

DEPLOYING LOW-COST AND LONG-RANGE INTERNET OF THINGS IN DEVELOPING COUNTRIES



PROF. CONG DUC PHAM
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UNIVERSITÉ DE PAU, FRANCE





IOT FOR DEVELOPMENT



Irrigation



Livestock farming



Fish farming & aquaculture



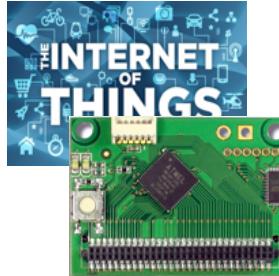
Storage & logistic



Agriculture



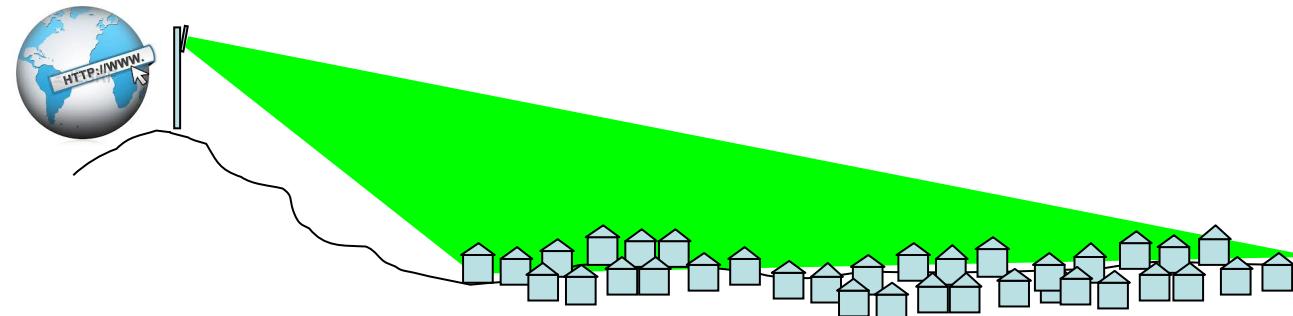
Fresh water



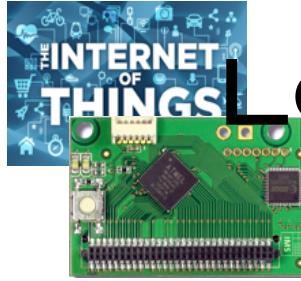
LONG-RANGE SENSING



Moisture/
Temperature of
storage areas



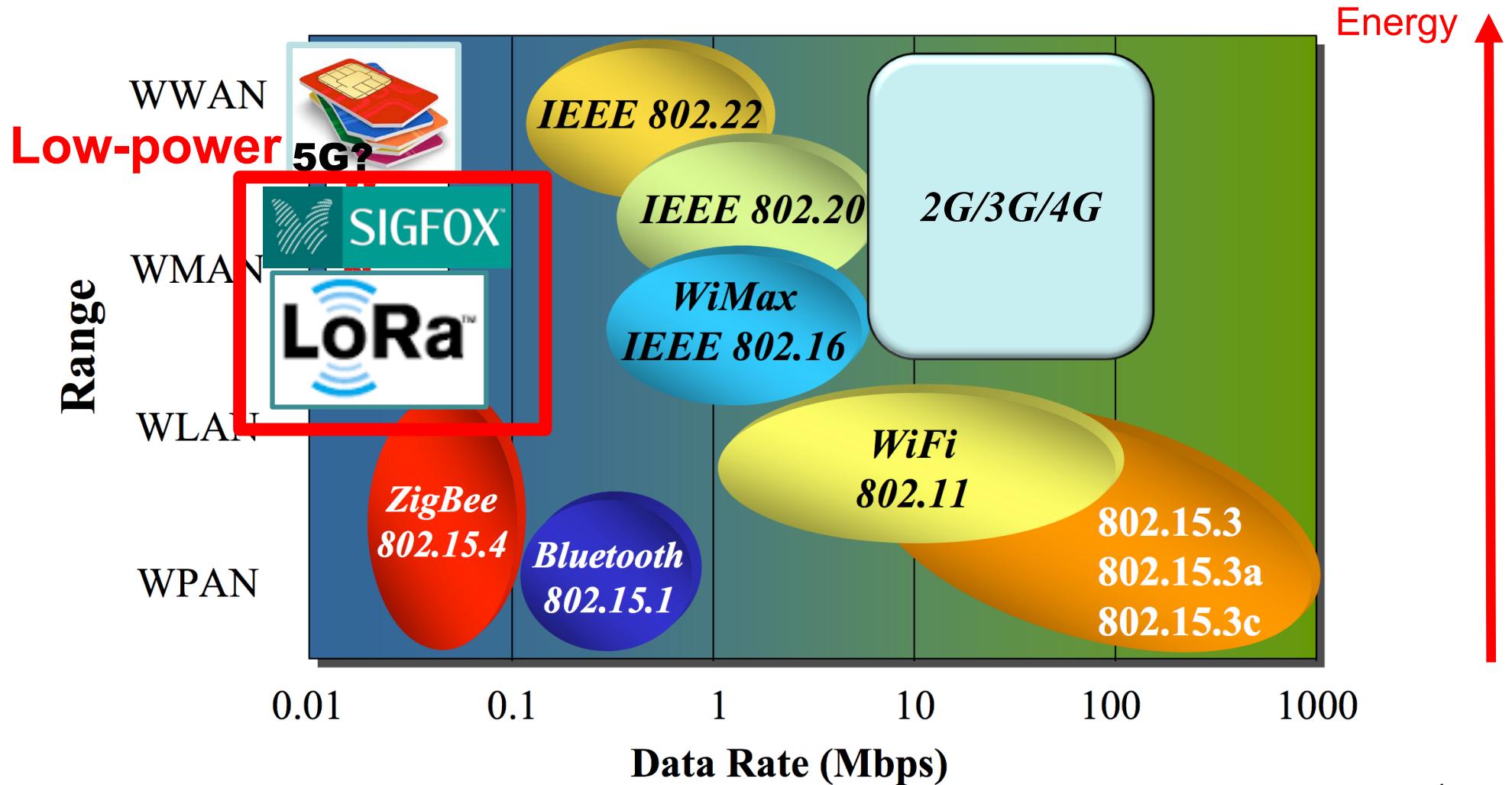
Technology	2G	3G	LAN
Range (I=Indoor, O=Outdoor)	N/A	N/A	O: 300m I: 30m
Tx current consumption	200-500mA	500-1000mA	100-300mA
Standby current	2.3mA	3.5mA	NC

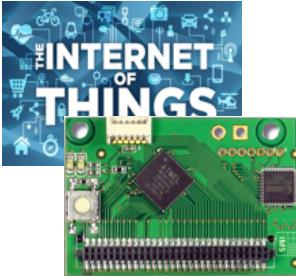


LOW-POWER & LONG-RANGE RADIO TECHNOLOGIES



Energy-Range dilemma





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	18mA
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 \$

Autonomy GSM with 2000mAh -



Autonomy LP WAN with 2000mAh -



Example for energy meter

1 year

5 years

10 years



MATURATION OF THE IoT MARKET...



Waste Container connected sensor





IOT BECOMES REALITY!



 SIGFOX
One network A billion dreams

NB-LTE

 LoRa™

 nwave

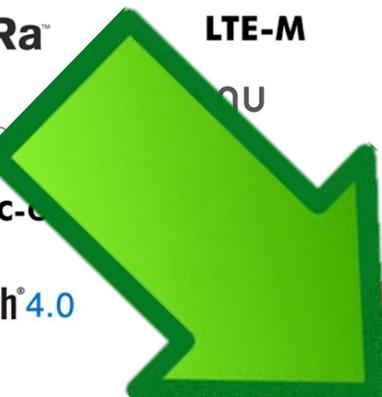
LTE-M

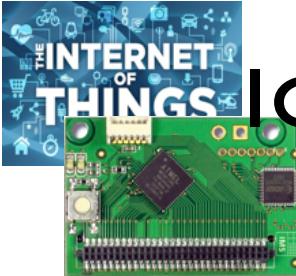
 WEIGHTLESS

EC-C

 DASH7™
ALLIANCE

 Bluetooth® 4.0

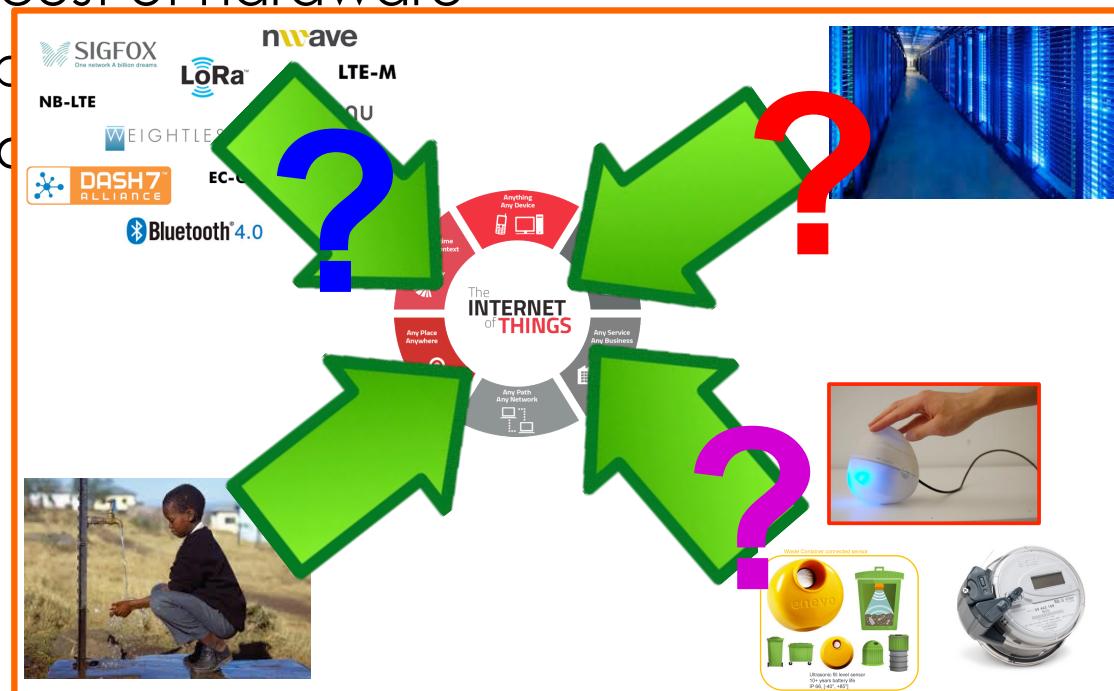




IoT IN DEVELOPING COUNTRIES OR RURAL AREAS?



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



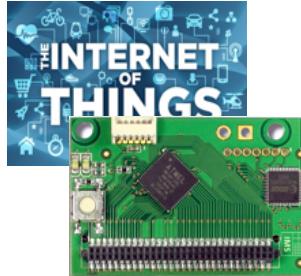
MATURATION OF THE IOT MARKET...



