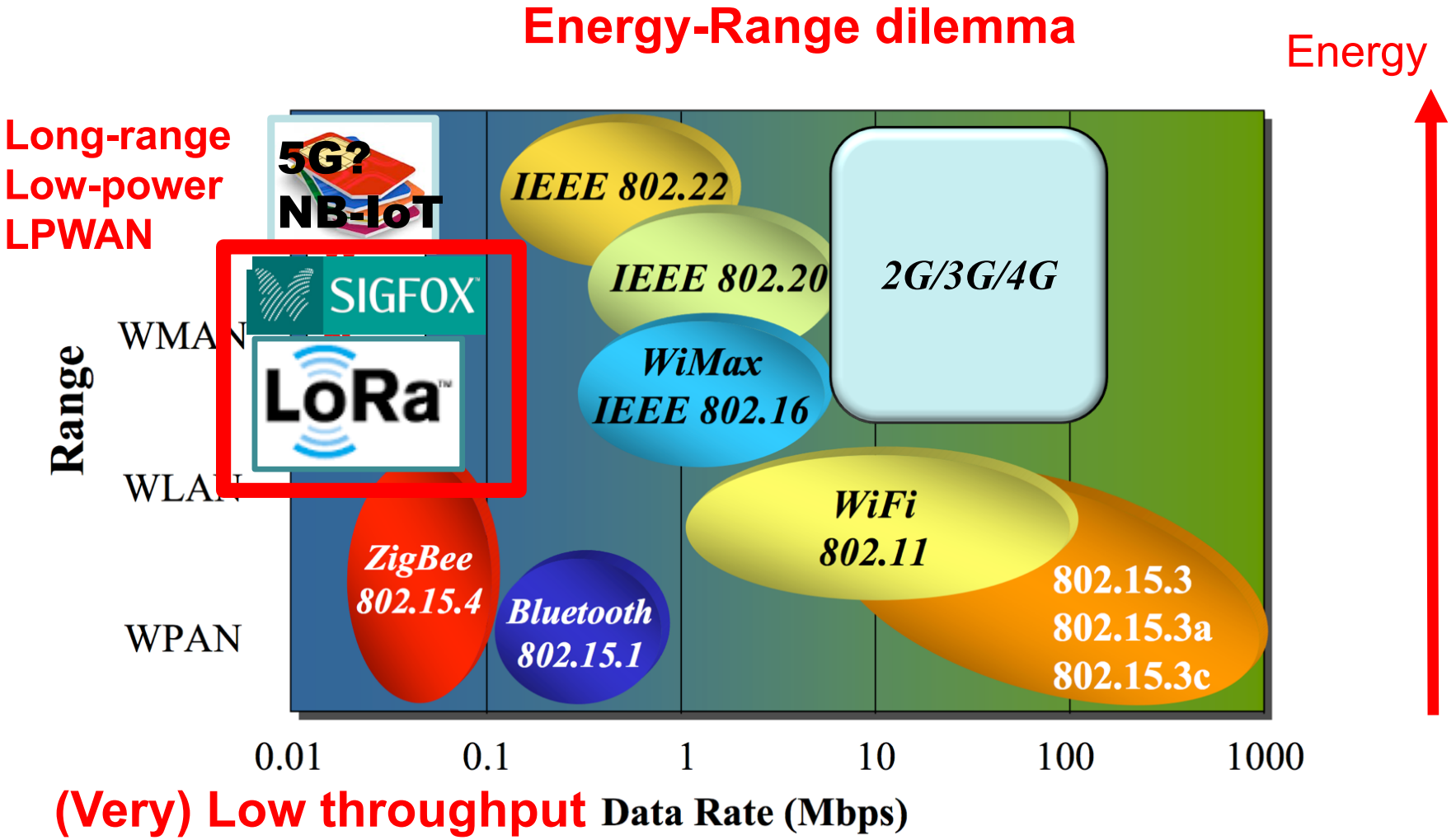
IoT device



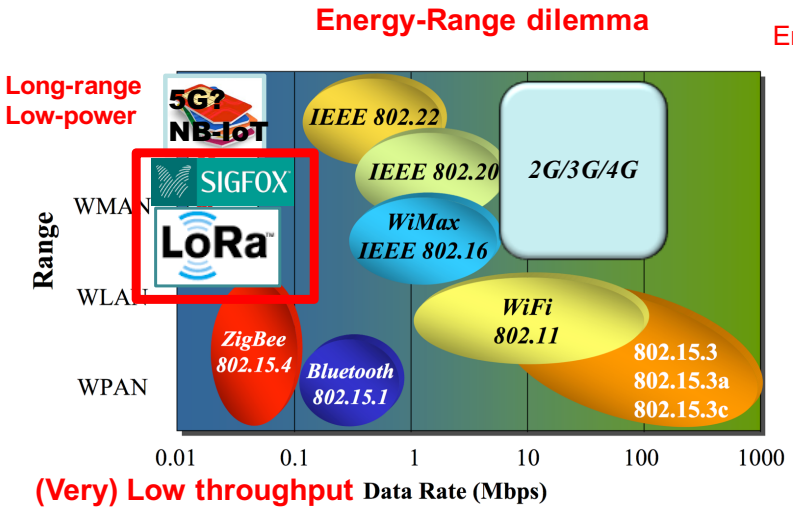
Low-cost microcontroller boards



Low-power & long-range radios



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

2500mA

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

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

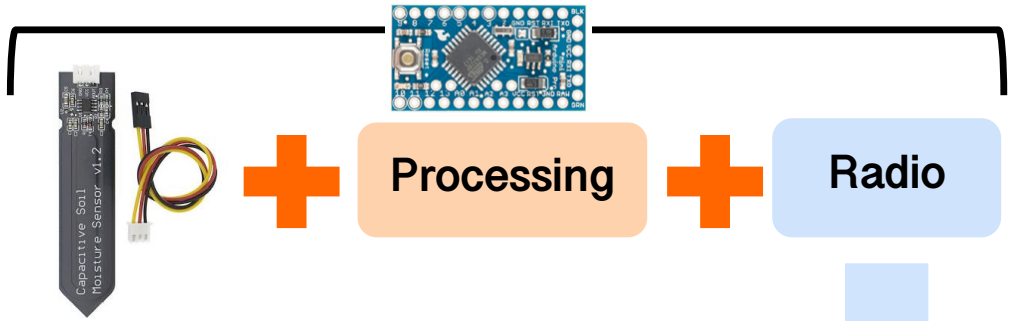
In most cellular networks, the device is still maintaining communication with BS even if it is inactive

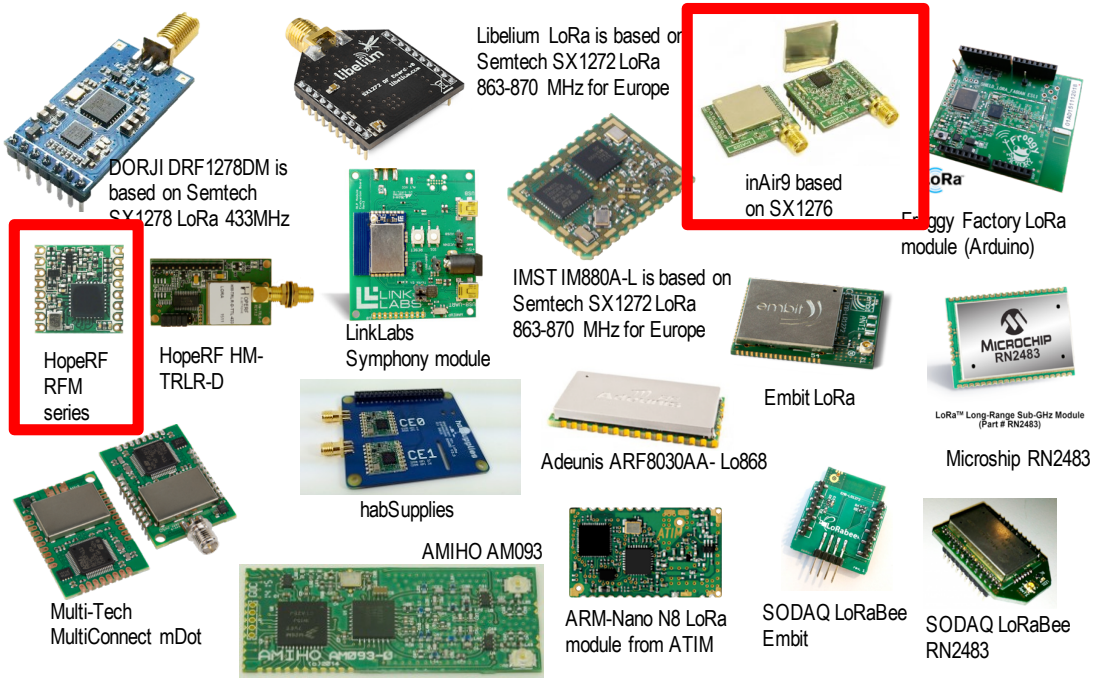
TX power: 40mA. Mean consumption: (2sx40+3598sx0.005)/3600=0.027mA

