Internet-of-Thing and reasons it is becoming a reality

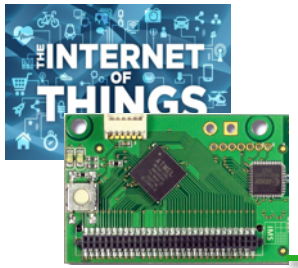
illustration with the H2030 WAZIUP project

BDAW'2016
American university in Bulgaria

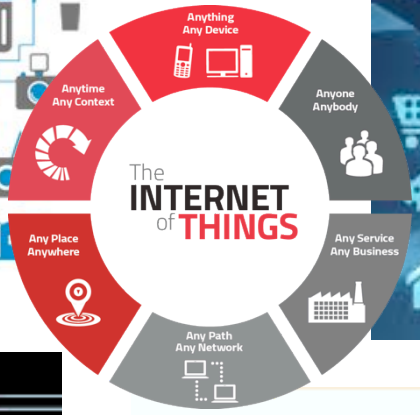
Blagoevgrad, Bulgaria

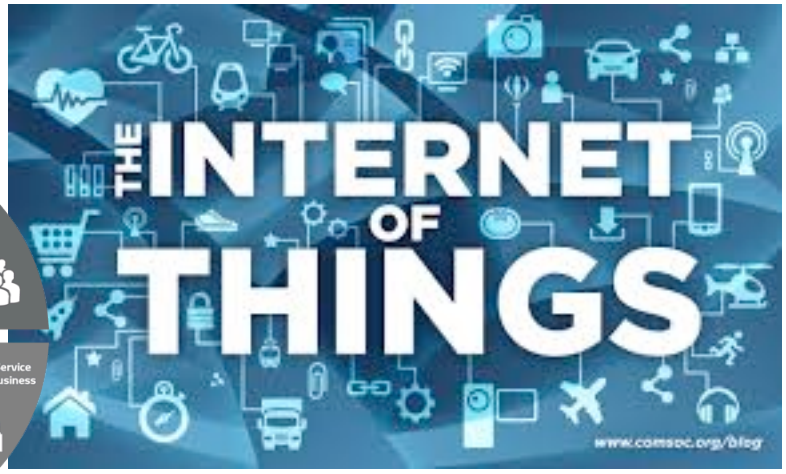
November, 10th, 2016

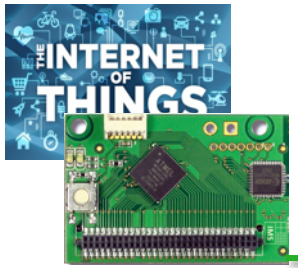
Prof. Congduc Pham
http://www.univ-pau.fr/~cpham
Université de Pau, France



Internet of Things



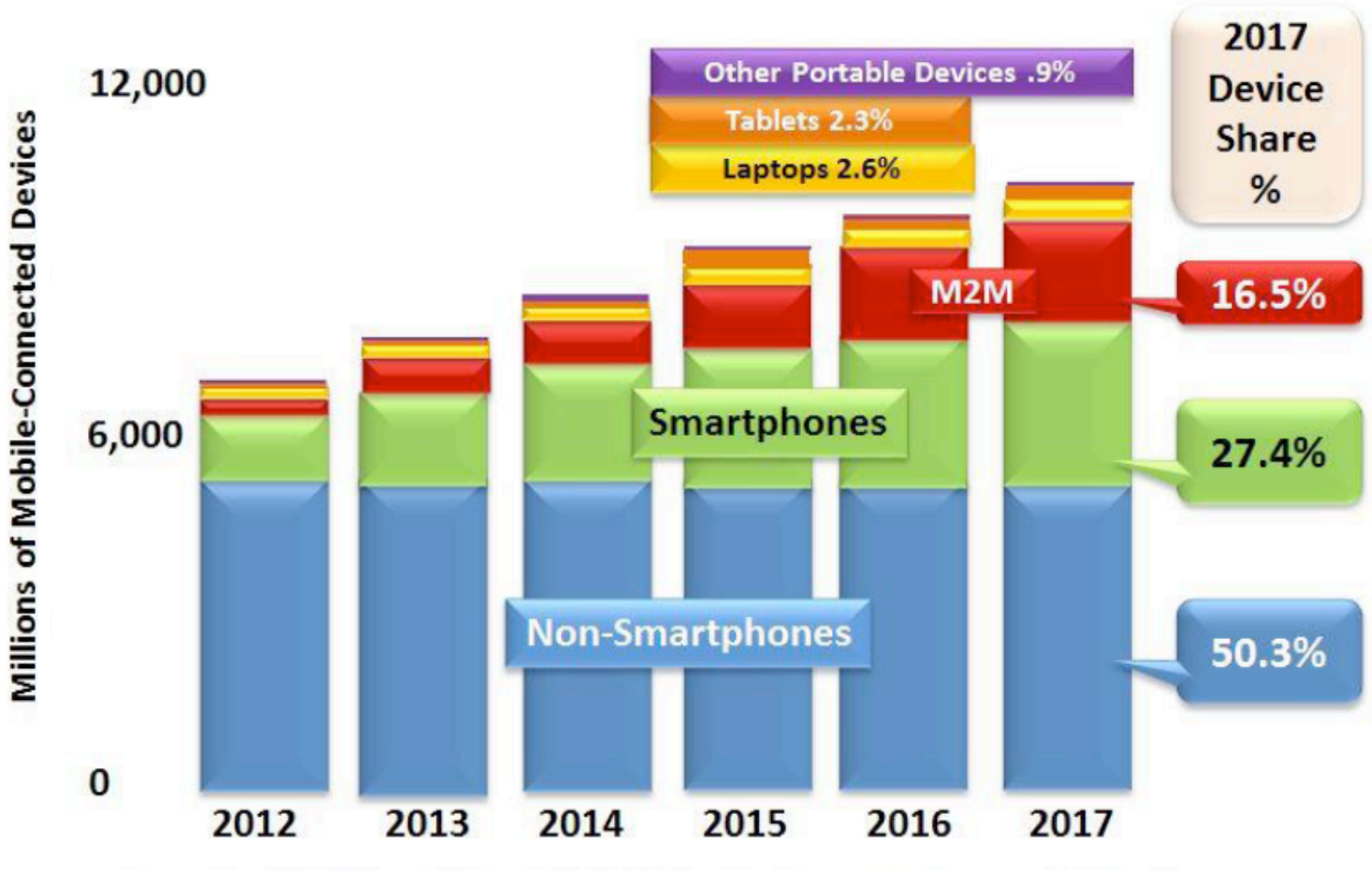


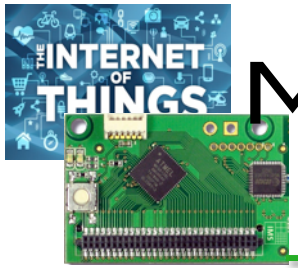


IoT, M2M, D2D,...

4G Americas / **4G Mobile Broadband Evolution: 3GPP Release 11 & Release 12 and Beyond** / February 2014

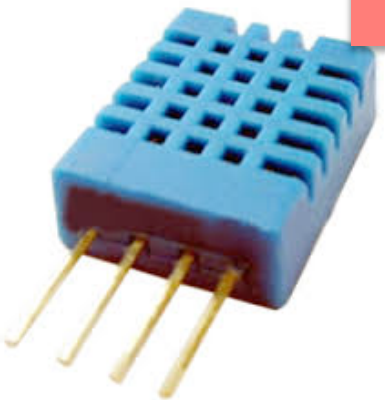
Global Mobile Device Growth by Type

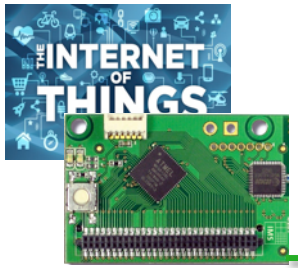




Measuring the physical world

Sensing





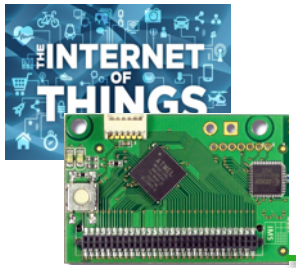
CONTROL, OPTIMIZE & INSTRUMENT !

DATA ANALYSIS, OPTIMIZATION & CONTROL

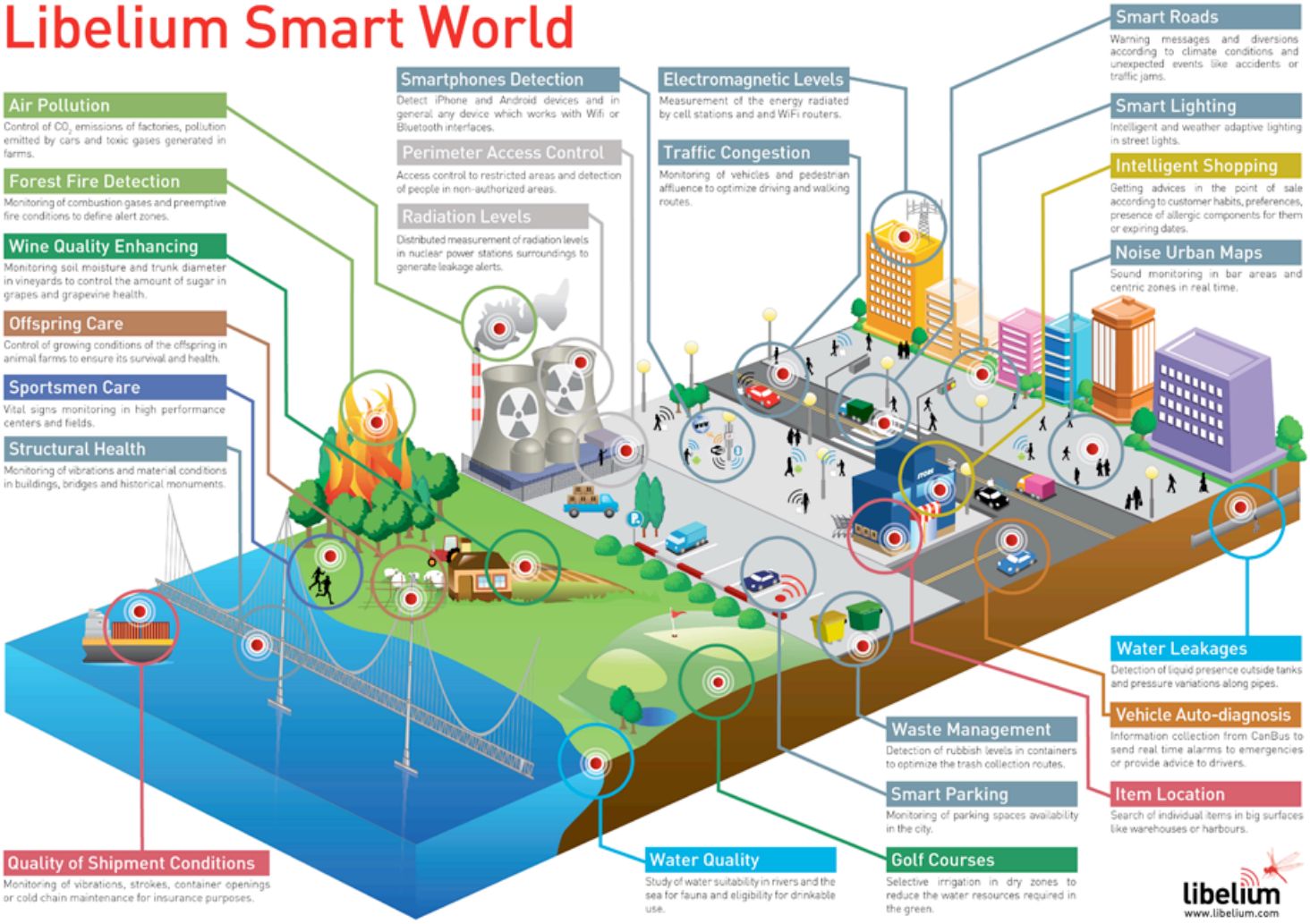
PERVASIVE SYSTEMS

SENSING

PEOPLES, INFRASTRUCTURES, BUILDINGS, VEHICULES



Example: Smart Cities



HTTP://WWW.LIBELIUM.COM/TOP_50_IOT_SENSOR_APPLICATIONS_RANKING/#SHOW_INFOGRAPHIC

Huge societal needs!

Irrigation

Livestock farming

Fish farming & aquaculture

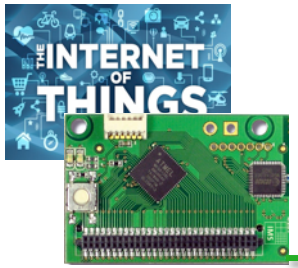
Storage & logistic

Agriculture

Fresh water

MATURATION OF THE IoT MARKET…

Waste Container connected sensor



1ST ISSUE: COLLECT DATA

DATA ANALYSIS, OPTIMIZATION & CONTROL

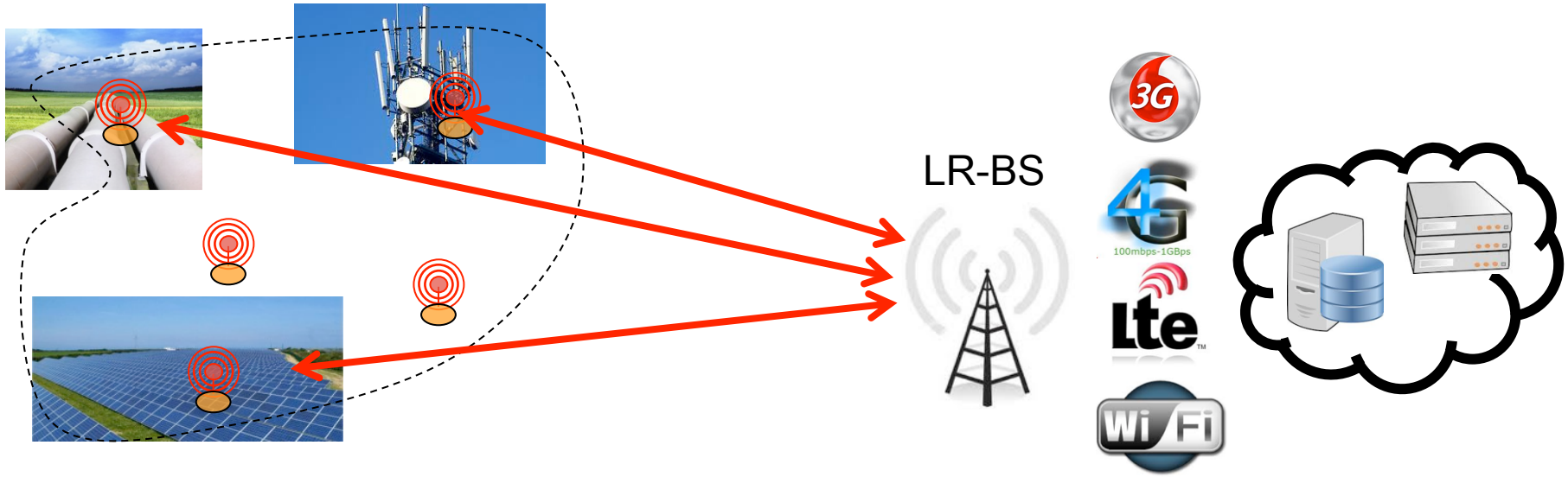
PERVASIVE SYSTEMS

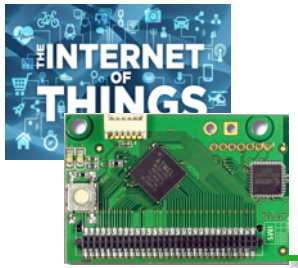
SENSING

PEOPLES, INFRASTRUCTURES, BUILDINGS, VEHICULES

SENSING/TELEMETRY SYSTEMS

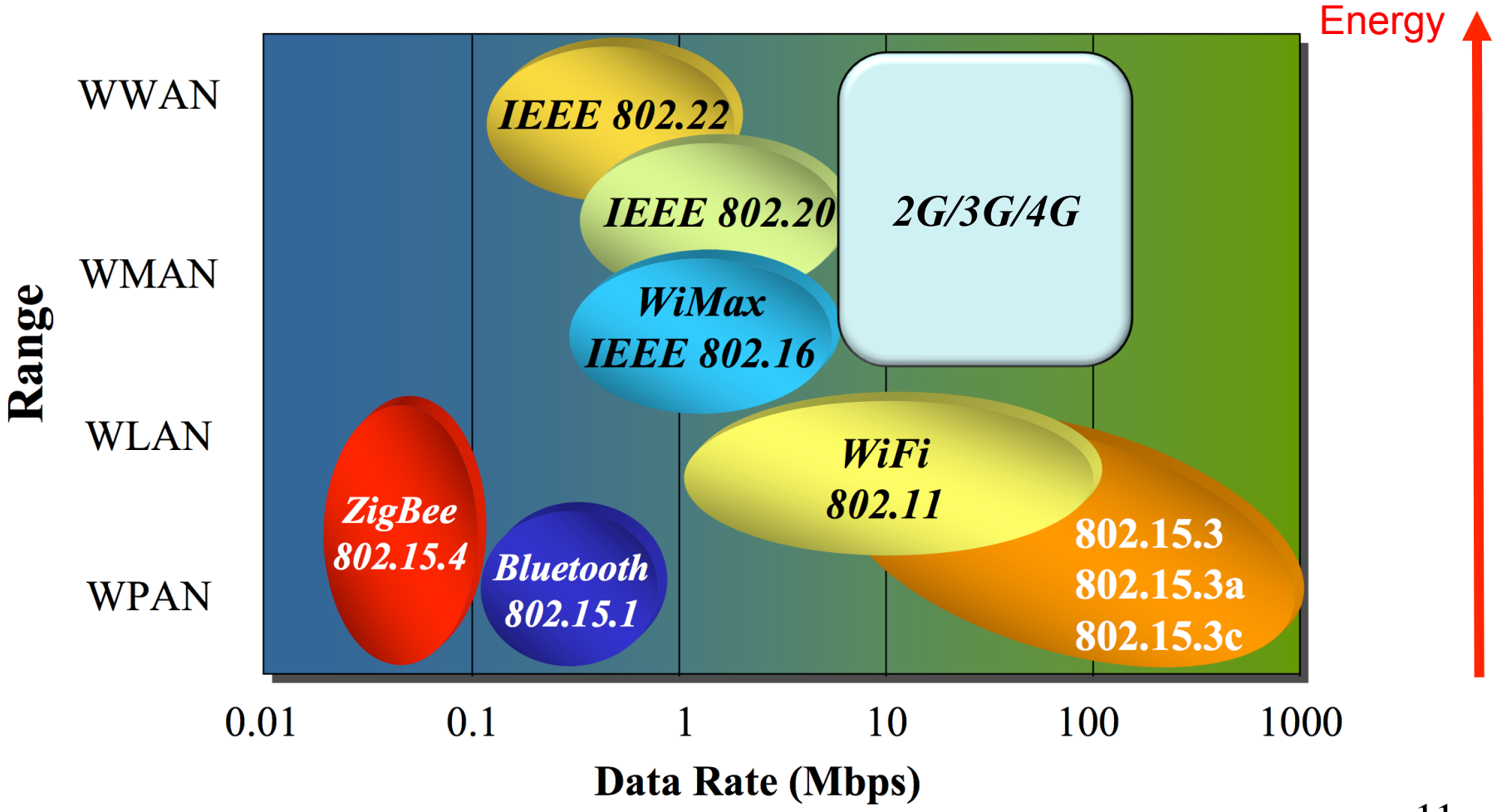
deployment made easier in single-hop model !!!

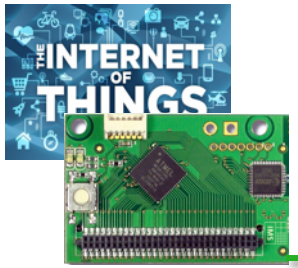




THE WIRELESS SPACE

Energy-Range dilemma

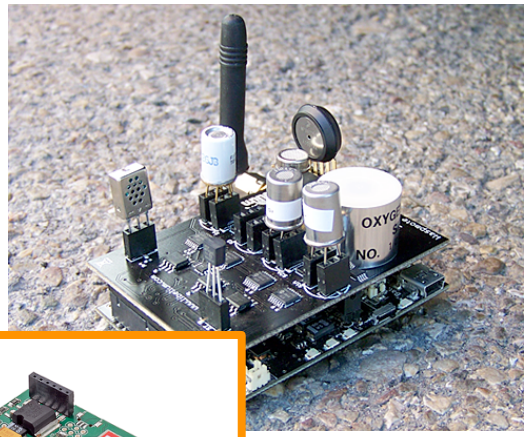


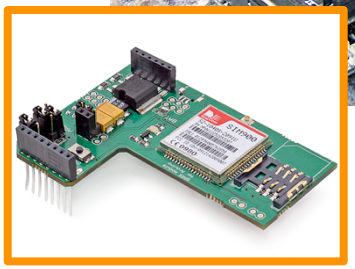


How costly is transmission?