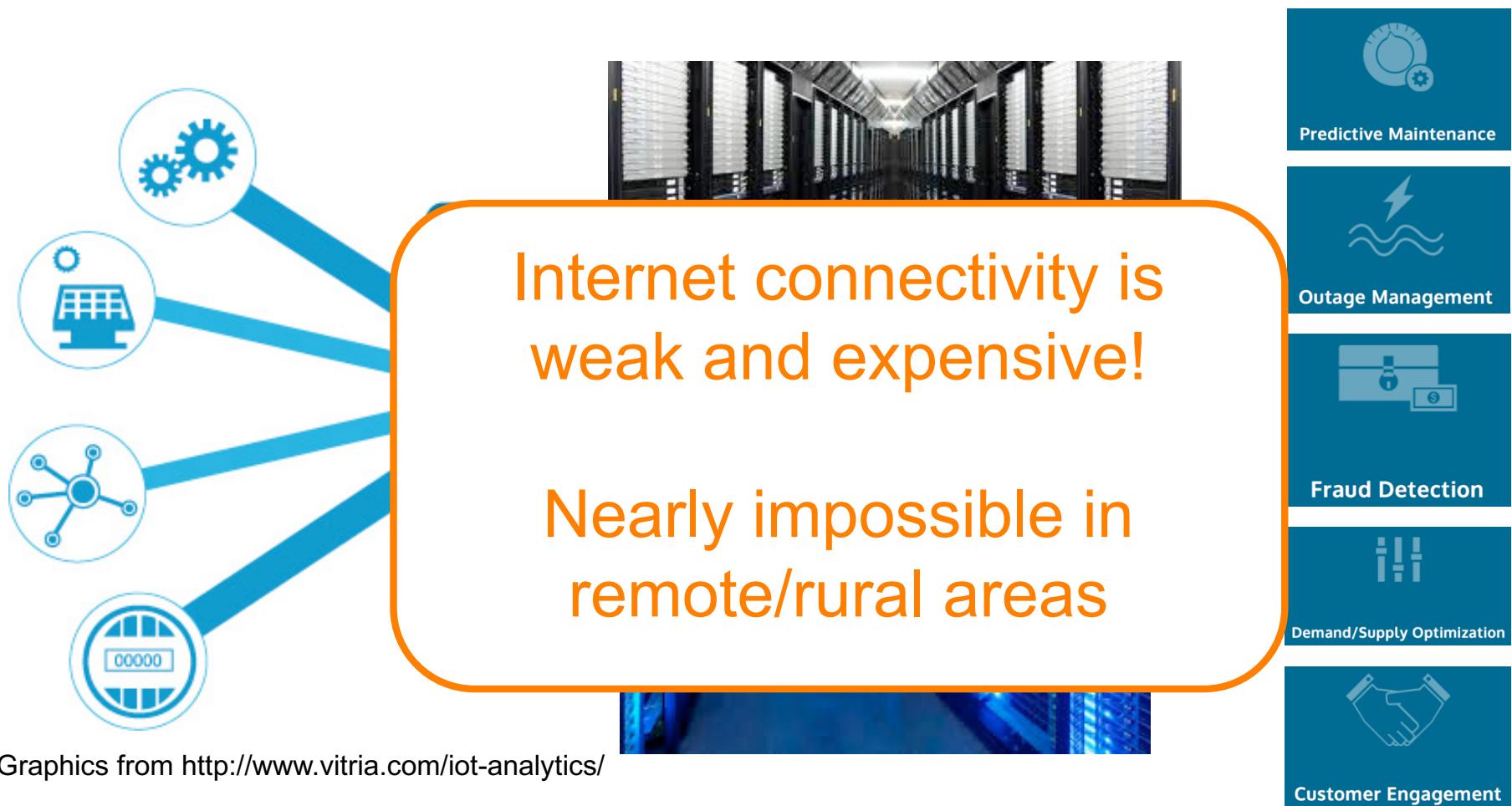
... but not adapted for rural developing countries context & environment

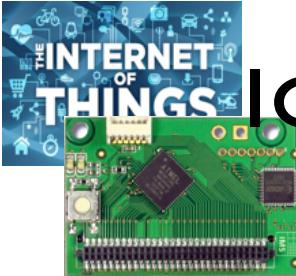
- Too expensive
- Too integrated
- Highly specialized
- Difficult to customize
- Difficult to upgrade





INTERNET, CLOUD & BIG DATA ANALYTICS

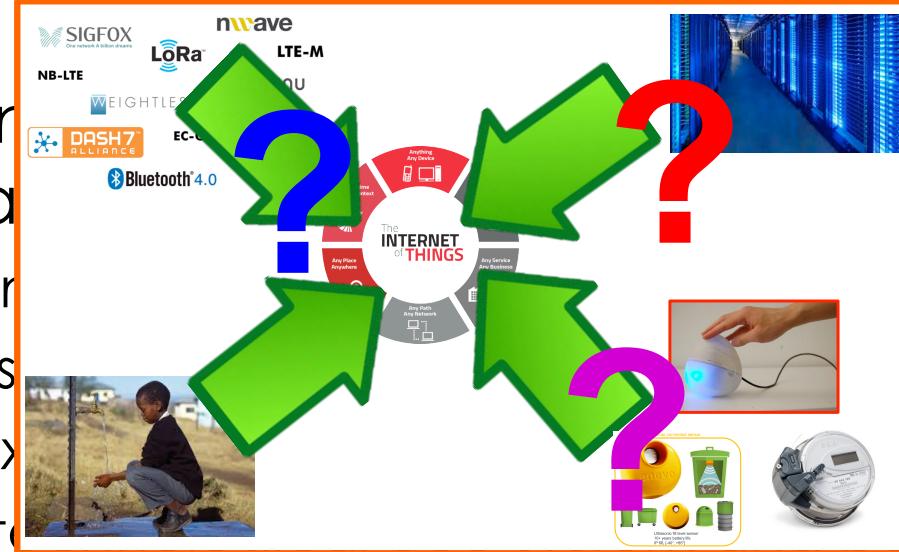




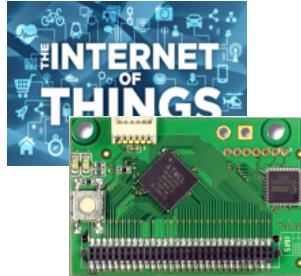
IoT IN DEVELOPING COUNTRIES AND RURAL AREAS



- ❑ Developing countries are still far from the benefit of IoT
 - ❑ being ready
 - ❑ lack of infrastructure
 - ❑ high costs
 - ❑ complex technologies
 - ❑ lack of technical background

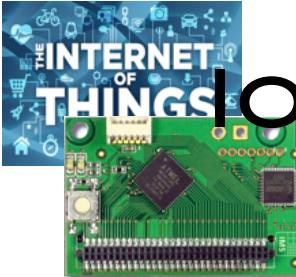


- ❑ **to deploy IoT in developing countries, it is necessary to target three major issues**
 - ❑ reduce cost of infrastructures, hardware and services
 - ❑ limit dependancy to proprietary infrastructures and provide local interaction models
 - ❑ target technology appropriation, push for local business models



WAZIUP: LOW-COST IoT

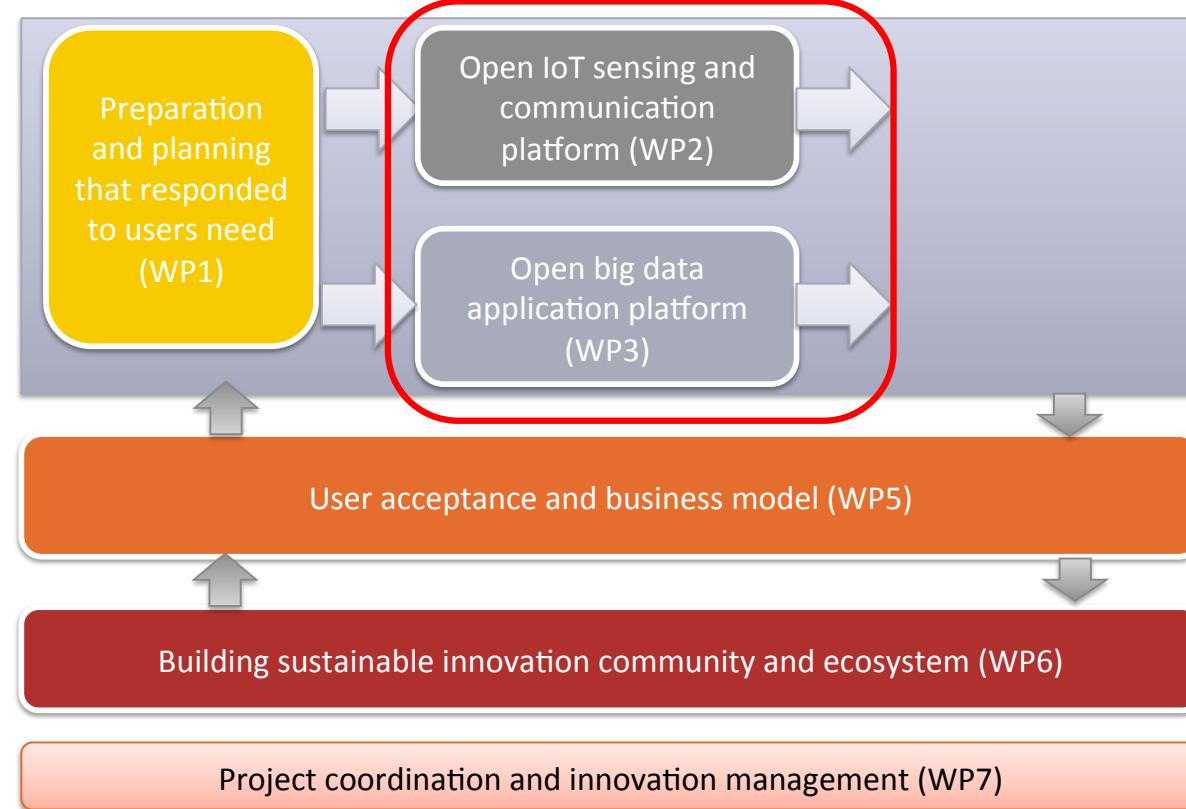
[ABOUT »](#)[TECHNOLOGIES »](#)[COMMUNITY](#)[NEWS & EVENT »](#)[DOWNLOADS](#)[DEV KIT](#)[FAQ](#)[CONTACT](#)

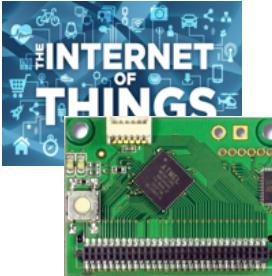


IoT FOR RURAL APPLICATIONS IN DEVELOPPING COUNTRIES



- ❑ 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 HARDWARE



WHAT IS ARDUINO?

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

ARDUINO BOARD

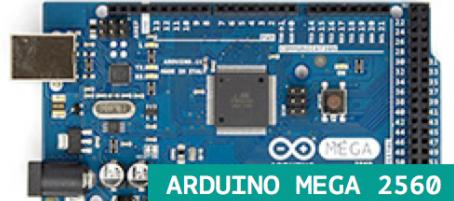
Arduino senses the environment by receiving inputs from many sensors, and affects its surroundings by controlling lights, motors, and other actuators.

