

LOW-COST, LONG-RANGE OPEN IOT FOR SMARTER RURAL AFRICAN VILLAGES



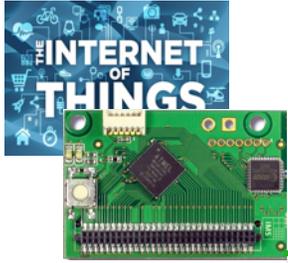
IEEE INTERNATIONAL SMART CITIES
CONFERENCE (ISC2'2016)

SEPTEMBER 14TH, 2016
TRENTO, ITALY



PROF. CONGDUC PHAM
[HTTP://WWW.UNIV-PAU.FR/~CPHAM](http://www.univ-pau.fr/~cpham)
UNIVERSITÉ DE PAU, FRANCE





IoT DOMAIN IN AFRICA



Irrigation & Agriculture



Livestock farming



Fish farming & aquaculture



Storage & logistic



Health



Water quality



IoT IN SUB-SAHARAN AFRICA

- ❑ Africa's countries are still far from being ready to enjoy the smallest benefit of IoT
 - ❑ lack of infrastructure
 - ❑ high cost of hardware
 - ❑ complexity in deployment
 - ❑ lack of technological eco-system and background
- ❑ to deploy IoT in Sub-Saharan Africa, it is necessary to target three major issues
 - ❑ longer range for rural access
 - ❑ cost of hardware and services
 - ❑ limit dependancy to proprietary infrastructures and provide local interaction models



RURAL SENSING

Moisture/
Temperature
of storage
areas

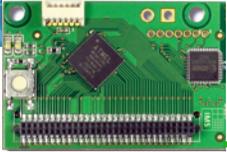


10-15kms

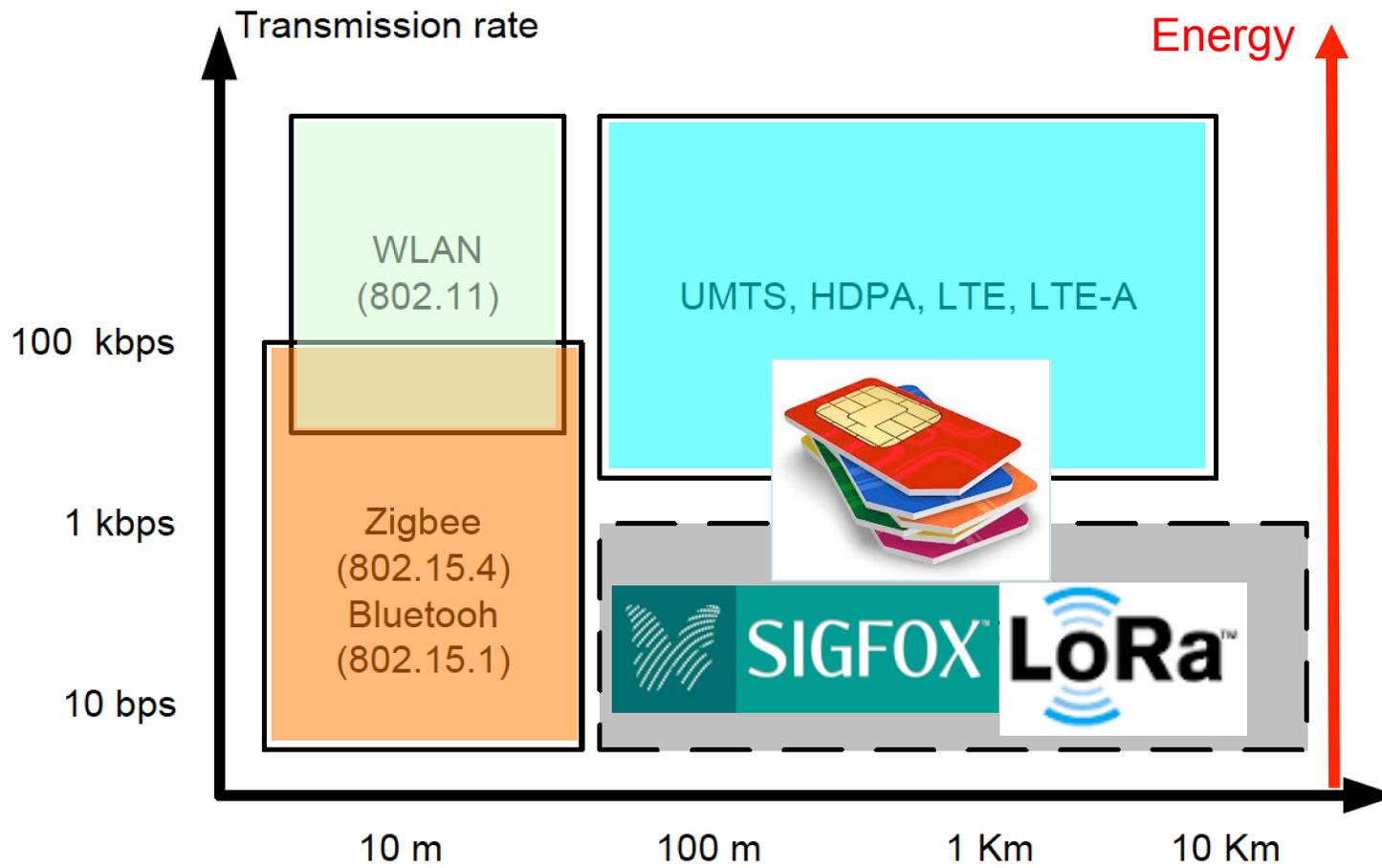


Pay subscription
Limitation of coverage
High energy consumption

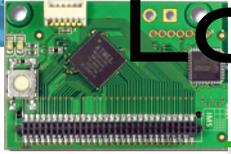
Technology	2G	3G	LAN
Range (I=Indoor, O=Outdoor)	N/A	N/A	O: 300m I: 30m
Tx current consumption	200-500mA	500-1000mA	100-300mA
Standby current	2.3mA	3.5mA	NC



LOW-POWER AND LONG-RANGE?



Enhanced from M. Dohler "M2M in SmartCities"



LOW POWER WAN (LPWAN) ?