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

LPWAN does not need to maintain connection if not in used

Low-power, long-range radios





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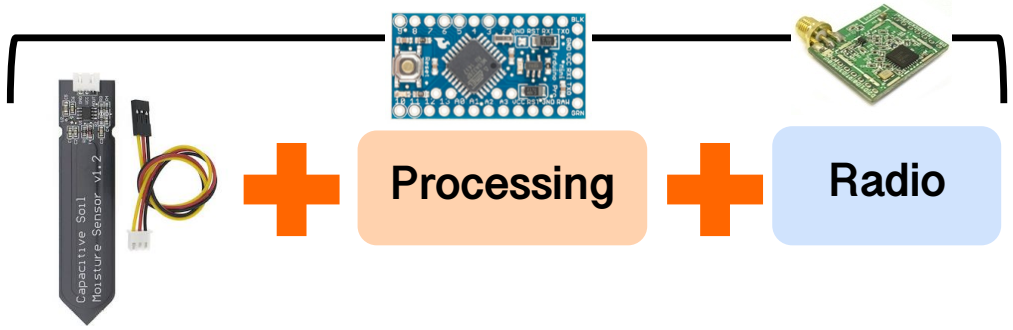
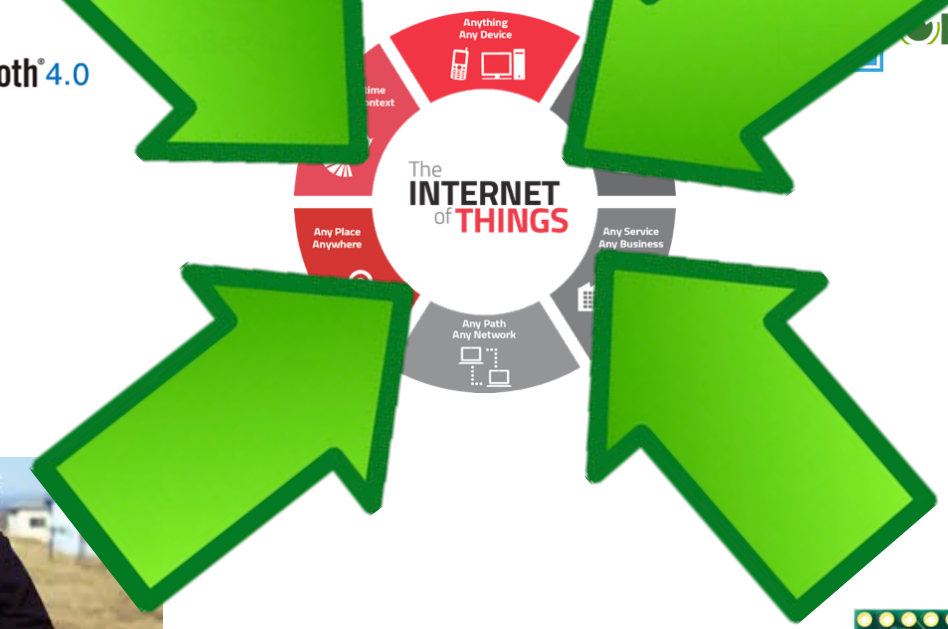
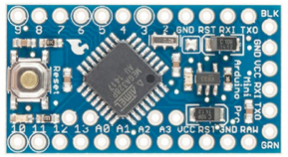
Last but not least: low-cost sensors!

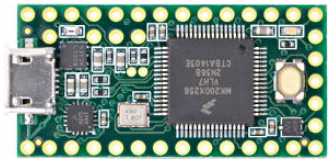


IoT-for-All can become reality!

SIGFOX
One network A billion dreams
LoRa
nwave
LTE-M
NB-LTE
WEIGHTLESS
DASH7 ALLIANCE
Bluetooth 4.0
Dropbox
Firebase
FIWARE
Axēda
ioBridge
Connect things.
ThingSpeak
GroveStreams
sorCloud
freeboard
Faster Analytics







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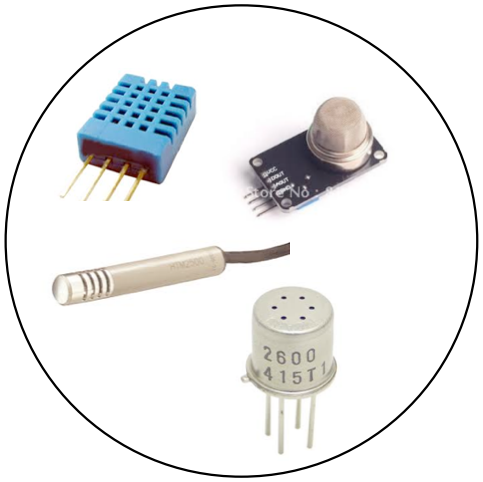
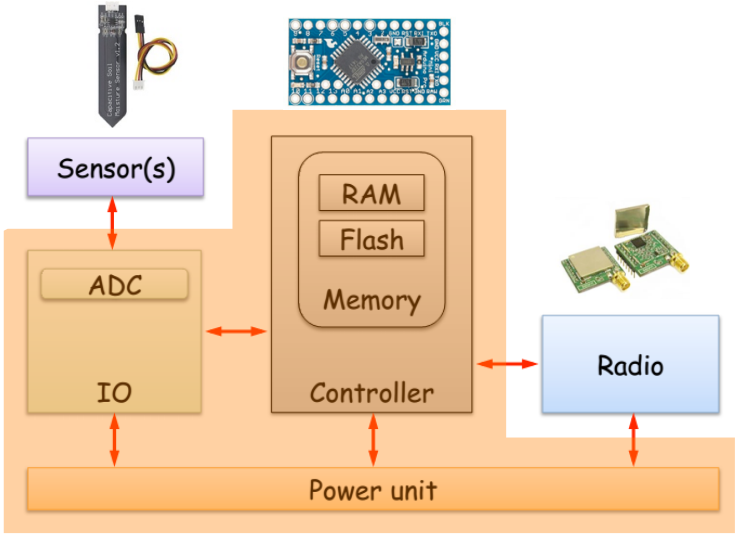
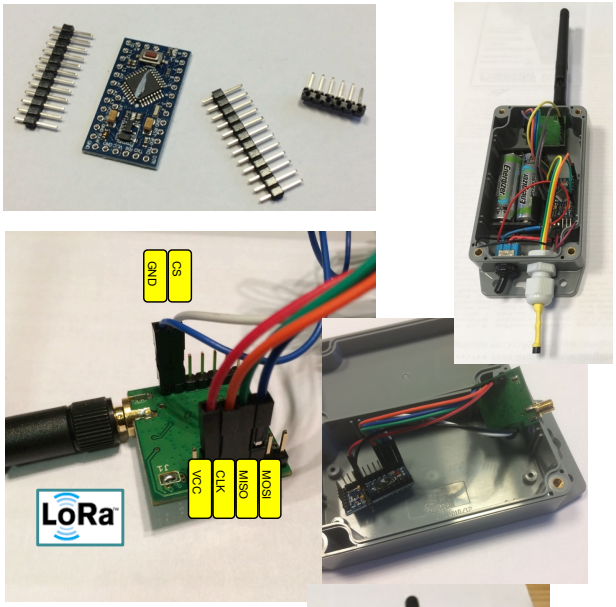
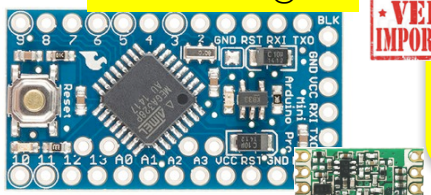
Do-It-Yourself IoT







Arduino Pro Mini @3.3V

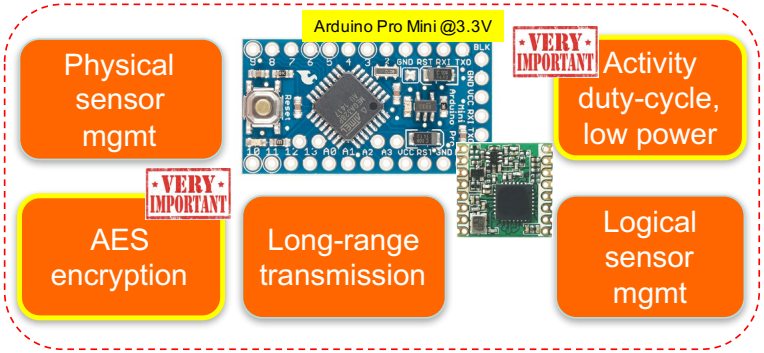


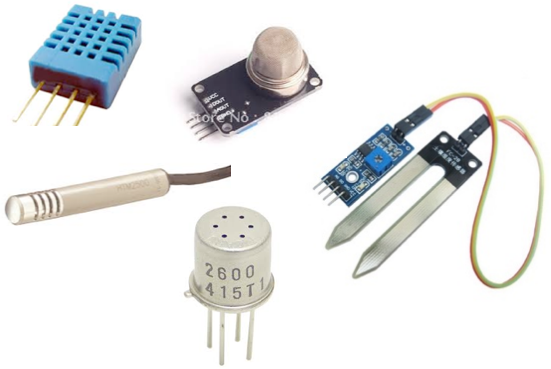
- Physical sensor mgmt
- VERY IMPORTANT — Activity duty-cycle, low power
- VERY IMPORTANT — AES encryption
- Long-range transmission
- Logical sensor mgmt

WAZIUP
IoT – from idea to reality
WAZIHUB

Generic IoT v.s. highly specialized

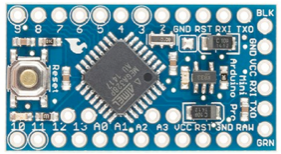
- Build low-cost, low-power, generic IoT platform
- Methodology for low-cost platform design
- Technology transfers to user communities, economic actors, stakeholders,...





