Feedbacks from deployment of ad-hoc LoRa solutions for rural applications in Africa

Embedded Systems and Communicating Objects scientific day
April 1st, 2019, CNAM, Paris

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

IoT – from idea to reality

Retour d'expérience sur le déploiement ad-hoc de solutions LoRa pour des applications rurales

Journée Systèmes Embarqués et Objets Communicants (SEOC)
1 avril 2019, CNAM, Paris

/seoc-cpham.pdf

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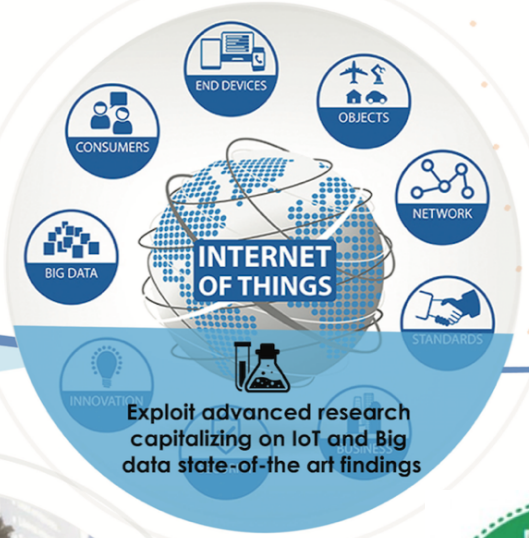
IoT – from idea to reality

WAZIUP Open IoT and Big data platform for Africans, by Africans

HORIZON 2020

Affordable technologies to empower rural economics



Exploit advanced research capitalizing on IoT and Big data state-of-the art findings

Develop IoT solutions and applications meeting African needs

DO MORE with LESS

www.waziup.eu

Waziup IoT

Waziup IoT

Waziup

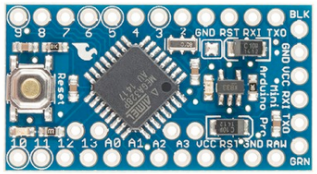
Waziup

CREATE-NET · CTIC · Farmerline · iSpace · coders africa · INNOTEC

waziup.community@create-net.org

Low-cost IoT

Arduino Pro Mini

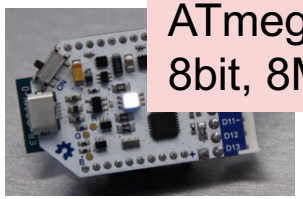


LoPy

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/

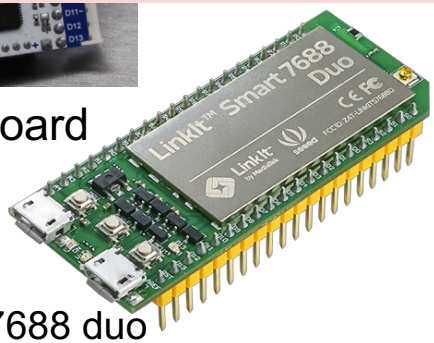
ATmega328P 3.3v
8bit, 8MHz, 32K flash, 2K RAM



