

INTERNET-OF-THING FOR ALL!

ILLUSTRATION WITH THE H2030 WAZIUP PROJECT

BASED ON VARIOUS PRESENTATIONS FOR WAZIUP

**COMPILED FOR WATERSENSE PROJECT TO SERVE AS
INTRODUCTION TO LONG-RANGE, LOW-COST IoT**



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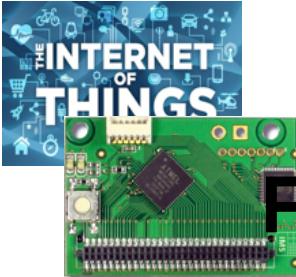




INTERNET OF THINGS

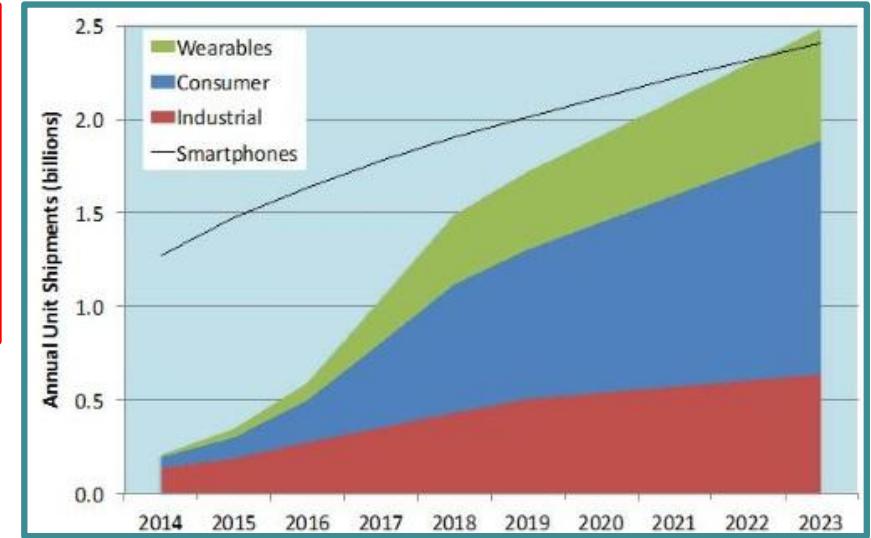
By Congduc Pham for WaterSense project





ONE OF THE MOST PROMISING MARKET IS IoT!

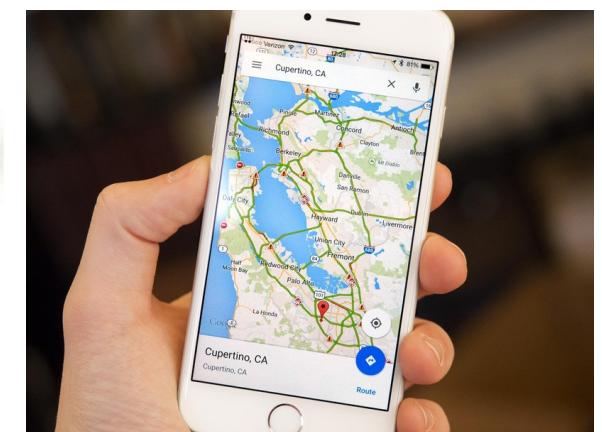
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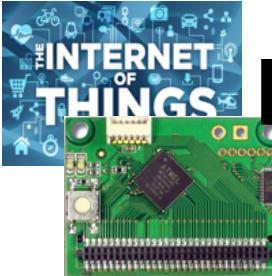




IOT & PHYSICAL WORLD

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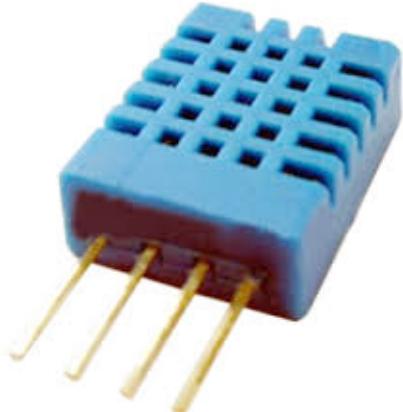


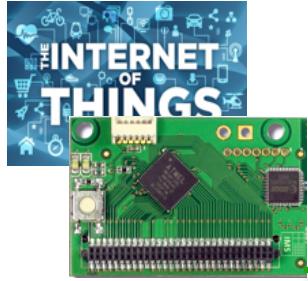
MEASURING THE PHYSICAL WORLD WITH SENSORS

By Congduc Pham for WaterSense project



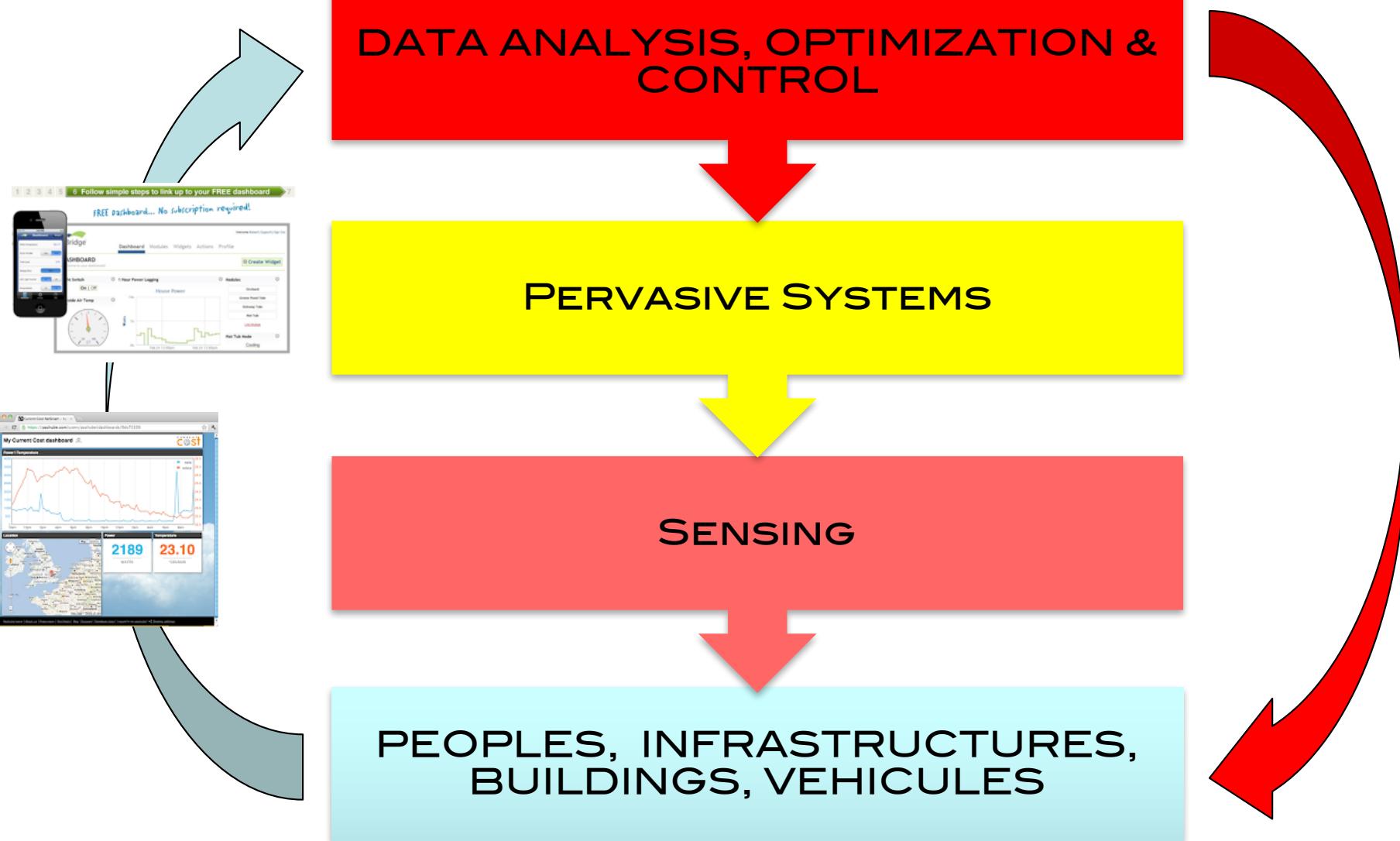
SENSING





CONTROL, OPTIMIZE & INSTRUMENT !

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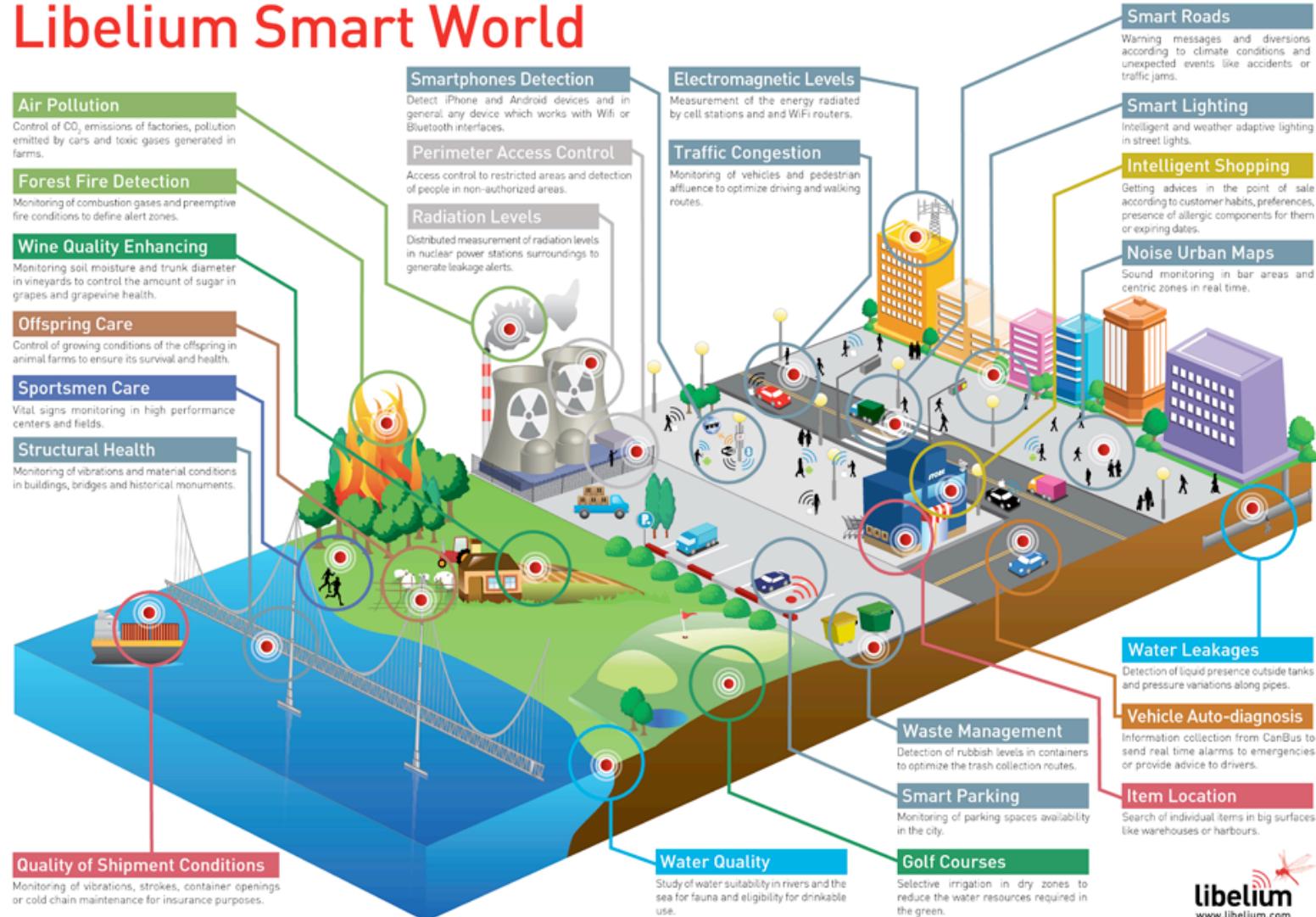


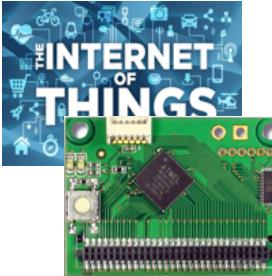


EXAMPLE: SMART CITIES

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Libelium Smart World





HUGE SOCIETAL NEEDS!

By Congduc Pham for WaterSense project



Irrigation



Livestock farming



Fish farming & aquaculture



Storage & logistic



Agriculture



Fresh water



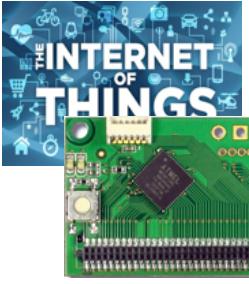
MATURATION OF THE IoT MARKET...

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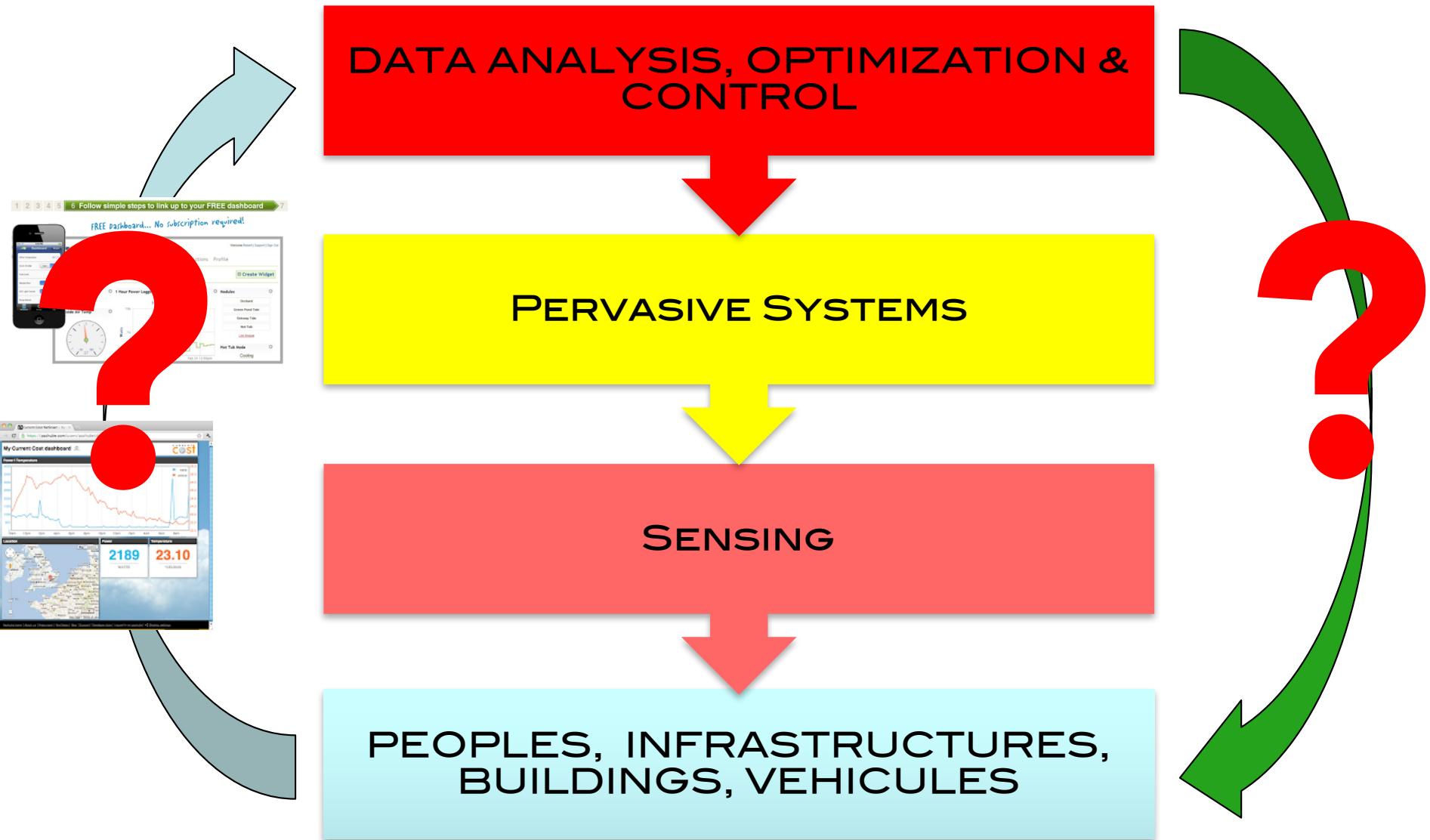
Waste Container connected sensor

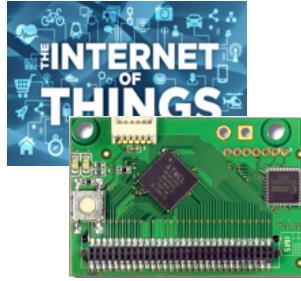




1ST ISSUE: COLLECT DATA

By Congduc Pham for WaterSense project

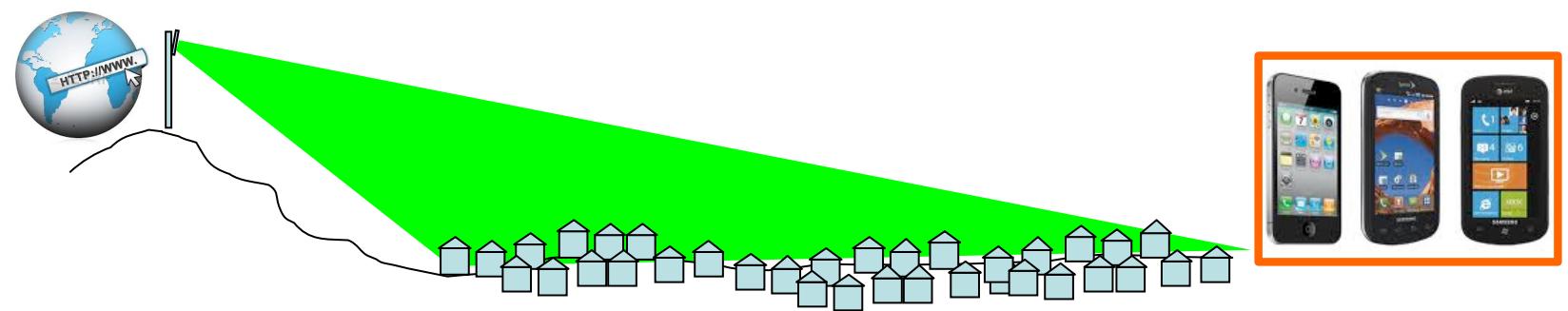
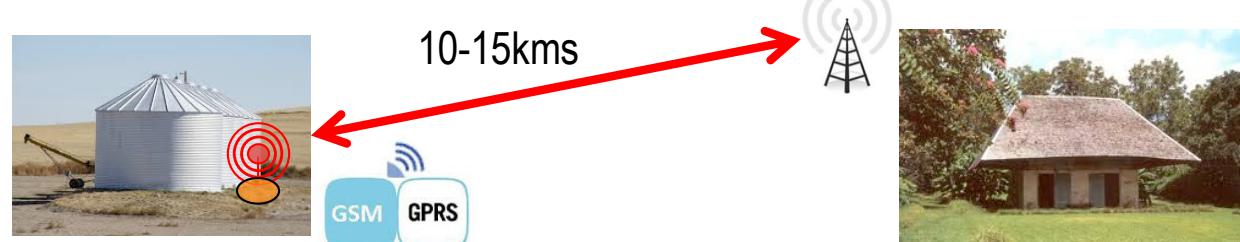




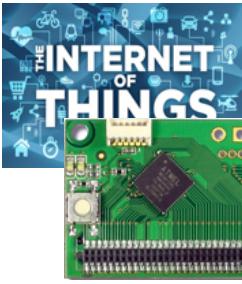
LONG-RANGE SENSING

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Moisture/
Temperature of
storage areas

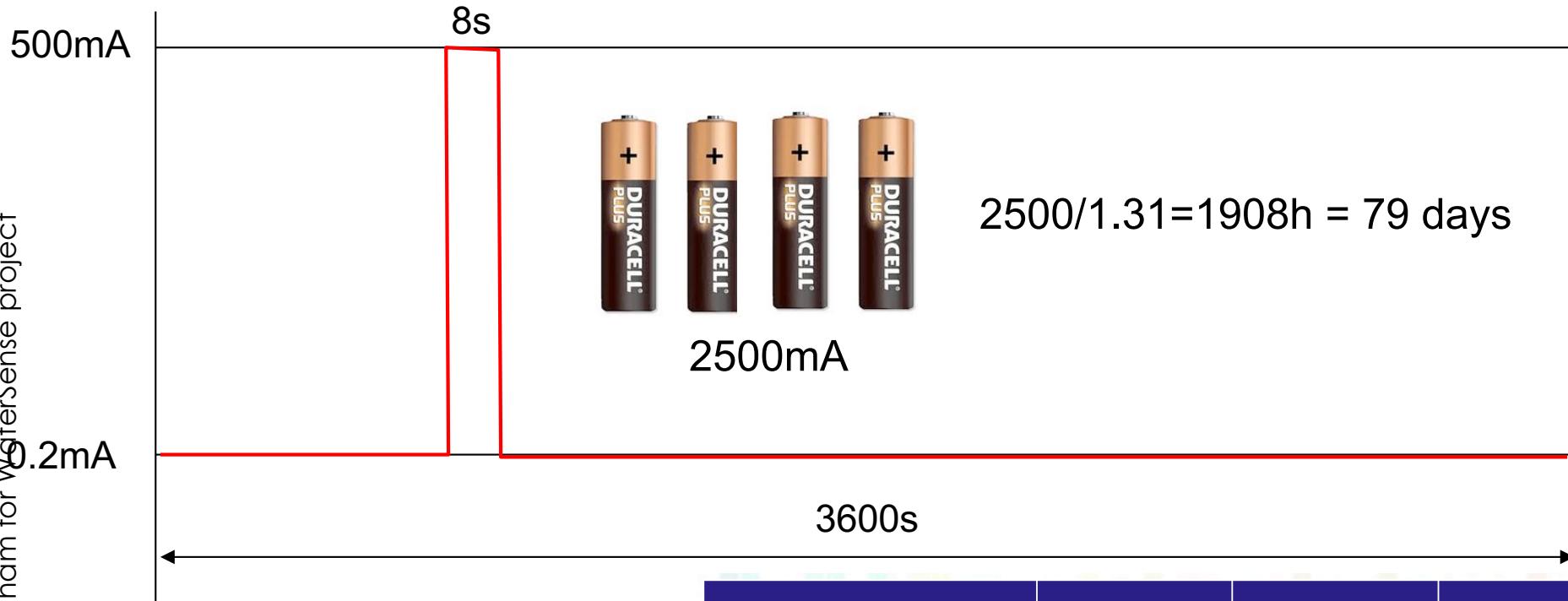


Technology	2G	3G	LAN
Range (I=Indoor, O=Outdoor)	N/A	N/A	O: 300m I: 30m
Tx current consumption	200-500mA	500-1000mA	100-300mA
Standby current	2.3mA	3.5mA	NC

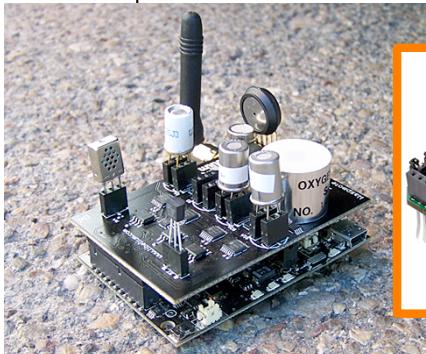


ENERGY CONSIDERATION

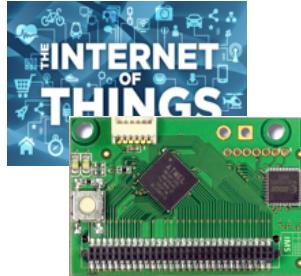
TX power: 500mA. Mean consumption: $(8 \times 500 + 3592 \times 0.2) / 3600 = 1.31\text{mA}$



By Congduc Pham for wioterSense project

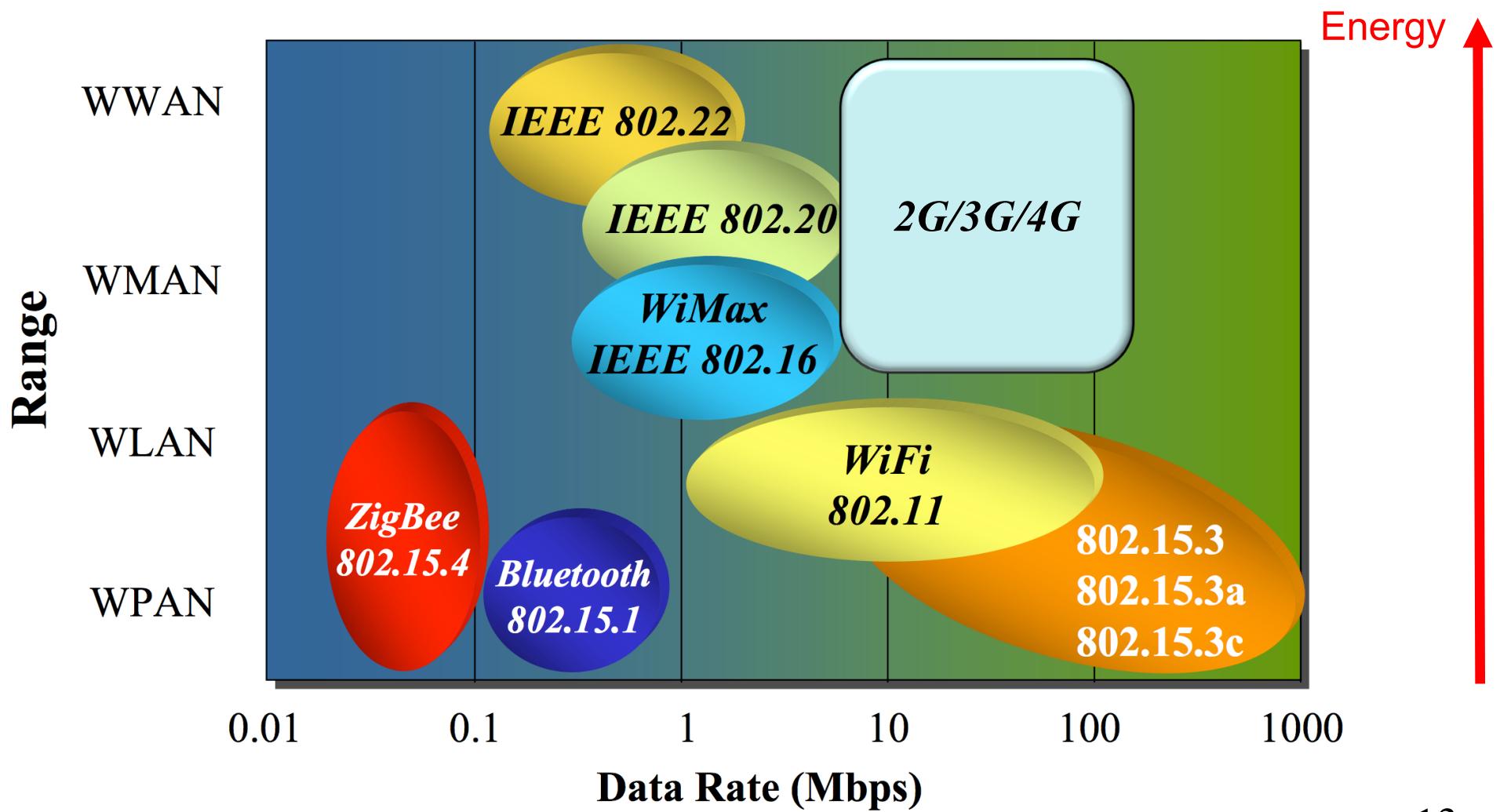


Technology	2G	3G	LAN
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THE WIRELESS SPACE

