# Building a TTN node

## Identifying the components

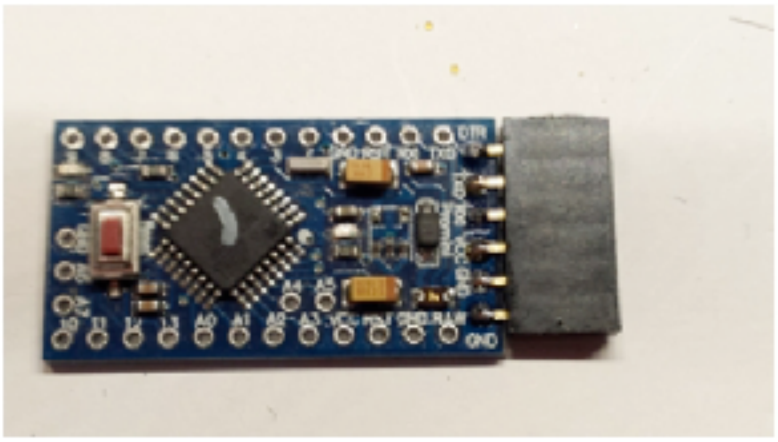
Our bill of materials (set available at [TinyTronics](TinyTronics))

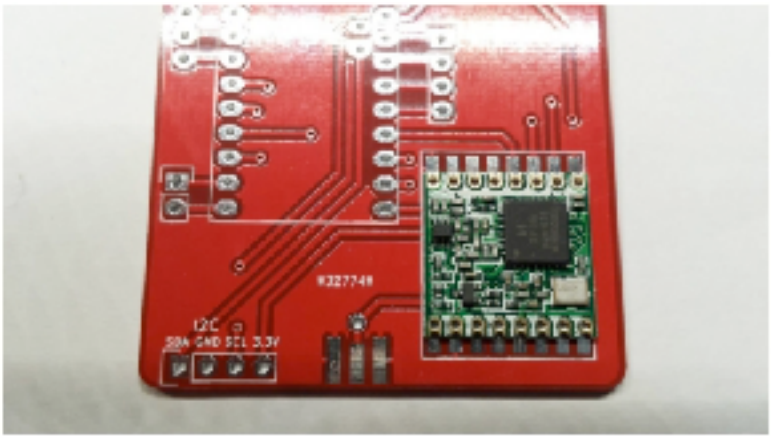
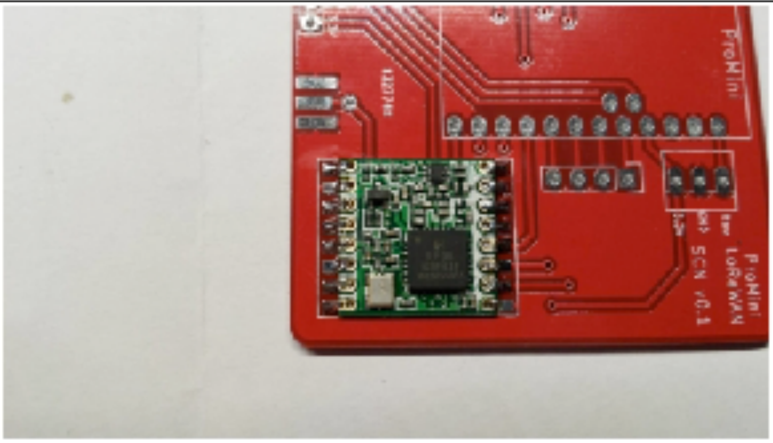
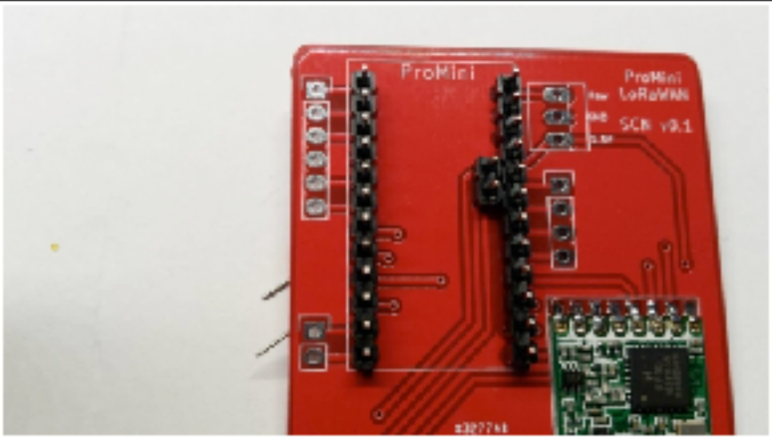
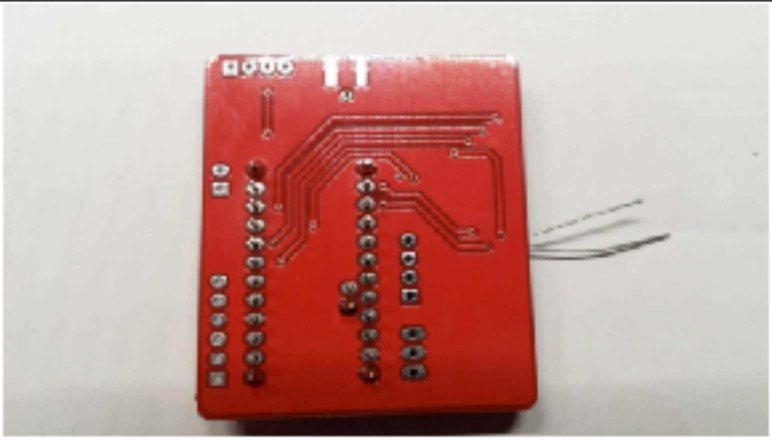
- RFM Module RFM95W (868 Mhz)
- Pro Mini 3.3V 8Mhz (5V will NOT work!!)
- FT232RL-3.3v-5v-TTL-USB-Serial-Port-Adapter (has to have a 3.3V option!)
- USB cable for FTDI
- 1x Led 3mm red
- 1x resistor 1k (brown-black-red)
- Header 6p female (Arduino programming)
- Header 40p divided in: 2x 4p, 1x 6p, 1x 3p and 1x 2p
- PCB 'DougLarue'
- Sensor BME280 (Temperature, humidity and air pressure)
- Battery holder 2 x AA
- 2 AA batteries
- optional: 2 x female headers 2p (battery and led connection)

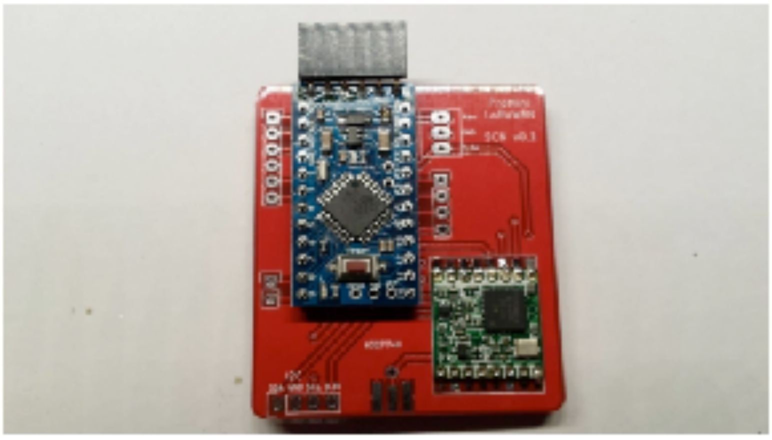
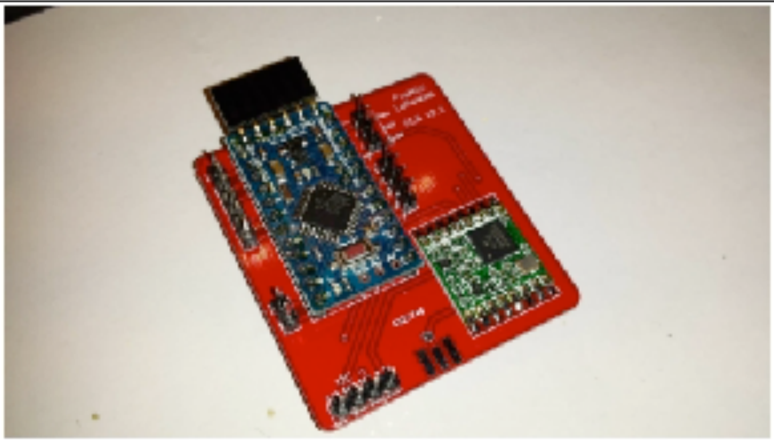
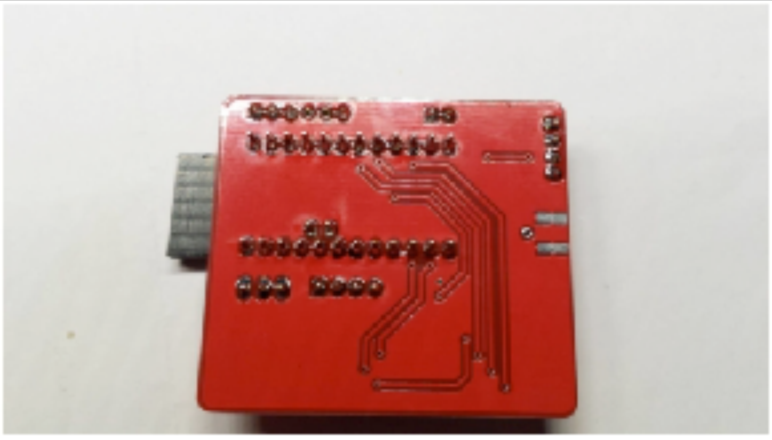
## Low Power the Arduino?

