Intelligent Sensing Anywhere

Ambient Assisted Living System

Local Monitoring Console

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Thank you all.

ABSTRACT

Ambient Assisted Living is a concept of growing importance in today's ageing society, as life expectancy and elderly people's percentage increases and, with it, healthcare system's efficiency becomes urgent. AAL can be defined as life in a supportive environment.

An AAL system should ideally be implemented as a series of modular, interoperable and intercommunicating concepts, aiming to build a sort of "virtual intelligence" around the user.

In recent years, there have been some attempts to create concentration modules for monitoring systems but, so far, none has been comprehensive enough to support an integrated AAL system. This project invests on a low-budget solution supporting different, already existing, health and environmental information-collection technologies to create such system.

Project's research and development resulted in a prototype software solution running over a Linux-based firmware, on a standard wireless router platform, with support for two different health monitoring devices and one energy-consumption monitor. Concept's validity has been proven and path for desired full-feature solution is now open.

RESUMO

Com o aumento da esperança média de vida, da percentagem de idosos e uma consequente urgência de melhoria de eficiência na prestação de cuidados de saúde, o conceito de *Ambient Assisted Living* tem vindo a ganhar importância na sociedade actual. Este conceito pode ser definido como vida em ambiente de apoio.

Idealmente, um sistema de AAL deve ser implementado como uma série de conceitos modulares, inter-operacionais e inter-comunicantes, com o objectivo de construir uma espécie de “inteligência virtual” em torno do utilizador.

Em anos recentes, têm sido criados lançados alguns projectos de módulos concentradores para sistemas de monitorização, sendo que, até hoje, nenhum apresentou abrangência suficiente para suportar um sistema integrado de AAL. Este projecto aposta numa solução de custo reduzido com suporte de diferentes tecnologias já existentes para a recolha de informação clínica e ambiental, que permita a criação de tal sistema.

O projecto de investigação e desenvolvimento resultou numa solução de software protótipo, a correr sobre um firmware baseado no sistema Linux, numa plataforma standard de router wireless com suporte para dois tipos de monitores de sinais vitais e um monitor de consumos energéticos. A validade do conceito foi comprovada e o caminho para uma solução completa encontra-se agora aberto.

INDEX

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

AAL	Ambient Assisted Living
CFE	Common Firmware Environment
CGI	Common Gateway Interface
CSS	Cascade Style Sheets
ECG	Electrocardiography
EDF	European Data Format
EDR	Enhanced Data Rate
EMG	Electromyography
GB	Gigabyte (1Gb = 2^{30} bytes)
GPL	GNU Public License
GPRS	General packet radio service
GSM	Global System for Mobile Communications
HTML	Hyper Text Markup Language
IP	Internet Protocol
JTAG	Standard Test Access Port and Boundary-Scan Architecture
LED	Light-Emitting Diode
M2M	Machine to Machine
MAC	Media Access Control
Mb	Megabyte (1Mb = 2^{20} bytes)
MHz	Megahertz (1MHz = 10^{6} Hertz)
MIPS	**M**icroprocessor **w**ithout **i**nterlocked **p**ipeline **s**tages (computer architecture)
NTP	Network Time Protocol
SpO2	Pulse Oximeter Oxygen Saturation
UMTS	Universal Mobile Telecommunication System
USB	Universal Serial Bus

CHAPTER 1: INTRODUCTION

This document is the author's thesis for a master degree in Biomedical Engineering at the University of Coimbra. It is the final result of a research project developed in an internship at ISA – Intelligent Sensing Anywhere, S.A. and aims on presenting the work there developed.

It also intends on being a reference for future improvements on the monitoring console and for future works and approaches to the theme.

1.1 DOMAIN AND MOTIVATION

"There is no reason for older people in Europe to miss out on the benefits of new technologies. The solutions and services resulting from this programme will help them to remain active in society as well as staying socially connected and independent for a longer time,"

Viviane Reding, EU Commissioner for the Information Society and Media (1)

Ambient Assisted Living means life in a supportive environment (2). It is a concept of growing importance nowadays, as life expectancy increases and, with it, elderly people's percentage and society's overall ageing.

As chronicle diseases and conditions have higher incidence among older people, there is a necessity to provide them with assistance, vigilance and safeness, while maintaining their privacy, independence and life quality. AAL is an approach to this scenario that uses advanced biomedical monitoring technologies integrated with domotic instrumentation and environment analyzers to monitor and assist people who live alone and/or people with special needs.

The AAL concept is very wide and comprehensive. Within it, there is a place for all the systems, devices, services as well as for supporting methods and concepts used in providing an unobtrusive support for daily life activities. Being dependent on the assisted individual's context, this support should be very user-oriented and should easily integrate with the user's personal environment. (3)

An AAL system should ideally be implemented as a series of modular, interoperable and intercommunicating concepts capable of adding/removing functionalities to the system, aiming to build of a sort of "virtual intelligence" around the user. (3)

Within the general monitoring solution, the local monitoring console is the module responsible for collecting and concentrating information from a large number of acquisition devices. It is then the first module to have a comprehensive perspective of the environment and, if there would be enough processing power, maybe the ideal to early detect anomalous situations, handle alarms and coordinate system's actions. The console shall also be a "gate" to the outside world, transmitting the collected information and receiving instructions to/from the healthcare provider or directly alerting the family, neighbors or a medical emergency team if an alert is deployed.

1.2 Objectives

This project's guiding objective is the development of a prototype for the concentration module. This prototype shall prove the concept's validity and provide a base for exploring the different application possibilities.

It is imperative to build an open system, able to support a variety of different devices, communication protocols and monitoring scenarios that could be configured and adapted to each particular case. For this reason, the software solution should be built in modules

It is also important for the console to work even when Internet access is not available, so it should bear the collected data's transmission to a remote server as well as supporting its local processing and storage, and it should enforce redundancy in the outgoing communications as a way of ensuring effective diffusion of alarms and critical data.

The console needs not to be seen as "another box", another system, another jigsaw with which is difficult to interact. Instead, it should aim on being an all-in-one central device, concentrating control of all the existing systems and providing a friendly and easy-to-use interface, appealing to the public.

Finally, being ISA actively enrolled in the seek for solutions on the energy efficiency problem, and one of this console's applications may well be monitoring domestic energy consumptions, it would be of great interest to find a solution with low power consumption.

1.3 Document Structure and Organization

This document is structured in seven chapters.

The present one introduces the theme, providing an overview on the project's domain, motivation and objectives.

The following chapter presents the project's development team, defined tasks and its planning and evolution.

Third chapter starts by analyzing context in which this project emerged by presenting a small state-of-the-art study. From there, an approach to a low-cost monitoring console will be described as well as research conducted on a solution using routers and open-source firmware.

The system's architecture is analyzed on Chapter 4, including system's hardware component, features and requirements and used communication protocols.

Chapter 5 is dedicated to the software solution, exploring the developed web-interface and monitoring modules, as well as how those pieces fit together.

The built prototypes are presented in Chapter 6, as well as performed tests and a report on the identified and unsolved bugs.

Final chapter – Chapter 7 – presents conclusions, makes a reflection on the developed work and points directions for eventual further improvements to this project.

Chapter 2: Project Management

The project has been developed under a partnership between the University of Coimbra, through the Electronic Instrumentation Center (CEI) of the Physics Department and ISA – Intelligent Sensing Anywhere, S.A, and in an internship at this company.

ISA is an international technological company, specialized in Telemetry and M2M Communications. Its innovative products and solutions granted it international recognition and leadership in several market segments, such as Oil & Gas, Energy, Environment, Building Management and more recently Healthcare and Medical Solutions.

2.1 Team

Table 1 presents the project's team.

Table 1 - Project's development team

Henrique Madeira	Student
Engineer Soraia Rocha	Project Manager / Main Supervisor
Engineer João Alves	Technical Advisor / Supervisor
Engineer Paulo Santos	Supervisor
Engineer José Luís Malaquias	Supervisor
Engineer Catarina Pereira	Supervisor
Professor José Basílio Simões	Advisor
Professor Jorge Landeck	Advisor

2.2 Tasks

The project started with a learning period in which the student has made contact with ISA's structure, its main projects and work/business areas and with the experience left by former interns that have developed their curricular projects at ISA, in previous years. This period was also used to improve the student's knowledge on tools and techniques that he would be using later on, during development phases. Among these, C programming language (including advanced topics, like linked lists, binary trees and memory mapping), GNU/Linux programming and web technologies (HTML, CSS and CGI scripting) received special attention and dedication.

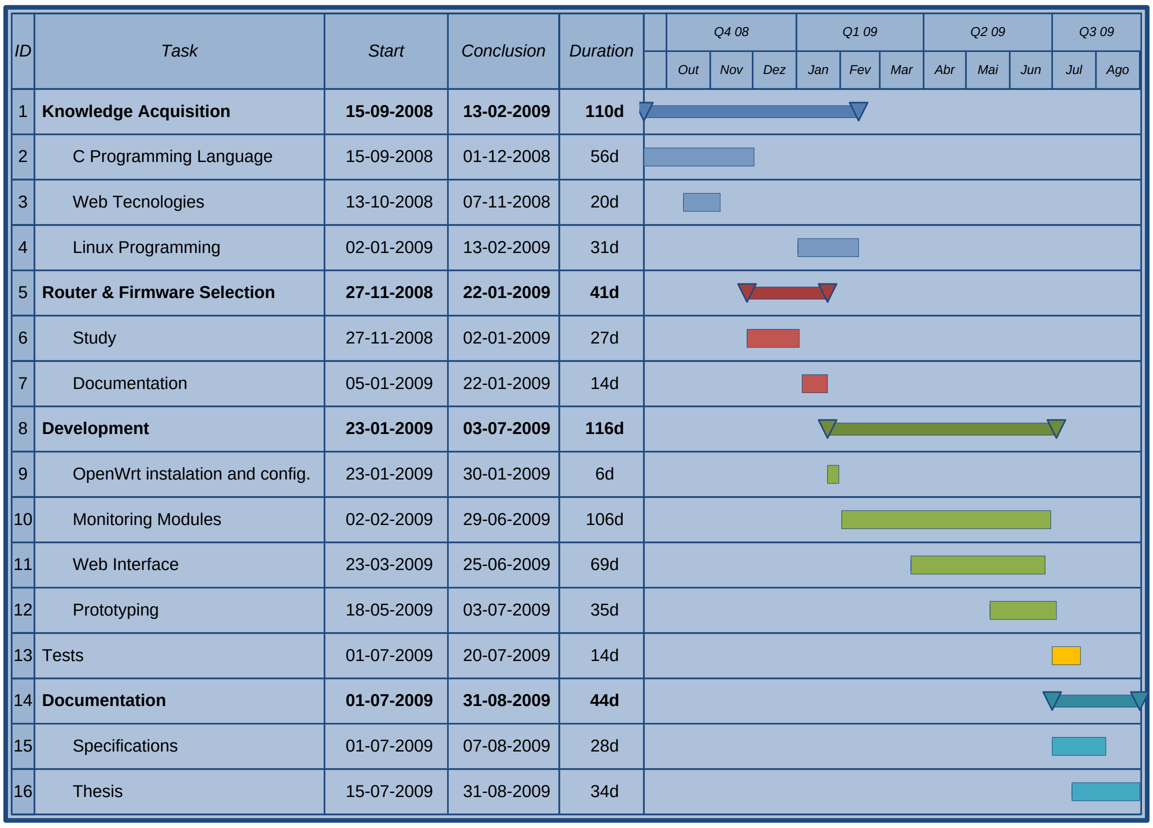
Monitoring console's basic idea presentation took place in a meeting that can be considered the milestone that deployed project's second main task, the research on an existing platform that could be customized with a new firmware and consequently handle the monitoring process. Having identified the Routers/Linux opportunity, this task also included the selection of the most suitable firmware and hardware for the application.

Third phase was the development one. It included installing and configuring OpenWrt in the Router as well as all the required applications/packages, the monitoring module's development and web-interface's construction. Finally, the modules were assembled together to create the prototypes, and the system was tested.

Fourth and last phase included creation of all the internal documentation, including user manuals and technical specifications, and the present document's writing.

2.3 Planning

The temporal distribution of the tasks described above is presented in Figure 1's Gantt Diagram.



ID	Task	Start	Conclusion	Duration
1	**Knowledge Acquisition**	**15-09-2008**	**13-02-2009**	**110d**
2	C Programming Language	15-09-2008	01-12-2008	56d
3	Web Tecnologies	13-10-2008	07-11-2008	20d
4	Linux Programming	02-01-2009	13-02-2009	31d
5	**Router & Firmware Selection**	**27-11-2008**	**22-01-2009**	**41d**
6	Study	27-11-2008	02-01-2009	27d
7	Documentation	05-01-2009	22-01-2009	14d
8	**Development**	**23-01-2009**	**03-07-2009**	**116d**
9	OpenWrt instalation and config.	23-01-2009	30-01-2009	6d
10	Monitoring Modules	02-02-2009	29-06-2009	106d
11	Web Interface	23-03-2009	25-06-2009	69d
12	Prototyping	18-05-2009	03-07-2009	35d
13	Tests	01-07-2009	20-07-2009	14d
14	**Documentation**	**01-07-2009**	**31-08-2009**	**44d**
15	Specifications	01-07-2009	07-08-2009	28d
16	Thesis	15-07-2009	31-08-2009	34d

Figure 1 - Project's Gantt Diagram

CHAPTER 3: PROBLEM ANALYSIS

This chapter presents the first steps of the AAL monitoring console's designing process. It starts by exposing the present context in home and health monitoring systems, discussing the eventual need for a different model. It then presents ISA's initial idea of a monitoring console and the 'routers & Linux' opportunity for creating such system.

3.1 STATE OF THE ART

In recent years, with the fast development of short-range, low-power wireless technologies, a huge number of wireless-enabled devices have appeared on the market, most of which as applications for home-monitoring/automation and personal/health-monitoring business areas. With them, there have also been created systems to control and collect information by them generated, the big majority of which with reduce or non-existent capability of interaction/integration with/of other devices and technologies.

Knowing that there isn't any AAL system on the market today, a representative set of the countless existing monitoring solutions was analyzed to determine how a system such as this should be designed.

3.1.1 VERA, BY *MI CASA VERDE*

Mi Casa Verde proposes itself to "bring home automation to the masses" and intends to do it with Vera (Figure 2), a low-budget home-control gateway with Z-Wave support.

Z-Wave is a short-range, low-power, proprietary wireless technology especially designed by Zensys to implement remote control in home-automation systems. (4)

The Vera gateway is a standard wireless router with a Linux-based firmware, attached to a Z-Wave USB dongle and running special built-in software. It hosts a user-friendly web interface with embed tutorial videos, that maintains a virtual model of the house (or the monitored environment) to which the user can add Z-Wave devices and with which he/she can define automation rules that the system will use to control the devices' functioning. For some devices (like light-bulbs, dimmers and power plugs), the system can store a max power value that it will use to estimate local energy consumption; these consumptions are then presented in the web-interface, giving the user an idea of how much he/she is spending. (5) (6)

This system also provides a remote-control application for Apple's iPhone and iPod Touch to allow real time interaction with the system, without the need for a computer, turning it into an almost completely stand-alone system. (7)

Figure 2 - Vera home-control gateway

Despite some initial disbelieve from the community on a supposed almost auto-configurable, super-simple system that “anyone could set up”, Vera has gain the public’s attention and has, so far, manage to level with the expectations.