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

Energy consideration





18720 Joules

TX power: 500mA

P = I x V = 500 x 3.3 = 1650mW

E = P x t -> t = E/P

11345s or 3h9mins

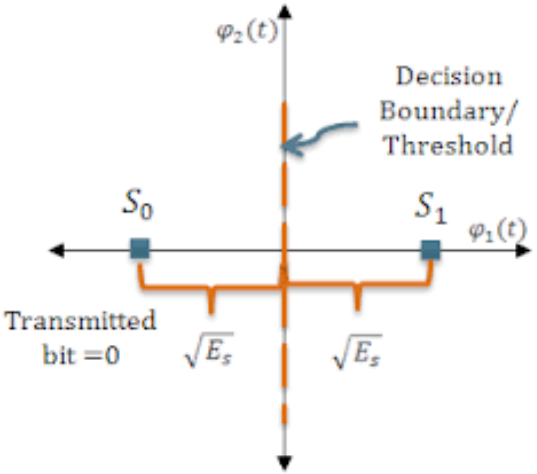
Technology	2G	3G
Range (I=Indoor, O=Outdoor)	N/A	N/A
Tx current consumption	200mA-500mA	500mA – 1000mA
Standby current	2.3mA	3.5mA

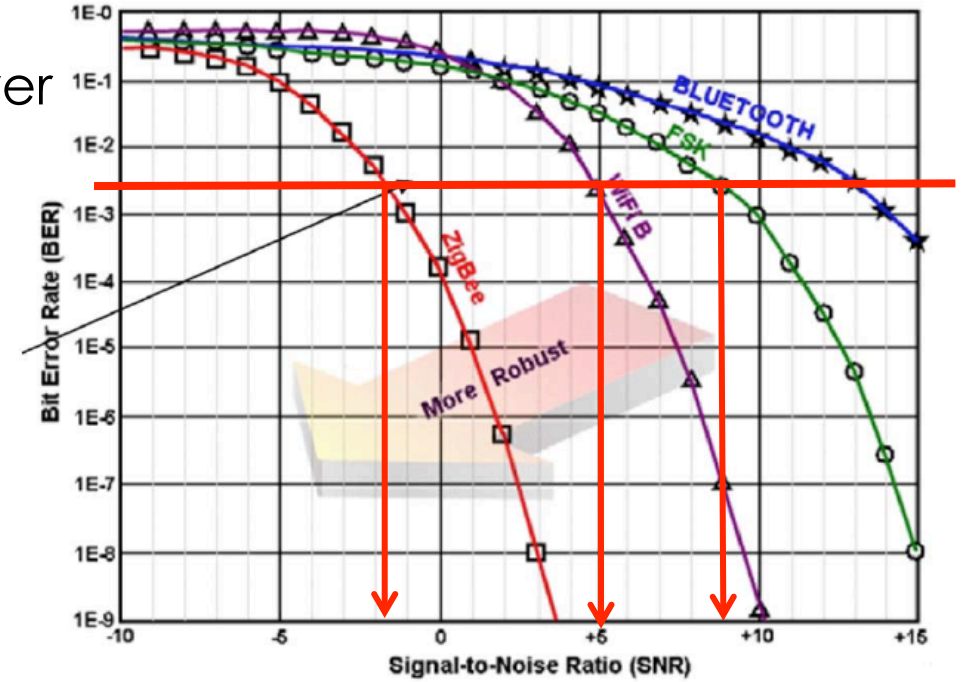
Haven't considered:

- Baseline power consumption of the sensor board
- RX consumption!
- Event capture consumption
- Event processing consumption

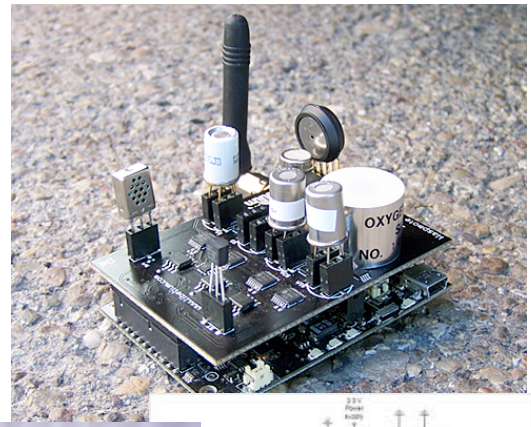
IEEE 802.15.4 in ISM 2.4GHz

- 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





Energy consideration



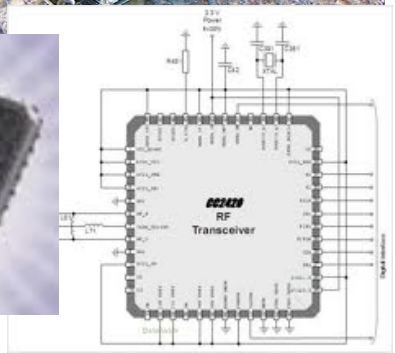
18720 Joules

TX power 0dbm: 17.4mA

P = I x V = 17.4 x 3.3 = 57.42mW

E = P x t -> t = E/P

326018s or 90.5h



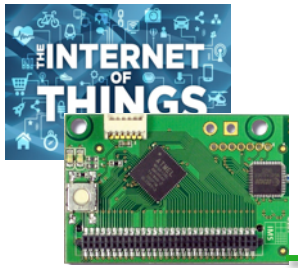
Chipcon Products from Texas Instruments

CC2420

Parameter	Min.	Typ.	Max.	Unit	Condition / Note
Current Consumption, transmit mode:					
P = -25 dBm		8.5		mA	The output power is delivered differentially to a 50 Ω singled ended load through a balun, see also page 55.
P = -15 dBm		9.9		mA	
P = -10 dBm		11		mA	
P = –5 dBm		14		mA	
P = 0 dBm		17.4		mA	

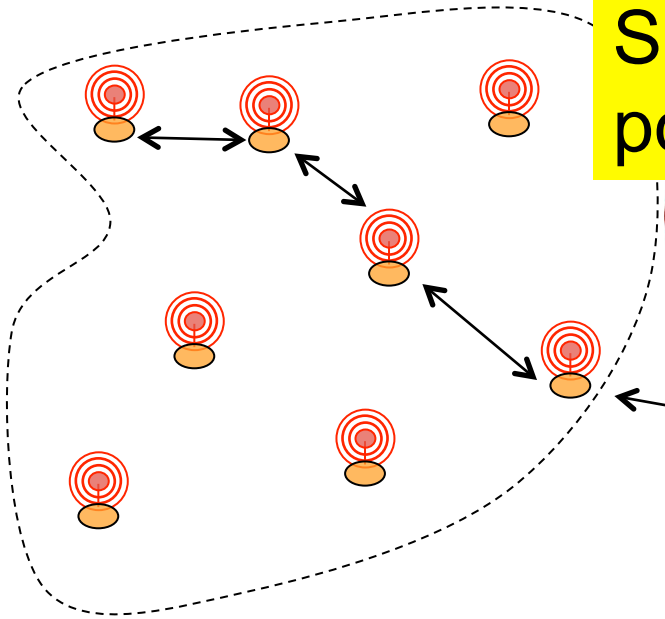
Haven't considered:

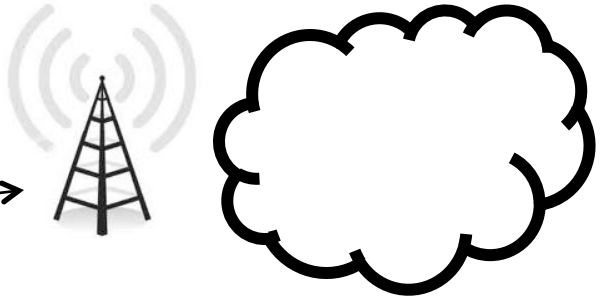
- Baseline power consumption of the sensor board
- RX consumption: 18.8mA!
- Event capture consumption
- Event processing consumption



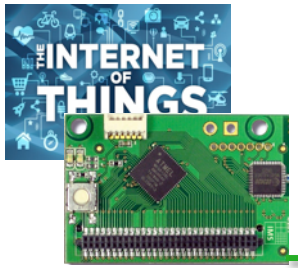
Lower energy means shorter range!

Short range, low power radio



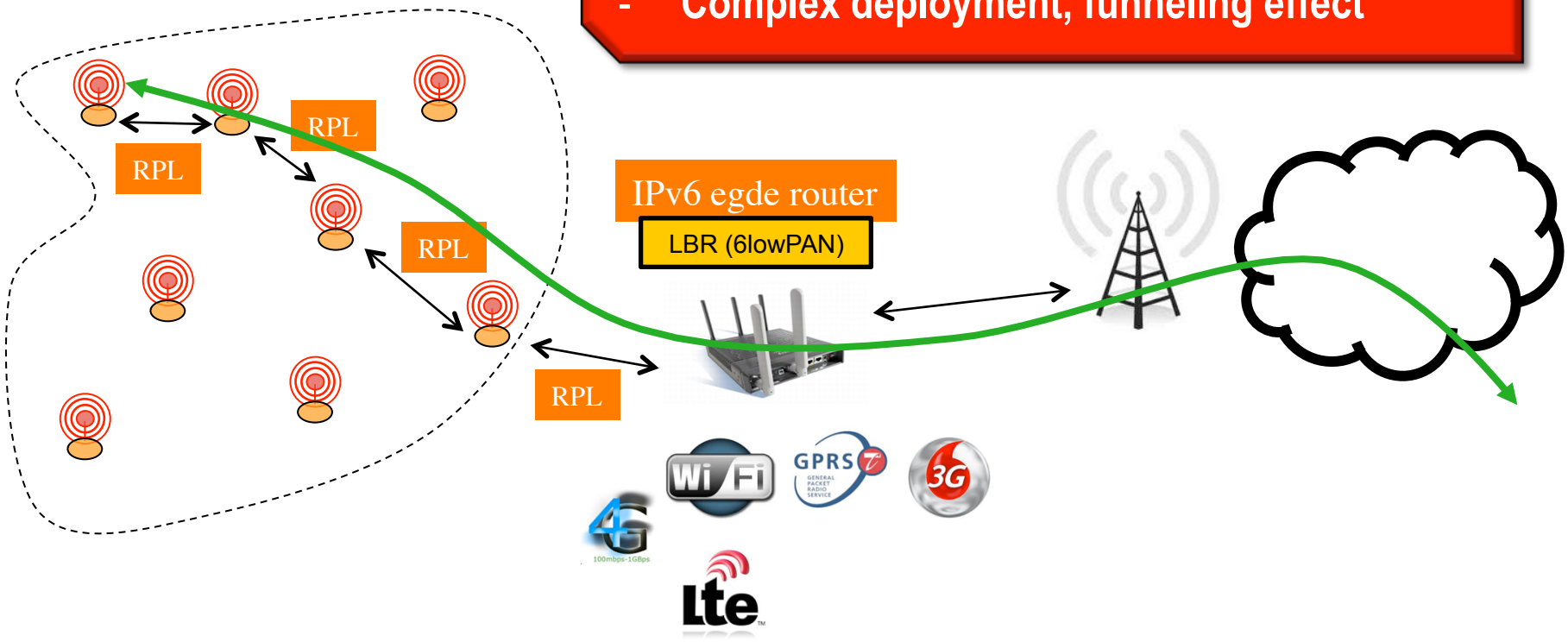


- Routing issues
- Medium Access issues



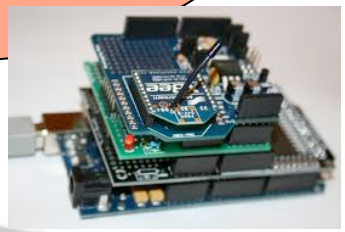
15 YEARS OF MULTI-HOP ROUTING?

- High packet loss rates
- Needs synchonization when duty-cycling
- Complex deployment, funneling effect

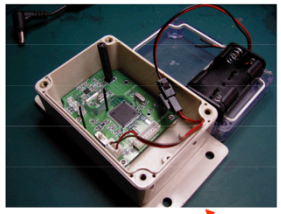


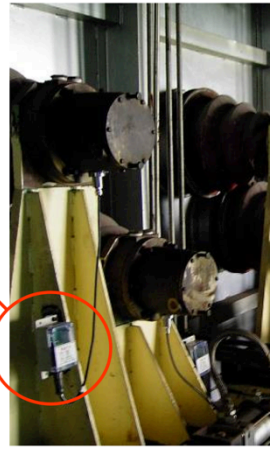
Academics vs Industries
Let's go back to reality!

Millions of sensors, self-organizing, self-configuring, with QoS-based multi-path routing, mobility, and …



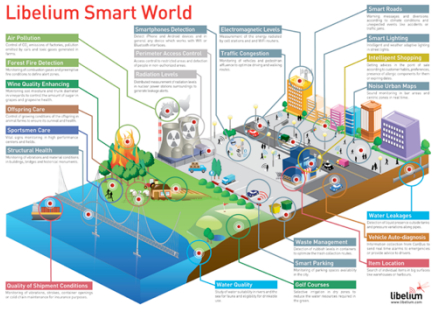
500 sensors, STATIC deployment, but need to have RELIABILITY, GUARANTEED LATENCY for monitoring and alerting. MUST run for 3 YEARS. No fancy stuff! CAN I HAVE IT?

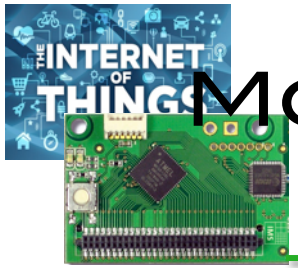




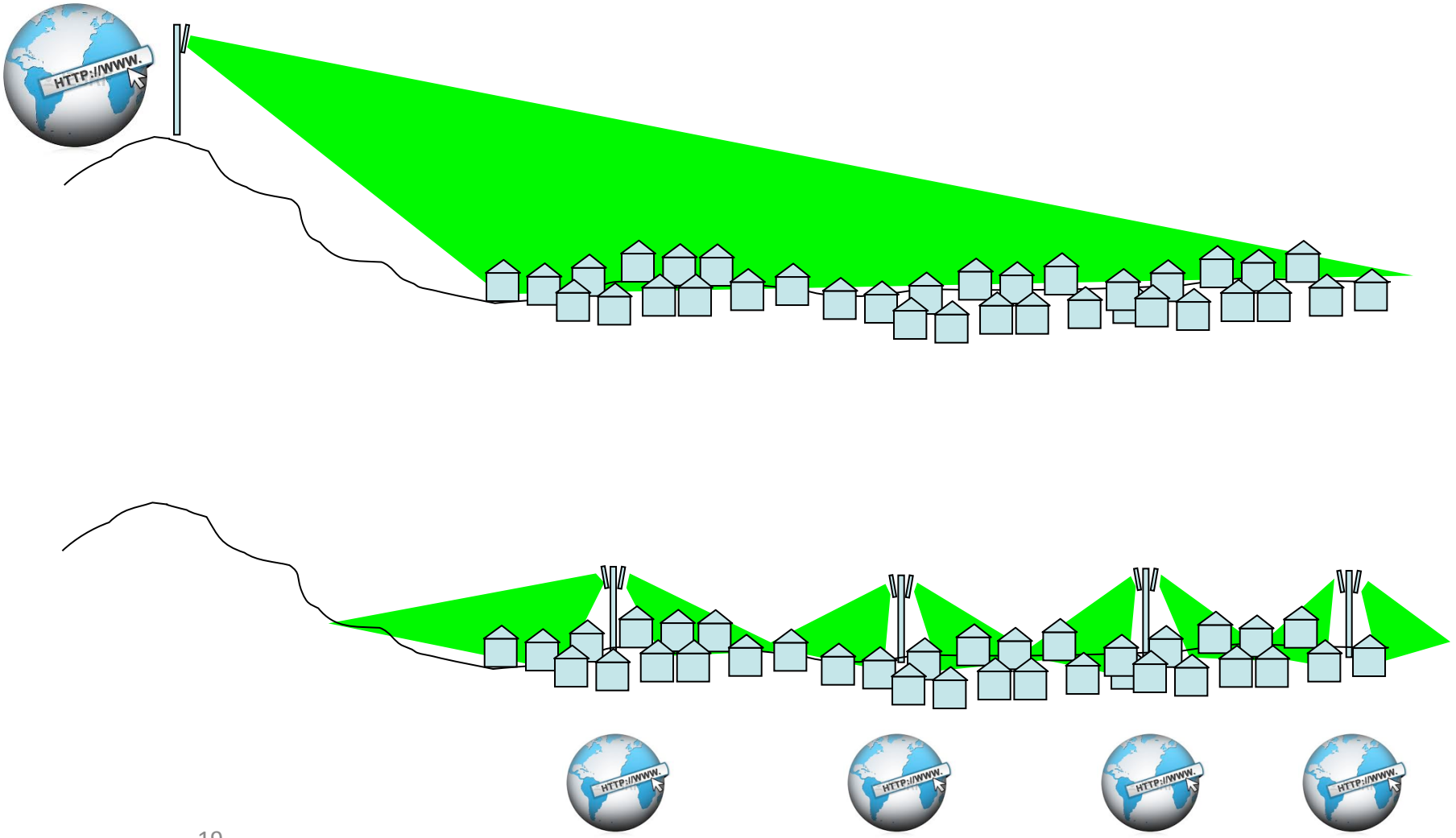
- Placement constraints
- Lifetime constraints

From Peng Zeng & Qin Wang

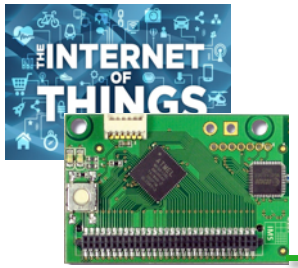




Most telemetry applications use the cellular model

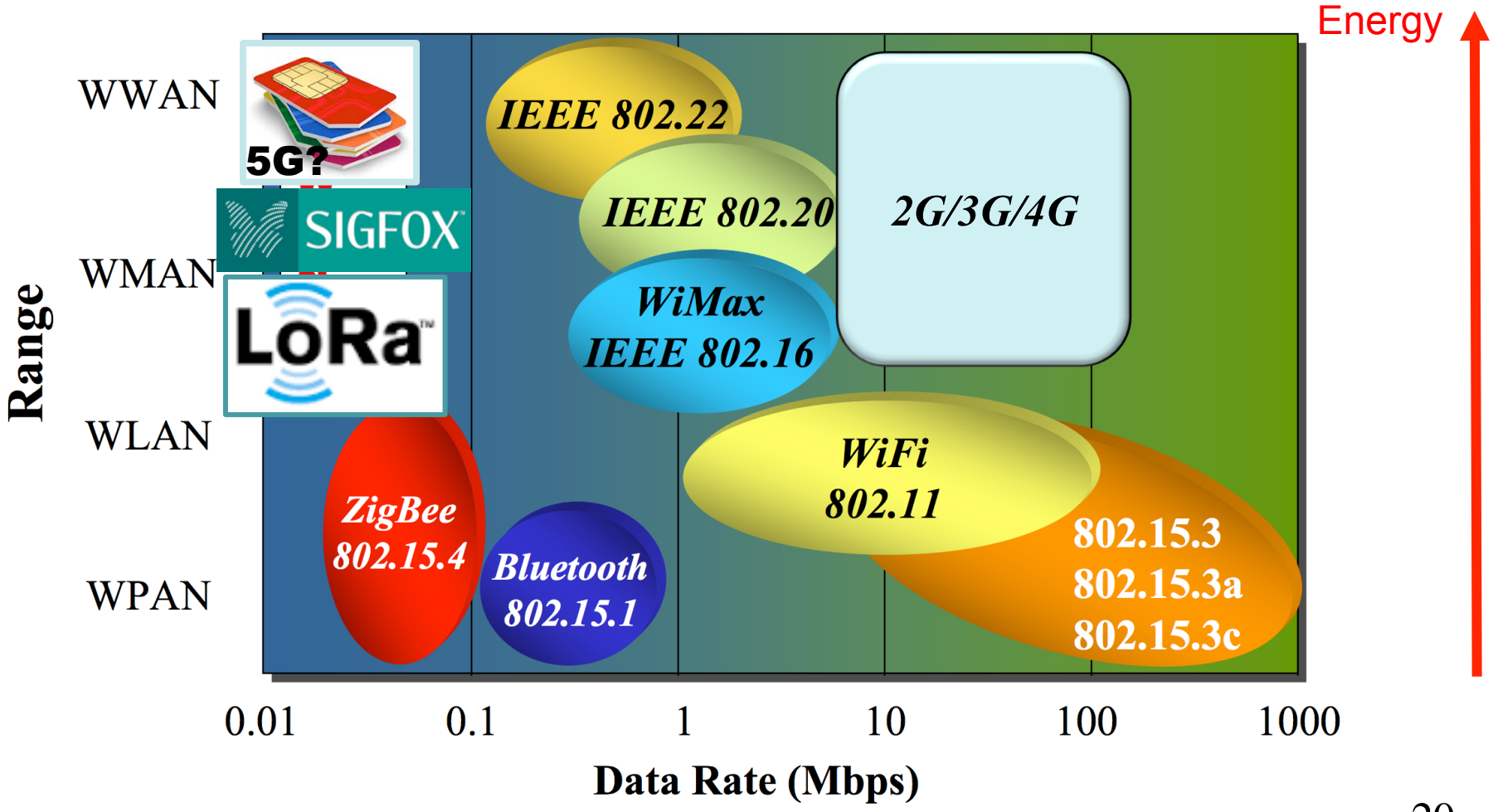


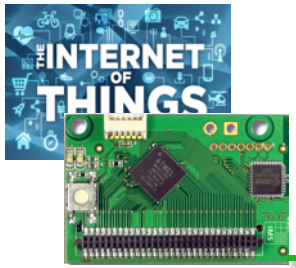
19



Low-power and long-range?

Energy-Range dilemma

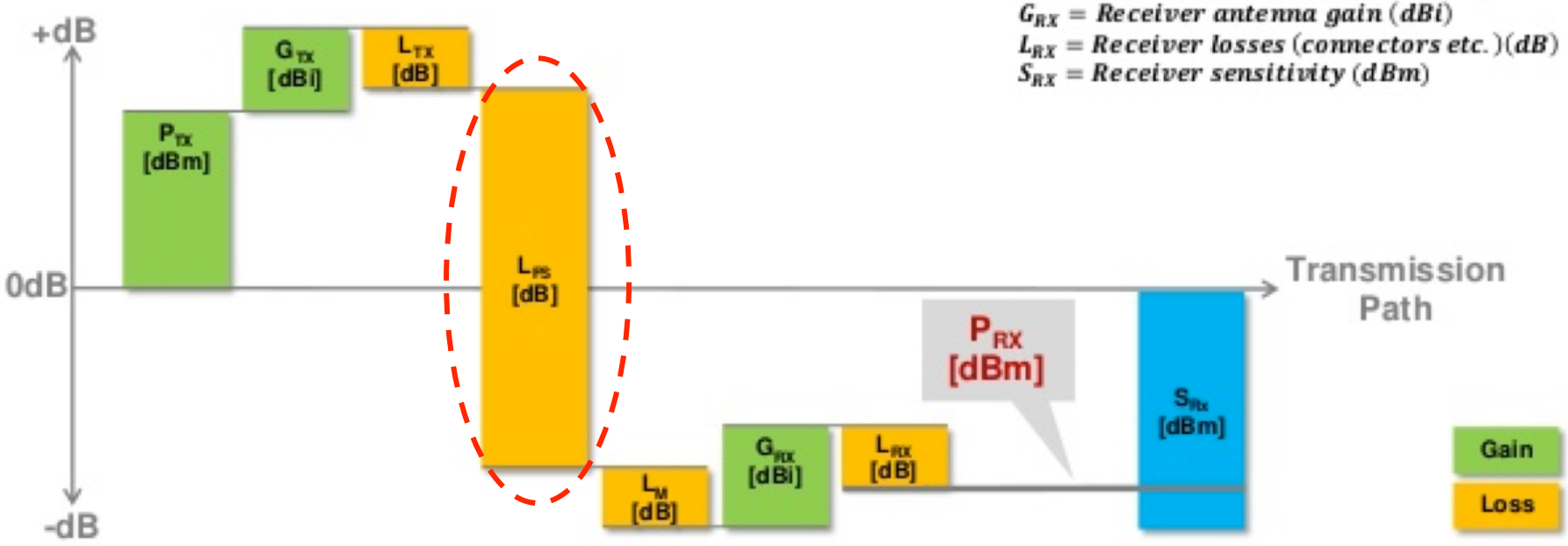




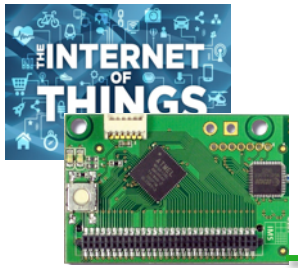
LINK BUDGET OF LPWAN

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

P_{RX} = Received power (dBm)
P_{TX} = Sender output power (dBm)
G_{TX} = Sender antenna gain (dBi)
L_{TX} = Sender losses (connectors etc.)(dB)
L_{FS} = Free space loss (dB)
L_M = Misc. losses (multipath etc.)(dB)
G_{RX} = Receiver antenna gain (dBi)
L_{RX} = Receiver losses (connectors etc.)(dB)
S_{RX} = Receiver sensitivity (dBm)

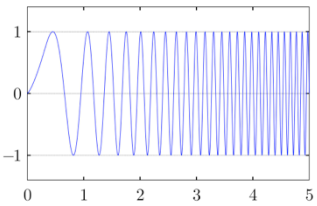


From Peter R. Egli, INDIGOO.COM

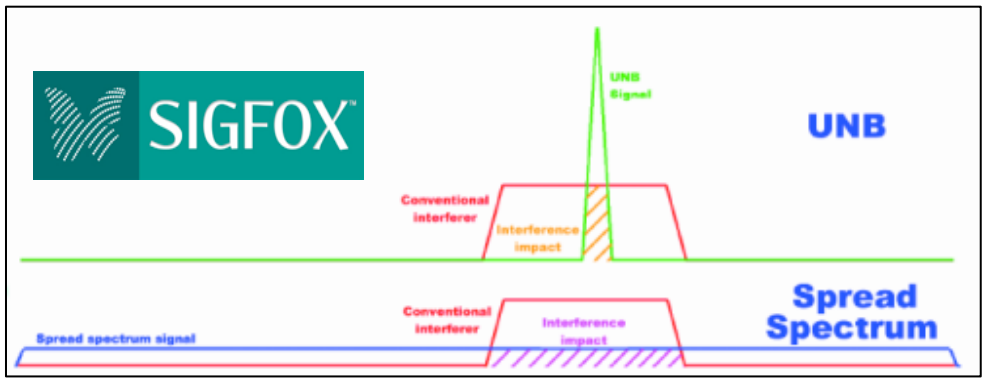


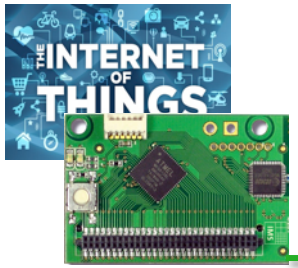
Increasing range?

