Deploying low-cost and long-range Internet of Things in developing countries

Prof. Congduc Pham

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

Université de Pau, France

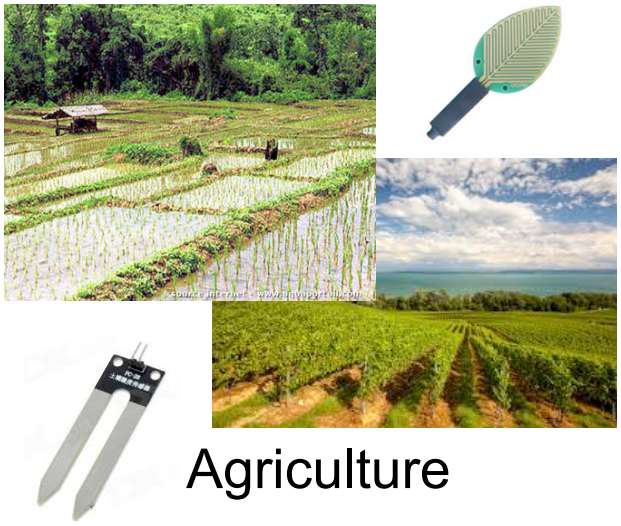
IoT FOR DEVELOPMENT

Irrigation

Livestock farming

Fish farming & aquaculture

Storage & logistic



Agriculture

Fresh water

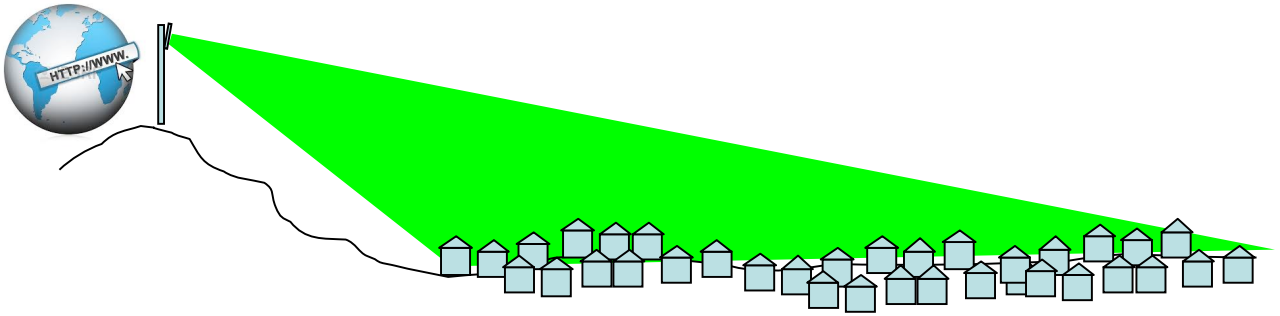
Long-range Sensing

Moisture/
Temperature of
storage areas

10-15kms

GSM GPRS

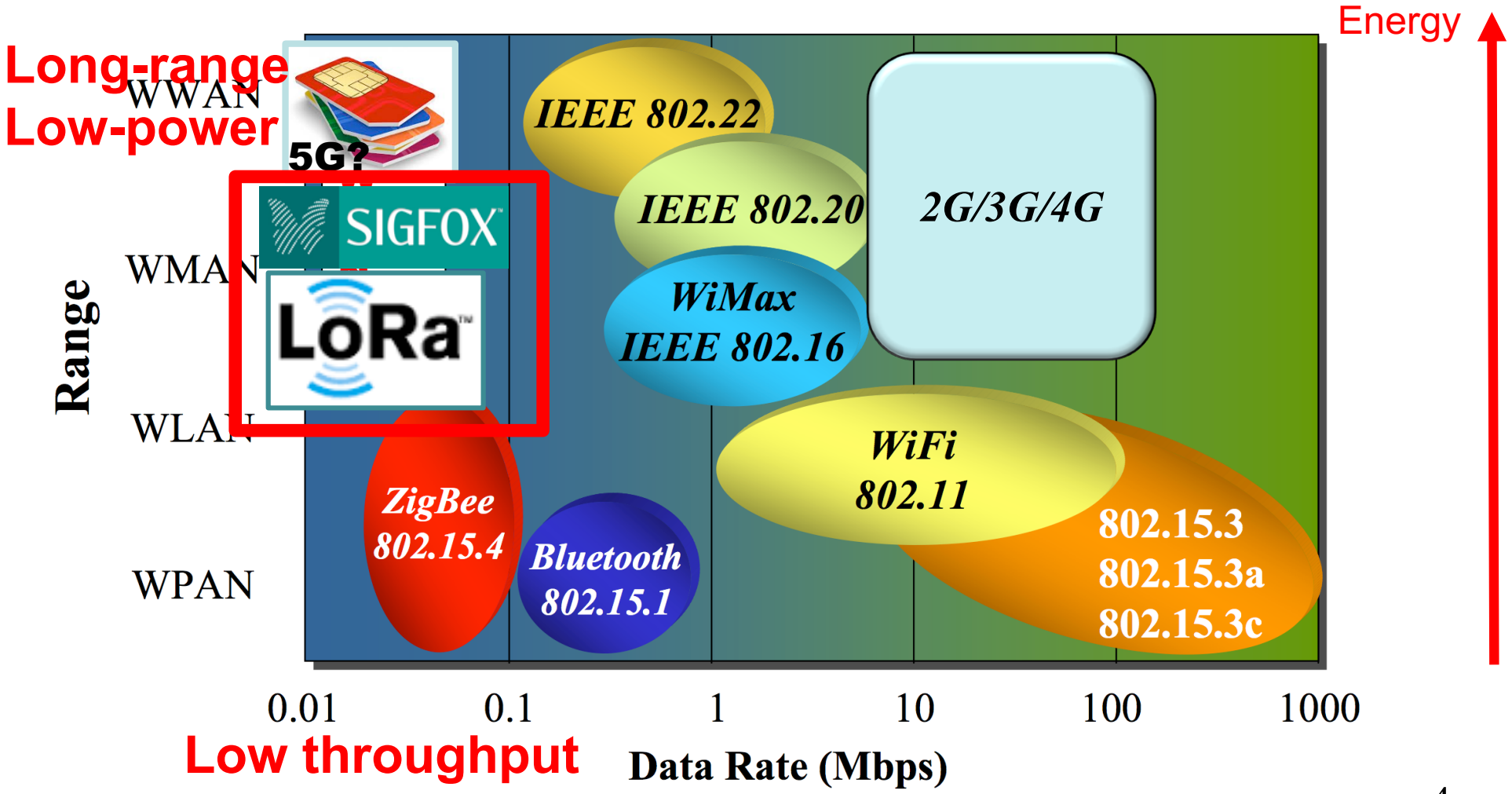
Pay subscription
Limitation of coverage
High energy consumption

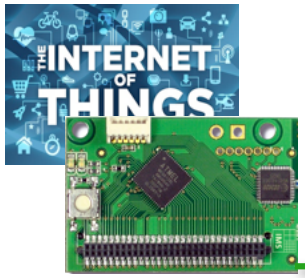


Technology	2G	3G	LAN
Range (I=Indoor, O=Outdoor)	N/A	N/A	O: 300m I: 30m
Tx current consumption	200-500mA	500-1000mA	100-300mA
Standby current	2.3mA	3.5mA	NC

LOW-POWER & LONG-RANGE RADIO TECHNOLOGIES

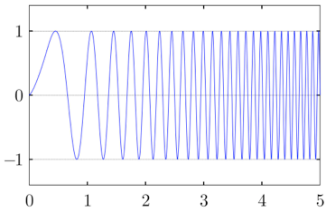
Energy-Range dilemma



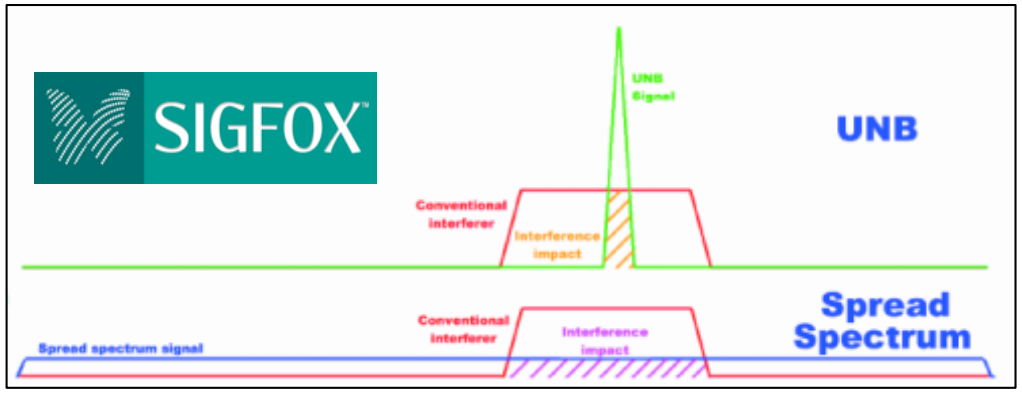


Increasing range?

- Generally, robustness and sensitivity can be increased when transmitting much slower
- A Sigfox message is sent relatively slowly in an ultra narrow band of spectrum. Max throughput=~100bps
- LoRa also increases time-on-air when maximum range is needed. But LoRa uses spread spectrum approach. Throughput=~300bps-37500bps

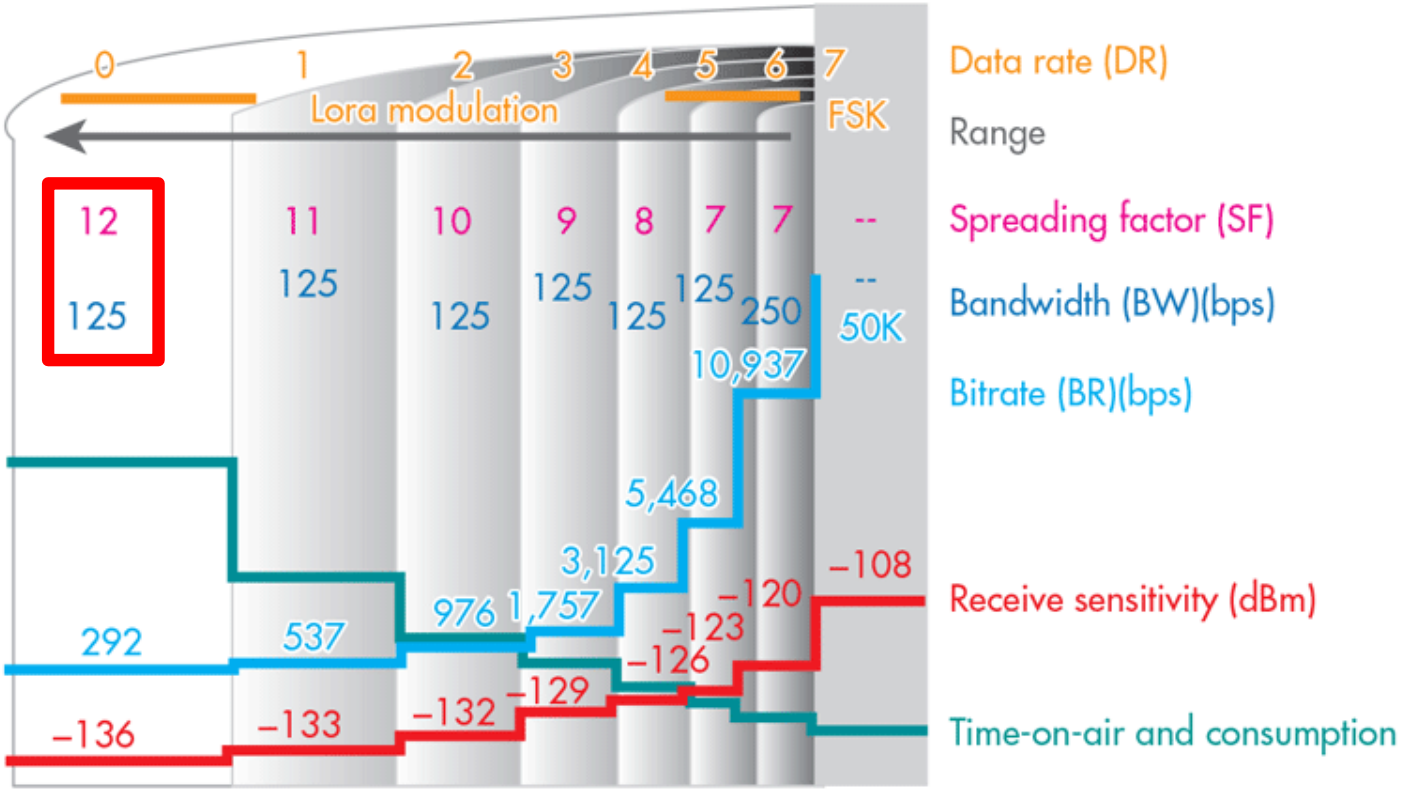


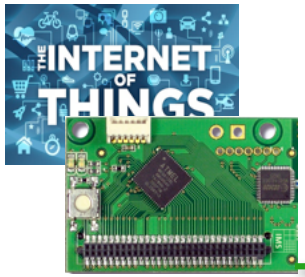
LoRa™



Main LoRa parameters

- Main parameters
  - Bandwidth: 62.5kHz, 125kHz, 250kHz, 500kHz
  - Spreading factor: 6 to 12





LoRa details specs

$$R_b = SF * \frac{Rate\ Code}{\left[\frac{2^{SF}}{BW}\right]}\ bits/sec$$

- Main parameters
  - Bandwidth: 62.5kHz, 125kHz, 250kHz, 500kHz
  - Spreading factor: 6 to 12
  - Rate code: 4/4+CR (CR=1, 2, 3, 4)

Sensitivity: lowest input power with acceptable link quality, typically 1% PER

SpreadingFactor (RegModemConfig2)	Spreading Factor (Chips / symbol)	LoRa Demodulator SNR
6	64	-5 dB
7	128	-7.5 dB
8	256	-10 dB
9	512	-12.5 dB
10	1024	-15 dB
11	2048	-17.5 dB
12	4096	-20 dB

Bandwidth (kHz)	Spreading Factor	Nominal Rb (bps)	Sensitivity (dBm)
125	6	9380	-122
125	12	293	-137
250	6	18750	-119
250	12	586	-134
500	6	37500	-116
500	12	1172	-131

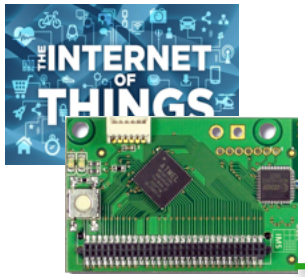
Rule of thumb

6dB increase = twice the range in LOS

12dB needed for urban areas

Bandwidth (kHz)	Spreading Factor	Coding rate	Nominal Rb (bps)	Sensitivity (dBm)
125	12	4/5	293	-137
250	12	4/5	586	-134
500	12	4/5	1172	-131

Tables from Semtech



LoRa Time-on-Air

Very low throughput

Transmission time can be several seconds

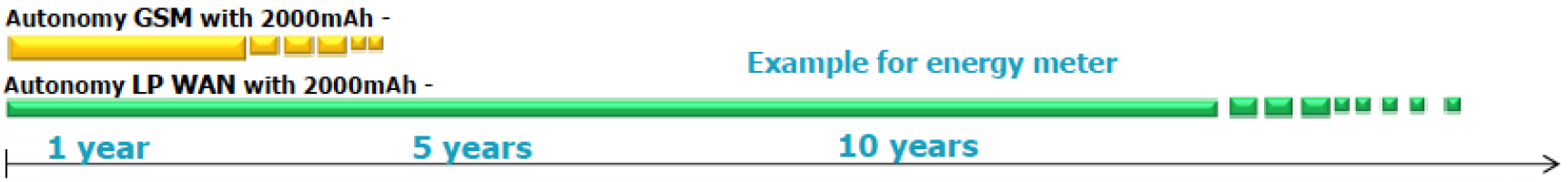
Range ↔ Throughput

LoRa mode	BW	CR	SF	time on air in second for payload size of 5 bytes	55 bytes	105 bytes	155 Bytes	205 Bytes	255 Bytes	max thr. for 255B in bps
1	125	4/5	12	0.95846	2.59686	4.23526	5.87366	7.51206	9.15046	223
2	250	4/5	12	0.47923	1.21651	1.87187	2.52723	3.26451	3.91987	520
3	125	4/5	10	0.28058	0.69018	1.09978	1.50938	1.91898	2.32858	876
4	500	4/5	12	0.23962	0.60826	0.93594	1.26362	1.63226	1.95994	1041
5	250	4/5	10	0.14029	0.34509	0.54989	0.75469	0.95949	1.16429	1752
6	500	4/5	11	0.11981	0.30413	0.50893	0.69325	0.87757	1.06189	1921
7	250	4/5	9	0.07014	0.18278	0.29542	0.40806	0.5207	0.63334	3221
8	500	4/5	9	0.03507	0.09139	0.14771	0.20403	0.26035	0.31667	6442
9	500	4/5	8	0.01754	0.05082	0.08154	0.11482	0.14554	0.17882	11408
10	500	4/5	7	0.00877	0.02797	0.04589	0.06381	0.08301	0.10093	20212

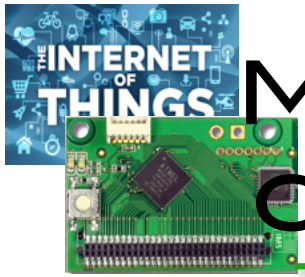
Energy consumption comparaison

Tables from Semtech

Technology	2G	3G	LAN	ZigBee	Lo Power WAN
Range (I=Indoor, O=Outdoor)	N/A	N/A	O: 300m I: 30m	O: 90m I: 30m	Same as 2G/3G
Tx current consumption	200-500mA	500-1000mA	100-300mA	18mA	20-40mA
Standby current	2.3mA	3.5mA	NC	0.003mA	0.001mA
Energy harvesting (solar, other)	No	No	No	Possible	Possible
Battery 2000mAh (LR6 battery)	4-8 hours(com) 36 days(idle)	2-4 hours(com) X hours(idle)	50 hours(com) X hours(idle)	60hours (com)	120 hours(com) 10 year(idle)
Module Revenue Annually	12 $	20 $	4 $	$3	3 $



More and more easy-to-connect LoRa modules!