Its main advantages are the relatively low price (approx. $300), the easy setup and the possibility of creating complex scenes and event-driven alerts. As it uses an open-source Linux-based firmware, it would be possible for a developer to add extra features to the gateway, even if it would not be possible to improve the MiCasaVerde software itself, since it is not open-source. As an AAL monitoring console it has a few handicaps, the biggest of which is the exclusive support of Z-Wave enabled devices, increasing development costs of eventual new monitoring modules and “closing the door" to many existing devices and monitoring applications, namely the health monitoring ones.

3.1.2 Wellness Connected™, by *A&D Medical*

The Wellness Connected combo (Figure 3) from A&D Medical/LifeSource is a health monitoring solution especially developed to promote self-monitoring. It combines three wireless-enabled health monitors with a software application that automatically receive, store and display measurements in graphs with an easy-to-use interface.

The integrated medical devices are a blood pressure monitor, a weight scale and an activity monitor (measures number of steps, activity times, calories burned, travelled distances and categorizes each activity as a run or a walk). They all work in a one-button-operation basis and cache the measures in internal memories that are “downloaded” by the software running on a personal computer through a special USB radio adapter, whenever the devices are within range. (8) (9)

A&D Medical offers an optional upgrade service in which data records are uploaded directly to a web server (there is still the need for a computer and an internet connection), making it virtually accessible from everywhere and enabling users to track their relatives’ or friends’ progress.

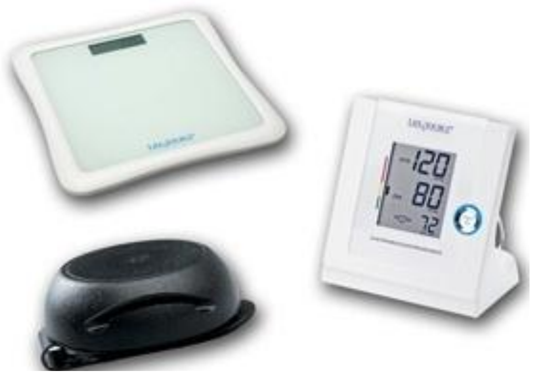


Figure 3 - Wellness Connected system

The user-friendliness and ease-of-use of this system makes it a good example of a home based, personal health monitor, this being its biggest advantage. Also, its Bluetooth-based wireless connectivity may allow the integration of its monitoring devices with other systems and networks.

From the AAL point of view, as a complete system/monitoring network this solution is rather limited, mostly because of its dependence on a computer to collect data, but also because it does not offer support for any other device and these three alone are often not enough. Also, this product seams to aim more on the fitness and well-being market than to the clinical monitoring and diagnosis one.

3.1.3 Home Control Center, by *There. Corporation*

There. Corporation is a spinoff from Nokia to the home automation and monitoring market. The company is preparing to launch, in the beginning of 2010, a new home control console that promises to fulfill the gap between the different systems and technologies, finally enabling communication between devices that “speak different languages”. (10)

The strategy is to develop a standard gateway-based platform, with embed Z-Wave, Wi-Fi, Ethernet support and open to other wireless technologies, controllable by cell-phone and by web-interface. This gateway hosts a user-interface capable of controlling not only There.’s provided devices but also third-party solutions and systems that extend the system reach and applicability. (11)

The company plans to launch a first version called “Safety 360” on the beginning of 2010, as a "security kit" for monitoring fire and water leakage alarms, intrusion detection and energy consumption. (12)

The Home Control Center is presented in Figure 4.

Figure 4 - There.'s Home Control Center

As it is not ready yet, there isn't much tangible information on the system's real capabilities and features. As it claims to be a comprehensive solution, able to monitor every "intelligent" system in the house and to integrate all the collected information, it may be appropriate to implement an AAL system, even if the monitoring of healthcare sensors and devices is not among the first applications of this system.

Previous descriptions leave the idea that it is not easy to find a standard solution to integrate information from very different sources. It seems that each application area has developed its own wireless technology and is doing everything to turn that technology into a wireless *de facto* standard instead of investing on integration. It became clear is not possible to develop a unique control center for networks with different scopes without supporting at least a few different wireless protocols and bridge the information between the sub-networks.

Another important consideration can be retrieved from the previous analysis. It regards the importance of including a user-friendly interface in the console to help the user configure the network and interact with the system.

In this scenario, there is clearly an opportunity for a system able to "talk different languages" and capable of integrating health and clinical monitors with the existing home monitoring networks and devices.

3.2 Initial Idea

The biggest challenge in developing an Ambient Assisted Living integrated system is to keep costs contained and still produce a comprehensive and functional solution, able to arouse the potential client's interest. To answer to this challenge, it is very important that every module is balanced with the whole, and has itself the lowest possible cost.

The vision that defines this project is therefore to produce a good performance and on the same time low-cost monitoring console. The chosen strategy was to take a fully developed, stable and tested commercial platform and, making use of open-source firmware/software, develop a software solution to handle the monitoring process.

Besides from the economical aspect, there were a few other guidelines to take into account:

1. The console should be flexible, capable of working in different modes and adaptable to various monitoring situations;
2. It is very important for the console not to be dedicated to a single short-range wireless protocol/technology;
3. Until the platform’s real processing capabilities have been properly tested, the priority should be to maximize the throughput and not the local data processing.

The first task was, then, to identify a solution that would fit these conditions.

3.3 Opportunity: Linux & Routers

The story begins in the earlier 2003, with the discovery of Linksys use of GPL code on their WRT54G wireless router firmware. According to GPL terms, anyone who modifies open code is required to release his/her modifications back to the community, as so, Linux enthusiasts had pressured Linksys and the company released its modified code under the GPL. (13)

With the release, also in 2003, of the first firmware customizing tools and some methods of cross-compiling code for the WRT54G router, the door to third-party firmware for routers had finally been open, and the number of available firmwares soon grew, and the list of “hackable” devices extended not only to other Linksys routers, but also to other brands. (13)

Searching the web, for discussion forums, wikis and websites on this topic, it is easy to discover the main purpose of switching the original firmware of a wireless router to a customized/customizable one – add new features and improve its performance. The general goal is to “turn a $60 router into a $600 one”. With that said, and having for a fact that there is always someone thinking outside the box, it is also not difficult to discover bold projects were the router’s role is very far from its original one:

- transforming a router into a web server;
- adding sensor to monitor temperature;
- share internet from a GSM/GPRS USB modem;
- create a VoIP server;
- adding a monitor and a keyboard — turn it into a computer!

In fact an electronic device with processing capability, static and operating memory, network interfaces, LEDs, buttons, eventually RS232 and USB ports where virtually any peripheral can be connected, running a ‘full feature’ operating system, with the possibility of developing cross-compiling new applications might well be a computer.

All of that for less than €100, in a book sized box that has a power consumption of less than 7 Watts (approximate). Looks like an appropriate solution for a low-cost monitoring console.

3.4 Firmware Selection

As referred above, the number of third-party firmwares for routers has had a big initial boom, mostly due to the fact that there were a lot of developers taking Linksys Linux-based code and customizing it for single purposes.

As a response to this increase of distributions, on January 2004 the recently created OpenWrt.org project team has released OpenWrt. Their approach was to develop a GNU/Linux-based core with minimal features that could support the router's processor and network interfaces. It would then be a Debbian-like package management system to give the user the means to customize each installation to his/her needs. The software development kit completes the package, allowing the user to develop and cross-compile his/her code. (13)

From 2004 until now, lots of different firmware solutions appeared and were abandoned, lots of different approaches were explored and the lists of available features have grown. Nevertheless, almost every one of today's available distributions were forked from OpenWrt, or had at some point adopted its kernel base (DD-WRT) and, from all of them, OpenWrt continues to be the one more suited for development, since it continues to leave to the user the decision of what features to include.

Another OpenWrt advantage is its big community of developers and users, which may be a great help to solve eventual problems during the development phase.

3.5 Hardware Selection

Having selected the firmware, the next step was to select the router, and the first natural criteria would be its compatibility with the previous.

The other identified criteria would be:

1. Hardware features (memory and processor);
2. Market availability;
3. Support (online forums and communities, books…);
4. USB connectivity (possibility of using storage and radio dongles);
5. Price.

Given OpenWrt's nature, the hardware requirements strongly depend on the user's objective, as is him who selects which packages/features to include. Even so, and as a reference, for a standard usage it's advisable not to use devices with Flash memory less than 4Mb and RAM memory less than 16Mb[1]. (14)

Analyzing the online forums and community sites available on the theme, one gets the feeling that, apart from the many users trying to enhance the old router they have at home and maybe get more out of it, the majority of projects involving open-source firmware for routers use the same three or four devices. By studying the supported hardware list kept on OpenWrt project's website and filtering the units which production has been discontinued and the ones which the average price is higher than $100, one easy understands why.

The fact is that the latest models and versions tend to be equipped with less memory, probably in a manufacturers attempt to reduce costs, which makes it hard for a open-source firmware to fit in and even harder for the user to include new features.

[1] It is possible to install OpenWrt in devices with as less as 2Mb Flash and 8Mb RAM, but the system will only be able to perform very basic operations. (15)

Table 2 presents the most used routers and their main characteristics.

Table 2 - Selected routers main characteristics (15)

Router	CPU	FLASH	RAM	USB	Price
ASUS WL-500Gp v1	MIPS32 - 266MHz	8Mb	32Mb	2x	77€
ASUS WL-500Gp v2	MIPS32 - 240MHz	8Mb	32Mb	2x	71€
Linksys WRT54GL	MIPS32 - 200MHz	4Mb	16Mb	-	60€
Netgear WGR614L	MIPS32 - 240MHz	4Mb	16Mb	-	58$ (amazon.com)

The WRT54G wireless router family has been, for historical reasons, the sand-box of open-source routing firmware development, it is very well documented, there are a lot of tutorials available online and they have been transformed in almost everything one can think of. It will not be too risky to affirm that this is probably the most successful router series ever made. Nevertheless, at one point Linksys tried to reduce costs, and after hardware version 4 of WRT54G, the memory was reduced and its Linux-based firmware was deprecated for a proprietary one. The WRT54GL is the open-source version that they decided to keep (and sell at a higher price) to appeal to the hacker community. (13)

The ASUS WL-500G premium router is a case of success. It is a very powerful router with its 266MHz processor, and its 8Mb Flash and 32Mb RAM are a big trump within this price level. The USB ports are also a very interesting attribute, since they may allow the easy connection of peripherals and the expansion of the platform. ASUS has launched a second hardware version of this router which uses a slightly slower processor and costs also slightly less, which presented a few issues with OpenWrt compatibility, but that seems to be overcome. The weak link of this platform is its wireless card, which driver doesn't work with Linux kernel 2.6 (there is an open-source driver – driver b43 – that may solve the problem, but is not yet stable). The solution would be the replacement of the wireless card or the use of kernel version 2.4.

Netgear had an original approach to the subject, they decided to embrace the open-source community and develop a low-cost, Linux based router compliant with the major third-party software requirements (it can come with OpenWrt, DD-DRT or Tomato firmware pre-installed), selling it as "the Open Source Route". The WGR614L has a slightly faster processor than the WRT54GL but doesn't bring any advantage when compared to the ASUS; its biggest trumps would be the 'official' support of open-source firmwares and the lower price, but as it is not available in Portugal, this last consideration is no longer valid.

The selection of the *ASUS WL-500G premium* (Figure 5) is easily explained by its superior characteristics. Given this project experimental nature, and the fact that one would be exploring a platform on tasks it wasn't designed for, it was very important to start with a solid base, and the larger memory, processing speed and USB connectivity of that device promised to fit the expectations. As for the hardware version of this router, there were some doubts on version 2 real compatibility with OpenWrt, and as version 1 was still available the decision went for this one. The wireless card issue was solved by using Linux kernel 2.4 OpenWrt version.

Figure 5 - The ASUS WL-500G Premium Wireless Broadband Router

CHAPTER 4: SYSTEM'S ARCHITECTURE

The monitoring console is, within the different applications, the local concentration module responsible for the generated signals' collection. It aims to be the system's local center, managing short range wireless communications, sending the collected data to a remote server and/or locally process and store that data.

The console consist on a standard wireless router, of which original Firmware has been replaced by a specific Linux distribution — OpenWrt. Over this operating system, runs a software solution that manages the entire monitoring process.

The logical model of the software solution is centered in the concept of a *Monitoring Network*, configurable by the user, which comprehends the devices to monitor and their configuration parameters.

Figure 6 illustrates the concept behind the monitoring console.

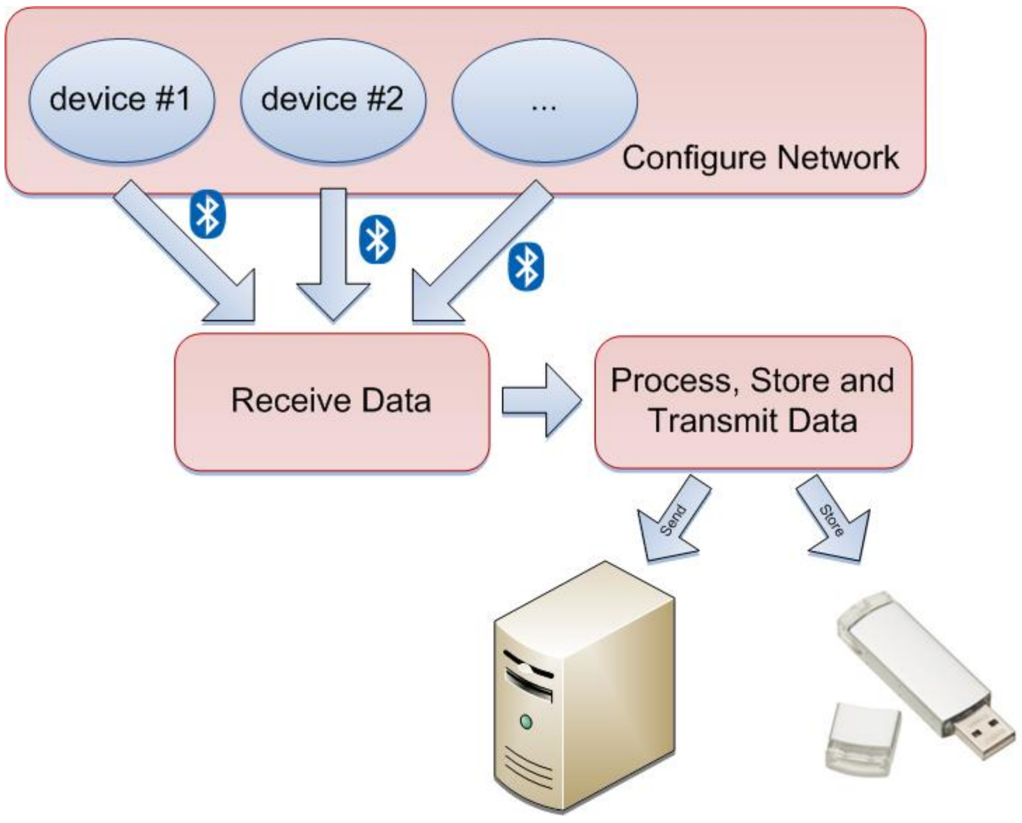


Figure 6 - Monitoring console's conceptual scheme

System's present version only uses Bluetooth communication protocol and the devices must be configured to either send the data to a remote server or store them locally.

