Smart IHU: an open source IoT project for Wireless Sensor Network based on the Raspberry platform – Web and mobile development

Georgios Sarigiannis

SID: 330717004

SCHOOL OF SCIENCE & TECHNOLOGY

A thesis submitted for the degree of

Master of Science (MSc) in Communications and Cybersecurity

October, 2019

THESSALONIKI – GREECE

INTERNATIONAL
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Acknowledgements

I would like to express my deepest appreciation to my supervisor, Dr. Stavros G. Stavrinides for his continuous support and guidance throughout the project.

I would like to thank my colleague Kostas Karaklas for his insight and dedication to the first part of the project. His extensive knowledge in matters related to hardware proved invaluable.

A thank you to the International Hellenic University for supporting this project financially and was kind enough to buy the required materials for the sensors and the nodes. I would also like to thank the IHU IT Department that was kind enough to set-up the VM server and help us determine the optimal locations around campus for the placement of the sensors.

Special thanks to my coworker and long-time friend George Fotos for his moral support as well as his tips and tricks regarding the development of the mobile app.

Finally, I would like to thank my family for their support in every step of the way, especially my brother Dr. Denis A. Sarigiannis, whose example I strive to follow.

Abstract

This dissertation was written as a part of the MSc in Communications and Cybersecurity at the International Hellenic University.

The Internet of Things has slowly but surely become an important part of every-day life for millions of users around the world and is a technology that is constantly evolving and adapting. This dissertation is essentially a project that aims to set up a wireless sensor network at the International Hellenic University Campus with the use of four (4) sensor nodes.

The nodes are based on the Raspberry Pi platform and their main function is to retrieve various forms of data such as weather conditions, noise levels, pictures and more. The data are then stored in a database created in a virtual server and afterwards displayed on a webpage built with Wordpress and a mobile application developed with Google's Android Studio.

Georgios Sarigiannis

07/12/2018

Contents

1 Internet of Things: An introduction

This chapter briefly describes the evolution of the Internet of Things (IoT) and its applications while attempting to properly define it. It also provides a brief overview of the Wireless Sensor Networks (WSN).

1.1 About the Internet of Things

Modern technologies, especially those of the information and communication sector are changing the living and working conditions and environments of the people in industrialized nations at an increasingly rapid rate. 15 years ago mobile phones were still in the market, but today they have become a product that is massively produced, a product that combines more and more capabilities and functions. Mobile telephony, internet access, satellite navigation, television, music and much more can now be found in a single device.

But apart from mobile phones, many other devices and products now have embedded logical functions and components that greatly increase their function range. For these devices, it has become increasingly possible, with the integration of sensory components, to interact with their surroundings, communicate with control units or with other objects via wired or wireless networks in order to exchange information.

Technological advancements in several areas such as network technology, electronics and sensors have laid out the foundations for the use of integrated knowledge or “technical intelligence” in devices that are now considered highly valuable, such as phones, televisions, gaming consoles, etc.

However, this is bound to change in the near future, as the rapid development of the Internet of Things could lead to its integration in many cheap, every-day products and low-value consumer goods thus making it way more popular. The Radio Frequency Identification (RFID), which is the main technology behind this, makes it possible to turn low-cost products into “smart” objects. Future developments in the area of electronics have the potential to make the cost of RFID tags drop even less, thus making the technology more accessible.

Along with such developments, the Internet has become a global medium; a source of ever-present information, communications and entertainment, the likes of which could not be foreseen in the previous century. But again, even the Internet seems to be changing.

The Internet of today is the “Internet of Persons” or the “Internet of Information”. It gives people the ability to connect and communicate with each other in many different ways in order to exchange information. However, the addition and use of “smart” objects in networking and information technology along with their associated control systems leads to the emergence of new types of networks.

These networks are in many ways comparable to the Internet; however, they now connect more than people; inanimate objects have entered the equation and thus the term “Internet of Things” became a reality.

Apart from networking, another important feature of the Internet of Things is its autonomy. Technological developments in several areas have enabled objects to act in an autonomous or semi-autonomous way, for example in engineering, medicine, infrastructure, household operations and more.

It is widely recognized that the concept of the Internet of Things was initially proposed by Kevin Ashton in 1999 [1], Greengaard traces the origin of the term back to the development of the LAN networks [2].

Kevin Ashton initially observed that the majority of the data on the Internet was handled by human beings. So essentially, a human user is a slow, inneficient router of data, prone to errors. The user also limits the quality and quantity of said data while sometimes he attempts to interpret it or correct it. An alternative to this approach would be to have these systems connect to sensors that make real-world measurements of events and properties directly. Essentially, systems rid themselves of the need for a human intermediary and attempt to make a direct connection to the internet in order to directly capture real-world data.

However, this idea does not constitute a definition but an observation and an important one at that. For if systems are able to access data directly from sensors, these data will most likely be more in number and less prone to errors. This field of study is known and worked on for decades; the Sensor Networks. So what is the real difference between the IoT and M2M or D2D communication, or even CPS? Under this basis, Peter Waher suggests the following definition [3]:

“THE INTERNET OF THINGS IS WHAT WE GET WHEN WE CONNECT THINGS, WHICH ARE NOT OPERATED BY HUMANS, TO THE INTERNET.”

The Internet of Things differs from sensor networks in the sense that neither Things need to be sensors, nor do sensor networks need a connection to the Internet. The Internet of Things is also different from Big Data since Things do not necessarily capture or generate data, nor is it necessary for data to be stored in big data stores located in the Cloud. The internet of Things is also different to M2M in the sense that users also can and want to access these Things too.

1.2 Wireless Sensor Networks (WSN)

Wireless Sensor Networks can be defined as self-configured and infrastructure-less wireless networks to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to a main location or sink where the data can be observed and analyzed.

The network and its users make use of a base station as an interface, while information retrieval can occur via query injection and data gathering directly from the base station. Wireless Sensor Networks can comprise of a few or even more, up to thousands of nodes which communicate with each other via radio signals. Wireless sensors consist of sensing and computing devices, radio transceivers and power components.

Every node in a Wireless Sensor Network has limited resources: processing speed, disk capacity and network bandwidth. After deployment, the nodes self-organize an appropriate network infrastructure and the sensors begin the collection of data.

Wireless Sensor Networks have become extremely popular due to their flexibility and their potential for solving many different problems; they have been successfully used in the following domains:

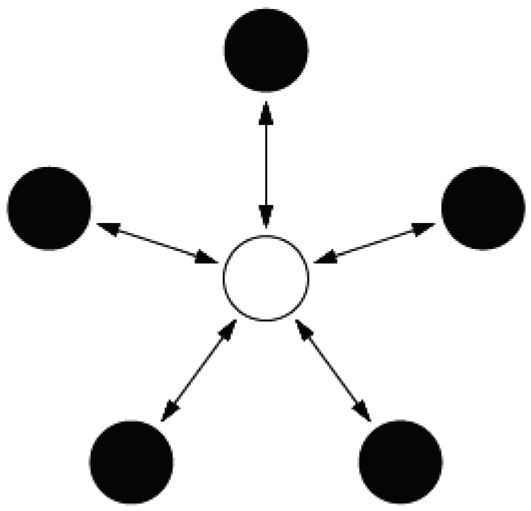
- Military applications

- Area monitoring
- Transportation
- Health application
- Environmental sensing
- Structural monitoring
- Industrial monitoring
- Agricultural sector

Wireless Sensor Networks have different topologies, briefly explained below:

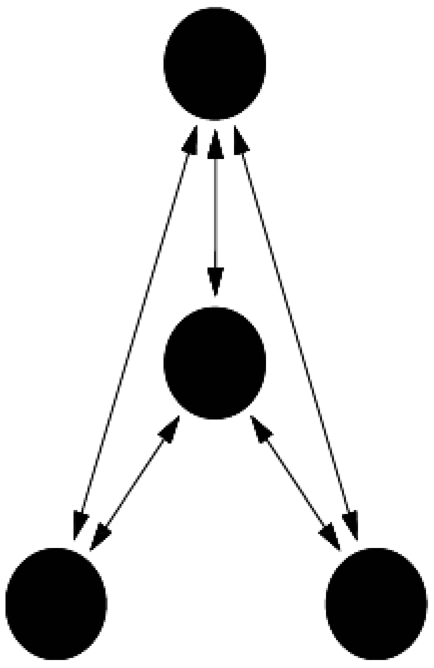
1.2.1 Star Network

In the star topology [4], each node connects directly to a base station. A gateway can send or receive messages to and from a number of nodes. Nodes are not allowed to communicate directly with one another. This enables the use of low-latency communications between a node and the base station. Since this topology enables a single node to handle the whole network, the base station must be within range of all individual nodes. It also helps keep the nodes' energy consumption to a minimum and is popular because of its simplicity, although it severely lacks in terms of robustness due to a single node managing the network.


Picture 1: Star Network Topology

1.2.2 Mesh Network

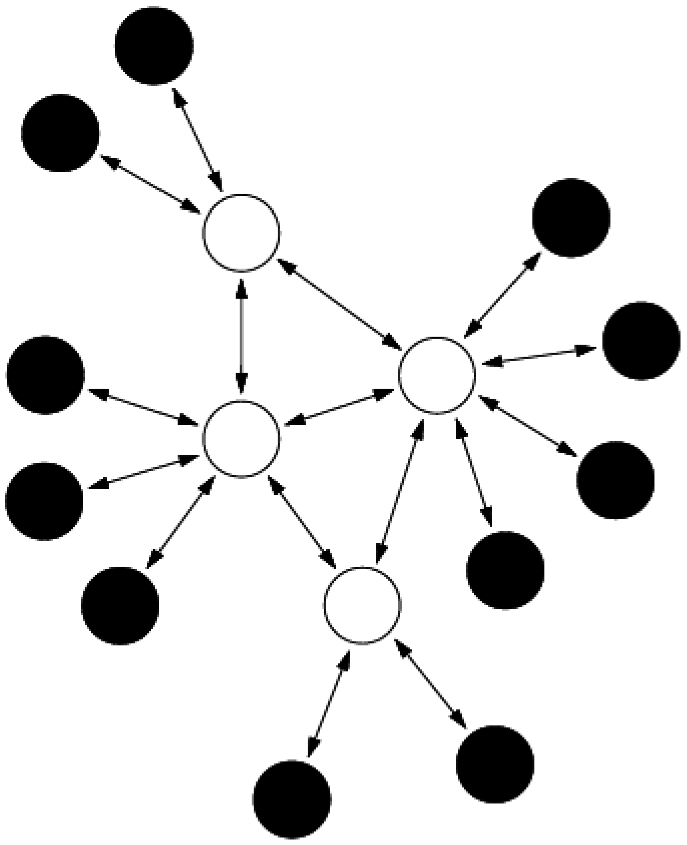
Mesh networks [4] allow communication between nodes that are within transmission range. If a node wants to send a message to a note that is located outside of transmission range, then it needs to use another node as an intermediary. The intermediary node forwards the message to the intended node. The advantage of this topology lies in the fact that its range can be extended by simply adding more nodes, while the fact that nodes communicate with each other makes it easier to isolate a node in the event it fails. It also allows for easier error detection. Disadvantages include the large cost (network scalability can make ultimately lead it to being huge), the high energy consumption of nodes that make use of multi-hop communications and the increased time it takes a message to be delivered depending on the number of hops required.



Picture 2: Mesh Network Topology

1.2.3 Hybrid Star – Mesh

A combination of the star and mesh networks [4], the hybrid provides many advantages in terms of versatility, robustness and low power usage. In this topology the nodes with the lowest power consumption do not possess the ability to forward messages while other nodes have the ability to multi-hop, thus being allowed to forward messages from low power nodes to the rest of the network.



Picture 3: Hybrid Star – Mesh Network Topology

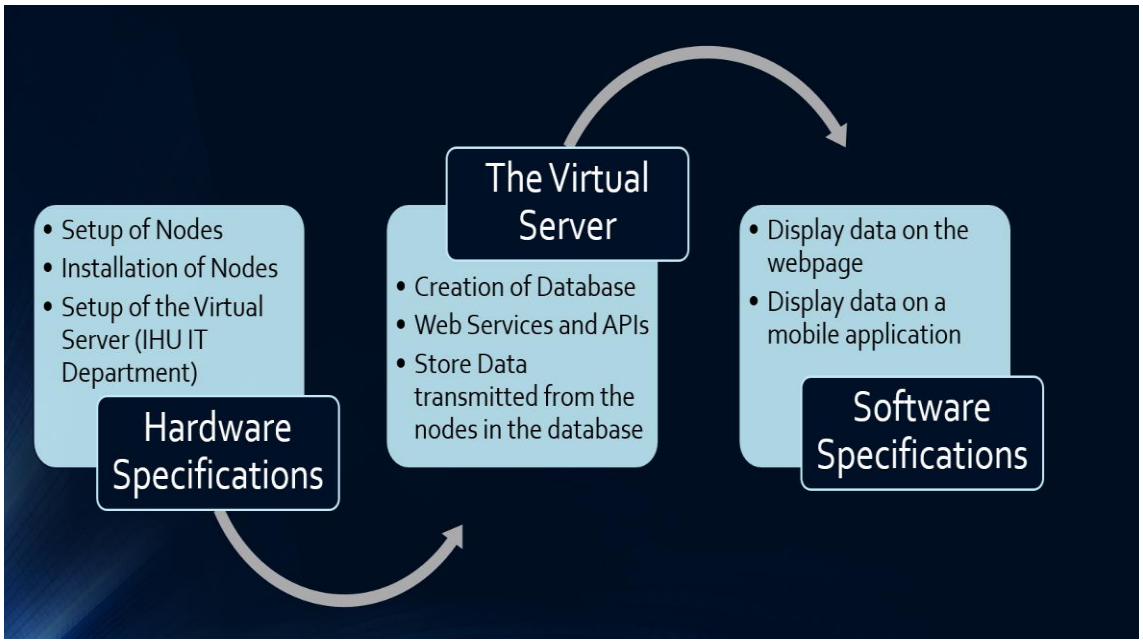
1.3 Smart IHU

The goal of this project is to setup a Wireless Sensor Network that includes four sensor nodes placed around the campus of the International Hellenic University in a star network topology. The nodes collect sensor readings and communicate with a virtual server where the data is stored. The data are ultimately displayed on a webpage created for this purpose, as well as a mobile app.

The main aim is to demonstrate that the Internet of Things should become an integral part of every higher education institute and that the data the sensors provide can be of use to staff, students, and academics alike. It should be noted that by the time this project is finished, the International Hellenic University will be one of the few Institutes in Greece to be making use of IoT technology in its campus.

1.4 Project planning

After consulting with colleague Kostas Karaklas, the planning for the project was divided into three parts:



• Setup of Nodes
• Installation of Nodes
• Setup of the Virtual Server (IHU IT Department)
Hardware Specifications
The Virtual Server
• Creation of Database
• Web Services and APIs
• Store Data transmitted from the nodes in the database
• Display data on the webpage
• Display data on a mobile application
Software Specifications

Picture 4: Project planning diagram

1.4.1 Hardware specifications

This part of the project was carried out by Kostas Karaklas with the assistance of the IT Department. It includes the studying of the various parts of the nodes, their assembly and their installation at distinct locations around the campus. Kostas also did the programming on the nodes and their services; the nodes store their data in MicroSD cards and via use of a service, send the data to the server in short intervals, depending on the sensor and the node. The IHU IT Department was responsible for setting up the Virtual Server and provide us with credentials to be able to access it via the IHU VPN.

1.4.2 The Virtual Server

After the Virtual Server was setup, the next step was to install the necessary components on it. Via use of the so-called “LAMP” stack, the server ended up running on Ubuntu Linux 18.04 with the Apache2 HTTP server, as well as MySQL and PHP version 7.2.

1.4.3 Software Specifications

The webpage was created with the use of Wordpress, one of the world’s most popular CMS, based on PHP and MySQL. It also makes use of the Bootstrap4 theme and a plugin was written in PHP in order to get the data from the sensors and display them on the page. The mobile application was programmed via the use of Android Studio, the official IDE for Google’s Android OS. The application was programmed in Java. As of the moment, an iOS version of the app is not planned for the near future.

2 Hardware specifications

This chapter describes the devices that were used for this project, their specifications, setup and functionality. After discussing this topic extensively with Prof. Stavros Stavrinides and colleague Kostas Karaklas, a conclusion was reached that the most time- and cost-efficient technology to use as a basis for this project was the Raspberry Pi Model 3B+. The chapter also describes the nodes and their respective sensors briefly. This part of the project is covered extensively by colleague Kostas Karaklas in his dissertation, titled “Smart IHU: an open source IoT project for wireless sensor network based on the Raspberry PI platform – Physical design and implementation”.

2.1 The Raspberry Pi

2.1.1 History

The Raspberry Pi (or, in short, RPi) is a series of small, portable devices that are classified as “single-board” computers; in other words, a computer that is built entirely on one single circuit board. The concept of the Raspberry Pi was conceived by the Raspberry Pi Foundation, a charitable organization that was founded in the United Kingdom in 2009. Its goal was to promote the teaching of the basics of Computer Science in low- and middle-income countries. The mind behind the conception of the RPi was Eben Upton, former CEO of the Raspberry Pi Foundation and Raspberry Pi (Trading), who at the time was working as director of studies at the Computer Science Department at the University of Cambridge’s St. John’s College. Upton, along with Jack Lang, an affiliated lecturer at the Computer Laboratory of Cambridge and Alan Mycroft, a Computing Professor at the same institution, became concerned when they realized that the students’ interest in computer science was waning, while the majority of the applicants of these institutions did not possess adequate programming skills. And so the RPi Foundation developed a model that was cheap, portable and ultimately, powerful enough to become popular, with the hope that more young people and future students would take an interest for computer science.

The full list of the original founders is as follows:

- Eben Upton
- Pete Lomas
- Robert Mullins
- Alan Mycroft
- David Braben
- Jack Lang

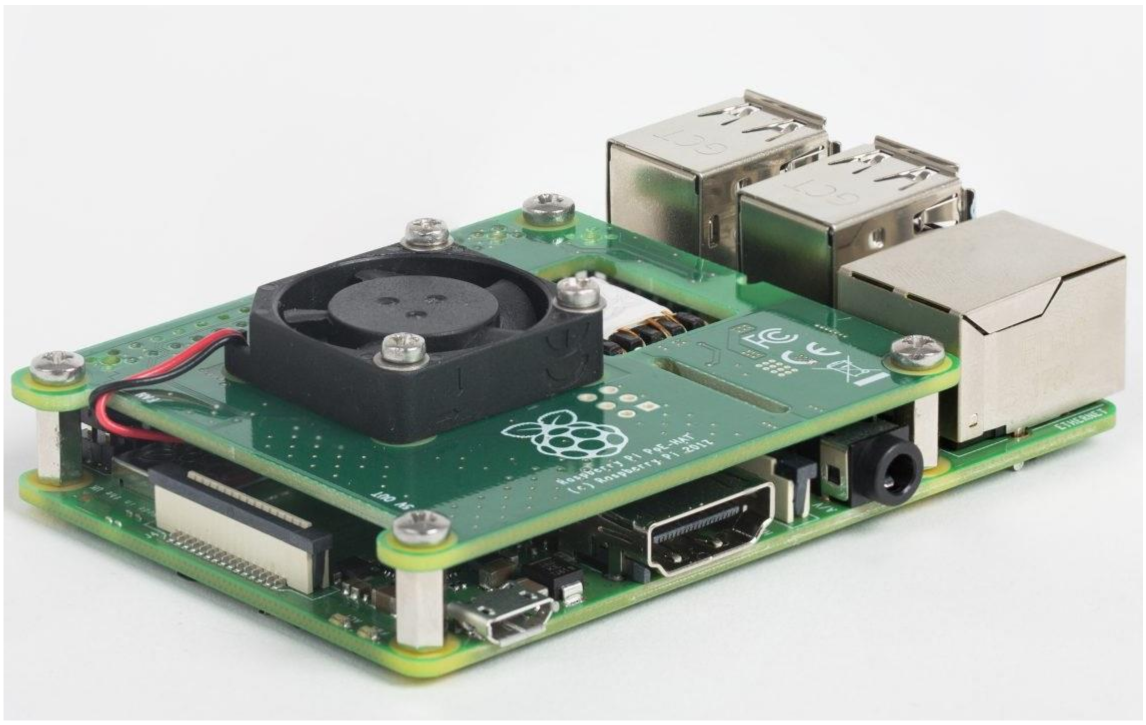
  The current chairman of the Raspberry Pi Foundation is David Cleevely; the charity employs 135 people out of Cambridge, UK.

