Tutorial on hardware & software for low-cost long-range IoT

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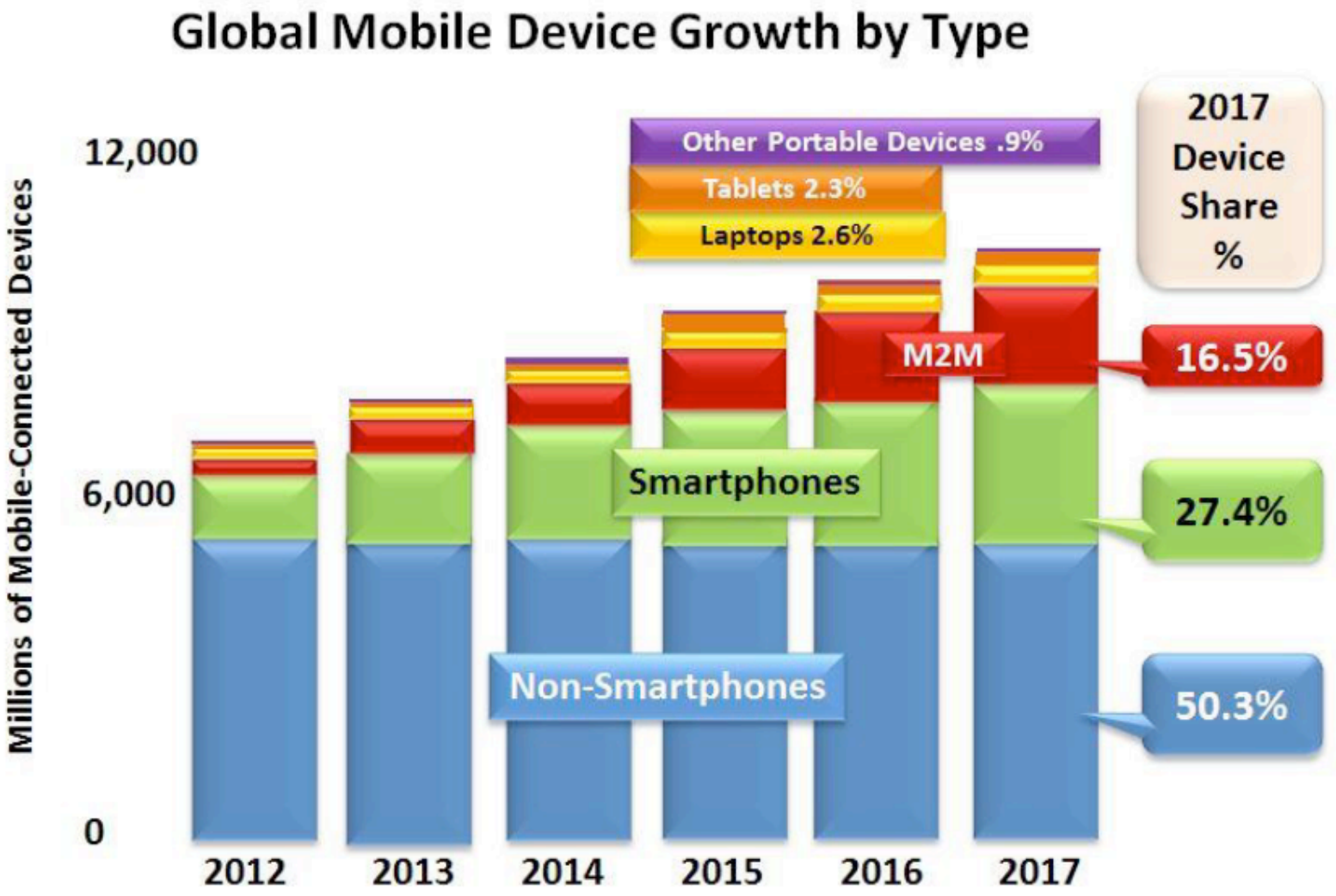
Université de Pau, France

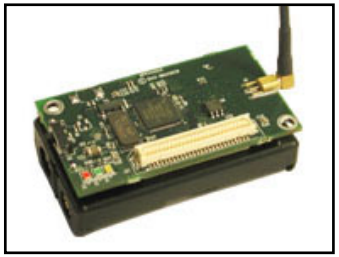
IoT, M2M, D2D,...

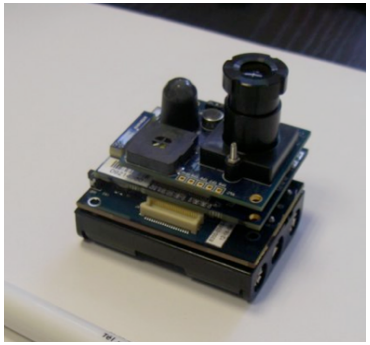
4G Americas / **4G Mobile Broadband Evolution: 3GPP Release 11 & Release 12 and Beyond** / February 2014

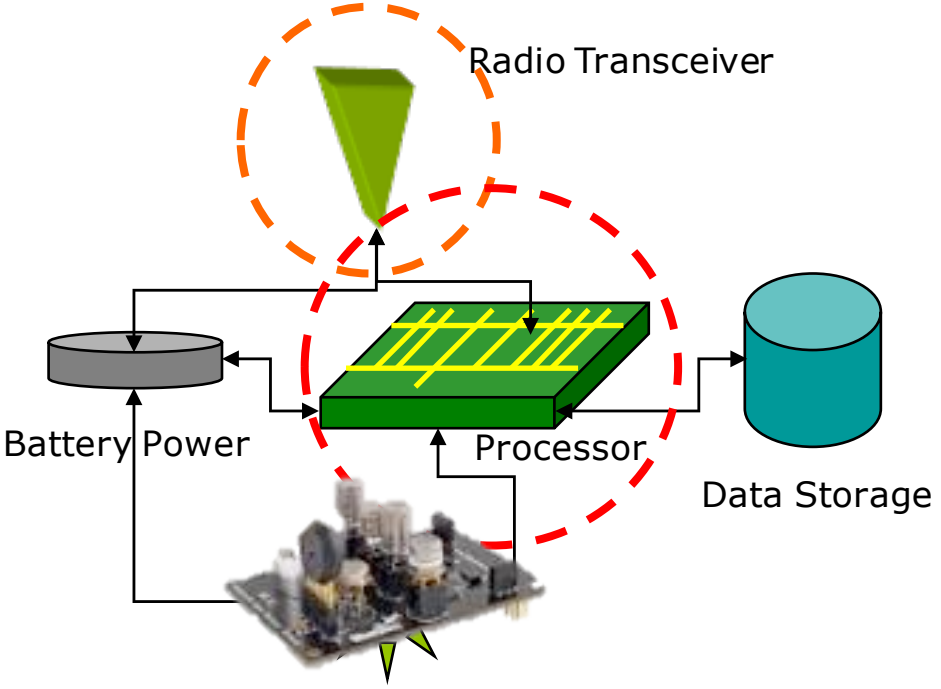


What's before IoT?

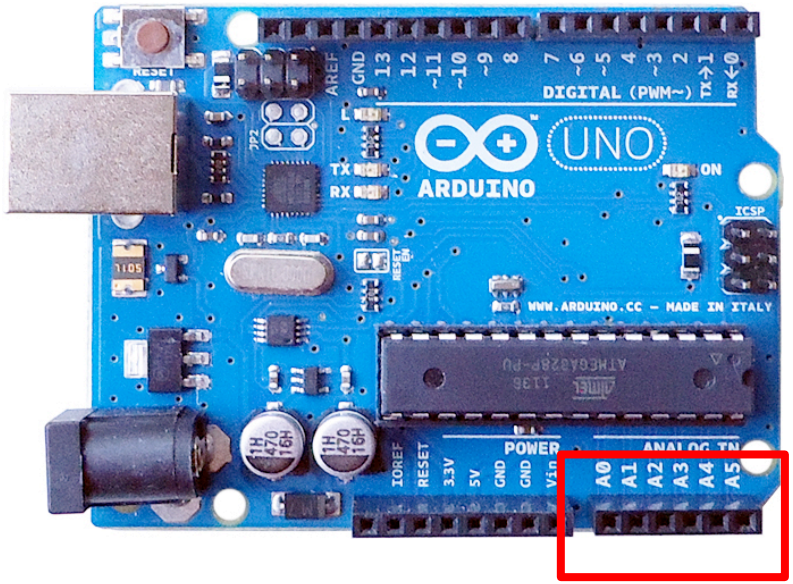
- Wireless Sensor Nodes/Networks
- Physical sensor + on-board processing



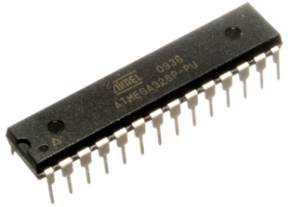


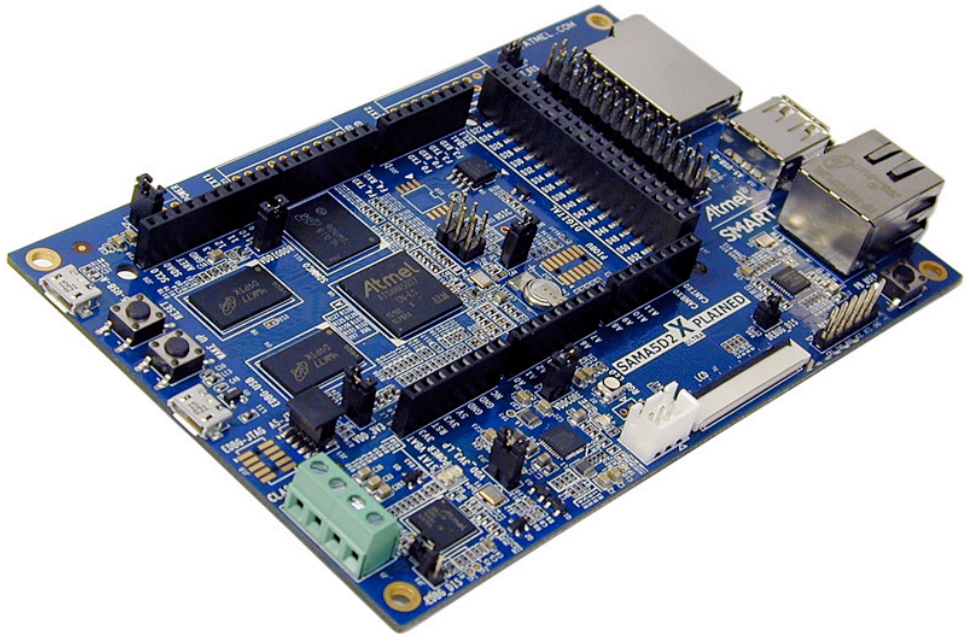


Powerfull micro-controller boards...