A simple temperature sensor example

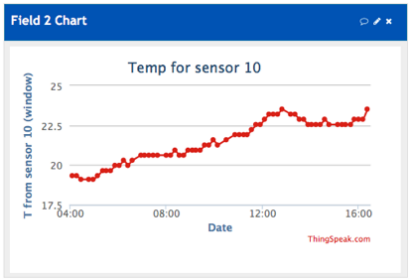
Arduino Pro Mini @3.3V



Modtronix inAir9

TMP36

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

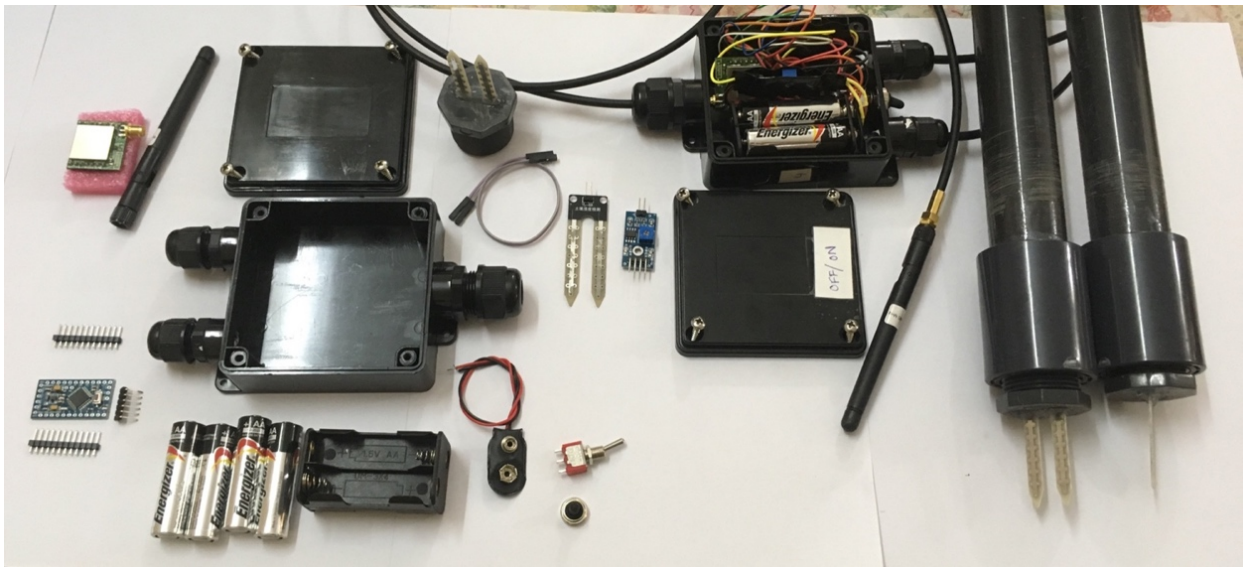


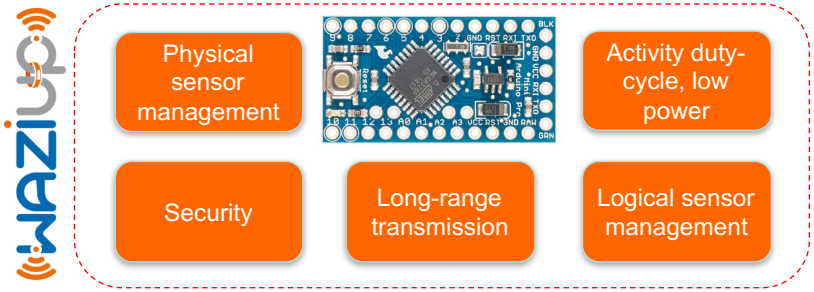
5µA in deep sleep mode, about 40mA when active and sending

More than 1 year with 1 measure/10min

Can run several years with 1 measure/1h

A soil humidity sensor example





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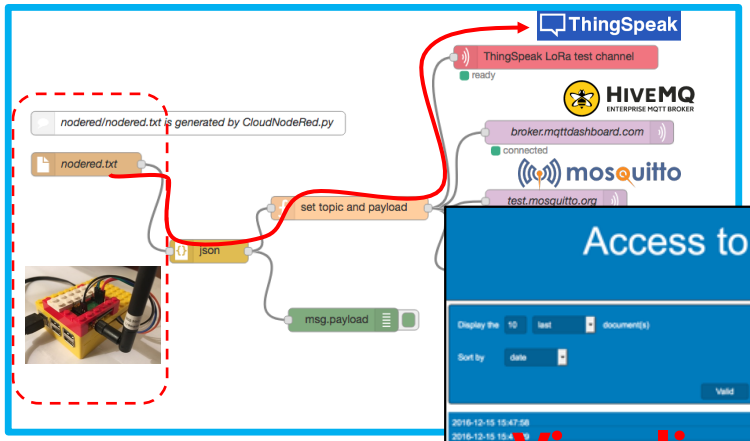
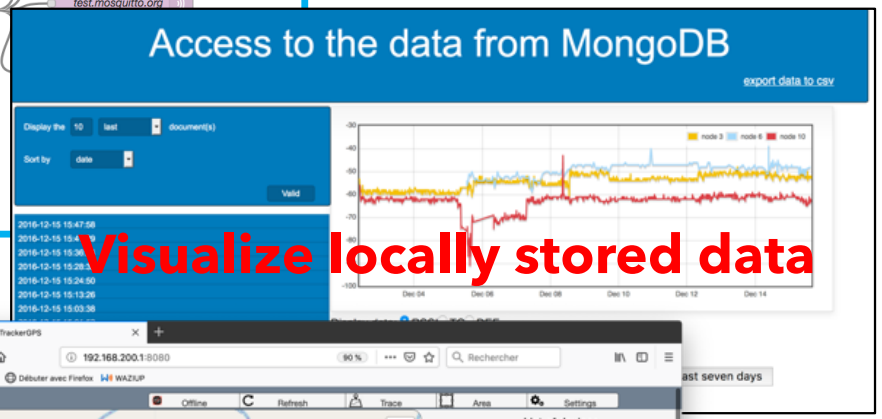
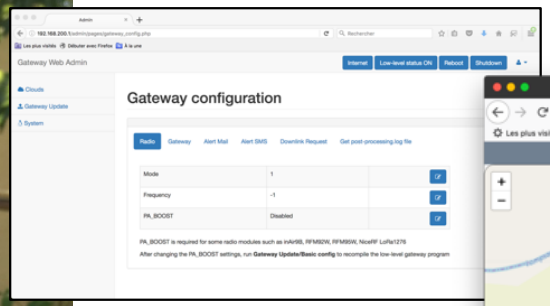
Open, versatile IoT gateway

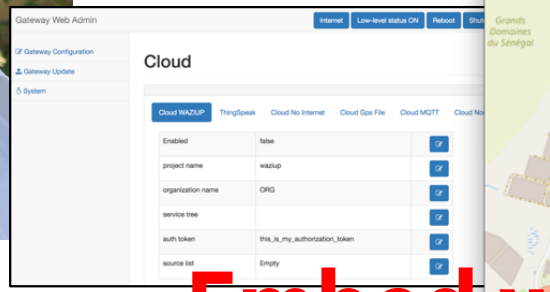


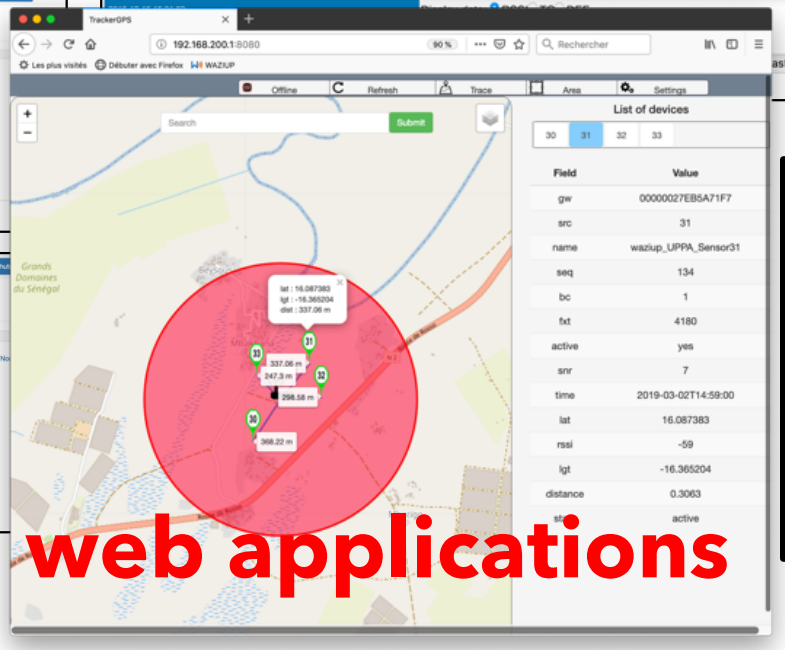
THE THINGS NETWORK

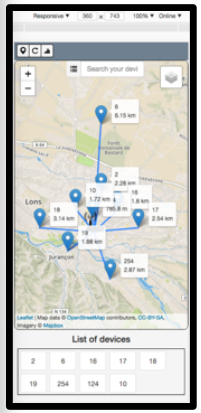


Visualize locally stored data









Embed web applications

Deployment for Nestlé's WaterSense

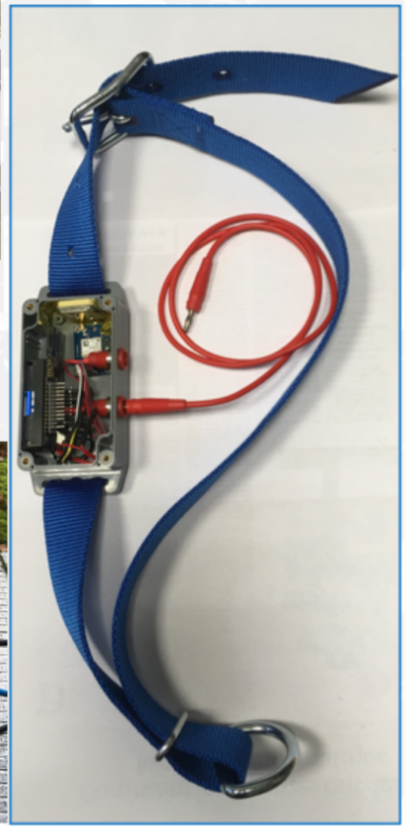
Minimum Viable Products (MVP)

Minimum Viable Products (MVP)

Fish farming solutions

Minimum Viable Products (MVP)

Cattle rusting and location monitoring



Making IoT happening!