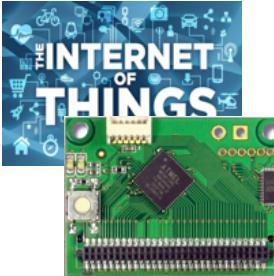


```
void setup() {  
}  
  
void loop() {  
}
```

ARDUINO SOFTWARE

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

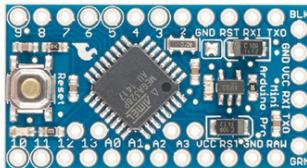




LARGE ECOSYSTEM, STILL GROWING!



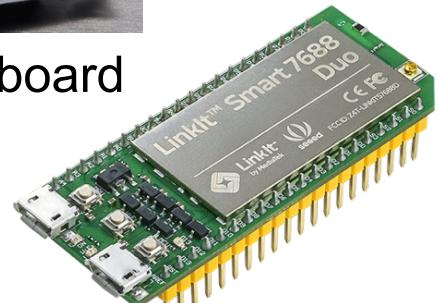
Arduino Pro Mini



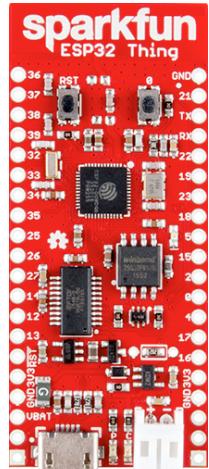
LoPy



Theairboard



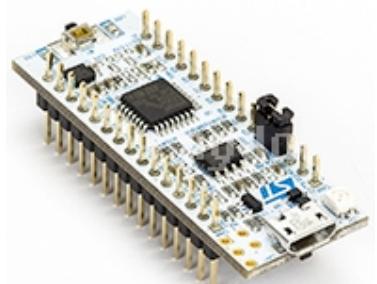
LinkIt
Smart7688 duo



Expressif ESP32



Teensy 3.2



STM32 Nucleo-32



Adafruit Feather



Sparkfun ESP32
Thing

Tessel

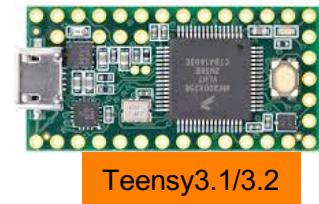
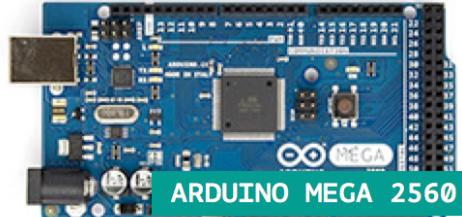


SodaqOnev2



Tinyduino

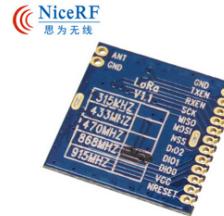
SW/HW BUILDING BLOCKS INTEGRATION



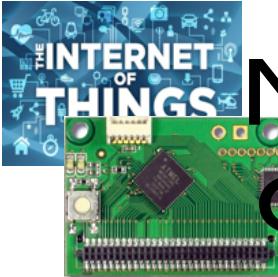
More to come...



LoRa radios that
our library already
supports



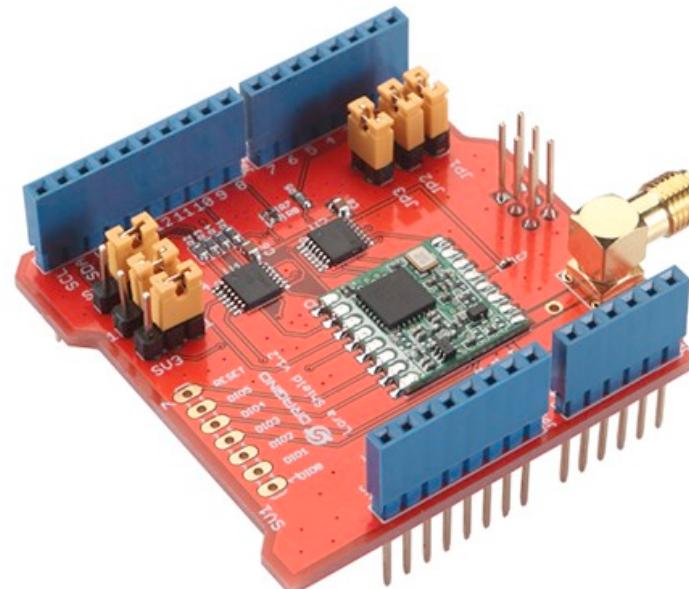
Long-Range communication library



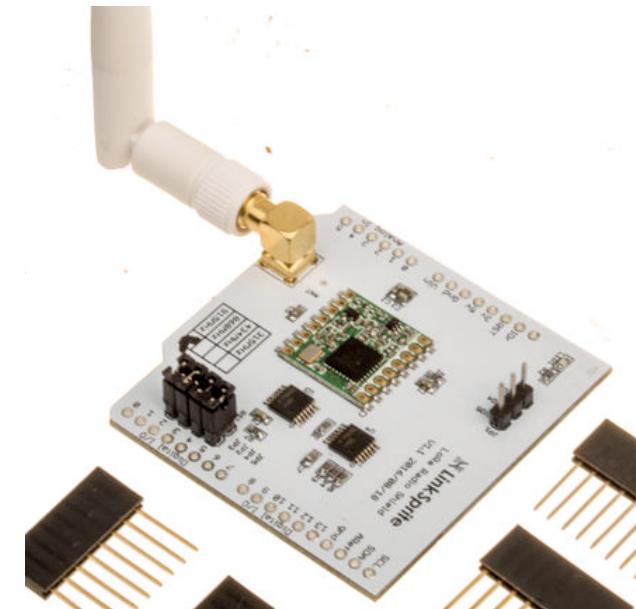
MORE AND MORE EASY-TO-CONNECT LoRA MODULES!



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



Dragino LoRa shield
for Arduino



LinkSprite LoRa shield
for Arduino



OPEN-SOURCE SOFTWARE



```
Arduino_LoRa_temp | Arduino 1.6.6
Arduino_LoRa_temp

/*
 * temperature sensor on analog 8 to test the LoRa gateway
 *
 * Copyright (C) 2015 Congduc Pham, University of Pau, France
 *
 * This program is free software: you can redistribute it and/or modify
 * it under the terms of the GNU General Public License as published by
 * the Free Software Foundation, either version 3 of the License, or
 * (at your option) any later version.
 *
 * This program is distributed in the hope that it will be useful,
 * but WITHOUT ANY WARRANTY; without even the implied warranty of
 * MERCHANTABILITY or FITNESS
 * GNU General Public License
 *
 * You should have received
 * along with the program.
 *
 *****
 */
// Include the SX1272
#include "SX1272.h"

// IMPORTANT
// please uncomment only 1 ch
// it seems that both HopeRF
// boards we set the initial
// comment if your radio is
#define RADIO_RFM92_95
// uncomment if your radio is
#define RADIO_INA198
// TINYSTICK
// AN OPEN PROJECT WRITTEN, DEBUGGED,
// AND SUPPORTED BY ARDUINO.CC AND
// THE ARDUINO COMMUNITY WORLDWIDE
// LEARN MORE ABOUT THE CONTRIBUTORS
// OF ARDUINO.CC ON arduino.cc/credits

11  Teensy 3.2 / 3.1, Serial, 72 MHz optimized, US English on /dev/cu.usbmodem1433801
```

CongducPham / LowCostLoRaGw

Watch 50 ⭐ Star 161 Fork 95

Code Issues 62 Pull requests 2 Projects 0 Pulse Graphs

Low-cost LoRa IoT & gateway with SX1272/76, Raspberry and Arduino

122 commits 1 branch 0 releases 2 contributors

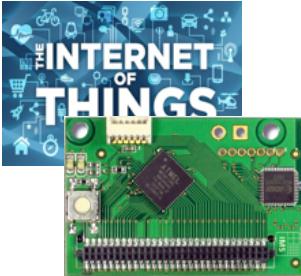
Branch: master New pull request Find file Clone or download

Congduc Pham bug fix in lora_gateway.cpp Latest commit a0daa4a a day ago

File	Commit Message	Date
Arduino	update SMS scripts	15 days ago
gw_full_latest	bug fix in lora_gateway.cpp	a day ago
tutorials	update SMS scripts	15 days ago
.gitignore	.DS_Store banished	10 months ago
README.md	update README	11 days ago

LowCostLoRaGw github has latest general distribution:
<https://github.com/CongducPham/LowCostLoRaGw>

WAZIUP-specific configuration can be found on
<https://github.com/Waziup/waziup-gateway>



LARGE VARIETY OF EXAMPLES



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_ucamll	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



