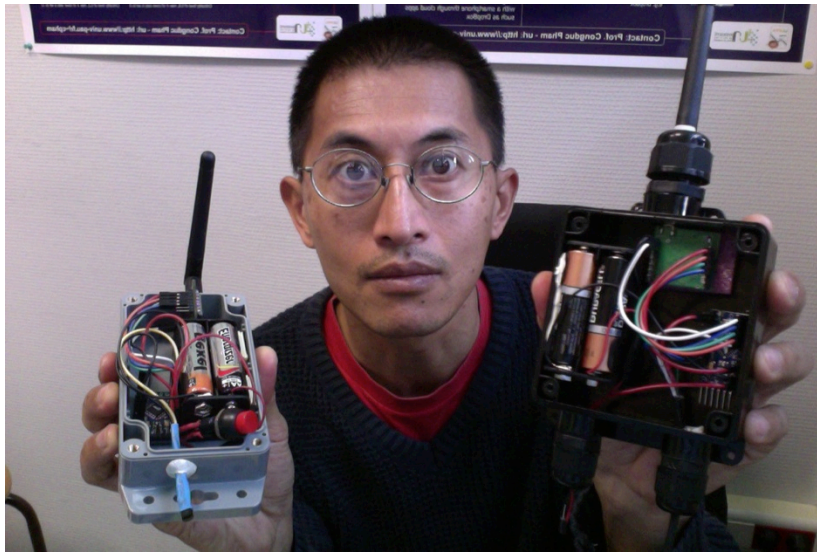


BUILDING LOW-COST GATEWAYS AND DEVICES FOR OPEN LORA IOT TEST-BEDS

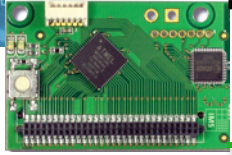


EAI TRIDENTCOM'16
HANGZHOU, CHINA,
JUNE 14TH, 2016

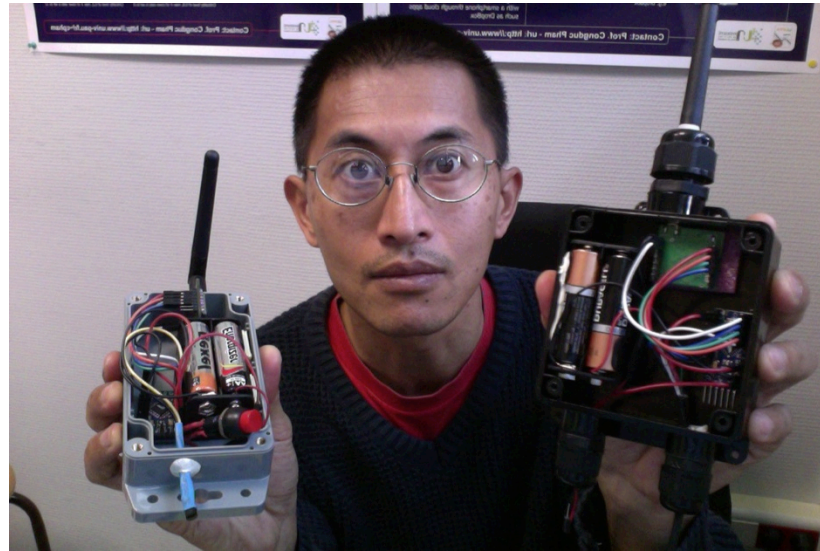


PROF. CONGDUC PHAM
[HTTP://WWW.UNIV-PAU.FR/~CPHAM](http://www.univ-pau.fr/~cpham)
UNIVERSITÉ DE PAU, FRANCE



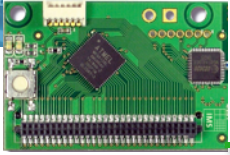


TIME FOR PRESENTATION



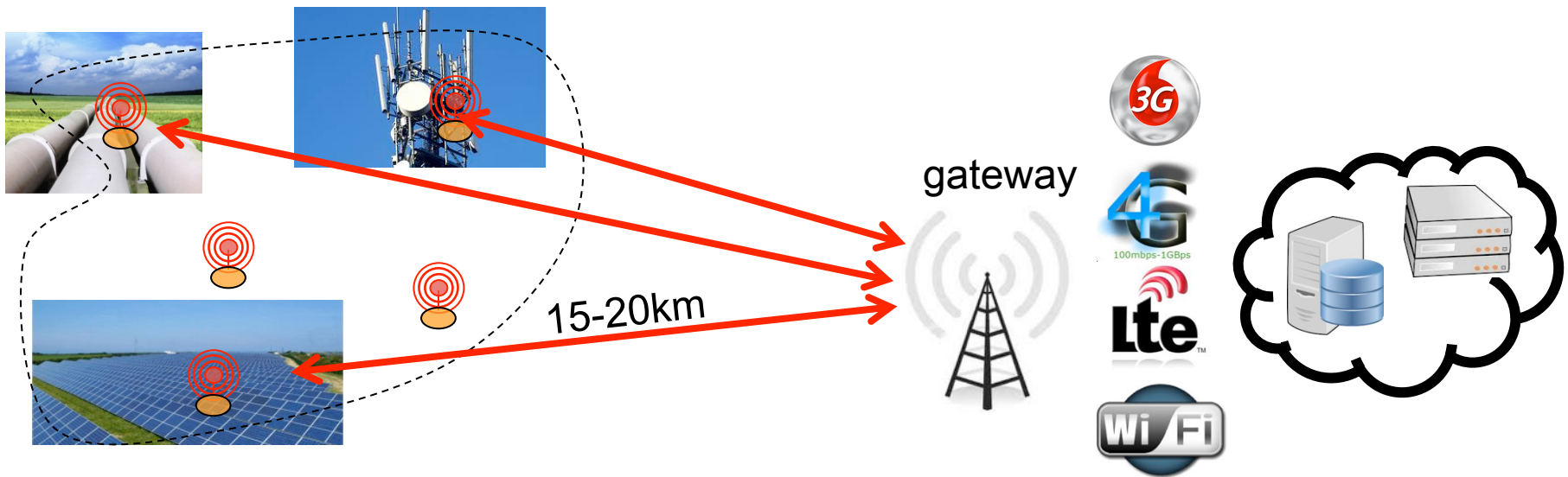
IS ABOUT 20 MINUTES

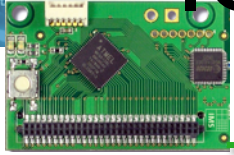




SENSING/IOT/TELEMETRY SYSTEMS

deployment made easier in single-hop model !!!

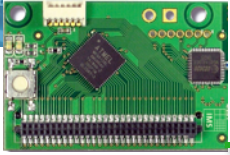




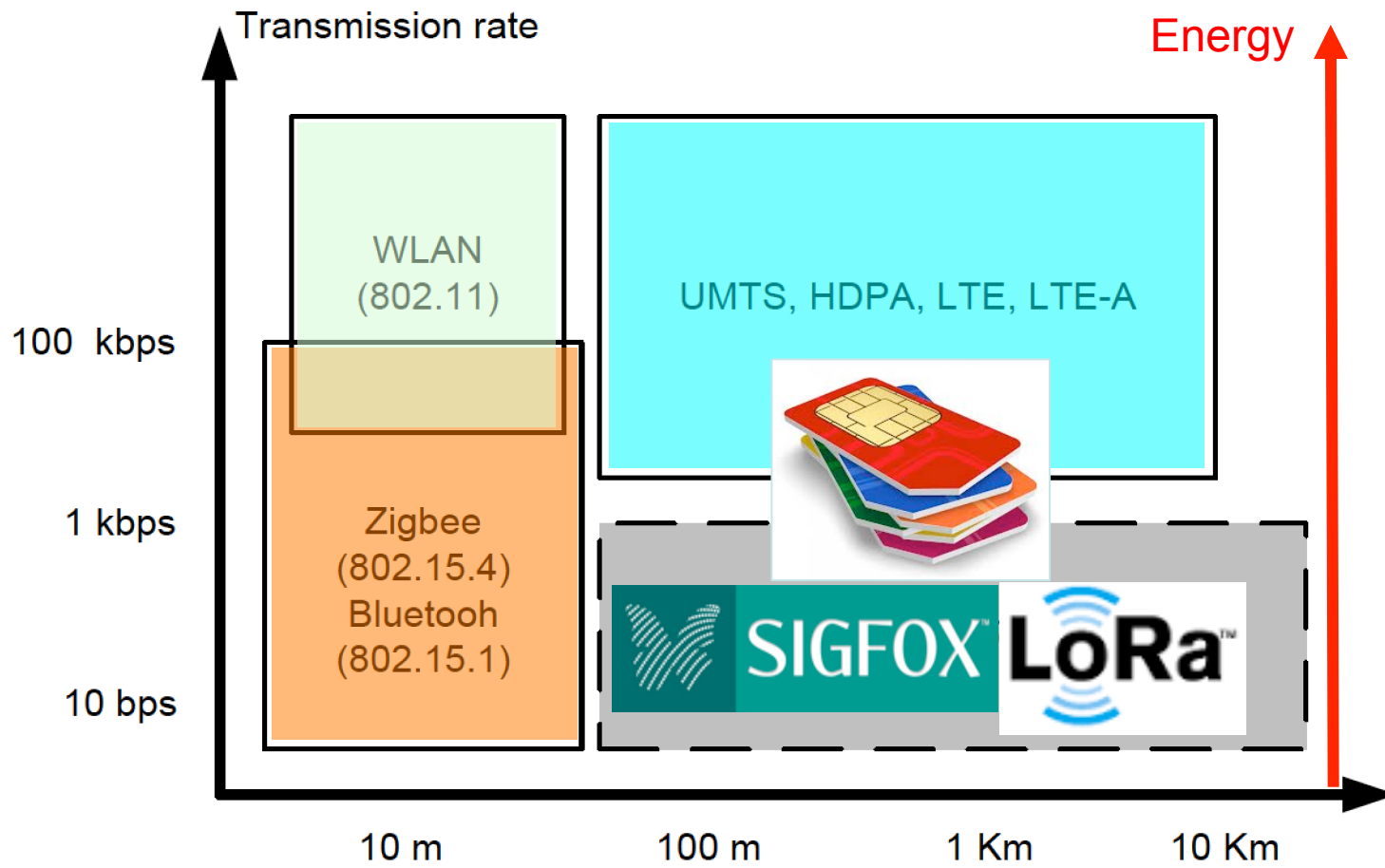
IoT NODES: HOW COSTLY IS TRANSMISSION?