Innovative IoT technologies

"IoT for All" paradigm

IoT infrastructures and use cases

Knowledge dissemination & training

Users/Developers engagement

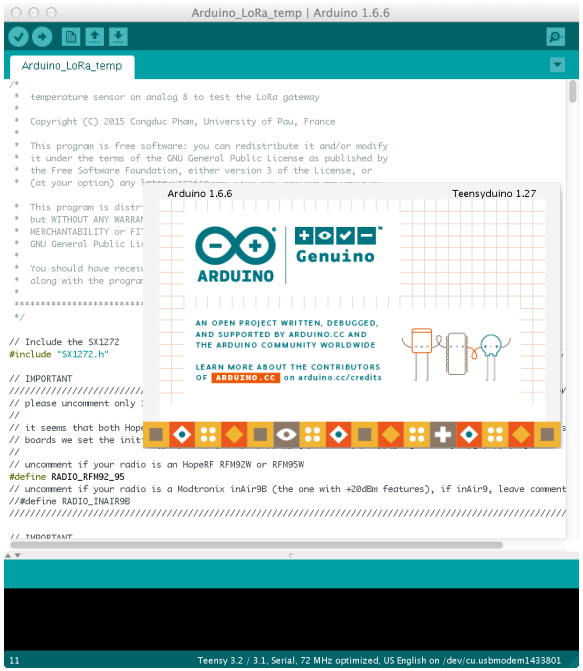
Innovative solutions adapted to local needs

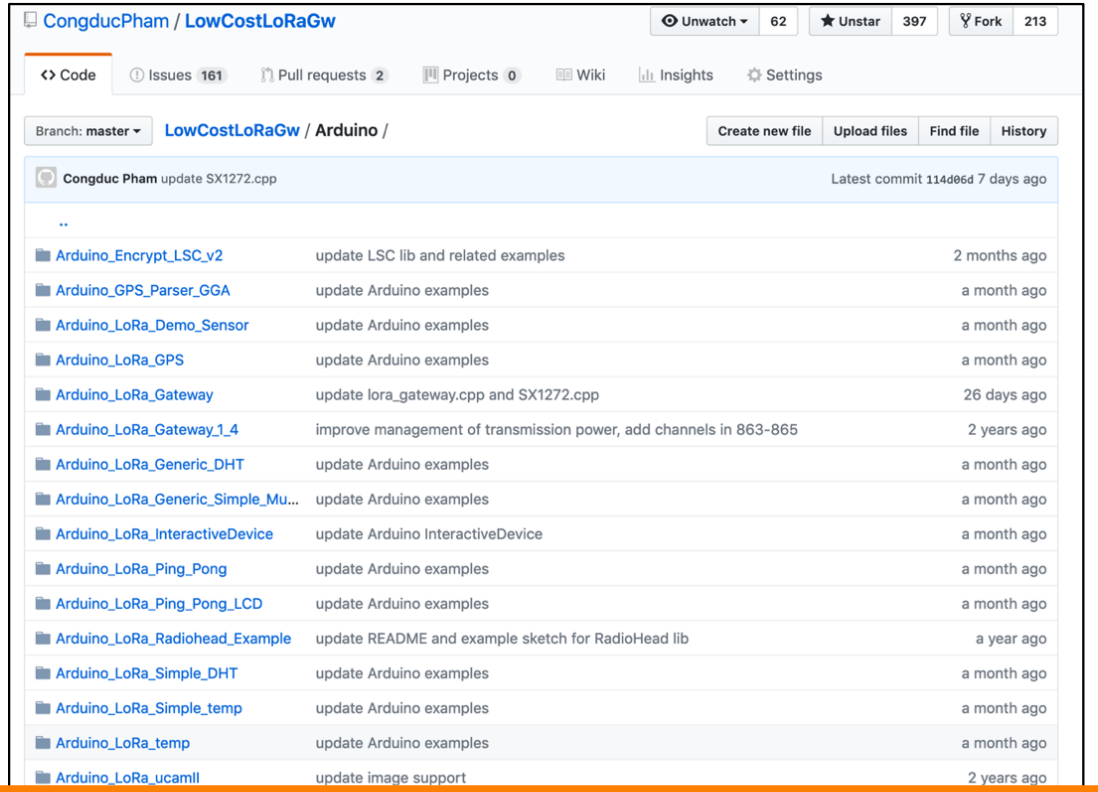
Exploitation plan and innovation hubs

Communication & community building

Sustainable & long-term innovation

100% open-source code templates





Many examples using various temp/hum sensors
https://github.com/CongducPham/LowCostLoRaGw/tree/master/Arduino

Community building for sustainable innovation

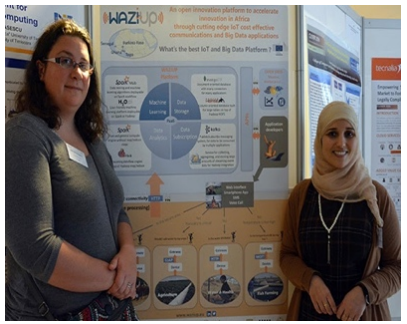
International Events
+ 20 organized & attended

Launch event (Senegal, CTIC Dakar)

Launch event (Ghana, iSpace)

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

IoTWeek2016 (Belgrade, EGM)



IoTBigData2016 (Italy, EGM)

IoTCareConference (Budapest, CNET)

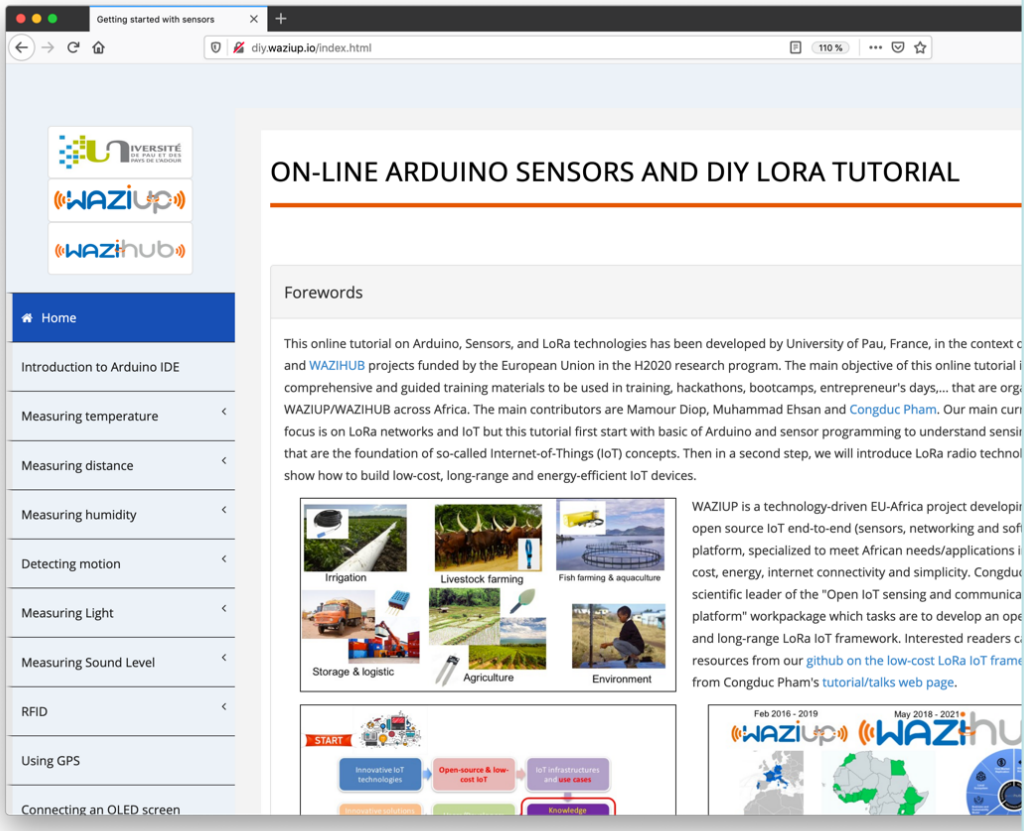
WAZIUP Workshop on IoT (Togo, L'Africaine d'Architecture)