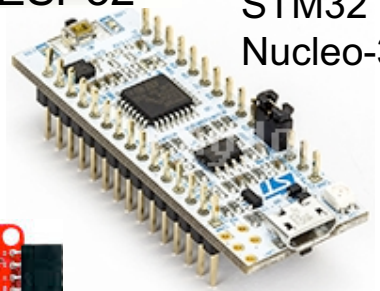
Theairboard

Teensy 3.2

Expressif ESP32



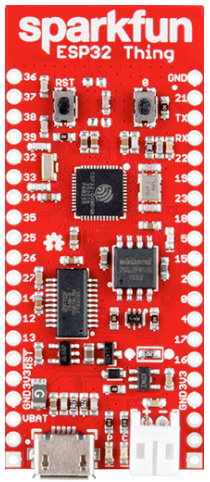
LinkIt
Smart7688 duo



STM32
Nucleo-32

Heltec ESP32 + OLED

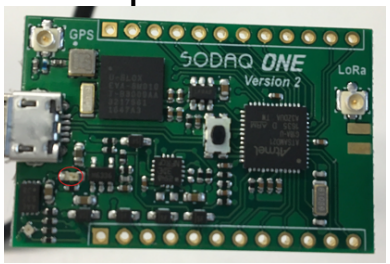
Adafruit Feather



Sparkfun ESP32
Thing

Tessel

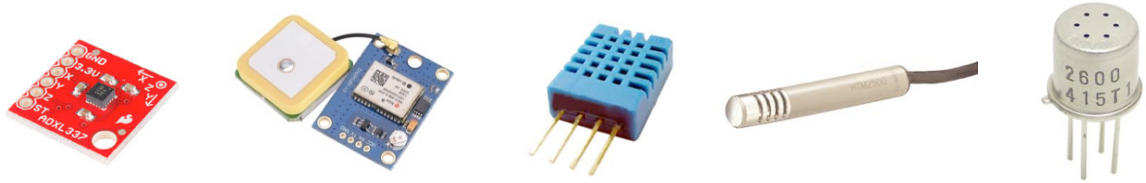
SodaqOnev2



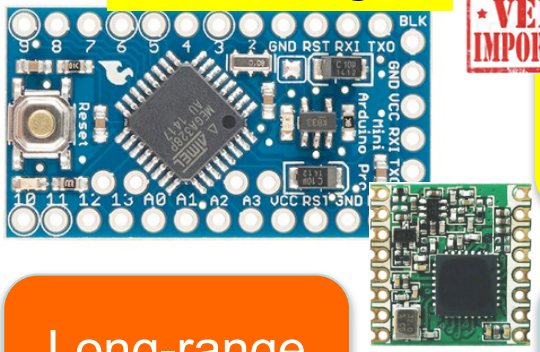
Tinyduino

Reduce development cost & time

Physical sensor | Physical sensor | Physical sensor



Arduino Pro Mini @3.3V



Physical sensor mgmt

VERY IMPORTANT

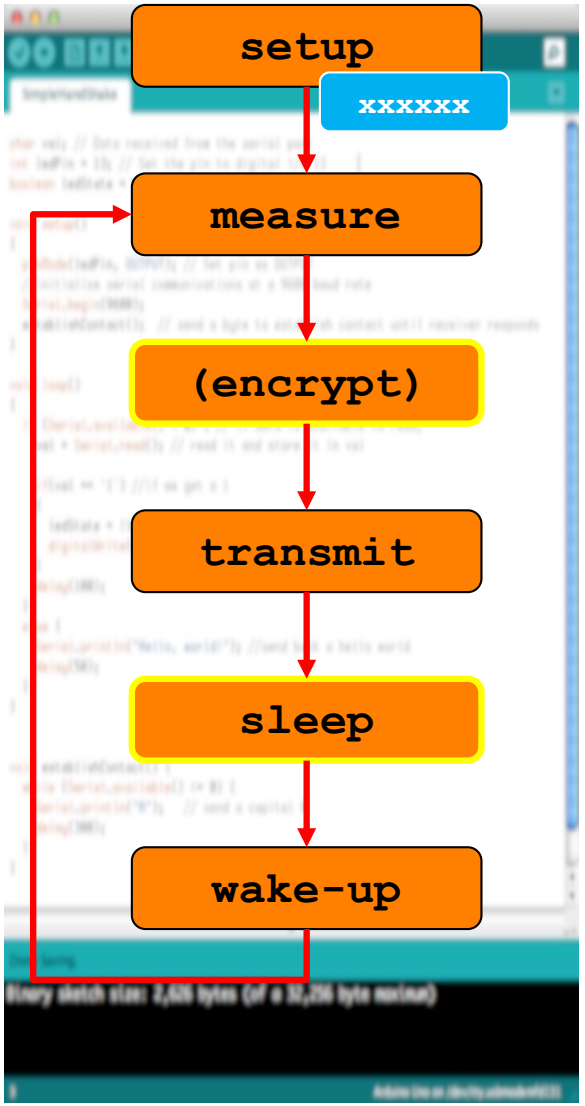
Activity duty-cycle, low power

VERY IMPORTANT

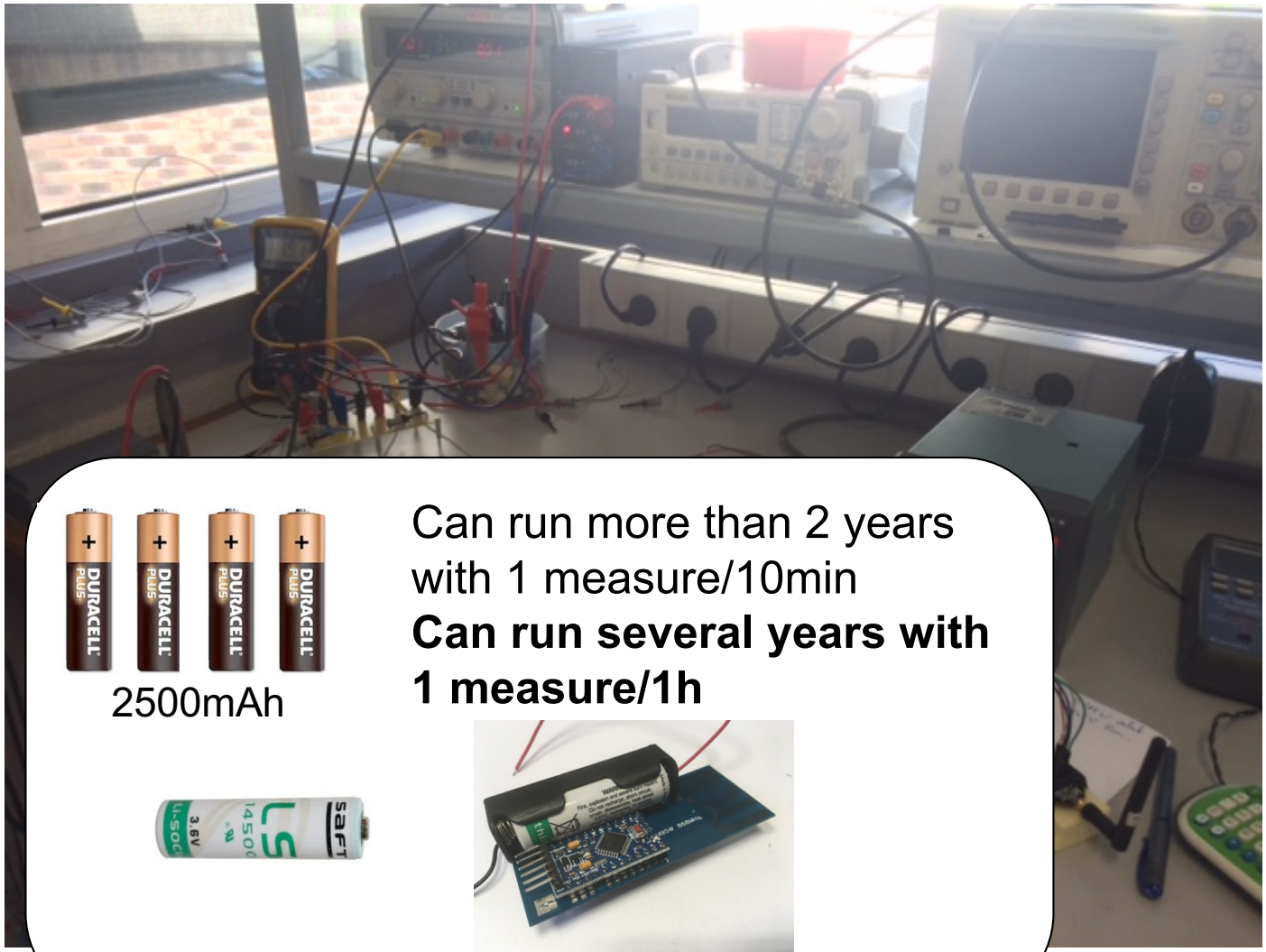
AES encryption

Long-range transmission

Logical sensor mgmt



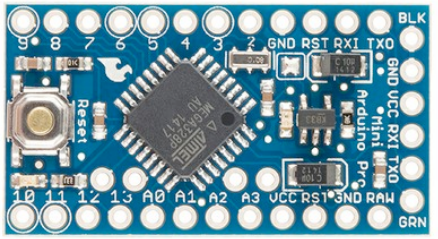
Low-power for longer lifetime!



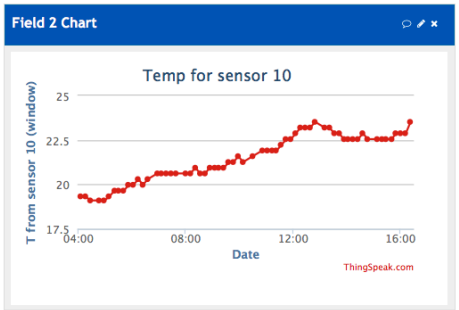
2500mAh

Can run more than 2 years with 1 measure/10min

Can run several years with 1 measure/1h



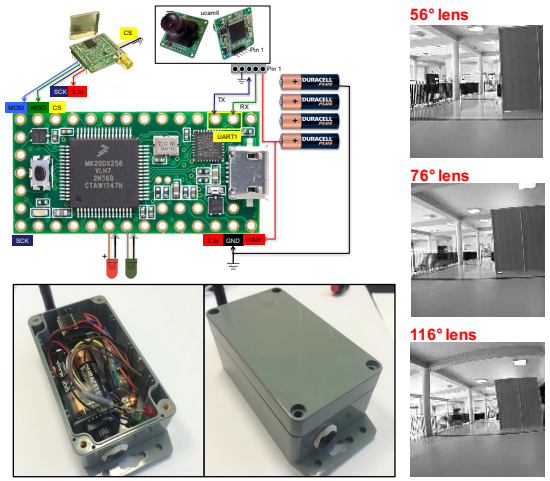
wakes-up every 10min, take a measure and send to GW

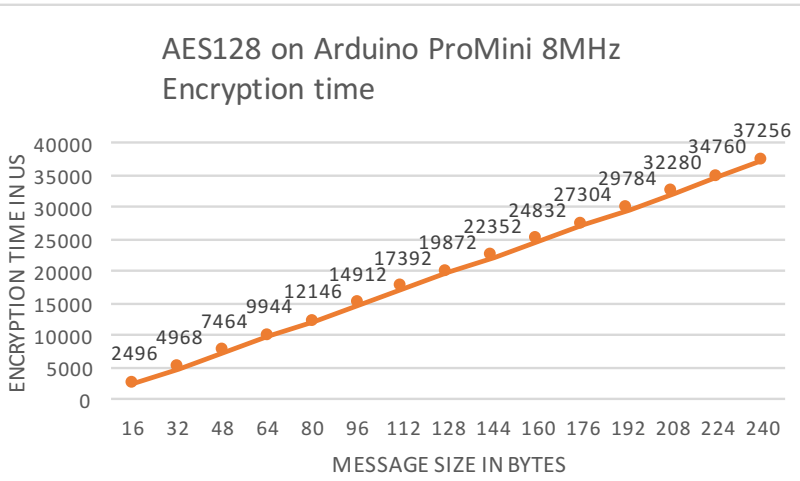


5µA in deep sleep mode, about 40mA when active and sending!

