Ateliers Creactifs - IoT

Connection d'un objet réel au monde de l'internet

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Outline

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The Internet of Things (IoT) describes the network of physical objects—"things"—that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet. [1] [2]

Following examples from : [3] [4]

1. https://www.oracle.com/internet-of-things/what-is-iot/
2. https://securelist.com/new-trends-in-the-world-of-iot-threats/87991/
3. https://www.metrikus.io/blog/10-weirdest-iot-enabled-devices-of-all-time
4. https://www.businessinsider.com/weirdest-smart-gadgets-internet-of-things-smart-home-2017-3?r=US&IR=T


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Smart Automatic Litter Box
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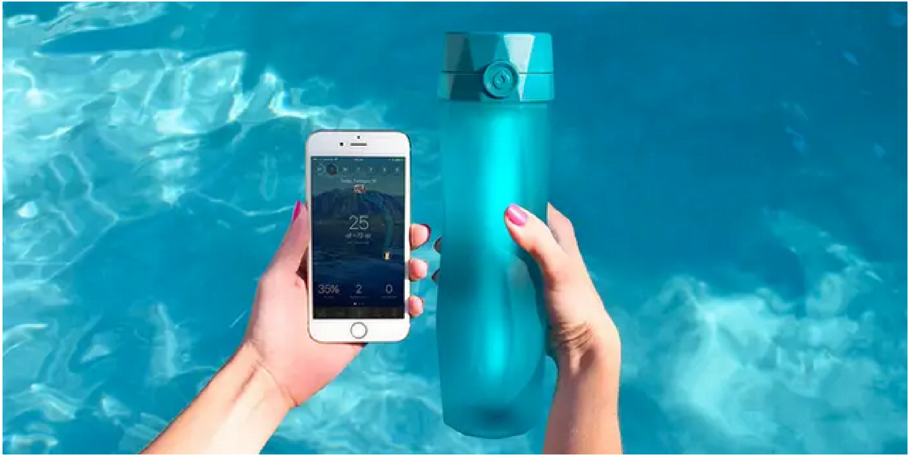
clickstick
clickstick


Success!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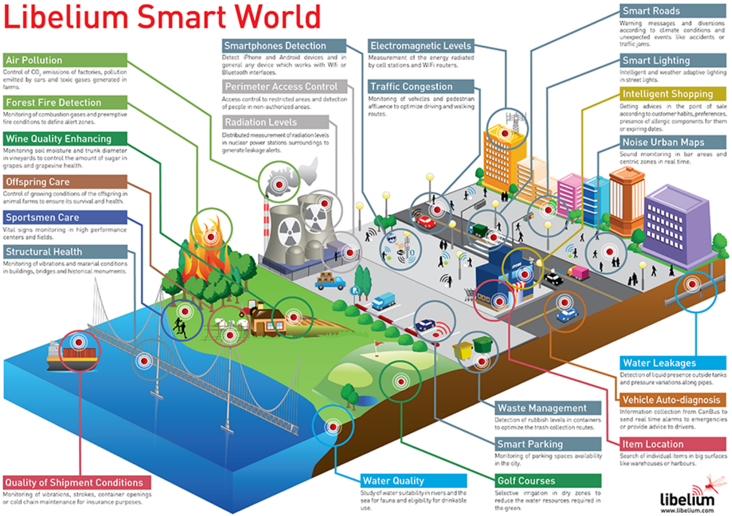


Figure – https://www.libelium.com/libeliumworld/top_50_iot_sensor_applications_ranking/

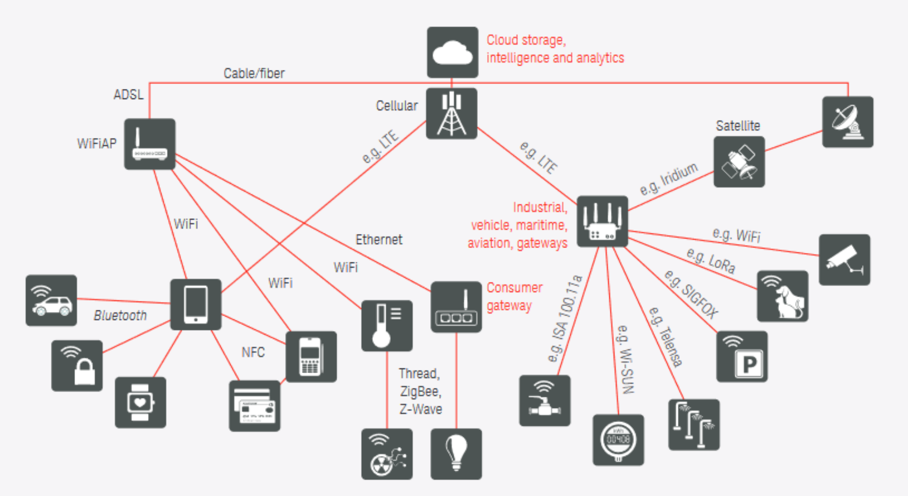
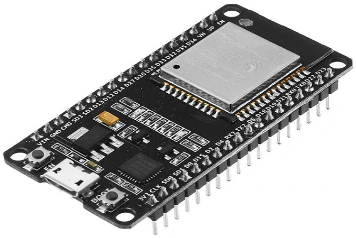


Figure – https://www.keysight.com/be/en/assets/7018-05008/application-notes/5992-1175.pdf

