UNIVERSITY of LIMERICK

OLLSCOIL LUIMNIGH

Interim Report

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Project Title:

Low-Power Wireless Inclinometer

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1. Introduction

This project will consist of building a low-power wireless inclinometer that will serve the purpose of measuring the tilt of an object, the tilt data should be accessible remotely through a browser without the need to directly interact with the device. The wireless standard should provide long range, low power consumption and quick encrypted transmission of data.

In order to measure tilt a 3-dimensional accelerometer will be used in combination with an ARM processor to process and decode the data sent from the sensor, using an ARM processor ideally should provide quick calculations and low power consumption.

After deploying the functional device the end user should be able to view the tilt sensor data online and be able to compare it to previous results for a prolonged period of time without the need to maintain it. This data can be used to assess how an object behaves(tilts) over a period of days, months and years, which could be extremely beneficial for remote applications.

The device should be energy efficient enough to guarantee months of uninterrupted data collection, the software that will be designed for this application should provide flawless operation and to a high degree ensure that no physical interaction is needed while it functions.

Potentially the device could also broadcast its location when deemed necessary, this would allow for easily locating a device in a case where multiple units are deployed.

2. Literature Survey

a) What is SigFox

SigFox is a LPWA (Low-Power-Wide-area) network that was designed to be used with IoT (Internet of Things) devices, the idea behind SigFox is to securely transmit data to and from the cloud whilst reducing the energy consumption and cost of transmitting the data.

b) Why SigFox?

I have considered multiple wireless technologies mainly focusing on Bluetooth, Mobile(3G/4G) and Wi-Fi technologies, after exploring these mentioned options I encountered SigFox which combined the advantages and eliminated the disadvantages of the aforementioned technologies for the purpose required in this project, to put things in perspective here is a little table.

	Pros	**Cons**
Bluetooth	➢ Fast ➢ Cheap ➢ Low-Power	▪ Small Range
Mobile 3G/4G	➢ Fast ➢ Global Coverage ➢ Power Intensive	▪ Expensive Data Transfer
Wi-Fi	➢ Reliable ➢ Inexpensive	▪ Mid-Range
SigFox	➢ Cheap ➢ National Coverage ➢ Low-Power	▪ Small Bandwidth

SigFox offers national coverage which means we do not have to worry about accessing the network, the data transfer is cost efficient and most importantly the solution features ultra-low power consumption, to top things off SigFox uses a triple diversity scheme which results in secure transmissions that cannot be intercepted by hackers.

The only considerable downside to SigFox is that it is not suitable for high-bandwidth usage communications but this is not a problem if we're transferring small amounts of data from a sensor.

