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PCB Design of A LoRa Module Integrated with Sensor Devices

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The aim of the thesis work was to design and implement a device for measurement of temperature, pressure and humidity of outdoor environments. The device will operate remotely in rural areas. This means that it should have low power consumption, require little maintenance and be able to withstand bad weather condition with a good protection.

The primary components of the device include a microcontroller ATmega2560, a sensor BME280 and a RF LoRa module. ATmega2560 is the main chip which controls the device. Meanwhile, the sensor monitors and records data from environmental variables. Then the RF LoRa module works as a radio module which transmits the collected data to a cloud server via the LoRa network provided by Digita. The device is powered by three triple-A batteries which are expected to last for a few months without replacement.

The end-product of this project did not meet the initial goal at the first prototype due to errors in the first design: Defective connections inside the schematic prevented the microcontroller from controlling the LoRa module. The schematic design has been revised and a second prototype is being assembled. However, due lack of time, the host company Arestech will take over the last stages of the project including testing of the device.

Keywords	IoT, LoRa, wireless communication, sensor. ATmega2560

Contents

List of Abbreviations

PCB	Printed Circuit Board.
LoRa	Long Range
RF	Radio Frequency
ADC	Analog-to-Digital Converter
LoRaWAN	Long Range Wide-Area Network
PHY	Physical
IoT	Internet of Things
ISM	Industrial, Scientific and Medical
AES	Advanced Encryption Standard
LPWAN	Low-Power Wide-Area Network
SPI	Serial Peripheral Interface
I^2C	Inter-integrated Circuit
SMT	Surface-Mount Technology
DIP	Dual In-line Package
GPS	Global Positioning System
ISP	In-System Programming
USB	Universal Serial Bus

1 Introduction

Recording and analyzing environmental variables such as temperature, humidity and pressure are important activities because they help monitor climate conditions. For example, high-quality weather forecasts, which are vital for many branches of industry and agriculture as well as daily activities in society, depend on pressure, wind and temperature data. Accurate measurements are easily achieved in areas where infrastructure is well equipped and accessible. However, it is far more difficult to achieve precise and frequent measurements in remote and rural locations. Such considerations provide the motivation for this thesis work: The goal was to design a device which can measure outdoor environment parameters in remote locations in Finland. This sets a few constraints on the design of the device: It ought to be able to function for extended periods of time without maintenance or other manual intervention. Operation in remote locations also requires that the power consumption of the device should be minimal so that it can be powered by battery.

The device was built from separated components mainly comprising a microcontroller Atmega2560, a sensor BME280, and a LoRa radio module. The microcontroller ATmega2560 is a high-performance chip taking full control of the device and BME280 sensor is used to measure data for temperature, humidity and pressure. Atmega2560 and BME280 were chosen because of their low power consumption. The third component, the LoRa module acts as an antenna wirelessly transmitting a data signal to a cloud server via the LoRa network. The device is powered by three AAA batteries and the whole device package is designed to fit into a small designated cover.

As mentioned above, the device uploads data onto a cloud server via the LoRa network. The-things-network webpage provides illustrations of the data gathered by the device and provides functionality for remote administration of the device via a console interface. In Finland, the LoRa network is provided by Digita operator and has wide coverage over almost the entire country.

Chapter 2 presents theoretical research of LoRa technology. The discussion is about LPWAN and how LoRa technology is developed along with its features. In the third chapter, the primary specifications of the main components are presented which are used in this project together with selected models and packages. The fourth chapter explains the software used to design the PCB as well as the planning work for the block diagram, the schematic and PCB layout. Finally, the last chapter states the conclusion as well as the result and solution proposal.

2 Background Research

2.1 Overview LPWAN

LPWAN is a type of wireless telecommunication network designed for long-range communication. It can send small data packages and is operated on a battery. The operation range of LPWAN varies from 1-5 km in municipal areas up to 10-40 km in rural areas. LPWAN technology has very high efficiency and low power consumption due to its low data exchange rate. Thus, it can even achieve battery life exceeding 10 years. Additional benefits of this technology include, use of unlicensed bands, a cheap radio chip set and low cost. [1]

Because its long-range, low power and low-cost characteristics, LPWAN is used increasingly in IoT applications of industrial and research communities, for example in security, asset tracking, agriculture, smart systems and smart homes. In short, in applications where use of other communication technologies such as short-range radio technology or cellular communication is limited by range or power consumption.[1]. Figure 1 presents the position of LPWAN in the telecommunication field compared to other wireless communication technologies.

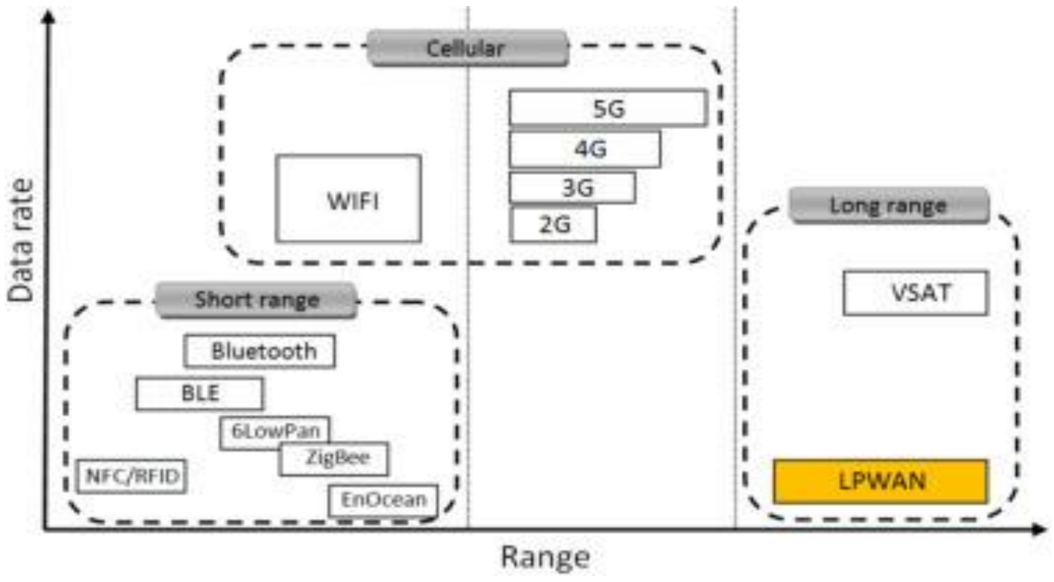

Figure 1: LPWAN position in telecommunication technologies [1]

At the present time, many LPWAN technologies are being developed and there are a number of stand-out competitors besides LoRa such as Sigfox, NB-IoT, etc.

2.2 LoRa Technology

2.2.1 LoRa and LoRaWAN

LoRa is an acronym for Long Range and it is an LPWAN technology based on so called spread spectrum modulation scheme which is a successor of the chirp spread spectrum technology (CSS). This proprietary technology was developed by a French company called Cycleo and later it was obtained by the Semtech Corporation in 2012. Semtech is also the founder of the LoRa Alliance which is a nonprofit association working for advancement of LoRa technology. [2]

LoRaWAN is a MAC layer based on cloud servers. It was developed to handle communication between gateways and end nodes. LoRaWAN defines LoRa communication protocol and network architecture while LoRa PHY manages long-range communication. Figure 2 shows the LoRa protocol stack including its application layer LoRaWAN, Physical layer LoRa and Radio Frequency. The protocol and network architecture have great impact on improving network capacity, service quality and security, determine the battery lifetime of the end node. [2]