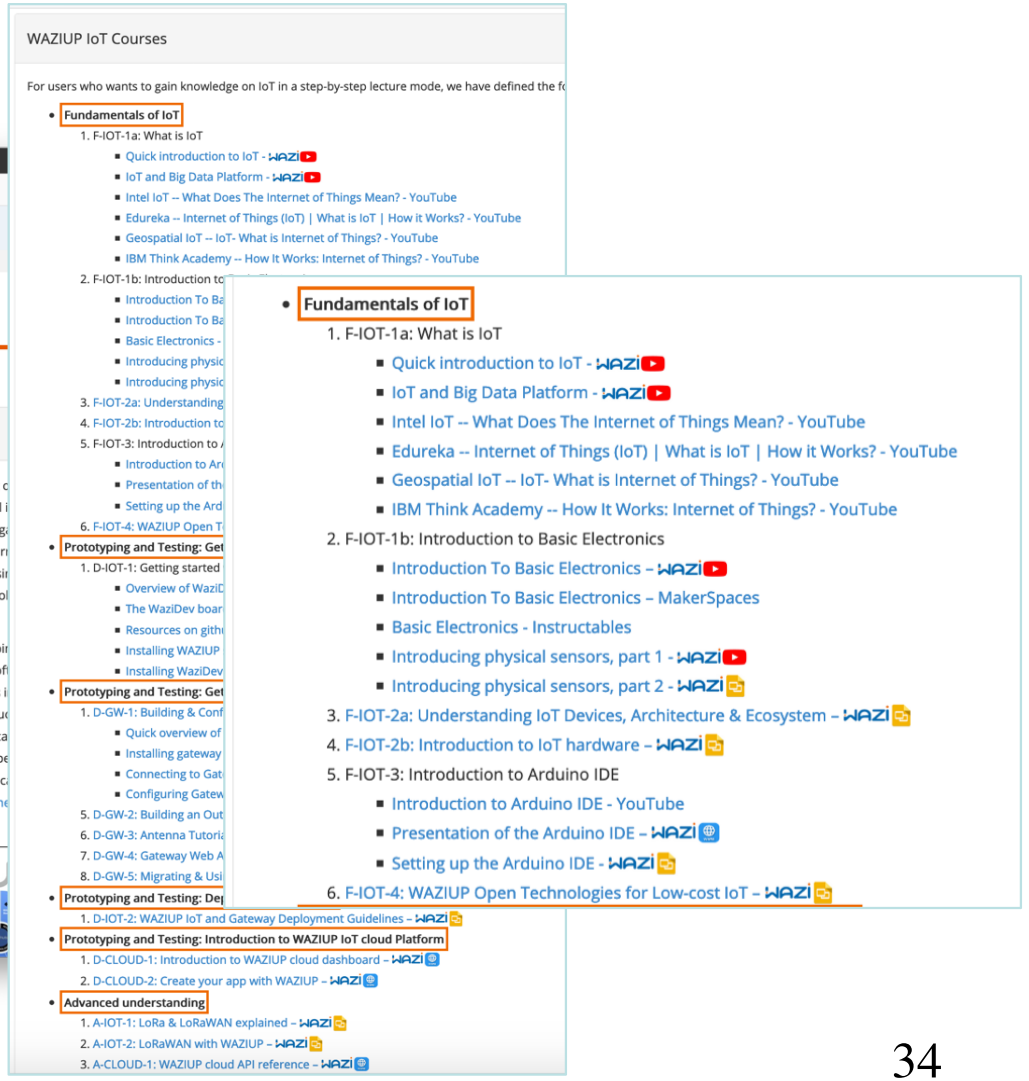
Credit: C. Vavasseur, CTIC Dakar

Workshop at the RESSACS 2016 (France, UPPA)

WAZIUP Online Course

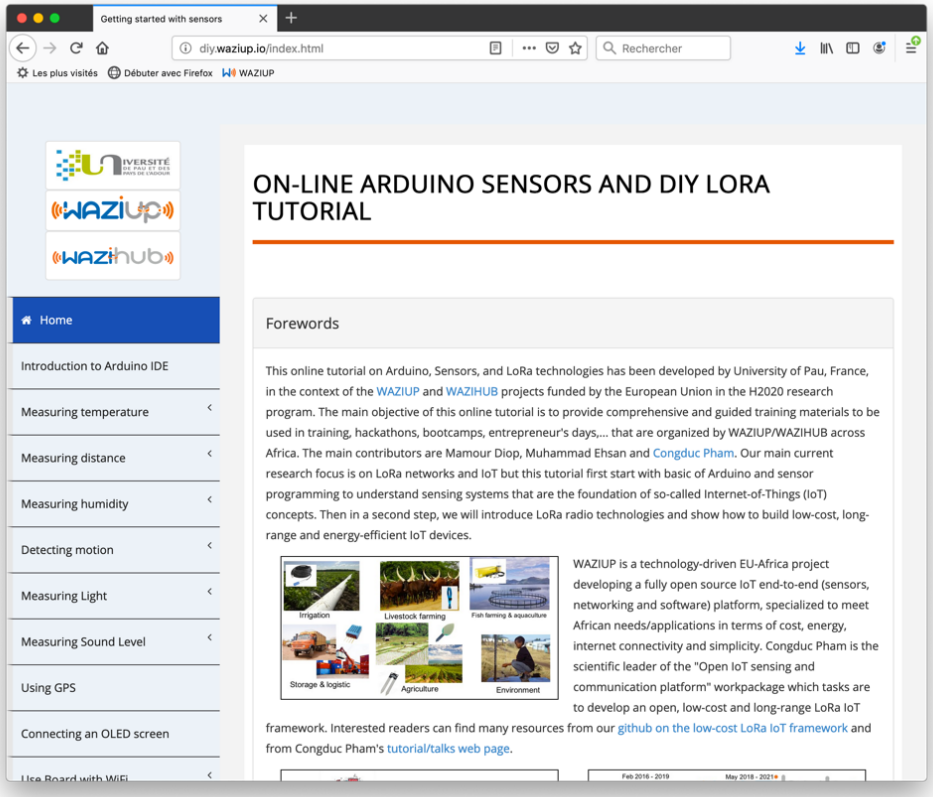
- http://diy.waziup.io





Training & hackathons

- Technical training sessions
- Hackathons, ...



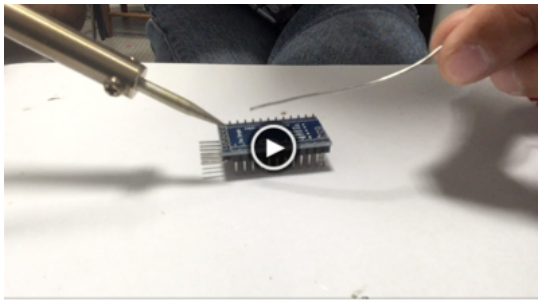
Online Arduino & IoT step-by-step tutorial
https://diy.waziup.io

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

Is it enough?

Q: what's missing?

Accuracy? Simplicity?

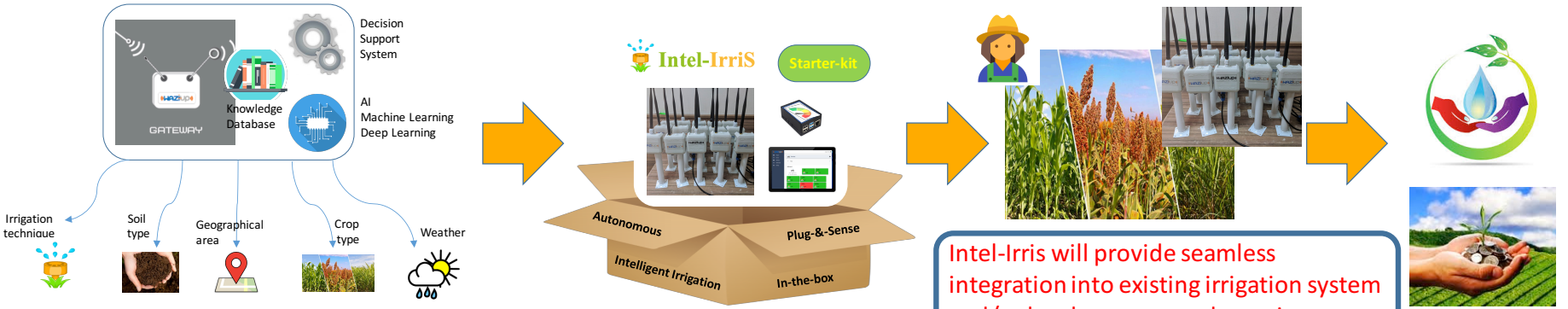
Intel-IrriS: Intelligent Irrigation-in-a-box

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

AI+Smart Agriculture=Win-Win!

Intel-IrriS

Low-cost system based on low-cost sensors and advanced water-soil-plants-climate interaction models for higher accuracy of collected measures

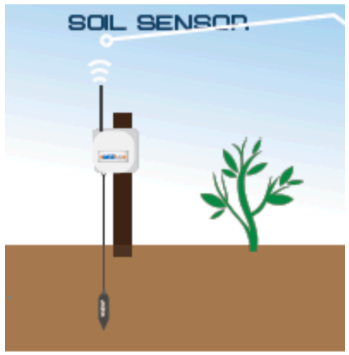


Intel-Irris will provide seamless integration into existing irrigation system and/or local customs and practices

Low-cost sensors: accuracy?