- 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



LoRa™





Simple loss in signal strength model

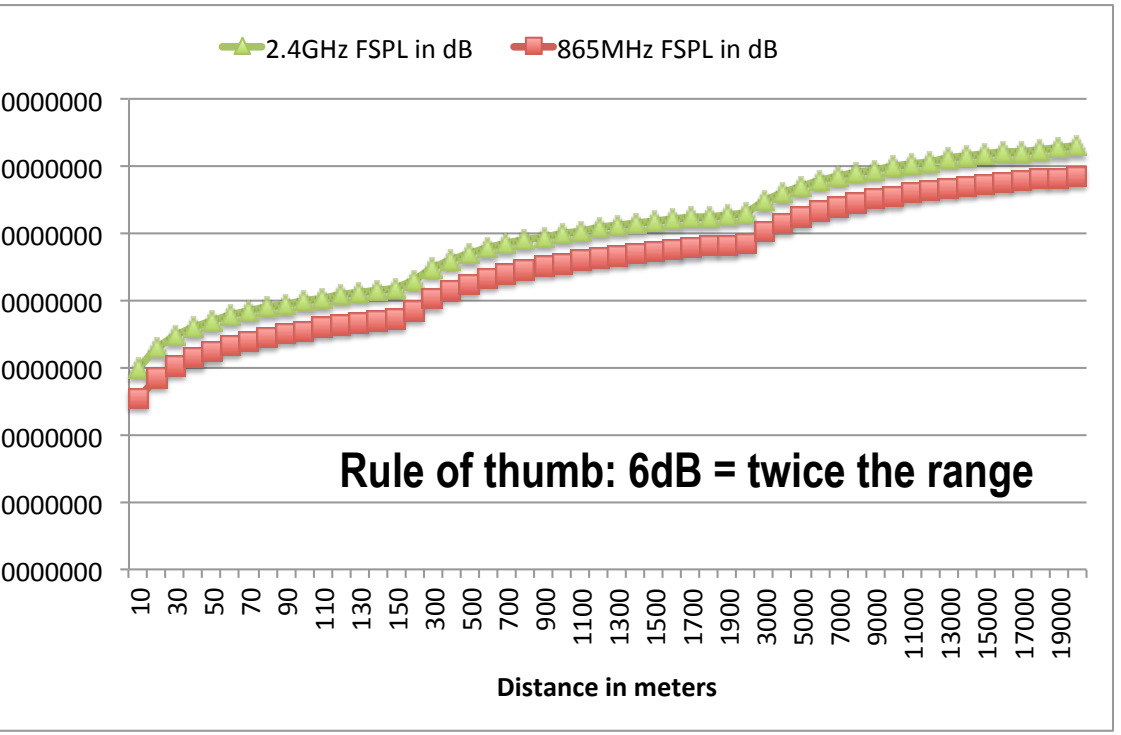
$$\text{FSPL} = \left(\frac{4\pi d}{\lambda}\right)^2 = \left(\frac{4\pi df}{c}\right)^2 \qquad FSPL = \frac{P_t}{P_r} G_t G_r$$

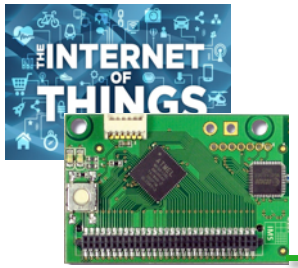
- Free Space Path Loss model

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

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

FSPL assume Gt=Gr=1



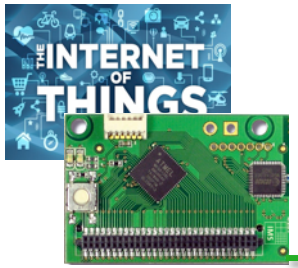


LINK BUDGET EXAMPLE

- 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,**

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



LINK BUDGET EXAMPLE

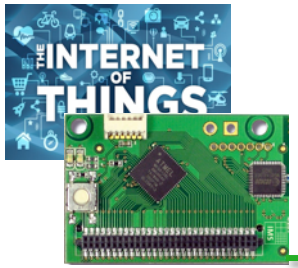
- Received Power (dBm) = Transmitted Power (dBm) + Gains (dB) – Losses (dB) [mainly FSL]
- Example
  - Transmitted power is +14dBm (25mw)
  - Losses (FSPL) is 1
  - Then Receiver P
- If you have a rece
  handle FSPL up to
- Rewriting the equ
  - Losses (dB) = Trans
  - Losses = link budg
  - Link budget = Tran
  - **151dB=14dBm - (-**

dBm – power referred to 1 mW,

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

KEY PRODUCT FEATURES

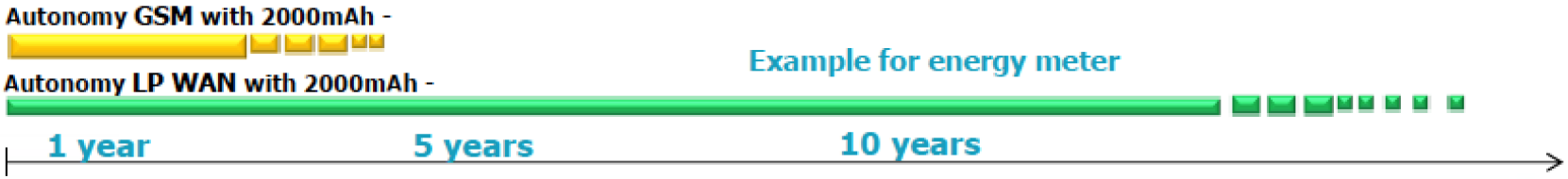
- LoRa™ Modem
- 157 dB maximum link budget
- +20 dBm at 100 mW constant RF output vs. V supply
- +14 dBm high efficiency PA
- Programmable bit rate up to 300 kbps
- High sensitivity: down to -137 dBm



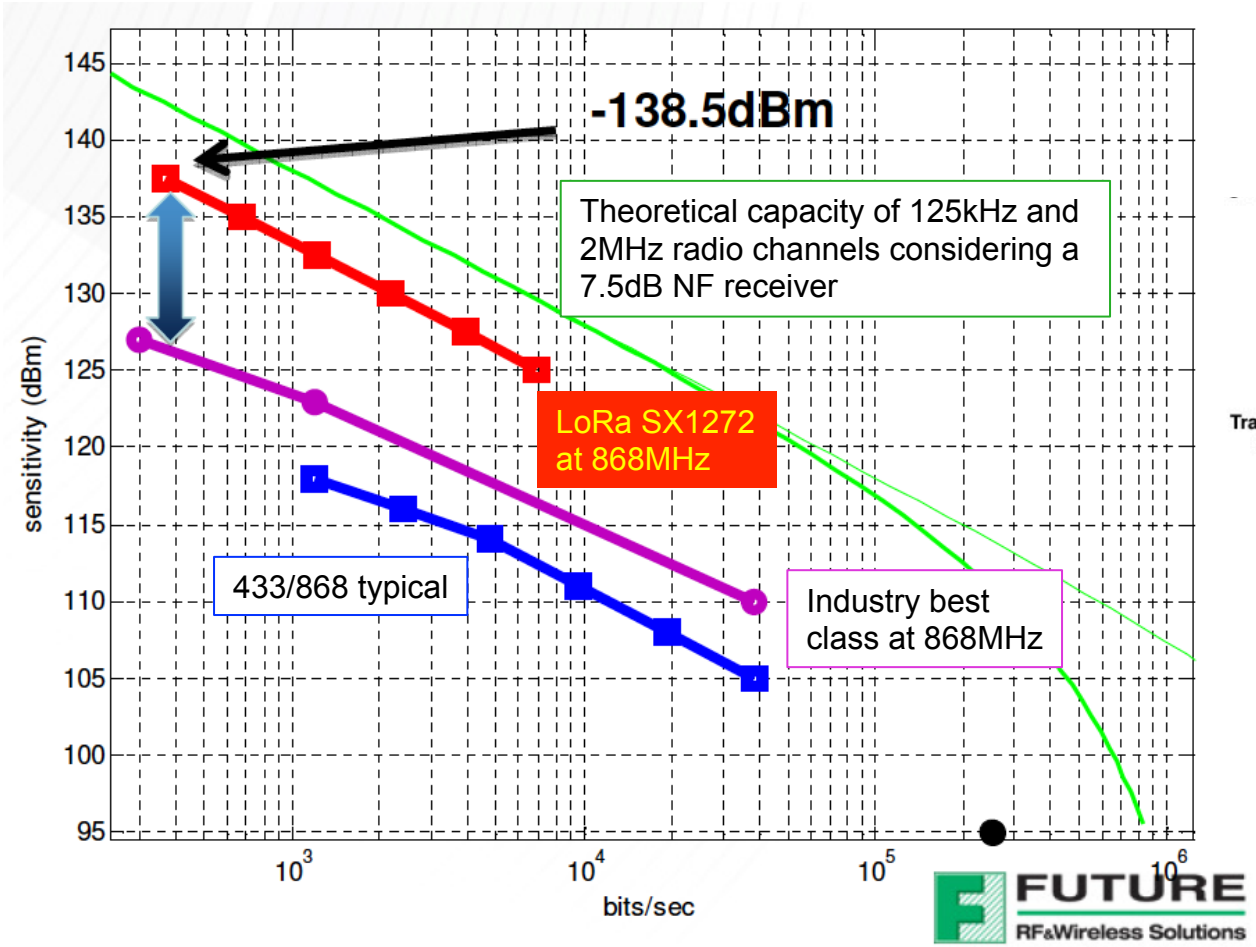
Low Power WAN ?

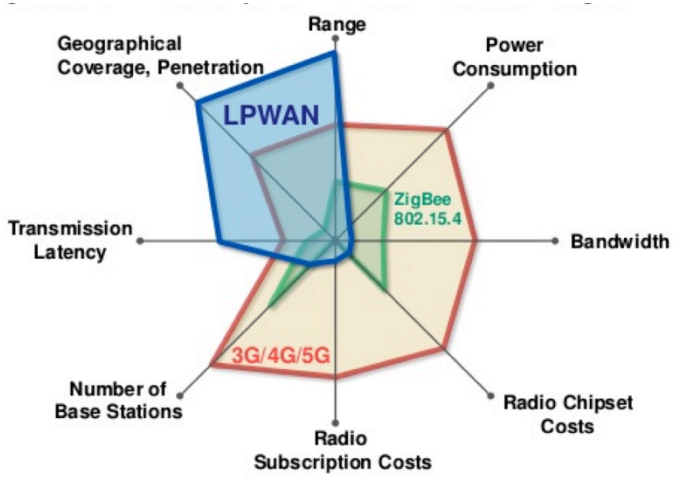
Tables from Semtech

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 $



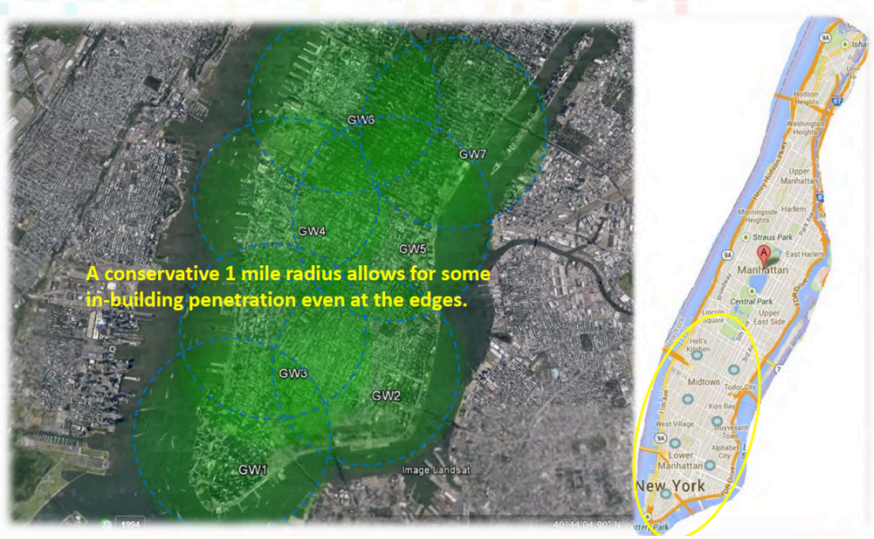
WHY THE LPWAN REVOLUTION?





From Peter R. Egli, INDIGOO.COM

Versatile LPWAN!



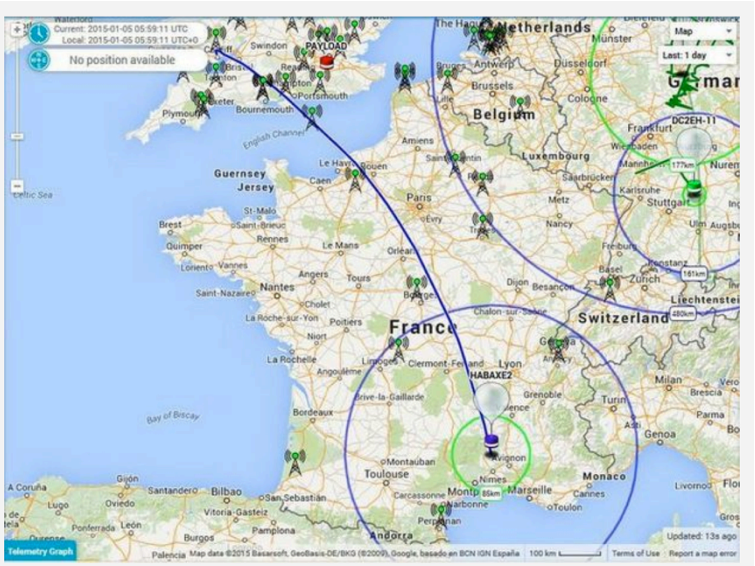
Dense urban areas

Rural areas

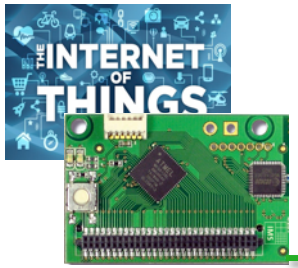
Indoor

Underground

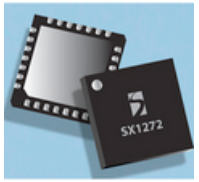
The higher the better!



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



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

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

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

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

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

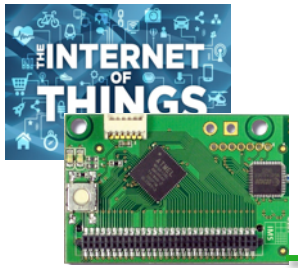
Rule of thumb

6dB increase = twice the range in LOS

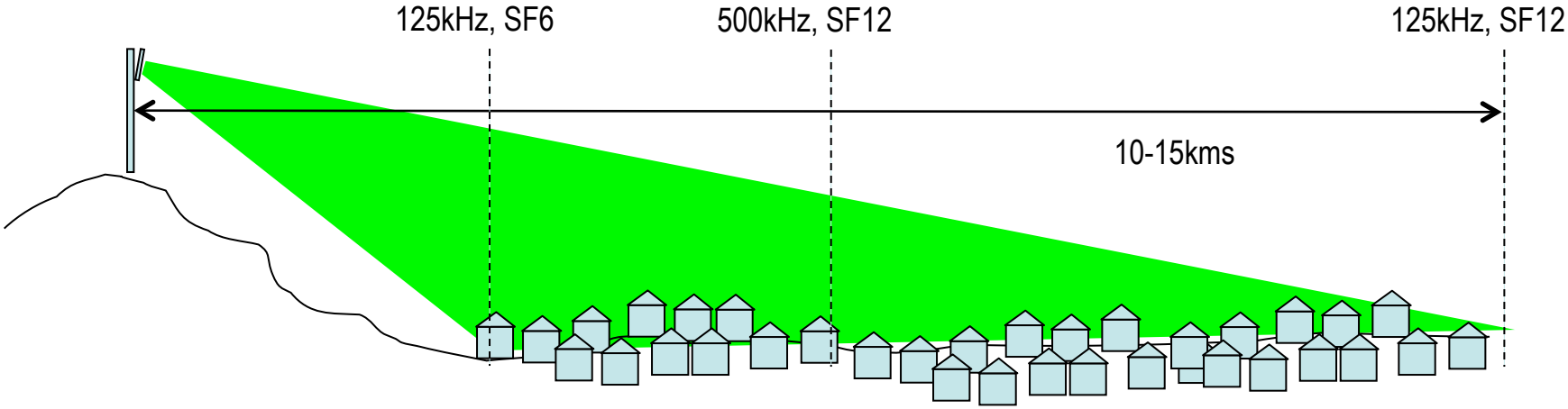
12dB needed for urban areas

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

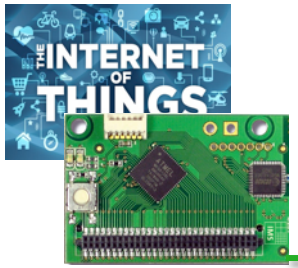
Tables from Semtech



Relation to range



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



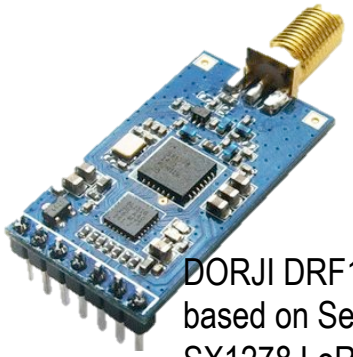
The price to pay!

Very low throughput
Transmission time can be several seconds

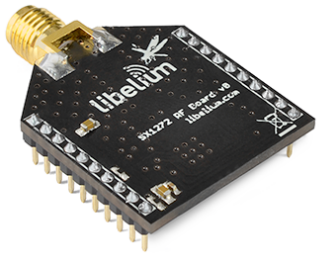
Range ↕ Throughput

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

LoRa modules from Semtech's SX127x chips



DORJI DRF1278DM is based on Semtech SX1278 LoRa 433MHz

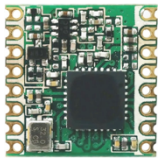


Libelium LoRa is based on Semtech SX1272 LoRa 863-870 MHz for Europe

inAir9/9B based on SX1276

Froggy Factory LoRa module (Arduino)

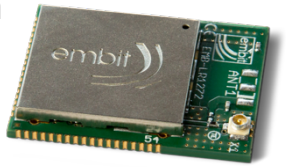
IMST IM880A-L is based on Semtech SX1272 LoRa 863-870 MHz for Europe



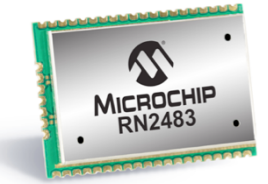
HopeRF RFM series

HopeRF HM-TRLR-D

LinkLabs Symphony module



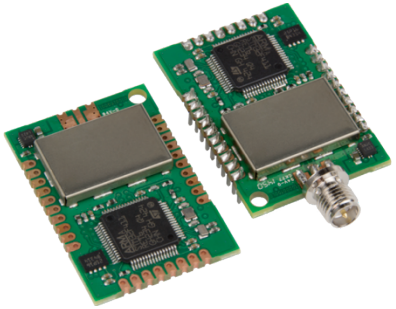
Embit LoRa



Microship RN2483

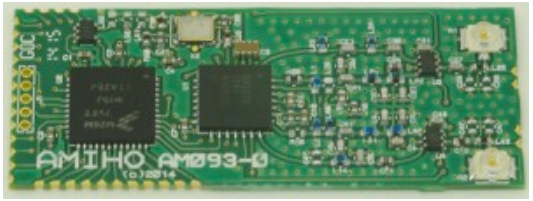
habSupplies

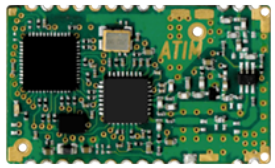
Adeunis ARF8030AA- Lo868



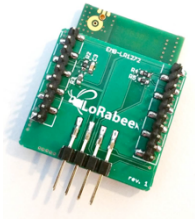
Multi-Tech MultiConnect mDot

AMIHO AM093





ARM-Nano N8 LoRa module from ATIM

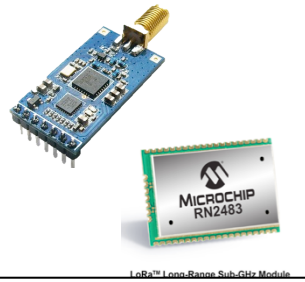


SODAQ LoRaBee Embit

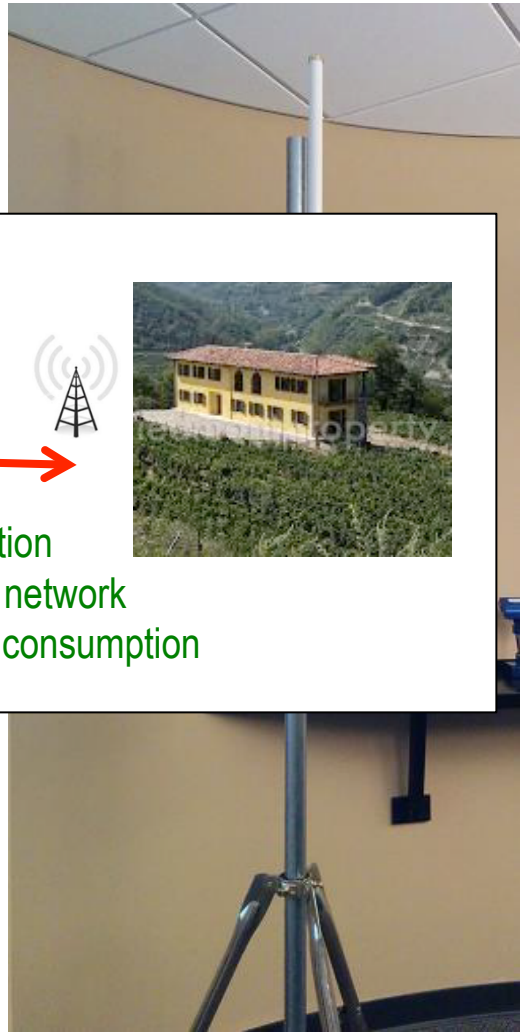
SODAQ LoRaBee RN2483

Build your own private LoRa LPWAN

Add LoRa radio module to your preferred dev platform



Install a LoRa gateway and start collecti



Soil moisture
Leaf wetness

10-15kms

LoRa™

No subscription
Deploy own network
Low energy consumption

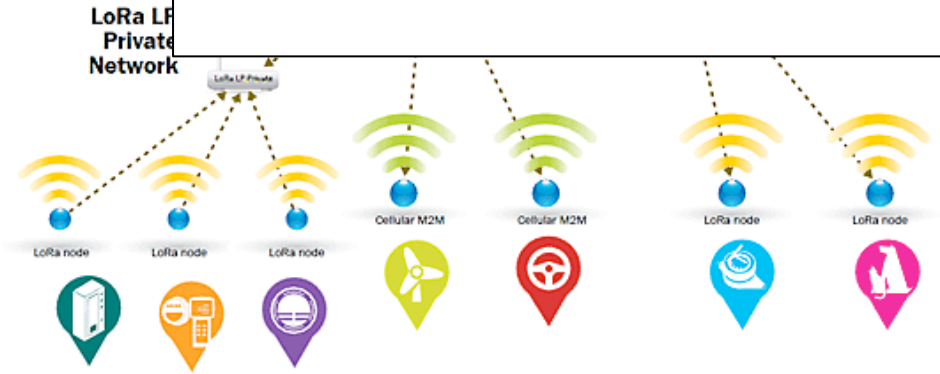
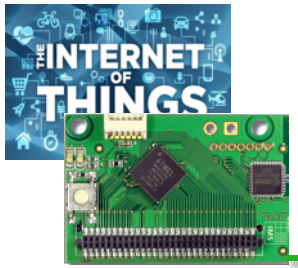


Figure from Semtech



OTHER LONG-RANGE TECHNOLOGIES

Weightless N, P

LTE Cat-M1 Cat-M2

RPMA (Ingenu)

802.11ah

NWave

Telensa

Amber Wireless

waviot

NB-IoT

2ND ISSUE: AT WHAT COST?