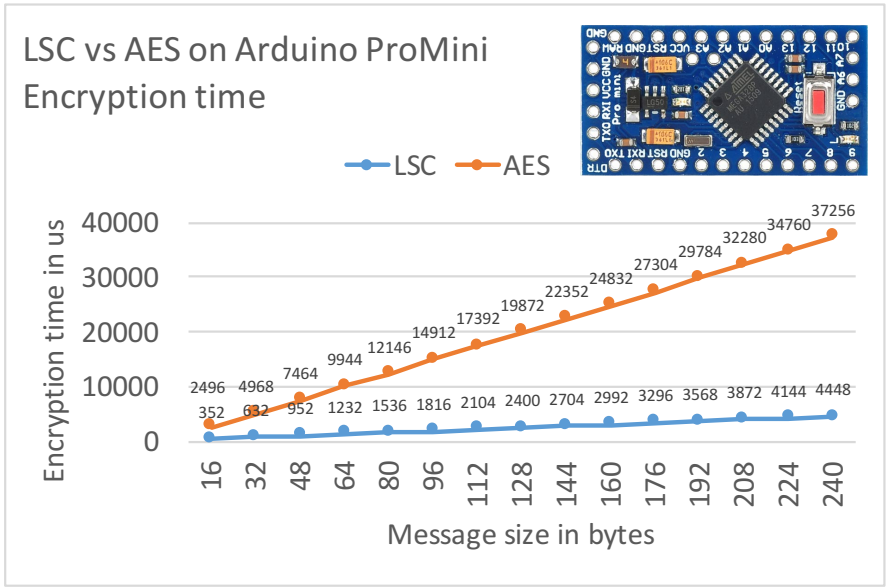
Cost of data encryption

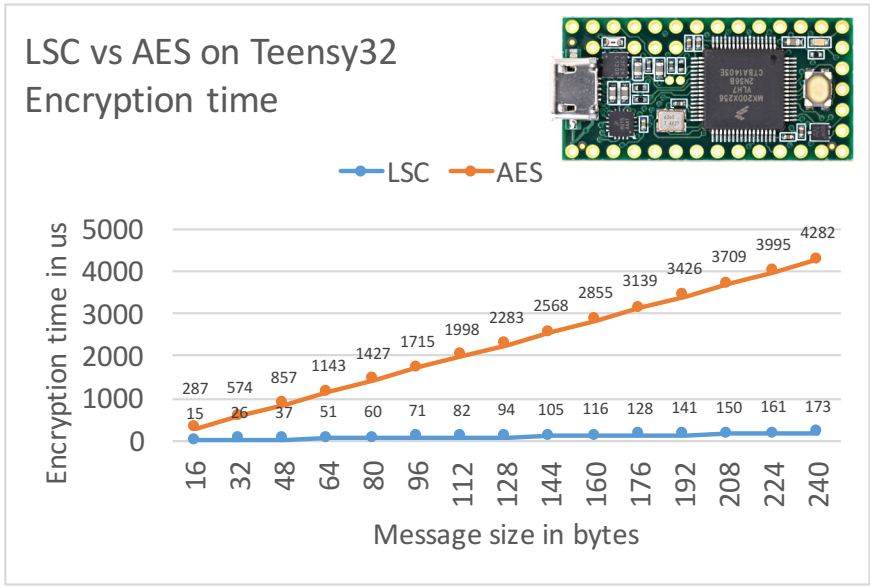
- AES128





- Lightweight Stream Cipher (LSC)

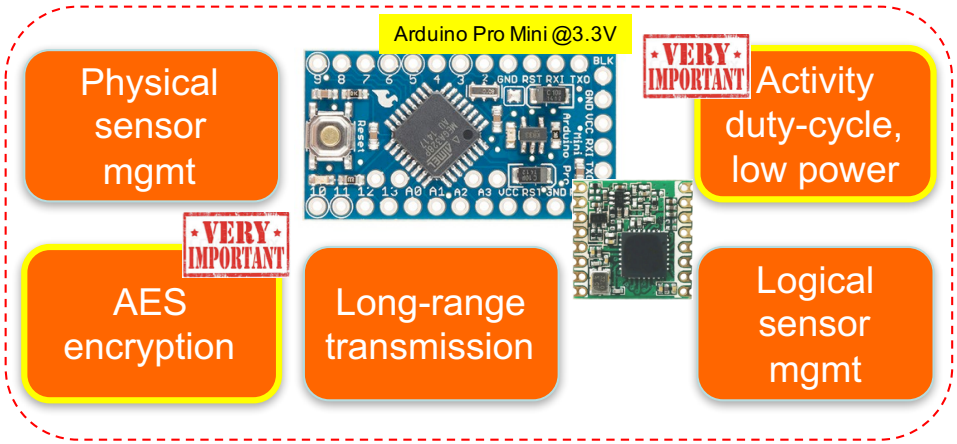


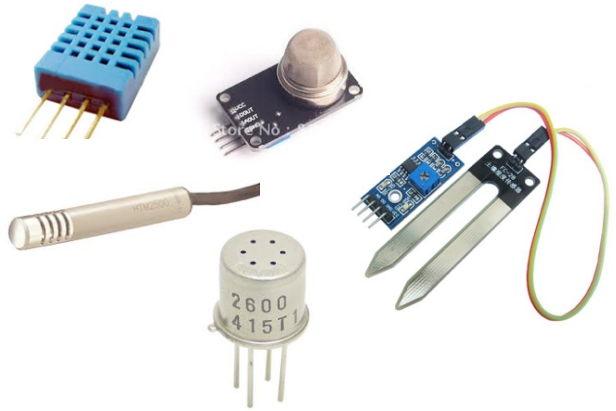


Work in collaboration with R. Couturier (Univ. Franche Comté) and Hassan Noura (American University of Beirut)

Generic sensing IoT device v.s. Highly specialized

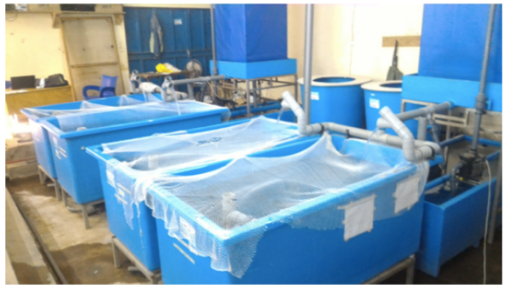
- Build low-cost, low-power, **long-range** enabled generic platform
- Methodology for low-cost platform design
- Technology transfers to user communities, economic actors, stakeholders,…

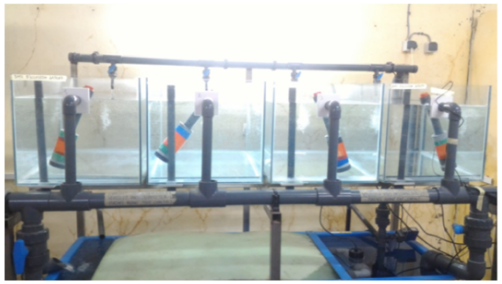




Hatchery experiment, Burkina Faso

- 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

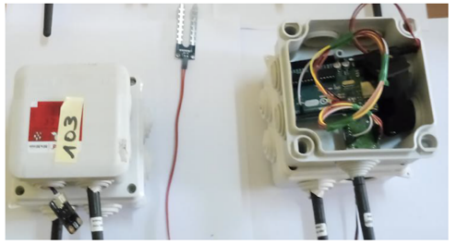
- Farm located at less than 2 km from UGB.
- One pond is dedicated for the Waziup application : 50x25m, average depth of 0.5 meters, populated by 4000 individuals of saltwater tilapia.
- The basin is irrigated via a water supply system fed by a river in proximity.
- The water in the pond is changed every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

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


Bananas field

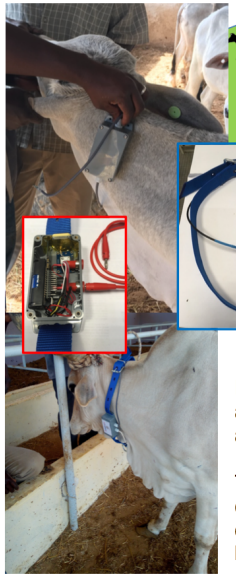

Papayas solos field

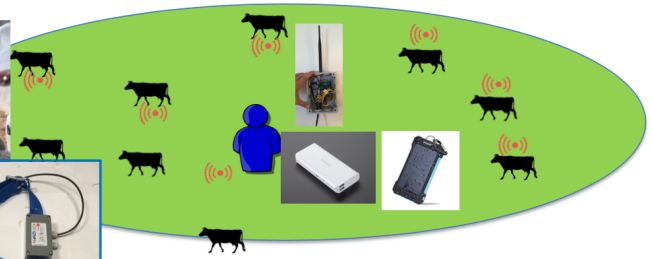

Banana plant


Papaya tree

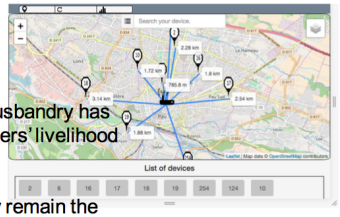
Urbannatic gardens, Togo


LOW-COST COLLAR FOR CATTLE RUTLING: CIMEL FARM, SENEGAL





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



In Africa, the practice of animal husbandry has always been and still remain farmers' livelihood and incomes

Their main problem in this activity remain the cattle rustling and some families are put in dramatic situation after a theft (reported 2 billions CFA losses)

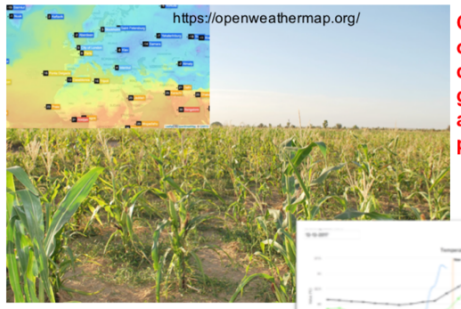
LOCAL WEATHER STATION FOR AGRICULTURE

In agriculture, different factors can be monitored. Having the ability to control those factors is the key to increase the productivity.