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

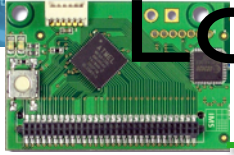
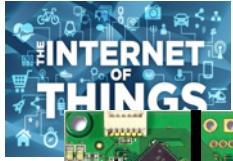




LOW-POWER AND LONG-RANGE?



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 -



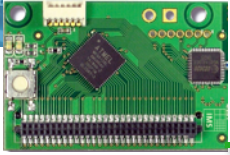
1 year

5 years

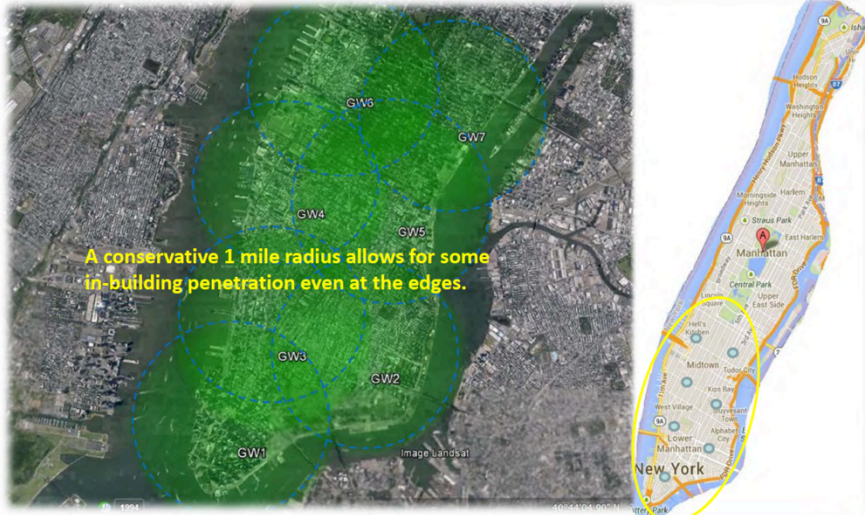
10 years

Example for energy meter



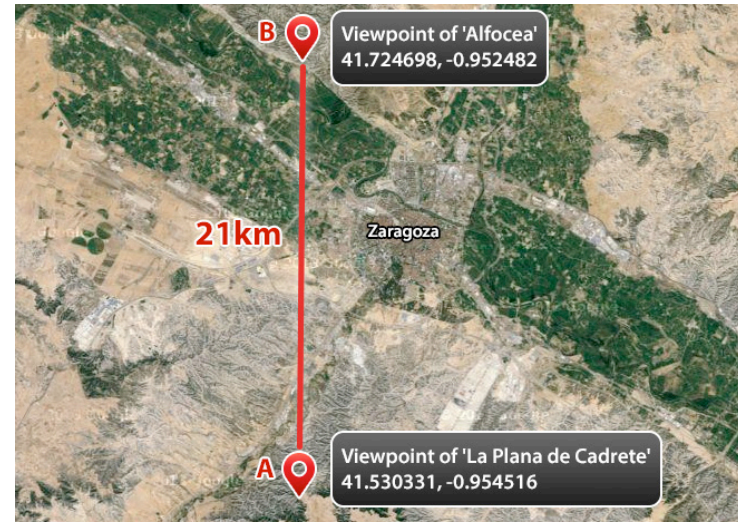


VERSATILE LPWAN!



A conservative 1 mile radius allows for some in-building penetration even at the edges.

Dense urban areas



Rural areas

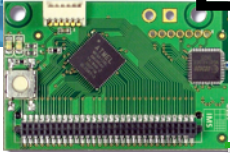


Indoor



Underground





DEPLOYING YOUR LPWAN NETWORK

OPERATOR-BASED
APPROACH (WITH
SUBSCRIPTION)