Wi-Fi and LoRa



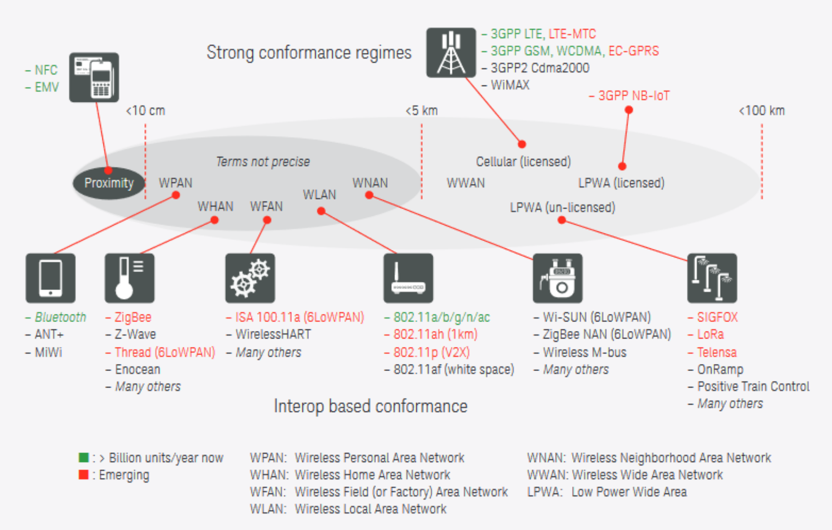


Figure – https://www.keysight.com/be/en/assets/7018-05008/application-notes/5992-1175.pdf

IoT-Lab

- Séance1 : Communication WiFi-ESP32 : apprendre à communicquer en WiFi avec le micro-contrôleur ESP32
- Séance2 : Communication WiFi-ESP32 : commander un servo-moteur grâce à l'ESP32 via son SmartPhone
- Séance3 : Communication LoRa : apprendre à communiquer en LoRa via le réseau TTN (The Things Network)
- Séance4 : Communication LoRa : récupérer des données d'un capteur sur une plateforme de collecte de datas grâce au réseau TTN

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References

- https://www.youtube.com/watch?v=ZsVhYiX4_6o
- https://www.thethingsnetwork.org/docs/lorawan/what-is-lorawan/
- https://lora-developers.semtech.com/documentation/tech-papers-and-guides/lora-and-lorawan/
- https://lora-alliance.org/about-lorawan/
- https://www.link-labs.com/blog/what-is-lora
- https://witekio.com/blog/lorawan-a-dedicated-iot-network/
- https://enless-wireless.com/en/lora-range/
- http://silanus.fr/sin/?p=1163
- https://flows.nodered.org/node/node-red-dashboard

LoRa

LoRa, essentially, is a clever way to get very good receiver sensitivity and low bit error rate (BER) from inexpensive chips.

LoRa is a wireless modulation technique derived from Chirp Spread Spectrum (CSS) technology. It encodes information on radio waves using chirp pulses - similar to the way dolphins and bats communicate !

LoRa modulated transmission is robust against disturbances and can be received across great distances.

LoRa is ideal for applications that transmit small chunks of data with low bit rates. Data can be transmitted at a longer range compared to technologies like WiFi, Bluetooth or ZigBee.

These features make LoRa well suited for sensors and actuators that operate in low power mode.

Why is LoRaWAN so awesome?

- **Ultra low power** - LoRaWAN end devices are optimized to operate in low power mode and can last up to 10 years on a single coin cell battery.
- **Long range** - LoRaWAN gateways can transmit and receive signals over a distance of over 10 kilometers in rural areas and up to 3 kilometers in dense urban areas.
- **Deep indoor penetration** - LoRaWAN networks can provide deep indoor coverage, and easily cover multi floor buildings.
- **License free spectrum** - You don't have to pay expensive frequency spectrum license fees to deploy a LoRaWAN network.
- **Geolocation**- A LoRaWAN network can determine the location of end devices using triangulation without the need for GPS. A LoRa end device can be located if at least three gateways pick up its signal.
- **High capacity** - LoRaWAN Network Servers handle millions of messages from thousands of gateways.
- **Public and private deployments** - It is easy to deploy public and private LoRaWAN networks using the same hardware (gateways, end devices, antennas) and software (UDP packet forwarders, Basic Station software, LoRaWAN stacks for end devices).
- **End-to-end security**- LoRaWAN ensures secure communication between the end device and the application server using AES-128 encryption.
- **Firmware updates over the air** - You can remotely update firmware (applications and the LoRaWAN stack) for a single end device or group of end devices.
- **Roaming**- LoRaWAN end devices can perform seamless handovers from one network to another.
- **Low cost** - Minimal infrastructure, low-cost end nodes and open source software.
- **Certification program**- The LoRa Alliance certification program certifies end devices and provides end-users with confidence that the devices are reliable and compliant with the LoRaWAN specification.
- **Ecosystem**- LoRaWAN has a very large ecosystem of device makers, gateway makers, antenna makers, network service providers, and application developers.

LoRaWAN use cases

Here are a few great LoRaWAN use cases provided by Semtech, to give you some insight into how LoRaWAN can be applied:

- **Vaccine cold chain monitoring** - LoRaWAN sensors are used to ensure vaccines are kept at appropriate temperatures in transit.
- **Animal conservation** - Tracking sensors manage endangered species such as Black Rhinos and Amur Leopards.
- **Dementia patients** - Wristband sensors provide fall detection and medication tracking.
- **Smart farms**- Real time insights into crop soil moisture and optimized irrigation schedule reduce water use up to 30%.
- **Water conservation**- Identification and faster repair of leaks in a city's water network.
- **Food safety**- Temperature monitoring ensures food quality maintenance.
- **Smart waste bins** - Waste bin level alerts sent to staff optimize the pickup schedule.
- **Smart bikes**- Bike trackers track bikes in remote areas and dense buildings.
- **Airport tracking** - GPS-free tracking monitors vehicles, personnel, and luggage.
- **Efficient workspaces** - Room occupancy, temperature, energy usage and parking availability monitoring.
- **Cattle health** - Sensors monitor cattle health, detect diseases and forecast calves delivery time.
- **LoRa in space** - Satellites to provide LoRaWAN-based coverage worldwide.

Some definitions

Check out this exchange :
https://electronics.stackexchange.com/questions/278192/understanding-the-relationship-between-lora-chips-chirps-symbols-and-bits

Bits : are the smallest unit of information, they are 0's and 1's describing the data.