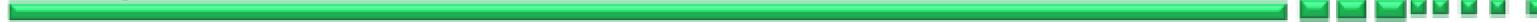
Tables from Semtech

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



LONG-RANGE RURAL SENSING

Moisture/
Temperature
of storage
areas

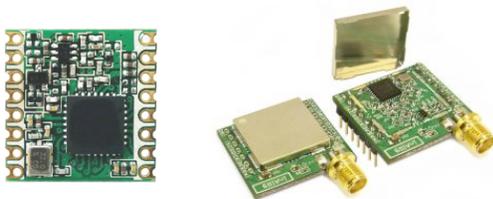


10-15kms



No subscription
Deploy own network
Low energy consumption

Add LoRa radio module
to your preferred dev
platform



Install a LoRa gateway
and start collecting data

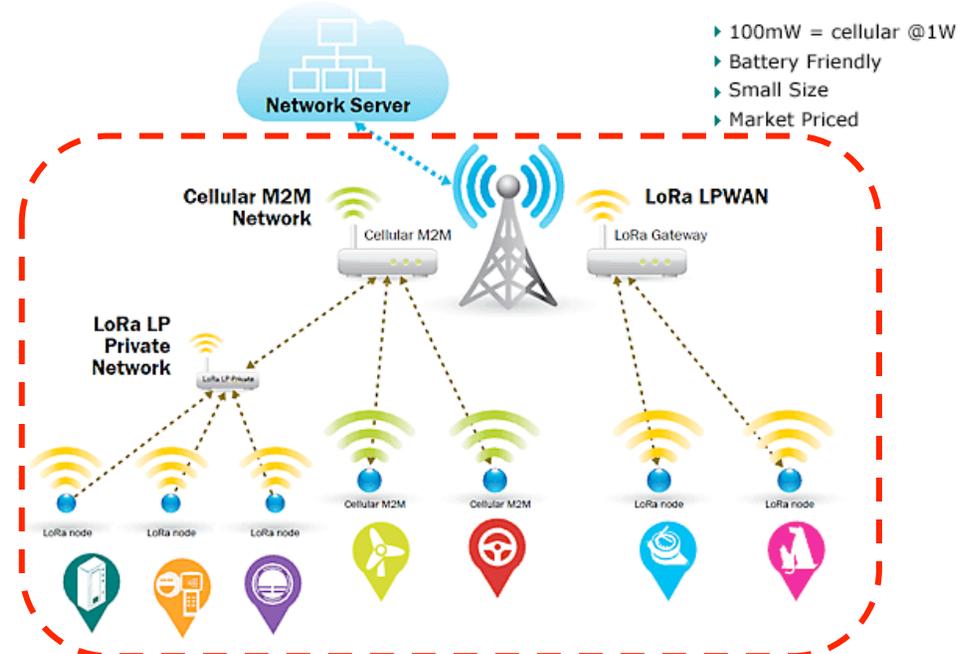
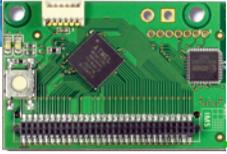


Figure from Semtech



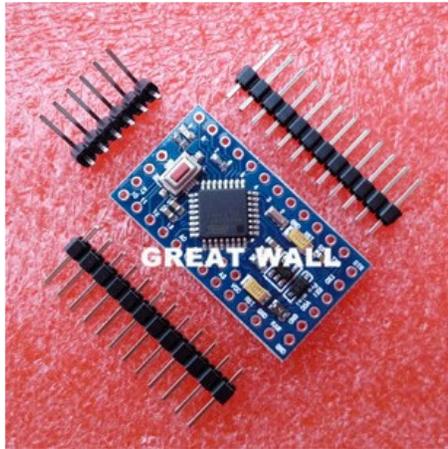
MATURATION OF THE IOT MARKET...





... BUT NOT ADAPTED FOR RURAL AFRICA CONTEXT

- ❑ Too expensive, too integrated, not flexible
- ❑ Do-It-Yourself approach with off-the-shelves components more adapted



Avec la bootloader 1 pcs Pro Mini ATMEGA328 Pro Mini 328 Mini ATMEGA328 3.3 V / 8 MHz pour Arduino

[View original title in English](#)

★★★★★ 4.9 (417 Votes) | 434 Commandes

Prix : **€ 1,49** / Kit

 Trouvez plus de deals sur l'App

Livraison : **€ 0,29 vers France via China Post Ordinary Small Packet Plus**

Livraison : 15-34 jours (envoyé en 7 jours ouvrables)

Quantité : Kit (55350 Kits available)

Montant total : **€ 1,78**

[Acheter maintenant](#) [Ajouter au panier](#)



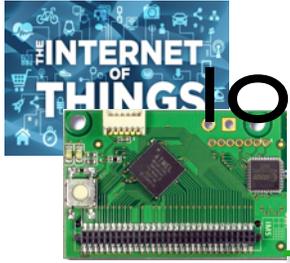
The Airboard on kickstarter



Tinyduino

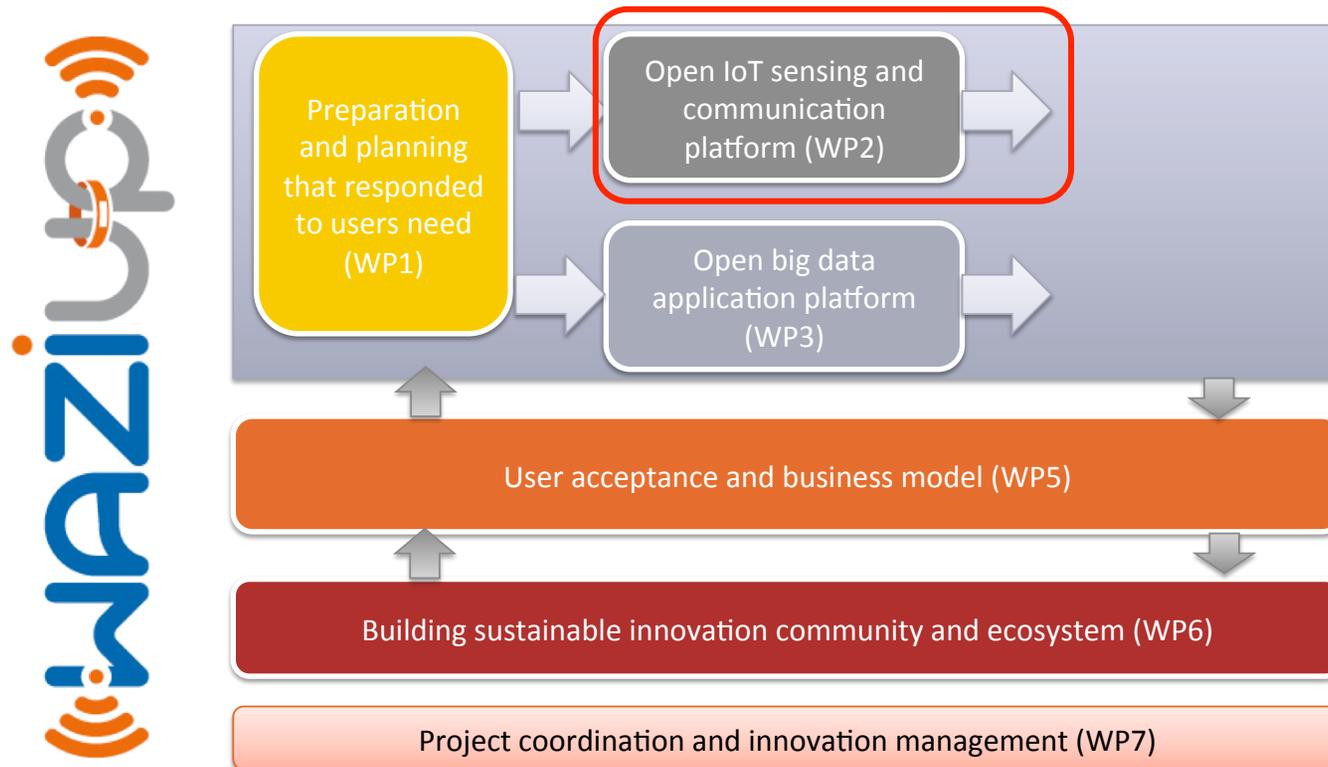


SODAq autonomo



IoT FOR RURAL APPLICATIONS IN DEVELOPPING COUNTRIES

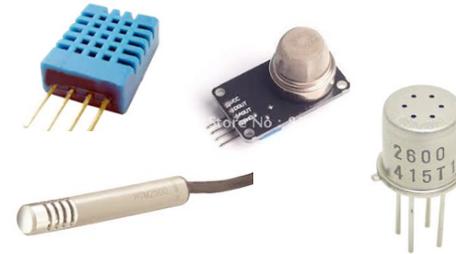
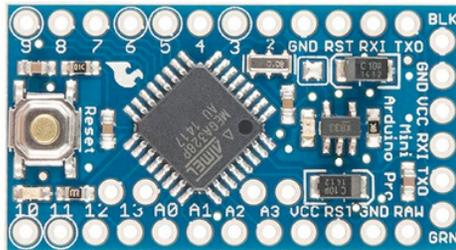
- ❑ WAZIUP is an EU H2020 project (2016-2019)
- ❑ contributes to long-range networks for rural applications with WP2

