

WEB-BASED WIRELESS SENSOR NETWORK PLATFORM

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FINAL DEGREE PROJECT

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Dedicado a mi familia y amigos.

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I would like to specially thank my family and friends for supporting me during these recent years of my life, and my supervisors, Toni Adame and Gabriel Martins, for helping me in the development of this project.

Abstract

The aim of this project is to design and implement a web-based platform for storing and visualizing the data retrieved by Wireless Sensor Networks (WSNs). This approach is part of the Entomatic project, an European Union (EU) funded plan for addressing a major problem faced by EU Associations of Olive growing Small and Medium-sized Enterprises (SMEs): the Olive fruit fly (*Bactrocera oleae*). Olive oil trees will feature a series of sensors, mainly consisting of olive fly traps as a way to track its population. Such sensors will output data through a gateway to be finally gathered by the platform proposed in this document. The system presented in this project consists of two parts: (1) a web-server that receives the sensed data and stores them in a database; and (2) a web-application for visualizing the obtained measurements including, among others, map node location, statistics, and charts. Cutting edge web technologies have been used in order to create a modern, yet maintainable and scalable platform.

Resumen

El objetivo de este proyecto es diseñar e implementar una plataforma web para gestionar una red de sensores inalámbrica (WSN). Esta propuesta es parte del proyecto Entomatic, un plan financiado con fondos de la Unión Europea (UE) para solucionar un problema creciente en las pequeñas y medianas empresas (Pymes) de cultivo de aceite de oliva: la mosca del Olivo (*Bactrocera oleae*). Diferentes tipos de sensores, principalmente trampas para moscas, serán colocados en los olivos como manera de controlar la población. Estos sensores generarán datos a través de una puerta de enlace (Gateway) para finalmente ser obtenidos por la plataforma propuesta en este documento. El sistema presentado en este proyecto consiste de dos partes: (1) un servidor web que recibe los datos obtenidos por los sensores y los almacena en una base de datos; y (2) una aplicación web para visualizar las medidas obtenidas, incluyendo, entre otros, localización de nodos en mapa, estadísticas, y gráficos. Tecnologías de estado del arte se han usado con la finalidad de crear un plataforma moderna, mantenible y escalable.

Index

	Page
Abstract.....	vii
1.INTRODUCTION.....	1
1.1 Project overview.....	1
1.2 Entomatic Project.....	2
1.1.2 Internet of the things (IoT).....	3
1.2.2 Wireless Sensor Networks (WSN).....	3
1.2.3 Cloud Computing.....	4
1.2.4 Problem to be solved.....	4
1.2.5 Motivation.....	5
1.2.6 Scope of the proposed project.....	5
1.2.7 Project planning.....	6
2. STATE OF THE ART.....	7
2.1 Existing WSN platforms.....	7
2.2 Web technologies.....	7
2.2.1 Web architecture.....	8
2.2.1.1 Client-server model.....	9
2.2.1.2 N-tier architecture.....	9
2.2.1.3 Uniform Resource Locators (URL).....	10
2.2.1.4 HTTP protocol.....	10
2.2.1.5 Messaging formats.....	11
2.2.1.6 Representational State Transfer.....	11
2.2.1.7 Web applications.....	11
2.3 Web frameworks.....	12
2.3.1 Backend frameworks.....	12
2.3.1.1 Architectural patters –MVC.....	12
2.3.1.2 Programming languages.....	14
2.3.1.3 Software design style.....	15
2.3.1.4 Object-relational mapping (ORM).....	15
2.3.1.5 Restful APIs.....	16
2.3.1.6 Considered platforms.....	17
2.3.2 Frontend Frameworks.....	19
2.3.2.1 Single page applications.....	20
2.3.2.2 Asynchronous JavaScript And XML (AJAX)...	20
2.3.2.3 JavaScript frameworks.....	20
2.3.2.4 CSS frameworks.....	23
2.3.3 Data Base Engines.....	23
2.3.3.1 Relational Data bases (SQL).....	23
2.3.3.2 No SQL DB.....	23
2.4 Code versioning.....	23
3. USED TECHNOLOGIES.....	25
3.1 Server side framework.....	25
3.2 Front End frameworks.....	26

3.3 Data Base engine.....	27
3.4 Versioning.....	27
4. PLATFORM IMPLEMENTATION.....	29
4.1 Design Strategy.....	29
4.1.1 Design constraints.....	29
4.1.2 Proposed design.....	29
4.2 Database.....	30
4.2.1 Requirements.....	31
4.2.2 Data model.....	31
4.3 Sails.js Backend.....	35
4.3.1 Project structure.....	35
4.3.2 WSN API.....	37
4.3.2.1 New gateway.....	38
4.3.2.2 New Sensor.....	39
4.3.2.3 New Measurement.....	41
4.3.2.4 New Alarm.....	44
4.3.3 Web app API.....	46
4.3.3.1 Page Controller.....	46
4.4 Front End.....	47
4.4.1 Angular.js app components.....	47
4.4.2 Login module.....	48
4.4.2.1 User authentication.....	48
4.4.3 Dashboard module (main module).....	49
4.4.3.1 CSS components.....	49
4.4.3.2 UI routing.....	49
4.4.3.4 Main.....	52
4.4.3.5 Home.....	53
4.4.3.6 Sensor Location.....	53
4.4.3.7 Statistics.....	54
4.4.3.8 Alarms.....	54
4.4.3.9 Configurations.....	55
4.5 Version control.....	55
5. WEB APPLICATION WALKTHROUGH.....	57
5.1 Login.....	57
5.2. Dashboard.....	58
5.2.1 Top Navigation bar.....	59
5.2.2 Lateral navigation bar.....	59
5.2.3 Home.....	60
5.2.4 Sensor location.....	61
5.2.5 Statistics.....	64
5.2.6 Alarms.....	66
5.2.7 Configurations.....	66
6. DEPLOYMENT AND TESTING.....	69
6.1 Deployment.....	69
6.2 Testing scenario.....	69
6.2.1 Measurement types.....	70

6.2.2 WSN Hardware.....	70
6.2.3 WSN simulation results.....	73
7. CONCLUSIONS.....	77
7.1 Future Work.....	77
Bibliography.....	79

Chapter 1: Introduction

1.1 Project overview

During the last decade, sensors have become part of our lives. We use them constantly: in our smartphones, factories tracking CO₂ emissions, heart monitoring implants, etc. Even the most unimaginable things can be sensed and tracked. In that sense, the reduction of manufacturing costs and the technological development of these devices have led to the spread of the phenomena of the Internet of things (IoT), a scenario in which objects, animals or people are provided with unique identifiers and the ability to transfer data over a network without requiring human interaction [1].

Moreover, the use of Wireless Sensor Networks (WSN) has made possible many IoT scenarios by the use of wireless distributed independent devices (within a network) that use sensors to monitor physical conditions, and therefore, making it easier in for certain applications that need the use of this technology [2].

Many interesting applications can be derived from these concepts including wide areas such as health and sports, military and defense or industrial use. The data generated from the sensors in these projects can be huge and any sort of managing platform is needed for storing, visualizing and manipulating the output. The use of graphical interfaces (GUI) with desktop or web applications combined with servers and data bases (DB) are a common way to solve this issue by providing user friendly access to data.

This project proposes, designs and implements a web platform for storing and visualizing the data retrieved by WSNs. This approach is part of the Entomatic Project, a European funded plan for tracking the olive fruit fly population. The system will be in charge of (1) obtaining and storing the data gathered by a WSN and (2) a web-application for visualizing the obtained measurements including, among others, map node location, statistics, and charts. Fig 1 shows an approximation of the system that is presented.

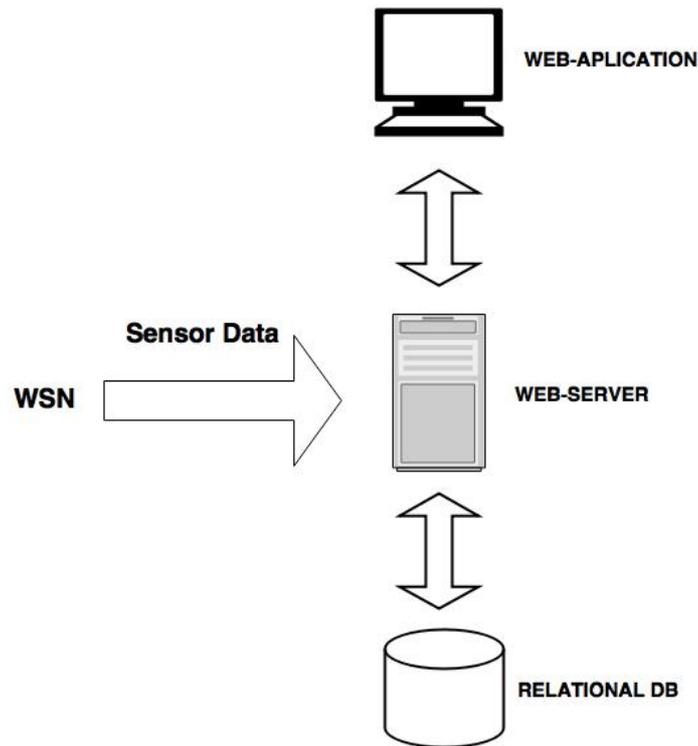


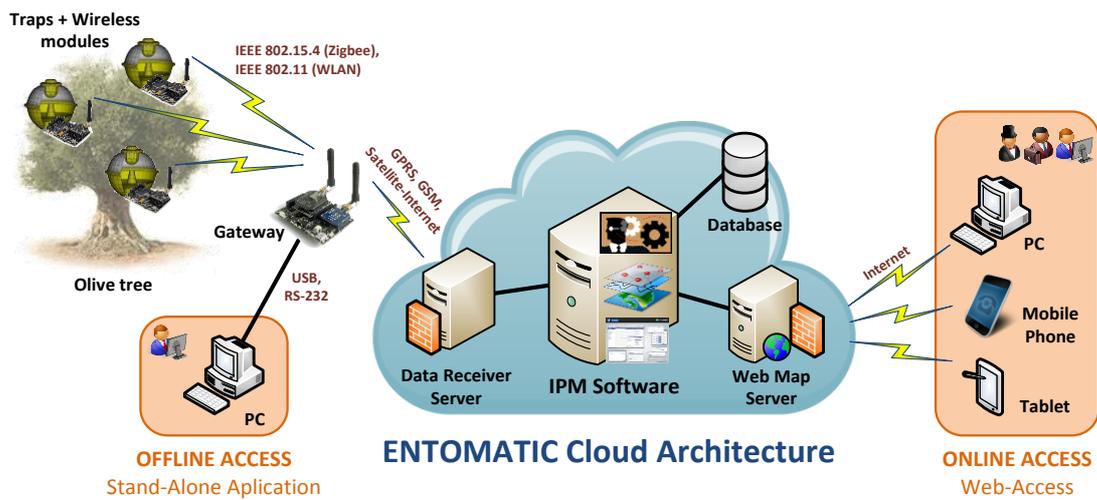
Fig. 1.1: The presented system

1.2 Entomatic Project

This section will provide information regarding the project in which the platform is framed.

The *Entomatic* project is a European for addressing a major problem faced by EU Associations of Olive growing Small and Medium-sized Enterprises (SMEs): the Olive fruit fly (*Bactrocera oleae*). This insect pest causes yearly economic losses estimated to be almost €600/ha. ENTOMATIC aims to develop a novel stand-alone field monitoring system comprising: a fully autonomous trap with integrated insect bioacoustic recognition embedded in a wireless sensor network and supported by a spatial decision support system. Olive producers will be able to track pest population and geographical status and receive advice on precision pesticide application. [3]

The architecture of the Entomatic project can be summarized in two parts: the WSN where sensors are placed and obtains the information, and the cloud platform for storing the data and managing the platform (where this project takes part).



IPM SOFTWARE
(Integrated Pest Management Software)

- Monitoring & Management Central**
- GIS (Geographic Information System)**
- GUI (Graphical User Interface)**

LEVELS OF DATA ACCESS

- Regional & national authorities**
- Organizations from a specific region**
- Single SME-AG**

Fig. 1.2: The Entomatic Architecture

1.2.1 Internet of things (IoT)

This project should be considered as part of the Internet of things (IoT). The Internet of things can be defined as “[..] A scenario in which objects, animals or people are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.” [1]. In this sense, Entomatic is providing a series of sensors meant for tracking the population of the olive oil fruit fly and thus making use of the IoT paradigm

1.2.2 Wireless Sensor Networks (WSN)

The whole Entomatic project relies on the WSN technology. In a WSN, wireless sensor nodes are spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc., and to

cooperatively pass their data through the network to a main location [2]. Entomatic is designed to feature two keys elements of a WSN:

- Wireless sensor nodes, such as the olive fruit fly traps, acting as end points.
- One or more gateways which transmit (as well as manage) all the nodes data to an external server.

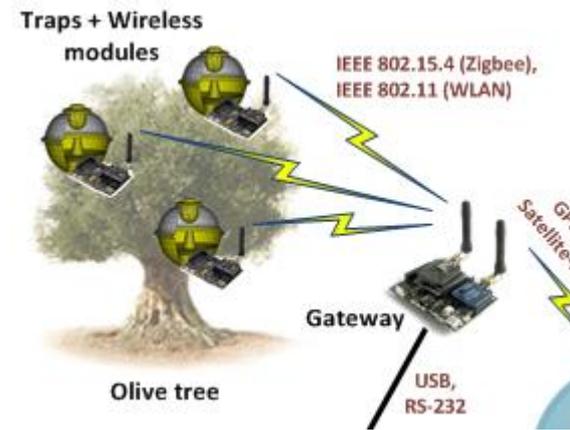


Fig. 1.3: Entomatic WSN

1.2.3 Cloud computing

Cloud computing is a paradigm in which computing services can be done through the internet [4]. Entomatic project relies over this term as all data coming from the different olive trees fields will be stored over a cloud platform, physically located away from where the data was acquired, and therefore relying on an internet resource. It is important to focus on this fact as the prototype proposed in this work will act as an early stage cloud cloud platform for Entomatic.

1.2.4 Problem to be solved

The problem to be solved relies on creating the cloud or web platform for the WSN. In its final form, this platform should provide a solution for SMEs to track their Olive tree fields and obtain meaningful data so as to increase their productivity. This will include, storing in a proper way all the data coming from the sensors; and a web application for showing the data regarding the obtained measurements, and the location of the nodes. Although the market provides a wide variety of tools for developing web platform,

research has been carried in order to show the current state of the art technologies as well providing with a scalable and maintainable system.

1.2.5 Motivation

The main motivation for carrying out this project was to be involved in a real project as my final degree work and to contribute to something meaningful.

Having been a developer in a consulting company for almost a year was also an extra motivation as to expand my knowledge into new technologies and to apply into a personal project the learned concepts.

1.2.6 Scope of the proposed system

The platform or system to be implemented should have to following specifications:

- Feature a Restful API for managing a WSN which should store the following information:
 - Gateway: The system should be able to store and sync with any gateway from the WSN.
 - Nodes: The platform should be capable of storing nodes and to synchronize with them.
 - Measurements: Store the different measurements the sensors output such as temperature, relative humidity among others.
 - Alarms: Handle alarms from the WSN (as way to notify if any problems happen in the network) and create any other if issues occur.
- Web Application to visualize data including the following features:
 - Provide a user authentication tool.
 - Map nodes and gateways location.
 - Manage different measurements from the sensors, and filter and sort them by different date periods.
 - Alarm handling as a way of managing the possible issues that the WSN may face.

1.2.7 Project planning

Before any development was done, a project planning was made in order to identify all the key aspects the project should take into account. The project was split into three major blocks: A state of the art research in web technologies, so as to find the best fitting solutions for the construction of the platform, a development and designing part, made for building the system, and a testing block, as way to validate the correct operation of the system and perform any further corrective actions if issues were found.