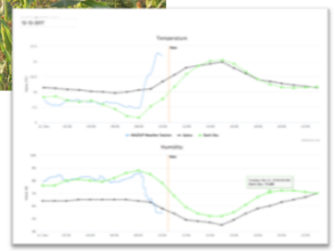
Agriculture MVP requirements:

Obtain and produce weather related information which will be used to advise the farmers!

Get local weather measurements

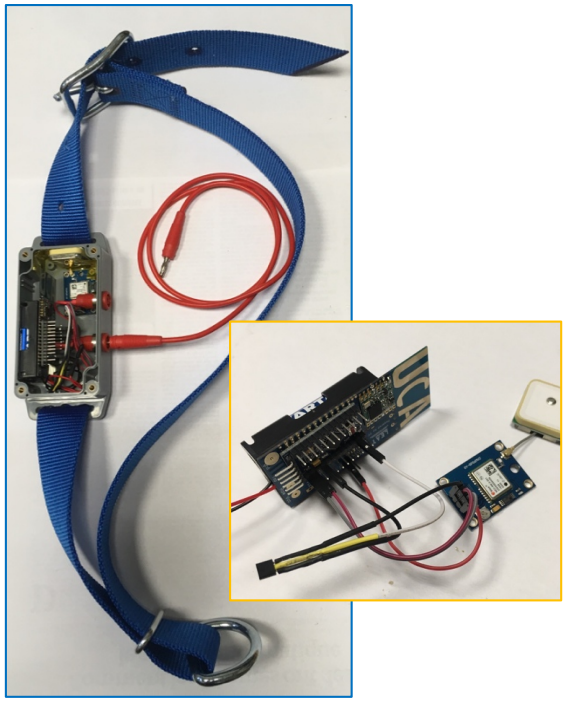


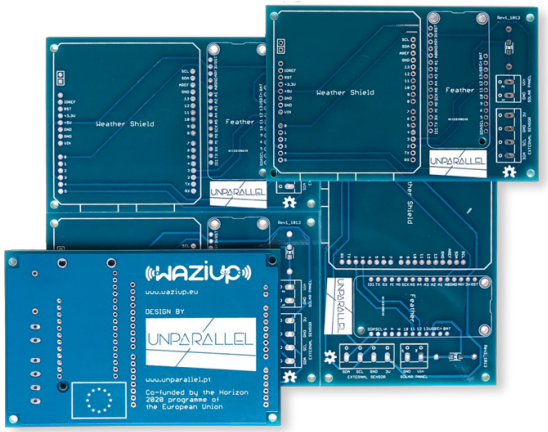
Combine with open weather data to get more accurate predictions



Weather Web App

Pilot sites: Senegal, Togo, Ghana, Burkina Faso





From Unparallel for WAZIUP

Impact analysis

Agriculture: waziup benefit to users

What do you think about technology to help you?
We were very happy to have the soil moisture sensors in our farm".
How do you feel the benefit that WAZIUP technology can bring to you?
"Water is a very essential component of our operations. And with the soil moisture sensors, we will be able to know how much water we should use to irrigate the vegetable beds. This will help us save water as we will not be over irrigating the farm"
Do you see already indirect or direct benefit?
"There is already a direct benefit because by knowing the moisture in the soil, we are able to use energy efficiently since we use manual means to do everything on the farm. Also, we will be conserving water which means we can have water all year round."

Mr. Douglas Ansah – Chief Farmer – Peace and Love Farms, Ghana

It's all about saving water, fertiliser &labour costs

Aquaculture: waziup benefit to users

- **What do you think about technology to help you?**

"In the past, we have researchers who bring their sensors when they are conducting research and then the sensors are taken away. Having an automatic sensor to measure the water quality of our ponds is welcome technology. And we are able to know what the water quality is and what measures we can take to resolve issues."

- **How do you feel the benefit that WAZIUP technology can bring to you?**

"With these sensors in our pond, we know the DO mostly goes very low between dawn and morning which made us reduce the quantity of fish in the pond in order to reduce the stress level. We are also working on getting a very low-cost aerator to install to help us increase the DO in the early mornings."

- **Do you see already indirect or direct benefit?**

"There is already a direct benefit because by knowing the challenge of the fish getting stress in the morning, we have taken measures to reduce the mortality rate which will increase our harvest."

- **What global statement can you make?**

"I believe the sensor is of immense benefit to we the fish farmers and I will always recommend it to my other farmers to get some. The project is good and it was interesting to see improvement in the sensors during the project phase."

Nana Siaw, Managing Director, Kumah Farms

It's all about to improve production thus revenue

Cattle rustling: benefit to users

- this is not a direct production benefit but an insurance to economic and physical risks (ie with violence)

Mor Sène, 20 years old

Interested by collar: Yes
Is 50 euros an acceptable price? No
Acceptable price : 30 to 40 euros
Cow cost : local cow 450 euros for a female and 750 to 900 euros for a male

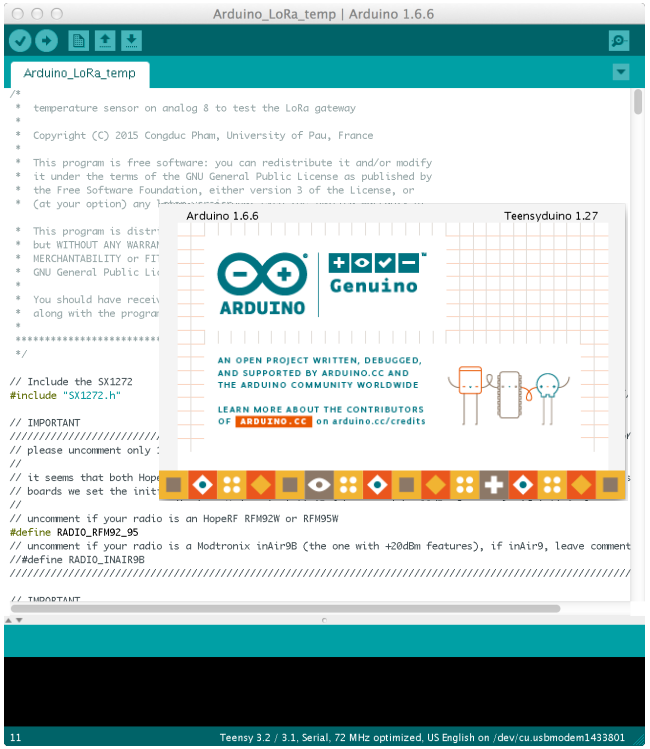
It's all about securing investment (the cattle)