Picture 5: The Raspberry Pi Logo, designed by Paul Beech

2.1.2 The Raspberry Pi Model 3B+

Picture 5: The Raspberry Pi Model 3B+

The Raspberry Pi Model 3B+ [5] features a quad-core CPU (Broadcom BCM2837B0, Cortex-A53 (ARMv8) 64-bit SoC), along with 1GB of LPDDR2 SDRAM. It also comes equipped with 2.4GHz and 5GHz IEEE 802.11.b/g/n/ac wireless LAN, Bluetooth 4.2, BLE, as well as Gigabit Ethernet over USB 2.0 with a maximum throughput of 300Mbps. The device has 4 USB 2.0 ports, a CSI camera port for connecting a Raspberry Pi Camera, a DSI display port for connecting a Raspberry Pi touchscreen display and a Micro SD port for loading the operating system and storing data. It also offers Power-over-Ethernet support (PoE) via the use of a separate PoE HAT.



Picture 6: Raspberry Pi Model 3B+ with attached HAT

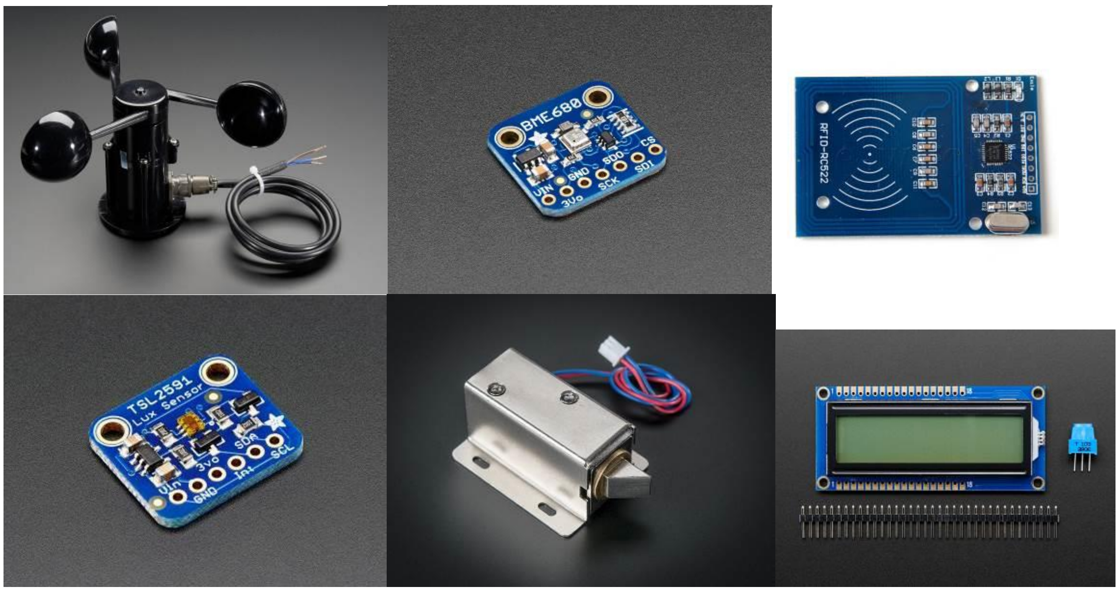
2.2 Node Analysis

2.2.1 Node #1 – Weather Station

The first and most complex node of the project essentially functions as a weather station, gathering various type of data. It is equipped with multiple sensors and its housing features an electronic lock which requires the use of a RFID card for access. The node is housed in a Stevenson screen [6] (also known as “instrument shelter”) which shelters the sensors from precipitation and heat radiation whilst allowing air to freely circulate around them. It is built out of wood and is painted white in order to reflect direct solar radiation. Some of the more sensitive sensors are stored within an IP65 rated (IEC standard 60529) plastic box which provides protection against dust and moisture. The full list of components can be found below:

- Raspberry Pi Model 3B+
- Power Supply for the Raspberry Pi / 5V – 2.5A

- MicroSD card - 64 GB. Required for the operating system and applications of the Raspberry Pi
- Adafruit Perma-Proto Full-sized Breadboard [7] - PCB used for the connections
- Adafruit Perma-Proto Half-sized Breadboard [8] - PCB used for the connections
- Adafruit BME680 [13] – sensor that measures temperature, humidity, barometric pressure and VOC gas
- Adafruit TSL2591 [9] – an advanced digital light sensor, capable of measuring infrared, full-spectrum or human-visible light separately
- Anemometer [12] – capable of measuring up to 32.4 m/s wind speed.
- RGB LCD screen [10] – used for data display
- Lock-style Solenoid [11] – an electronic lock controlled by either the keypad or the RFID sensor
- Power supply for the Solenoid / 12V – 5A
- MFRC522 module [14] – RFID reader-antenna which is used to control the solenoid
- Magnetic contact switch – a switch used to alert the user in the event that the second door of the Stevenson Screen is opened



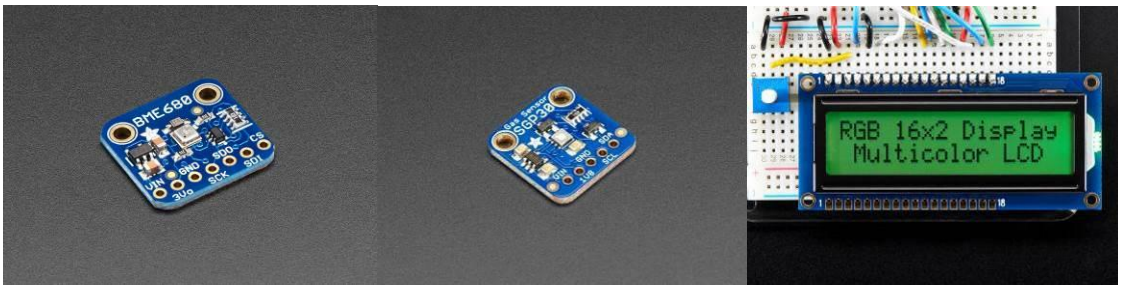
Picture 7: Sample pictures of the Weather Station components

Picture 8: Exterior of a Stevenson Screen

2.2.2 Node #2 – Internal Weather Node

The internal weather node contains sensors that again measure weather data. It will be installed in a classroom in order to monitor the environmental conditions of the IHU interior and determine the air quality of the space. It also measures temperature and humidity. It will be housed in a custom, open-style box made out of wood and plexiglass. The full list of components can be found below:

- Raspberry Pi Model 3B+
- Power Supply for the Raspberry Pi / 5V – 2.5A
- MicroSD card - 64 GB. Required for the operating system and applications of the Raspberry Pi
- Adafruit Perma-Proto Half-sized Breadboard [8] - PCB used for the connections.
- Adafruit BME680 [13] – sensor that measures temperature, humidity, barometric pressure and VOC gas
- Adafruit SPG30[15] – an indoor air quality monitoring sensor capable of detecting a wide range of Volatile Organic Compounds (VOCs). The sensor also calculates eCO2 values
- RGB LCD[10] screen – used for data display



Picture 9: Sample pictures of the Node #2 components

2.2.3 Node #3 – Campus entrance node

The third node of the project is located near the campus entrance. It serves a dual purpose; Take pictures of the horizon and also counts the number of vehicles that enter or exit the campus. The components are housed in plastic boxes of various sizes, similar to the IP65 rated plastic boxes used for the weather station. The full list of components can be found below:

- Raspberry Pi Model 3B+
- Power Supply for the Raspberry Pi / 5V – 2.5A
- MicroSD card - 64 GB. Required for the operating system and applications of the Raspberry Pi
- Adafruit Perma-Proto Quarter-sized Breadboard [16] - PCB used for the connections.
- Raspberry Pi Camera [17] – 8MP camera used for the pictures
- 2 x IR Distance Sensor [18] – Two SHARP sensors used to determine how far away from them objects are. Good for short-range detection

Picture 10: Sample pictures of the Node #3 components

2.2.4 Node #4 – The “Smart Mirror”

The final node of the project is an internal node that will be installed near the reception of the IHU’s building A. A smart mirror is a two-way mirror with an electronic display behind the glass. The display will be showing the viewer different kinds of information in the form of widgets, such as weather, time, date, etc. It will be housed in a custom wooden enclosure designed as a mirror with a frame. The full list of components can be found below:

- Raspberry Pi Model 3B+
- Power Supply for the Raspberry Pi / 5V – 2.5A
- MicroSD card - 64 GB. Required for the operating system and applications of the Raspberry Pi.
- PIR Sensor [19] – A motion sensor used to detect movement and trigger the node
- Adafruit Perma-Proto HAT [20] – A HAT PCB used for the connections
- 2-way mirror
- Monitor – A 23-inch monitor for the display of data

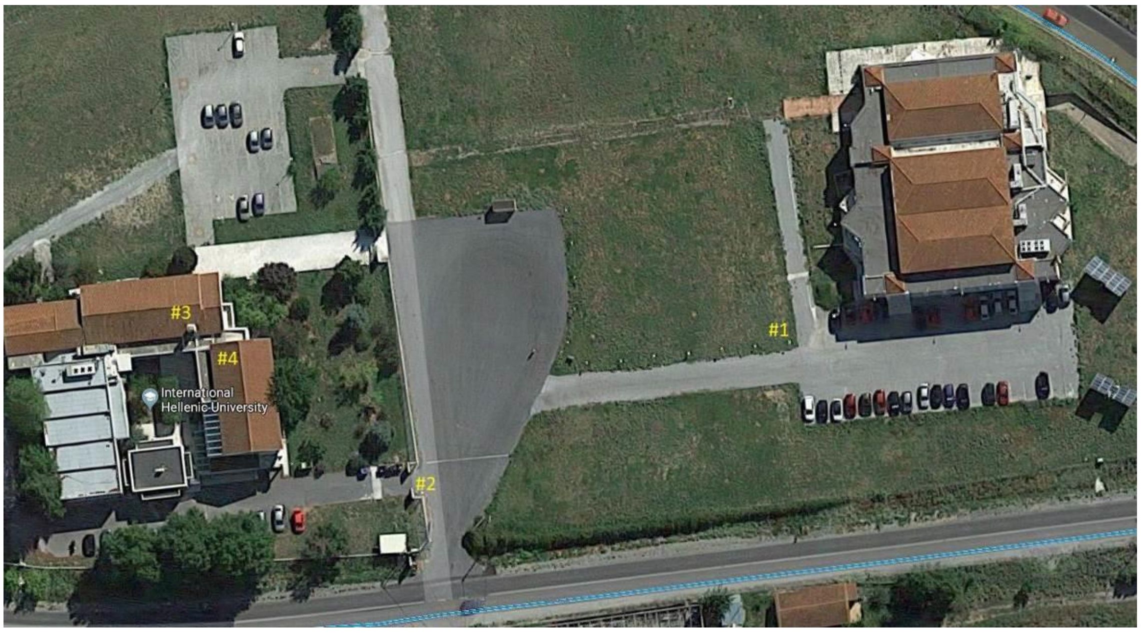
2.3 Node placement & topology

2.3.1 Node placement

By making use of the IHU infrastructure and after determining optimal positions for each node in order to maximize its efficiency, the nodes were placed as follows:

1. The weather station is placed near building B at an elevated position in order to get more accurate readings for the environmental data. Power supply and network coverage are possible via resources from building B.
2. The campus entrance node is placed to the left of the main entrance of the campus at an elevated position in order to be able to take better pictures of the horizon and also be able to provide accurate data regarding the vehicles entering and exiting the campus. Power supply and network coverage are possible via resources from building A.

3. The magic mirror is placed near the reception of building A after determining that this point is one with high traffic – most faculty, staff or students pass by daily.
4. The internal weather node is placed inside a classroom in building A.

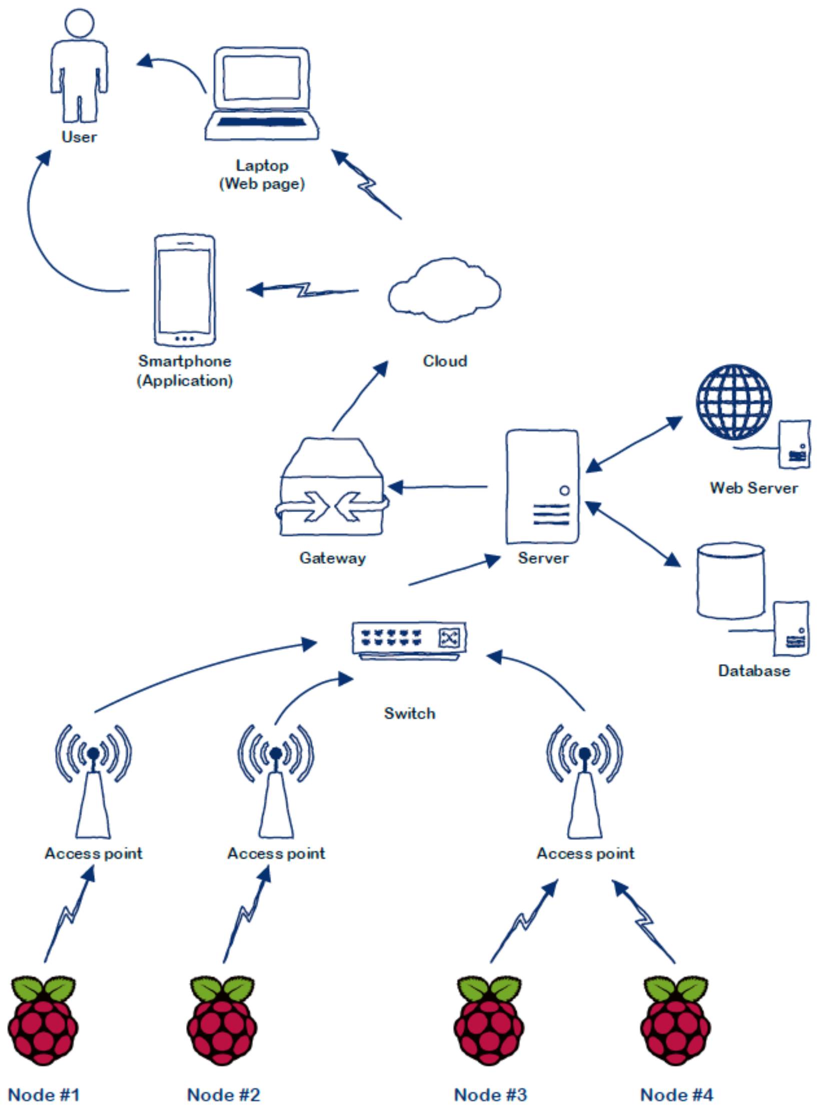


Picture 11: Node placement as seen from above (IHU campus)

At this point it should be noted that during the time this dissertation is being written, the "Magic Mirror" sensor is not functional due to the fact that the required parts to set it up have not arrived. As such, no further mention will be made for this node in this document.

2.3.2 Topology

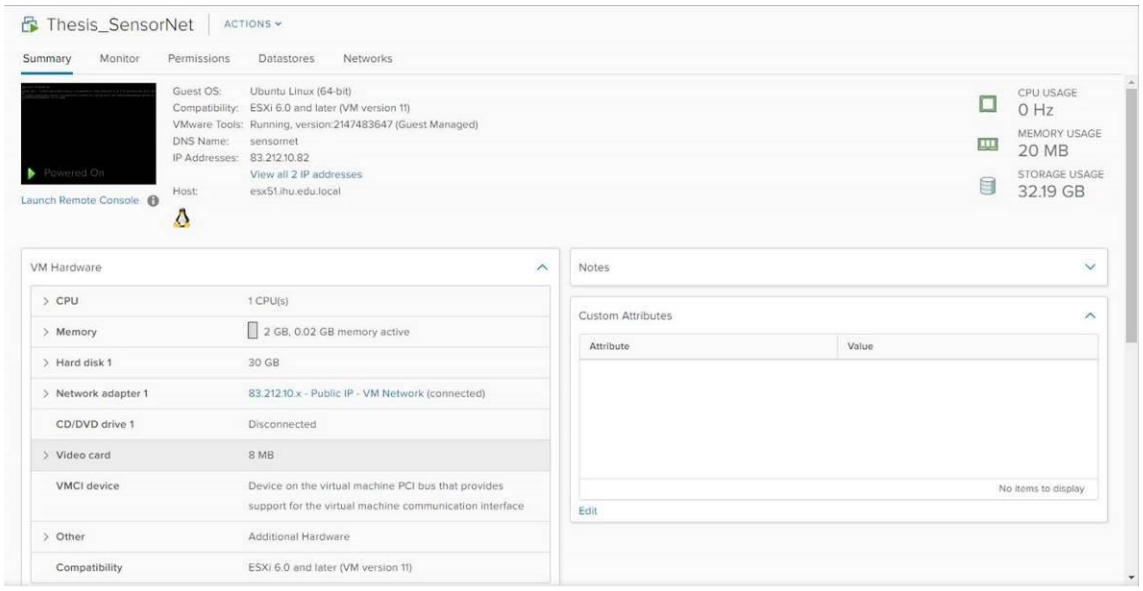
Since this project makes use of IHU's infrastructure, all nodes are connected to the university's network, essentially in a star-network topology. The nodes make use of different access points that all lead to the same gateway, as shown in the diagram that follows.



Picture 12: Detailed diagram of the project

3 The Virtual Server

The virtual server for this project was set up by the IT department of the IHU. It runs the 64-bit version of Ubuntu Linux, and the shared resources include 2 GB of RAM and 30GB of disk space. These values were dimmed adequate for the current needs of the project, however they may be altered in the future. Afterwards, the Apache2 HTTP server was installed, along with PHP version 7.2, as well as MySQL. Thus, the so-called "LAMP stack", the archetypal model of web service stacks was used for this project.



Guest OS:	Ubuntu Linux (64-bit)
Compatibility:	ESXi 6.0 and later (VM version 11)
VMware Tools:	Running, version:2147483647 (Guest Managed)
DNS Name:	sensornet
IP Addresses:	83.212.10.82
	View all 2 IP addresses
Host:	esx51.ihu.edu.local

CPU USAGE 0 Hz
MEMORY USAGE 20 MB
STORAGE USAGE 32.19 GB

VM Hardware

CPU	1 CPU(s)
Memory	2 GB, 0.02 GB memory active
Hard disk 1	30 GB
Network adapter 1	83.212.10.x - Public IP - VM Network (connected)
CD/DVD drive 1	Disconnected
Video card	8 MB
VMCI device	Device on the virtual machine PCI bus that provides support for the virtual machine communication interface
Other	Additional Hardware
Compatibility	ESXi 6.0 and later (VM version 11)

Notes

Custom Attributes

Attribute	Value

No items to display

Edit

Picture 13: Virtual server information and specifications

3.1 Ubuntu Linux 18.04

Ubuntu is one of many Linux distribution, and a relatively new one at that. Its source code originates from an older distribution known as Debian. Although Debian is still a popular distribution, its lack of frequent updates, user-friendly installation and difficult maintenance has made users turn to Ubuntu, which provides a much better overall user experience [21]. The following features made Ubuntu a much more desirable choice when it comes to picking an open-source operating system:

- Frequent and predictable release cycles

- Better localization and accessibility
- Ease-of-use; a user-friendly experience on desktop computers
- A desire to build a community-driven project

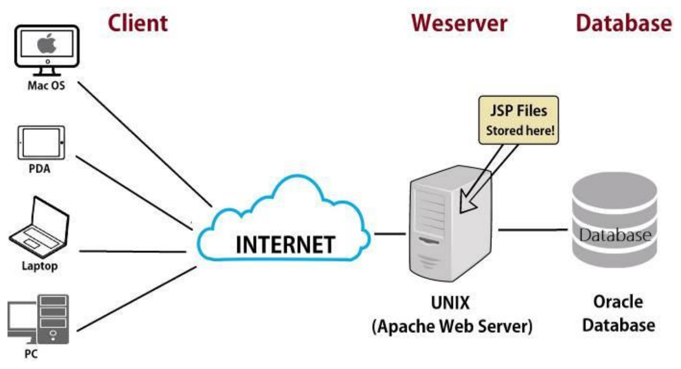
Although the LAMP stack clearly requires a Linux distribution, picking Ubuntu was the only real choice for this project. As the setup of the operating system was performed by the IHU IT Department, this dissertation will not go into any further details regarding this subject.