2008-2012

2000-2007

libelium
comunicaciones inalámbricas distribuidas

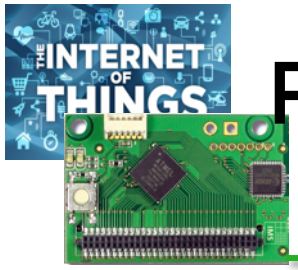
ARDUINO

TST

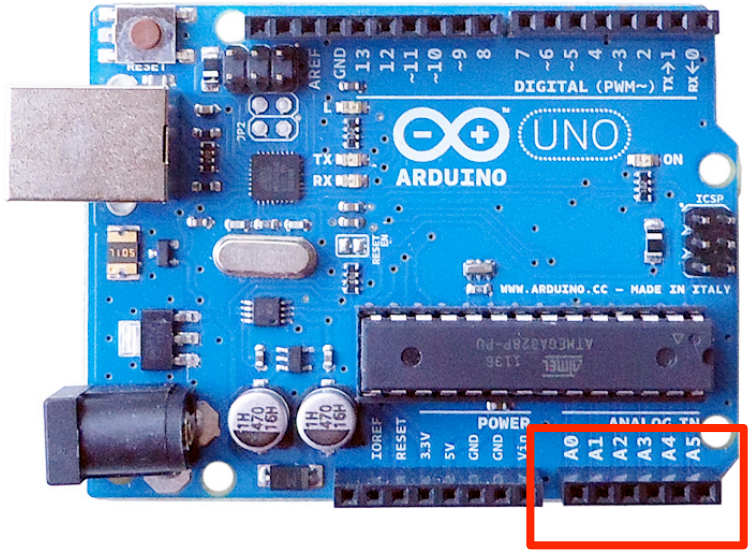
MICROCHIP

Genet
Generation Next
Technology Laboratories

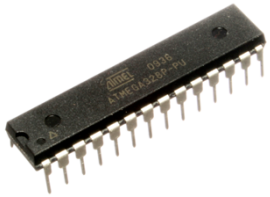
Jennic
TECHNOLOGY FOR A CHANGING WORLD

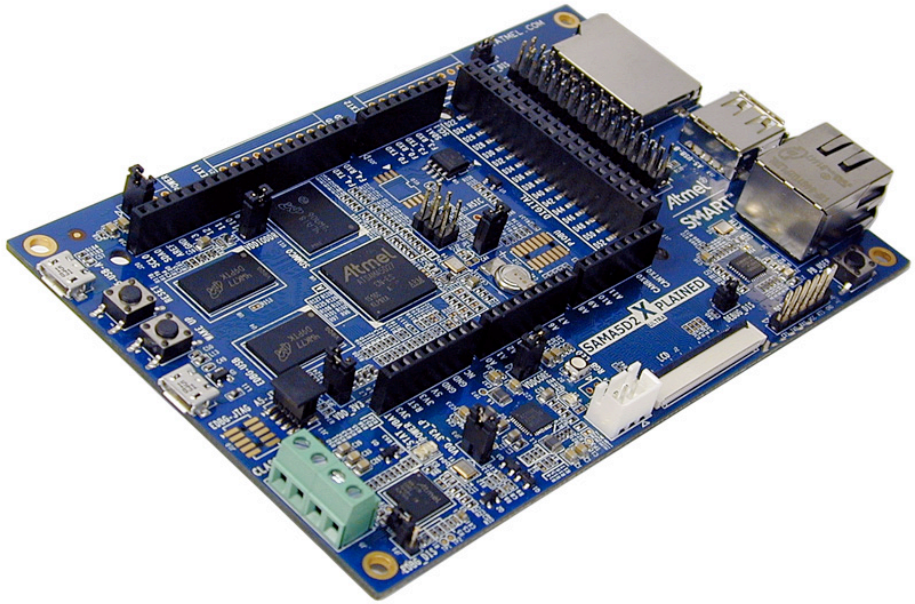


Powerfull μcontroler boards



Analog pins

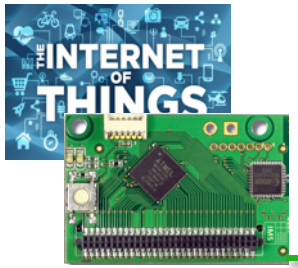




Atmel | SMART SAMA5D2

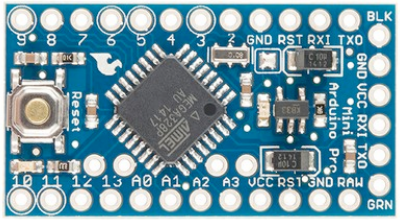
Come with build-in analog-to-digital converter (ADC) which usually have 10-bit resolution:

0V means 0
3.3V or 5V means 1024 = 2^{10}



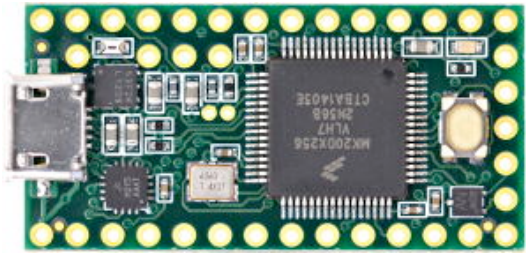
...GETTING SMALLER AND SMALLER...

Arduino Pro Mini

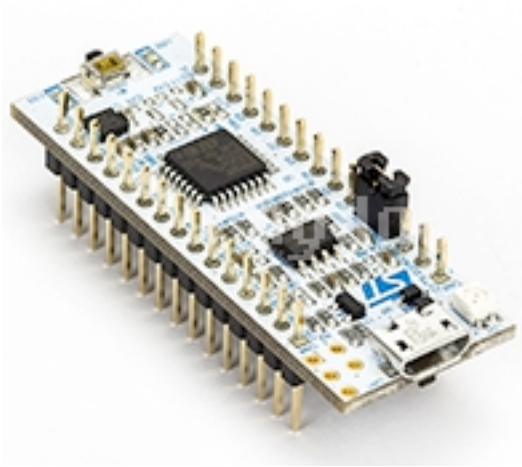


http://blog.atmel.com/2015/12/16/rewind-50-of-the-best-boards-from-2015/

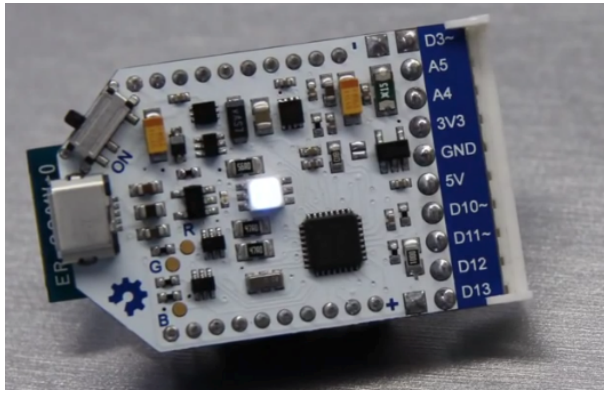
http://blog.atmel.com/2015/04/09/25-dev-boards-to-help-you-get-started-on-your-next-iot-project/



Teensy 3.2

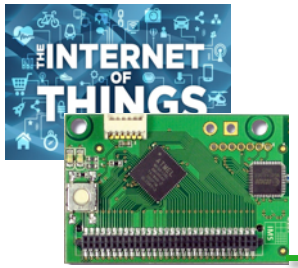


STM32 Nucleo-32

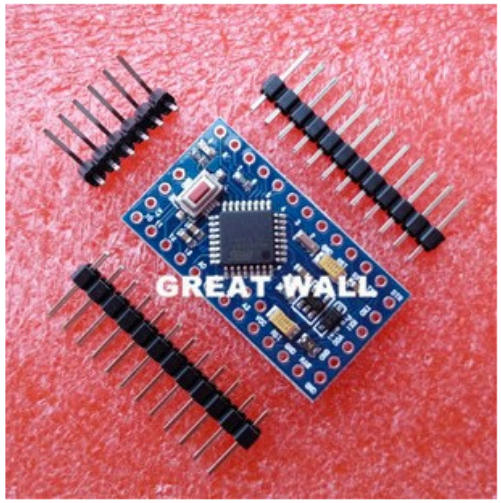


Theairboard on kickstarter

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

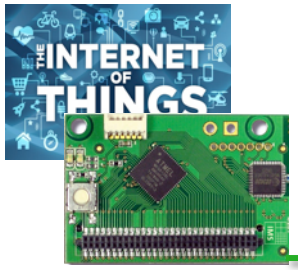
Livraison : € 0,29 vers France via China Post Ordinary Small Packet Plus

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

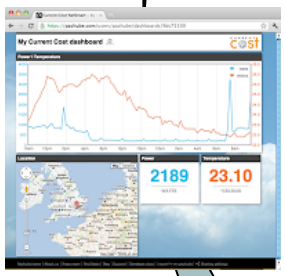
Quantité : – 1 + Kit (55350 Kits available)

Montant total : € 1,78

Acheter maintenant | Ajouter au panier



3RD ISSUE: BIG DATA!

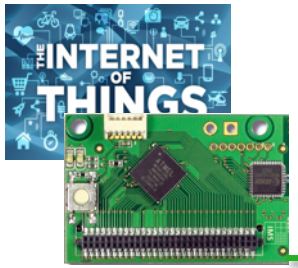


DATA

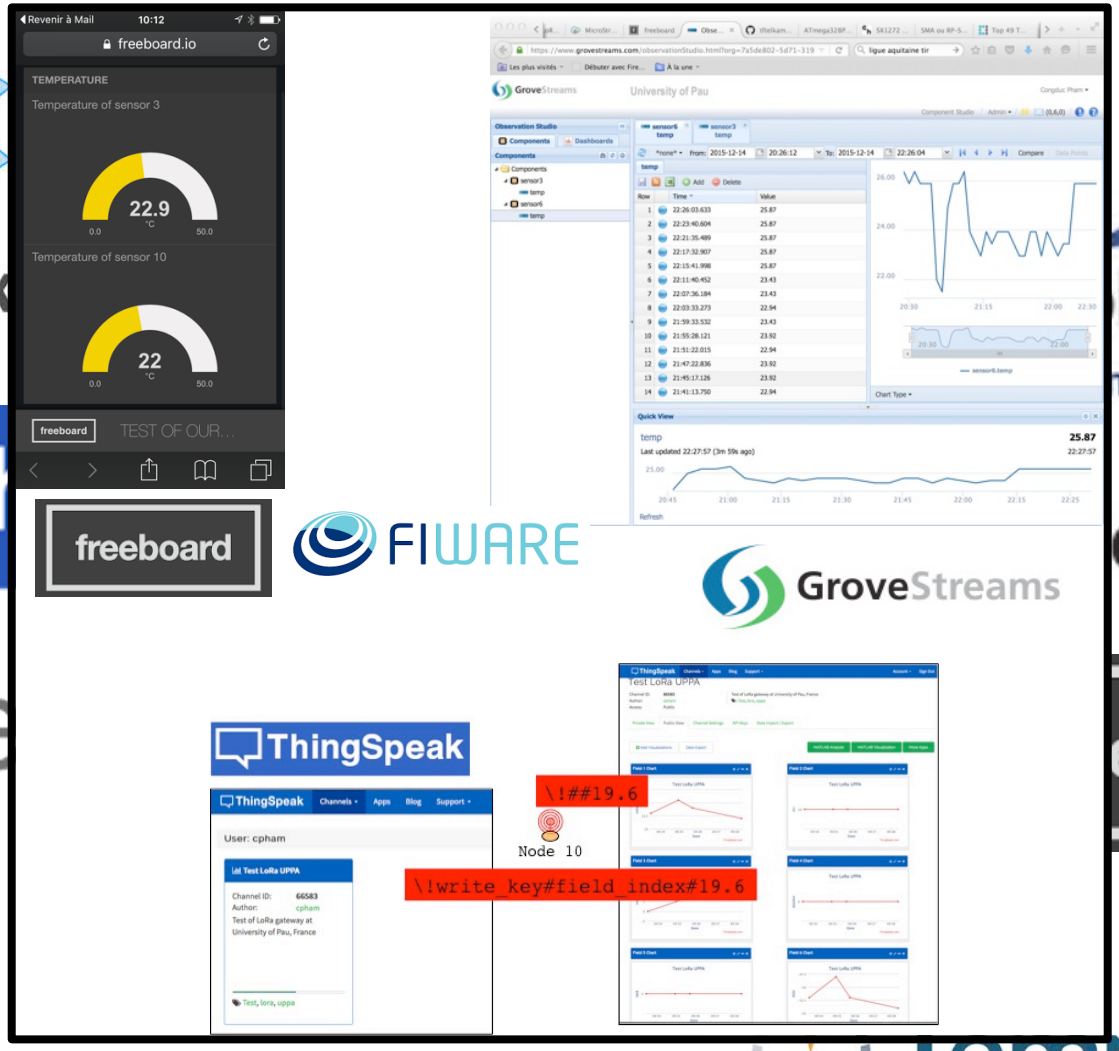
TION &

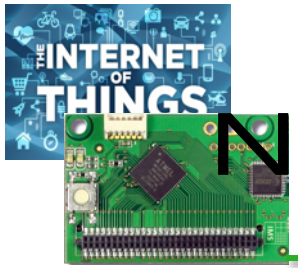
SENSING

PEOPLES, INFRASTRUCTURES, BUILDINGS, VEHICULES



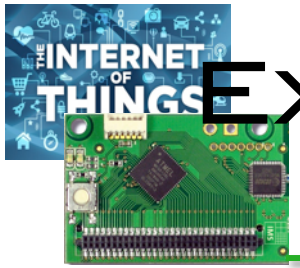
Need IoT data cloud?



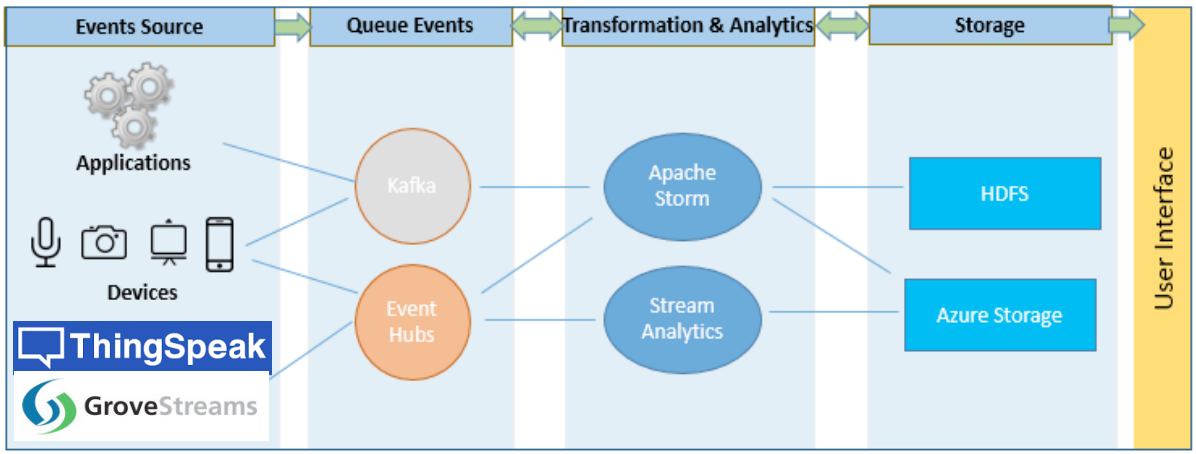


NEED BIG DATA ANALYTICS?

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

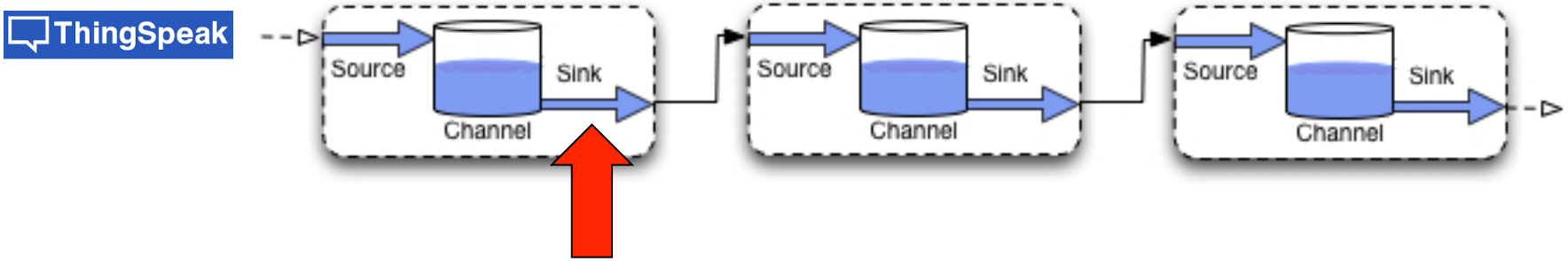


Example: Apache Big Data Ecosystem

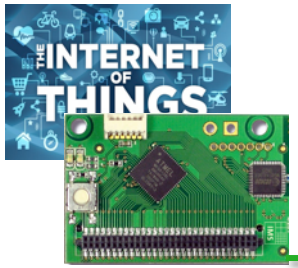


SensorCloud

kafka

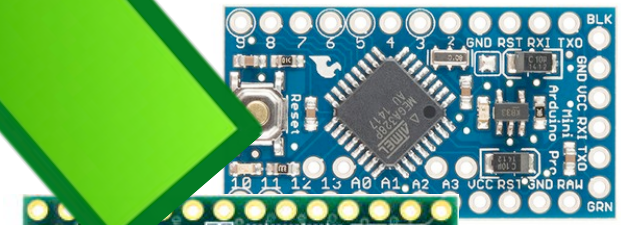


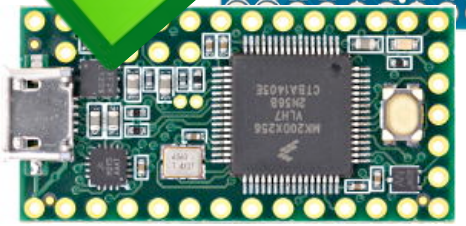
Advanced & customized data management

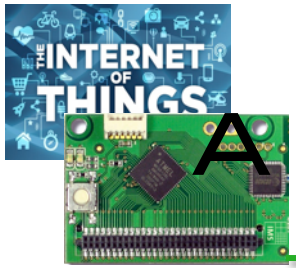


IoT BECOMES REALITY!

SIGFOX
One network A billion dreams
LoRa
nwave
LTE-M
NB-LTE
WEIGHTLESS
DASH7 ALLIANCE
Bluetooth 4.0
Dropbox
Firebase
FIWARE
Axēda
ioBridge
Connect things.
ThingSpeak
GroveStreams
sorCloud
freeboard
Faster Analytics
Real-Time
Streaming Analytics
Predictive Analytics
Historical Analytics
Anything Any Device
Any Service Any Business
Any Path Any Network
Any Place Anywhere
The INTERNET of THINGS



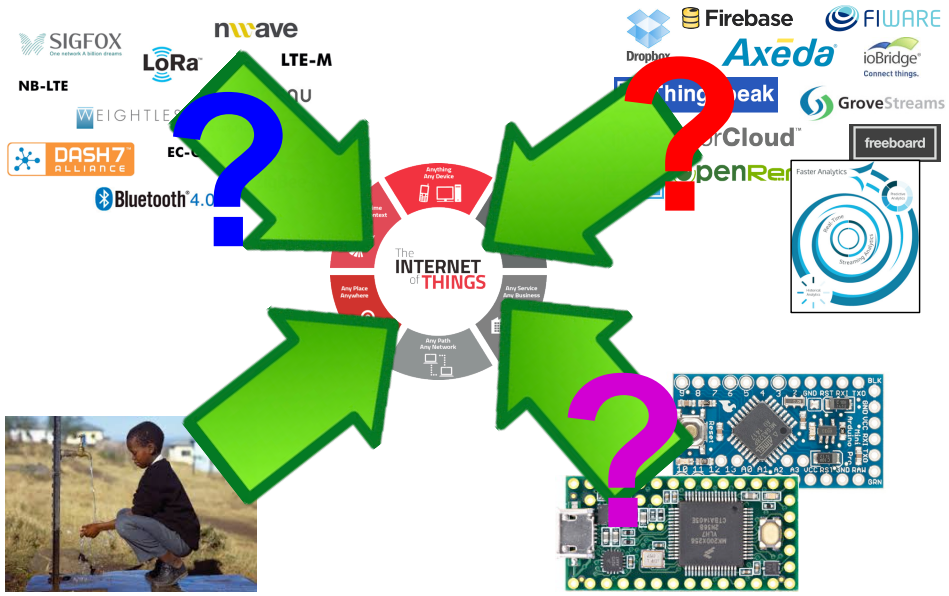


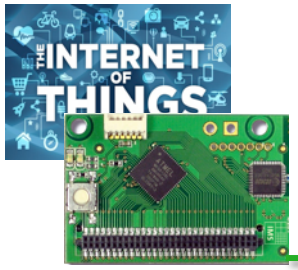


A REALITY FOR EVERYBODY?

IoT in developing countries?