Energy-Range dilemma

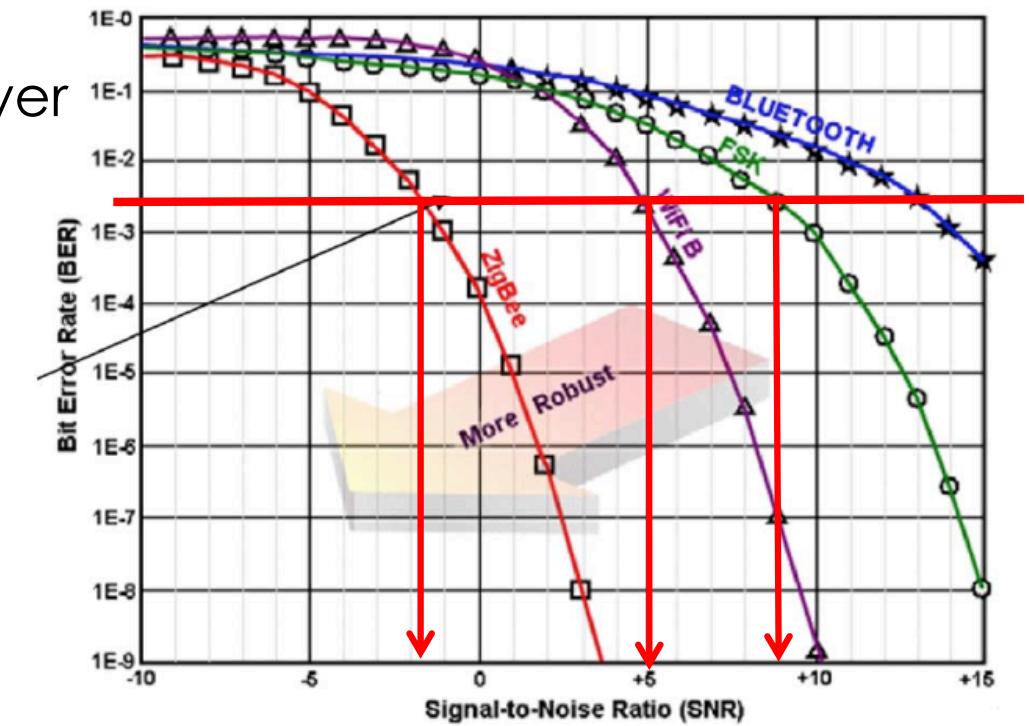
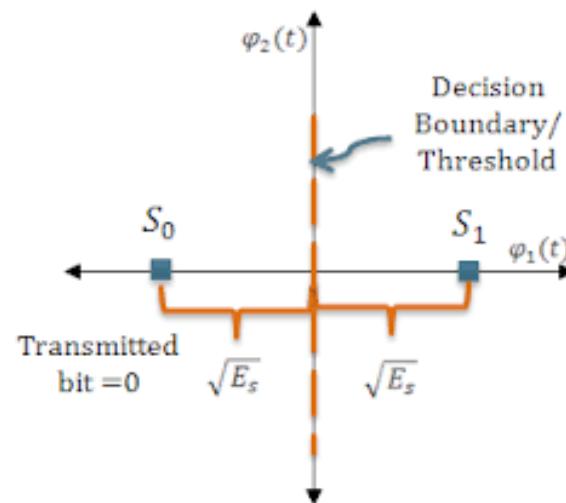


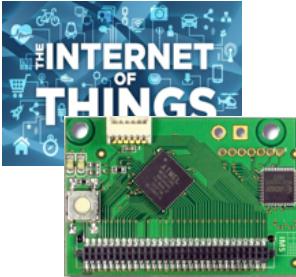


IEEE 802.15.4 IN ISM 2.4GHz

- Low-power radio in the 2.4GHz band offering **250kbps** throughput at physical layer
- Power transmission from 1mW to 100mW for range from 100m to about 1km is LOS
- CSMA/CA
- BPSK, used as physical layer in ZigBee

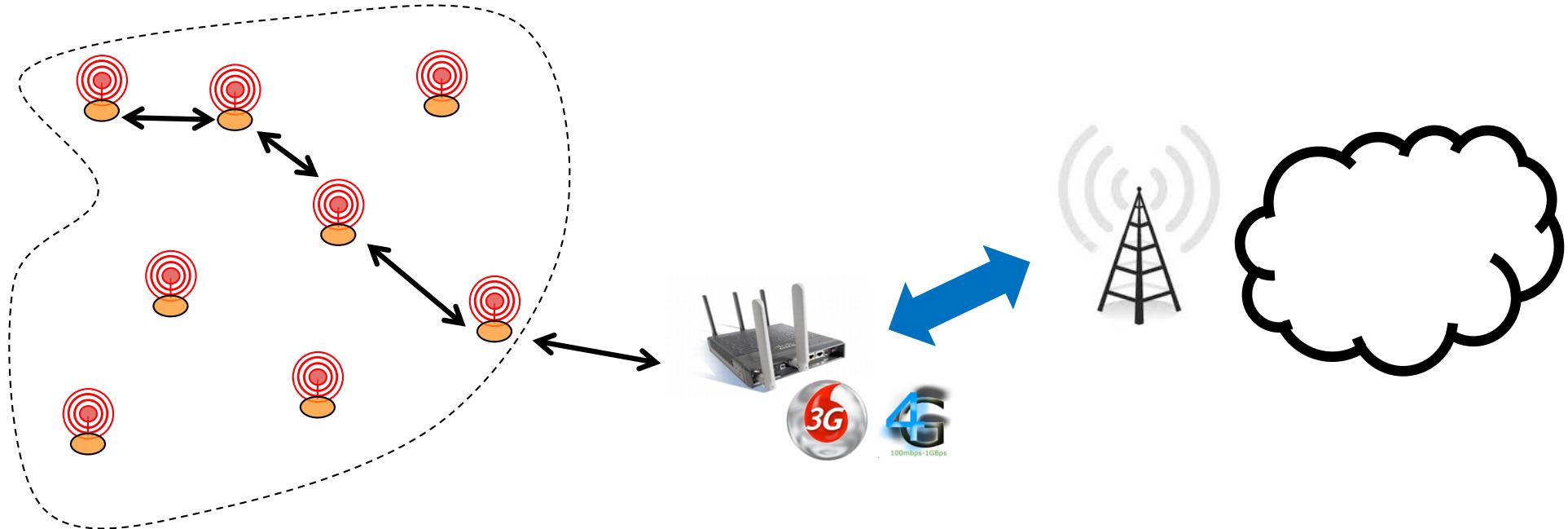
By Conaduc Pham for WaterSense project





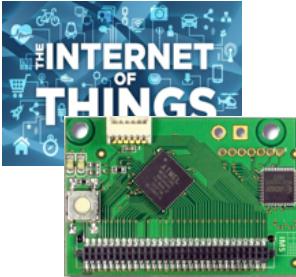
LOWER ENERGY MEANS SHORTER RANGE!

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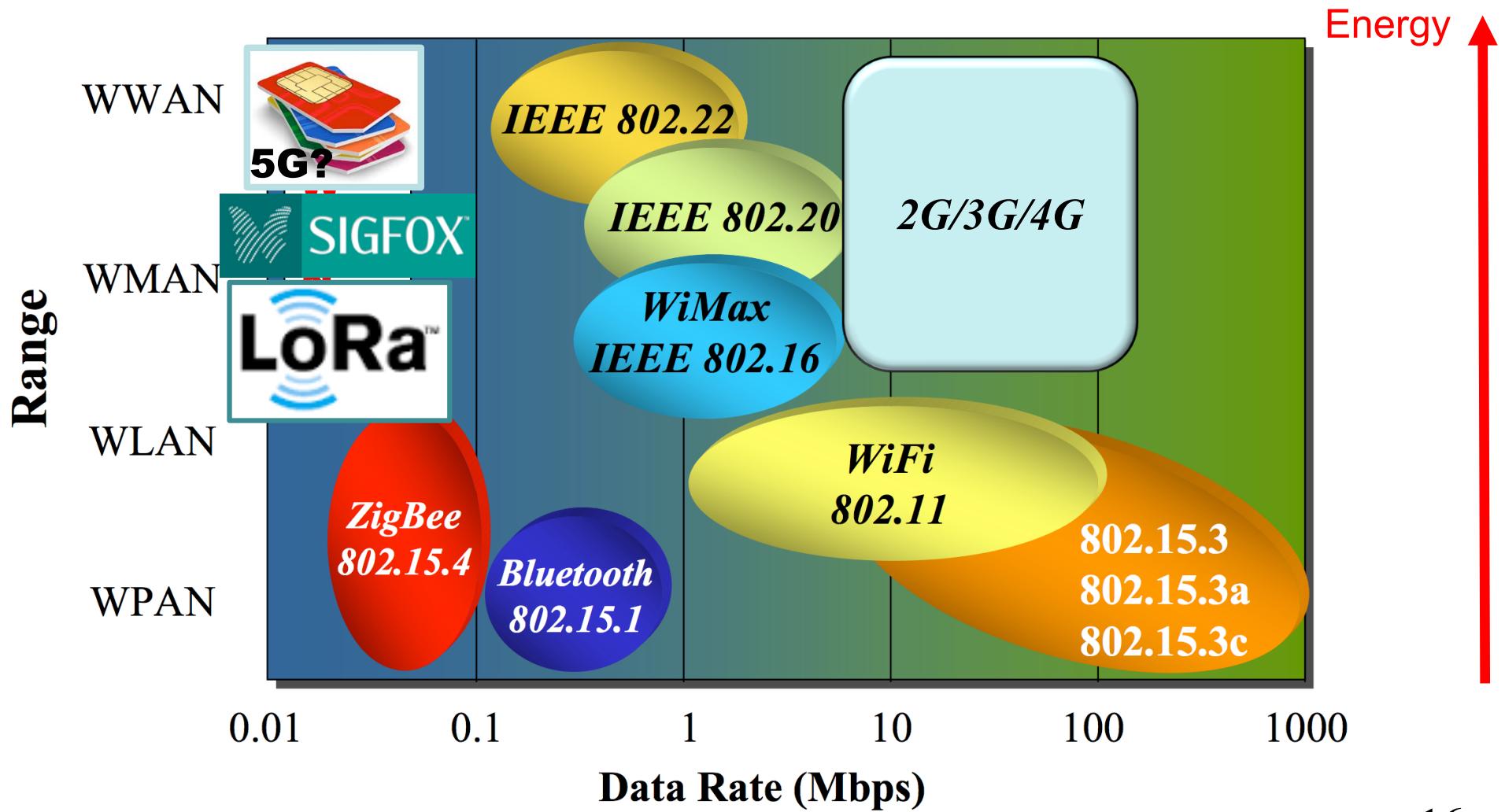
How bad is multi-hop routing?

- Increases packet loss rate
- Increases end-to-end delivery time
- Consumes more energy as intermediate nodes must relay packets
- Limits energy saving mechanism benefits as both sender and intermediate node must be somehow synchronized
- Is impacted by intermediate node failure



LOW-POWER AND LONG-RANGE?

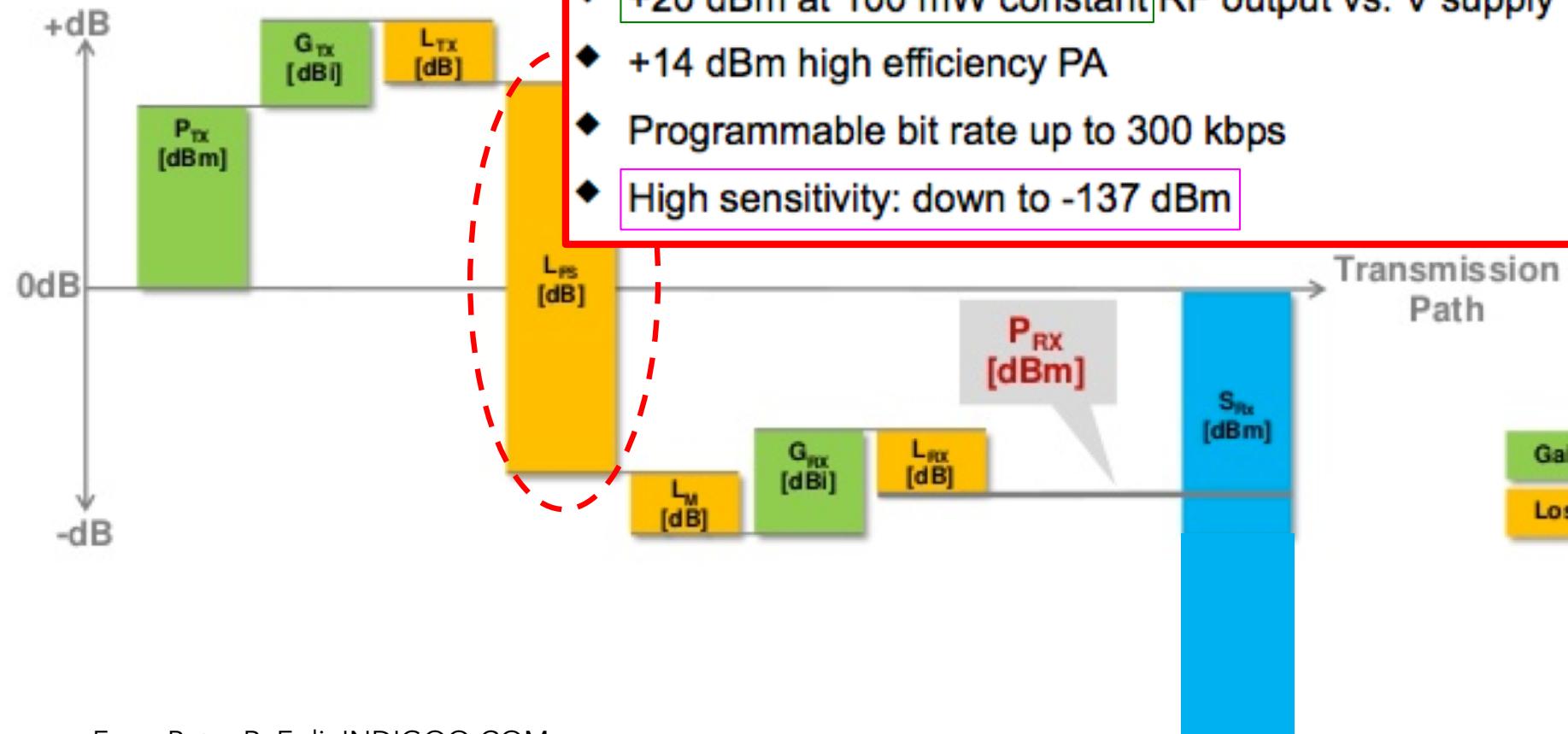
Energy-Range dilemma

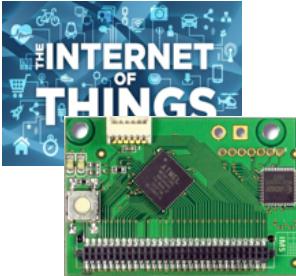




LINK BUDGET OF LPWAN

$$P_{RX} = P_{TX} + G_{TX} - L_{TX} -$$

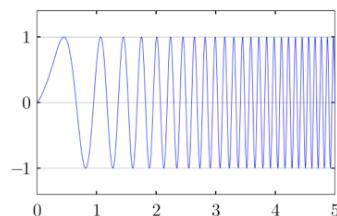




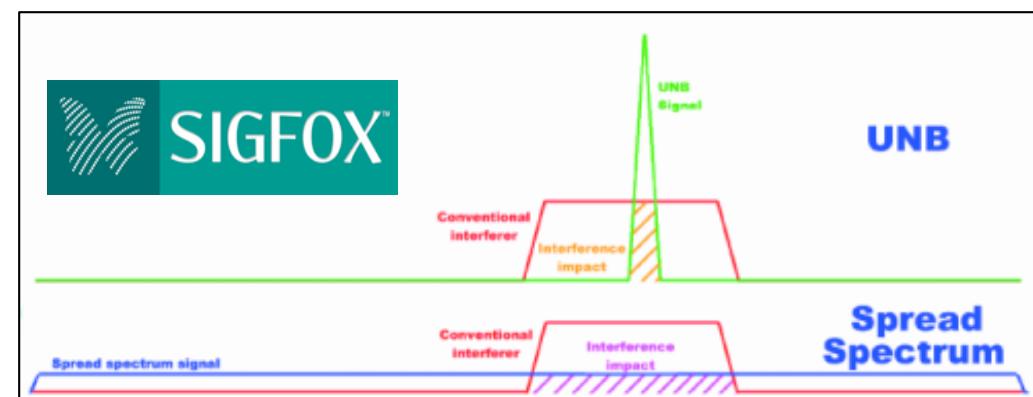
INCREASING RANGE?

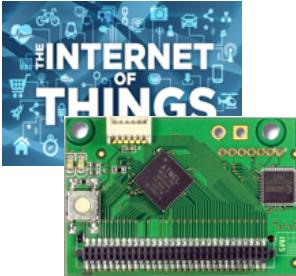
- Generally, robustness and sensitivity can be increased when **transmitting much slower**
- A Sigfox message is sent relatively slowly in a very narrow band of spectrum. **Max throughput=~100bps**
- LoRa also increases time-on-air when maximum range is needed. But LoRa uses spread spectrum instead of UNB. **throughput=~300bps-37.5kbps**

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LoRa™





SIMPLE LOSS IN SIGNAL STRENGTH MODEL

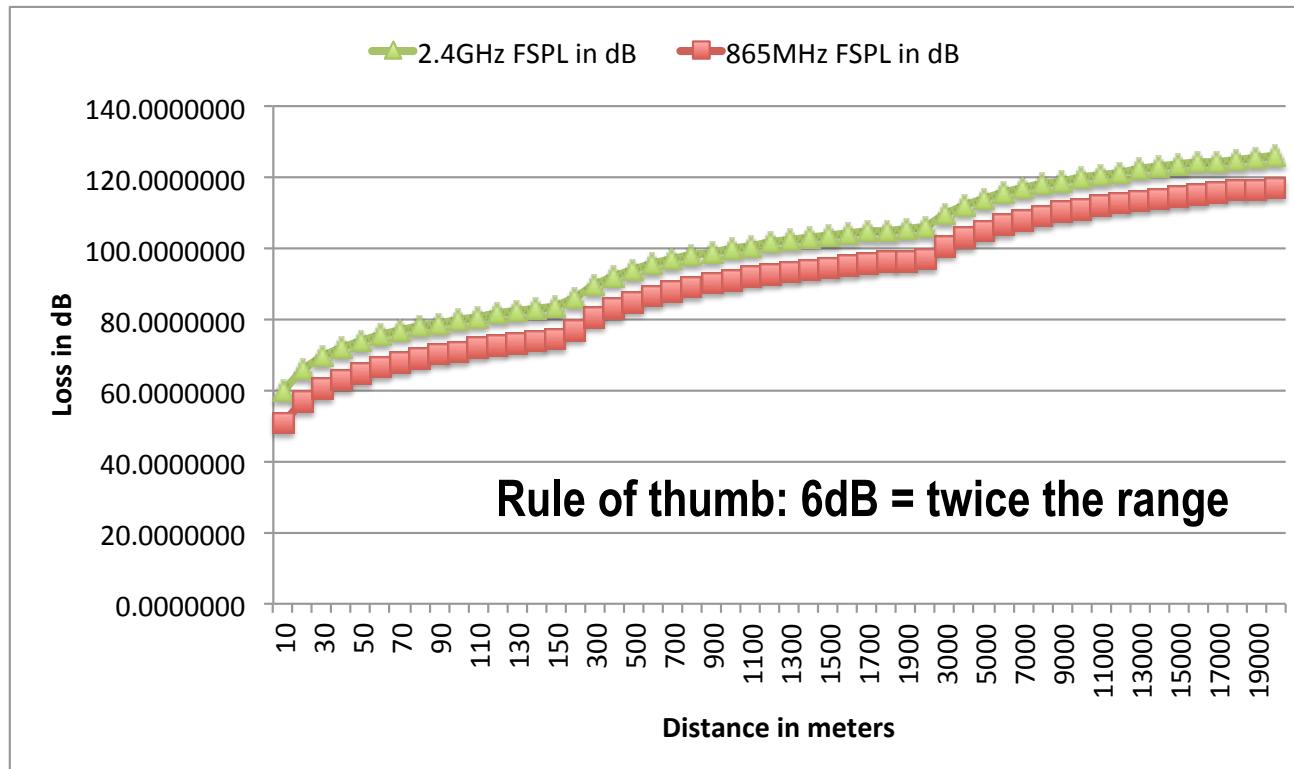
□ Free Space Path Loss model

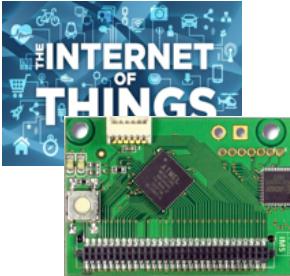
$$L_{(dB)} = 10 \log\left(\frac{P_t}{P_r}\right) = 20 \log\left(\frac{4\pi d}{\lambda}\right) = 20 \log\left(\frac{4\pi f d}{c}\right)$$

$$\text{FSPL} = \left(\frac{4\pi d}{\lambda}\right)^2 \quad FSPL = \frac{P_t}{P_r} G_t G_r \\ = \left(\frac{4\pi d f}{c}\right)^2$$

FSPL assume Gt=Gr=1

$$L_{(dB)} = 20 \log(f) + 20 \log(d) - 147,55 \text{ dB}$$



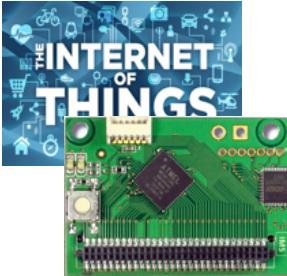


LINK BUDGET EXAMPLE

- Received Power (dBm) = Transmitted Power (dBm) + Gains (dB) – Losses (dB) [mainly FSL]
- Example
 - Transmitted power is +14dBm (25mw)
 - Losses is 120dB
 - Then Receiver Power (dBm) is -106dBm
- If you have a receiver sensitivity of -137dBm you can handle FSPL up to 151dB!
- Rewriting the equation
 - Losses (dB) = Transmitted Power (dBm) - Received Power (dBm)
 - Losses = link budget & Received Power = max receiver sensitivity
 - Link budget = Transmitted Power - max receiver sensitivity
 - **151dB=14dBm - (-137dBm)**

dBm – power referred to 1 mW,

$$P_{\text{dBm}} = 10 \log(P/1\text{mW})$$



LINK BUDGET EXAMPLE

- Received Power (dBm) = Transmitted Power (dBm) + Gains (dB) – Losses (dB) [mainly FSL]

- Example

- Transmitted power is +14dBm (25mw)
 - Losses (FSPL) is 100 dB
 - Then Receiver P

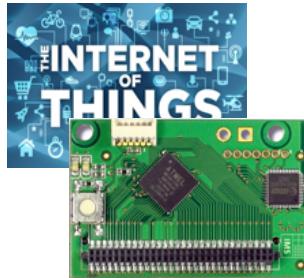
dBm – power referred to 1 mW,

$$P_{\text{dBm}} = 10 \log(P/1\text{mW})$$

- If you have a receiver, handle FSPL up to
- Rewriting the equation
 - Losses (dB) = Transmitter Power (dBm) – Received Power (dBm)
 - Losses = link budget
 - Link budget = Transmitter Power (dBm) – Losses
 - **151dB=14dBm - (-14dBm)**

KEY PRODUCT FEATURES

- ◆ LoRa™ Modem
- ◆ **157 dB maximum link budget**
- ◆ **+20 dBm at 100 mW constant RF output vs. V supply**
- ◆ +14 dBm high efficiency PA
- ◆ Programmable bit rate up to 300 kbps
- ◆ High sensitivity: down to -137 dBm



ENERGY CONSUMPTION COMPARAISON

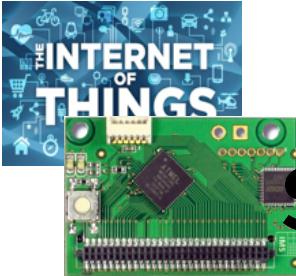
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Technology	2G	3G	LAN	ZigBee	Lo Power WAN
Range (I=Indoor, O=Outdoor)	N/A	N/A	O: 300m I: 30m	O: 90m I: 30m	Same as 2G/3G
Tx current consumption	200-500mA	500-1000mA	100-300mA	18mA	18mA-40mA
Standby current	2.3mA	3.5mA	NC	0.003mA	0.001mA
Energy harvesting (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)

TX power: 30mA. Mean consumption: $(8 \times 30 + 3592 \times 0.2) / 3600 = 0.266\text{mA}$

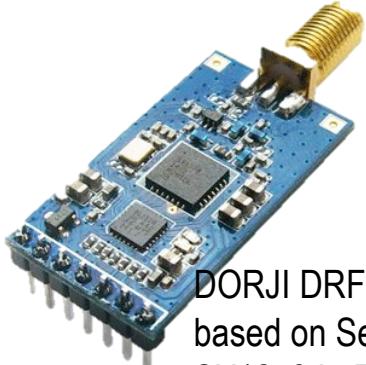
$$2500 / 0.266 = 9398\text{h} = 391\text{ days} = 13\text{ months}$$

Tables from Semtech



LORA MODULES FROM SEMTECH'S SX127X CHIPS

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DORJI DRF1278DM is based on Semtech SX1278 LoRa 433MHz



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



inAir9/9B based on SX1276



Froggy Factory LoRa module (Arduino)



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)