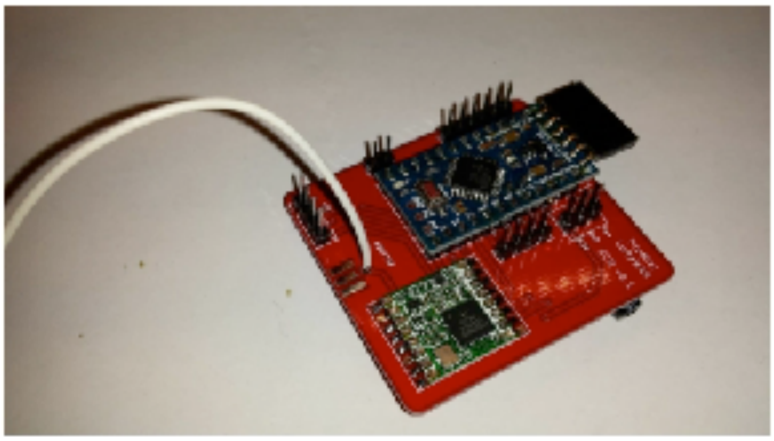
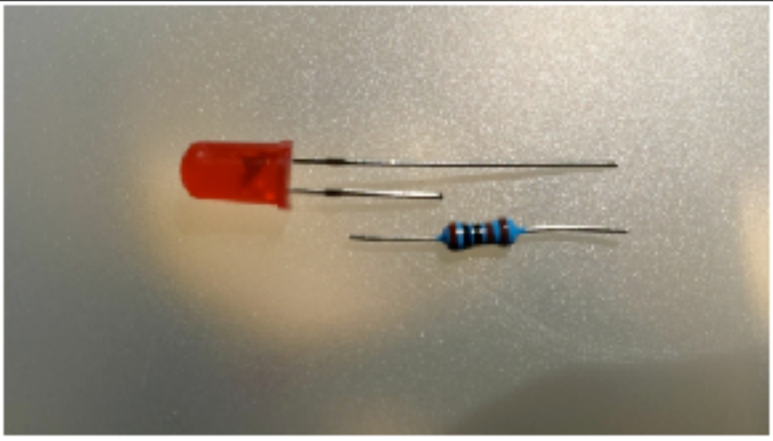
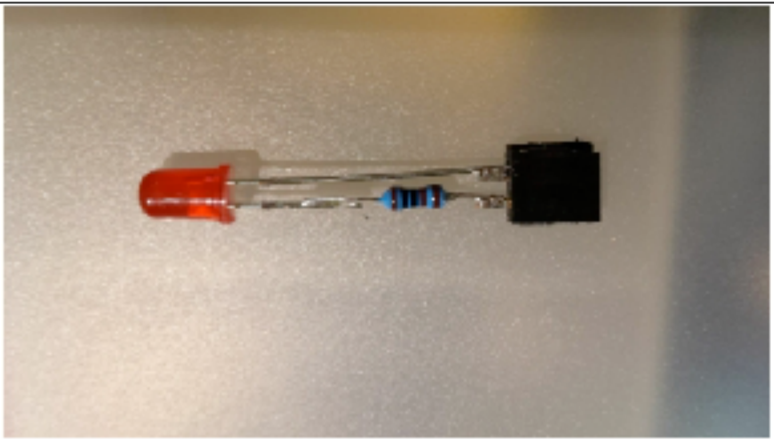
There is an option to 'low power' the Arduino. BUT this requires some precise soldering! The setup will work without removing the components. So if you are a novice solderer, skip the first part! It requires a sharp knife to remove the power converter, and to cut the connections for the two on board leds. If you want to battery power your node for a longer time (weeks or more) this is the option for you. Current in sleep mode will be reduced to <100uA. Look at the instructions at the end of this manual

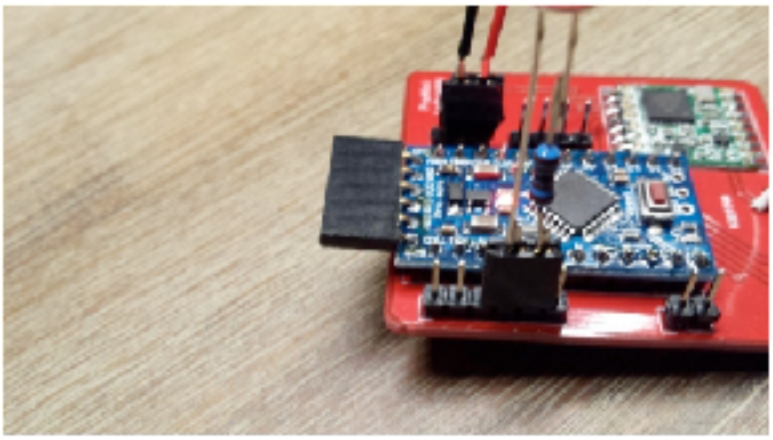
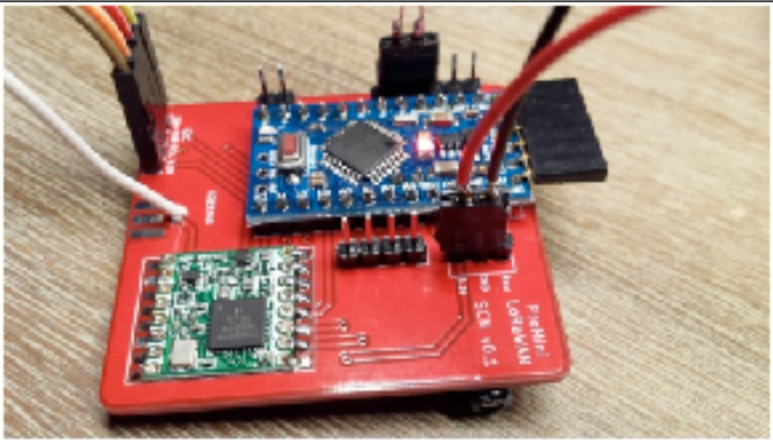
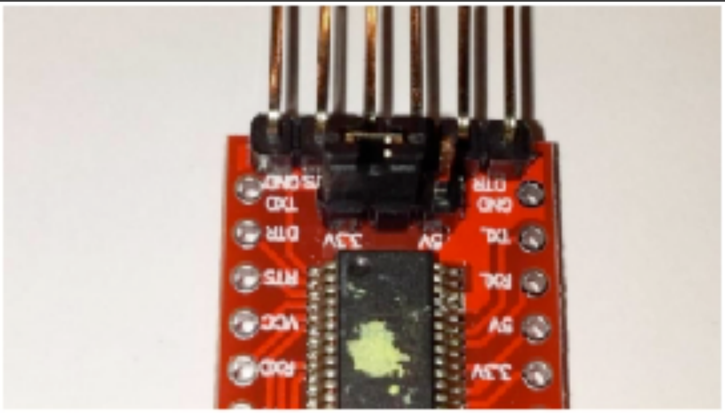
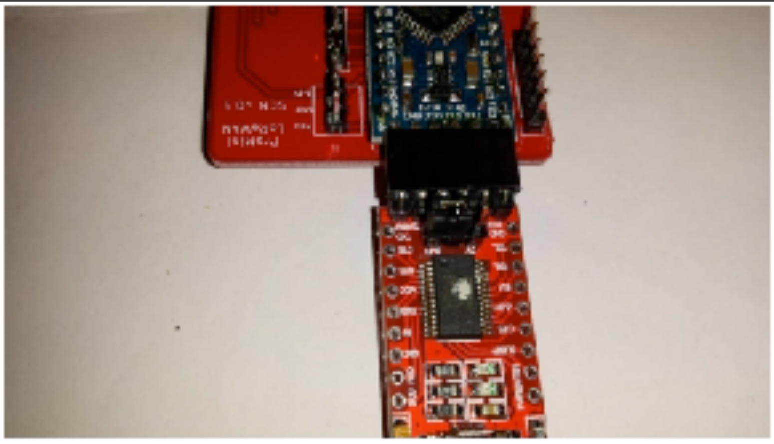
## Building the Node

