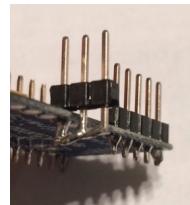
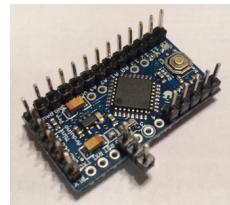
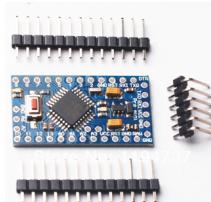
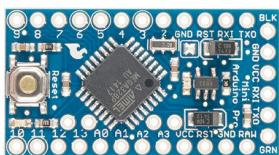


## The generic hardware platform

### The Arduino Pro Mini

The Arduino Pro Mini is a compact form factor Arduino board based on the ATmega328P microcontroller  
Use the **3.3v and 8MHz version** of the Arduino Pro Mini for lower power consumption



You can get the original board designed by Sparkfun or get one of the various clones available mainly from Chinese manufacturer. The last solution is very cost-effective as the Pro Mini board can be purchased for a bit more than 1€ a piece.

Depending on how many sensors you want to connect, the number of ground (GND) pins may be limited. You can extend a GND pin with a header pin where all pins are soldered together.

### The LoRa radio module

There are various LoRa radio modules that are all based on the Semtech SX1272/1276 chips family



Fully tested LoRa  
radio modules



HopeRF RFM92W/95W



Liberium LoRa



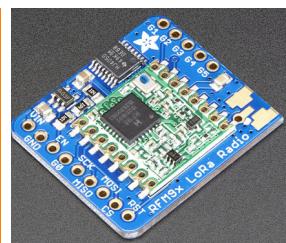
Modtronix inAir4/9/9B



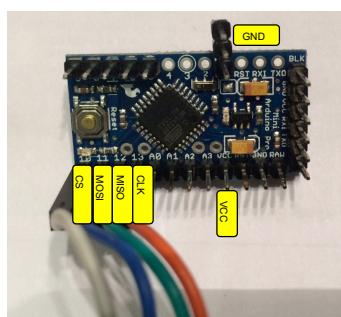
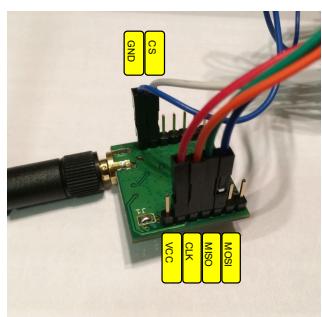
LoRa1276  
NiceRF LoRa1276

Most of SPI-based LoRa radio modules are supported. We recommend the Modtronix inAir model if you don't have delicate soldering experience as this module can come with header pins ready to be connected with Dupont wires.

The RFM95W can be found assembled (Adafruit) or an adapter can be purchased (from Ideetron for instance)



## Connect the LoRa radio module



Connect the corresponding SPI pins of the radio module to the SPI pins on the Pro Mini board. MOSI (blue) is pin 11, MISO (green) is pin 12, CS (white) is pin 10 and CLK (orange) is pin 13 (right picture). Then connect also the VCC (red) and the GND (black) of the radio module to the VCC and the GND of the board (right picture). The VCC of the Pro Mini board gets 3.3v from the on-board voltage regulator.

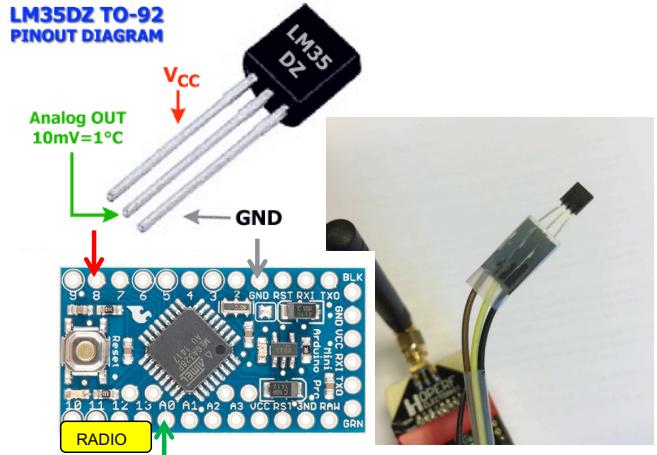
## Connecting a sensor

### Use a simple temperature sensor: LM35DZ

Connect sensor's VCC pin to Pro Mini's digital pin 8 to power the sensor

Connect sensor's Analog OUT to Pro Mini's analog pin A0 to read value from sensor