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

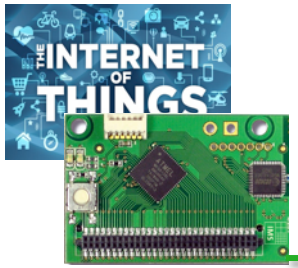




MATURATION OF THE IoT MARKET…

… but not adapted for rural developing countries context & environment

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



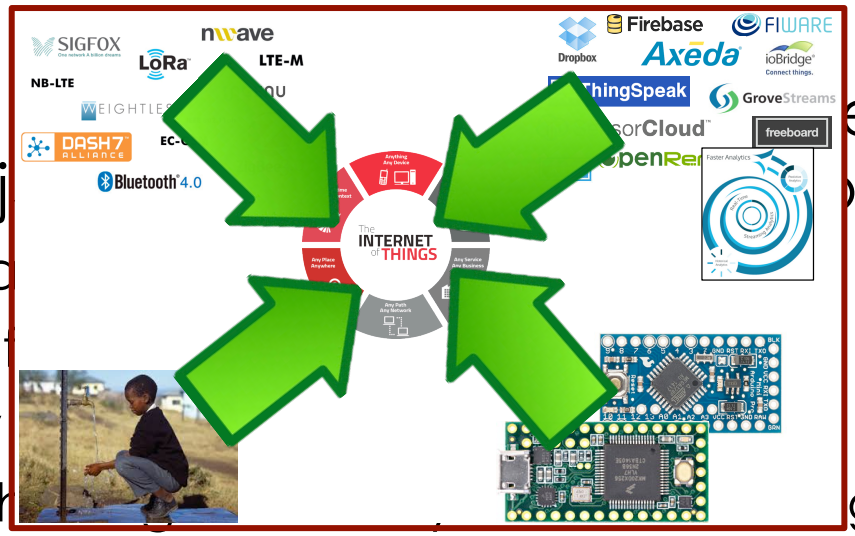
Cloud & big data analytics

Internet connectivity is weak and expensive

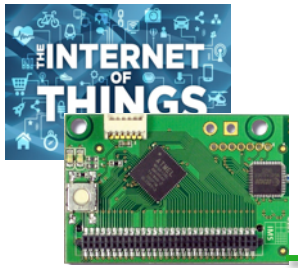
Graphics from http://www.vitria.com/iot-analytics/

IoT IN DEVELOPING COUNTRIES

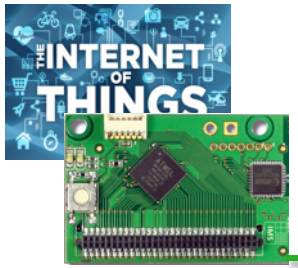
- Developing … eing ready to enj … T
  - lack of infra …
  - high cost of …
  - complexity …
  - lack of tech … ground



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



WAZIUP: LOW-COST IOT



Low-cost hardware

WHAT IS ARDUINO?

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

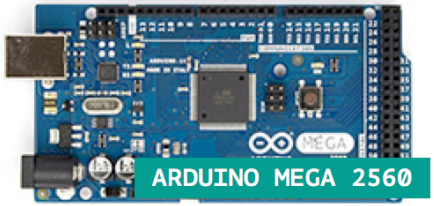
ARDUINO BOARD

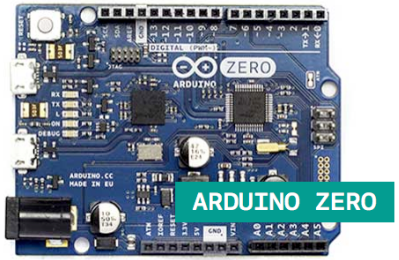
Arduino senses the environment by receiving inputs from many sensors, and affects its surroundings by controlling lights, motors, and other actuators.

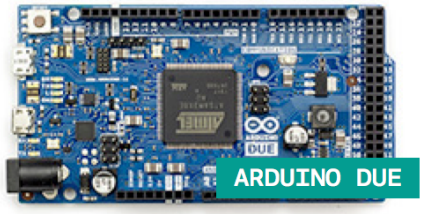
```
void setup() {
}

void loop() {
}
```

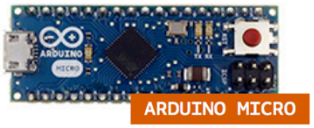
ARDUINO SOFTWARE

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

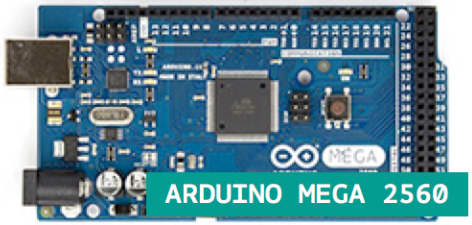


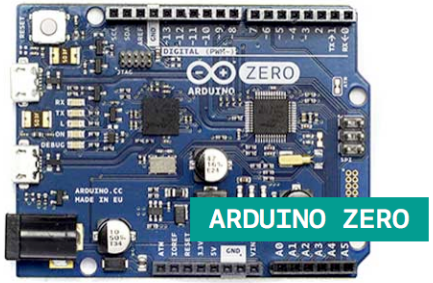


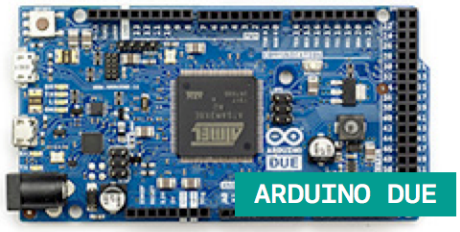


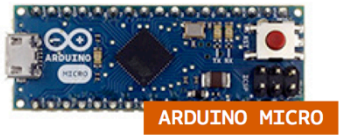


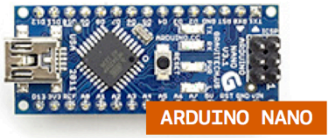
SW/HW BUILDING BLOCKS INTEGRATION

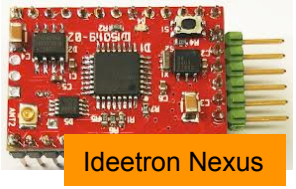






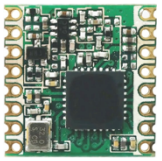






LoRa™

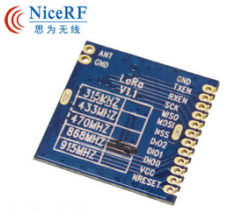
LoRa radios that our library already supports



HopeRF RFM92W/95W

Libelium LoRa

Modtronix inAir9/9B

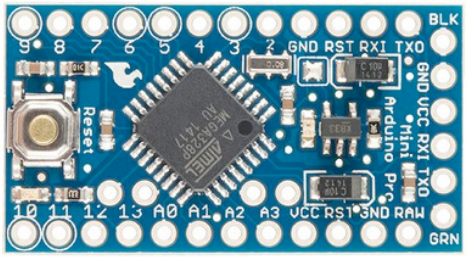


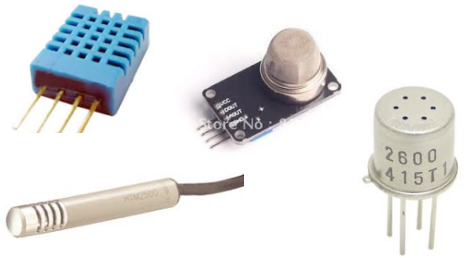
NiceRF LoRa1276

Long-Range communication library

Generic sensing IoT device

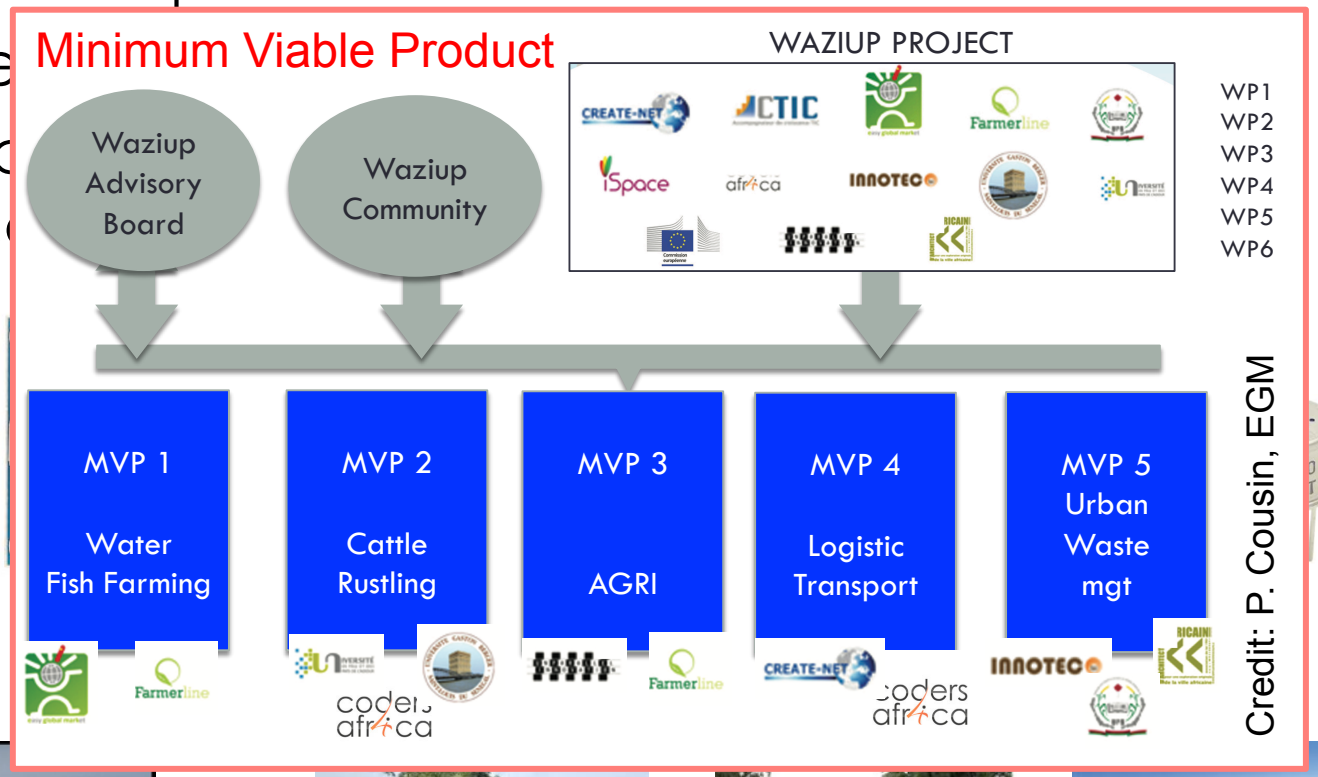
- Build low-cost, low-power, Long-range enabled generic platform
- Methodology for low-cost platform design
- Technology transfers to user communities, economic actors, stakeholders,…

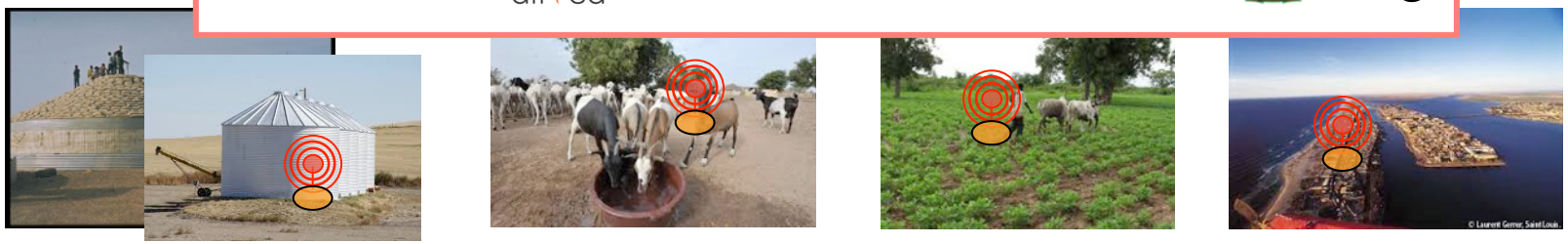




Generic sensing IoT device

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



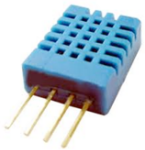


Ready-to-use templates

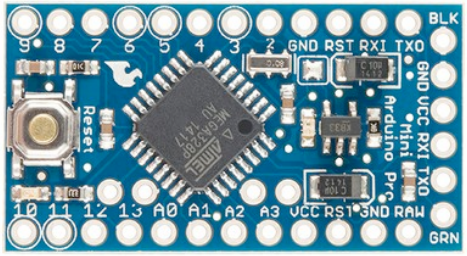
Physical sensor reading

Physical sensor reading

Physical sensor reading



Physical sensor management

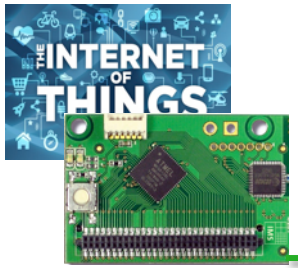


Activity duty-cycle, low power

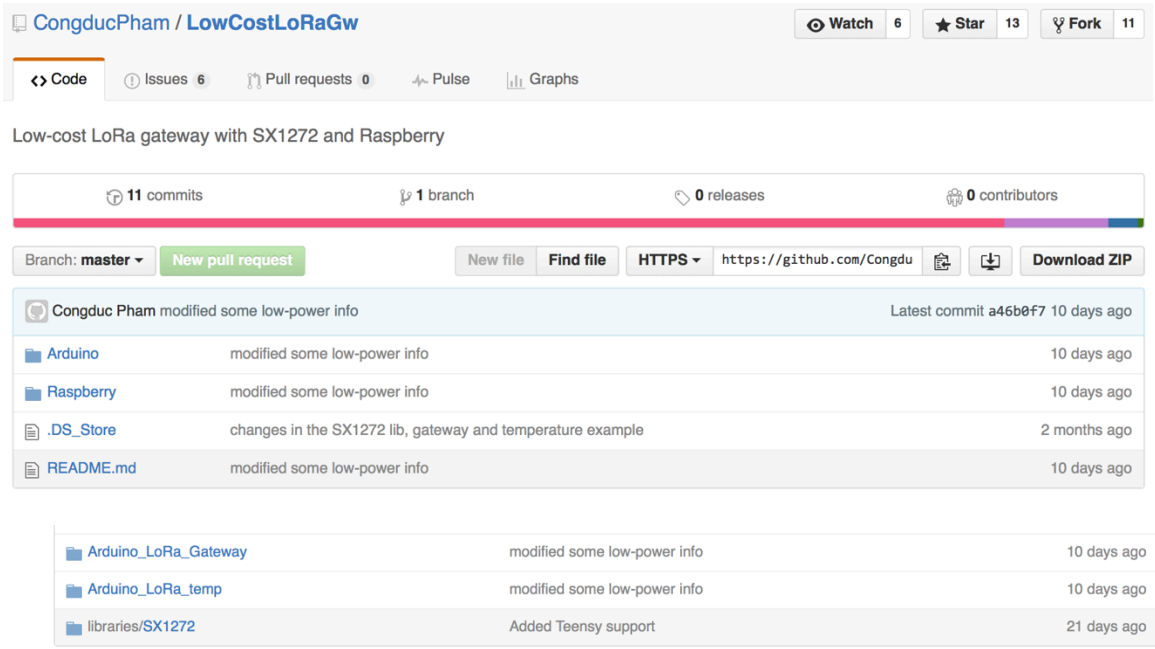
Security

Long-range transmission

Logical sensor management

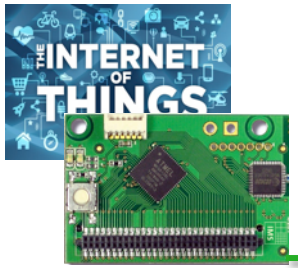


GETTING THE SOFTWARE

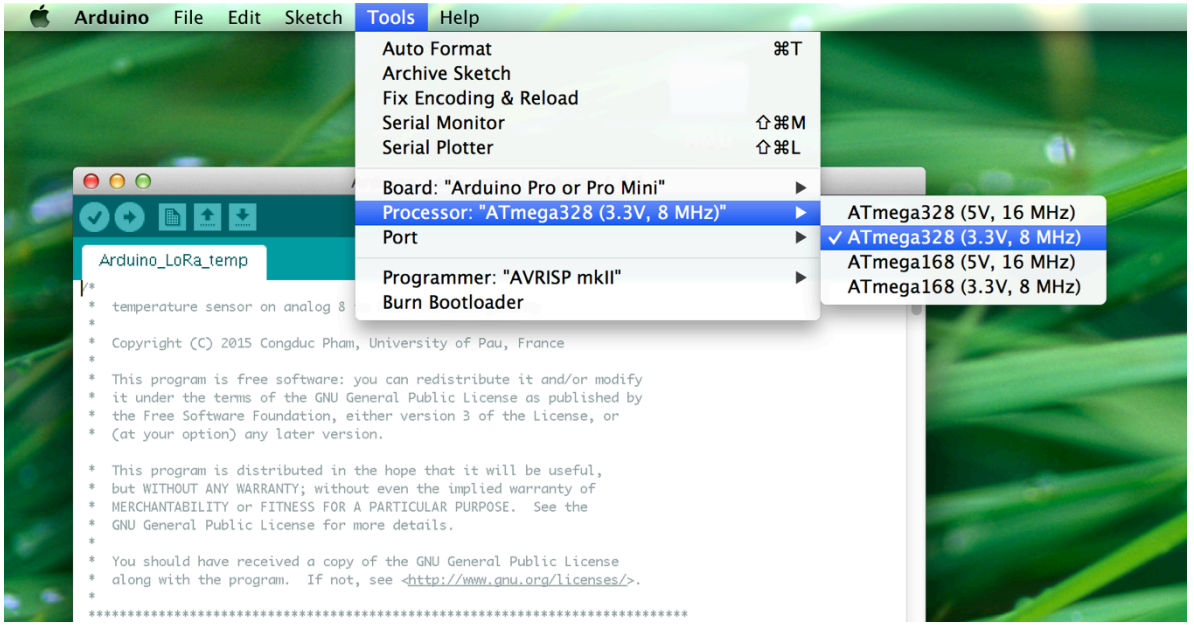


Fisrt, you will need the Arduino IDE 1.6.6 or later (left). Then get the LoRa library from our github: https://github.com/CongducPham/LowCostLoRaGw (right).

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”

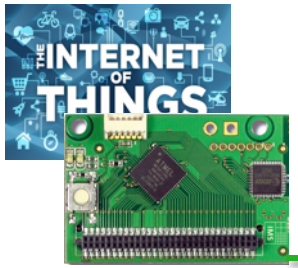


Compiling

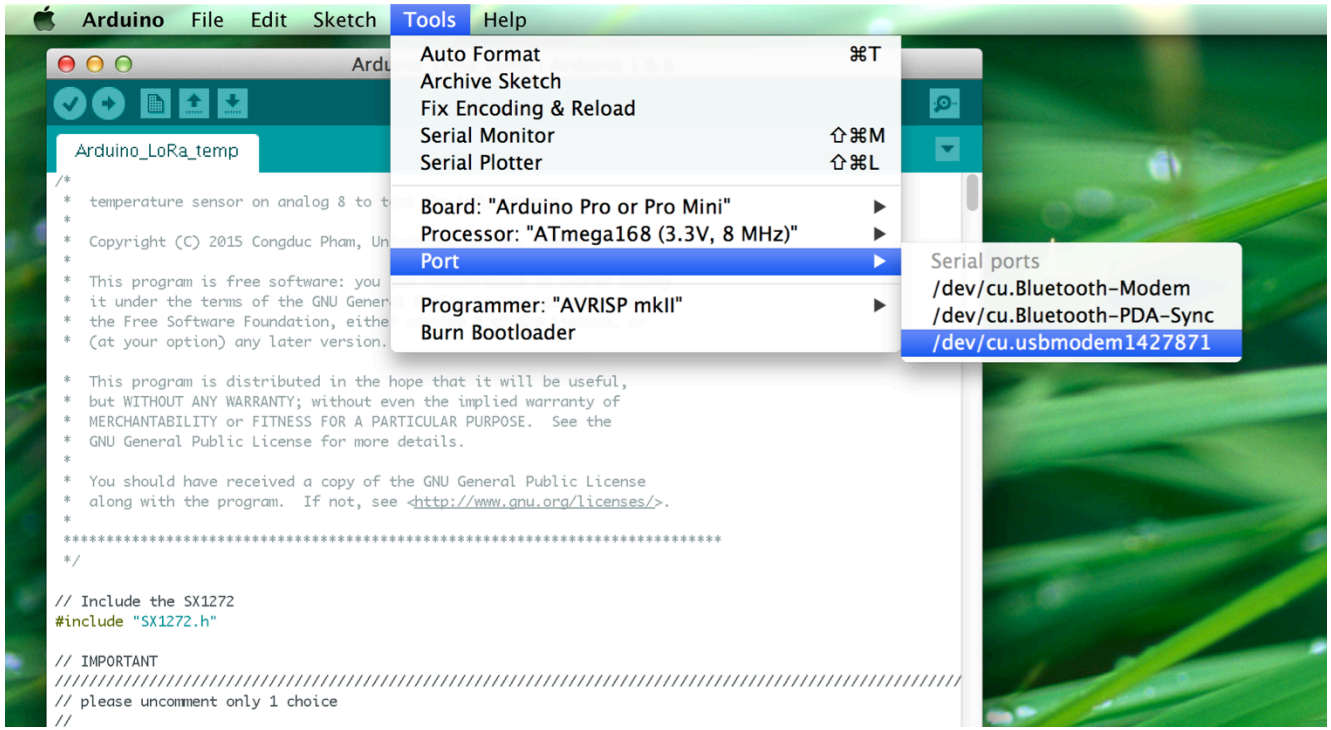


Open the Arduino_LoRa_temp sketch and select the Arduino Pro Mini board with its 3.3V & 8MHz version.