Multi-Tech MultiConnect mDot



habSupplies



Adeunis ARF8030AA- Lo868



AMIHO AM093

AMIHO AM093 LoRa module based on Semtech SX1272, 863-870 MHz for Europe



SODAQ LoRaBee Embit

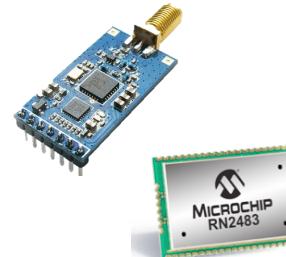


SODAQ LoRaBee RN2483

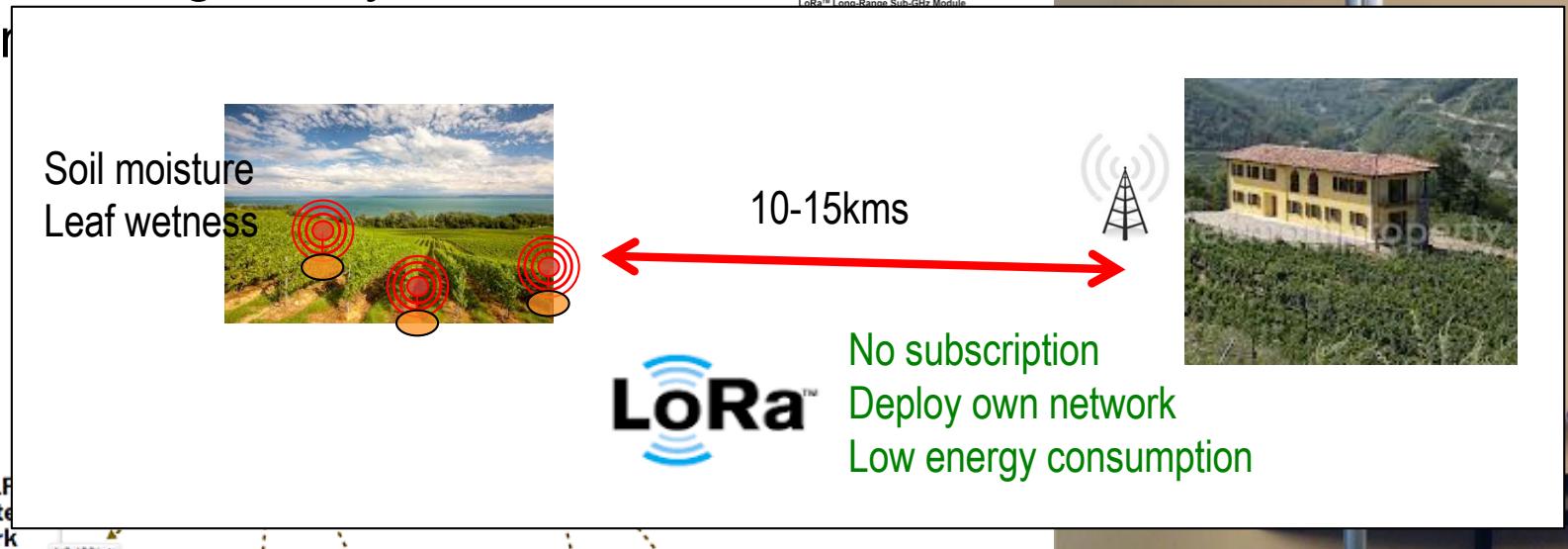


BUILD YOUR OWN PRIVATE LoRA LPWAN

Add LoRa radio module to your preferred dev platform

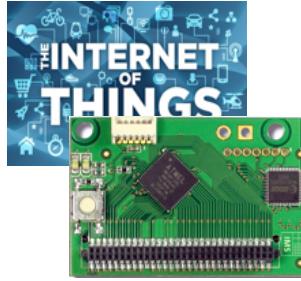


Install a LoRa gateway and start collecting



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Figure from Semtech

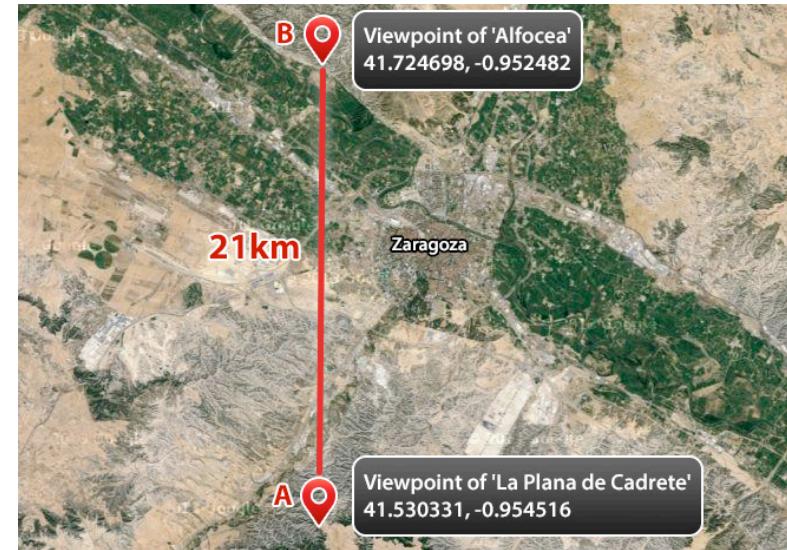


VERSATILE LPWAN!

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Dense urban areas



Rural areas



Indoor

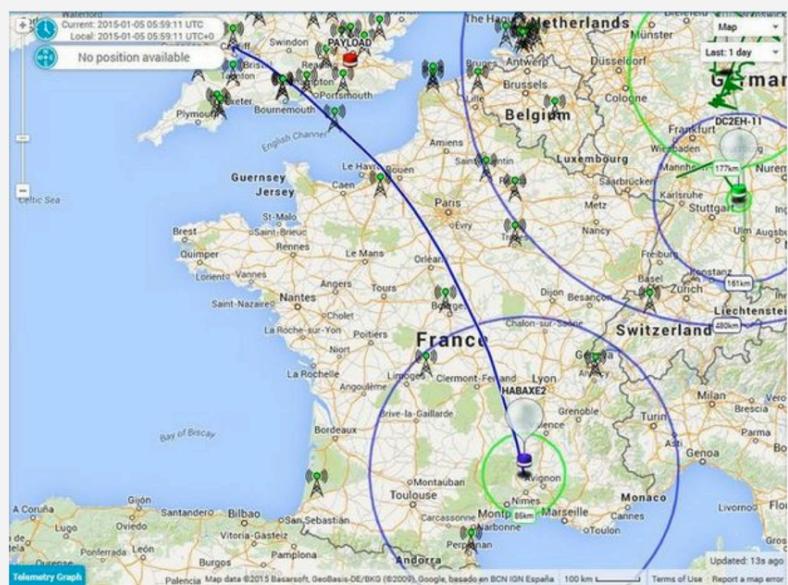


Underground

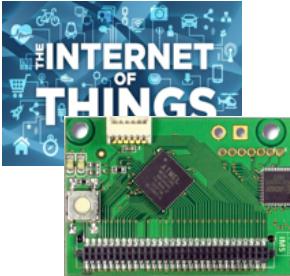


THE HIGHER THE BETTER!

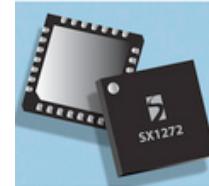
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UK HAB (High Altitude Ballooning) trials gave 2 way LoRa™ coverage at up to 240 km. Lowering the data rate from 1000bps to 100bps should allow coverage all the way to the radio horizon, which is perhaps 600 km at the typical 6000-8000m soaring altitude of these balloons. Balloon tracking can be made



LORA'S PARAMETERS



By Congduc Pham for WaterSense project

□ Parameters

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

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

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

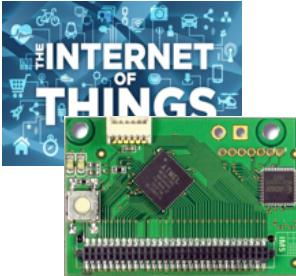
Rule of thumb

6dB increase = twice the range in LOS

12dB needed for urban areas

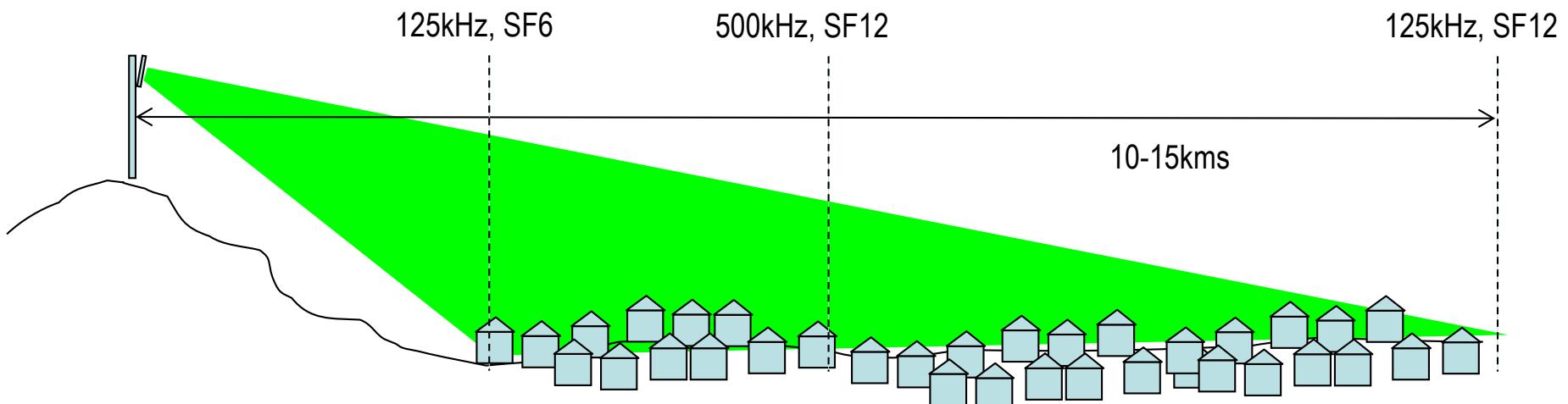
Bandwidth (kHz)	Spreading Factor	Coding rate	Nominal Rb (bps)	Sensitivity (dBm)
125	12	4/5	293	-137
250	12	4/5	586	-134
500	12	4/5	1172	-131

Tables from Semtech



RELATION TO RANGE

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Bandwidth (kHz)	Spreading Factor	Coding rate	Nominal R _b (bps)	Sensitivity (dBm)
125	12	4/5	293	-137
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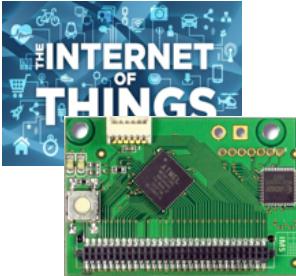
L-PWAN = LOW THROUGHPUT

Very low throughput
Transmission time can be several seconds

By Congduc Pham for WaterSense project

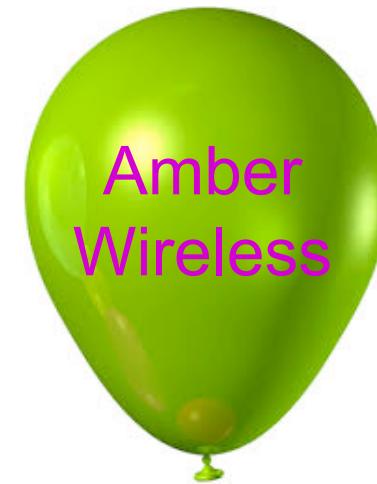
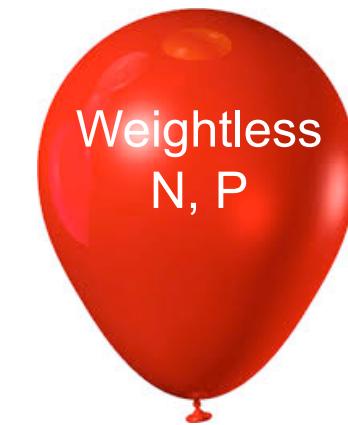
Range ↑
↓ Throughput

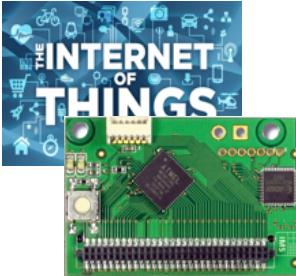
LoRa mode	BW	CR	SF	time on air in second for payload size of						max thr. for 255B in bps
				5 bytes	55 bytes	105 bytes	155 Bytes	205 Bytes	255 Bytes	
1	125	4/5	12	0.95846	2.59686	4.23526	5.87366	7.51206	9.15046	223
2	250	4/5	12	0.47923	1.21651	1.87187	2.52723	3.26451	3.91987	520
3	125	4/5	10	0.28058	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



OTHER LONG-RANGE TECHNOLOGIES

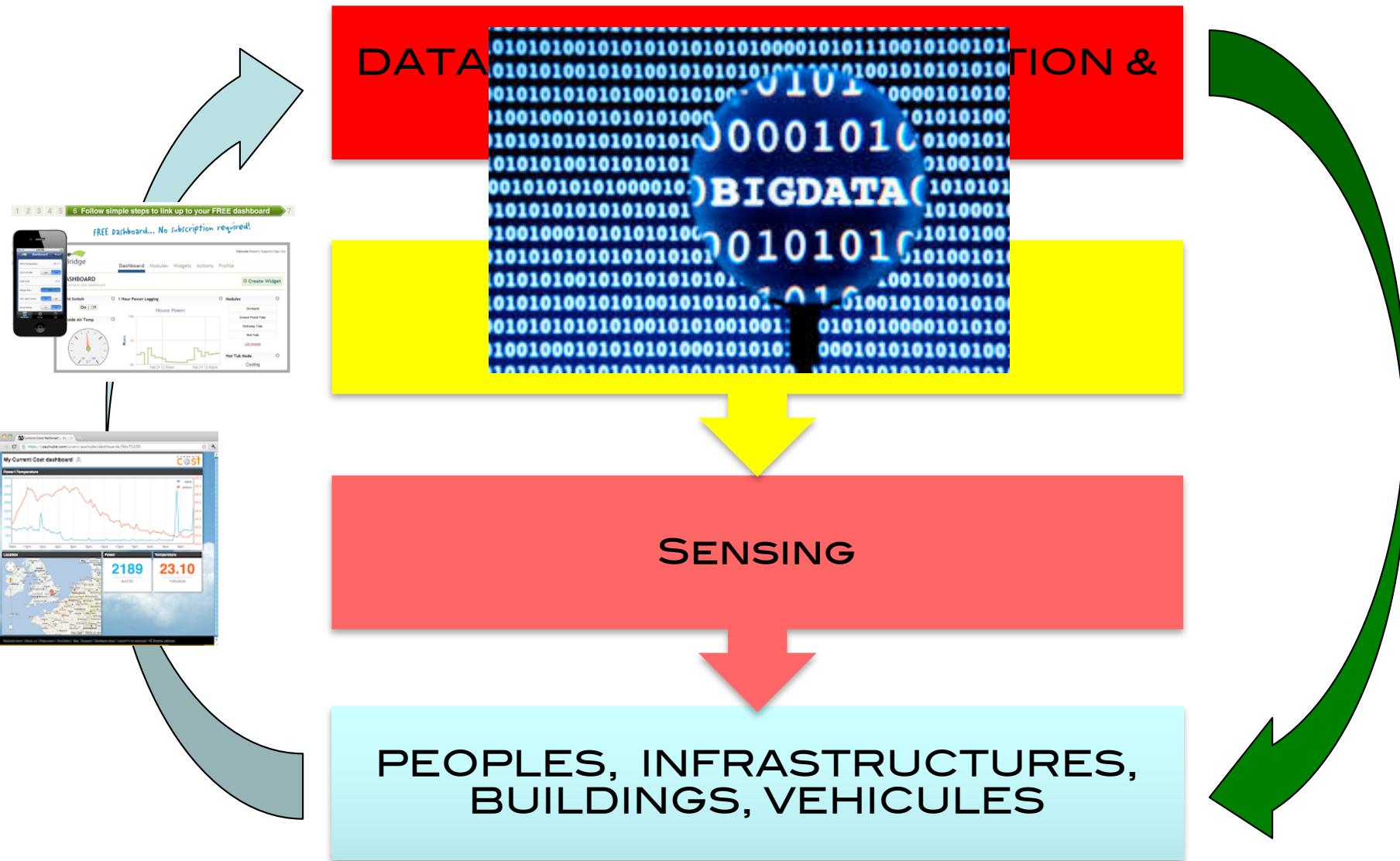
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2ND ISSUE: BIG DATA!

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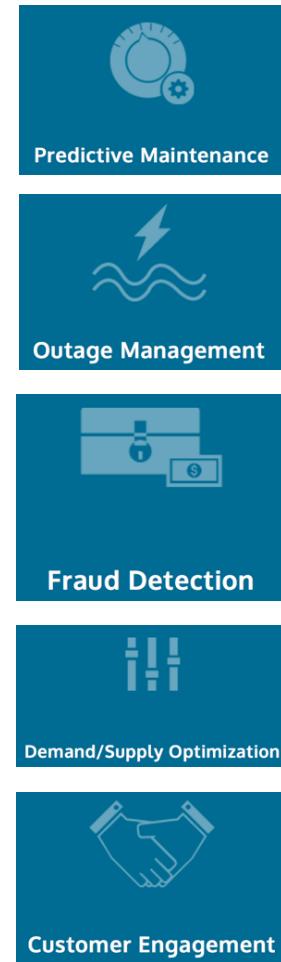


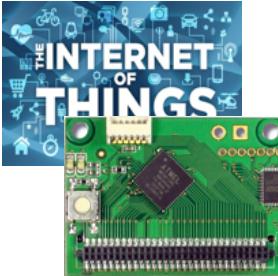
NEED BIG DATA ANALYTICS?

By Congduc Pham for WaterSense project

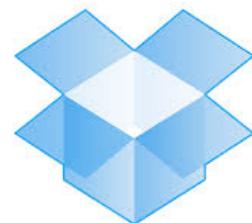


Graphics from <http://www.vitria.com/iot-analytics/>





DEDICATED IoT CLOUD



Dropbox



Firebase



FIWARE

Axēda®

ioBridge®
Connect things.

ThingSpeak



GroveStreams

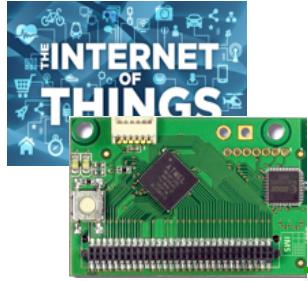


SensorCloud™



openRemote

TempoIQ



USING ThingSpeak

By Congduc Pham for WaterSense project



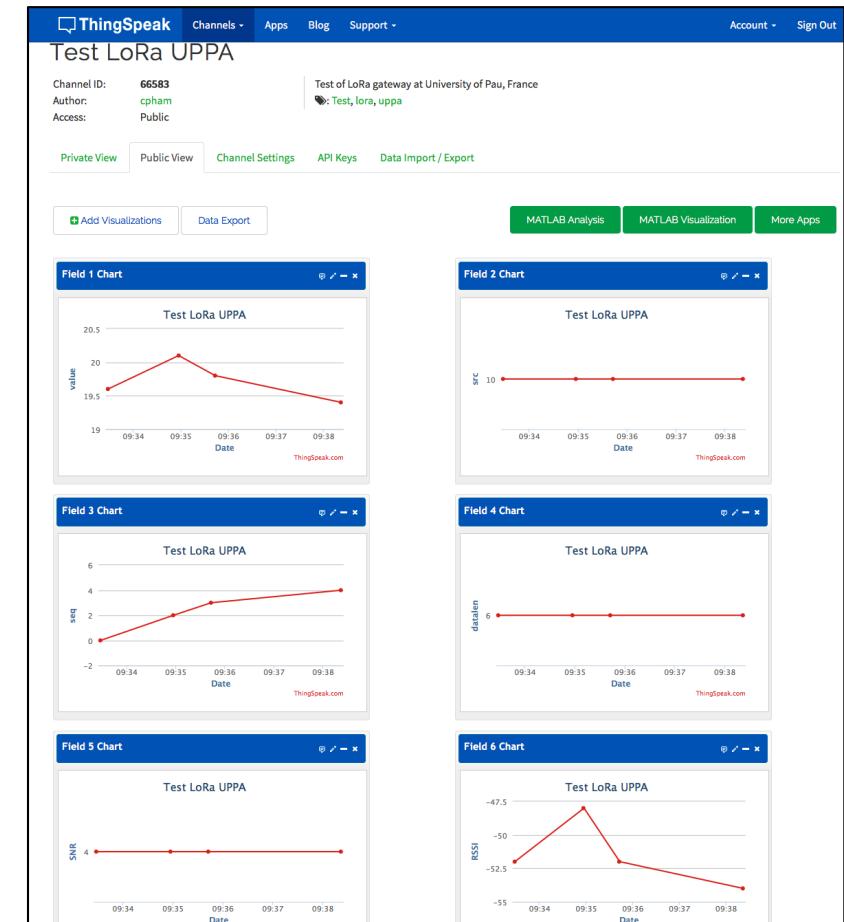
ThingSpeak | Channels | Apps | Blog | Support

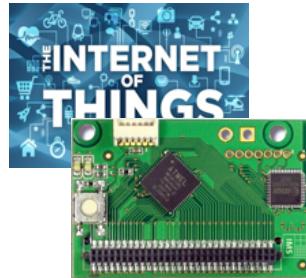
User: cpham

Test LoRa UPPA

Channel ID: 66583
Author: cpham
Test of LoRa gateway at University of Pau, France

Test, lora, uppa





USING GroveStreams

Screenshot of the GroveStreams Observation Studio interface showing temperature data from two sensors over time.

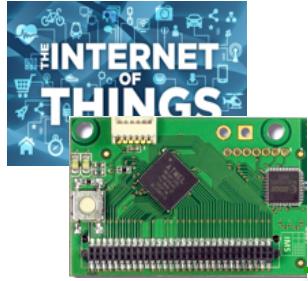
The interface includes:

- Observation Studio** sidebar with **Components** and **Dashboards** tabs.
- Components** list showing **sensor3** and **sensor6** components, each with a **temp** data series.
- temp** table showing 14 data points from sensor6.temp:

Row	Time	Value
1	22:26:03.633	25.87
2	22:23:40.604	25.87
3	22:21:35.489	25.87
4	22:17:32.907	25.87
5	22:15:41.998	25.87
6	22:11:40.452	23.43
7	22:07:36.184	23.43
8	22:03:33.273	22.94
9	21:59:33.532	23.43
10	21:55:28.121	23.92
11	21:51:22.015	22.94
12	21:47:22.836	23.92
13	21:45:17.126	23.92
14	21:41:13.750	22.94

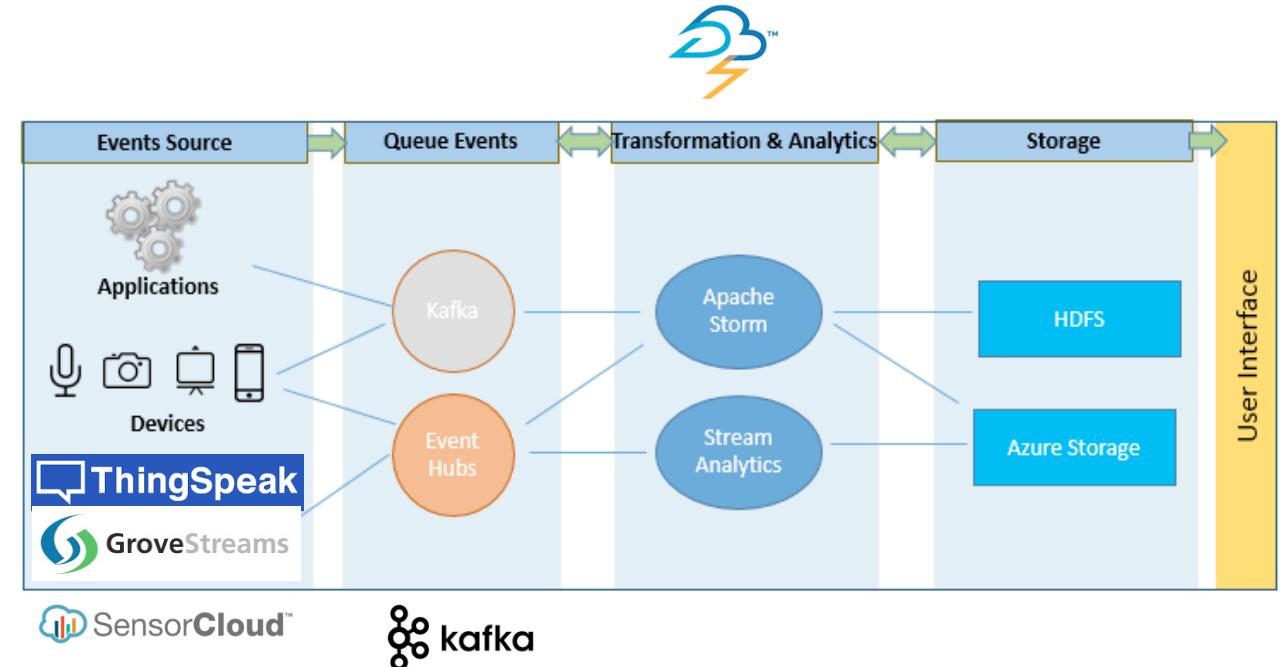
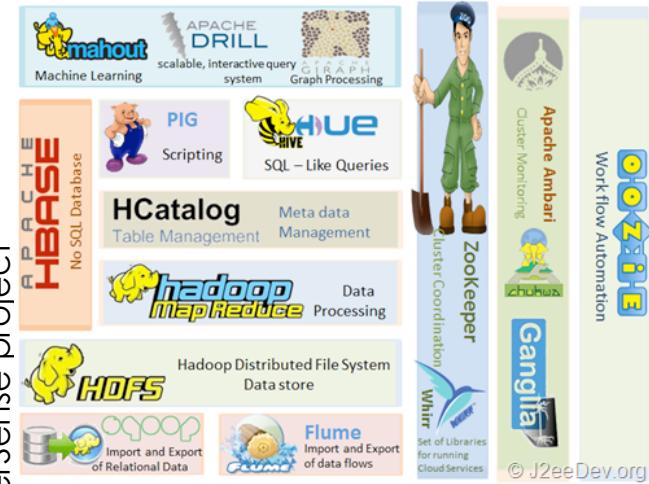
- Chart Type** dropdown.
- Quick View** panel showing the last updated value: **25.87** at **22:27:57**.
- Two line charts: one for **sensor6.temp** and one for **temp**.