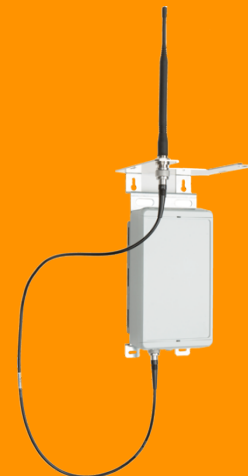


PRIVATELY-BASED
APPROACH



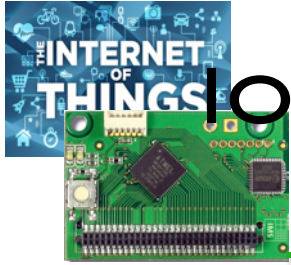
Multi-Tech
Conduit

**DIY low-
cost
gateway**



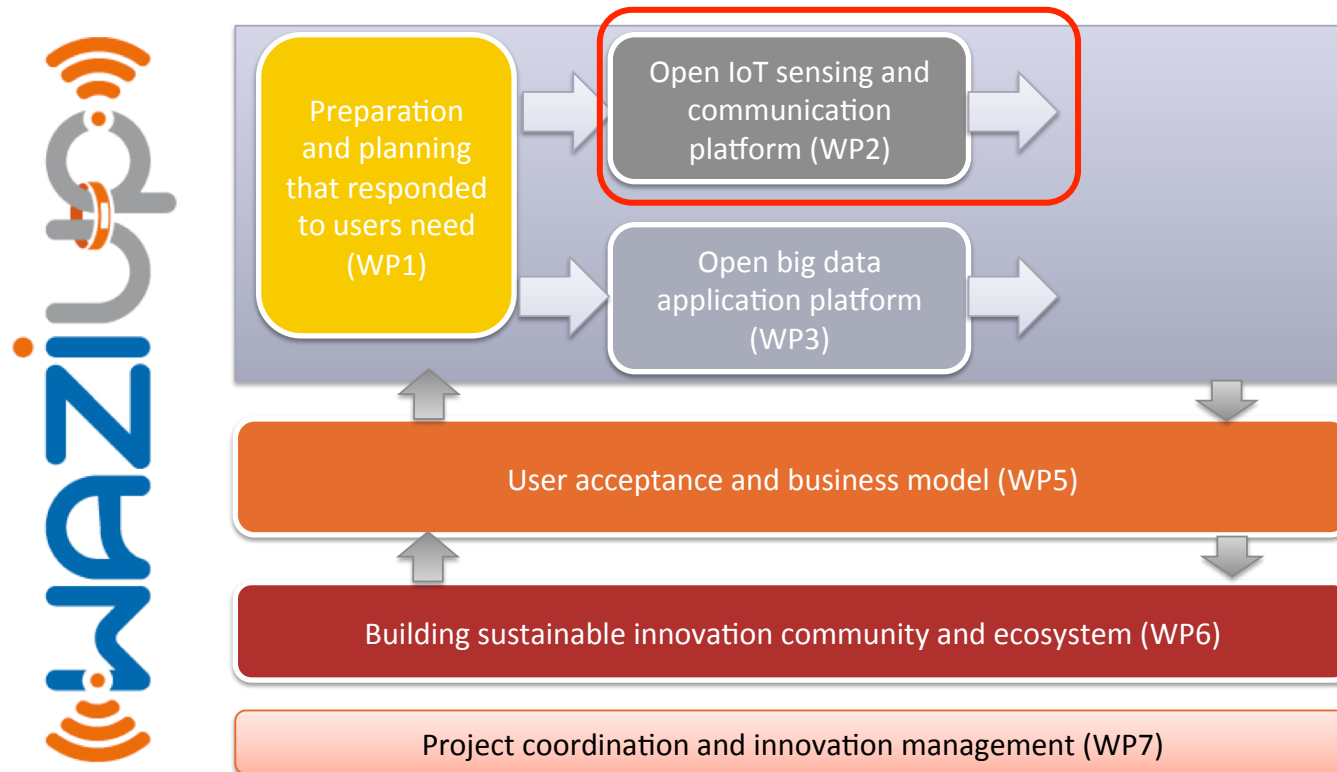
Kerlink
IoT Station

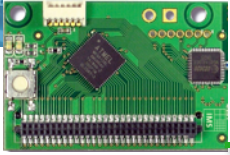




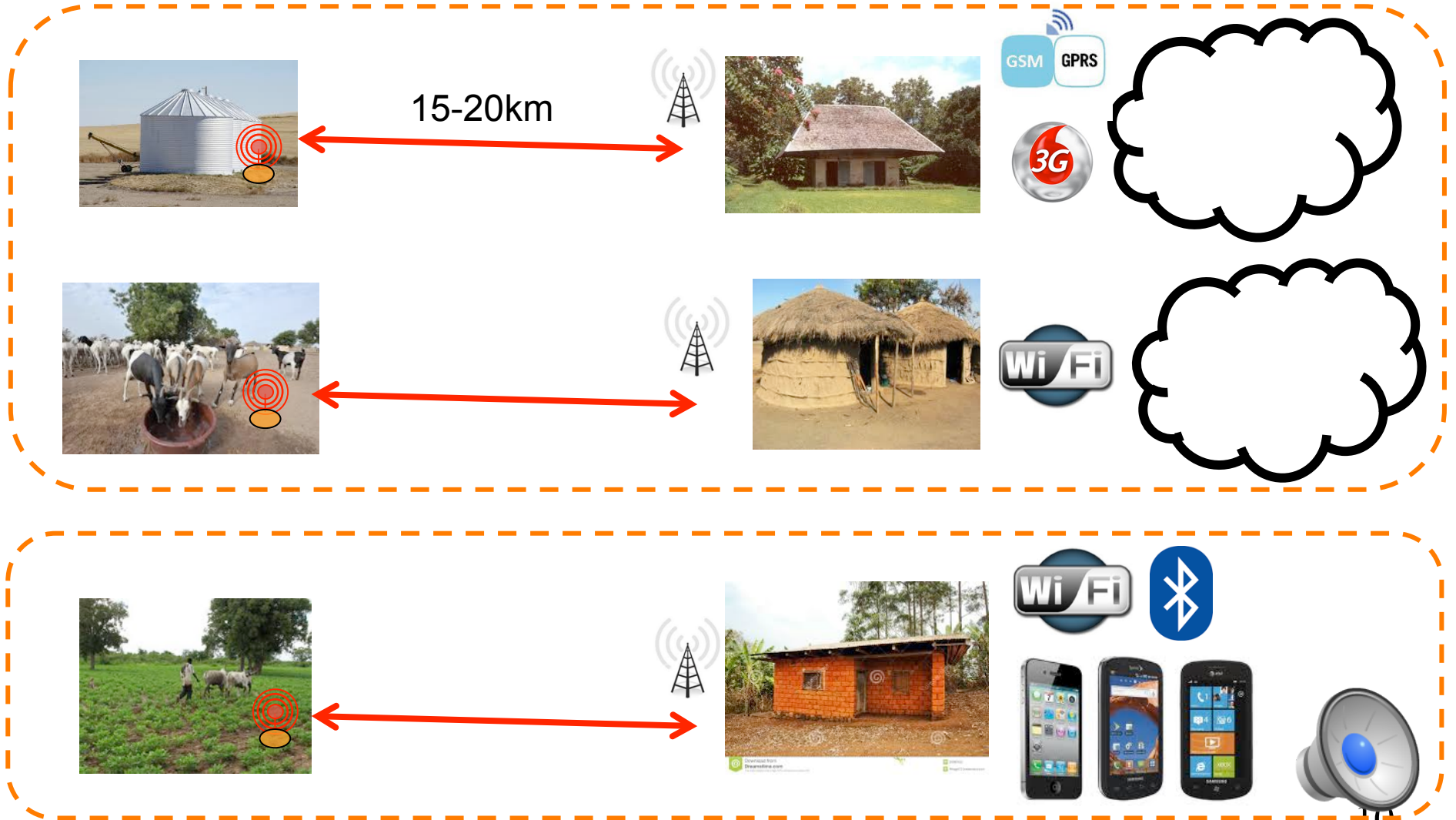
IoT FOR RURAL APPLICATIONS IN DEVELOPPING COUNTRIES

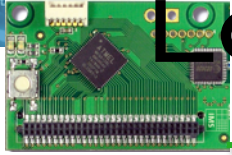
- ❑ WAZIUP is an EU H2020 project (2016-2019)
- ❑ contributes to long-range networks for rural applications with WP2





TYPICAL SCENARIOS





LOW-COST LORa GATEWAYS

Commercial gateways

- Target low power
- Use advanced protocols
- Costs in the hundreds

Low-cost gateways

- Use regular protocols
- From end users
- Use off-the-shelf components
- Lower-cost

- 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

inAir9/9B based on SX1276

Froggy Factory LoRa module (Arduino)

Embit LoRa

Microchip RN2483

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

Adeunis ARF8030AA- Lo868

Microship RN2483

habSupplies

Multi-Tech MultiConnect mDot

AMIHO AM093

ARM-Nano N8 LoRa module from ATIM

SODAQ LoRaBee Embit

SODAQ LoRaBee RN2483

31

cost

medium-

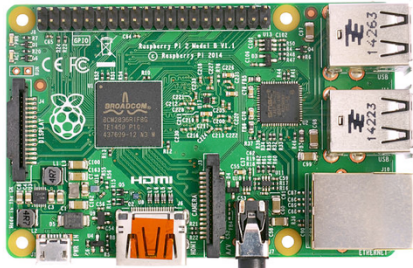
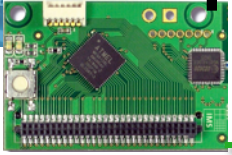
nection »

rms for much

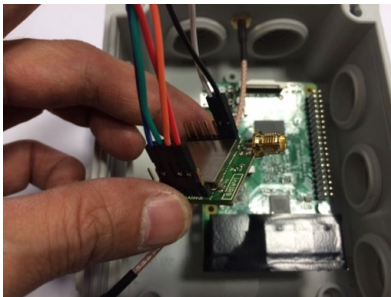


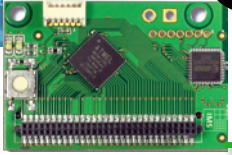


RASPBERRY-BASED LORA GATEWAY

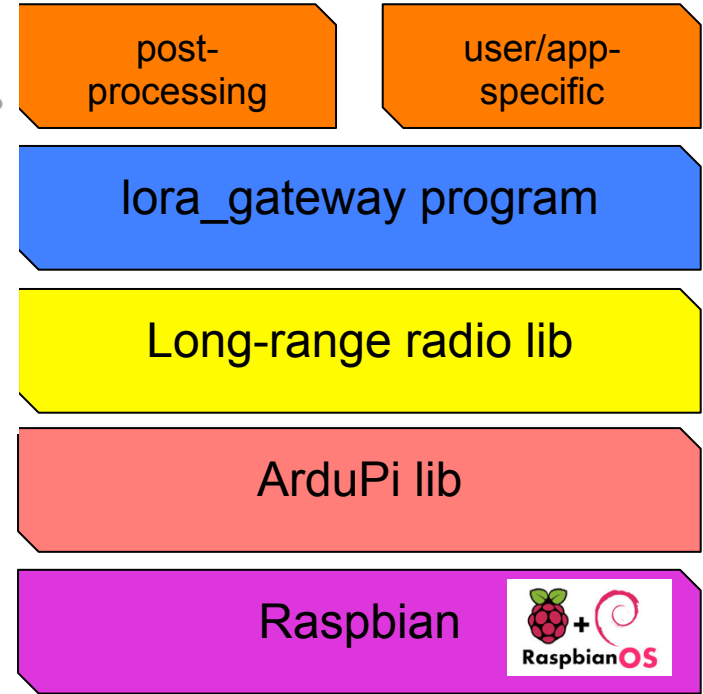
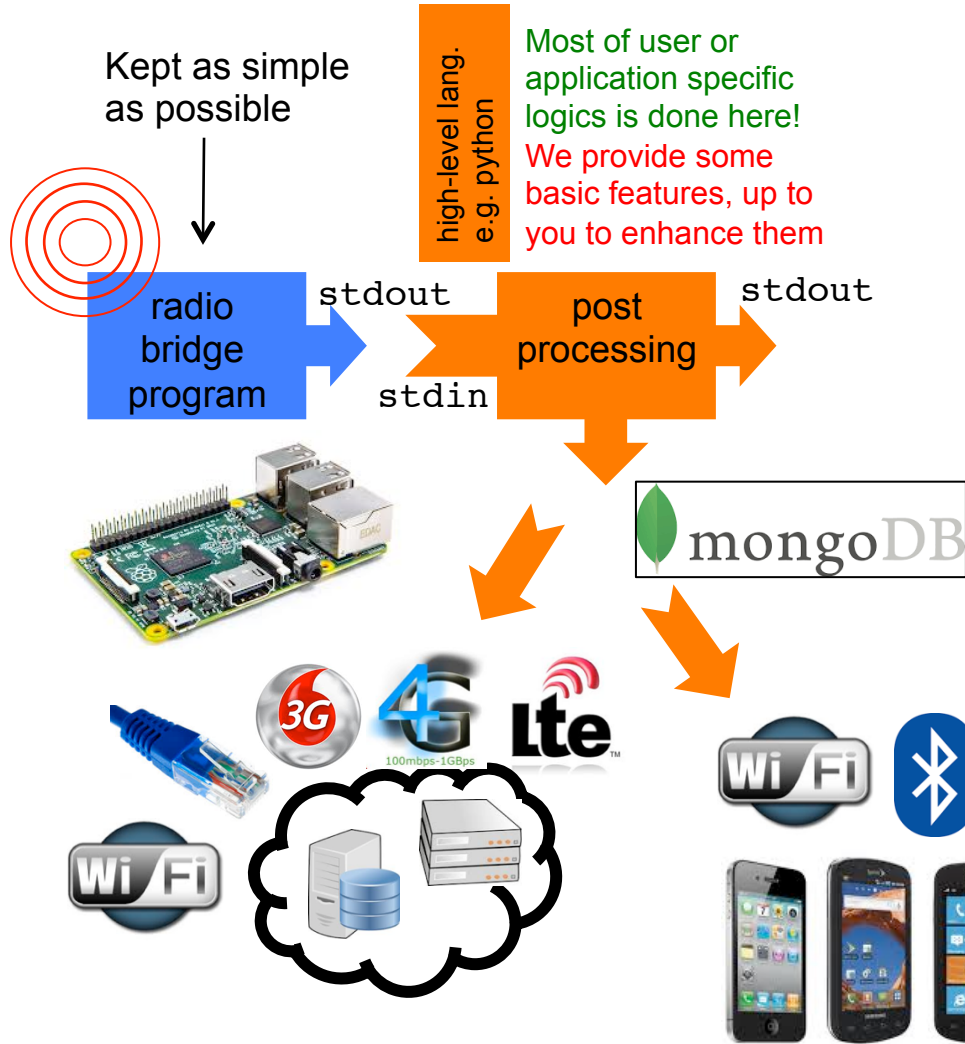


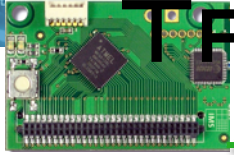
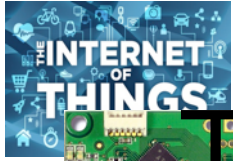
We can use all model of Raspberry. The most important usefull feature is the Ethernet interface for easy Internet connection. Then WiFi and Bluetooth can be added with USB dongles. RPI3 provides built-in Ethernet, WiFi and Bluetooth!