| | |
|---|---|
| Connect the 6p female header to the Arduino. To get it low profile bow it so it is straight with the PCB. |  |

| | |
|---|---|
| Position the RFM95 radio chip. The crystal should be in the right lower corner (as shown in the picture). Start with just a little solder in two opposite corners. |  |
| Align the solder pads and if the module is in place, solder the other pads. Do use as little as possible solder! Check the connections carefully! |  |
| Put two 12p headers into the ProMini socket. Also put the 2p header inside the ProMini area. By holding them with a piece of paper you can turn around the PCB. (You can also use the ProMini to keep the pins in place by using an elastic band.) |  |
| First solder the end pins, align the headers straight and solder all the other pins. |  |

| | |
|---|---|
| Turn around the PCB and solder the ProMini in place. Do not forget the two pin header! |  |
| Now solder the 6p, 2p, 3p and 4p header. |  |
| |  |
| Cut a piece of wire, length 82.2 mm. This is a ¼ wave length antenna. You may add some short soldering end. | Wavelength =300/868 = 0.3456m<br>Wavelength /4 = 0,0864 m<br>correction 0.95*0.0864=0.0822m (to determine the precise length you can do some experiments, or use proper test equipment like a SWR meter) |

| | |
|---|---|
| Solder the Antenna into the hole near the connector pins. It is also possible to solder a SMA edge connector. |  |
| Solder a header on the BME280 barometric sensor | |
| Prepare the LED, this requires a 'helping hand' for soldering. Cut the longest wire of the LED ('+'), and the 1K resistor as shown |  |
| Now solder the resistor, you may use a spare female header to create a 'connector' or some female jumper wires |  |

| | |
|---|---|
| Put the LED 'connector' to pins 4 and 5 of the 6 pin jumper, as shown (Pin 4: GND, PIN 5 - D2), the resistor pin ('+') goes to pin 5 / D2. You may even solder the pins directly |  |
| You can solder the battery holder on the pins GND (black) and 3.3V (red), you may use a female header here as well |  |
| Put the Jumper on the FTDI board on 3.3V position! |  |
| Connect the USB cable to the FTDI board, the FTDI board to the Arduino as shown. |  |

## Starting up the Arduino Environment

https://www.arduino.cc/en/Guide/HomePage

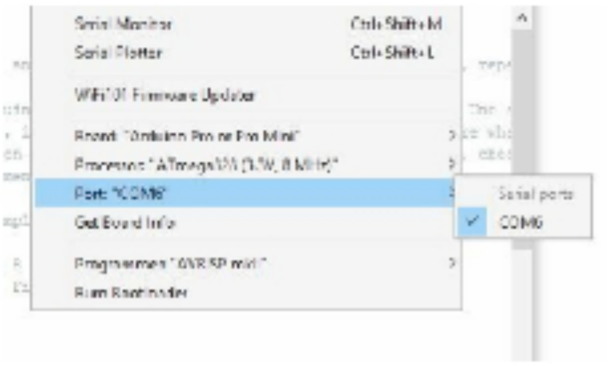
Install the Arduino IDE on your favourite platform (Mac, Linux or Windows). These examples work only with the latest Arduino IDE (tested on 1.6.9)!

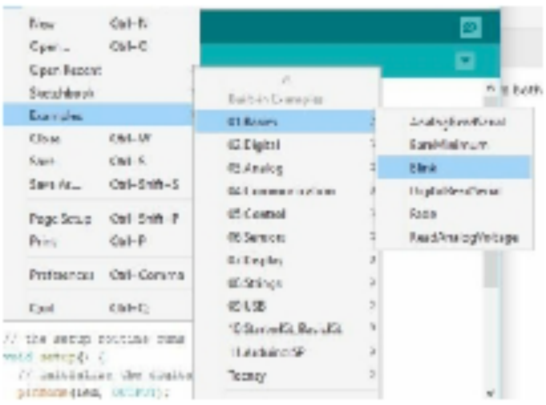
https://www.arduino.cc/en/Guide/ArduinoProMini

Use the FTDI, ensure that the jumper is on the '3V' side. Battery power turned off (check the switch)

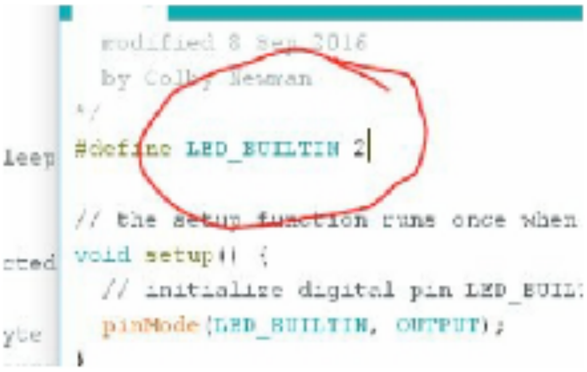
Connect the FTDI and the Pro Mini so that the components are both facing up.

- Start the Arduino IDE
- Select the board: 'Arduino Pro or Pro mini'
- Select the Processor 'ATmega328 (3.3V, 8Mhz)
- Select the COM port given


Serial Monitor Ctrl+Shift+M
Serial Plotter Ctrl+Shift+L
WiFi101 Firmware Updater
Board: "Arduino Pro or Pro Mini"
Processor: "ATmega328 (3.3V, 8 MHz)"
Port: "COM6"
Get Board Info
Programmer: "AVR ISP mkII"
Burn Bootloader
Serial ports
COM6



Select the default 'BLINK' example, change the LED pin from 13 to 2, in the newest blink example you may change 'LED_BUILTIN' to 2.



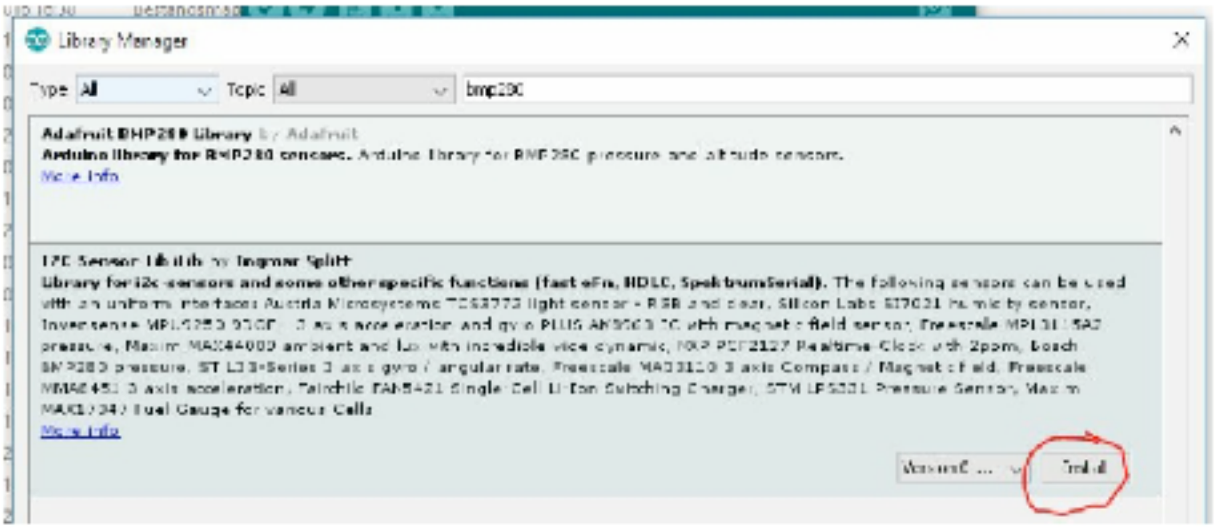
```
  modified 8 Sep 2016
  by Colby Newman
*/
#define LED_BUILTIN 2

// the setup function runs once when
void setup() {
  // initialize digital pin LED_BUIL
  pinMode(LED_BUILTIN, OUTPUT);
}
```

Load the code with CTRL-U to the Pro Mini. After compilation and uploading the led on the board should blink at 1 Hz. Great: we have a working programming environment!

## Testing the sensors

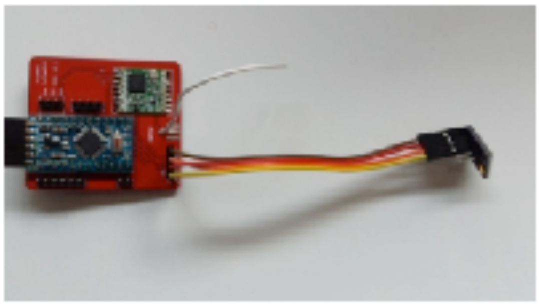
1. Install the Adafruit_BME280 library: Sketch-> include library -> manage libraries
2. Search for BME280:



**Adafruit BMP280 Library** by Adafruit
**Arduino library for BMP280 sensors.** Arduino library for BMP280 pressure and altitude sensors.