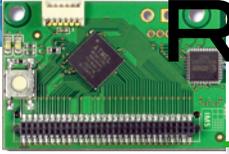




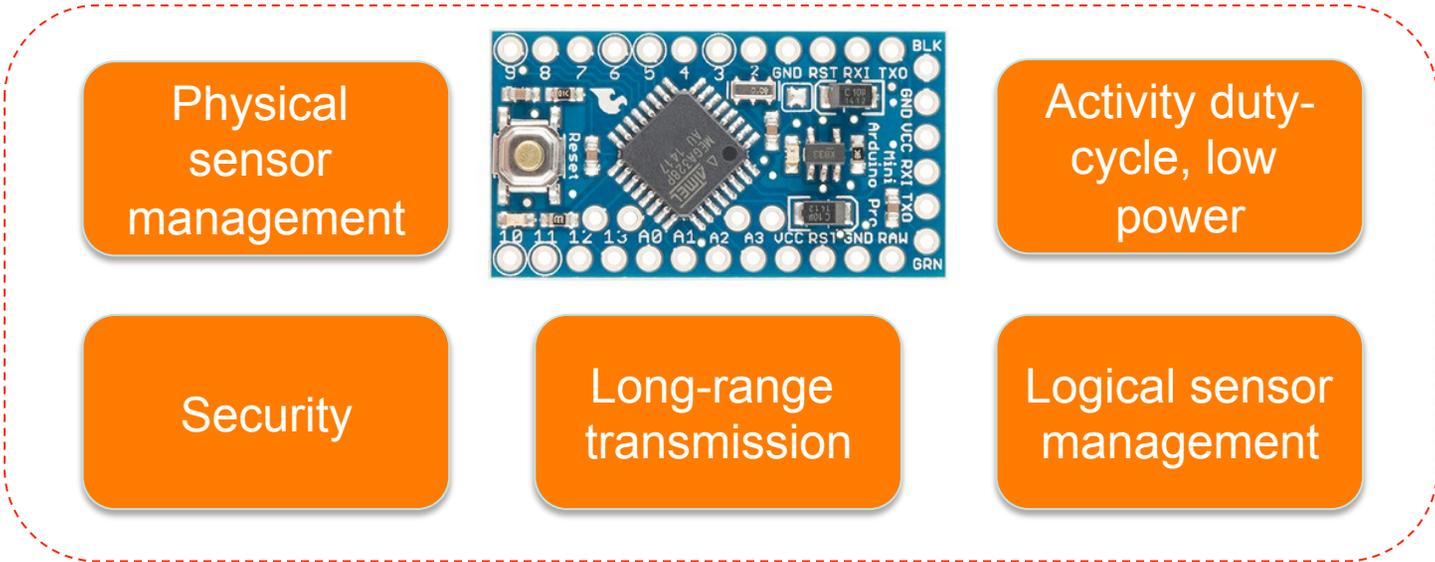
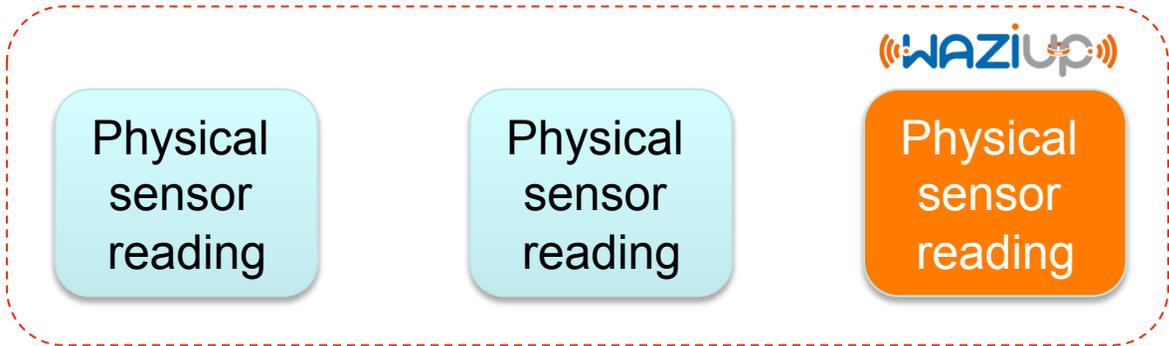
GENERIC SENSING IOT DEVICE

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





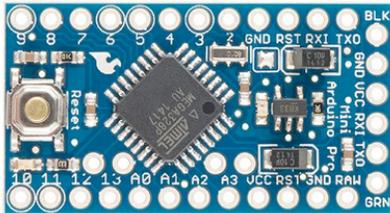
READY-TO-USE TEMPLATES



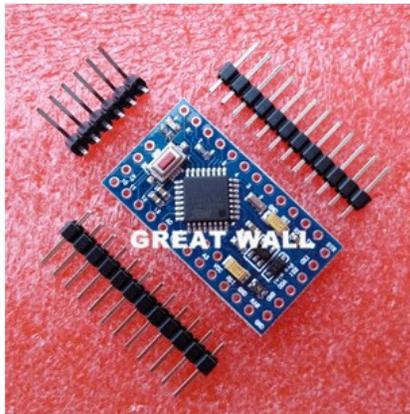
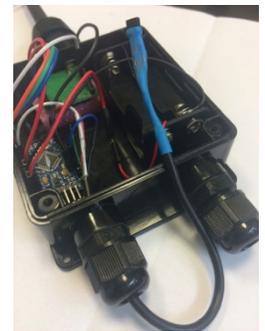
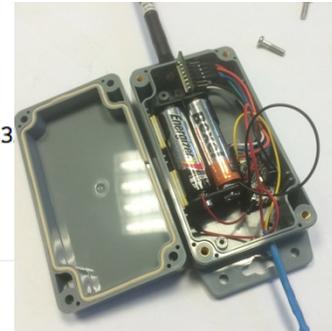
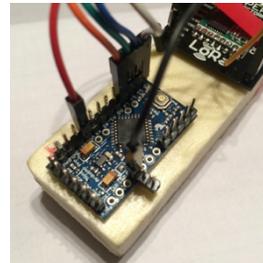
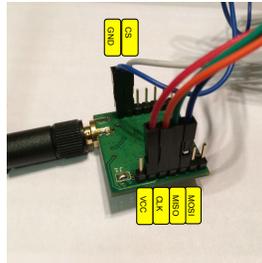
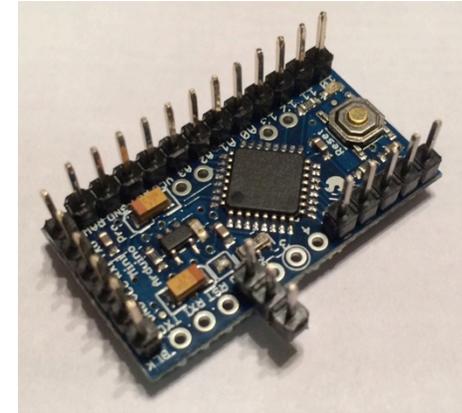
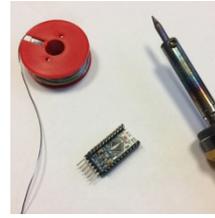
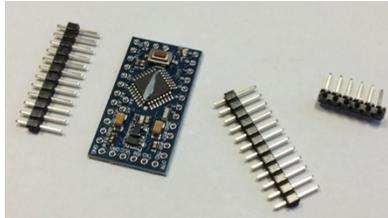