Analog pins





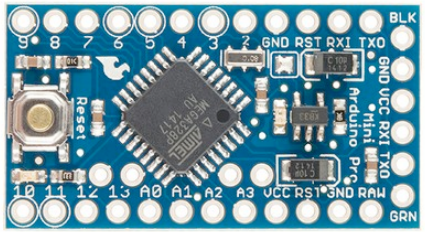
Atmel | SMART SAMA5D2

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 !!

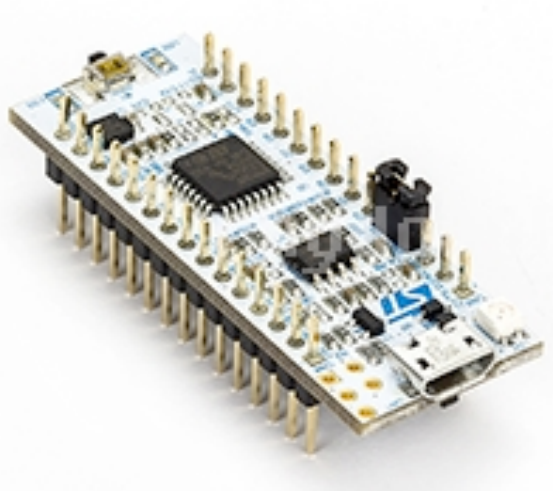
Arduino Pro Mini



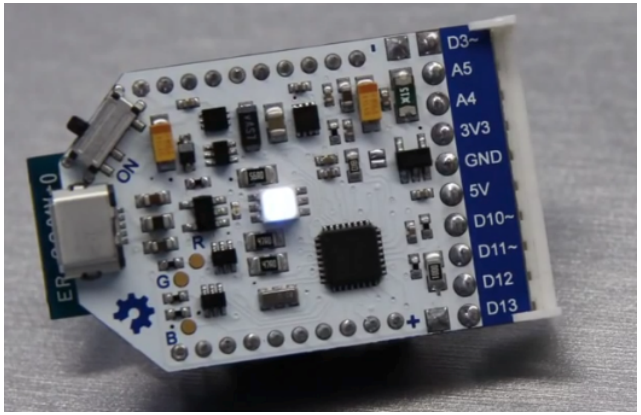
http://blog.atmel.com/2015/12/16/rewind-50-of-the-best-boards-from-2015/

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

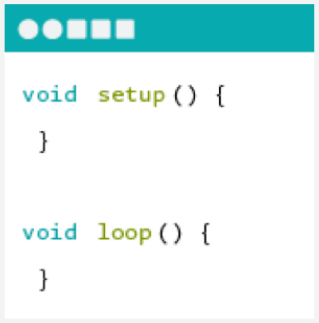
ARDUINO

WHAT IS ARDUINO?

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

ARDUINO BOARD

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



ARDUINO SOFTWARE

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

- In WAZIUP, Arduino-like boards are main development platforms for IoT because they are open, cheap and easy to use
- In addition, there are huge developer communities for these boards

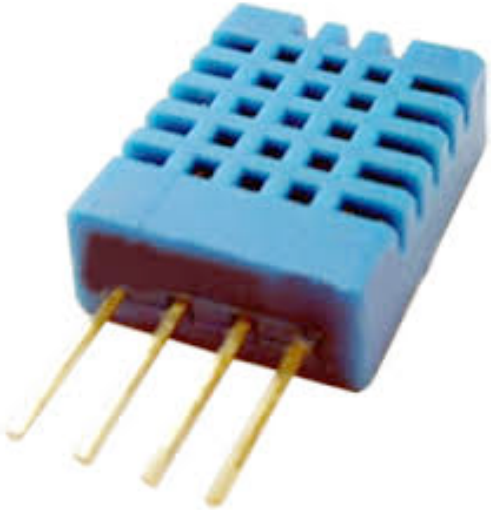
Step 1: measuring the physical world

Sensing

Using physical sensor

- Example: an analog temperature sensor

Sensor diversity

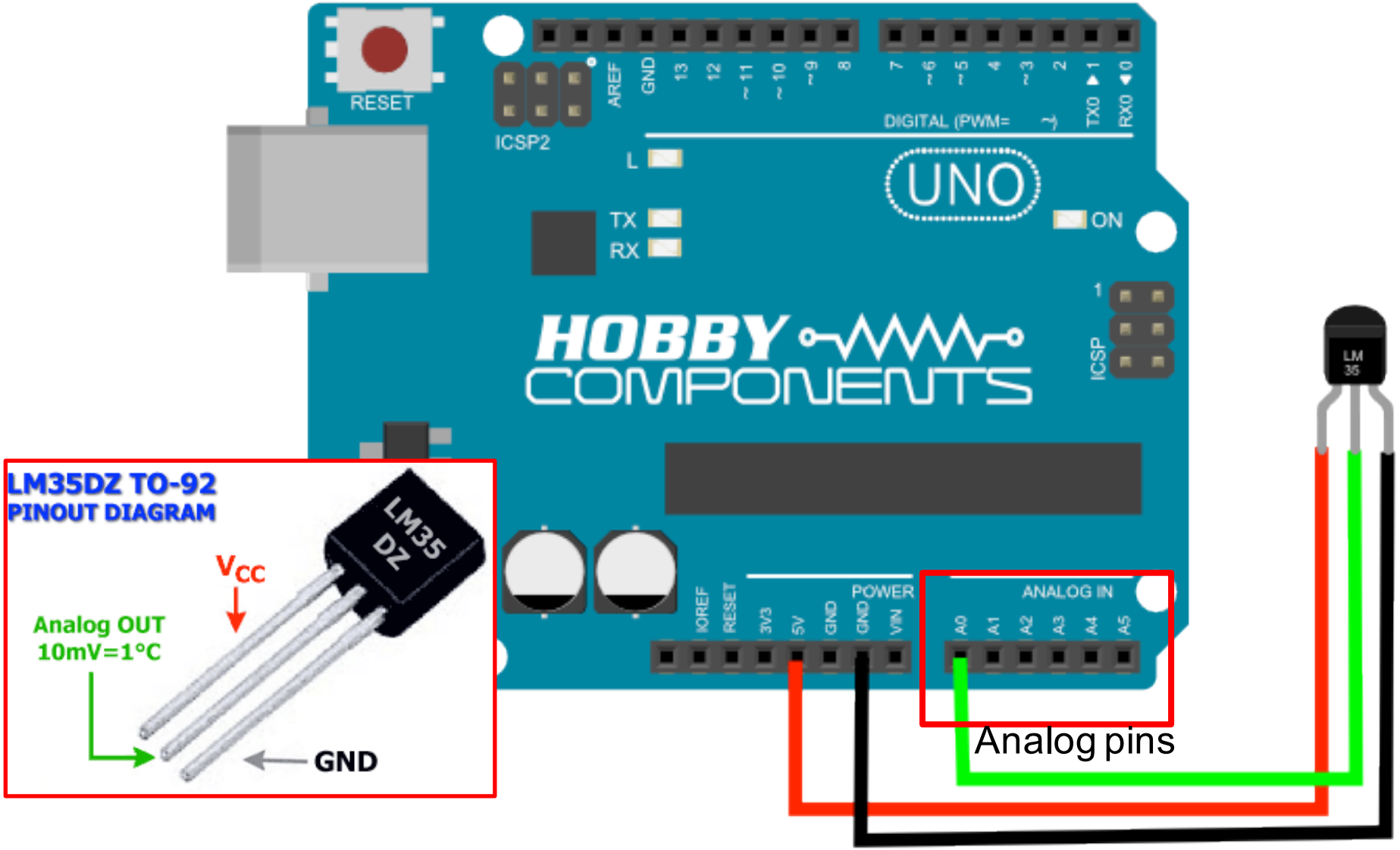


Step 2: store, process

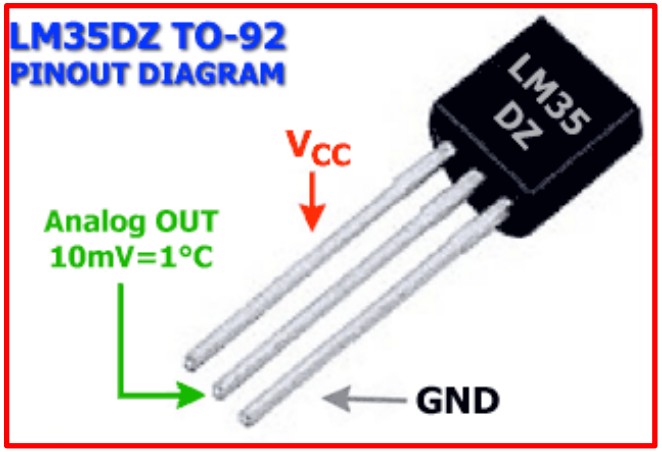
Pervasive Systems

Sensing

Connect the sensor

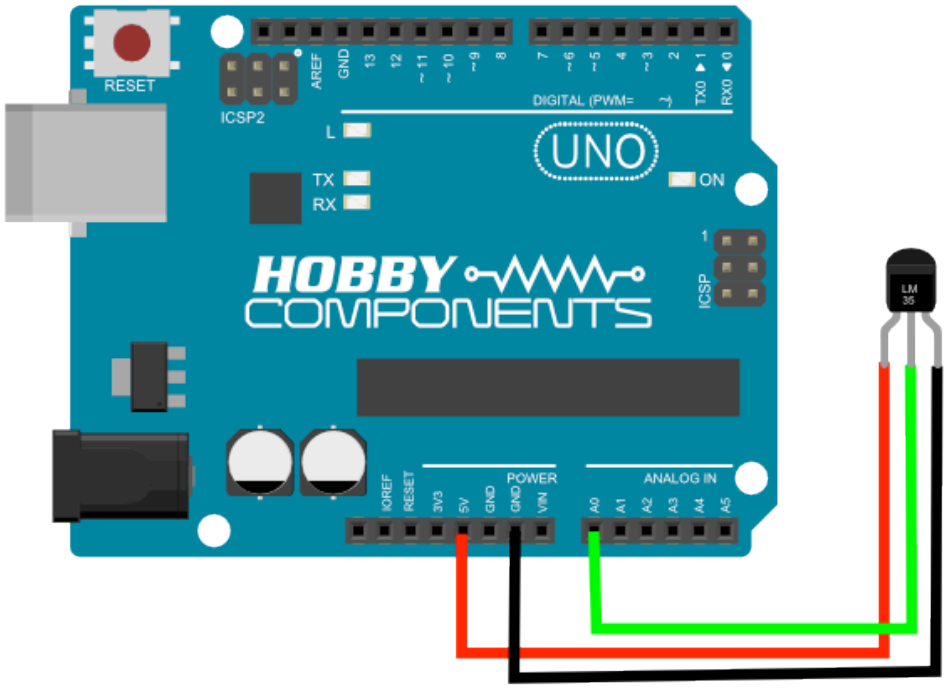


Temperature & analog output



- Vcc is 5V
- If 0 means 0V and 1024 means 5000mV (10-bit resolution) then 5000mV/1024=4.88mV is the granularity of the measure
- A digital value of 100 means 100*4.88mV=488mV
- If the sensor output is 10mV/1°C then the physical temperature is 488mV/10mV=48.8°C