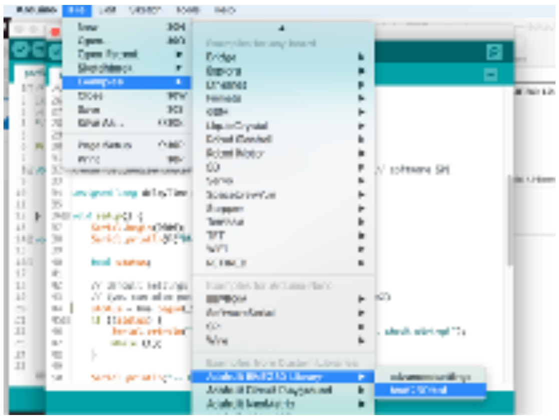
**I2C Sensor Lib iLib** by Ingmar Splitt
**Library for i2c-sensors and some other specific functions (fast eFn, HDLC, SpektrumSerial).** The following sensors can be used with an uniform interface: Austria Microsystems TCS3772 light sensor - RGB and clear, Silicon Labs SI7021 humidity sensor, Invensense MPU9250 9DOF - 3 axis acceleration and gyro PLUS AK8963 IC with magnetic field sensor, Freescale MPL3115A2 pressure, Maxim MAX44009 ambient and lux with incredible wide dynamic, NXP PCF2127 Realtime-Clock with 2ppm, Bosch BMP280 pressure, ST L3G-Series 3 axis gyro / angular rate, Freescale MAG3110 3 axis Compass / Magnetic field, Freescale MMA8451 3 axis acceleration, Fairchild FAN5421 Single Cell Li-Ion Switching Charger, STM LPS331 Pressure Sensor, Maxim MAX17047 Fuel Gauge for various Cells

3. Install the library ‘I2C-Sensor-Lib’
4. Connect the BME280 sensor:

| | |
|---|---|
|  | Connect the BME280 sensor with female-female jumper wires to the I2C connector: GND-> GND, SDA->SDA, SCL->SCL, VCC->+3.3V. The CSB en SDO are left open (only used in SPI connection). You can not connect straight forward, but you should twist the two wires in the middle. |

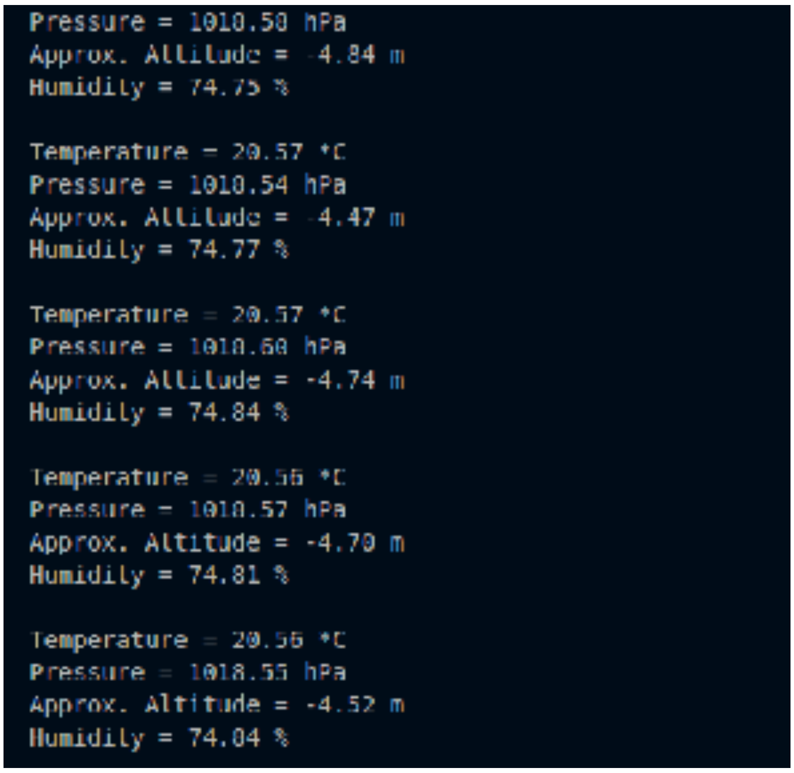
5. Load the the i2c_BME280 example (File->Examples->Adafruit BME280 Library>BME280test).

**You will need to change the Adafruit_BME280.h file (in your Arduino Libraries folder). Edit it with your favourite editor - change line 32 from 0x77 to 0x76.**



opening the Serial Monitor (115200 bps) you will see the humidity, pressure and temperature of the sensor. Put your finger on the sensor (the small metal unit) and see the temperature rise.

The Serial Monitor should display something like this:



```
Pressure = 1010.58 hPa
Approx. Altitude = -4.84 m
Humidity = 74.75 %

Temperature = 20.57 *C
Pressure = 1010.54 hPa
Approx. Altitude = -4.47 m
Humidity = 74.77 %

Temperature = 20.57 *C
Pressure = 1010.60 hPa
Approx. Altitude = -4.74 m
Humidity = 74.84 %

Temperature = 20.56 *C
Pressure = 1010.57 hPa
Approx. Altitude = -4.70 m
Humidity = 74.81 %

Temperature = 20.56 *C
Pressure = 1010.53 hPa
Approx. Altitude = -4.52 m
Humidity = 74.84 %
```

## Getting things started on 'The Things Network'

Download the LMIC library from Github:

1. Goto https://github.com/matthijskooijman/arduino-lmic
2. Choose 'Clone or download'
3. Download ZIP
4. Mark the location
5. Go to Arduino IDE
6. Select 'Sketch->Include Library->Add .ZIP Library'
7. Select the downloaded Arduino-lmic-master.zip file from your download location
8. Goto https://github.com/rocketscream/Low-Power
9. Choose 'Clone or Download'
10. Download ZIP
11. Mark the location
12. Go to Arduino IDE
13. Select 'Sketch->Include Library->Add .ZIP Library'
14. Select the downloaded low-power-master.zip file from your download location

To help joining OTAA faster (seconds in stat of 7 minutes) you may alter the LMIC library. You can find LMIC.C file in <My Documents>\Arduino\Libraries\Arduino-lmic-master\src\lmic

1. Open the file in your favourite source code browser (or use WordPad)
2. Go to line 684 (or find 'setDrJoin' to find the line below)
3. Change setDrJoin(DRCHG_SET, DR_SF7); to: setDrJoin(DRCHG_SET, DR_SF9);
4. Save LMIC.C

## The Things Network Dashboard

Your applications and devices can be managed by The Things Network Dashboard.

### Create an Account

To use the dashboard, you need a The Things Network account. You can create an account here:

https://account.thethingsnetwork.org/users/login .

After registering and validating your email address, you will be able to log in to The Things Network Dashboard.

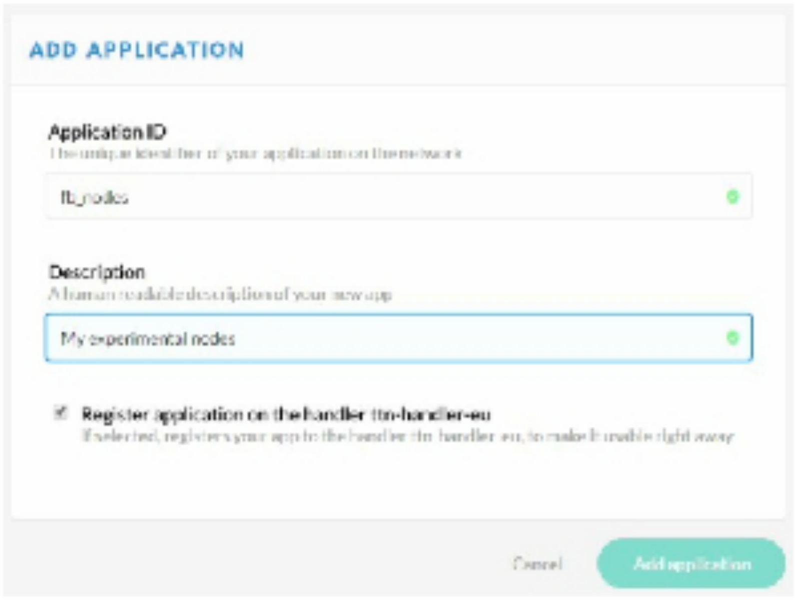
### Create an Application

https://console.thethingsnetwork.org/applications

Choose 'add application'

Give your Application a unique ID. You can use ONLY lowercase! You can add an unique number to get uniqueness over the ttn network (this is a global ID)

Your description can be any description you like.