EASY INTEGRATION AND CUSTOMIZATION

Arduino Pro Mini



3.3v and 8MHz version



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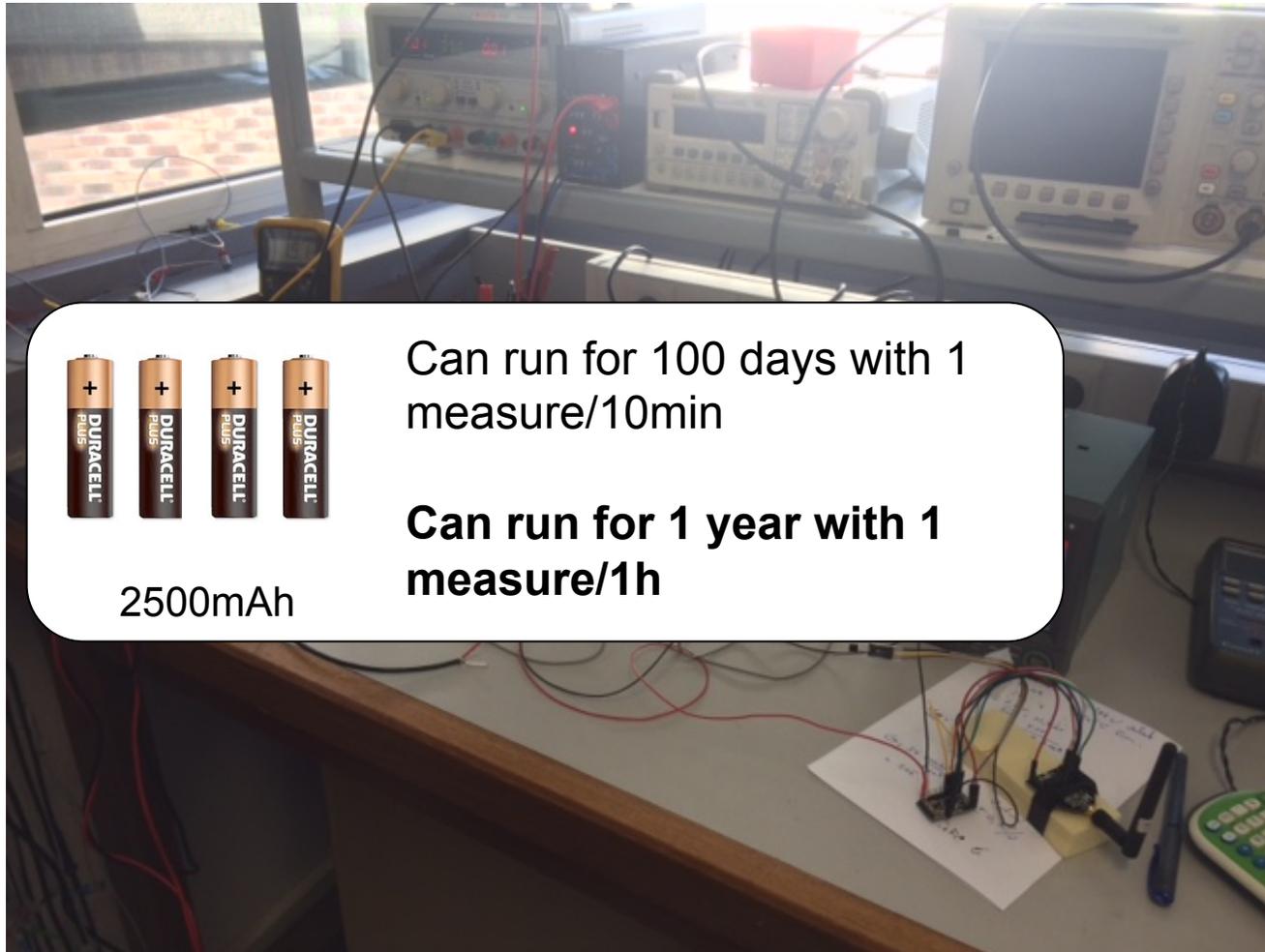
Ajouter au panier





RUNNING FOR 1 YEAR WITH LOW-POWER MODE!

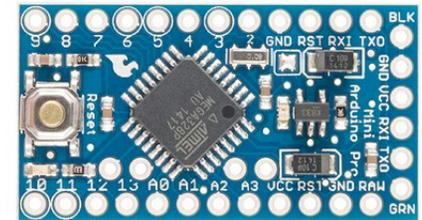
Low-Power library from RocketScream



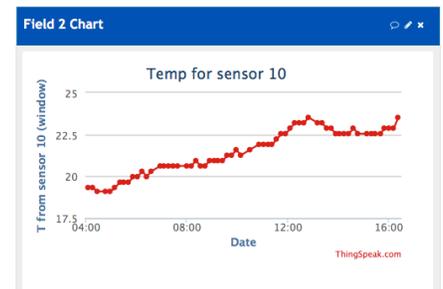
2500mAh

Can run for 100 days with 1 measure/10min

Can run for 1 year with 1 measure/1h



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



146µA in deep sleep mode, 93mA when active and sending

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



LORA GATEWAYS (NON EXHAUSTIVE LIST)



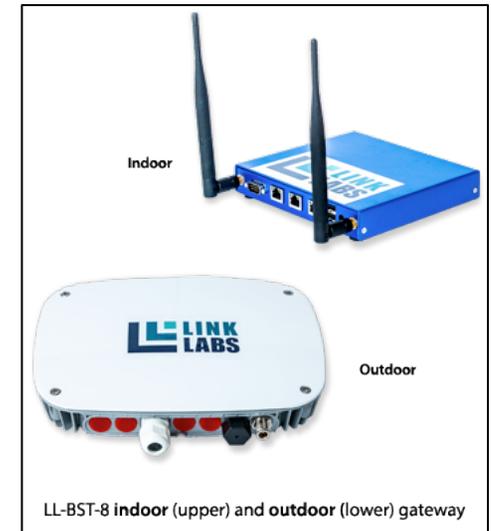
Multi-Tech Conduit



Embedded Planet
EP-M2M-LORA



Ideeatron Lorank 8



LinkLabs Symphony



Kerlink IoT Station

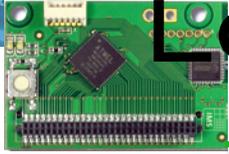


PicoWAN from
Archos



TheThingNetwork

Or build your own one:
Arduino, Raspberry Pi, ...