Then, click on the « verify » button

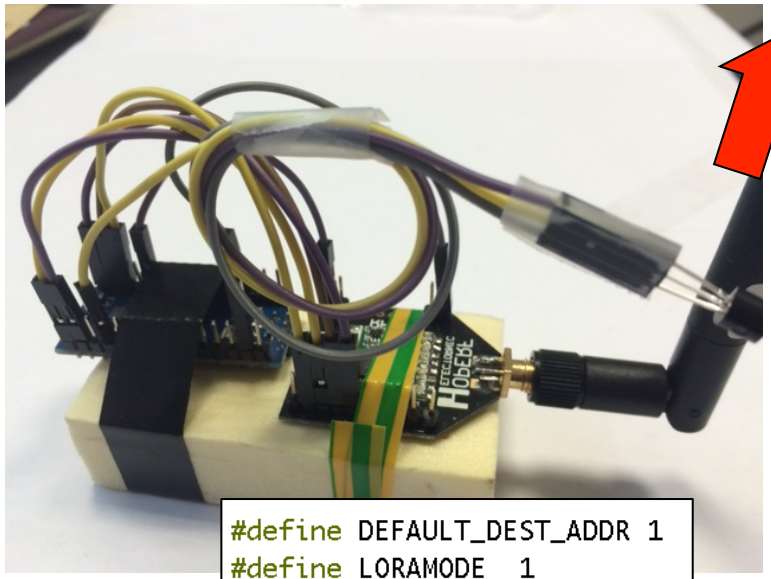


Uploading



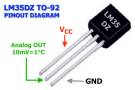
Connect the USB end to your computer and the USB port should be detected in the Arduino IDE. Select the serial port for your device. It may have another name than what is shown in the example. Then click on the « upload » button

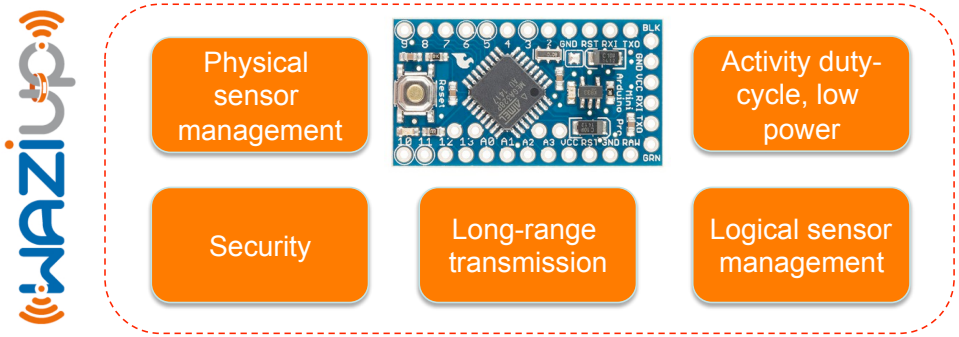
Basic example with temperature sensor



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

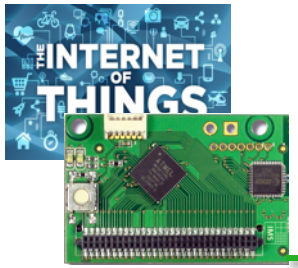
\!##TC/18.5





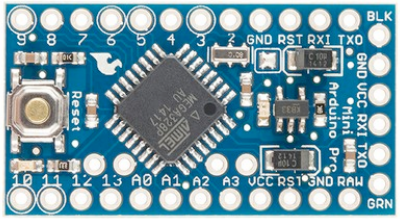
The default configuration in the Arduino_LoRa_temp example is:

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

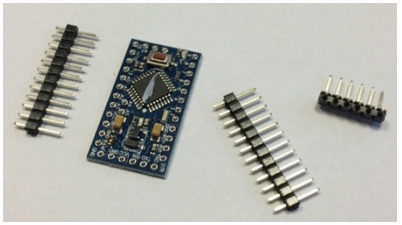


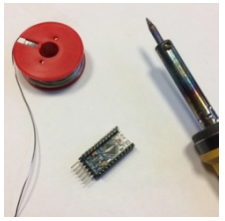
Easy integration and customization

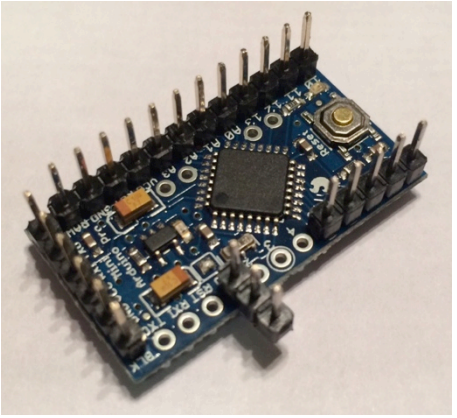
Arduino Pro Mini

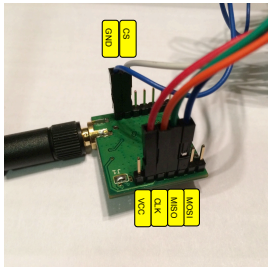


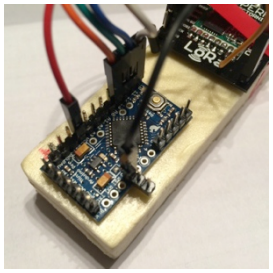
3.3v and 8MHz version

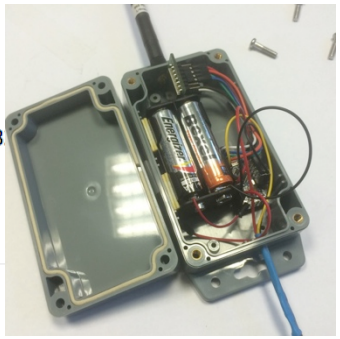


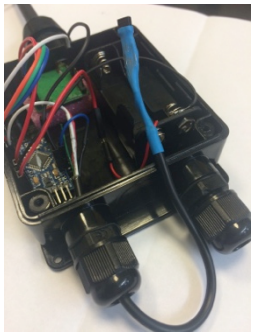


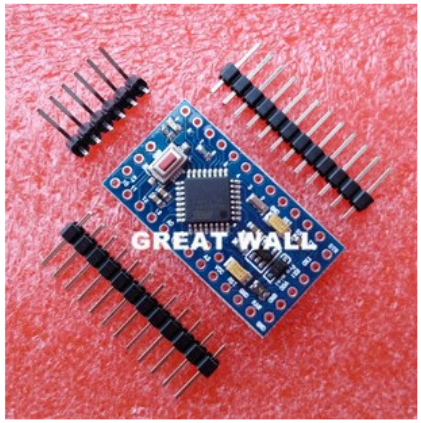












Avec la bootloader 1 pcs Pro Mini ATMEGA328 Pro Mini 3
MHz pour Arduino

View original title in English

4.9 (417 Votes) | 434 Commandes

Prix : € 1,49 / Kit

Trouvez plus de deals sur l'App

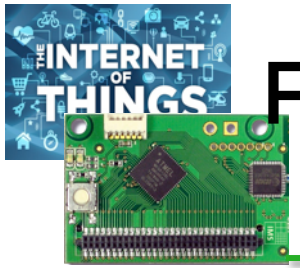
Livraison : € 0,29 vers France via China Post Ordinary Small Pac

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

Quantité : – 1 + Kit (55350 Kits available)

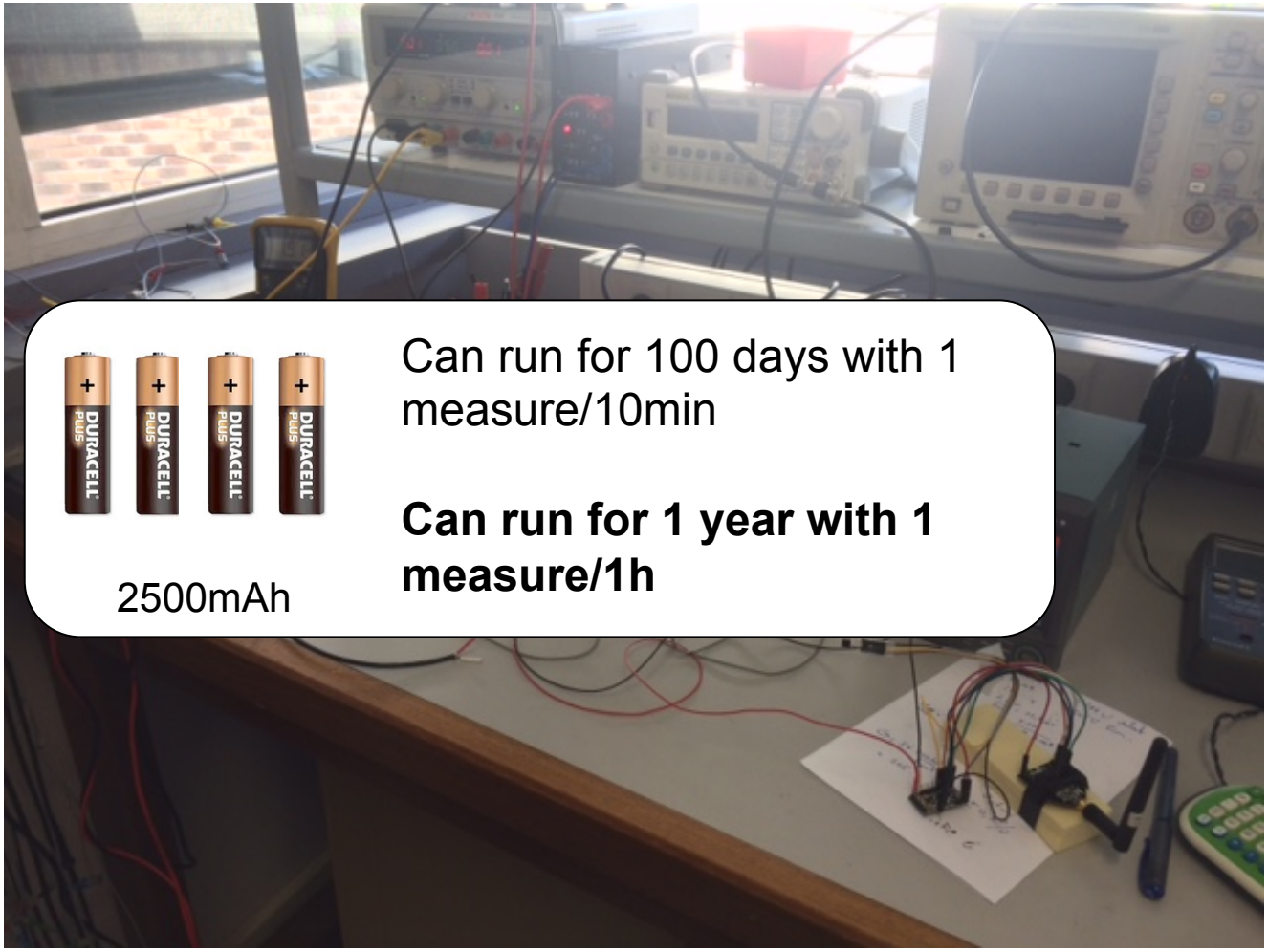
Montant total : € 1,78

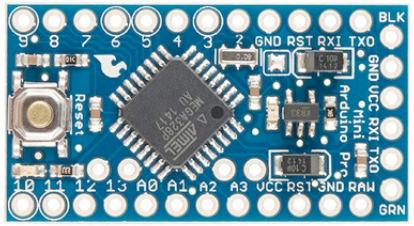
Acheter maintenant | Ajouter au panier



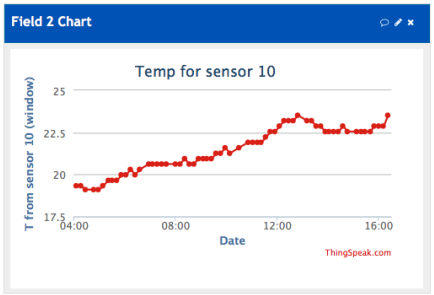
Running for 1 year with low-power mode!

Low-Power library from RocketScream





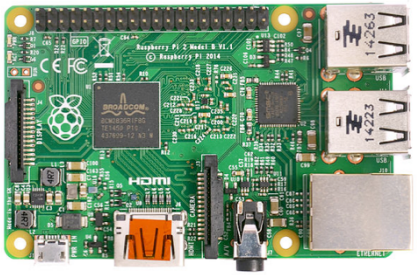
Wakes-up every 10min, take a measure (temp) and send to GW



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

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

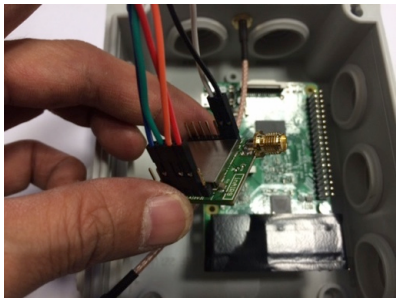
Raspberry-based LoRa gateway

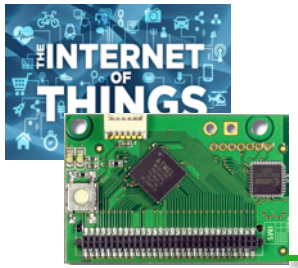


We can use all model of Raspberry. The most important usefull feature is the Ethernet interface for easy Internet connection. Then WiFi and Bluetooth can be added with USB dongles.
RPI3 provides built-in Ethernet, WiFi and Bluetooth!

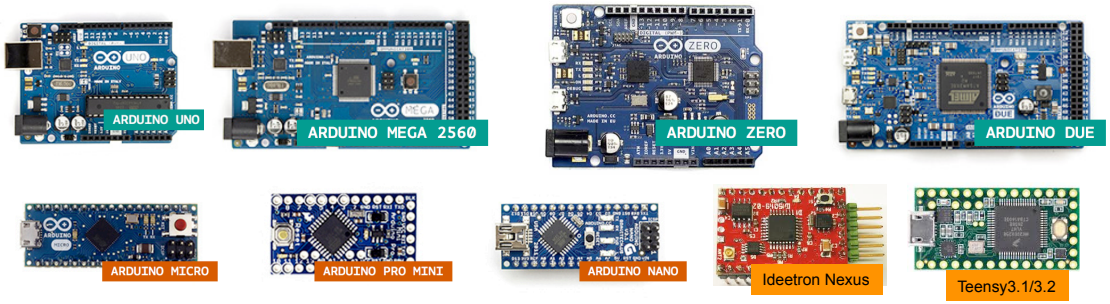



Less than 50€

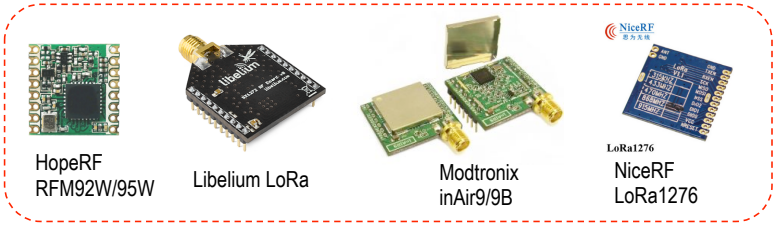


Simplicity!



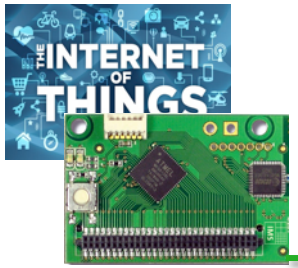
LoRa radios that our library already supports



Long-Range communication library

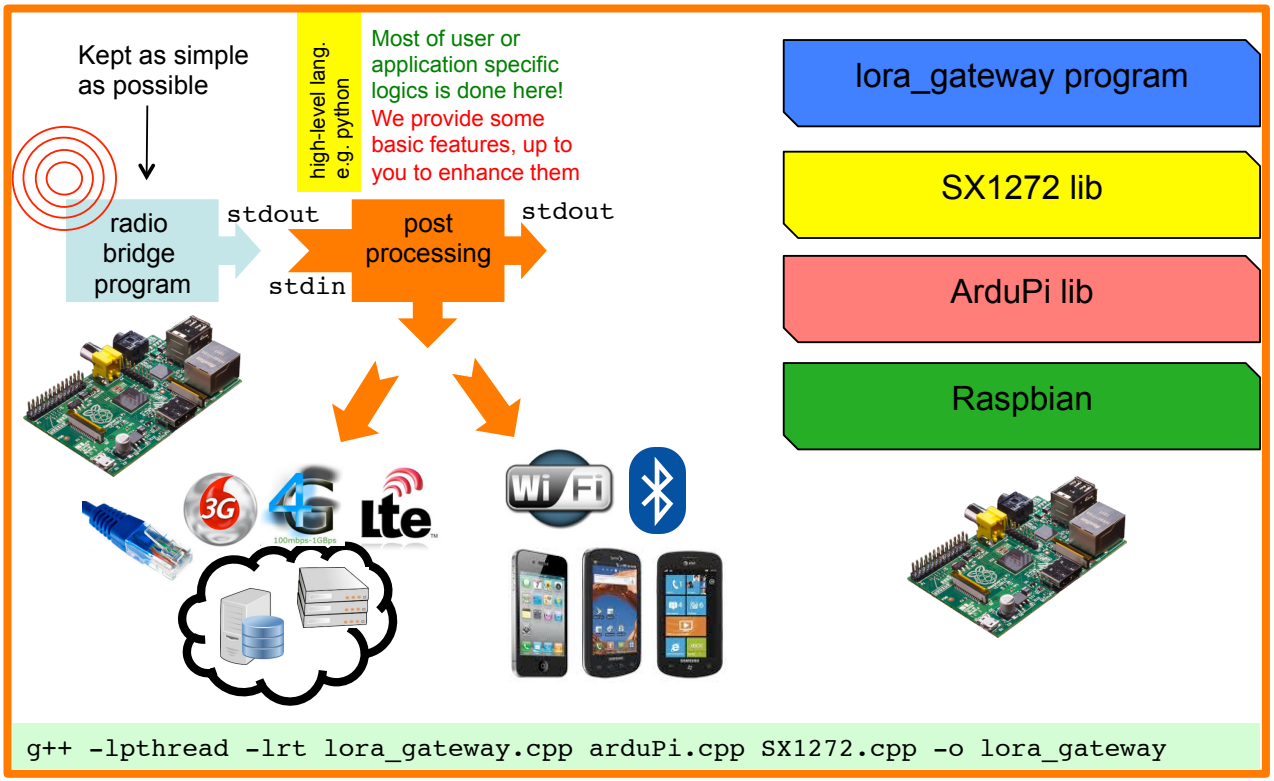
```
sendPacketTimeout("18.5");
// sends to gateway
// 18.5 : temperature message
```

1 send function!



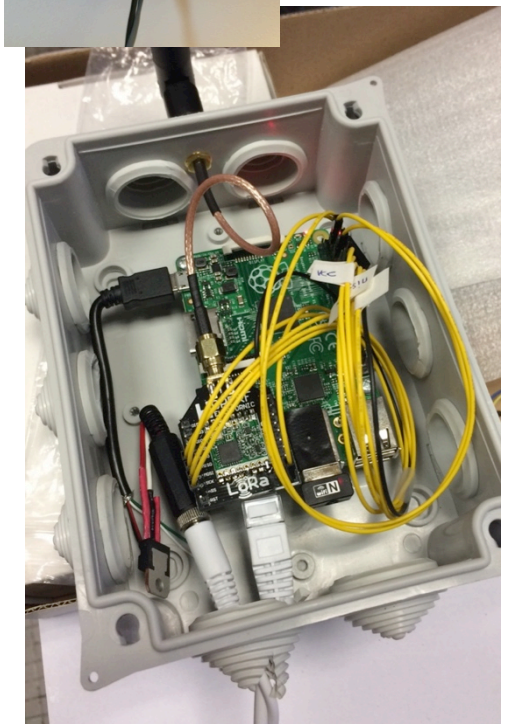
From GW to Cloud platforms

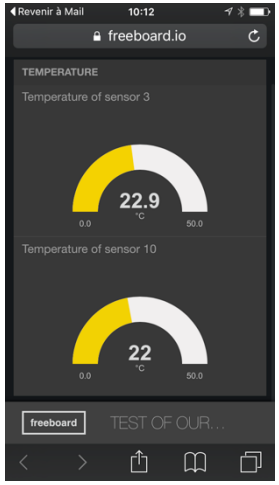
Once data is received at gateway, traditional Internet tools can be used to push data to cloud



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

Templates for various clouds

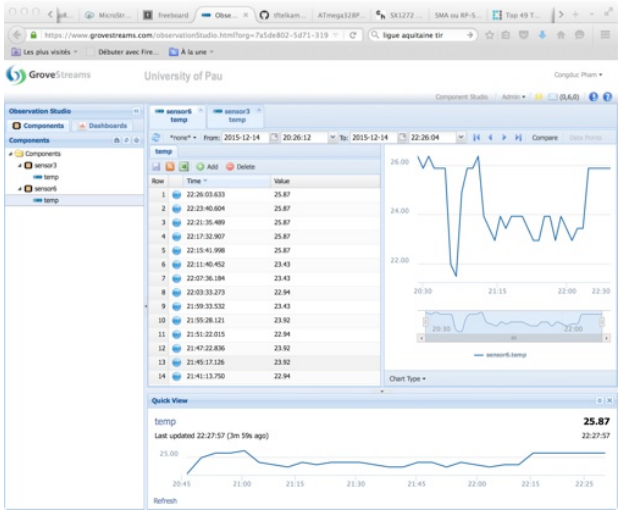




Dropbox

freeboard

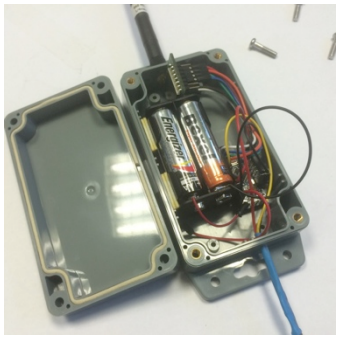
FIWARE

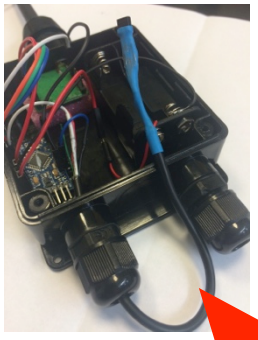


GroveStreams

SensorCloud™

Do it yourself !