ADD APPLICATION

Application ID
The unique identifier of your application on the network
ttn_nodes

Description
A human readable description of your new app
My experimental nodes

[✓] Register application on the handler ttn-handler-eu
If selected, registers your app to the handler ttn-handler-eu, to make it usable right away

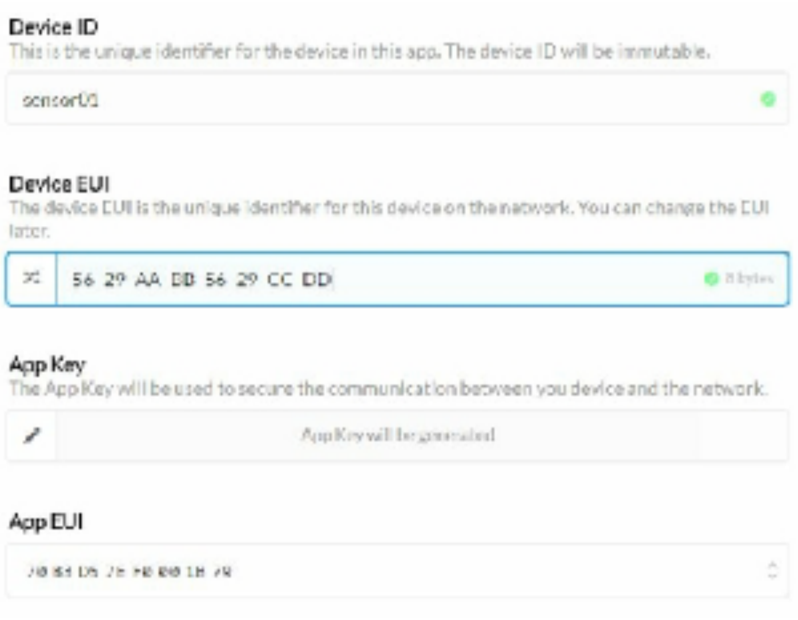
First download the code for ttn_bmp280i.ino from https://github.com/galagaking/ttn_nodeworkshop

You can download the ZIP and unzip the file to get the examples:

1. Goto https://github.com/galagaking/ttn_nodeworkshop
2. Choose 'Clone or download'
3. Download ZIP
4. Open the ZIP in explorer
5. Open the example **ttn_bmp280.ino**
6. Create the sketch folder for the application

## Register the device

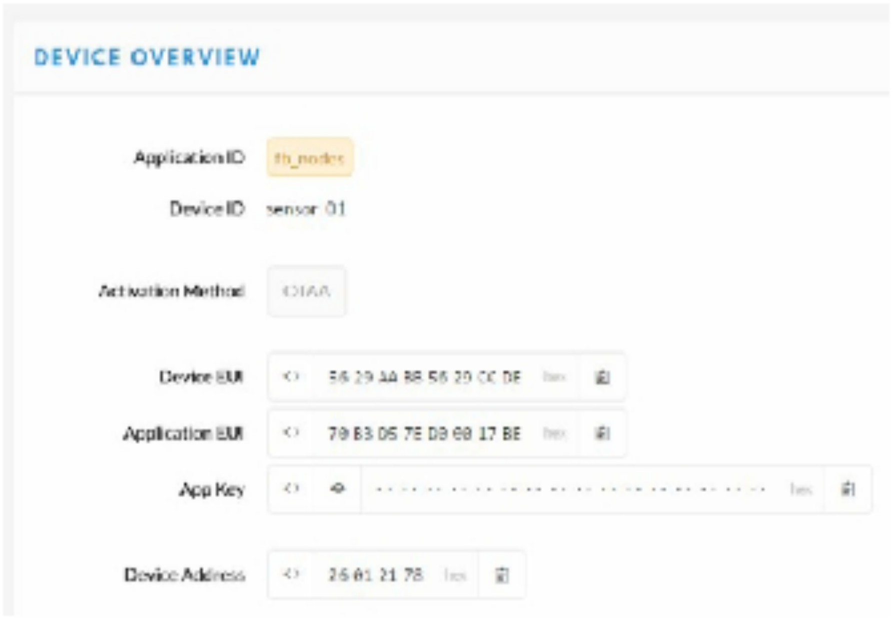
Now register your device. We will use OTAA in this example. This is 'Over the Air Authentication'. You have to define an address for yourself. This is a kind of MAC address, but because there is no registration yet of these, define some RANDOM 8 byte value, using your postcode and some values in between.


Device ID
This is the unique identifier for the device in this app. The device ID will be immutable.
sensor01

Device EUI
The device EUI is the unique identifier for this device on the network. You can change the EUI later.
56 29 AA DB 56 29 CC DD 8 bytes

App Key
The App Key will be used to secure the communication between you device and the network.
App Key will be generated

App EUI
70 B3 D5 7E F0 00 1B 7A

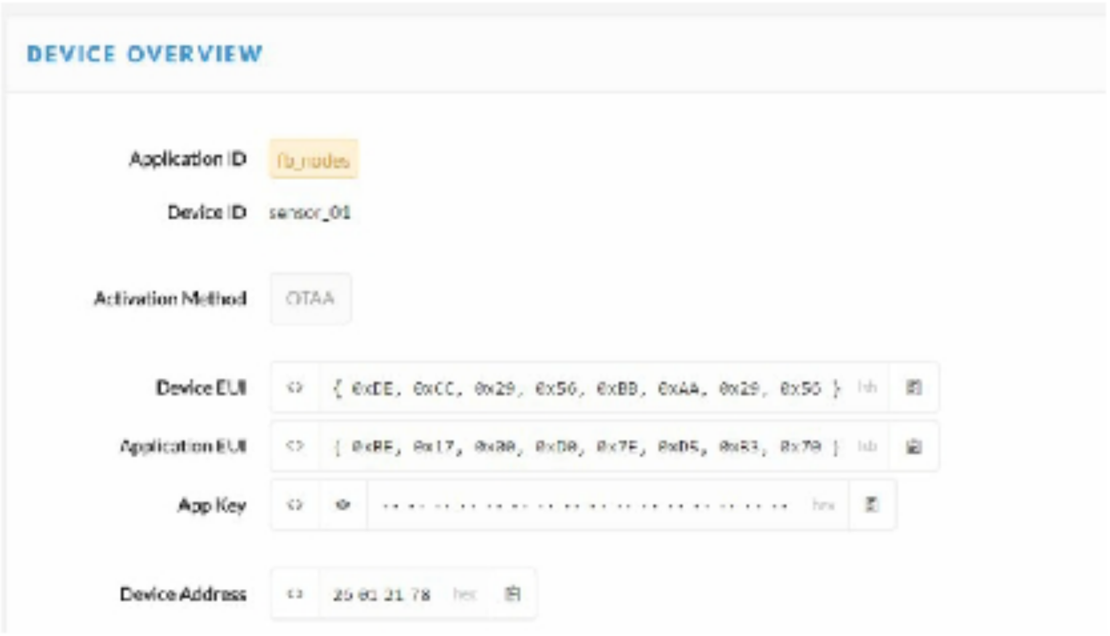

DEVICE OVERVIEW

| | |
|---|---|
| Application ID | ttn_nodes |
| Device ID | sensor 01 |
| Activation Method | OTAA |
| Device EUI | 56 29 AA BB 56 29 CC DE hex |
| Application EUI | 70 B3 D5 7E D0 00 17 BE hex |
| App Key | ・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・ hex |
| Device Address | 26 01 21 78 hex |

There are three values you should copy into your Arduino Code. Dev EUI (the device identifier), App EUI (The application identifier) and the App key.

## Dev EUI

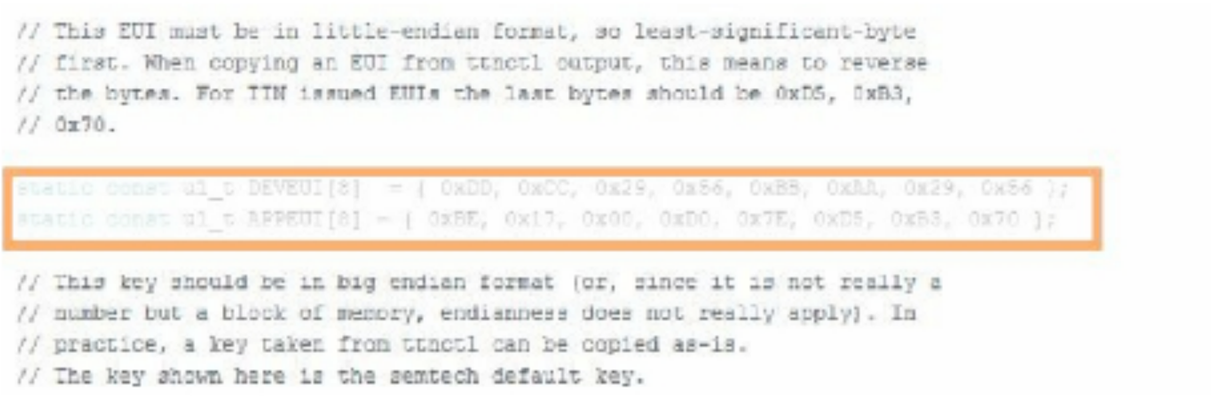
With the <> sign you can select different ‘views’. We need the **‘LSB’** view, also called little Endian or Least Significant Byte First.
*NOTE: For the App Key we need MSB, not LSB.*


DEVICE OVERVIEW

| | |
|---|---|
| Application ID | fb_nodes |
| Device ID | sensor_01 |
| Activation Method | OTAA |
| Device EUI | { 0xDE, 0xCC, 0x29, 0x56, 0xBB, 0xAA, 0x29, 0x56 } lsb |
| Application EUI | { 0xBE, 0x17, 0x00, 0xD0, 0x7E, 0xD5, 0xB3, 0x70 } lsb |
| App Key | •• •• •• •• •• •• •• •• •• •• •• •• •• •• •• •• hex |
| Device Address | 26 01 21 78 hex |

Both Dev EUI and App EUI will be used in LSB or little Endian format.