READING ANALOG PIN VALUE

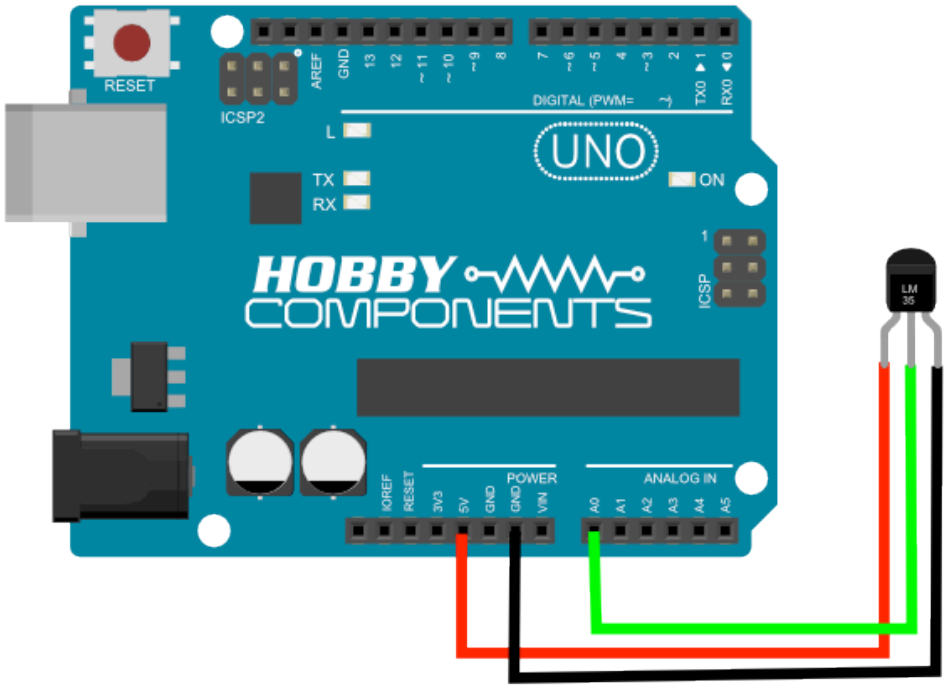



```
// sensor output connected to A0 analog pin

value = analogRead(A0);

// now need to convert to Celcius degree
```

Converting into Celcius




```
value = analogRead(A0);

Temp = value * 5000.0/1024.0;      // 5000/1024=4.88

Temp = Temp / 10;                  // 10mV means 1°C

// now process and transmit the data
```

Generalization

- Depending on the sensor type, getting the physical measure from the analog/digital value follows a specific function provided by the sensor's manufacturer
- Depending on the microcontroller board, the number of I/O pins and the operating voltage may differ
- However the process is always the same:
  - Connect the sensor to the microcontroller board
  - Read analog or digital pin
  - Convert read value into meaningful physical measure
  - Then process and/or transmit

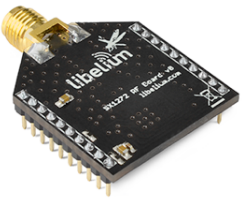
STEP 3: CONNECT, INTERACT

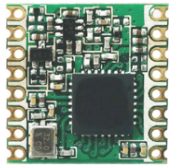
PERVASIVE SYSTEMS

SENSING

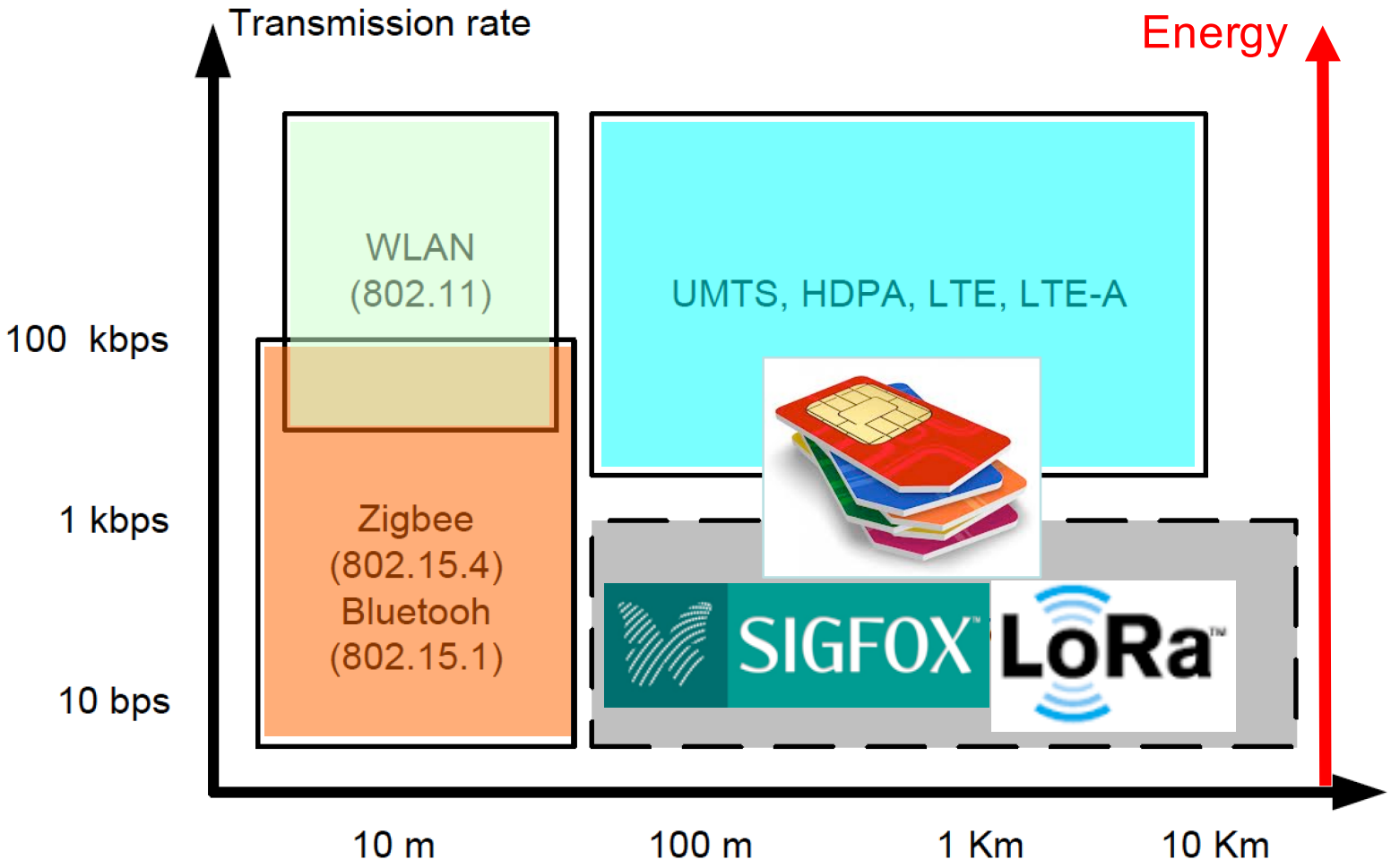
PEOPLES, INFRASTRUCTURES, BUILDINGS, VEHICULES,...

Wireless Communication made easy



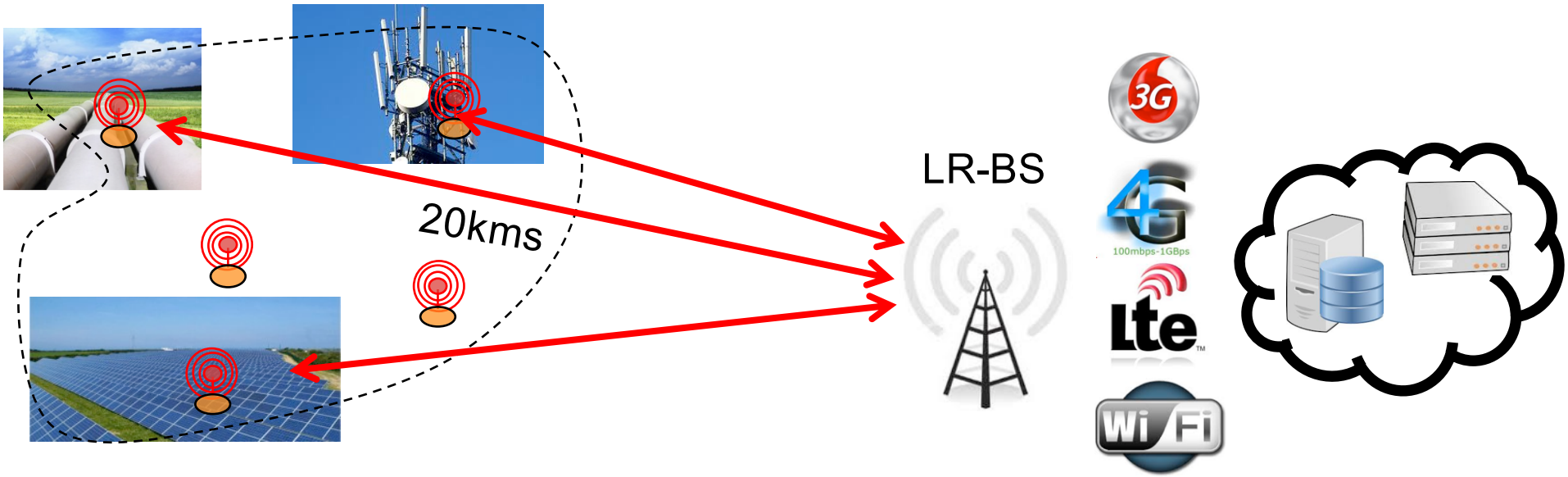


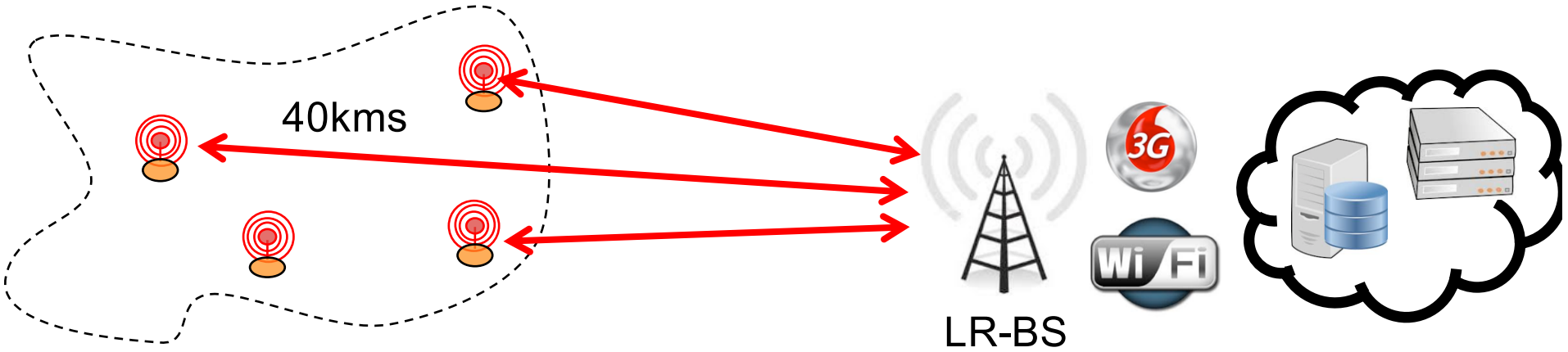
Low-power and long-range?



