3. SENSOR KIT HARDWARE AND SOFTWARE

3.1 Hardware

I reused most of the parts of the Bora kit (see chapter 1):

- The main control board: Arduino Uno
- The sensors:
    - nitrogen dioxide (NO2), NO2-B43F from alphasense
    - particulate matter (dust), PPD42NS from Shinyei
    - temperature and humidity, DHT22

The new entry was the Lora Radio Module, I used the ADAFRUIT RFM95W LORA RADIO TRANSCEIVER BREAKOUT - 868 MHZ, the selection of the frequency depends on the operation region, Europe in our case.

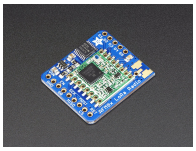


Fig3.1, Adafruit RFM95W Lora Radio

The actual transceiver is the RFM95W (chip sx1276) from Hoperf, http://www.hoperf.com/rf_transceiver/lora/RFM95W.html.

Fig3.2, Adafruit RFM95W Lora Radio

It is a complete transceiver, Lora Modulation compatible, with SPI interface, easy to connect and control using the dedicated communication pins. The disadvantage is the operating range, max power supply 3.7V. The Arduino's domain is 5V and I would have damaged the radio connecting each other pins, actually I did and I was pretty surprised by the fact that the module lasted two weeks working at 5V.
To resolve the problem, generate a strong enough 3V source and level-shift the communication lines, I opted for the out of shelf product of Adafruit that intagret 3V LDO and level-shifters on SPI pins.

The Antenna is 868MHz 90deg SMA, the Adafruit transceiver has the solder pads for the implementation.

Based on the same approach of the Bora kit, I needed to design a board interface to host the terminals/connections of all the parts (main controller, sensors, Lora module).
I used Eagle software to define the schematic of the interface pcb and to generate the digital files to produce the Arduino shield.