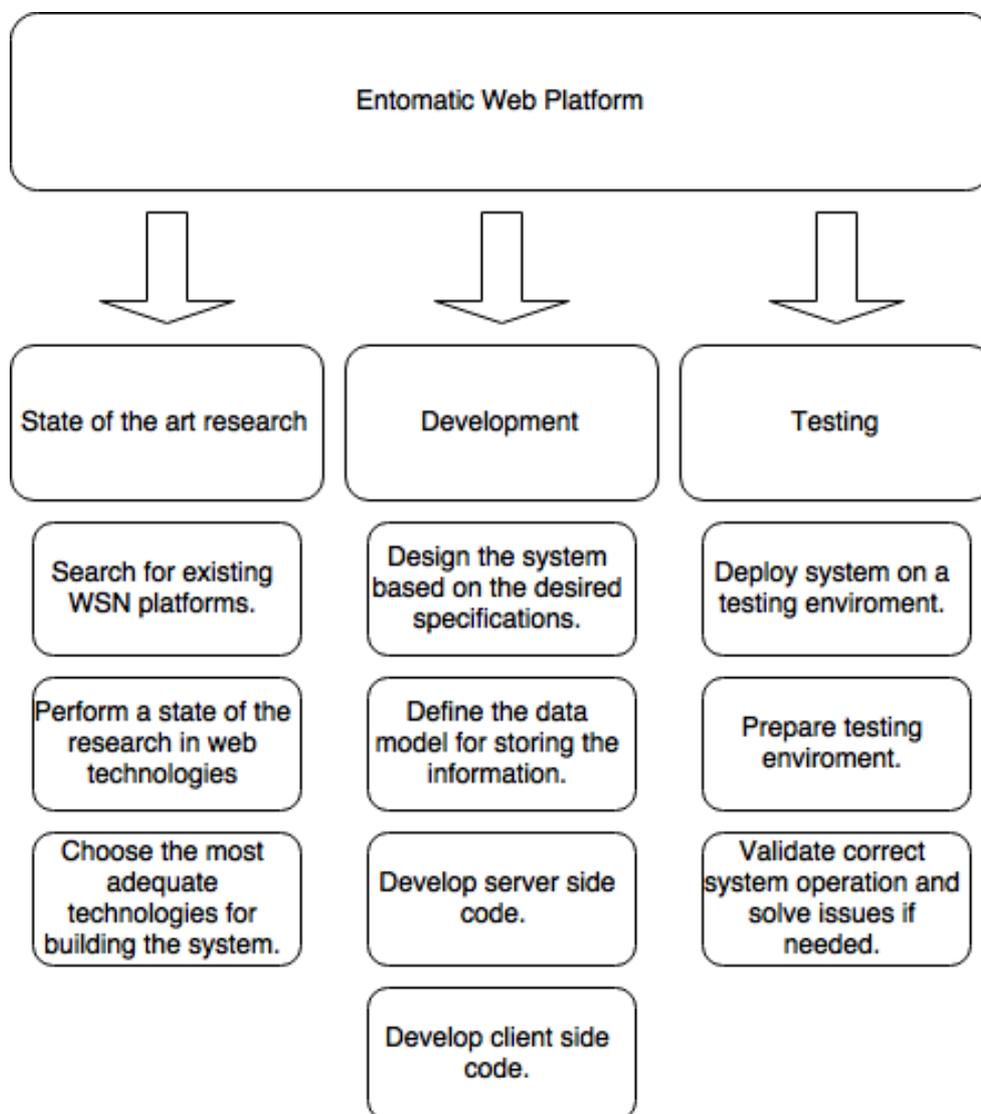


Fig. 1.3: Project planning

Chapter 2: State of the art

This chapter will feature the current state of the art as far as web technologies for developing modern web platforms are concerned as well as giving brief information about the existing platforms for managing WSNs.

2.1 Existing WSN platforms

WSNs have become a quite popular technology in both academic and commercial use. Not always custom solutions are needed. Here are presented some commercial solutions:

- **MOTEVIEW:** Moteview is a platform designed for the crossbow platform MOTE is designed to be an interface (“client layer”) between a user and a deployed network of wireless sensors. Moteview provides users the tools to simplify deployment and monitoring. It also makes it easy to connect to a database, to analyze, and to graph sensor readings.
- **OCTOPUS:** Octopus is an open-source dashboard to visualize and to control a wireless sensor network in the TinyOS 2.x environment. Octopus provides users with a graphical user interface (GUI) for viewing the live sensor network topology. It also allows the user to dynamically control the behavior of sensor nodes, such as the energy consumption, the sampling period, the radio duty cycle and formulating application queries to the nodes.

2.2 Web technologies

This section will provide information about the current state of the art technologies as far as web technologies for developing modern web platforms are concerned.

Web technologies have evolved significantly since the early days of the internet. This has provided not only the adoption of the World Wide Web by end users, but also web development has become notably easier, and as a result, fast prototyping and

implementation of web applications, like the one proposed in this work, could be made possible.

In order to introduce the reader the different solutions available, prior explanations will be carried about core concepts regard how web platforms are designed followed by more specific technology point of view implementations of the available technologies.

2.2.1 Web architecture

A web architecture represents how a network enabled system is designed from a high level perspective. Figure 2.1 shows an approximation of how the proposed web architecture should look like from web architecture perspective.

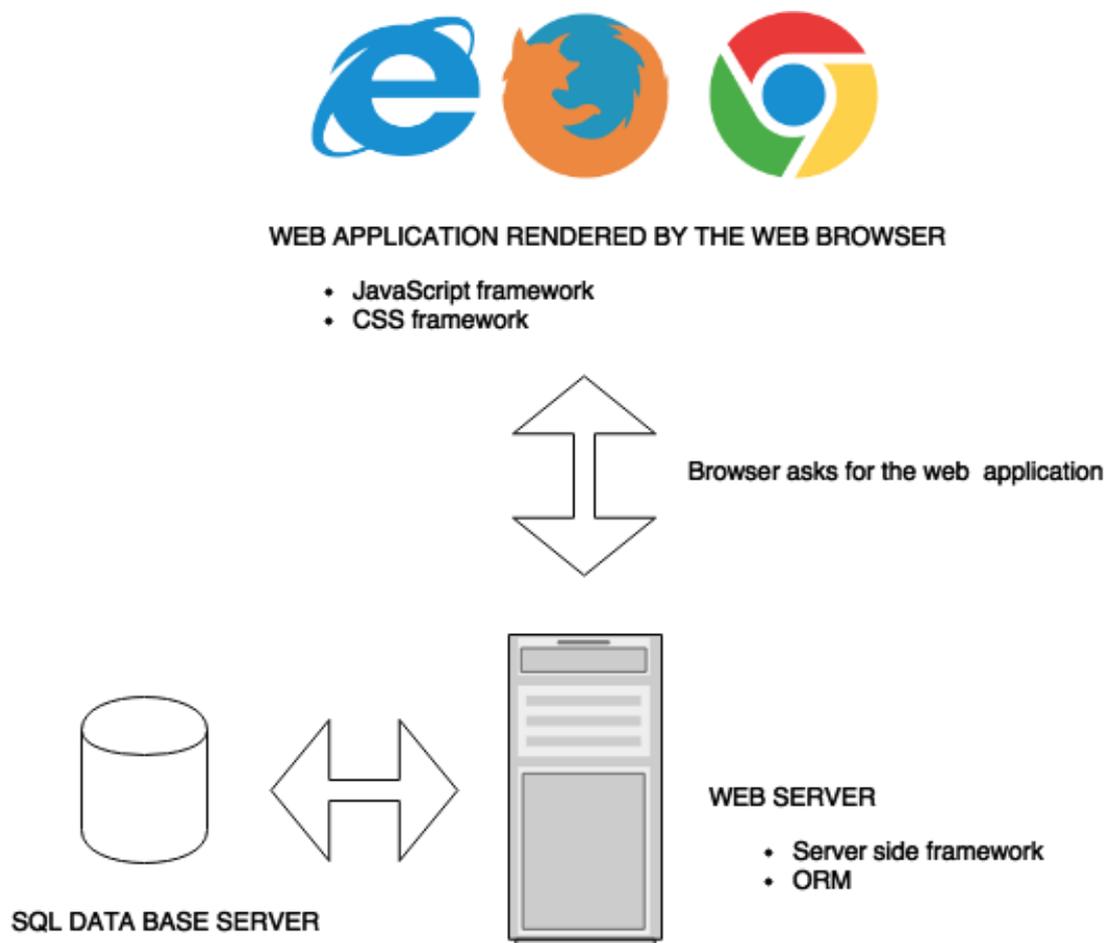


Fig. 2.1: Resume of the proposed web architecture

2.2.1.1 Client-server model

The client-server model is the de-facto way of how web-enabled systems work. The application proposed in this document will feature this model. This type of distributed computing model splits the tasks or workloads between the providers of a resource or service, called servers, and service requesters, called clients [5].

In the proposed web-application there will be the following distinction:

Clients:

- Data coming from the WSNs (sensors placed in the olive trees).
- Web explorer (i.e. Chrome, Firefox etc.) requesting for the web-application for visualizing and managing the WSN data.

Server:

- Web-server in charge of gathering the data and serving the web-application.
- Data base server for storing the WSNs information as well as other web application related information.

2.2.1.2 N-tier architecture

In addition to the client-server model, further divisions can be done. Typical web architectures will feature the n-tier or multi-tier architectures, usually consisting of 3 or 4 tiers, which can be listed as:

- **Client tier:** Usually consisting of a web applications or client end points.
- **Application tier:** The web server and the app server (which can be sometimes split) that accepts the requests from the clients and performs the business logic.
- **Data tier:** The data layer provides access to external systems such as a data base. Databases provide a solution for persisting data and for managing all the related transitions.

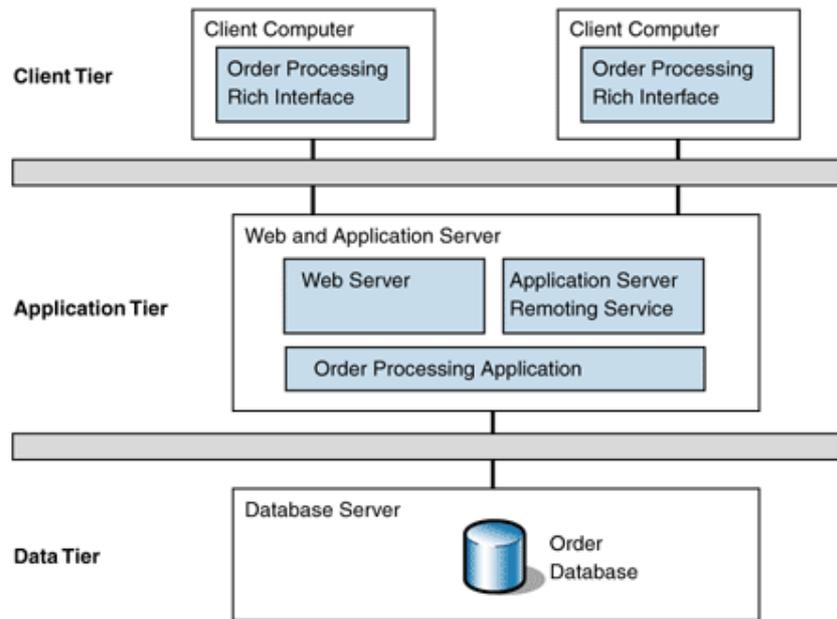


Fig. 2.2: Example 3-tier architecture

2.2.1.3 Uniform Resource Locators (URL)

A uniform resource locator (URL) is a reference to a resource that specifies the location of the resource on a computer network and a mechanism for retrieving it [6]. URLs are the standard way web browsers and in general any connected device to the internet uses for obtaining a result.

2.2.1.4 HTTP Protocol

In order to provide with an application protocol for exchanging data between clients and server, HTTP is the standard protocol for this purpose. The HTTP protocol is based on a request-response model. The client requests data from a web application that resides on a physical machine. The web application in turn responds to the request with the data requested by the user. [7]

The HTTP protocol contains a series of methods (or verbs) meant for the different types of requests the client can send, which in turn represent different intentions on the client side. The main methods are:

- GET: For accessing data.
- POST: For submitting data.

- PUT: For updating existing data.
- DELETE: For deleting resources.

2.2.1.5 Messaging formats

The most used formats of messaging using the HTTP protocol are the following:

- XML: Extensible Markup Language (XML) is a markup language that defines a set of rules for encoding documents in a format which is both human-readable and machine-readable.
- JSON: JavaScript Object Notation (JSON) is an open standard format that uses human-readable text to transmit data objects consisting of attribute–value pairs. It is used primarily to transmit data between a server and web application, as an alternative to XML.

2.2.1.6 Representational State Transfer (Rest)

Representational State Transfer (Rest) defines a set of architectural principles by which Web services can be designed that focus on a system's resources, including how resource states are addressed and transferred over HTTP by a wide range of clients written in different languages [8]. Rest defines 4 basic rules:

- The basic use of HTTP methods explicitly.
- Stateless, meaning the server never stores a state from any client.
- Expose directory structure-like URLs.
- Transfer XML, JavaScript Object Notation (JSON), or both.

Most modern web systems use this approach as the standard way of communication between clients and server.

2.2.1.7 Web applications

A web application is a software that runs in a web-browser, and therefore, relies on a web-server for serving the data [14]. A general web page or application is composed of the following elements:

- HTML code: The html code defines the elements in a webpage. Version 5
- CSS Style Sheet: The CSS is the style that will be applied to the webpage.
- JavaScript: Expands the functionality of the basic HTML features by applying an underneath logic beneath it.

2.3 Web frameworks

A web application framework is a type of framework, or foundation, specifically designed to help developers build web applications. These frameworks typically provide core functionality common to most web applications, such as user session management, data persistence, and templating systems. By using an appropriate framework, a developer can often save a significant amount of time building a web application[9].

By following this definition, the main reason for using a framework will be time constraints and for available documentation, which will enable developing features with better ease.

There are several frameworks available, but in this project I will consider the most active ones as having a proven trajectory of being successful in production environments.

2.3.1 Backend frameworks

Backend frameworks are the frameworks that reside on the server side of the application, and are responsible for accepting the HTTP requests and communicating with the data base servers (application tier). Different framework types can vary significantly depending on the purpose of their usage; whether they are enterprise oriented (robust and reliable platforms) or more prototype-oriented such as start-up companies.

2.3.1.1 Architectural software Patterns - MVC

Software architecture refers to how a software is structured from a high level point of view. In an analogous way, it could be considered as an equivalent of the architecture of a building. There are many ways of describing the type of software architecture, but

because of the scope of this paper, only the de-facto industry standard for web applications will be explained.

Model–view–controller (MVC) is one of the most popular software architecture patterns. This pattern, intended for implementing interfaces, divides the software into three interconnected layers as way to separate internal representations from what the user should see [9].

Keys components of this pattern are:

- **Models:** Models represent knowledge. A model could be a single object or it could be some structure of objects. For instance, a model could represent a data base table.

- **Views:** A view is a (visual) representation of its model. It would ordinarily highlight certain attributes of the model and suppress others. It is thus acting as a presentation filter. A view is attached to its model (or model part) and gets the data necessary for the presentation from the model by asking questions.

- **Controllers** A controller is the link between a user and the system. It provides the user with input by arranging for relevant views to present themselves in appropriate places on the screen. It provides means for user output by presenting the user with menus or other means of giving commands and data. The controller receives such user output, translates it into the appropriate messages and passes these messages on to one or more of the views.

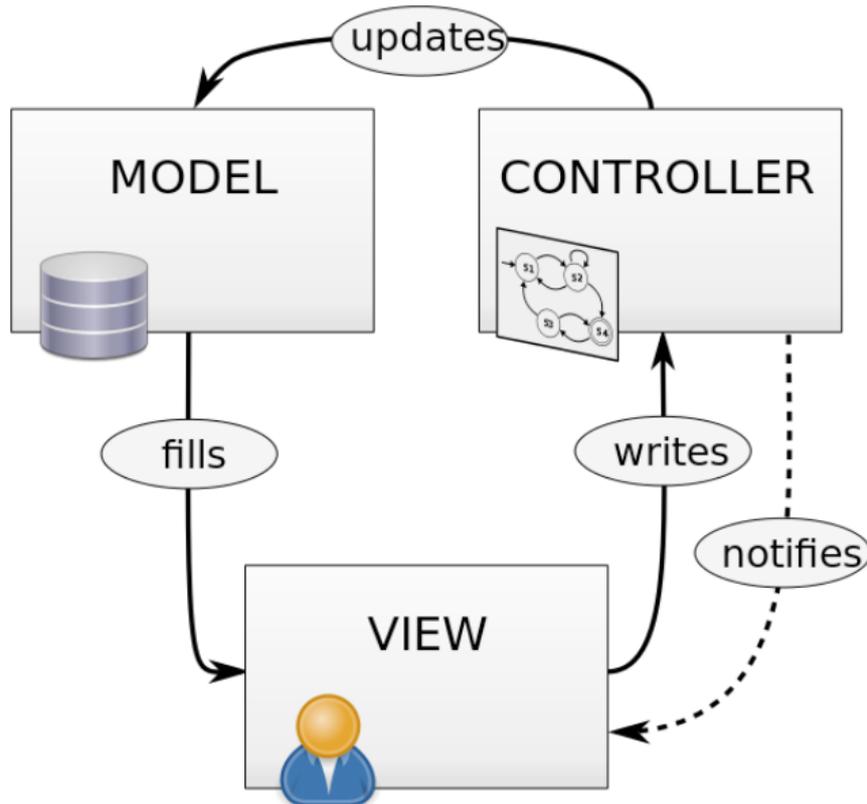


Fig. 2.3: The MVC model

2.3.1.2 Programming languages

Programming languages are the basic tool for creating computer software. The considered programming languages will be Object oriented as they are the industry standard for web development.

Two basic distinctions can be made from the maintainability point of view of a programming language:

- Type Safe languages: Variables are declared as fixed types thus providing with better maintainability. The main drawback is that development is slower and can be a crucial aspect for fast prototyping.
- Type Unsafe languages: Variables are not declared as static types with the gain of development speed at the cost of worst maintainability.