Connect sensor's GND pin to one of Pro Mini's GND pin



## Uploading our temperature template code

### Get the Arduino libraries and code templates

Get the entire ZIP archive of the **LowCostLoRaGw** github repository at <https://github.com/CongducPham/LowCostLoRaGw>

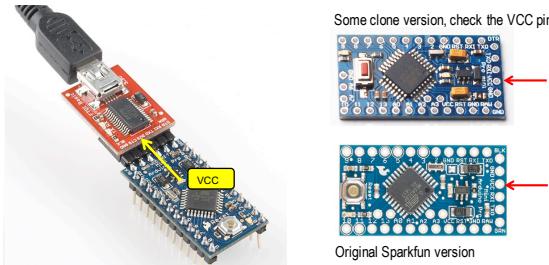
Unzip the archive and copy the content of the **Arduino** folder in your Arduino IDE sketch folder

If you already have a **libraries** folder in your sketch folder, copy the content of the new libraries folder in your libraries folder

Open the **Arduino\_LoRa\_Simple\_temp** sketch and select the Arduino Pro Mini board in its 3.3V & 8MHz version

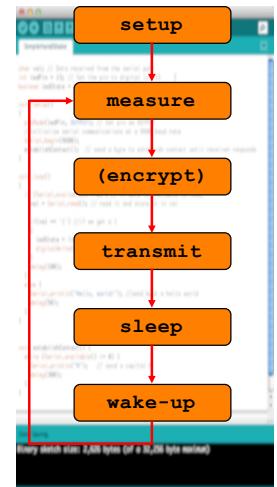
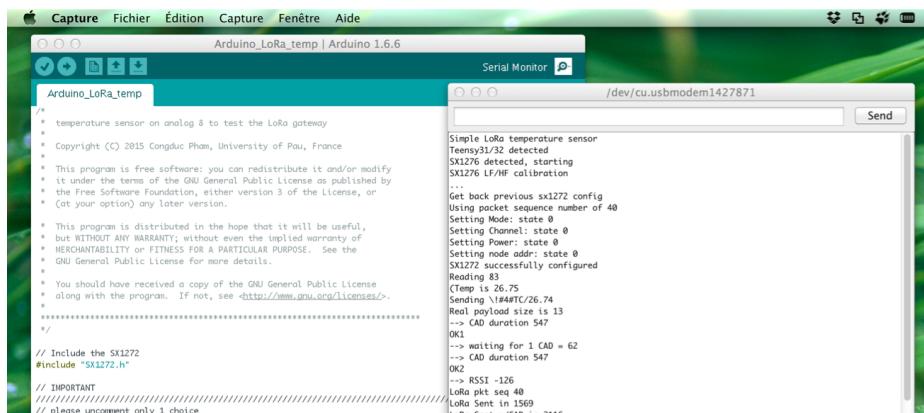
Connect the Arduino Pro Mini to an FTDI breakout USB cable (in 3.3v version). Check the VCC pin and make it to correspond to the VCC pin of the FTDI breakout

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. Then click on the « upload » button



Use the Serial Monitor to check the device output

The template will cycle through **measure-transmit-sleep(10min)-wake up** with low-power mode



## Sending LoRa messages

### Device default configuration

Default configuration uses BW=125kHz, CR=4/5, SF=12 i.e. LoRa mode 1

This configuration allows for the longest range

The default gateway radio configuration is similar

The default frequency at the end-device depends on the selected band. Using the default configuration (865.2 MHz) allows for out-of-the-box reception at the gateway