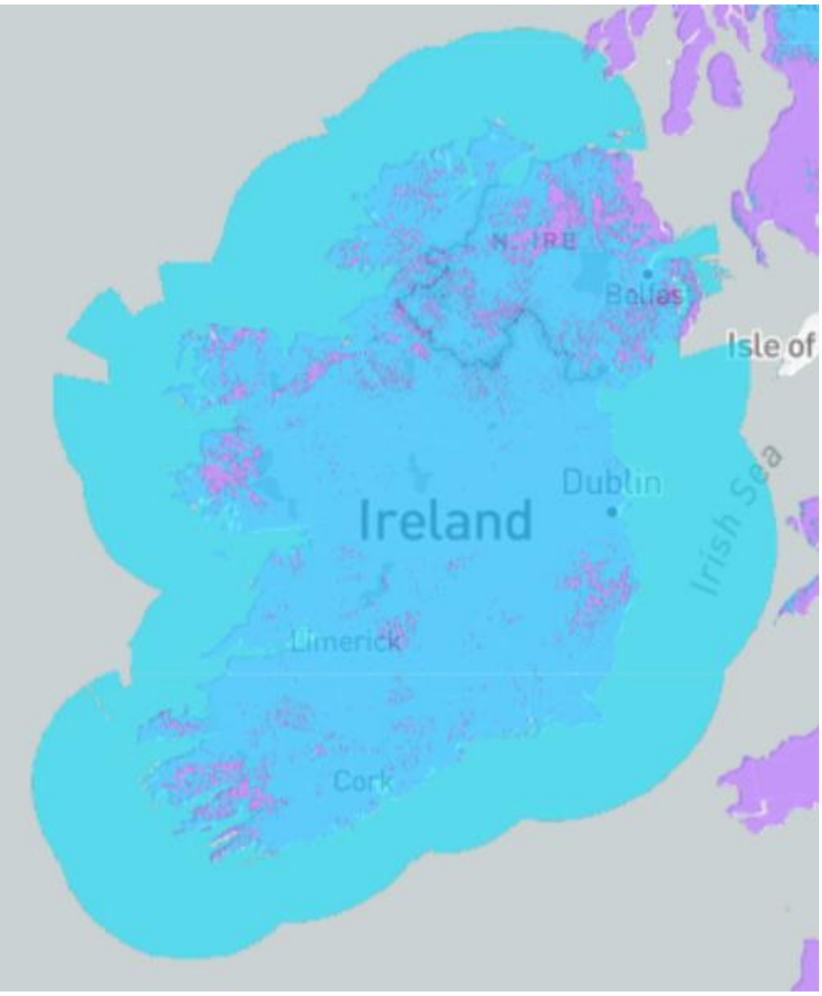

Figure.1 Representation of the SigFox coverage map of Ireland.

Above in Figure.1 is the live SigFox coverage of Ireland the blue area is the area covered by the network whilst the purple areas do not offer coverage these are usually mountainous or depression areas.