Enhanced from M. Dohler "M2M in SmartCities"

IoT DEPLOYMENT MADE EASIER IN SINGLE-HOP MODEL





Typical scenarios (1)

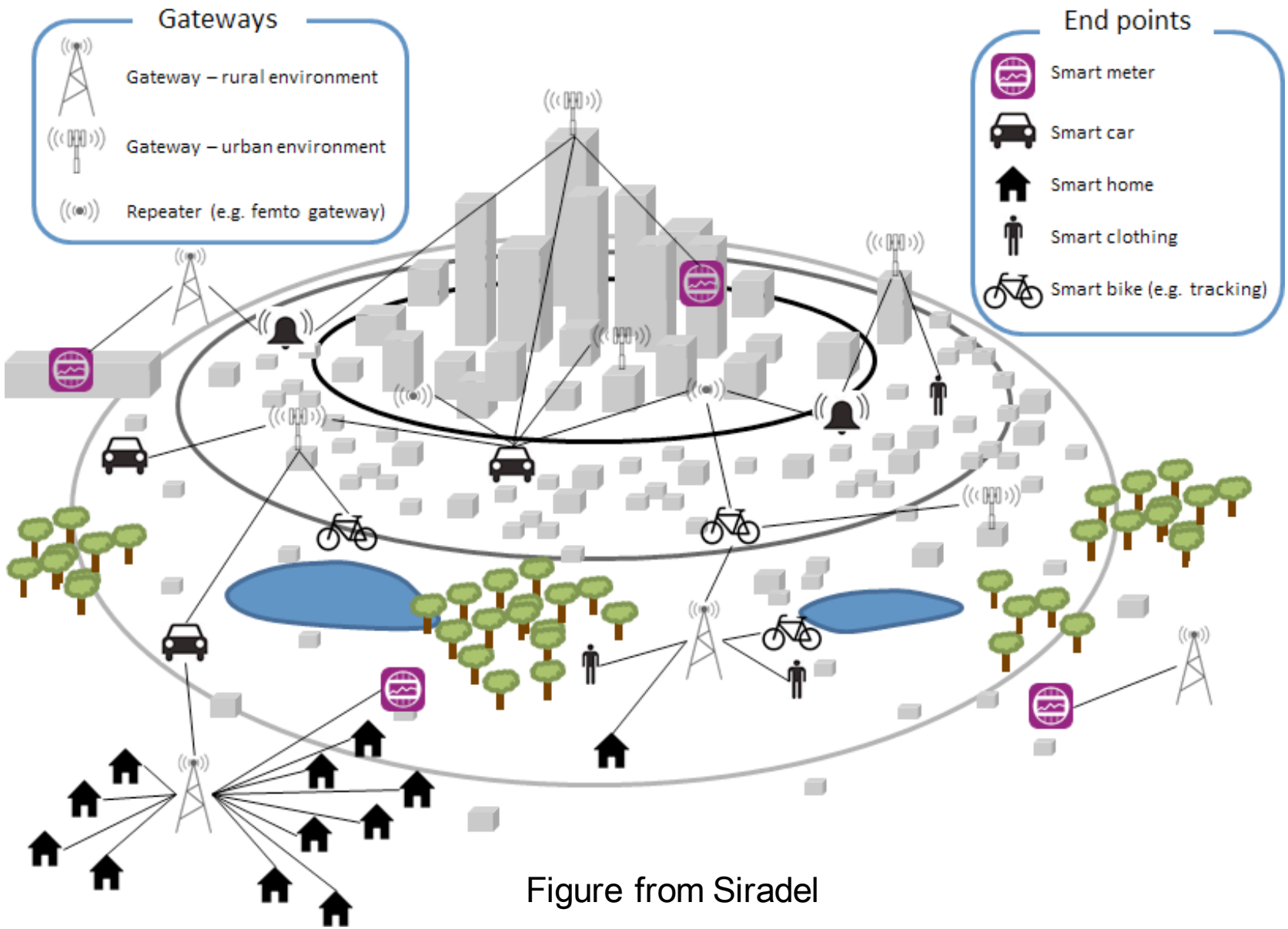
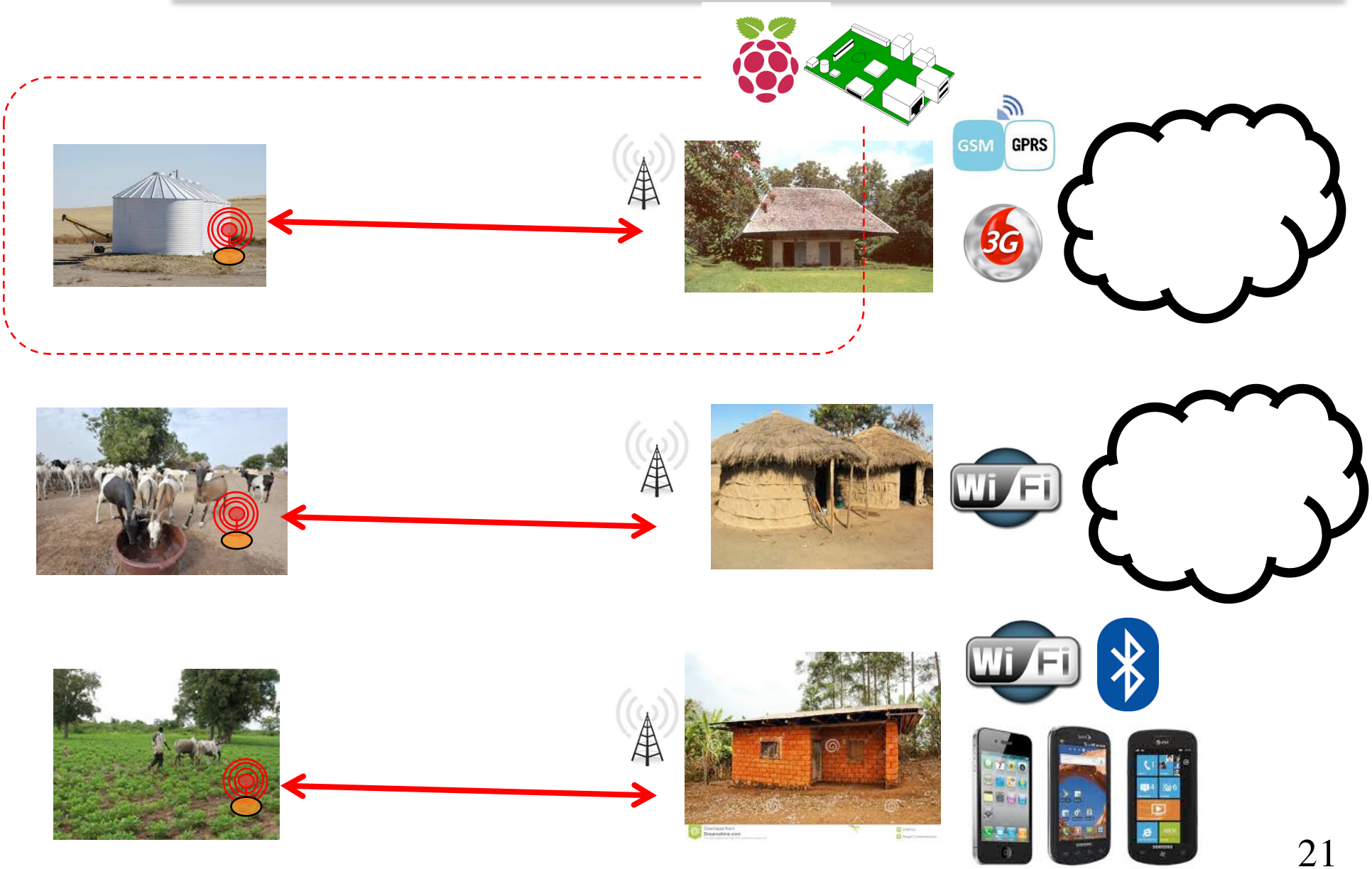
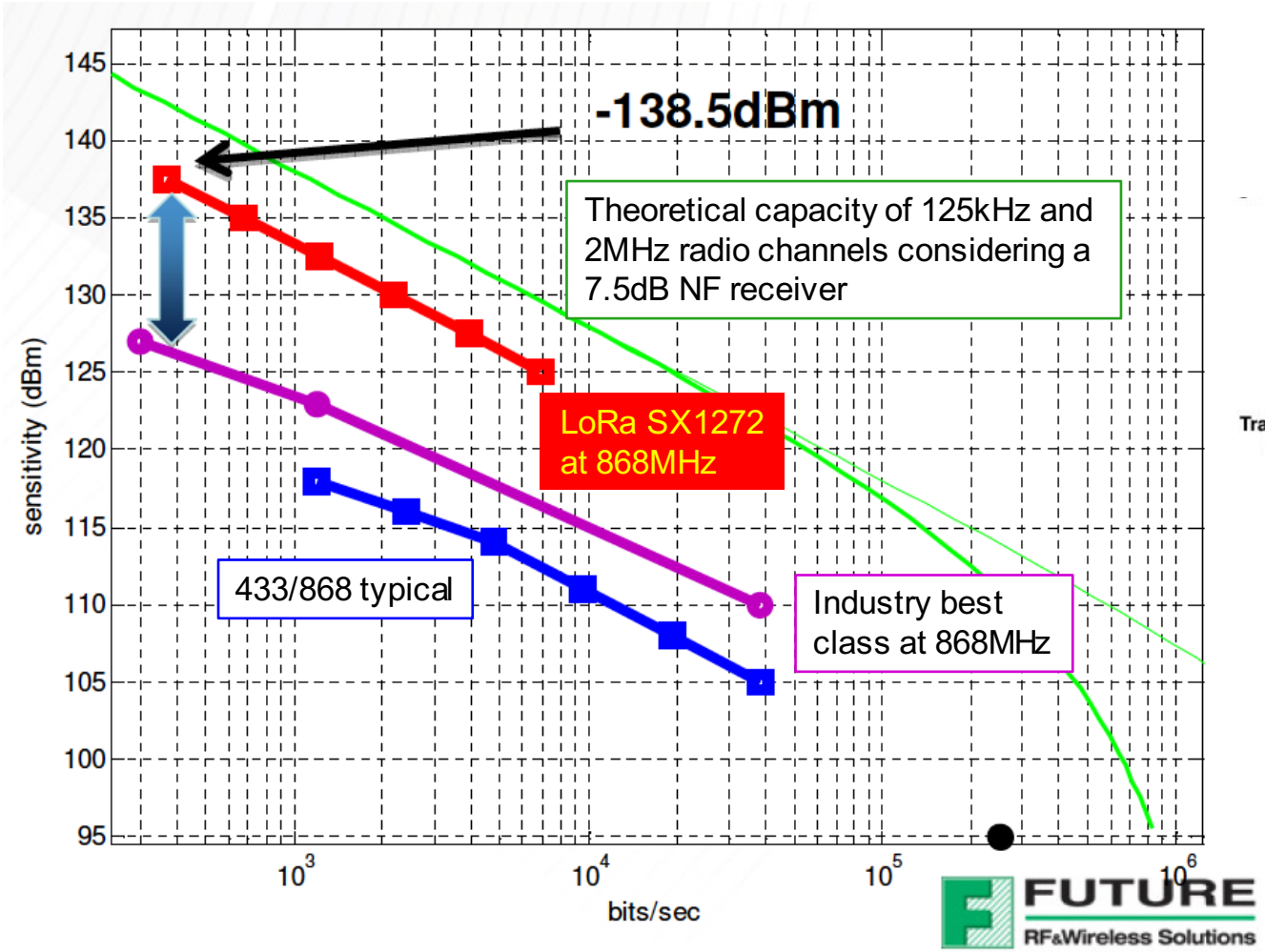