4.1 System Features & Requirements

4.1.1 Hardware

The present version of the monitoring console uses the following devices:

1. ASUS WL-500G premium Broadband Wireless Router;
2. SWEEX BT211 Bluetooth Adapter;
3. USB storage device ("Pen").

This section presents a description of these components and the requirements in which their selection was made.

4.1.1.1 THE ROUTER

As stated in section 3.5, the selected router has been the ASUS Wl-500G premium. The arguments on which the selection was made had also been described.

Since the goal was to use an existing platform without altering its hardware (at least as a first approach), no deep hardware study done. Nevertheless, the platform features are presented in Table 3.

Table 3 - ASUS WL-500Gp hardware features (16)

PROCESSOR	**Architecture**	MIPS
	Vendor	Broadcom
	Bootloader	CFE
	System-On-Chip	Broadcom BCM94704
	CPU Speed	266 Mhz
MEMORY	**Flash size**	8MiB (Spansion S29GL064M90)
	RAM	32MiB (2* HY50U281622ETP-5, some older units have only 16MiB enabled)
CONNECTIVITY	**Wireless**	MiniPCI Broadcom 802.11b/g BCM4318 802.11 Wireless LAN Controller
	Ethernet	Robo switch BCM5325
	USB	2x USB 2.0
	Serial	Yes
	JTAG	No

The router is in fact the key part of the puzzle, and the requirements for it were simply to have a relatively fast processor (not comparing it to a real computer, of course), enough memory for software development, and high connectivity and/or expansibility.

4.1.1.2 THE BLUETOOTH ADAPTER

The Bluetooth devices have two classifications, the Class and the protocol version. The Class of a Bluetooth device defines the power of its radio and consequently its range, as described in Table 4.

Table 4 - Bluetooth Class features (17)

CLASS	MAXIMUM PERMITTED POWER (MW / DBM)	APPROXIMATE RANGE
Class 1	100mW / 20dBm	~100m
Class 2	2.5mW / 4dBm	~10m
Class 3	1mW / 0dbm	~1m

The Bluetooth protocol version identifies the different phases in this technology evolution path. Apart from the addition of new features, that evolution has brought successive increases on the data-transfer rate and the last version (2.0 with EDR) can reach speeds of 3Mbit/s.

The main concerns about the adapter to use are that it should not create a bottle-neck in the communications and it should be compatible with Linux's Bluetooth Stack – BlueZ. On the other hand, its price should be as low as possible.

The selected adapter, the *SWEEX BT211*, is a Class 1, Bluetooth 2.0 with EDR adapter with a retail price of less than 10€. As for the BlueZ compatibility, it is not very common for a manufacturer to ensure Linux operating systems compatibility to his products, so the only way to check this was by testing it, and it worked.

4.1.1.3 THE USB STORAGE DEVICE

The USB storage device should have enough memory to store at least the information generated during one monitoring session. The total amount of information has not been defined and will depend on the monitoring devices' number, their sample rate, the data package size generated by each one and the duration of a "monitoring session".[2]

Another concern is that large memory storage devices, may require external power supply, and that may not be desirable.

4.1.1.4 THE SUPPORTED DEVICES

As the console development depends also on the devices it is supposed to monitor, this sub-section is meant to describe in general those devices and their function.

4.1.1.4.1 BIOPLUX

Bioplux is a wireless enabled, miniaturized signal acquisition system especially designed to acquire electrophysiological signals. It provides up to 8 analog channels and one digital I/O port, allowing the monitoring up to 6 variables, using the provided sensor set. It uses the

[2] As an example, to store the entire data-string generated by an iMeterPlug's [4.1.1.4.3] live measurement (approx. 550 bytes) at a frequency of 1Hz, one 1 GB device would be enough for about 21 days.

Bluetooth protocol to send the raw, digitalized data to a computer. The 8 channel, research version is displayed in Figure 7.

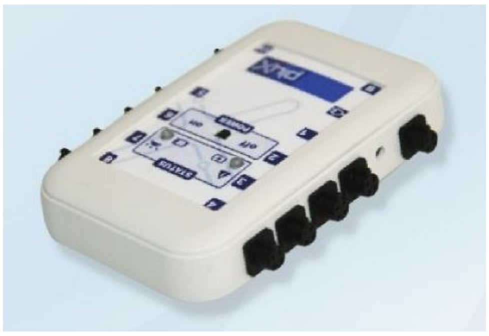


Figure 7 - Bioplux Mini Research

The list of sensors supported by this device includes peripheral thermometer, EMG dipole probes, light sensors, ECG triode, Electrodermal sensors or air pressure sensors. This amount of different sensors definitely contributes to Bioplux's versatility and increases the usage possibilities.

Despite of this project's implementation of Bioplux protocol is independent of the data type (what the console receives are just numbers), the main intention of using this device was to take advantage of its ECG sensors.

The Electrocardiographic signal is by many considered the first and eventually most important signal in vital signs monitoring. It consists of a trans-thoracic interpretation of the heart's electrical activity. (18) The signal is obtained by measuring the electrical potential difference between the different electrodes placed on the patient's chest (in this case, since Bioplux has only a 3 channel ECG). It is in general a very important tool to diagnose both acute and chronic cardiac conditions.

4.1.1.4.2 OXIMETER

A pulse oximeter is a device that performs non-invasive, indirect measures of blood's oxygen saturation. It can also monitor the patient's heart rate and perform photoplethysmographic studies of skin's blood volume. (19)

The O2 saturation is calculated from the relative percentage of oxyhemoglobin in the arterial blood's hemoglobin. It uses a set of two light sources with defined wave-lenghts (red at 660nm and infrared at 905, 910 or 940 nm) and a photodiode that measures the light absorption. As oxyhemoglobin and deoxyhemoglobin light absorptions, at these wave lengths, are very different, their relative concentrations can be calculated and, consequently, also the SpO2. (19)

This simplicity and speed of these devices make them extremely important in emergency medicine and for monitoring patient with respiratory or cardiac conditions, including the diagnosis of some diseases (sleep apnea, for example). (19)

NONIN's 4100 Digital Pulse Oximeter allows SpO_2, heart rate, and plethysmographic data to be transmitted wirelessly through a Bluetooth radio to a Bluetooth-enabled device. (20) It can function in different modes, allowing continuous monitoring as well as configurable spot-checks, with sample rates of 1Hz or 75Hz and different resolutions.

Figure 8 shows this device.

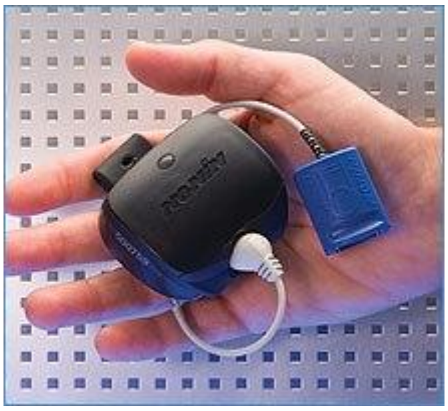


Figure 8 - NONIN 4100 digital pulse oximeter

4.1.1.4.3 IMETERPLUG

iMeterPlug is an electrical Energy consumption monitor, and it is included in this project as an example of how the Ambient Assisted Living comprehends not only the monitoring of individuals' vital physiological information, but also of his/her environment, especially the home.

As its name suggests, iMeterPlug is a device that can be placed in an electrical plug and measures the electricity consumption of device(s) to it attached. Figure 9 shows ISA's iMeterPlug.

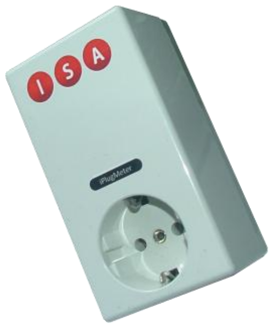


Figure 9 - ISA's iMeterPlug

From the moment it is connected to a plug, the iMeterPlug starts monitoring. It has an internal circular log to which it saves records in configurable periods of time (resolution: 1 minute); the user can then download these records using the Bluetooth RFCOMM profile. iMeterPlug does not have a mode for continuous monitoring, but its protocol have a command ('LV') to which the device respond with a live measure, and one can use this command to get a more frequent sampling (this project's implementation manage to get a sampling rate of nearly 1Hz).

The available data fields are:

1. Time entry;
2. Power (-Gen +Con);

3. Cumulative Power (Gen);
4. Cumulative Power (Con);
5. Frequency;
6. RMS Voltage;
7. RMS Current;
8. Plogg on time;
9. Reactive Power (-G/+C);
10. Acc Reactive Pwr (Gen);
11. Acc Reactive Pwr (Con);
12. Phase Angle (V/I);
13. Equipment on time;

The user can configure which of these fields should be stored in automatic records, but "live measures" can't be configured and return all of the fields. ISA's protocol for this device only requires the storage of:

1. Time entry;
2. Power (-Gen +Con);
4. Cumulative Power (Con);
9. Reactive Power (-G/+C);
11. Acc Reactive Pwr (Con);

As so, and in order to get high sample rates, the strategy to follow should then be to continuously request live measures to the iMeterPlug and then parse the data frame for the information to store.

4.1.2 Software

The software is what turns the ordinary wireless router into a monitoring console. Its mission is to manage the entire monitoring process, from the monitoring network's management (device adding and configuring) to the actual data acquisition and processing.

As said before, the developed software runs over a special Linux-based firmware program – OpenWrt. This means that, from the programmer's point of view, it is not necessary to test and release the entire firmware when developing an application, allowing him/her to concentrate on the application itself. (21)

Given the router's reduced memory space, it was not possible for OpenWrt developers to include standard *GNU Compiler Collection* (GCC), *GNU C Library* (glibc) or GNU C++ Library (glibc++). As so, OpenWrt standard images come with uClibc installed, which is a C library for embedded Linux systems, much smaller than the glibc, but that supports nearly all applications developed with this library. uClibc++ is also provided, but as an optional package. The compilation issue couldn't be solved this way, the only option was to create a cross-compilation mechanism and compile the applications in another system, installing the executable files afterwards.

OpenWrt can then be seen as a development platform, and it comes with a Software Development Kit (SDK) that contains the appropriate libraries and cross-compilers for the user to create installable packages with his/her applications.

The SDK is a stripped-down version of the OpenWrt build system, which can build packages using the same package directory format as the full Buildroot. (21) The package creation is mediated by GNU's 'make' tool and user defined make-files.

In this project all applications were written using C programming language. This allowed not to install the C++ library and to save some space. The decision do not translate any compromise on functionality as C is a very powerful programming language and is perfectly suited to the development of these kind of applications.

C is one of the most important programming languages ever developed. It was originally designed for the UNIX operating system, and has been ever since mostly used for system software implementation (operating systems, compilers, other languages…). It is used in a very wide set of platforms, and on almost every computer architecture, mostly because of the relatively easiness of creating a C compiler for a specific architecture. It is also widely employed on writing application programs. (22) (23)

C's success is much due to its minimalistic design that gives it simplicity, efficiency, flexibility and small memory requirements. Programs written in C are also highly portable, as the C compilers and libraries are available for numerous platforms.

Despite being a high-level language (as its syntax is closer to standard English than to machine language), it is often considered as lower-level when compared to other programming languages as it provides a set of low-level features (direct memory access, for example).

4.1.2.1 WEB INTERFACE

The scope of a web interface inclusion is to provide users with a friendlier way to configure a monitoring network (relatively to manual edition of config files) and avoid errors. By configure it is meant adding and removing devices to and from the network, and setting each device monitoring parameters.

The interface also displays network current content.

4.1.2.2 MONITORING SOFTWARE

The monitoring modules are the system's functional blocks. They need to handle the Bluetooth connections, to implement each device communication protocol, collect the data, process the received packages and send/store the information.

4.1.3 Short Range Communication Protocols

Despite the earlier intention of creating an open platform, capable of supporting a wide range of communication protocols, the monitoring devices available all used Bluetooth. As so, and for this first version, only Bluetooth is supported.

4.1.3.1 BLUETOOTH

Bluetooth is likely to be the most popular WPAN creation technology. It is an unlicensed wireless radio technology, designed for low-power, short-range data exchange between electronic devices. (17) (24) It was first created with the intention of replacing serial cabled connections, but its field of applications has became wider, and now Bluetooth stands as an alternative to almost every cabled connection.

Bluetooth’s biggest advantage is in fact its price. It starts for being an open technology, not requiring the payment of licenses and/or royalties of any kind; second, it uses low-cost transceiver micro-chips on its radios making them very cheap for mass-production; third, as it keeps transmission power at very low levels, it is a great option for battery powered devices.

For ensuring safety in data transmission, Bluetooth offers optional encryption in device connections. For the user, this encryption takes the form of the PIN, which is used to generate the encryption-key and if not equal in the two devices, connecting will not be possible.

CHAPTER 5: SOFTWARE DEVELOPMENT

The software solution includes a web interface that edit the files that contain the network device's configuration, one application that reads those files and starts the monitoring process, and a set of pairs of applications that, for each device, establish the Bluetooth connection and collect the data (*receiveBioplux*, *receivePlogg*), and take care of the processing, storing and transmission of the information (*processBioplux*, *processPlogg*).

Figure 10 is a diagram of how these modules relate to each other.

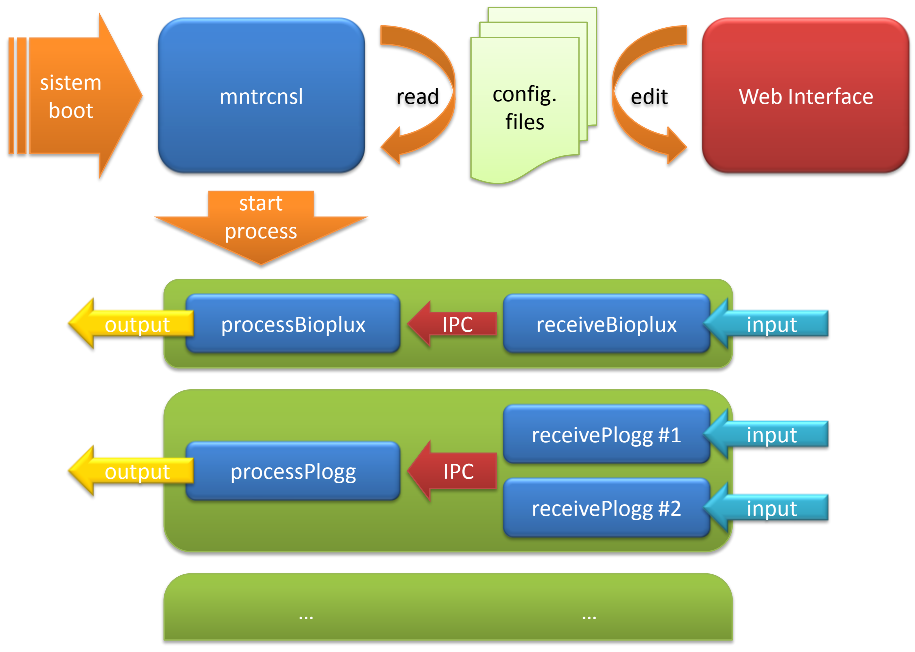


Figure 10 - Software solution's general architecture

Because a transmission protocol to send the collected data to an external server has not yet been design, in this system's current version, the processing applications do not support this feature. As so, it was decided the integration on the final prototype (Prototype #1) of the demonstration modules *demoBioplux*, *demoOx* and *demoPlogg* that collect and transmit the date directly from the devices to visualization applications in remote computers.