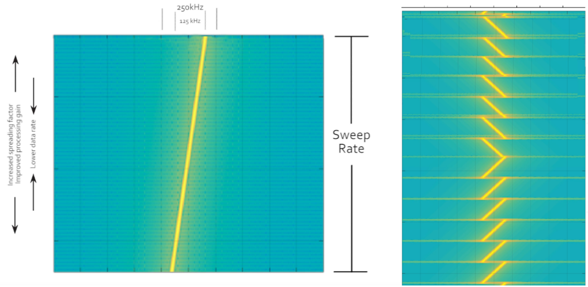
Symbol : If you want to transmit over some type of media (air, copper,...), you have to describe and transmit those bits of information in a way, that it would reach its destination. A symbol represents one, or more bits of data, it can be a type of waveform, or a code (line-coding).

Some definitions

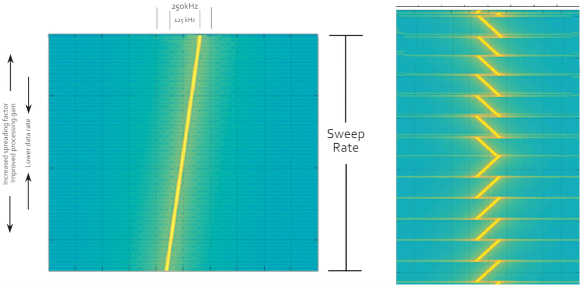
Chip : Chip is the basic binary element of the sequence of data in the context of spread spectrum transmissions. Spread spectrum is the idea of having your data spread through a bandwidth, this way the transmission will be more redundant, less prone to jamming. Symbol rate is lower than or equal to the bit rate, chip rate is higher than symbol rate and also higher than the bit rate.

Chirp : is a signal in which the frequency increases (up-chirp) or decreases (down-chirp). In QPSK, BPSK and many types digital modulation, they used sinusoidal waves as symbols, but in CSS they use chirps, which are not varying voltage/power in time, but changing frequency in time.

Video on the computer



YouTube Video



Preamble

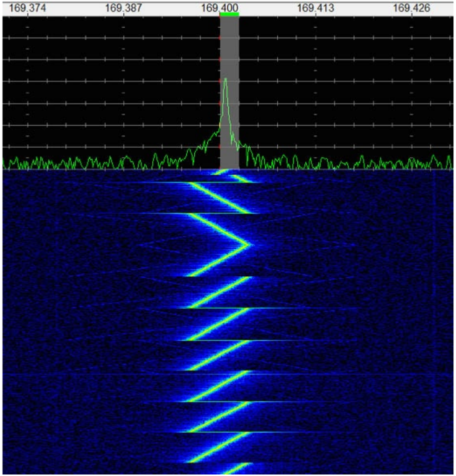
When processing a LoRa message, additional processing gain is achieved due to the modem's ability to filter on the constant ramp chirp signal. This is how high sensitivity is achieved. In order to achieve "lock" to the LoRa signal, a long "constant chirp" preamble is transmitted.

This is really the power of LoRa, that an inexpensive chip with a cheap crystal can achieve very high sensitivity.

The structure being a repetition of unmodulated upchirps which number can be defined by the user (n between 6 and $2^{16} - 1 = 65535$), 2 modulated upchirps and 2.25 unmodulated downchirps. The preamble has thus a total length between 10.25 and 65539.25 symbols.

In the common case where $n = 6$ we have 8 upchirps followed by 2.25 downchirps.

Preamble

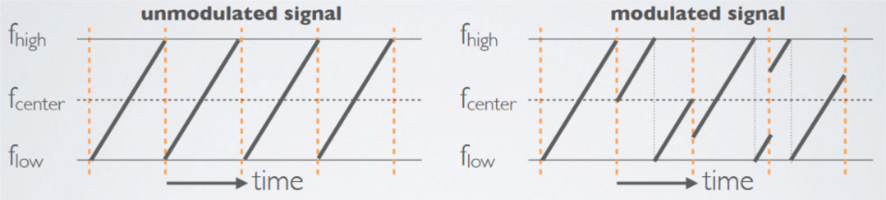


Data signal

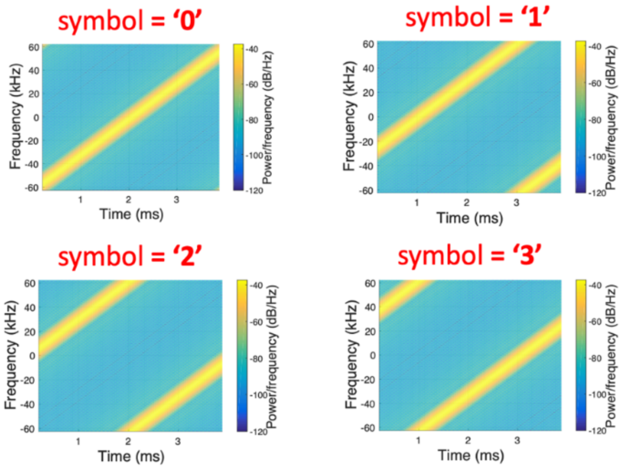
Then the data transmission begins, which has a series of "symbols" that function much like M-ARY FSK symbols, but instead happen on a chirp.

Chirp Spread Spectrum (CSS) is a spread spectrum technique that uses wideband linear frequency modulated chirp pulses to encode information.

Data-carrying chirps are chirps that are cyclically-shifted, and this cyclical shift carries the information.