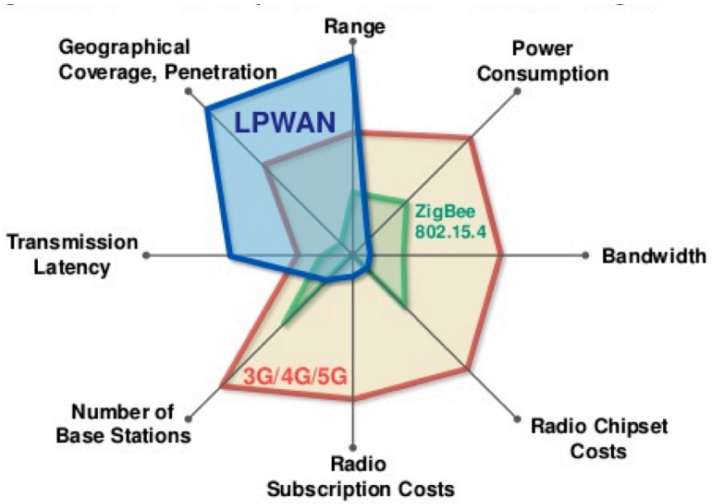
Figure from Siradel

TYPICAL SCENARIOS (2)



THE LOW POWER WAN (LPWAN) REVOLUTION

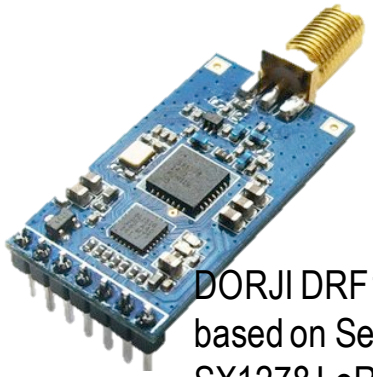




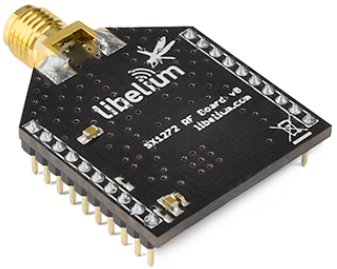
From Peter R. Egli, INDIGOO.COM

The lower the receiver sensitivity, the longer is the range!

LoRa modules from Semtech's SX127x chips



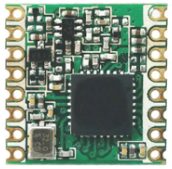
DORJI DRF1278DM is based on Semtech SX1278 LoRa 433MHz



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

inAir9 based on SX1276

Froggy Factory LoRa module (Arduino)



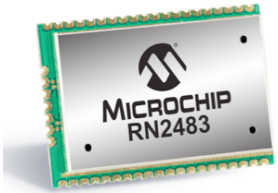
HopeRF RFM series

HopeRF HM-TRLR-D

LinkLabs Symphony module

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

Embit LoRa

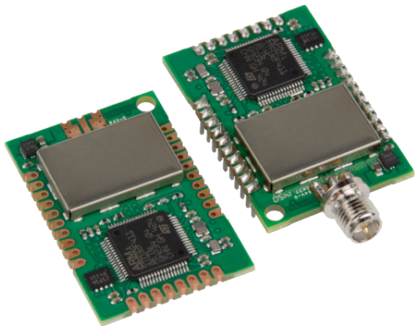


LoRa™ Long-Range Sub-GHz Module (Part # RN2483)

Microship RN2483

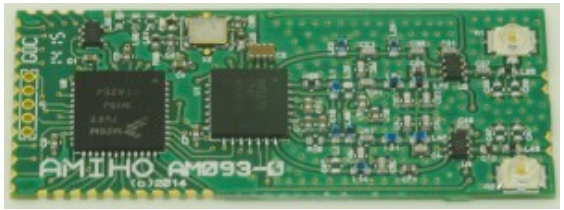
habSupplies

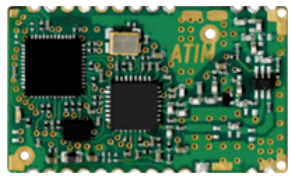
Adeunis ARF8030AA- Lo868



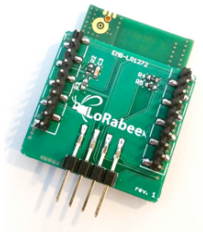
Multi-Tech MultiConnect mDot

AMIHO AM093





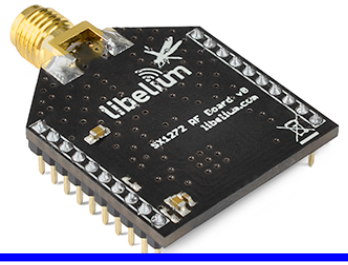
ARM-Nano N8 LoRa module from ATIM



SODAQ LoRaBee Embit

SODAQ LoRaBee RN2483

LoRa modules from Semtech's SX127x chips



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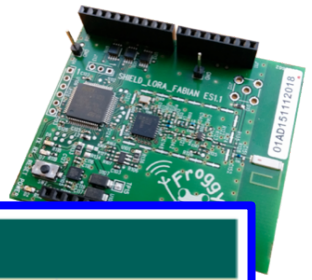
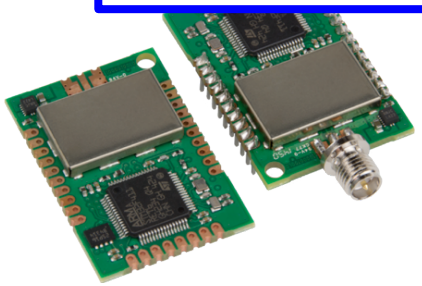


LoRa® Transceivers

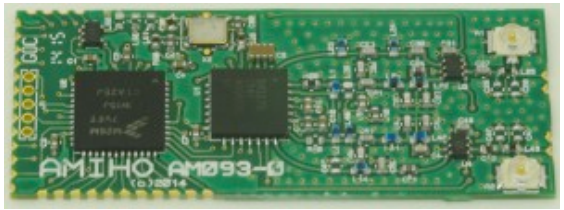
Part Number	Frequency Range (MHz)	Link Budget (dB)	Rx Current (mA)	FSK max DR (kbps)	LoRa DR (kbps)	Max Sensitivity (dBm)	Tx Power (dBm)
SX1272	860 – 1020	158	10	300	0.3 – 37.5	-137	+ 20
SX1273	860 – 1020	150	10	300	1.7 – 37.5	-130	+ 20
SX1276	137 – 1020	168	9.9	300	0.018 – 37.5	-148	+ 20
SX1277	137 – 1020	158	9.9	300	1.7 – 37.5	-139	+ 20
SX1278	137 – 525	168	9.9	300	0.018 – 37.5	-148	+ 20