Range ↑  
↓ Throughput

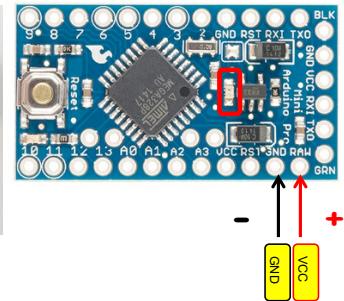
LoRa mode	BW	CR	SF
1	125	4/5	12
2	250	4/5	12
3	125	4/5	10
4	500	4/5	12
5	250	4/5	10
6	500	4/5	11
7	250	4/5	9
8	500	4/5	9
9	500	4/5	8
10	500	4/5	7

ch	F(MHz)	ch	F(MHz)	ch	F(MHz)
04	863.2*	00	903.08	00	433.3*
05	863.5*	01	905.24	01	433.6*
06	863.8*	02	907.40	02	433.9*
07	864.1*	03	909.56	03	434.3*
08	864.4*	04	911.72	-	-
09	864.7*	05	913.88	-	-
10	865.2	06	916.04	-	-
11	865.5	07	918.20	-	-
12	865.8	08	920.36	-	-
13	866.1	09	922.52	-	-
14	866.4	10	924.68	-	-
15	867.7	11	926.84	-	-
16	867.0	12	915.00	-	-
17	868.0	-	-	-	-
18	868.1*	-	-	-	-

## Achieving ultra low power consumption

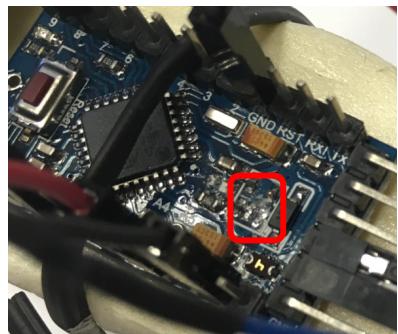
### Run on battery

You can use 4 AA batteries to provide  $4 \times 1.5v = 6v$ . This will be injected into the RAW pin of the board, using the on-board voltage regulator to get 3.3v. Remove the power led to greatly reduce power consumption: in sleep mode, the board draws about 54uA and can run for more than 18 months on the basis of 1 measure/hour



### Ultra low power

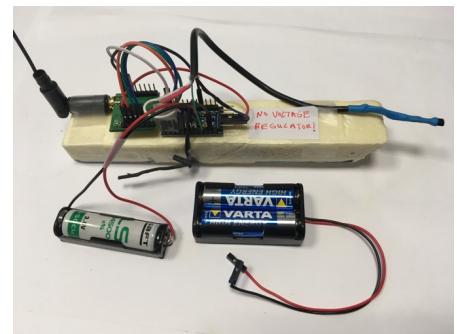
Remove the voltage regulator and directly inject 3.1v – 3.6v to the VCC pin of the board



By removing the voltage regulator, you can use a single 3.6v Lithium-based battery or 2 regular AA batteries that provides about 3.1v

You can use the VCC pin on the programming header to power the board, as the other VCC pin is needed for the radio module

In sleep mode, the board now draws about 12uA, allowing for much longer lifetime



## Additional resources & tutorials

The general github repository <https://github.com/CongducPham/LowCostLoRaGw>

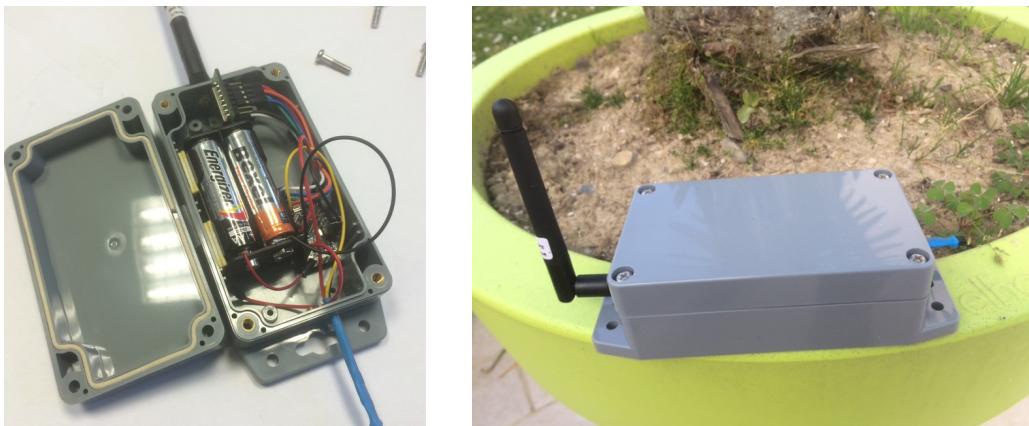
The WAZIUP github <https://github.com/Waziup>