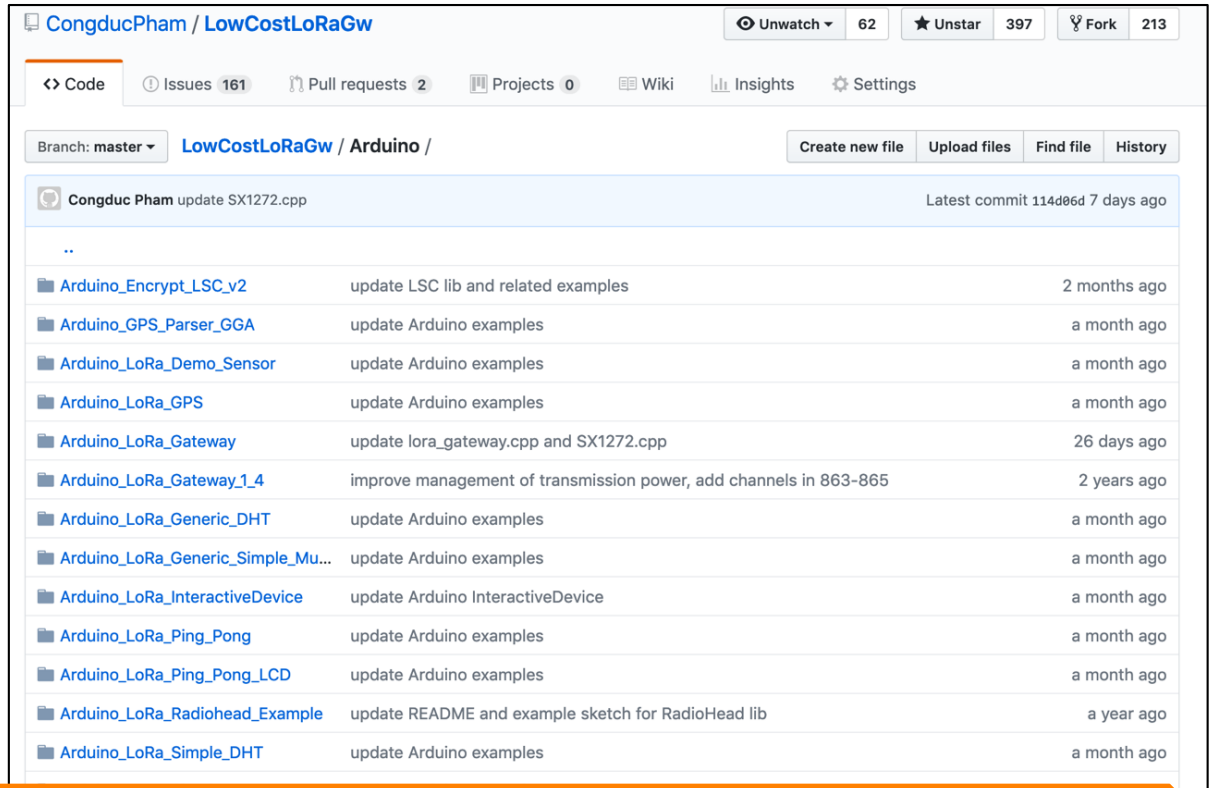
Aquaculture : waziup impact

- Emilie Vital Coly, Manager of Agriculture organisation of Ndiawdoune, Senegal : « *Per season, I have a turnover of 2,5 to 3 Millions CFA. The benefice is about 1 million CFA. I could be ready to give 1/5 (= 200 000 CFA, approx.* ***300 euros****) for renting on 6 months (duration of the season)"*
- *Ibrahima Khalil & Seydina Kane, Management of fish farm, St Louis, Senegal « On each season we observed a loss of 50000 CFA (about 80 euros) due to mortality. I am ready to invest 300 000 CFA (approx.* ***457 euros****) for a device if data would be reliable »*

From WAZIUP project

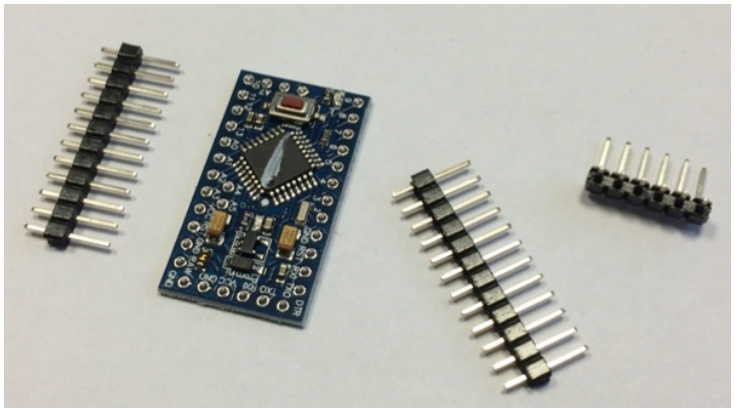
100% open-source code templates

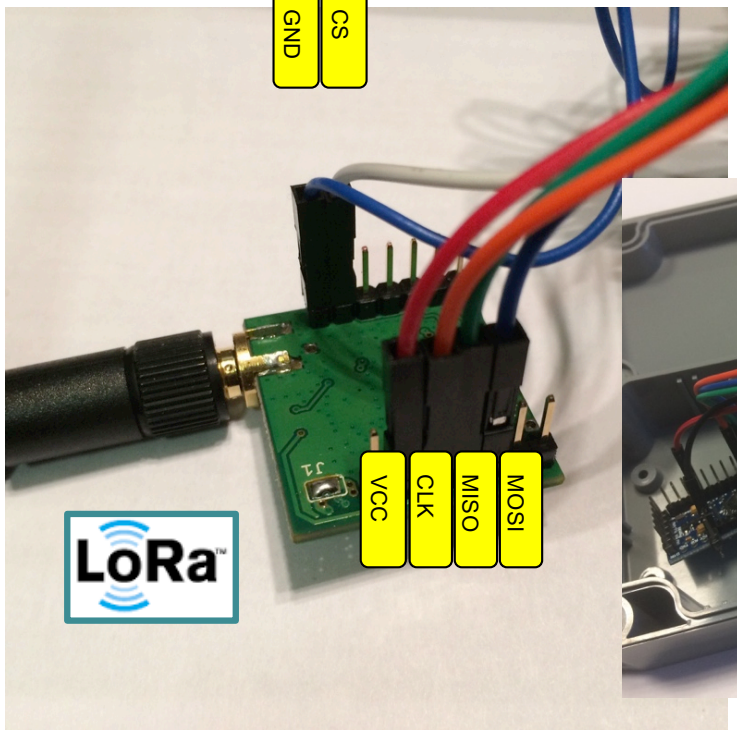


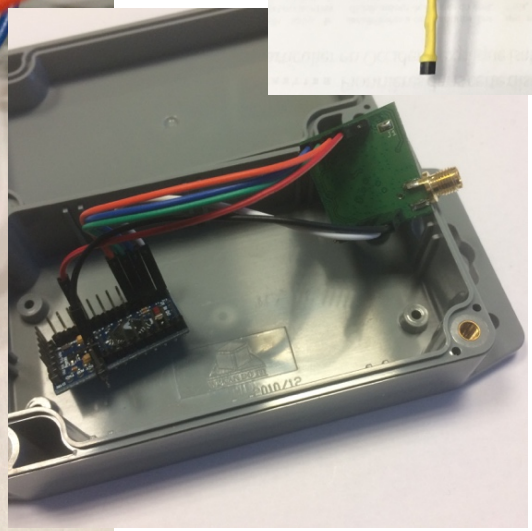


LowCostLoRaGw github has latest general distribution:
https://github.com/CongducPham/LowCostLoRaGw
Many examples using various temp/hum sensors
https://github.com/CongducPham/LowCostLoRaGw/tree/master/Arduino

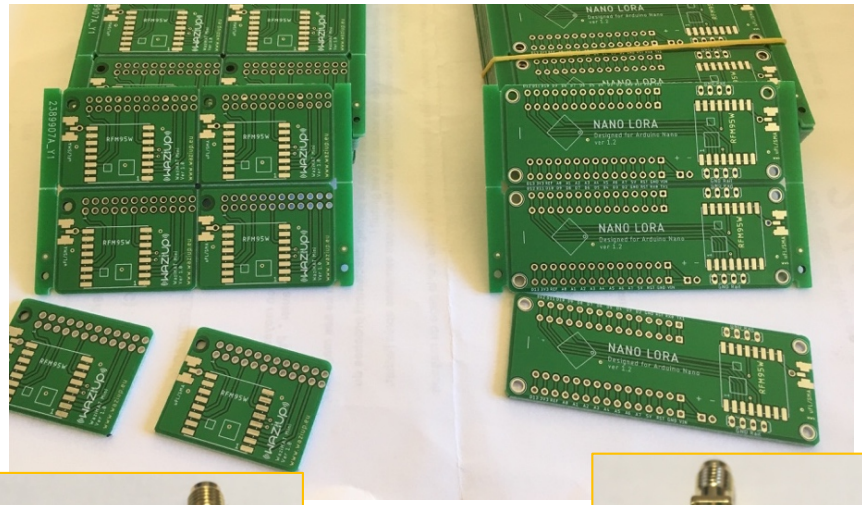
From full Do-It-Yourself approach

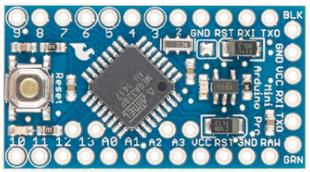






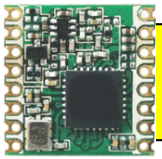
…to simple PCB for easy integration



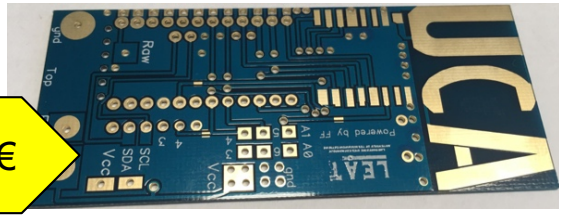


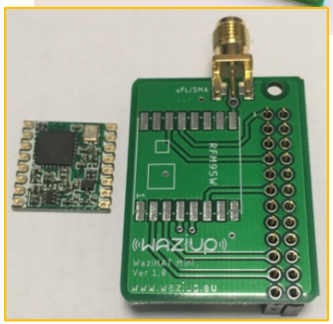
1.5€

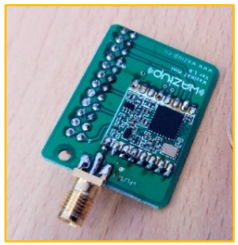
https://github.com/FabienFerrero/UCA_Board