LoRa™

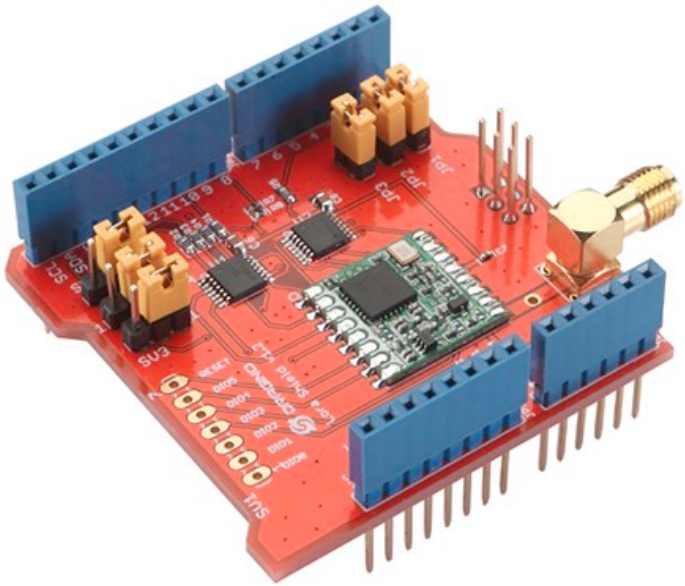
HopeRF
RFM92W/95W

Libelium LoRa

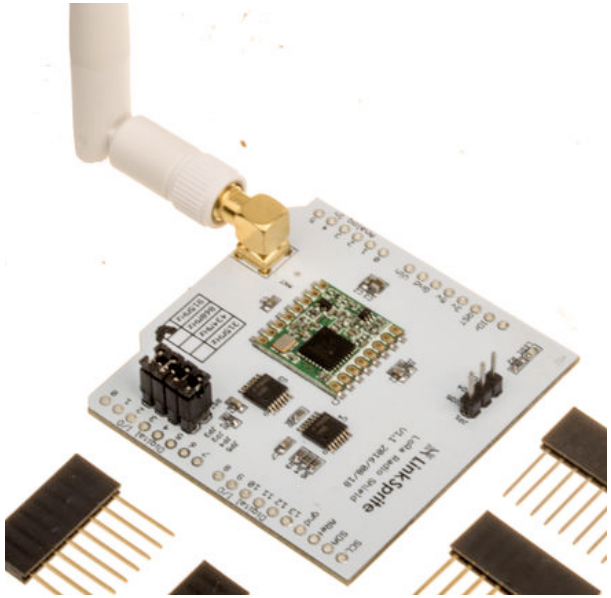
Modtronix
inAir9/9B

NiceRF
LoRa1276

LORANGA LoRa + 2G/3G board, mainly for Raspberry PI

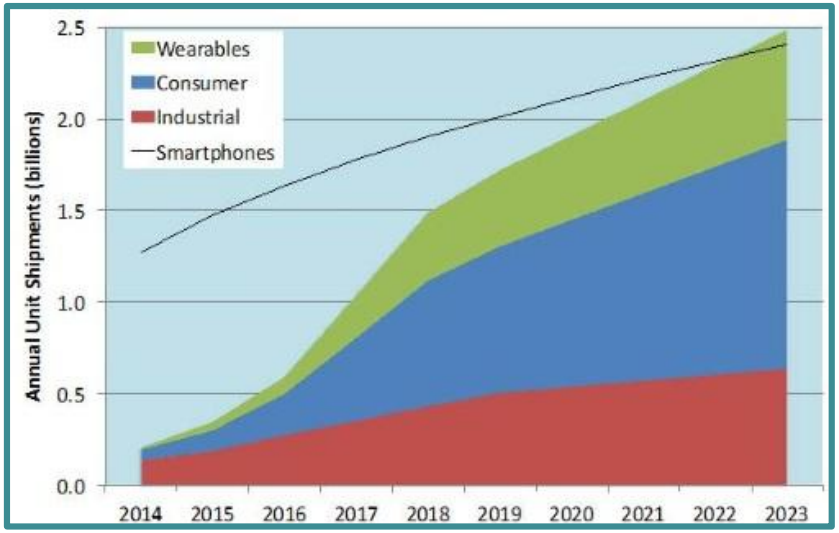


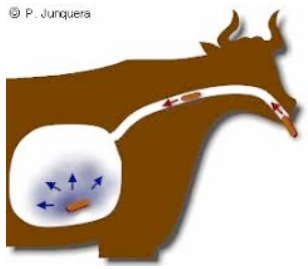
Dragino LoRa shield for Arduino



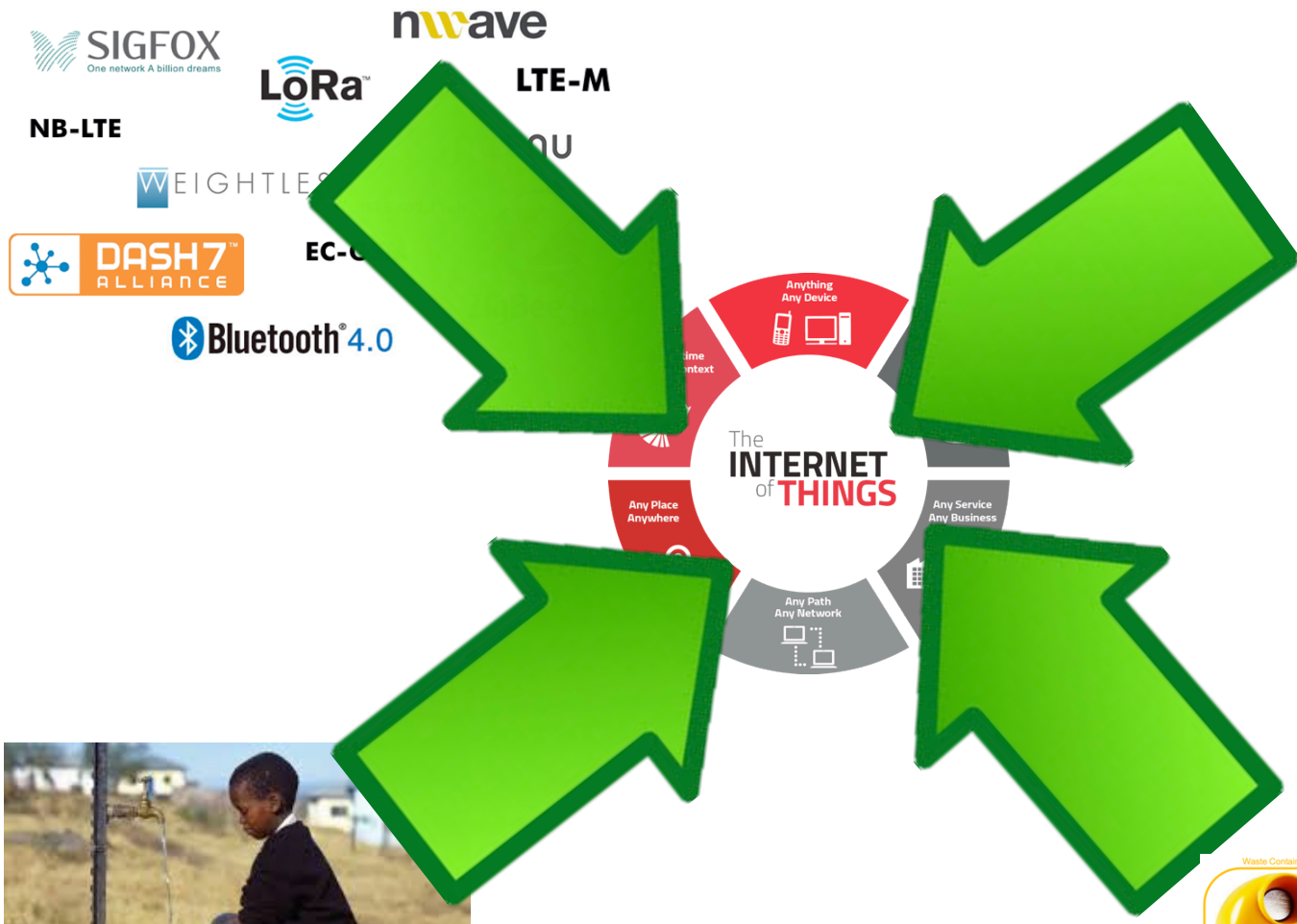
LinkSprite LoRa shield for Arduino

MATURATION OF THE IoT MARKET…



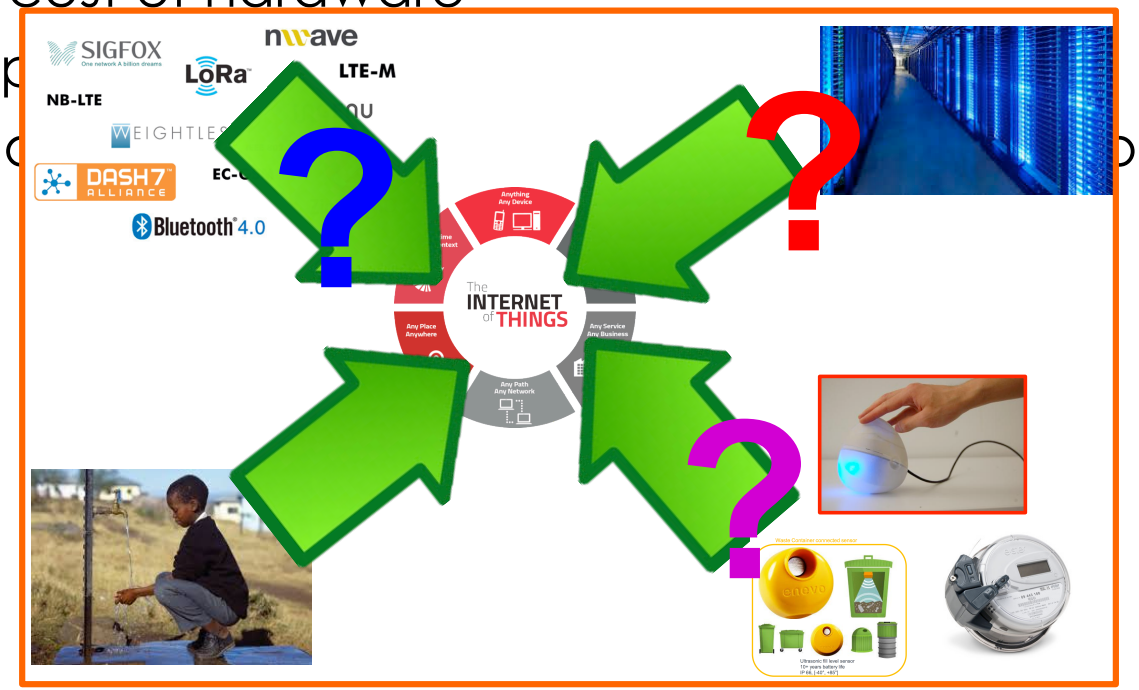


IoT becomes reality!

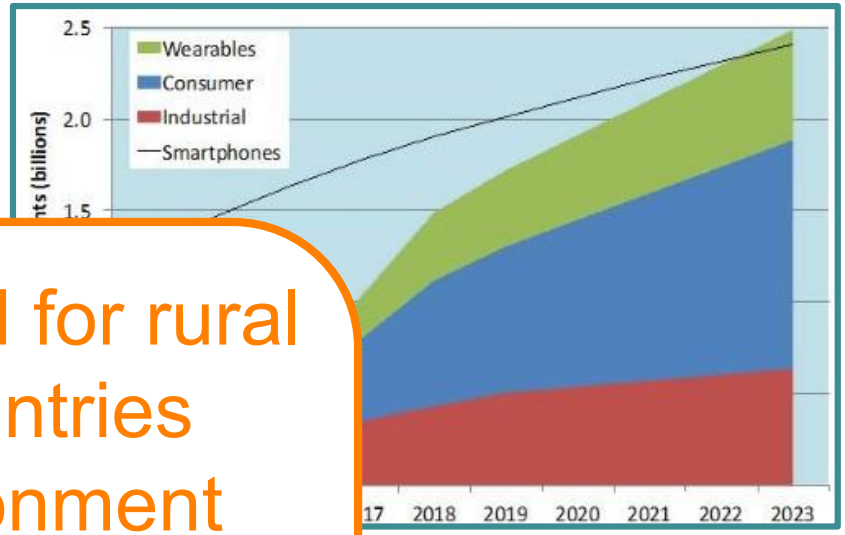


IoT IN DEVELOPING COUNTRIES OR RURAL AREAS?

- Developing countries/rural areas are still far from being ready to enjoy the smallest benefit of IoT
  - lack of infrastructure
  - high cost of hardware
  - comp
  - lack o

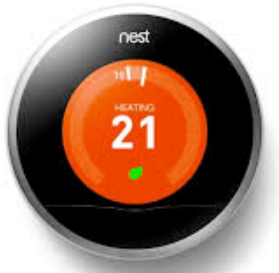


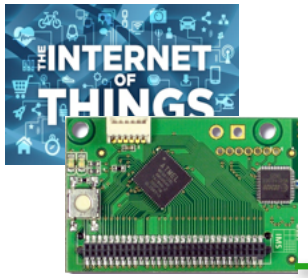
MATURATION OF THE IoT MARKET…



… but not adapted for rural developing countries context & environment

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

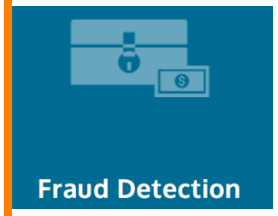


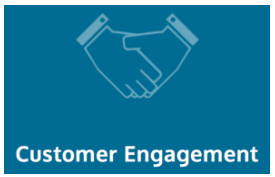


Internet, Cloud & big data analytics

Internet connectivity is weak and expensive!

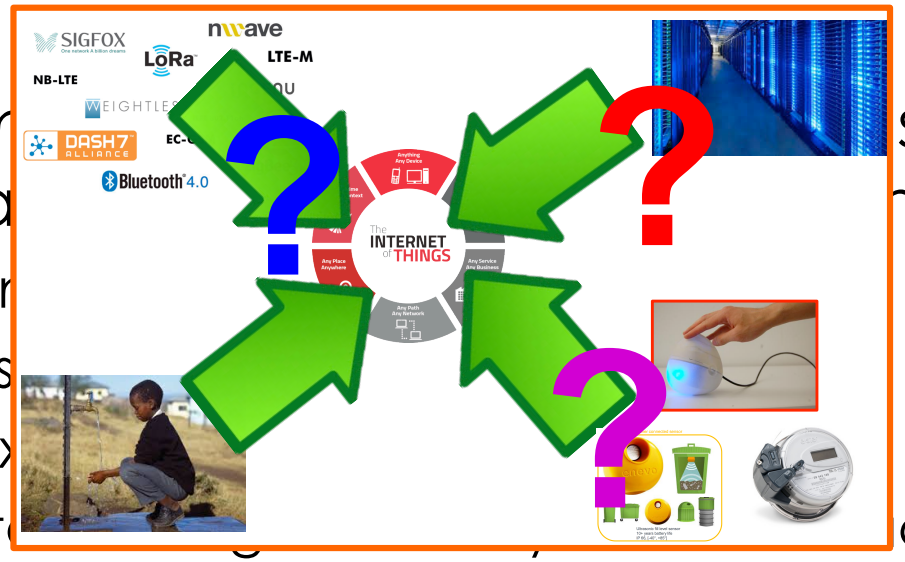
Nearly impossible in remote/rural areas



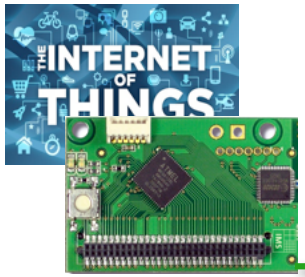


Graphics from http://www.vitria.com/iot-analytics/

IoT IN DEVELOPING COUNTRIES AND RURAL AREAS



- Developir… still far from being rea… nefit of IoT
  - lack of ir…
  - high cos…
  - complex…
  - lack of t… ckground
- **to deploy IoT in developing countries, it is necessary to target three major issues**
  - **reduce cost of infrastructures, hardware and services**
  - **limit dependancy to proprietary infrastructures and provide local interaction models**
  - **target technology appropriation, push for local business models**

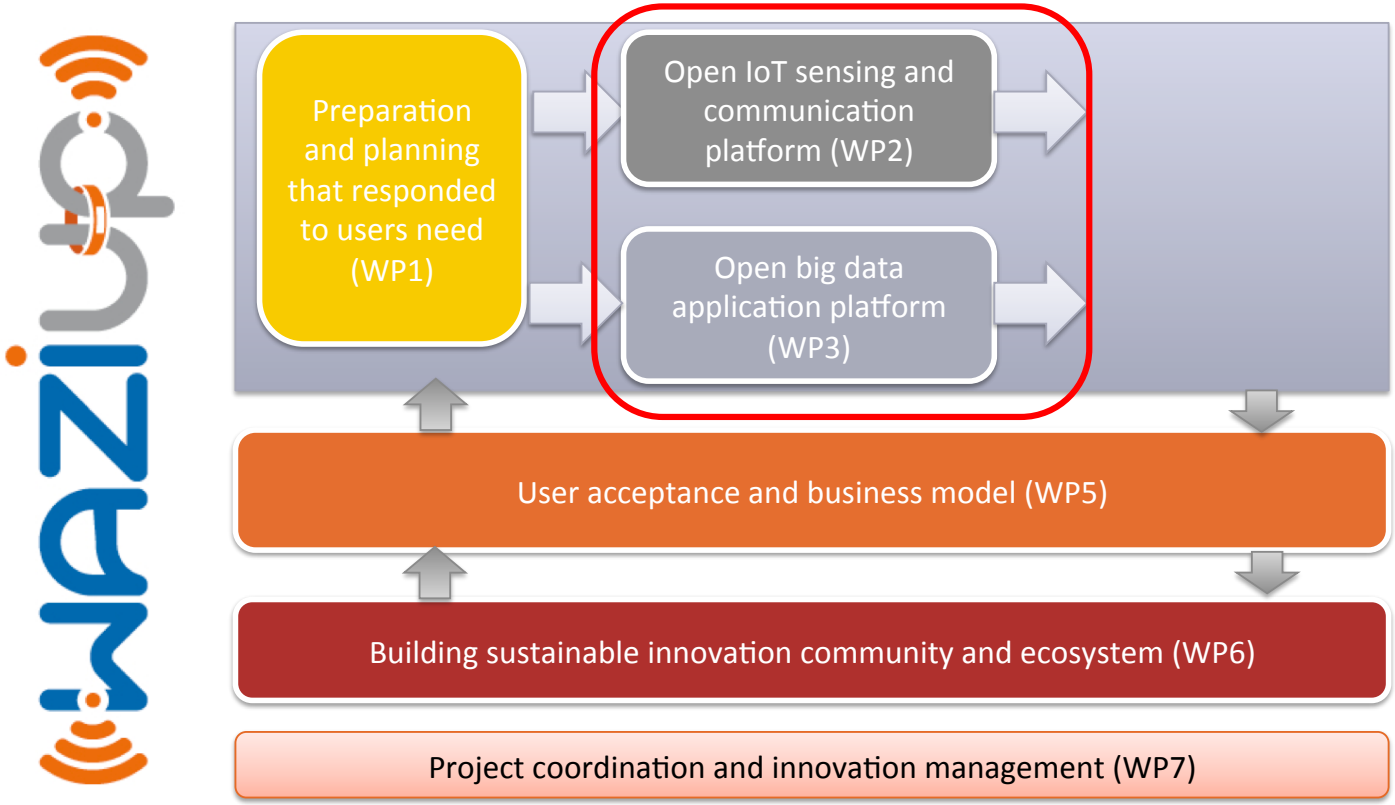


WAZIUP: LOW-COST IoT

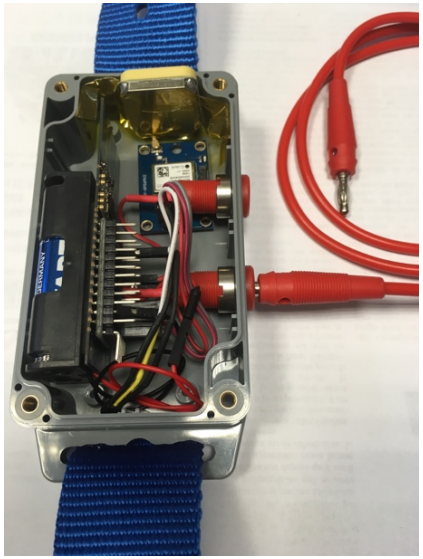
WAZIUP ABOUT » TECHNOLOGIES » COMMUNITY NEWS & EVENT » DOWNLOADS DEV KIT FAQ CONTACT

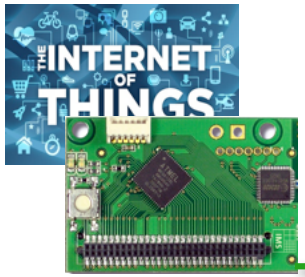
IoT FOR RURAL APPLICATIONS IN DEVELOPPING COUNTRIES

- WAZIUP is an EU H2020 project (2016-2019)
- contributes to long-range networks for rural applications with WP2 and big data with WP3



Low-cost IoT devices





Low-cost hardware initiative

WHAT IS ARDUINO?

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

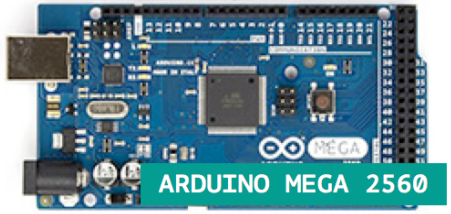
ARDUINO BOARD

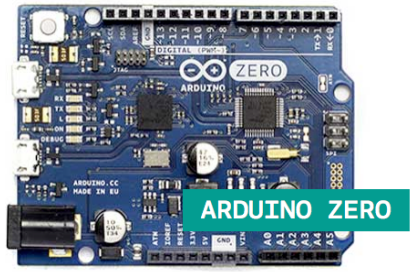
Arduino senses the environment by receiving inputs from many sensors, and affects its surroundings by controlling lights, motors, and other actuators.