LOW-COST LoRa GATEWAYS

Commercial gateways

- Target low cost
- Use advanced technology
- hundreds of channels

Low-cost gateways for scale ad-hoc networks

- Use regular components from end users
- Use off-the-shelf lower-cost components

- Use standard UNIX tools and high-level language for maximum flexibility and evolution

LoRa MODULES FROM SEMTECH'S SX127X CHIPS

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

DORJI DRF1278DM is based on Semtech SX1278 LoRa 433MHz

HopeRF RFM series

HopeRF HM-TRLR-D

LinkLabs Symphony module

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

Embit LoRa

LoRa™ Long-Range Sub-GHz Module (Part # RN2483)

Microchip RN2483

inAir9/9B based on SX1276

Froggy Factory LoRa module (Arduino)

habSupplies

Multi-Tech MultiConnect mDot

AMIHO AM093

Adeunis ARF8030AA- Lo868

ARM-Nano N8 LoRa module from ATIM

SODAQ LoRaBee Embit

SODAQ LoRaBee RN2483

31

cost
medium-
connection »
forms for much



RASPBERRY-BASED 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!





SW/HW BUILDING BLOCKS



LoRa radios that our library already supports



HopeRF RFM92W/95W



Libelium LoRa



Modtronix inAir9/9B



NiceRF LoRa1276

Long-Range communication library



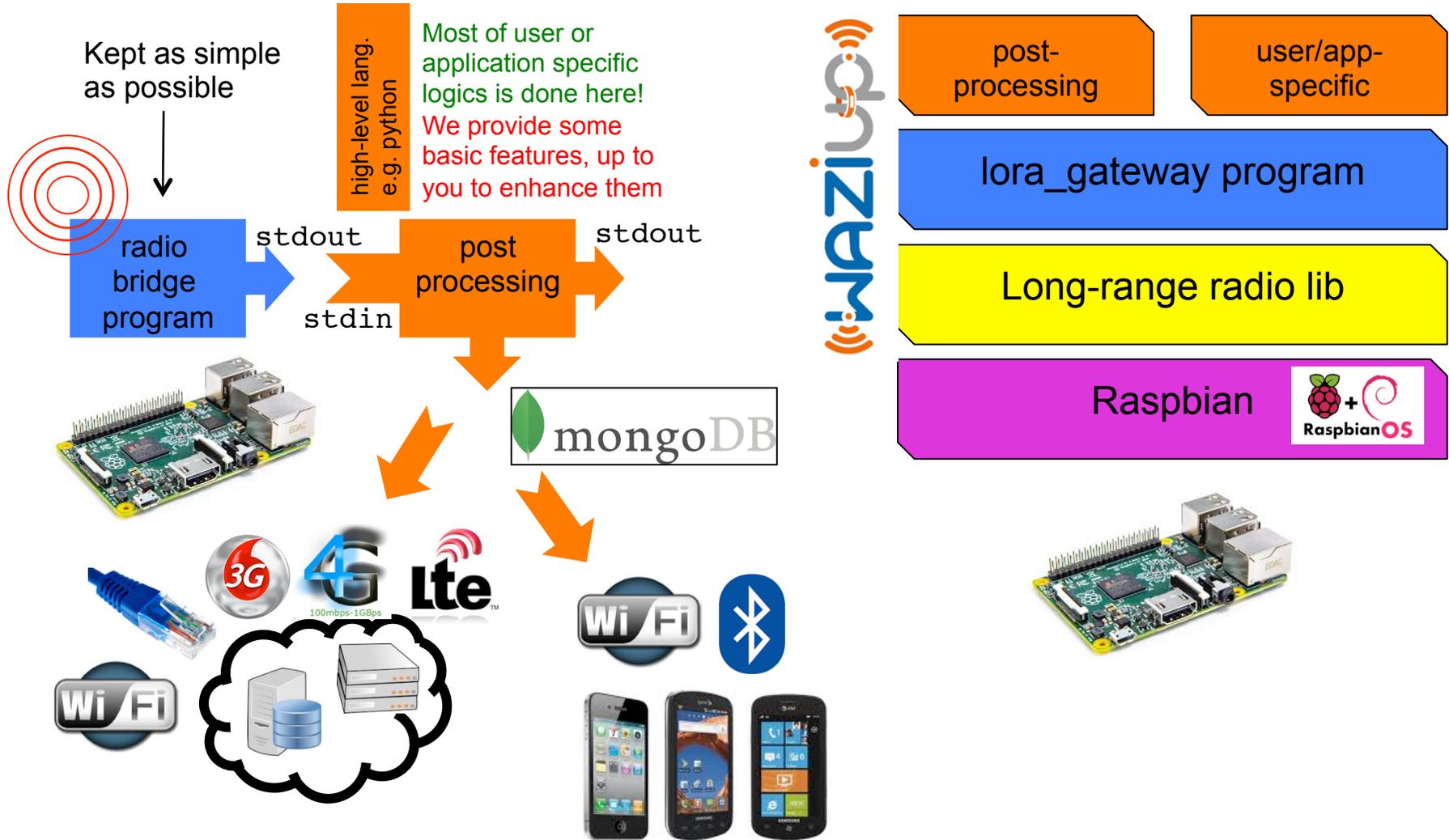
```
sendPacketTimeout("18.5");
// sends to gateway
// 18.5 : temperature message
```

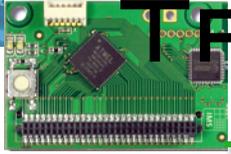
1 send function!



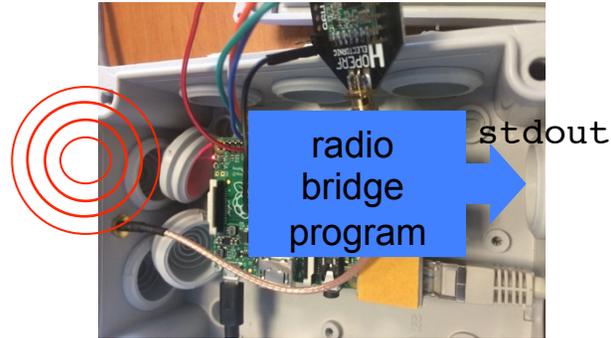
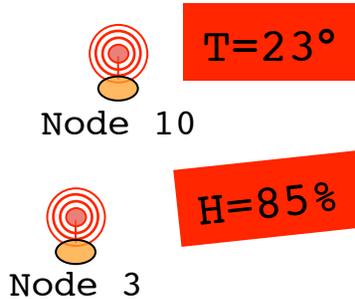