c) Tilt Angle Measurement

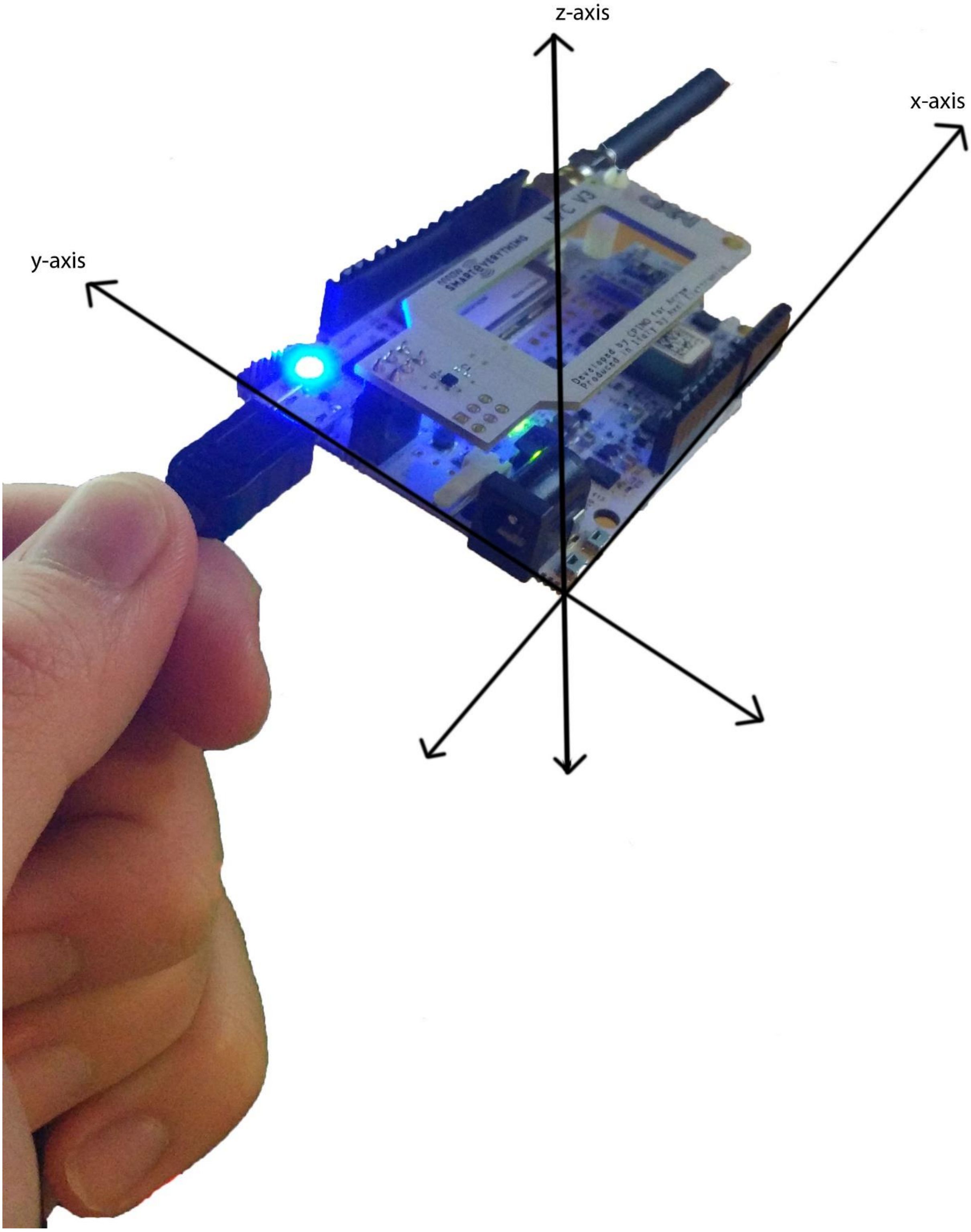

Figure.2 Axis representation.

Roll – is the rotation around the x-axis

Pitch – is the rotation around the y-axis

Yaw – is the rotation around the z-axis

Gx, Gy, Gz represent the acceleration in the x y and z plane.

Roll formula: $\tan^{-1}\frac{Gy}{Gz}$

Pitch formula: $\tan^{-1} - \frac{Gx}{\sqrt{(G^2y+G^2z)}}$

The results returned by the above formulas is in Radians therefore it is multiplied by $\frac{180}{\pi}$ which gives a result in degrees.

Yaw calculation is not considered as it would require the use of a magnetometer to obtain precise values due to the fact that there is no change in the force of gravity in the z-plane.

d) Applications:

After performing my research, I have found that there are many existing wireless tilt sensors[4][5] and a broad range of interesting applications for a tilt sensor in different fields, one interesting application is using the sensor to measure the tilt of a window in a house security system[4] therefore to activate the alarm a burglar attempts to pry open the window the tilt sensor will detect discrepancies and sound the alarm.

3. Requirements

- MCS761- Development Board[6]
- Registering the SigFox device with the SigFox network
- Computer with compiler software in this case the Arduino IDE
- Various Software Libraries to support the Board.
- USB Data Cable for uploading the software to the board
- A battery for remote testing
- Multimeter for measuring the current used by the device

4. Detailed Action Plan

1. Product Research – 11th September – 1st October 2017.
2. Design of Device – 11th September – 15th October 2017.
3. Ordering Parts – 16th October – 22nd October 2017.
4. Interim Report – 23rd October – 19th November 2017.
5. Tilt Sensing Implementation – 30th October – 26th November 2017.
6. Wireless Communication Implementation – 13th November – 10th December 2017.
7. Functionality Testing – 4th December – 17th December 2017.
8. Low Power Improvement – 11th December – 31st December 2017.
9. Final Testing – 25th December – 3rd February 2018.
10. FYP Report Completion – 14th January – 16th March 2018.