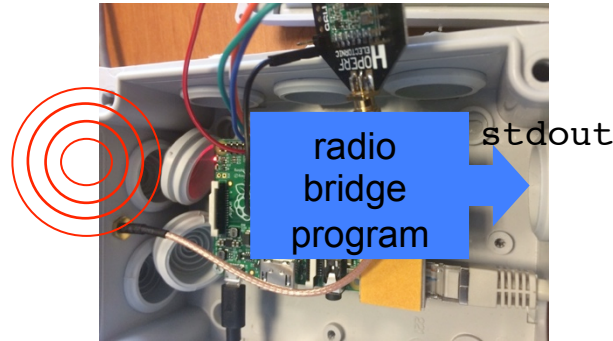
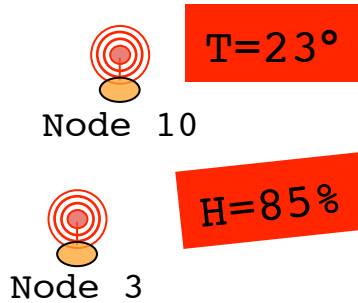


OUR LOW-COST GATEWAY ARCHITECTURE





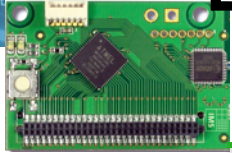
TRANSPARENT LORA BRIDGE



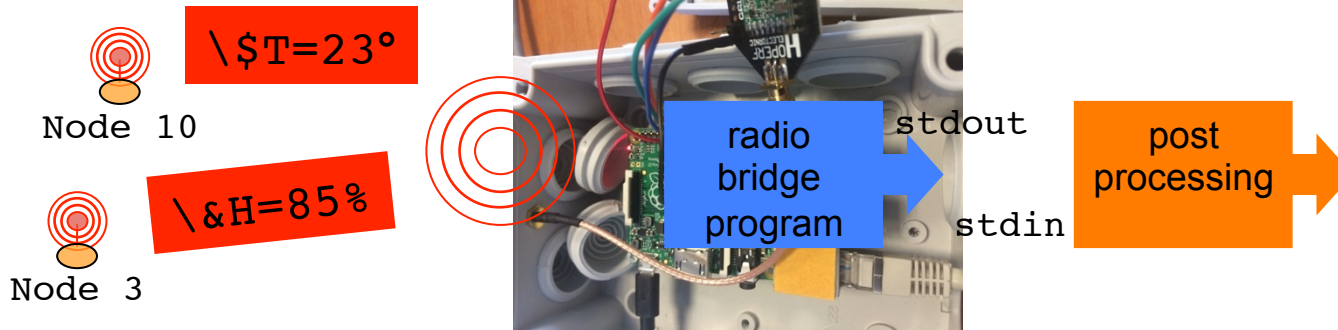
```
> sudo ./lora_gateway
Power ON: state 0
LoRa mode: 4
Setting mode: state 0
Channel CH_10_868: state 0
Power M: state 0
Get Preamble Length: state 0
Preamble Length: 8
LoRa addr 1 : state 0
SX1272/76 configured as LR-BS. Waiting RF input for transparent RF-serial bridge

--- 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

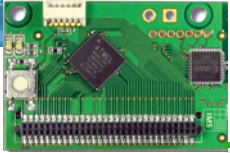


```
> sudo ./lora_gateway | python ./post_processing_gw.py
Power ON: state 0
LoRa mode: 4
Setting mode: state 0
Channel CH_10_868: state 0
Power M: state 0
Get Preamble Length: state 0
Preamble Length: 8
LoRa addr 1 : state 0
SX1272/76 configured as LR-BS. Waiting RF input for transparent RF-serial bridge

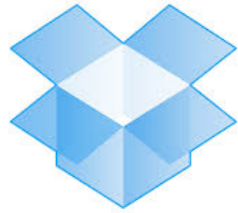
--- rxlor. dst=1 type=0x10 src=10 seq=0 len=5 SNR=9 RSSIpkt=-54
Rcv ctrl packet info 1,16,10,0,5,9,-54
(dst=1 type=0x10 src=10 seq=0 len=5 SNR=9 RSSI=-54)
rcv msg to log (\$) on dropbox : T=23°
--- rxlor. dst=1 type=0x10 src=3 seq=0 len=5 SNR=8 RSSIpkt=-54
Rcv ctrl packet info 1,16,3,0,5,8,-54
(dst=1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





IoT CLOUD?



Dropbox



Firestore



FIWARE

Axeda®

ioBridge®
Connect things.

ThingSpeak



GroveStreams



SensorCloud™

freeboard

dweet.io

OpenRemote

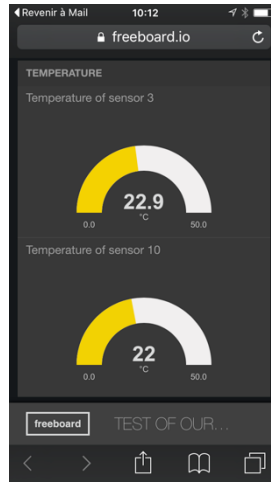
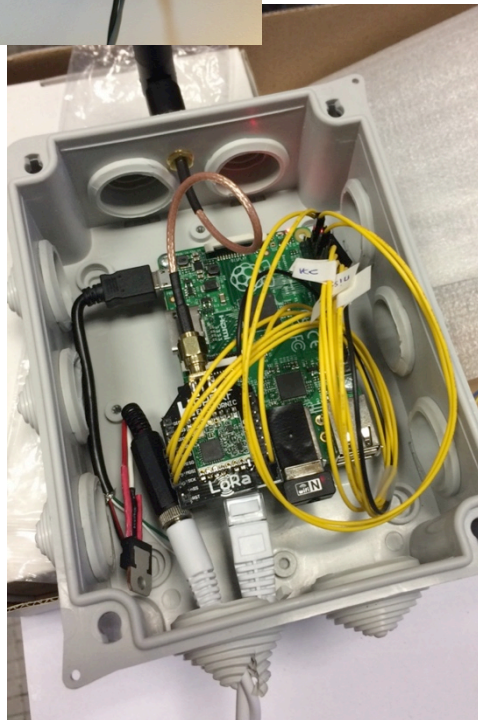


TempoIQ





TEMPLATES FOR VARIOUS CLOUDS



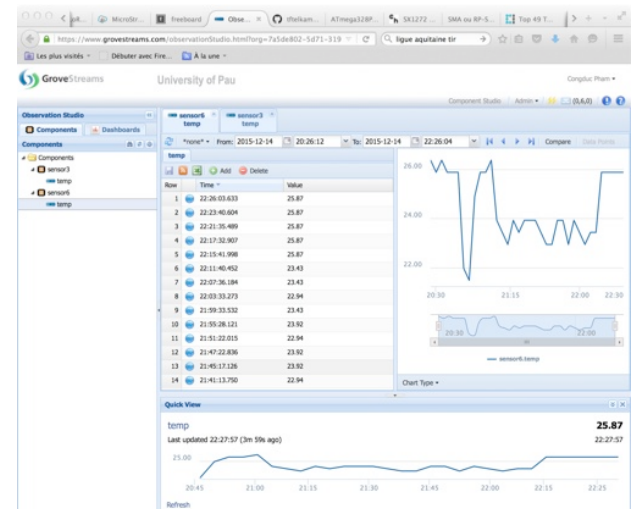
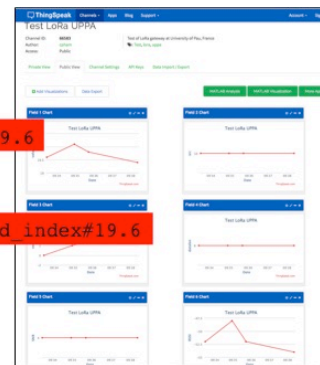
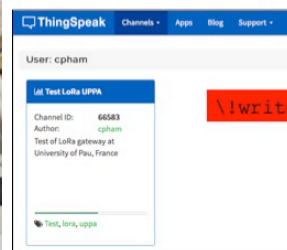
Dropbox