3.2 Apache HTTP Server

Apache is an open-source, free web server software. Created by the Apache Software foundation, it powers around 46% of websites around the world. It is considered to be one of the most reliable web servers and was originally launched back in 1995[22].

The task of a web server is to serve websites on the internet. In a way, a web server acts as a middleman between server and client machines. Upon user request, it delivers content from the server to the web. However, many users might request different pages at the same time and therein lies the biggest challenge for a web server; being able to serve multiple users at the same time.

Web servers also process files that are written in several different programming languages. They turn these files into static HTML files and serve them in each user's browser. Essentially, a web server is the key to a successful server-client communication.



Picture 14: Example of a web server's functionality

Apache was the web server of choice for this project due to the many advantages it offers:

- It is an open-source software which is free even for commercial use
- It is stable and reliable
- The software is being updated on a regular basis
- Its module-based structure makes it extremely flexible
- It is easy to configure
- Works on different platforms (both on Unix and Windows servers)
- Works very efficiently with Wordpress sites
- Boasts a wide community that provides fast and effective support

Even though Apache comes off as a stable and versatile platform, it also comes with disadvantages that hinder its functionality when it comes to dealing with heavy-traffic webpages. Finally, its many configuration options can lead to security threats as the system is left vulnerable.

Since the project is rather small in terms of scale at the moment (prone to change in the future, a revision might be required) and the infrastructure and security measures of the IHU provide us with a safe network, Apache was the web server of choice.

3.3 MySQL

MySQL is a Database Management System (DBM). A database is a structured collection of data and in order to perform any kind of action such as access, add, or process data that is stored in a database, a DBM such as MySQL server is necessary.

MySQL databases are relational; the data is stored in separate tables and the structures are organized into physical files in order to promote speed optimization. The SQL standard has been evolving since 1986 [24] and as of today, several different versions exist. MySQL is open-source and thus serves the project's needs; the software can be used and modified by anyone. Advantages of MySQL include speed, reliability, flexibility and ease-of-use. It is written in C and C++ and is available in many platforms, the most notable being Windows, Linux, Mac and Unix. In terms of security, MySQL makes use of an access privilege and an encrypted password system which enables host-based verification. Despite the fact that MySQL is an efficient and user-friendly DBM, it is not suitable for projects that deal with large size data; as the data grows, so does its performance decrease and more complex queries may take a significant amount of time to be fulfilled. MySQL also has serious issues in terms of scalability. For larger projects, this presents an issue. MySQL was picked for this project due its small size, but this might need to be revised in the future.

3.4 PHP

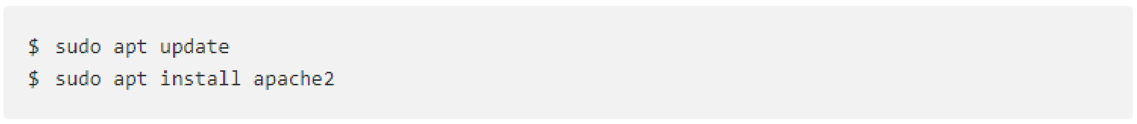
PHP is an acronym for *Hypertext Preprocessor*. It is a scripting language that is used very often for server-side web development and can be embedded into HTML. Scripting languages (other examples include JavaScript and Ruby) are a set of programming languages that are used for the automation of processes that under different circumstances would need to be executed step-by-step in a webpage's code every time they occur. As opposed to client-side languages (like Java), PHP code is executed on the server and the HTML generated is then sent to the client. Essentially the client-side receives the results of running a script but does not have access to the underlying code. PHP is equally suitable for beginners and professional programmers, being easy to learn but at the same time offering many advanced features. PHP is the main component of WordPress and its development, from static pages to themes and plugins [23]. For the needs of this project, it was the obvious choice, since a decision was made to develop the web page using WordPress.

3.5 Setup of the LAMP stack

After installing Ubuntu on the Virtual Server, the next step would be to install the rest of the open-source software that comprise the "LAMP" stack.

3.5.1 Installation of Apache

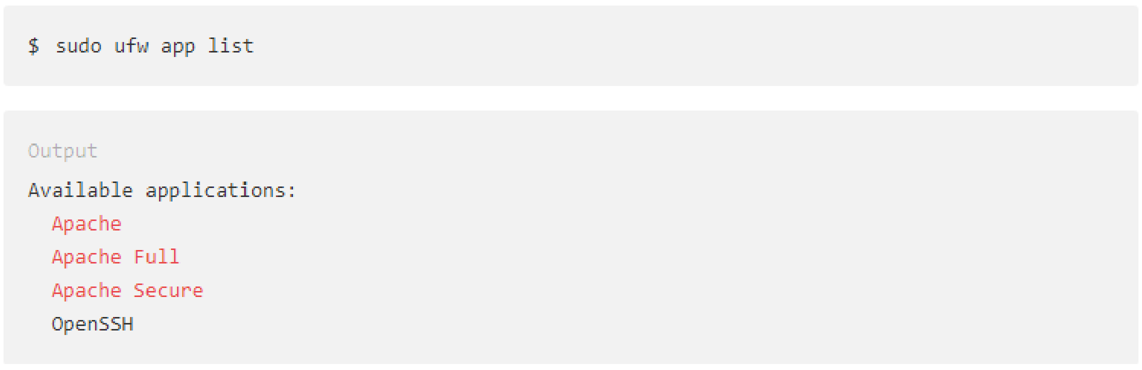
Apache was installed via the use of Ubuntu's package manager, *apt*:



```
$ sudo apt update
$ sudo apt install apache2
```

Picture 15: Apache installation step #1

Sudo commands execute operations with root privileges. After the packages were installed, the next step would be to adjust the firewall in order to allow HTTP and HTTPS traffic. The UFW firewall was already enabled during the server setup, so a check should be made to confirm that a UFW profile was created for Apache.

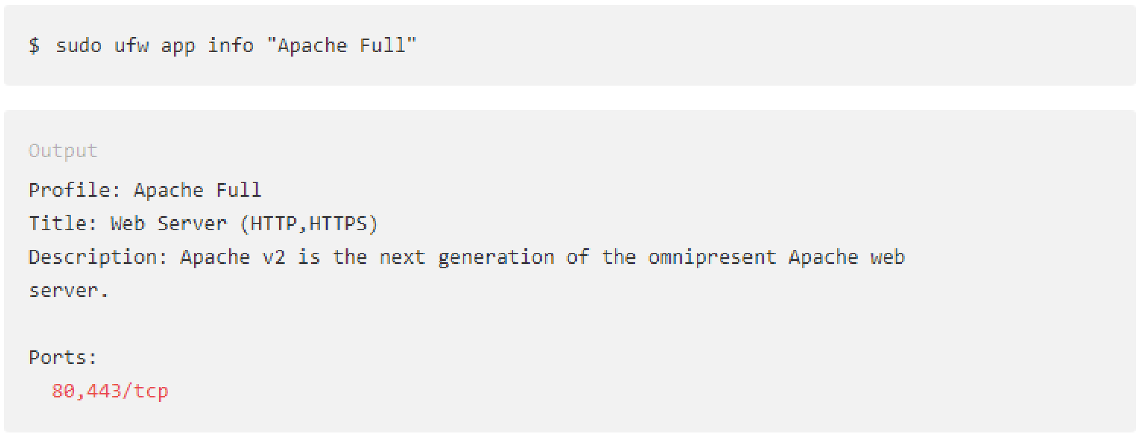


```
$ sudo ufw app list
```

```
Output
Available applications:
  Apache
  Apache Full
  Apache Secure
  OpenSSH
```

Picture 16: Apache installation step #2

A check on the *Apache Full* profile should show that traffic is enabled to ports *80* and *443*.

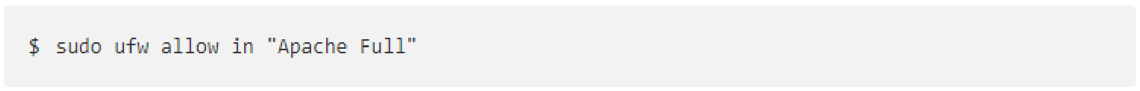


```
$ sudo ufw app info "Apache Full"
```

```
Output
Profile: Apache Full
Title: Web Server (HTTP,HTTPS)
Description: Apache v2 is the next generation of the omnipresent Apache web
server.

Ports:
  80,443/tcp
```

Picture 17: Apache installation step #3

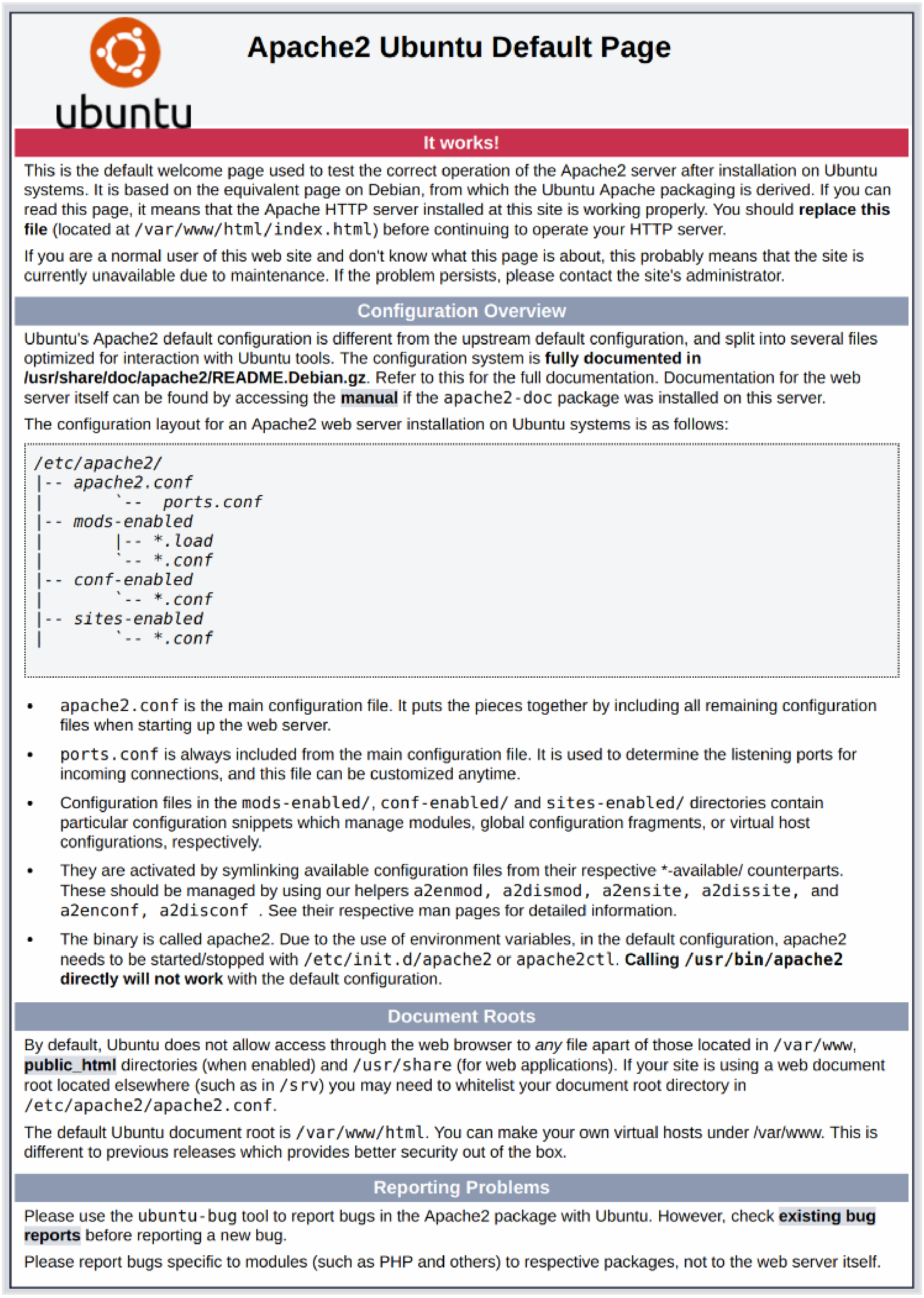
In order to allow incoming HTTP and HTTPS traffic for the specific profile the *ufw allow* command is used:



```
$ sudo ufw allow in "Apache Full"
```

Picture 18: Apache installation step #4

In order for the installation process to be successfull, the following page should be now showing in the browser:



Apache2 Ubuntu Default Page

It works!

This is the default welcome page used to test the correct operation of the Apache2 server after installation on Ubuntu systems. It is based on the equivalent page on Debian, from which the Ubuntu Apache packaging is derived. If you can read this page, it means that the Apache HTTP server installed at this site is working properly. You should **replace this file** (located at `/var/www/html/index.html`) before continuing to operate your HTTP server.

If you are a normal user of this web site and don't know what this page is about, this probably means that the site is currently unavailable due to maintenance. If the problem persists, please contact the site's administrator.

Configuration Overview

Ubuntu's Apache2 default configuration is different from the upstream default configuration, and split into several files optimized for interaction with Ubuntu tools. The configuration system is **fully documented in /usr/share/doc/apache2/README.Debian.gz**. Refer to this for the full documentation. Documentation for the web server itself can be found by accessing the **manual** if the `apache2-doc` package was installed on this server.

The configuration layout for an Apache2 web server installation on Ubuntu systems is as follows:

```
/etc/apache2/
|-- apache2.conf
|       `--  ports.conf
|-- mods-enabled
|       |-- *.load
|       `-- *.conf
|-- conf-enabled
|       `-- *.conf
|-- sites-enabled
|       `-- *.conf
```

- `apache2.conf` is the main configuration file. It puts the pieces together by including all remaining configuration files when starting up the web server.
- `ports.conf` is always included from the main configuration file. It is used to determine the listening ports for incoming connections, and this file can be customized anytime.
- Configuration files in the `mods-enabled/`, `conf-enabled/` and `sites-enabled/` directories contain particular configuration snippets which manage modules, global configuration fragments, or virtual host configurations, respectively.
- They are activated by symlinking available configuration files from their respective *-available/ counterparts. These should be managed by using our helpers `a2enmod, a2dismod, a2ensite, a2dissite,` and `a2enconf, a2disconf` . See their respective man pages for detailed information.
- The binary is called apache2. Due to the use of environment variables, in the default configuration, apache2 needs to be started/stopped with `/etc/init.d/apache2` or `apache2ctl`. **Calling `/usr/bin/apache2` directly will not work** with the default configuration.

Document Roots

By default, Ubuntu does not allow access through the web browser to *any* file apart of those located in `/var/www`, **public_html** directories (when enabled) and `/usr/share` (for web applications). If your site is using a web document root located elsewhere (such as in `/srv`) you may need to whitelist your document root directory in `/etc/apache2/apache2.conf`.

The default Ubuntu document root is `/var/www/html`. You can make your own virtual hosts under /var/www. This is different to previous releases which provides better security out of the box.

Reporting Problems

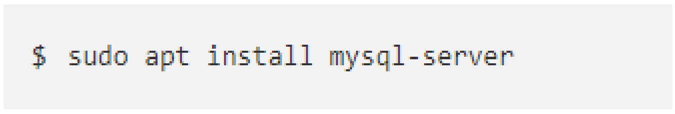
Please use the `ubuntu-bug` tool to report bugs in the Apache2 package with Ubuntu. However, check **existing bug reports** before reporting a new bug.

Please report bugs specific to modules (such as PHP and others) to respective packages, not to the web server itself.

Picture 19: Default Ubuntu 18.04 Apache web page

3.5.2 Installation of MySQL

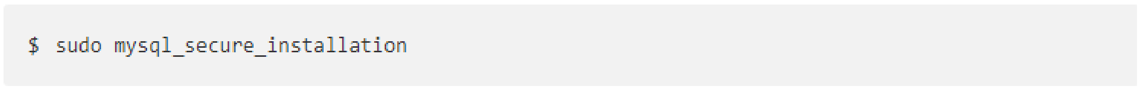
After finishing with the web server installation, the next step was installing MySQL. Again, as with Apache, the installation process begins with the use of the *apt* command:



```
$ sudo apt install mysql-server
```

Picture 20: MySQL installation step #1

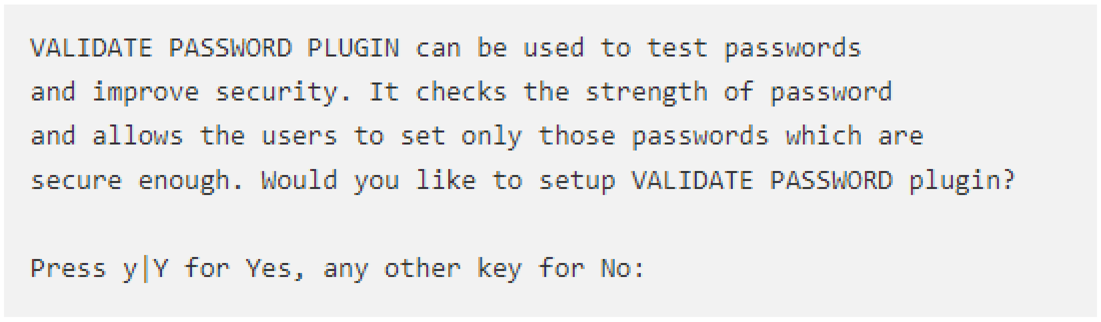
After the installation of the packages is complete, a simple security script that comes pre-installed with MySQL was executed. It removes default settings that may cause security issues and locks down access to the database system:



```
$ sudo mysql_secure_installation
```

Picture 21: MySQL installation step #2

Running the script prompts the user to answer whether they want to configure the *VALIDATE PASSWORD PLUGIN*. This feature carries some degree of risk since this project makes use of the phpMyAdmin software. phpMyAdmin automatically configures MySQL user credentials and a weak password along with the use of this plugin may cause issues. Regardless, the plugin was used along with a strong password.