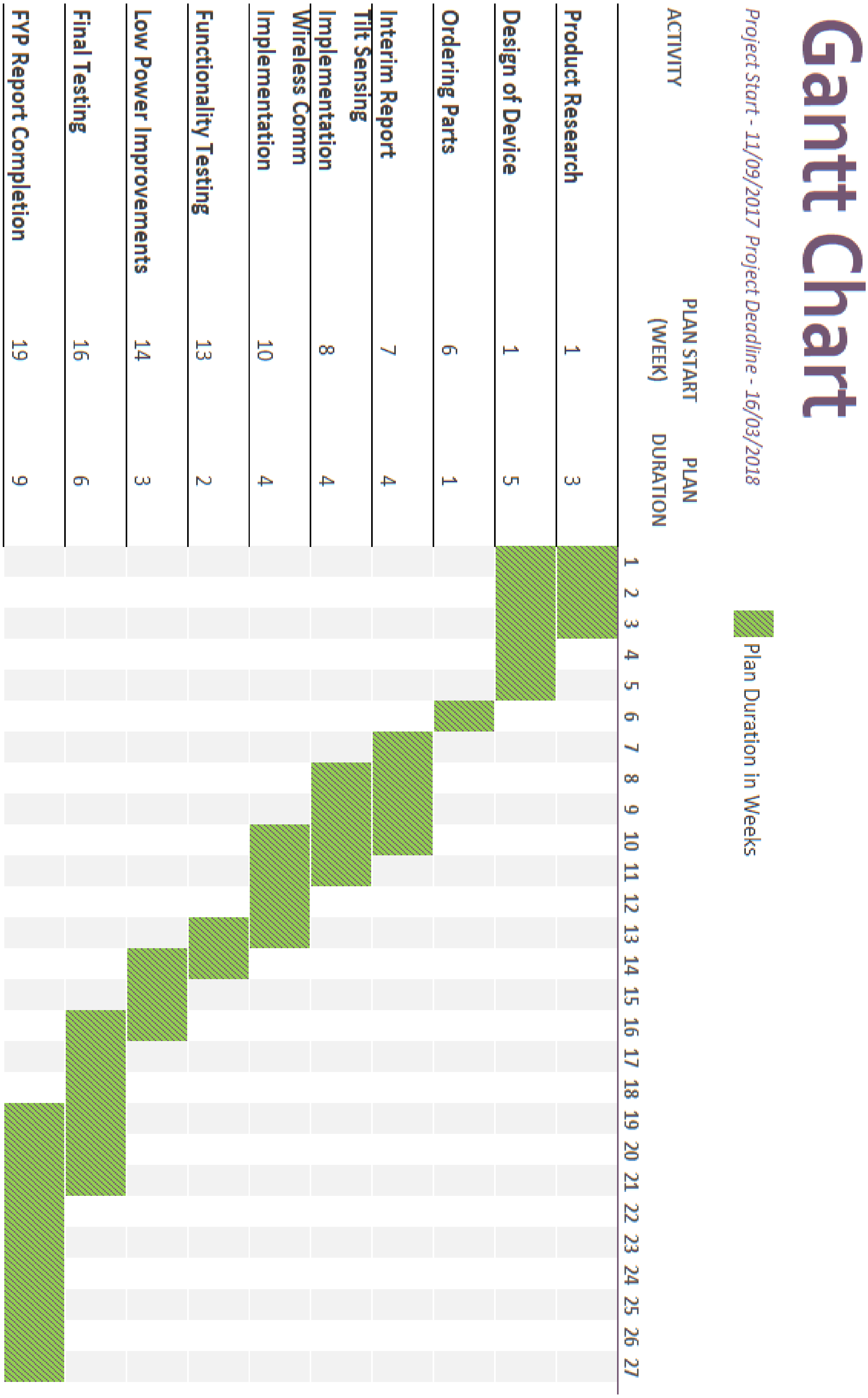

Figure.3 Gantt Chart

5. Outline Designs

a) Initial Set-Up

The initial set-up consisted of downloading and installing the Arduino IDE software, registering the SigFox module using an ID and a Hex key provided with the board and then acquiring all the necessary libraries that will be used for this project. The libraries used are as follows:

Arduino SAMD Package – Used to communicate with the ARM MCU.

Arduino Low Power Library – Used to manage the interrupts on the board.

SmartEverything LSM9DS1 Library – Used by the accelerometer.

SmartEverything SIGFOX LE51-868 Library – Used by the SigFox module.