IoT device video [https://www.youtube.com/watch?v=YsKbJeeav\\_M](https://www.youtube.com/watch?v=YsKbJeeav_M)

Gateway video <https://www.youtube.com/watch?v=peHkDhiH3IE>

## Examples of integration into production device

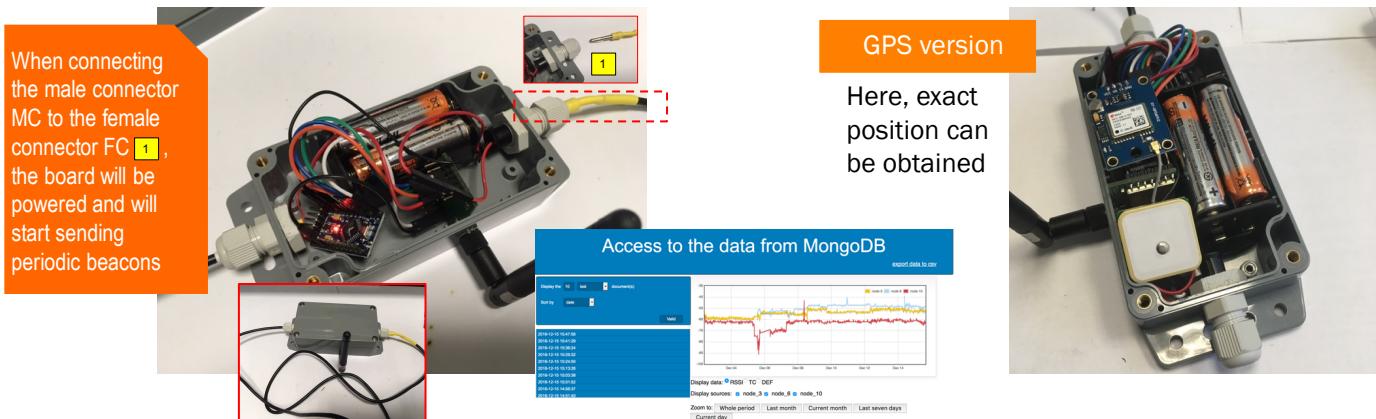
### Simple temperature device



### Multiple-level soil moisture device



### Collar for cattle rustling applications



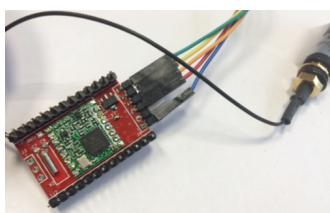
## Using other platforms

### Platforms with integrated LoRa radio modules

There are many boards that integrate a LoRa radio, mostly the HopeRF RFM95W radio module

These boards are often based on the ATmega328P (similar to the Arduino Pro Mini) or the ATmega32U4 where compatibility with the Arduino IDE is provided. They provide easier LoRa integration but are generally much more expensive than a Pro Mini + inAir radio module combination

We tested many of them and verified that our template code is working fine, including the low-power mode. Note that the Pro Mini with both power led and voltage regulator removed shows the lowest power consumption in sleep mode: 12uA.



Ideetron Nexus  
ATmega328P



Wisen WhisperNode  
ATmega328P



LowPowerLab Moteino  
ATmega328P



RFM95/96



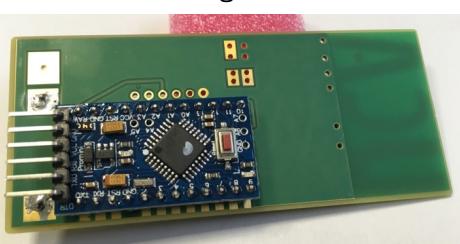
Adafruit Feather32U4  
ATmega32U4

## Using PCB design for easier integration

### Simple PCB for easier integration

A simple PCB can be designed to just facilitate the integration of the Arduino Pro Mini board and an RFM95W radio module

Here, the designed PCB from Fabien Ferrero of University of Nice, France, proposes an integrated antenna to avoid external fragile part when deploying the device



### More integrated PCB

A more advanced PCB integration project can use the ATmega328P microcontroller to provide a customized solution: 2 soil moisture sensors per device for the Nestlé's WaterSense project using WAZIUP software

Here, the new project from Zahoor Ahmad of LUMS University, Pakistan, integrates the ATmega328P and provides header for easy connection of the inAir Lora module. The new board uses a single 3.6v battery