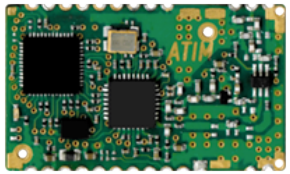


Multi-Tech MultiConnect mDot

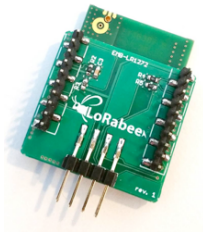
habSupplies

AMIHO AM093





ARM-Nano N8 LoRa module from ATIM



SODAQ LoRaBee Embit

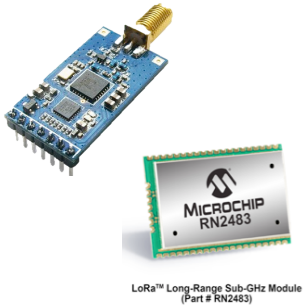
SODAQ LoRaBee RN2483

Adeunis ARF8030AA-Lo868

Microship RN2483

Building private long-range networks

Add LoRa radio module to your preferred dev platform



Install a LoRa gateway and start collecting data

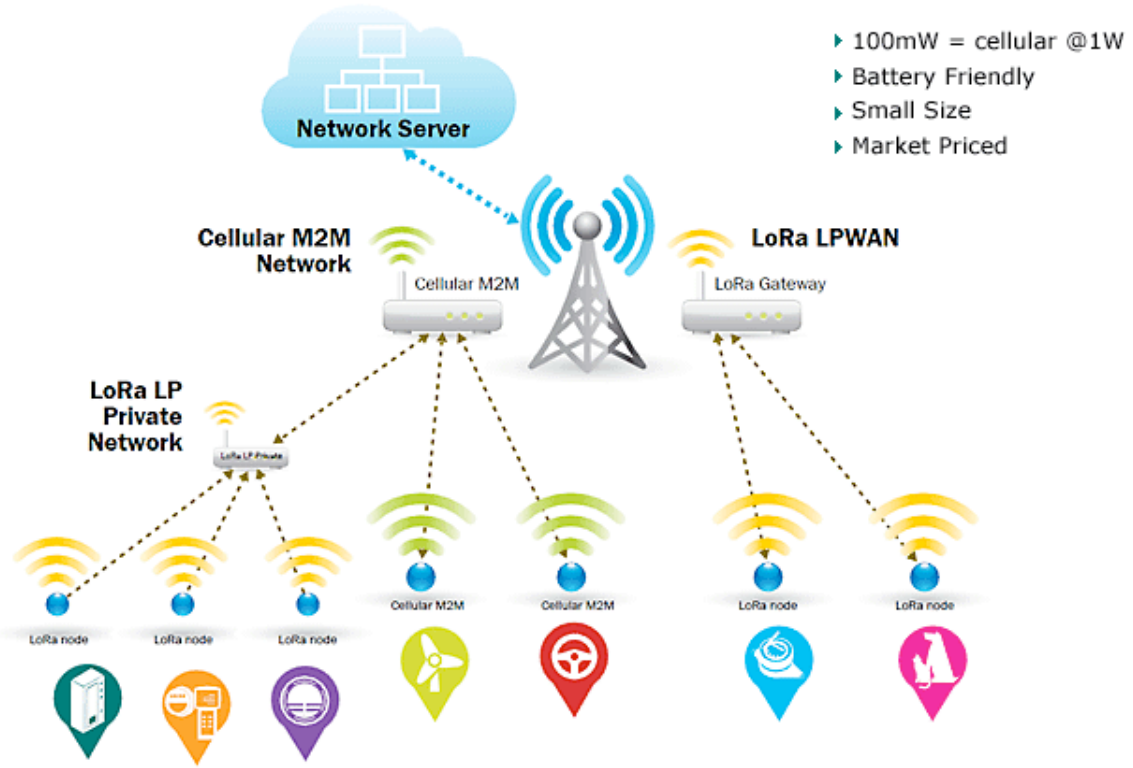


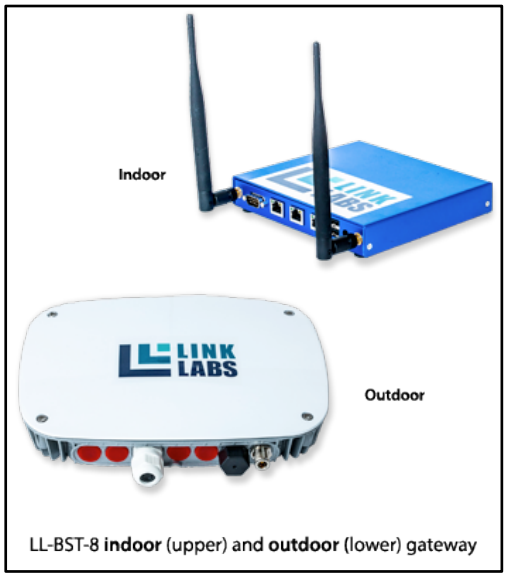
Figure from Semtech

LoRa Gateways
(non exhaustive list)

Multi-Tech Conduit

Embedded Planet
EP-M2M-LORA

Ideetron Lorank 8



LinkLabs Symphony

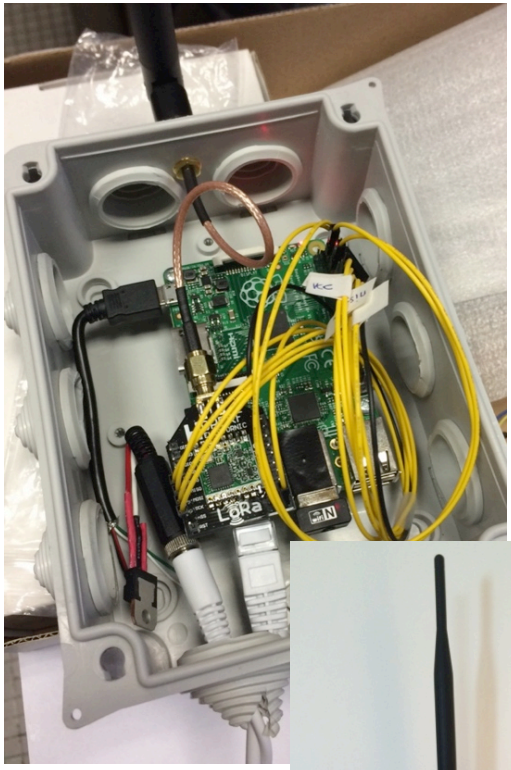
PicoWAN from
Archos

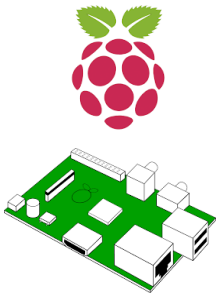
TheThingNetwork

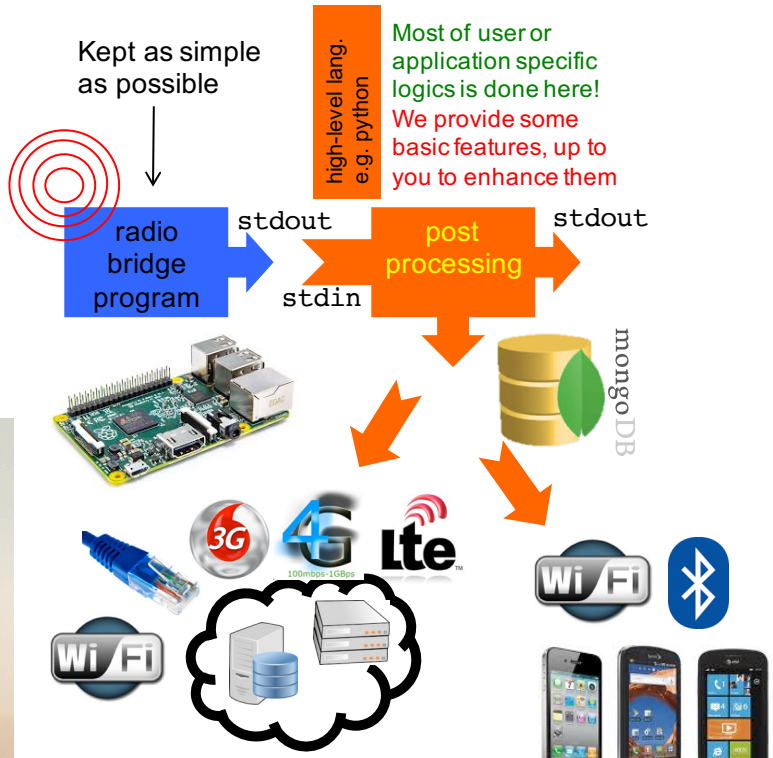
Kerlink IoT Station

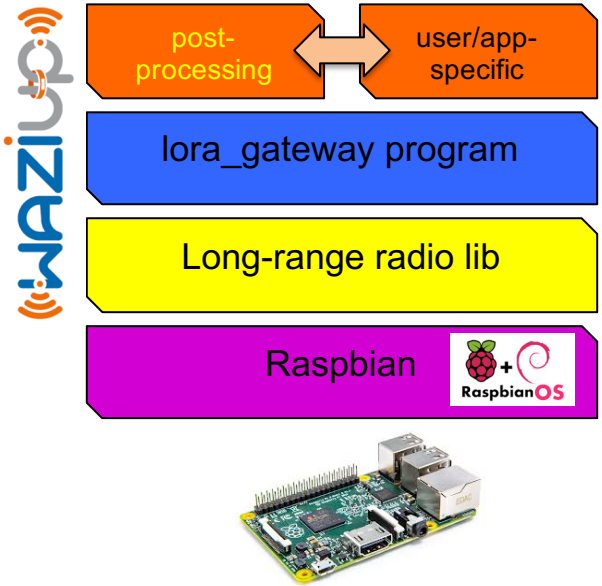
Or build your own one:
Arduino, Rasperry PI, …

Our low-cost LoRa Gateway: less than 50€

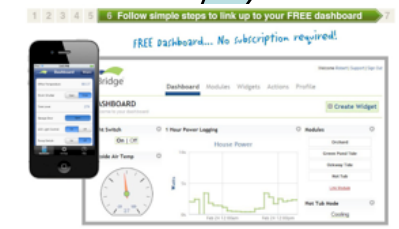








Step 4: control, optimize & instrument !



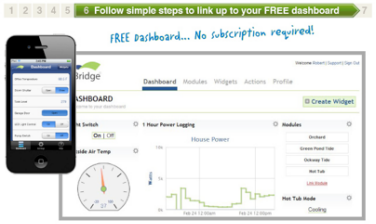
DATA ANALYSIS, OPTIMIZATION & CONTROL

PERVASIVE SYSTEMS

SENSING

PEOPLES, INFRASTRUCTURES, BUILDINGS, VEHICULES

LINK WITH BIG DATA!



PERVASIVE SYSTEMS

SENSING

PEOPLES, INFRASTRUCTURES, BUILDINGS, VEHICULES

IoT cloud?


Dropbox


Firebase


FIWARE


Axēda®


ioBridge®
Connect things.