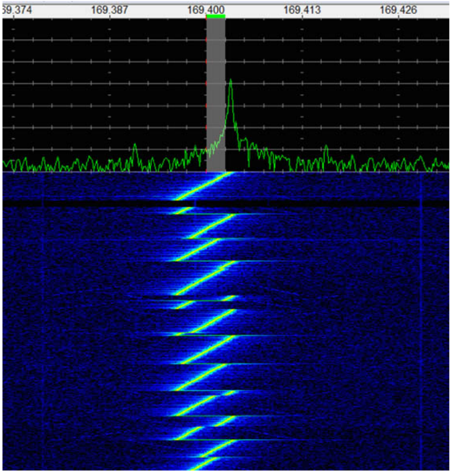


Links : `https://lora.readthedocs.io/en/latest/`



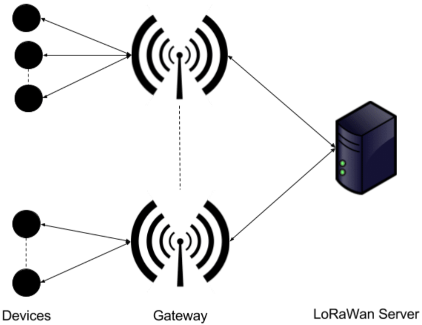
Links : https://courses.engr.illinois.edu/ece463/fa2018/Lab/ECE463_Fall2018_Lab10.pdf

Data signal

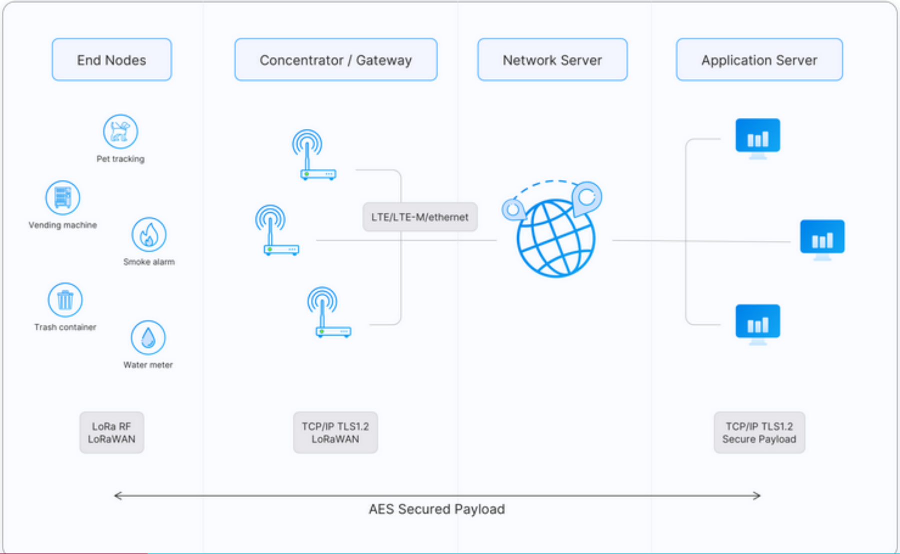


LoRaWAN network

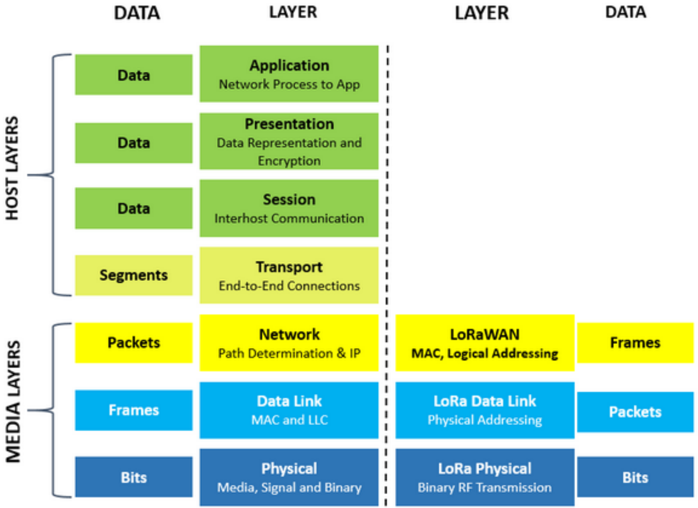
For communication, this network network uses a star network,a topology where a central device (here the gateway) act as a conduit to transmit messages.
For this kind of network, all the devices communicate to a Gateway using the LoRa technology. The Gateway, which has an internet connection, will forward the data received from the devices to the server and vice-versa.



LoRaWAN Architecture



LoRaWAN in the 7 layer OSI model

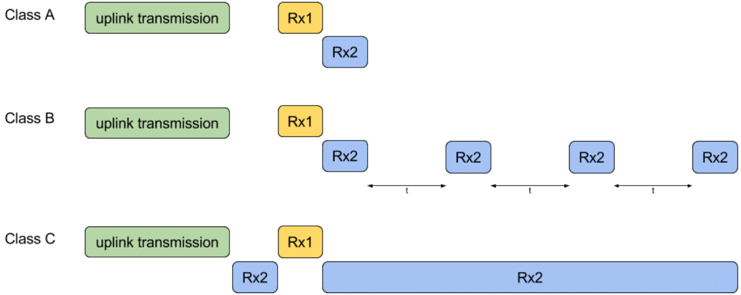


LoRaWAN Classes

The specifications define 3 different modes that can be used within a LoRaWan network :

- Classe A : The communication can be initiated only by the end device. When the end device has a message to send, it will send it and listen for a response during a short time. To do that, it will listen on the same frequency it used to send the message (Rx1) and then it will listen on a specific frequency known by the devices and gateways (Rx2).
- Class B : This mode is like the Class A but the device will also open short regularly reception windows (Rx2).
- Class C : In this mode, the device can send a message whenever it wants, and it will listen for an incoming message at all time (Rx2).