By Congduc Pham for WaterSense project



APACHE BIG DATA ECOSYSTEM

By Congduc Pham for WaterSense project

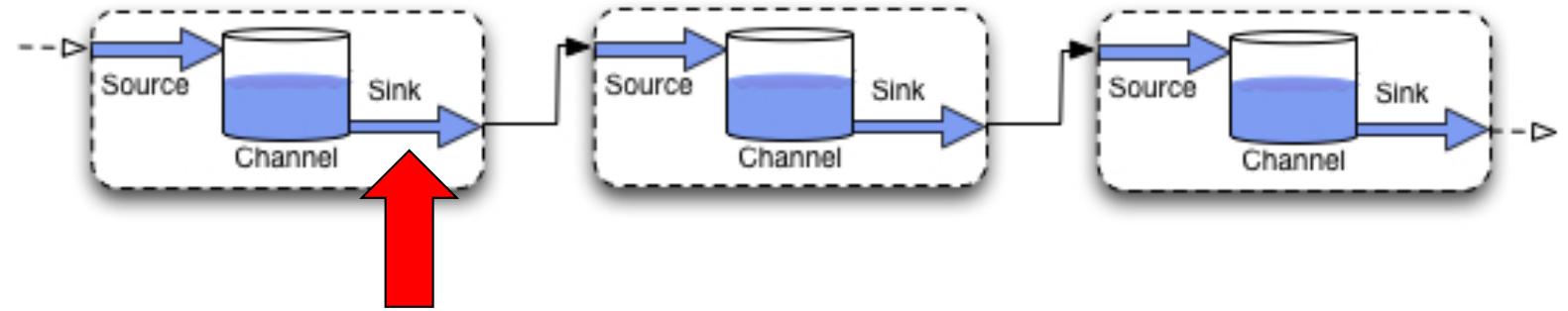


SensorCloud™

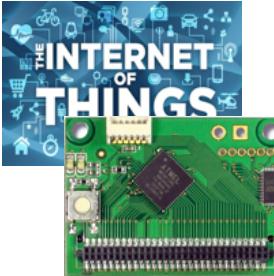
kafka



ThingSpeak

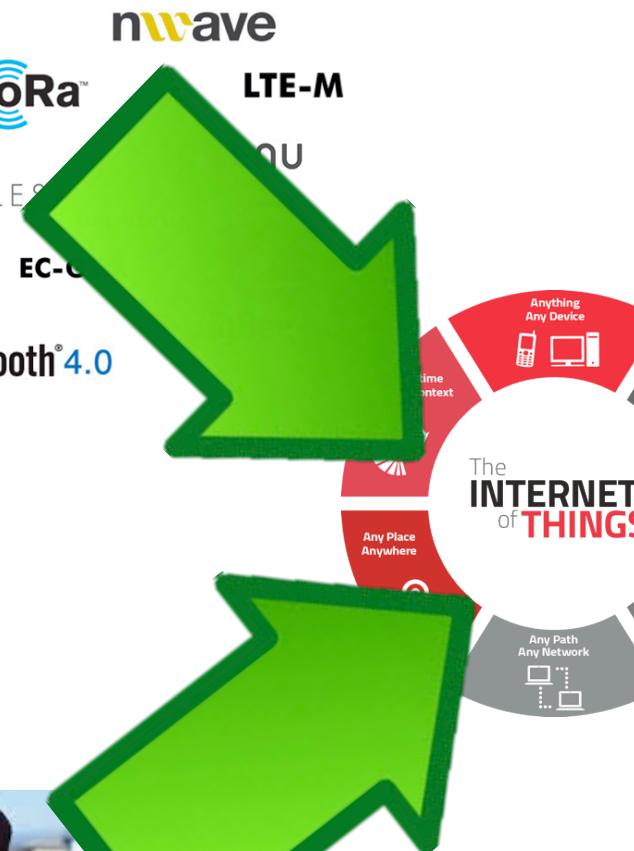


Advanced & customized data management



IOT BECOMES REALITY!

By Congduc Pham for WaterSense project



SIGFOX
One network A billion dreams

LoRa™

NB-LTE

WEIGHTLESS

DASH7™
ALLIANCE

Bluetooth® 4.0

nwave

LTE-M

EC-Council

OU



Firebase

FIWARE

Axeda

ioBridge®
Connect things.

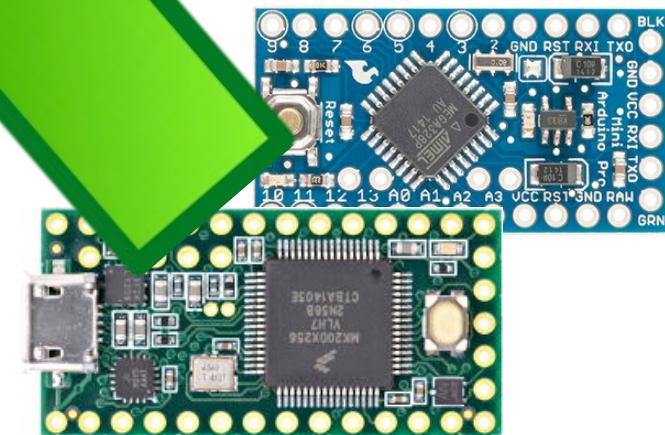
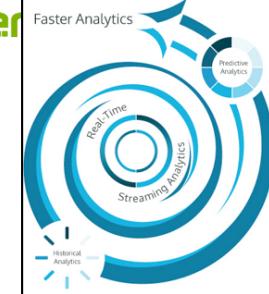
ThingSpeak

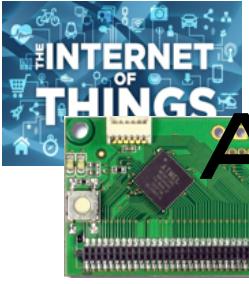
ensorCloud™

openRan

GroveStreams

freeboard

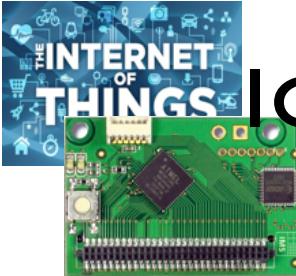




A REALITY FOR EVERYBODY?

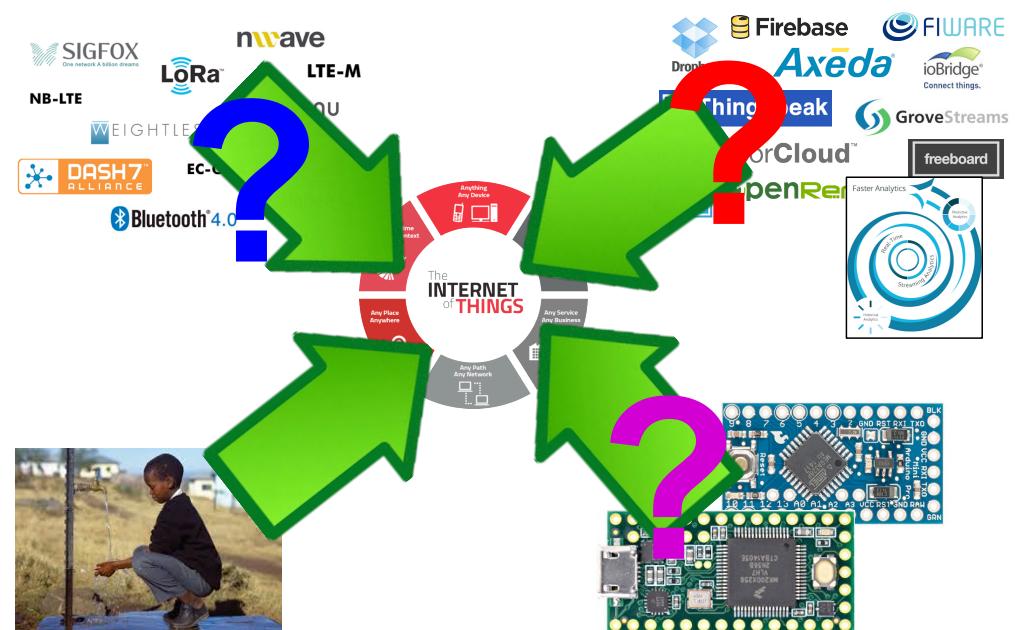
By Congduc Pham for WaterSense project





IoT IN DEVELOPING COUNTRIES OR RURAL AREAS?

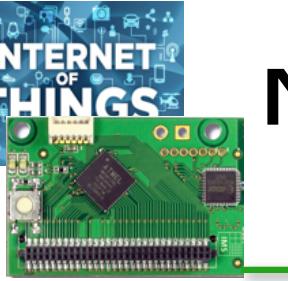
- ❑ Developing countries/rural areas are still far from being ready to enjoy the smallest benefit of IoT
 - ❑ lack of infrastructure
 - ❑ high cost of hardware
 - ❑ complexity in deployment
 - ❑ lack of technological eco-system and background





MATURATION OF THE IoT MARKET...

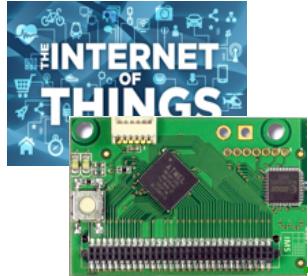
By Congduc Pham for WaterSense project



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

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



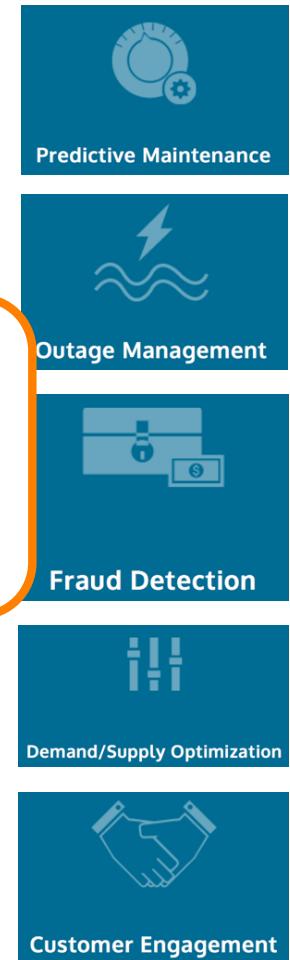


CLOUD & BIG DATA ANALYTICS

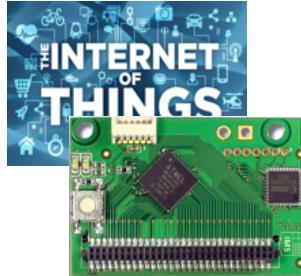
By Congduc Pham for WaterSense project



Internet connectivity is weak
and expensive



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



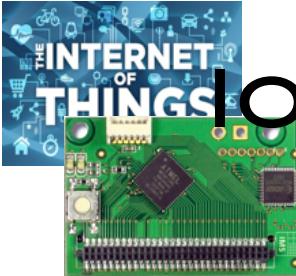
WAZIUP: LOW-COST IoT

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

AFFORDABLE
TECHNOLOGIES
TO
EMPOWER
RURAL ECONOMIES

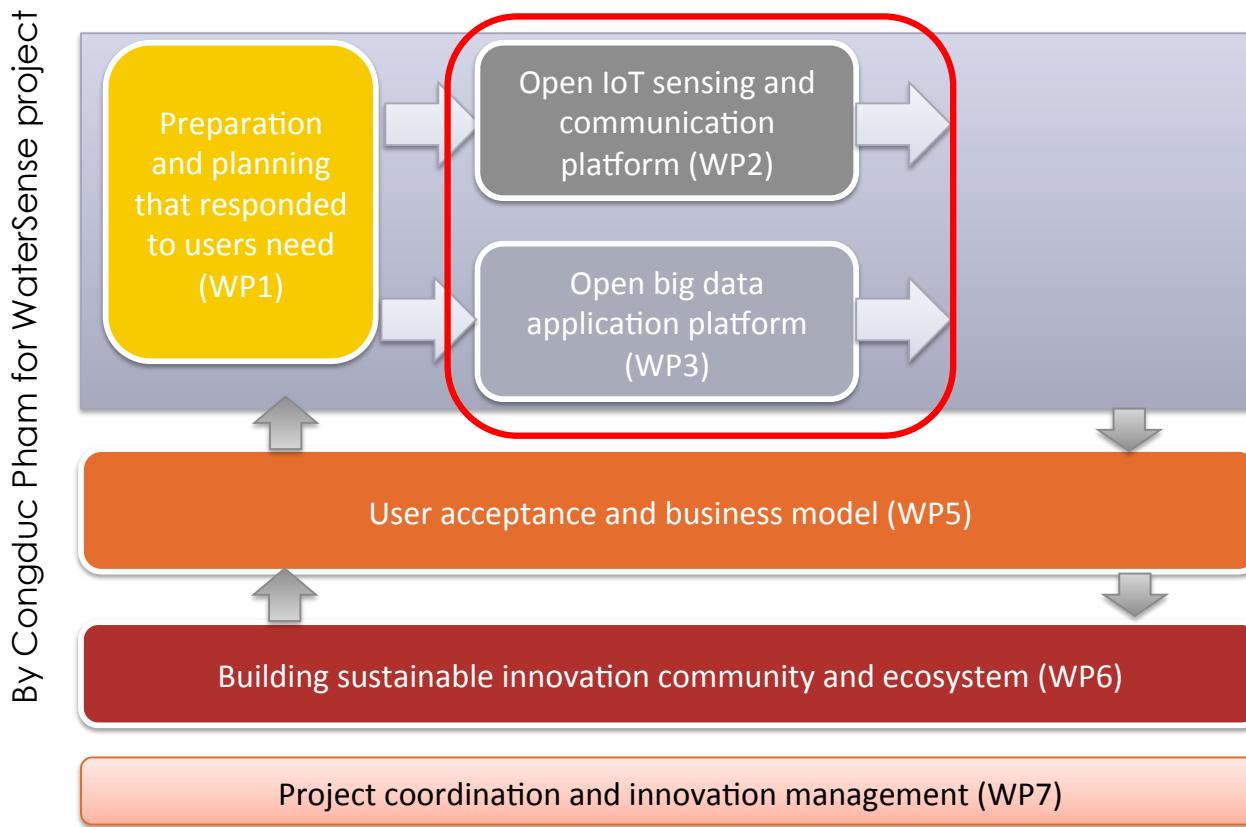
By Congduc Pham for WaterSense project

-
- FBK/CREATENET, Italy (Coordinator)**
 - EASY GLOBAL MARKET, France**
 - UNIVERISY of PAU, France**
 - UNPARALLEL INNOVATION, Portugal**
 - INNOTEC21, Germany**
 - UNIVERSITY GASTON BERGER, Senegal**
 - CODER4AFRICA , Senegal**
 - CTIC DAKAR, Senegal**
 - UNIVERSITY of BOBO-DIOULASSO, Burkina-Faso**
 - ISPACE, Ghana**
 - FARMERLINE, Ghana**
 - LAFRICAINE DARCHITECTURE, Togo**



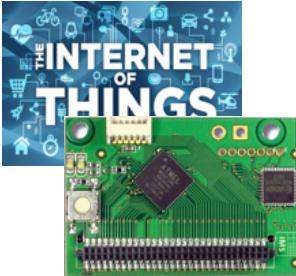
IoT FOR RURAL APPLICATIONS IN DEVELOPPING COUNTRIES

- ❑ WAZIUP is an EU H2020 project (2016-2019)
- ❑ contributes to long-range IoT & open big data with WP2 & WP3



By Congduc Pham for WaterSense project





LOW-COST HARDWARE

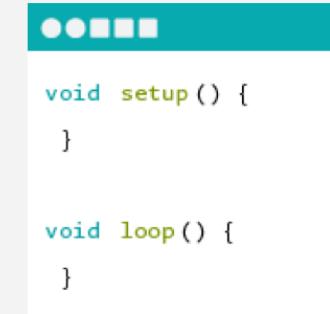


WHAT IS ARDUINO?

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

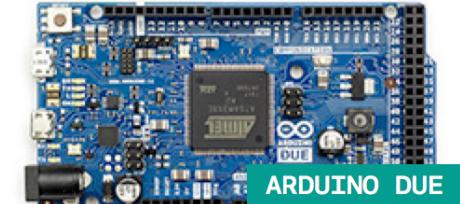
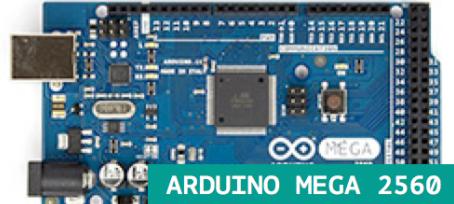
ARDUINO BOARD

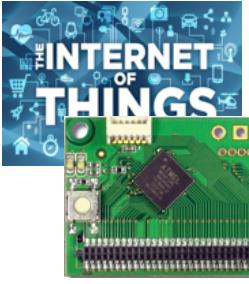
Arduino senses the environment by receiving inputs from many sensors, and affects its surroundings by controlling lights, motors, and other actuators.



ARDUINO SOFTWARE

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

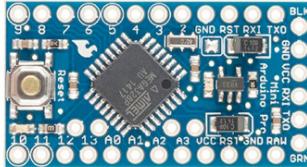




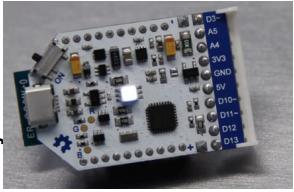
LARGE ECOSYSTEM, STILL GROWING!

By Congduc Pham for WaterSense project

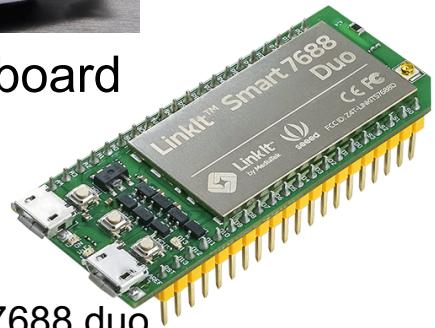
Arduino Pro Mini



LoPy



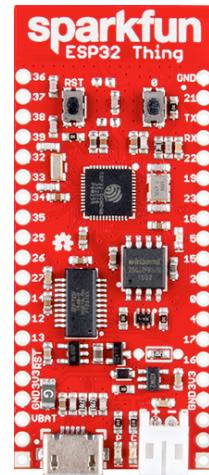
Theairboard



LinkIt
Smart7688 duo



Adafruit Feather



Sparkfun ESP32
Thing



Expressif ESP32



Tessel

<http://www.postscapes.com/internet-of-things-hardware/>

<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/>



Teensy 3.2



STM32 Nucleo-32



SodaqOnev2

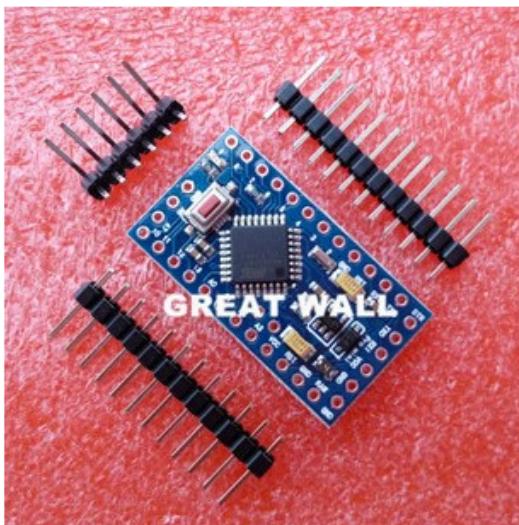


Tinyduino



AND TERRIBLY CHEAPER !!!

By Congduc Pham for WaterSense project



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**

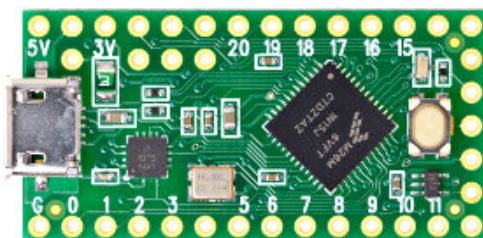
Livraison : 15-34 jours (envoyé en 7 jours ouvrables)

Quantité : Kit (55350 Kits available)

Montant total : **€ 1,78**

[Acheter maintenant](#)

[Ajouter au panier](#)

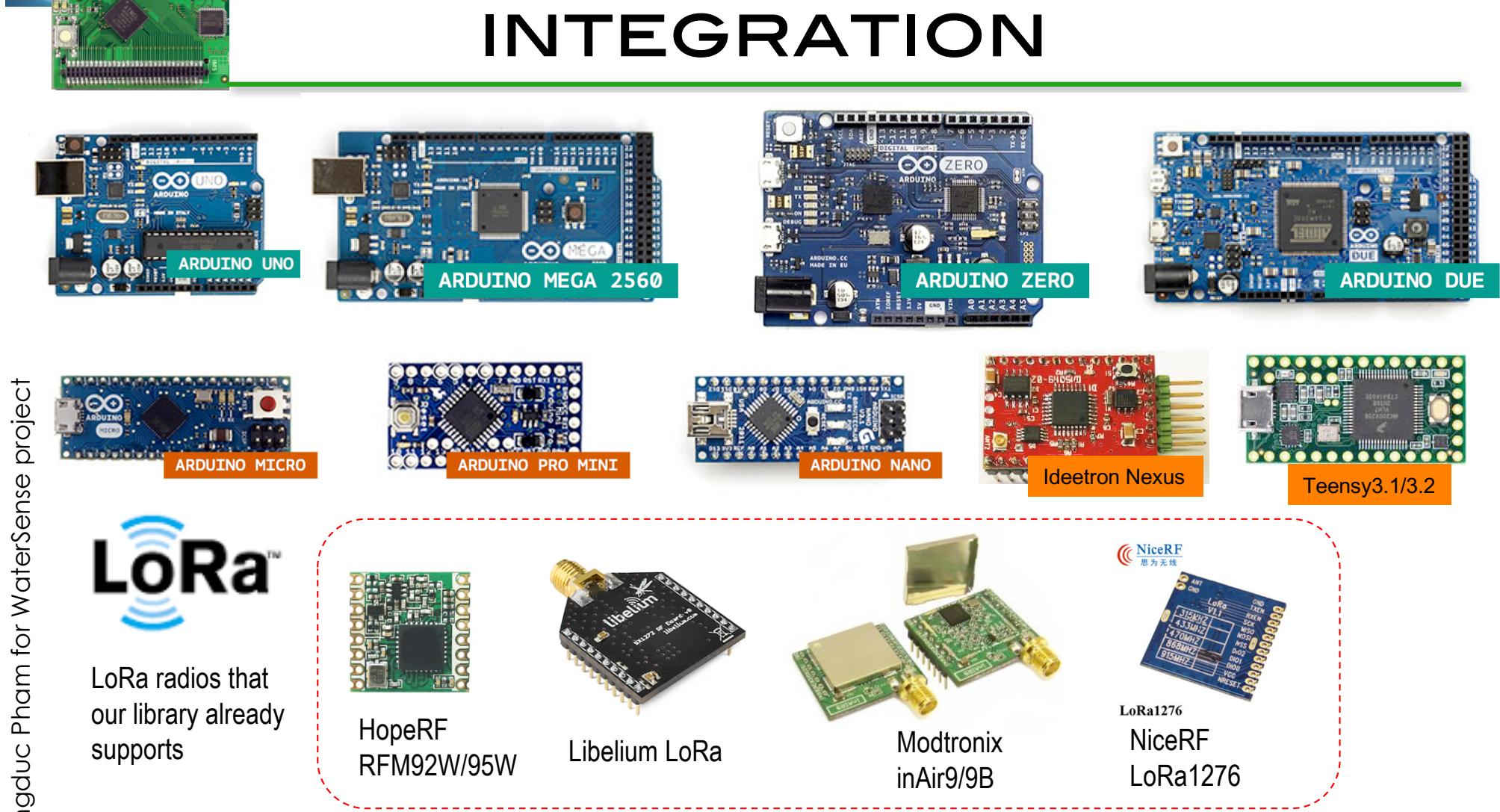


ARM Cortex-M0+ processor at 48 MHz, 62K Flash, 8K RAM, 12 bit analog input & output, hardware Serial, SPI & I2C, USB, and a total of 27 I/O pins

10€



SW/HW BUILDING BLOCKS INTEGRATION



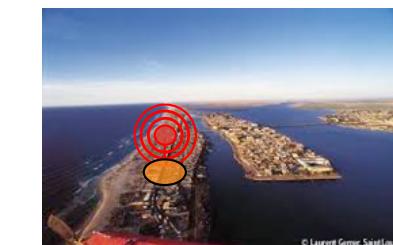
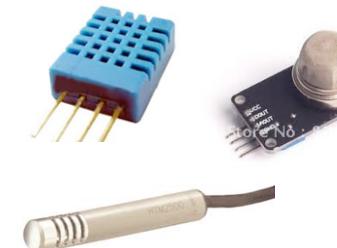
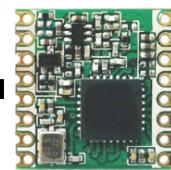
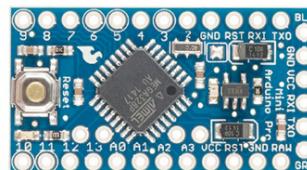
Long-Range communication library



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,...