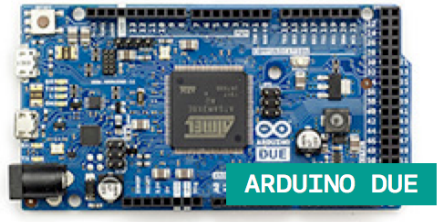
ARDUINO SOFTWARE

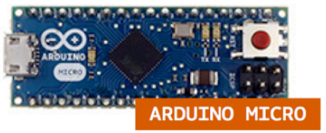
```
void setup() {
}

void loop() {
}
```

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



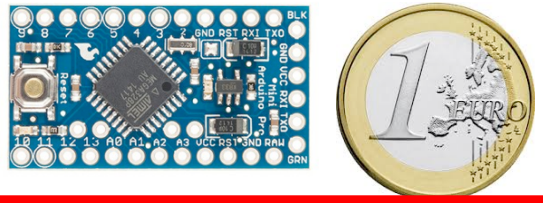






LARGE ECOSYSTEM, STILL GROWING…

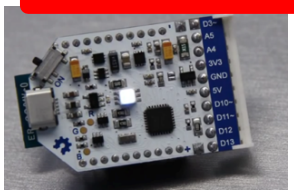
Arduino Pro Mini



LoPy

http://blog.atmel.com/2015/12/16/rewind-50-of-the-best-boards-from-2015/

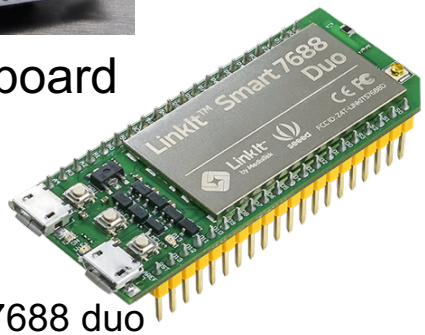
http://blog.atmel.com/2015/04/09/25-dev-boards-to-help-you-get-started-on-your-next-iot-project/



Theairboard

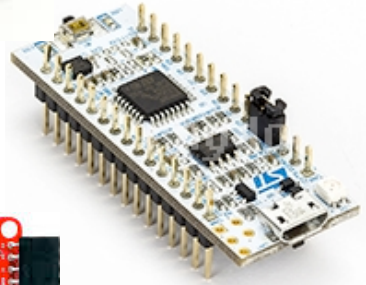
Expressif ESP32

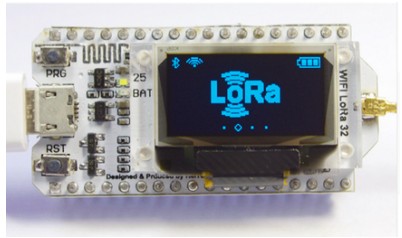
Teensy 3.2



LinkIt Smart7688 duo

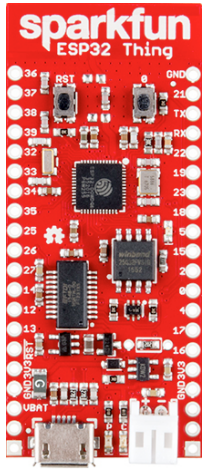
STM32 Nucleo-32





Heltec ESP32 + OLED

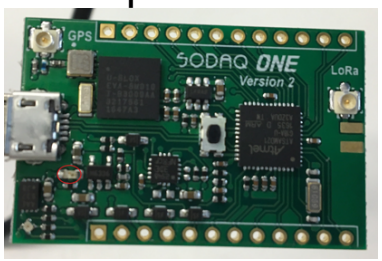
Adafruit Feather



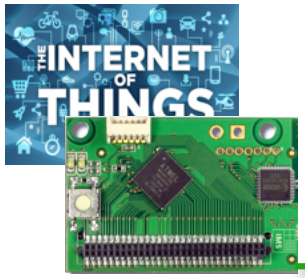
Sparkfun ESP32 Thing

Tessel

SodaqOnev2

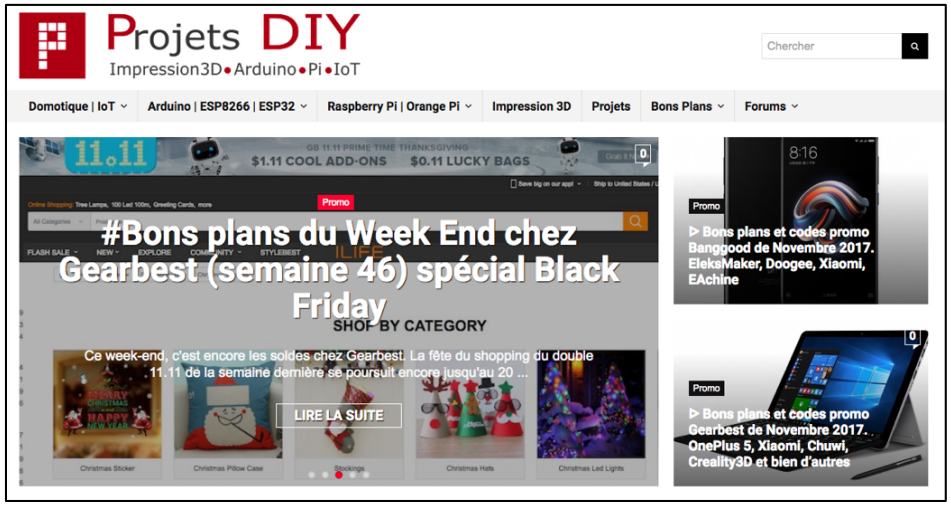


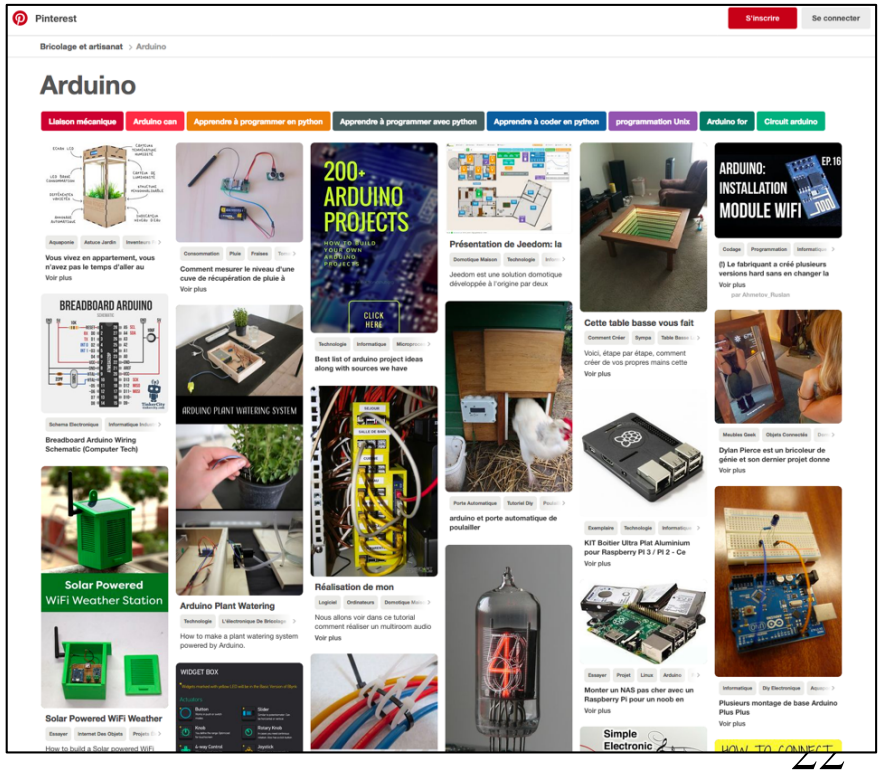
Tinyduino



… STIMULATING "DO-IT-YOURSELF" WORLDWIDE

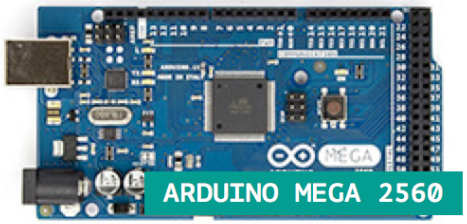
- DIY usually means
  - More open-source software from larger community
  - More flexibility

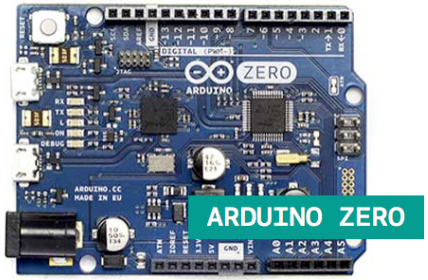


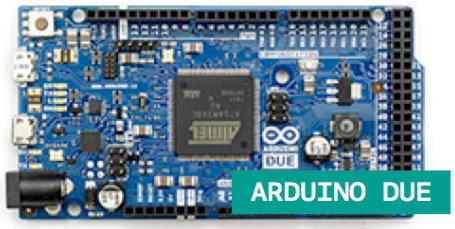


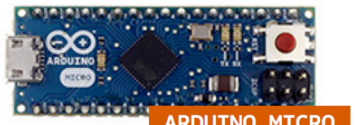
WAZIUP PROVIDES SW/HW BUILDING BLOCKS INTEGRATION


ARDUINO UNO

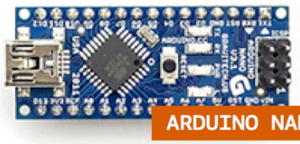

ARDUINO MEGA 2560

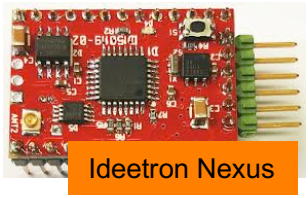

ARDUINO ZERO


ARDUINO DUE


ARDUINO MICRO


ARDUINO PRO MINI


ARDUINO NANO

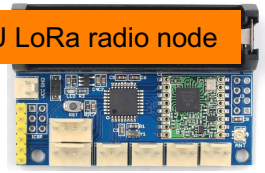

Ideetron Nexus


TeensyLC/3.1/3.2


Adafruit Feather 32u4/M0


Expressif ESP8266/ESP32

IoT-MCU LoRa radio node

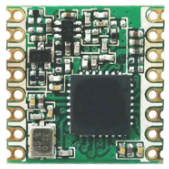



Heltec LoRa

More to come…

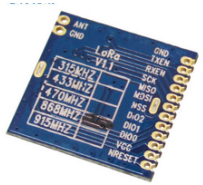
LoRa™

LoRa radios that our library already supports


HopeRF RFM9x

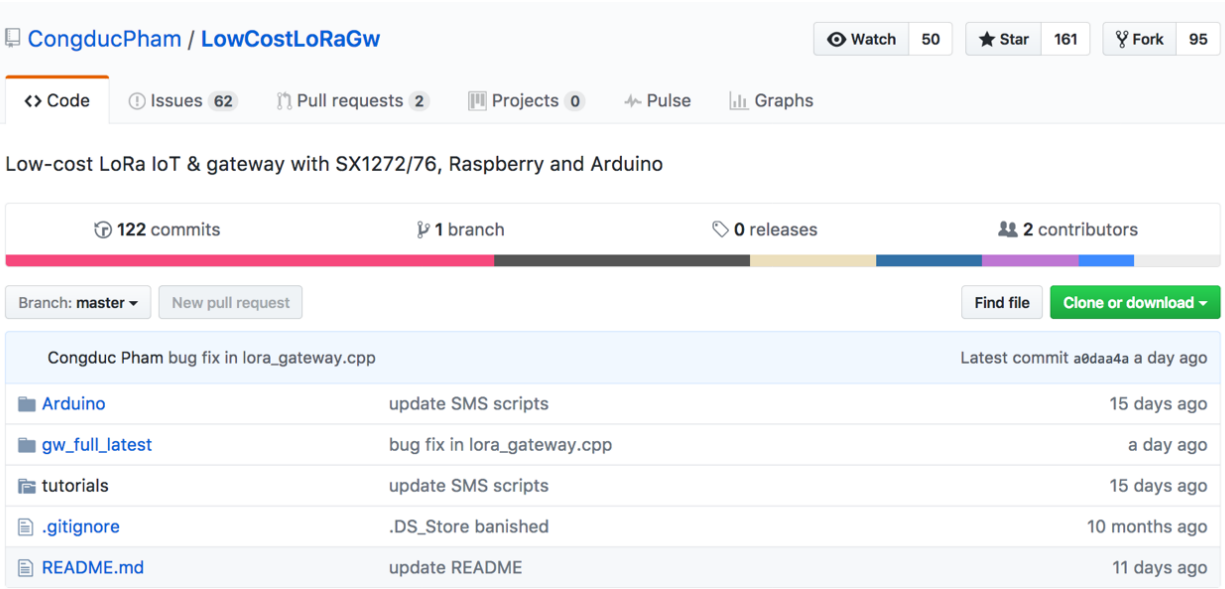

Libelium LoRa


Modtronix inAir4/9/9B


NiceRF LoRa1276

Long-Range communication library

WAZIUP PROPOSES 100% OPEN-SOURCE SOFTWARE



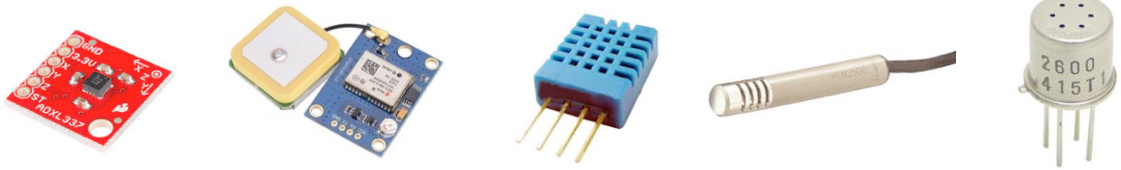
LowCostLoRaGw github has latest general distribution:
https://github.com/CongducPham/LowCostLoRaGw
WAZIUP-specific configuration can be found on
https://github.com/Waziup/waziup-gateway

READY-TO-USE TEMPLATES

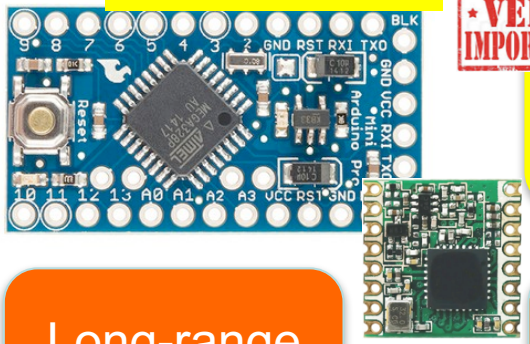
Moisture/
Temperature of
storage areas

10-15kms

Physical sensor | Physical sensor | Physical sensor



Arduino Pro Mini @3.3V



Physical sensor mgmt

VERY IMPORTANT

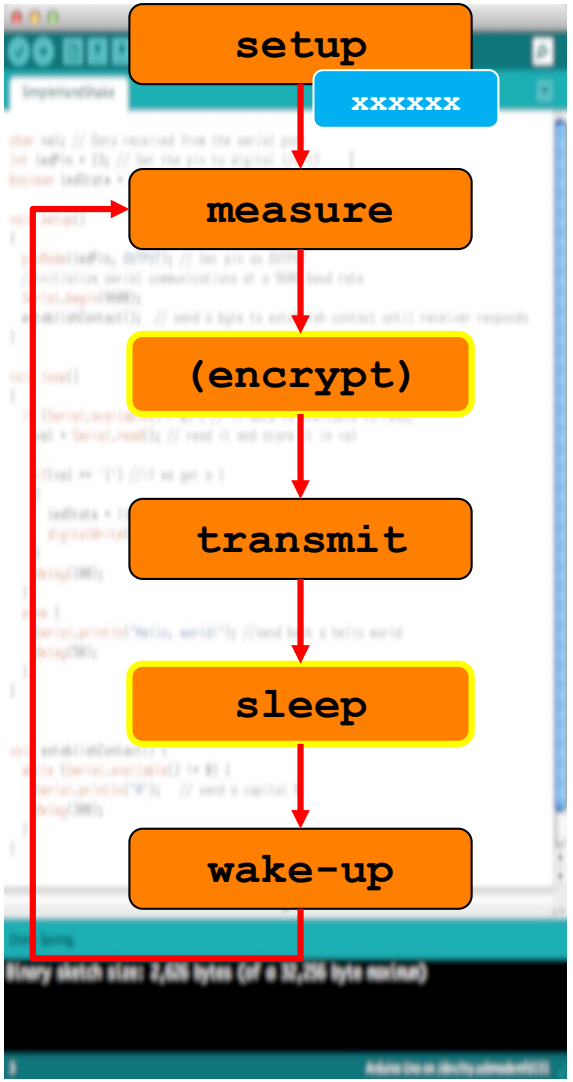
Activity duty-cycle, low power

VERY IMPORTANT

AES encryption

Long-range transmission

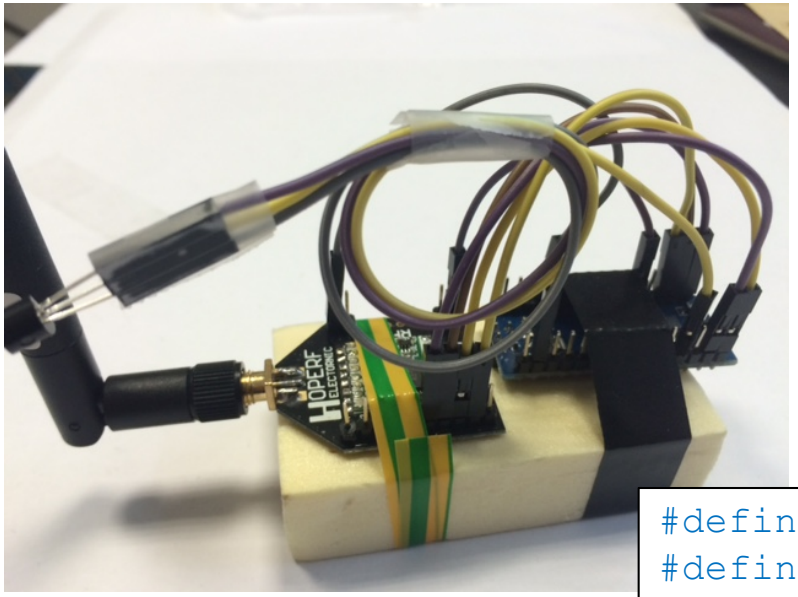
Logical sensor mgmt



Build your first LoRa IoT device

Connect the USB end to your computer and the USB port should be detected in the Arduino IDE. Select the serial port for your device. It may have another name than what is shown in the example. Then click on the « upload » button

Default configuration



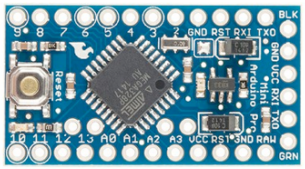
\!TC/18.5

```
#define DEFAULT_DEST_ADDR 1
#define LORAMODE  1
#define node_addr 6
```

The default configuration in the Arduino_LoRa_Simple_temp example is:

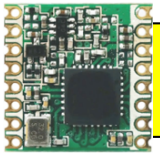
Send packets to the gateway (one or many if in range)
LoRa mode 1
Node short address is 6

LOW-COST INTEGRATION

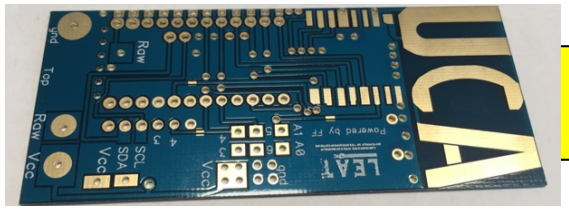


1.5€

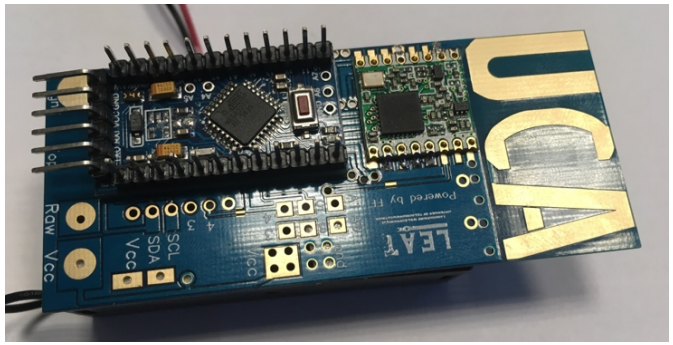
https://github.com/FabienFerrero/UCA_Board