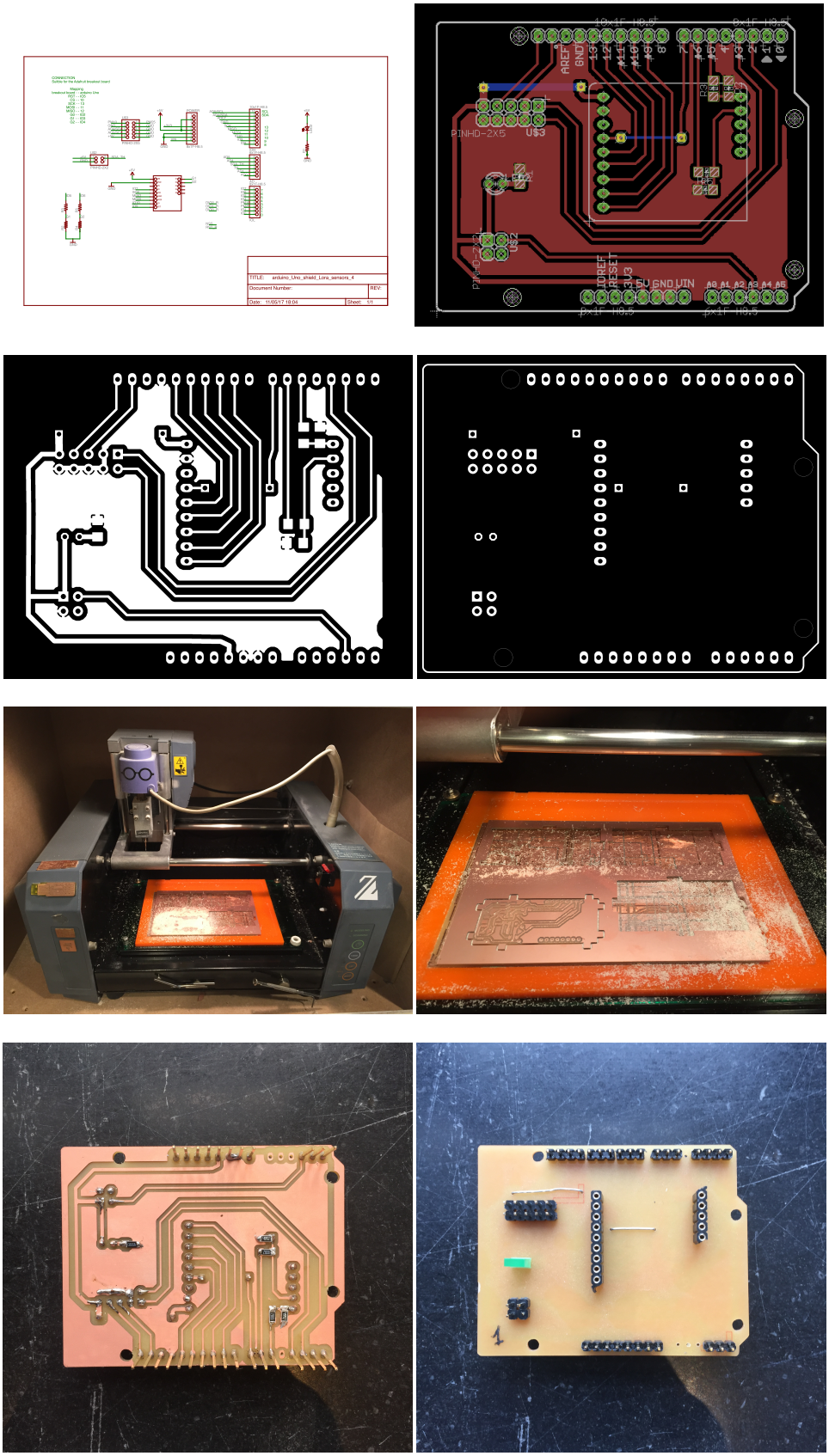
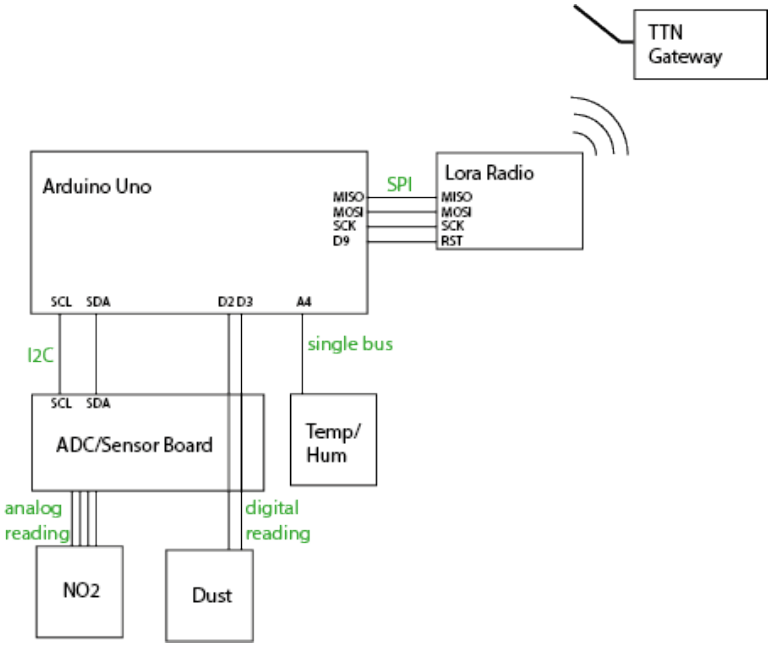


Fig3.3, Schematic view, Layout view, traces machine file, cut-out machine file, machine, milled pcb bottom, milled pcb top.

Communication Block Diagram



3.2 Software

The code is an adaptation of the ttn-abp example that comes with the library lmic.h, https://github.com/matthijskooijman/arduino-lmic. The activation mode of the device was set to ABP.

The part of the code that manages the sensor readings is taken from the Bora Kit pilot study, https://github.com/waagsociety/making-sensor/tree/master/sensor_kit/code (datalogger.ino).

The code of the Bora Lora kit can be found in:
https://github.com/waagsociety/Bora_Lora_Kit

The kit sends the following data:
temperature: 2Byte
humidity: 1Byte
no2_a: 2Byte
no2_b:2Byte
pm2.5: 2Byte
pm10: 2Byte

for example a payloAd on the TTN server side would appear like:
04 AB 04 C8 09 C4 17 01 23 00 00 00.