READY-TO-USE TEMPLATES

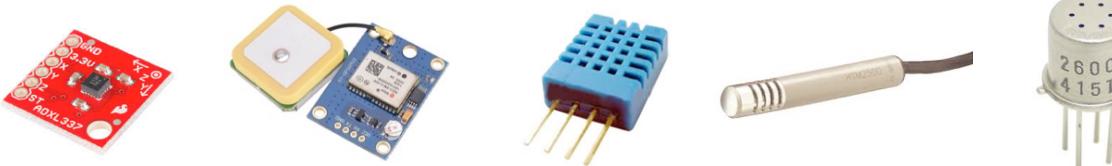


Physical sensor reading

Physical sensor reading

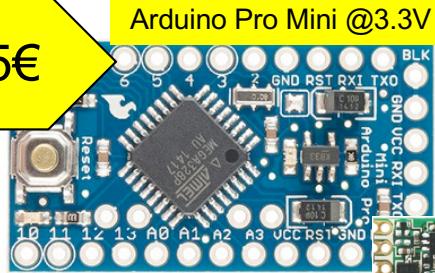


Physical sensor reading



Physical sensor mgmt

1.5€



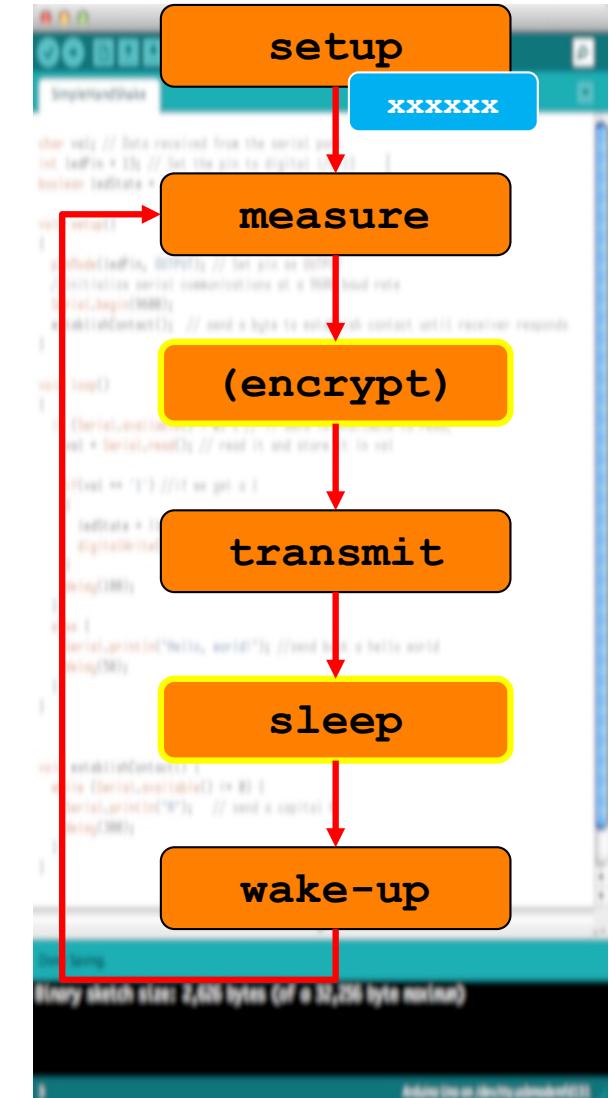
★ VERY ★
IMPORTANT

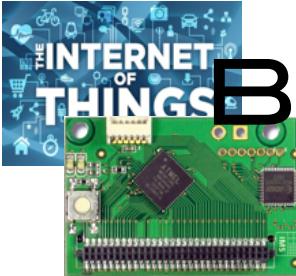
Activity duty-cycle,
low power

AES encryption

Long-range transmission

Logical sensor mgmt





BUILD YOUR FIRST LORA IOT DEVICE



The screenshot shows the Arduino IDE interface with the following details:

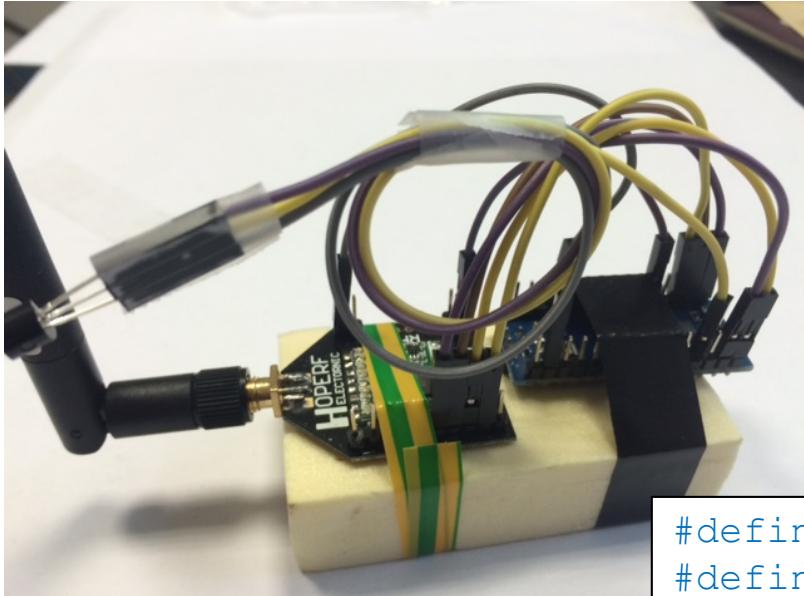
- Code Preview:** The code is titled "Arduino_LoRa_temp". It includes comments for the LM35 temperature sensor connected to analog pin 8 and the SX1272 LoRa module.
- Tools Menu:** The "Port" option is selected, showing available serial ports:
 - /dev/cu.Bluetooth-Modem
 - /dev/cu.Bluetooth-PDA-Sync
 - /dev/cu.usbmodem1427871**
- Hardware:** A physical Arduino Pro or Pro Mini is shown connected to a breadboard. The breadboard has several components and wires, including an LM35 temperature sensor, a breadboard power supply, and a LoRa module.
- Pinout Diagram:** An LM35DZ TO-92 pinout diagram is displayed, showing pins V_{CC}, GND, and Analog OUT (10mV=1°C).

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

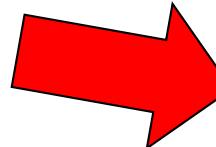




DEFAULT CONFIGURATION



\!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



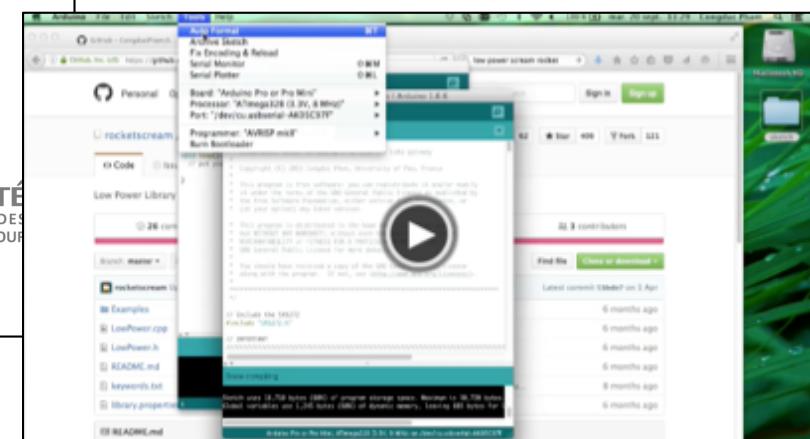
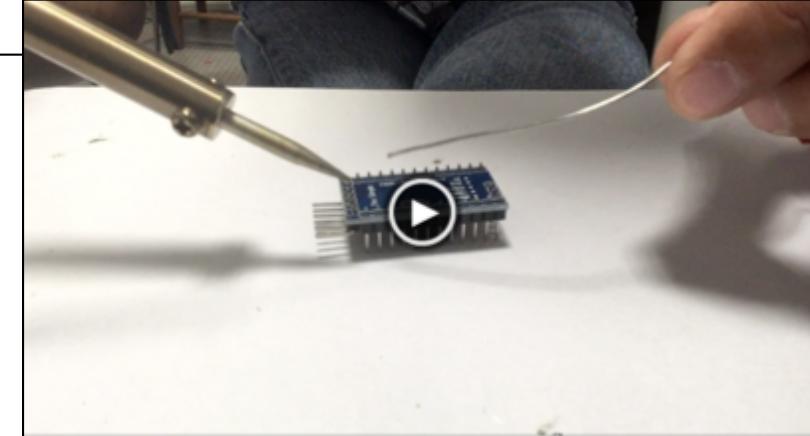
TUTORIALS AND VIDEOS



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



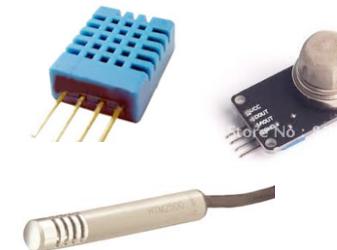
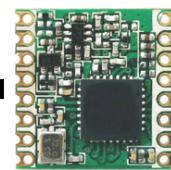
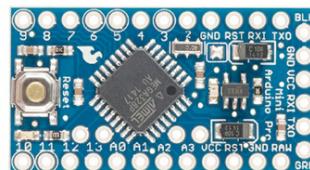
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UNIVERSITÉ DE PAU, FRANCE





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
- Meet the needs of the end users
- Technical and economic feasibility

Minimum Viable Product

Waziup
Advisory
Board

Waziup
Community

WAZIUP PROJECT



WP1
WP2
WP3
WP4
WP5
WP6

MVP 2
Cattle
Rustling



MVP 3
AGRI



MVP 4
Logistic
Transport

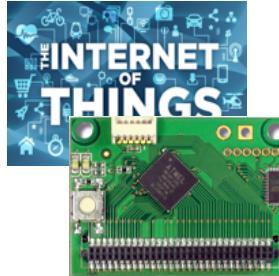


MVP 5
Urban
Waste
mgt

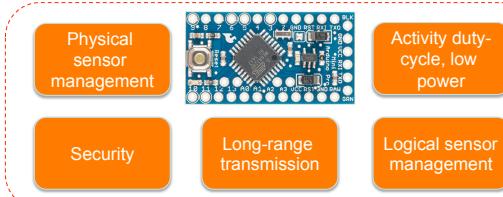
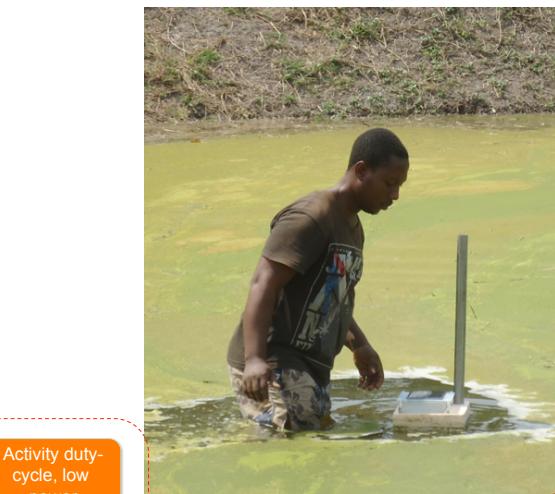