ThingSpeak


GroveStreams


SensorCloud™

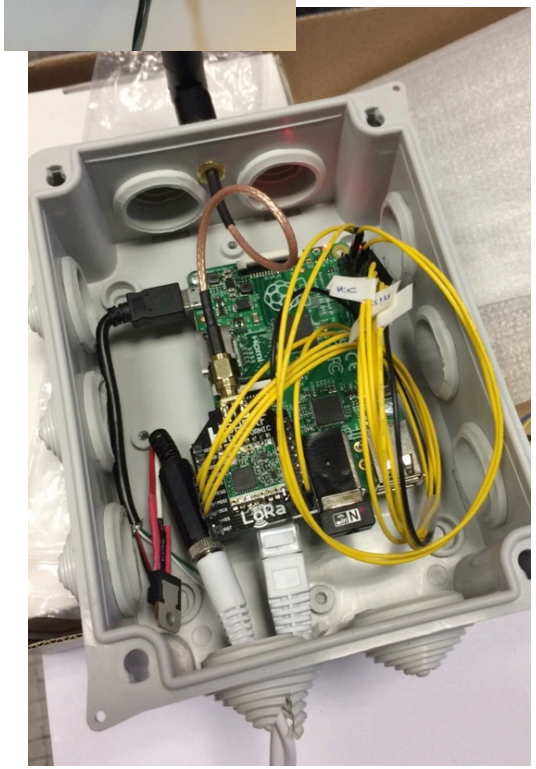

freeboard

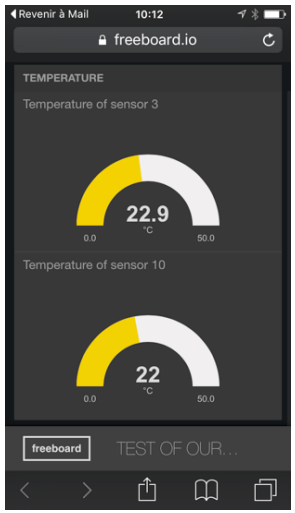

dweet.io


OpenRemote


TempoIQ

Our low-cost LoRa gateway can push data to any cloud

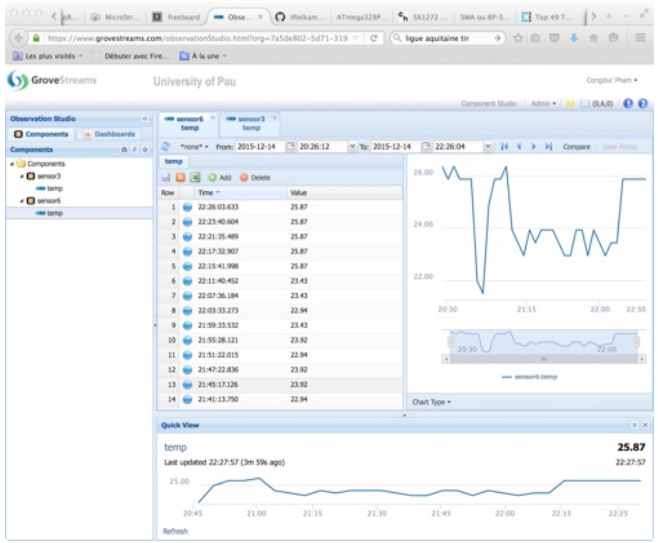


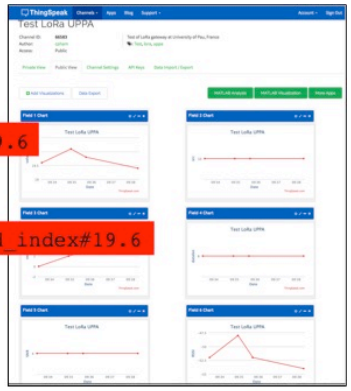


Dropbox

freeboard

FIWARE





\!##19.6

Node 10

\!write_key#field_index#19.6

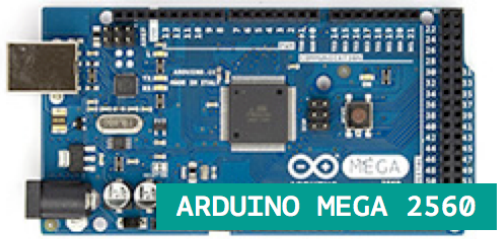
GroveStreams

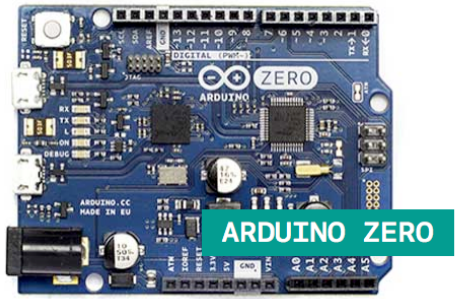
SensorCloud™

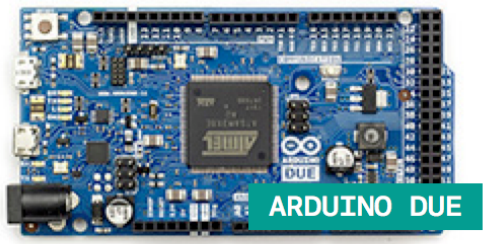
EU H2020 WAZIUP

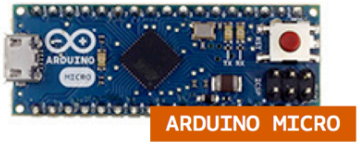
- The WAZIUP project is a collaborative research project using cutting edge technology applying IoT and Big Data to improve the working conditions in the rural ecosystem of Sub-Saharan Africa
- WAZIUP has support from multiple African stakeholders with the aim of defining new innovation space to advance the African Rural Economy
- WAZIUP will deliver a communication and big data application platform and generate locally the know how by training by use case and examples

SW/HW BUILDING BLOCKS

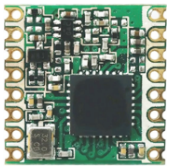




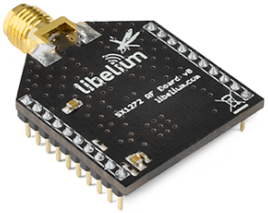




LoRa radios that our library already supports

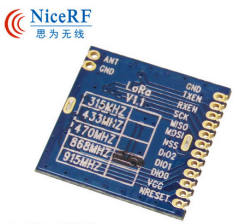


HopeRF RFM92W/95W



Libelium LoRa

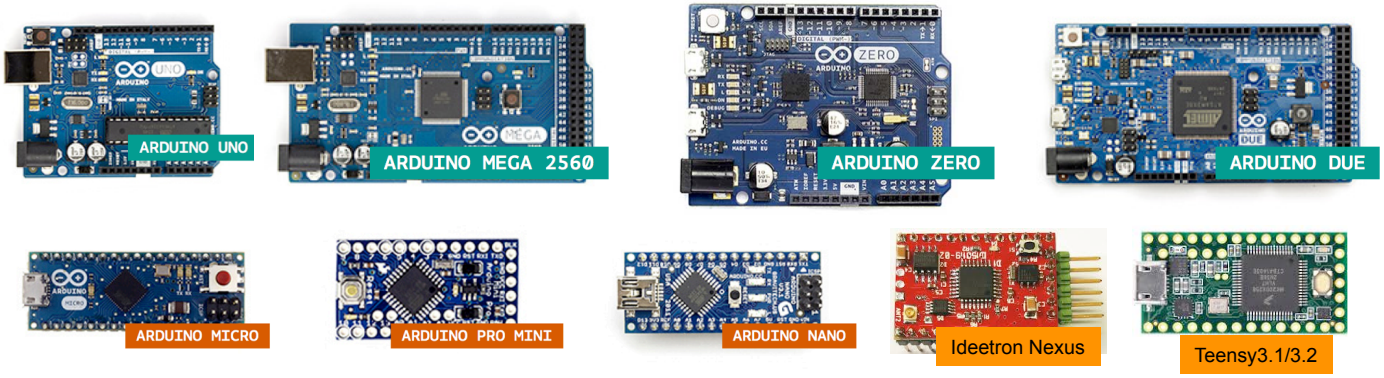
Modtronix inAir9/9B



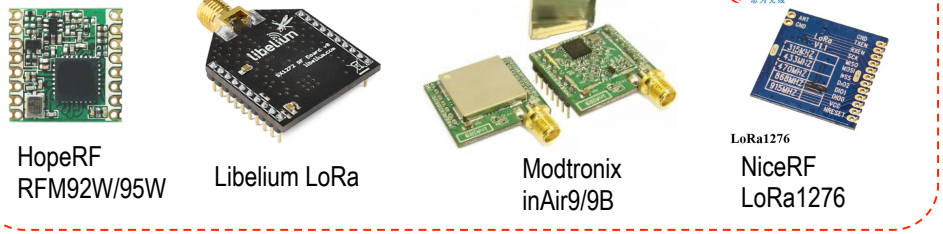
NiceRF LoRa1276

Long-Range communication library
(mostly sending functions)

Communication to gateway is straightforward for developers



LoRa radios that our library already supports



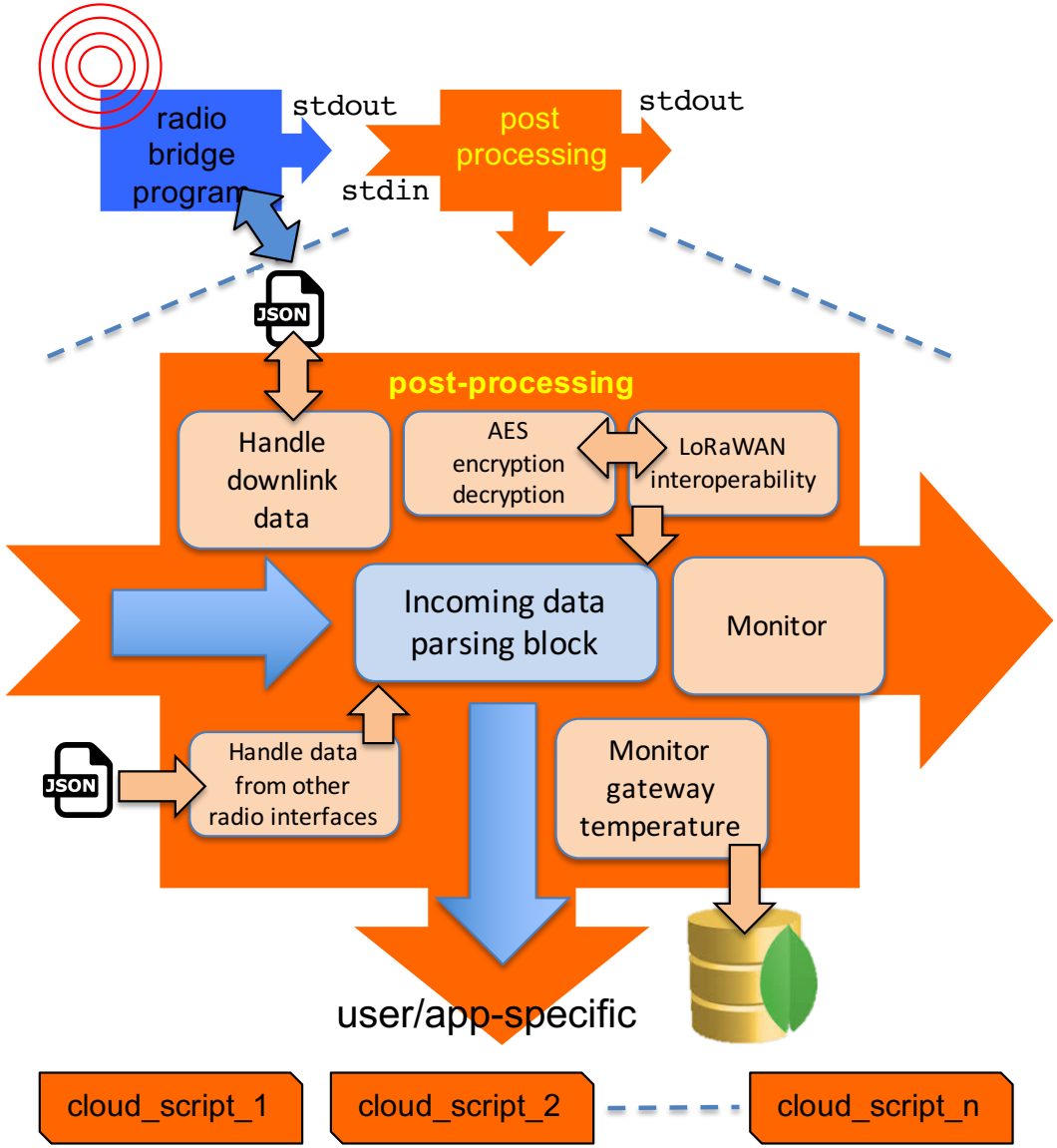
```
sendPacketTimeout(1, "18.5", 4);
// 1: sends to gateway
// 18.5 : temperature message
// 4 : message size
```

1 send function!