LoRaWAN Classes



Duty cycle and time-on-air

Duty cycle and time-on-air (dwell time) restrictions

- Both end devices and gateways must respect them
- In different regions:
  - may or may not apply
  - may have different limits
- Imposed by the local authorities
  - make sure to check your local government regulations!
  - see LoRaWAN Regional Parameters

Frequency plan	EU	US
Duty cycle	0.1%-10%	No limit
Dwell time	No limit	400ms for channels 0-63

Image source: "RP002 - 1.0.2. LoRaWAN Regional Parameters", specification by LoRa Alliance (lora-alliance.org)

Spreading factor

Another powerful feature of LoRa is the ability to demodulate several orthogonal or simultaneous signals at the same frequency, assuming they have different chirp rates. In the datasheet, LoRa chirp rates are called "spreading factors", with higher spreading factors denoting slower chirps.
Spreading factors call FSK (Frequency-shift keying). These spreading factors are used to adjust the radio signal speed depending on the distance.

In short, the spreading factor indicates the number of databits per second. The higher the factor, the slower the communication is. Increasing the spreading factor increases the time it takes to send a message, consumption increass then also.

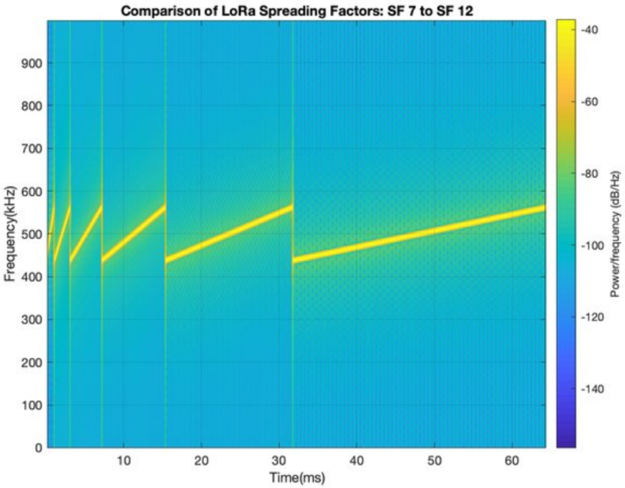
Lower SF $\rightarrow$ shorter range $\rightarrow$ less time on air $\rightarrow$ lower energy consumption $\rightarrow$ higher data rate

It is a trade of to make.

Spreading factor

DataRate	Configuration	Indicative physical bit rate [bit/s]
0	LoRa: SF12 / 125 kHz	250
1	LoRa: SF11 / 125 kHz	440
2	LoRa: SF10 / 125 kHz	980
3	LoRa: SF9 / 125 kHz	1760
4	LoRa: SF8 / 125 kHz	3125
5	LoRa: SF7 / 125 kHz	5470
6	LoRa: SF7 / 250 kHz	11000
7	FSK: 50 kbps	50000
8..15	RFU	

Spreading factor



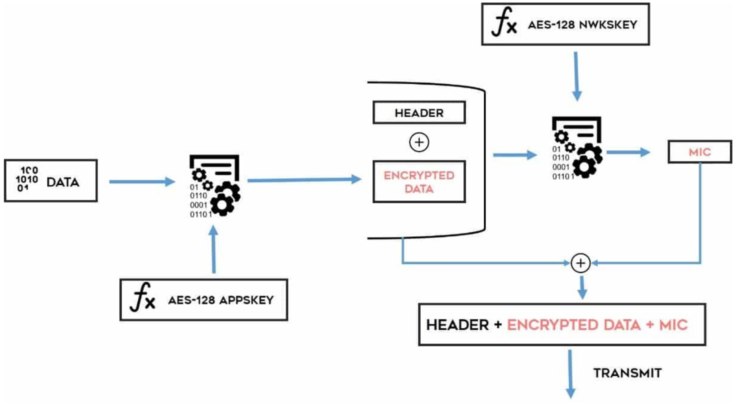
Data encryption

Key1 is the AppSKey (Application Session Key) that is shared between the application owner and the LoRa device. This key is used to encrypt the message payload and is unique per Application.

Key2 is the NwkSKey (Network Session Key) shared between the LoRaWan network provider and the LoRa device. This key is used to calculate a message integrity code from the previous encrypted payload and a network header added to the message. It is unique per Network.

The message composed with a header, the payload and the Message Integrity Code (MIC) is then sent to the LoRaWan network provider that will verify the message integrity to the MIC and NwkSKey. Whether the MIC is good, the LoRaWan network provider will then send the message to the application that will be able to read the payload to the AppSKey.

Data encryption



Outline

Installs

Install Atom :
`https://atom.io/`

Open installer in atom and search for pymakr, install pymakr frompycom
or use : `https://atom.io/packages/pymakr`

If needed, install additional drivers :
`https://docs.pycom.io/gettingstarted/software/drivers/`

More detailed infos here :
`https://docs.pycom.io/gettingstarted/software/atom/`

Note : it may be necessary to install VS-cores and Node.js first !

Installs

Install Node Red docs : `https://nodered.org/docs/getting-started/local`

In short :

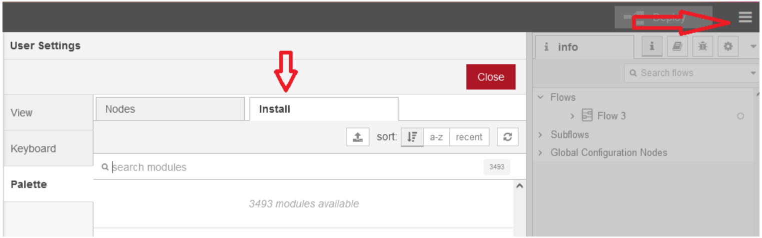
- install Node.js and npm : `https://nodejs.org/en/download/`
- install Node-red : npm install -g –unsafe-perm node-red

Open Node-Red :

- type "node-red" in cmd
- in your browser go to : `localhost:1880`
- later for interfacing : `localhost:1880/ui`