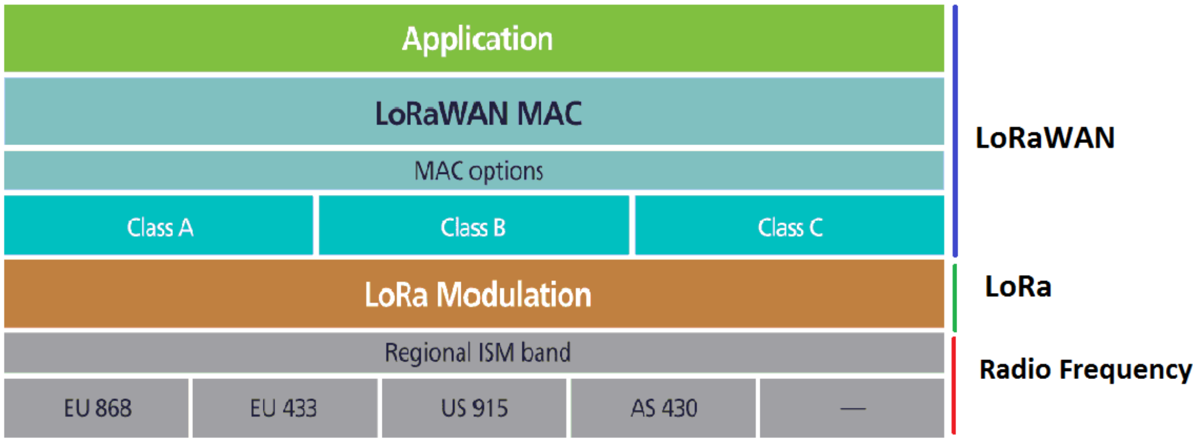

Figure 2: LoRa Protocol Stack [3]

A physical LoRa module commonly called an end-node or end-device includes two main parts: a radio module and a microprocessor. The end-node is typically powered by battery, but it can also be main-powered. To send a signal to the gateway, the modulator of the radio module encodes data into a carrier signal. There are many types of modulation and as mentioned above, LoRa uses the spread spectrum modulation technique to modulate the signal. Military and space communication have used this technique for decades due to its capacity for long-range communication and low susceptibility for interference, but this is the first time the technique is applied for commercial purposes. [3]

2.2.2 LoRa Modulation

LoRa modulation is developed from chirp spectrum modulation. The term chirp and spread spectrum can be defined as following:

- Chirp is a kind of signal in which the frequency increases (called up-chirp) or decreases (down-chirp) with time. It is also known as sweep signal. [4]
- Spread spectrum technique is the method by what a signal spreads consciously in frequency domain. [5]

Hence, LoRa modulation is attained by generating a chirp signal which varies continuously in frequency domain. The data rate of LoRa modulation is expressed as follows:

$$R_b = SF * \frac{BW}{2^{SF}} * \frac{4}{[4 + CR]} \ (bits/sec)$$

Where:

- R_b: is data rate or bit rate which denotes the speed of transmission (bits/sec).
- BW: is modulation bandwidth (Hz).
- SF: is spreading factor which decides how many chirps are sent per second. LoRa designated its value is between 7 and 12.
- CR: is the code rate. This is the proportional of transmitted data and actual carried information. LoRa nominated code rate values including: 1, 2, 3, 4. [3]

2.2.3 LoRaWAN Network Architecture and Security

The LoRaWAN network architecture is formed in a star topology which is rather simple to implement and very reliable. As Figure 3 illustrates, there are four main factors in the LoRa network:

- End nodes
- Concentrator/Gateway:
- Network Server
- Application Server

By exploiting the long-range feature of LoRa PHY, wireless communication allows an end node to send a signal of a sensor to one or many gateways in the form of RF packages. The gateways convert the RF packages to IP packages and forward them to the network server using standard IP connection. The network server will filter duplicate packages, identify the gateway with the best reception and route the received package to the correct application server. The application server which acts as the end-user will analyze the sensor data. If the network server receives a response message from the application server, it will decide which gateway is the best one for forwarding a message to the end node. [6]

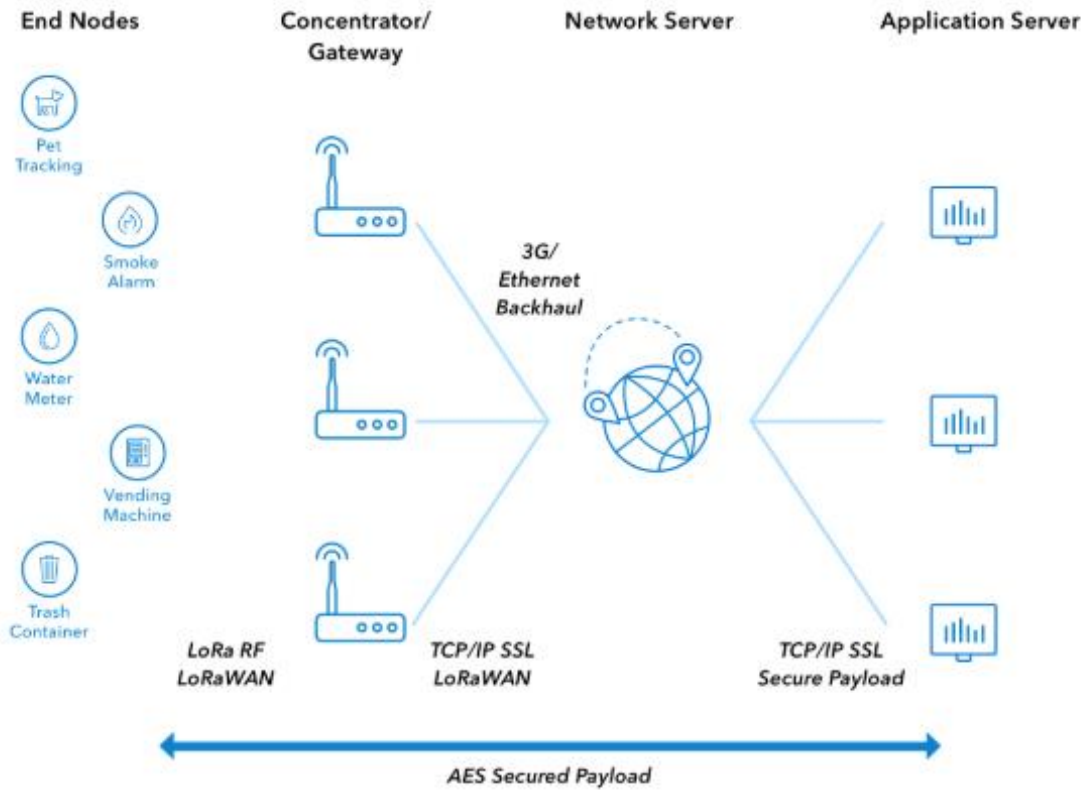

Figure 3: LoRaWAN network architecture [6]

The communication between all the modes is bi-directional and they are secured by Advanced Encryption Standard with two 128-bit security keys: Network Session Key (NwkSKey) and Application Session Key (AppSKey). The NwkSKey is used for communication between the end node and the network server while the AppSKey is used to encrypt and decrypt the payload or in other words, it is used between the end node and the application server. [7]

2.2.4 LoRa Classes

LoRaWAN comprises three classes: class A, B and C. Each class has different downlink communication latency versus battery life. The Figure 4 presents their main properties: [8]

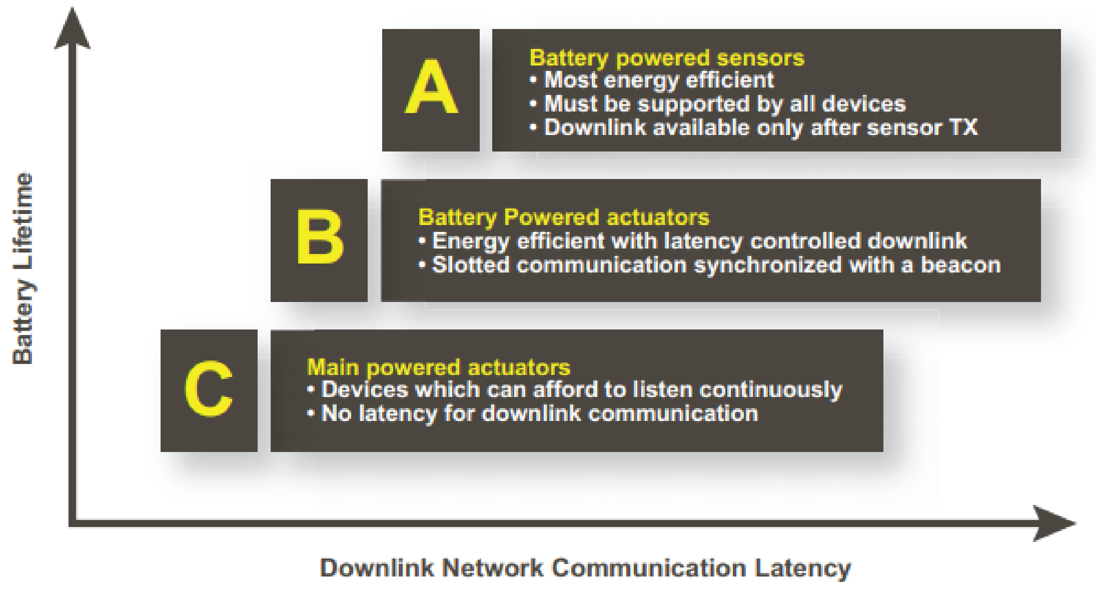

Figure 4: LoRaWAN classes [8]