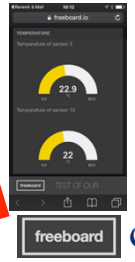


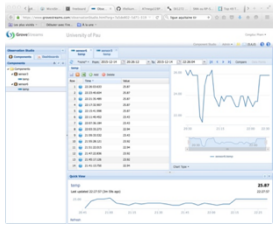


Step-by-step tutorial and source code available

Step-by-step tutorial and source code available

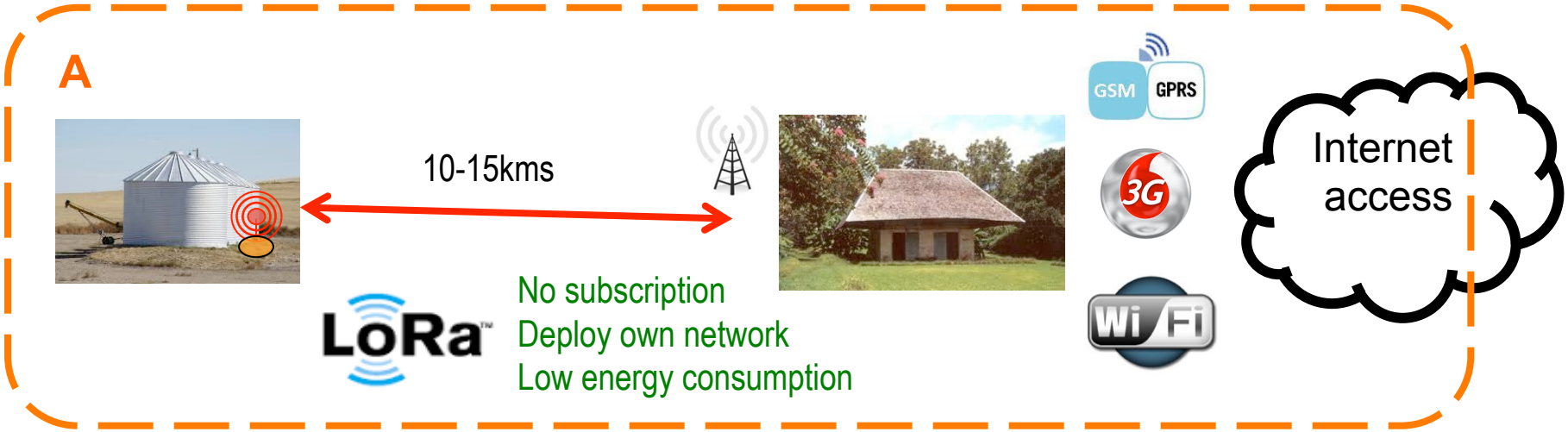
Python scripts available



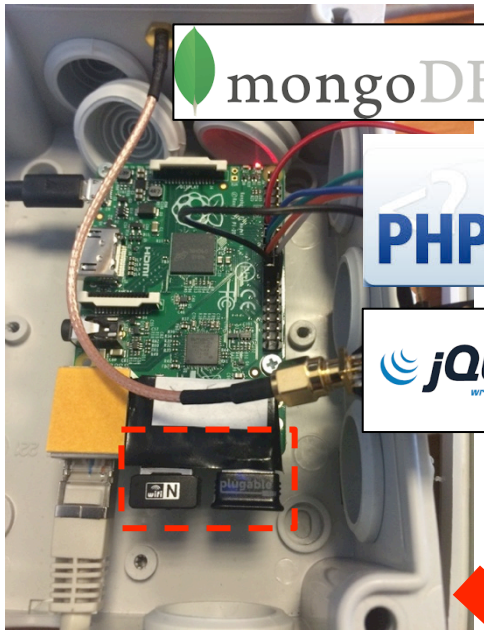


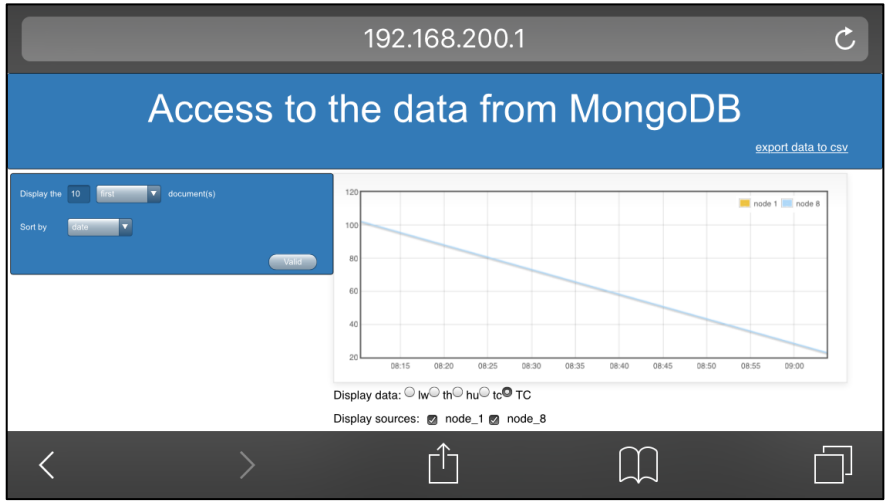
https://github.com/CongducPham/LowCostLoRaGw

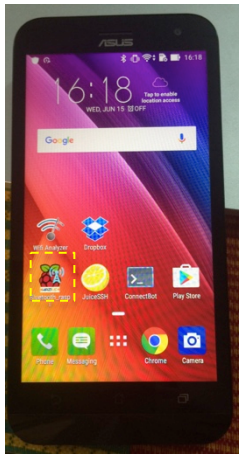
Working without Internet access

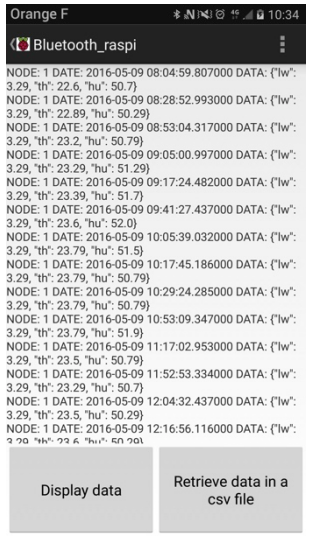


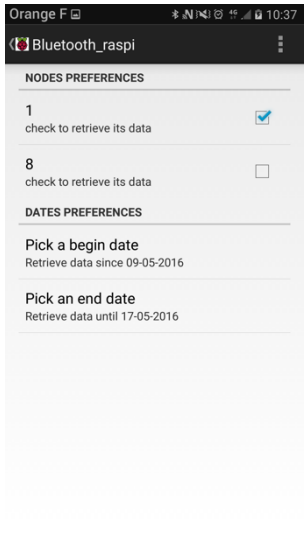
Standalone gateway

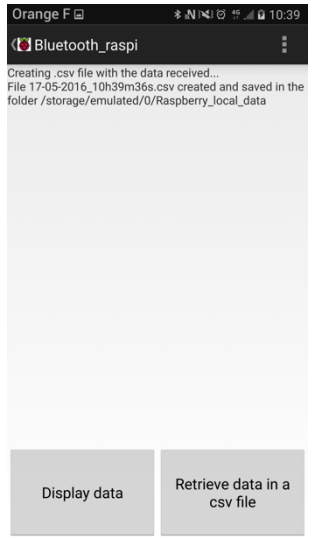


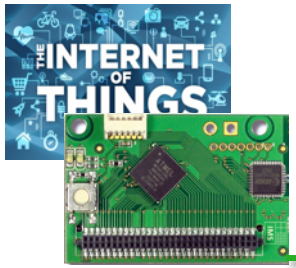




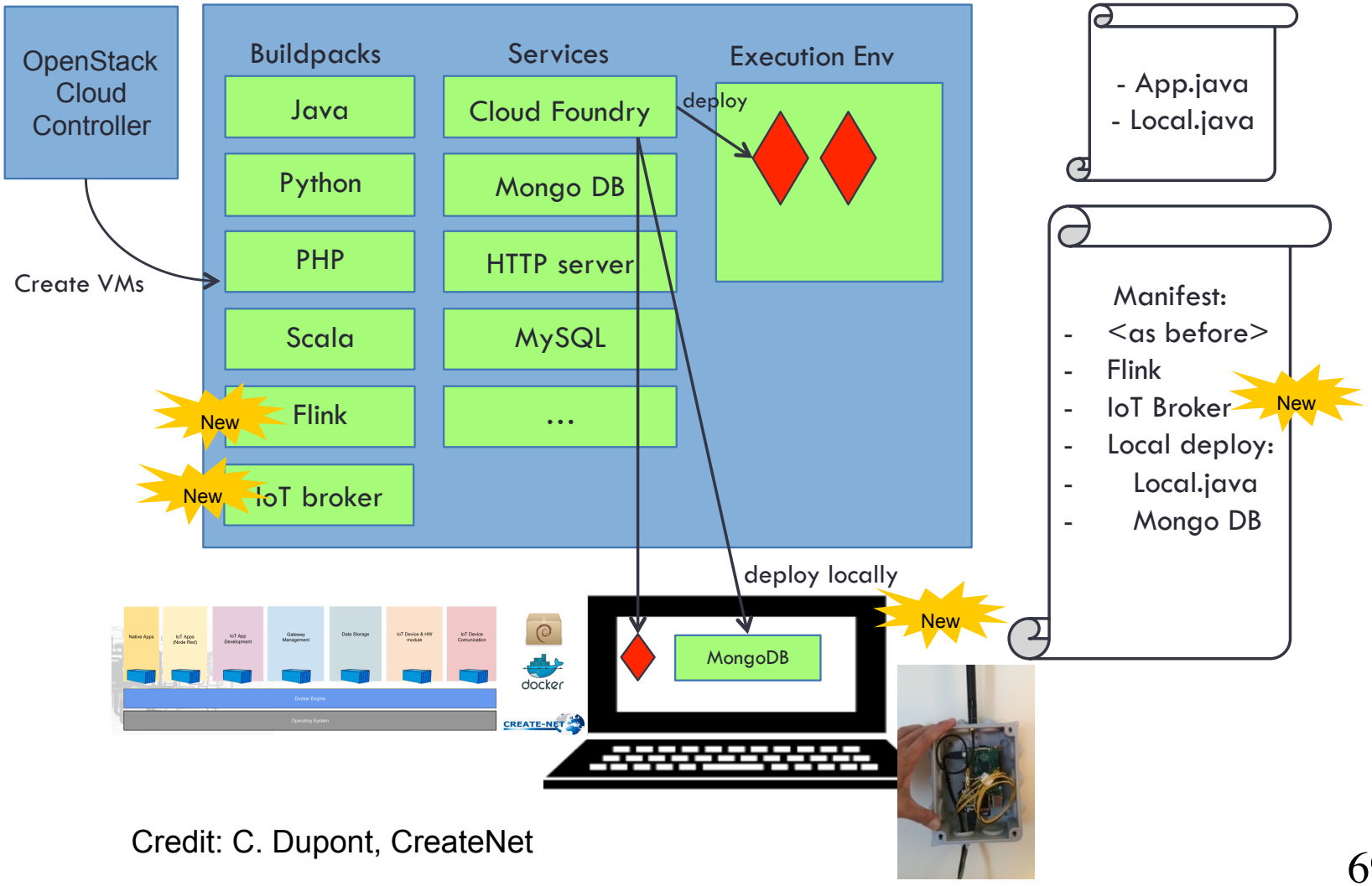








LOCAL DATA ANALYTICS



Credit: C. Dupont, CreateNet

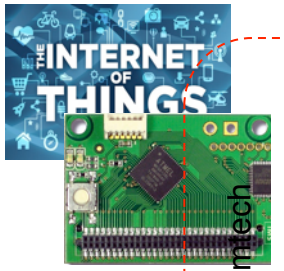
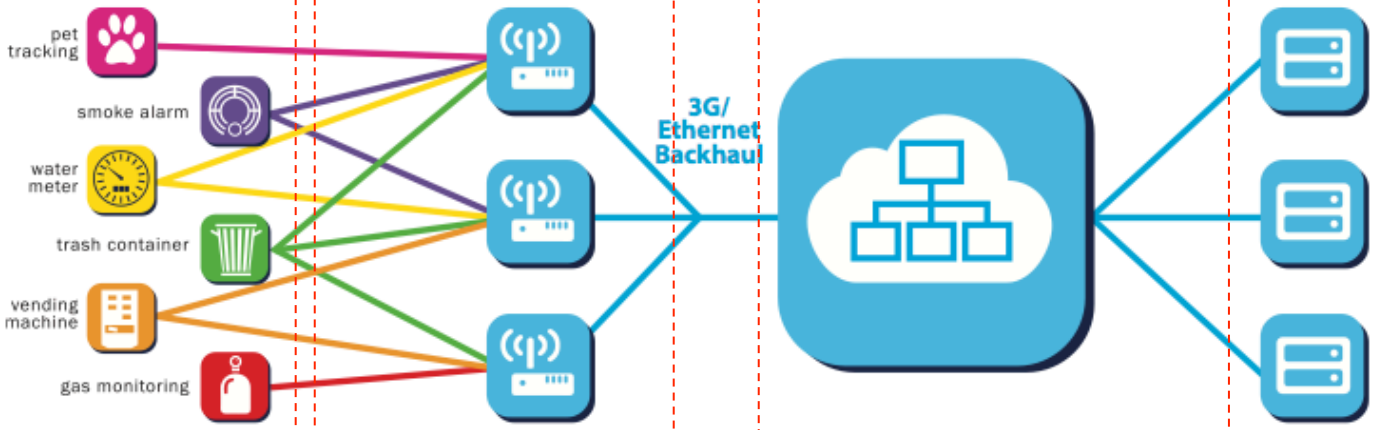


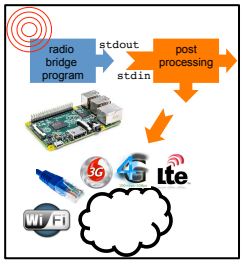
Figure from Semtech



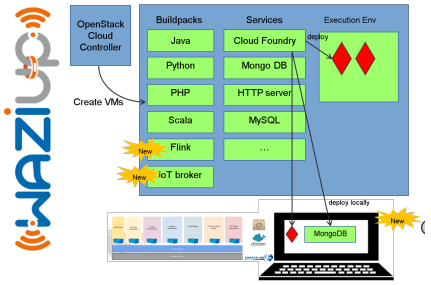
A

Application, MVP

WAZIUP Sensor platform

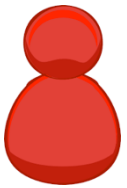


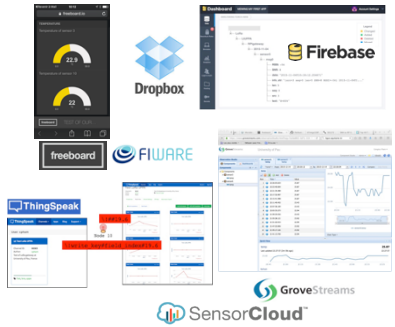
WAZIUP gateway platform

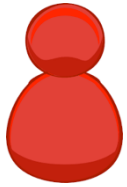


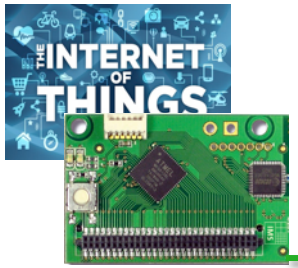
WAZIUP platform

B

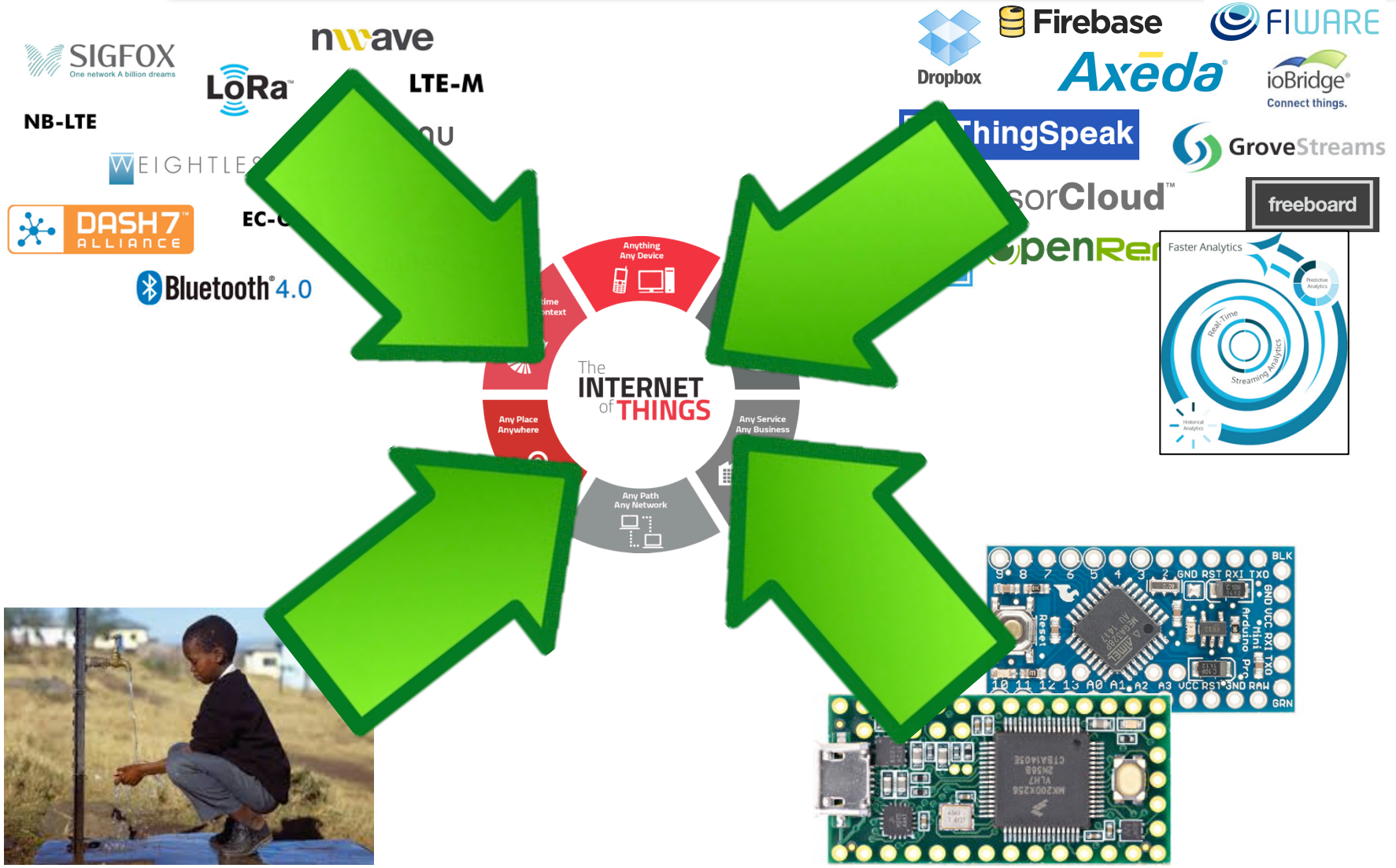


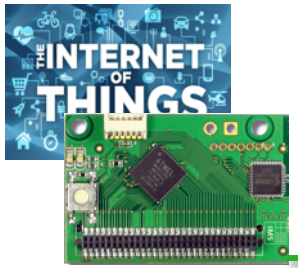






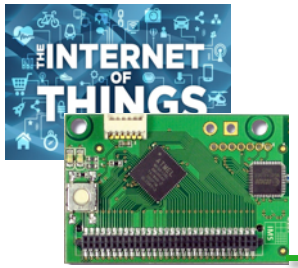
Now,
IoT becomes reality!





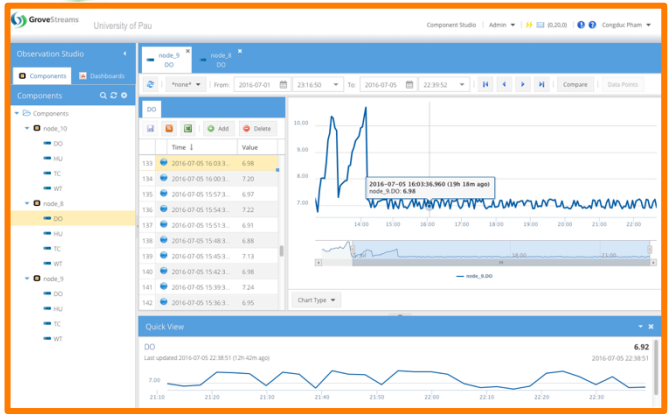
Use case: fish pond monitoring

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



Out-of-the-box !

GroveStreams

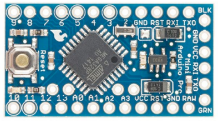


Waziup

Physical sensor reading

Waziup

Physical sensor management



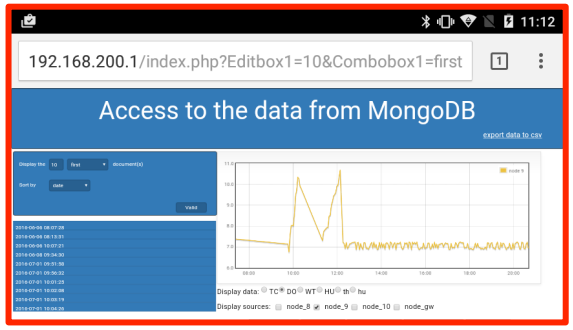
Activity duty-cycle, low power

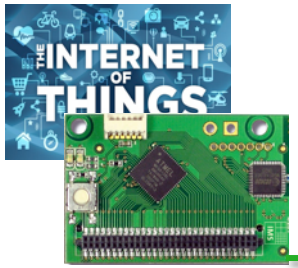
Security

Long-range transmission

Logical sensor management

Wi Fi

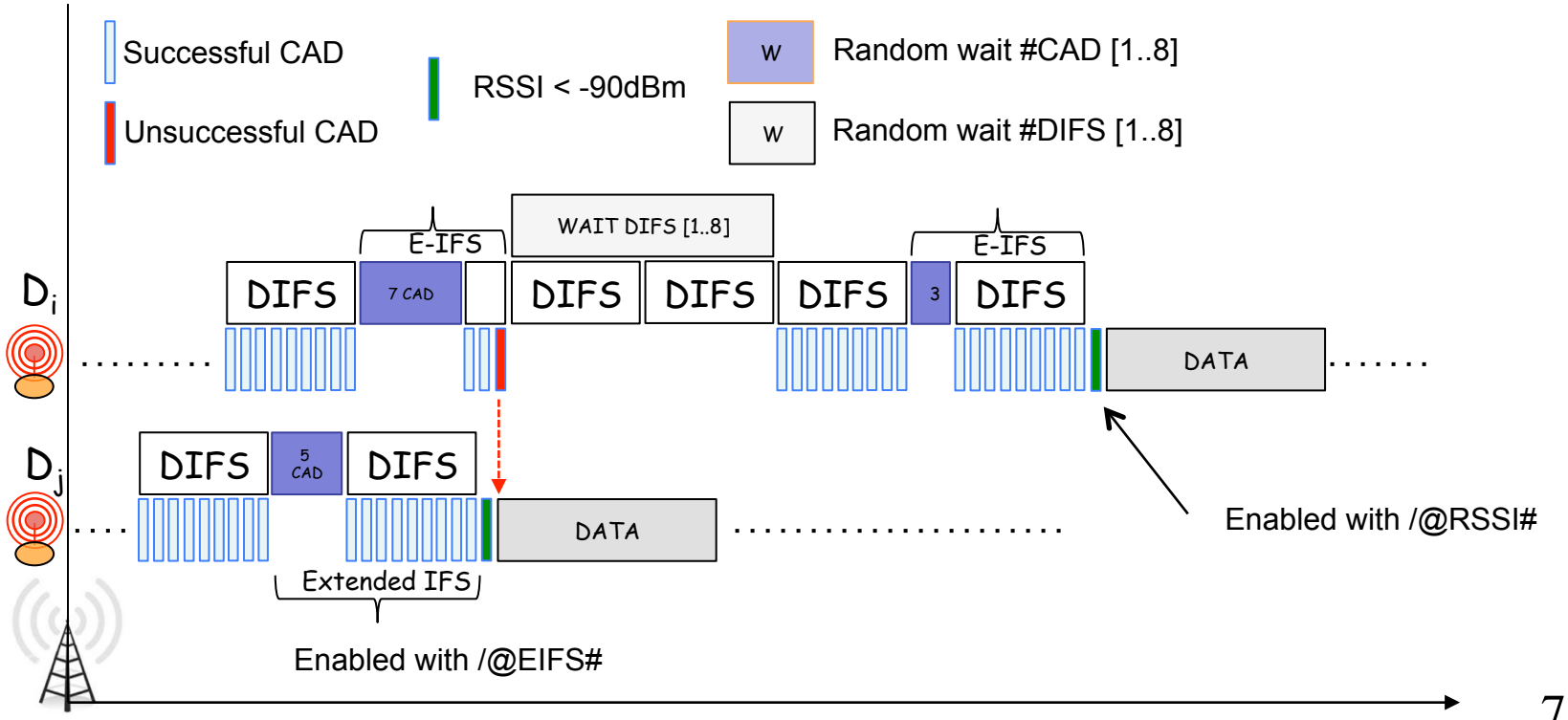




THING WE DO FOR RESEARCH

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#



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.