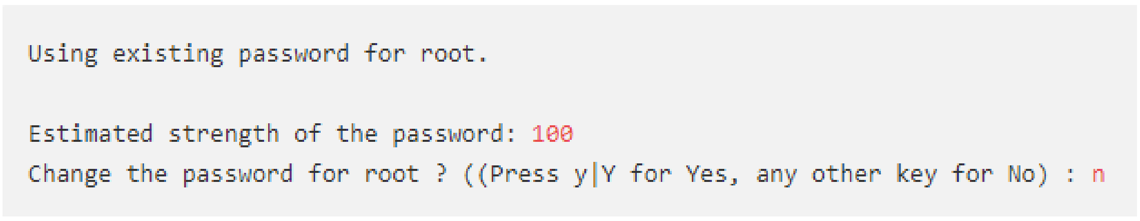


```
VALIDATE PASSWORD PLUGIN can be used to test passwords
and improve security. It checks the strength of password
and allows the users to set only those passwords which are
secure enough. Would you like to setup VALIDATE PASSWORD plugin?

Press y|Y for Yes, any other key for No:
```

Picture 22: MySQL installation step #3

After pressing *y* to enable this feature, the system asks for the preferred level of password validation. In our case, the option *1(MEDIUM Length)* was selected. After this selection the system asks for the selection and confirmation of a password for the MySQL *root* user. After selecting an appropriate password, since the VALIDATE-

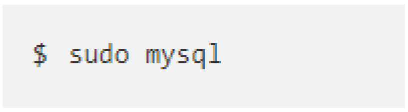
PASSWORD PLUGIN was enabled, the next system message also shows the strength level of the password that was chosen:



```
Using existing password for root.

Estimated strength of the password: 100
Change the password for root ? ((Press y|Y for Yes, any other key for No) : n
```

Picture 23: MySQL installation step #4

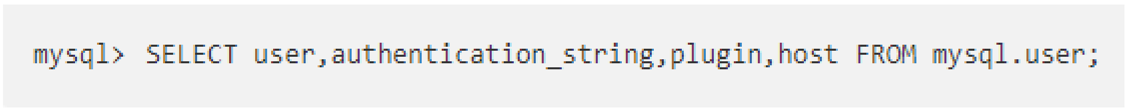
The next step includes removing the test database and some anonymous users that are created by default, as well as remove root logins and load the new rules that were applied in the previous steps and are implemented on the spot. Since the MySQL version this project uses is older than version 5.7, the default user authentication happens with the use of the *auth_socket* plugin. Although this method is more secure, it may cause problems when accessing the user via the phpMyAdmin application. Since this is the case, the next action would be to change the authentication method to allow for the root user to be authenticated via password. In order to achieve this, the authentication method will be changed from *auth_socket* to *my_sql_native_password*. In order to do this, firstly the MySQL prompt is accessed.



```
$ sudo mysql
```

Picture 24: MySQL installation step #5

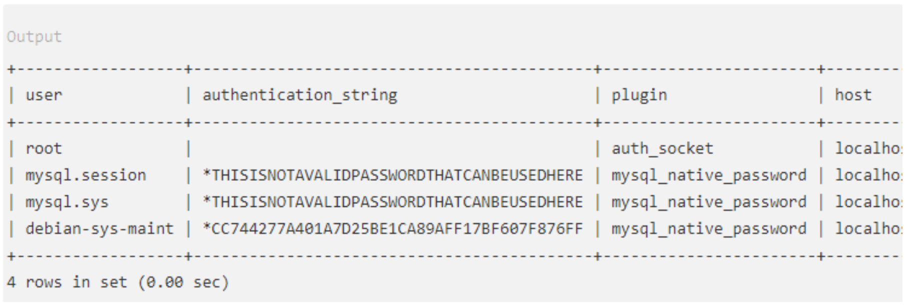
The next command checks the authentication method of the existing MySQL user accounts:



```
mysql> SELECT user,authentication_string,plugin,host FROM mysql.user;
```

Picture 25: MySQL installation step #6

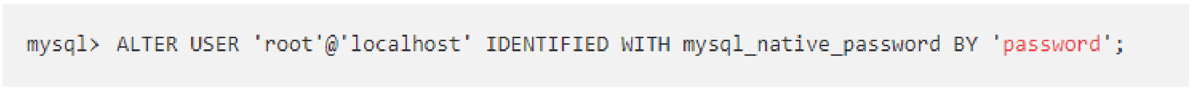
The received output displays the current authentication method and confirms the fact that the *auth_socket* method is used for the authentication of the root user:



```
Output
+------------------+-------------------------------------------+-----------------------+--------
| user             | authentication_string                     | plugin                | host
+------------------+-------------------------------------------+-----------------------+--------
| root             |                                           | auth_socket           | localho
| mysql.session    | *THISISNOTAVALIDPASSWORDTHATCANBEUSEDHERE | mysql_native_password | localho
| mysql.sys        | *THISISNOTAVALIDPASSWORDTHATCANBEUSEDHERE | mysql_native_password | localho
| debian-sys-maint | *CC744277A401A7D25BE1CA89AFF17BF607F876FF | mysql_native_password | localho
+------------------+-------------------------------------------+-----------------------+--------
4 rows in set (0.00 sec)
```

Picture 26: MySQL installation step #7

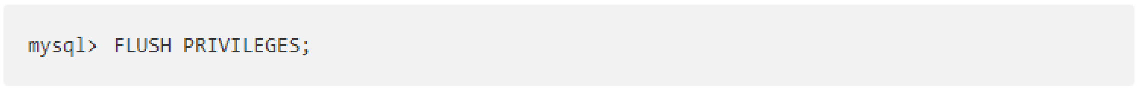
In order to change the authentication method, the *ALTER USER* command will be used:



```
mysql> ALTER USER 'root'@'localhost' IDENTIFIED WITH mysql_native_password BY 'password';
```

Picture 27: MySQL installation step #8

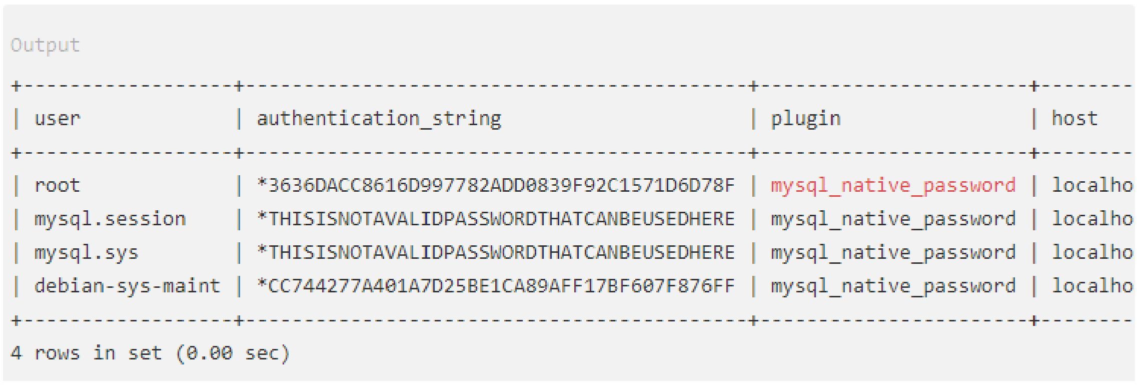
After choosing a strong password, the command FLUSH PRIVILEGES was used in order to reload the grant tables and bring the changes into effect:



```
mysql> FLUSH PRIVILEGES;
```

Picture 28: MySQL installation step #9

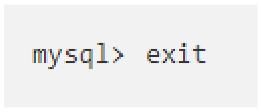
By using the query from Picture 25 again it is now confirmed that the root MySQL user is authenticated via the *my_sql_native_password* method:



```
Output
+------------------+-------------------------------------------+-----------------------+--------
| user             | authentication_string                     | plugin                | host
+------------------+-------------------------------------------+-----------------------+--------
| root             | *3636DACC8616D997782ADD0839F92C1571D6D78F | mysql_native_password | localho
| mysql.session    | *THISISNOTAVALIDPASSWORDTHATCANBEUSEDHERE | mysql_native_password | localho
| mysql.sys        | *THISISNOTAVALIDPASSWORDTHATCANBEUSEDHERE | mysql_native_password | localho
| debian-sys-maint | *CC744277A401A7D25BE1CA89AFF17BF607F876FF | mysql_native_password | localho
+------------------+-------------------------------------------+-----------------------+--------
4 rows in set (0.00 sec)
```

Picture 29: MySQL installation step #10

All that remains is exiting the MySQL shell with the *exit* command:

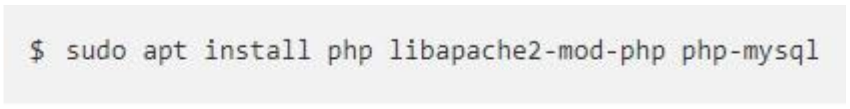


```
mysql> exit
```

Picture 30: MySQL installation step #11

3.5.3 Installation of PHP

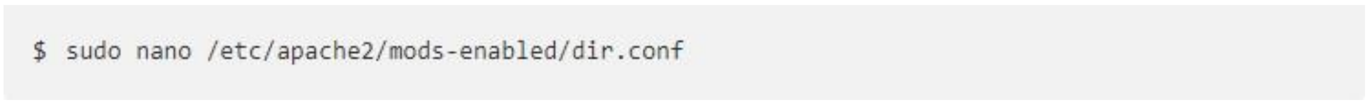
The installation once again begins with the download and setup of the required packag-es via the use of the *apt* system:



```
$ sudo apt install php libapache2-mod-php php-mysql
```

Picture 31: PHP installation step #1

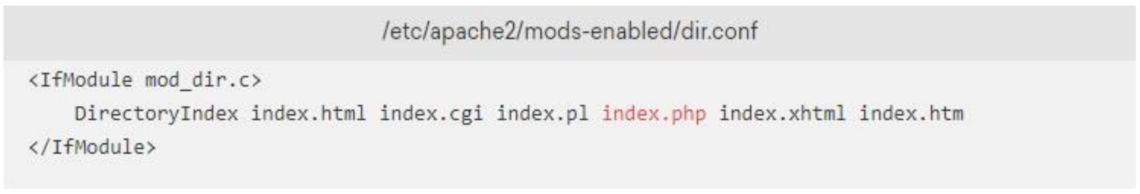
After the installation finishes, it was necessary to modify the way Apache serves files upon a directory request. As things stand, Apache looks for a file called *index.html* whenever a user request a directory from the server. The server should prioritize PHP files over others, so priority will be given to the file named *index.php*. In order to do this, the *dir.conf* file must be accessed with root privileges and be opened via text edi-tor. This is done with the following command:



```
$ sudo nano /etc/apache2/mods-enabled/dir.conf
```

Picture 32: PHP installation step #2

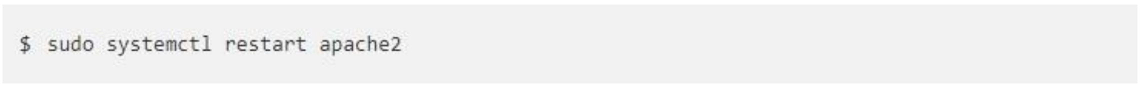
The *dir.conf* file has the following structure:



```
/etc/apache2/mods-enabled/dir.conf
<IfModule mod_dir.c>
    DirectoryIndex index.html index.cgi index.pl index.php index.xhtml index.htm
</IfModule>
```

Picture 33: PHP installation step #3

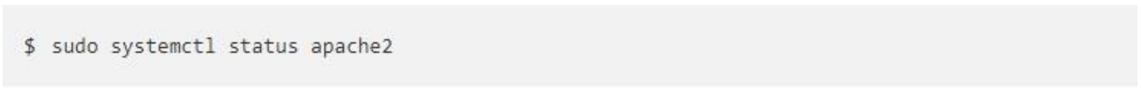
The *index.php* file needs to be moved to the first position, directly after *DirectoryIndex*. After successfully moving the file, the Apache web server needs to be restarted in order for the changes to apply. In order to restart Apache, the following command needs to be executed:



```
$ sudo systemctl restart apache2
```

Picture 34: PHP installation step #4

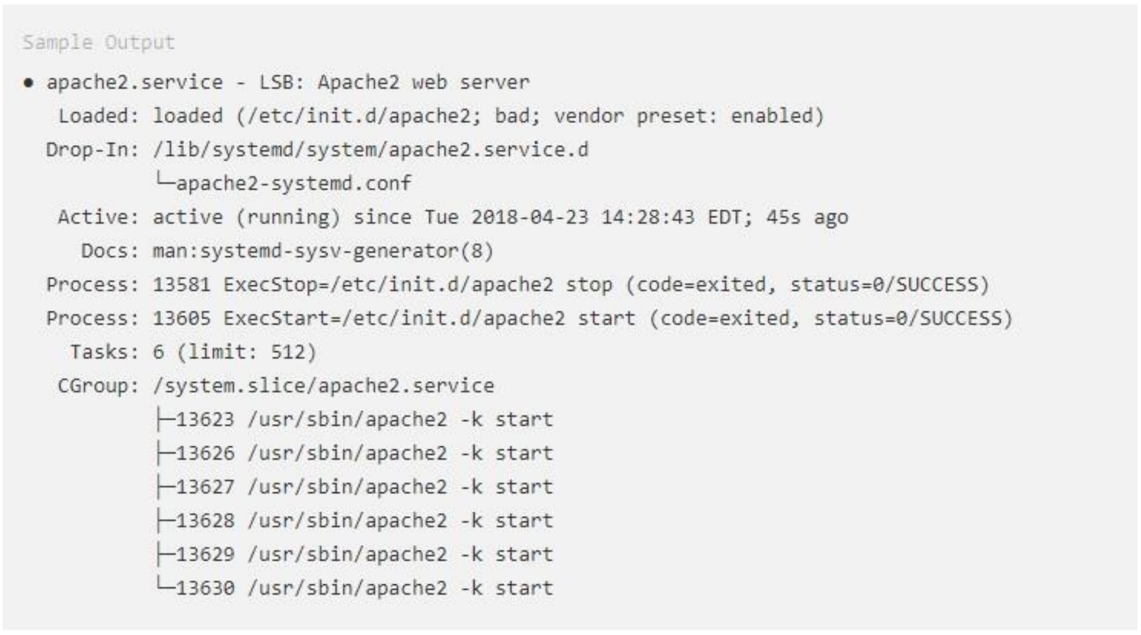
The status of the apache2 service can be checked by using the *systemctl* command:



```
$ sudo systemctl status apache2
```

Picture 35: PHP installation step #5

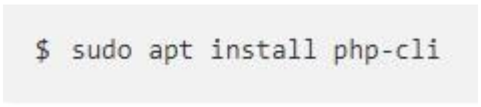
The following output is displayed. Pressing *Q* exits this output:



```
Sample Output
● apache2.service - LSB: Apache2 web server
   Loaded: loaded (/etc/init.d/apache2; bad; vendor preset: enabled)
  Drop-In: /lib/systemd/system/apache2.service.d
           └─apache2-systemd.conf
   Active: active (running) since Tue 2018-04-23 14:28:43 EDT; 45s ago
     Docs: man:systemd-sysv-generator(8)
  Process: 13581 ExecStop=/etc/init.d/apache2 stop (code=exited, status=0/SUCCESS)
  Process: 13605 ExecStart=/etc/init.d/apache2 start (code=exited, status=0/SUCCESS)
    Tasks: 6 (limit: 512)
   CGroup: /system.slice/apache2.service
           ├─13623 /usr/sbin/apache2 -k start
           ├─13626 /usr/sbin/apache2 -k start
           ├─13627 /usr/sbin/apache2 -k start
           ├─13628 /usr/sbin/apache2 -k start
           ├─13629 /usr/sbin/apache2 -k start
           └─13630 /usr/sbin/apache2 -k start
```

Picture 36: PHP installation step #6

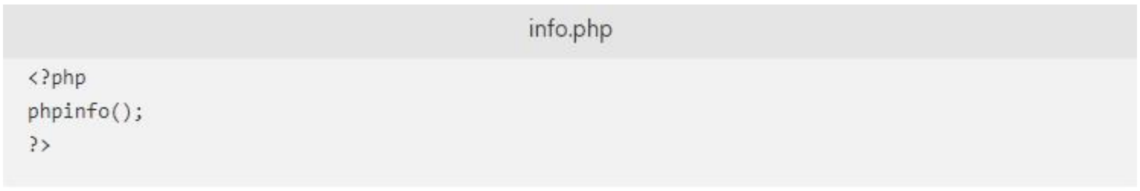
In order to be able to get the most out of PHP and to be able to develop our web page and plugins properly, the package named *php-cli* will also need to be installed. This package is a command line interpreter for the PHP scripting language. It provides the /usr/bin/php command interpreter which is useful for testing PHP scripts from a shell, as well as performing general shell scripting tasks. In order to install it, the following command was executed:



```
$ sudo apt install php-cli
```

Picture 37: PHP installation step #7

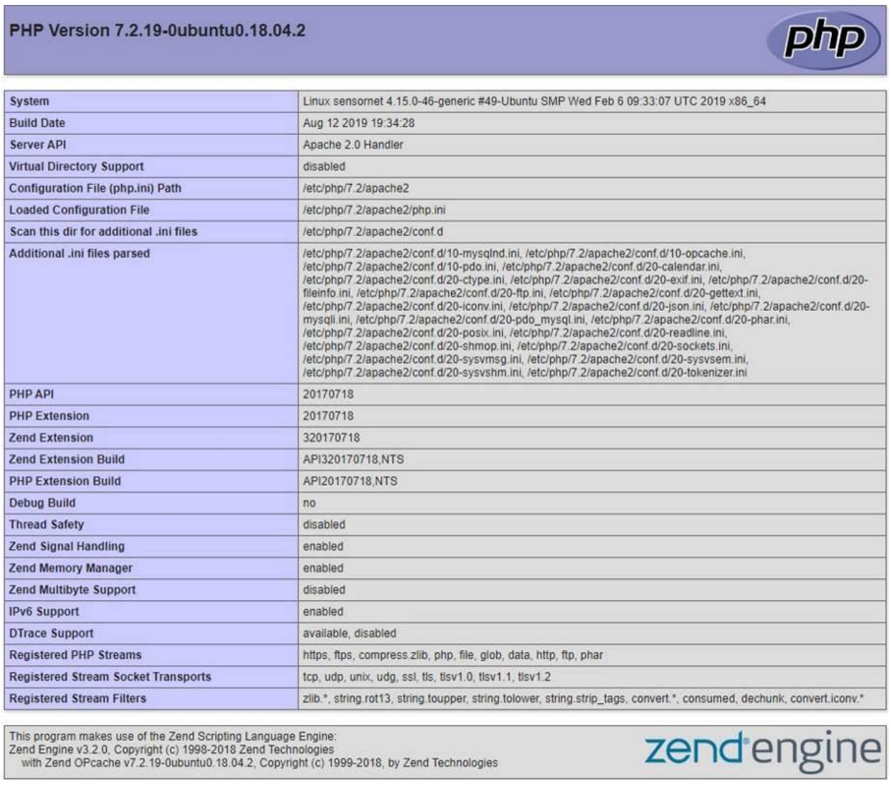
At this point the installation of PHP has been completed successfully. All that remains is to test that the system has been configured properly for PHP. In order to do this, a basic PHP script called *info.php* was created. The script was stored in the web root directory, in order for Apache to locate it and serve it correctly. After visiting the correct url (in our case http://sensornet.ihu.edu.gr/info.php) a page that provides basic information regarding the server from the perspective of PHP. This is used for debugging and in order to ensure the correct application of the settings. The file was removed after confirmation that everything was installed properly.



info.php

```
<?php
phpinfo();
?>
```

Picture 38: PHP testing step #1



PHP Version 7.2.19-0ubuntu0.18.04.2

System	Linux sensornet 4.15.0-46-generic #49-Ubuntu SMP Wed Feb 6 09:33:07 UTC 2019 x86_64
Build Date	Aug 12 2019 19:34:28
Server API	Apache 2.0 Handler
Virtual Directory Support	disabled
Configuration File (php.ini) Path	/etc/php/7.2/apache2
Loaded Configuration File	/etc/php/7.2/apache2/php.ini
Scan this dir for additional .ini files	/etc/php/7.2/apache2/conf.d
Additional .ini files parsed	/etc/php/7.2/apache2/conf.d/10-mysqlnd.ini, /etc/php/7.2/apache2/conf.d/10-opcache.ini, /etc/php/7.2/apache2/conf.d/10-pdo.ini, /etc/php/7.2/apache2/conf.d/20-calendar.ini, /etc/php/7.2/apache2/conf.d/20-ctype.ini, /etc/php/7.2/apache2/conf.d/20-exif.ini, /etc/php/7.2/apache2/conf.d/20-fileinfo.ini, /etc/php/7.2/apache2/conf.d/20-ftp.ini, /etc/php/7.2/apache2/conf.d/20-gettext.ini, /etc/php/7.2/apache2/conf.d/20-iconv.ini, /etc/php/7.2/apache2/conf.d/20-json.ini, /etc/php/7.2/apache2/conf.d/20-mysqli.ini, /etc/php/7.2/apache2/conf.d/20-pdo_mysql.ini, /etc/php/7.2/apache2/conf.d/20-phar.ini, /etc/php/7.2/apache2/conf.d/20-posix.ini, /etc/php/7.2/apache2/conf.d/20-readline.ini, /etc/php/7.2/apache2/conf.d/20-shmop.ini, /etc/php/7.2/apache2/conf.d/20-sockets.ini, /etc/php/7.2/apache2/conf.d/20-sysvmsg.ini, /etc/php/7.2/apache2/conf.d/20-sysvsem.ini, /etc/php/7.2/apache2/conf.d/20-sysvshm.ini, /etc/php/7.2/apache2/conf.d/20-tokenizer.ini
PHP API	20170718
PHP Extension	20170718
Zend Extension	320170718
Zend Extension Build	API320170718,NTS
PHP Extension Build	API20170718,NTS
Debug Build	no
Thread Safety	disabled
Zend Signal Handling	enabled
Zend Memory Manager	enabled
Zend Multibyte Support	disabled
IPv6 Support	enabled
DTrace Support	available, disabled
Registered PHP Streams	https, ftps, compress.zlib, php, file, glob, data, http, ftp, phar
Registered Stream Socket Transports	tcp, udp, unix, udg, ssl, tls, tlsv1.0, tlsv1.1, tlsv1.2
Registered Stream Filters	zlib.*, string.rot13, string.toupper, string.tolower, string.strip_tags, convert.*, consumed, dechunk, convert.iconv.*

This program makes use of the Zend Scripting Language Engine:
Zend Engine v3.2.0, Copyright (c) 1998-2018 Zend Technologies
with Zend OPcache v7.2.19-0ubuntu0.18.04.2, Copyright (c) 1999-2018, by Zend Technologies

Picture 39: PHP testing step #2

After successfully testing the PHP settings, the setup of the LAMP stack is now complete. More work will be needed later in order to install phpMyAdmin and Wordpress but this is part of the web development process and is described in the next chapter.