The inclusion of these applications has the purpose of demonstrating the system's capability of transmitting data collected in real time from a device to a remote system, at the same time that it locally stores data from another device. It was also a way of testing the developed web interface.

To complete the previous scheme, the blocks in Figure 11 should be added.

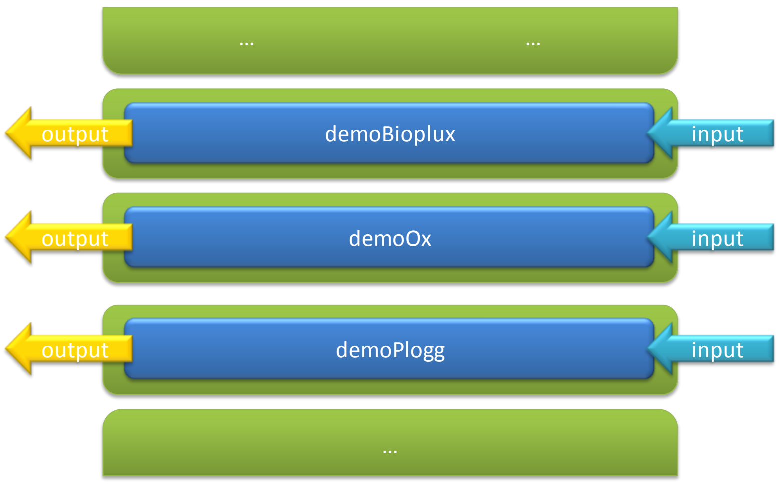


Figure 11 - Demonstration modules used for direct transmission of the data

5.1 Web Interface

The web interface has been developed using HTML and CSS languages. Its design is optimized to be displayed with Microsoft's Internet Explorer 7 and Mozilla Firefox 3 web browsers, and with screens with a minimum resolution of 800x600 pixels.

The HTML forms processing is done using CGI programs. CGI is an acronym for *Common Gateway Interface* which is a standard protocol for interfacing external application software with an information server, commonly a web server. (25) These applications can be written in any programming language, and in the current case C programming language was used.

All the forms use the POST method to collect input data.

5.1.1 Layout and Organization

The interface's layout was structured in four different visual areas that stand from a textured blue background. On top, a white horizontal bar holds ISA's logo and creates a visual connection to the company and beneath it there is a black navigation bar. On the left, superimposed to the first two, lies a red, semi-transparent vertical menu bar that displays buttons that link with the interface's main areas & tools. The content is displayed in a white, expandable rectangle on left-right corner. [Annex A: Web interface main page]

The design was meant to be simple and intuitive, and was based on ISA's image color scheme.

5.1.1.1 SITE MAP

The web site is organized in three sections, the "Add Device" tool and the "My Health" and "My Home" network display areas. Within these last two areas there is also a division by device type.

The conceptual organization of the website is shown in Figure 12. The arrows intend to express form processing

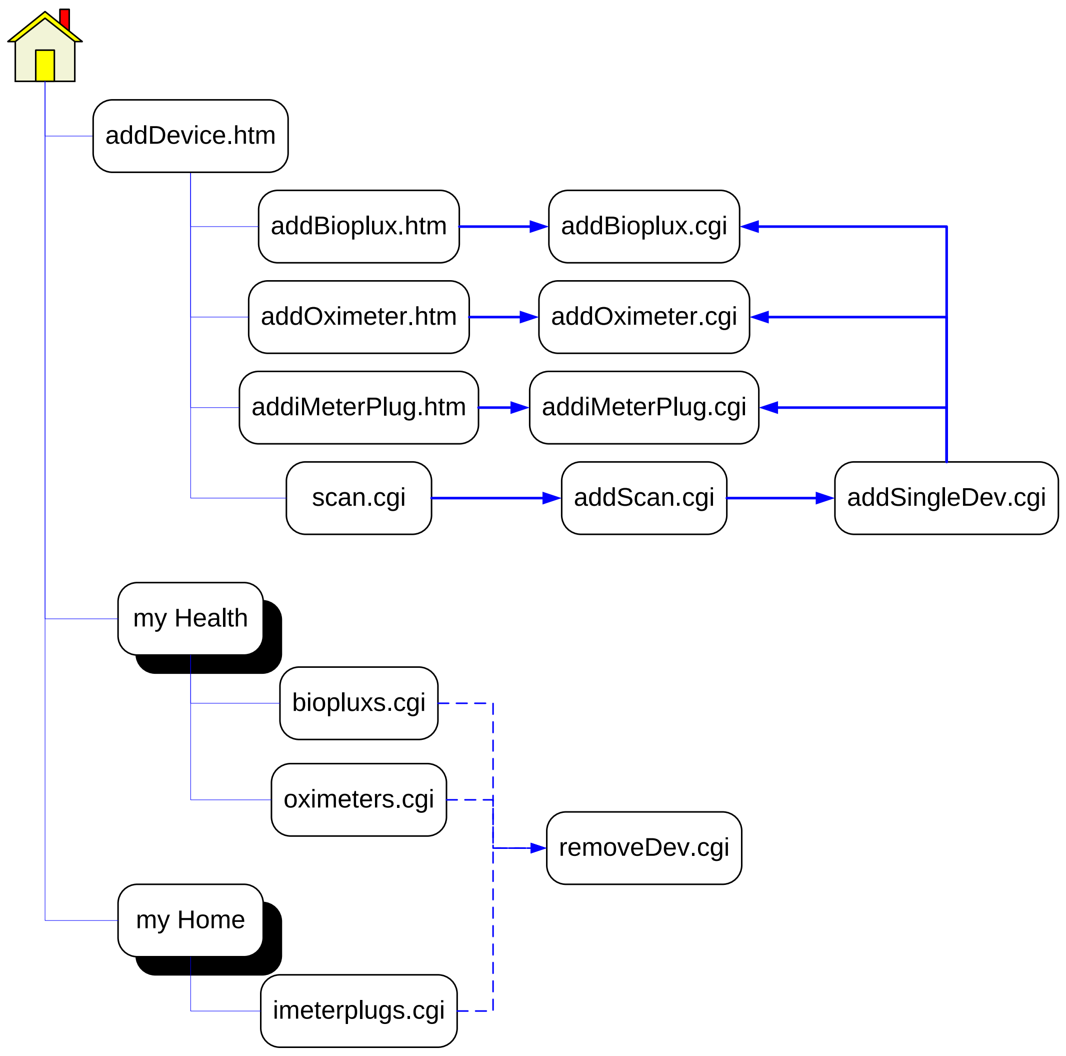


Figure 12 - Web Interface site-map

5.1.2 HTML FORMS & CGI PROGRAMS

As this web interface's scope is to display, add and remove devices to/from the monitoring network, mainly every one of the web pages have a HTML form.

Adding a new device to the network typically involves a webpage with an HTML form, and a CGI program to process it. The output of the process is a new line in the devices configuration file. These forms are organized by information type, in two or three areas:

1. Device identification Bluetooth communication parameters;
2. Monitoring parameters (just for Bioplux);
3. Data handling information.

The program reads the data from standard input and stores them as structured text, in configuration files. [Annex B: Configuration files' structuring]

The CGI applications that display the network access these files, parse them and structurally print the devices' configuration information into a web page.

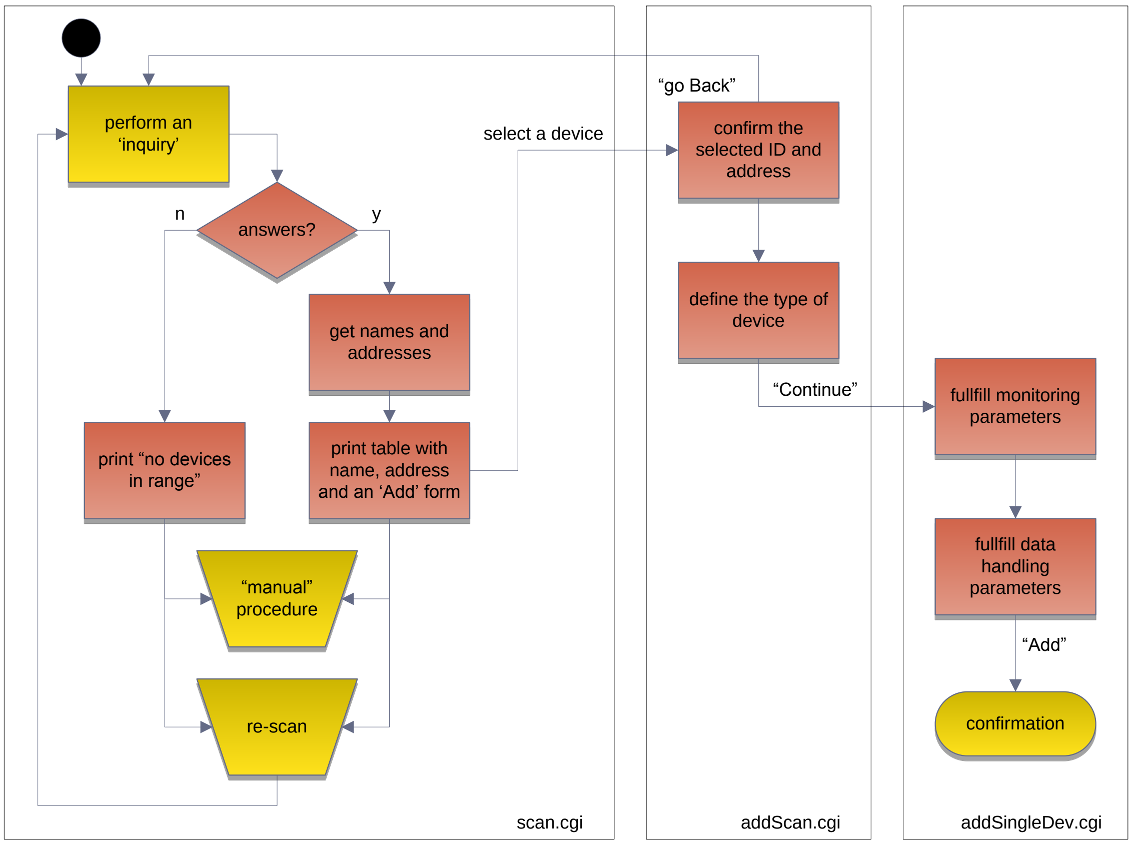
5.1.2.1 ADD DEVICE FROM SCAN

Other than being a more user-friendly method of configuring the monitoring network, the web interface offers another advantage relatively to the manual edition of the configuration files. It has an application that scans for nearby devices, presenting a list of MAC addresses and ID's for the user to choose from. This feature may prevent the need to know the Bluetooth MAC address in advance (since it is normally not visible) and the need to insert it manually.

The flowchart of this procedure is presented in Figure 13.

The three different CGI programs involved in the process are:

1. *scan.cgi*, that performs the scan and presents a list of nearby devices to the user (its output is presented in Annex C:);
2. *addScan.cgi*, which displays the selected device's name and MAC address and asks for the type of device;
3. *addSingleDev.cgi*, that presents an input form and collects monitoring and data handling parameters.



perform an 'inquiry'
answers?
n
y
get names and addresses
print "no devices in range"
print table with name, address and an 'Add' form
"manual" procedure
re-scan
select a device
"go Back"
confirm the selected ID and address
define the type of device
"Continue"
fullfill monitoring parameters
fullfill data handling parameters
"Add"
confirmation
scan.cgi
addScan.cgi
addSingleDev.cgi

Figure 13 - Adding nearby devices procedure using the 'scan' tool

5.2 Monitoring Modules

5.2.1 Monitoring Session Boot - *mntrcnsld*

This application works as a bridge between the user's instructions and the monitoring modules. It is started by the system's boot and loads the other applications, passing them the parameters defined in the configuration files.

Its architecture consists of three main functions called sequentially — startBiopluxs, startOximeters, startPloggs. Figure 14 represents the general flowchart for these functions.

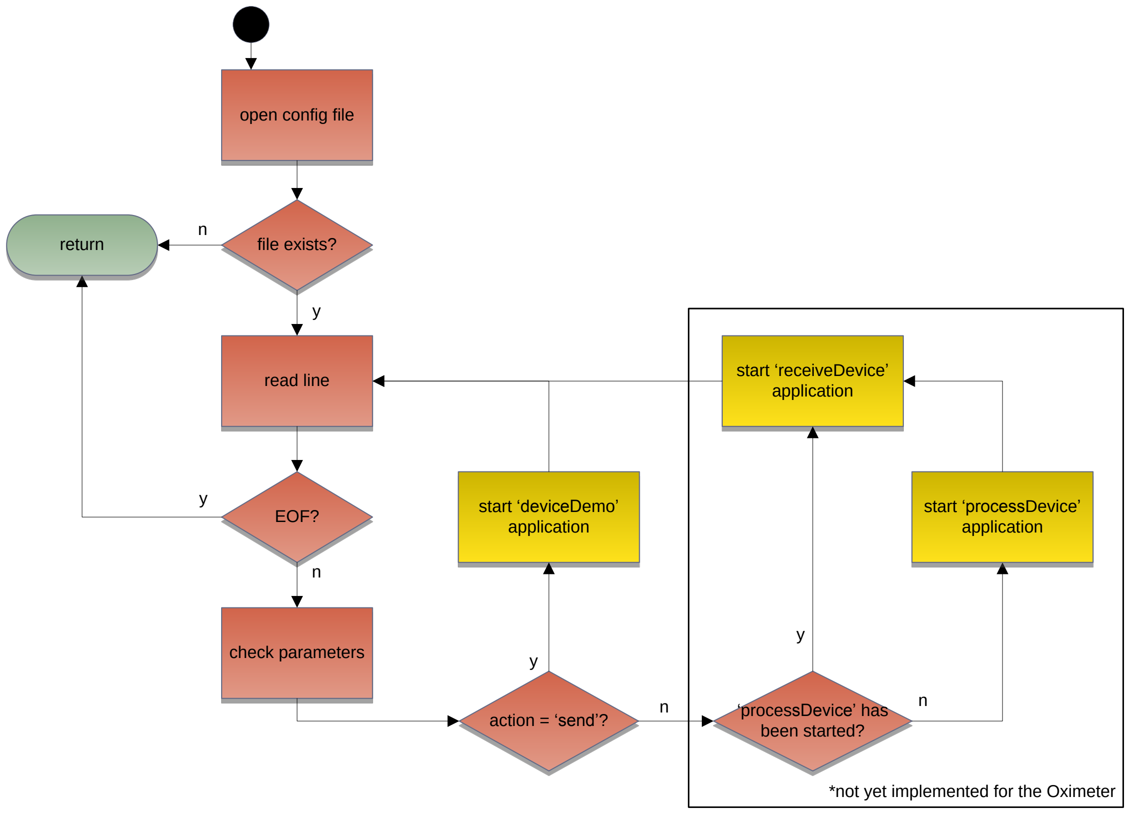

open config file
file exists?
n
return
y
read line
EOF?
y
n
check parameters
action = 'send'?
y
n
start 'deviceDemo' application
start 'receiveDevice' application
start 'processDevice' application
'processDevice' has been started?
y
n
*not yet implemented for the Oximeter

Figure 14 - *mntrcnsls* main function's flowchart

For the oximeter there is only the demonstration application (that doesn't support the local storage of data), so *startOximeters* only starts the monitoring of devices configured in 'sending' mode.

