Universitat Pompeu Fabra

Bachelor Thesis

Open Sensor Network

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for the degree of Graduate in Telematic Engineering

in the

Research Group Name
Department or School Name

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Declaration of Authorship

I, Alejandro ANDREU ISÁBAL, declare that this thesis titled, 'Open Sensor Network' and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
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Signed: ____

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"Thanks to my solid academic training, today I can write hundreds of words on virtually any topic without possessing a shred of information, which is how I got a good job in journalism."

Dave Barry

UNIVERSITAT POMPEU FABRA

Abstract

Escola Superior Politècnica
Department or School Name

Graduate in Telematic Engineering

Open Sensor Network

by Alejandro ANDREU ISÁBAL

The Thesis Abstract is written here (and usually kept to just this page). The page is kept centered vertically so can expand into the blank space above the title too...

Acknowledgements

The acknowledgements and the people to thank go here, don't forget to include your project advisor…

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Abbreviations

ADC	**A**nalog to **D**igital **C**onverter
BuB	**B**ottom-**u**p **B**roadband
ISM	**I**ndustrial **S**cientific and **M**edical
LAN	**L**ocal **A**rea **N**etwork
LoS	**L**ine **o**f **S**ight
PAN	**P**ersonal **A**rea **N**etwork

Physical Constants

Speed of Light $c = 2.997\ 924\ 58 \times 10^{8}\ \mathrm{ms^{-S}}$ (exact)

Symbols

a	distance	m
P	power	W (Js^{-1})
ω	angular frequency	rads^{-1}

For/Dedicated to/To my…

Chapter 1

Introduction

During the last years, we the Internet users just had one chance to know how things are managed, from top to bottom. That is, telecom operators reserve some resources (optic fiber, certain bandwidth, etc.) for each one of their clients and charge them for this service. In a top-down approach the consumer remains completely passive and has to solemnly accept what the telco dictates. Now, a new model pretends to turn this trend upside down.

This new way to do things is called *bottom-up broadband*, and is also how this project is posed. The very same users that were before passive will become very active, helping not only by designing the network but also deploying and maintaining it, thus participating in every step of the system lifecycle. Hence, without a central authority the usufructuaries are the only ones that conform this kind of networks.

Bottom-up broadband (BuB from now on) schemes have several important advantages over those that follow a conventional top-down approach, such as: easier and faster setup due to the lack of a central authority (as it happens in peer-to-peer networks), it can be adapted to anyone's needs since they are the caretakers of the system, and could also become the solution to those that live in an area that is not economically attractive to regular ISPs[].

As for disadvantages, a BuB network creation can be very time consuming, since users participate in every single step of this endeavor[].

Sensor networks are very important nowadays and its objective is to gather data.

> Data itself isn't good nor bad. Data just represents the surrounding reality. The more data we may access, the more accurate model we may create of the

reality, thereby also define our actions in ways that are maximally beneficial to our aims[].

But, does it make sense building such a sytem under a BuB model? The answer is yes, it does. As it happened with traditional telecom operators, the information that is obtained through sensor networks is kept by the agencies that own them without even making a public API to "play" with this data.

Therefore the main goal of this project is to design and deploy a sensor network that gathers real-time information and that enables developers to create applications that will ultimatelly help the citizenship improve their daily lives. Intrinsically this can be divided in more specific objectives, such as:

- Allow citizens, individuals belonging an organization or even enterprises to connect scattered sensor nodes.
- Collect different kinds of information and transmit it to the Internet.
- Samples (values of sensors) must be gathered ofen enough to be almost real-time.
- Use of open technologies to allow easier replicating and modification as well as reducing final costs.
- The project shall become a tool so anyone that needs or wants to deploy a sensor network can do it as soon as possible.

Chapter 2

State Of The Art

Sensor networks, as many other technological advances see their origin on military research. They date back to the early 60's during the Cold War, when the United States deployed an underwater system to detect Soviet submarines called SOSUS (sound surveillance system). However, it is not until the beginnings of the 21st century that more applications were found beyond warfare. The main causes for that to happen is that the cost and the size of the components did decrease.

Also, new sets of wireless standars did see the light: IEEE 802.11[] and IEEE 802.15[], which enable wireless communication to experiment similar bitrates to those obtained in a wired network.