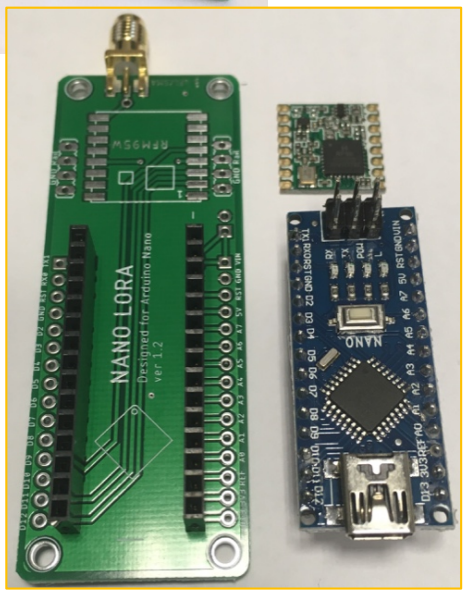


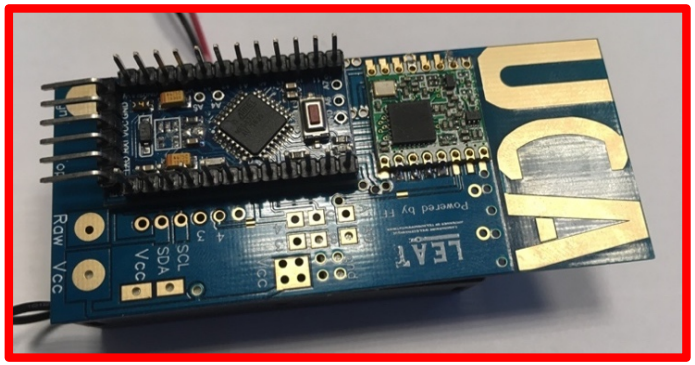
5€

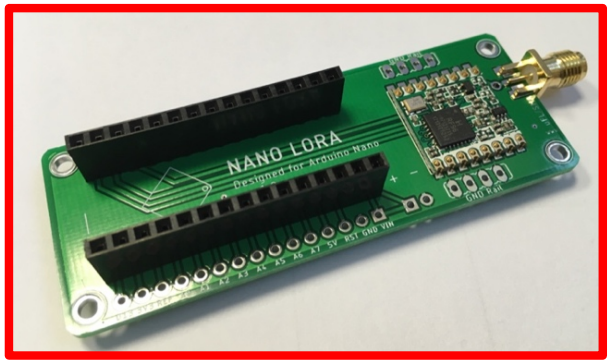


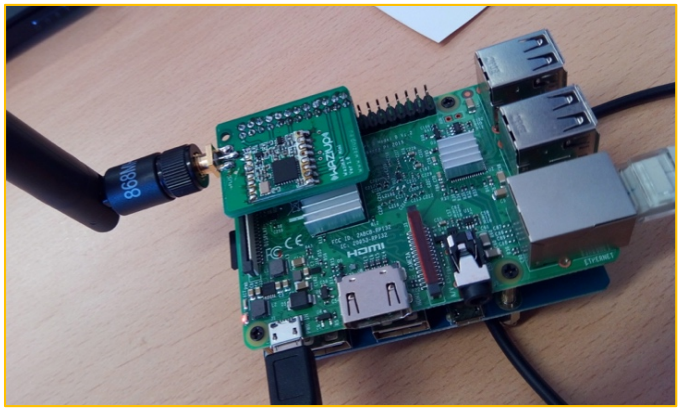




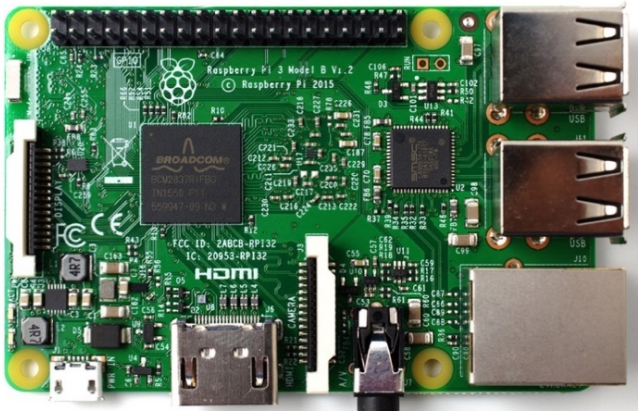


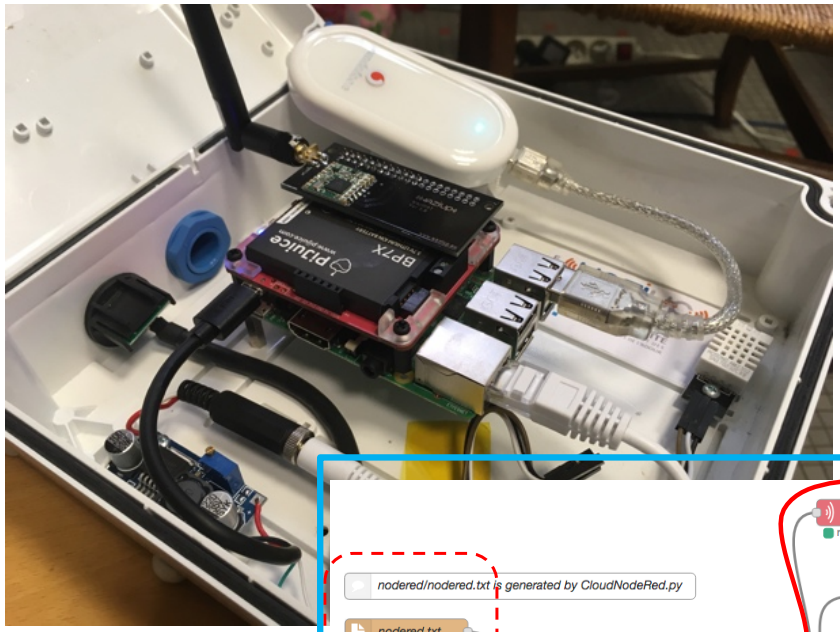




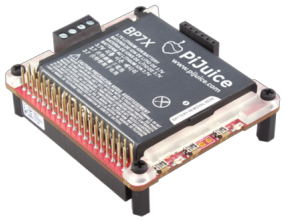


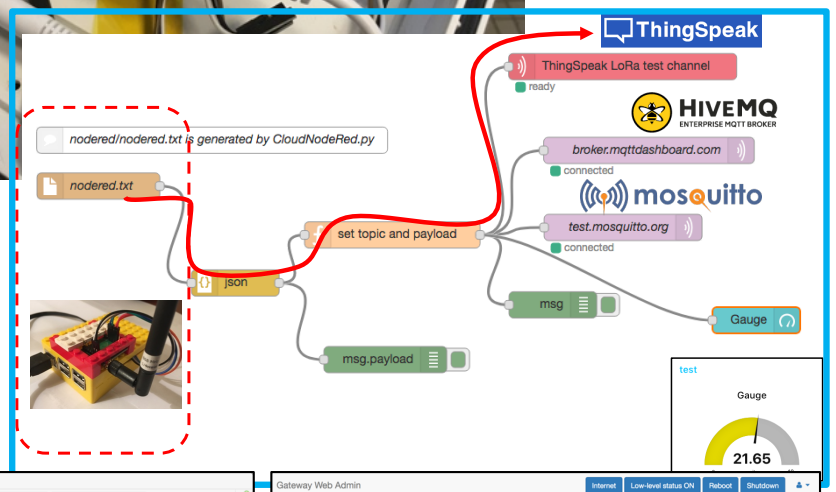
Open, versatile IoT gateway

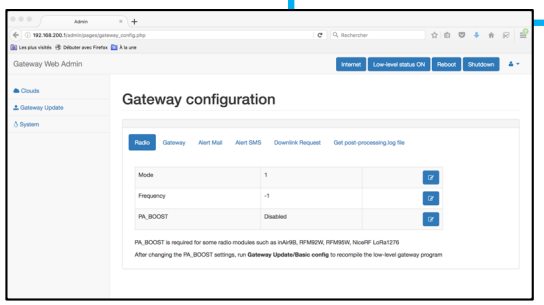


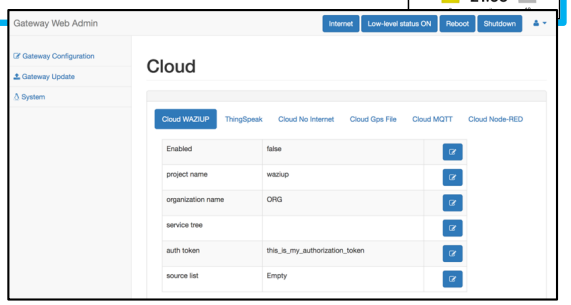


Raspberry PI: lots of libraries, lots of software, lots of hardware, lots of shields,…