- Class A is a default class. It is supported by all LoRaWAN end devices. In class A, the end device always communicates initially with the gateway and communication is asynchronous. At any time, the end device may transmit an uplink signal to the gateway. After that it opens two downlink windows which allows for bi-directional communication between the end device and gateway. The gateway can respond to the first or second downlink window but not to both at the same time. The end device can be set into sleep mode at any time by its application which results in lower power consumption for class A compared to classes B and C. [9]

- Class B resembles class A: After transmitting an uplink signal, the end device will open two downlink windows. However, the end device will additionally open extra downlink windows at scheduled times. In class B, the end device communicates synchronously with the gateway using beacons. This allows the gateway to send downlink signals with a determined latency. The beacon will then notify the gateway when the end device receives the response signal. These factors consume extra power compared to class A, but class B devices still have sufficiently low power consumption to be powered by battery. [9]

- Class C also resembles class A by opening two downlink windows after its uplink transmission. However, the end device always remains open so that the gateway can transmit a downlink signal at any time. The communication is bi-directional without latency. Hence, the end device of class C consumes power continuously which means that it is not suitable for battery operation. In other words, this application should be main powered. [9]

2.2.5 LoRa Regional Parameters

LoRaWAN operates on ISM radio bands. ISM radio bands are a part of the radio spectrum which anyone can use to transmit signals without a license. This means that customers do not have to pay for transmission when using LoRaWAN devices. ISM bands are available all over the world, but the specific frequencies can differ between countries. However, some frequencies like 2.4GHz and 5GHz are assigned for ISM bands worldwide. These frequencies are used by WiFi devices and everyone can use them without a permit or license requirement. [8]

While exploiting ISM radio bands, LoRaWAN faces the challenge of unifying the frequencies which are assigned for ISM bands in different countries. Hence the LoRaWAN consortium defines a number of frequency bands for each region. The official specifications for regions are called Regional Parameters. However, the specifications do not determine everything, they are just enough to cover countries with common denominator. [10]

The Figure 5 gives the LoRaWAN regional parameters for a number of countries. For Europe and North America, the specifications details operation frequencies, channels, data rate for uplink and downlink, etc. But for Asian countries, LoRa just defines the frequency bands while other parameters are determined by the local technical committee

	Europe	North America	China	Korea	Japan	India
Frequency band	867-869MHz	902-928MHz	470-510MHz	920-925MHz	920-925MHz	865-867MHz
Channels	10	64 + 8 +8	In definition by Technical Committee	In definition by Technical Committee	In definition by Technical Committee	In definition by Technical Committee
Channel BW Up	125/250kHz	125/500kHz				
Channel BW Dn	125kHz	500kHz				
TX Power Up	+14dBm	+20dBm typ (+30dBm allowed)				
TX Power Dn	+14dBm	+27dBm				
SF Up	7-12	7-10				
Data rate	250bps- 50kbps	980bps-21.9kpbs				
Link Budget Up	155dB	154dB				
Link Budget Dn	155dB	157dB				

Figure 5: Example of LoRaWAN specification [8]

Besides the advantages of being free and unlicensed, the ISM radio band also has its drawbacks. Specifically, data transmission is subject to a lot of interferences because the fact is that everyone can access those frequencies. To avoid heavy transmission traffic and make sure the frequencies are usable, the government issues the regulation for the duty cycle limits as well as the transmission power restriction for the network uplink and downlink. Commonly, the duty cycle is set at 1% but it should be applied according to local rules in addition to conditions of the network operator. [10]

2.2.6 LoRa Alliance and LoRaWAN Coverage

The LoRa Alliance is a nonprofit association established in 2015 with more than five hundred member organizations all over the world. The association also defines the LoRaWAN protocol and specifications. Its members are growing fast with commitment to cooperate and develop LoRaWAN by standardizing and expanding LPWAN to enhance the IoT system globally.

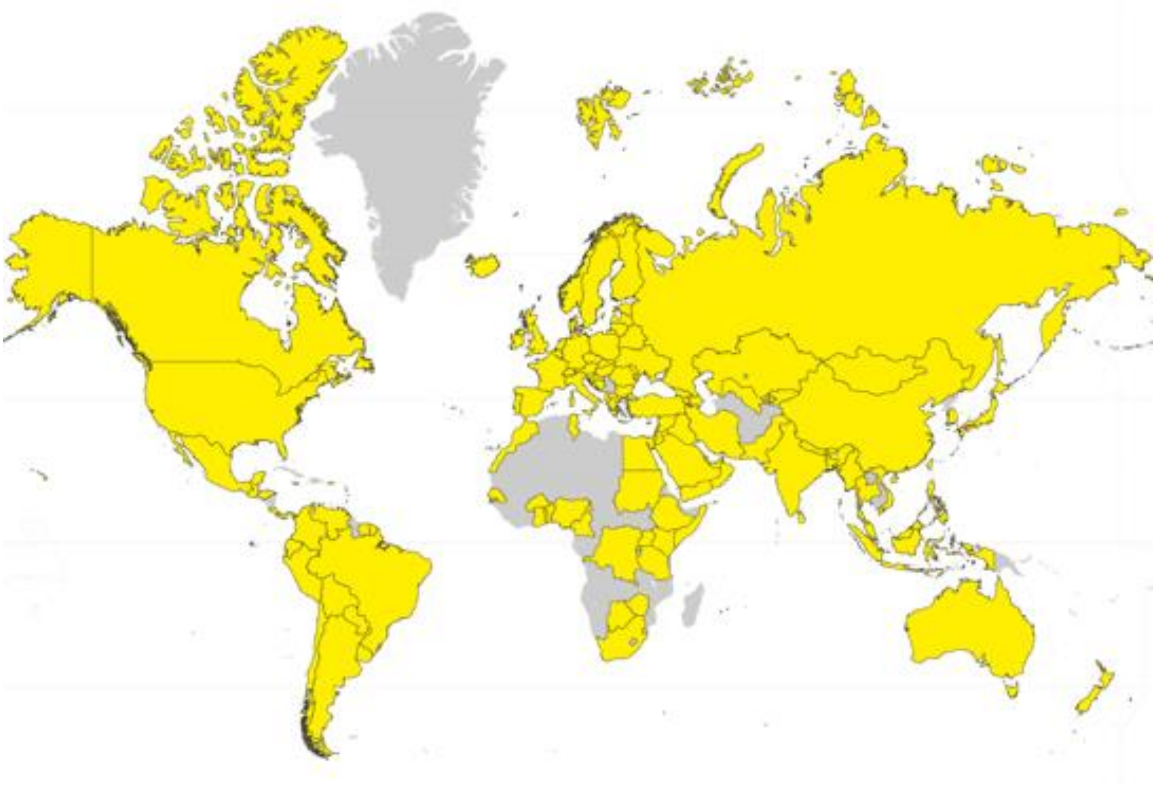

Figure 6: LoRaWAN wolrdwide coverage map [12]

LoraWAN has been deployed in 157 countries as displayed by Figure 6. The coverage is illustrated by yellow color. With 137 net-work operators in 58 countries, LoRaWAN network coverage is still spreading significantly every month. [11]

In Finland, LoRa network is managed by Digita Oy. The company not only provides and operates the wireless communication network, they also have other services such as TV and mobile network, data center, site service. This company is invested by an American company called Digital Colony.