5.2.2 Data Processing

This group of applications is responsible for the creation of the Interprocess Communication (IPC) mechanism — System V Message Queues (MQ), in this case — and for the structured storage of the collected data in the USB storage device.

Despite the existence of one data collecting application for each individual device, there is only one process running the data processing application for each device type, and all of those processes use the same MQ. The processing uses the message's label (*msg_ID*) to separate data from different sources. As the label needs to be a long integer (System V Message Queue's requirement) it is created from the device's line, on the configuration file.

The general flowchart of this type of applications is represented in Figure 15.

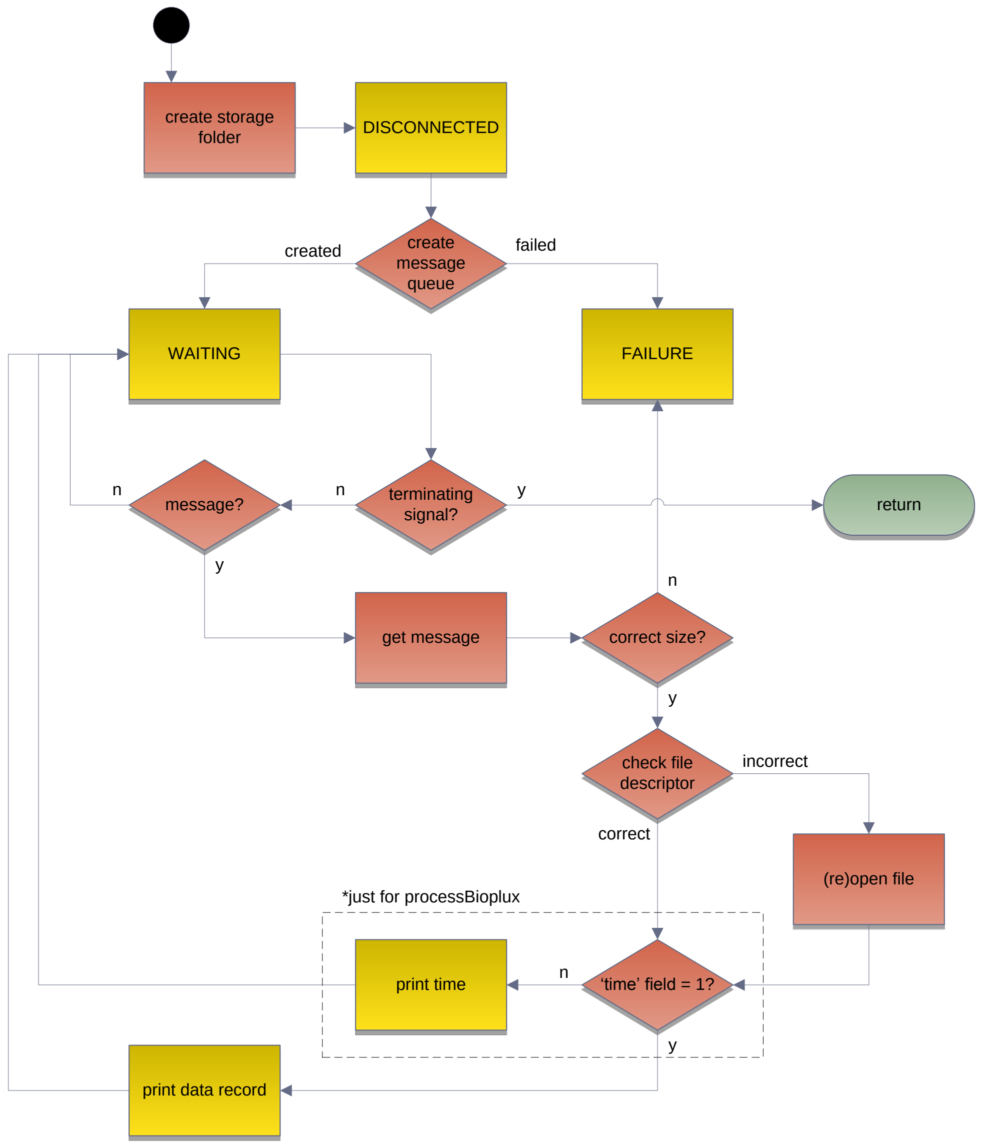


Figure 15 - Processing applications flowchart

The application uses a variable to store the label from the last received message and a file descriptor that points to that msg_ID's corresponding file. Whenever the label from an incoming message is different from the stored one, the file descriptor is redirected to the correct file.

5.2.2.1 *PROCESSBIOPLUX*

Bioplux's data message structure is the following:

```
struct parsedData {
    long msg_ID;
    char bp_ID[30];
    unsigned char frnumber;
    unsigned char digitalPort;
    short chValue[8];
    time_t time;
    };
```

The packages sent by the Bioplux contain sequential measurements of the fisical/fisiological parameters that should be organized by session, defined as an uninterrupted record sequence. In order to store more than one session in the same file, every time a connection with the device is established, the system generates a 'date & time' message that is then printed to the file, separating records from different sessions. This is 'time' field's scope — in the data structure and in "normal" messages this field is set to 1. The 'date & time' line has the following shape:

```
Bioplux 'X'   time(): Y
```

X is the internal ID of the Bioplux (defined during configuration) and Y a *time_t* integer representing system's date and time at the beginning of the session.

The records are stored as lines with the digital port value in first place, followed by the eight analogical channel values. The separation is made with 'tabs'.

5.2.2.2 *PROCESSPLOGG*

iMeterPlug's data records are created with lower frequency and every record has a timestamp of its own with the device's date/time of creation. Consequently, there is no need to split the file in sessions.

The structure of the incoming message is:

```
struct parsedData {
    long msg_ID;
    char plgg_ID[30];
    char timestamp;
    float plogg[4];
    };
```

Table 5 shows the information stored in 'plogg' array.

Table 5 - iMeterPlug's stored data

plogg[0]	Power
plogg[1]	Consumed Energy
plogg[2]	Reactive Power
plogg[3]	Consumed Reactive Energy

In the file, the records are stored as lines and the information is sequenced as: timestamp > plogg[0] > plogg[1] > plogg[2] > plogg[3], with "tab" separation.

5.2.3 Data Collection and Parsing

This application group is responsible for the establishment and management of the Bluetooth connections, the implementation of the communication protocols of each supported device, the collection and parsing of the data frames. The parsed information is passed to the processing applications through the different message queues.

5.2.3.1 *RECEIVEBIOPLUX*

This application takes, as input, a long integer to identify the outgoing messages (*msg_ID*), the name/ID of the device, its MAC address and Bluetooth PIN. The generated messages structure is the one described for the *processBioplux* application.

Within the application, there is a *Finite State Machine* (FSM) mechanism that interchanges between NOT_CONNECTED, CONNECTED, PREPARED, ACQUIRING, ACQ_LAST and FAILURE states. This states where defined after the second version of Bioplux's communication protocol. The flowchart of this FSM is the one in Figure 16.

NOT_CONNECTED state is the one in which there is no established connection and, if no terminating signal has been received, in which the system tries to create a Bluetooth connection with the device, using RFCOMM protocol.

If a connection exists, the application switches into CONNECTED mode and the following action is sending a preparation command, requiring for a confirmation of the device's firmware version that, if received, takes the application into PREPARED state. If this action is unsuccessful the system closes the connection and returns to the initial state.

In PREPARED mode, a Start Message is created and sent to the device, containing the channel bitmask, sample rate and resolution that shall be use for the monitoring session. This information is defined in the configuration files and is given to the application as input. As an answer to this message, Bioplux starts collecting data and the application changes into ACQUIRING mode.

In acquisition mode, packages are received and pre-processed into structured messages that are put in the MQ created by the *processBioplux*. The application continues to work in this mode until a signal is received or an error occurs.

Telling the device to stop acquiring data is done by sending a 'terminating command'. Because there is always some delay between sending a command and its reception, it is normal that a few packages may yet to be received in the socket buffer, so the system shall switch into ACQ_MODE to collect these last packages, and then re-send another request for the firmware version to confirm the reception of all the packages.

FAILURE mode results from an error in the package parsing function. Every other error situation makes the application to disconnect and restart the process.

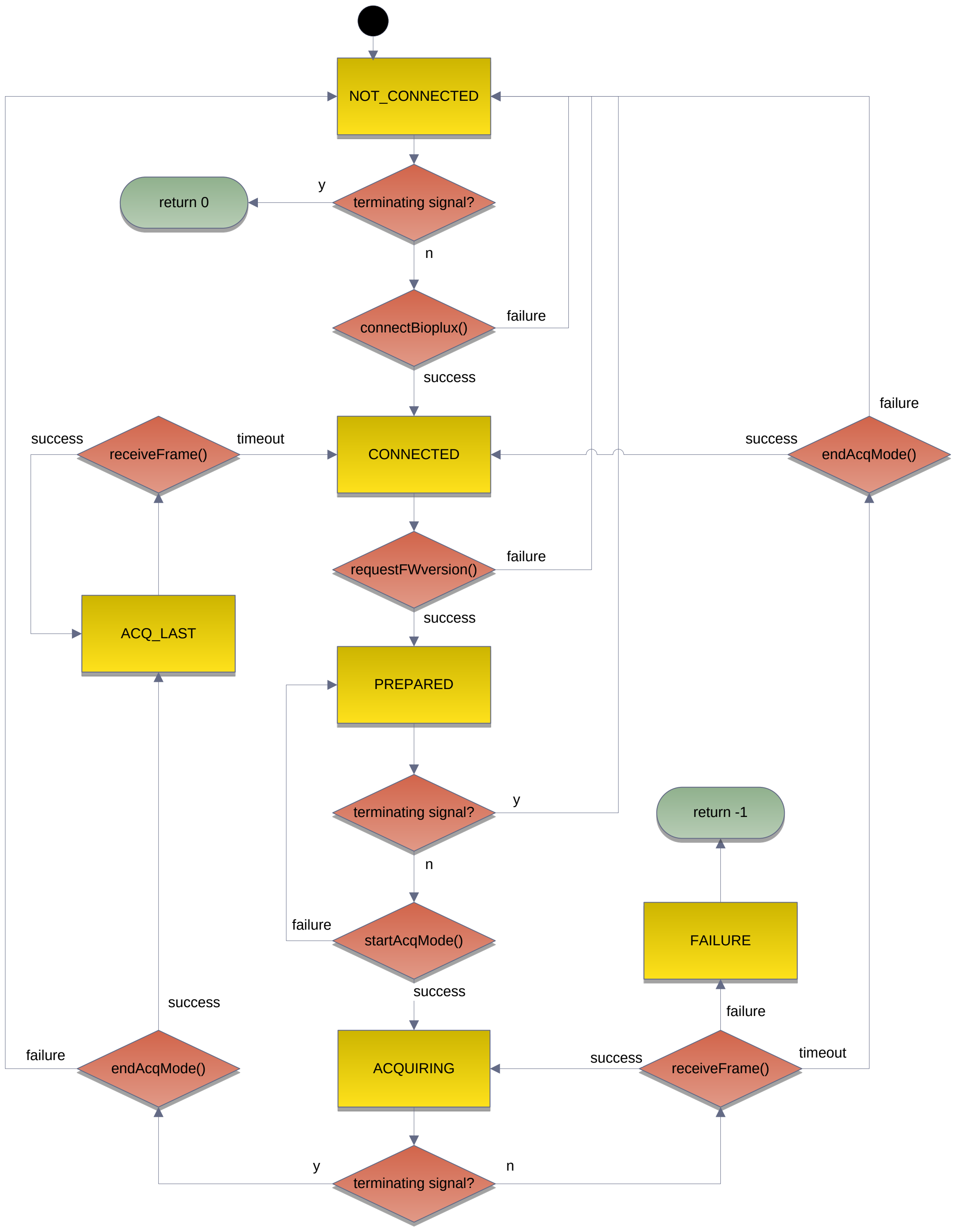


Figure 16 - *receiveBioplux*'s FSM flowchart

Bluetooth communications with Bioplux are encrypted and, as so, before establishing a connection there is the need to change the console's Bluetooth PIN to match the devices. In order to achieve do so, this application, before starting the described protocol, changes system variable "pin" and restarts the application that controls HCI protocol (the lowest within the overall Bluetooth protocol).

5.2.3.2 *RECEIVEPLOGG*

iMeterPlug's (or "Plogg's") protocol offers a few possibilities for remote systems to collect data from these devices. Because the initial goal was to maximize throughput, to test the router's capabilities, it was decided to use recurrently 'LV' command, which asks the device for one measurement. This method enables sample rates of about 1 Hertz. The "sleep()" function called after receiving one package allows this frequency to be decreased.

The application also works with a FSM, but with only two states: NOT_CONNECTED and CONNECTED.

From the received data string, the system collects the timestamp and the information in Table 5. With this data fields a message is created and sent to the process running the processing application.

Figure 17 displays this application's FSM flowchart.