Sensor part

Intel-IrriS



- Build on low-cost, low-power IoT expertise WAZIUP
- Increase accuracy of low-cost sensors by advanced calibration
- Enable deployment of several complementary low-cost sensors: soil conductivity, volumetric water content, …
- Include agricultural models / knowledge with corrective & predictive analytics

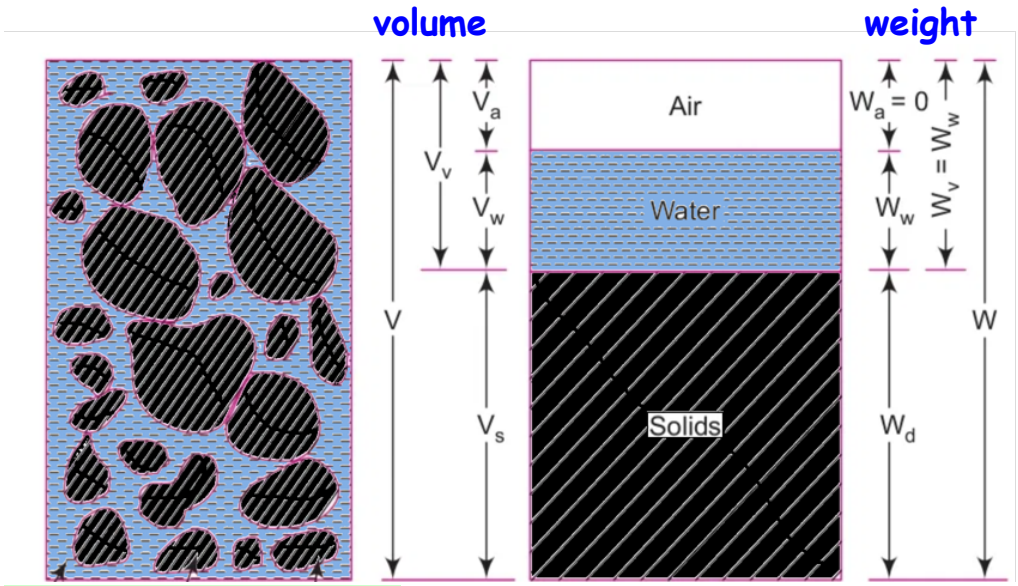
Understanding soil water

Source: Christian Hartmann, IRD

- Low-cost sensors usually measure soil water content
- Soil = a pile of aggregates ➡ 3 phases: solid + air & water

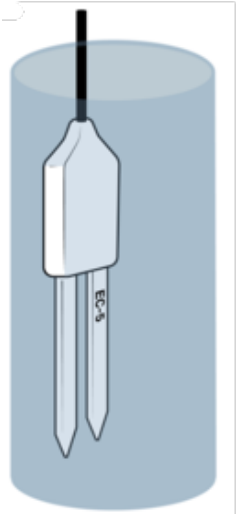
Geometry of the aggregates & pores

Schematical view of the 3 phases



Saturated soil

water volume capacitive sensors



Decagon EC5
120 euros

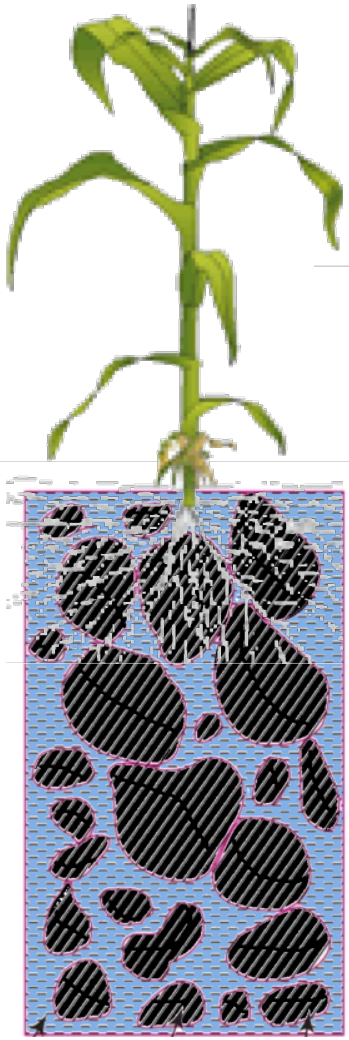
accurate

Gravity SEN193
6 euros

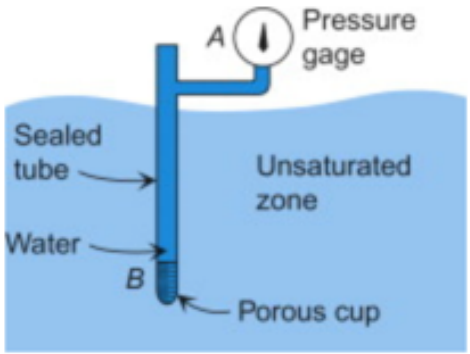
under test

Soil water? Not enough!

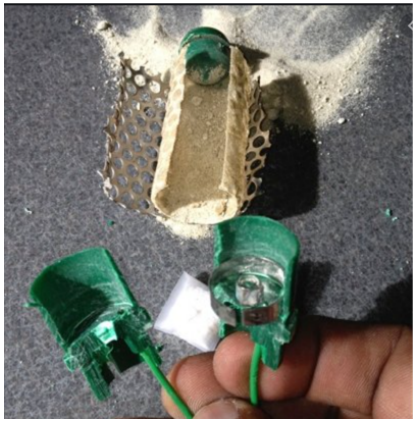
Source: Christian Hartmann, IRD



- in the soil, the water is UNDER TENSION
  = it is hold by CAPILLARY FORCES
- Water tension is also needed!



SDEC
100 euros



WATERMARK
40 euros

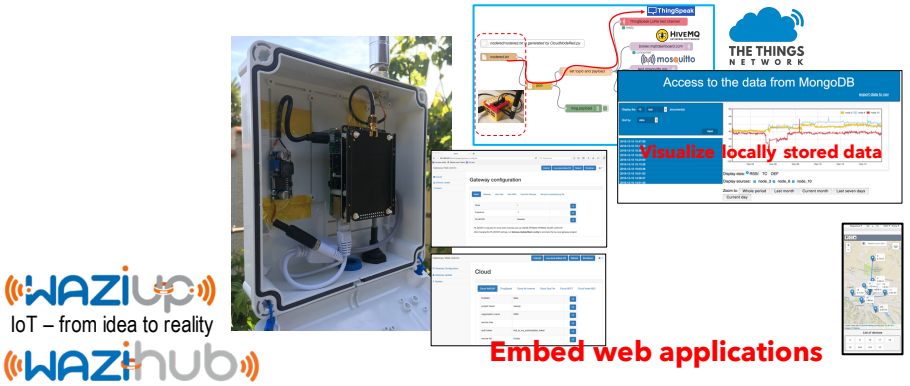
IRD
< 5 euros?

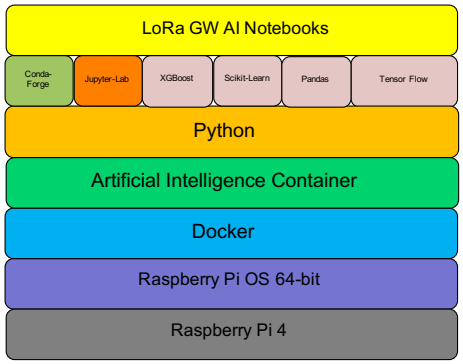
Smart embedded control

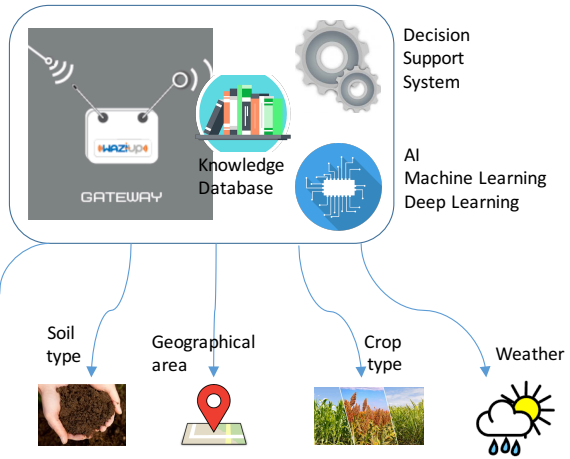
- Build on low-cost embedded & open IoT gateway expertise
- Implement the “Itelligent Irrigation in-the-box” vision
- Model complex interactions: water-soil-plant interaction, evapotranspiration,...
- Embed Decision Support System (DSS) and disruptive Artificial Intelligence (AI)
- Integration of multiple knowledge streams
- Fully autonomous

Edge-AI for fully autonomous system

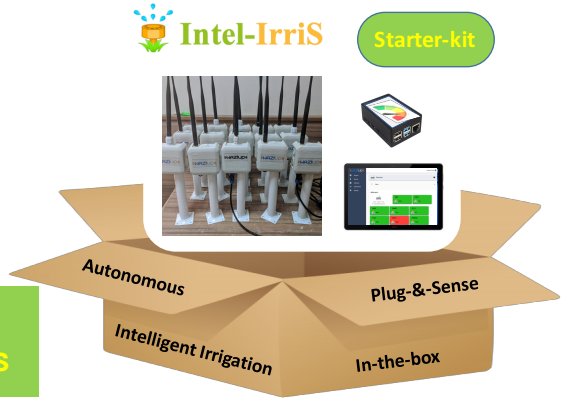
- Embed every thing on the IoT gateway to provide a fully autonomous system for the "Intelligent Irrigation-in-the-box"