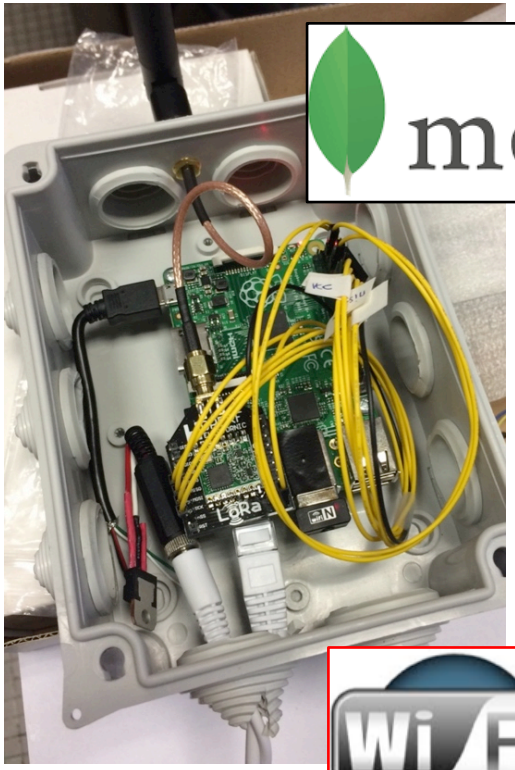
From GW to Cloud Platforms

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

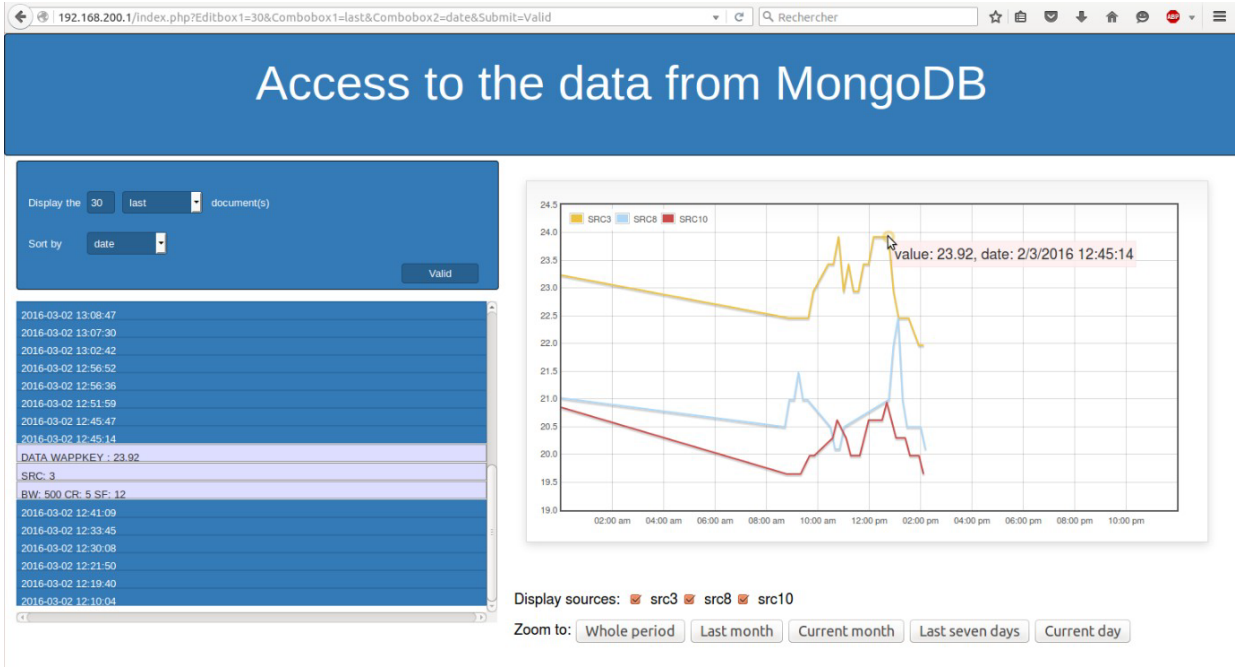
High-level scripting language provides connectivity to any cloud platforms depending on end-user needs



Running without Internet access



mongoDB



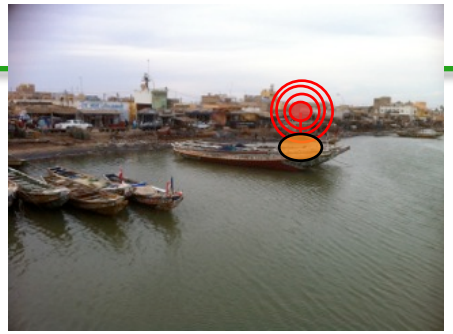
Wi Fi

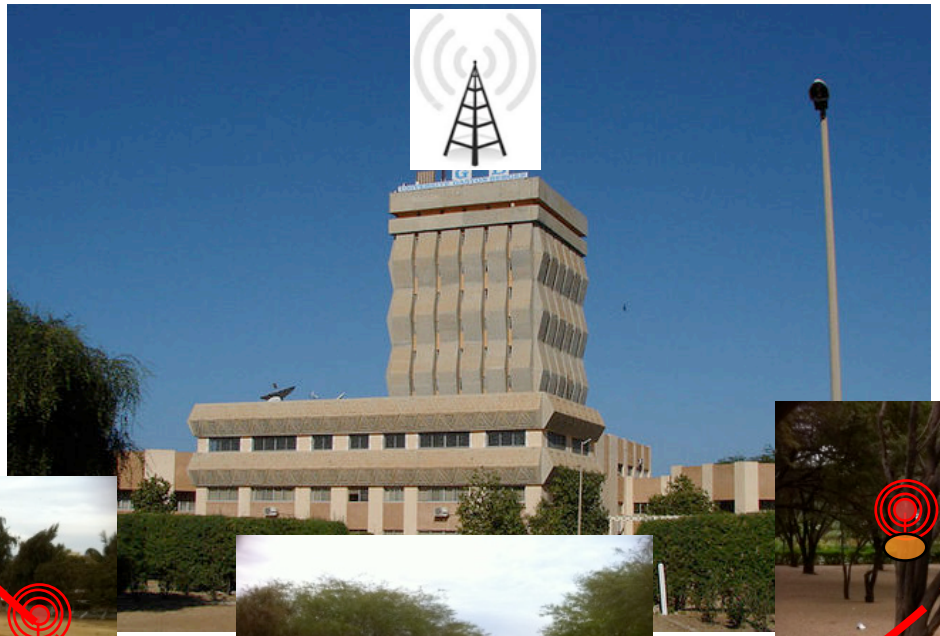
PHP

jQuery
write less, do more.

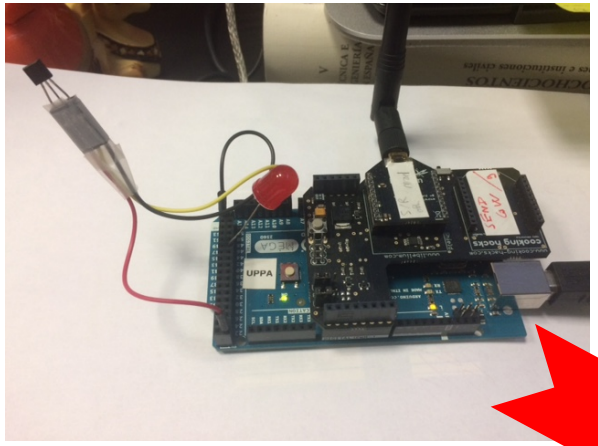
Internship of N. Bertuol, collaboration with ConnectingNature (F. Duvignac)

LONG-RANGE TEST-BED & BENCHMARK





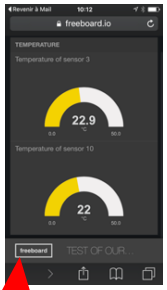
FULL EXAMPLE IS PROVIDED

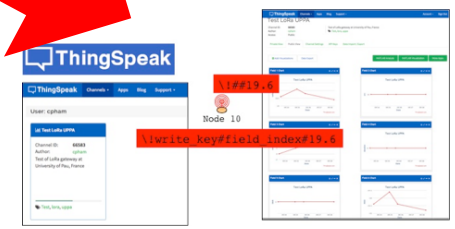


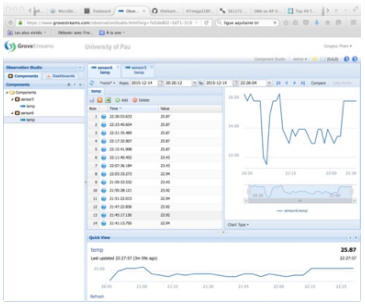
Source code available

Source code available

Python scripts available







GroveStreams

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https://github.com/CongducPham/LowCostLoRaGw

What a use case survey should provide?

- For each use case, it is important to know
  - What physical measures are needed (e.g. temperature and humidity)?
  - What is the frequency of these measures: min, max, avg (e.g. 1 every 10mins)?
  - How many point of measure (e.g. 15)?
  - What is the typical environment where measures should be captured (e.g. near the ground, in the water,…)?
  - Typical deployment size (e.g. 5km circular area)?
  - Is power available somewhere on site (e.g. yes, at farmer's premise)?
  - Is Internet access available (e.g. yes, at farmer's premise)?
  - How end-users want to get/visualize their data (e.g. on cloud and on a smartphone)?

WANT TO KNOW MORE?

- Arduino tutorials
  - Check the web: « arduino tutorial » in Google. There are plenty of nice tutorials!
  - Example: http://blog.hobbycomponents.com/?p=89
- LoRa technology survey
  - http://cpham.perso.univ-pau.fr/Paper/Talk-Rescom-16-LPWAN-review.pdf
    - Also available on WAZIUP Redmine
    - Documents/Project Meetings/KOM/Workshop and other presentation
- Our low-cost LoRa gateway
  - http://cpham.perso.univ-pau.fr/LORA/RPIgateway.html
  - http://cpham.perso.univ-pau.fr/LORA/resources/RPIgateway.pdf
    - Also available on WAZIUP Redmine
    - Documents/Project Meetings/KOM/Workshop and other presentation
- Building your LoRa end-devices
  - http://cpham.perso.univ-pau.fr/LORA/LoRaDevices.html
- Source code
  - https://github.com/CongducPham/LowCostLoRaGw