One of the motivations to develop an open sensor network is that normally those who are the owners of the information keep it to themselves, a situation on which nothing is given back to society. Thus social, cultural and urban development gets narrowed[1].

Also, deploying sensor networks significantly contributes to the growth of smart cities ICT structures which, at the same time, makes urban areas thrive[2].

There are already some initiatives that make use of wireless sensor networks. The word “initiative” is not intended to refer just to companies but also to organizations and individuals. At the time of writing, we can distinguish between two main kind of sensor networks, company or community driven networks, depending on who shapes the system.

These networks can originate a big amount of data creating the necessity of storing this information and making it always available for further usage. There are already some websites with the only objective of storing this information and providing beautiful visualization tools.

2.1 Company-led sensor networks

These kind of systems work normally in an opaque or translucent way but with the advantage that they have very clear objectives. Also, they usually have more resources, being the main motivation making money.

expandir

2.1.1 Libelium

This is one of the biggest companies in the world built around wireless sensor networks. It offers the mechanisms and tools to deploy/build systems around the Internet of Things, smart cities and M2M communications.

The majority of the products they sell are focused on one specific application, such as waste management, structural health, etc. These are intended to be bought by system integrators for end users. However, they also offer the so-called "Waspmote", which is a sensor device for developers that can be freely customized and reprogrammed, since this is an open source product.

Their products are being widely used across more than 75 countries and they are definitely one of the leaders of the wireless sensor network industry.

2.2 Community-led sensor networks

Projects that are driven by the community give all the decision making power as well as resources to the community. The individuals that conform the community are very passionate about what they do and the *forma de trabajar* is highly transparent.

Community-driven projects give more control to the individual user. *expandir*

2.2.1 Air Quality Egg

This is a sensor network that aims, as its own name indicates, to measure the air quality through NO_2 and CO levels.

Each user is supposed to connect their egg to their local network via an Ethernet inferface. Then, a bunch of outdoor sensors are placed outside and communicate their readings to the base station (the egg) wirelessly through a radio frequency transmitter. Finally the data is sent in real time to Cosm, an open data portal that will be described in the next section.

It is worth mentioning that the AQE project is completely open, hence anyone can improve the platform as well as building his own egg from scratch without having to actually buy one. All the information related to the hardware, software and sensor calibration can be found in their wiki.

2.2.2 Smart Citizen

Although this is a very young project (still in beta stage) it intends to create the biggest community around social sensing. It was initially crowdfounded in 2012 through a Goteo campaign and they are planning on going to Kickstarter soon.

The Smart Citizen platform allows its users to precisely geolocate their data and see other users' information. There is also a very big emphasis in data sociability, since every value or datastream[1] can be shared through any social networking site or even inside the same web application.

Openness is as well one of their main values, since every piece of code (including the website) is open source licensed.

2.3 Open data services

All gathered information must be stored in some place, and this is where open data portals come in play.

These websites provide users with an open API so they can upload new values, create new feeds (representation of an environment), retrieve the data end even create customized triggers, such as sending a push notification to a smartphone or even "tweeting" something. This way, we cannot only sense but *act* to certain kinds of events.

Because data by itself is usually worthless, one of their most important features are data visualization tools. They allow us to easily detect patterns and also even correlate certain factors.

Good examples of these sites are, as mentioned before, Cosm and Sen.se. Both are free to use and very easy to interact with (mainly through HTTP packets).

In case we want to host our own cloud for the Internet of Things, there is also a great solution called Nimbits. It is open source software and anyone

[1]Set of values that represent an individual sensor.

can install it in its own server. It is very easy to fetch and push data to the platform, since it has a RESTful API.

Chapter 3

Technologies

Three essential blocks form a sensor network. Namely sensors, processors and communication devices[3]. In the next sections all of them will be explained and in the next chapter I will show how are these related. There is even a case where a device (Digi XBee®) fulfills two of these roles.