The coverage map of LoRa in Finland is shown as Figure 7. The map is generated by computer and shows estimated covered area. The coverage is presented by pale-blue color including indoor and outdoor area. [13]

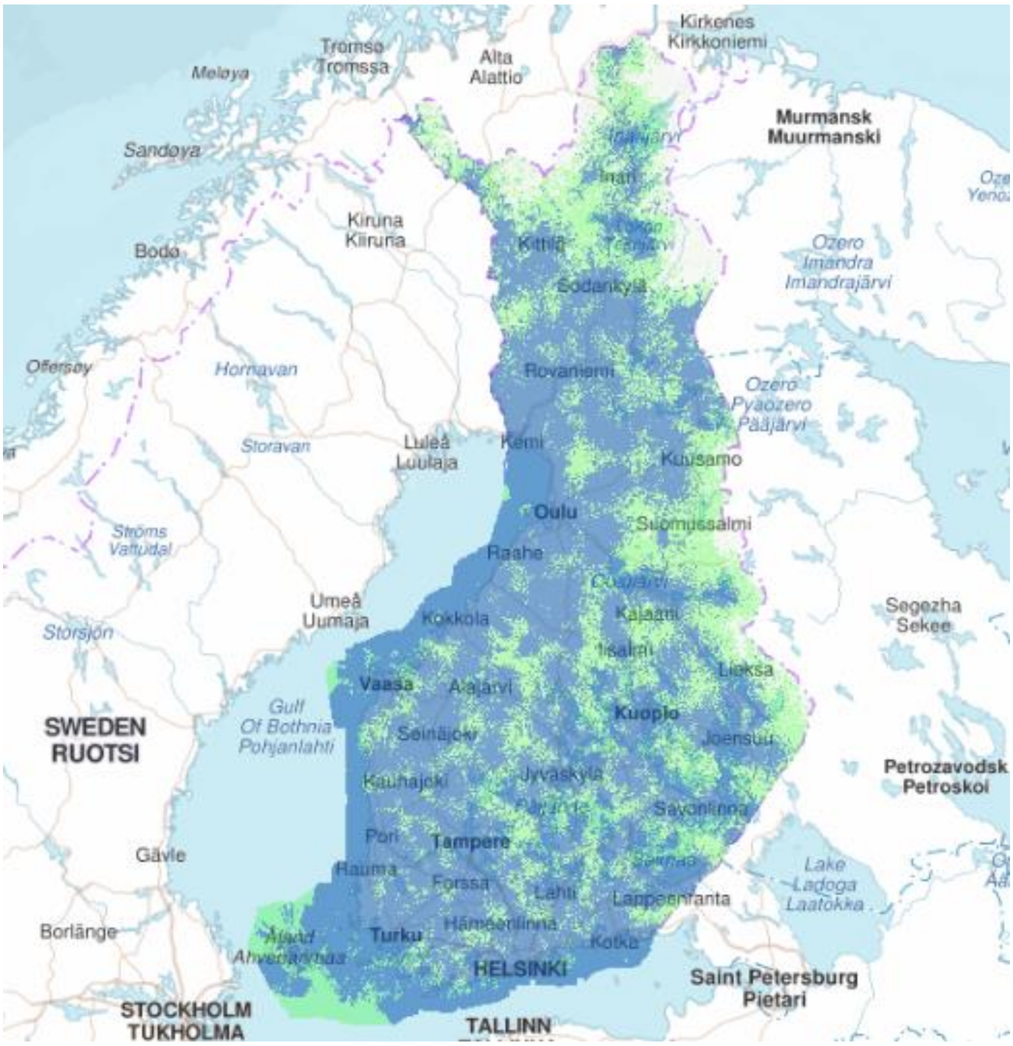

Figure 7: LoRaWAN coverage map in Finland [13]

3 Components

3.1 Microcontroller ATmega2560

The ATmega2560 is a low power and high performance 8-bit microcontroller, a member of AVR microcontroller family developed and produced by Atmel Corporation. By using advanced RISC architecture, the ATmega2560 can perform 135 powerful instructions in one single clock cycle. The microcontroller can be programmed with built-in flash memory 256KB, EEPROM 4KB and RAM 8KB. The ATmega2560 is provided with two package options 100-lead and 100-ball. In this project, the selected package is 100-lead TQFP (Thin Quad Flat Package)-pinout shown in Figures 8 and 9. [14]

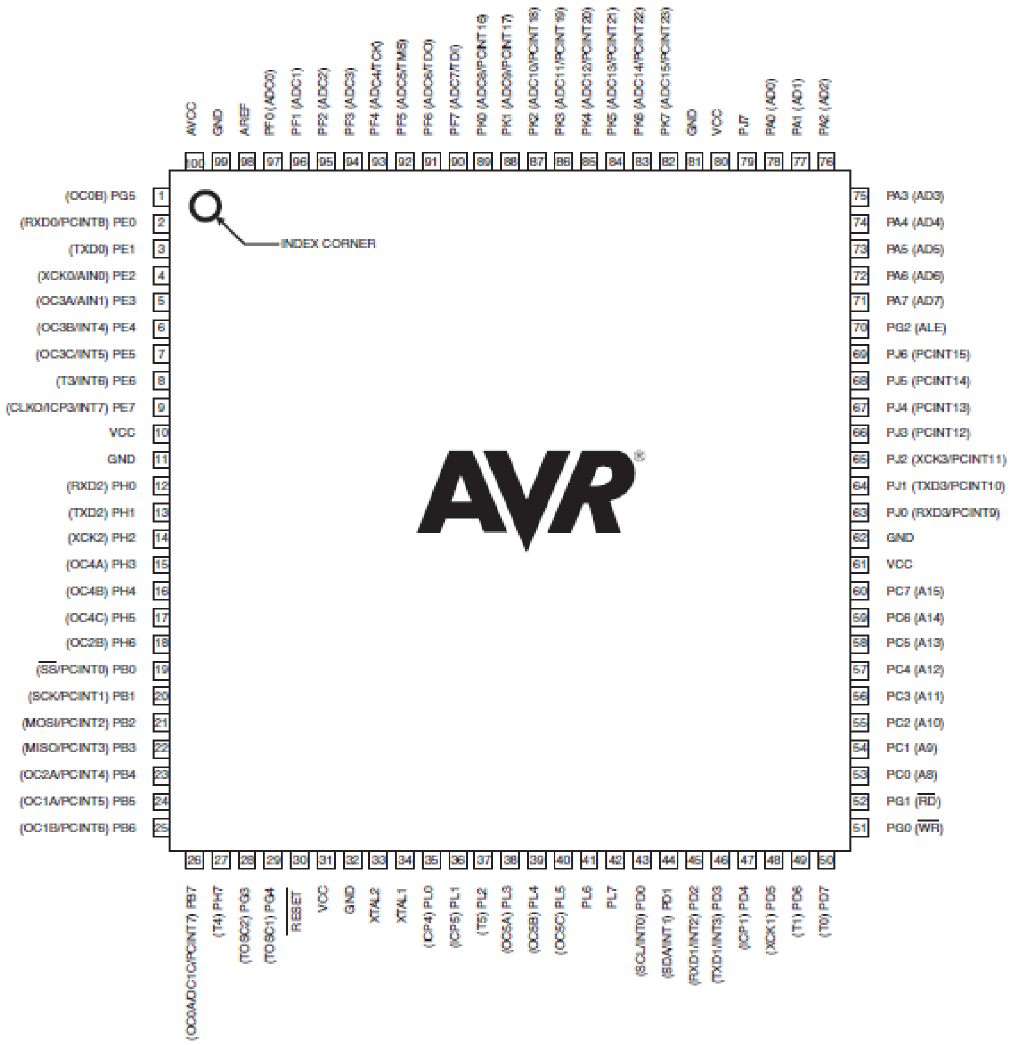

Figure 8: Microcontroller ATmega2560 pins [14]

Figure 9: Microcontroller ATmega2560 [14]

The 100 pins comprise:

- 4 pins Vcc: Digital power supply pins
- 5 pins GND: Ground connection pins

- 86 I/O pins: General purpose input/output pins
- 1 pin RESET: Reset input pin
- 1 pin XTAL 1: Input to inverting oscillator amplifier
- 1 pin XTAL 2: Output from the oscillator amplifier
- 1 pin AVCC: Power supply for port F and AD converter
- 1 pin AREF: Analog reference pin for AD converter

The microcontroller has power supply range Vcc from 1.8V to 5.5V and operation temperature between -40°C and 85°C. When working under condition Vcc = 2V and oscillator frequency= 1MHz, the ATmega2560 has very low power consumption at active mode 0.5mA and idle mode 0.14mA.[14]

The ATmega2560 is able to communicate via 3 communication peripherals: SPI (Serial Peripheral Interface), USART (Universal Synchronous and Asynchronous Receiver Transmitter) and I2C (Inter-integrated Circuit). Due to lack of USB support, the device in this project will be programmed by ISP (In System Programming) method through SPI interface. ISP is one of the best way to program an AVR microcontroller.[14]

3.2 RF LoRa Module

The RF LoRa module is a transceiver radio module. This means that the module can both send and receive signals. The module is a product of RF Solutions company and manufactured based on the SX1272 LoRa Modem produced by the Semtech Corporation. The RF LoRa module has very high performance and low power consumption but can still transmit data over large distances up to 16km. It is widely used for IoT application such as sensor networks and home automation. The module can be programmed via SPI communication. [15]

The RF Solutions company produces two models: RF-LORA and RF-LORA2 shown in Figures 10 and 11. Both models ship with two packages: SMT and DIP. Both models have small size: 23mm x 20mm.

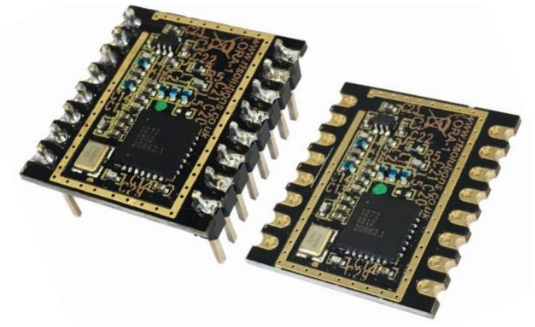

Figure 10: RF-LORA module [15]

Figure 11: RF-LORA2 module [15]

The RF-LORA module provides a choice between two ISM band frequencies: 868MHz and 915MHz while the only band frequency available for RF-LORA2 is 915MHz. Depending on the location where the module will be used, the appropriate frequency should be chosen to comply with local rules. The RF LoRa module provides a built-in mechanism for ensuring that the correct frequency is supported: Every RF LoRa module displays two color dots. A green dot signifies “test passed”. In addtion, either a blue dot signifying the 868MHz frequency band or a brown dot signifying the 915MHz frequency band will be present. In this project, the RF-LORA module with DIP package will be used and the selected frequency is 868MHz. [15]

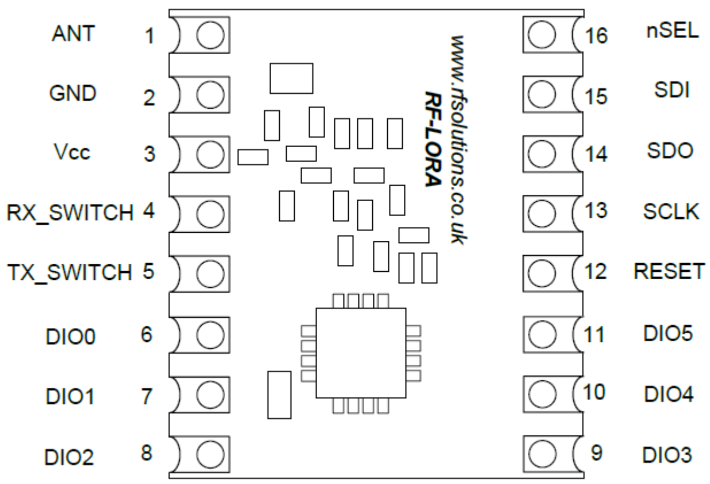

Figure 12: RF-LORA pin description [15]

As illustration of Figure 12, RF-LORA has 16 pins as following:

- ANT: antenna connection pin
- GND: ground connection
- Vcc: Power supply
- RX_SWITCH: receive
- TX_SWITCH: transmit
- DIO0, DIO1, DIO2, DIO3, DIO4, DIO5: digital input/output
- RESET: reset pin
- SCLK: serial clock input
- SDO: serial data output
- SDI: serial data input
- nSEL: select active low.

The radio module operates at recommended voltage range between 2.2V and 3.7V at temperature 0 °C to 55 °C. Its current consumption at standby of the power saving mode is 50nA, while the module typically consumes 10mA at receive mode and 90mA at transmit mode. The module has been tested by the factory at the condition TA = +25°C, VDD= +3.3V, humidity 45%. It was able to transmit over a distance of 3km when non-line of sight and beyond 12km in-line of sight. [15]

3.3 BME280 Sensor

The BME280 is a high accuracy sensor used to measure temperature, humidity and pressure. The product is manufactured by Bosch Sensortec with small dimension of

2.5mm Length x 2.5mm Width x 0.93mm Height and covered by a solid metal housing. With its tiny size as showed in Figure 13, the sensor consumes very low energy so it is optimal to implement for small and battery-powered device such as GPS devices, fitness gears, handsets. [16]

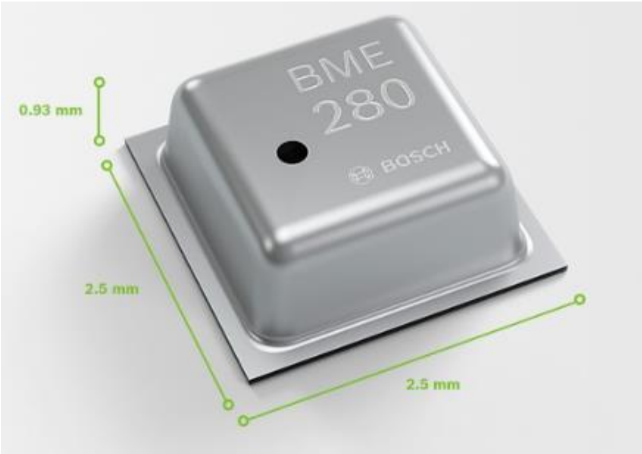

Figure 13: BME280 sensor [16]

The sensor has temperature range from -40°C to 85°C, 0 to 100% relative humidity and 300 to 1100hPa. Every measurement period includes temperature, pressure and humidity measurement and either of them can be enabled or skipped independently. As the illustration of Figure 14, the cycle starts with temperature measurement and the process is controlled by osrs_t setting which can be enabled or disabled. The process applies similar to the next measurement of pressure and humidity. If IIR filter (Infinite Impulse Response) is enabled, the pressure and temperature resolutions are 20 bits, and if the IIR filter is disabled, the pressure and temperature resolutions are 16+ bit. Meanwhile humidity measurement has fixed resolution at 16 bits. [16]