First copy the Dev EUI with the clip board sign on the right. Paste the string into your code at the static const u1_t DEVEUI. Remember to respect the semicolon at the end of the line.


```
// This EUI must be in little-endian format, so least-significant-byte
// first. When copying an EUI from ttnctl output, this means to reverse
// the bytes. For TTN issued EUIs the last bytes should be 0xD5, 0xB3,
// 0x70.

static const u1_t DEVEUI[8]  = { 0xDD, 0xCC, 0x29, 0x56, 0xBB, 0xAA, 0x29, 0x56 };
static const u1_t APPEUI[8] = { 0xBE, 0x17, 0x00, 0xD0, 0x7E, 0xD5, 0xB3, 0x70 };

// This key should be in big endian format (or, since it is not really a
// number but a block of memory, endianness does not really apply). In
// practice, a key taken from ttnctl can be copied as-is.
// The key shown here is the semtech default key.
```

## APP EUI

Next copy APP EUI, select **LSB** for this one as well. Copy to APPEUI in your code.

## APP KEY

The last key is a secret hash, so this one just shows when you click the 'EYE' icon. After that you can copy this to the clipboard. This one can be copied in **MSB** format.

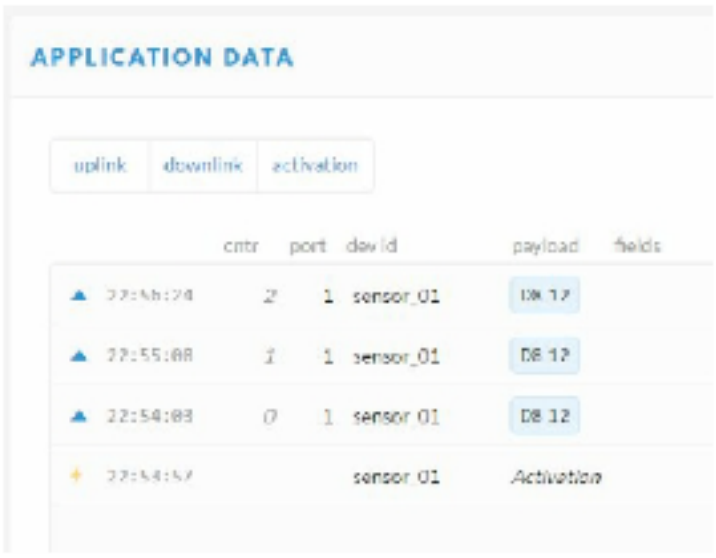
Copy the 16 bytes APPKEY after static const u1_t APPKEY[16] = .

The BME280 sensor should be connected!

Upload your code to the Arduino.

The LED will blink during the JOIN process. The Arduino gets his keys from TTN, thereby all information sent will be encrypted with these keys.

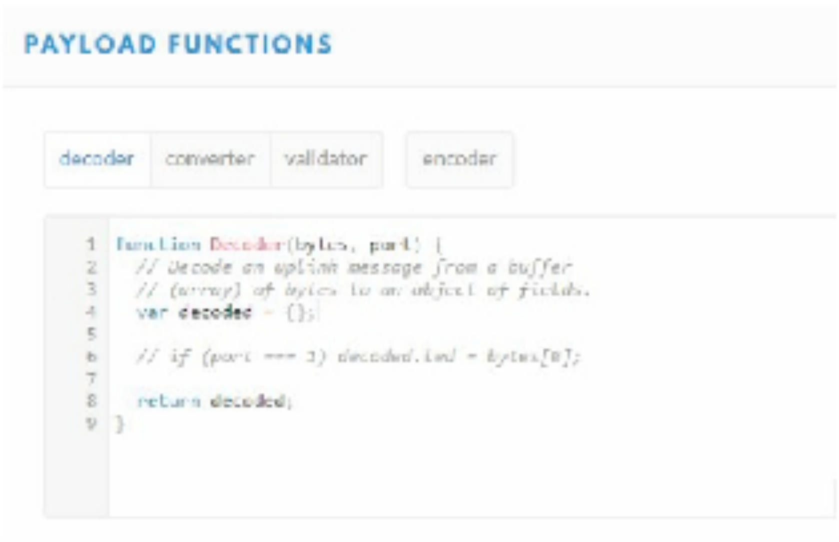
You can also follow this process by activating the ‘data’ view:


APPLICATION DATA

| | cntr | port | dev id | payload | fields |
|---|---|---|---|---|---|
| ▲ 22:56:24 | 2 | 1 | sensor_01 | D8 12 | |
| ▲ 22:55:08 | 1 | 1 | sensor_01 | D8 12 | |
| ▲ 22:54:03 | 0 | 1 | sensor_01 | D8 12 | |
| ✦ 22:54:57 | | | sensor_01 | Activation | |

After a few minutes, the LED will stop blinking. You will see the information coming in into the dashboard. This is coded information, because some algorithm is used to put temperature and humidity in two bytes.

To get the right display format, we can create a decoder in our application. Select your application and open the ‘Payload Functions’:


PAYLOAD FUNCTIONS

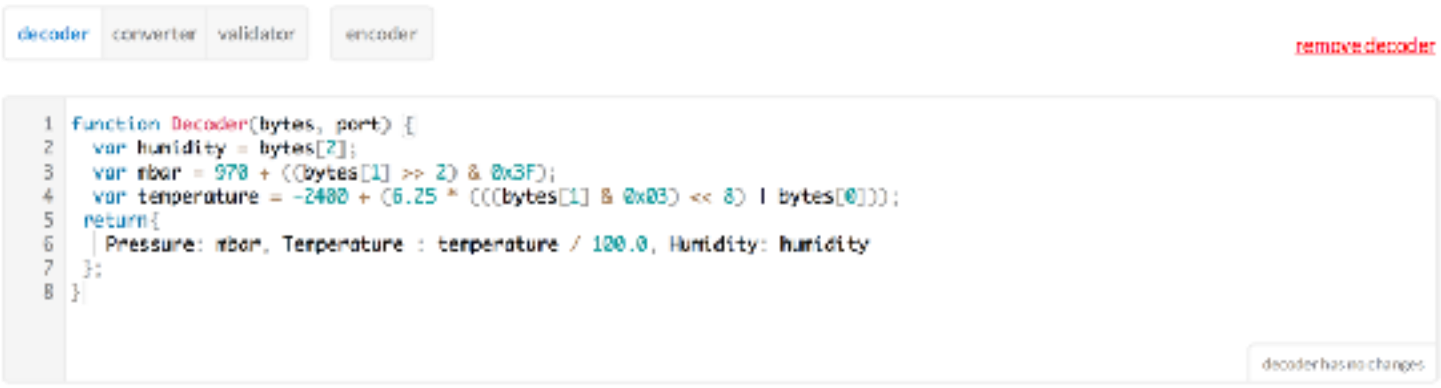
```
function Decoder(bytes, port) {
  // Decode an uplink message from a buffer
  // (array) of bytes to an object of fields.
  var decoded = {};

  // if (port === 1) decoded.led = bytes[0];

  return decoded;
}
```