After registering for the SigFox network which is hosted by VT Networks in Ireland. After sending the first message to the network we obtain the signal strength statistics visible in Figure.4 and a very rough location approximation seen in Figure.5.

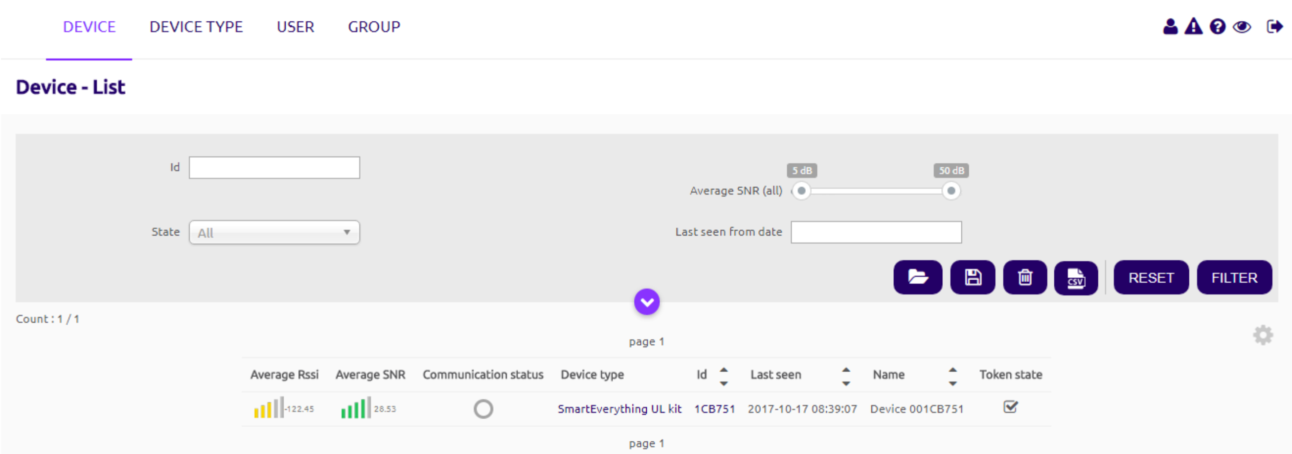

Figure.4 Backend view of the SigFox cloud web service.