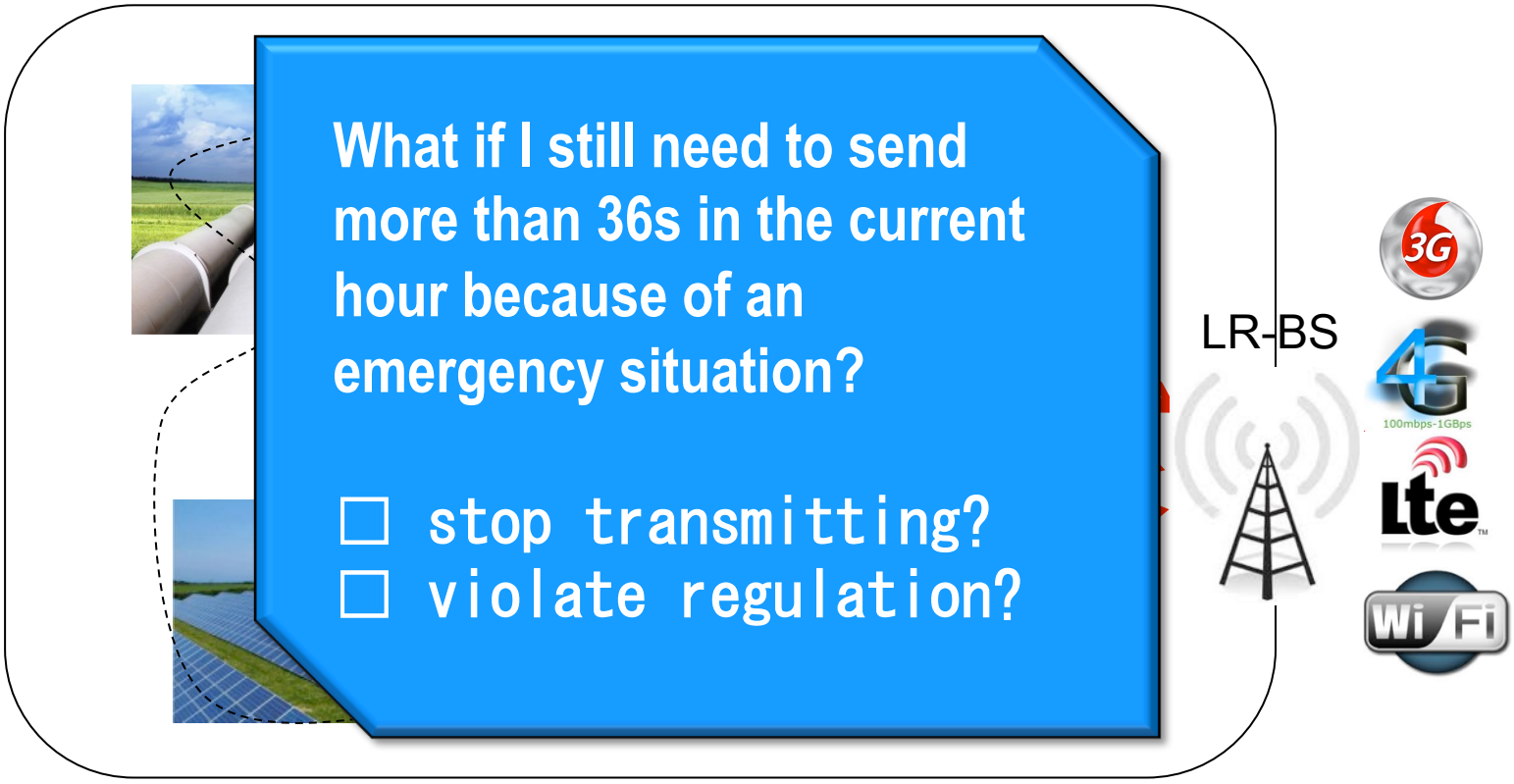
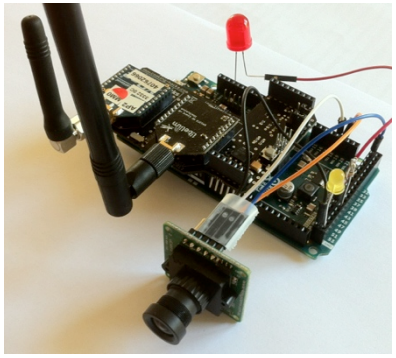
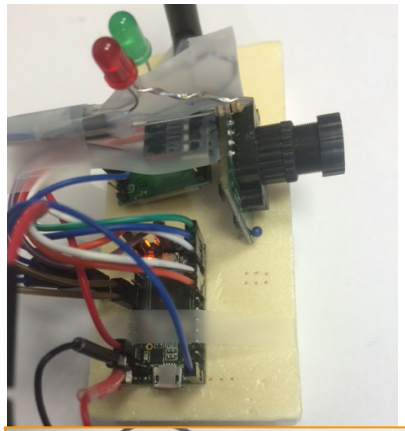
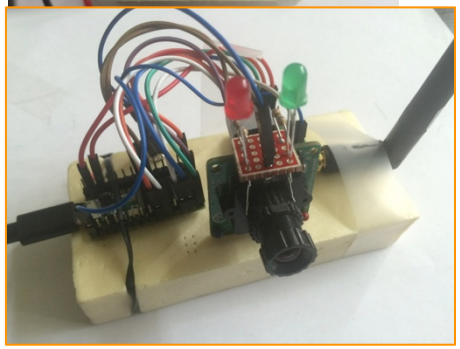
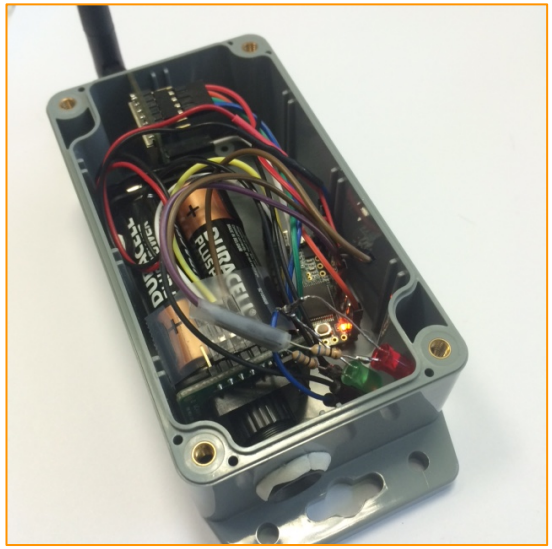


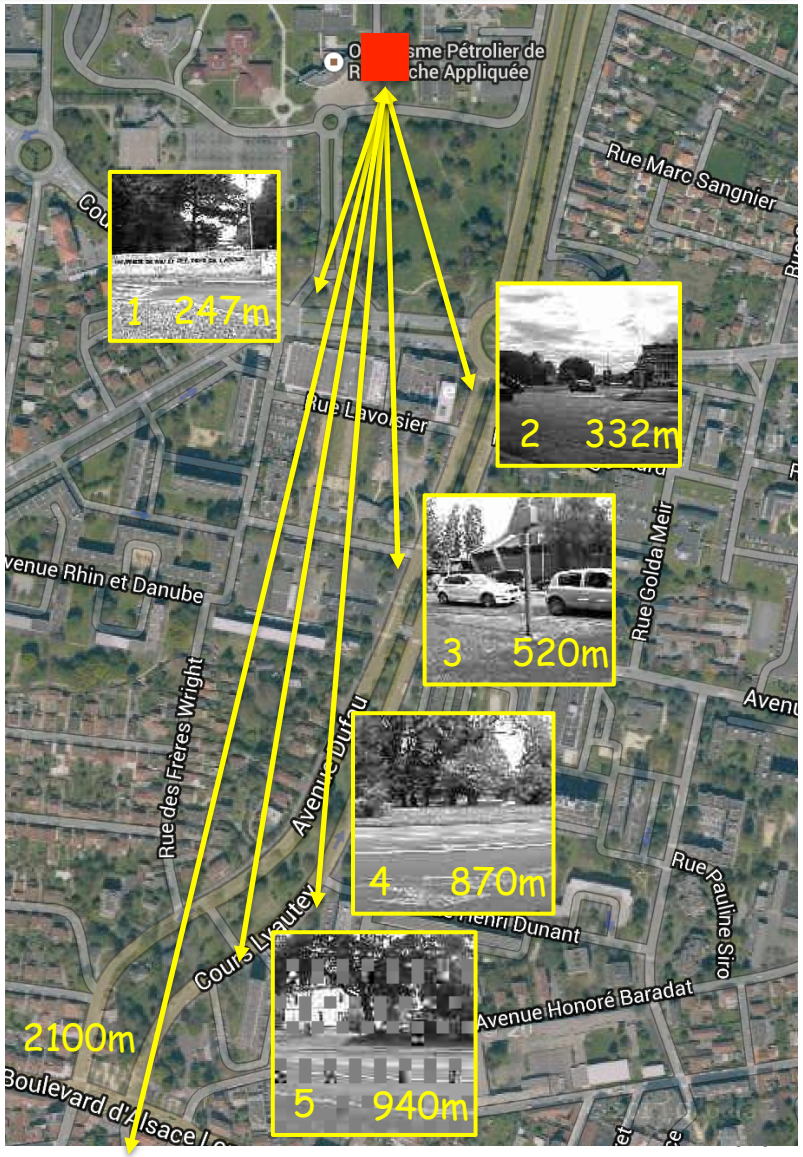
IMAGE SENSOR WITH LONG RANGE RADIO



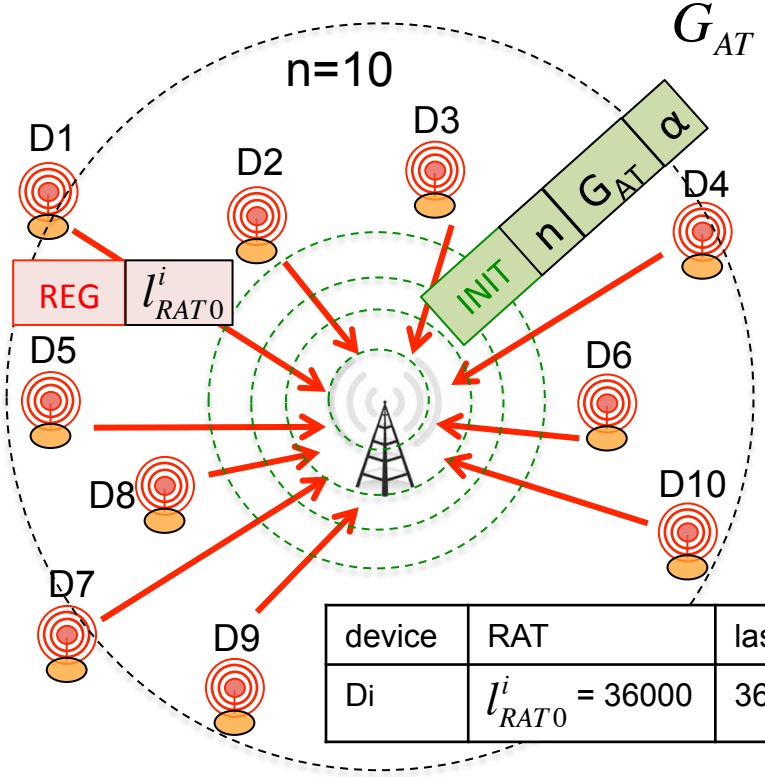






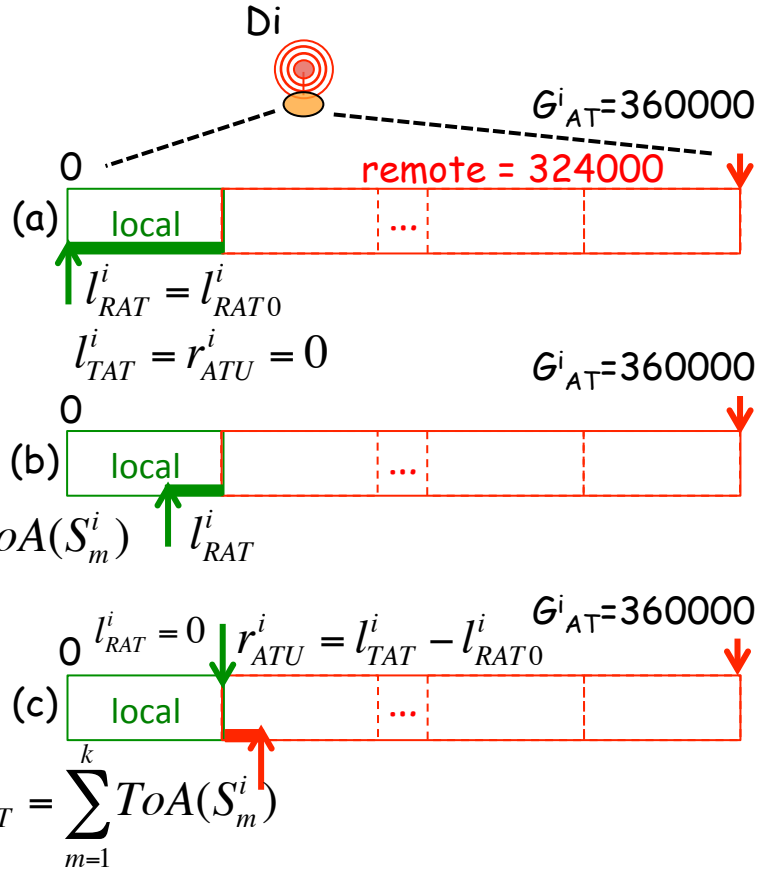


Long-range Activity Sharing (LAS)



device	RAT	lastRAT
Di	l^i_{RAT0} = 36000	36000

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

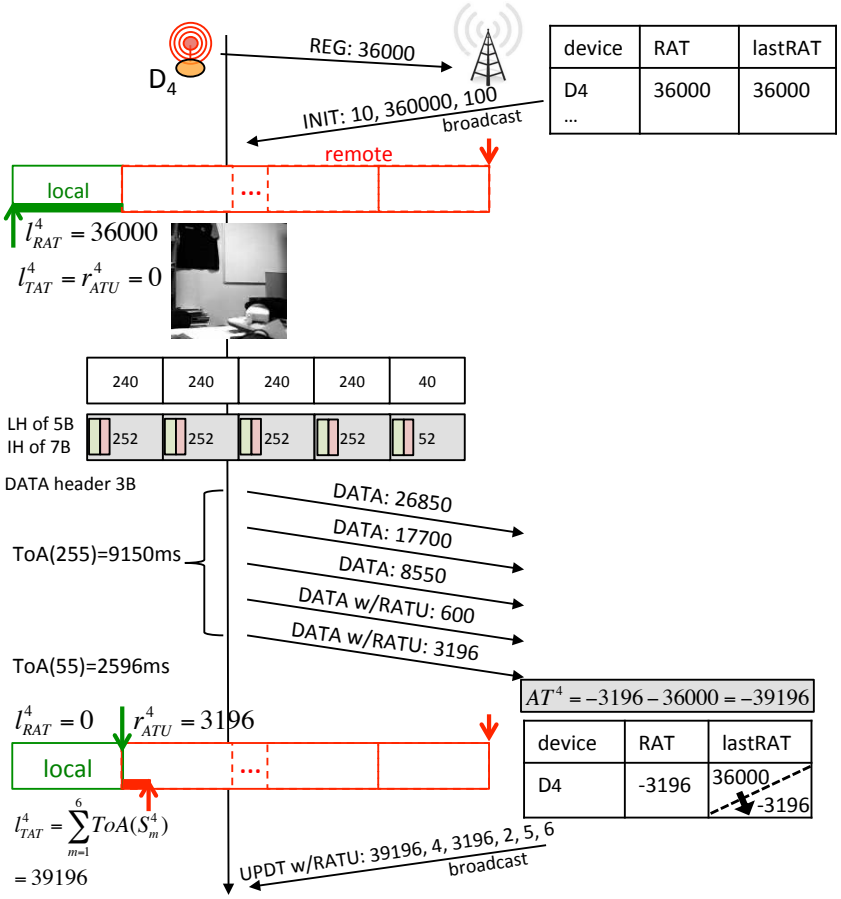


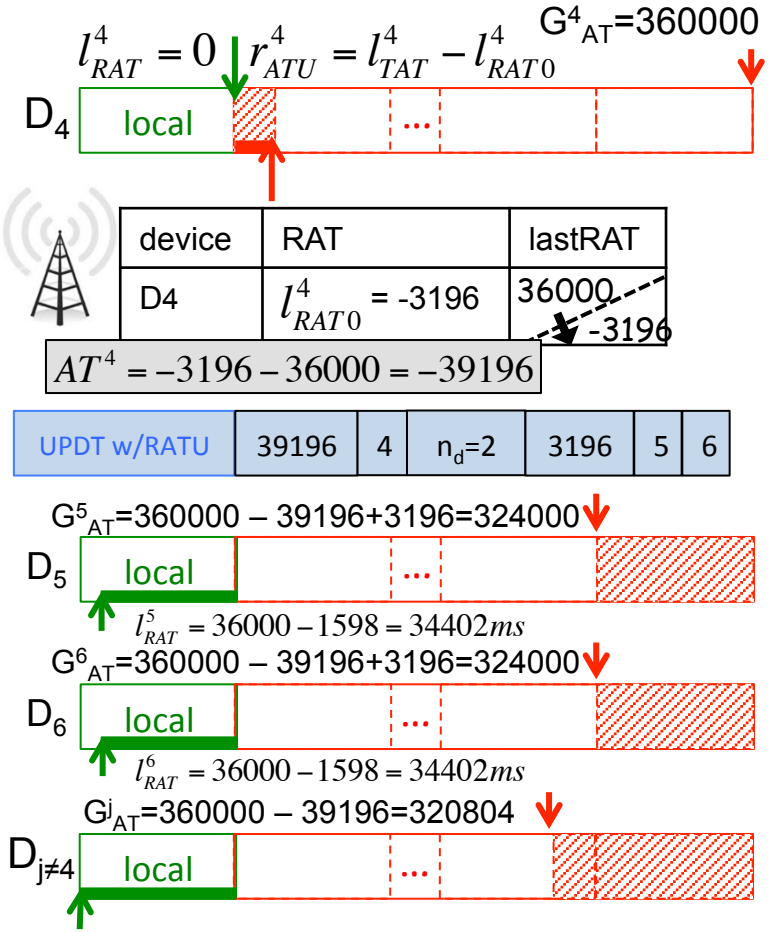
$$l^i_{TAT} = \sum_{m=1}^{k} ToA(S^i_m)$$

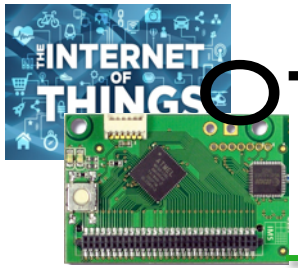
$$l^i_{TAT} = \sum_{m=1}^{k} ToA(S^i_m)$$

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

Distributing Remote Activity Time Usage

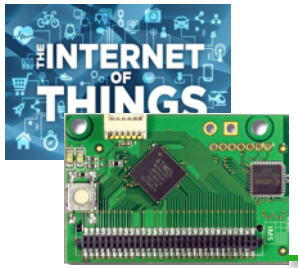




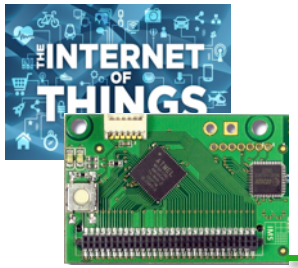


OTHER ISSUES TO TAKE INTO ACCOUNT

- 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

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

Credit: C. Vavasseur, CTIC Dakar

Building WAZIUP community and ecosystem

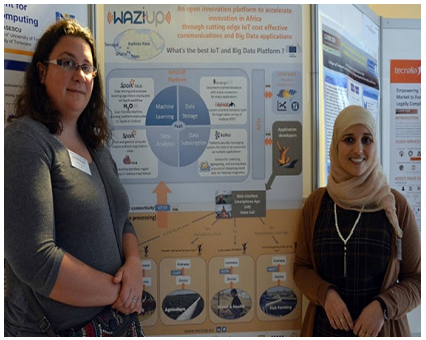
International Events
+ 20 organized & attended

Launch event (Ghana, iSpace)

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

Launch event (Senegal, CTIC Dakar)

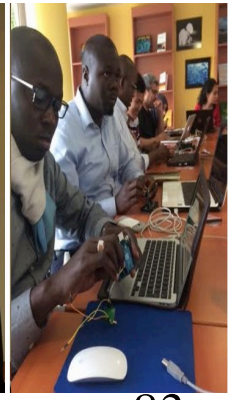
IoTWeek2016 (Belgrade, EGM)



IoTBigData2016 (Italy, EGM)

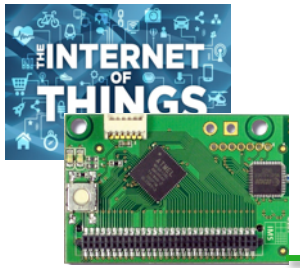
IoTCareConference (Budapest, CNET)

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

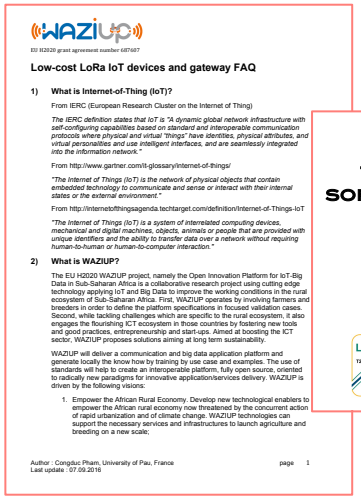


Credit: C. Vavasseur, CTIC Dakar

Workshop at the RESSACS 2016 (France, UPPA)



TUTORIALS/RESOURCES



EU H2020 grant agreement number 687607

Low-cost LoRa IoT devices and gateway FAQ

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

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

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

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

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

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

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

2) What is WAZIUP?

The EU H2020 WAZIUP project, namely the Open Innovation Platform for IoT-Big Data in Sub-Saharan Africa is a collaborative research project using cutting edge technology applying IoT and Big Data to improve the working conditions in the rural ecosystem of Sub-Saharan Africa. First, WAZIUP operates by involving farmers and breeders in order to define the platform specifications in focused validation cases. Second, while tackling challenges which are specific to the rural ecosystem, it also engages the flourishing ICT ecosystem in those countries by fostering new tools and good practices, entrepreneurship and start-ups. Aimed at boosting the ICT sector, WAZIUP proposes solutions aiming at long term sustainability.

WAZIUP will deliver a communication and big data application platform and generate locally the know how by training by use case and examples. The use of standards will help to create an interoperable platform, fully open source, oriented to radically new paradigms for innovative application/services delivery. WAZIUP is driven by the following visions:

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 technologies can support the necessary services and infrastructures to launch agriculture and breeding on a new scale;

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LOW-COST LORA IOT: USING THE WAZIUP DEMO KIT

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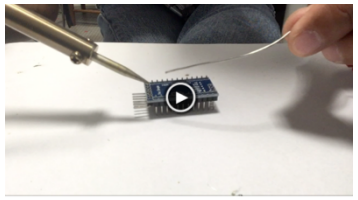

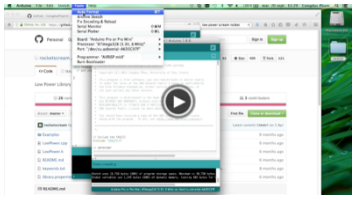

Thanks.

Let's keep in touch

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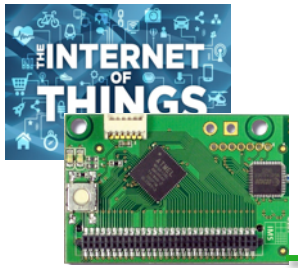

Conclusions

- Low-power, long-range transmission is a break-through 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!