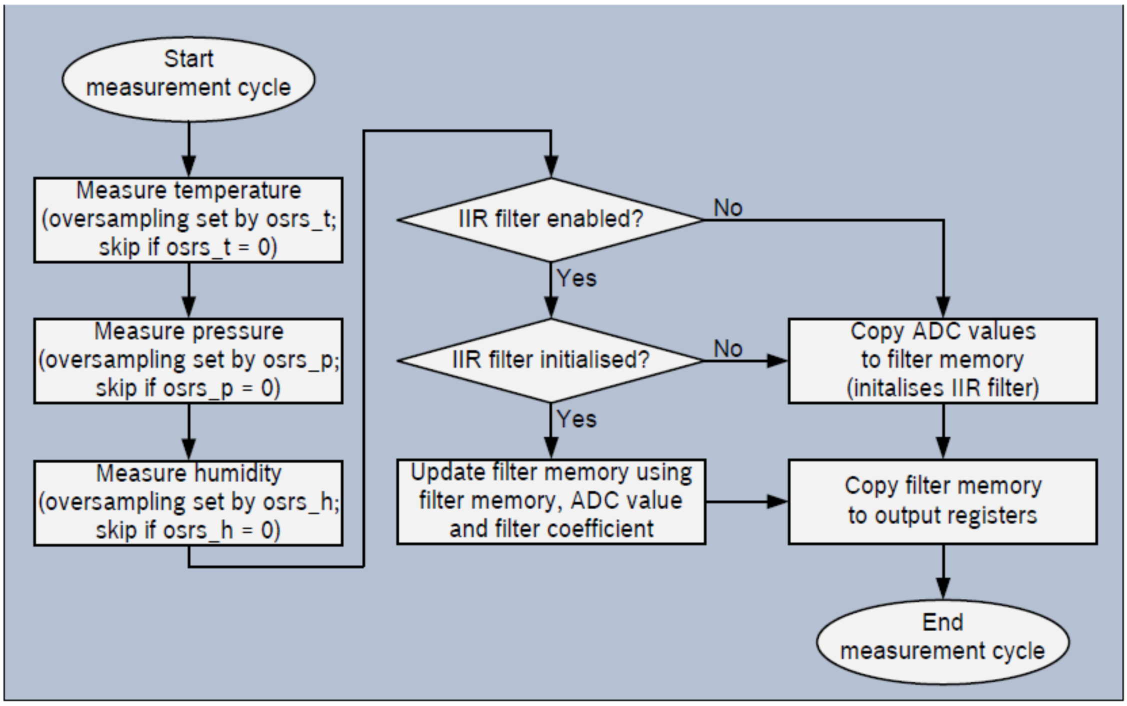

Figure 14: BME280 measurement cycle [16]

The BME280 has three power modes: sleep mode, normal mode and force mode while its current consumption for sleep mode is extremely low at 0.1µA. The sensor supports two communication interfaces: SPI and I2C, and in this project I2C interface is used for wiring connection showing by Figure 15. It has 8 following pins:

- Pin 1 GND: Ground connection
- Pin 2 CSB: Chip select, active low
- Pin 3 SDI: Serial data input
- Pin 4 SCK: Serial clock
- Pin 5 SDO: Serial data output
- Pin 6 VDDIO: Digital / interface power supply
- Pin 7 GND: Ground connection
- Pin 8 VDD: Analog power supply

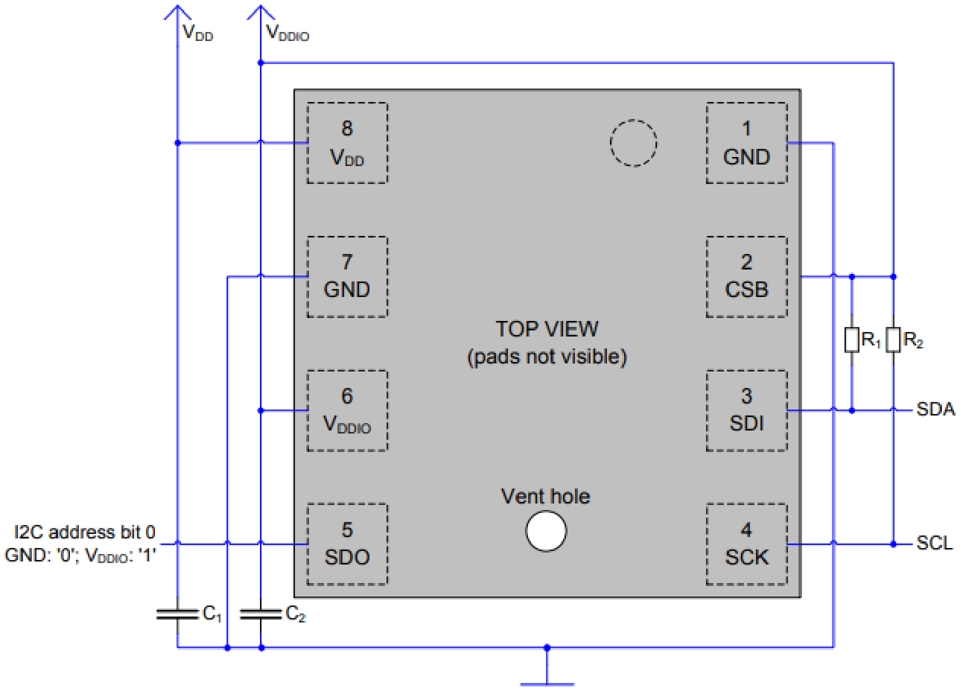

Figure 15: I2C wiring connection [16]

By the specification, the recommended value of capacitors on the I2C wiring diagram is 100nF and the resistor R1 and R2 is 4.7 kΩ. Besides, the sensor BME280 also requires two power supplies: 1.71V-3.6V for VDD analog supply and 1.2V-3.6V for VDDIO digital interface supply.[16]

3.4 Regulator MCP1700

Since the device is intended to operate at remote locations, it is poorly suitable for a main powered design. Instead, the intention is to use three AAA batteries which is totals a 4.5V power supply. However, some components could not tolerate the power supply 4.5V hence the regulator MCP1700 is used to maintain a steady designated output.

The regulator MCP1700 is a low dropout voltage regulator. It has very low quiescent current at 16.6 µA hence it is ideally used for battery-powered device. The regulator has input voltage range between 2.3V and 6.0V, and output voltage range 1.2 to 5.0V. It operates at temperature -40°C to +125°C. [17]

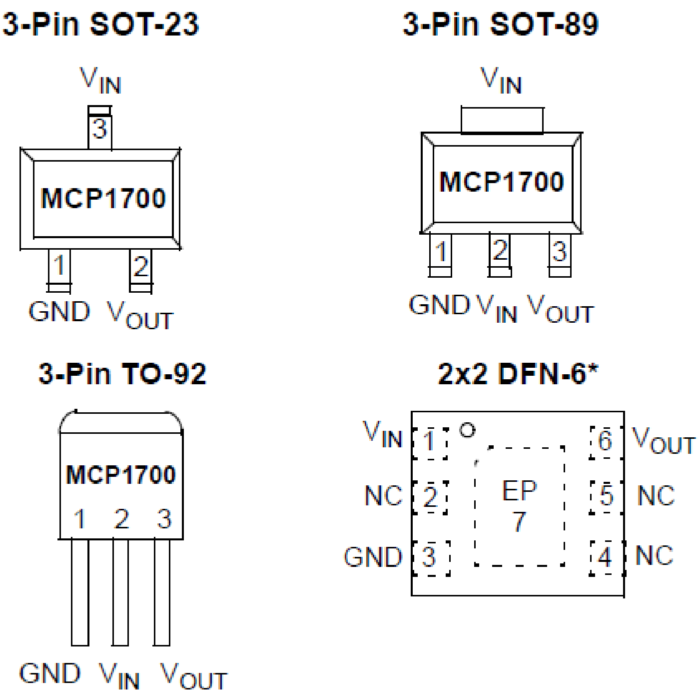

Figure 16: Regulator MCP1700 package options [17]

As illustrated by Figure 16, the regulator MCP1700 has 4 package type: 3-Pin SOT-23, 3-Pin SOT-89, 3-Pin TO-92, and 2x2 DFN-6. The package 3-Pin SOT-23 is chosen to use for the project.

4 Circuit design

4.1 KiCad Design Software

- The project uses KiCad software to design the schematic and PCB layout. KiCad is a free open source software used for Electronic design automation. The software is easy to be used with friendly interface and operates on Windows, Linux and macOS. Kicad has seven main parts and each of them is a stand-alone software [18]:

  - KiCad: is the Project manager
  - Eeschema: is an interface to design schematic, edit or create components for library

- Pcbnew: is used to edit circuit board, routing and create footprint. It also allows to view the PCB in 3D form.
- GerbView: is where users can view and check Gerber and drill files.
- Bitmap2Componen: converts bitmap files to footprint or components for PCB
- PCB Calculator: is a tool to calculate values of components, track PCB size, color codes.
- Pl Editor: edits page layout.

With no limitation for board size, KiCad can manage 32 copper layers, 14 technical layers and 4 auxiliary layers besides its well performance on complex electronics boards. [18].