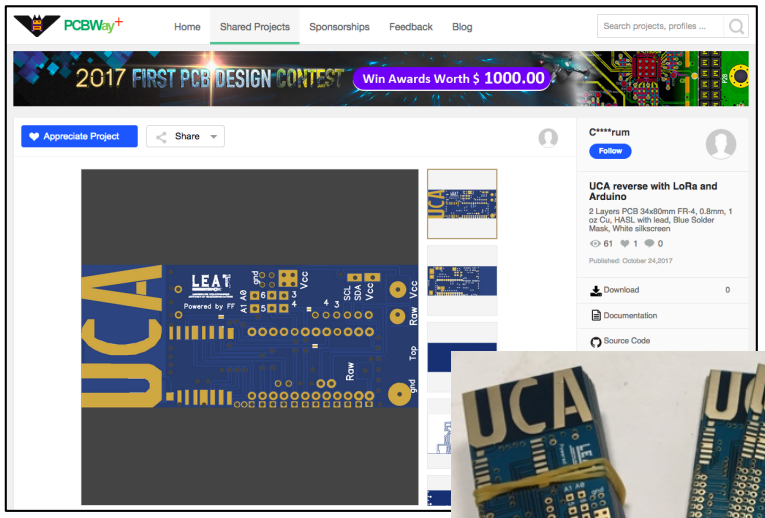


4€



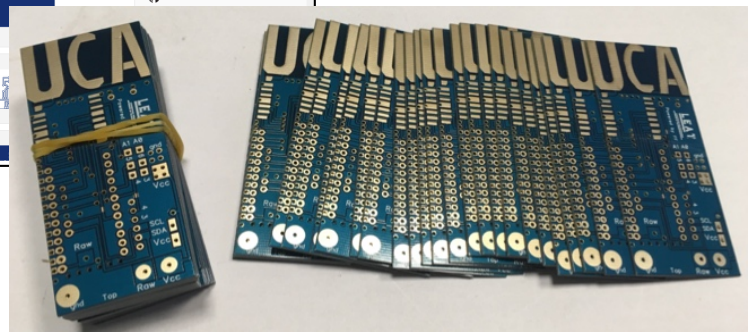
1€

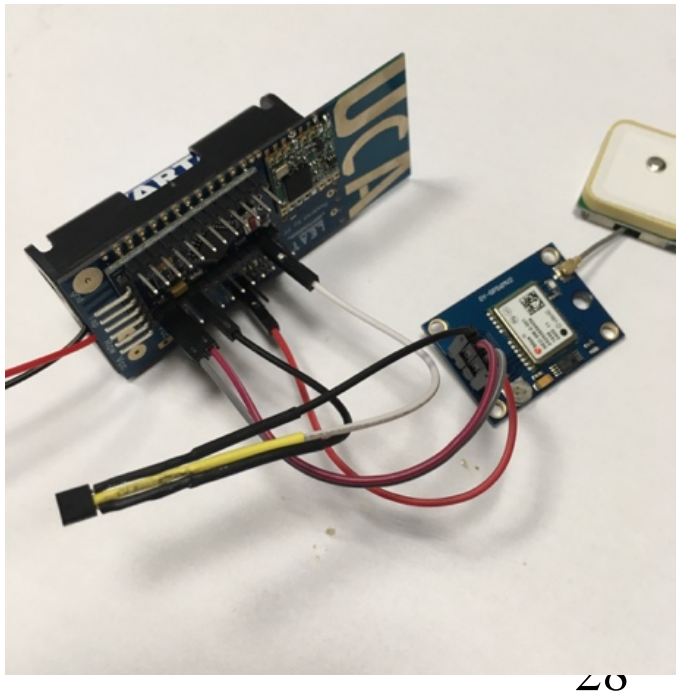




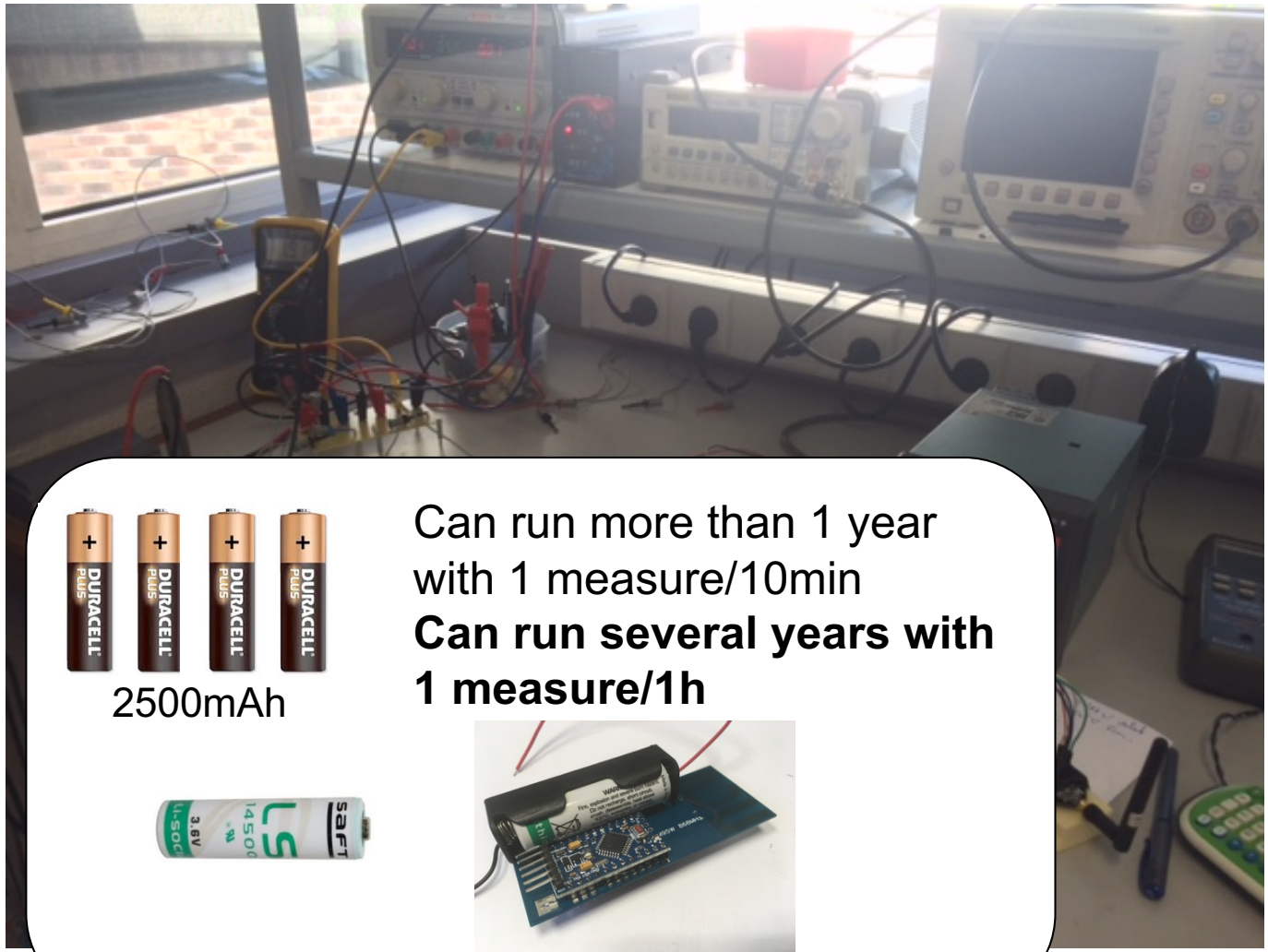
1-click order

Less than 10€/device



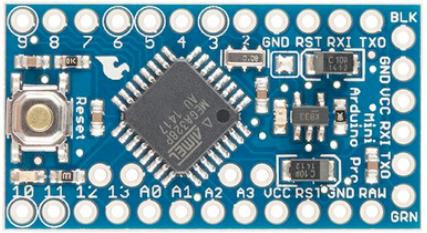


Low-power for longer lifetime!

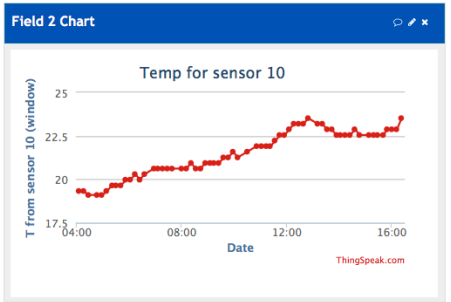


2500mAh

Can run more than 1 year with 1 measure/10min
Can run several years with 1 measure/1h



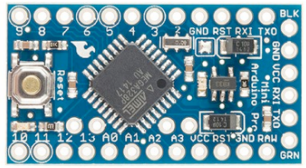
Wakes-up every 10min, take a measure (temp) and send to GW



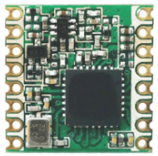
5µA in deep sleep mode, about 40mA when active and sending!

A SIMPLE TEMPERATURE SENSOR EXAMPLE

Arduino Pro Mini @3.3V

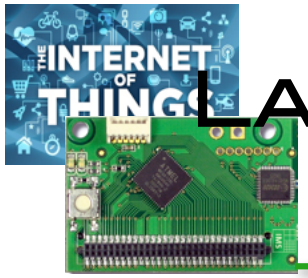


Modtronix inAir9



RFM95W

TMP36



LARGE VARIETY OF EXAMPLES TO LEARN AND ADAPT

CongducPham / LowCostLoRaGw

Unwatch 49 | Unstar 216 | Fork 120

Code | Issues 96 | Pull requests 2 | Projects 0 | Wiki | Insights | Settings

Branch: master ▾ LowCostLoRaGw / Arduino / Create new file | Upload files | Find file | History

Congduc Pham update README files, fix MD5 digest computation of gw id, always use ... Latest commit aba3ed2 2 days ago

..		
Arduino_LoRa_GPS	update README	19 days ago
Arduino_LoRa_Gateway	update gateway related files and some sketch	4 months ago
Arduino_LoRa_Gateway_1_4	improve management of transmission power, add channels in 863-865	a year ago
Arduino_LoRa_Generic_Sensor	update Arduino examples	a month ago
Arduino_LoRa_InteractiveDevice	update Arduino examples	a month ago
Arduino_LoRa_Ping_Pong	update Arduino examples	a month ago
Arduino_LoRa_Simple_BeaconCol...	update Arduino example	23 days ago
Arduino_LoRa_Simple_SoilHum	update Arduino examples	a month ago
Arduino_LoRa_Simple_temp	update Arduino examples	a month ago
Arduino_LoRa_SoilHum	update Arduino examples	a month ago
Arduino_LoRa_temp	update Arduino examples	a month ago
Arduino_LoRa_ucamII	update image support	3 months ago
libraries	update README files, fix MD5 digest computation of gw id, always use ...	2 days ago
README.md	update README	19 days ago

TUTORIALS AND VIDEOS

LOW-COST LORA IOT DEVICE: A STEP-BY-STEP TUTORIAL

PROF. CONGDUC PHAM
HTTP://WWW.UNIV-PAU.FR/~CPHAM
UNIVERSITÉ DE PAU, FRANCE

Congduc Pham, http://cpham.perso.univ-pau.fr

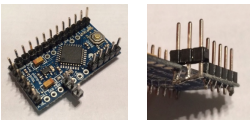
http://www.waziup.eu

The generic hardware platform

The Arduino Pro Mini

The Arduino Pro Mini is a compact form factor Arduino board based on the ATmega328P microcontroller
Use the **3.3v and 8MHz version** of the Arduino Pro Mini for lower power consumption

You can get the original board designed by Sparkfun or get one of the various clones available mainly from Chinese manufacturer. The last solution is very cost-effective as the Pro Mini board can be purchased for a bit more than 1€ a piece.



Depending on how many sensors you want to connect, the number of ground (GND) pins may be limited. You can extend a GND pin with a header pin where all pins are soldered together.

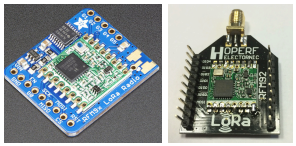
The LoRa radio module

There are various LoRa radio modules that are all based on the Semtech SX1272/1276 chips family

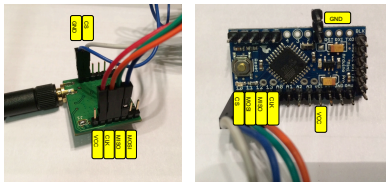
Fully tested LoRa radio modules | HopeRF RFM92W/95W | Libelium LoRa | Modtronix inAir4/9/9B | NiceRF LoRa1276

Most of SPI-based LoRa radio modules are supported. We recommend the Modtronix inAir model if you don't have delicate soldering experience as this module can come with header pins ready to be connected with Dupont wires.

The RFM95W can be found assembled (Adafruit) or an adapter can be purchased (from Ideetron for instance)



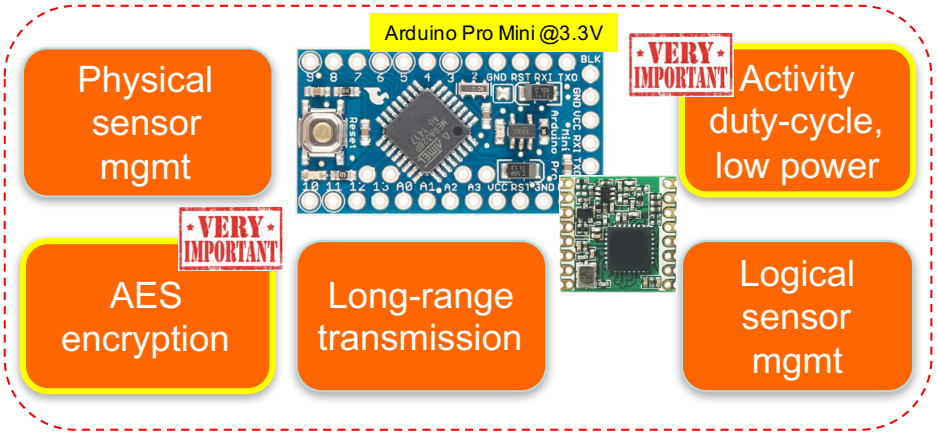
Connect the LoRa radio module

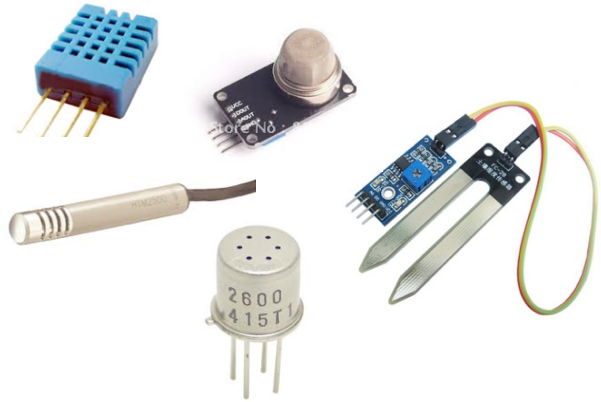


Connect the corresponding SPI pins of the radio module to the SPI pins on the Pro Mini board. MOSI (blue) is pin 11, MISO (green) is pin 12, CS (white) is pin 10 and CLK (orange) is pin 13 (right picture). Then connect also the VCC (red) and the GND (black) of the radio module to the VCC and the GND of the board (right picture). The VCC of the Pro Mini board gets 3.3v from the on-board voltage regulator.