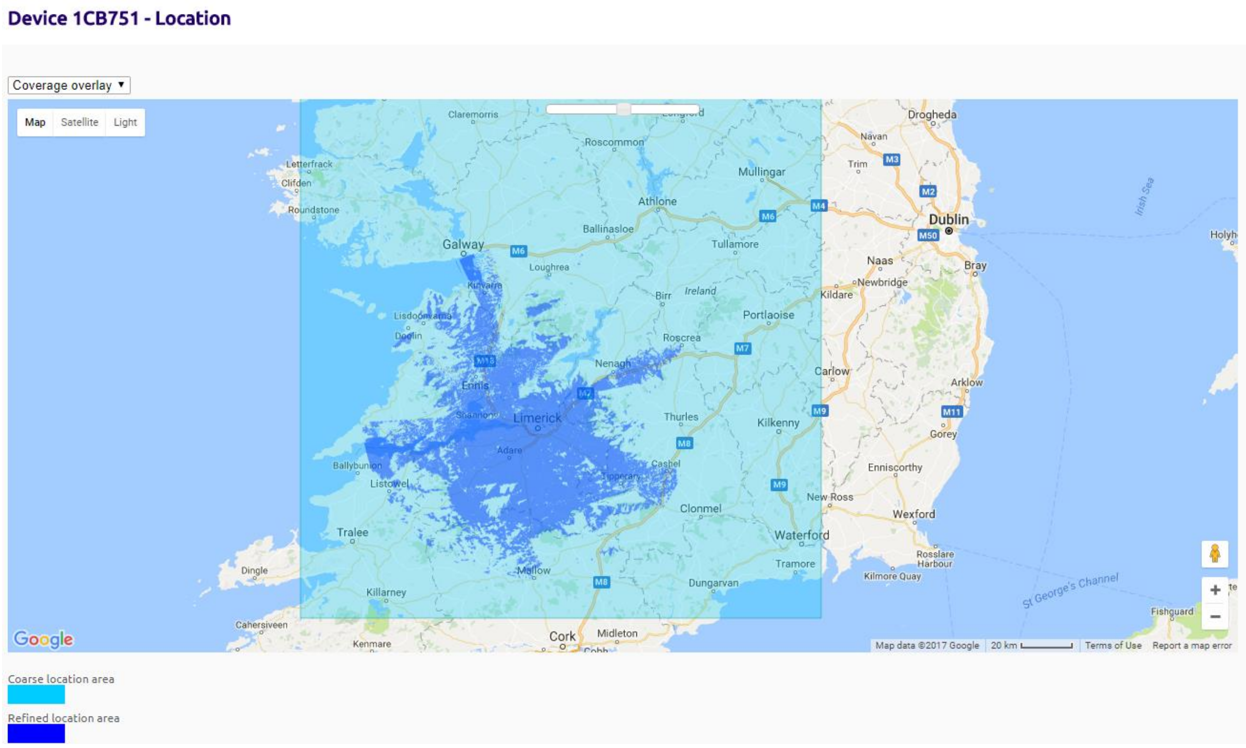

Figure.5 Rough approximation of the SigFox module location.

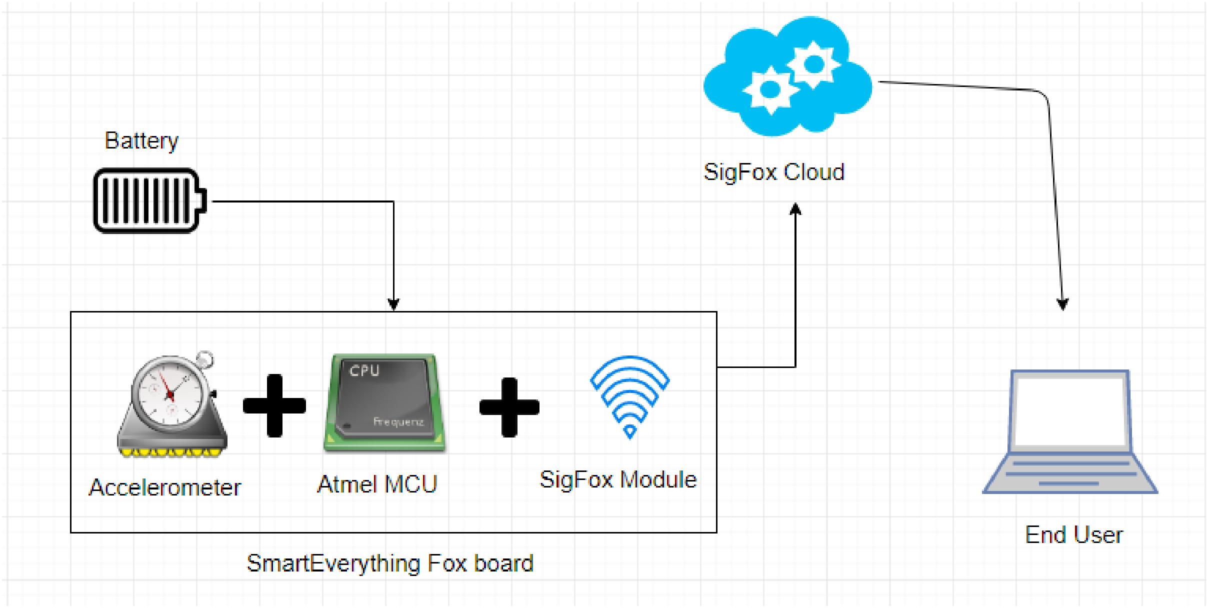

Figure.6 Representation of the set-up.

After the above libraries were installed the unit’s modules and sensors were tested to verify they were functional. In Figure.7 the testing of the accelerometer can be seen.