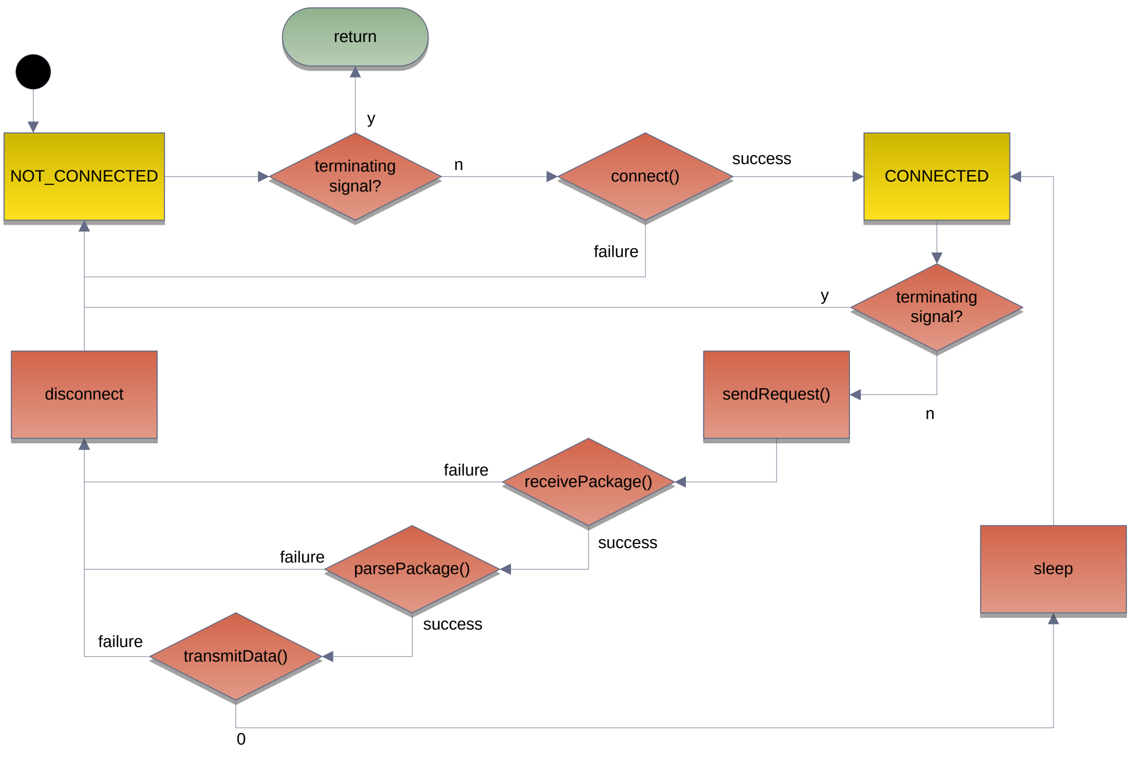


Figure 17 - *receivePlogg*'s FSM flowchart

5.2.4 Demonstration Applications

This group of applications has been developed merely for the demonstration prototype. The aim of this prototyped was (as described above) to collect live data from the devices and transmit it via Ethernet or Wi-Fi to a computer. Collected data should then be displayed in a set of graphical interfaces.

5.2.4.1 *OXDEMO*

This application has the particularity of not performing any kind of pre-processing over the received data packages. These are transmitted exactly as received, a single byte at a time to the remote server.

The flowchart of this application's FSM is shown in Figure 18.

After successfully establishing a connection with the device, the system tries to connect with the remote server, when that occurs a start command is sent to the Oximeter and the process shifts into Acquisition/Transmission state. In this state, the system receives a single byte at a time from the device and sends it to the server; this cycle is broken when a 'terminating signal' is received or when one of the peers closes connection. In case of failure, application shuts down.

The Oximeter, as the Bioplux, uses encryption in Bluetooth communications and this application also changes console's Bluetooth PIN to match the device's when trying to connect to it.

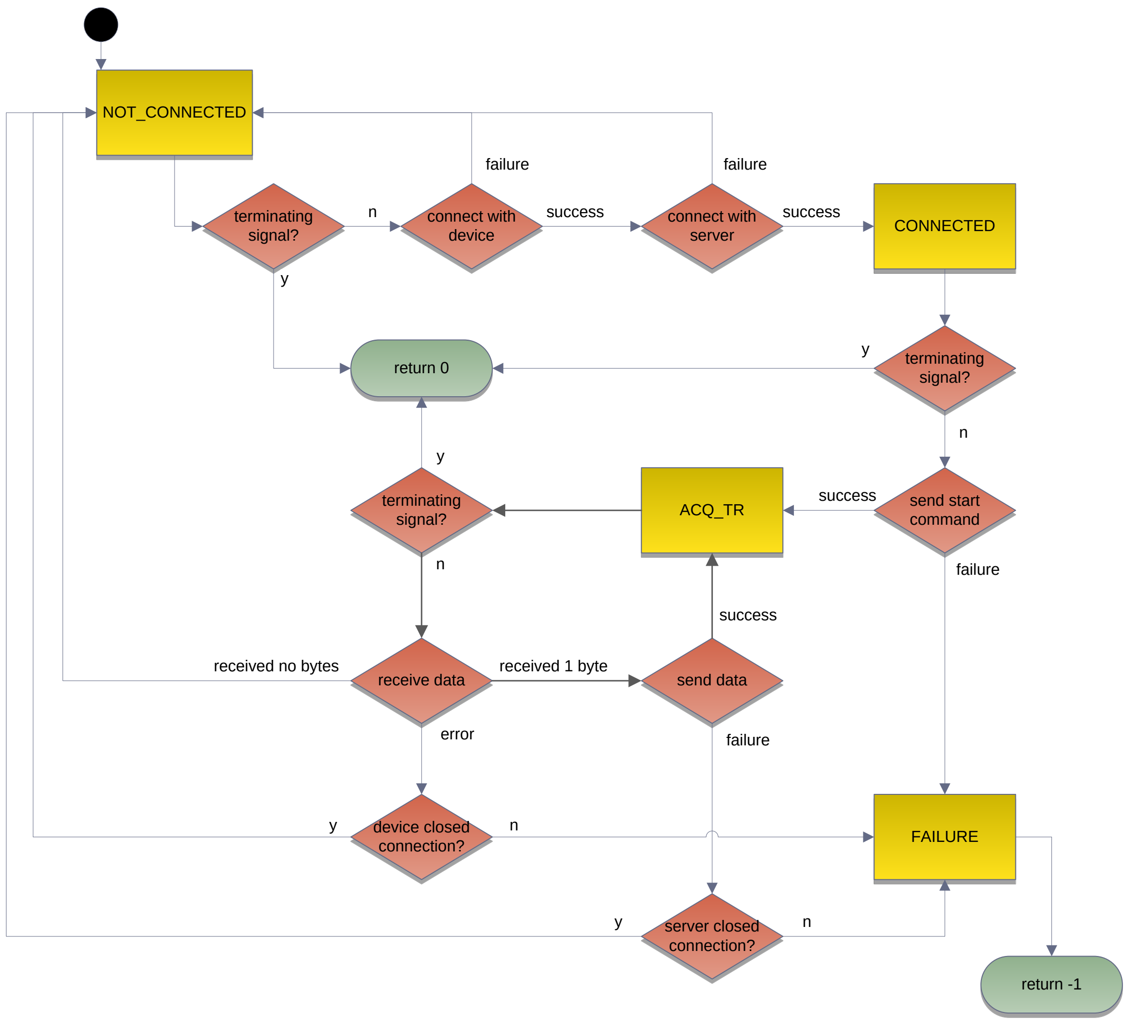


Figure 18 - *oxDemo*'s FSM flowchart

5.2.4.2 *BIOPLUXDEMO*

This application has been developed from *receiveBioplux* and is similar to this one except on the destiny given to pre-processed data and on the transition between NOT_CONNECTED and CONNECTED states.

In this case, data is sent through a TCP/IP socket to a remote server with which the application tries to connect after successfully connecting with Bioplux. If it is not possible to connect with the server, Bluetooth connection is closed and the process restarted.

In this scenario, as data is destined to live presentation, there is no need to separate non sequential data (the application on the remote system will do it) and, as so, the ‘time’ is dropped from the output data structure as well as the ‘msg_ID’ label (it is no longer a message queue, and there is only one source transmitting through the socket).

5.2.4.3 *PLOGGDEMO*

In this case, and contrarily to the other devices, the graphical interface already existed and the application needed to be built accordingly to its requirements.

This graphical interface was first meant to directly connect with the iMeterPlug, sending it commands and collecting readings. As it was not desirable to re-build the entire interface, and the option was to change it as least as possible, it was decided to build the application to work as a bridge between the remote system and the iMeterPlug, re-transmitting the commands and the data from one side to the other, without processing.

The decision’s main consequences were that the only change that needed to be made in the graphical interface was switching the Bluetooth socket by a TCP/IP one, and that the new application couldn’t use the same structure/mechanist as *receivePlogg*.

The plan has been to build a FSM with two main working states for the application to switch during the monitoring session: TR_COMMAND and TR_DATA.

TR_COMMAND is the state when the console is transmitting remote system’s commands to the iMeterPlug and TR_DATA the one when data is being transmitted from this device to the remote system. Transmission is made a byte at a time, and the switching between states is triggered by timeout mechanisms.

Another difference between this and the other demonstration applications is that it needs to work as a server and wait for the remote system to connect.

Figure 19 presents the flowchart of *ploggDemo*’s FSM.

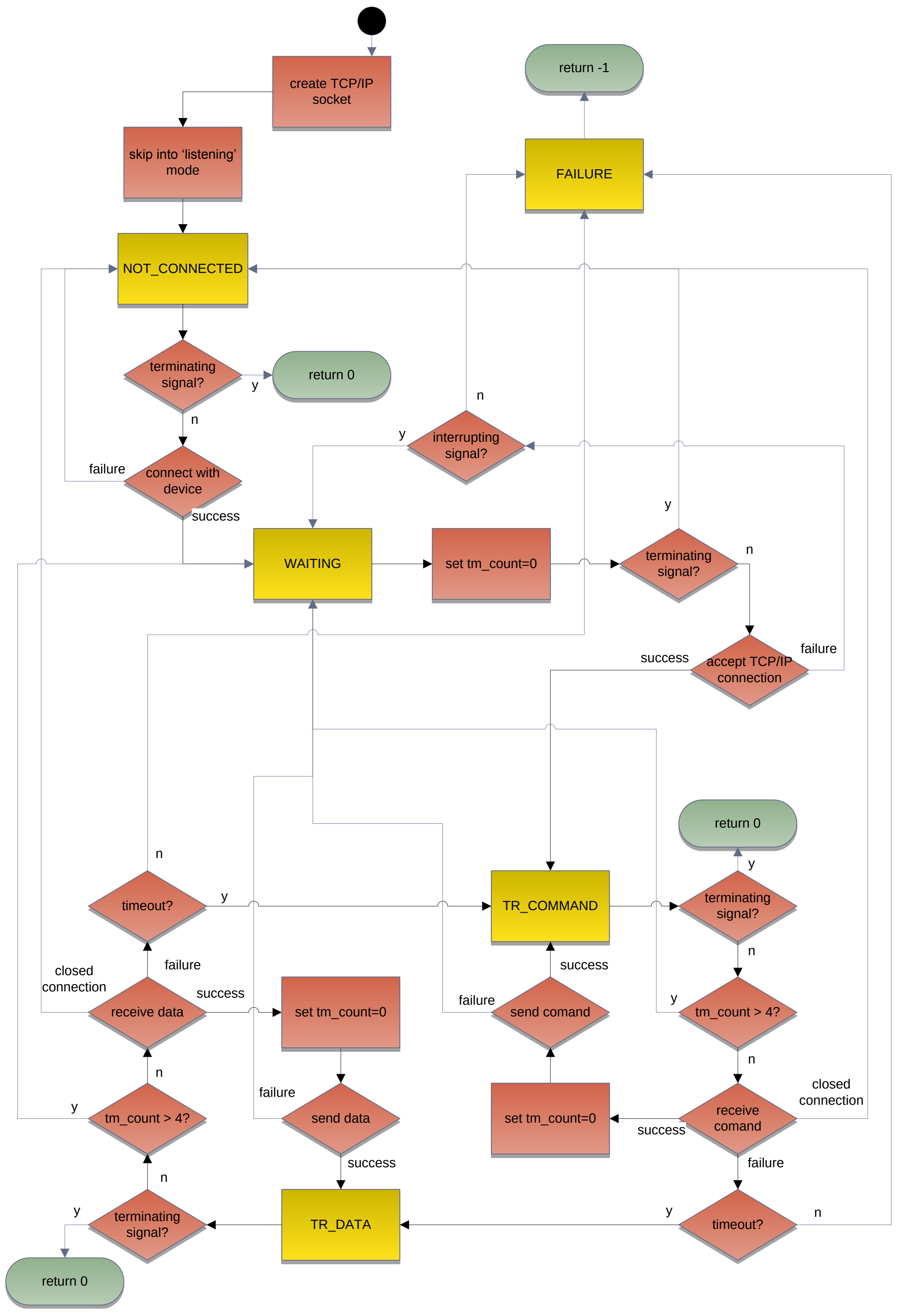


Figure 19 - *ploggDemo*'s FSM flowchart

CHAPTER 6: PROTOTYPING AND TESTING

6.1 PROTOTYPES

There have been set two different prototypes with different scopes during the project. Prototype number one is, in a way, the final result of the project. It was configured as a demonstration of all that has been developed during the project and of all the functionalities already implemented. It was also used to test the system.

Prototype number 2 was developed first than the previous. Its scope was to be a quick demonstration of the AAL Monitoring Console's concept.

6.1.1 PROTOTYPE #1

This is the AAL monitoring console prototype, version 1. Its conceptual scheme is the one described in *Chapter 5: Software Development*, Figure 10 and Figure 11.

It uses the same router that has been used as a sandbox to develop and test all the software as well as to test OpenWrt itself. This router has been reset and re-configured in order to remove all the obsolete files and install the latest versions of the monitoring modules, proper configuration files, the web interface and the *mntrcnsls* application. Table 6 presents the steps followed to configure this prototype.

Table 6 - Prototype #1 setting

Step	Action	Obs.
1	Re-flash of OpenWrt;	Reset to the standard configuration;
2	Time Synchro;	Add an NTP client and set the appropriate time zone - this is necessary because the router has no hardware clock;
3	Add USB support;	Install OpenWrt provided packages;
4	Add USB storage support;	Install packages to support storage through USB and to support FAT file systems;
5	Create an automount shell script for the storage devices;	It should analyze the devices that are connect via USB and, if one is of the storage type, mount it to /mnt folder; It should be started at boot;
6	Add Bluetooth support;	BlueZ packages;
7	Install the monitoring modules;	
8	Install the *mntrcnsls* application;	
9	Set the system to start *mntrcnsls* at boot;	It should be last process to be started by *init*;
10	Install the web interface;	It should be placed in the /www folder;
11	Create /usr/mynetwork folder;	This is where the configuration files will be stored.

6.1.2 Prototype #2

The development of a demonstration prototype started as a parallel task during the development phase, while the communication modules were being developed.

For its first version, the requirements were that it should collect real-time data from the oximeter and transmit them via Wi-Fi to a laptop, were they would be displayed in specific graphical interface. As at the time, router #1 was being used as a sand box to develop the communication modules, it was an opportunity to install OpenWrt in a new router from the beginning and configure it for an exact purpose. A first version of the application *oxDemo* was also developed specifically to this prototype. At the time *oxDemo* received a single input field with a filename on which it read the parameters, this was changed later on.

Table 7 shows the steps that were followed when setting this prototype.

Table 7 - Creation of the demonstration prototype

Step	Action	Obs.
1	Flash of the OpenWrt	Original firmware replacement.
2	Time Synchro	Add an NTP client and set the appropriate time zone;
3	Add USB support	Install OpenWrt provided packages;
4	Add Bluetooth support	BlueZ packages;
5	Install the *oxDemo* application	
6	Set the system to always attribute a known IP address to the designated laptop.	Add a rule to iptables with the chosen IP address and the laptop's MAC adress
7	Set the system to start *oxDemo* on boot;	with the oximeter and server parameters

Support for other devices was included in subsequent versions, through the creation of Bioplux's and iMeterPlug's demonstration applications, following the same strategy as for the oximeter.