Generic sensing IoT device

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





Generic sensing IoT device

- Build low-cost, low-power, Long-range enabled generic platform
- Me
- Tec
  ec

Minimum Viable Product

WAZIUP PROJECT

Waziup Advisory Board

Waziup Community

WP1
WP2
WP3
WP4
WP5
WP6

Physical sensor mgmt

AES encryption

VERY IMPORTANT

MVP 1
Water
Fish Farming

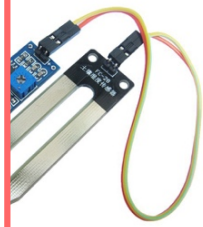
MVP 2
Cattle
Rustling

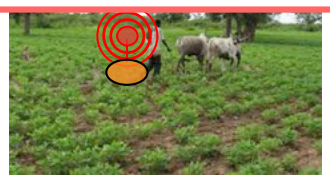
MVP 3
AGRI

MVP 4
Logistic
Transport

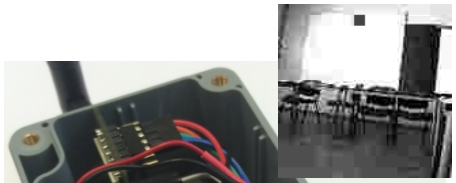
MVP 5
Urban
Waste
mgt

Credit: P. Cousin, EGM

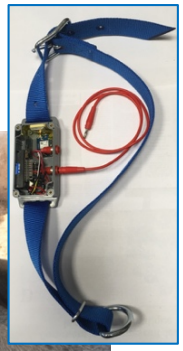


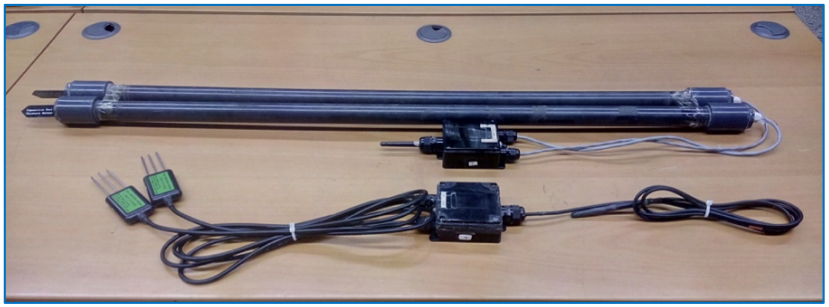


From generic to specific applications



GPS collar





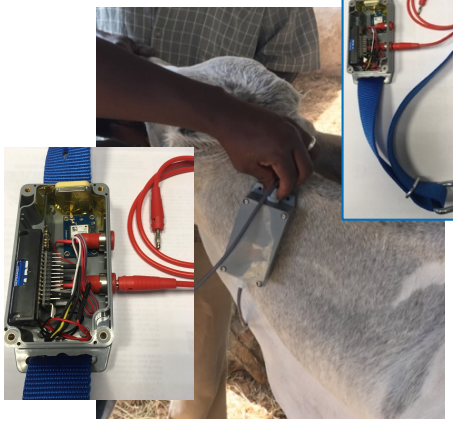


Image sensors

Soil Moisture

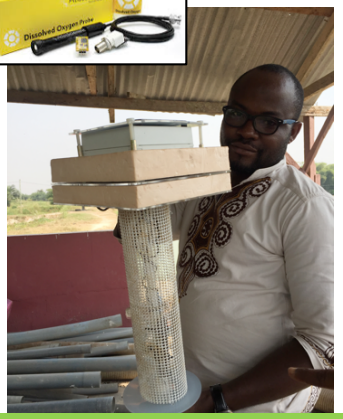


Photo from EGM

Buoy for water quality

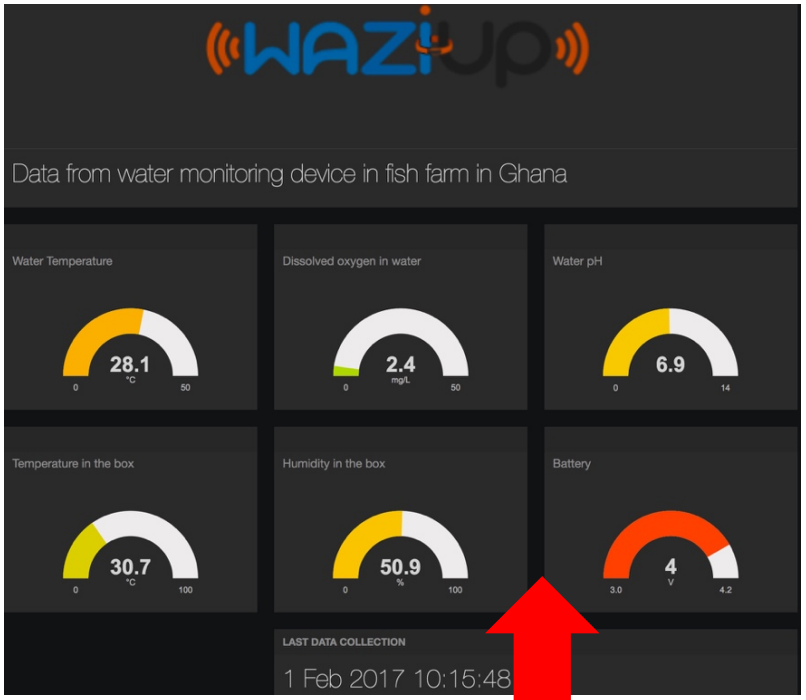
Weather Station

Photo from Unparallel

Bin presented at Woelab

Waste Mngt

Low-cost buoy for fish farming MVP



Physical sensor reading

Credit: EGM

Physical sensor management

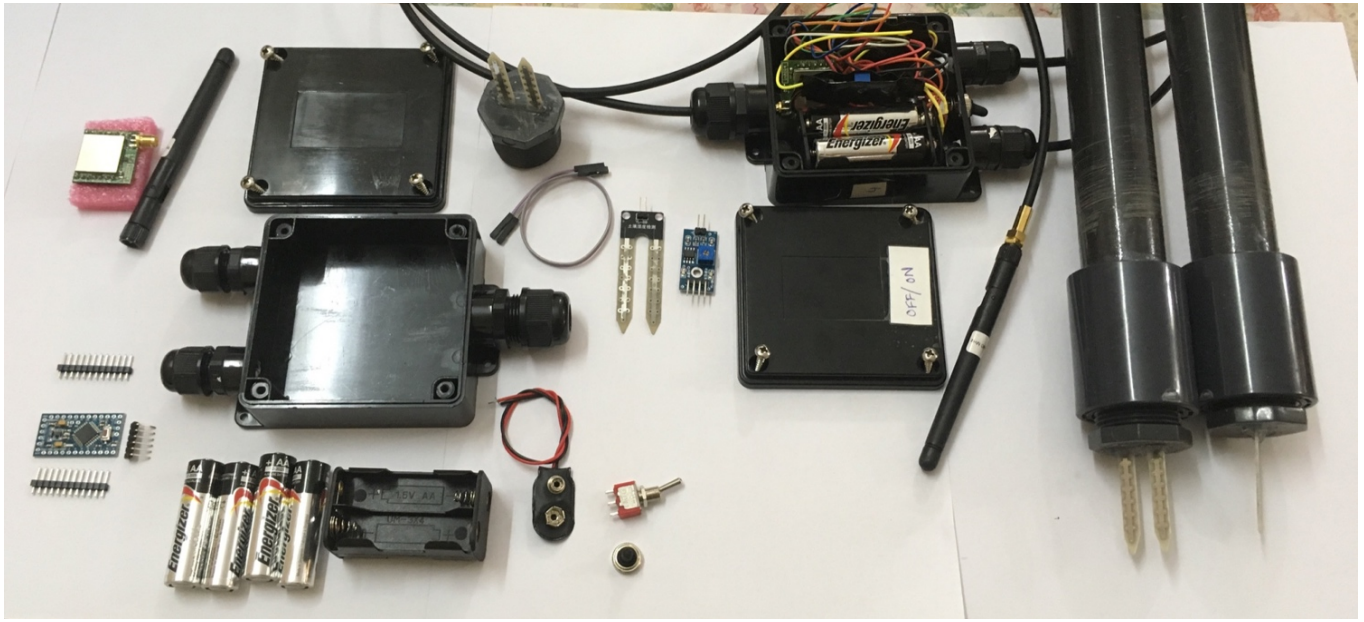
Activity duty-cycle, low power

Security

Long-range transmission

Logical sensor management

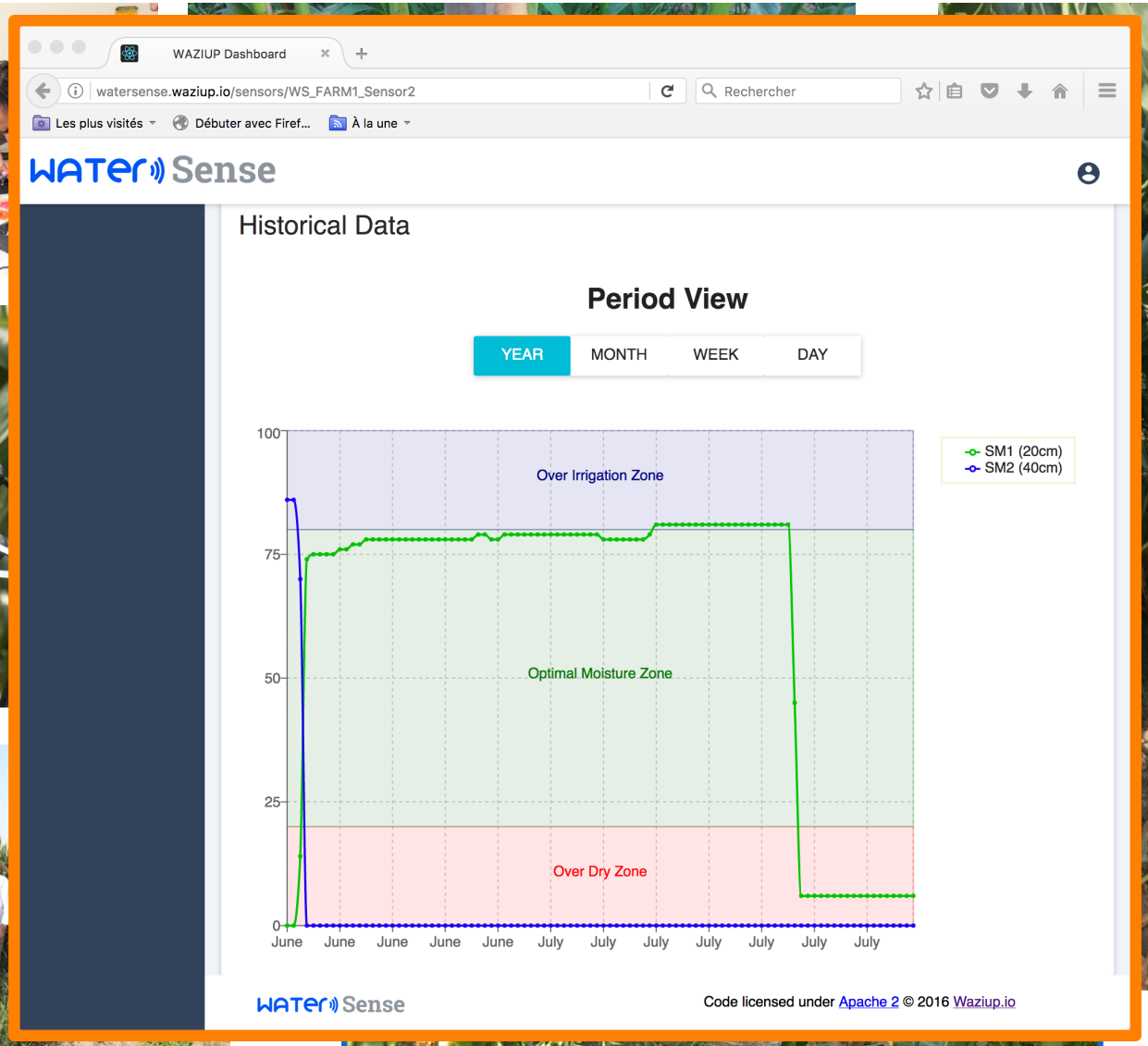
SOIL HUMIDITY SENSORS FOR AGRI MVP



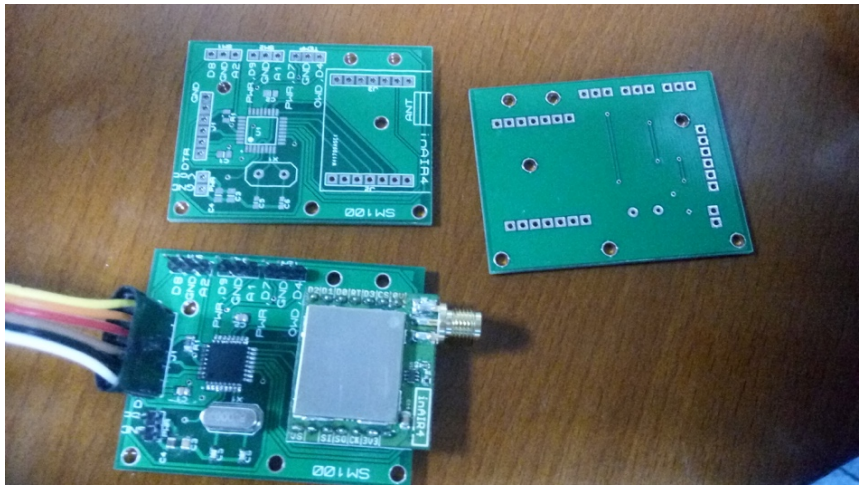
- Physical sensor management
- Activity duty-cycle, low power
- Security
- Long-range transmission
- Logical sensor management

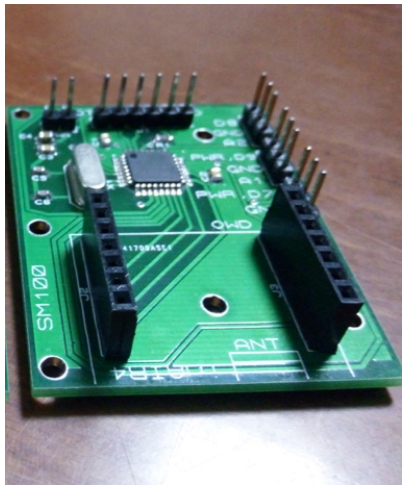
Deployment for Nestlé's WaterSense project

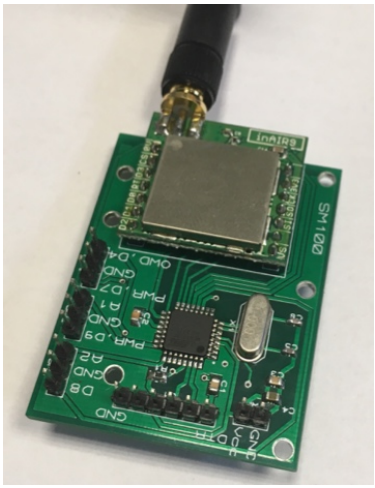
Deployment for Nestlé's WaterSense project

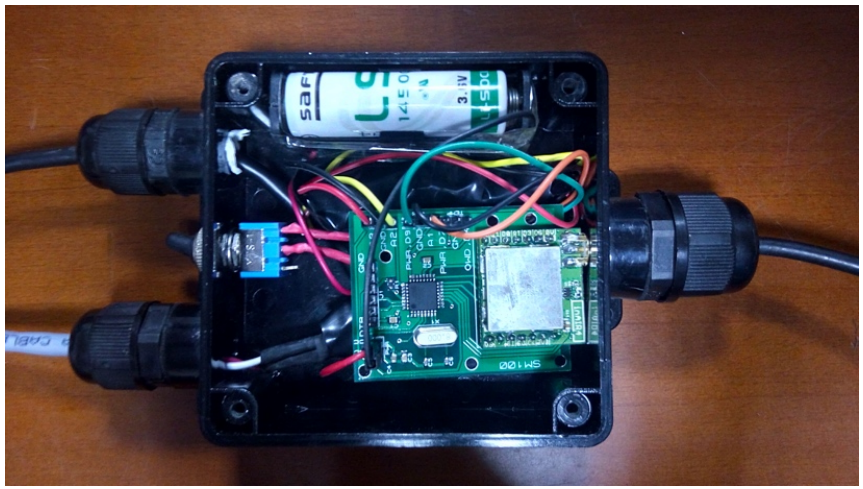


LOCAL INTEGRATION WITH TECHNOLOGY TRANSFER

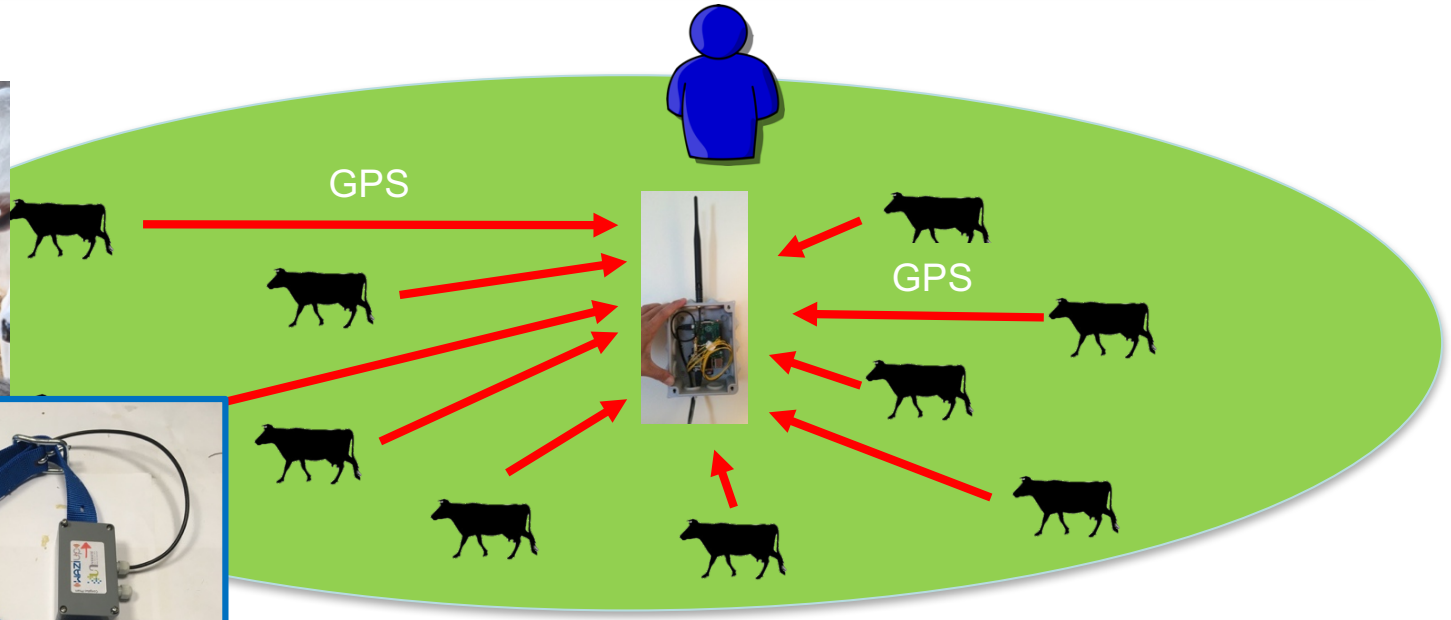








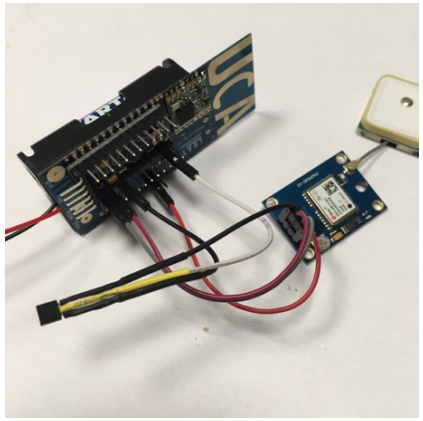
Collar for Cattle Rustling MVP

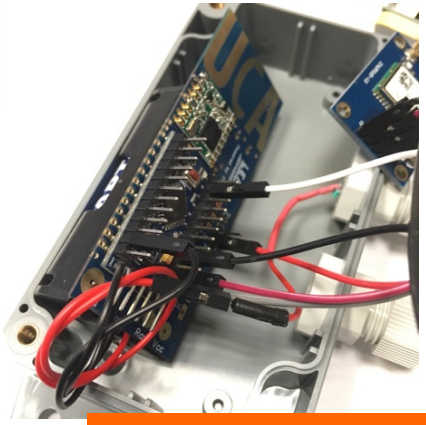


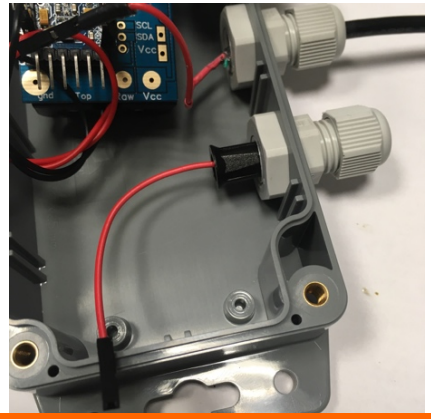
In Africa, the practice of animal husbandry has always been and still remain farmers' livelihood and incomes

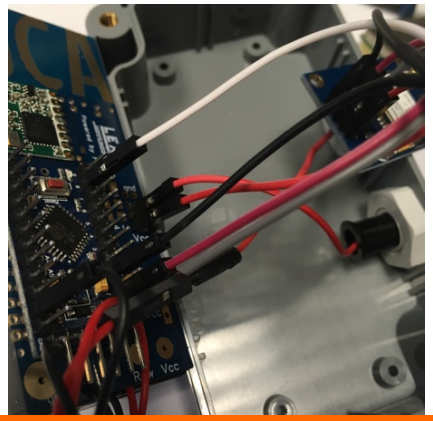
Their main problem in this activity remain the cattle rustling and some families are put in dramatic situation after a theft (reported 2 billions CFA losses)

Easy integration and customization

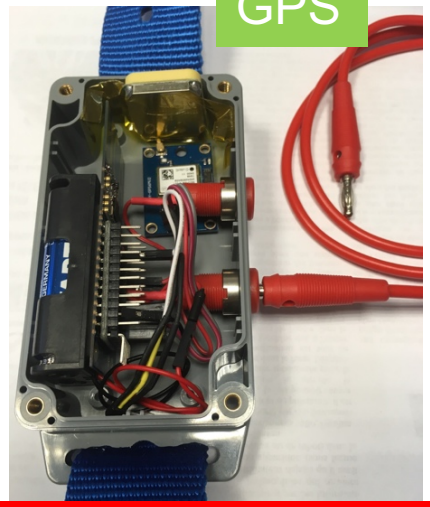


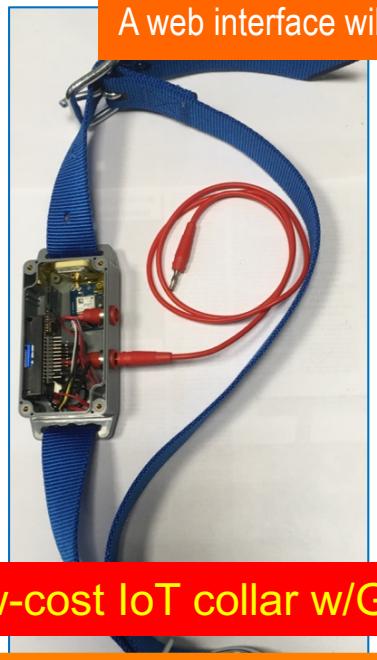






GPS



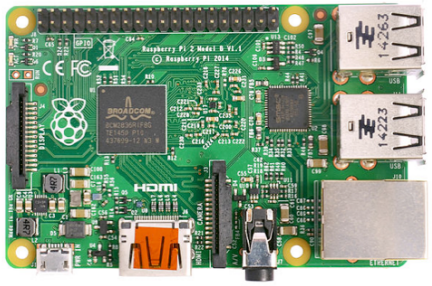


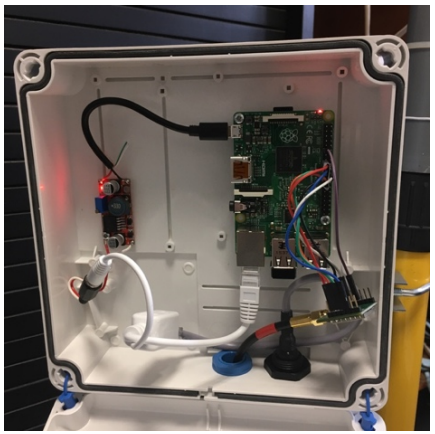
A web interface will display the position of the gateway and those of the remote GPS devices

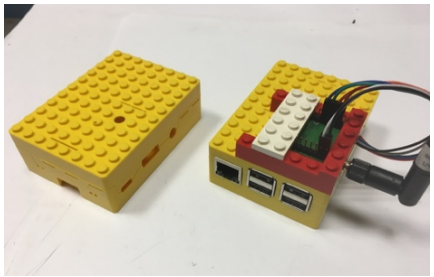
Dedicated tutorial on low-cost IoT collar w/GPS

https://github.com/CongducPham/tutorials/blob/master/Low-cost-LoRa-Collar.pdf

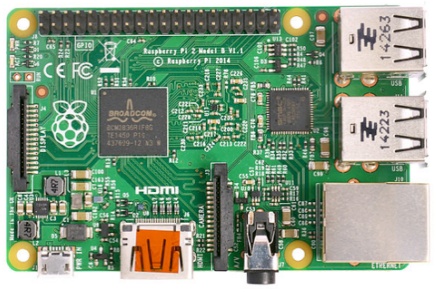
The versatile IoT gateway







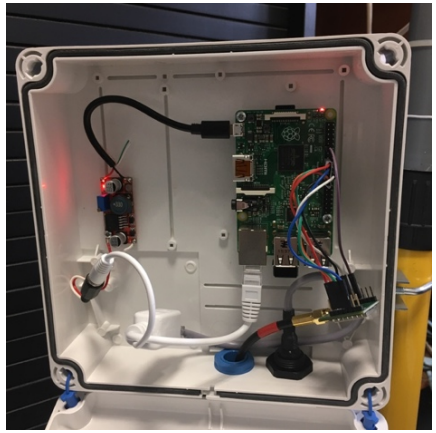
Raspberry-based low-cost LoRa gateway



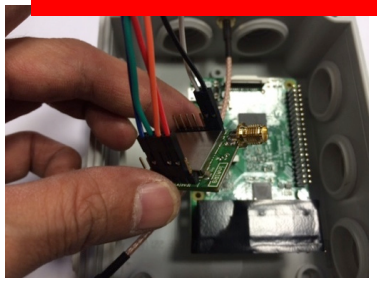
We can use all model of Raspberry. The most important usefull feature is the Ethernet interface for easy Internet connection. Then WiFi and Bluetooth can be added with USB dongles.
RPI3 provides built-in Ethernet, WiFi and Bluetooth!



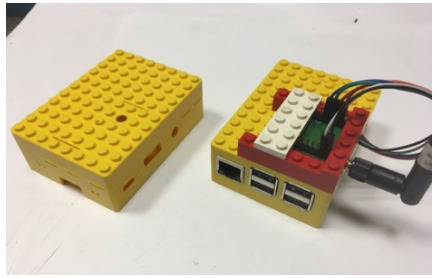




Less than 50€



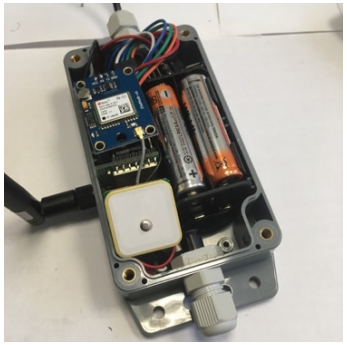


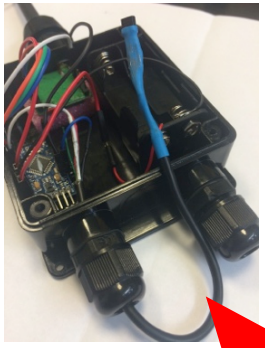


Get the ready-to-use SD card image

http://cpham.perso.univ-pau.fr/LORA/WAZIUP/raspberrypi-jessie-WAZIUP-demo.dmg.zip

100% DO-IT-YOURSELF !