Credit: P. Cousin, EGM





LOW-COST BUOY FOR FISH FARMING MVP

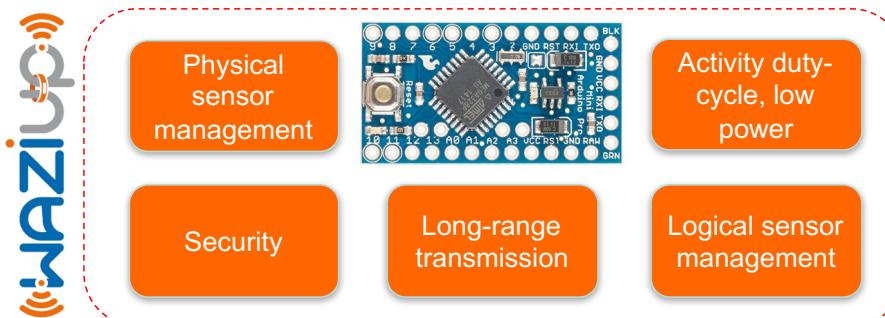
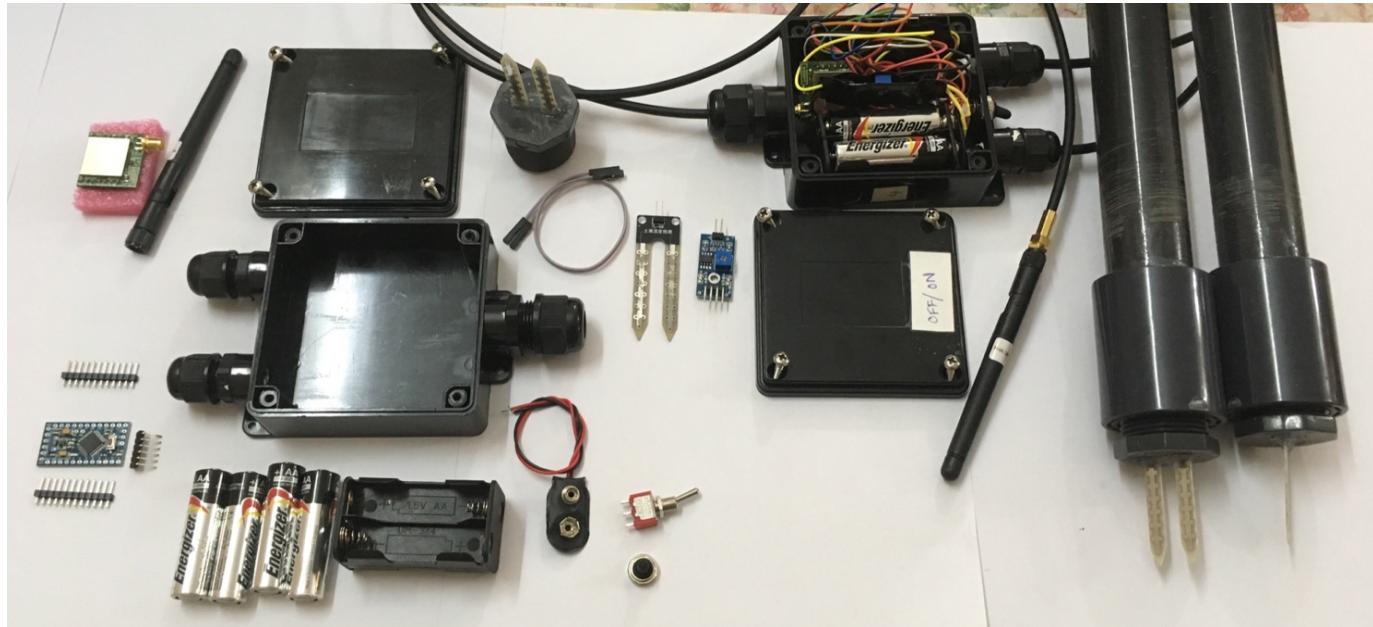


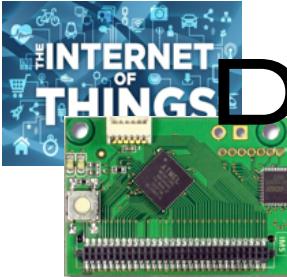
Credit: EGM





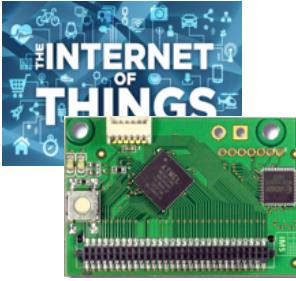
SOIL HUMIDITY SENSORS FOR AGRI MVP



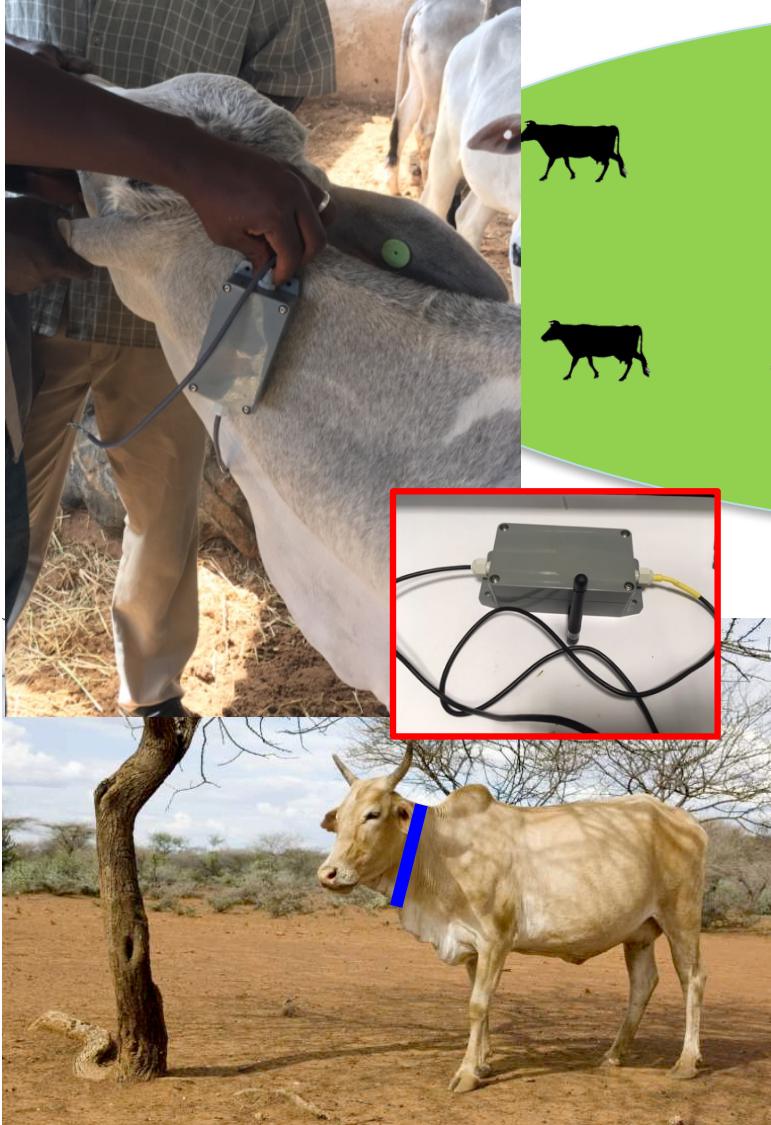


DEPLOYMENT FOR NESTLÉ'S WATERSENSE PROJECT





COLLAR FOR CATTLE RUSTLING MVP

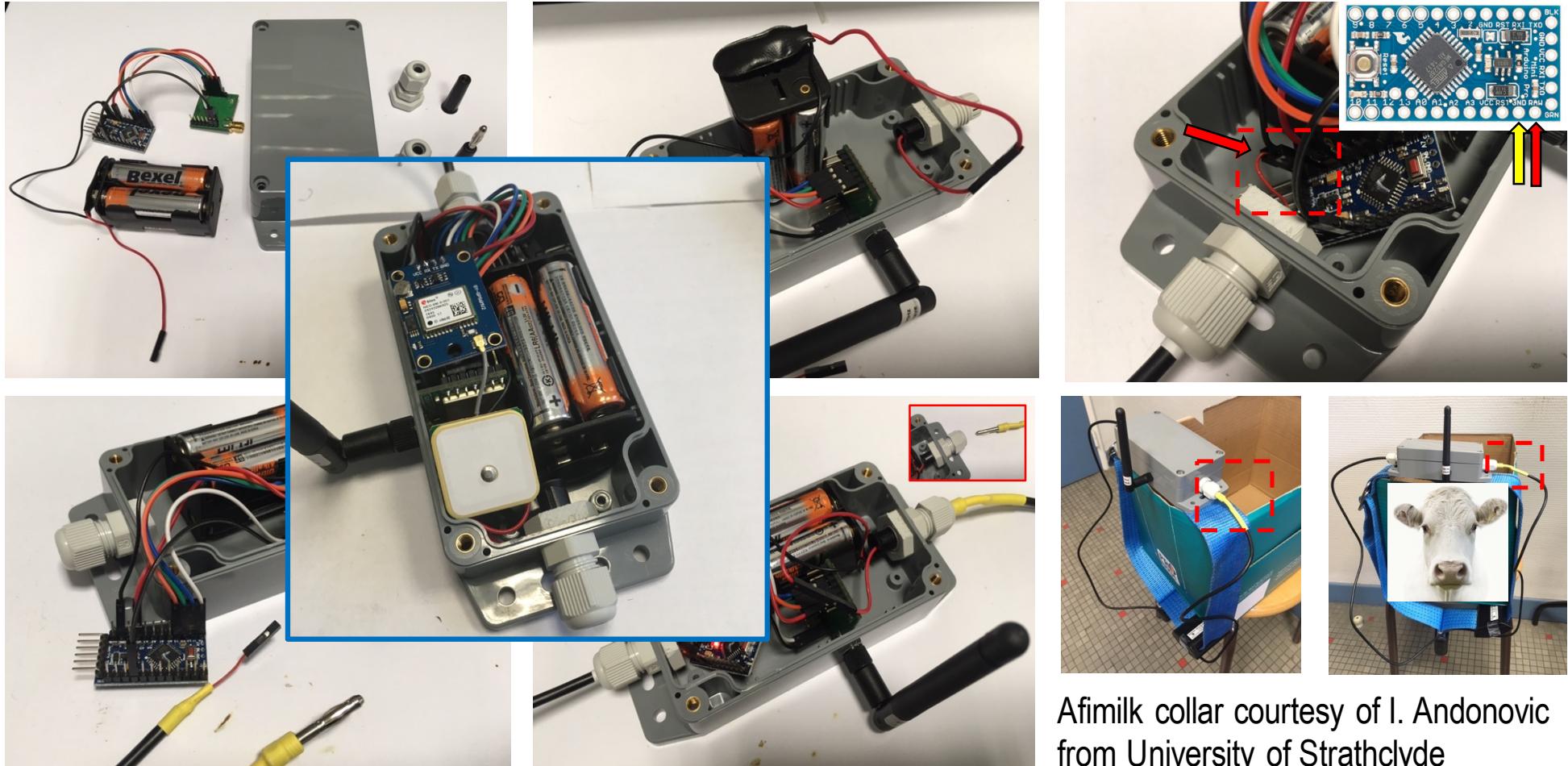


In Africa, the practice of animal husbandry has always been and still remain farmers' livelihood and incomes