OUR LOW-COST GATEWAY ARCHITECTURE



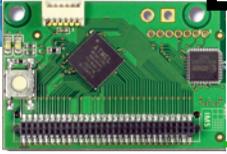


TRANSPARENT LORA BRIDGE

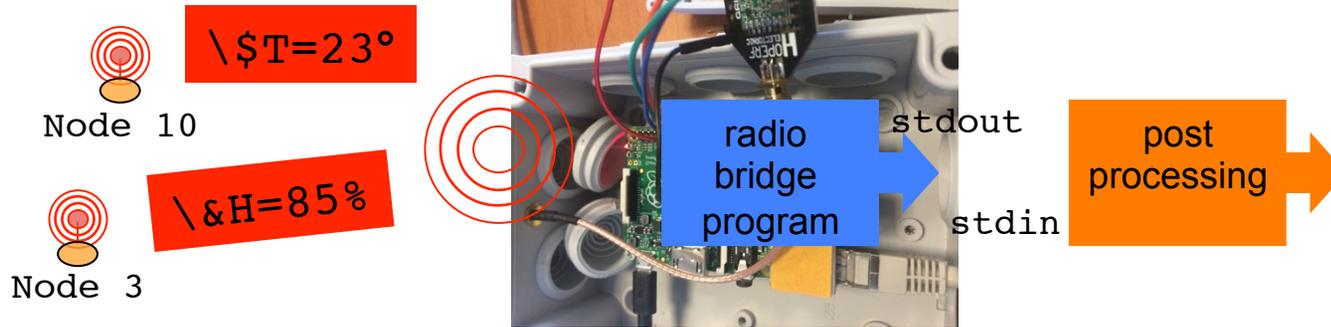


```
> sudo ./lora_gateway
Power ON: state 0
LoRa mode: 4
Setting mode: state 0
Channel CH_10_868: state 0
Power M: state 0
Get Preamble Length: state 0
Preamble Length: 8
LoRa addr 1 : state 0
SX1272/76 configured as LR-BS. Waiting RF input for transparent RF-serial bridge

--- rxloro. dst=1 type=0x10 src=10 seq=0 len=5 SNR=9 RSSIpkt=-54
^p1,16,10,0,5,9,-54
T=23°
--- rxloro. dst=1 type=0x10 src=3 seq=0 len=5 SNR=8 RSSIpkt=-54
^p1,16,3,0,5,8,-54
H=85%
```



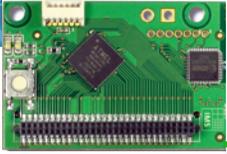
LOG RECEIVED MESSAGES USING CLOUD SERVICES



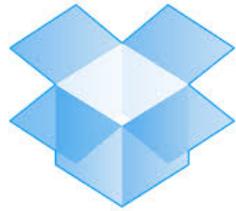
```
> sudo ./lora_gateway | python ./post_processing_gw.py
Power ON: state 0
LoRa mode: 4
Setting mode: state 0
Channel CH_10_868: state 0
Power M: state 0
Get Preamble Length: state 0
Preamble Length: 8
LoRa addr 1 : state 0
SX1272/76 configured as LR-BS. Waiting RF input for transparent RF-serial bridge

--- rxlor. dst=1 type=0x10 src=10 seq=0 len=5 SNR=9 RSSIpkt=-54
Rcv ctrl packet info 1,16,10,0,5,9,-54
(dst=1 type=0x10 src=10 seq=0 len=5 SNR=9 RSSI=-54)
rcv msg to log (\$) on dropbox : T=23°
--- rxlor. dst=1 type=0x10 src=3 seq=0 len=5 SNR=8 RSSIpkt=-54
Rcv ctrl packet info 1,16,3,0,5,8,-54
(dst=1 type=0x10 src=3 seq=0 len=5 SNR=8 RSSI=-54)
rcv msg to log (\&) on firebase : H=85%
```

`\$` or `\&` before the data indicates that the data should be logged on a file or server. It is up to the end-device to decide which option



NEED IOT CLOUD?



Dropbox



Firestore



FIWARE

Axeda®

ioBridge®
Connect things.



ThingSpeak



GroveStreams



SensorCloud™

freeboard

dweet.io

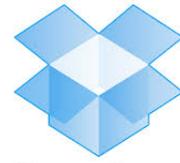
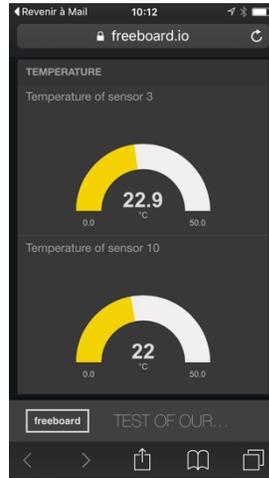
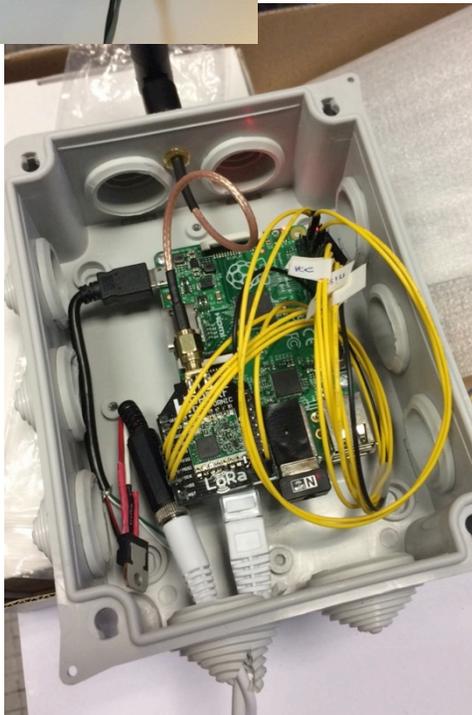
OpenRemote



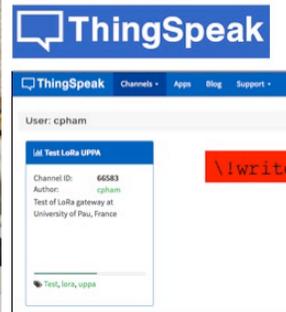
TempoIQ



TEMPLATES FOR VARIOUS CLOUDS



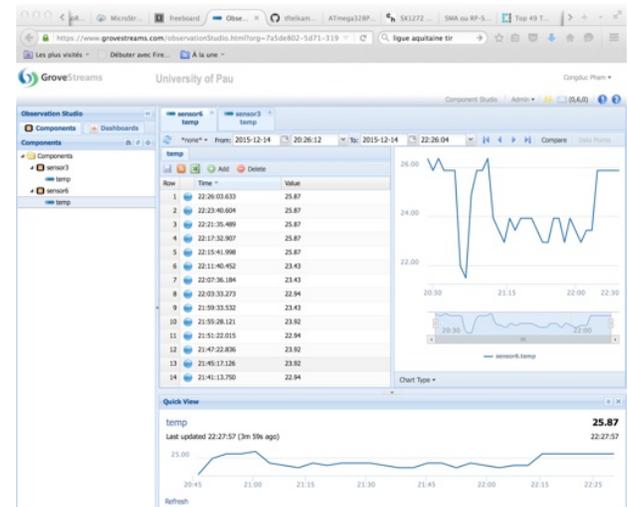
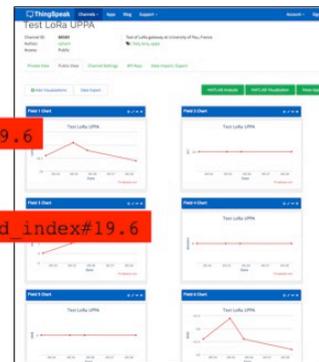
Dropbox

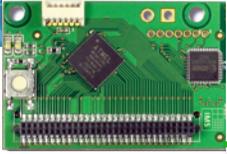


!:#19.6

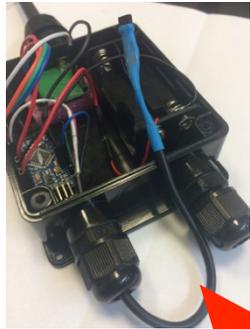
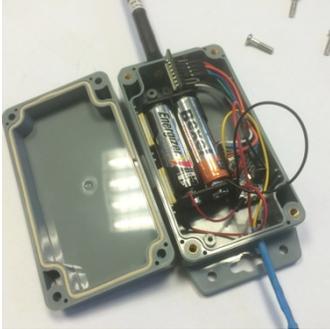
Node 10

!write_key#field_index#19.6





DO IT YOURSELF !