And from a performance point of view:

- **Compiled languages:** The programmed code is compiled into machine code and then run by the server natively or in a virtual machine. They provide better performance at the cost of being slower at deploying the application.
- **Interpreted languages:** Code is executed at the run time, meaning compiling is not needed, but peak performance can be worse compared with compiled ones.

Programming language	Type Safe	Compiled/Interpreted
Java	Yes	Compiled
Php	No	Interpreted
Python	No	Interpreted
JavaScript	No	Interpreted
C#	Yes	Compiled
Ruby	No	Interpreted

Table 2.1: Main Web oriented programming languages

2.3.1.3 Software design style.

From a software design perspective, a framework can be:

- **Opinioned:** The framework guides the developer of how things should be done, giving no margin for alternative implementations. The main advantage of this is that the development is less prone to errors as things can only be made one way.
- **Unopinioned:** Developer should make its own decisions of how the system will be implemented and therefore relying on its experience. This type of software design can be useful for more custom solutions and experienced programmers.

2.3.1.4 Object-relational mapping (ORM)

Object relational mapping (ORM) is a technique for mapping table entities (data base) to object oriented programming languages. This is crucial part for easy data base access as abstracts the developer from the querying language layer. [10]

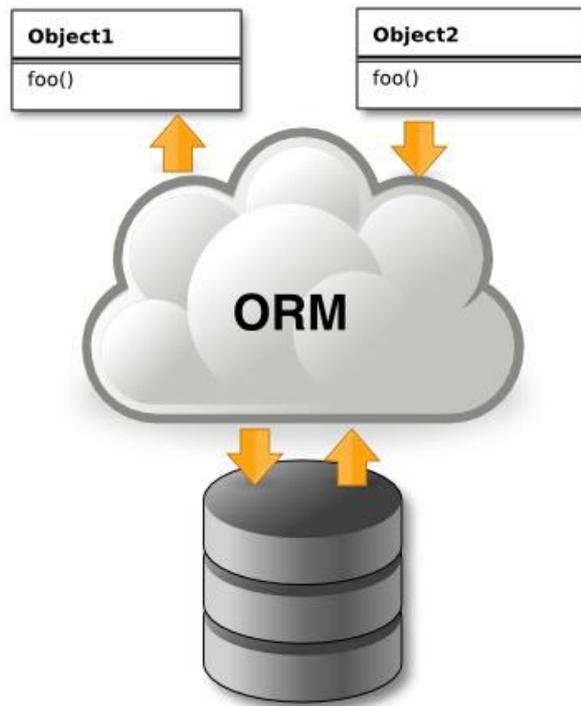


Fig. 2.4: Object relational mapping (ORM)

2.3.1.5 Restful APIs

An application programming interface (API) is a set of routines, protocols, and tools for building software applications. An API expresses a software component in terms of its operations, inputs, outputs, and underlying types. An API defines functionalities that are independent of their respective implementations, which allows definitions and implementations to vary without compromising each other.[14]

In that sense and following the Rest paradigm, the use of APIs that are Restful are the most common used way of providing web resources using the HTTP protocol.

A standard Restful API should look like a series of URLs that provide a resource. For example, imagine a server that implements the URL */getCookies* using the HTTP verb GET. When accessing this URL, the system should provide with all the cookies.

Because of the use the HTTP protocol, the RestFul APIs are programming language independent.

2.3.1.6 Considered platforms

Based on the previous constraints, the considered platforms for the backend are the following:

- **Django:** *Django* is a web-framework which uses Python as the programming language to write applications. It supports the MVC pattern and it is widely used in large scale systems (such as Instagram, Disqus, Pinterest, Bitbucket, etc.). It offers good documentation and great community support. The main weak point might be its weak performance in high concurrency environments due to its interpreted language nature.



Fig. 2.5: Django logo

Ruby on Rails: *Ruby on Rails* is among the most popular web-frameworks used nowadays. It uses ruby as the programming language and has even better support than Django. Production environments such as Github or Twitter proof the excellence of this tool. The main disadvantage of this tool is its weak performance in the same cases of Django.



Fig 2.6: Ruby on Rails logo

- **Play!** *Play!* is a web-framework written in the Scala programming language. It supports Java and Scala as main programming languages. It is not as widely used or documented as Rails or Django, but it offers better performance and better concurrency management due to its asynchronous petition handling capabilities. Also, Java and Scala are typesafe programming languages and therefore can make the code easily maintainable.



Fig 2.7: Play framework logo

- **Node.js:** *Node.js* it is not a web framework, but a run-time using Google's V8 JavaScript engine, enabling the use of JavaScript in the server side. It features a great performance in high concurrent situations, but its support for relational DBs is weaker when compared to the other platforms described above. Also, JavaScript language is known for not being easily maintainable due to its callback nature so, which can make things difficult for future development. Notable frameworks for Node.js are the following:

- **Express.js:** Express is a minimalistic and an unopinioned framework providing with the basic tools for web development. It has become a very popular platform in the latest years due its simplicity and excellent performance.
- **Sails.js:** Sails is a framework that lies upon Express.js and tries to replicate the ruby on rails paradigm on the node platform by providing an ORM (object relational mapping) and an opinioned way of developing web applications. Available documentation might be its weakest point.



Fig 2.8 Node logo

Table 2.1 shows a summary of the considered frameworks main features:

Framework	Programming language	Typesafe?	Opinioned?	Restful API	MVC	ORM	Performance
Django	Python	No	Yes	Yes	Yes	Yes	Good
Ruby on Rails	Ruby	No	Yes	Yes	Yes	Yes	Good
Play	Java/Scala	Yes	Yes	Yes	Yes	Yes	Best
Express.js	JavaScript	No	No	Yes	No	No	Very Good
Sails.js	JavaScript	No	Yes	Yes	Yes	Yes	Very Good

Table 2.2: Different specifications for the proposed frameworks

2.3.2 Frontend frameworks

Raw HTML client side pages offer only static information. As a way to offer dynamic content, JavaScript was created for providing with extra functionalities. Javascript

frameworks have become an important part in modern development to offer decoupled and scalable systems. CSS part

Because of the modern approach of this project, the frontend will be developed using the Single Page approach.

2.3.2.1 Single page applications

A single-page application (SPA) is a web application or web site that fits on a single web page with the goal of providing a more fluid user experience akin to a desktop application. In a SPA, either all necessary code – HTML, JavaScript, and CSS – is retrieved with a single page load or the appropriate resources are dynamically loaded and added to the page as necessary, usually in response to user actions. The page does not reload at any point in the process, nor does control transfer to another page.

Interaction with the single page application often involves dynamic communication with the web server behind the scenes[13].

2.3.2.2 Asynchronous JavaScript And XML (AJAX)

Asynchronous JavaScript And XML (AJAX) and its JSON variant AJAJ, is a group of interrelated web development techniques used on the client-side to create asynchronous web applications [14]. The selected framework should be based on this principle as communication.

2.3.2.3 JavaScript frameworks

The considered JavaScript frameworks are the following:

- **AngularJs:** AngularJS is a fully client-side library. AngularJS's templating is based on bidirectional UI data binding. Data-binding is an automatic way of updating the view whenever the model changes, as well as updating the model whenever the view changes. The HTML template is compiled in the browser. The compilation step creates pure HTML, which the browser re-renders into the live view. The step

is repeated for subsequent page views. In traditional server-side HTML programming, concepts such as controller and model interact within a server process to produce new HTML views. In the AngularJS framework, the controller and model state are maintained within the client browser. Therefore new pages are generated without any interaction with a server.



Fig. 2.9: AngularJS logo

- **EmberJs:** Ember.js is a client-side JavaScript web application framework based on the model-view-controller (MVC) software architectural pattern. It allows developers to create scalable single-page applications by incorporating common idioms and best practices into a framework that provides a rich object model, declarative two-way data binding, computed properties, automatically-updating templates powered by Handlebars.js, and a router for managing application state.



Fig. 2.10: EmberJS logo

2.3.2.4 CSS frameworks

The CSS part is in charge of styling the html components.

The considered frameworks are the following:

- **Twitter Bootstrap:** Bootstrap is a free and open-source collection of tools for creating websites and web applications. It contains HTML- and CSS-based design templates for typography, forms, buttons, navigation and other interface components, as well as optional JavaScript extensions. The bootstrap framework aims to ease web development.



Fig. 2.11: Bootstrap logo

- **Foundation:** is a responsive front-end framework. Foundation provides a responsive grid and plenty of HTML and CSS UI components, templates, and code snippets, including typography, forms, buttons, navigation and other interface components, as well as optional JavaScript extensions. Bootstrap is also a JavaScript library available for multiple frameworks (such as Angular.js or JQuery).



Fig. 2.11: Foundation framework

2.3.2 Data Base Engines

In order to provide with a persistence layer for storing all the data, a data base engine should be considered (data base tier).

2.3.2.1 Relational Data bases (SQL)

Structured Query language (SQL) is the industry standard for reliable relational data bases. Most world computer systems use SQL databases. SQL is based on the Create, Read, Update, Delete (CRUD) principle for managing data. Data is stored in tables and is accessed using the SQL query language [15]

There are several open source implementations (most of them are quite similar), of which I have considered:

- **MySql:** Most used DB engine in the world but becoming less popular due to its weak support from Oracle company.
- **PostgreSQL:** Good alternative to MySql and widely used, offering better performance than mySQL
- **MariaDB:** Open Source alternative to MySql.

2.3.2.2 No SQL DB

On the other hand, NoSQL databases offer a different approach compared to relational ones, but because of the nature of this project, there will not be considered.

2.4 Code versioning

Code versioning or revision control is a software in charge of managing the source code of a computer program[16]. In the case of this work, the repository will be used for storing the source code and provide a history of all the different commits done during the development. The main revision control solutions available are:

- **GIT:** GIT is an open source decentralized versioning software that enables the developer to version its code using a branch system. One of advantages of being a decentralized system is that it does not rely on a server to store the code thus enabling the use of a local repository. A very popular web platform implementing GIT is Github.
- **SUBVERSION (SVN):** SVN is an open source code versioning software that relies on a server for versioning the code. It is also based on the branch system, but as opposed to GIT, no local repositories can be made, so a running server is always needed for versioning the code.

Chapter 3: Used Technologies

This chapter will show the used technologies for the implementation of the platform. Although in the previous chapter state of the art research was done for finding the best fitting technologies, as shown by the Entomatic specification sheet, the platform is expected to use the Sails.js framework as backend technology, AngularJS for frontend, and PostgreSQL as data base server. Despite this fact, final decisions criteria are explained in the following sections.

Platform component	Used Technology
Back end framework	Node.js with Sails.js framework
Data base engine	PostgreSQL
Front end framework	Angular.js
CSS	Twitter Bootstrap framework

Table 3.1: Chosen technologies

3.1 Server side framework

Being a Java programmer for the last years biased my opinion into selecting a Java based solution as learning curve was going to be steeper. The Play! framework, while keeping away from other enterprise based solutions the Java platform is known for, provided an interesting and solid tool with production tested environments.

On the other hand, the Sails.js framework is an opinioned framework, and development should not be difficult as things can only be done in one way. The fact that JavaScript is the programming language is also positive because of its C like syntax which in a certain way is similar to Java and the learning curve was going to be shallower. So the final decision was to use Sails.js.

3.2 Front End frameworks

Despite not having prior HTML and JavaScript web development experience, AngularJS was de facto solution from the beginning as is becoming a quite popular tool for its easy use and fast development capabilities as shown by fig 3.1 and 3.2.

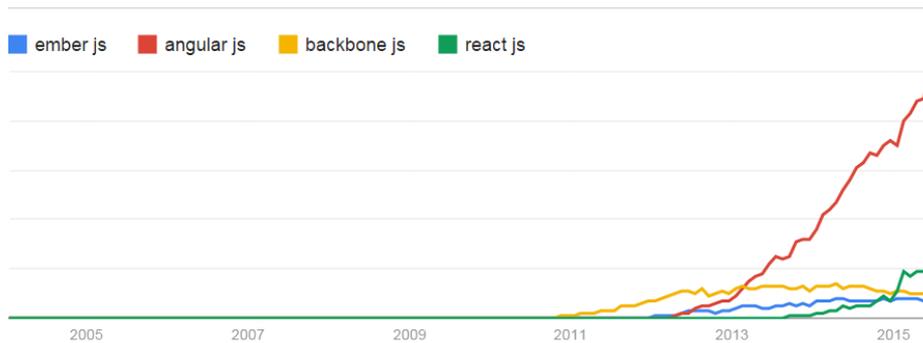


Fig. 3.1 Front end Framework popularity based on google searches[18]

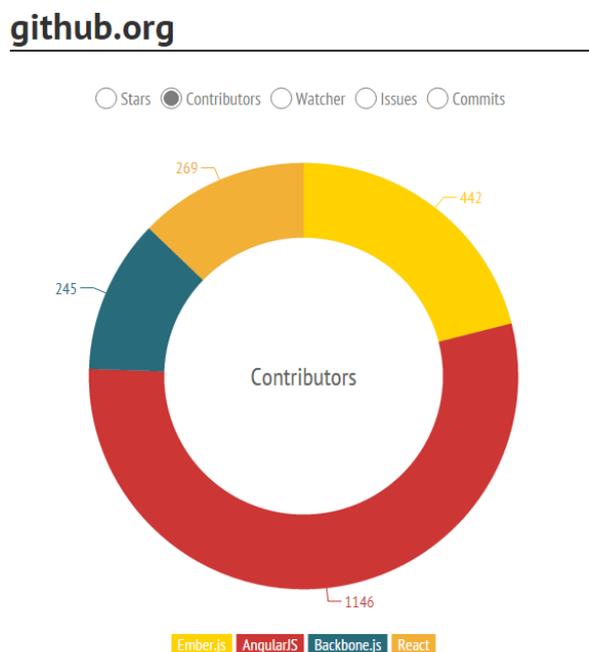


Fig. 3.2 Front end Framework popularity based on Github contributors

As for the CSS framework, twitter bootstrap is the chosen one for being the most popular framework for fast prototyping [18].

3.3 Data Base engine

SQL data base servers do not vary a lot from one solution to another as they are all based on the relational data base principles. My previous experience included MySQL and Oracle solutions, so the initial preference was to use the first one. Because of the project specifications, PostgreSQL was chosen.

3.4 Versioning

The main versioning website aimed for open source developers is the GitHub platform. Github offers free public Git repositories and is the most used one aimed for both amateur and professional developers. It also provides with issue reporting for making the supervisors easier to report problems. For this reason, github will be chosen for this project. The code was be stored in the following repository:
<https://github.com/jose908/entomatic-server>

Chapter 4: Platform Implementation

Once the development technologies have been selected, next step is designing and developing the whole system. Sails framework provides with interesting, out of the box features for making modern web applications. First steps will be carrying out the platform design strategy so as to make the development as easy as possible and therefore, providing with the mentioned constraints for a maintainable and scalable system. Once this is done, data base, backend and frontend development can be done based on the initial premises.

All the code can be found on the github repository, so only basic code will be shown.

4.1 Design Strategy

This section describes the constraints taken into account for the design of the platform as well as showing the final proposed design.

4.1.1 Design constraints

The considered constraints for modern and scalable platforms are the following:

- Provide with a Restful API for making easier the gathering of the data (HTTP Requests).
- Should be loosely coupled, meaning each systems (clients and server) should not depend one with each other.[17]
- Platform independent, meaning that not only the proposed web app client will work, but also a Smartphone app (i.e. Android) could obtain data from the system.

4.1.2 Proposed design

The proposed design follows an approximation of the service oriented architecture (SOA) and the Web services paradigm. This can be broken into main parts:

- **WSN API:** This will include all the methods needed for accepting the requests from the WSN such the sensor association and the measurement receiving.
- **Web-app API:** In charge of serving the web-app, managing the session and serving the data asked by the client.

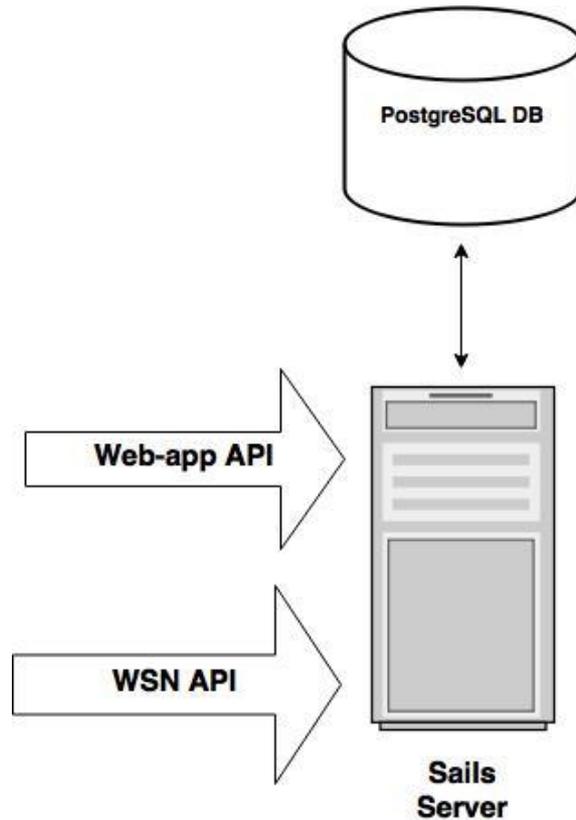


Fig 4.1: Integrator view of the system

4.2 Database

The database will be supported by the PostgreSQL server using SQL standard ways of storing information and maintaining data consistency, which include:

- Data tables with rows for basic data storage.