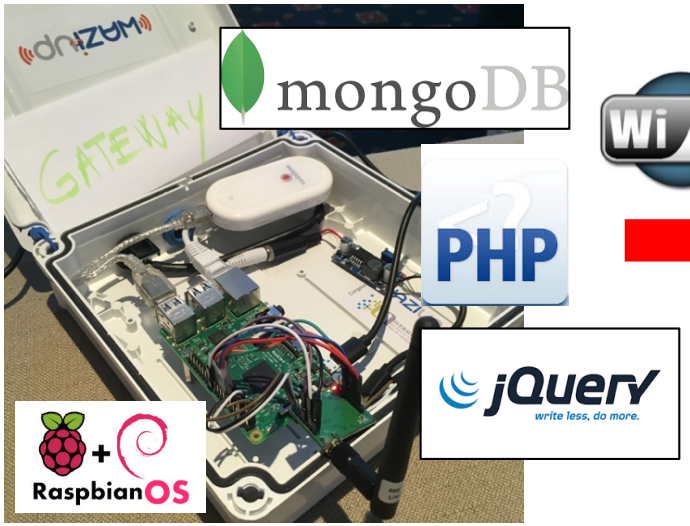


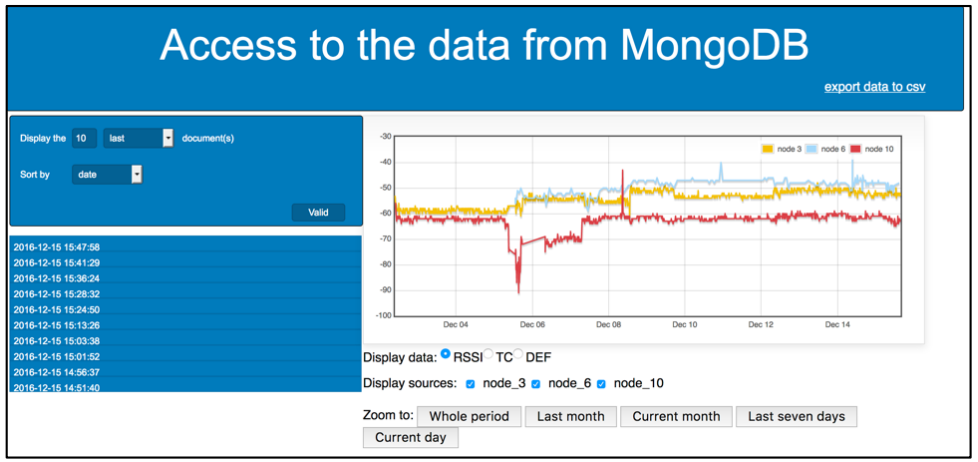


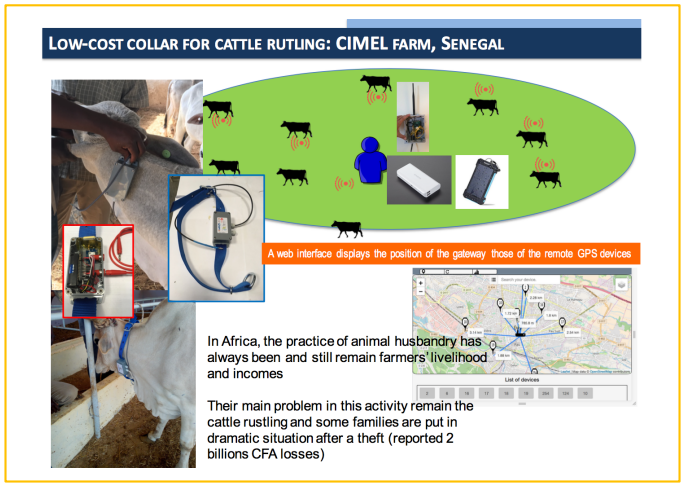
Deployment in rural areas
no Internet ☹

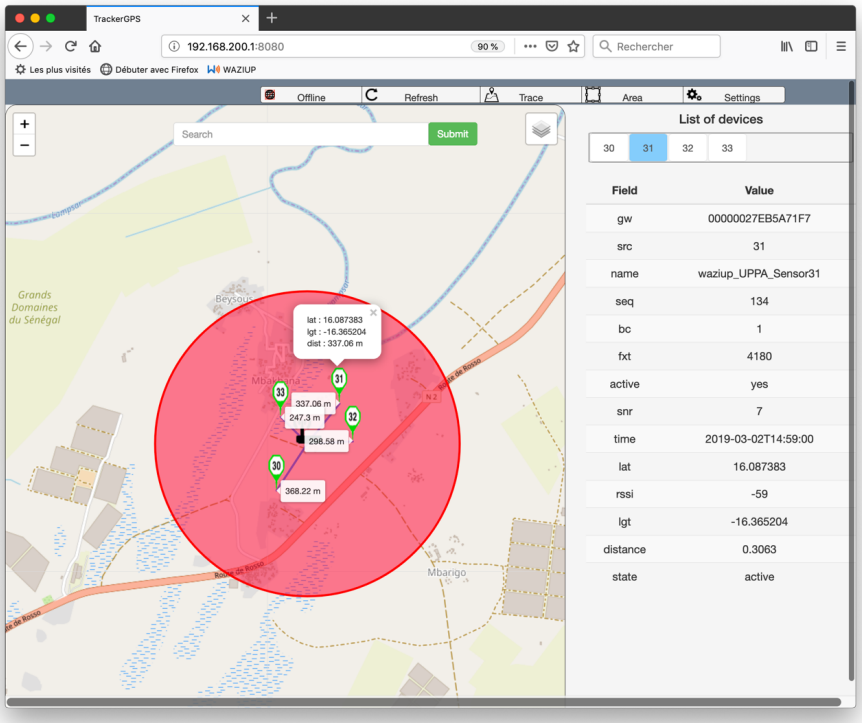
- deploying IoT in very isolated areas…
- … where internet and electricity are not stable!

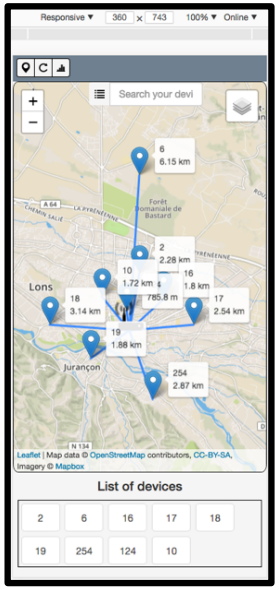
Autonomous gateway







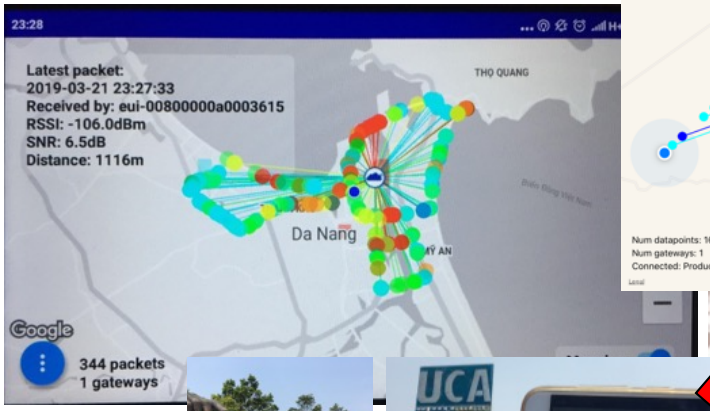


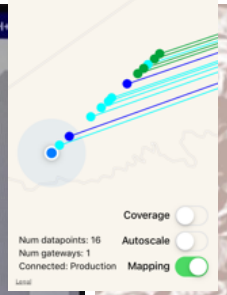


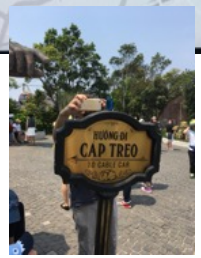
Link to a short demo video of the collar web interface: https://youtu.be/meFDav1SLPI

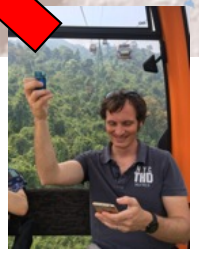
City environment
high building=large coverage

- LoRaWAN gateway on top of DSP building by F. Ferrero (U. Nice), U. Danang and DSP team. Congrats Fabien!