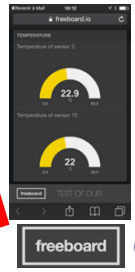


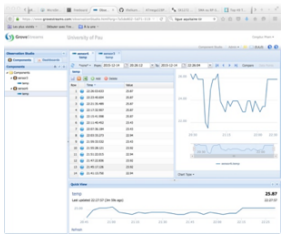


Step-by-step tutorial and source code available

Step-by-step tutorial and source code available

Python scripts available

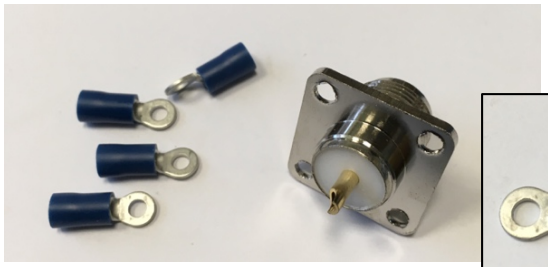
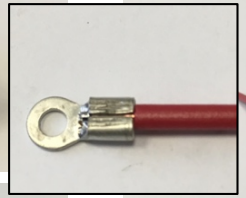
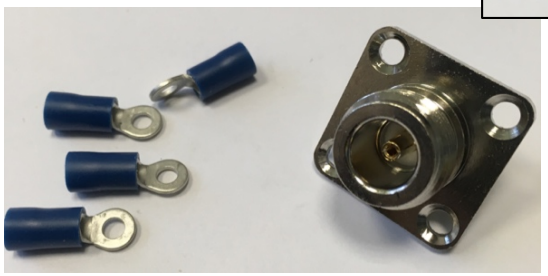


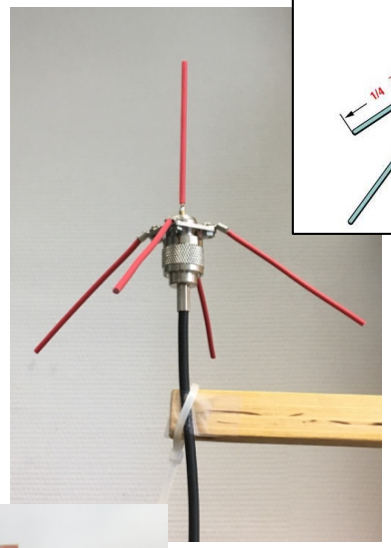
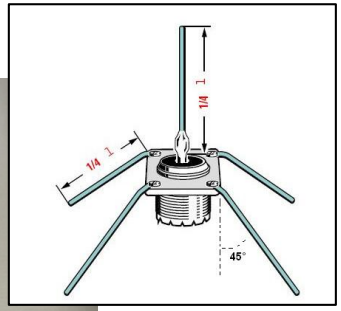


https://github.com/CongducPham/LowCostLoRaGw

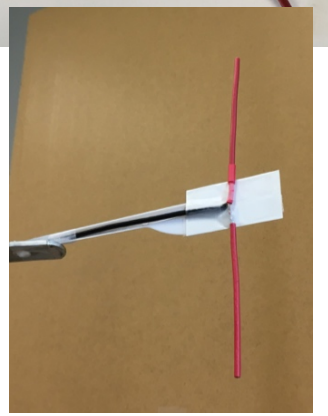
DIY ANTENNA AS WELL

- The ground plane antenna can be made with 5 pieces of ¼ wave wires. ¼ wave in 868MHz is about 8.2cm.

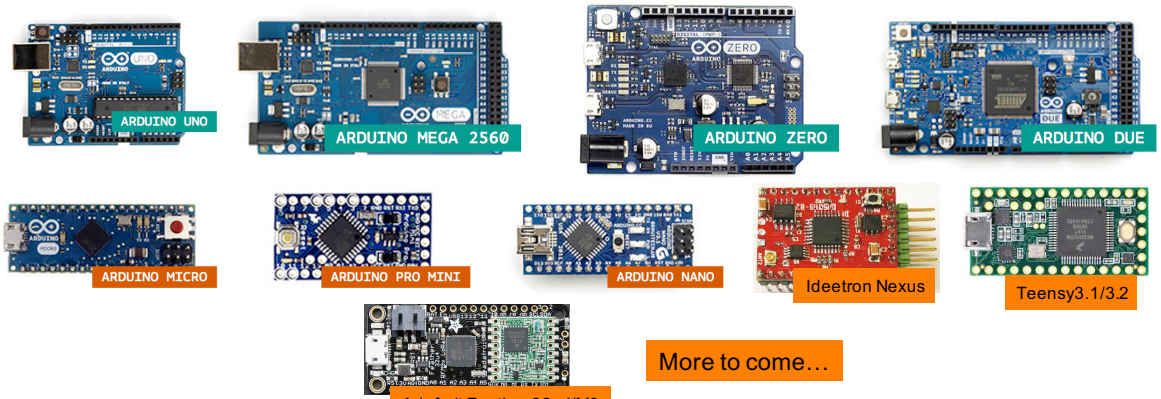




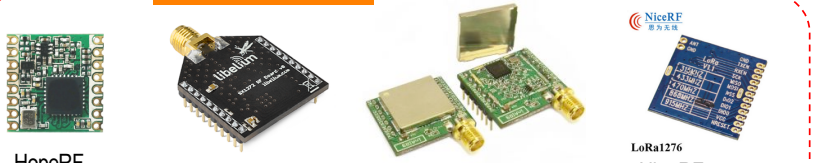
- Simple dipole antenna




SIMPLICITY!



LoRa radios that our library already supports

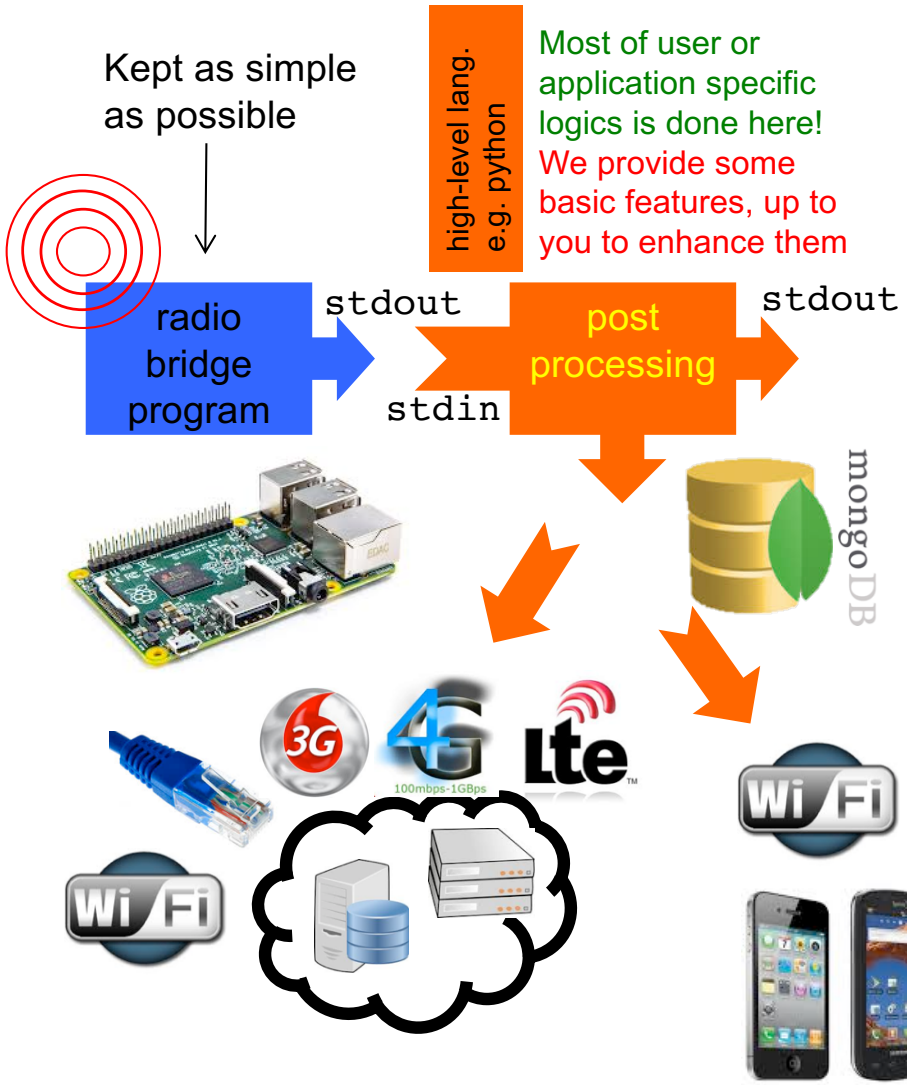


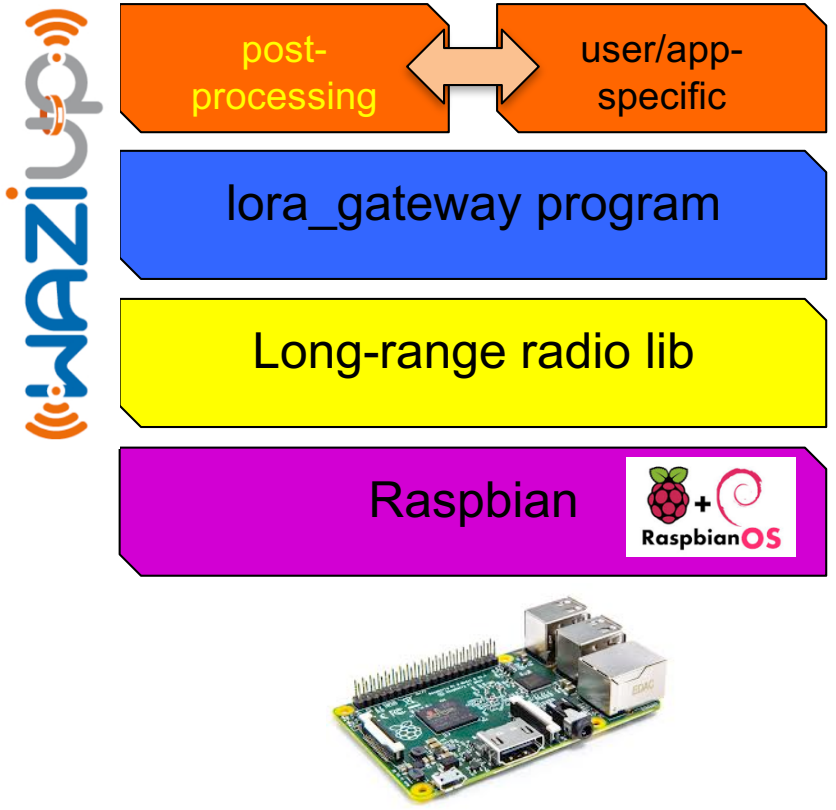
Long-Range communication library

```
sendPacketTimeout("TC/18.5");
// sends to gateway
// TC : temperature celcius
// 18.5 : value
```

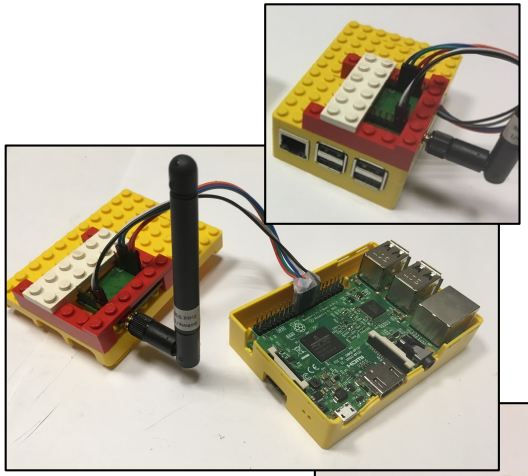
1 send function!

Our Low-Cost gateway architecture





Data post-processing stage



RPI 3
WiFi
LoRa

RPI ZeroW
WiFi
LoRa+2G/3G shield

RPI 3
LoRa
WiFi
PoE
2G/3G dongle
DHT22 in-case sensor

radio bridge program

stdout

stdin

post processing

stdout

JSON

post-processing

Handle downlink data

AES encryption decryption

LoRaWAN interoperability

Incoming data parsing block

Periodic task

JSON

Handle data from other radio interfaces

Monitor gateway temperature

user/app-specific

Cloud definition

cloud_script_1

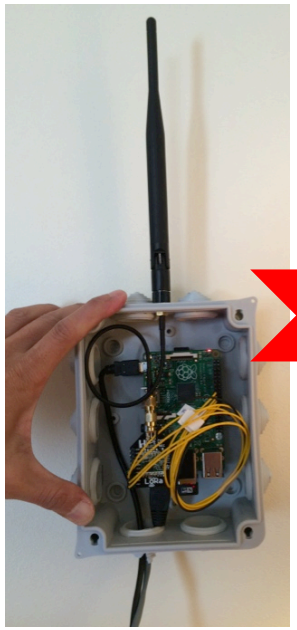
cloud_script_2

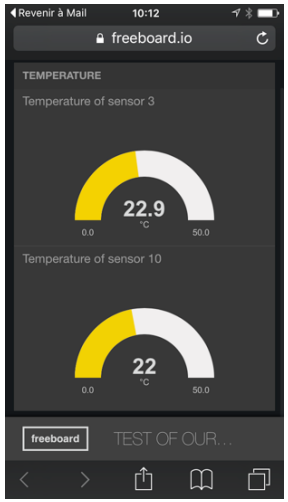
cloud_script_n

WAZIUP

local database

Templates for various clouds



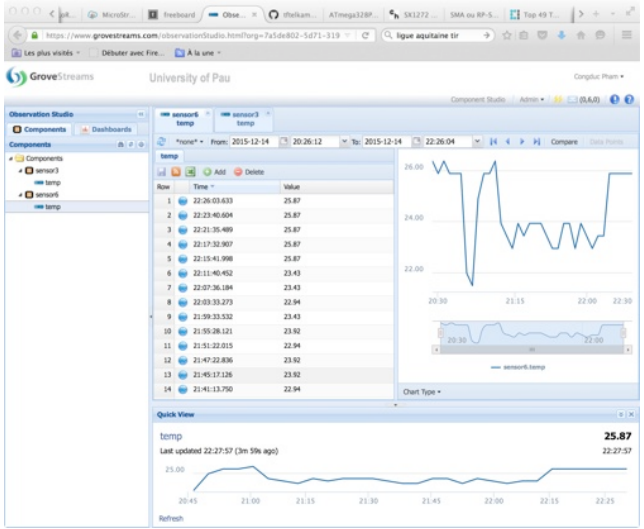


Dropbox

SensorCloud™

freeboard

FIWARE



\!##19.6

Node 10

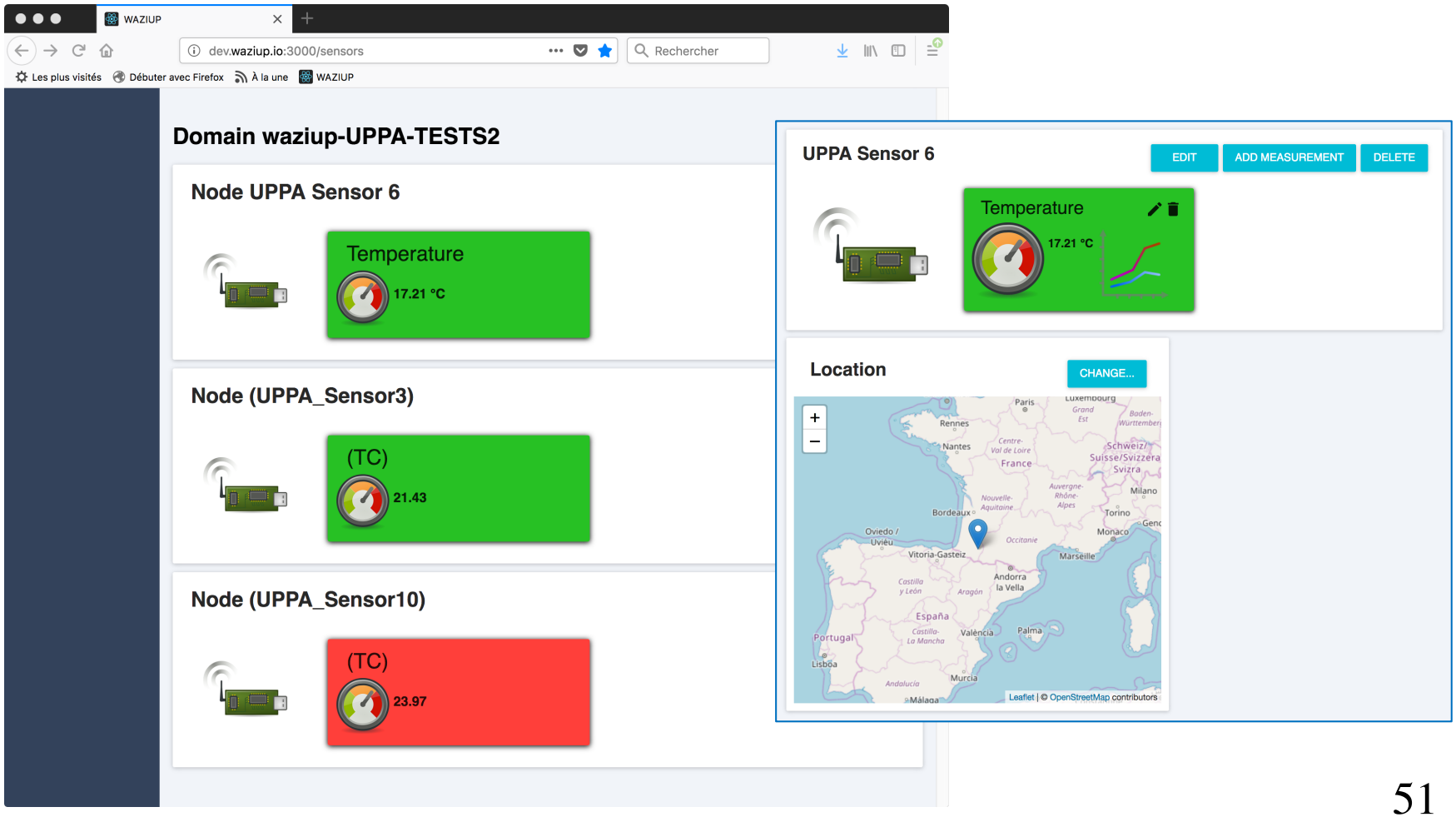
\!write key#field index#19.6

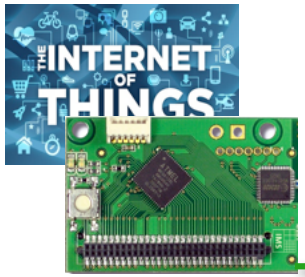
GroveStreams

And much more: HTTP, FTP, MQTT, Node-Red…

The WAZIUP cloud platform

- dashboard.waziup.io





CLOUDS.JSON


```
{
  "clouds": [
    {
      "notice": "do not remove the MongoDB cloud declaration",
      "name": "Local gateway MongoDB",
      "script": "python CloudMongoDB.py",
      "type": "database",
      "max_months_to_store": 2,
      "enabled": true
    },
    {
      "name": "WAZIUP Orion cloud",
      "script": "python CloudOrion.py",
      "type": "iotcloud",
      "write_key": "",
      "enabled": true
    },
    {
      "name": "ThingSpeak cloud",
      "script": "python CloudThingSpeak.py",
      "type": "iotcloud",
      "write_key": "",
      "enabled": true
    },
    {
      "name": "GroveStreams cloud",
      "script": "python CloudGroveStreams.py",
      "type": "iotcloud",
      "write_key": "",
      "enabled": false
    },
    {
      "name": "Firebase cloud",
      "script": "python CloudFireBase.py",
      "type": "jsoncloud",
      "write_key": "",
      "enabled": false
    },
```

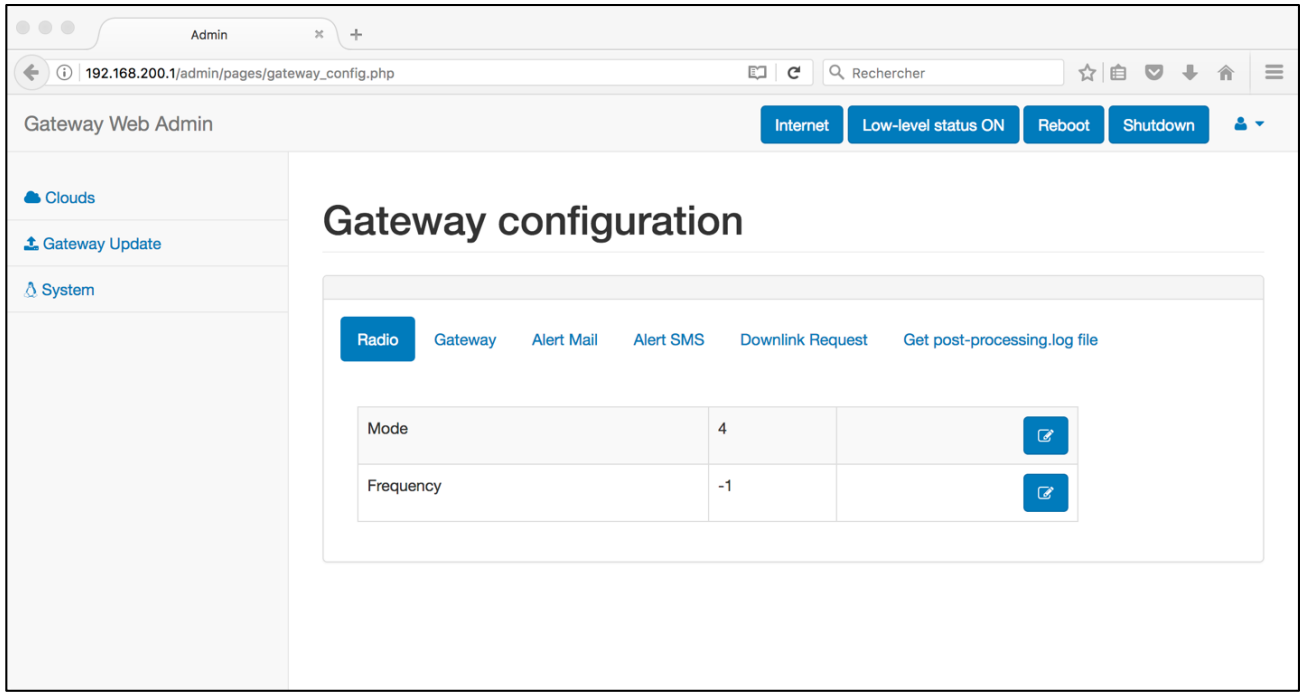

For each cloud, you have to provide a script and the launcher program (e.g. python)