4.2 Block Diagram Design

The block diagram illustrated as Figure 17 presents the basic concept design of the device:

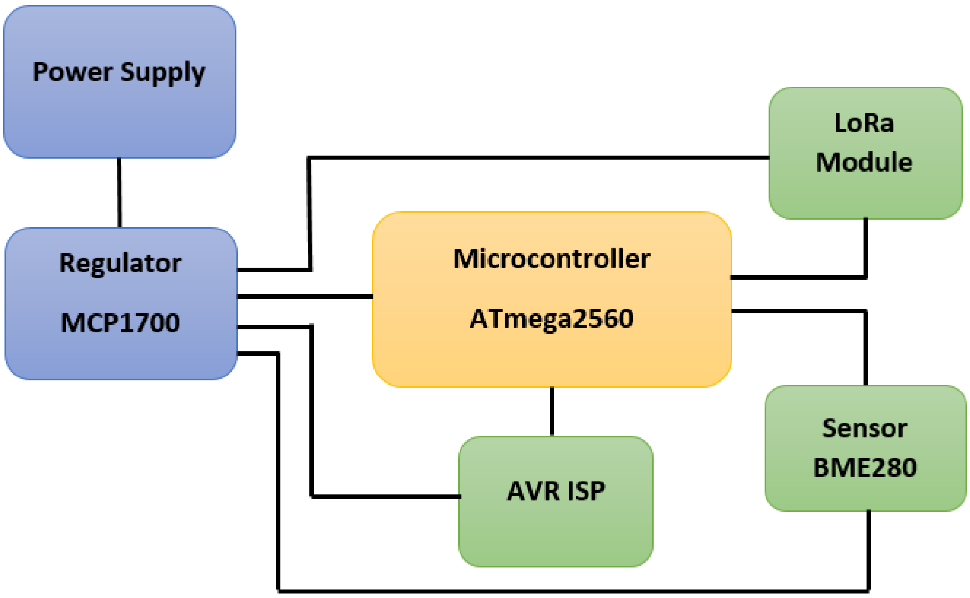

Figure 17: Block diagram design concept

- The power supply powers the Microcontroller and the other components in the device. The power source is regulated by the regulator MCP1700 to make sure a stable output voltage.

- The microcontroller assumes full control the device: Among other things, it collects data from sensor, prompts the radio module to transmit a signal and toggles the choice between sleep mode and active mode. The microcontroller is programmed via AVR ISP programmer.

4.3 Schematic Design

The schematic of the device is designed from discrete components based on the block diagram in Figure 17 and the work is executed using the Eeschema interface of the Kicad program.

Firstly, the power supply consisting of three batteries is connected to the regulator. The output voltage of the regulator is then distributed to the microcontroller, sensor, LoRa module and ISP port. The schematic in Figure 18 presents the wiring connection of the regulator MCP1700 with the batteries and its output distribution.

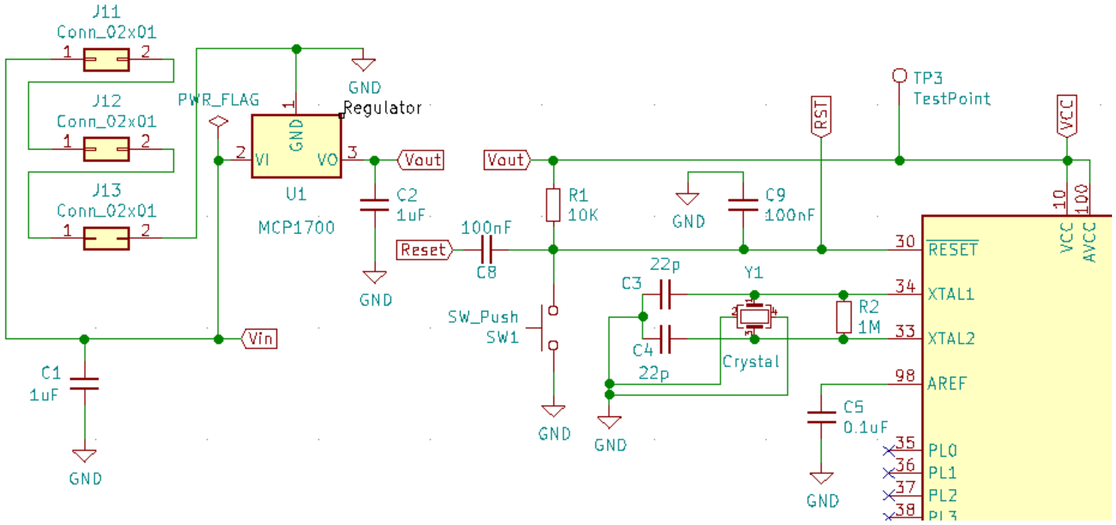

Figure 18: Wiring connection of regulator with batteries and microcontroller

Next, the microcontroller is wired to the BME280 sensor via the I2C interface and to the LoRa module via SPI and UART communication. The microcontroller is also connected to the AVR ISP programmer which is used to program the device. A 6 pin ISP symbol was chosen to allow for easier integration with the microcontroller as shown as Figure 19.

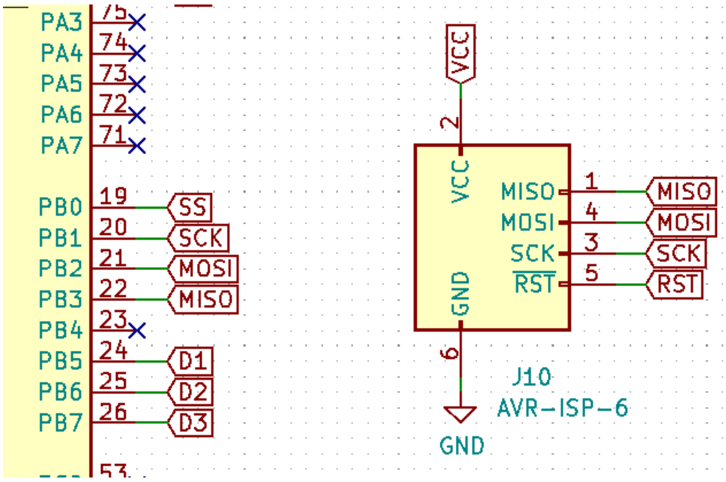

Figure 19: AVR ISP port wiring connection.

Finally, a number of extra output ports are added in order to test the device. These allow for testing the power supply, analog and digital outputs, transmit and receive ports, etc. In order to test the schematic, the electrical rules check provided by the Kicad program will be performed to make sure there is no error within the circuits.

4.4 PCB Design

The layout of the PCB is generated from the completed schematic design using the netlist function provided by the Kicad program. Most of the components have their own footprint in the KiCad library. However, the footprints of the LoRa module and BME280 sensor are not available, hence their footprints need to be created from scratch based on the product specification.

Then the board is formed in size 40mm x 60mm which meets the requirements because the aim is to place the device in a cover box with dimensions 45mm x 65mm. The PCB will have 4 layers: top layer, bottom layer and 2 inner layers for ground and power supply. For other parameters like grid, track and wiring size, the layout uses Kicad default values. The completed routing layout is demonstrated in Figure 20. The Figure also presents the 3D image of the PCB.