Using the decoder function on the dashboard the payload is transformed in a readable format:

```
{
 "hum": 23,
 "op1": 1195,
 "op2": 1224,
 "pm10": 0,
 "pm25": 291,
```

"temp": 25
}

Using mosquito_sub, it's possible to read the package directly from the TTN server:

{"app_id":"makingsense","dev_id":"xxx","hardware_serial":"xxx","port":1,"counter":1586,"payload_raw":"BMcFTAfQJQECAccc","payload_fields":{"hum":37,"op1":1223,"op2":1356,"pm10":0,"pm25":258,"temp":20},"metadata":{"time":"2017-04-05T14:24:30.097582156Z","frequency":868.5,"modulation":"LORA","data_rate":"SF7BW125","coding_rate":"4/5","gateways":[{"gtw_id":"eui-0000024b08060712","timestamp":4157431915,"time":"","channel":2,"rssi":-57,"snr":8,"rf_chain":1,"latitude":52.36936,"longitude":4.8623486}]}}

Current Consumption

The most consuming parts of the kit are the sensors and this information guided our choice of a wall-supplied solution.

	Nominal Current (mA)	Process
dht22	<2	datasheet
no2-43bf	10	measured
ppd42	90	measured

The RFM95W module, by datasheet, consumes from 20 up to 120mA.
The Microcontroller consumes between 5uA and 20mA depending on the operation.

3.3 BOM

Material for one KIT	Amount	Cost	Supplier
Main Board			
Arduino UNO Rev3	1	20,00 €	arduino
Lora Radio			
Adafruit RFM95W LoRa Radio Transceiver Breakout - 868 or 915 MHz	1	19,95 €	adafruit
Arduino shield			
FR1 copper plate	1	0,80 €	inventables
female pins 1x14	14	2,94 €	farnell
male short pins	14	0,29 €	farnell
male long pins	23	1,21 €	conrad
smd 1206 res 1k	3	0,02 €	farnell
smd 1206 res 5k	4	0,03 €	farnell
jumper wires	2		
led 3mm tht	1	0,41 €	farnell
Cable for sensors			
connector IDC 2x2	2	0,69 €	digikey
connector IDC 2x5	4	1,23 €	farnell

ribbon cable	30cm	3,99 €	farnell
Sensor NO2 and support board			
NO2-B42F + IBS	1	150,00 €	alphasense
adafruit ADS1115 breakoutboard	1	17,00 €	kiwi electronics
female pins 1x6	1	1,00 €	farnell
smd 1206 capacitor 10nF	1	0,07 €	farnell
smd 1206 capacitor 100nF	1	0,07 €	farnell
Sensor temp/hum and support board			
FR1 copper plate	1	1	Fablab Barcelona
dht22	1	10,95 €	kiwi electronics
smd res 1k	1	0,02 €	farnell
smd cap 10nF	1	0,07 €	farnell
male short pins	4	0,29 €	farnell
Sensor Dust			
ppd42ns dust sensor	1	19,00 €	kiwi electronics
Power			
usb cable for printer	1	0,95 €	Alle kables
5V usb adapter	1	9,95 €	iprototype
TOTAL COST		261,93 €	

3.4 Three kits for three schools.

I needed three gateways to guarantee connectivity so I asked to The Things Network if I could temporary use their hardware.
The schools' locations and the three kits are shown in the images below.