Installs

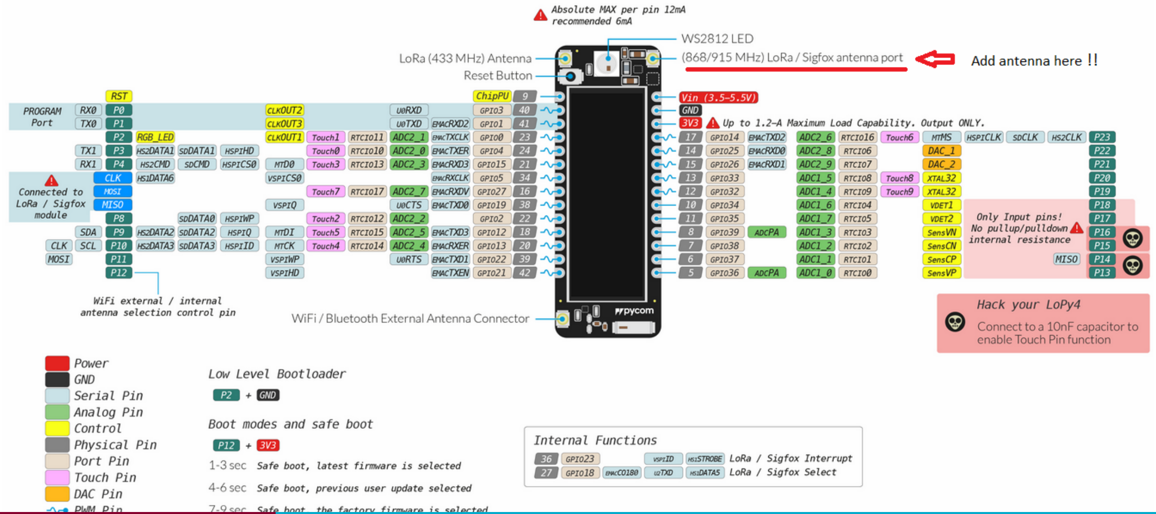
In your browser on the right go to settings ...



Then palette on the left and select install, then add :
node-red-dashboard
and :
node-red-contrib-aedes (if you want to create a localhost broker at home)

Outline

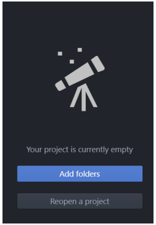
The LoPy4


Absolute MAX per pin 12mA
recommended 6mA
WS2812 LED
LoRa (433 MHz) Antenna
(868/915 MHz) LoRa / Sigfox antenna port
Add antenna here !!
Reset Button
PROGRAM Port
Connected to LoRa / Sigfox module
Vin (3.5-5.5V)
GND
3V3
Up to 1.2-A Maximum Load Capability. Output ONLY.
Only Input pins! No pullup/pulldown internal resistance
WiFi external / internal antenna selection control pin
WiFi / Bluetooth External Antenna Connector
pycom
Hack your LoPy4
Connect to a 10nF capacitor to enable Touch Pin function
Power
GND
Serial Pin
Analog Pin
Control
Physical Pin
Port Pin
Touch Pin
DAC Pin
PWM Pin
Low Level Bootloader
P2 + GND
Boot modes and safe boot
P12 + 3V3
1-3 sec Safe boot, latest firmware is selected
4-6 sec Safe boot, previous user update selected
7-9 sec Safe boot, the factory firmware is selected
Internal Functions
36 GPIO23 VSPIID HS1STROBE LoRa / Sigfox Interrupt
27 GPIO18 EMACCO180 U2TXD HS1DATA5 LoRa / Sigfox Select

Programming the LoPy4

First connect the Lopy4 to you computer (using the expansion board and the usb A to micro B cord, add antenna also)

Open the Atom software, the device should be detected automatically



Create a projects folder (name it projects).

Inside this folder create another folder and name it first_exchange

Programming the LoPy4

Add 2 files into the folder (you can also use the atom file tree on the left)

Name them boot.py and main.py, they are saved as python files (.py).

And/Or use codes on github :
`https://github.com/verogeorl/CREACTIF_IOTLAB/tree/main/IoT_LoRa`

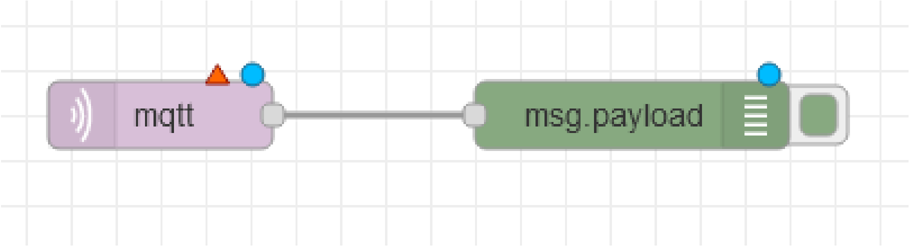
Programming the LoPy4

Additional informations :

- https://docs.pycom.io/gettingstarted/
- https://www.codecademy.com/articles/f1-text-editors
- https://pycom.io/wp-content/uploads/2020/04/Lesson-2-Setting-up-Pymakr-LoPy4.pdf

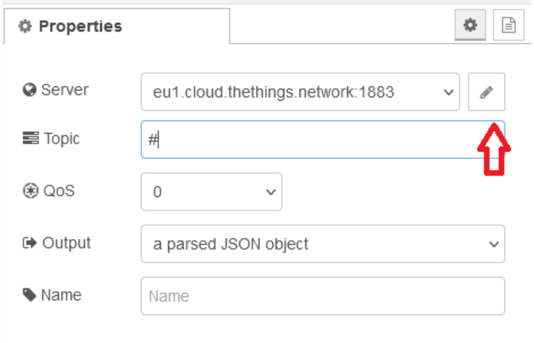
Outline

MQTT-first steps



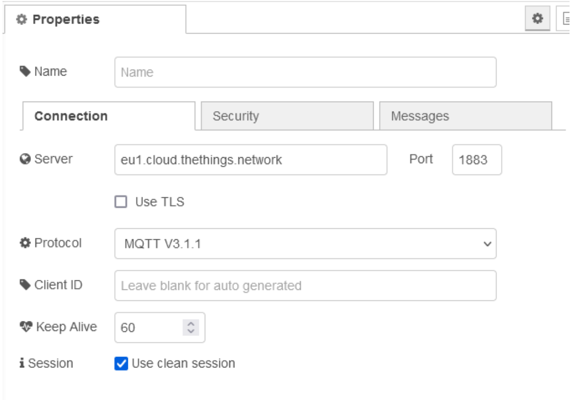
Add the MQTT in node as well as a debug node.