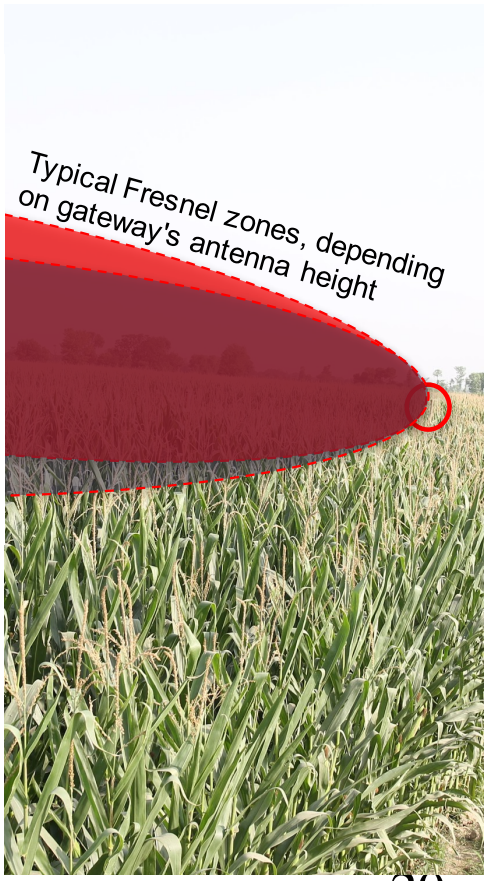




See TTN Mapper
https://ttnmapper.org/

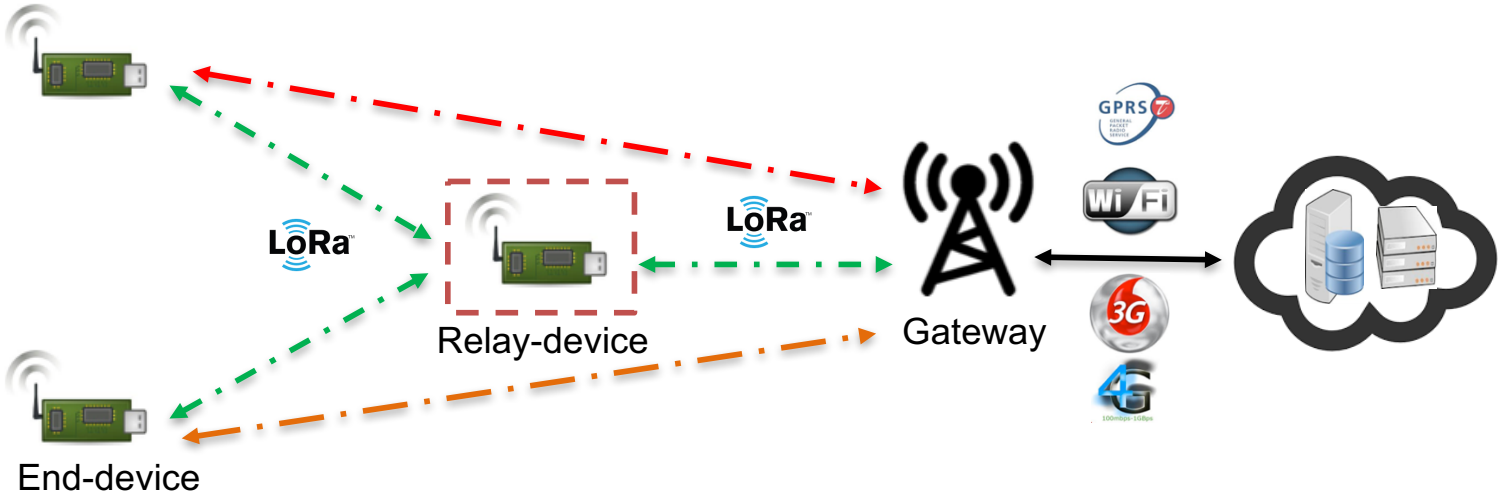
Deployment in rural areas
no high building ☹

- Expected range: about 2-4kms
- 1-hop connectivity to gateway is difficult to achieve in real-world, remote, rural scenarios



2-hop long-range approach

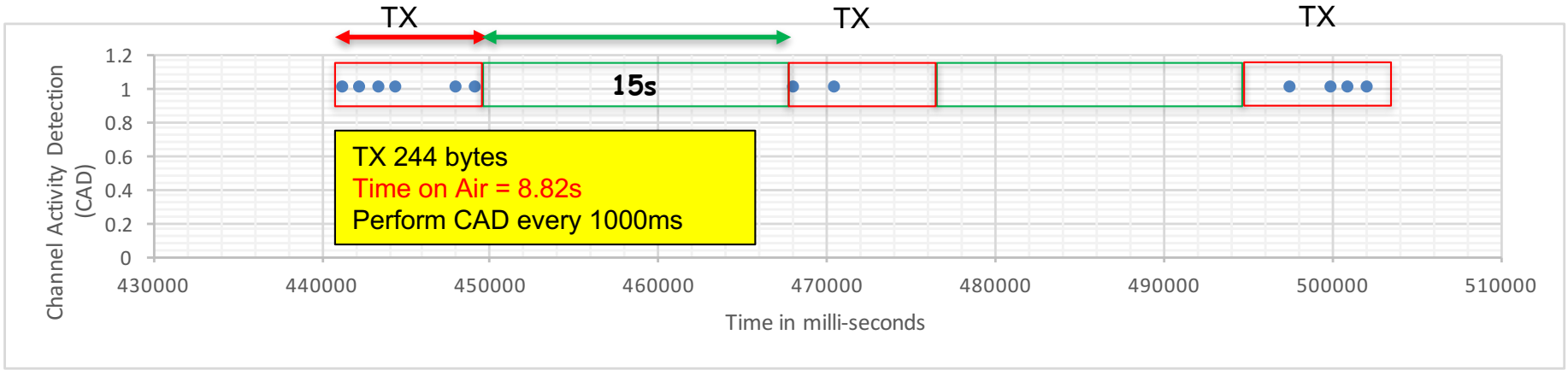
- **smart, transparent** relay node should be able to be inserted at anytime between end-devices and gateway to increase range



- **2 approaches**
  - Use short Channel Activity Detection (CAD) to dynamically detect uplink messages (draft from Semtech)
  - Use observation phase to determine device's schedule

LoRa's Channel Activity Detection

- CAD reliability decreases as distance increases
  - A CAD returning false does not mean that there is no activity!
- However, during a long transmission (i.e. several seconds) there is usually at least one CAD returning true **But ad-hoc mechanism is needed**

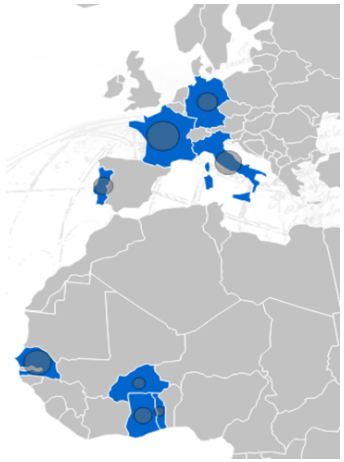


Observation phase approach

- On-the-fly learning of incoming traffic from end-devices: **observation phase**
- Just-in-time wake up in **data forwarding phase**
- Continuous re-synchronization➔only 500ms of guard time is sufficient
- No additional hardware ➔ sensor nodes can be recycled as relay
- Advanced features
  - Insertion of new isolated end-devices
  - Handling downlink messages
  - Similarity detection between devices

Scaling up!

Feb 2016 - 2019



May 2018 - 2021

WAZIUP has been developing the open, low-cost IoT technologies/frameworks and use-cases

WAZIHUB will focus on dissemination, community building and entrepreneurship