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



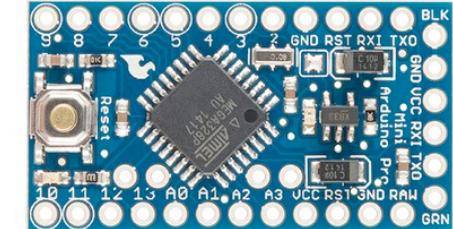
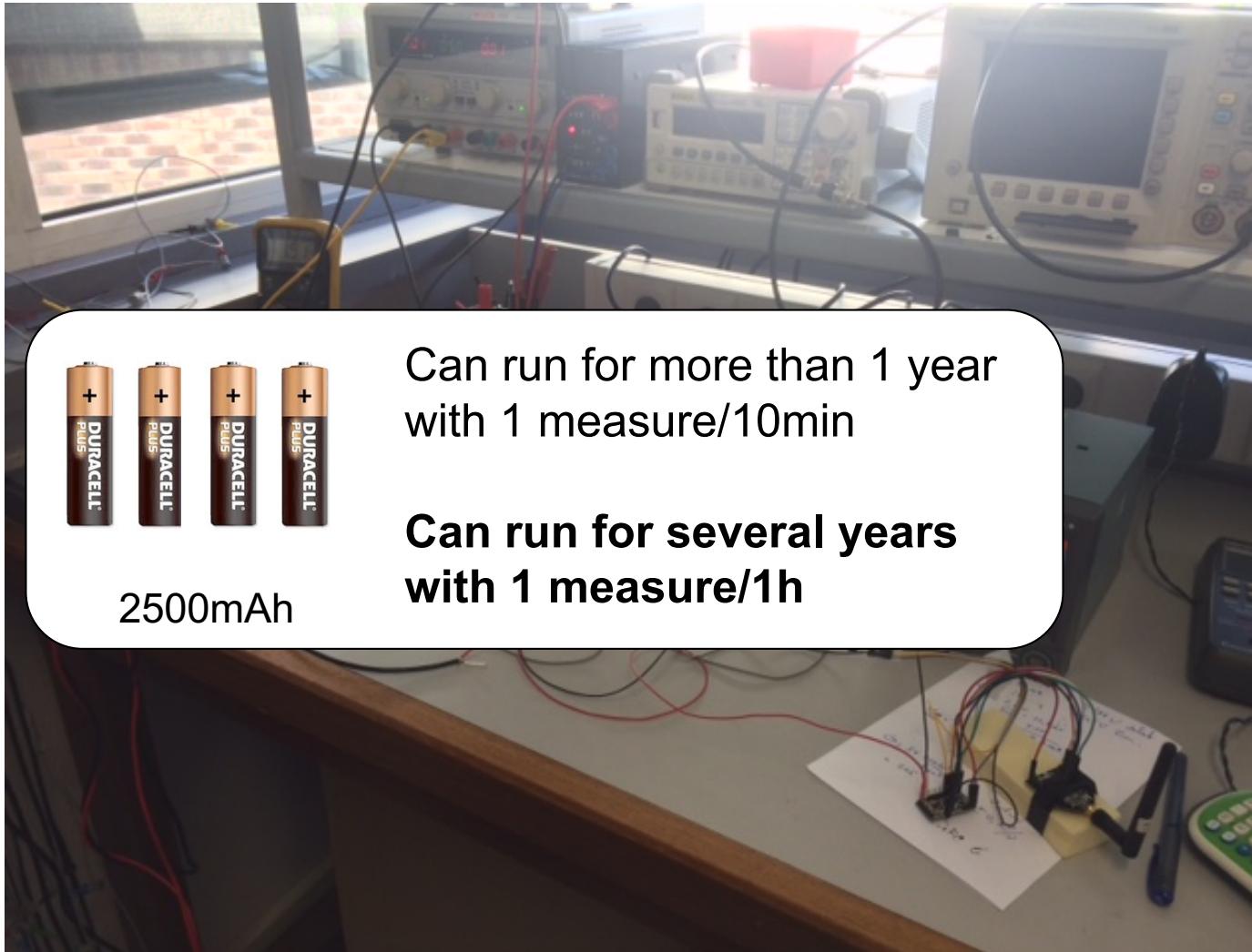
Afimilk collar courtesy of I. Andonovic
from University of Strathclyde



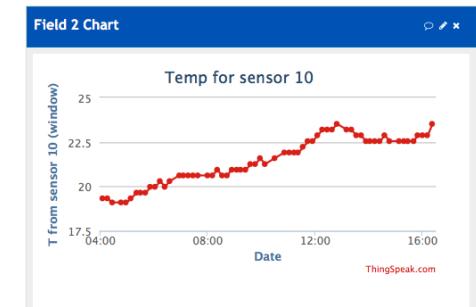
RUNNING FOR SEVERAL YEARS!



Low-Power library from RocketScream

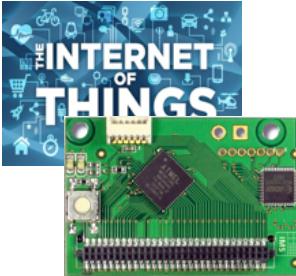


Wakes-up every
10min, take a
measure (temp) and
send to GW



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

Thanks to T. Mesplou and P. Plouraboué for their help



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>



SIMPLICITY!



More to come...



LoRa radios that our library already supports



Long-Range communication library



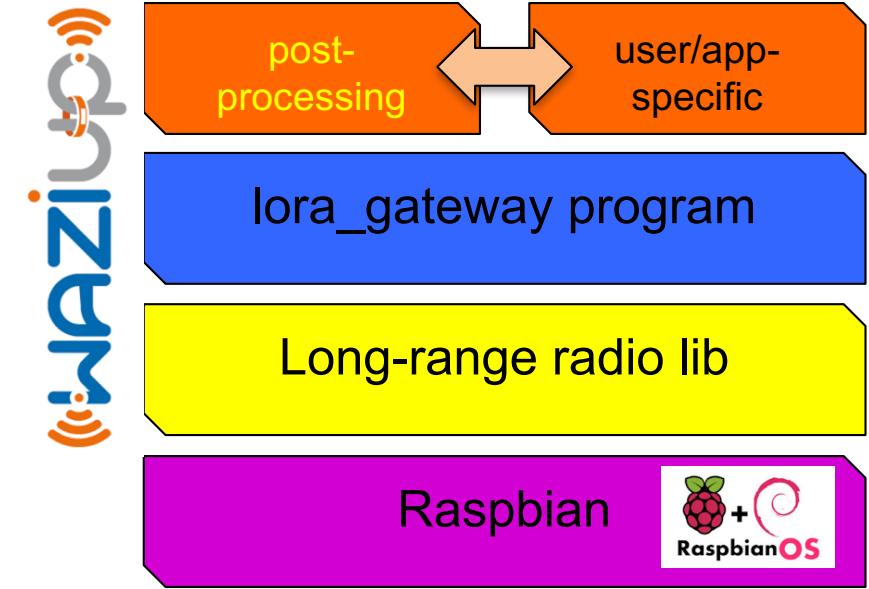
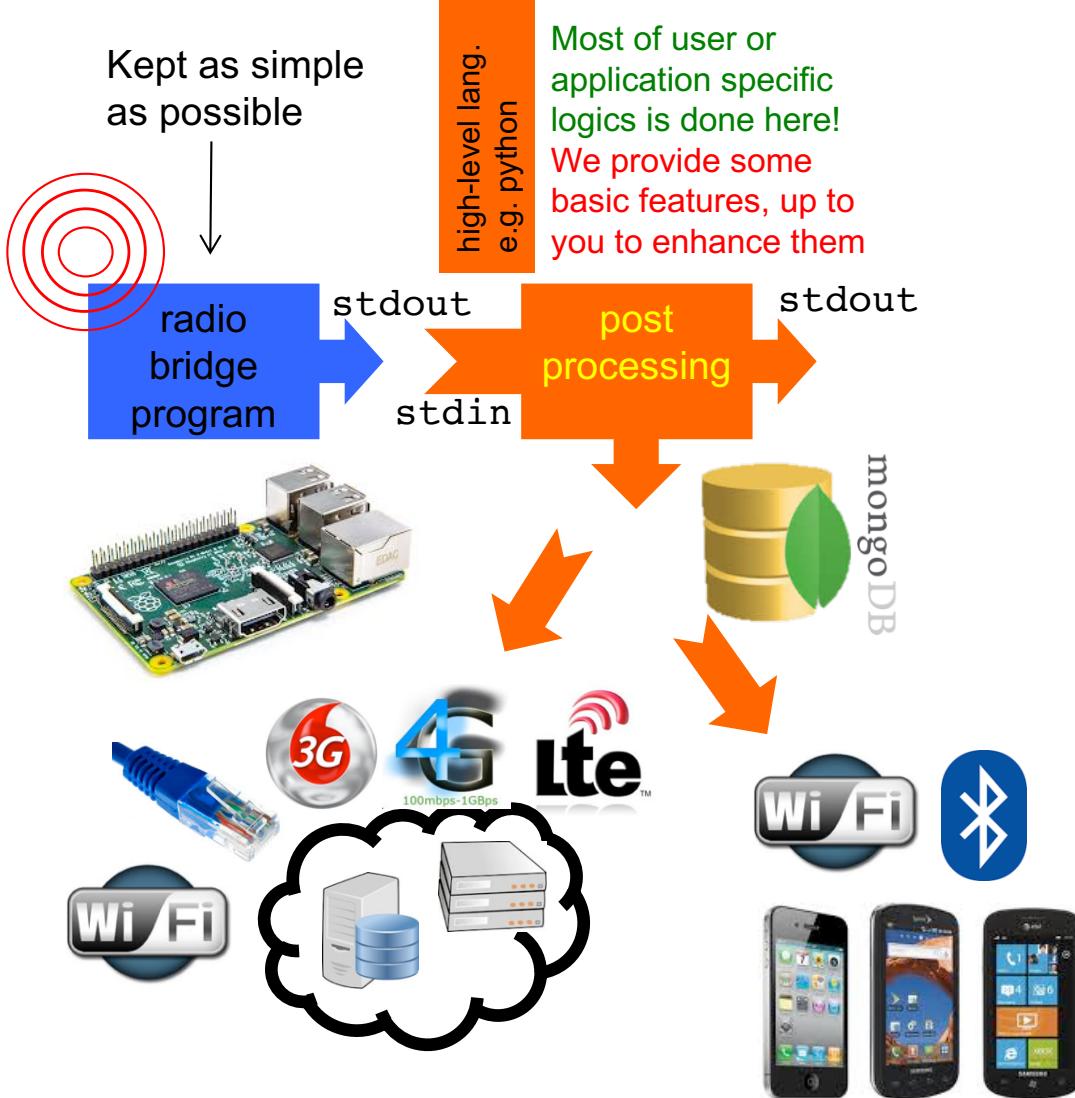
```
sendPacketTimeout("TC/18.5");
// sends to gateway
// TC : temperature celcius
// 18.5 : value
```

1 send function!