By Congduc Pham for WaterSense project





READY-TO-USE TEMPLATES

By Congduc Pham for WaterSense project



Physical
sensor
reading



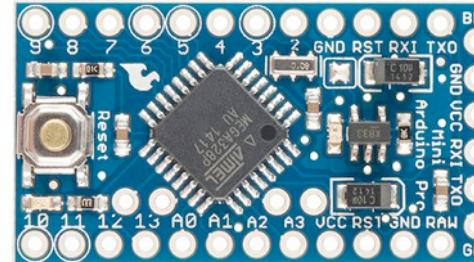
Physical
sensor
reading



Physical
sensor
reading



Physical
sensor
management

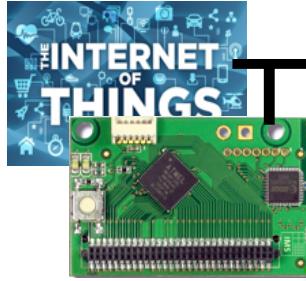


Activity duty-
cycle, low
power

Security

Long-range
transmission

Logical sensor
management



TEMPLATES ARE AVAILABLE ON GITHUB

By Congduc Pham for WaterSense project

```
/*
 * temperature sensor on analog 0 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
 * MERCHANTABILITY or FITNESS FOR
 * GNU General Public License for
 *
 * You should have received a copy
 * along with the program. If not
 */
*****  

// Include the SX1272
#include "SX1272.h"  

//  

// IMPORTANT  

// please uncomment only 1 choice  

// it seems that both HopeRF and M  

// boards we set the initial power  

// uncomment if your radio is an H  

#define RADIO_RF95_05  

// uncomment if your radio is a No  

#define RADIO_INA198  

//  

// THINGS  

*****  

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

CongducPham / LowCostLoRaGw

Code Issues 6 Pull requests 0 Pulse Graphs

Low-cost LoRa gateway with SX1272 and Raspberry

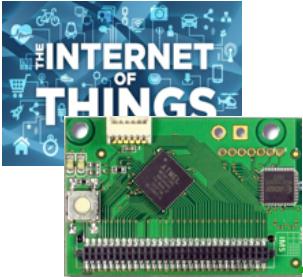
11 commits 1 branch 0 releases 0 contributors

Branch: master New pull request New file Find file HTTPS https://github.com/CongducPham/LowCostLoRaGw Download ZIP

File	Author	Message	Date
Arduino_LoRa_Gateway	Arduino	modified some low-power info	10 days ago
Arduino_LoRa_temp	Arduino	modified some low-power info	10 days ago
libraries/SX1272		Added Teensy support	21 days ago
CONTRIBUTORS	Congduc Pham	modified some low-power info	Latest commit a46b0f7 10 days ago
Arduino_LoRa_Gateway	Raspberry	modified some low-power info	10 days ago
.DS_Store	.DS_Store	changes in the SX1272 lib, gateway and temperature example	2 months ago
README.md	Arduino	modified some low-power info	10 days ago

Fisrt, you will need the Arduino IDE 1.6.6 or later (left). Then get the LoRa library from our github: <https://github.com/CongducPham/LowCostLoRaGw> (right).

Get into the Arduino folder and get both Arduino_LoRa_temp and SX1272 folder. Copy Arduino_LoRa_temp into your “sketch” folder and SX1272 into “sketch/libraries”



COMPILING

By Congduc Pham for WaterSense project

```
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 FOR A PARTICULAR PURPOSE. See the
 * GNU General Public License for more details.
 *
 * You should have received a copy of the GNU General Public License
 * along with the program. If not, see <http://www.gnu.org/licenses/>.
 */
*****  

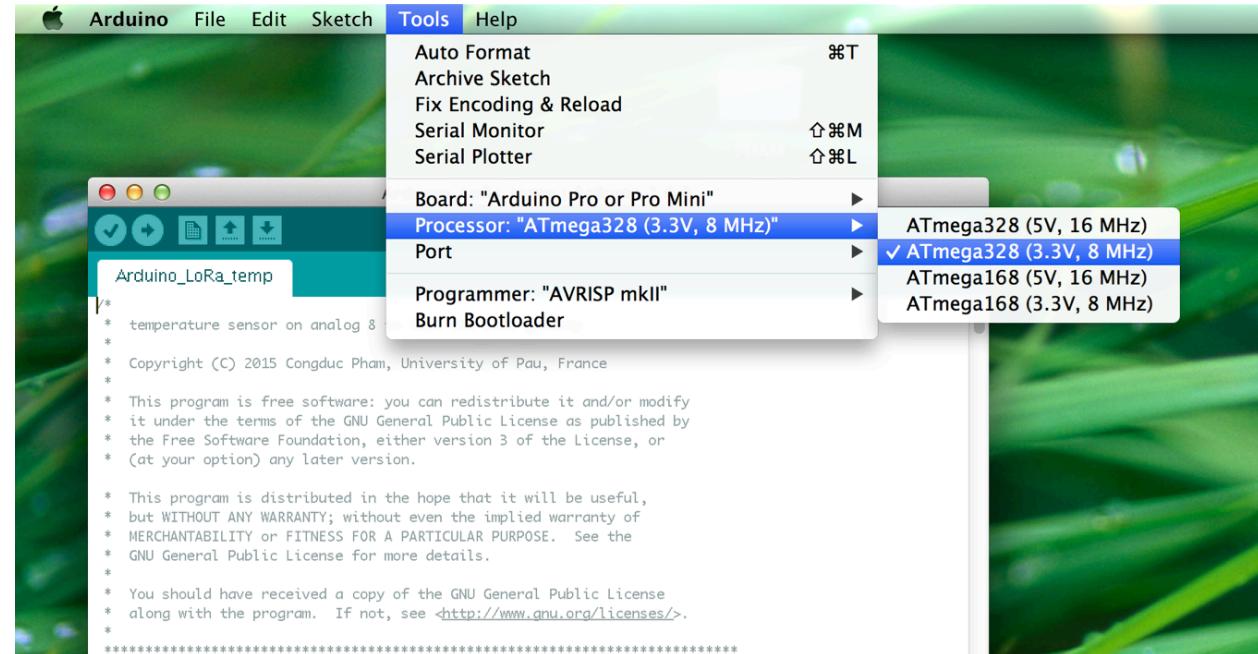
// Include the SX1272
#include "SX1272.h"  

// IMPORTANT
// please uncomment only 1 choice
// it seems that both HopeRF and Medionix board use the PA_BOOST pin and not the RFO. Therefore, for these
// boards we set the initial power to 'x' and not 'W'. This is the purpose of the define statement
// uncomment if your radio is an HopeRF RFM92W or RFM95W
#define RADIO_RF95_2_95
// uncomment if your radio is a Medionix inAir98 (the one with +20dBm features), if inAir9, leave comment
//#define RADIO_INAIR98
//  

// THROTTLE
*****  

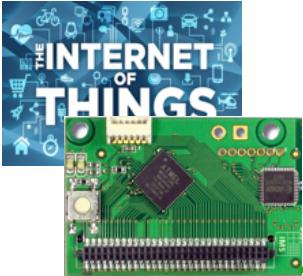
11  Teensy 3.2 / 3.1, Serial, 72 MHz optimized, US English on /dev/cu.usbmodem1433801
```



Open the Arduino_LoRa_temp sketch and select the Arduino Pro Mini board with its 3.3V & 8MHz version.

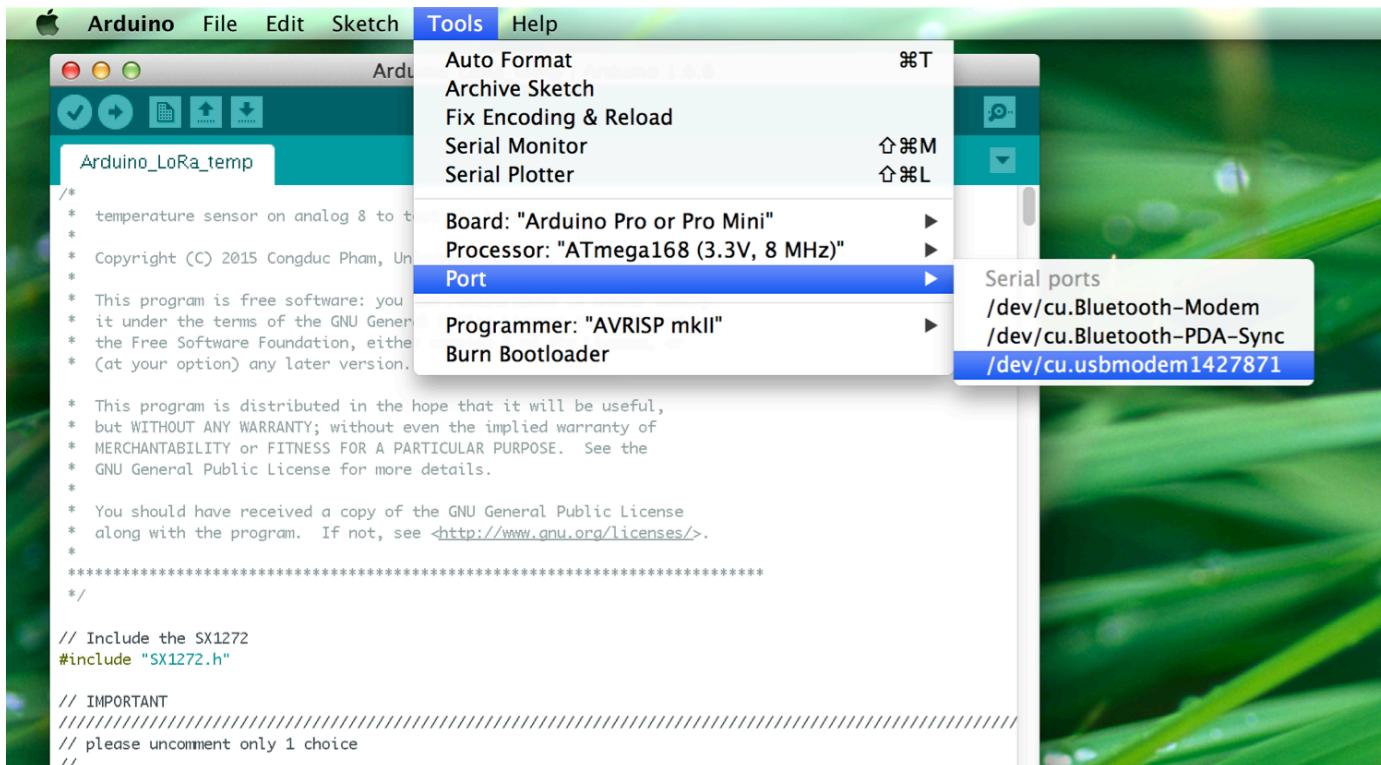
Then, click on the « verify » button





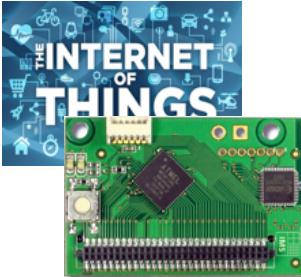
UPLOADING

By Congduc Pham for WaterSense project

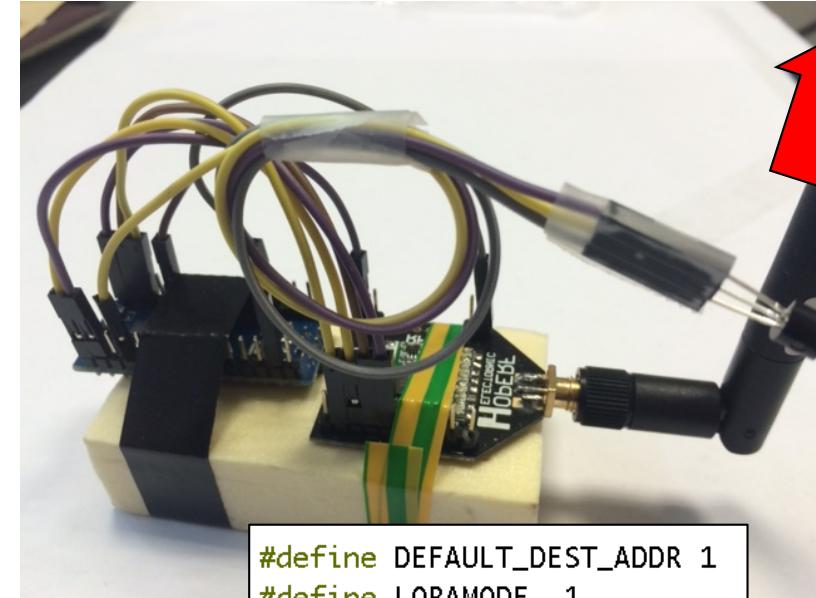


Connect the USB end to your computer and the USB port should be detected in the Arduino IDE. Select the serial port for your device. It may have another name than what is shown in the example. Then click on the « upload » button





BASIC EXAMPLE WITH TEMPERATURE SENSOR

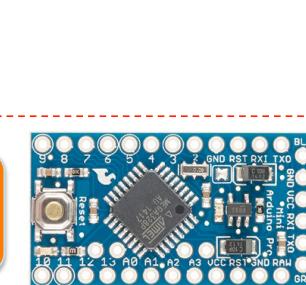