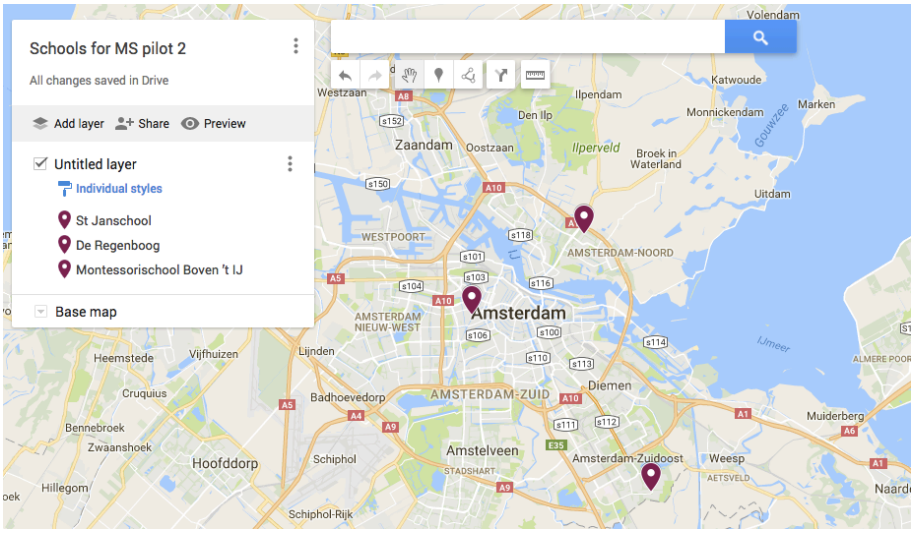


Fig3.4, location of the school.

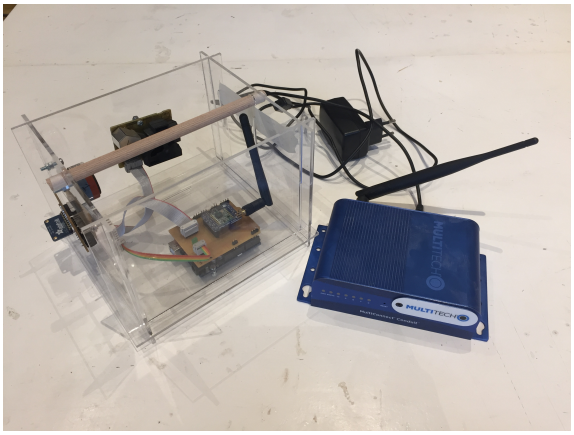


Fig3.5, Bora Lora kit and gateway in Noord.

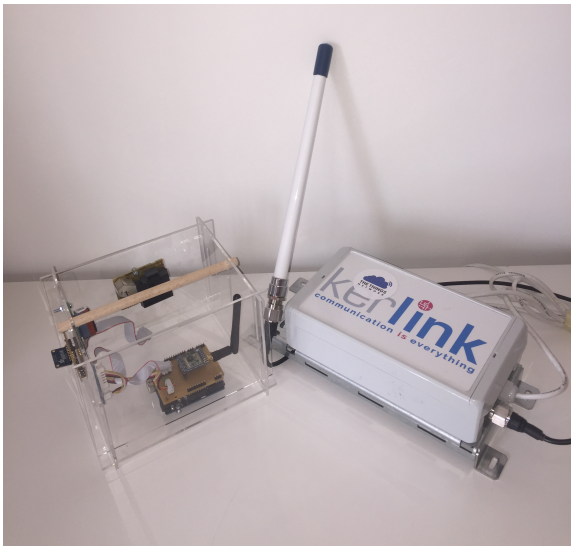


Fig3.6, Bora Lora kit and gateway in West.

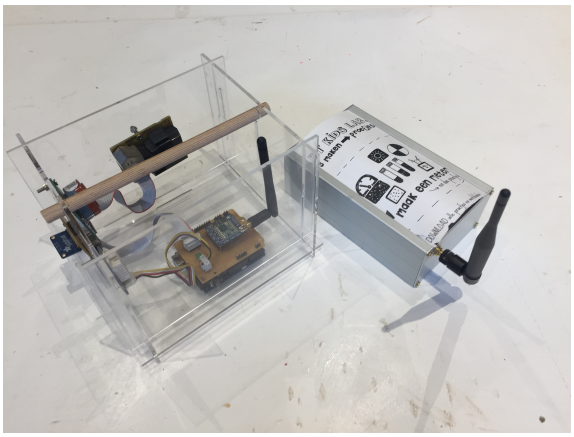


Fig3.7, Bora Lora kit and gateway in ZuidOost.

3.5 Installation in the schools

Fig3.8, Bora Lora kit installation.