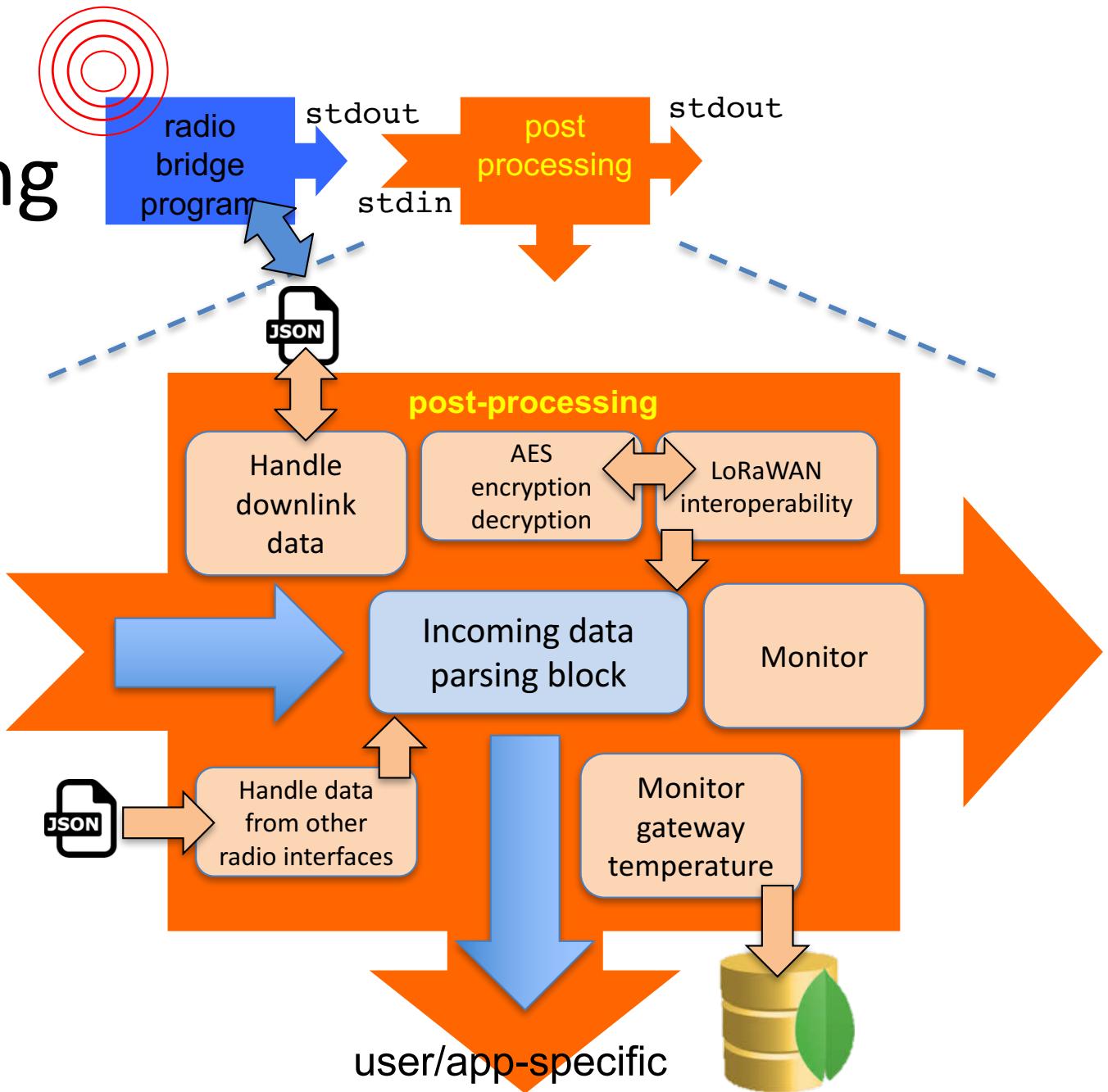




OUR LOW-COST GATEWAY ARCHITECTURE



Post-processing stage



cloud_script_1

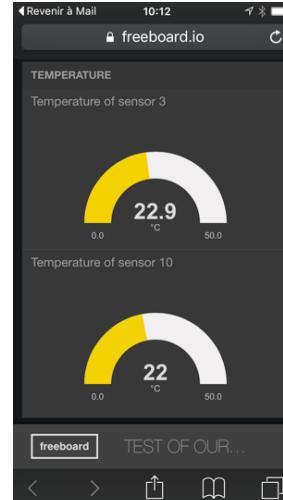
cloud_script_2



cloud_script_n



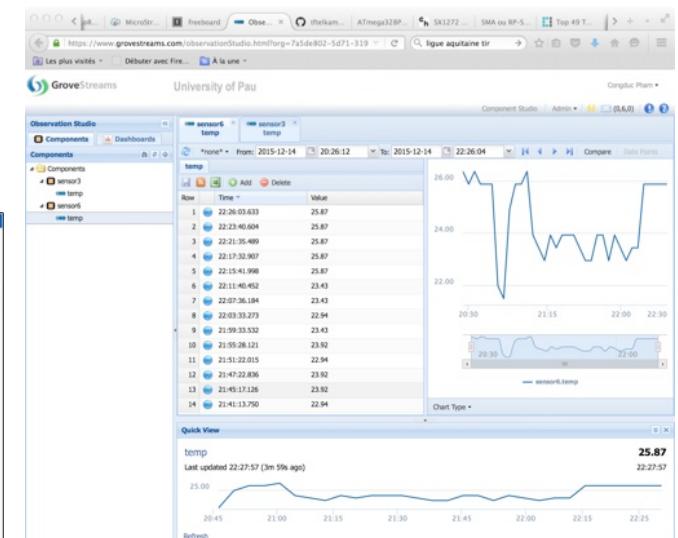
TEMPLATES FOR VARIOUS CLOUDS



Dropbox



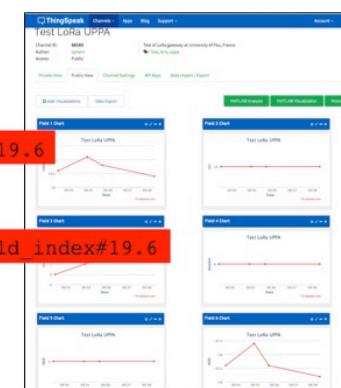
Firebase



ThingSpeak



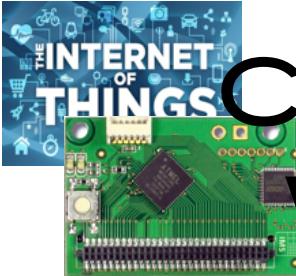
Node 10



 **SensorCloud™**

 **GroveStreams**





CONFIGURE YOUR GATEWAY WITH THE WEB INTERFACE



□ <http://192.168.200.1/admin>

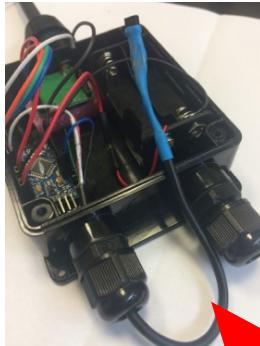
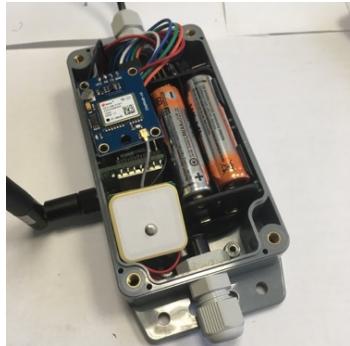
- Login: admin
- Password: loragateway

Gateway configuration

Mode	4	
Frequency	-1	



100% DO-IT-YOURSELF !