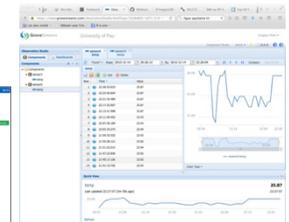


Step-by-step tutorial
and source code
available



Step-by-step tutorial
and source code
available

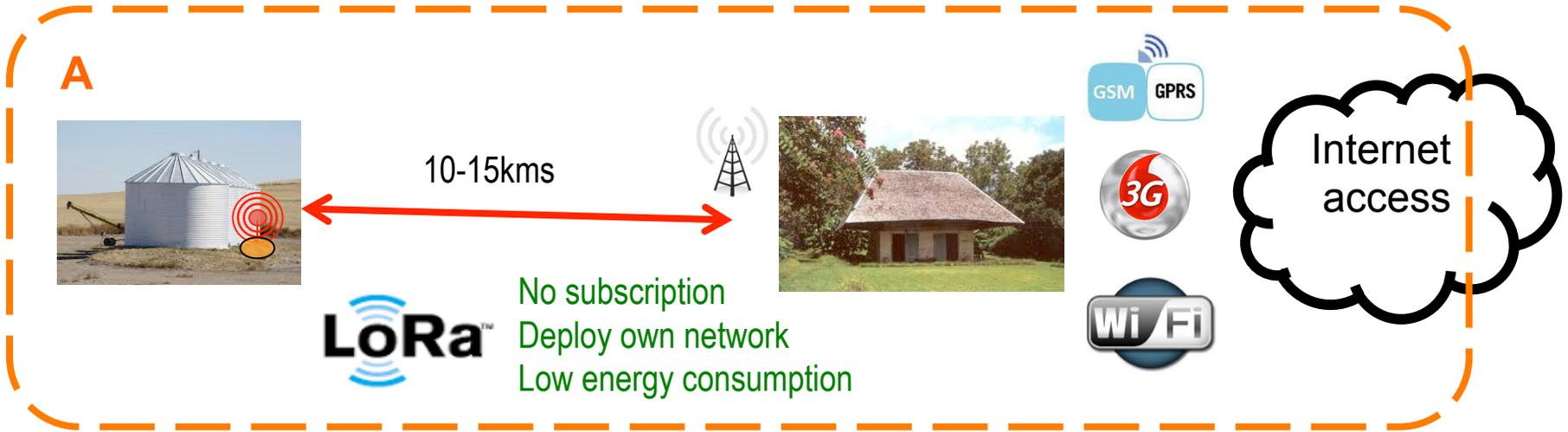
Python scripts
available

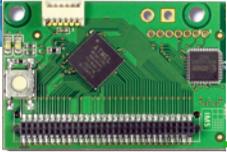


<https://github.com/CongducPham/LowCostLoRaGw>



WORKING WITHOUT INTERNET ACCESS





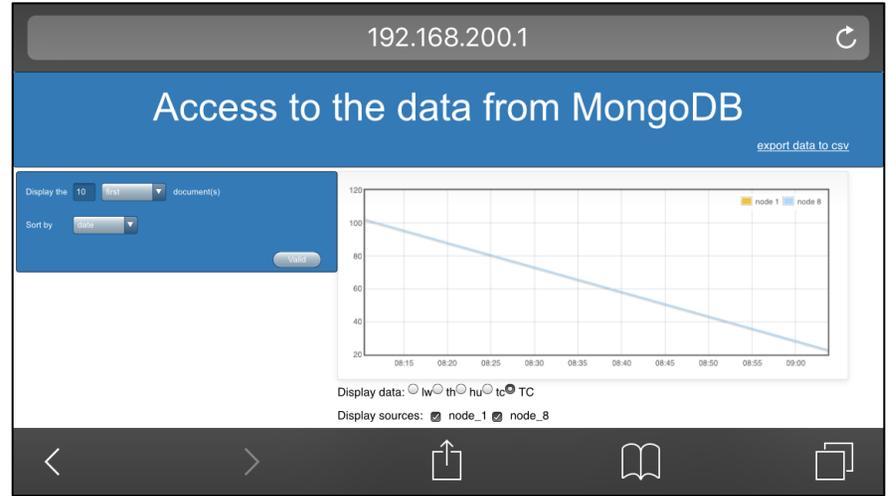
STANDALONE GATEWAY



mongoDB

PHP

jQuery
write less, do more.