Firebase



FIWARE

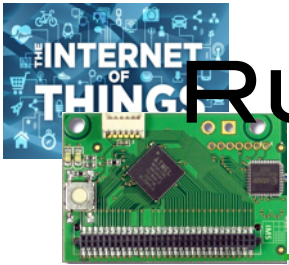


SensorCloud™

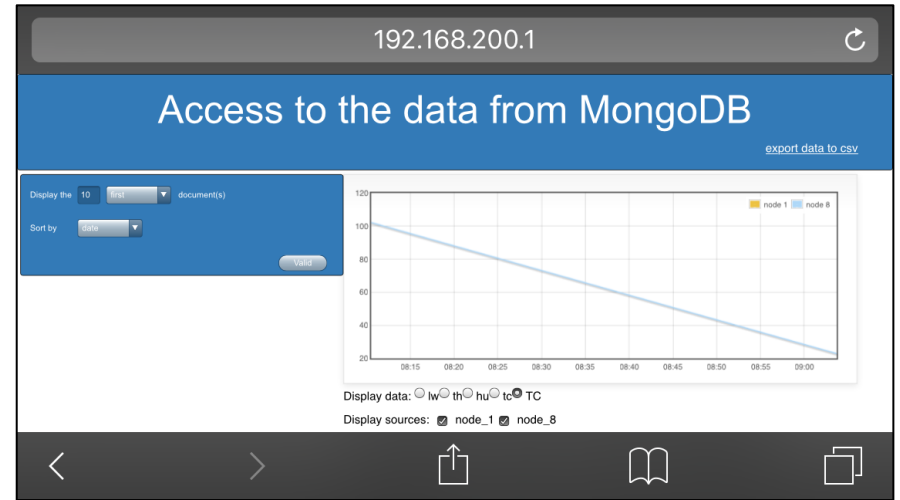
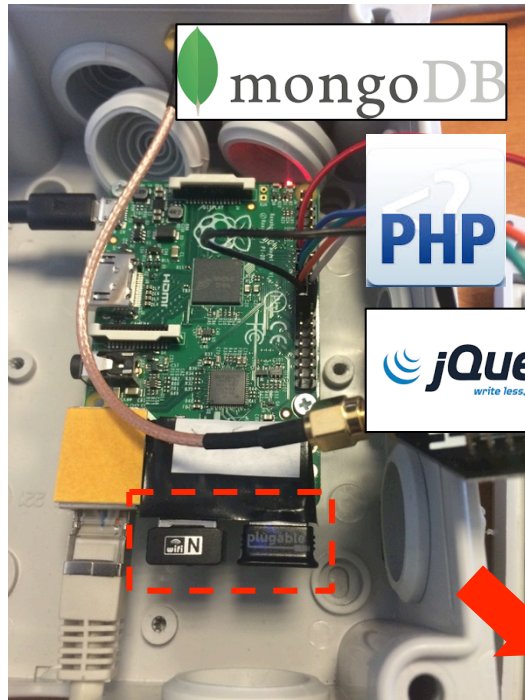


GroveStream





RUNNING WITHOUT INTERNET ACCESS



Isolated areas



Orange F 10:34

Bluetooth_raspi

```

NODE: 1 DATE: 2016-05-09 08:04:59.807000 DATA: ("lw": 3.29, "th": 22.6, "hu": 50.7)
NODE: 1 DATE: 2016-05-09 08:28:52.993000 DATA: ("lw": 3.29, "th": 22.89, "hu": 50.29)
NODE: 1 DATE: 2016-05-09 08:53:04.317000 DATA: ("lw": 3.29, "th": 23.2, "hu": 50.79)
NODE: 1 DATE: 2016-05-09 09:05:00.997000 DATA: ("lw": 3.29, "th": 23.29, "hu": 51.29)
NODE: 1 DATE: 2016-05-09 09:17:24.482000 DATA: ("lw": 3.29, "th": 23.39, "hu": 51.7)
NODE: 1 DATE: 2016-05-09 09:41:27.437000 DATA: ("lw": 3.29, "th": 23.6, "hu": 52.0)
NODE: 1 DATE: 2016-05-09 10:05:39.032000 DATA: ("lw": 3.29, "th": 23.79, "hu": 51.5)
NODE: 1 DATE: 2016-05-09 10:17:45.186000 DATA: ("lw": 3.29, "th": 23.79, "hu": 50.79)
NODE: 1 DATE: 2016-05-09 10:53:09.347000 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": 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": 50.9)
    
```

Display data Retrieve data in a csv file

Orange F 10:37

Bluetooth_raspi

NODES PREFERENCES

1 check to retrieve its data

8 check to retrieve its data

DATES PREFERENCES

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

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

Display data Retrieve data in a csv file

Orange F 10:39

Bluetooth_raspi

Creating csv file with the data received...
File 17-05-2016_110139m36s.csv created and saved in the folder /storage/emulated/0/Raspberry_local_data

Display data Retrieve data in a csv file

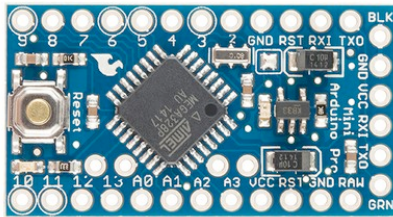




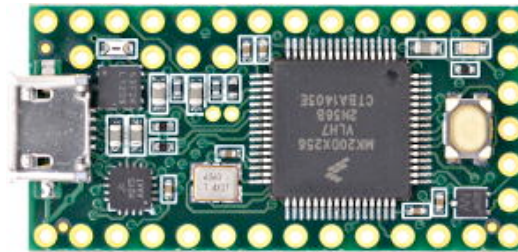
POWERFULL UCONTROLLER BOARDS GETTING SMALLER...

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

Arduino Pro Mini



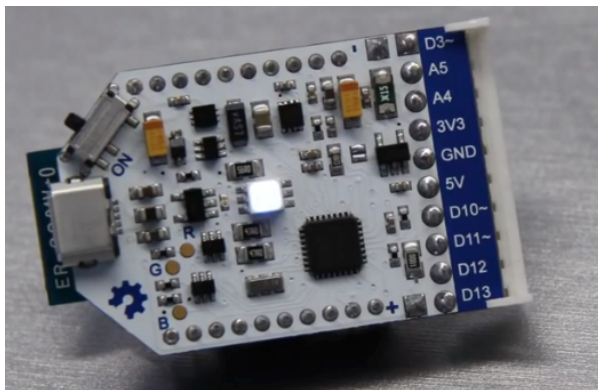
<http://blog.atmel.com/2015/04/09/25-dev-boards-to-help-you-get-started-on-your-next-iot-project/>



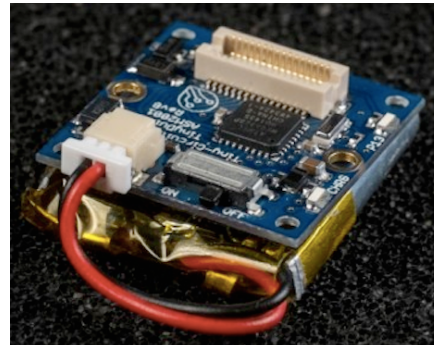
Teensy 3.2



STM32 Nucleo-32

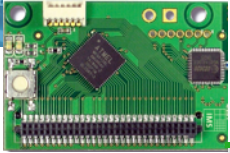


Theairboard on kickstarter

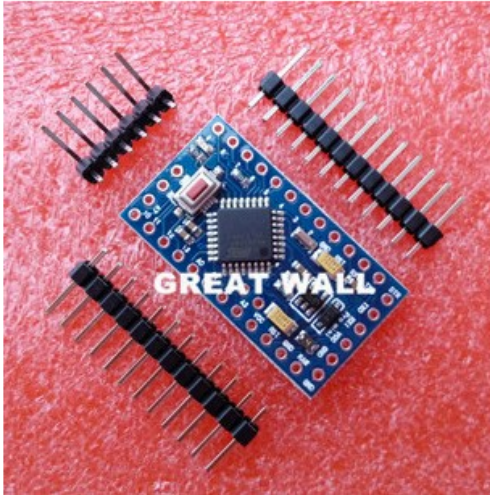


Tinyduino





...AND CHEAPER !!!



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**

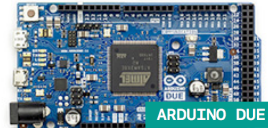
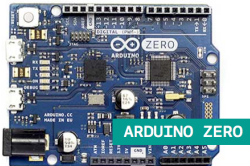
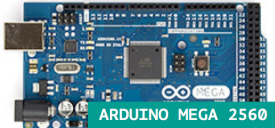
Acheter maintenant