- Primary Keys and Foreign keys for data consistency.
- Sequences for primary key Id generators.
- Indexes, as way for increasing querying performance.

4.2.1 Requirements

The required data to be stored, as described on the project specification of the first chapter, should be the following:

- **Gateway:** The system should be able to store the gateways connected to the system and provide with information such as the date they were inserted, the identifier, the MAC address, the coordinates and the update date.
- **Sensor:** In the same way as the gateway, sensors should provide an identifier, the MAC address, the coordinates, the inserted date and the update date. Moreover, one sensor must be linked to a gateway, meaning a gateway can have up to N^1 sensors.
- **Measurements:** The sensors will send measurements and the system will need to store them in a table. Different measurements types should also be considered. A sensor can have N measurements, and a measurement type can have N measurements. Insertion dates are also to be expected.
- **Alarms:** In the same way as the measurements, an alarm can be linked to a sensor and different alarms type should also be considered, meaning 1 sensor can have N alarms, and 1 alarm type can have N alarms.
- **User:** Storing user authentication data and passwords for the client.

4.2.2 Data model

Figure 4.2 and table 4.1 shows the implemented data model:

¹ N meaning numerous values or the Nth value. For now on it should be considered as this.

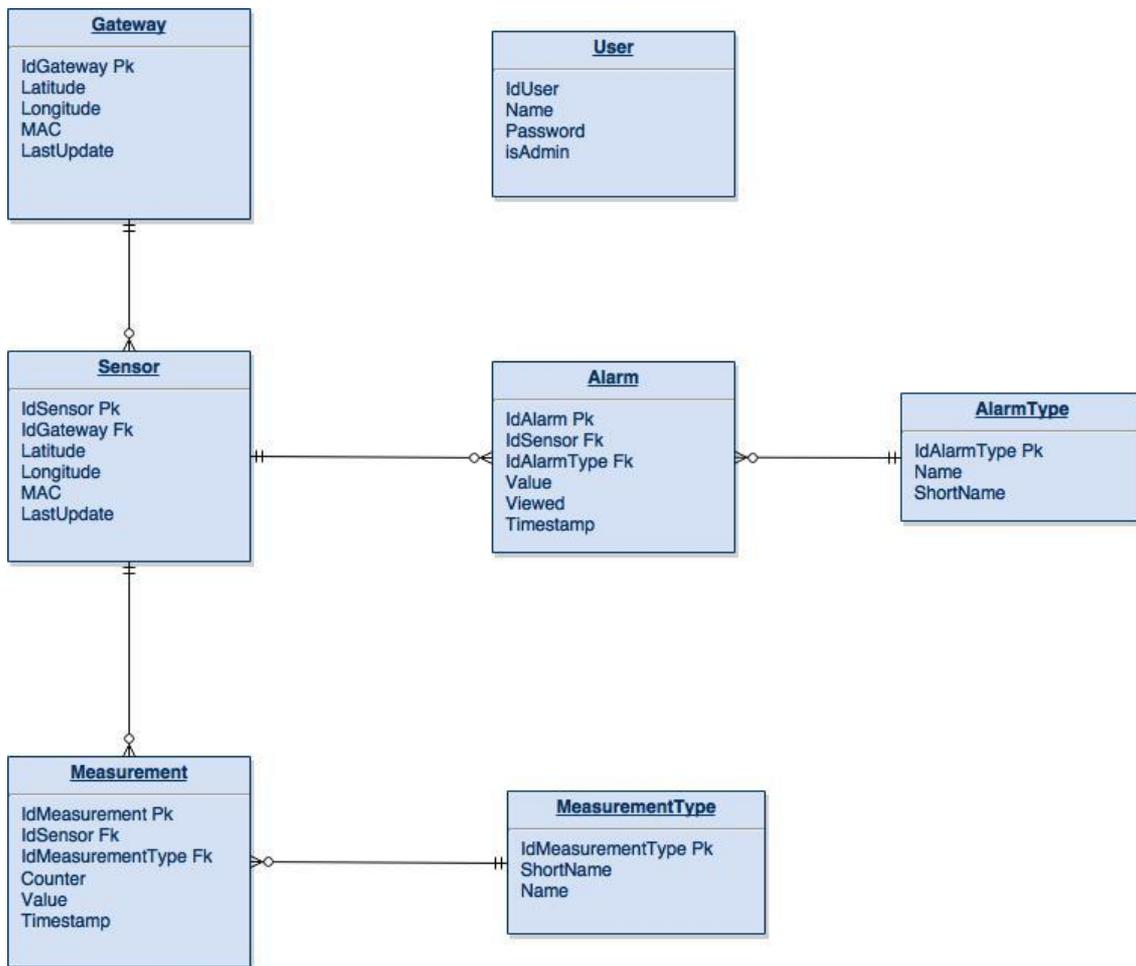


Fig 4.2: The data model for storing the WSN Data

Table name	Fields	Description
Gateway	<p>IdGateway: The primary key Id for the gateway.</p> <p>Latitude: The coordinate parameter.</p> <p>Longitude: The coordinate parameter.</p> <p>MAC: The gateway Mac</p>	Table for storing the current active gateways of the system

	<p>LastUpdate: Timestamp for last system synchronization.</p>	
Sensor	<p>IdSensor: The primary key Id for the gateway.</p> <p>IdGateway: The foreign key to relate a sensor to gateway.</p> <p>Latitude: The coordinate parameter.</p> <p>Longitude: The coordinate parameter.</p> <p>Mac: The node MAC</p> <p>LastUpdate: Timestamp for last system synchronization.</p>	<p>Table for storing the current active nodes/sensors of the system. Each sensor must be related to a gateway.</p>
MeasurementType	<p>IdMeasurement: The primary key for the measurement type.</p> <p>ShortName: This name will be used as an identifier in the http request.</p> <p>Name: The type name.</p>	<p>The types of measurements the system should expect coming from the sensors. This provides easy scalability options for new types of measurements.</p>
Measurement	<p>IdAlarm: The primary key Id for the Alarm.</p> <p>IdSensor: The foreign key that relates a measurement to a sensor.</p> <p>IdMeasurementType: The foreign key that relates a measurement to a measurement type.</p>	<p>The table for storing the measurements from the sensor. A measurement is related to a measurement type and to a sensor.</p>

	<p>Counter: The epoch value for server syncing with the WSN.</p> <p>Value: The value of the reading.</p> <p>TimeStamp: The timestamp for knowing when the register was inserted.</p>	
AlarmType	<p>IdAlarm: The primary key for the alarm type</p> <p>ShortName: This name will be used as an identifier in the http request.</p> <p>Name: The type name.</p>	<p>The types of Alarms the system should expect coming from the sensors.</p> <p>This provides easy scalability options for new types of alarm.</p>
Alarm	<p>IdAlarm: The primary key for the alarm.</p> <p>IdAlarmType: The foreign key that relates an alarm to an alarm type</p> <p>IdSensor: The foreign key that relates an alarm to a sensor (if required).</p> <p>Value: The value of the alarm (if required).</p> <p>Viewed: Boolean value for checking if the user has seen the alarm.</p> <p>TimeStamp: The timestamp value for knowing when the register was inserted</p>	<p>The table for storing the Alarms. An alarm is related to an alarm type and can be related to a sensor.</p>

User	<p>UserId: The user Id primary key.</p> <p>Name: The name of the user.</p> <p>Password: The hashed user password.</p> <p>isAdmin: Boolean for knowing if a user has administrator permissions.</p>	Table for storing the user authentication information.
------	--	--

Table 4.1: The data model explained

4.3 Sails.js Backend

The backend section will provide information regarding how the server has been developed.

4.3.1 Project structure

Because of its nature of being an opinionated framework, Sails.js project basic structure is always the same. Following fig 4.3, project folder structure can be summarized in:

- **API:** Features the tools for implementing a restful API following the MVC architecture pattern:
 - **Models:** Each data base object (i.e., table) has a mapping with a JavaScript object through the waterline ORM, and a file defining this model. For example, the sensor table will have a sensor.js file mapping it to make CRUD operations really controllable. The models defined in the project are the following:
 - Gateway: gateway table
 - Sensor: sensor table
 - MeasurementType: measurement_type table
 - Measurement: measurement table
 - AlarmType: alarmType table
 - Alarm: Alarm table

- User: User table
- **Controllers:** In addition to models, each one of these features a controller. A controller is a file where all the logic business is defined and where CRUD operations are done. The controllers defined are the following:
 - GatewayController: All the logic relating the gateways will be defined in this file.
 - SensorController: All the logic relating the sensors will be defined in this file.
 - MeasurementTypeController: All the logic relating the measurement types will be defined in this file.
 - MeasurementController: All the logic relating the measurements will be defined in this file.
 - AlarmTypeController: All the logic relating the Alarm types will be defined in this file.
 - AlarmController: All the logic relating to the Alarm will be defined in this file.
 - UserController: All the logic relating to the User will be defined in this file.
 - PageController: All requests for the web client will be handled in this file.
- **Assets:** These folder will include all the files required by the client such as JavaScript files, .CSS files, HTML files, and images.
- **Config:** Two main folder types can be distinguished:
 - **Routes.js:** The file where the URLs are defined so as to find the proper route to map them and perform an action. For example, when trying to access the */newSensor* URL, the system is programmed to link with the sensor controller that will perform the desired logic. I will later explain all the used routes.
 - **Configuration folders:** Here system settings can be configured such as the database connection, among others.

- **Views:** Sails provides a template engine for generating HTML files for the client, so any views to be delivered to the browser are placed in here. Because of the single page nature of the web app, only two views will be supplied.

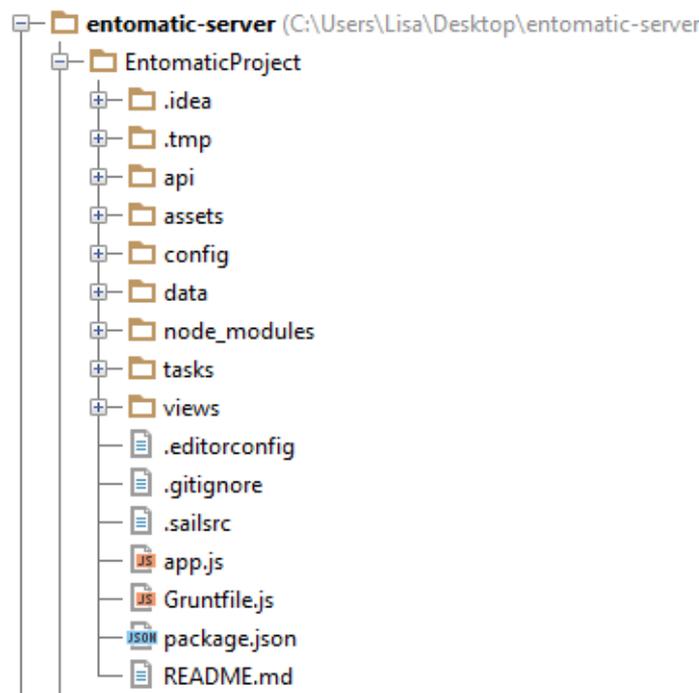


Fig. 4.3: project structure

4.3.2 WSN API

Although the Restful API is the same for all the system (all the Http requests are defined in the same route.js file), the division of the methods used for the WSN, and the ones used for the Web-app has been made for better understanding.

The methods used and their explanation can be found in the next sections.

The WSN API is used to get all the information from the WSN regarding the data structure explained before.

Http Method	URL	ACTION
GET	/newGateway	Creates a new gateway
GET	/newSensor	Creates a new sensor

GET	/newMeasurement	Creates a new measurement
GET	/newAlarm	Creates a new Alarm

Table 4.2: The URLs used by the WSN

4.3.2.1 New gateway

The gateway is the link where the WSN sends messages to the internet.

When a new gateway is connected to the WSN, a new petition is made to the server.

This petition is done via a GET request and has the following URL encoded information:

- MAC adress
- Latitude
- Longitude

The gateway makes the petition to the */newGateway* URL defined in the routes.js file

When the system receives this, the following actions are performed:

- A call to the newGateway function within the gateway controller is made.
- System searches in the database if the informed MAC address is already inserted as gateways can switch off and therefore once they turn on a new server engagement is needed.
- If the mac is not found, a new gateway is inserted in the DB with the data supplied by the request and a response message is send indicating the success of the link and informing the server date for synchronization reasons.
- If the mac is found, means the gateway has switched on and therefore the response will be the same as the previous one but without inserting the new gateway on the data base.
- Otherwise, if any error occurs, an error message is sent to the gateway and an alarm is created to indicate the bad gateway association.

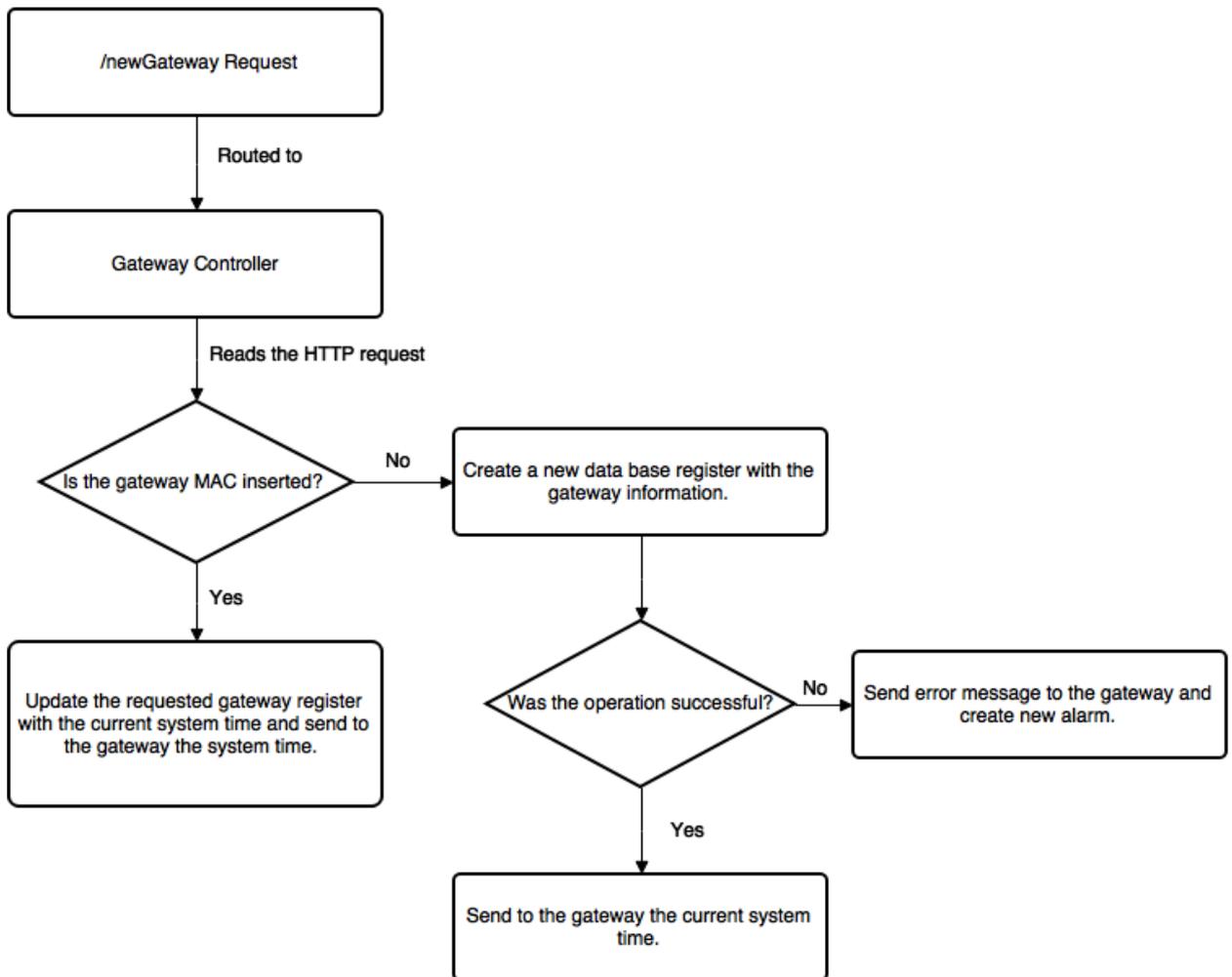


Fig. 4.4: New Gateway flowchart

4.3.2.2 New Sensor

A wireless sensor node is linked to a gateway, meaning a gateway can have N linked sensors. Nodes are in charge of supplying the measurement data from their sensors.

The new sensor function is mapped through the **/newSensor** URL.

Sensor requests provide with the following information:

- Gateway mac.
- Wireless sensor node MAC.
- Latitude.
- Longitude.