Enter the function below, overwriting the standard function

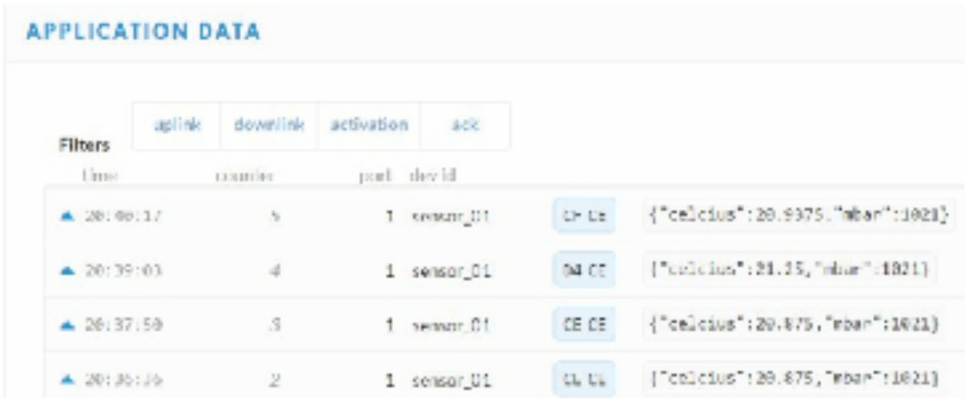
```
function Decoder(bytes, port) {
var mbar = 970+((bytes[1] >> 2) & 0x3F);
var temperature = -2400+6.25*(((bytes[1] & 0x03) << 8) | bytes[0]);
return {
mbar: mbar,
celcius: temperature / 100.0
};
}
```



```
function Decoder(bytes, port) {
  var humidity = bytes[2];
  var mbar = 978 + ((bytes[1] >> 2) & 0x3F);
  var temperature = -2400 + (6.25 * (((bytes[1] & 0x03) << 8) | bytes[0]));
 return{
  Pressure: mbar, Temperature : temperature / 100.0, Humidity: humidity
 };
}
```

First test the function with three dummy bytes EF C6 3B, And then Save the

function. Return to your data and look what happens:

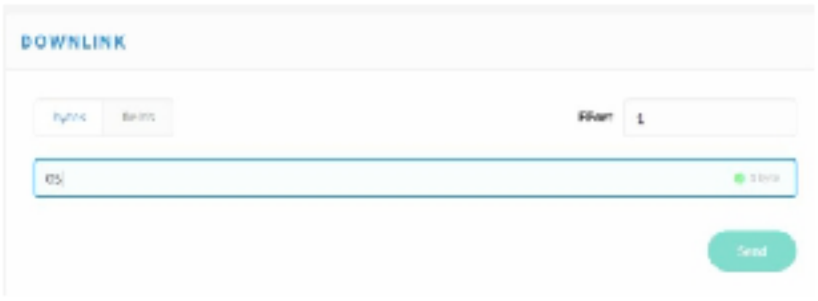


| time | counter | port | dev id | | |
|---|---|---|---|---|---|
| 20:40:17 | 5 | 1 | sensor_01 | [illegible] | {"celcius":20.9375,"mbar":1021} |
| 20:39:03 | 4 | 1 | sensor_01 | D4 CE | {"celcius":21.25,"mbar":1021} |
| 20:37:50 | 3 | 1 | sensor_01 | CE CE | {"celcius":20.875,"mbar":1021} |
| 20:36:36 | 2 | 1 | sensor_01 | [illegible] | {"celcius":20.875,"mbar":1021} |

*This way you can put several values into a byte string. Sending in clear ASCII is possible but due to bandwidth limitations not preferable in production environments. To make this even more scalable take a look at*[*https://github.com/thesolarnomad/lora-serialization*](https://github.com/thesolarnomad/lora-serialization).

## DOWNLINK

To send bytes to our node we can use the ‘Downlink’ section: in the console, click on your device and scroll down in the Overview page . Enter one byte (two hex digits, 05 for example) and click Send.



The information will be send to the node after the next time the node contacts the gateway. With a sample rate of approx. 60 seconds, that is the maximum time this data will be received. The Led will blink this amount of times, with a maximum of 10 (0x0A).

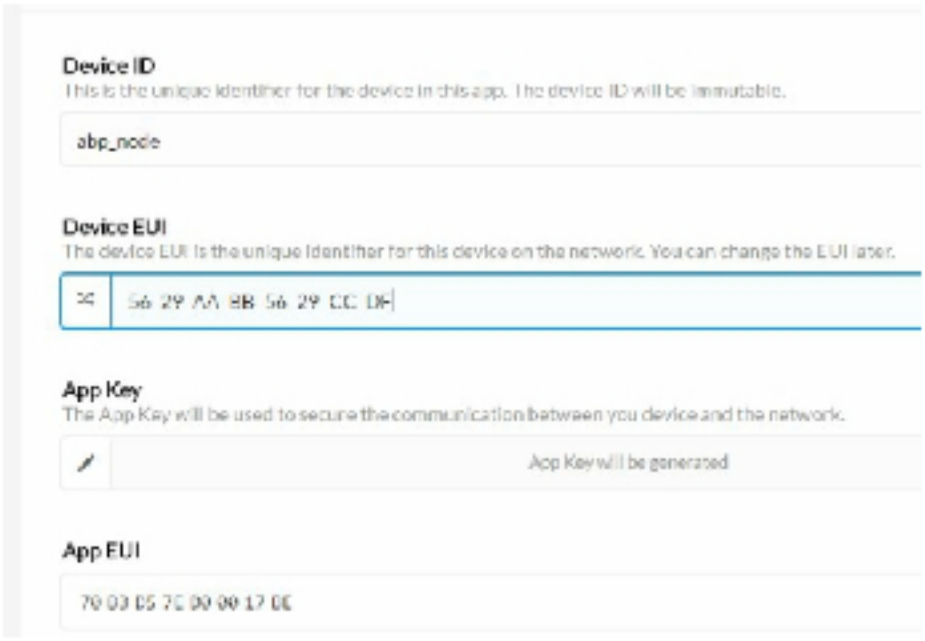
**Congratulations! You successfully completed the workshop.**

## The Moment of truth

Now, it's time for a live demonstration. It's important to gather a small audience which you can impress with your node. Also, don’t forget to make a picture and post it on Twitter using @thethingsntwrk

## ABP

Activation by Personalization (ABP) is a method where the security keys are stored in the device. Not as safe as the OTAA method, but for experiments it works OK. There is no join procedure, nodes will work right away.



Device ID
This is the unique identifier for the device in this app. The device ID will be immutable.
abp_node

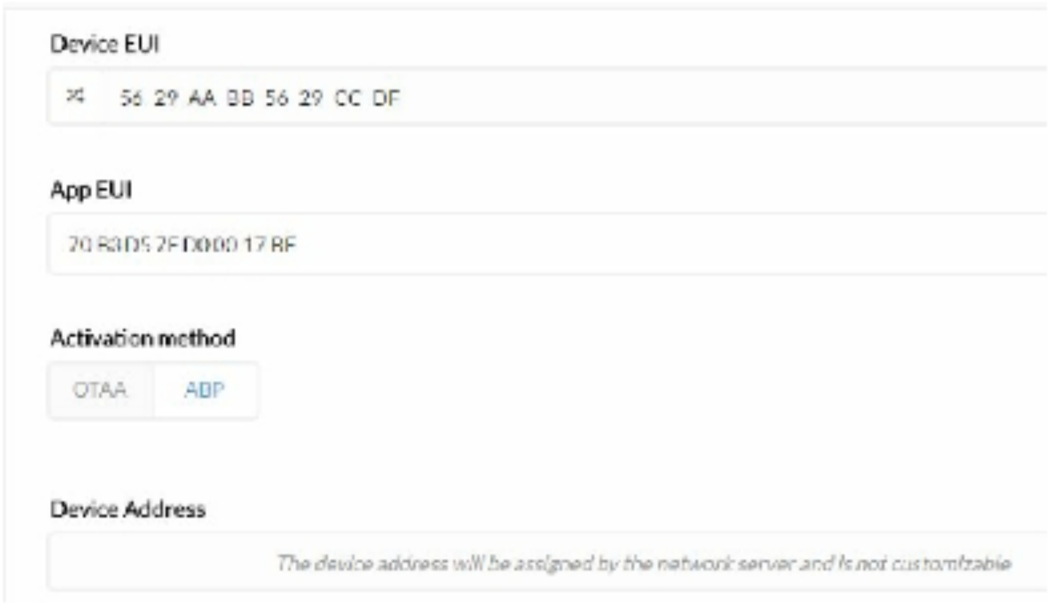
Device EUI
The device EUI is the unique identifier for this device on the network. You can change the EUI later.
56 29 AA BB 56 29 CC DF

App Key
The App Key will be used to secure the communication between you device and the network.
App Key will be generated

App EUI
70 B3 D5 7E D0 00 17 BE

Register the device.

Now edit the settings of the device and choose ABP (OTAA will be selected by default)



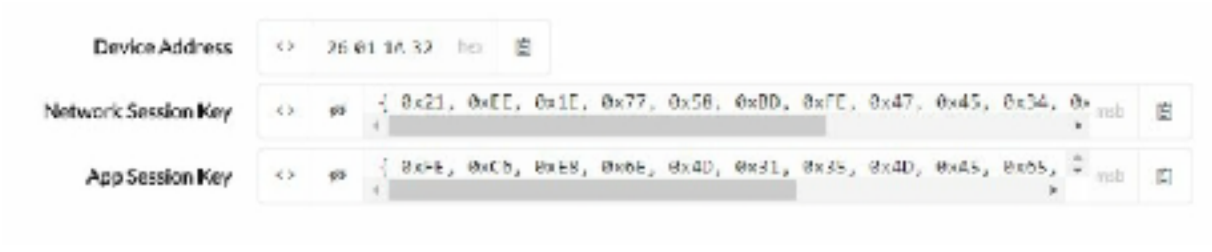
Device EUI
56 29 AA BB 56 29 CC DF

App EUI
70 B3 D5 7E D0 00 17 BE

Activation method
OTAA [✓ ABP]

Device Address
*The device address will be assigned by the network server and is not customizable*

Select 'save'. Now some values are system generated and we have to copy them to our code. We use the ttn_bmp280_abp.ino example here.