Ajouter au panier





SW/HW BUILDING BLOCKS



LoRa radios that our library already supports



HopeRF RFM92W/95W



Libelium LoRa



Modtronix inAir9/9B



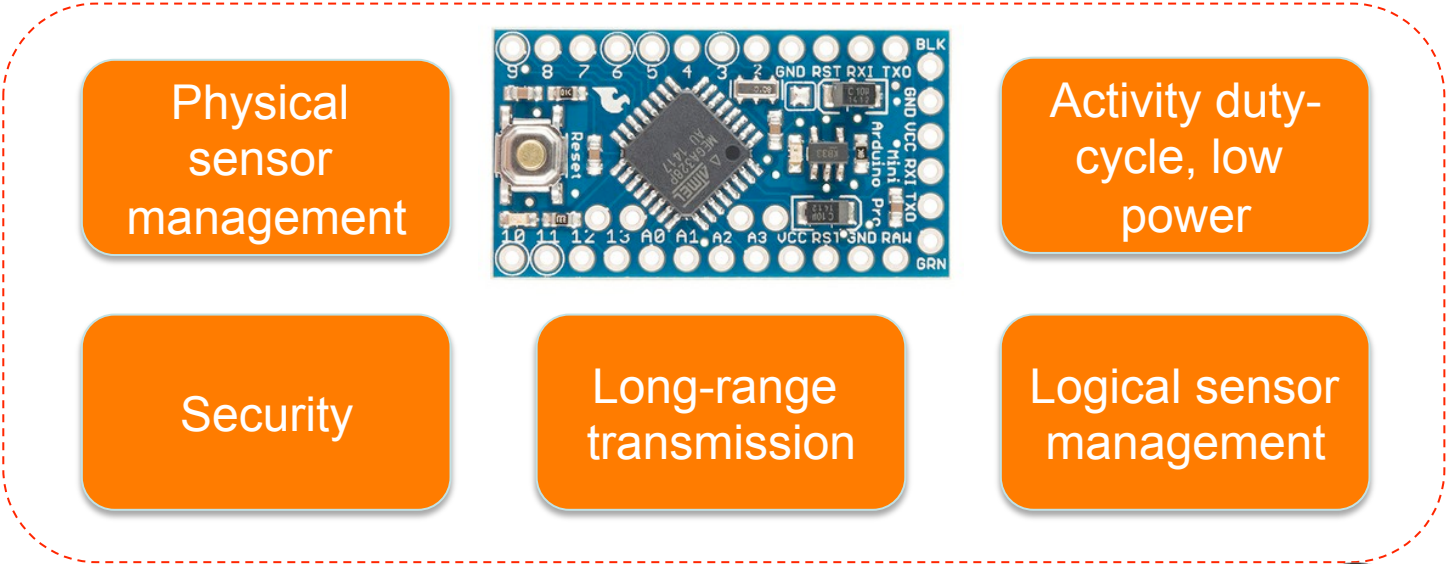
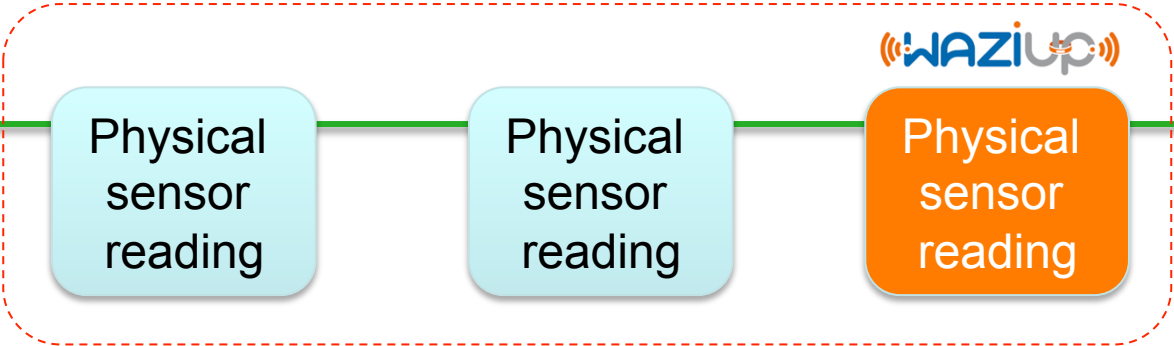
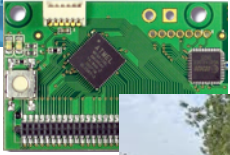
NiceRF LoRa1276

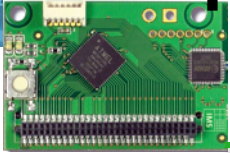
Long-Range communication library

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



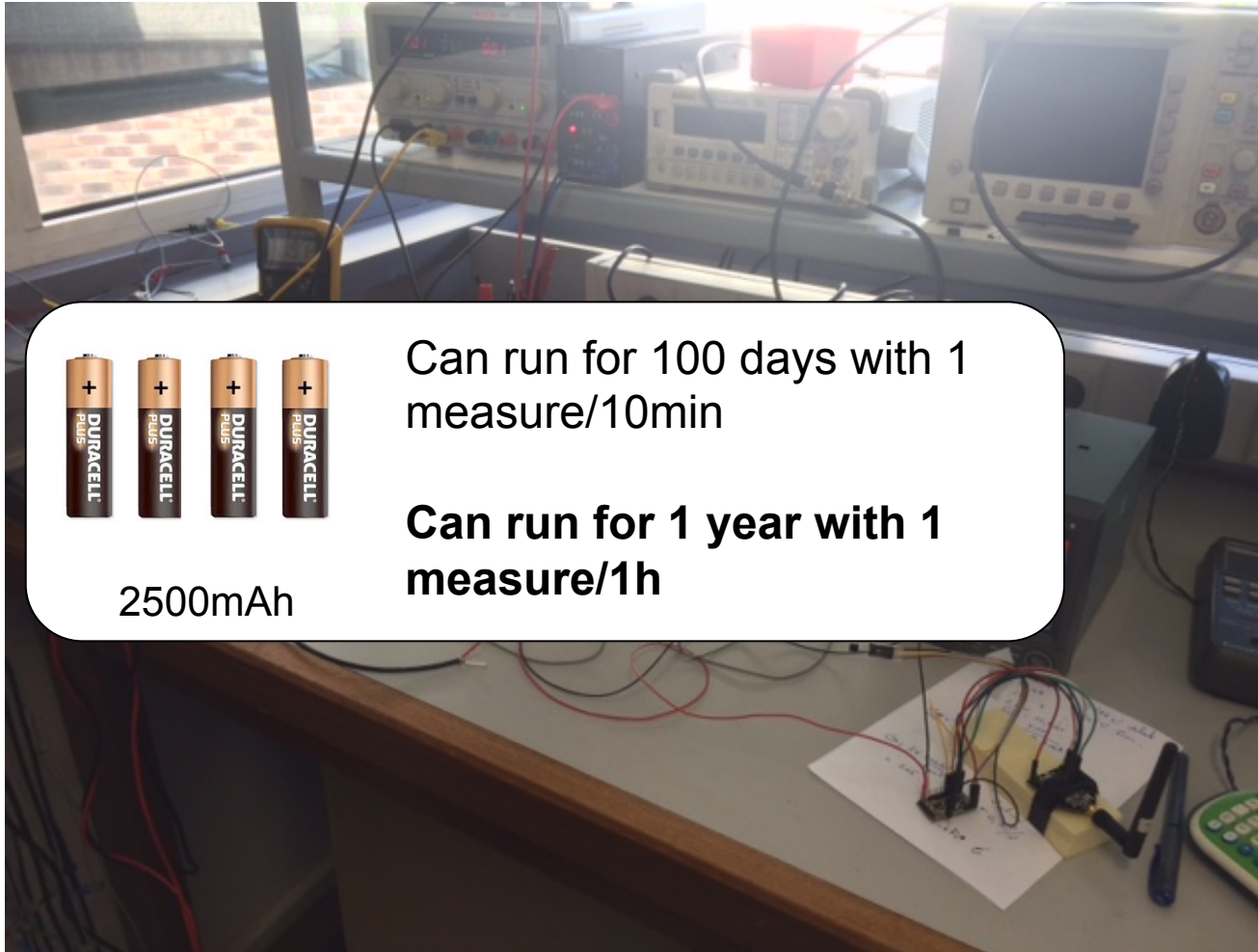
1 send function!





RUNNING FOR 1 YEAR WITH LOW-POWER MODE!

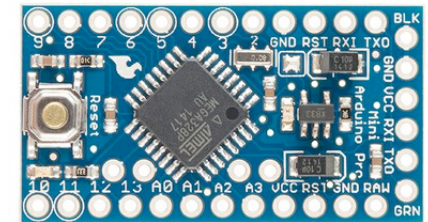
Low-Power library from RocketScream



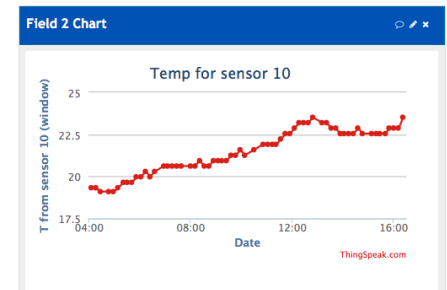
2500mAh

Can run for 100 days with 1 measure/10min

Can run for 1 year with 1 measure/1h



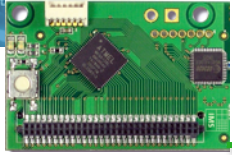
Wakes-up every 10min, take a measure (temp) and send to GW



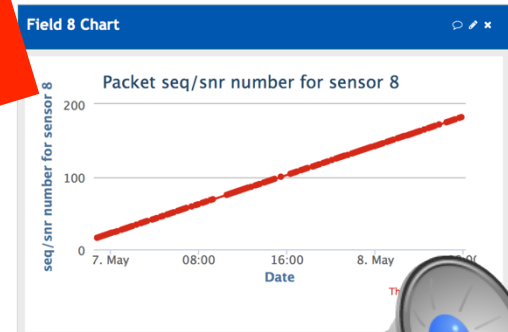
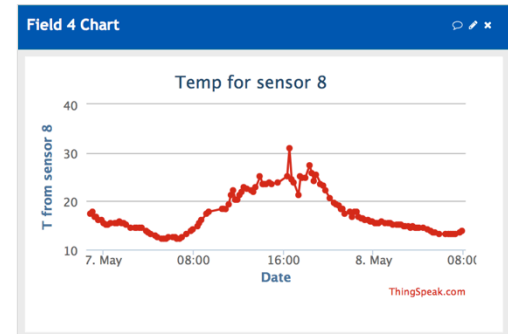
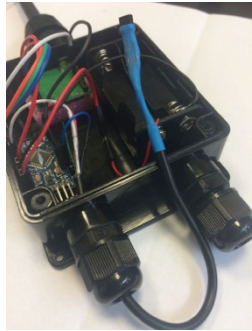
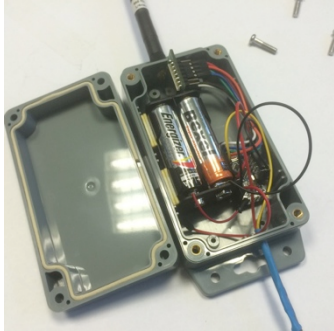
146µA in deep sleep mode, 93mA when awake and sending