```
#define DEFAULT_DEST_ADDR 1  
#define LORAMODE 1  
#define node_addr 6
```

!\#\#TC/18.5



Physical sensor reading



Physical sensor management



Security

Activity duty-cycle, low power

Long-range transmission

Logical sensor management

By Congduc Pham for WaterSense project

The default configuration in the Arduino_LoRa_temp example is:

Send packets to the gateway (one or many if in range)

LoRa mode 1

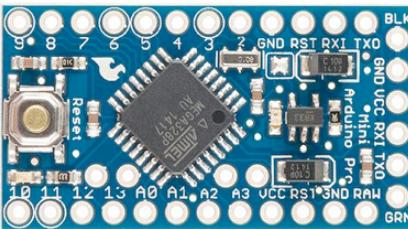
Node short address is 6



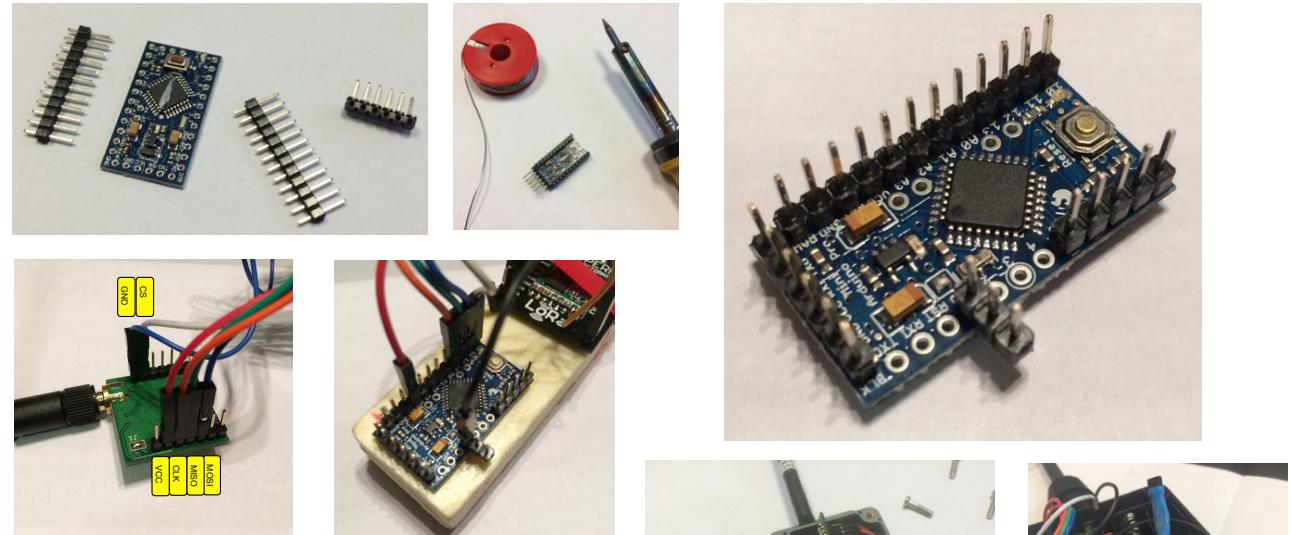
EASY INTEGRATION AND CUSTOMIZATION

By Congduc Pham for WaterSense project

Arduino Pro Mini



3.3v and 8MHz version



Avec la bootloader 1 pcs Pro Mini ATMEGA328 Pro Mini 3 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 Pack

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

Quantité :

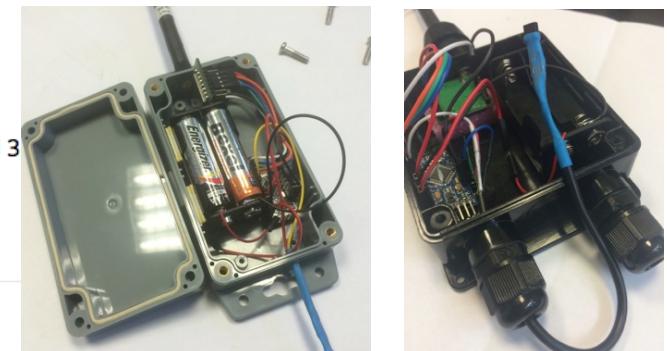
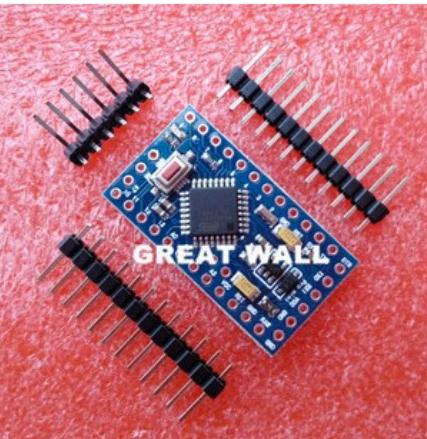
— 1 + Kit (55350 Kits available)

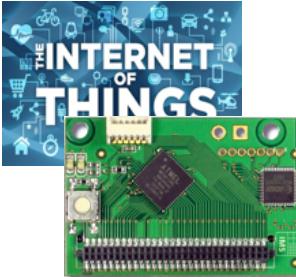
Montant total :

€ 1,78

[Acheter maintenant](#)

[Ajouter au panier](#)

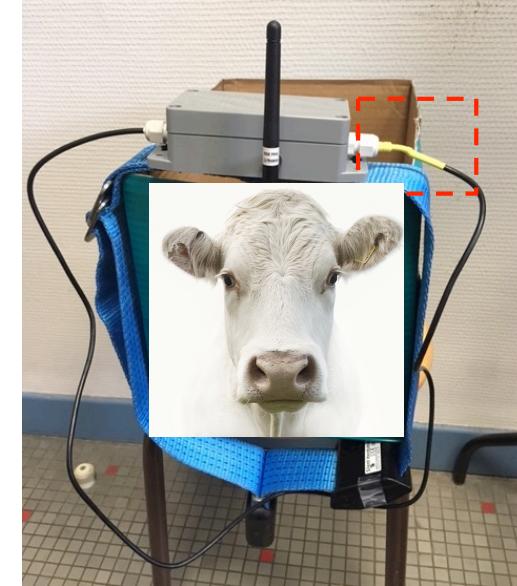
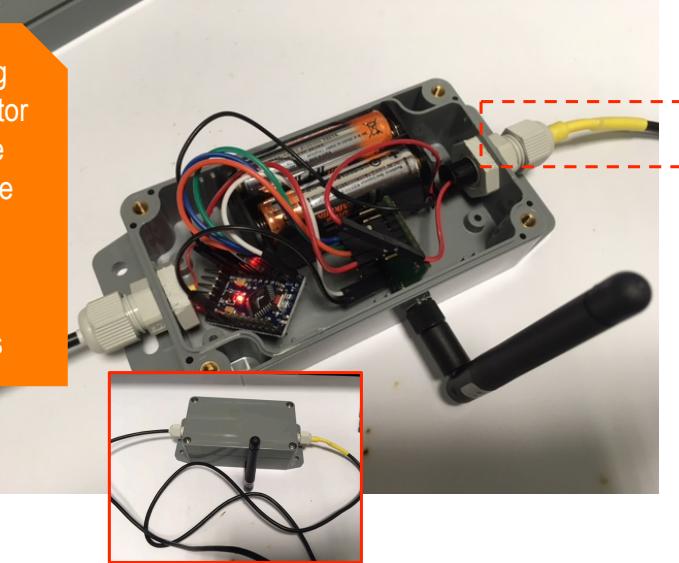




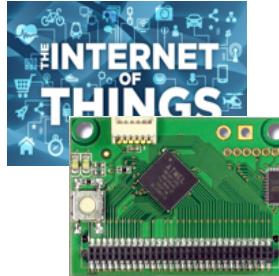
LOW-COST COLLAR FOR CATTLE RUSTLING

By Congduc Pham for WaterSense project

When connecting the male connector MC to the female connector FC, the board will be powered and will start sending periodic beacons

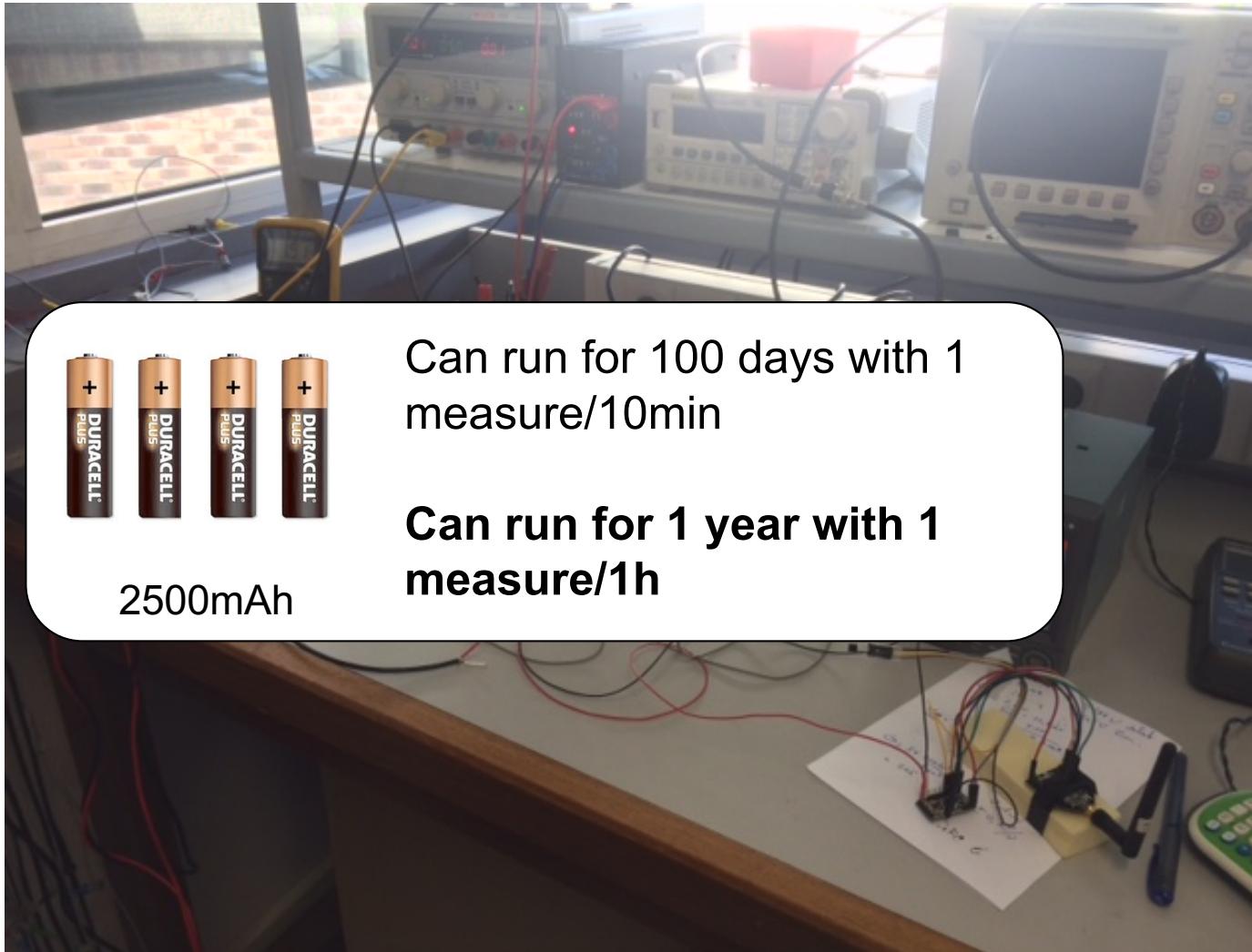


- The collar will be fixed to the cow, around neck. Example picture from Afimilk Silent Herdsman for health monitoring
- In our case, reception of beacon means that the cattle is in range
- If out-of-range, disconnected or damaged device, an alarm can be raised
- To detect collar cutting, the power wire will also goes around the cattle's neck

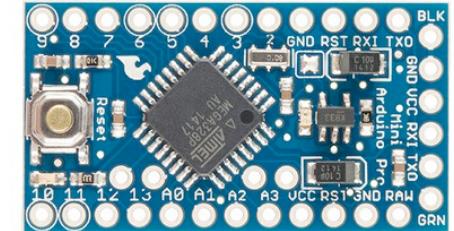


RUNNING FOR 1 YEAR WITH LOW-POWER MODE!

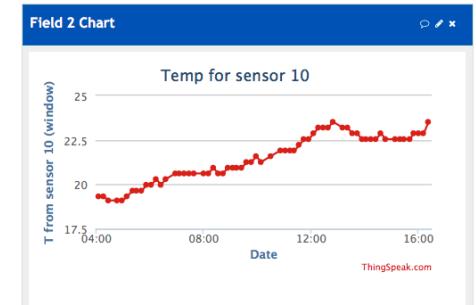
Low-Power library from RocketScream



By Congduc Pham for WaterSense project

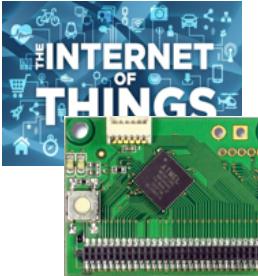


Wakes-up every 10min, take a measure (temp) and send to GW



120 μ A in deep sleep mode, 93mA when active and sending

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



RASPBERRY-BASED LORA GATEWAY

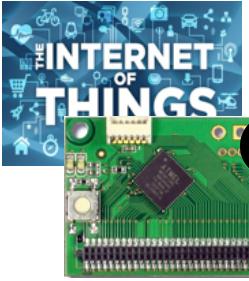


We can use all model of Raspberry. The most important useful feature is the Ethernet interface for easy Internet connection. Then WiFi and Bluetooth can be added with USB dongles. RPI3 provides built-in Ethernet, WiFi and Bluetooth!



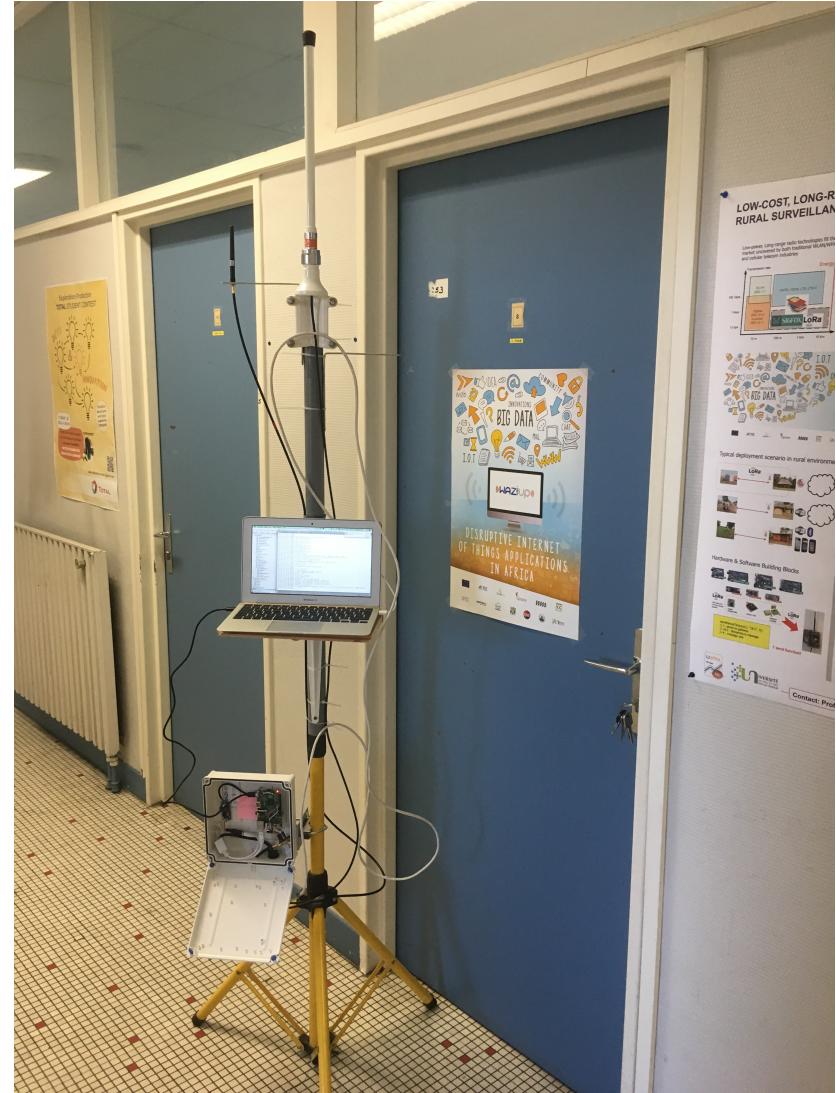
Less than 50€





OUR NEW GATEWAY CASING

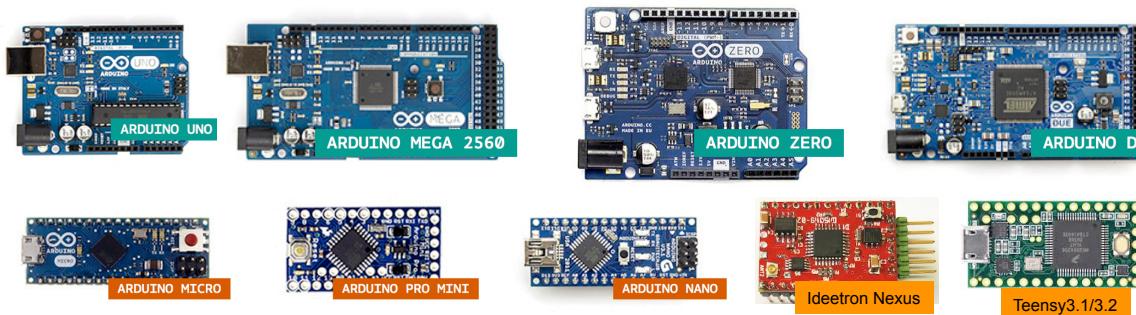
By Congduc Pham for WaterSense project



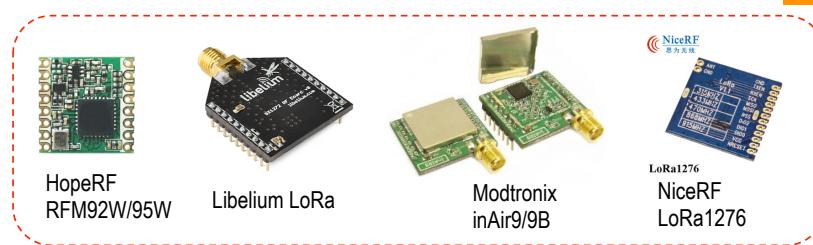


SIMPLICITY!

By Congduc Pham for WaterSense project



LoRa radios that our library already supports



Long-Range communication library

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

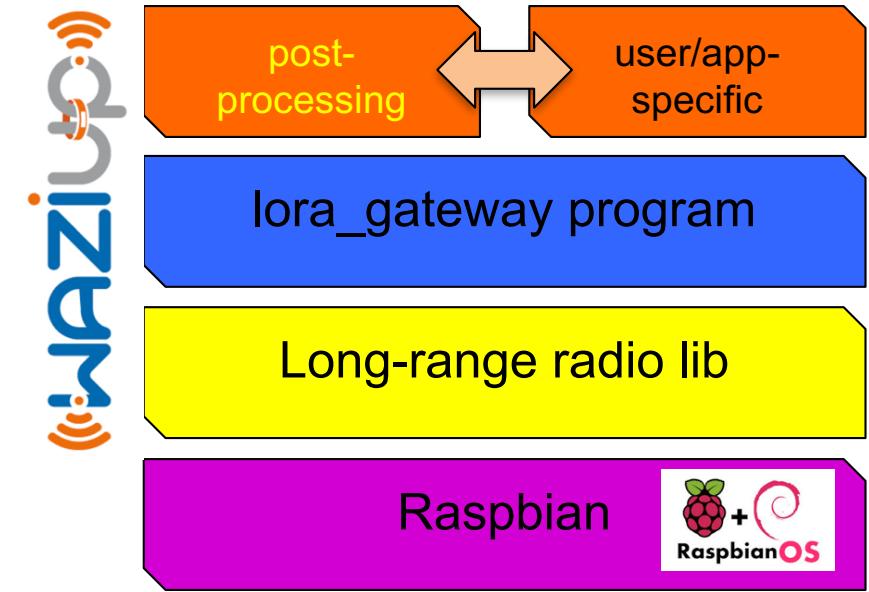
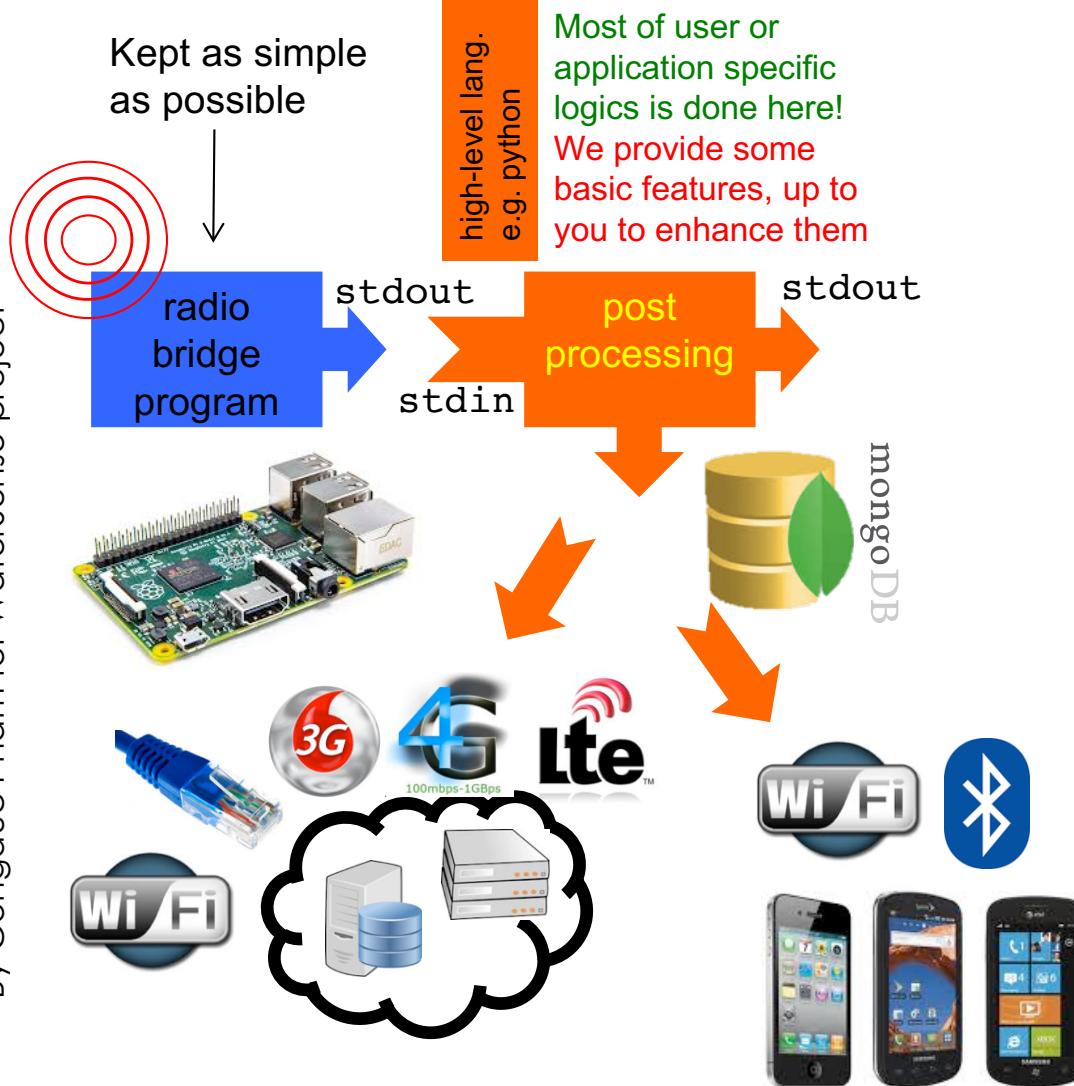
1 send function!

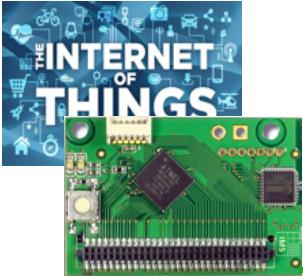




OUR LOW-COST GATEWAY ARCHITECTURE

By Congduc Pham for WaterSense project



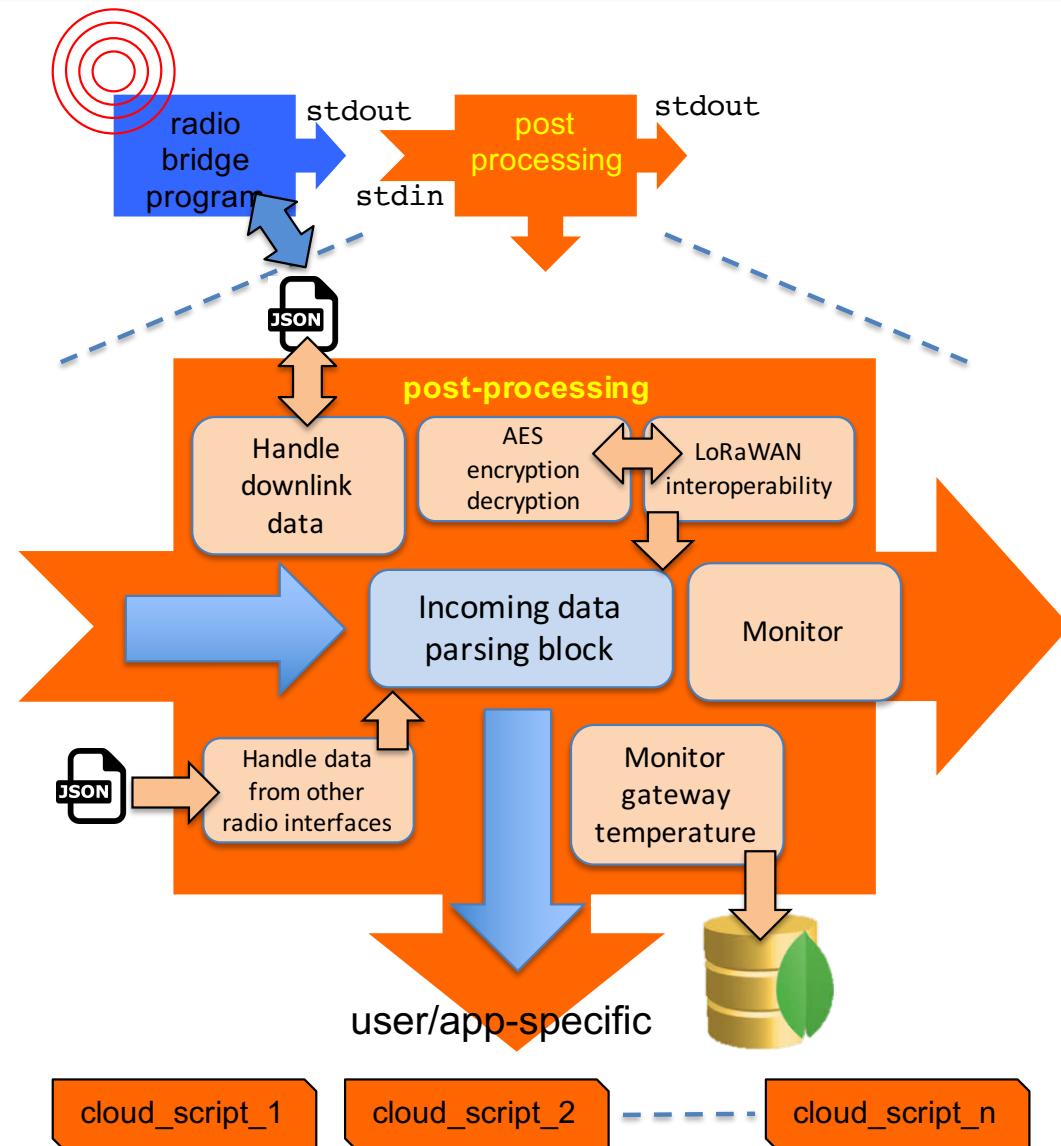


FROM GW TO CLOUD PLATFORMS

By Congduc Pham for WaterSense project

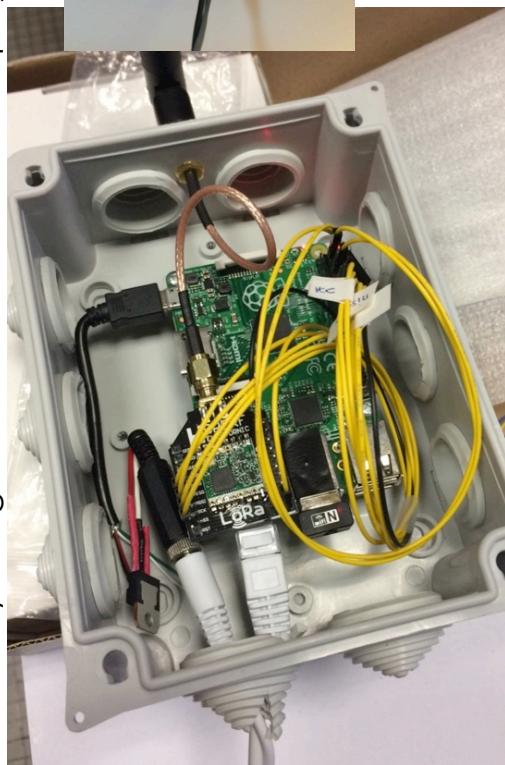
Once data is received at gateway, traditional Internet tools can be used to push data to cloud

High-level scripting language provides connectivity to any cloud platforms depending on end-user needs

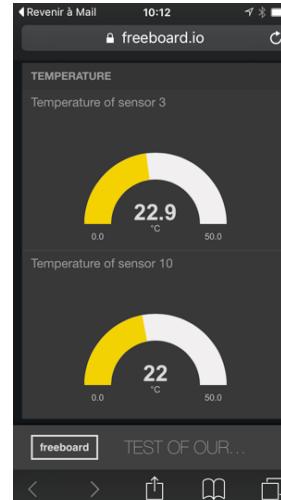




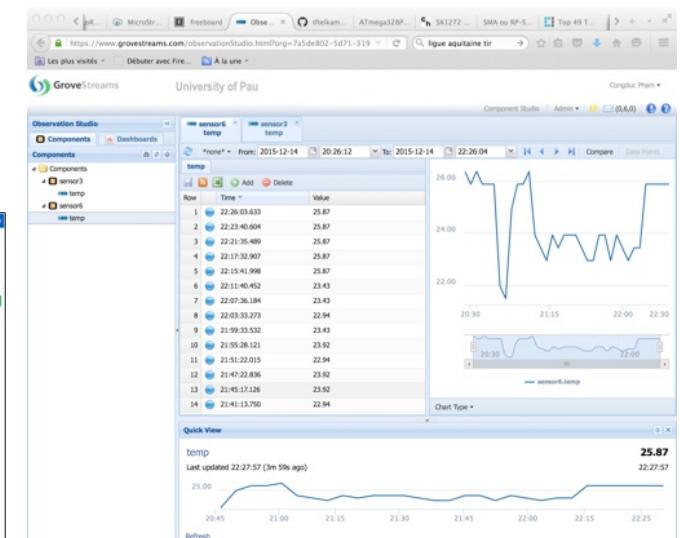
By Congduc Pham for WaterSense project



TEMPLATES FOR VARIOUS CLOUDS

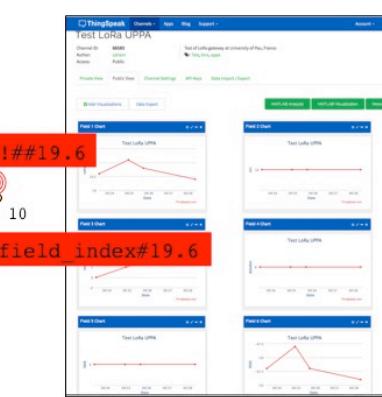
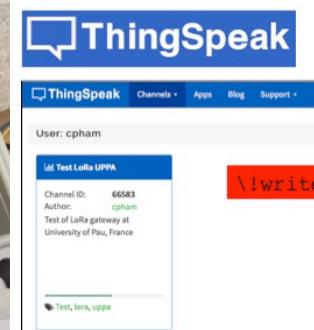


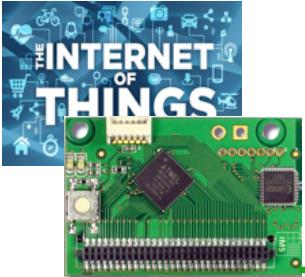
Dropbox



GroveStreams

SensorCloud™





DO IT YOURSELF !

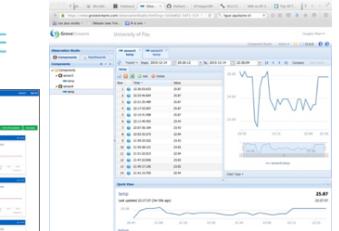
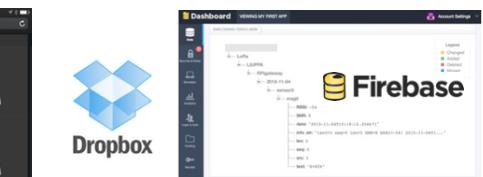
By Congduc Pham for WaterSense project



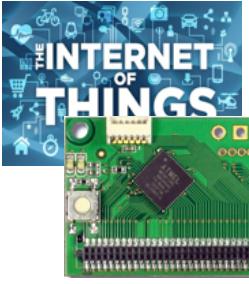
Step-by-step tutorial
and source code
available



Step-by-step tutorial
and source code
available

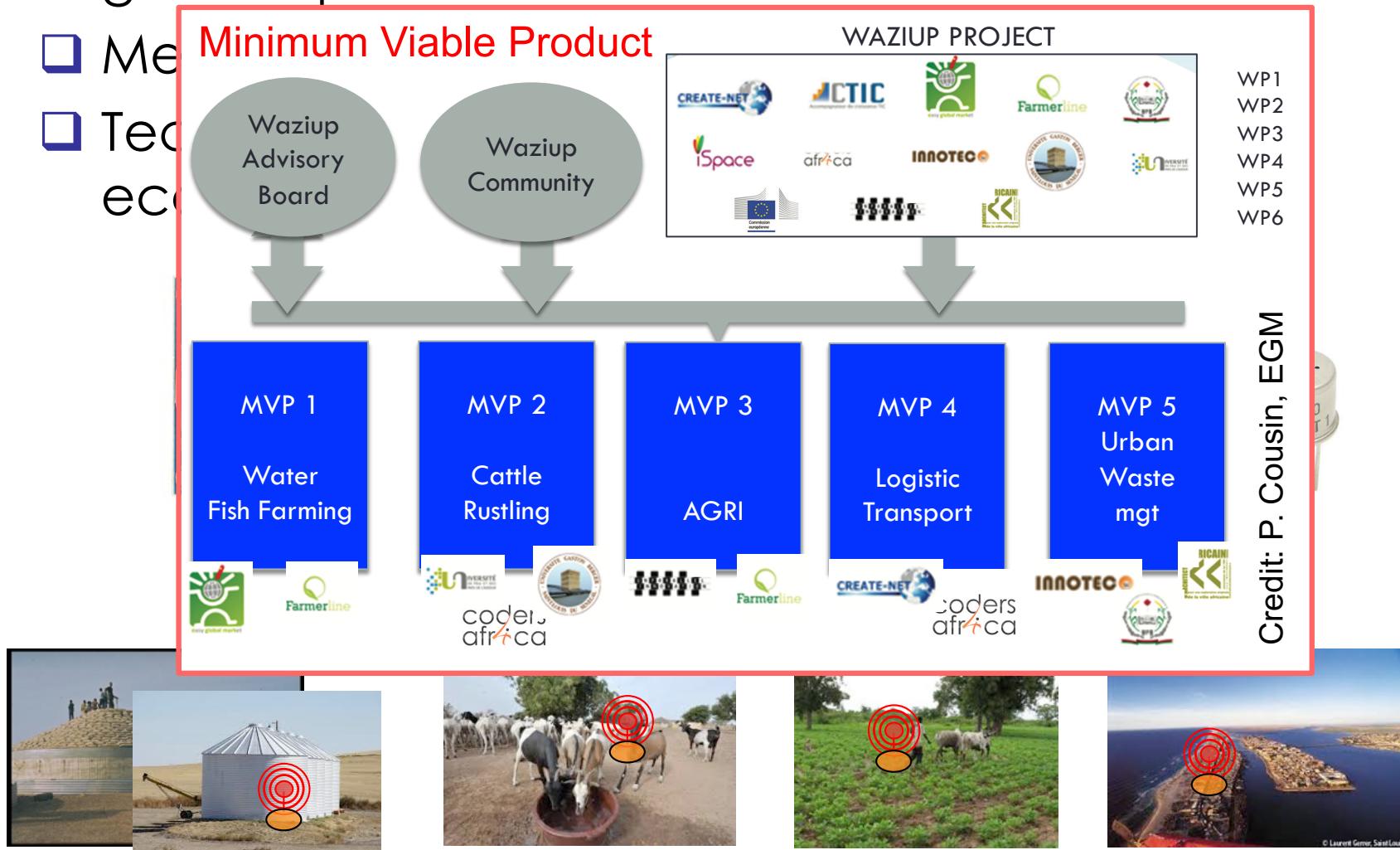


Python scripts
available

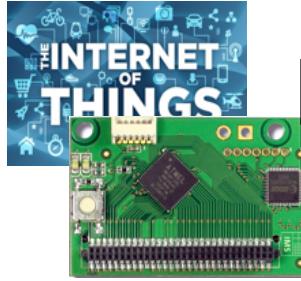


GENERIC SENSING IoT DEVICE

- Build low-cost, low-power, Long-range enabled generic platform