Enabled clouds will be called by the post-processing stage

Each cloud script can incorporate parameters from a dedicated configuration file, e.g. key_ThinkSpeak.py for CloudThinkSpeak.py

CONFIGURE YOUR GATEWAY WITH THE WEB INTERFACE

- http://192.168.200.1/admin
  - Login: admin
  - Password: loragateway



Working without Internet access

A

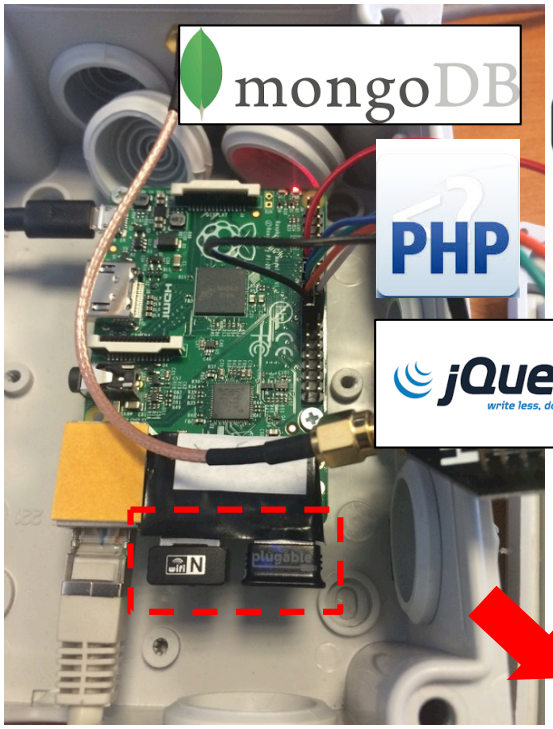
10-15kms

LoRa™

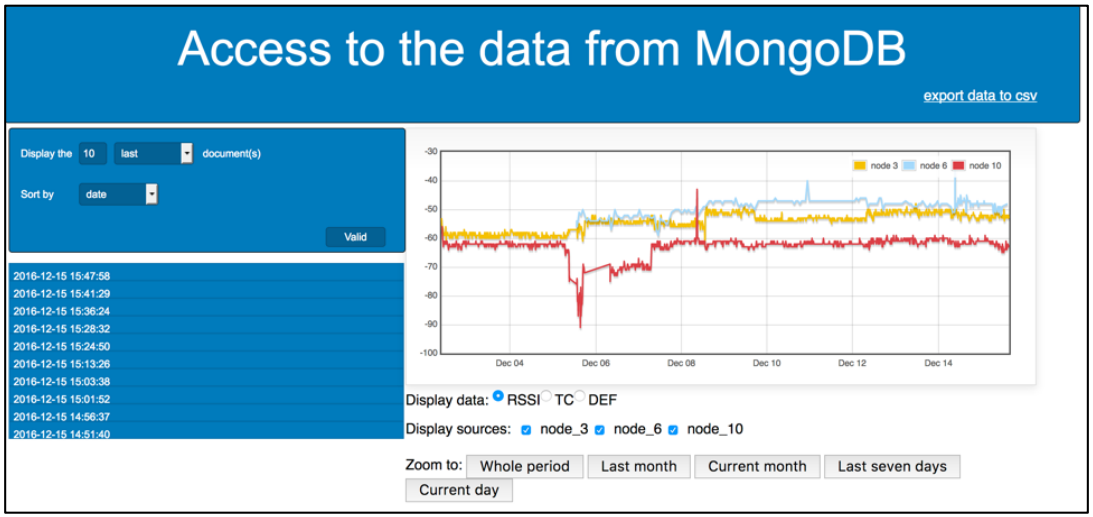
No subscription
Deploy own network
Low energy consumption

B

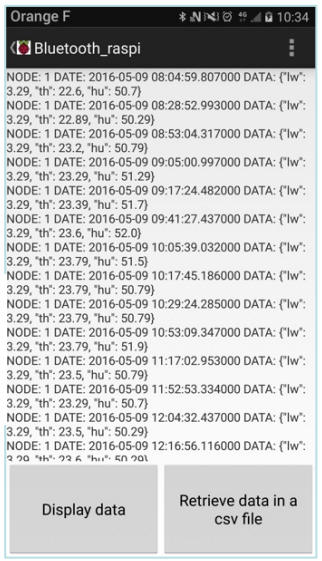
STANDALONE GATEWAY

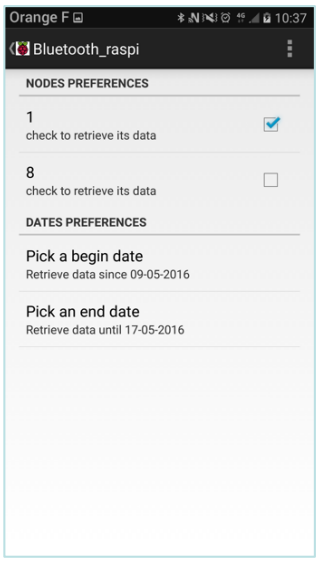


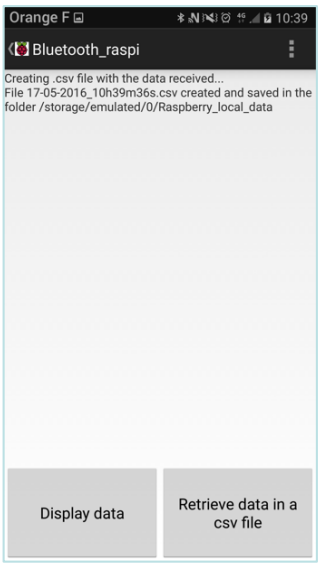
Wi Fi

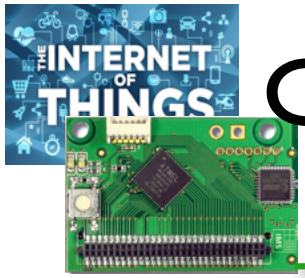


Isolated areas



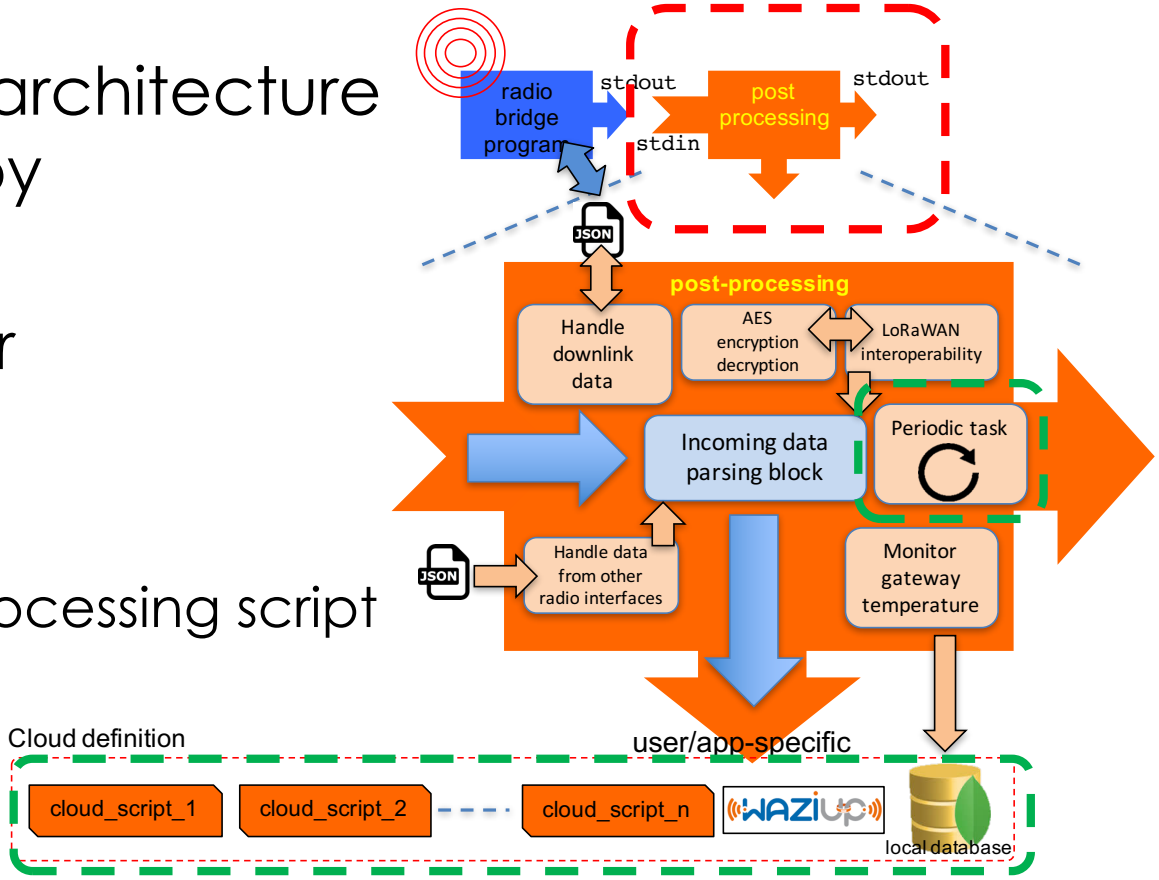


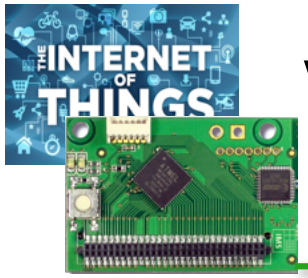




Customizing/Extending your gateway

- The flexible gateway architecture offers high versatility by customization
- There are 3 options for customization
- The geek way
  - Modify/extend post-processing script
- The "smarter" way
  - Add "cloud" scripts
    - On packet reception
  - Add periodic tasks
    - Independant from packet reception





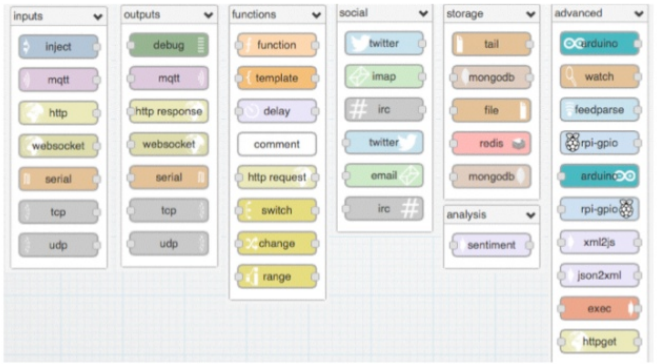
Write your own cloud script

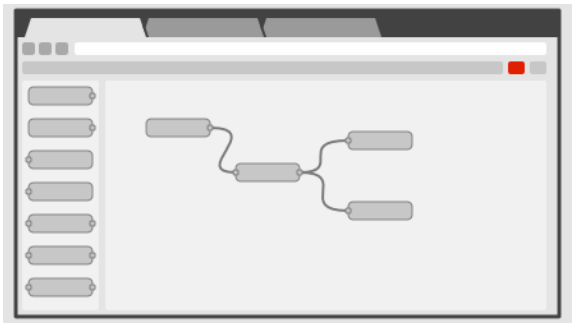
- Use our templates to write your own cloud script
- A cloud script is called with 5 arguments
  - ldata: the received data
    - e.g. #4#TC/21.5 as 1st argument (sys.argv[1] in python)
  - pdata: packet information
    - e.g. "1,16,3,0,10,8,-45" as 2nd argument (sys.argv[2] in python)
    - interpreted as dst,ptype,src,seq,len,SNR,RSSI for the last received packet
  - rdata: the LoRa radio information
    - e.g. "500,5,12" as 3rd argument (sys.argv[3] in python)
    - interpreted as bw,cr,sf for the last received packet
  - tdata: the timestamp information
    - e.g. "2016-10-04T02:03:28.783385" as 4th argument (sys.argv[4] in python)
  - gwid: the gateway id
    - e.g. 00000027EBBEDA21 as 5th argument (sys.argv[5] in python)

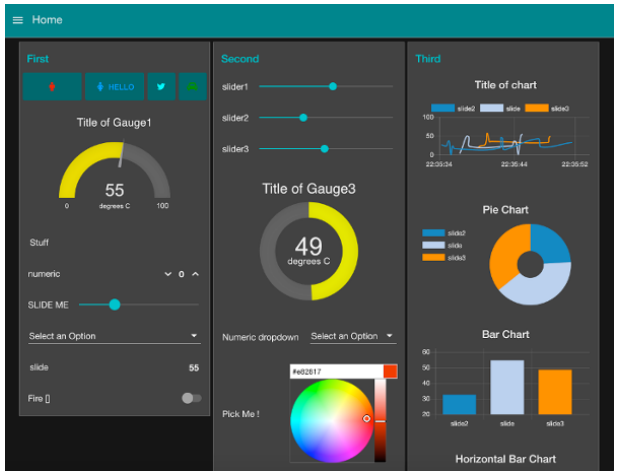
These parameters are passed to the script. It is up to the cloud script to use these parameters or not.

Ex: Node-Red

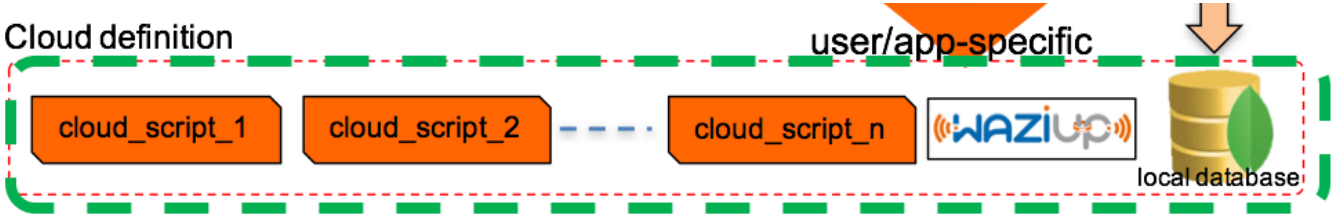
- Node-RED is a programming tool for wiring together hardware devices, APIs and online services, e.g. clouds of various types
- provides a browser-based flow editor to wire together flows with a wide range of nodes





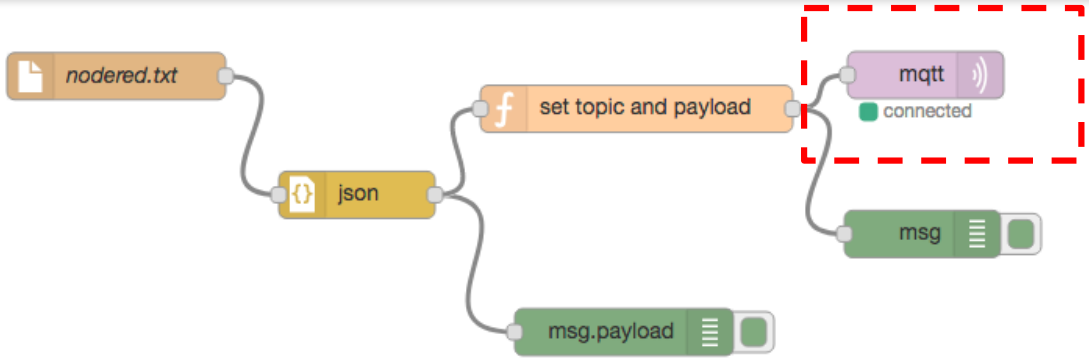


CloudNodeRed.py



- `CloudNodeRed.py` shows how interface with Node-Red can be simply implemented to benefit from the facility offered by Node-Red
- 3 variables will be used by `CloudNodeRed.py`
  - `project_name="waziup"`
  - `organization_name="UPPA"`
  - `sensor_name="Sensor"`
- when a device which address is 2 sends "TC/21.65/HU/85" to the gateway, `CloudNodeRed.py` will generate the following json entries in `nodered/nodered.txt` file
  - `{"source":"waziup/UPPA/Sensor2","measure":"TC","value":21.65}`
  - `{"source":"waziup/UPPA/Sensor2","measure":"HU","value":85}`

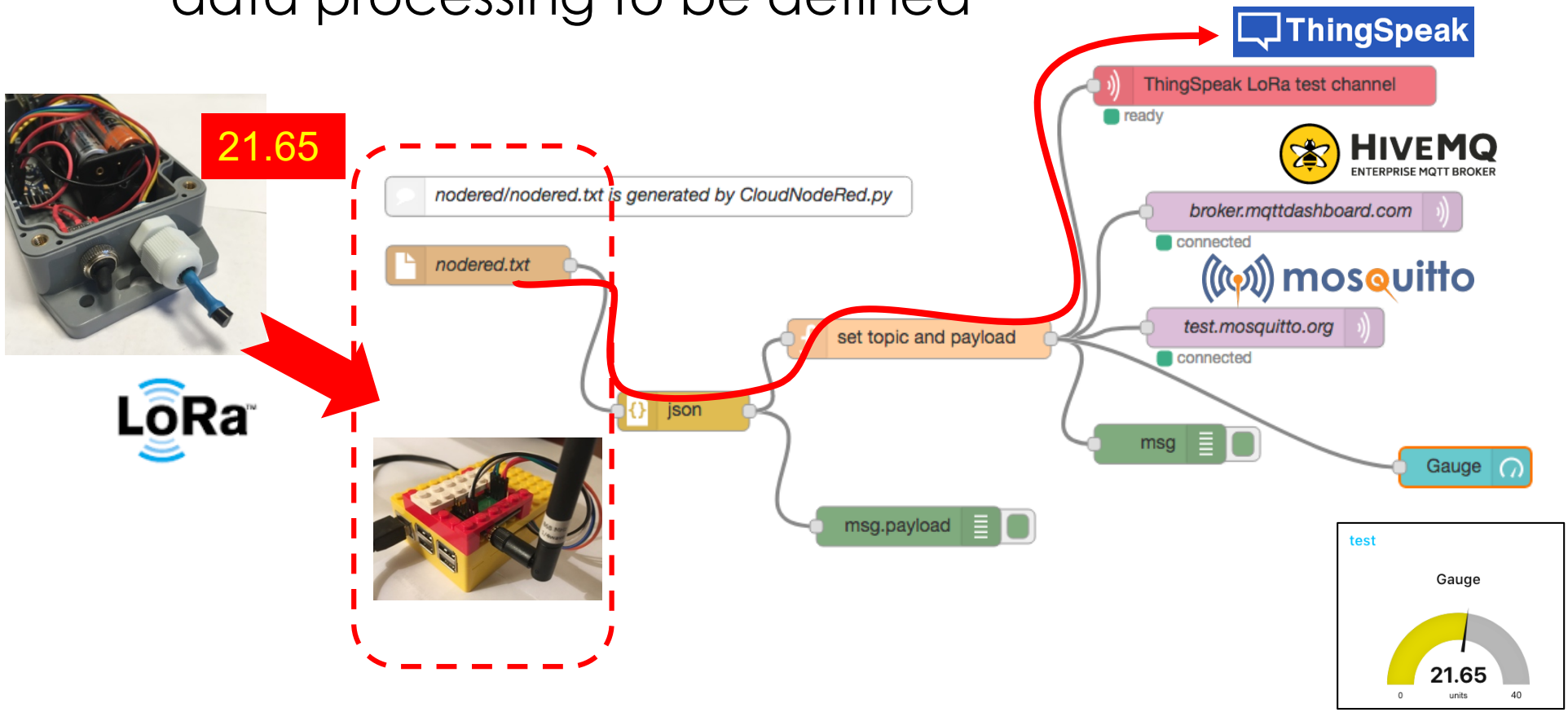
Adding MQTT

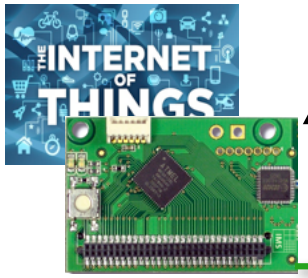


- An MQTT node using the `test.mosquitto.org` broker will receive the messages with the topic defined as `waziup/UPPA/Sensor2/TC` and `waziup/UPPA/Sensor2/HU`
- It will then respectively publish 21.65 and 85 under these topics
- More information on:
  - `https://github.com/CongducPham/LowCostLoRaGw/blob/master/gw_full_latest/README-NodeRed.md`

The Node-RED enabled gateway

- Messages received on the gateway can be injected into a Node-Red flow, allowing complex data processing to be defined