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



OUT-OF-THE-BOX SURVEILLANCE



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





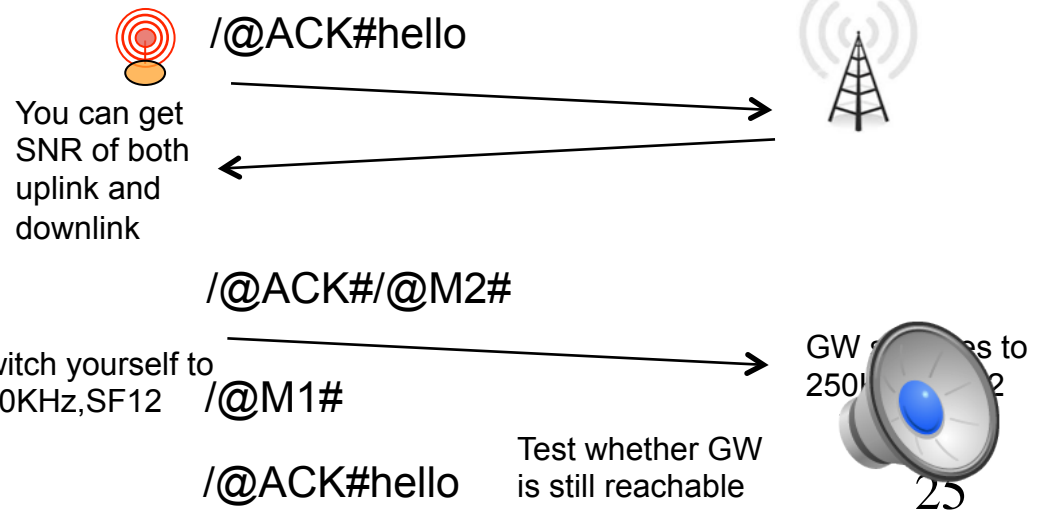
BUILD YOUR OWN TEST-BED

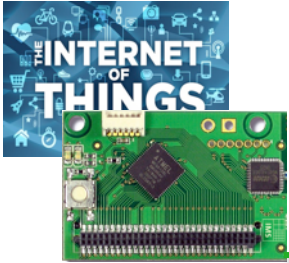
Interactive end-device

```

/dev/cu.usbmodemFA131 (Arduino/Genuino M
Hello world
6477 bytes of free memory.
SX1276 detected, starting
SX1276 LF/HF calibration
...
^$*****Power ON: state 0
^$Default sync word: 0x12
^$LoRa mode 4
^$Setting mode: state 0
^$Channel CH_10_868: state 0
^$Set LoRa Power to x
^$Power: state 0
^$Get Preamble Length: state 0
^$Preamble Length: 8
^$LoRa addr 6: state 0
^$$SX1272/76 configured as device. Waiting serial input for serial-RF bridge
Rcv serial: hello world
Sending. Length is 11
hello world
Payload size is 11
ToA is w/5B Libelium header 322
Packet number 0
LoRa Sent in 545
LoRa Sent w/CAD in 545
Packet sent, state 0
    
```

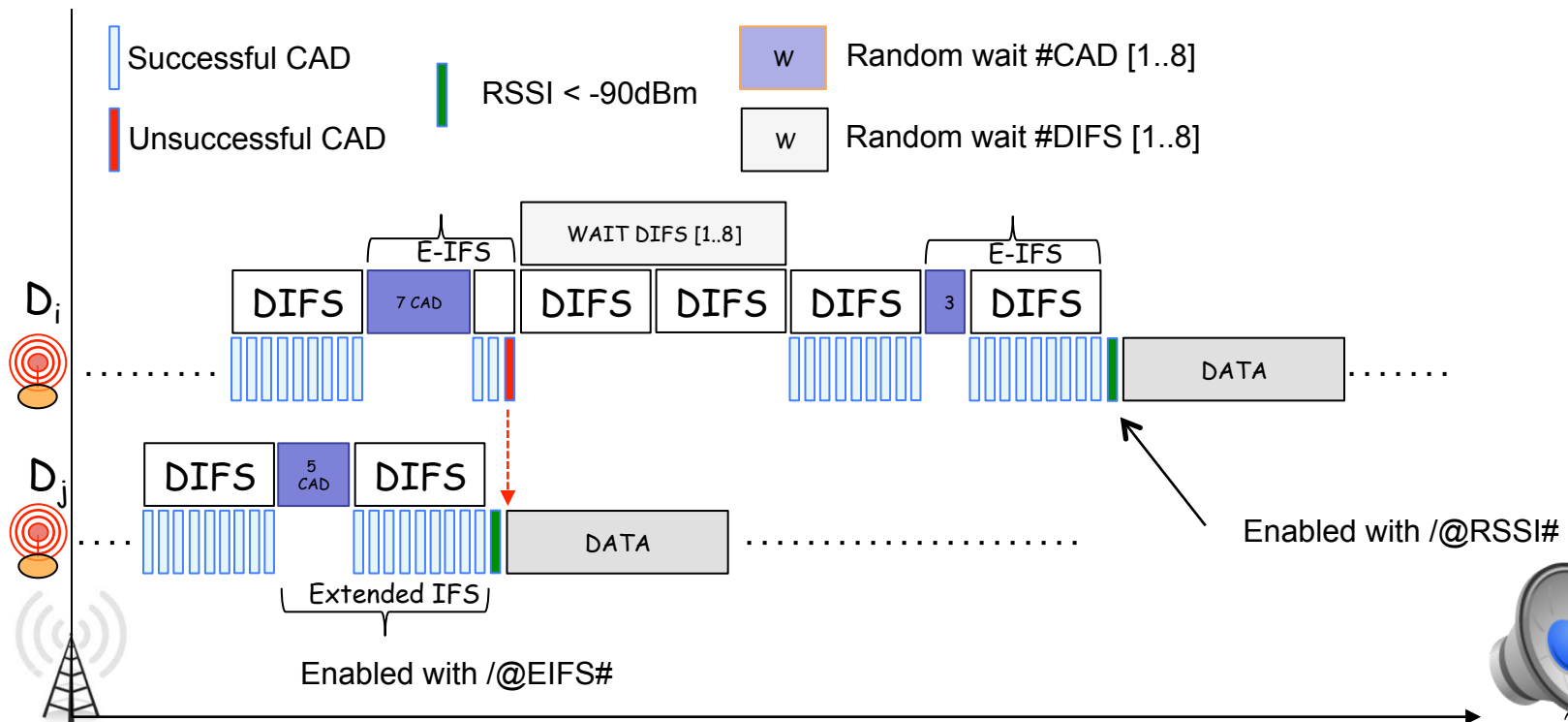
Command	Action
/@M1#	set LoRa mode 1
/@C12#	use channel 12
/@PL/H/M/x/X#	set power to Low, High, Max, extreme (PA_BOOST), eXtreme (+20dBm)
/@A9#	set node addr to 9
/@ACK#hello w/ac	sends "hello w/ack" and request an ACK
/@ACKON#	enables ACK (for all messages)
/@ACKOFF#	disables ACK
/@CAD#	performs an SIFS CAD, i.e. 3 or 6 CAD depending on the LoRa mode
/@CADON3#	uses 3 CAD when sending data (normally SIFS is 3 or 6 CAD, DIFS=3SIFS)
/@CADOFF#	disables CAD (IFS) when sending data
/@RSSI#	toggles checking of RSSI before transmission and after CAD
/@EIFS#	toggles for extended IFS wait
/@T5000#	send a message at regular time interval of 5000ms. Use /@T0# to disable periodic sending
/@TR5000#	send a message at random time interval between [2000, 5000]ms.
/@Z200#	sets the packet payload size to 200 for periodic sending
/@S50#	sends a 50B user payload packet filled with '#'. The real size is 55B with the protocol header
/@D56#	set the destination node to be 56, this is permanent, until the next D command
/@D56#hello	send "hello" to node 56, destination addr is only for this message
/@D1#/@M1#	send the command string "/@M1#" to node 1 (i.e. gateway)