With the web interface's creation, and the modifications on the parameter passing mechanism, the prototype was once more altered and it became structurally similar to prototype #1, with the exception that it only has the demonstration modules and the network is configured with the demonstration devices parameters and to send the data to the specified laptop.

6.2 Performed Tests

The system's testing was done in two separate moments, with two different objectives. In a first moment, the web interface was tested to verify its capability of correctly produce and handle the configuration files. The tests focused on the addition and removal of devices from the network and were held immediately after the creation of the web interface.

On a second moment, after the development phase finish, the system was tested as a whole and the focus was set on the user-friendliness of the web interface and the network configuring process, as well as on the unroll of the monitoring process.

Despite the above, in this section, tests are split into tests on the Web interface and tests on the monitoring process.

6.2.1 Web Interface Testing

The intention of including a web interface on this system was, as described on section 4.1.2.1, to create a friendlier way to configure the network and to avoid errors on the configuring files. As so, when testing it, one of the objectives was to see if its reading/writing operations introduced, or not, errors in the configuration files.

6.2.1.1 ADDING A DEVICE TO THE NETWORK

Table 8 presents the results from testing the adding devices mechanism.

Table 8 - Test 1: adding a device to the network

DEVICE	TEST	RESULT	OBS
All	All fields filled	ok	'IP' and 'Port' fields are accepted even when 'STORE' is selected;

All	name unfilled;
	mac unfilled;
		ok	An error is issued (*empty field*); No information is stored on file;

Bioplux, Oximeter	pin unfilled;	ok	Stored as '-'
Bioplux	No channel selected (bitmask)	failed	A device is added with 'bitmask=00000000'; It would be better to notify the user;
Bioplux	srate unfilled;	ok	An error is issued (*empty field*); No information is stored on file;

All	ip_x empty - STORE selected;
	ip empty - STORE selected;
	port empty - STORE selected;
		ok*	Not detected;
			These values will not be used, so it shall not be a problem;

All	ip_x empty - SEND selected;
	ip empty - SEND selected;
	port empty - SEND selected;
		ok	An error is issued (*empty field*); No information is stored on file;

All	Invalid characters (letters in numeric fields, special character...) [mac, pin, srate, ip e port]	failed	There is no validation of the type of data;

There should be noted that the system does not assume the insertion of an IP address and/or TCP port as an error when 'Store' is selected because in this case, those values will not be used. Another notice should be pointed on the fact that 'Store' is not yet available for the oximeter, and the system doesn't notify the user for that fact.

6.2.1.2 DISPLAYING THE NETWORK'S CONTENT

When one presses 'Biopluxs', 'Oximeters' or 'iMeterPlugs' buttons on the menu, the system searches for the correspondent configuration files at /usr/mynetwork/. If these files don't exist, or are empty, the system will return a message informing the user that currently there isn't any device of that kind configured in the network. Unless configuration files get corrupted[3], there shouldn't be any errors associated with the display of the network's content.

6.2.1.3 REMOVING A DEVICE

The removal of a device from the network is achieved simply by clicking the associated 'Remove' button on the display page. By analyzing the underlying mechanism, there should be no errors associated with this action and, during testing, no errors were ever been identified.

6.2.1.4 TESTING THE USER EXPERIENCE

The second series of tests were destined to verify the network configuration process, and how user-friendly the web-interface is. These tests were done by a third-party, with no previous knowledge of the system and using only the provided user-manual.

As the tester was not familiar with the Bluetooth technology and with the monitoring devices, he experienced some difficulties to understand the configuration procedures, namely Bioplux's monitoring options, the Bluetooth PIN and the difference between "send" and "store" data-handling actions.

The tester's analysis identified, from the user's point of view, a few liabilities on the web interface:

1. The devices' Bluetooth user-friendly names [in Annex C: *scan.cgi* application's output] are often inexpressive and difficult to associate with the actual device, making it hard for the user to choose the correct device from the list;
2. The system does not verify if the actual device-type matches the user-specified one;
3. The system also does not offer any kind of validation for the input fields, not alerting the user to eventual inaccuracies.
4. The configurations errors are especially relevant since there is no feedback on the system performance other than the produced output and the connection establishment with the devices.

The tester's overall impression of the interface was that it is agreeable and intuitive, but would much benefit from feedback mechanisms to aid the user on the configuration and to display the monitoring status of each device, and/or the errors associated with it.

6.2.2 MONITORING PROCESS TESTING

The monitoring system was thought to work continuously, restarting the monitoring process every time an error occurs. This is due to the inexistence of feedback mechanisms that allow

[3] The writing operations executed by the interface on the files do not corrupt them. The only chance for this to happen is the by manually alter the files, and eventually during simultaneous access from different users.

notifying the user when something is not right, and also to the fact that the most common error situation is when a device gets out of range.

Tests to the monitoring process were done with the intention of verifying system's recovery capability in several exception situations, for the different devices. They also took into account the integrity of the data after one of these situations.

Results are presented in Table 9.

Table 9 - Monitoring process testing

#	Test	Bioplux	iMeterPlug	Oximeter
1	Device out of range initially;	System stays in NOT_CONNECTED mode and continuously tries to establish a connection;		
2	Device that gets out of range (and eventually returns…);	Session is closed, the system changes into NOT_CONNECTED and tries to re-connect;		
3	Disconnected device;	It's the same as being out of range;		
4	USB storage device not in place;	This situation is not detected. The system writes the data in the router's file system;		–
5	Different devices using the same ID (data-handling action is 'send')	No problem;		
6	Different devices using the same ID (data-handling action is 'store')	Data gets mixed up in the same file		–
7	Many devices connected at the same time;	It has been possible to test the router with 2 Bioplux(s), 3 iMeterPlugs and 1 oximeter simultaneously and with different sampling rates and it didn't failed.		

6.2.3 Identified Bugs

During development and testing phases, a few bugs have been identified and most of them have been corrected. Some of them have however remained unsolved (the reasons for this were their late discovery, their reduced impact on the system's performance or the fact that they're part of something that will/needs to be revised soon), and are here reported.

In the web interface, other than the problems referred above, there are other unsolved problems:

1. The system does not verify if the device that the user is trying to insert isn't already part of the network;
2. There is no control on the devices' IDs singularity;

As for the monitoring modules, the only identified situation is that the package parsing mechanism in *receiveBioplux* and *biopluxDemo* applications does not support every possible channel bitmask combination. It reads the 'n' channel values from the package and stores the data into the first 'n' position of the destination array, without taking into account that data may not come from the first ‘n’ channels. As so, the only bitmask options for which the system works properly are the ones in Table 10.

Table 10 - Channel bitmask valid options

00	00000000
01	00000001
03	00000011
07	00000111
0F	00001111
1F	00011111
3F	00111111
7F	01111111
FF	11111111

There is also an unclear situation about the oximeter. When a connection with this device is lost, it is necessary to hold the device disconnected or out of range for about five seconds before a new attempt. The reason for this could not be identified, but its origin is probably in the device’s connection protocol.

Chapter 7: Conclusions and Future Work

Previews chapters intend to describe the development steps of the AAL monitoring console, project's stages, its inputs and outputs as well as to mirror work progression during the internship.

This chapter looks back on the initial objectives and goals, on the outlined solutions and developed components and tries to summarize what have been done, what could be improved and which directions could be followed. Finally, a reflection on the project's meaning is made.

7.1 Project Status

Project's main goal has been accomplished; it has been possible to take an existing, fully developed, stable and expandable platform and customize it into a wireless sensor monitoring console.

On the hardware level, the console was built using a broadband wireless router, an USB Bluetooth radio adapter and a USB storage device. The router's original firmware has been replaced with an OpenWrt image (a Linux based open-source firmware) and upon it runs a software solution that handles the monitoring process.

The use of a standard wireless router and open-source firmware, instead of creating a platform from scratch, considerably decreased project's development period, human resources assignment and development costs. It also has reduced the estimated price of the final product.

The software was designed to be modular; it comprehends a web interface, a set of monitoring modules that provide support for each device's communication protocol and handle data collection, and a special application that bridges configuration instructions from the web interface to the monitoring applications.

So far, the console supports three devices' communication protocols, Plux's vital signs monitor (Bioplux), NONIN's 4100 oximeter and ISA's iMeterPlug. The system also supports local storage of collected data and its transmission to a remote server through a TCP/IP connection.

Console's web interface has been implemented as a monitoring network configuration tool, and aids the user to add and remove devices to the network, to set each device monitoring parameters and to check the content of the network.

The information collected by the web interface is stored in configuration files that are read by a special application — *mntrcnsld*. This application sequentially opens each device-type configuration file, and launch new processes running the monitoring applications with the parameters specified for each device.

Two prototypes have been assembled, one for commercial demonstration of the concept, and another as the final result of the project. The first one collects information from preconfigured devices and transmits it in real time to a laptop, through Wi-Fi, where it is displayed in demonstration graphical applications. The second prototype has the whole set of developed applications, support all the implemented features, and was used for testing.

During testing, the system has been set to monitor 5 individual devices, of the three supported types with different configurations, for a reasonable period of time and worked properly and without delays.

Concluding, the existing monitoring console's prototype is a valid implementation of the concept presented in the first chapters of this document, and has potential to evolve into the idealized full-feature, all-in-one home control center.

7.2 Possible Future Developments

Being a proof-of-concept and only a first prototype, the current version of ISA's AAL monitoring console has a lot of improvement possibilities that can be implemented, some on a shorter term, as the correction of the indentified bugs, and other on the medium/long term, as extending support to more devices and to other wireless short-range technologies. This section will present the structural improvements that can be developed in the system's future versions.

One of the issues pointed by the person that tested the prototype was the lack of feedback from the system during configuration and the monitoring process itself, especially when things don't work, or errors occur. It would then be important to create an error log that could be consulted with the web interface, in which the system would record error events with information on the episode's time and the application/function where it occurred. From another point of view, it would be interesting to add a diagnostic tool to the web interface that would, for each device, check if monitoring is being done properly and display the result together with configuration information.

Still relatively to the web interface, the introduction client-side scripts' support would improve its dynamics and allow it not only to work as a configuration tool, but also to display information in real time such as resource usage statistics, activity diagnostics or the actual collected data.

As for the monitoring software, a necessary upgrade would be the design of a data transmission protocol to remote servers and its implementation on the different processing applications. However, this requires a thorough study of possible monitoring scenarios, conditions in which a live transmission should be done, possibility of collecting all the data into a file and send the entire file at the end of the "exam", how should the system act when connection with the server fails, how should a 'temporary cache' mechanism be implemented and how should data be transmitted when connection is re-established.

Besides continuous monitoring of the patient and his/her routines and environment, the AAL system (with proper sensors) could be used to perform medical exams at home. This would have particular relevance in chronic condition cases that need frequent periodic check-ups and, for example, in diagnosing sleep disorders, reducing costs and improving chances of a correct diagnosis. To do such exams, the console would need to support discontinuous monitoring ("spot-checks") and to be able to store data in some special medical file-types, such as EDF/EDF+ for electroencephalographic and polysonographic data.

Another interesting upgrade would be enabling the console to use GSM/GPRS/UMTS USB modems, as a way of expand system's connectivity, creating redundancy in communication channels and increasing applicability.

On the home-monitoring side, it would be a waste not taking advantage of ISA's world leading energy & environment monitoring solutions and not integrating information on real energy and water consumptions, and air quality, for example.

Finally, integrating all health and home-monitoring solutions with home-automation devices, a communications central, broadband internet access, high definition digital television and routine analysis' data-mining software and an alert manager into a single 'box' should be considered as the long-term goal for the ultimate AAL monitoring console.

7.3 Final Appreciation

European Union's objectives regarding Ambient Assisted Living programme are mainly to extend the time elderly people can live autonomously in their homes, increasing life quality and, on the same time, improving health systems' efficiency, eventually reducing their overall costs.

Within that scope, this project pursues the idea of integrating health monitoring devices with home-monitoring networks and advanced data-mining software to create a comprehensive solution that can effectively assist people at their homes. Furthermore, it pursues the idea of creating a very flexible system, able to perform complex medical exams remotely.

The project isn't finished, yet an important step has been taken. A prototype has proven that such a system works, can be based in existing technology and be built with a relatively low budget.

Being part of this project and having the opportunity to work in a technological innovative company such as ISA has definitely contributed to my professional and personal development. This experience has provided me with the technical competences, soft-skills and knowledge of the enterprise world that I was seeking for, a year ago.

BIBLIOGRAPHY

1. **European Union.** "Ageing well": European Commission unleashes €600m for development of new digital solutions for Europe's elderly people. *Europa.* [Online] June 23, 2008. [Cited: August 1, 2009.] http://europa.eu/rapid/pressReleasesAction.do?reference=IP/08/994&format=HTML&aged=0&language=EN&guiLanguage=en.

2. **Federal Ministry of Transport, Innovation and Technology.** AAL FORUM '09 Vienna . *BMVIT.* [Online] [Cited: August 22, 2009.] http://www.bmvit.gv.at/en/innovation/aalforum/index.html.

3. **Wikipedia.** Ambient Assisted Living. *Wikipedia, the free encyclopedia.* [Online] August 3, 2009. [Cited: August 23, 2009.] http://en.wikipedia.org/wiki/Ambient_Assisted_Living.

4. —. Z-Wave. *Wikipedia, the free encyclopedia.* [Online] September 3, 2009. [Cited: September 4, 2009.] http://en.wikipedia.org/wiki/Z-Wave.

5. **Rosenthal, Avi.** Review: Mi Casa Verde Vera, Z-Wave Automation System. *Electronic House.* [Online] April 27, 2009. [Cited: September 4, 2009.] http://www.electronichouse.com/article/review_mi_casa_verde_vera_z_wave_automation_system/.

6. **Bartholomew, Daniel.** Control Your Home with Vera from Mi Casa Verde. *Linux Journal.* [Online] May 1, 2009. [Cited: September 4, 2009.] http://www.linuxjournal.com/article/10302.

7. **MiCasaVerde.com.** Intro Universal Remote. *MiCasaVerde - Wiki.* [Online] January 4, 2009. [Cited: Saptember 4, 2009.] http://wiki.micasaverde.com/index.php/Intro_Universal_Remote.

8. **A&D Medical.** CP-1THW. *Life Source.* [Online] [Cited: September 4, 2009.] http://www.andmedical.com/and_med.nsf/html/CP-1THW.

9. **Fox, Jeff.** A&D Medical Releases Multi-Language Wellness Connected Software. *Reuters.* [Online] April 27, 2009. [Cited: September 4, 2009.] http://www.reuters.com/article/idUS131323+27-Apr-2009+MW20090427.

10. **There.** Home. *Smart home solutions.* [Online] [Cited: September 4, 2009.] http://smarthomepartnering.com/cms/.

11. —. Product. *There.* [Online] [Cited: September 4, 2009.] http://www.therecorporation.com/product.html.