When this URL is called, the following logic is performed:

- A call to the *newSensor* function within the sensor controller is made.
- The systems checks if the supplied gateway mac is inserted in the system.
- If it is not found, an error message is sent.
- If the gateway is found, a query is made for checking if there are any sensors inserted with that mac.
- If no sensor is found, a new sensor is inserted and a primary key ID is sent as a response to the WSN (the WSN will communicate via this Id for to create new measurements) as well as indicating the success of the operation.
- If a sensor is found, it means that the sensor was switched off and now is on, and the Id found is sent back.
- Otherwise, if any error occurs, an error message is sent and an alarm is created.

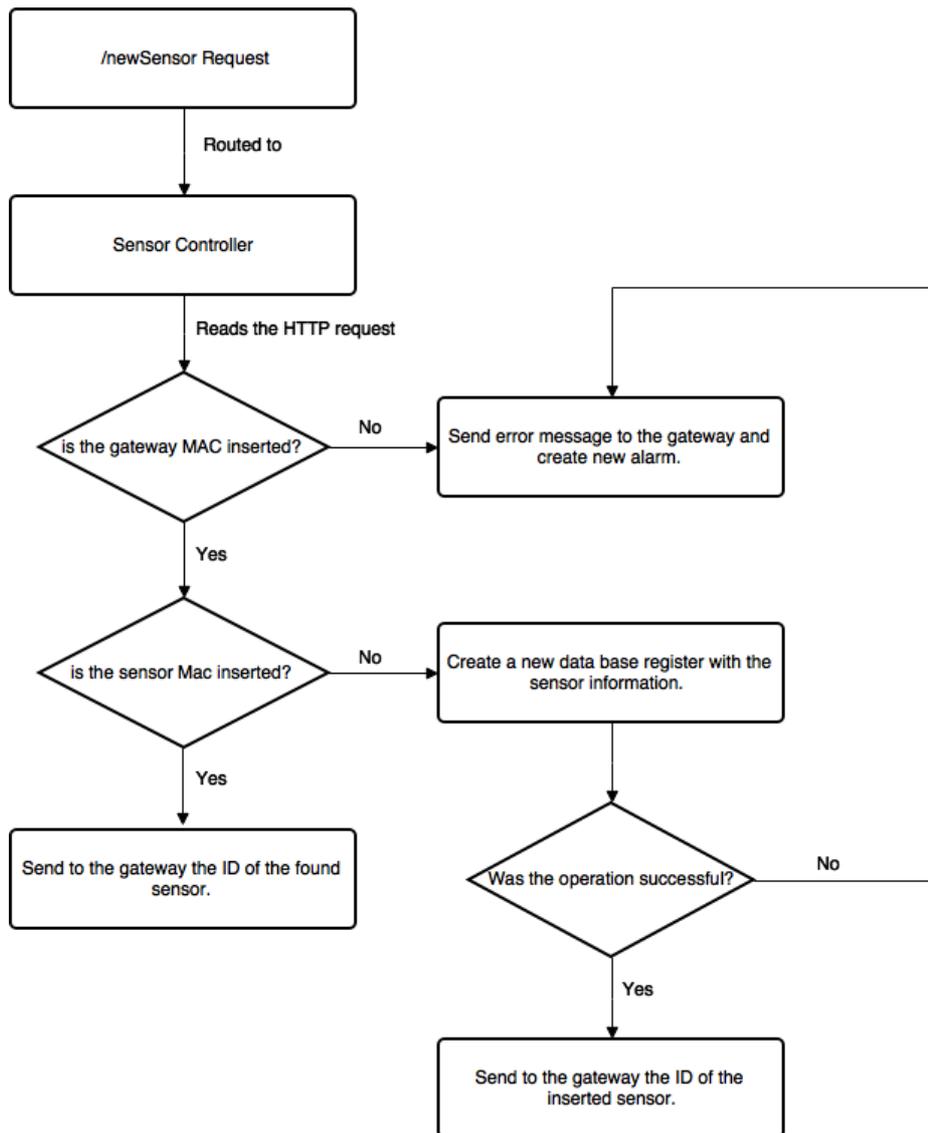


Fig. 4.5: New Sensor flowchart

4.3.2.3 New Measurement

Once a gateway and a sensor are signed up in the system, the WSN is ready for sending measurements data. The *measurement_type* table includes all the expected measurements to be found in the URL encoded http request via the *short_name* field.

The new measurement request should provide the following information:

- The Id associated with the measurements.
- All the values for the measurements with URL key value being the same as the short name.

The new measurement is inserted through the */newMeasurement* URL. When a request is received, the following logic is performed:

- A call to the *newMeasurement* function within the measurement controller is made.
- System checks if the sensor is inserted in the DB.
- If it is not found, an error message is sent.
- If it is found, a query is made to the *measurement_type* for obtaining all the measurement types in the system.
- The URL values are looped checking for the short values found in the query of the previous step.
- If a value is found, then a register is created in the measurement table.
- Finally, if everything ends successfully, an Ok response is sent.

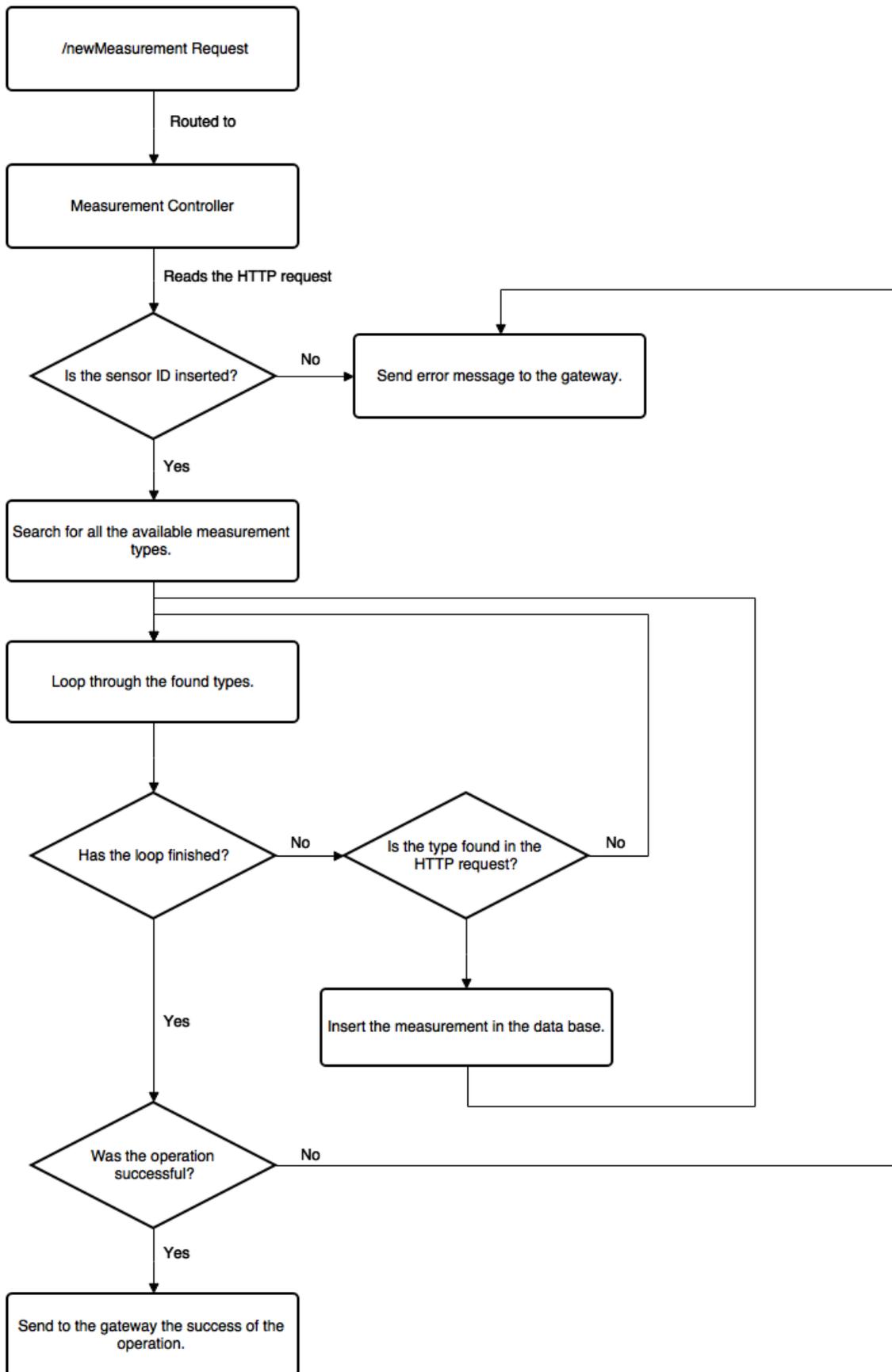


Fig. 4.6: New measurement flowchart

4.3.2.4 New Alarm

Alarms work in the same way as measurements, but with the tables Alarm and Alarm types. The new alarm request is mapped through the */newAlarm Url*. When a request is received, the following logic is performed:

- A call to the *newAlarm* function within the measurement controller is made.
- System checks if the sensor is inserted in the DB.
- If it is not found, an error message is sent.
- If it is found, a query is made to the *AlarmType* table for obtaining all the alarm types in the system.
- The URL values are looped checking for the short values found in the query of the previous step.
- If a value is found, then a register is created in the alarm table.
- Finally, if everything ends successfully, an Ok response is sent.

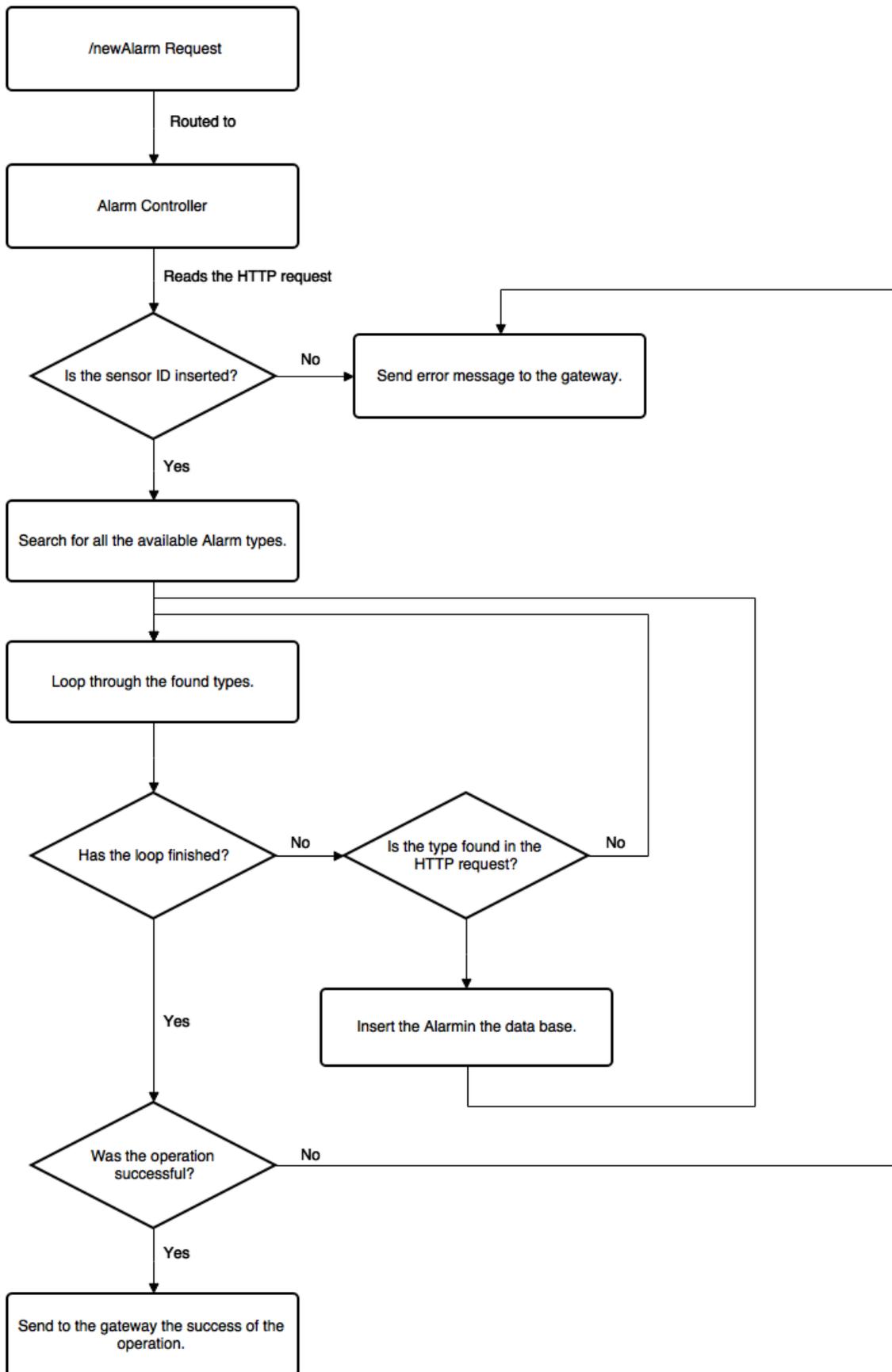


Fig. 4.7: New Alarm flowchart

4.3.3 Web app API

The web app API, or the URLs designed for the client side, are the ones used by the angular frontend application. Although they have been designed for this application, because of the decoupled nature of the system architecture, these could be used for serving any other client side device like a smartphone. No extensive explanation will be carried in this section as this will later discussed in the front end section.

4.3.3.1 Page Controller

The page controller located in the controllers folder is a crucial part in the user control of the proposed web-app. When a request is made to the server asking for the web-app, the “/” URL is routed to the page controller and check if the user has logged in. If the user is logged in, then dashboard angular app is served. If not, then the log in page is served. Everything is controlled by the user authentication layer of Sails, helping the developer from further development in that area.

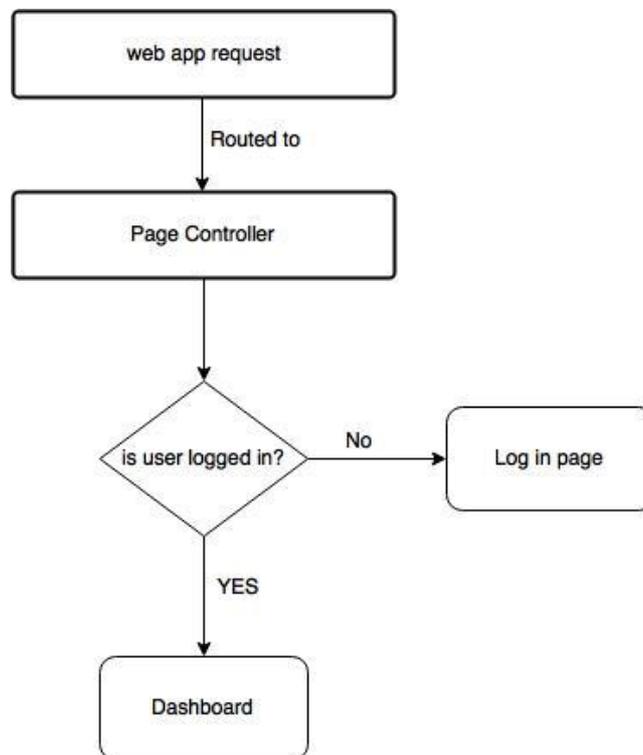


Fig. 4.8: Page controller logic

The rendered views are located in the views folder under homepage.ejs for the login and dashboard/index.ejs for the dashboard (rendered by Sails template engine)

4.4 Front End

The front end section will include all the logic for developing the web application. As mentioned in previous chapter, the app will use as main components the Angular.js framework and Twitter Bootstrap CSS style framework.

This section will provide information regarding the logical implementation with no regards to the user interface design as this will be covered in the next chapter. A detailed view of the application will be featured in the next chapter.

4.4.1 Angular.js app components

Angular.js is a single page style framework, which means that the browser does not refresh or access new html files every time a link is clicked. Therefore all the logic relies beneath the JavaScript layer. Any Angular application should contain the following elements:

- **Directives:** Directives are extended Html attributes with the prefix –ng. Any Angular element defined in the webpage should contain this prefix to be interpreted as an Angular element. Apart from the stock directives, custom ones can be created for encapsulating new functionalities. This project will include some 3rd party open source directives for maps and statistics manipulation.
- **Angular Module:** An angular module is a directive that defines an Angular app. So every single page application should be defined as angular module. This component is defined in a JavaScript file and imported into the html. The Entomatic web app will feature two modules (as described in page controller section):
 - **Login Module**
 - **Dashboard Module**
- **Controller:** A controller is the a directive that creates a communication layer between the HTML and the JavaScript for DOM manipulation. At least one

Controller is needed for each module. As a way of providing with good practices, the app will have a controller for each screen.

Other no essential components but that will be used in the implementation:

- **Services:** So as to group all the HTTP requests to the API, the framework provides a service characteristic for encapsulating and avoiding repetition of common used server requests. The proposed platform will feature a service file for grouping all HTTP requests. The different controllers will implement the HTTP server request via the service injection (dependency injection).
- **Router:** Organizing the different screens (user interface elements) into router logic helps application maintenance and the development of new features. Angular features a stock router but with limited features. The *ui-router* directive[19] that will be used in this project, is the de-facto interface routing used in Angular apps, and provide with extra functionalities.