Step-by-step tutorial
and source code
available



Step-by-step tutorial
and source code
available



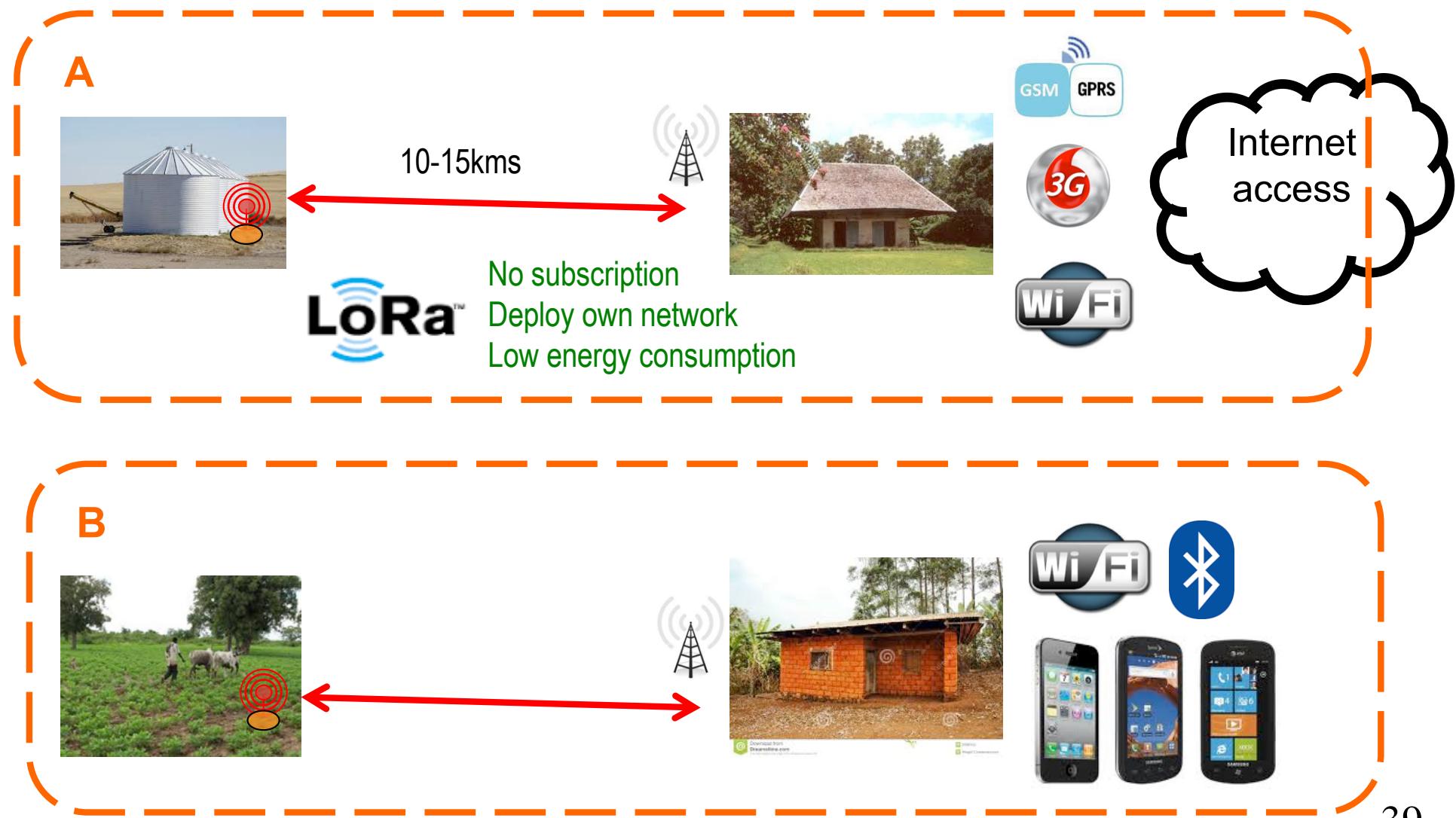
Python scripts
available



<https://github.com/CongducPham/LowCostLoRaGw>

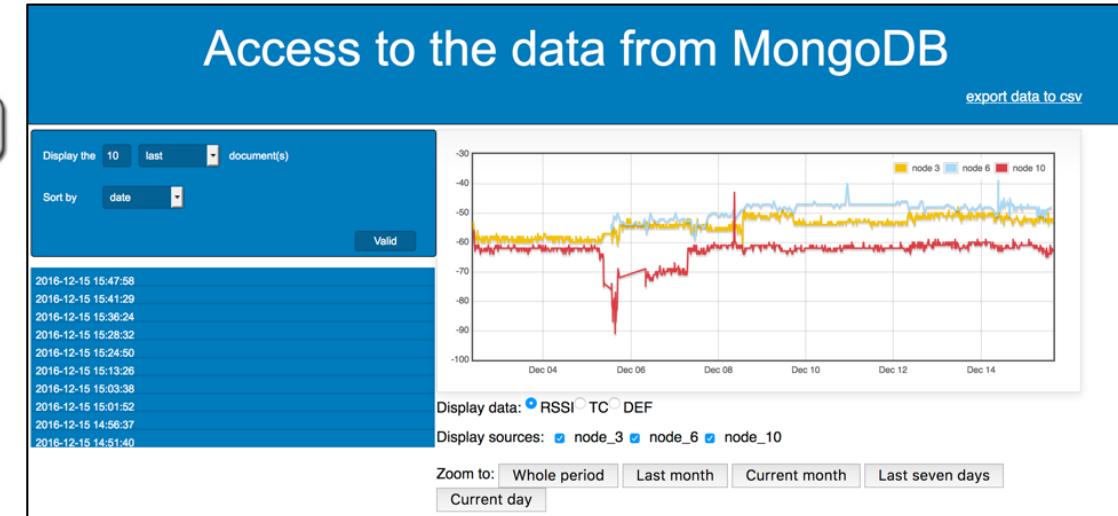
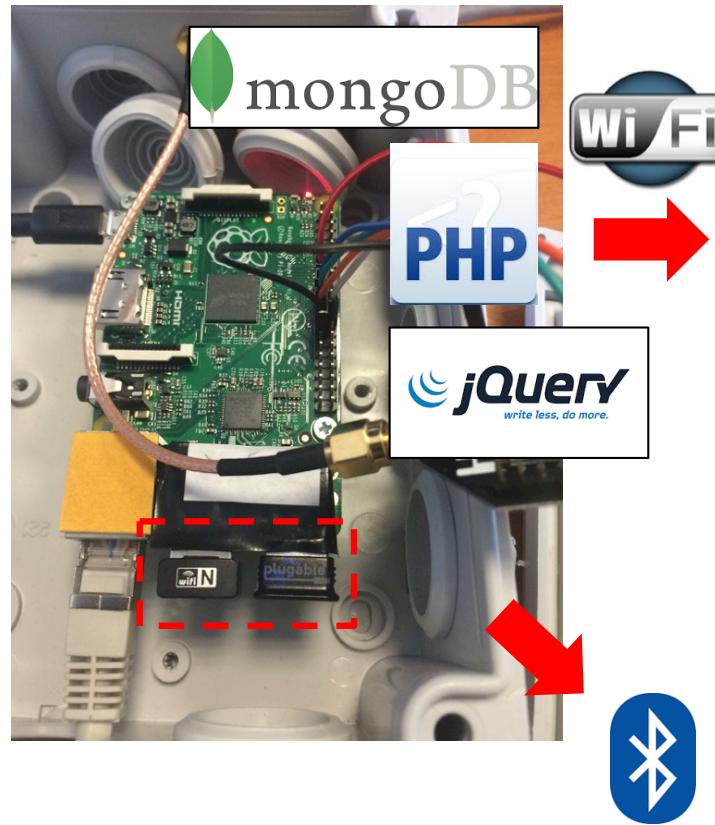


WORKING WITHOUT INTERNET ACCESS





STANDALONE GATEWAY



Orange F * 10:34

Bluetooth_raspi

NODE: 1 DATE: 2016-05-09 08:04:59.807000 DATA: {"lw": 3.29, "th": 22.6, "hu": 50.7}

NODE: 1 DATE: 2016-05-09 08:28:52.993000 DATA: {"lw": 3.29, "th": 22.89, "hu": 50.29}

NODE: 1 DATE: 2016-05-09 08:53:04.317000 DATA: {"lw": 3.29, "th": 23.2, "hu": 50.79}

NODE: 1 DATE: 2016-05-09 09:05:00.997000 DATA: {"lw": 3.29, "th": 23.29, "hu": 51.29}

NODE: 1 DATE: 2016-05-09 09:17:24.482000 DATA: {"lw": 3.29, "th": 23.39, "hu": 51.7}

NODE: 1 DATE: 2016-05-09 09:41:27.437000 DATA: {"lw": 3.29, "th": 23.6, "hu": 52.0}

NODE: 1 DATE: 2016-05-09 10:05:39.032000 DATA: {"lw": 3.29, "th": 23.79, "hu": 51.5}

NODE: 1 DATE: 2016-05-09 10:17:45.186000 DATA: {"lw": 3.29, "th": 23.79, "hu": 50.79}

NODE: 1 DATE: 2016-05-09 10:29:24.285000 DATA: {"lw": 3.29, "th": 23.79, "hu": 50.79}

NODE: 1 DATE: 2016-05-09 10:53:09.347000 DATA: {"lw": 3.29, "th": 23.59, "hu": 51.9}

NODE: 1 DATE: 2016-05-09 11:17:02.953000 DATA: {"lw": 3.29, "th": 23.5, "hu": 50.29}

NODE: 1 DATE: 2016-05-09 11:52:53.334000 DATA: {"lw": 3.29, "th": 23.29, "hu": 50.7}

NODE: 1 DATE: 2016-05-09 12:04:32.437000 DATA: {"lw": 3.29, "th": 23.5, "hu": 50.29}

NODE: 1 DATE: 2016-05-09 12:16:56.116000 DATA: {"lw": 3.29, "th": 23.6, "hu": 50.29}

Display data Retrieve data in a csv file

Orange F * 10:37

Bluetooth_raspi

NODES PREFERENCES

1 check to retrieve its data

8 check to retrieve its data

DATES PREFERENCES

Pick a begin date Retrieve data since 09-05-2016

Pick an end date Retrieve data until 17-05-2016

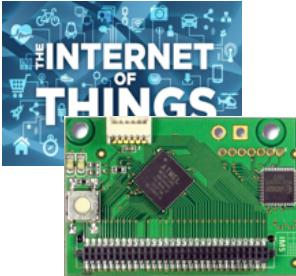
Display data Retrieve data in a csv file

Orange F * 10:39

Bluetooth_raspi

Creating csv file with the data received... File 17-05-2016_10h39m36s.csv created and saved in the folder /storage/emulated/0/Raspberry_local_data

Display data Retrieve data in a csv file



Now,

IoT BECOMES REALITY!



NB-LTE



nwave

LTE-M

EC-C

DU

time context

anywhere

any device

any place

anywhere

any service

any business

any path

any network

The
INTERNET
of THINGS



Dropbox

Firebase

Axeda

ThingSpeak

SensorCloud™

openRan

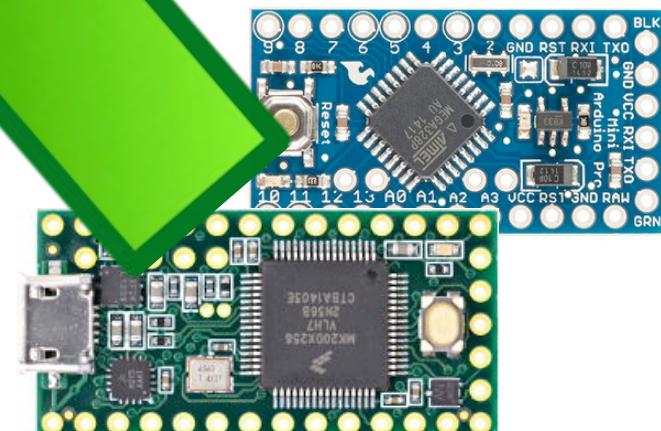
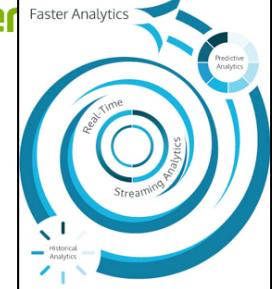
FIWARE

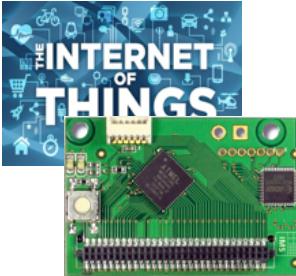
ioBridge®

Connect things.

GroveStreams

freeboard





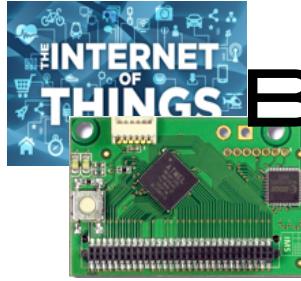
INVOLVING INNOVATION HUBS/STAKEHOLDERS



- **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 personally & 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)

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



IoTWeek2016 (Belgrade, EGM)



IoTBIGDATA2016
(Italy, EGM)



IoTCareConference (Budapest, CNET)

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



Credit: C. Vavasseur, CTIC Dakar

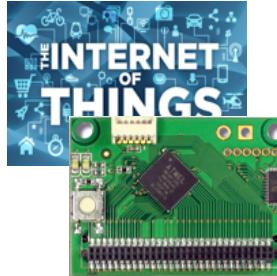


RESSACS 2016



Workshop at the RESSACS 2016 (France, UPPA) 43





TUTORIALS/RESOURCES



WAZIUP
EU H2020 grant agreement number 647107

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 and technologies, where 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/glossary/internet-of-things/
"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 exchange data over a network without requiring human-to-human or human-to-computer interaction."
From http://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT

2) **What is WAZIUP?**
The EU H2020 WAZIUP project, namely the Open Innovation Platform for IoT-Big Data in Sub-Saharan Africa, is a consortium of researchers and partners from 10 countries in Sub-Saharan Africa and Europe. The main goal is to improve the working conditions in the rural ecosystem of Sub-Saharan Africa. First, WAZIUP operates by involving farmers and technicians in the design of IoT solutions for their specific needs in the rural ecosystem. Second, while tackling challenges which are specific to the rural ecosystem, it also engages the flourishing ICT ecosystem in those countries by fostering new tools and technologies to support the development of the rural economy and the ICT sector. WAZIUP proposes solutions aiming at long term sustainability.

WAZIUP will deliver a communication and big data application platform and generate knowledge by training by use case and examples. The use cases will help to create an open source and fully open access platform oriented to radically new paradigms for innovative applications/services delivery. WAZIUP is driven by the need to support the rural economy.

1. Empower the African Rural Economy: Develop new technological enablers to empower the African rural economy now threatened by the concurrent action of rapid urbanization and of climate change. WAZIUP can support farmers and technicians to access new services and infrastructures to launch agriculture and breeding on a new scale;

Author: Congduc Pham, University of Pau, France
Last update : 07.09.2016
page : 1

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



PROF. CONGDUCK PHAM
[HTTP://WWW.UNIV-PAU.FR/-CPHAM](http://WWW.UNIV-PAU.FR/-CPHAM)
UNIVERSITÉ DE PAU ET DES PAYS DE L'ADOUR



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



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

LOW-COST LoRA IoT DEVICE: SUPPORTED PHYSICAL SENSORS



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



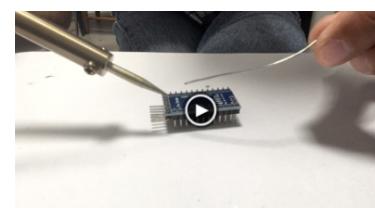
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LOW-COST LoRA IoT: USING THE WAZIUP DEMO KIT



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Thanks.
Let's keep in touch



Carine VAVASSEUR

Communication & Event Manager

Carine.vavasseur@cticdakar.com

www.cticdakar.com
contact@cticdakar.com



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github.com/waziup