12. **Ricker, Thomas.** Nokia spins off Home Control Center team as There Corporation, slips product into 2010. *engadget.* [Online] May 28, 2009. [Cited: September 4, 2009.] http://www.engadget.com/2009/05/28/nokia-spins-off-home-automation-team-to-there-corporation-slips.

13. **Asadoorian, Paul and Pesce, Larry.** *Linksys WRT54G Ultimate Hacking.* Burlington : Syngress Publishing, Inc, 2007. 978-1-59749-166-2.

14. **Kollasch, Jonathan.** MinimumSystemRequirements . *OpenWRT wiki.* [Online] 12 28, 2005. http://wiki.openwrt.org/MinimumSystemRequirements.

15. **OpenWrt.org.** Table Of Hardware. *OpenWrt wiki.* [Online] June 10, 2009. [Cited: August 18, 2009.] http://wiki.openwrt.org/oldwiki/tableofhardware.

16. —. ASUS WL-500GPremium. *OpenWrt wiki.* [Online] April 23, 2009. [Cited: August 20, 2009.] http://wiki.openwrt.org/oldwiki/openwrtdocs/hardware/asus/wl500gp.

17. **Wikipedia.** Bluetooth. *Wikipedia, the free encyclopedia.* [Online] August 18, 2009. [Cited: August 18, 2009.] http://en.wikipedia.org/wiki/Bluetooth.

18. —. Electrocardiography. *Wikipedia, the free encyclopedia.* [Online] August 19, 2009. [Cited: August 21, 2009.] http://en.wikipedia.org/wiki/Electrocardiography.

19. —. Pulse oximeter. *Wikipedia, the free encyclopedia.* [Online] August 10, 2009. [Cited: August 21, 2009.] http://en.wikipedia.org/wiki/Pulse_oximeter.

20. **NONIN Medical, Inc.** 4100 Bluetooth® Wireless Pulse Oximeter. *Nonin Medical.* [Online] [Cited: August 21, 2009.] http://www.nonin.com/documents/4100%20Brief.pdf.

21. **Fietkau, Felix.** OpenWrt Hacking. [Online] December 6, 2005. [Cited: January 22, 2009.] http://events.ccc.de/congress/2005/fahrplan/attachments/567-Paper_HackingOpenWRT.pdf.

22. **The Linux Information Project.** The C Programming Language: A Very Brief Introduction. *LINFO.* [Online] June 28, 2006. [Cited: August 26, 2009.] http://www.linfo.org/c.html.

23. **Wikipedia.** C (programming language). *Wikipedia, the free encyclopedia.* [Online] August 26, 2009. [Cited: August 26, 2009.] http://en.wikipedia.org/wiki/C_(programming_language).

24. **BlueTomorrow.com .** What is Bluetooth Technology? *BlueTomorow.com.* [Online] [Cited: August 18, 2009.] http://www.bluetomorrow.com/content/section/10/37/.

25. **Wikipedia.** Common Gateway Interface. *Wikipedia, the free encyclopedia.* [Online] August 11, 2009. [Cited: August 18, 2009.] http://en.wikipedia.org/wiki/Common_Gateway_Interface.

26. **Damas, Luís.** *Linguagem C.* Lisboa : FCA - Editora de Informática, 1999. ISBN 9789727221561.

27. **Huang, Albert S. and Rudolph, Larry.** *Bluetooth Essentials for Programmers.* Cambridge : Cambridge University Press, 2007. ISBN-13 978-0-511-35583-7.

28. **Mitchell, Mark, Oldham, Jeffrey and Samuel, Alex.** *Adavanced Linux Programming.* Indianapolis : New Riders Publishing, 2001. ISBN: 0-7357-1043-0.

29. **Stallman, Richard M., McGrath, Roland and Smith, Paul D.** *GNU Make Manual.* Boston : Free Software Foundation, 2006. ISBN 1-882114-83-5.

30. **LeBlanc, Dee-Ann and Blum, Richard.** *Linux for Dummies.* 8th Edition. Indianapolis : Wiley Publishing, 2007. ISBN: 978-0-470-11649-4.

31. **Matthew, Neil and Stones, Richard.** *Beggining Linux Programming.* 4th Edition. Indianapolis : Wiley Publishing, 2008. ISBN: 978-0-470-14762-7.

32. **Yaghmour, Karim, et al.** *Building Embedded Linux Systems.* 2nd Edition. Sebastopol : O'Reilly Media, 2008. ISBN: 978-0-596-52968-0.

33. **Flickenger, Rob.** *Wireless Hacks.* Sebastopol : O'Reilly & Associates, 2003. ISBN : 0-596-00559-8 .

34. **Parlante, Nick.** Essencial C. *Stanford CS Education.* [Online] 2003. [Cited: November 13, 2008.] http://cslibrary.stanford.edu/101/EssentialC.pdf.

35. —. Pointers And Memory. *Stanford CS Education.* [Online] 2000. [Cited: November 13, 2008.] http://cslibrary.stanford.edu/102/PointersAndMemory.pdf.

36. —. Linked List Basics. *Stanford CS Education.* [Online] April 2001. [Cited: November 13, 2008.] http://cslibrary.stanford.edu/103/LinkedListBasics.pdf.

37. —. Binary Trees. *Stanford CS Education Library.* [Online] 2001. [Cited: November 13, 2008.] http://cslibrary.stanford.edu/110/BinaryTrees.pdf.

38. **Martin, Robert C.** UML Tutorial: Finite State Machines. *Object Mentor.* [Online] June 1998. [Cited: April 16, 2009.] http://www.objectmentor.com/resources/articles/umlfsm.pdf.

39. **Gookin, Dand.** *C for Dummies.* Indianapolis : Wiley Publishing, 2004. ISBN: 0-7645-7068-4.

40. **Heffermanand, Linda and Dornfest, Asha.** *Microsoft Expression Web For Dummies.* Indianapolis : Wiley Publishing, 2007. ISBN:9780470115091.

41. **Duckett, Jon.** *Beggining Web Programming with HTML, XHTML, and CSS.* 2nd Edition. Indianapolis : Wiley Publishing, 2008. ISBN: 978-0-470-25931-3.

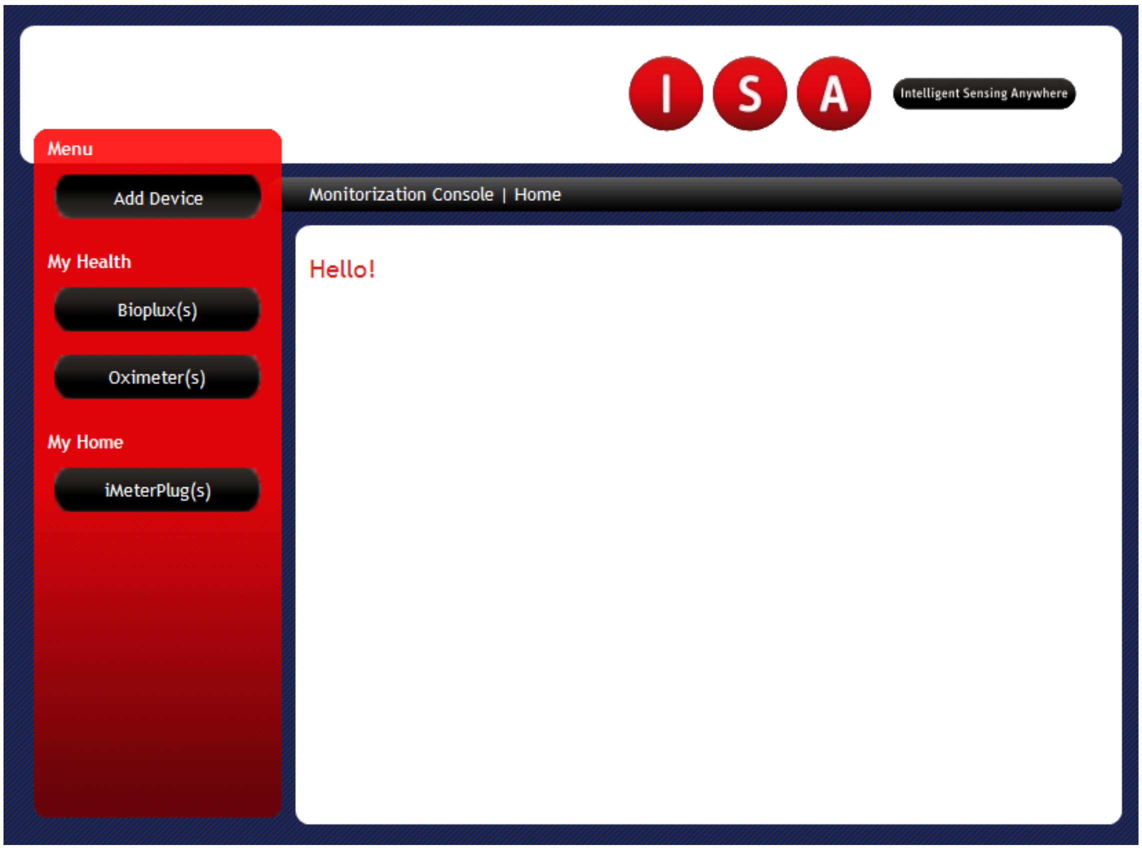
42. **Wise, Cheryl D.** *Foundations of Microsoft Expression Web: The Basics and Beyond.* Berkeley : Apress, 2007. ISBN-13: 978-1-59059-805-4.

43. **OpenWrt.org.** Kamikase documentation. *OpenWrt DOcs.* [Online] [Cited: February 2, 2009.] http://downloads.openwrt.org/kamikaze/docs/openwrt.pdf.

ANNEXES

ANNEX A: WEB INTERFACE MAIN PAGE

The image shows the web interface's main page as an example of its general layout.



ANNEX B: CONFIGURATION FILES' STRUCTURING

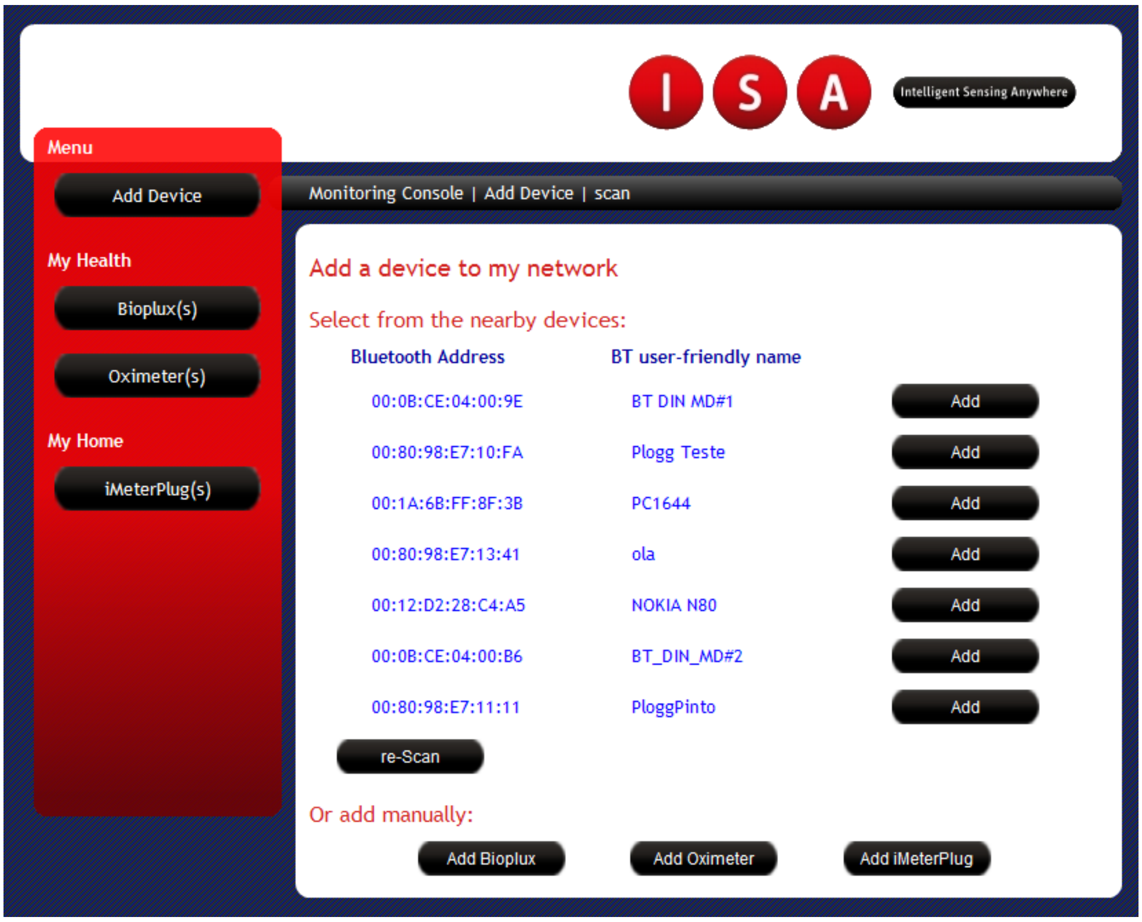
The following table presents how the configuration information, collected from the web interface is stored on the configuration files. These files are organized in lines, each one referring to a single device, and holding all its configuration fields.

Device:	File Name (and Path):	Line Format:
BioPlux	/usr/mynetwork/bioplux	"a" bb:bb:bb:bb:bb:bb "c" dddddddd eeee ff "g" hhh.hhh.hhh.hhh "i"
Oximeter	/usr/mynetwork/oximeter	"a" bb:bb:bb:bb:bb:bb "c" "g" hhh.hhh.hhh.hhh "i"
iMeterPlug	/usr/mynetwork/imeterplug	"a" bb:bb:bb:bb:bb:bb "g" hhh.hhh.hhh.hhh "i"

References:

"a"	ID - device's identification name
bb:bb:bb:bb:bb:bb	Device's Bluetooth MAC address
"c"	Bluetooth PIN
dddddddd	Bioplux's Cannel Bitmask
eeee	Bioplux's Sample Rate (Hz)
ff	Bioplux's Resolution
"g"	Data handling action ("Store" or "Send")
hhh.hhh.hhh.hhh	Server's IP Address (default: 000.000.000.000)
"i"	Server's TCP port (default: "-")

ANNEX C: *SCAN.CGI* APPLICATION'S OUTPUT


Intelligent Sensing Anywhere
Menu
Add Device
My Health
Bioplux(s)
Oximeter(s)
My Home
iMeterPlug(s)
Monitoring Console | Add Device | scan

Add a device to my network

Select from the nearby devices:

Bluetooth Address	BT user-friendly name	
00:0B:CE:04:00:9E	BT DIN MD#1	Add
00:80:98:E7:10:FA	Plogg Teste	Add
00:1A:6B:FF:8F:3B	PC1644	Add
00:80:98:E7:13:41	ola	Add
00:12:D2:28:C4:A5	NOKIA N80	Add
00:0B:CE:04:00:B6	BT_DIN_MD#2	Add
00:80:98:E7:11:11	PloggPinto	Add

re-Scan

Or add manually:

Add Bioplux   Add Oximeter   Add iMeterPlug