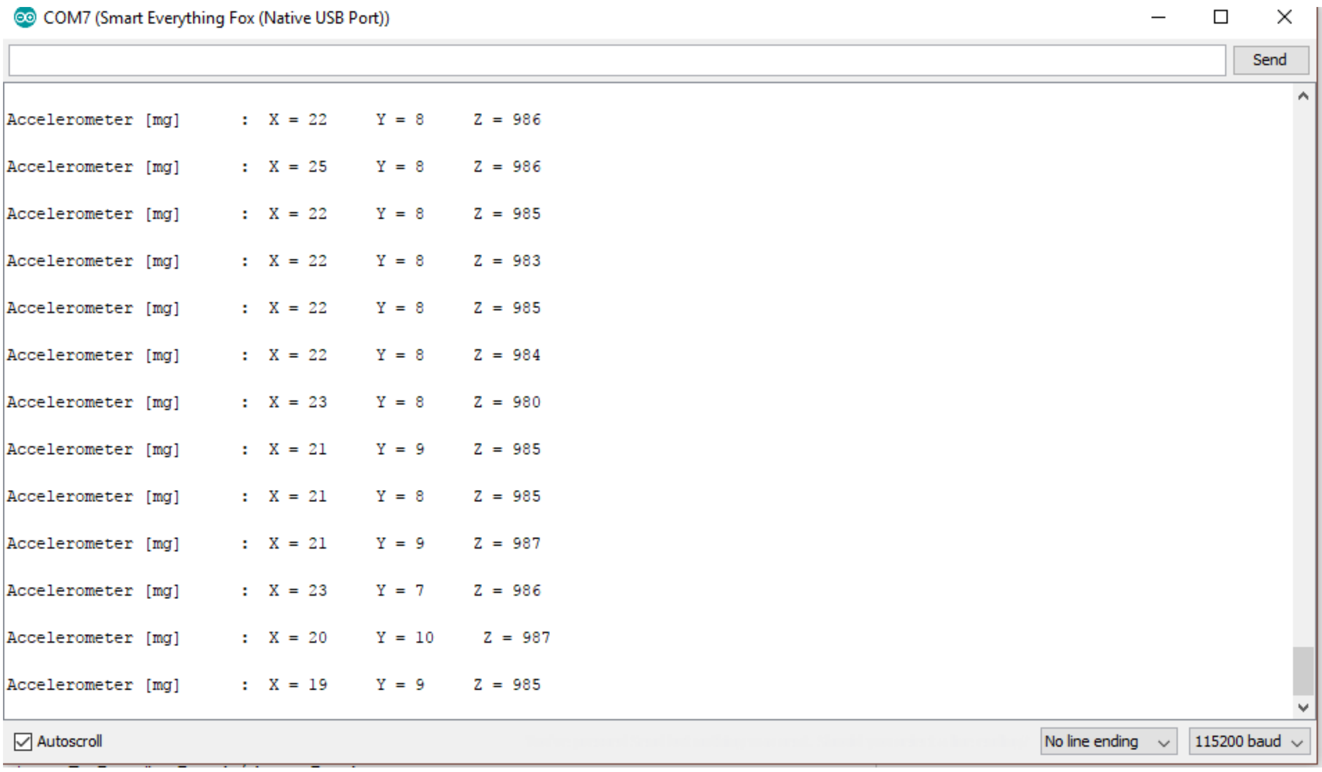

Figure.7 Serial Port output from the microcontroller.