MQTT-first steps



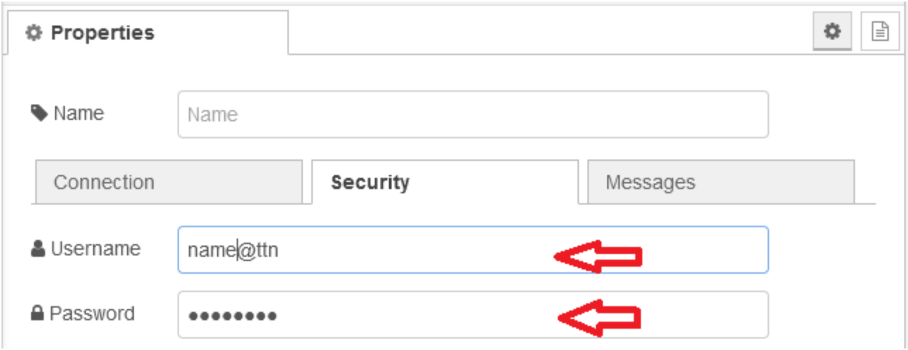
Write # in topic, this will send you every info available.
Select a Quality of service (QoS) of 0.
The output should be a parsed JSON object.
Then select the pen to edit the server (see red arrow).

MQTT-first steps



As server use : eu1.cloud.thethings.network
and Port : 1883

MQTT-first steps



Input the username and password given to you. Finally, deploy the system.

Outline

Connection test

After installation connect the Lopy4 to the computer and try to run the 'Blink' example.

Try to change the color of the led.

Enable/Disable heartbeat.

Dev_EUI

Adding a device to the ttn server.

Try the find_DevEUI code
Links to set up a device on TTN :
`https://docs.pycom.io/gettingstarted/registration/lora/ttn/`
`https://www.thethingsnetwork.org/docs/devices/node/quick-start/`
`https://www.thethingsnetwork.org/docs/devices/registration/`

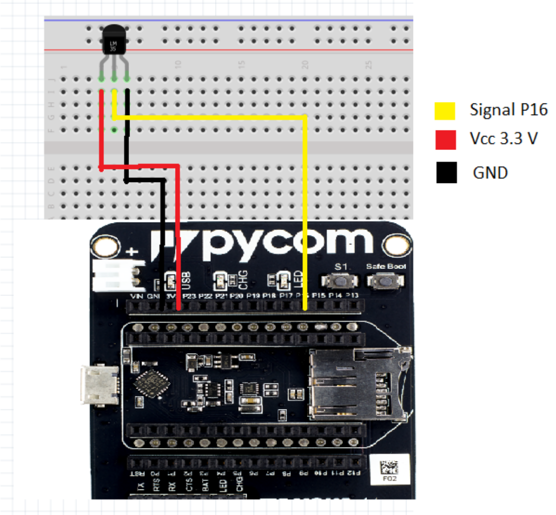
Send a message to the TTN server

Use the 'first_exchange' code and send your group number to The Things Network server.

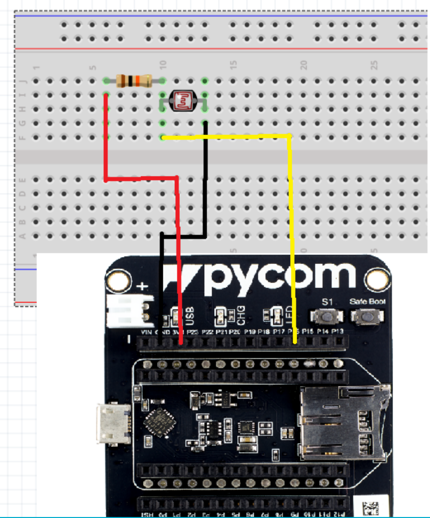
For example group 2 sends 222 in bytes, you will see the message on the TTN Live data.