All the necessary JavaScript files are located in the Sails.js assets folder.

4.4.2 Login module

The login module, linked to the view *homepage.ejs*, is in charge of providing the user a way to access to the web app. User authentication includes a username and a password as way to authenticate. Once the user has been authenticated, the page controller redirects the user to the dashboard view.

4.4.2.1 User authentication

User authentication data is stored in the users table. The user information includes user name and a bcrypt [20] hashed password.

The system enables to create, log in, and log out users. The angular controller, *loginController*, is responsible of obtaining the data of the form and sending it to Sails. Authentication is done in the following way:

- The loginController obtains the data and is sent to Sails via the PUT method `/login`.

- The user controller function of the server encrypts the password and checks if the user is in data base and if the supplied password matches with the one stored.
- If user authentication is succesful, the user associated with the client is stored in the Sails session manager and the pageController redirects the user to the dashboard.
- Otherwise, a bad request is sent to the front end meaning something has failed and an error message is shown.

4.4.3 Dashboard module (main module)

The Dashboard module includes the main app for managing the data from the WSN and is the core part of the web application. The angular module is defined in the mainModule.js file. All the application uses Bootstrap components for representing the different contents of the screen.

4.4.3.1 CSS components

All the application uses the CSS components from the bootstrap framework. Some of items that will be used are the following:

- Buttons.
- Panels.
- Navigation Bar.
- Dropdown menus.
- Tables.
- Pagination components.

4.4.3.2 UI routing

Following the initial specifications regarding the basic requirements to be implemented, and using the UI-Router directive for interface routing, fig 4.5 shows the logic interface diagram of the application.

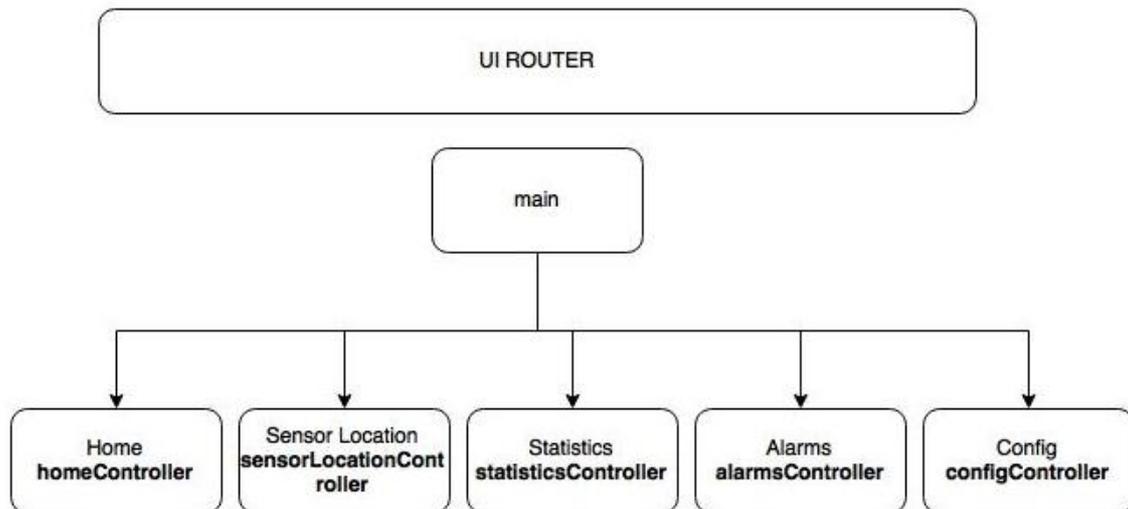


Fig. 4.9: Interface Structure dependency

The routing file is located under `assets\js\private\dashboard\Router` and defines the routes of the diagram:

```

angular.module('MainModule').config(function($stateProvider, $urlRouterProvider){

  // For any unmatched url, send to /route1
  $urlRouterProvider.otherwise("/main/home");

  $stateProvider
    .state('main', {
      url: "/main",
      templateUrl: '/views/main.html',
      controller: 'MainController'
    })
    .state('main.home', {
      url: "/home",
      templateUrl: '/views/home.html',
      controller: 'HomeController'
    })
    .state('main.sensorLocation', {
      url: "/sensorLocation",
      params: {
        param: 'noSensor'
      },
      templateUrl: '/views/sensorLocation.html',
      controller: 'SensorLocationController'
    })
    .state('main.statistics', {
      url: '/statistics',
      params: {
  
```

```
        param: 'noSensor'
    },
    templateUrl: '/views/statistics.html',
    controller: 'StatisticsController'
  })
  .state('main.alarms', {
    url: '/alarms',
    params: {
      param: 'noSensor'
    },
    templateUrl: '/views/alarms.html',
    controller: 'AlarmController'
  })
  .state('main.config', {
    url: '/config',
    templateUrl: '/views/config.html',
    controller: 'ConfigController'
  })
});
```

Each different screen is a state, meaning the app knows where the user is located and making it possible to easily move from one screen to another. Each different view depends of the main screen and is defined in a separate HTML file as shown in the code extract.

For a view, the following html tag is inserted in the main document:

```
<div ui-view></div>
```

All html files can be located under */assets/views*.

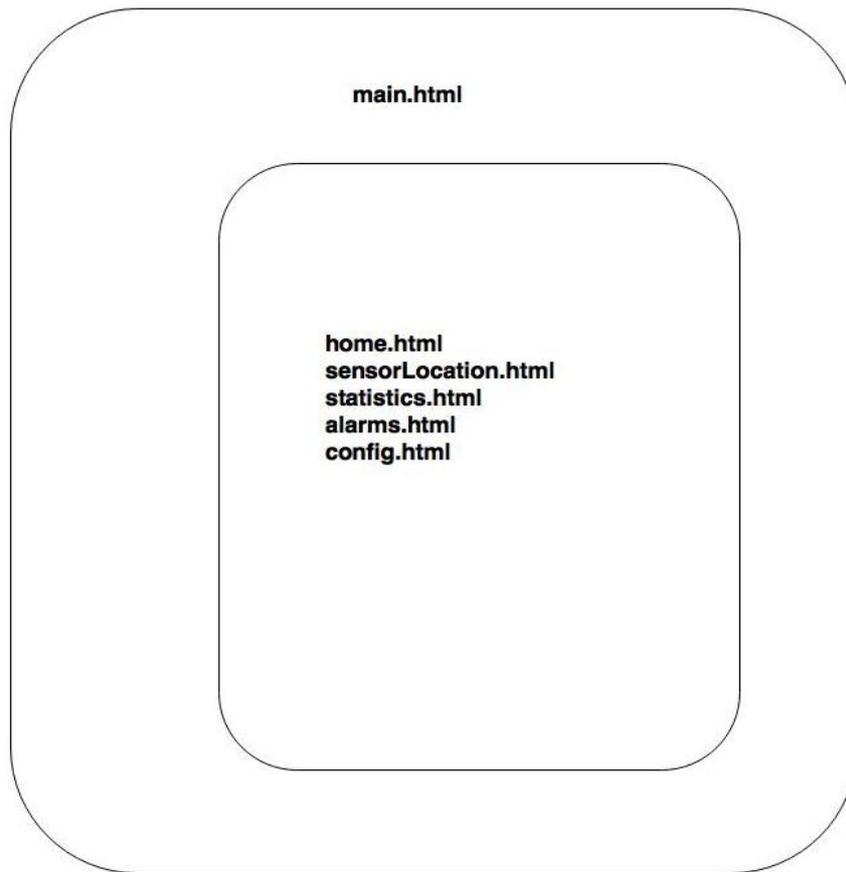


Fig. 4.10: The dashboard screen distribution

4.4.3.4 Main

The main screen, defined in the *main.html* and using the *mainController.js*, is the template screen for containing the nested views.

The included elements are the following:

- Top Navigation Bar:
 - User name information
 - Log Out button
- Lateral navigation bar for accessing the different screens.

This screen uses the following backend API methods via AJAX calls for obtaining the user information and for logging out.

```
'GET /logout': 'UserController.logout'  
'GET /getInitValues': 'UserController.getInitValues'
```

4.4.3.5 Home

The home screen is the default view that is rendered when accessing the application. The screen is defined in the *home.html* file and uses the *homeController.js* controller. This view provides this information:

- Lists all the active nodes and gateways
- Gets the last 24h node/sensor measurement

This is done via the following AJAX call:

```
'GET /getDailyReport': 'GatewayController.getDailyReport'
```

4.4.3.6 Sensor Location

The sensor location screen is defined in the *sensorLocation.html* file and uses the *sensorLocationController.js*.

In the sensor location screen the user is able to view in a map the active gateways and their sensors. The map service is provided by Google Maps using the Angular Google Maps directive. The information for showing this data is done through the following API methods:

```
'GET /getGateways': 'GatewayController.getGateways',  
'GET /getSensors': 'SensorController.getSensors'
```

WebSockets technology (offered as a stock option from Sails.js) is used for offering real-time gateway and sensor synchronization information.

This is done by using the publish-subscribe pattern in which the application is subscribed to the event of new gateway or new sensor synchronization. When the event

is triggered, the Angular application refreshes the screen with the new inserted information.

4.4.3.7 Statistics

The sensor location screen is defined in the *statistics.html* file and uses the *statisticsController.js*.

This screen is meant for visualizing the sensor's measurement data filtered by the measurement type, the sensor and a time period. The data is visualized through a chart, provided by Google Chart API and packaged through a custom directive, and a table for raw data visualization. An export to CSV option is also available.

The following API methods are used for retrieving the data:

```
'GET /getSensors': 'SensorController.getSensors'  
'GET /getMeasurementTypes': 'MeasurementTypeController.getMeasurementTypes',  
'GET /getSelectedMeasurement': 'MeasurementController.getSelectedMeasurement',
```

WebSockets technology is also used in a similar way as the sensors location for real time measurement updates.

4.4.3.8 Alarms

The sensor location screen is defined in the *alarms.html* file and uses the *alarmsController.js*.

The alarms screen is composed by two main features: One collapsable panel enables the user to view the new alarms and mark them as viewed, and another one that should be used for searching the historic alarms.

A new alarm is no longer a new alarm when the Boolean value *viewed* from database has been set on true.

The following API methods are used for this purpose:

```
'GET /getSelectedAlarms': 'AlarmController.getSelectedAlarms',  
'GET /getUnviewedAlarms': 'AlarmController.getUnviewedAlarms',  
'PUT /setViewedAlarm': 'AlarmController.setViewedAlarm',  
'GET /getSensors': 'SensorController.getSensors',  
'GET /getAlarmTypes': 'AlarmTypeController.getAlarmTypes'
```

4.4.3.9 Configurations

The sensor location screen is defined in the *config.html* file and uses the *configController.js*.

This screen is used for adding new types of measurement, new types of alarm, and to create new users.

The following API methods are used:

```
'POST /newMeasurementType': 'MeasurementTypeController.newMeasurementType',  
'POST /newAlarmType': 'AlarmTypeController.newAlarmType',  
'POST /signup': 'UserController.signup',
```

4.5 Version control

Although no special focus was made into version control, several commits were done during the development of the system. The main use of the repository was a way to store all the source code so then it could be easy to be deployed in the server using the clone command.

Also, using the provided *issue* tool from GitHub, supervisors were able to report all the problems related with the application in a proper way.

Feb 22, 2015 – Jun 20, 2015

Contributions: **Commits** ▾

Contributions to master, excluding merge commits

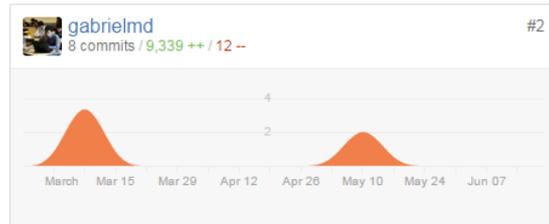
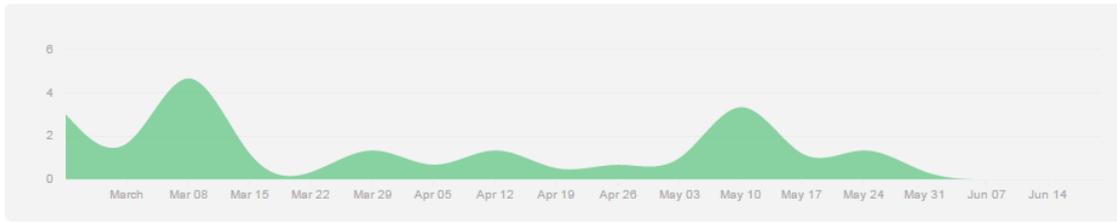


Fig. 4.11 Github Repository commit graph.

Chapter 5: Web Application walkthrough

This chapter contains information regarding the user interface and usage of the developed web application.

5.1 Login

When the user accesses the “/” default URL through a web browser, the login application is served. The user is then asked for its credentials (fig X)

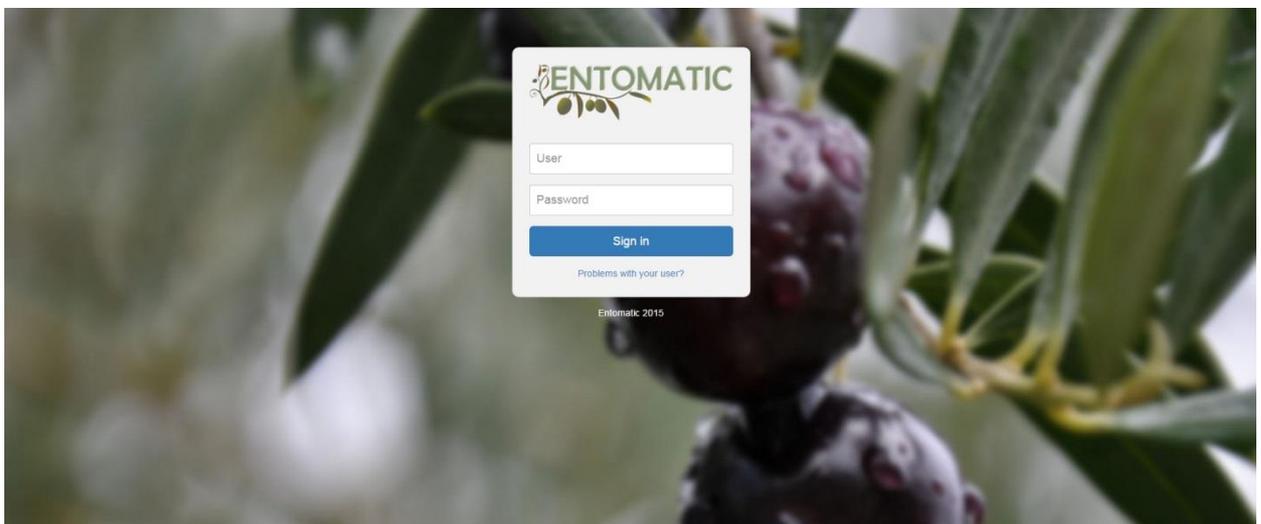


Fig. 5.1: Login screen

If the authentication fails, either because the user doesn't exist or the password is wrong, an error message is shown. If authentication is successful, then browser redirects to the dashboard page.

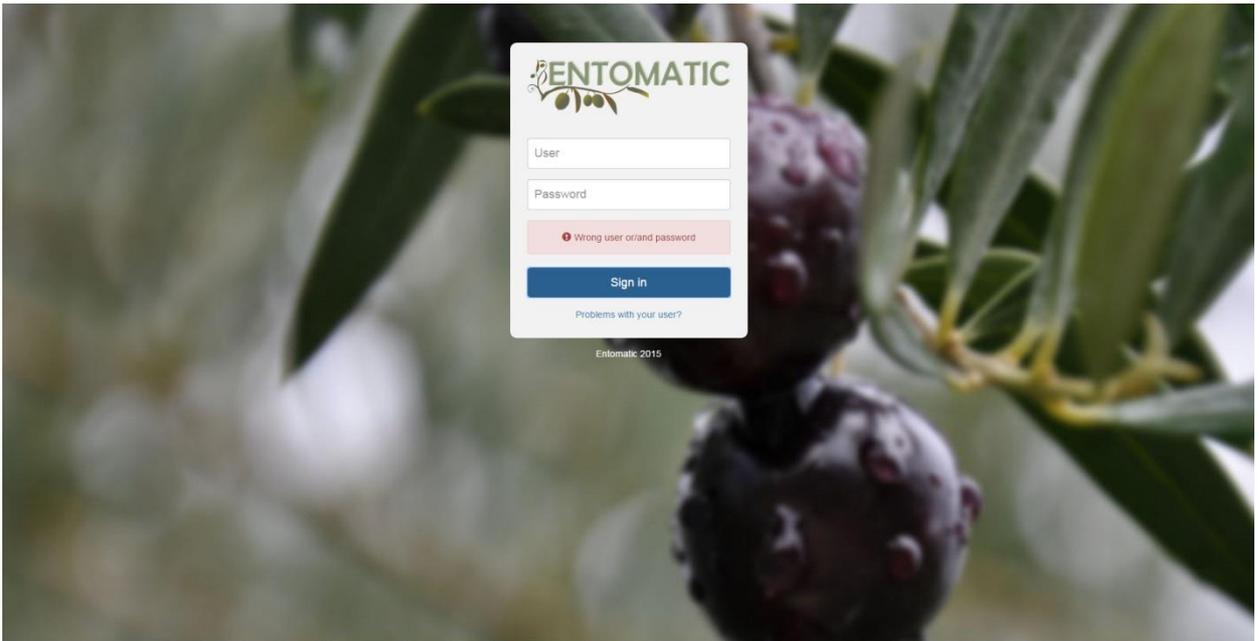


Fig. 5.2 Login authentication has failed.