b) Program Structure

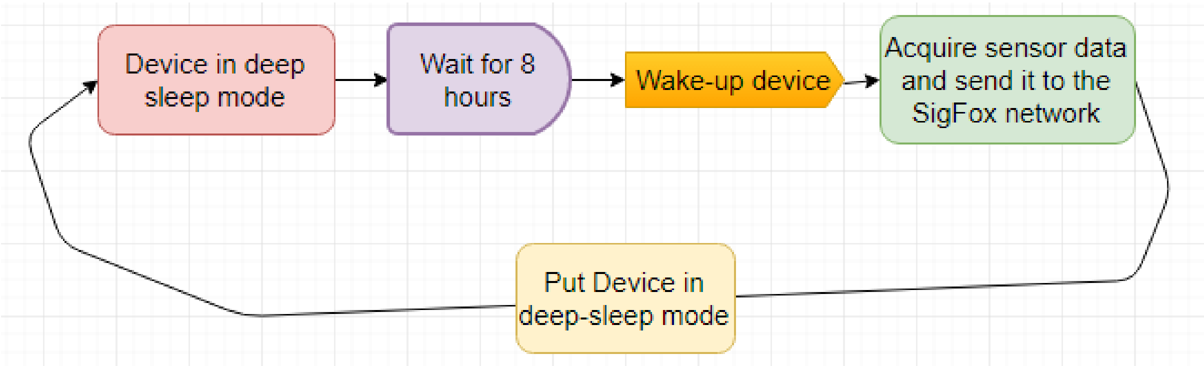

Figure.8 Code structure.

To optimize the battery life, the sensor data will be collected and sent to the SigFox network 3 times per day as visible above in Figure.8. Due to the optimization a much longer operating time should be achievable which means the unit will be maintenance free for a longer time.

c) Power Consumption

Power Consumption according to data sheet specifications.

Current Consumption	Atmel SAM D21 (ARM MCU) [1]	Telit LE51-868 S (SigFox module) [2]	LSM9DS1 (Accelerometer) [3]
Sleep Mode (Standby)	23uA	2uA	0A
Running (Low Power Mode)	50uA	Rx:32mA Tx:55mA	1.9mA

Looking at the above table we obtain a value of 25uA while the device is in sleep mode and averaging around 50mA while transmitting and acquiring the sensor data.

Using the above specifications and the following assumptions:

- The time frame to acquire and send the data is 1 minute.
- The battery used has a capacity of 500mAh
- The device goes to deep sleep immediately after the data is sent.
- External factors are not taken into regard.
- A month taking an average of 730 hours.

We come to these hypothetical conclusions:

Sleep Mode – 27 months of operation ($\frac{500mAh}{0.025mA} = 20000$ hours).

Running Mode – 10 hours of operation ($\frac{500mAh}{50mA} = 10\ hours$).

- Continuing we get 600 minutes from the 10 hours, at 3 data acquisitions per day we conclude hypothetically the device could last for 200 days without changing batteries.

6. References and sources of information

The specification on the SigFox module and its functionality has been obtained from its official website www.sigfox.com

The Arduino Libraries used for this project are developed by "SmartEverything" the open source libraries can be found at https://github.com/ameltech

The Tilt measurement research has been aided by an Application Note "AN4509" created by "STMicroElectronics", www.st.com and by www.dfrobot.com

Further Tilt Measurement research aided by "Mark Pedley", www.nxp.com

Further Tilt Measurement research aided by "Bosch Sensortec", www.bosch-sensortec.com

[1] Data sheet specification for the Atmel SAM D21 MCU, found at http://www.atmel.com/Images/Atmel-42472-Peripheral-Power-Consumption-in-Standby-Mode-for-SAM-D-Devices_ApplicationNote_AT6490.pdf

[2] Data sheet specification for the Telit LE51-868 S SigFox module, found at https://www.telit.com/wp-content/uploads/2017/09/Telit_LE51-868_S_Datasheet.pdf

[3] Data sheet specification for the ST LSM9DS1 iNEMO Inertial module accelerometer http://www.st.com/content/ccc/resource/technical/document/datasheet/1e/3f/2a/d6/25/eb/48/46/DM00103319.pdf/files/DM00103319.pdf/jcr:content/translations/en.DM00103319.pdf

[4] Idea for an application from Honeywell https://www.security.honeywell.com/hsc/products/intruder-detection-systems/wireless/door-window-sensor/568365.html

[5] A wireless accelerometer with smaller range from Tartsensors https://www.tartssensors.com/product/wireless-tilt-sensor

[6] Development board by Arrow http://ie.rs-online.com/web/p/radio-frequency-development-kits/9015121/