Orange F

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 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": 23.79, "hu": 51.9)
NODE: 1 DATE: 2016-05-09 11:17:02.953000 DATA: ("lw": 3.29, "th": 23.5, "hu": 50.79)
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": 50.90)

```

Display data Retrieve data in a csv file

Orange F

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

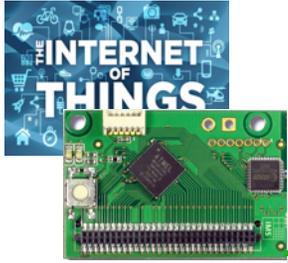
Display data Retrieve data in a csv file

Orange F

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

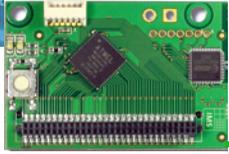
Display data Retrieve data in a csv file



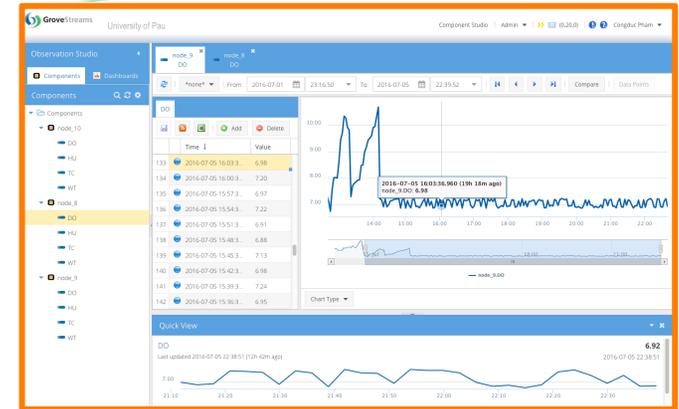
USE CASE: FISH POND MONITORING

- ❑ Farmerline in Ghana
- ❑ Water temperature and dissolved oxygen for monitoring fish ponds

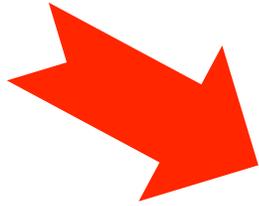




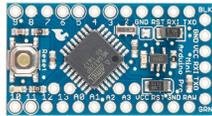
OUT-OF-THE-BOX!



Physical sensor reading



Physical sensor management

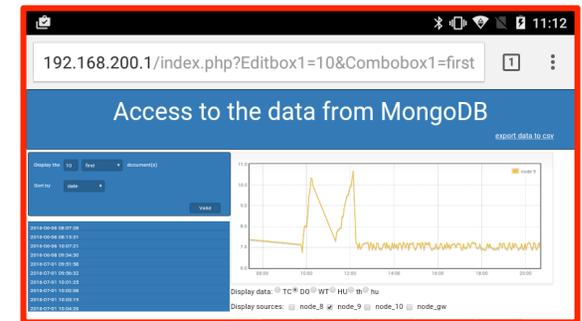


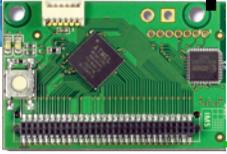
Activity duty-cycle, low power

Security

Long-range transmission

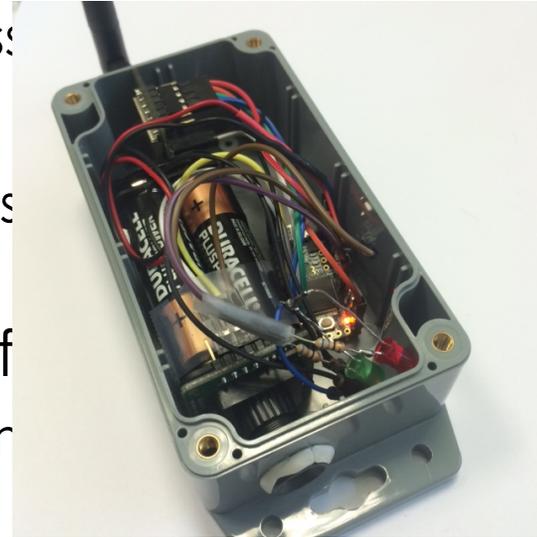
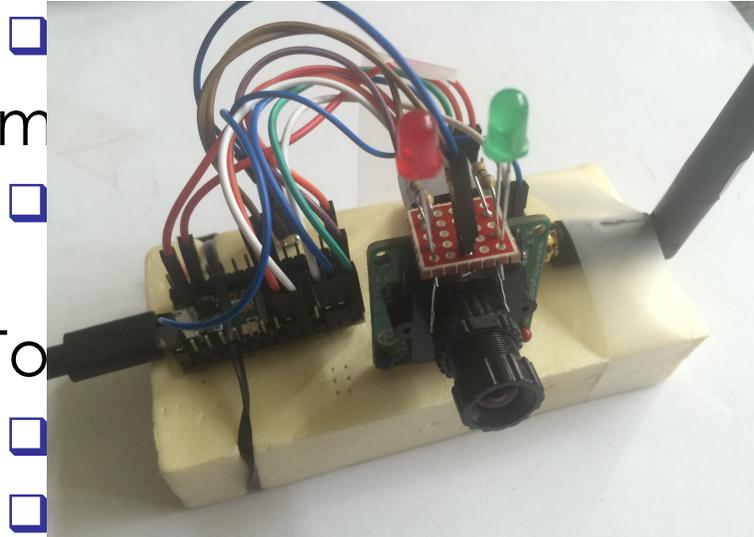
Logical sensor management





THINGS WE ARE DOING FOR RESEARCH

- ❑ To leverage the « single » connection gateway approach



- ❑ The proposed framework can be used to set-up your own LoRa test-bed for implementing advanced mechanisms



WHO IS DEPLOYING TEST-BEDS?

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



CongducPham / LowCostLoRaGw

Unwatch 13 Star 22 Fork 11

Code Issues 7 Pull requests 0 Wiki Pulse Graphs Settings

Stargazers

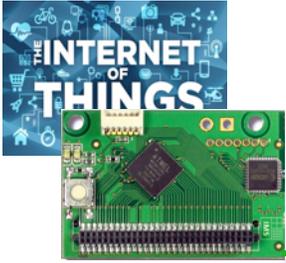
- ujeani** (Joined on Feb 9, 2012)
- iBrick** (Joined on Jul 3, 2013)
- Arn van der Pluijm** (urbanlink.nl)
- Dapeng Lan** (KTH, Sweden, TU Berlin, Germany)
- Steve Brett** (Pandora Technology)
- ICSBloom** (Joined on Jan 16, 2013)
- pedronf65** (Joined on Oct 13, 2012)
- kjendal** (Joined on Jun 8, 2015)
- khalilcharfi** (Joined on Jun 30, 2013)
- Vasilis** (Greece)
- Adrien Chapelet** (IG2I)
- Jason Biegel** (Biesel Co)
- robi772** (Joined on Jul 16, 2013)
- sirfragles** (Joined on Feb 24, 2016)
- Svenson** (Joined on Jun 24, 2012)
- ftp2010** (Joined on Feb 12, 2014)
- BMWLab-Ken**
- Daniel Mahony** (Australia)
- joehunt588** (Joined on Sep 26, 2013)
- yoyellow** (Joined on Jan 2, 2013)
- luytms** (Joined on Apr 8, 2014)
- Andrew McDonnell** (Down Under)

<p>University Gaston Berger, Saint-Louis, Senegal</p> <p>The gateway will be used to deploy low-cost IoT solutions in the context of the H2020 WAZIUP project.</p>	
<p>Easy Global Market, Nice, France</p> <p>The gateway will be used to deploy LoRa service for various demonstration purposes</p>	
<p>As part of the WAZIUP project, a starter kit with a gateway will be deployed at project's partner's site:</p> <ul style="list-style-type: none"> 1- Farmerline (Ghana) 2- iSpace (Ghana) 3- CTIC (Senegal) 	
<p>IIDRE SAS</p> <p>The gateway will be used to deploy LoRa service for various demonstration purposes</p>	
<p>Connecting Nature</p> <p>The gateway will be used to deploy and test LoRa-based telemetry services for various agriculture applications</p> <p>Chuck Swiger from West Virginia (US)...</p> <p>has a ds18b20 temp probe ThinkSpeak channel using our gateway</p>	
<p>The Oceanographic Observatory of Banuyls/mer (part of University of Paris 6)</p> <p>The gateway will be used to deploy and test LoRa-based telemetry services for various environmental surveillance applications</p>	
<p>Matthew Way from New Zealand</p> <p>Develops great LoRa-based pest surveillance system. He is testing our solution as well as his own custom design solutions.</p>	



WHY NOT USING LoRAWAN

- ❑ Cost of gateway concentrator chip
- ❑ No custom behavior at gateway level, every thing is at application server level
- ❑ No P2P (senso-sensor) communications, prevent defining elaborated interaction models
- ❑ LoRaWAN channels are well defined and shared on larger scale, thus increasing probability of interferences
- ❑ Difficult (impossible?) to add additional mechanisms for advanced channel access, QoS, shared activity time,...



CONCLUSIONS

- ❑ Low-power, long-range transmission is a breakthrough technology for large-scale IoT deployment
- ❑ With low-cost, off-the-shelves hardware, IoT is entering the DIY era without giving up for performance and functionalities
- ❑ The whole IoT eco-system is becoming mature with availability of IoT clouds and advanced big data analytic platforms/frameworks
- ❑ We presented our IoT framework with design orientations to meet Sub-Saharan Africa needs