5.2. Dashboard

The Dashboard page is where the WSN management is done. The dashboard is capable of locating in a map the gateways and the nodes/sensors attached to the system, visualizing through a chart the desired measurements, and manage the alarms generated by the system.

Fig 5.3 shows the home page of the dashboard.

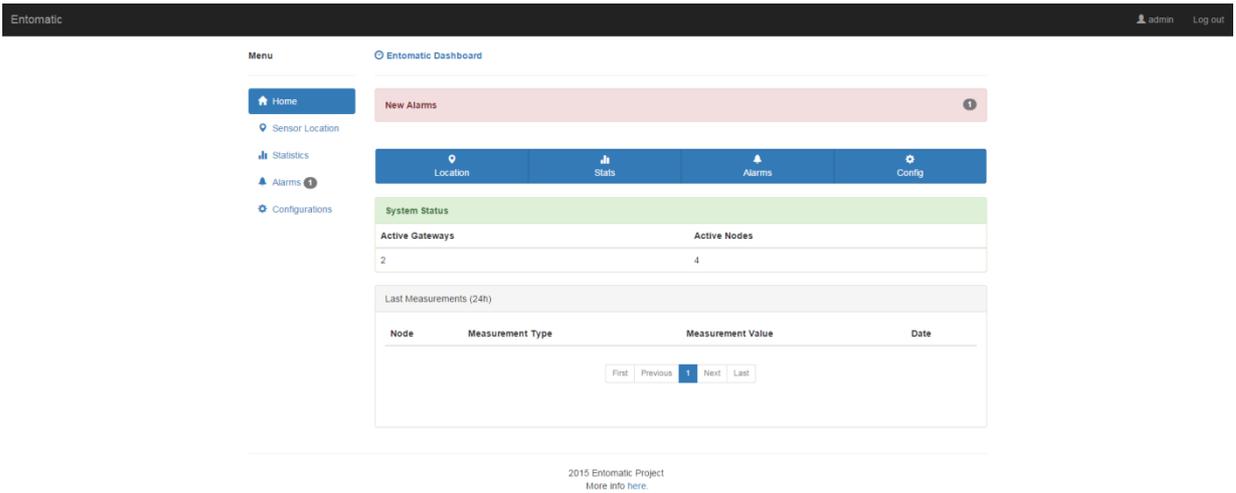


Fig. 5.3: General view of the dashboard

5.2.1 Top Navigation bar

The top navigation bar is used for user information and for logging the user out.

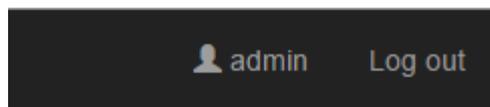


Fig: 5.4 top navigation bar detail

5.2.2 Lateral navigation bar

The lateral bar is meant for accessing the different screens that the dashboard is composed of. The Alarm icon provides a number for showing the current unviewed alarms.

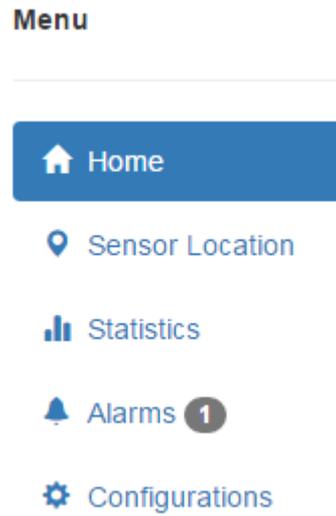


Fig. 5.5: Lateral navigation bar detail

5.2.3 Home

The home screen is the start point of the dashboard where the user is informed with relevant data such as the number of active gateways and nodes, as well as showing the last 24h measurements. Also, a quick link access to different screens is found.

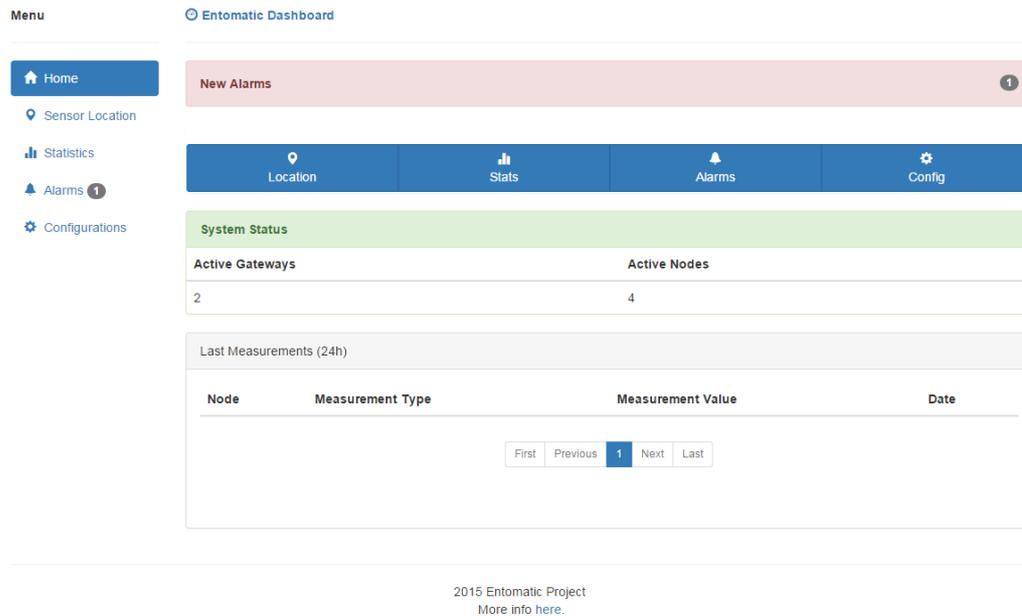


Fig. 5.6: Home page detail

5.2.4 Sensor location

In the sensor location screen the user can locate through a map the sensors and gateways attached to the system. Gateways are marked in blue while sensors in red. When a sensor or gateway is clicked, a window appears. This window shows information about the coordinates, the id, and the mac. Also, if a sensor is selected, the user can access its measurements and alarms.

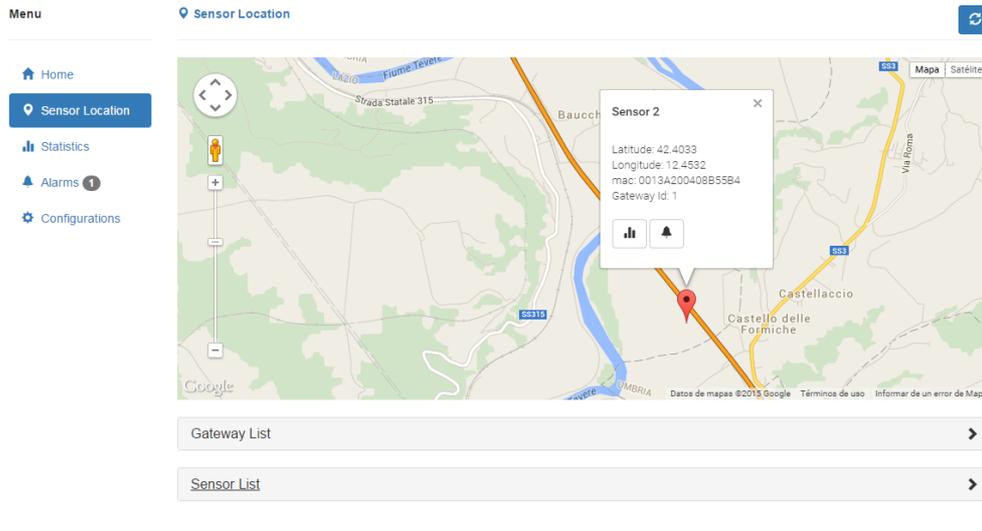


Fig 5.7: Map detail from the sensor location screen

Apart from the map view, there are two collapsible lists:

- **Gateway:** Shows all the gateways attached to the system. If one item is clicked, then map will navigate to the gateway point and open the gateway window.
- **Sensor:** If a sensor is clicked, then the map will show the selected item. Also, obtaining information regarding the gateway, the measurements and alarms can be done via click to the icons.

Gateway List				
Gateway id	Latitude	Longitude	mac	Created at
1	44.4033	32.4532	0013A200408BCD4B	Wednesday, May 13th 2015, 6:04:53 pm
2	44.4033	32.4532	0013A200408BCD4C	Wednesday, May 13th 2015, 6:27:16 pm

Sensor List						
Sensor id	Latitude	Longitude	mac	Created at	Gateway	
1	41.4033	12.4532	0013A200408B55B3	Wednesday, May 13th 2015, 8:21:52 pm	1	 
2	42.4033	12.4532	0013A200408B55B4	Wednesday, May 13th 2015, 11:30:19 pm	1	 
3	41.4033	12.4532	0013A200408B55B8	Saturday, May 23rd 2015, 10:03:56 pm	2	 
4	41.4033	12.4532	0013A200408B55B1	Sunday, May 24th 2015, 12:24:07 pm	2	 

Fig. 5.8: Gateway and Sensor detail list

One interesting feature is the capability that share the sensor location, the statistics and alarms screen of switching between different screens for a selected node.

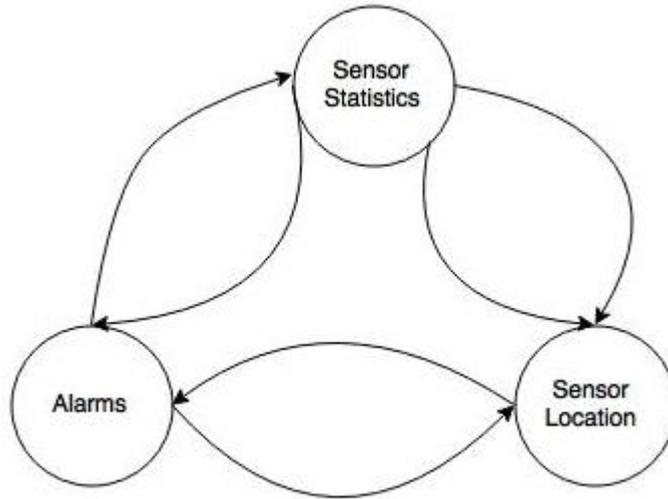


Fig. 5.9. Graph showing the relations between the different screens

5.2.5 Statistics

From the statistics screen, the user can visualize the measurements in a chart for a selected sensor.

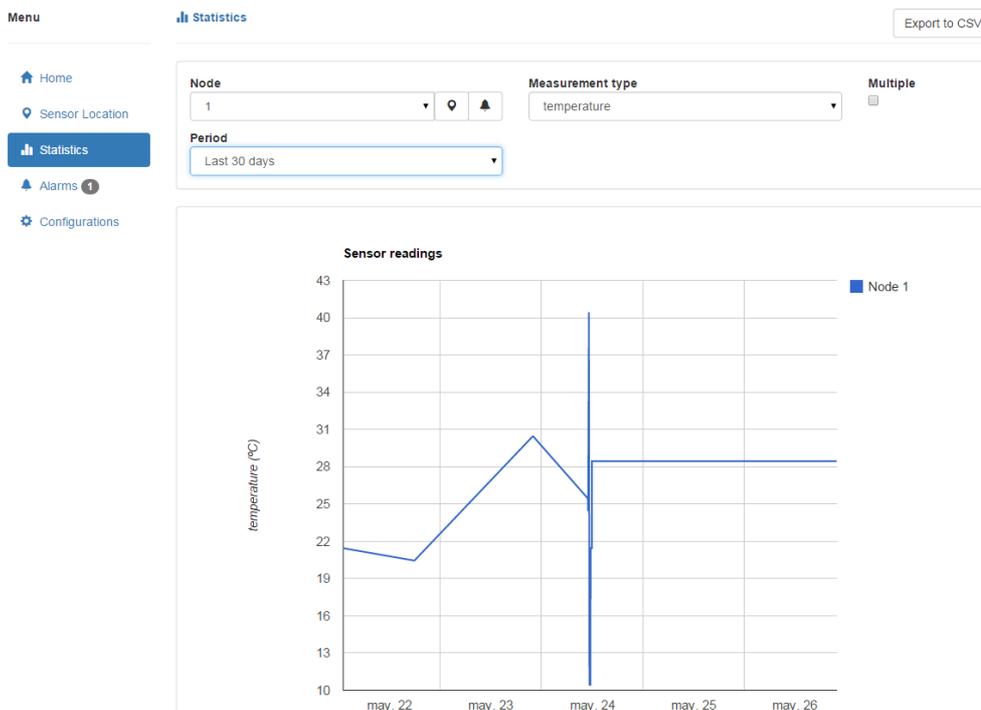


Fig. 5.10: Statistics screen overview

The screen has a node selector and a measurement type selector, from which the user can obtain a chart representation in desired time period.

The screenshot shows a form for filtering statistics. It contains the following elements:

- Node:** A dropdown menu with '1' selected. To its right are icons for location and alarms.
- Measurement type:** A dropdown menu with 'temperature' selected.
- Multiple:** A checkbox that is currently unchecked.
- Period:** A dropdown menu with 'Custom Date' selected.
- From:** A date picker showing '04-March-2015'.
- To:** A date picker showing 'Mon Jun 15 2015 06:06:37 GMT+0200 (Centra)'.

Fig. 5.11: Statistics filter

Also, access to the selected node map location and alarms can also be found. If the multiple check is selected, then multiple nodes can be visualized for a selected measurement type and period type.

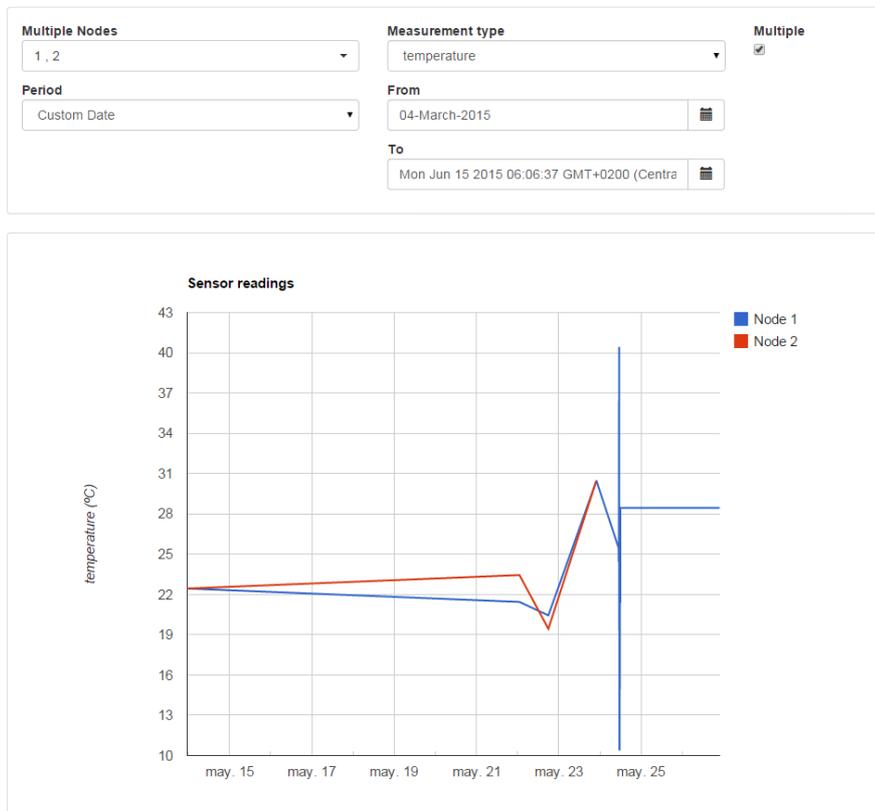


Fig. 5.12: More than one node per graph

5.2.6 Alarms

The Alarms screen has two main collapsible panels: One enables the user to view the new alarms and mark them as viewed, and the other is used for searching the historic alarms.

The screenshot shows the 'Alarms' screen with a left-hand menu and two main panels. The menu includes 'Home', 'Sensor Location', 'Statistics', 'Alarms 1', and 'Configurations'. The 'New Alarms' panel displays a table with one row of data and a 'viewed' button. The 'Node' panel includes filters for 'Node' and 'Alarm type', and a table of historic alarms.