4 Web Development

This chapter describes the process of developing the webpage of the project, which is one of the main goals of this dissertation. As it has been stated before, the page was created with Wordpress, while the database management system of choice was phpMyAdmin. The initial testing of the page's and plugin's functionality was done using XAMPP, while the code was written in JetBrains' PhpStorm IDE.

4.1 Web development process

This section briefly describes the steps that were followed for the development process. Unlike most people think, web development[25] is not entirely code-based, if anything, coding is just a small part of the whole process.

4.1.1 Information Gathering

This part of the process involves the initial planning and the setting of goals. The goal was to create a web page that would be simple, easy in the eye yet efficient in the way it transmits information to the user. Its target audience would initially be users that are directly or indirectly related to the IHU, such as guests, students, staff and faculty. The webpage would provide all the basic information regarding the project, as well as information regarding the IHU. It would also go on to provide basic information regarding the sensors in use, the node location, while also providing a link for the mobile application. Finally, it would be mobile-friendly. The data from the nodes would be displayed on the home page.

4.1.2 Wireframe creation - Sitemap

At this stage it is time to create data in order to assess how the webpage will look like, as well as pick a technology stack that will be used for the development process. As far as the technology stack is concerned, as it has been mentioned often so far, the decision was made to develop the page with WordPress based on the use of the LAMP stack. The theme of choice was *Bootstrap 4*. The programming language would be PHP and the coding would be done with the use of PhpStorm. Regarding the sitemap, the main page would come with a top menu which provides access to multiple pages which provide information about the campus, the nodes and their components, images of their locations, as well as a blog for the latest news regarding the IoT technology, which will be maintained by the IHU. Finally, the page will provide information and background regarding the mobile application along with a link for the *.apk* file, as well as contact information for the developer and content manager.

4.1.3 Page layouts / Review / Approval

At this stage of development, all the visual content of the web page is created, gathered and shown to colleagues in order to agree on the final content. A rough layout of the webpage is designed, along with a choice for a logo, as well as relevant images from the nodes, the campus and the components that were used in the project. The final step of this process included discussing the selected content with colleague Kostas Karaklas and Prof. Stavros Stavrinides, who both approved the selection.

4.1.4 Content writing and management

Although this step of the process might appear trivial, it is crucial in order to attract visitors and keep them interested in navigating around the website. This step included the writing of texts about the nodes, the campus, the project and the Internet of Things as a topic in general. Headlines were also picked along with other content that aim to provide the user with a wholesome and comprehensible navigating experience.

4.1.5 Coding

This step involves the actual coding of the plugin that was created in order to display the sensors' reading in real time on the webpage. It also involved the creation of the database, along with the frontend coding in order to make the webpage user-friendly and mobile-friendly.

4.1.6 Testing, Review and Launch

The functionality of the plugin and the webpage was tested in a local environment with the use of the XAMPP cross-platform web server solution pack. For the database management phpMyAdmin was used, a free software tool written in PHP which is responsible for handling the administration of MySQL over the Web. After the webpage functionality was tested successfully, the page was reviewed by the author’s colleagues. Finally, the webpage was launched on the IHU Virtual Server.

4.1.7 Maintenance and updates

This stage refers to the future of the project; the WordPress CMS, along with the theme and the installed plugins need to be kept updated on a regular basis; the content also needs to be kept up-to-date with the latest news regarding the technology of the Internet of Things. This is a continuous process, to be handled by the author and future students of the Department willing to assist in keeping this project alive.

4.2 Development tools

4.2.1 Phpstorm

Phpstorm is a commercial, cross-platform IDE built by Jetbrains[26]. It provides the developer with a PHP, HTML and Javascript editor along with on-the-fly code analysis, error prevention and automated refactorings for PHP and Javascript code. The application can be extended by plugins that are developed by Jetbrains or a developer can write their own plugin. Since the author of this dissertation already works as a web developer, the IDE choice was easy enough to make.

4.2.2 phpMyAdmin

phpMyAdmin is a free software tool written in PHP, responsible for handling the administration of MySQL over the Web[27]. It supports a wide range of operations on MySQL and MariaDB. The tool comes with a user interface while providing the developer with the ability to execute any SQL statement. The software is extremely well-documented and the development team also provides excellent support.

4.2.3 XAMPP

XAMPP is a free, open-source cross-platform web server solution stack package developed by Apache Friends[28]. It mainly consists of the Apache HTTP Server, MariaDB database, as well as interpreters for scripts written in PHP and Perl. XAMPP is an excellent choice for testing since it provides all the features that are installed in the Virtual server, which made the transition from a localhost environment to the live server possible.

4.2.4 Wordpress

Wordpress is currently the most popular Content Management System (CMS) in the world, powering more than 30% of the websites globally[29]. A content management system is a web application that allows website owners, authors and editors to manage their website and publish content. Wordpress makes use of PHP and MySQL which are both widely supported. Even though CMS platforms were originally used for blogging, any WordPress site can be turned into anything a developer desires. Wordpress is open-source and free for everyone, while its interface is flexible and extremely user-friendly. It also boasts an excellent community and support with millions of plugins and themes created by users and developers alike.

The advantages of Wordpress include its low cost, the easy installation and update process, simplicity of management, custom design and functionality, as well as a very active and helpful community.

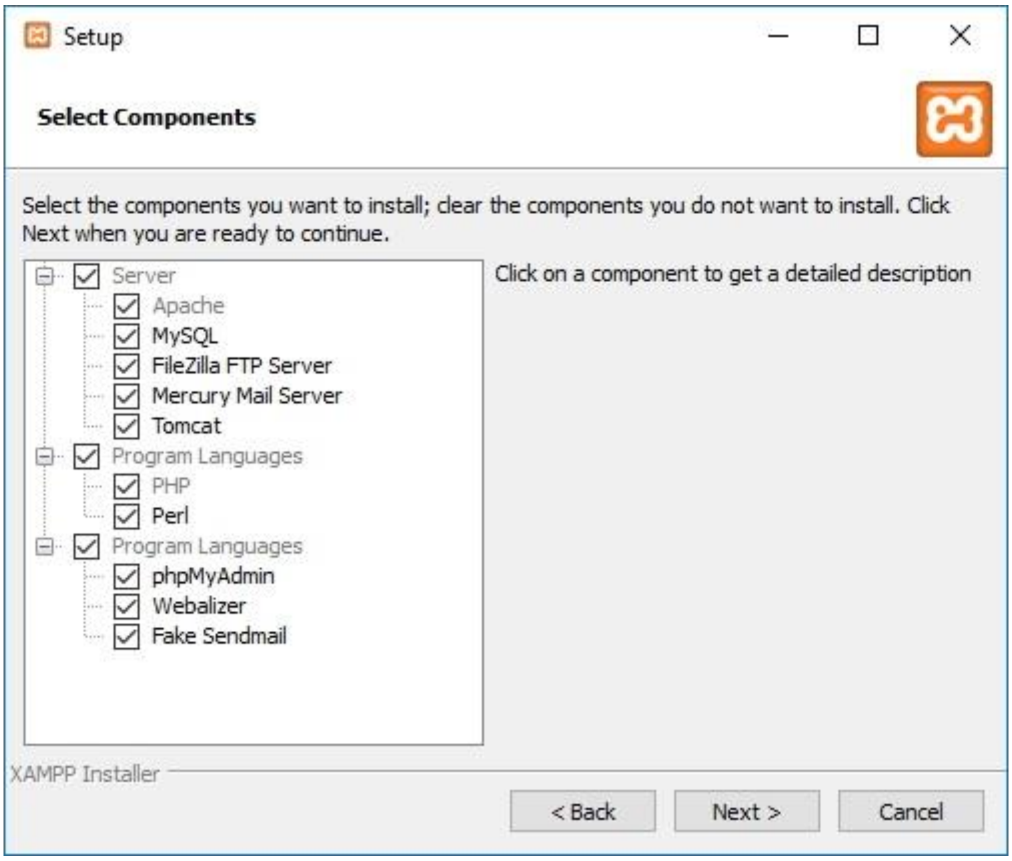
However, Wordpress also comes with a couple of disadvantages; since it powers a huge number of webpages globally, Wordpress also comes under attack from hackers very often. The installation of a security plugin is strongly recommended. Another disadvantage has to do with the third-party plugins and themes. Even though many of those are created by other developers or users and they are free of charge, sometimes they can turn out to be buggy. Finally, a Wordpress page with too many installed plugins may become laggy and produce long loading times.

4.3 Coding preparation

This chapter will briefly describe the steps taken to install and configure the tools that will be used for the web development process.

4.3.1 XAMPP Setup & Configuration

After downloading the executable file, XAMPP offers a list of components that can be installed. Even though all components are installed, for this project we will mostly need PHP, phpMyAdmin and MySQL.



Setup

Select Components

Select the components you want to install; clear the components you do not want to install. Click Next when you are ready to continue.

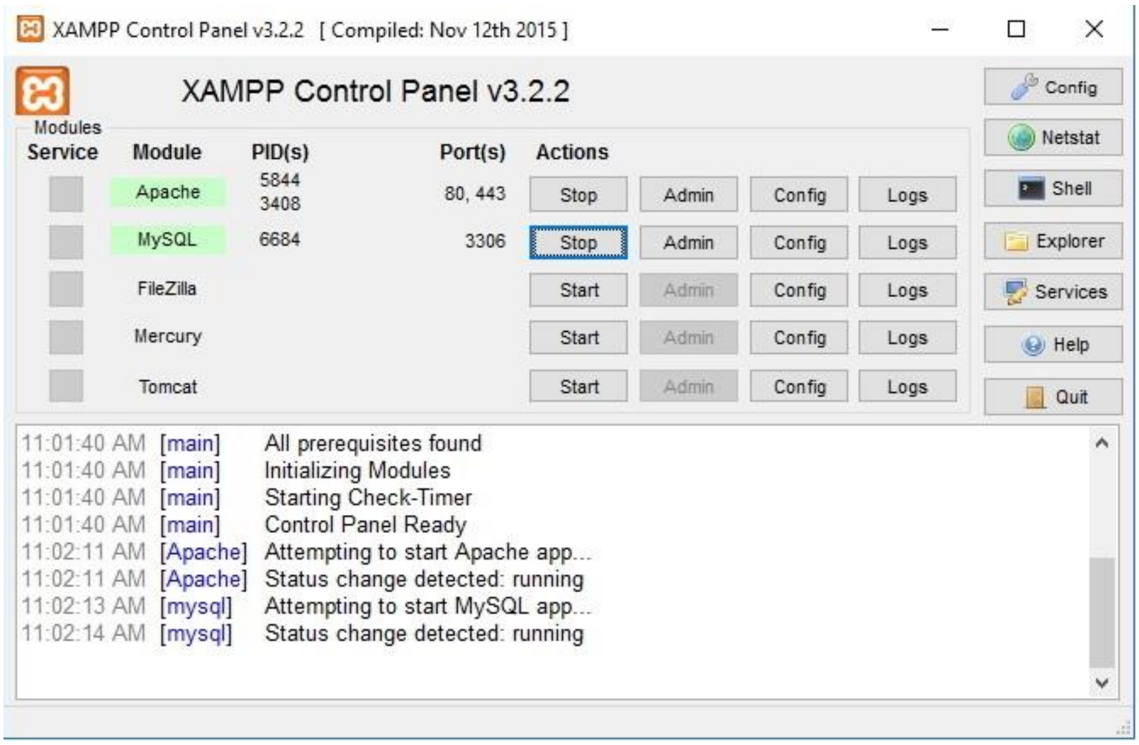
- [✓] Server
  - [✓] Apache
  - [✓] MySQL
  - [✓] FileZilla FTP Server
  - [✓] Mercury Mail Server
  - [✓] Tomcat
- [✓] Program Languages
  - [✓] PHP
  - [✓] Perl
- [✓] Program Languages
  - [✓] phpMyAdmin
  - [✓] Webalizer
  - [✓] Fake Sendmail

Click on a component to get a detailed description

XAMPP Installer

Picture 40: XAMPP components list

After successfully completing the installation, the XAMPP control panel launches. The services that need to be launched from the control panel are Apache and MySQL.



XAMPP Control Panel v3.2.2 [Compiled: Nov 12th 2015]

XAMPP Control Panel v3.2.2

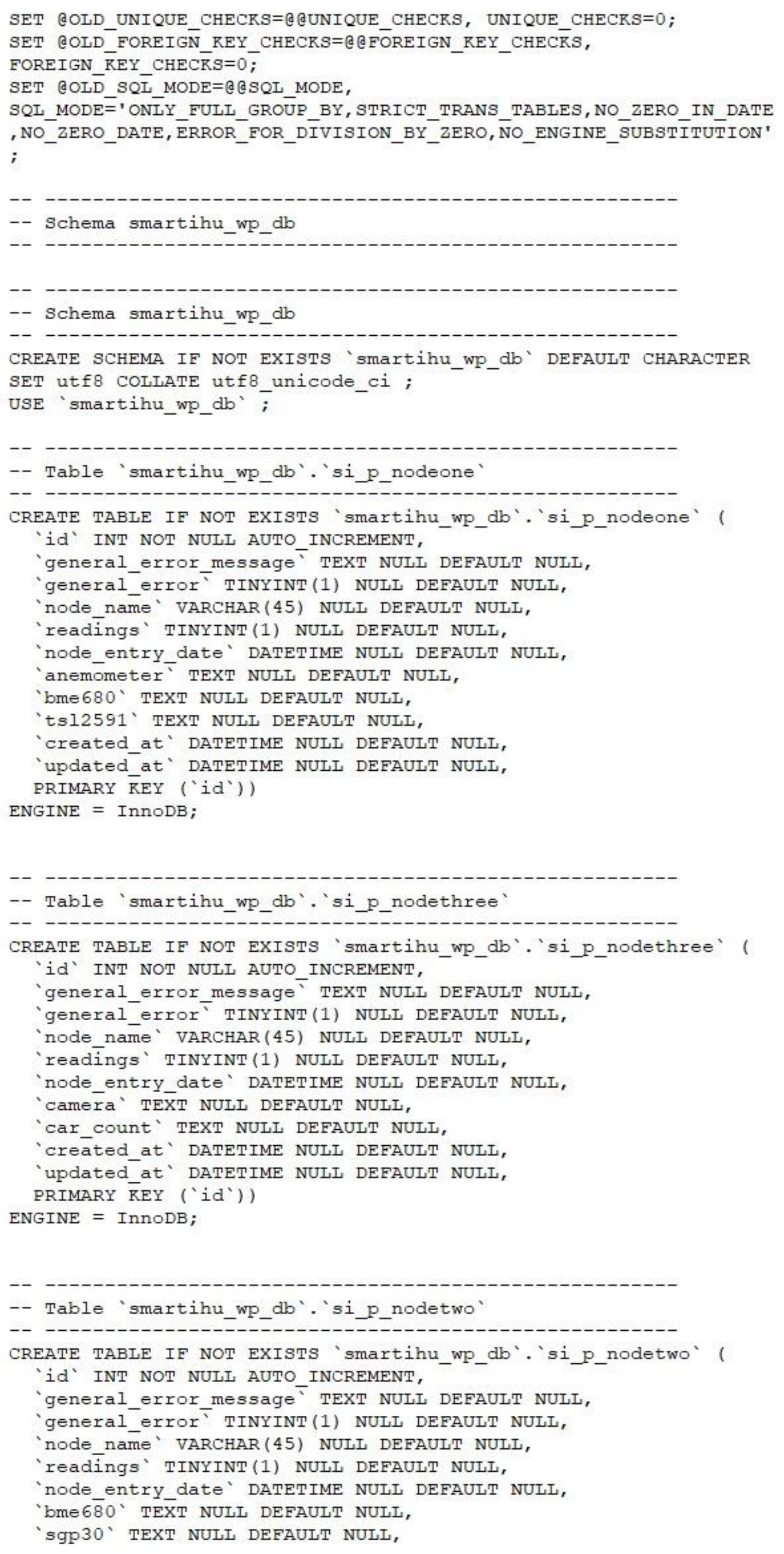
Service	Module	PID(s)	Port(s)	Actions			
	Apache	5844 3408	80, 443	Stop	Admin	Config	Logs
	MySQL	6684	3306	Stop	Admin	Config	Logs
	FileZilla			Start	Admin	Config	Logs
	Mercury			Start	Admin	Config	Logs
	Tomcat			Start	Admin	Config	Logs

```
11:01:40 AM  [main]     All prerequisites found
11:01:40 AM  [main]     Initializing Modules
11:01:40 AM  [main]     Starting Check-Timer
11:01:40 AM  [main]     Control Panel Ready
11:02:11 AM  [Apache]   Attempting to start Apache app...
11:02:11 AM  [Apache]   Status change detected: running
11:02:13 AM  [mysql]    Attempting to start MySQL app...
11:02:14 AM  [mysql]    Status change detected: running
```