Device Address 26 01 1A 32 hex

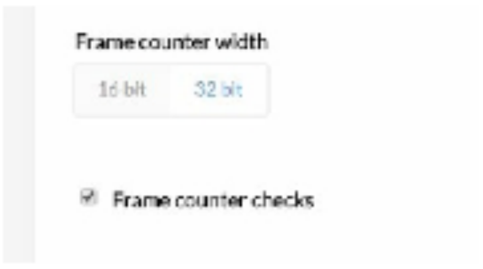
Network Session Key { 0x21, 0xEE, 0x1E, 0x77, 0x58, 0xDD, 0xFE, 0x47, 0x45, 0x34, 0x msb

App Session Key { 0x[illegible], 0xC[illegible], 0xE8, 0x6E, 0x4D, 0x31, 0x35, 0x4D, 0x45, 0x65, msb

- Copy the Device Address as a HEX value to DEVADDR in the example, so 26 01 1A 32 will be 0x26011A32.
- Copy the Network Session Key as MSB to NWSKEY.
- Copy the App Session Key as MSB to APPSKEY.

Compile and upload the code. Check in the dashboard the working.

You might want to uncheck the frame counter check



Frame counter width

16 bit [✓ 32 bit]

[✓] Frame counter checks

If the frame counter is checked, you must respect the sequence number, and probably copied packages are refused on the network. Though restarting you node, and thereby resetting the frame counter, will disable your node. So to get this working, you have to disable this check by unchecking this box. You can integrate the code of ttn_bmp280 in the abp example.

## TTN Mapper

On www.ttnmapper.org you can look at the coverage of The Things Network in your neighbourhood.

You can even contribute to this map by using the ttnmapper app on your Android Smartphone. You can use your TTN credentials to select your sensor

## LMIC Pin Mapping

If you are using other 'LMIC' or TTN examples, there is ONE part to take care of, the pin setting of the RFM95 module. Most times you have to adjust this to the pinout of the board:

```
// Pin mapping is hardware specific
const lmic_pinmap lmic_pins = {
    .nss = 10,
    .rxtx =
    LMIC_UNUSED_PIN, .rst =
    .dio = {4, 5, 7}, //DIO0, DIO1 and DIO2 connected
};
```

## And even more…

- You can add professional Antenna's on the PCB by using the appropriate connector.
- Support: https://www.thethingsnetwork.org/forum/

Thanks to Doug Larue for his PCB design and sharing his manuals.

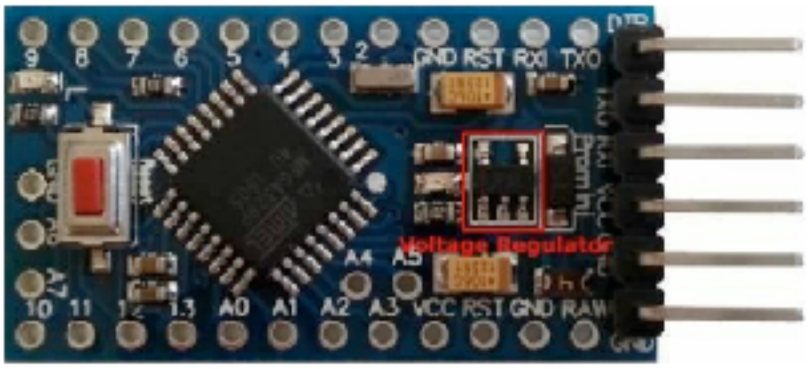
Frank Beks

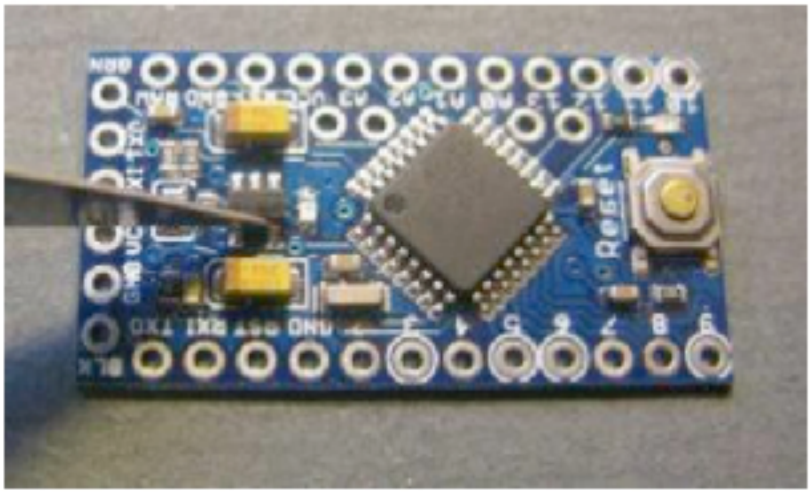
March 2017

## Low Power the Arduino (Optional)

### Remove the Regulator

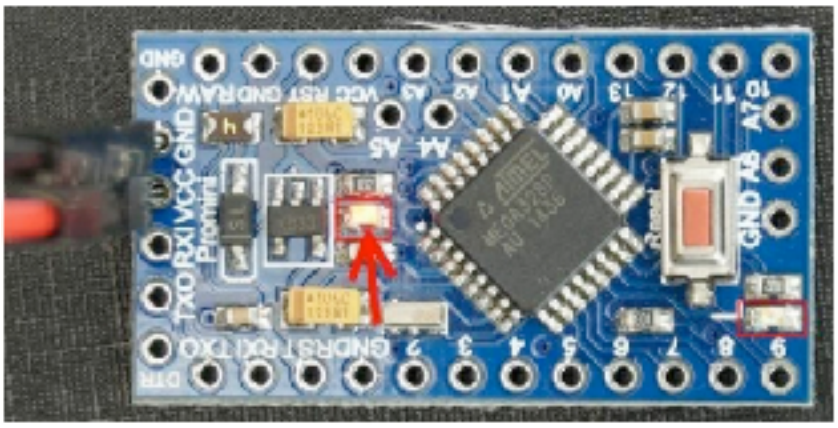
The easiest way to remove the regulator and not damage the board is to use a very sharp scalpel to cut through the regulator leads at the point they join the regulator body.





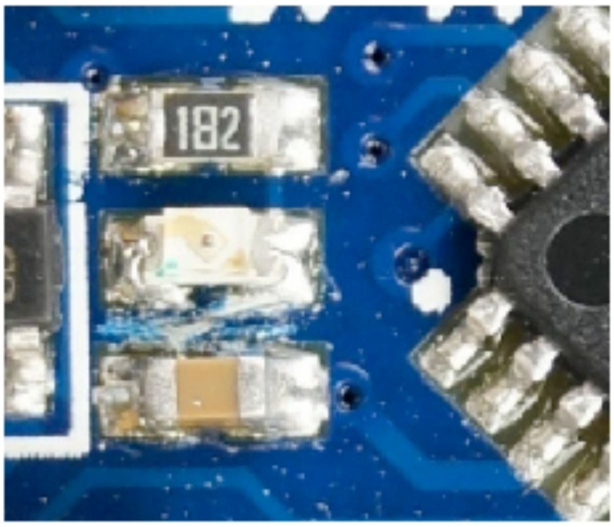
### Remove the LEDs

There are two LEDs on the Pro Mini board. The two LEDs are marked with a red square in the following picture. The power LED is marked with an arrow. If you are not sure where the power LED is on your board, then you can just power it and you will see the LED.



When you found the power LED, then try to locate at least one trace that leads to the LED. In the second picture below, I marked the traces on my board. A high-resolution picture with a lot of light helps to find the traces.

When you found a trace to the power LED, then you take a knife and break the trace, so that it will not conduct any more. You can see my result in the third picture below.



Removing the LEDs can be tricky, so it's easier to remove the series resistors for the LEDs instead. This version of Pro Mini also has a resistor feedback network for the regulator across VCC, these consume power so should be removed. Just push the resistors aside with a soldering iron. The picture shows the Pro Mini with unwanted parts removed, locations of the removed components are circled in red.

More on this subject you may find at: https://andreasrohner.at/posts/Electronics/How-to-modify-an-Arduino-Pro-Mini-clone-for-low-powe r-consumption/