Sensor id	Alarm type	Value	Date
1	battery	5	Wednesday, May 27th 2015, 12:08:01 am

Sensor id	Alarm type	Value	Date
1	battery	9%	Tuesday, May 26th 2015, 10:44:50 pm
1	battery	5	Tuesday, May 26th 2015, 11:16:34 pm
1	battery	5	Tuesday, May 26th 2015, 11:20:32 pm
1	battery	5	Tuesday, May 26th 2015, 11:18:29 pm
1	battery	5	Tuesday, May 26th 2015, 11:17:07 pm
1	battery	5	Wednesday, May 27th 2015, 12:08:01 am

Fig. 5.13: Alarm screen

Also, access to the selected node map location and measurements can be found.

5.2.7 Configurations

Configuration screen is designed to add new users, new measurement types, and new alarm types.

Menu 📍 Configurations

- 🏠 Home
- 📍 Sensor Location
- 📊 Statistics
- 🚨 Alarms 1
- ⚙️ Configurations

New measurement type

Measurement Name <input type="text"/>	Units <input type="text"/>	Short Name <input type="text"/>
---	--------------------------------------	---

Create

New Alarm type

Alarm Name <input type="text"/>	Short Name <input type="text"/>
---	---

Create

New User

User Name <input type="text"/>	Password <input type="text"/>	Admin <input type="checkbox"/>
--	---	--

Create

2015 Entomatic Project
[More info here.](#)

Fig. 5.14: Configurations screen

6. Deployment and Testing

Once the platform has been developed and tested in a local environment, integrated tests in a simulated real environment should be done for verifying the correct operation of the system.

6.1 Deployment

The Sails.js server and the PostgreSQL database server have been deployed in a testing environment supplied by the university. This server is located at the UPF facilities and can only be accessed within the network or through the VPN, using the following URL: <http://em-test.s.upf.edu/> (port 80)

6.2 Testing scenario

As a way to test the platform in a real scenario, a WSN was simulated in the laboratory using a gateway and a node. The features tested by the WSN were gateway synchronization, sensor/node synchronization and sensor measurements. The testing scenario was composed of two nodes linked to a gateway which sent through the university network the data gathered by the WSN to the platform server.

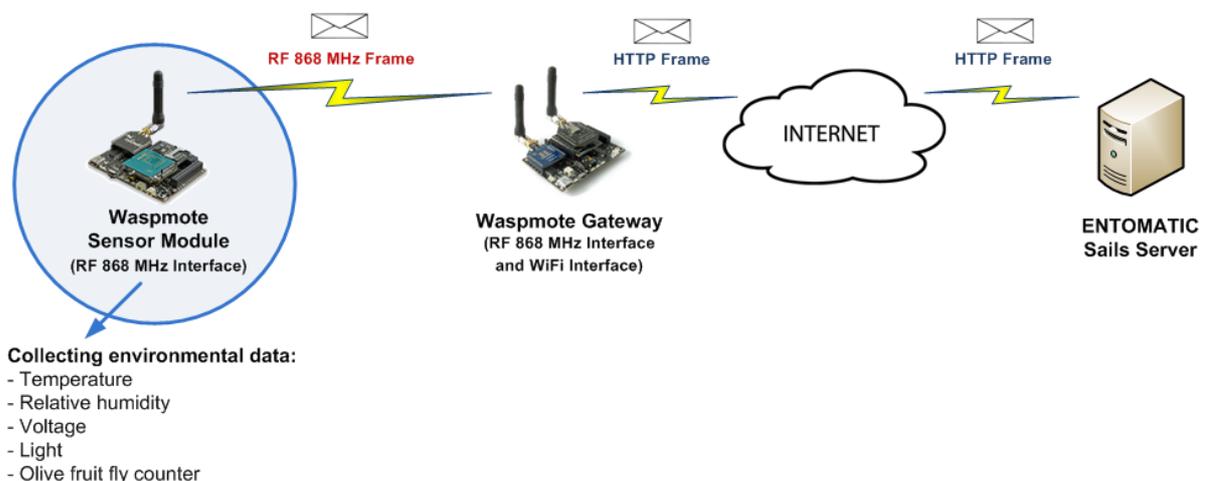


Fig. 6.1: Testing scenario

6.2.1 Measurement types

The measurements expected by the system were (where physical sensor was not available, simulated data was used):

- **Temperature:** Provided by a temperature sensor.
- **Voltage:** The current voltage value supplied by the battery.
- **Relative humidity:** Provided by a relative humidity sensor.
- **Light:** Fixed value set to 50%.
- **Olive fruit fly counter:** Using a random number generator.

These types of measurements were inserted in the system via the *MeasurementType* table for proper recognition by the system.

6.2.2 WSN Hardware

The hardware used for the simulation were two Wasp mote nodes, one acting as a node, and the other one acting as a gateway.

The information relating to the coordinates was also simulated.

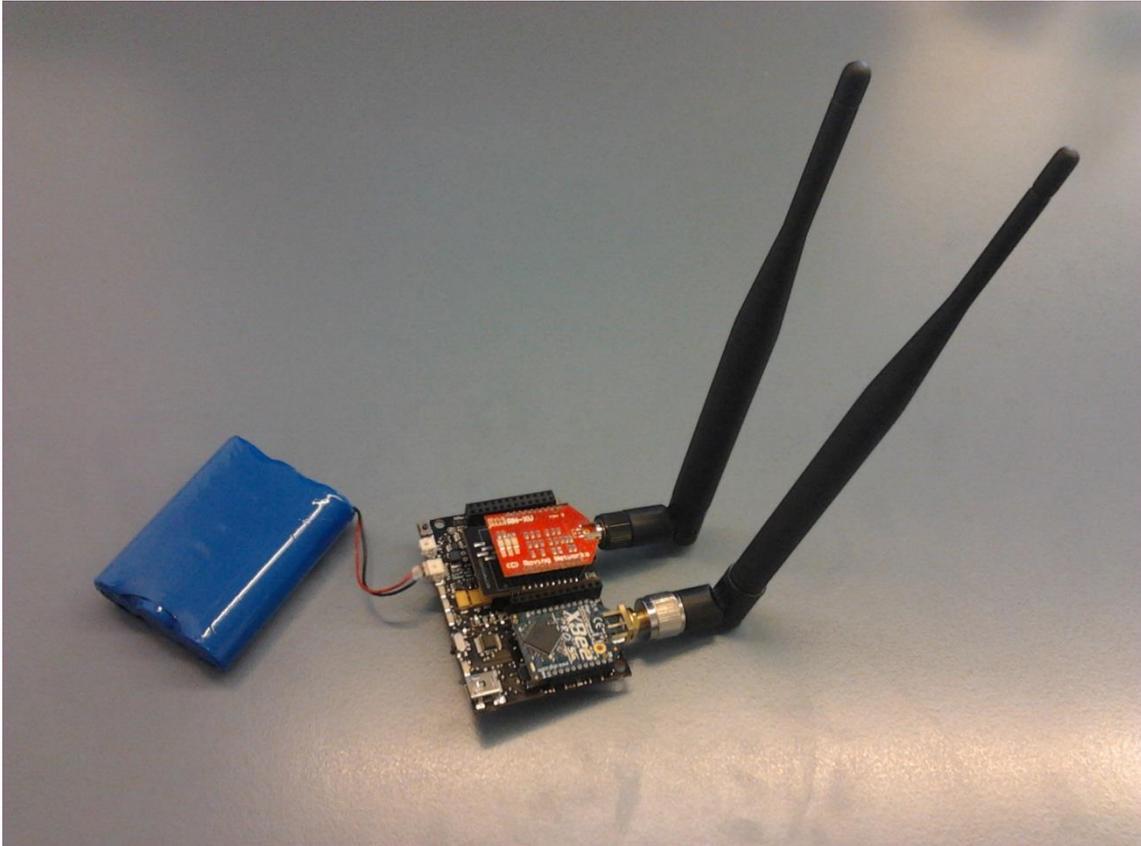


Fig. 6.2: Wasp mote Gateway



Fig: 6.3 Wasp mote Gateway with a case.



Fig: 6.4 Waspote Node with temperature sensor.



Fig. 6.5: Waspote Node

6.2.3 WSN simulation results

Two major results were crucial in order to validate the correct operation of the system, the WSN synchronization with the platform server, and the validation of the sent measurements.

- WSN synchronization: As shown on figure 6.5, gateway 3 corresponds to the synchronized gateway and is correctly located in the map. Gateway 3 has 2 linked nodes, sensor 4 and sensor 5. Both sensors were correctly linked to its gateway and placed in the map.



Fig: 6.5 simulated gateway and Node location

- WSN measurements: Validating the measurements sent by the sensors was a way to make sure the usefulness of the platform. Fig 6.6 shows the measurement for sensor (node) 5 with the olive fruit fly measurement type selected. Because the values were randomly generated, no data interpretation can be made. More interesting is the chart showed in figure 6.7. The room where the sensors were placed had an air conditioning system which switched off every 30 minutes. As a result, the temperature oscillated, increasing when the air conditioning was off, and decreasing when it was on.

Node
 5

Measurement type
 Olive Fly

Multiple

Period
 Last 7 days

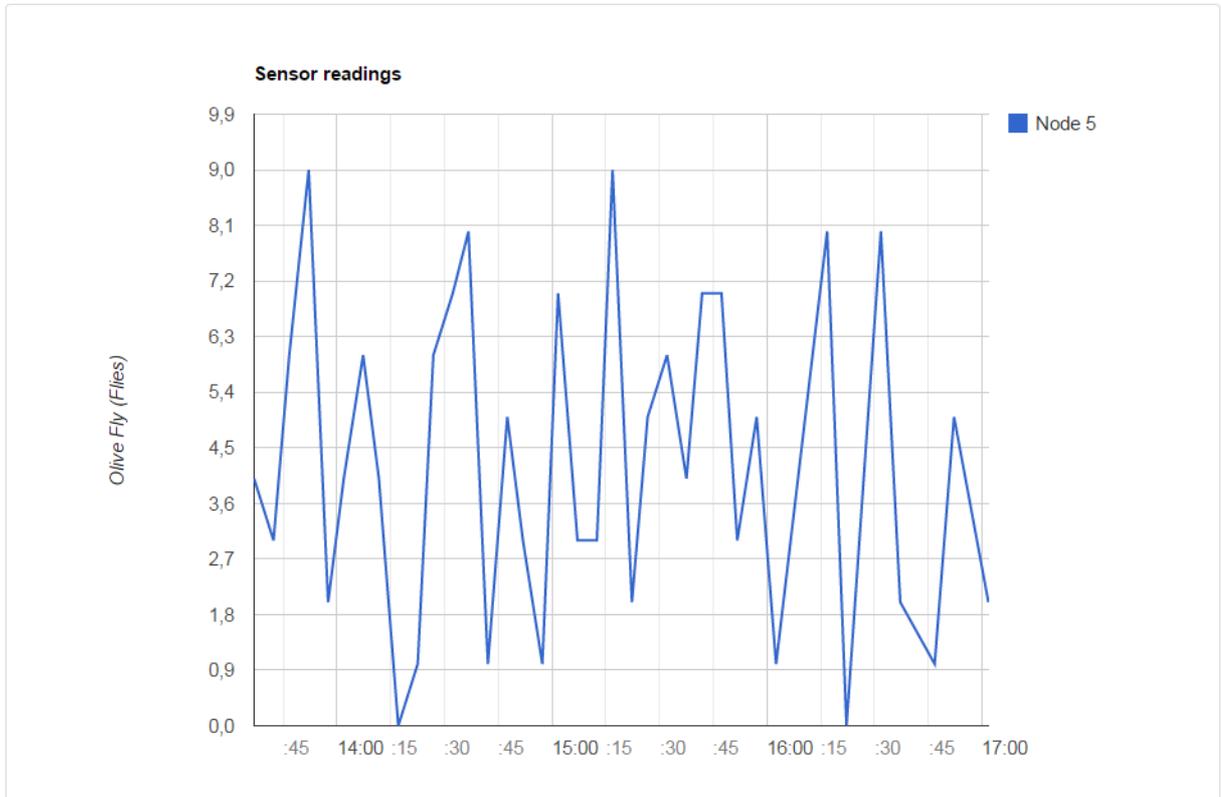


Fig: 6.6 Olive fruit fly measurements

Node
5

Measurement type
temperature

Multiple

Period
Last 7 days

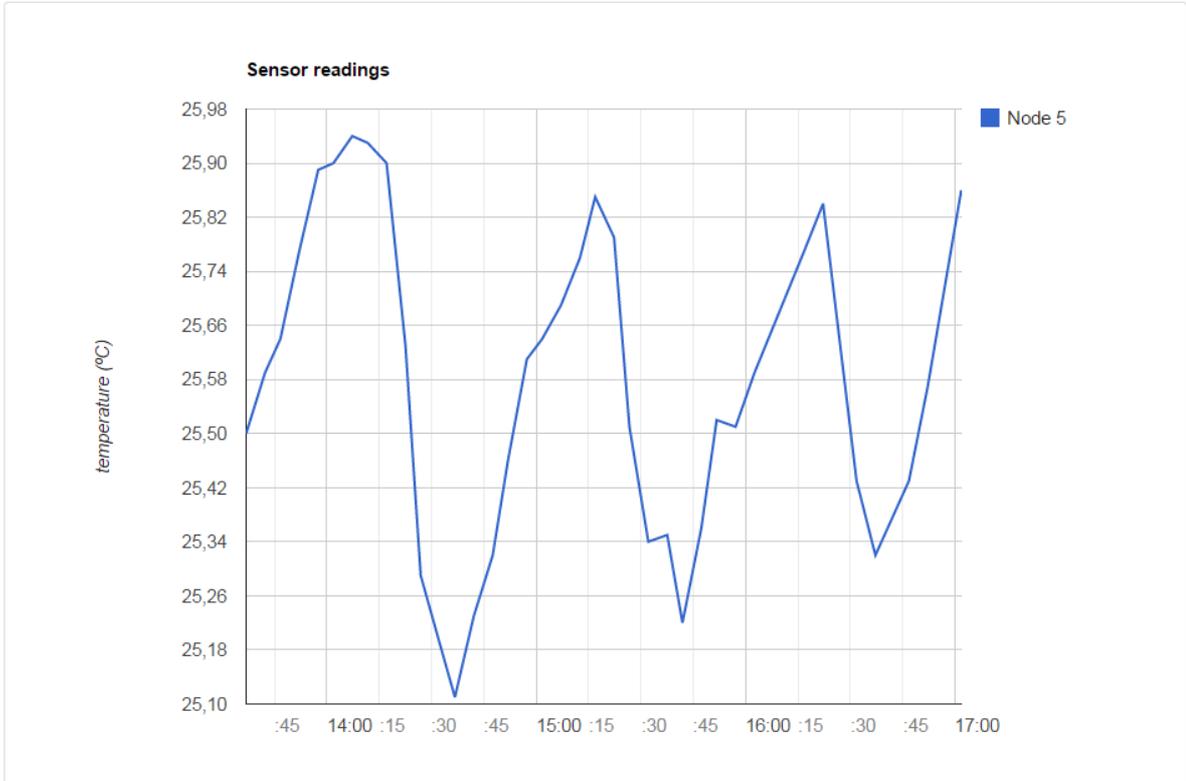


Fig: 6.7 temperature measurements

Chapter 7: Conclusions

A web platform for managing WSNs has been presented. The first chapters included an introduction to the concept of WSN to later introduce the reader into the available technologies for developing the platform. Although the selected tools were the ones suggested by the specification of the Entomatic project, their use provided an easy development with a moderate learning curve.

The development was carried taking into account maintainability and scalability constraints, thus providing a viable model for the early development of the Entomatic project. The platform testing was the crucial part for ensuring the correct functioning of system, although close communication was established with the supervisors for ensuring that everything was going in the right direction.

In spite of being a simple prototype, the results have provided to fulfill with the original set project scope and being completely functional in development environments.

It has been a wonderful opportunity to develop from scratch a system for managing WSNs and being able to solve complex problem using the available resources. Learning new technologies has also provided me with a new perspective of modern web development, helping me in developing my professional career.

7.1 Future work

The implemented platform could be improved in several ways:

- **Security:** The testing environment was set within a private network, meaning undesired access was not going to be found. If the platform had to be set in a production environment, the following points should be taken into account:
 - **API private keys:** The way the restful API is designed, it is not guaranteed that any unwanted user can perform undesired actions. Using a private key for API clients ensures that only users with this key can use it.
 - **Client password encryption:** Although password user's passwords are stored encrypted in the data base, client sends the HTTP authentication request with no encryption, which means that any network sniffer could trace and obtain the user

credentials. Using the HTTPS protocol could be an easy solution for solving this problem.

- **User permissions:** The current implementation has no support for user permissions. Final product should have user filtering depending on the user that wishes to access the platform.
- **Custom UI:** Instead of using the Bootstrap framework, which is ideal for this sort of prototype development, final product could use a custom framework for more specific and accurate design.
- **Bidirectional WSN communication:** Current WSN communication with the system is only done in one direction. In other words, only data coming from it can be received. Bidirectional communication would increase system reliability as more WSN information can be obtained (check if sensors are switched off, battery status etc.).

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