3.1 Sensors

We now live in a world where we hear a lot the word "sensor", but what is exactly a sensor? *A sensor is a converter that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument.*[4]

This definition might seem (and is) quite simple, but complexity resides on calibration and coming up with actual useful applications. Since every sensor from the same family is equal in terms of design but different in reality (due to small random variations during the fabrication process) output has to be adjusted to agree with a given standard. When it comes to applications, RFID tags can be used to determine wether a book is on the right spot in a library or not, or with a very intense light beam we can detect how the blood flows through a vein thus succesfully sensing heart rate. These are just two imaginative uses for nowaday sensors.

In the first (and only at the time) iteration of this pilot only environmental factors have been measured since those have been tested over and over for the last years and they serve as a proof of concept for this network.

3.1.1 Aosong DHT22

The DHT22[5] is a low cost humidity and temperature sensor designed by Aosong Electronics, a Chinese corporation. This is a digital sensor, which means that the output is represented in the form of bits, thus requiring some amount of computational power to "interpret" the results. The output format is precisely described in the datasheet of this product, and luckily there already are some library implementations to work with the DHT22. Then, this device will only work with platforms that allow digital input, such Arduino.

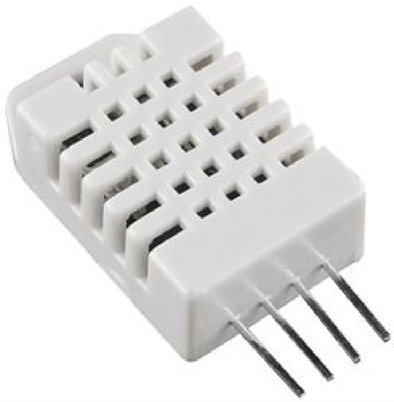

Figure 3.1: DHT22 humidity and temperature sensor.

3.1.2 Emartee Mini Sound Sensor

Manufactured by Emartee, can also be found by the name of "Emartee part number 4021", and can be used to measure noise levels among other uses. Esentially, it consists on a microphone with a built-in amplifier onto a breakout board, which can be useful to work directly with perfboards or breadboards (both construction bases for rapid prototyping of electronic circuits).

The output signal is analog and is increased by a factor that allows an Arduino or any device with analog I/O pins to detect it easily[6]. Its operating voltage is 5V.

3.1.3 Sharp GP2Y1010AU0F

This is an inexpensive optical dust sensor, used to measure air quality. It is made out of an infrarred emitting diode which with a well positioned phototransistor can measure the reflected IR rays thus detecting dust levels in the air[7]. This device, which can be powered with up to 7V gives an output voltage (analog) proportional to dust density in the air. Some of its applications are air monitoring and air conditioning.

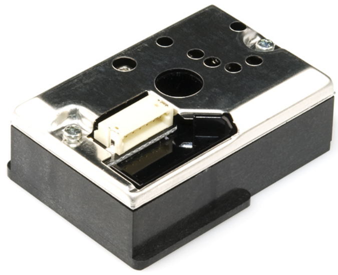

FIGURE 3.2: Sharp GP2Y1010AU0F optical dust sensor.

Surprisingly, this detector, which is worth at the time of writing about $12, gives very precise results, similar to those offered by an expensive laser particle counter.[8]

3.2 Digi XBee® Wireless RF Module

These radio modules are based on the IEEE 802.14.4 standard and provide an unexpensive, low power, low rate communication. They mainly use ISM bands. Despite their size provide us with many interesting features, such as 128-bit encryption, over-the-air configuration and ADC/digital input/output pins[9].

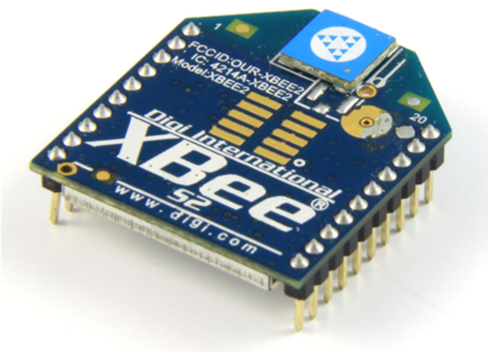

FIGURE 3.3: Digi XBee® Wireless RF Module

There are two versions of these modules, named “Series 1” and “Series 2”. The older one (Series 1) implements the previously mentioned IEEE 802.15.4 standard which allows point to point (or star) topologies. On the other hand however, the latter implements a standard specification called *ZigBee*. This protocol, although more complex has mesh networking capabilities which can be a key feature in some sensor networks.