Picture 41: XAMPP control panel

4.3.2 phpMyAdmin / database setup

As it was mentioned in the previous chapter, installing XAMPP automatically installed phpMyAdmin. After the installation of Wordpress and the creation of its database, the following SQL script is executed in order to create the database tables for the sensor nodes.



```
SET @OLD_UNIQUE_CHECKS=@@UNIQUE_CHECKS, UNIQUE_CHECKS=0;
SET @OLD_FOREIGN_KEY_CHECKS=@@FOREIGN_KEY_CHECKS,
FOREIGN_KEY_CHECKS=0;
SET @OLD_SQL_MODE=@@SQL_MODE,
SQL_MODE='ONLY_FULL_GROUP_BY,STRICT_TRANS_TABLES,NO_ZERO_IN_DATE
,NO_ZERO_DATE,ERROR_FOR_DIVISION_BY_ZERO,NO_ENGINE_SUBSTITUTION'
;

-- -----------------------------------------------------
-- Schema smartihu_wp_db
-- -----------------------------------------------------

-- -----------------------------------------------------
-- Schema smartihu_wp_db
-- -----------------------------------------------------
CREATE SCHEMA IF NOT EXISTS `smartihu_wp_db` DEFAULT CHARACTER
SET utf8 COLLATE utf8_unicode_ci ;
USE `smartihu_wp_db` ;

-- -----------------------------------------------------
-- Table `smartihu_wp_db`.`si_p_nodeone`
-- -----------------------------------------------------
CREATE TABLE IF NOT EXISTS `smartihu_wp_db`.`si_p_nodeone` (
  `id` INT NOT NULL AUTO_INCREMENT,
  `general_error_message` TEXT NULL DEFAULT NULL,
  `general_error` TINYINT(1) NULL DEFAULT NULL,
  `node_name` VARCHAR(45) NULL DEFAULT NULL,
  `readings` TINYINT(1) NULL DEFAULT NULL,
  `node_entry_date` DATETIME NULL DEFAULT NULL,
  `anemometer` TEXT NULL DEFAULT NULL,
  `bme680` TEXT NULL DEFAULT NULL,
  `tsl2591` TEXT NULL DEFAULT NULL,
  `created_at` DATETIME NULL DEFAULT NULL,
  `updated_at` DATETIME NULL DEFAULT NULL,
  PRIMARY KEY (`id`))
ENGINE = InnoDB;


-- -----------------------------------------------------
-- Table `smartihu_wp_db`.`si_p_nodethree`
-- -----------------------------------------------------
CREATE TABLE IF NOT EXISTS `smartihu_wp_db`.`si_p_nodethree` (
  `id` INT NOT NULL AUTO_INCREMENT,
  `general_error_message` TEXT NULL DEFAULT NULL,
  `general_error` TINYINT(1) NULL DEFAULT NULL,
  `node_name` VARCHAR(45) NULL DEFAULT NULL,
  `readings` TINYINT(1) NULL DEFAULT NULL,
  `node_entry_date` DATETIME NULL DEFAULT NULL,
  `camera` TEXT NULL DEFAULT NULL,
  `car_count` TEXT NULL DEFAULT NULL,
  `created_at` DATETIME NULL DEFAULT NULL,
  `updated_at` DATETIME NULL DEFAULT NULL,
  PRIMARY KEY (`id`))
ENGINE = InnoDB;


-- -----------------------------------------------------
-- Table `smartihu_wp_db`.`si_p_nodetwo`
-- -----------------------------------------------------
CREATE TABLE IF NOT EXISTS `smartihu_wp_db`.`si_p_nodetwo` (
  `id` INT NOT NULL AUTO_INCREMENT,
  `general_error_message` TEXT NULL DEFAULT NULL,
  `general_error` TINYINT(1) NULL DEFAULT NULL,
  `node_name` VARCHAR(45) NULL DEFAULT NULL,
  `readings` TINYINT(1) NULL DEFAULT NULL,
  `node_entry_date` DATETIME NULL DEFAULT NULL,
  `bme680` TEXT NULL DEFAULT NULL,
  `sgp30` TEXT NULL DEFAULT NULL,
```

Picture 42: SQL script for table creation

The script essentially creates three tables, one for each node. After creating the tables, the database of the project looks like this:

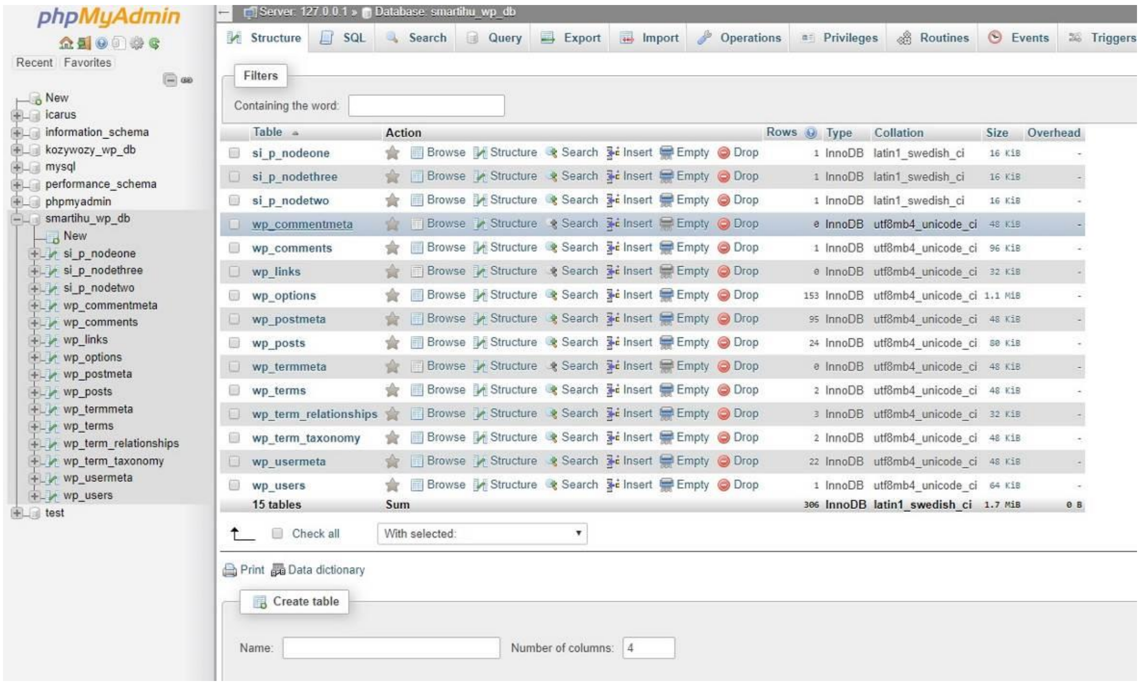
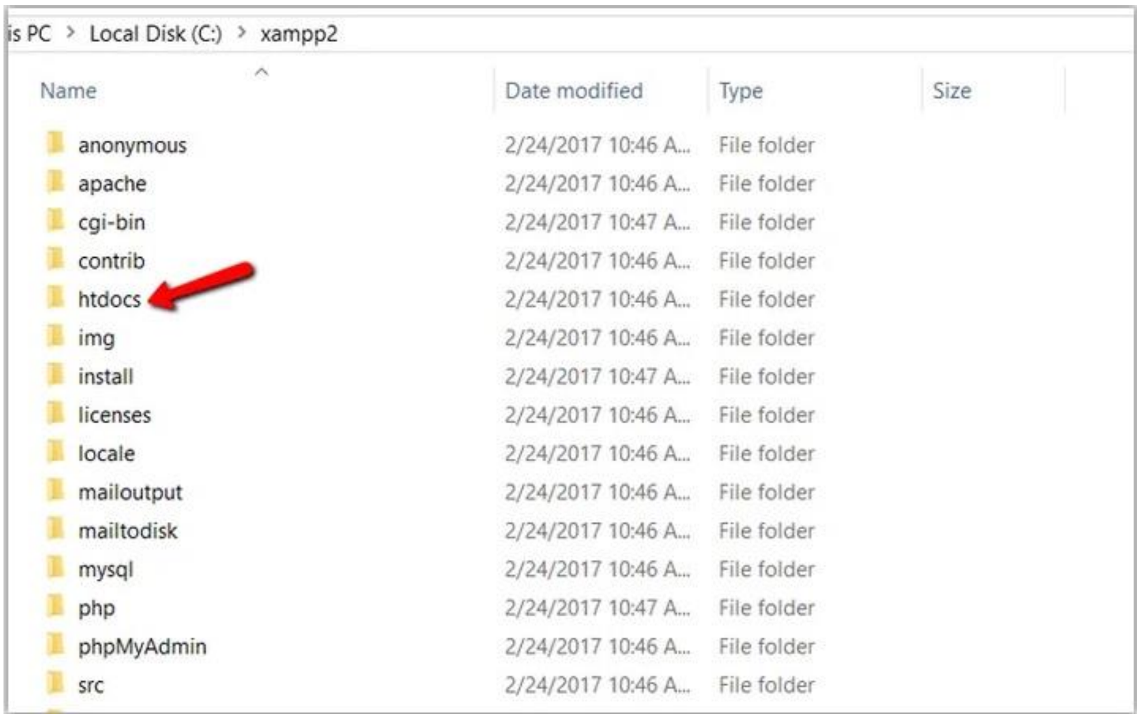


Table	Action	Rows	Type	Collation	Size	Overhead
si_p_nodeone	Browse Structure Search Insert Empty Drop	1	InnoDB	latin1_swedish_ci	16 KiB	-
si_p_nodethree	Browse Structure Search Insert Empty Drop	1	InnoDB	latin1_swedish_ci	16 KiB	-
si_p_nodetwo	Browse Structure Search Insert Empty Drop	1	InnoDB	latin1_swedish_ci	16 KiB	-
wp_commentmeta	Browse Structure Search Insert Empty Drop	0	InnoDB	utf8mb4_unicode_ci	48 KiB	-
wp_comments	Browse Structure Search Insert Empty Drop	1	InnoDB	utf8mb4_unicode_ci	96 KiB	-
wp_links	Browse Structure Search Insert Empty Drop	0	InnoDB	utf8mb4_unicode_ci	32 KiB	-
wp_options	Browse Structure Search Insert Empty Drop	153	InnoDB	utf8mb4_unicode_ci	1.1 MiB	-
wp_postmeta	Browse Structure Search Insert Empty Drop	95	InnoDB	utf8mb4_unicode_ci	48 KiB	-
wp_posts	Browse Structure Search Insert Empty Drop	24	InnoDB	utf8mb4_unicode_ci	80 KiB	-
wp_termmeta	Browse Structure Search Insert Empty Drop	0	InnoDB	utf8mb4_unicode_ci	48 KiB	-
wp_terms	Browse Structure Search Insert Empty Drop	2	InnoDB	utf8mb4_unicode_ci	48 KiB	-
wp_term_relationships	Browse Structure Search Insert Empty Drop	3	InnoDB	utf8mb4_unicode_ci	32 KiB	-
wp_term_taxonomy	Browse Structure Search Insert Empty Drop	2	InnoDB	utf8mb4_unicode_ci	48 KiB	-
wp_usermeta	Browse Structure Search Insert Empty Drop	22	InnoDB	utf8mb4_unicode_ci	48 KiB	-
wp_users	Browse Structure Search Insert Empty Drop	1	InnoDB	utf8mb4_unicode_ci	64 KiB	-
15 tables	Sum	306	InnoDB	latin1_swedish_ci	1.7 MiB	0 B

Picture 43: Database tables

4.3.3 Wordpress Setup

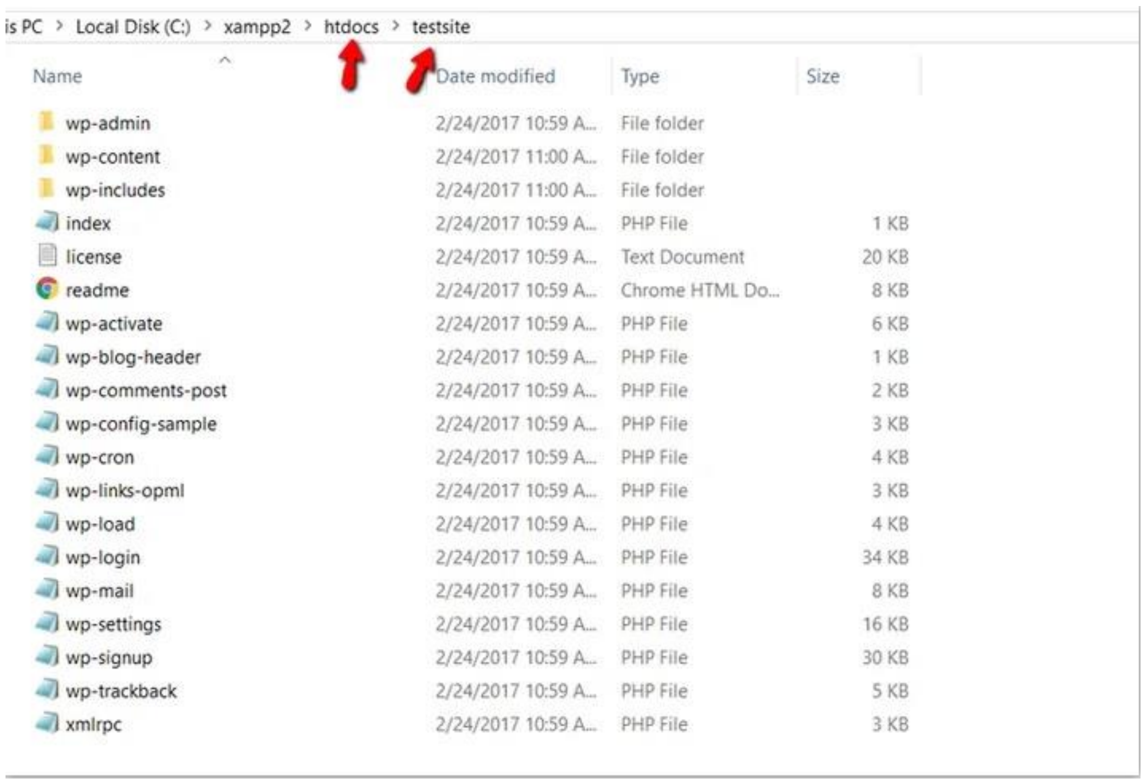
Before beginning the plugin development, Wordpress needs to be setup. After downloading the Wordpress files from the official webpage and since XAMPP and phpMyAdmin is already installed, the Wordpress files need to be placed in the local XAMPP folder, inside the *htdocs* subfolder.



Name	Date modified	Type	Size
anonymous	2/24/2017 10:46 A...	File folder	
apache	2/24/2017 10:46 A...	File folder	
cgi-bin	2/24/2017 10:47 A...	File folder	
contrib	2/24/2017 10:46 A...	File folder	
htdocs	2/24/2017 10:46 A...	File folder	
img	2/24/2017 10:46 A...	File folder	
install	2/24/2017 10:47 A...	File folder	
licenses	2/24/2017 10:46 A...	File folder	
locale	2/24/2017 10:46 A...	File folder	
mailoutput	2/24/2017 10:46 A...	File folder	
mailtodisk	2/24/2017 10:46 A...	File folder	
mysql	2/24/2017 10:46 A...	File folder	
php	2/24/2017 10:47 A...	File folder	
phpMyAdmin	2/24/2017 10:46 A...	File folder	
src	2/24/2017 10:46 A...	File folder	

Picture 44: Placement of Wordpress files

The file structure of Wordpress looks like this:

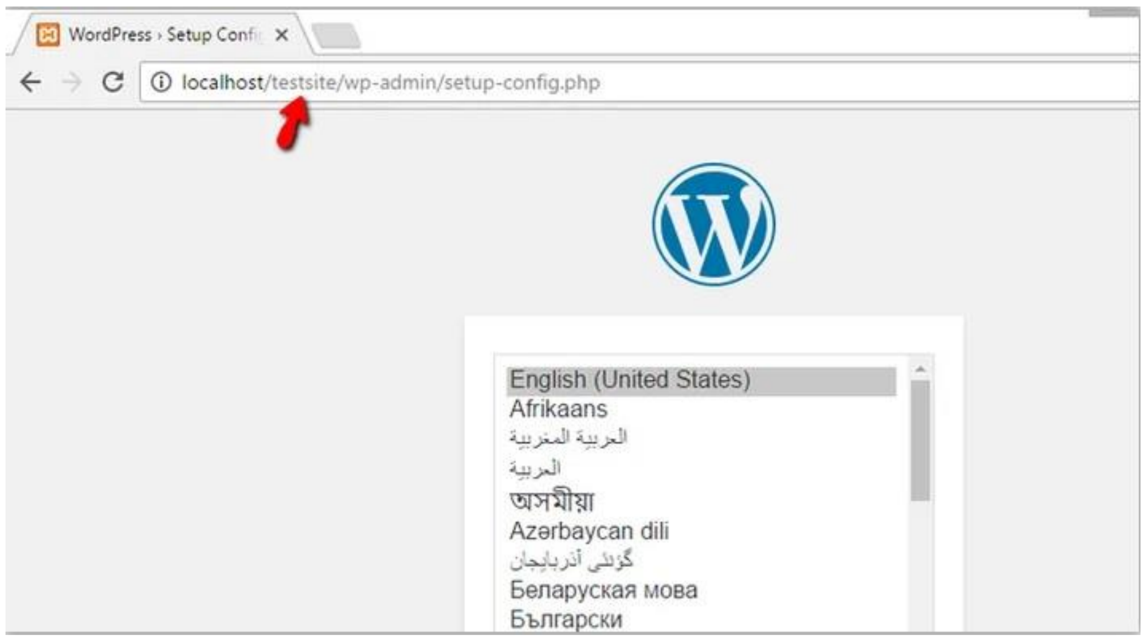


is PC > Local Disk (C:) > xampp2 > htdocs > testsite

Name	Date modified	Type	Size
wp-admin	2/24/2017 10:59 A...	File folder	
wp-content	2/24/2017 11:00 A...	File folder	
wp-includes	2/24/2017 11:00 A...	File folder	
index	2/24/2017 10:59 A...	PHP File	1 KB
license	2/24/2017 10:59 A...	Text Document	20 KB
readme	2/24/2017 10:59 A...	Chrome HTML Do...	8 KB
wp-activate	2/24/2017 10:59 A...	PHP File	6 KB
wp-blog-header	2/24/2017 10:59 A...	PHP File	1 KB
wp-comments-post	2/24/2017 10:59 A...	PHP File	2 KB
wp-config-sample	2/24/2017 10:59 A...	PHP File	3 KB
wp-cron	2/24/2017 10:59 A...	PHP File	4 KB
wp-links-opml	2/24/2017 10:59 A...	PHP File	3 KB
wp-load	2/24/2017 10:59 A...	PHP File	4 KB
wp-login	2/24/2017 10:59 A...	PHP File	34 KB
wp-mail	2/24/2017 10:59 A...	PHP File	8 KB
wp-settings	2/24/2017 10:59 A...	PHP File	16 KB
wp-signup	2/24/2017 10:59 A...	PHP File	30 KB
wp-trackback	2/24/2017 10:59 A...	PHP File	5 KB
xmlrpc	2/24/2017 10:59 A...	PHP File	3 KB