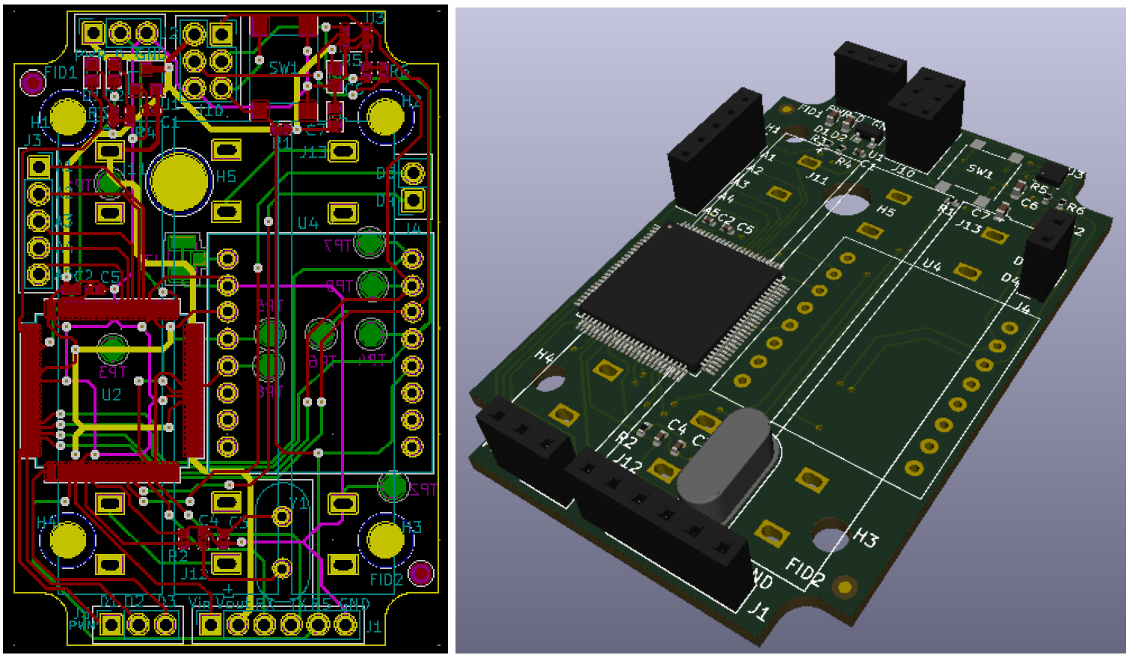

Figure 20: Printed circuit board in 2D and 3D view

The last step is to create Gerber files for PCB manufacturing and those drill files can be checked by Gerber interface.

5 Result of The First Prototype

5.1 Assembling The Device

The first prototype was manufactured and partly assembled by the factory. The rest of components were then assembled at Arestech company and the completed device is shown in Figures 21 and 22.

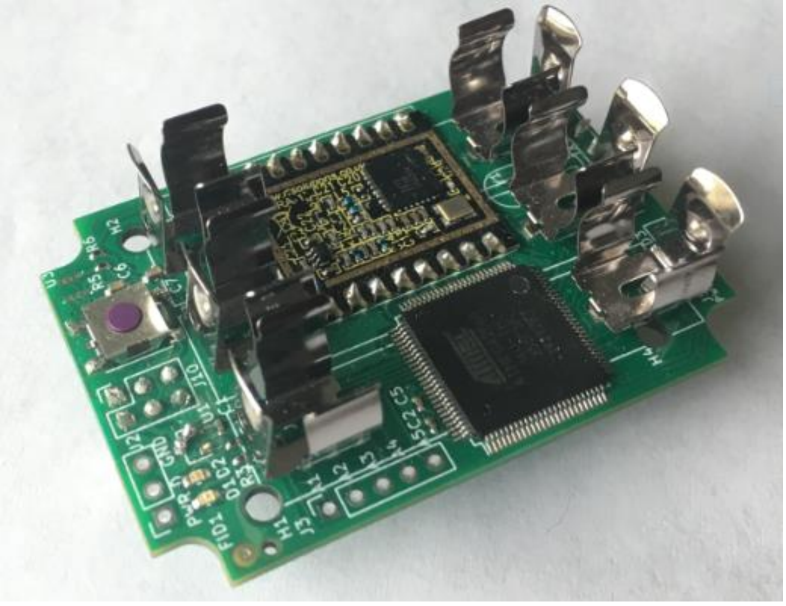

Figure 21: The completed prototype

Figure 22: The prototype with batteries inside the cover box

As Figure 22 demonstrates, the device with its batteries does fit inside its box. However, the battery holders are too close and they touch each other which could easily result in a short circuit. To circumvent this problem, isolation layers can be placed between the holders to separate the individual batteries.

5.2 Programming The Device and Results

To allow for programming, the device is connected to a computer using the AVRISP mkII kit. This toolkit allows all AVR microcontrollers to be programmed via the ISP programmer. It has 2 ports: the first one connects the toolkit and the testing device and the other one connects the toolkit to the computer via USB. The software used for programing is Atmel Studio which is a free integrated development platform. It allows users to write, build and debug applications in C or C++. Meanwhile, it can also import Arduino sketches. The connection between the toolkit and device is demonstrated in Figure 23. During programming, the device has to be powered because the programmer AVRISP does not provide a power supply. The toolkit monitors the voltage of the device and transmits this information to the computer.

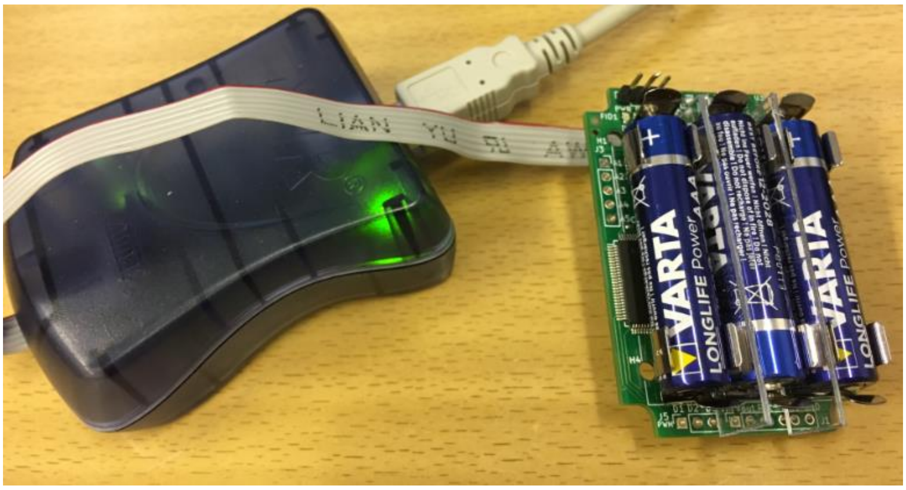

Figure 23: The device is connected to AVR ISP programmer

When the AVR ISP programmer is successfully connected to the computer, 2 LED lights in the programmer turn green. The software can then read the target supply voltage which in this case should be approximately 3.3V. Subsequently, the software installs a bootloader (or Hex file) on the target device. This will allow the device to be programmed over serial port.

After the bootloader has been successfully installed, the target device can be tested. The first test is to control the LED light of the target device. A successful test is indicated when the LED light and it is blinking. The next step is to test the LoRa module transmission. The idea of this test is to send a signal from the LoRa module to an available gateway in the office. Despite several trials, no signals were received by the gateway which means that the LoRa module in its current state cannot send a signal. By examining the schematic and PCB connection layout, the errors were found. There were defective connections within the schematic design: the UART connection was shared with the LoRa module and debugging connection with the computer. This may possibly prevent the chip from controlling the radio module.

5.3 Solution

The proposed solution is to manufacture a second prototype with a number of modifications:

- Fix the schematic connection by adding one UART connection for debugging.
- Modify the battery holders so that they have enough space to prevent short circuit without resorting to isolation layers.

The schematic and PCB layout have been revised and the second prototype is ready for remanufacturing. However, due to insufficient time, the thesis partner Arestech company will continue development and monitor the end results of the project. Consequently, the thesis report cannot describe the final testing results.

6 Conclusion

Overall, the goal of the thesis project was to develop a device to monitor and collect the variables of outdoor temperature, humidity and pressure in rural areas. In order to be able to operate remotely in remote locations, the device should have a low power footprint and require low maintenance with robust protection.

To achieve the desired size, the device was designed from scratch using discrete components in order to optimize the space requirement of the PCB. Since the power source of the device came from three triple A battery and the device is intended to last a few months without maintenance, the ATmega2560 microcontroller and BME280 sensor were chosen due to their low power consumption. Additionally, an integrated LoRa module acts as a radio module which transmits the recorded data from the sensor to a cloud server via LoRa network provided by Digita.

The initial design contained errors because there were defective connections within the schematic design. As a result of the defectiveness, the first prototype did not operate properly as the microcontroller failed to control the LoRa module. However, the chip still could be programmed and was responsive during test. The schematic design has been fixed with some modifications. In addition, the PCB layout has been revised, and the second prototype is now ready to be assembled. Nevertheless, due to lack of time, the project will be undertaken by Arestech company where development and production will continue.

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