- Measure environmental parameters
- Technical specification for ecosystem

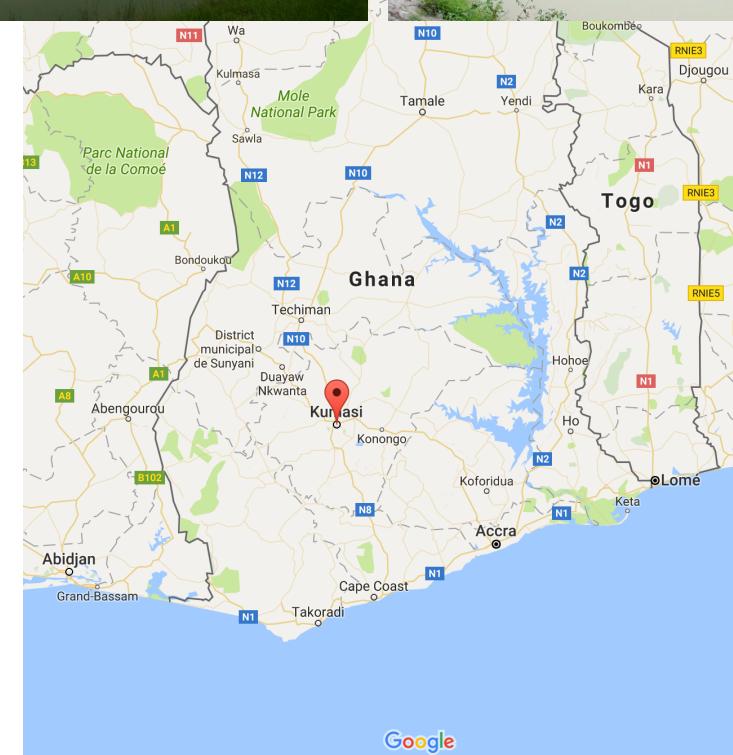


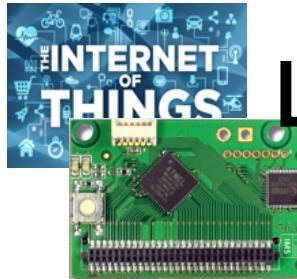
By Congduc Pham for WaterSense project



FISH FARMING IN KUMASI, GHANA

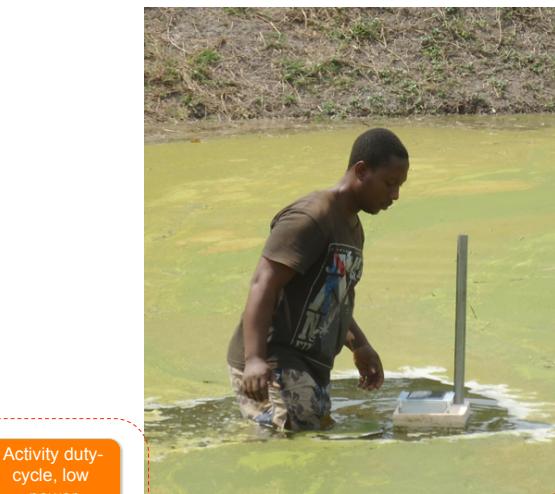
By Congduc Pham for WaterSense project



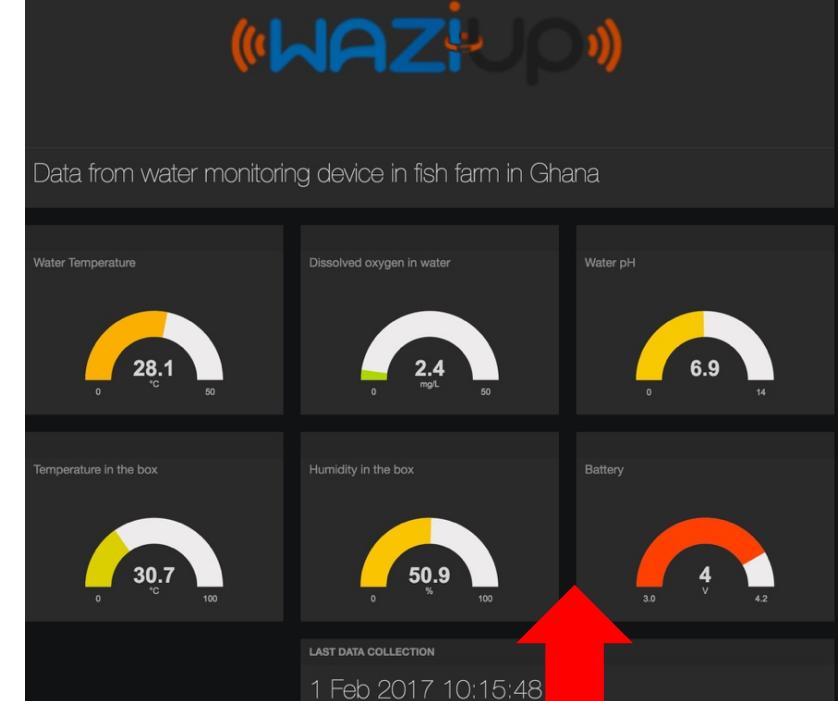


LOW-COST BUOY FOR FISH FARMING MVP

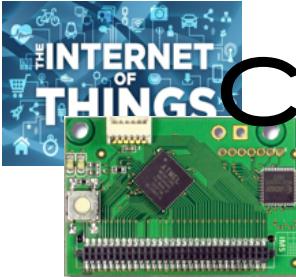
By Congduc Pham for WaterSense project



Credit: EGM

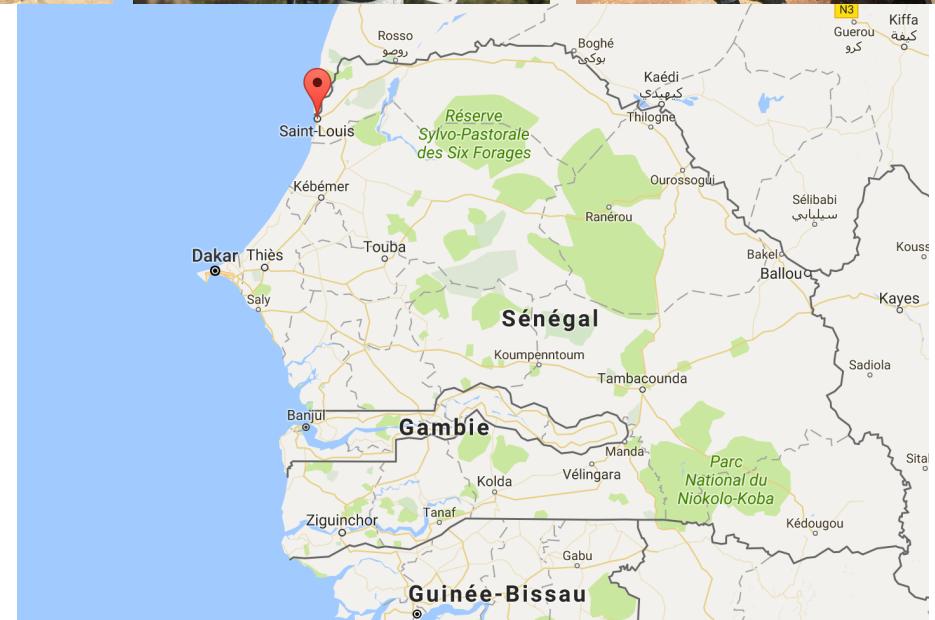
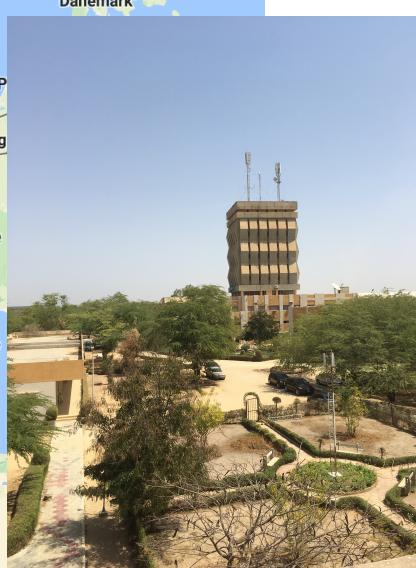


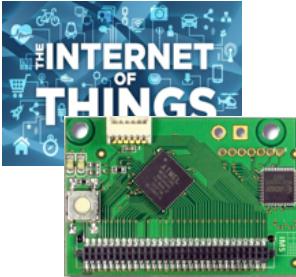
FIWARE



CATTLE RUSTLING IN SAINT-Louis, SENEGAL

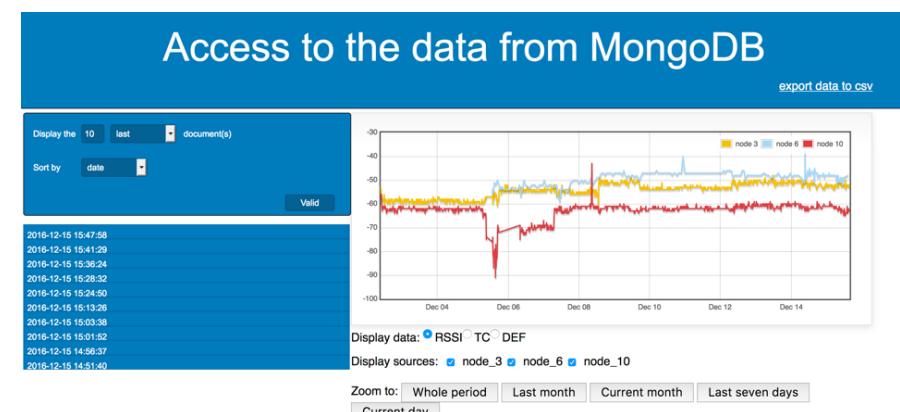
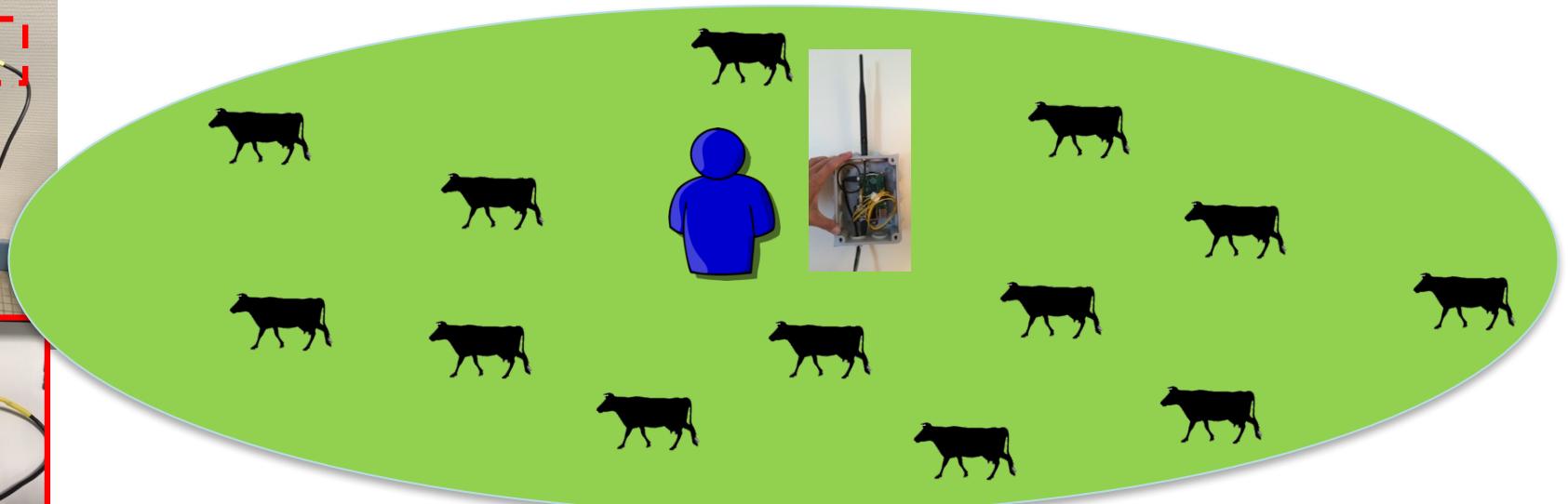
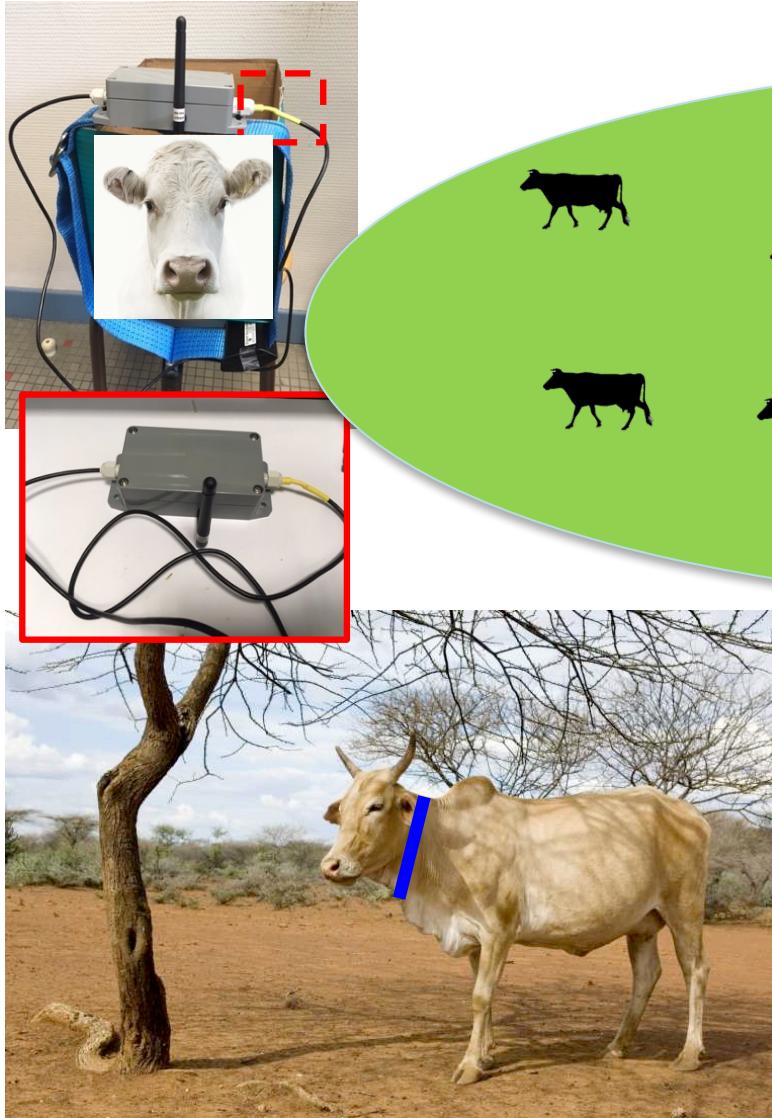
By Congduc Pham for WaterSense project

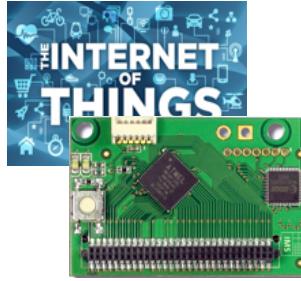




COLLAR FOR CATTLE RUSTLING MVP

By Congduc Pham for WaterSense project





TEST AT CIMEL, SAINT-LOUIS, SENEGAL

By Congduc Pham for WaterSense project





WORKING WITHOUT INTERNET ACCESS

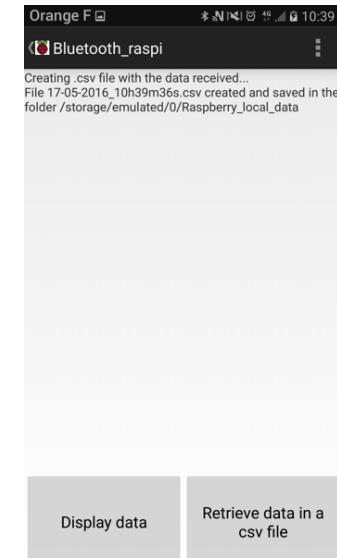
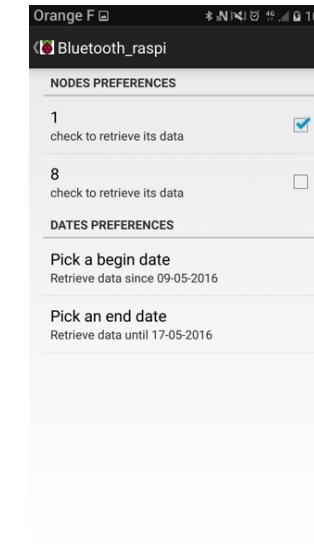
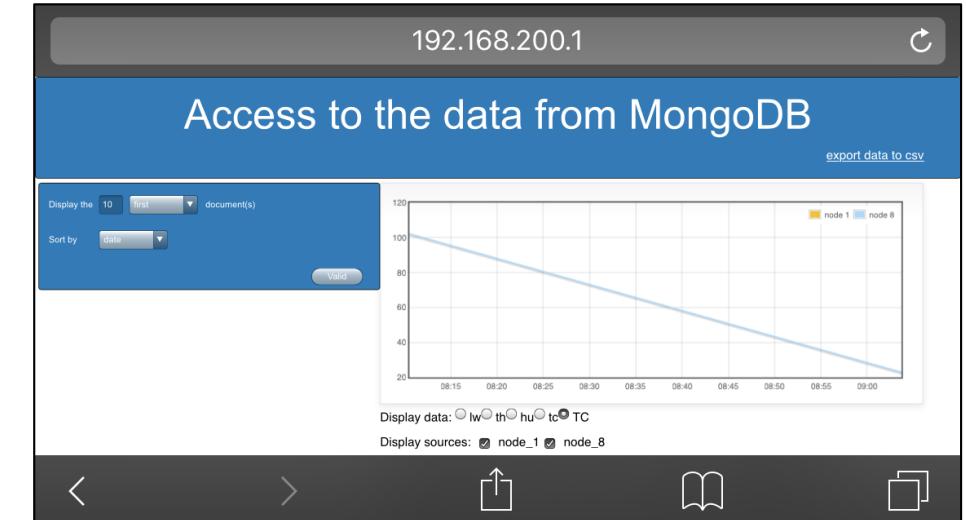
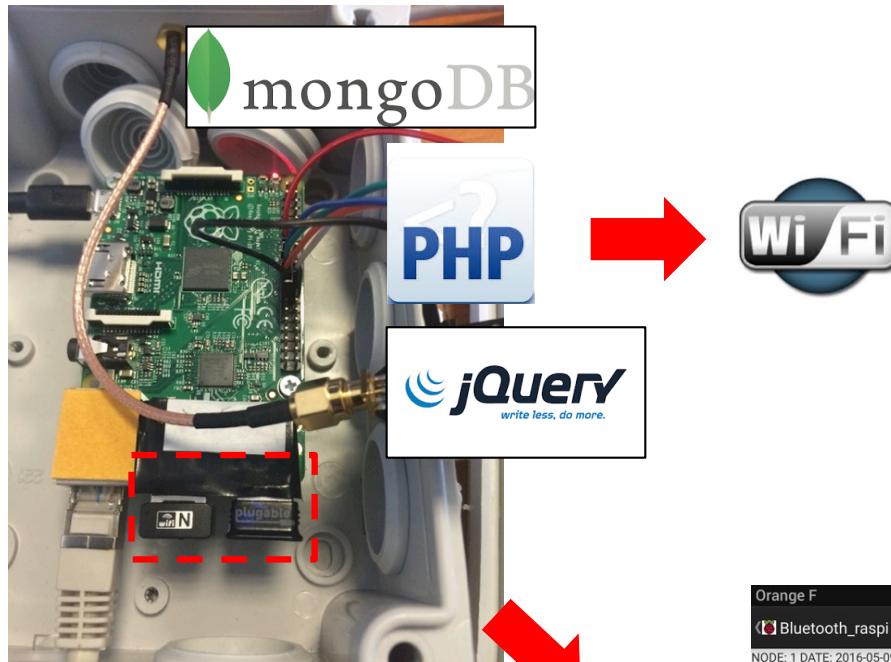
By Congduc Pham for WaterSense project

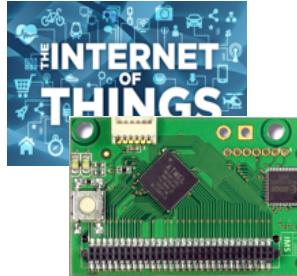




STANDALONE GATEWAY

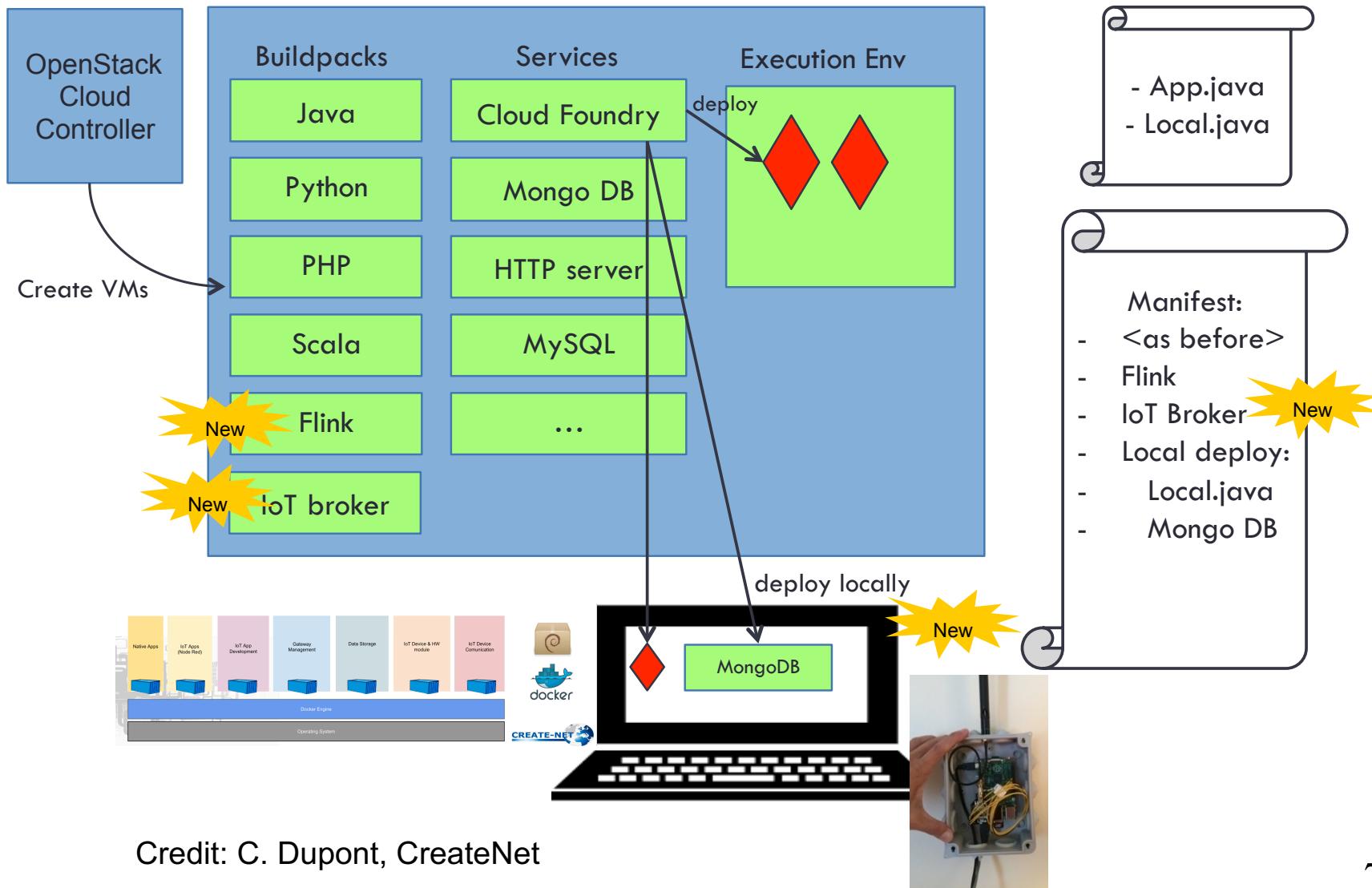
By Congduc Pham for WaterSense project





LOCAL DATA ANALYTICS

By Congduc Pham for WaterSense project



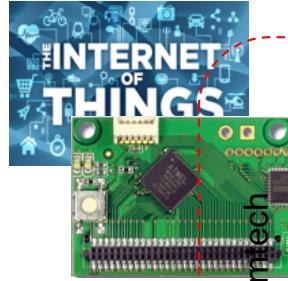


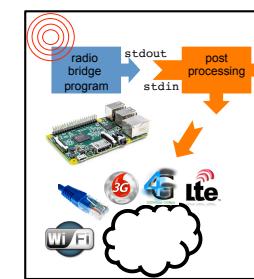
Figure from Semtech

By Congduc Pham for WaterSense project

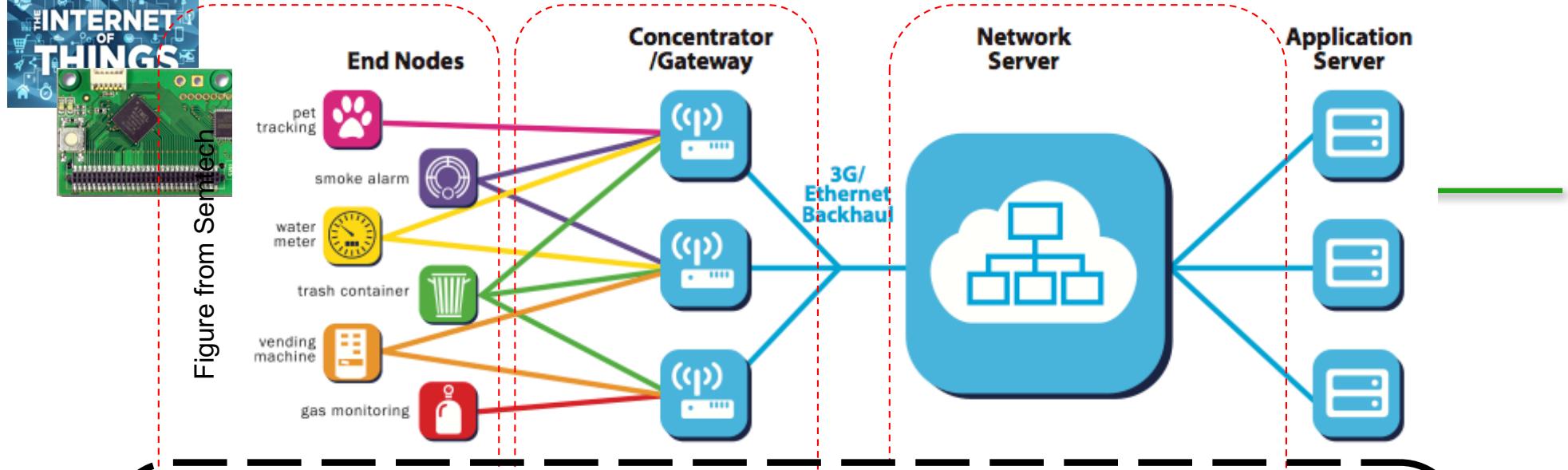
A



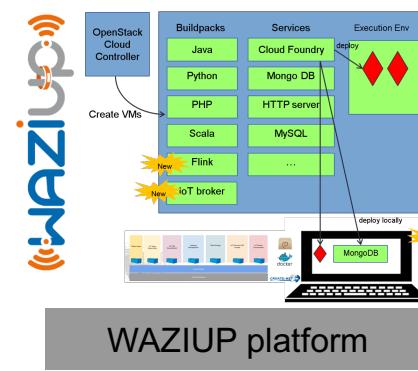
Application, MVP
WAZIUP Sensor platform



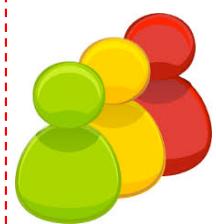
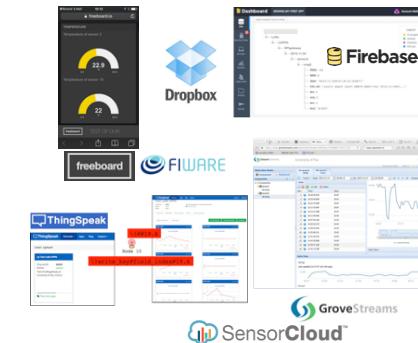
WAZIUP gateway platform

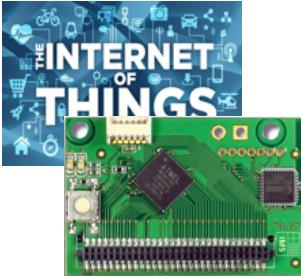


B



WAZIUP platform

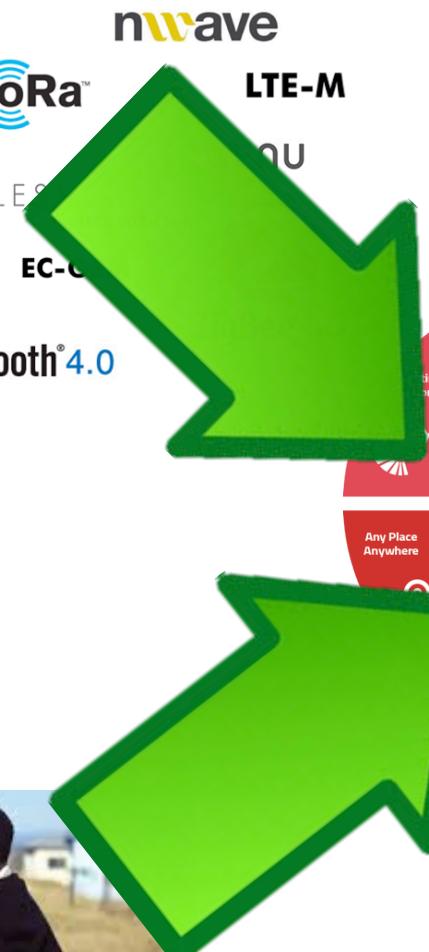




Now,

IoT BECOMES REALITY!

By Congduc Pham for WaterSense project



nwave

LTE-M

NB-LTE

WEIGHTLESS

DASH7™
ALLIANCE

Bluetooth® 4.0

EC-C

LoRa™

OU

The
INTERNET
of THINGS



Anything
Any Device



Anytime
Anywhere



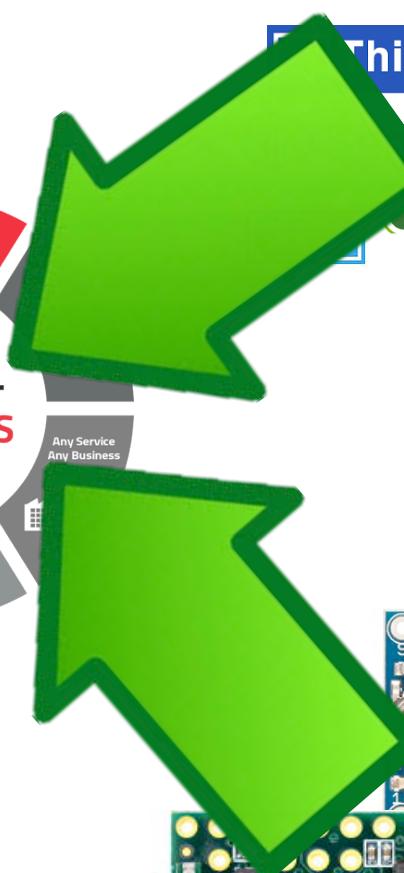
Any Place
Anywhere



Any Service
Any Business



Any Path
Any Network

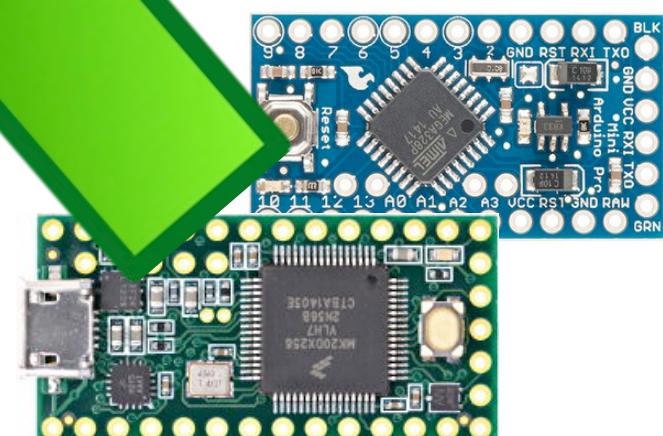


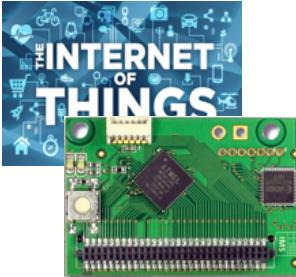
Dropbox

ThingSpeak

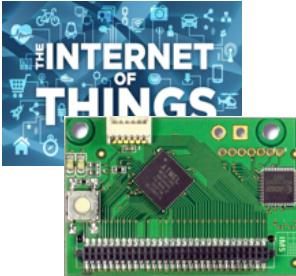
ensorCloud™

openRan





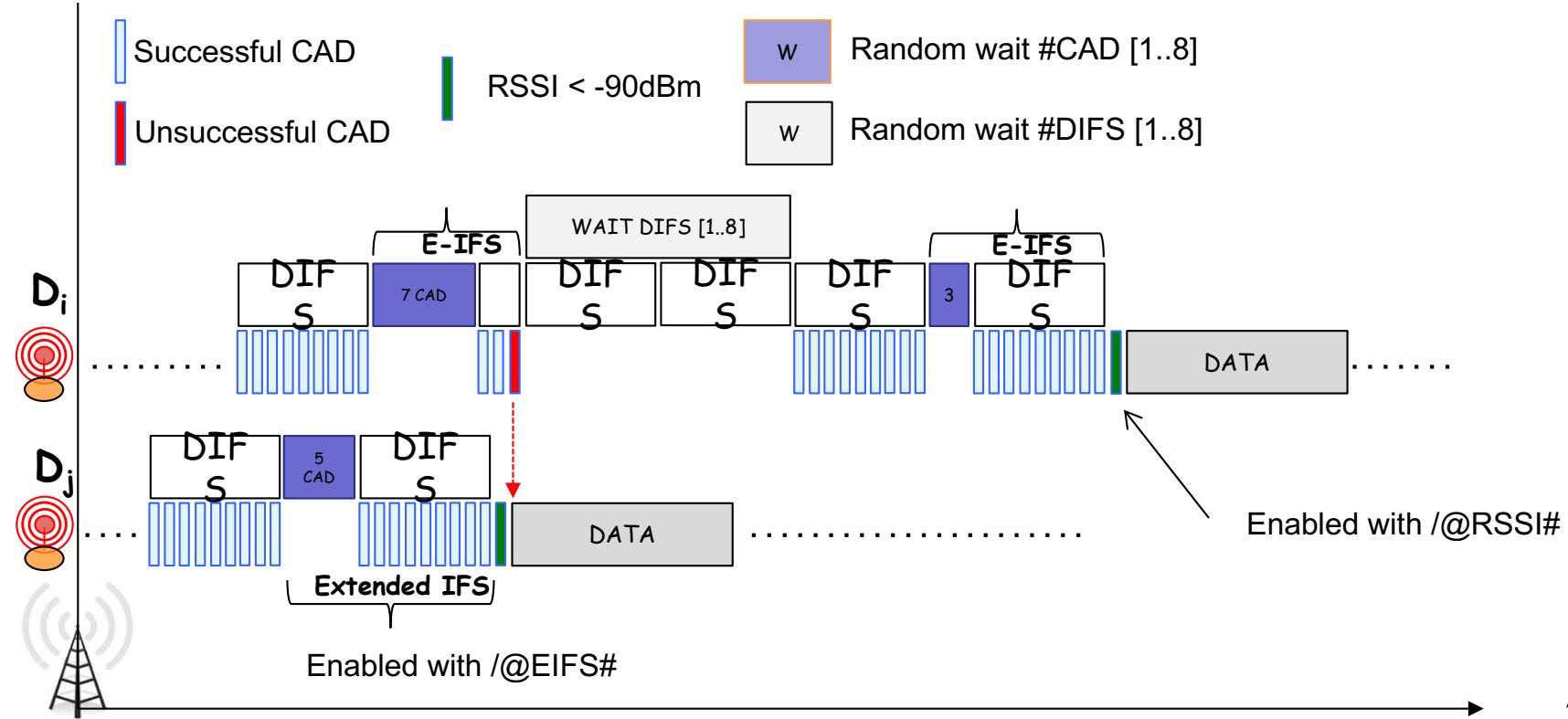
THING WE DO FOR RESEARCH

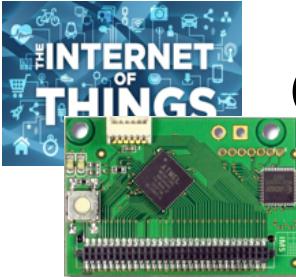


ADVANCED CHANNEL ACCESS METHODS

- ❑ Implement & test channel access methods
 - ❑ SIFS=xCAD; DIFS=3SIFS; set x with /@CADONx#
 - ❑ Use background traffic generator devices
 - ❑ /@T2000# or /@TR5000#

By Congduc Pham for WaterSense project





QUALITY OF SERVICE FOR LONG RANGE RADIO?

Regulations stipulate that **radio activity duty-cycle** should be enforced at **devices** and that end-users should not be able to modify it « easily ».

LoRaWAN specification from LoRa Alliance is a first attempt to standardize LoRa networks but **no issues on quality of service**.

By Congduc Pham for WaterSense project

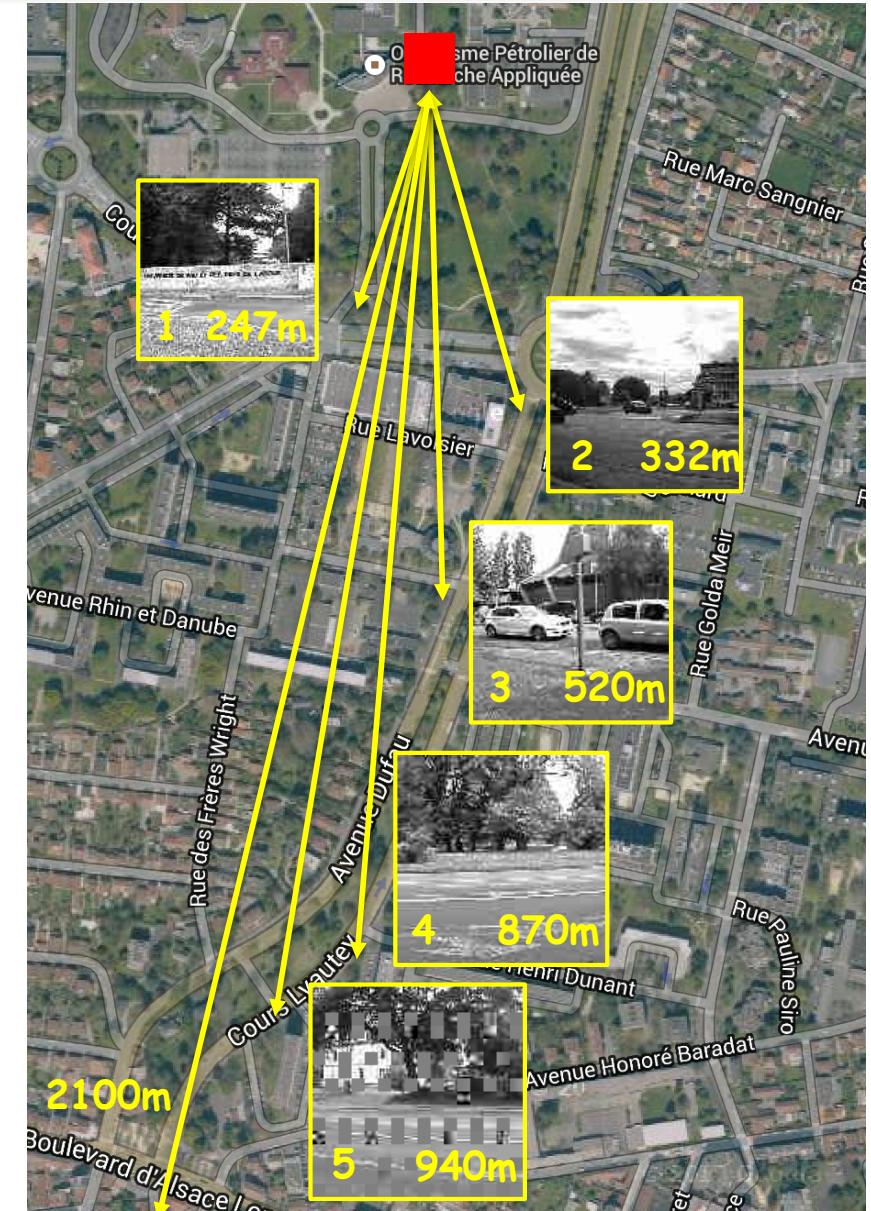
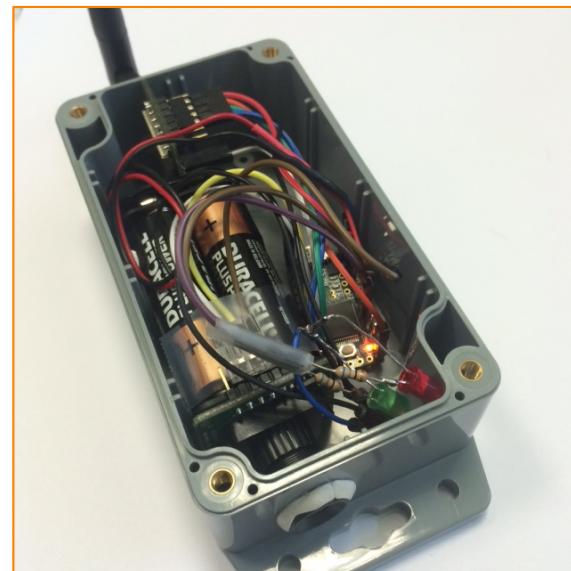
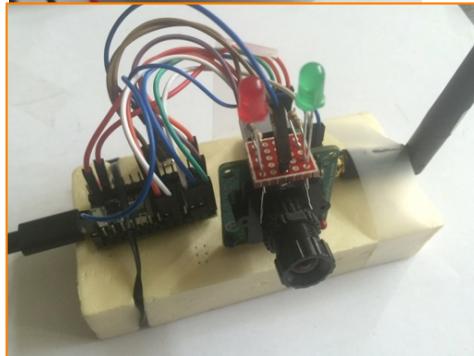
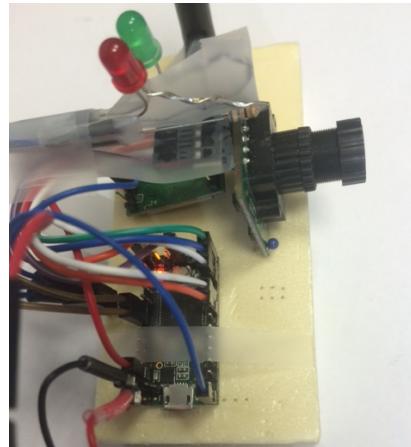
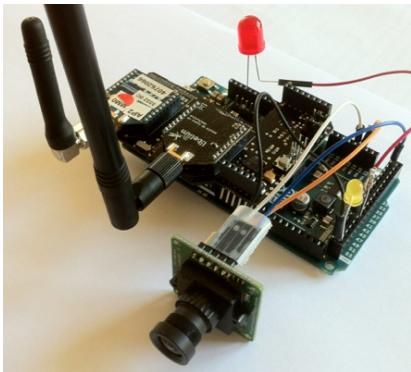
What if I still need to send more than 36s in the current hour because of an emergency situation?

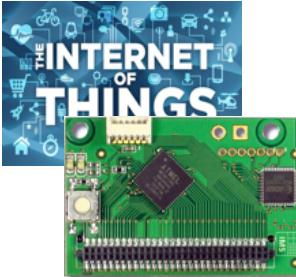
- stop transmitting?
- violate regulation?



IMAGE SENSOR WITH LONG RANGE RADIO

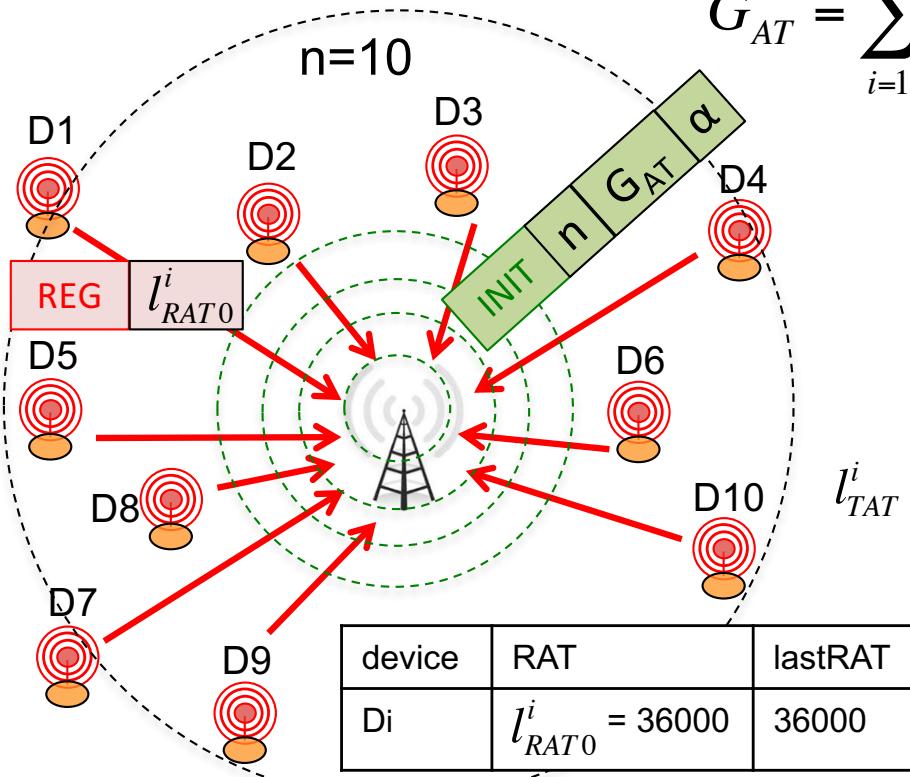
By Congduc Pham for WaterSense project





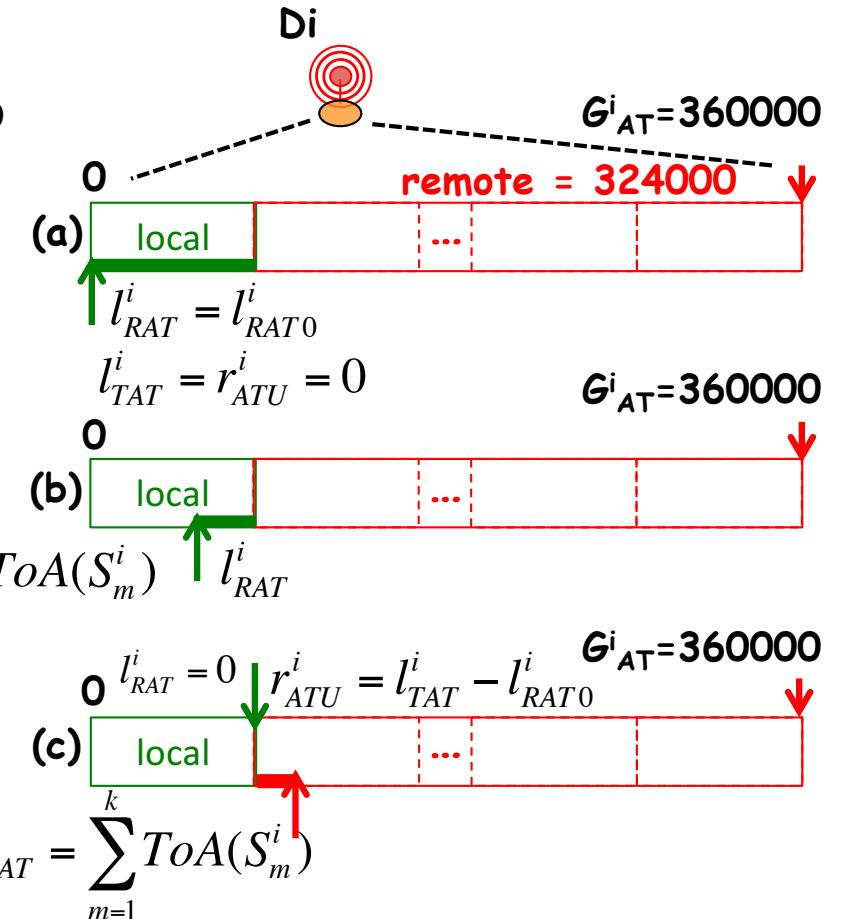
LONG-RANGE ACTIVITY SHARING (LAS)

By Congduc Pham for WaterSense project



$$G_{AT} = \sum_{i=1}^n l^i_{RAT0}$$

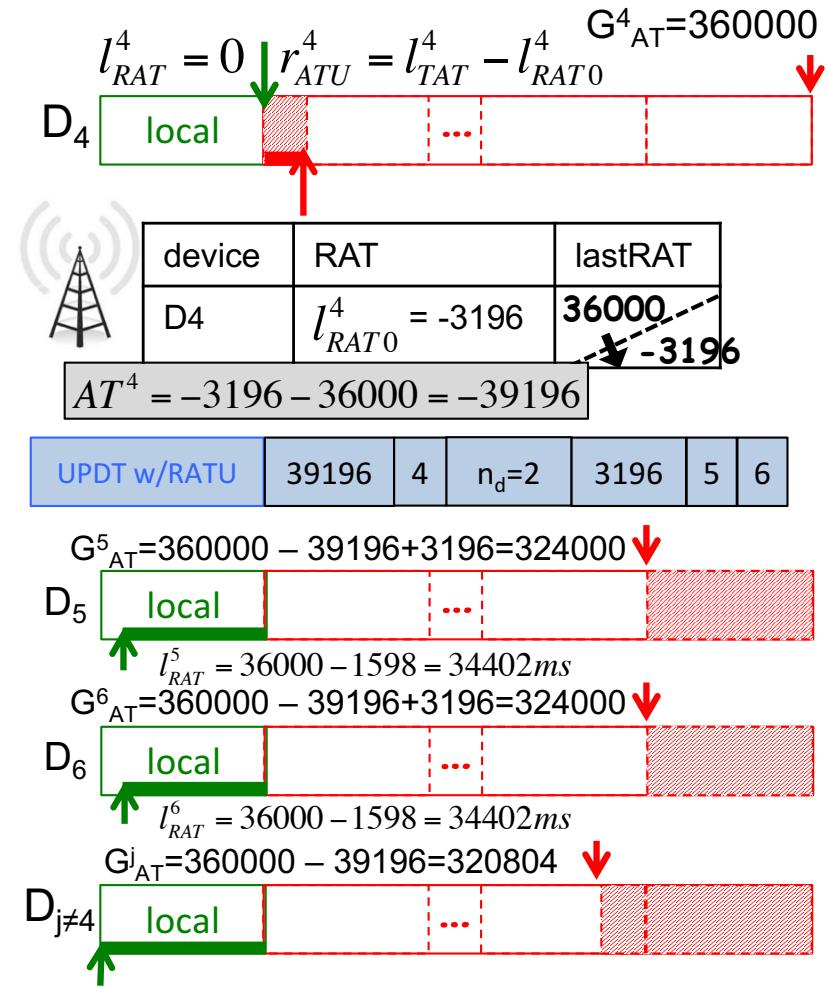
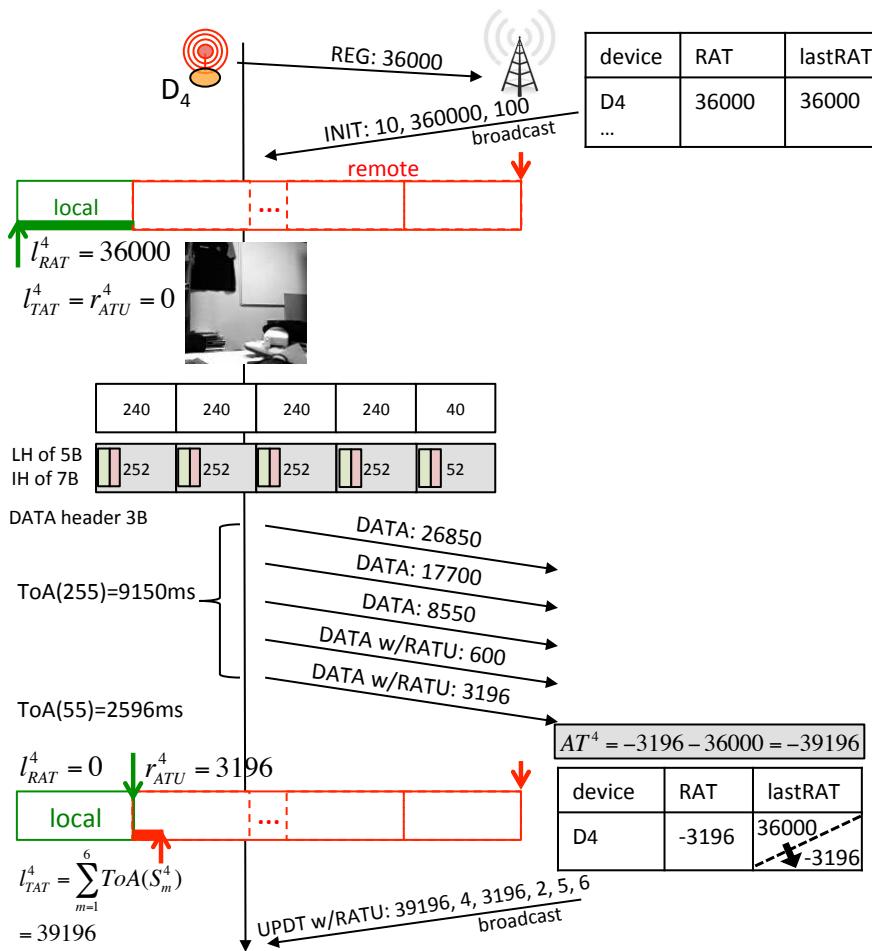
$$l^i_{TAT} = \sum_{m=1}^k ToA(S_m^i)$$

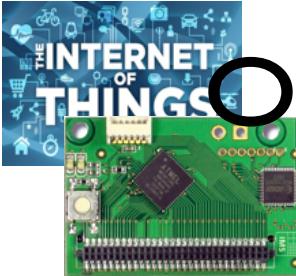


A device can transmit more if needed, provided that other devices will decrease their radio activity time accordingly.



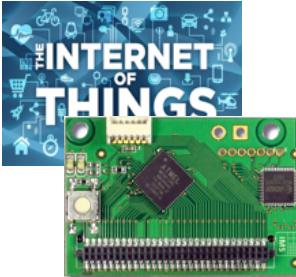
By Congduc Pham for WaterSense project



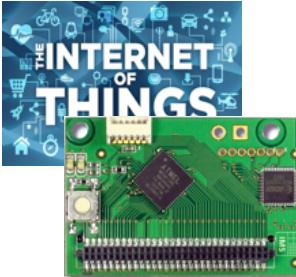