Integration of multiple knowledge streams

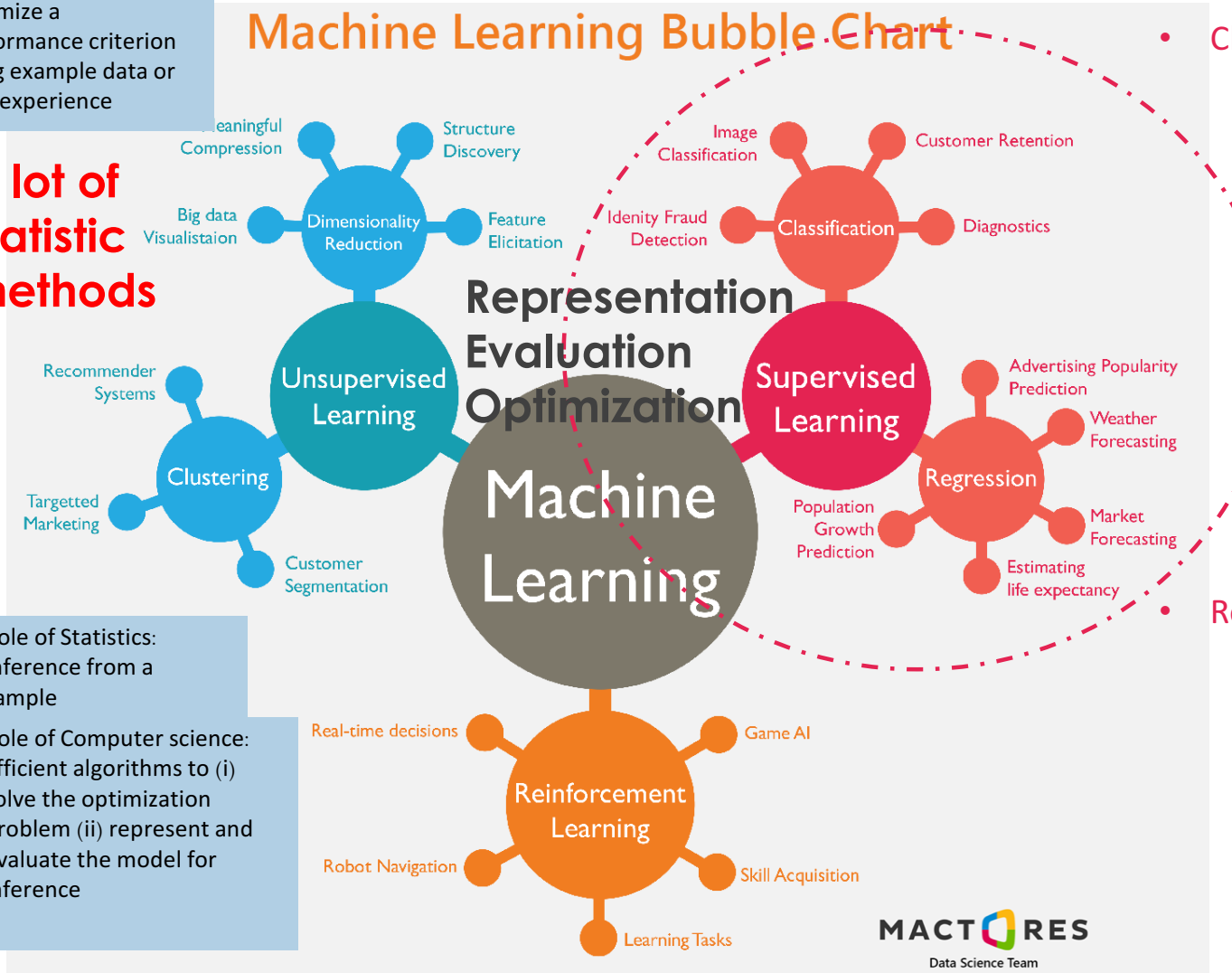


Fully autonomous

Machine Learning Techniques

Optimize a performance criterion using example data or past experience

A lot of statistic methods



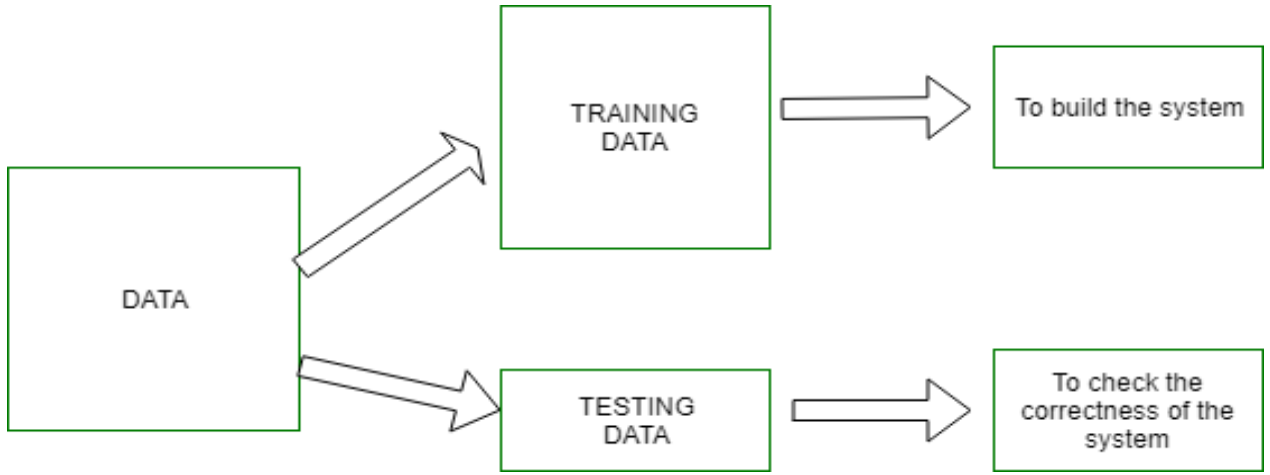
Role of Statistics: Inference from a sample

Role of Computer science: Efficient algorithms to (i) solve the optimization problem (ii) represent and evaluate the model for inference

- Classification
  - Logic
  - SVM
  - Random Forest
  - Hidden Markov
  - …
- Regression
  - Lasso
  - Ridge
  - Loes
  - KNN
  - Spline
  - XGBoost
  - …

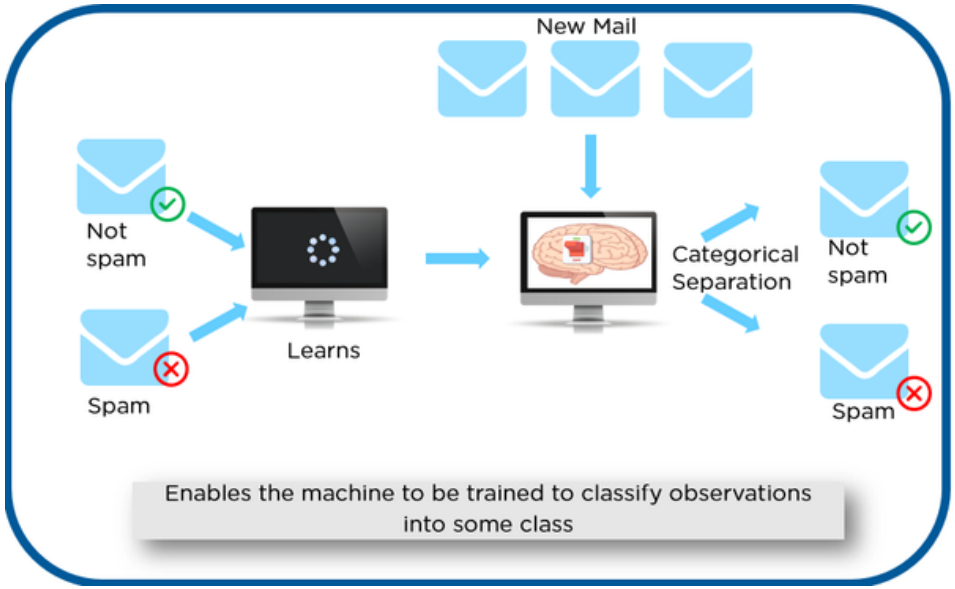
Supervised Learning

- ML model is presented with *input data* which is labeled
  - Each *input data* is tagged with the correct label.
- The goal is to approximate math operations in the ML model so well that when presented with new *input data*, the ML model can **predict** the output variables for that *input data*.



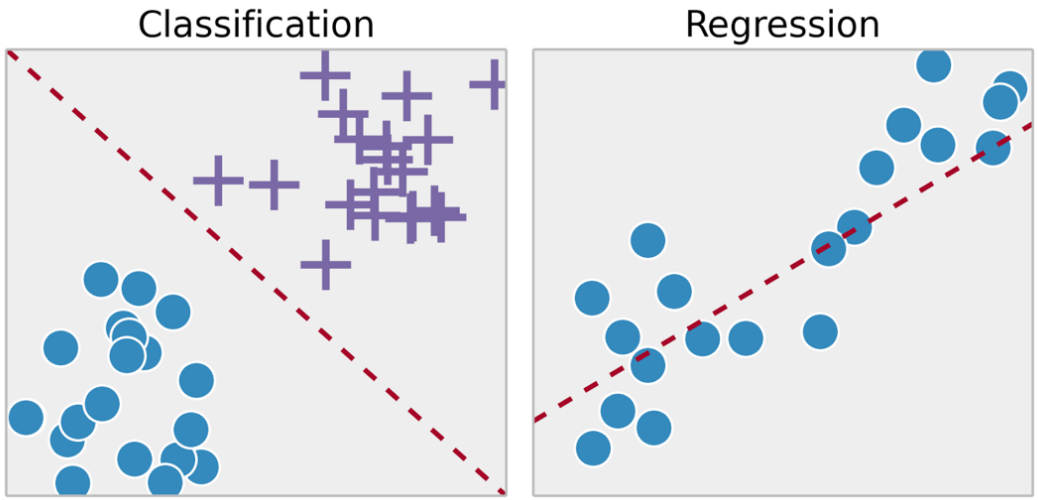
Spam Mail Example

- On the left side of the image, some data is marked as ‘Spam’ or ‘Not Spam’. This is *labeled data.* This data is used to train the supervised model, the *intelligent* program (at center of the image).
- Trained model is tested with new mails (on the top of the image) and checking if the output of the supervised model is correct (on the right side of the image).