Outline

Temperature sensor



LDR sensor

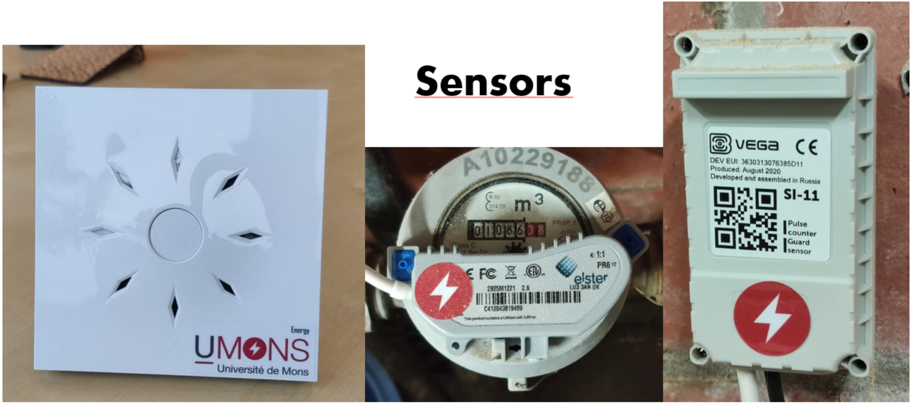


Signal P16

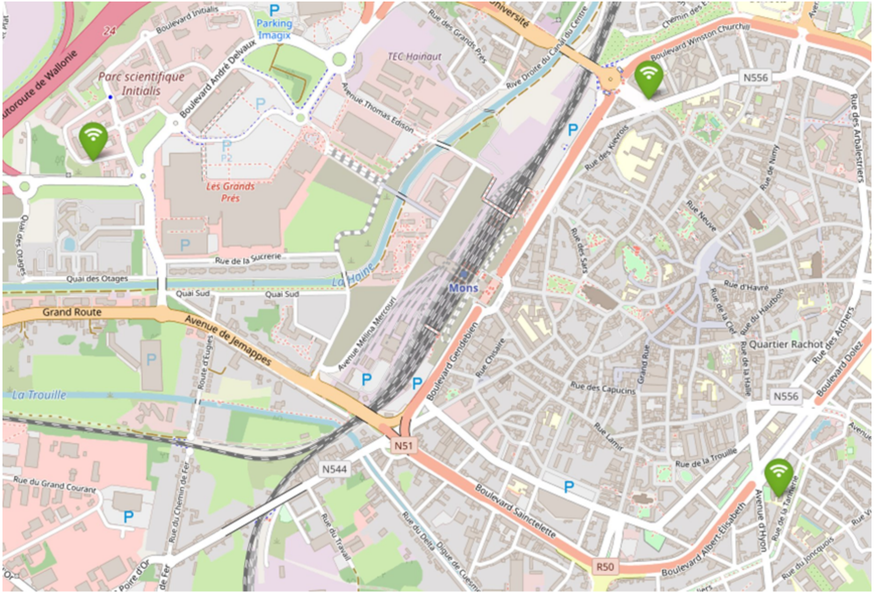
Vcc 3.3 V

GND

Outline

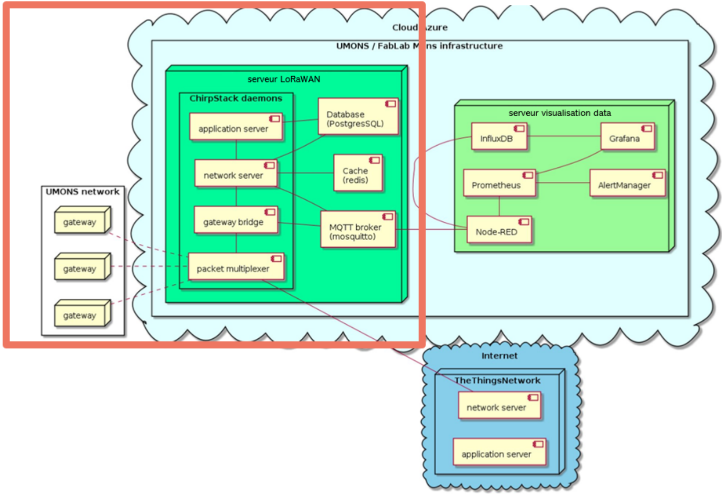


CO2 and water consumption sensors.

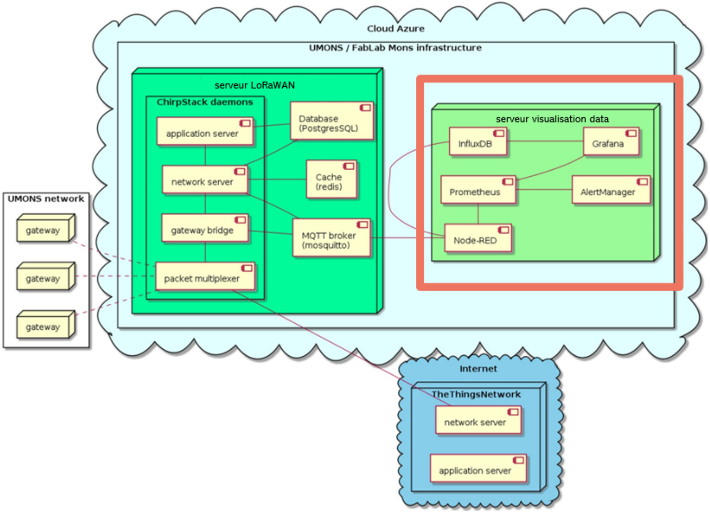


Autoroute de Wallonie
24
Boulevard Initialis
Parking Imagix
Parc scientifique Initialis
Boulevard André Delvaux
TEC Hainaut
Avenue Thomas Edison
Rue des Grands Prés
Université
Rive Droite du Canal du Centre
Boulevard Winston Churchill
Chemin des
N556
Rue des Arbalestriers
P2
Les Grands Prés
Rue des Kiévrois
Rue de Nimy
Rue Neuve
Rue des Sars
Quai des Otages
Rue de la Sucrerie
La Haine
Quai Sud
Mons
Rue d'Havré
Rue de la Clef
Rue du Hautbois
Grand Route
Avenue de Jemappes
Avenue Mélina Mercouri
Boulevard Gendebien
Rue Chisaire
Quartier Rachot
Rue des Archers
Boulevard Dolez
Rue de la Halle
Grand Rue
Rue des Capucins
La Trouille
Route d'Eugies
N51
N544
Rue Lamir
Rue de la Trouille
Rue du Grand Courant
Rue du Chemin de Fer
Rue du Travail
Rue du Delta
Digue de Cuesmes
Boulevard Sainctelette
R50
Boulevard Albert-Elisabeth
Avenue d'Hyon
Rue de la Tannerie
Rue du Joncquois
Poirier d'Or

Infrastructure réseau



Infrastructure de traitement



Even if the project of UMons can be categorized among the bigger projects, everybody should be able to set up his own sensors and connect them via the Lora stacks.

If you want to see more 'real' applications, check out :
`https://lora-developers.semtech.com/solutions/case-studies/`

If you do not want to put up a gateway yourself, you can look up if TTN gateways are neighbouring you :
`https://www.thethingsnetwork.org/map`

Ateliers Creactifs - IoT

Connection d'un objet réel au monde de l'internet

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