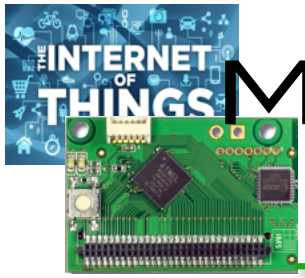


Another example with CloudGpsFile.py

- `CloudGpsFile.py` is a dedicated "cloud" module that will search in incoming messages a valid 'LAT' and 'LGT' field such as in "`BC/9/LAT/43.31402/LGT/-0.36370/FXT/4180`"
- You can enable `CloudGpsFile.py` in `clouds.json`. When a message with valid GPS coordinates is received, `CloudGpsFile.py` will write an entry in `gps/gps.txt` file containing relevant packet and GPS information, including the distance (in km) between the gateway and the GPS device

```
src waziup_UPPA_Sensor15 seq 188 bc 9 snr 5 rssi -90 time 2017-11-20T14:18:54 gw
00000027EB5171F7 fxt 4180 lat 43.31402 lgt -0.36370 distance 0.0224
```

- For distance calculation, the gateway position MUST be provided in the `gateway_conf.json` file (see Annex)
- For range test campaign, you can import (or copy/paste) this file in an Excel sheet to plot distance against SNR/RSSI

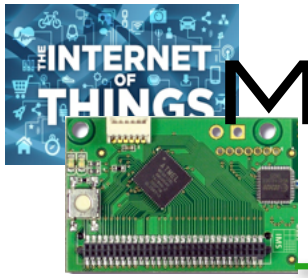


Maintaining a list of GPS devices (1)

- `CloudGpsFile.py` also maintains a list of GPS devices in `gps/gps.json`

```
{
    "devices": [
        {
            "gw": "00000027EB5171F7",
            "src": "waziup_UPPA_Sensor15",
            "seq": 188,
            "distance": 0.0224,
            "fxt": 4180,
            "bc": 9,
            "lat": 43.31402,
            "snr": 8,
            "time": "2017-11-20T14:18:54",
            "active": "yes",
            "rssi": -45,
            "lgt": -0.3637
        }
    ]
}
```

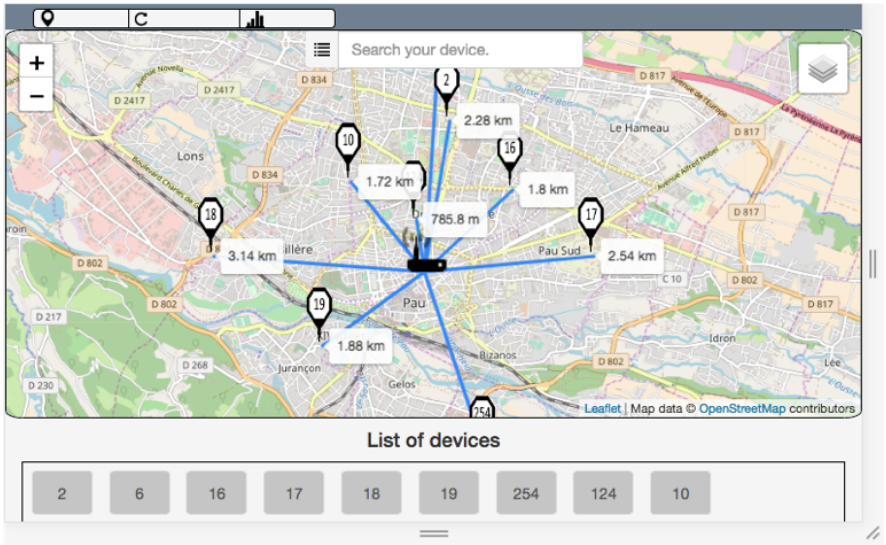
- New devices (from `src` field) will be added, while existing devices will be updated



Maintaining a list of GPS devices (2)

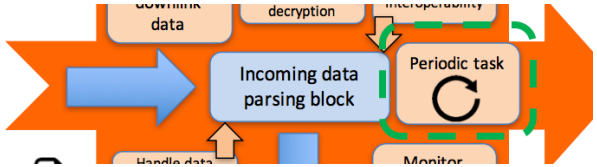
- `CloudGpsFile.py` also extract from the list of GPS devices those that have sent GPS information in during the last time window
- `key_GpsFile.py` defines
  - `active_interval_minutes=20`
  - For instance, devices that have sent GPS info in the last 20 minutes will be indicated as active
- Those active devices are further maintained in `gps/active_gps.json`
- Further versions can also create kml or gpx file or any combination that would allow more complex visualization features

A WEB INTERFACE FOR TRACKING GPS DEVICES



- A web interface could use `gps/gps.json` and `gps/active_gps.json` to show:
  - the last updated GPS device
  - active devices (in the last time window)
  - inactive devices that have not been updated in the last time window
- Especially usefull in mobility scenario

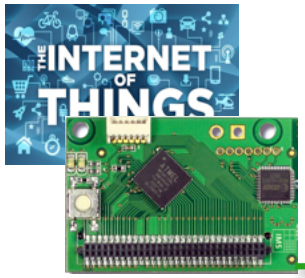
Extending by adding a new periodic task



- Illustration with dynamic gateway GPS position
- The gateway's coordinates are stored in `gateway_conf.json`

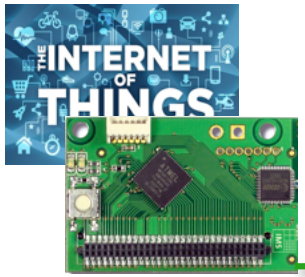
```
"gateway_conf" : {
        "gateway_ID" : "000000XXXXXXXXXX",
        "ref_latitude" : "43.31416",
        "ref_longitude" : "-0.36430",
```

- In a mobility scenario, the position of the gateway can be updated
- `post_status_processing_gw.py` which is periodically called by the main post-processing loop can be extended to get the position of the gateway using a connected GPS module.



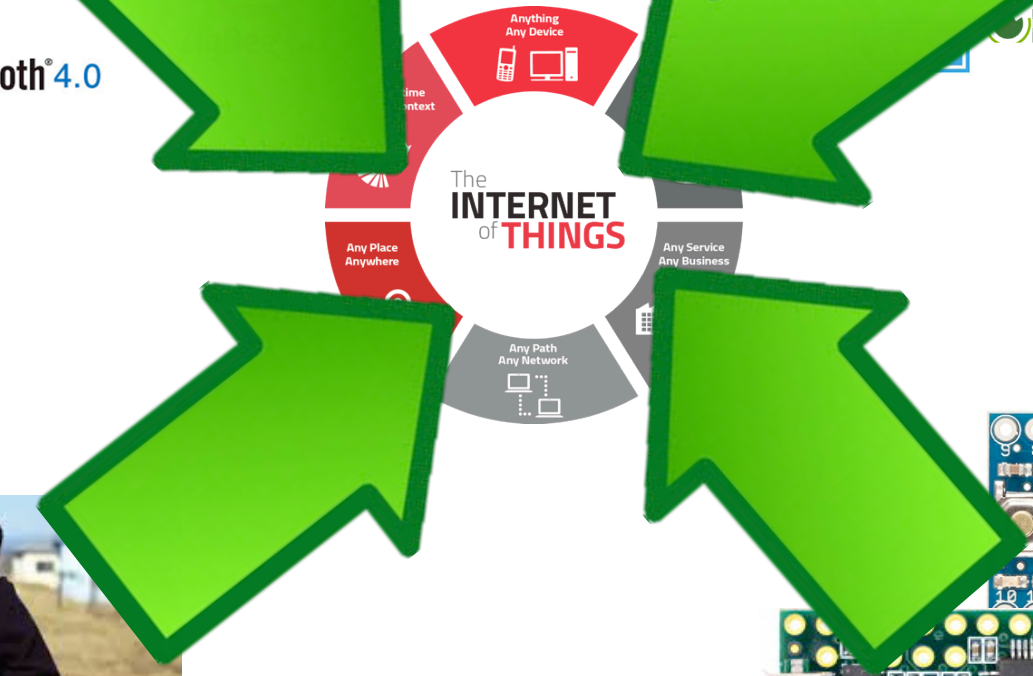
When enabling dynamic_gps

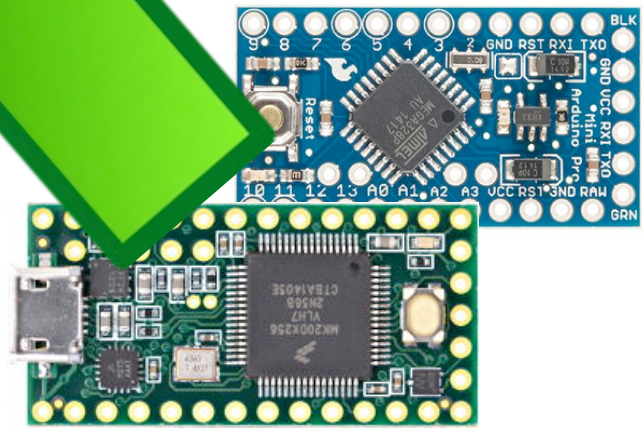
- Enabling `dynamic_gps` in `gateway_conf.json` activates the following tasks
  - `post_status_processing_gw.py` which is periodically called by `post_processing_gw.py` will try to get the position of the gateway using a connected GPS module. It uses `get_gps.py` in the `sensors_in_raspi` folder
  - `get_gps.py` produces a `gateway_gps.txt` file if a valid GPS fix is obtained. The file simply contains the coordinates in decimal degree: `43.31427,-0.36424`
  - If `post_status_processing_gw.py` finds a `gateway_gps.txt` file, it will update in `gateway_conf.json` the GPS coordinate fields used by `CloudGpsFile.py`



Now,
IoT BECOMES REALITY!

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





Involving innovation hubs/stakeholders

- **Close to dev & entrepreneurs** communities
- Have their **own community and com channels** (community builders & catalysts)
- Used to organizing disruptive events
- **On the field** (know the targets personaly & the market)
- **Used to empowering startups & businesses** (coaching, business dev, incubation, acceleration…)
- Affiliated to **international networks** that could be involved in dissemination or Business dev (Afrilabs)

Credit: C. Vavasseur, CTIC Dakar

BUILDING WAZIUP COMMUNITY AND ECOSYSTEM

International Events
+ 20 organized & attended

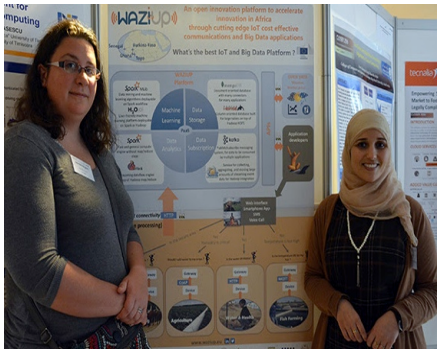
Launch event (Senegal, CTIC Dakar)

Launch event (Ghana, iSpace)

IoTWeek2016 (Belgrade, EGM)

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

IoTBigData2016 (Italy, EGM)



IoTCareConference (Budapest, CNET)

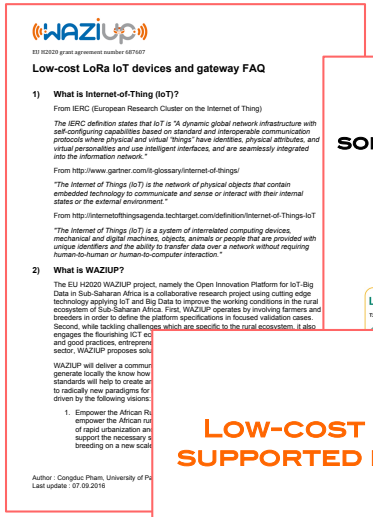
WAZIUP Workshop on IoT (Togo, L'Africaine d'Architecture)

Workshop at the RESSACS 2016 (France, UPPA)

Credit: C. Vavasseur, CTIC Dakar

TUTORIALS/RESOURCES

https://github.com/CongducPham/tutorials



Low-cost LoRa IoT devices and gateway FAQ

1) What is Internet-of-Thing (IoT)?

From IERC (European Research Cluster on the Internet of Thing)

The IERC definition states that IoT is "A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network."

From http://www.gartner.com/it-glossary/internet-of-things/

"The Internet of Things (IoT) is the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment."

From http://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT

"The Internet of Things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction."

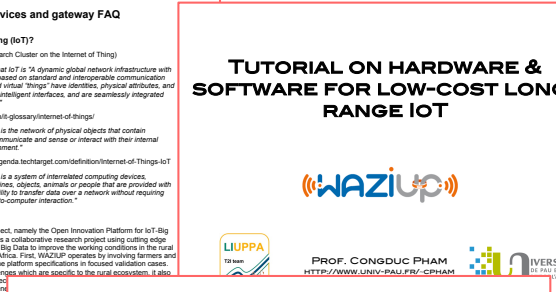
2) What is WAZIUP?

The EU H2020 WAZIUP project, namely the Open Innovation Platform for IoT-Big Data in Sub-Saharan Africa is a collaborative research project using cutting edge technology applying IoT and Big Data to improve the working conditions in the rural ecosystem of Sub-Saharan Africa. First, WAZIUP operates by involving farmers and breeders in order to define the platform specifications in focused validation cases. Second, while tackling challenges which are specific to the rural ecosystem, it also engages the flourishing ICT ec and good practices, entrepren sector, WAZIUP proposes solu

WAZIUP will deliver a commun generate locally the know how standards will help to create a to radically new paradigms for driven by the following visions:

1. Empower the African Ru empower the African ru of rapid urbanization an support the necessary s breeding on a new scal

Author : Congduc Pham, University of Pa
Last update : 07.09.2016

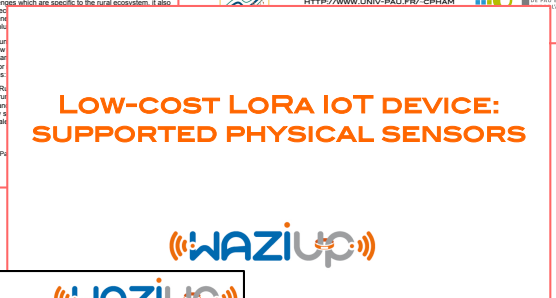


TUTORIAL ON HARDWARE & SOFTWARE FOR LOW-COST LONG-RANGE IOT

PROF. CONGDUC PHAM
HTTP://WWW.UNIV-PAU.FR/~CPHAM

LOW-COST LORA IOT DEVICE: A STEP-BY-STEP TUTORIAL

BUILDING AN IOT DEVICE FOR OUTDOOR USAGE: A STEP-BY-STEP TUTORIAL



LOW-COST LORA IOT DEVICE: SUPPORTED PHYSICAL SENSORS

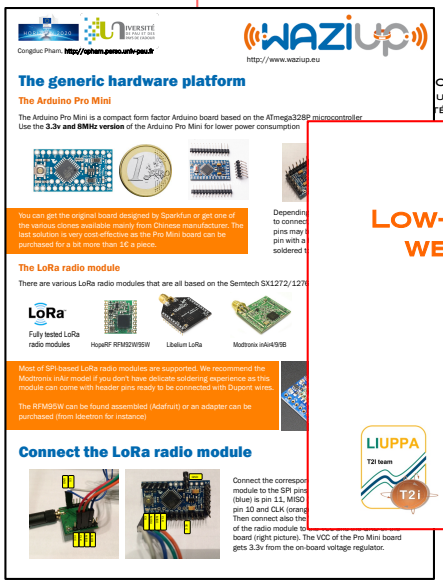
ONGDUC PHAM
UNIV-PAU.FR/~CPHAM
É DE PAU, FRANCE

LOW-COST LORA GATEWAY: A STEP-BY-STEP TUTORIAL

PROF. CONGDUC PHAM
HTTP://WWW.UNIV-PAU.FR/~CPHAM
UNIVERSITÉ DE PAU, FRANCE

LOW-COST LORA IOT: USING THE WAZIUP DEMO KIT

PROF. CONGDUC PHAM
HTTP://WWW.UNIV-PAU.FR/~CPHAM
UNIVERSITÉ DE PAU, FRANCE



Congduc Pham, http://cpham.perso.univ-pau.fr
http://www.waziup.eu

The generic hardware platform

The Arduino Pro Mini

The Arduino Pro Mini is a compact form factor Arduino board based on the ATmega328P microcontroller. Use the **3.3v and 8MHz version** of the Arduino Pro Mini for lower power consumption

You can get the original board designed by Sparkfun or get one of the various clones available mainly from Chinese manufacturer. The last solution is very cost-effective as the Pro Mini board can be purchased for a bit more than 1€ a piece.

The LoRa radio module

There are various LoRa radio modules that are all based on the Semtech SX1272/127

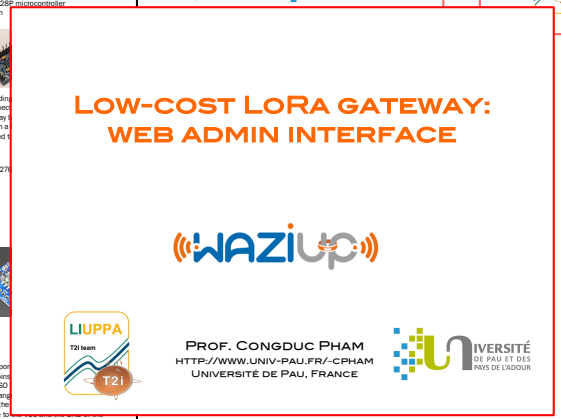
LoRa
Fully tested LoRa radio modules
HopeRF RFM92W/95W
Libelium LoRa
Modtronix inAir4/9/9B

Most of SPI-based LoRa radio modules are supported. We recommend the Modtronix inAir model if you don't have delicate soldering experience as this module can come with header pins ready to be connected with Dupont wires.

The RFM95W can be found assembled (Adafruit) or an adapter can be purchased (from Ideetron for instance)

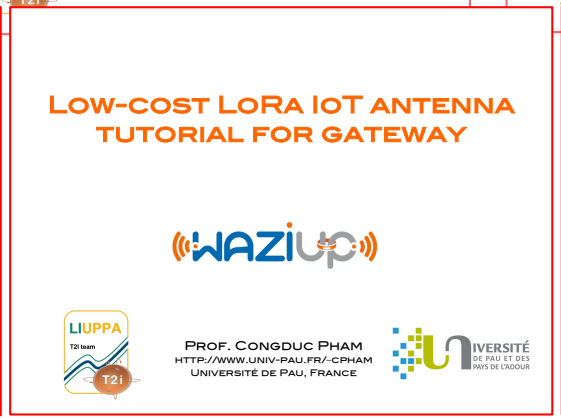
Connect the LoRa radio module

Connect the correspon module to the SPI pins (blue) is pin 11, MISO pin 10 and CLK (orang Then connect also the of the radio module t board (right picture). The VCC of the Pro Mini board gets 3.3v from the on-board voltage regulator.



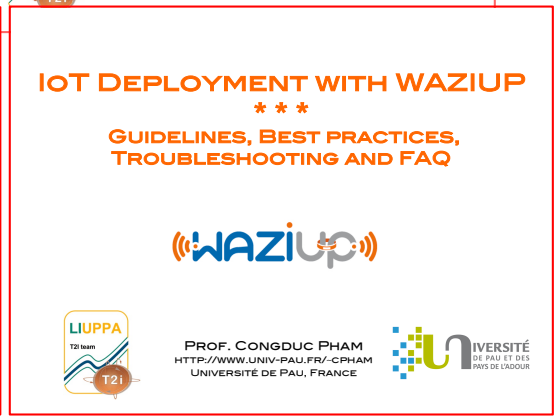
LOW-COST LORA GATEWAY: WEB ADMIN INTERFACE

PROF. CONGDUC PHAM
HTTP://WWW.UNIV-PAU.FR/~CPHAM
UNIVERSITÉ DE PAU, FRANCE



LOW-COST LORA IOT ANTENNA TUTORIAL FOR GATEWAY

PROF. CONGDUC PHAM
HTTP://WWW.UNIV-PAU.FR/~CPHAM
UNIVERSITÉ DE PAU, FRANCE



IOT DEPLOYMENT WITH WAZIUP

* * *

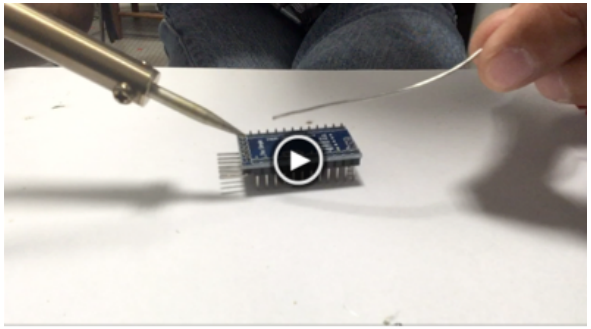
GUIDELINES, BEST PRACTICES, TROUBLESHOOTING AND FAQ

PROF. CONGDUC PHAM
HTTP://WWW.UNIV-PAU.FR/~CPHAM
UNIVERSITÉ DE PAU, FRANCE

YOUTUBE VIDEOS

Low-cost LoRa IoT device

+73000 views



Low-cost LoRa IoT gateway

+11000 views

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

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

Extreme low-power LoRa IoT

Setting up a gateway in 5mins

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

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

Thanks.

Let's keep in touch

ICTIC
Accompagnateur de croissance TIC

Carine VAVASSEUR

Communication & Event Manager

Carine.vavasseur@cticdakar.com

www.cticdakar.com
contact@cticdakar.com

HORIZON 2020

WAZIUP

facebook.com/waziuploT

twitter.com/waziuploT

linkedin.com/groups/8156933

github.com/waziup