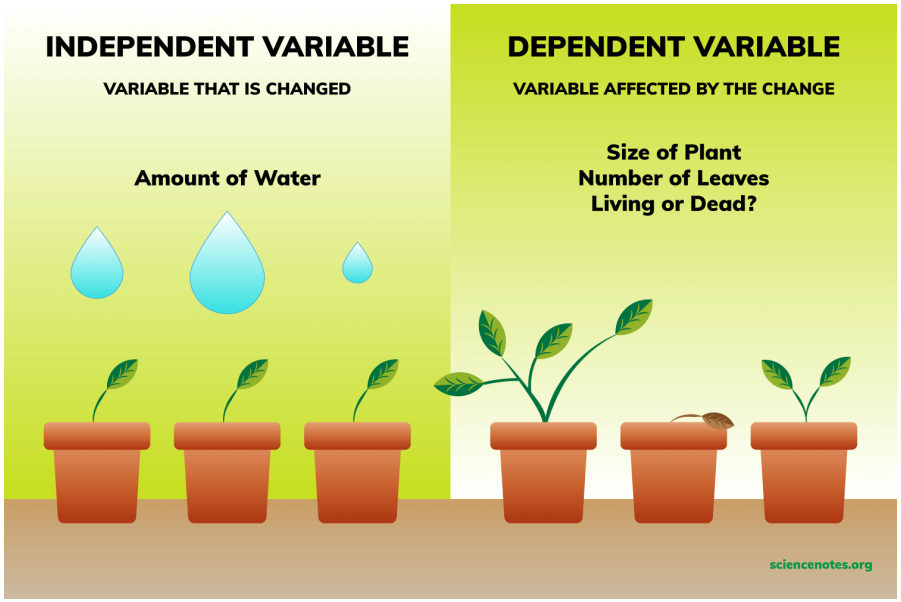
Types of Supervised Learning

- **Classification**: A classification problem is when the output is a category, such as “red” or “blue” or “disease” and “no disease”.
- **Regression**: A regression problem is when the output is a real number, such as “dollars” or “weight”.



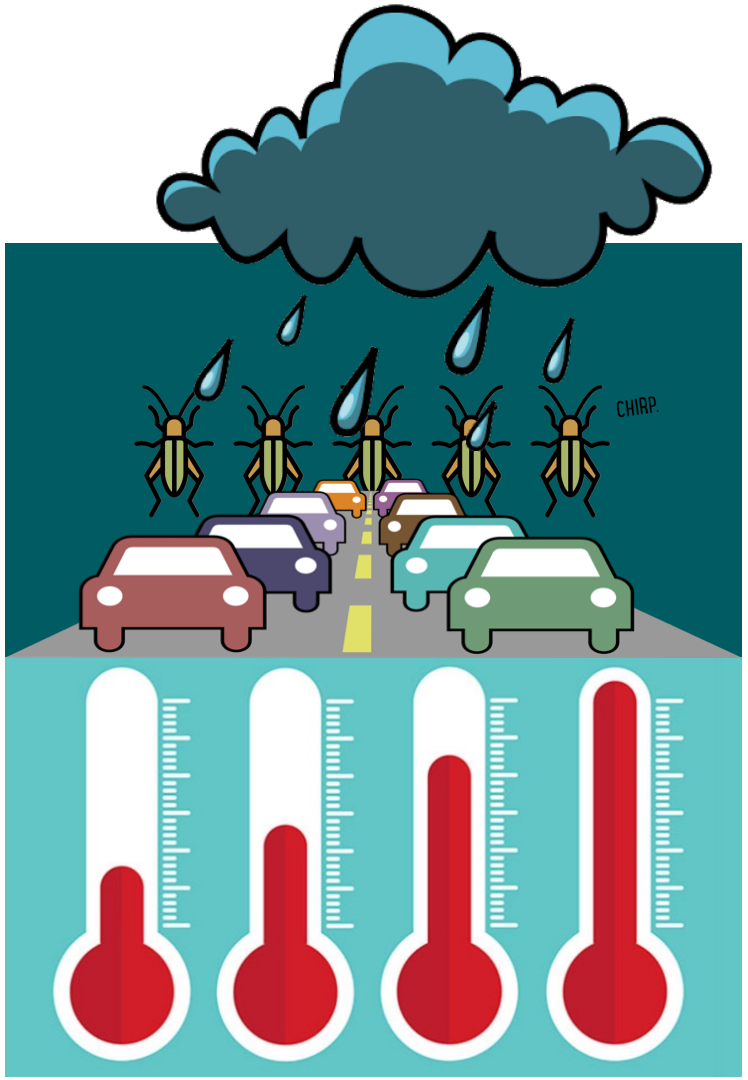
Regression

- **Dependent variables:** the main event or factor to understand or predict. Also known as *explanatory variable.*
- **Independent variables:** the events or factors suspected to have an impact on the dependent variable. Also known as *response variable.*



Types of Regression

- **Simple regression:** single independent variable for a single dependent variable. It is very common to name the independent variable as x and **Y** as the dependent variable
  x: number of cricket chirps
  Y: temperature
- **Multivariable regression:** multiple independent variables, x_1, x_2, x_3, for a dependent variable **Y**.
  x_1: number of cricket chirps
  x_2: rainfall
  x_3: automobile traffic
  Y: temperature



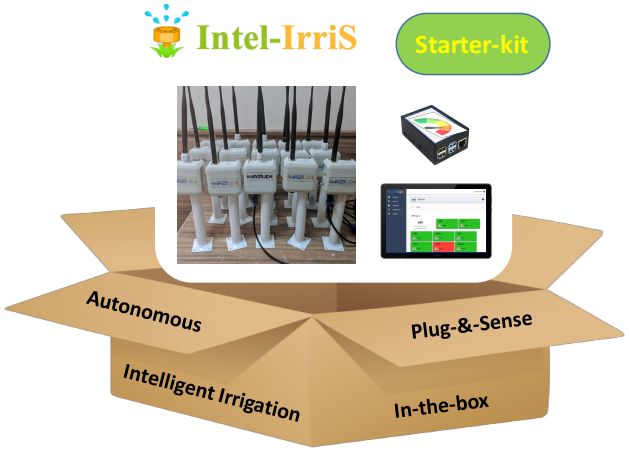
It is NOT ONLY about technology!

4 Improve farmer's knowledge on water-related issues, foster local adaptation of technologies, increase local innovation capacity and facilitate technology appropriation

5 Large-scale adoption of low cost smart irrigation system by smallholders, stimulating synergies between various local actors

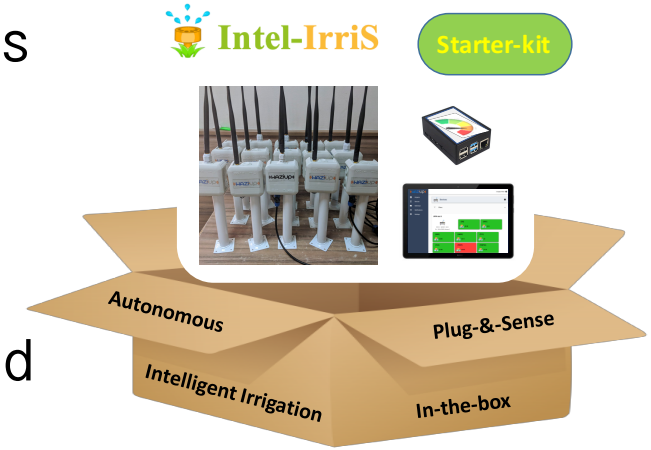
Smallholder Piloting Program

- Participatory approach to co-design & test the innovative solutions in fields
- Take into account region-dependent technical, agricultural, social, climatic and environmental aspects
- Will run for 30 months to ensure that the proposed irrigation systems are well tailored for the specificities of the regional context
- 9 farms already enrolled to participate in the Piloting Program
- Scale-up to involve at least 20 small-scale farms



Farmer Training Program

- Run in parallel to the Smallholder Piloting Program
- Increase smallholders' knowledge so that they can familiarize with the proposed technologies, tools and practices
- Specific training materials will be created for that purpose and dedicated training sessions will be organized in coordination with the Smallholder Piloting Program
- Increase engagement of final users
- Recruit for Smallholder Piloting Program and distribution of starter-kits



Conclusions

- Internet-of-Things provides the unique feature to make things "talk" to us: localisation, surrounding environmental conditions,...
- It has unique capabilities in helping humanity to reach more sustainable development
- Adapting IoT solution for smallholders is the next decade challenge!
- Next generation sensors such as cameras, spectrometers, hyperspectral cameras,... will provide possibilities to further optimize a number of complex processes
- We have more than 8 years expertise in developping & deploying low-cost IoT in Africa with 4 EU H2020/PRIMA projects

Designing and deploying low-cost IoT: digital agriculture opportunity for smallholders

Presented on May 26th, 2021

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Université de Pau, France

PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

Intel-IrriS

UNIVERSITÉ DE PAU ET DES PAYS DE L'ADOUR

LIUPPA

WAZIUP
IoT – from idea to reality
WAZIHUB