This is why for the sake of this project “Series 2” has been chosen. It is worth saying that each of the two versions can transmit with different power levels thus varying the effective communication range[10]. More detailed information can be found in the table below.

Version	Power	Indoor range	LoS range[1]
Series 1	1mW	30m	100m
Series 1 PRO	63mW[2]	90m	1600m
Series 2	2mW	40m	120m
Series 2 PRO	63mW[2]	90m	1500m

TABLE 3.1: Comparison of different versions of XBee®.

Also, if extra range is needed (up to 40km in line of sight) there are also XBee® devices that transmit in lower ISM bands (900 and 868 MHz). However, when transmitting in these frequencies neither ZigBee nor IEEE 802.15.4 can be used. DigiMesh™ networking protocol is the only option and it is property of Digi International Inc.

3.3 Arduino

Arduino is the leading protopying platform nowadays. It is completely open source including the schematics of the hardware itself, which is a single-board microcontroller. Anyone can program the board through a programming language very similar to C/C++ and based on Wiring. To upload a sketch (a program) to the microcontroller they also have developed an Arduino IDE based on Processing.

The amount of projects related to this platform is incredibly big, and it has gained huge popularity amongst designers, hackers, programmers and hobbyists these past years. It offers several advantages over similar devices, because it is really cheap, cross-platform and has every benefit inherent to

[1] LoS range refers to line of sight range, where a straight line can be drawn from the transmitter to the receiver. In this situation, there are no obstacles between them and better bitrates and/or ranges can be achieved.

[2] This output power can be obtained using high gain antennas.

the open source initiative. Also, like other open projects Arduino comes in many "flavours" depending on the characteristics of the project.

As it can be seen on the next picture, the board has many input/output pins that are compatible with analog and digital values. It's not just that but also it can establish a serial communication with a computer so interaction between programs and the platform can take place.

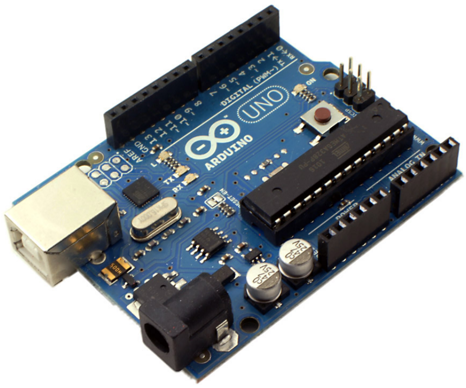

FIGURE 3.4: Arduino UNO prototyping platform.

Arduino UNO is the one "flavour" that has been chosen to perform this project, since it is cheap and also the most common. That means all shields[1] work by default on it and the community it has is the biggest. In particular, this model has the following features[11]:

Feature	Value
Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by bootloader
SRAM	KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

TABLE 3.2: Characteristics of the Arduino UNO.

[1]A shield is another board plugged on top of the Arduino to extend its functionalities.

Chapter 4

Methodology

The first step I took to complete this project was having a deep look at the state of the art. There are a lot of sensor network designs and some are as well open sourced, but the majority of them require either advanced knowledge on PCB fabrication or are focused on just one particular area (they aim to solve just one problem). Thus developing a system which is multipurpose and uses well-known technologies for rapid deployment are some of the key requirements that this network should meet (apart from the initial objectives).

Once all initial requirements are identified I had to choose one appropriate life cycle for the project. The pilot scope was not strictly constrained thus changes shall be handled in some way. Consequently, I chose an agile[] approach.

Agile management is a special case of iterative management, driven by changes[**?**]. Development of small modules is the usual thing, with deadlines every two or four weeks. Also, stakeholders are highly involved which is very related to the approach we followed all the components of BuB4EU. Each month there was a scheduled workshop where every participant informed the rest of the team about his/her last advancements. This method is very useful for getting constant feedback hence improving the overall quality of the project.

At the same time, the pilot followed an open development model, since it was (and still is) available on GitHub from the beginning. Open projects present several advantages over closed ones[], such as: penisses.

Appendix A

Appendix Title Here

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