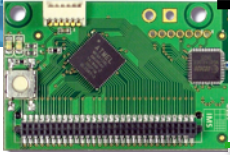




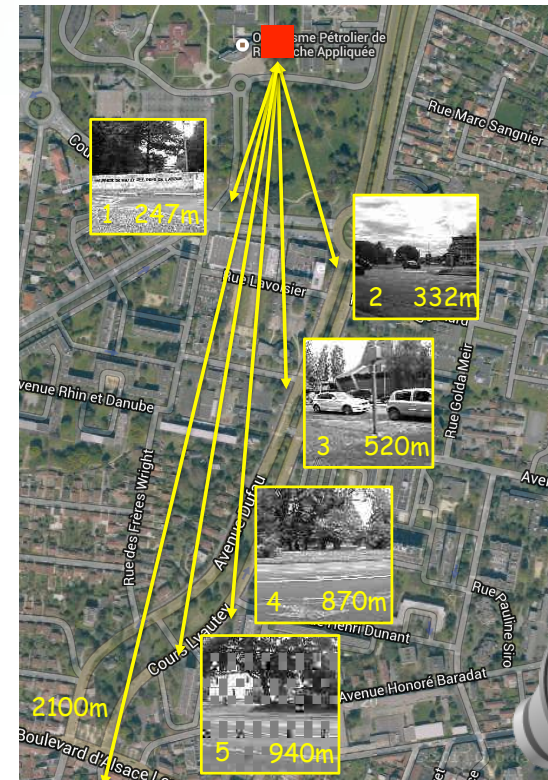
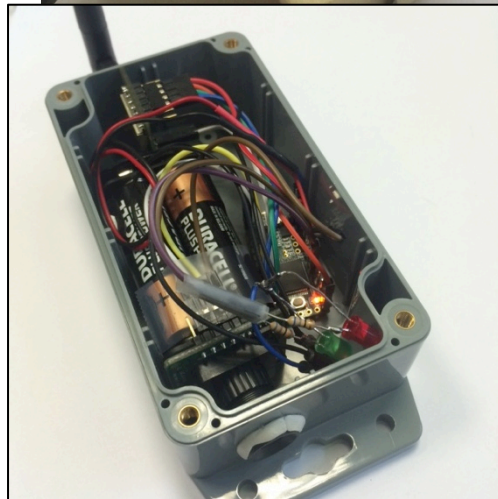
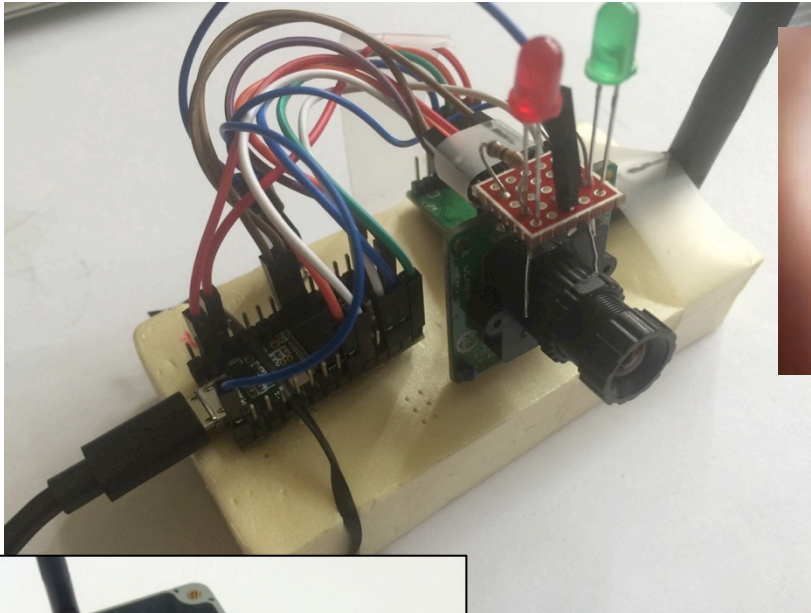
TEST ADVANCED CHANNEL ACCESS

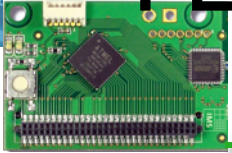
- Implement & test channel access methods
 - SIFS=xCAD; DIFS=3SIFS; set x with /@CADONx#
 - Use background traffic generator devices
 - /@T2000# or /@TR5000#



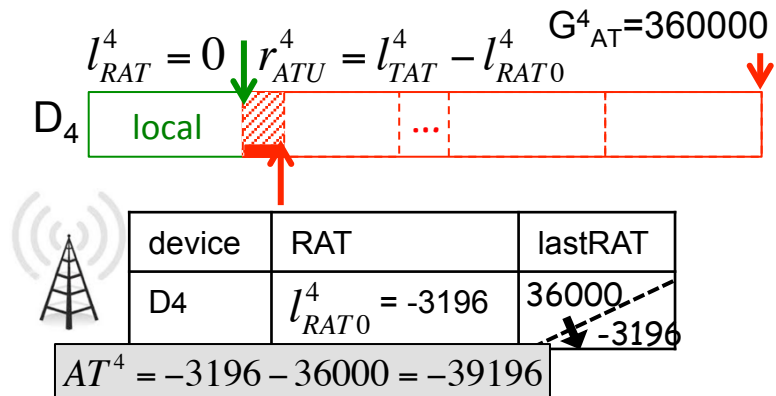
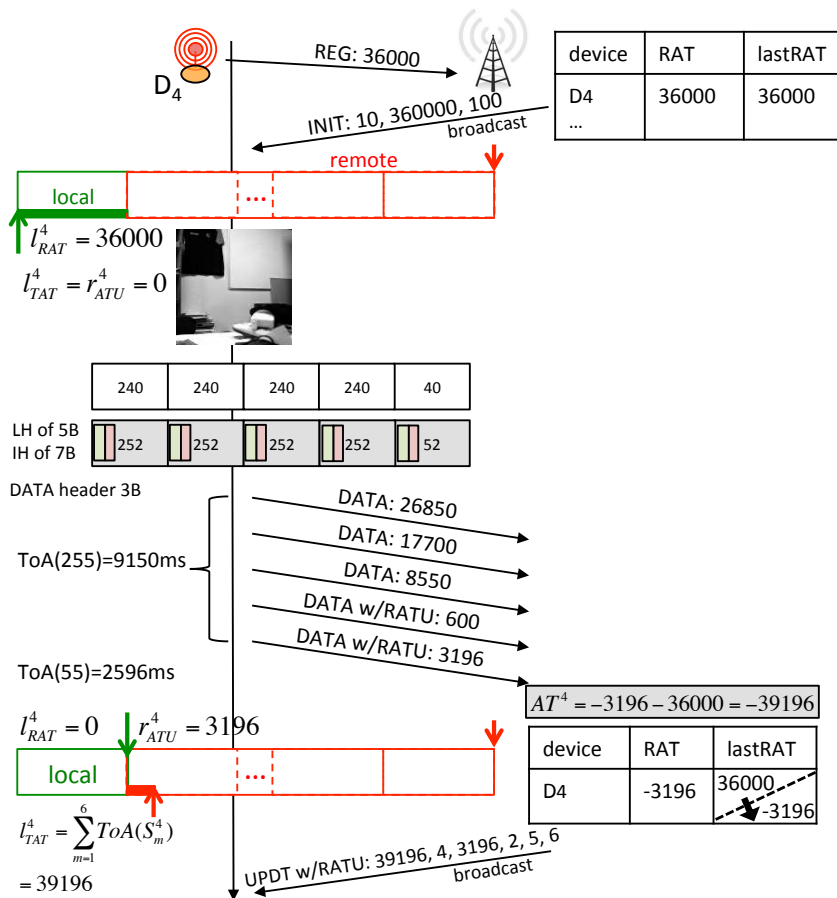


TEST IMAGING SYSTEM

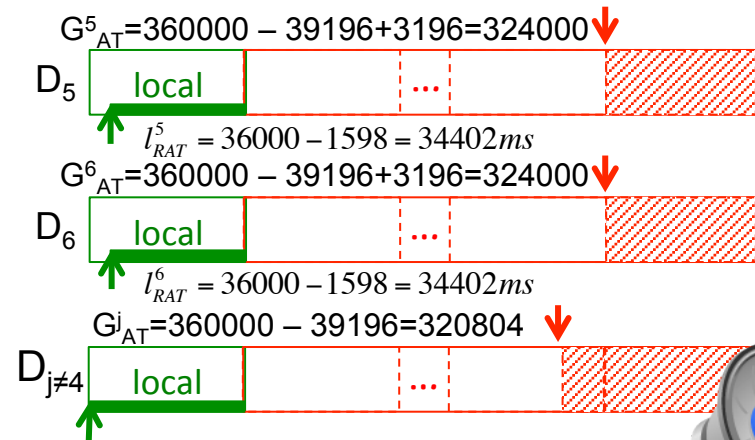




TEST QUALITY OF SERVICE MECHANISMS



UPDT w/RATU	39196	4	$n_d=2$	3196	5	6
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WHO IS DEPLOYING TEST-BEDS?

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























CongducPham / LowCostLoRaGw

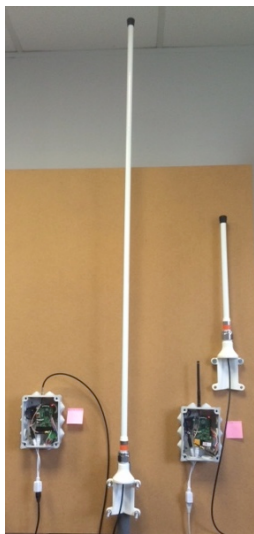
Unwatch 13 Star 22 Fork 11







Code Issues 7 Pull requests 0 Wiki Pulse Graphs Settings

Stargazers

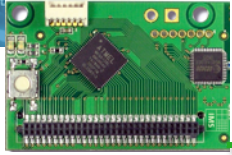
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<p>University Gaston Berger, Saint-Louis, Senegal</p> <p>The gateway will be used to deploy low-cost IoT solutions in the context of the H2020 WAZIUP project.</p>	
<p>Easy Global Market, Nice, France</p> <p>The gateway will be used to deploy LoRa service 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> <ol style="list-style-type: none"> Farmerline (Ghana) iSpace (Ghana) 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 Banyuls/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>	





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
- ❑ Deploying low-cost, long-range test-beds is important prior to any application deployment: our framework allows both out-of-the-box deployment and more research-oriented studies