OTHER ISSUES TO TAKE INTO ACCOUNT

- ❑ Minimise the number of UPDT messages sent by the gateway because the gateway's radio time is also limited
 - ❑ UPDT can have cumulative behavior if no remote activity time has been used
- ❑ Support sleep periods of end-devices
 - ❑ The network is synchronized for control messages (REG, INIT, UPDT). UPDT msg that can not use cumulative behavior are queued for transmission at next transmission slot. At rcv, UPDT have to be applied sequentially.
- ❑ Maintain (loose) synchronization
 - ❑ If no UDPT are scheduled, the gateway periodically sends a BEACON. Clock drift is limited to a BEACON period
- ❑ Dynamic insertion of new end-devices
 - ❑ New devices can either stay out of the managed pool (then only 36s of activity time/h is allowed), or join by waiting for the next UPDT/BEACON msg
 - ❑ Every hour, end-devices decide if they want to join the pool or not
- ❑ Give priority to control msg
 - ❑ SIFS/DIFS mechanism are implemented using LoRa Channel Activity Detection
- ❑ Avoid interleaving of several image transmissions
 - ❑ Use DIFS for first image packet, then SIFS
- ❑ Improve LoRa network efficiency
 - ❑ Move from pure ALOHA to CSMA mechanism with CAD+RSSI tests prior to any transmission



ADDED-VALUE



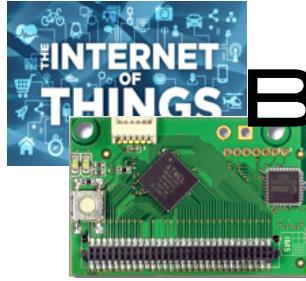
INVOLVING INNOVATION HUBS/STAKEHOLDERS

By Congduc Pham for WaterSense project

- **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

By Congduc Pham for WaterSense project

International Events
+ 20 organized & attended



Launch event (Ghana, iSpace)



IoTCareConference (Budapest, CNET)

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



Credit: C. Vavasseur, CTIC Dakar

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



IoTWeek2016 (Belgrade, EGM)

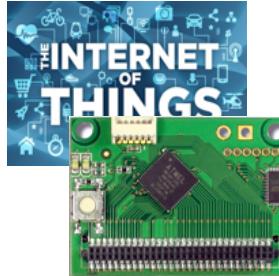


IoTBIGDATA2016 (Italy, EGM)



RESSACS 2016
Workshop at the RESSACS 2016 (France, UPPA) 85





TUTORIALS/RESOURCES

By Congduc Pham for WaterSense project



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 that links the physical world and the virtual world, so objects can communicate and sense or interact with their internal states or the external environment."

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."

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 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 their families in the design of the system. Second, it proposes solutions for the ICT sector. WAZIUP also addresses the challenges of 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. Finally, 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 source oriented to radically new paradigms for innovative applications/services delivery. WAZIUP is driven by the need to support the rural ecosystem in Sub-Saharan Africa.

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 the rural economy by providing services and infrastructures to launch agriculture and breeding on a new scale;

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



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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



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LOW-COST LoRA IoT DEVICE: SUPPORTED PHYSICAL SENSORS



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



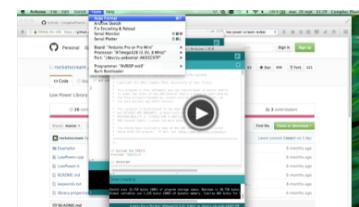
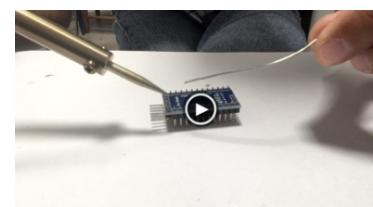
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LOW-COST LoRA IoT: USING THE WAZIUP DEMO KIT



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Thanks.
Let's keep in touch



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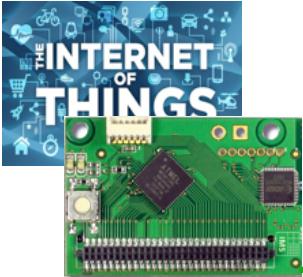
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github.com/waziup



CONCLUSIONS

- ❑ Low-power, long-range transmission is a breakthrough technology for IoT and large-scale deployment of wireless (sensor) devices
- ❑ Coupled with low-cost, off-the-shelves hardware, IoT design is entering the DIY era
- ❑ The whole IoT eco-system is becoming mature with availability of IoT clouds and advanced big data analytic platforms/frameworks
- ❑ As IP and TCP provided tools for building more advanced applications in the early Internet, the whole IoT ecosystem can boost innovative IoT developments and deployments, in all countries!