Picture 45: Wordpress file structure

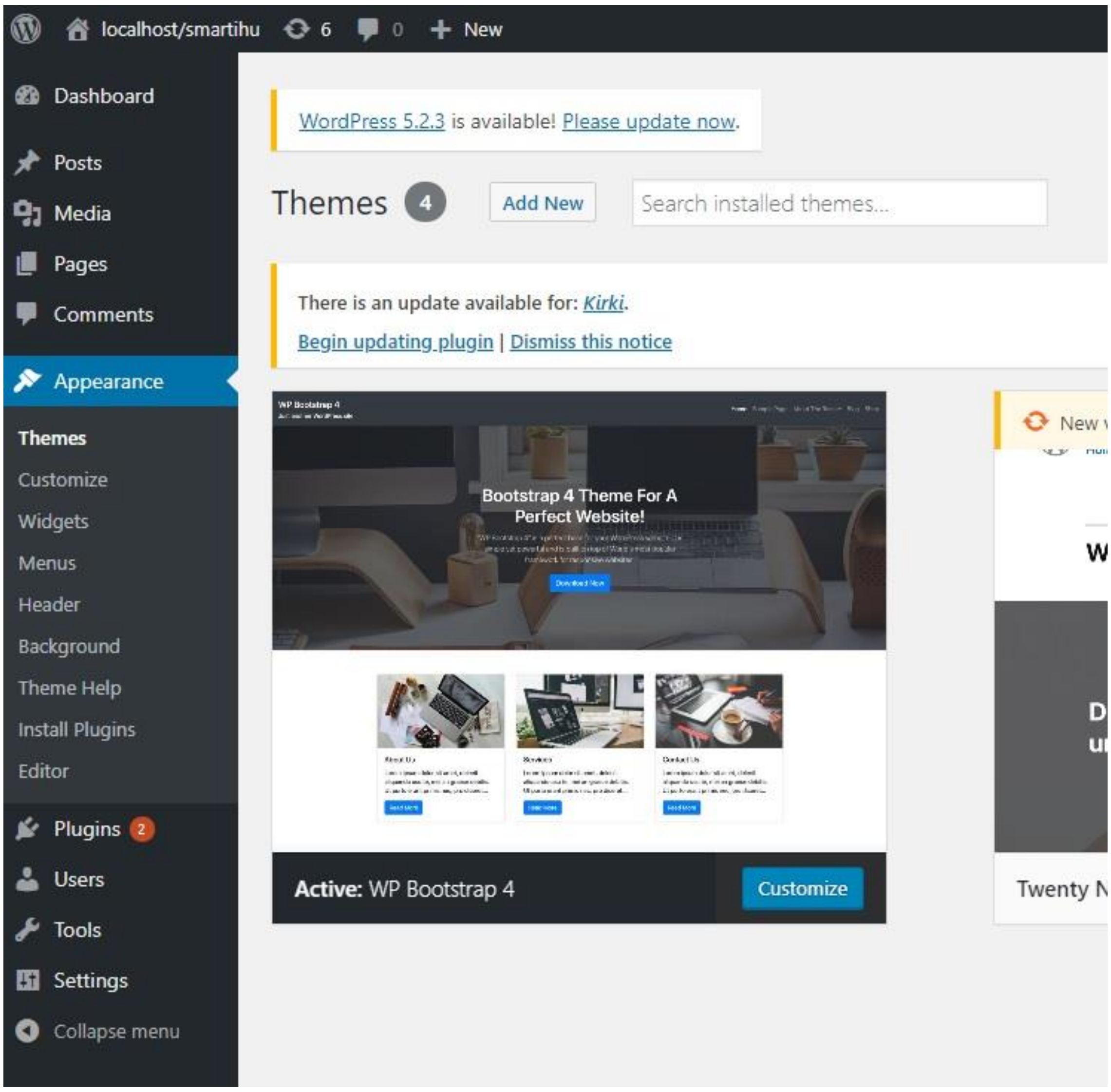
Since phpMyAdmin is already installed and as it was mentioned in the previous chapter the database is already setup, the next step would be to access the localhost location from the browser and begin the main installation.



English (United States)
Afrikaans
العربية المغربية
العربية
অসমীয়া
Azərbaycan dili
گؤنئی آذربایجان
Беларуская мова
Български

Picture 45: Wordpress installation

After the installation is successful, the only thing that remains before beginning the plugin development is choosing a Wordpress theme. For the needs of this project, the Bootstrap4 theme was chosen and then installed in the webpage.



WordPress 5.2.3 is available! Please update now.

There is an update available for: Kirki.

Begin updating plugin | Dismiss this notice

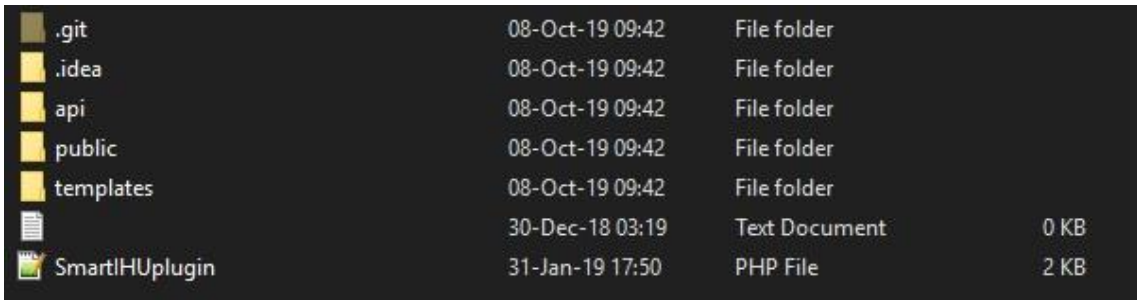
Active: WP Bootstrap 4

Picture 46: Wordpress admin dashboard – Bootstrap 4 theme

4.4 Code Review

The logic behind the development of the plugin is rather simple; the main use of the plugin is to pull sensor data from the database via a GET request in order to query the database over time. The response of this GET request is a JSON string. This method applies for every sensor node table in the database. This dissertation will not discuss the frontend development of the webpage in detail, but will rather review the backend code that displays the node data live on the webpage.

The file structure of the plugin looks like this:

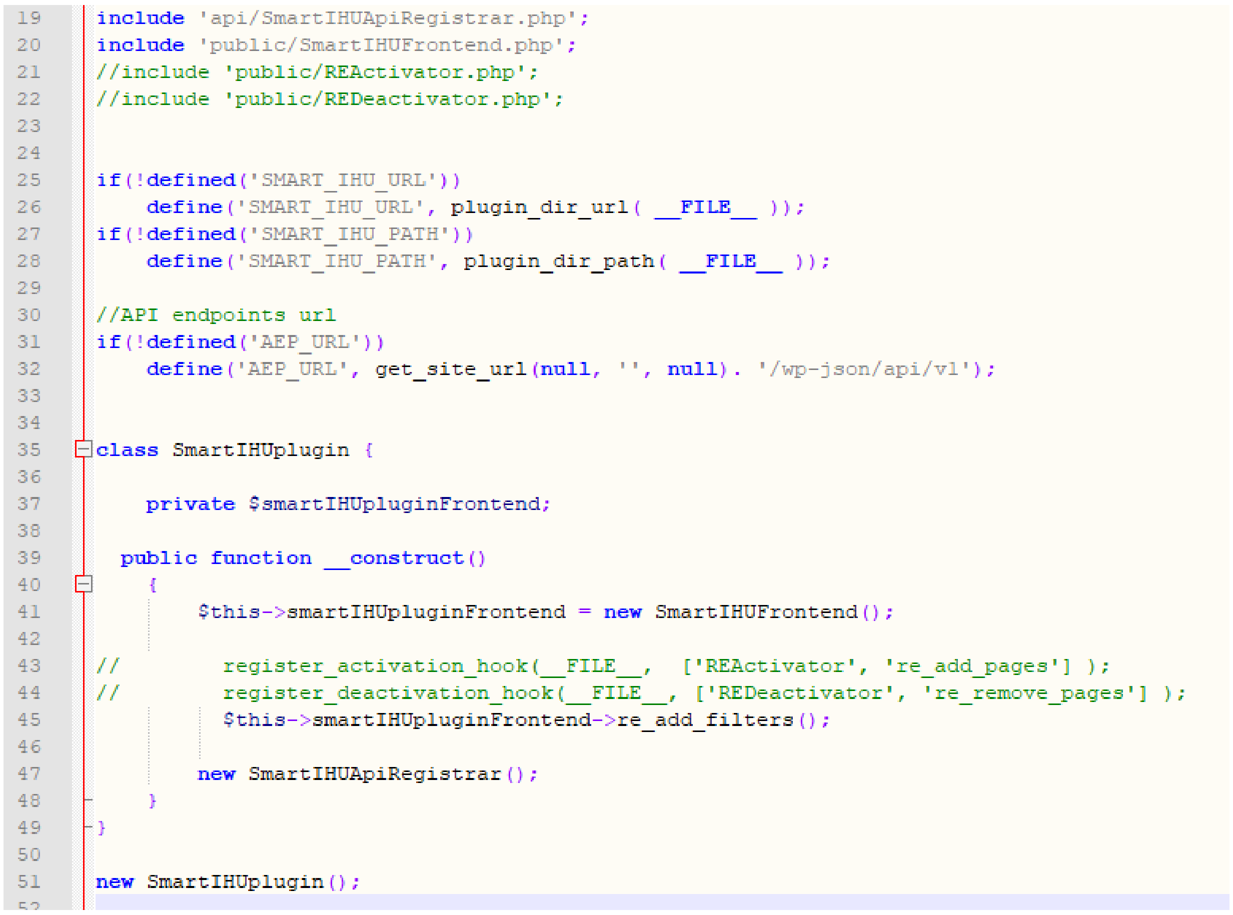


.git	08-Oct-19 09:42	File folder	
.idea	08-Oct-19 09:42	File folder	
api	08-Oct-19 09:42	File folder	
public	08-Oct-19 09:42	File folder	
templates	08-Oct-19 09:42	File folder	
	30-Dec-18 03:19	Text Document	0 KB
SmartIHUplugin	31-Jan-19 17:50	PHP File	2 KB

Picture 47: Wordpress plugin file structure

- The *api* folder contains the controllers and the models of the plugin.
- The *public* folder contains files related to the frontend.
- The *templates* folder contains templates that are used in the frontend.

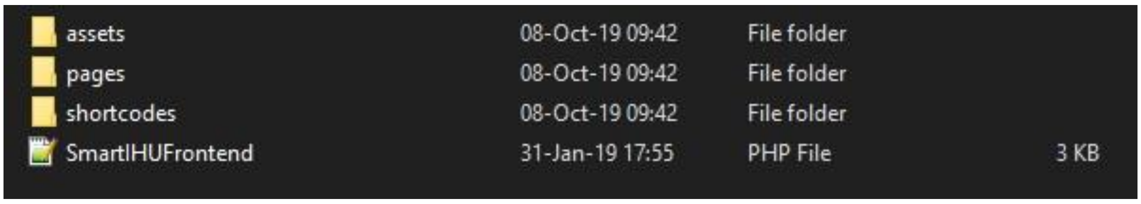
The *SmartIHUplugin.php* file contains a class that initializes the plugin, includes the files that are necessary for the initialization process and declares global variables that are used in the plugin. It also contains the internal Wordpress path of the plugin and the url of the API endpoint.



```php
include 'api/SmartIHUApiRegistrar.php';
include 'public/SmartIHUFrontend.php';
//include 'public/REActivator.php';
//include 'public/REDeactivator.php';


if(!defined('SMART_IHU_URL'))
    define('SMART_IHU_URL', plugin_dir_url( __FILE__ ));
if(!defined('SMART_IHU_PATH'))
    define('SMART_IHU_PATH', plugin_dir_path( __FILE__ ));

//API endpoints url
if(!defined('AEP_URL'))
    define('AEP_URL', get_site_url(null, '', null). '/wp-json/api/v1');


class SmartIHUplugin {

    private $smartIHUpluginFrontend;

  public function __construct()
    {
        $this->smartIHUpluginFrontend = new SmartIHUFrontend();

//          register_activation_hook(__FILE__,  ['REActivator', 're_add_pages'] );
//          register_deactivation_hook(__FILE__, ['REDeactivator', 're_remove_pages'] );
          $this->smartIHUpluginFrontend->re_add_filters();

        new SmartIHUApiRegistrar();
    }
}

new SmartIHUplugin();
```

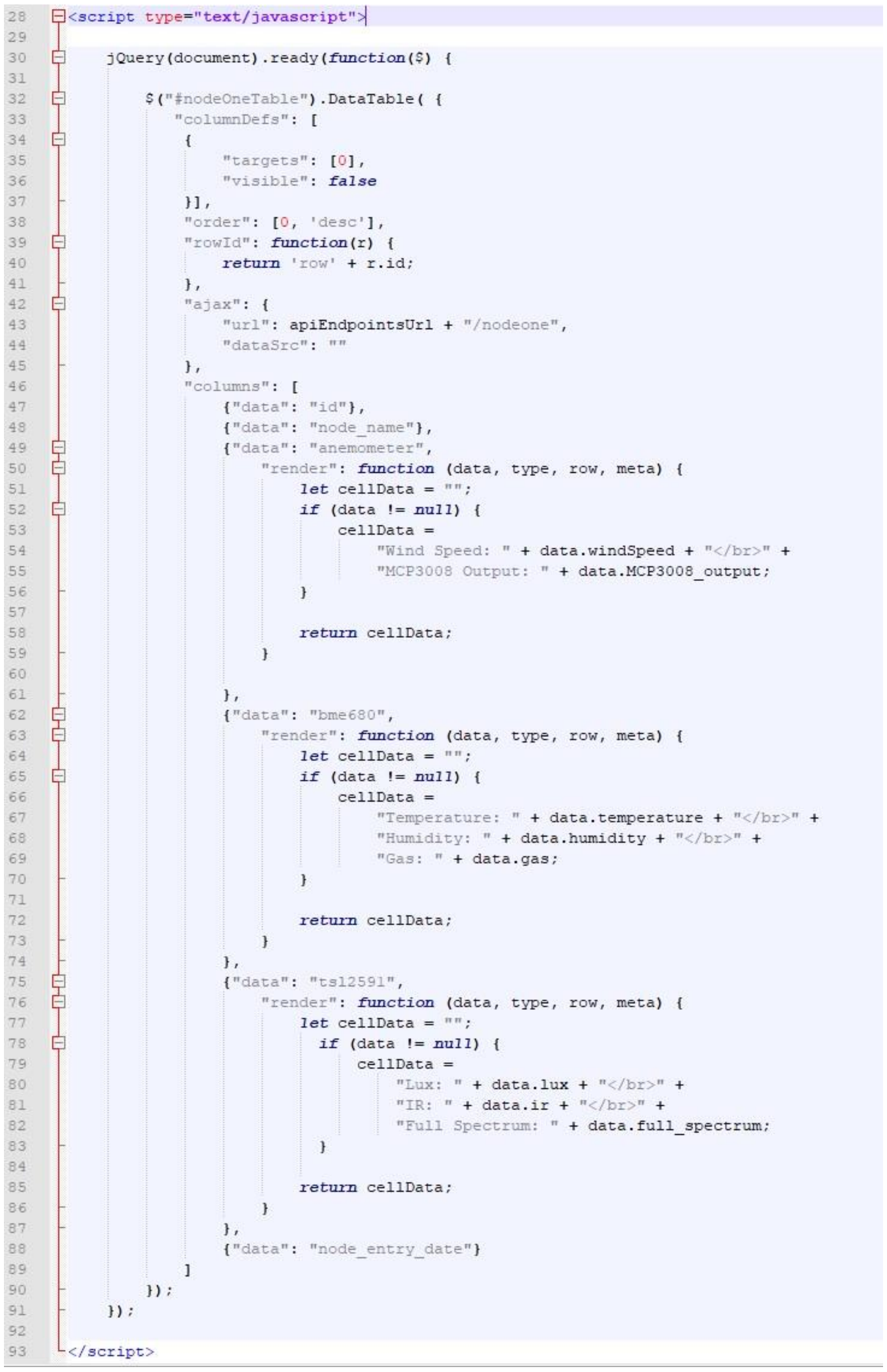
Picture 48: SmartIHUplugin.php

Within the *public* folder the file structure looks like this:



assets	08-Oct-19 09:42	File folder	
pages	08-Oct-19 09:42	File folder	
shortcodes	08-Oct-19 09:42	File folder	
SmartIHUFrontend	31-Jan-19 17:55	PHP File	3 KB

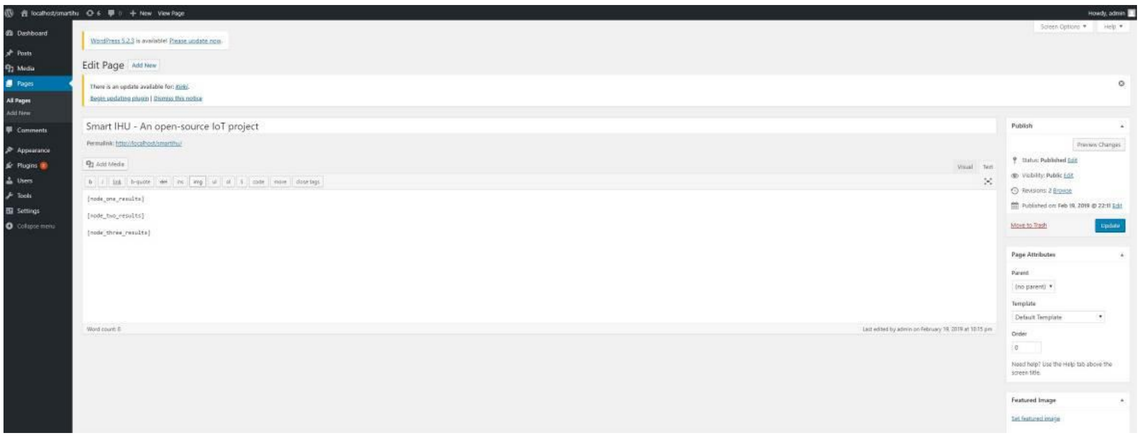
- The *assets* folder contains Javascript and CSS files that are used for the development of the frontend.
- The *pages* folder is of no use since in order to display the data from the nodes on the webpage, we use shortcodes.
- The *shortcodes* displays the data from the nodes in data table view. Using shortcodes in wordpress provides the developer with the ability to display the data in whichever page of the site he wishes.
    - Within the *shortcodes* folder there are three PHP files, one for each node.



```
<script type="text/javascript">

    jQuery(document).ready(function($) {

        $("#nodeOneTable").DataTable( {
           "columnDefs": [
            {
                "targets": [0],
                "visible": false
            }],
            "order": [0, 'desc'],
            "rowId": function(r) {
                return 'row' + r.id;
            },
            "ajax": {
                "url": apiEndpointsUrl + "/nodeone",
                "dataSrc": ""
            },
            "columns": [
                {"data": "id"},
                {"data": "node_name"},
                {"data": "anemometer",
                    "render": function (data, type, row, meta) {
                        let cellData = "";
                        if (data != null) {
                            cellData =
                                "Wind Speed: " + data.windSpeed + "</br>" +
                                "MCP3008 Output: " + data.MCP3008_output;
                        }

                        return cellData;
                    }

                },
                {"data": "bme680",
                    "render": function (data, type, row, meta) {
                        let cellData = "";
                        if (data != null) {
                            cellData =
                                "Temperature: " + data.temperature + "</br>" +
                                "Humidity: " + data.humidity + "</br>" +
                                "Gas: " + data.gas;
                        }

                        return cellData;
                    }
                },
                {"data": "tsl2591",
                    "render": function (data, type, row, meta) {
                        let cellData = "";
                          if (data != null) {
                            cellData =
                                  "Lux: " + data.lux + "</br>" +
                                  "IR: " + data.ir + "</br>" +
                                  "Full Spectrum: " + data.full_spectrum;
                          }

                        return cellData;
                    }
                },
                {"data": "node_entry_date"}
            ]
        });
    });

</script>
```

Picture 49: Example of a shortcode PHP file (Node #1)

This way the data tables of the nodes can be added in this way in any page around the Wordpress page:



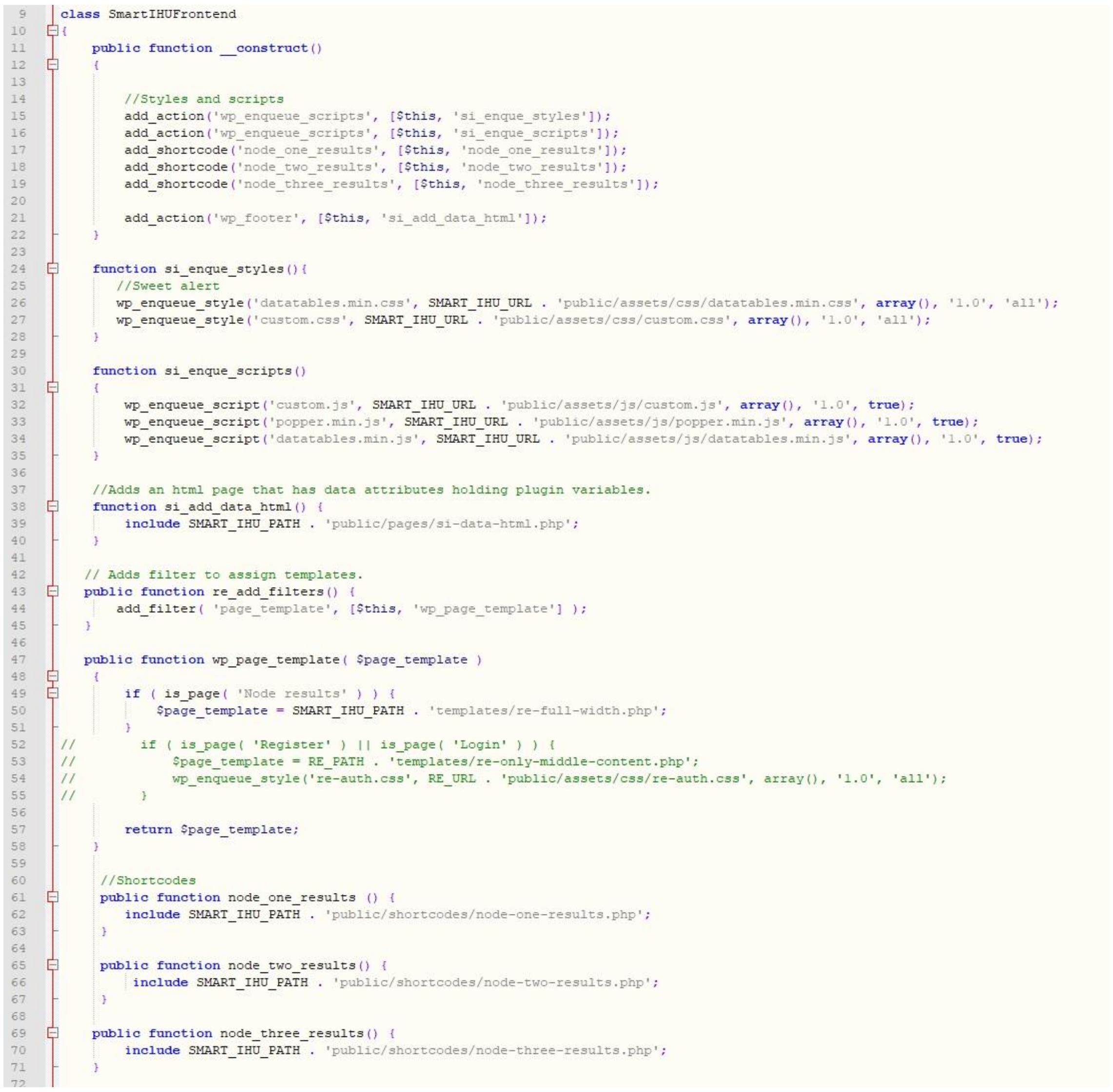
Smart IHU - An open-source IoT project

Permalink: http://localhost/smartihu/

```
[node_one_results]

[node_two_results]

[node_three_results]
```

Picture 50: Adding the shortcodes in the main page

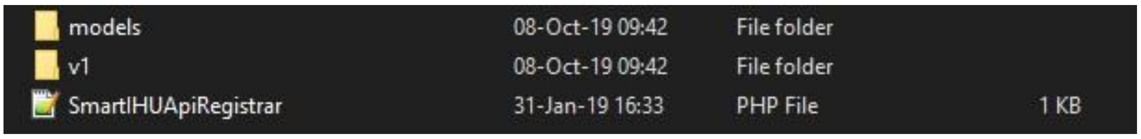
- Finally, the *SmartIHUFrontend.php* contains a class that is called by *SmartI-HUPlugin.php* and contains methods that include the styles and scripts that are used by the shortcodes. The class also sets the full-width template for the pages that will be using the shortcodes. Finally, it creates the shortcodes.



```php
class SmartIHUFrontend
{
    public function __construct()
    {

        //Styles and scripts
        add_action('wp_enqueue_scripts', [$this, 'si_enque_styles']);
        add_action('wp_enqueue_scripts', [$this, 'si_enque_scripts']);
        add_shortcode('node_one_results', [$this, 'node_one_results']);
        add_shortcode('node_two_results', [$this, 'node_two_results']);
        add_shortcode('node_three_results', [$this, 'node_three_results']);

        add_action('wp_footer', [$this, 'si_add_data_html']);
    }

    function si_enque_styles(){
       //Sweet alert
       wp_enqueue_style('datatables.min.css', SMART_IHU_URL . 'public/assets/css/datatables.min.css', array(), '1.0', 'all');
       wp_enqueue_style('custom.css', SMART_IHU_URL . 'public/assets/css/custom.css', array(), '1.0', 'all');
    }

    function si_enque_scripts()
    {
        wp_enqueue_script('custom.js', SMART_IHU_URL . 'public/assets/js/custom.js', array(), '1.0', true);
        wp_enqueue_script('popper.min.js', SMART_IHU_URL . 'public/assets/js/popper.min.js', array(), '1.0', true);
        wp_enqueue_script('datatables.min.js', SMART_IHU_URL . 'public/assets/js/datatables.min.js', array(), '1.0', true);
    }

    //Adds an html page that has data attributes holding plugin variables.
    function si_add_data_html() {
        include SMART_IHU_PATH . 'public/pages/si-data-html.php';
    }

   // Adds filter to assign templates.
   public function re_add_filters() {
       add_filter( 'page_template', [$this, 'wp_page_template'] );
   }

   public function wp_page_template( $page_template )
    {
        if ( is_page( 'Node results' ) ) {
            $page_template = SMART_IHU_PATH . 'templates/re-full-width.php';
        }
//          if ( is_page( 'Register' ) || is_page( 'Login' ) ) {
//              $page_template = RE_PATH . 'templates/re-only-middle-content.php';
//              wp_enqueue_style('re-auth.css', RE_URL . 'public/assets/css/re-auth.css', array(), '1.0', 'all');
//          }

        return $page_template;
    }

     //Shortcodes
     public function node_one_results () {
        include SMART_IHU_PATH . 'public/shortcodes/node-one-results.php';
     }

     public function node_two_results() {
         include SMART_IHU_PATH . 'public/shortcodes/node-two-results.php';
     }

    public function node_three_results() {
        include SMART_IHU_PATH . 'public/shortcodes/node-three-results.php';
    }
```

Picture 51: SmartIHUfrontend.php file

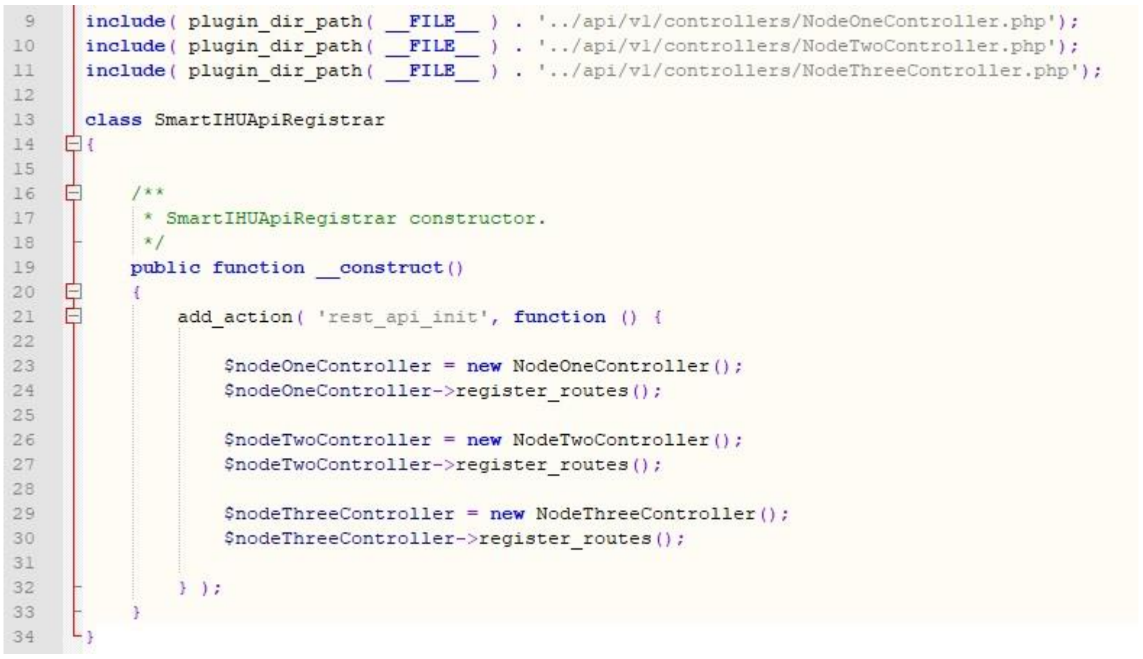
Finally, the *api* folder structure looks like this:



```
models               08-Oct-19 09:42    File folder
v1                   08-Oct-19 09:42    File folder
SmartIHUApiRegistrar 31-Jan-19 16:33    PHP File       1 KB
```

Picture 52: *api* folder structure

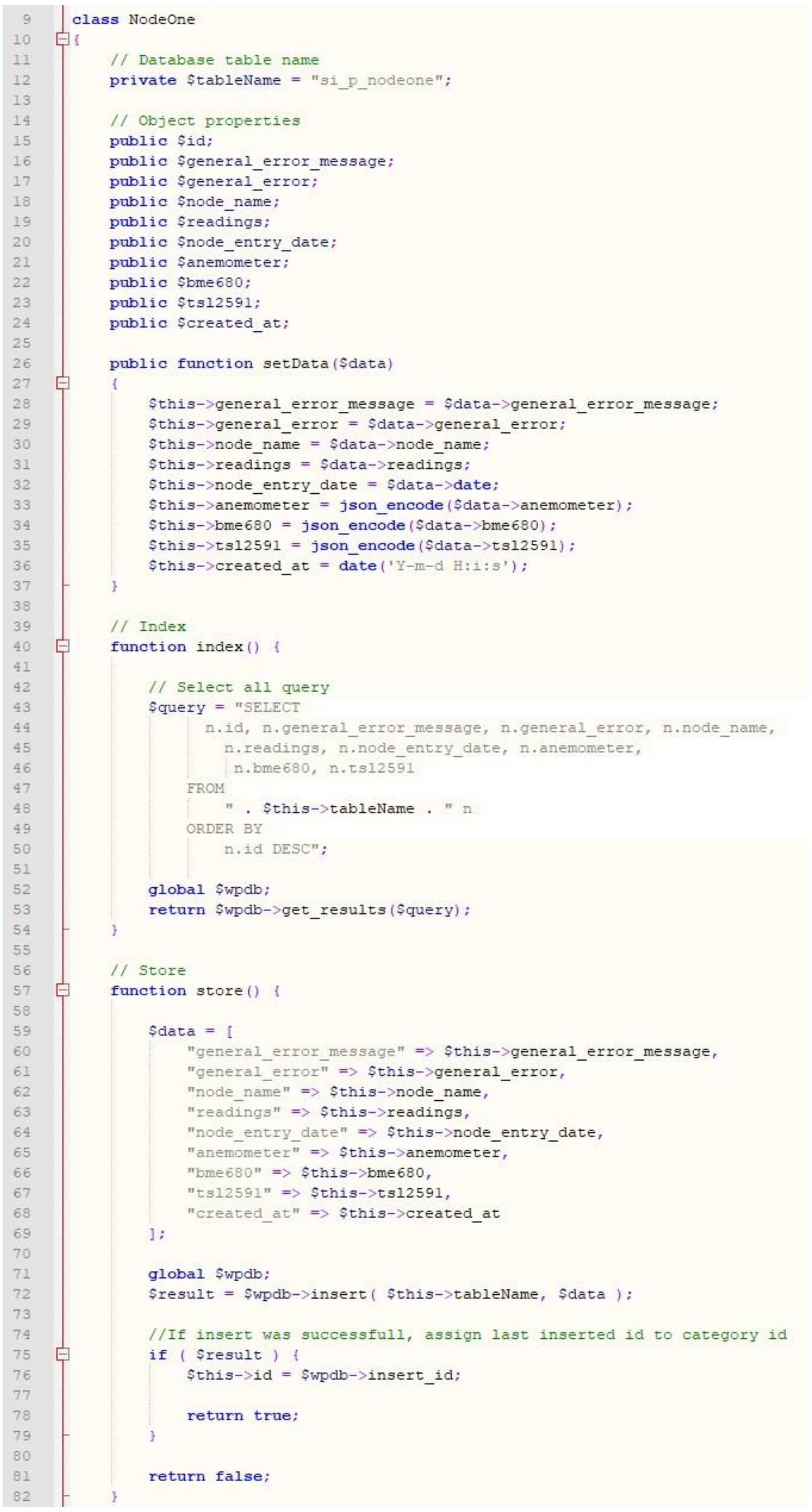
- The *SmartIHUApiRegistrar.php* file creates the API endpoints for every controller:



```php
include( plugin_dir_path( __FILE__ ) . '../api/v1/controllers/NodeOneController.php');
include( plugin_dir_path( __FILE__ ) . '../api/v1/controllers/NodeTwoController.php');
include( plugin_dir_path( __FILE__ ) . '../api/v1/controllers/NodeThreeController.php');

class SmartIHUApiRegistrar
{

    /**
     * SmartIHUApiRegistrar constructor.
     */
    public function __construct()
    {
        add_action( 'rest_api_init', function () {

            $nodeOneController = new NodeOneController();
            $nodeOneController->register_routes();

            $nodeTwoController = new NodeTwoController();
            $nodeTwoController->register_routes();

            $nodeThreeController = new NodeThreeController();
            $nodeThreeController->register_routes();

        } );
    }
}
```

Picture 52: SmartIHUApiRegistrar.php file

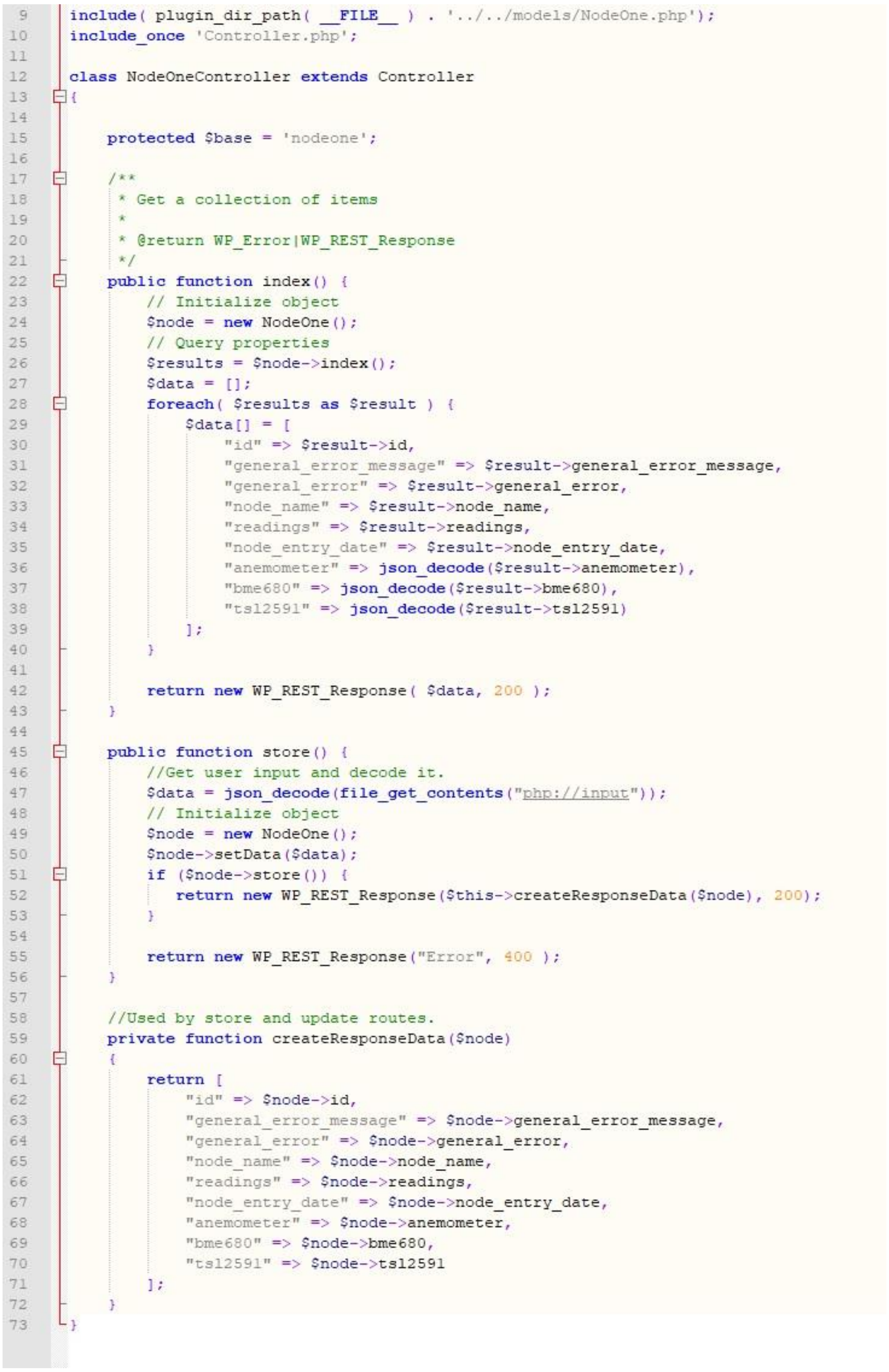
- The *models* folder contains the models for every node as well as methods for data manipulation and storing.



```php
class NodeOne
{
    // Database table name
    private $tableName = "si_p_nodeone";

    // Object properties
    public $id;
    public $general_error_message;
    public $general_error;
    public $node_name;
    public $readings;
    public $node_entry_date;
    public $anemometer;
    public $bme680;
    public $tsl2591;
    public $created_at;

    public function setData($data)
    {
        $this->general_error_message = $data->general_error_message;
        $this->general_error = $data->general_error;
        $this->node_name = $data->node_name;
        $this->readings = $data->readings;
        $this->node_entry_date = $data->date;
        $this->anemometer = json_encode($data->anemometer);
        $this->bme680 = json_encode($data->bme680);
        $this->tsl2591 = json_encode($data->tsl2591);
        $this->created_at = date('Y-m-d H:i:s');
    }

    // Index
    function index() {

        // Select all query
        $query = "SELECT
              n.id, n.general_error_message, n.general_error, n.node_name,
                n.readings, n.node_entry_date, n.anemometer,
                 n.bme680, n.tsl2591
            FROM
                " . $this->tableName . " n
            ORDER BY
                n.id DESC";

        global $wpdb;
        return $wpdb->get_results($query);
    }

    // Store
    function store() {

        $data = [
            "general_error_message" => $this->general_error_message,
            "general_error" => $this->general_error,
            "node_name" => $this->node_name,
            "readings" => $this->readings,
            "node_entry_date" => $this->node_entry_date,
            "anemometer" => $this->anemometer,
            "bme680" => $this->bme680,
            "tsl2591" => $this->tsl2591,
            "created_at" => $this->created_at
        ];

        global $wpdb;
        $result = $wpdb->insert( $this->tableName, $data );

        //If insert was successfull, assign last inserted id to category id
        if ( $result ) {
            $this->id = $wpdb->insert_id;

            return true;
        }

        return false;
    }
```

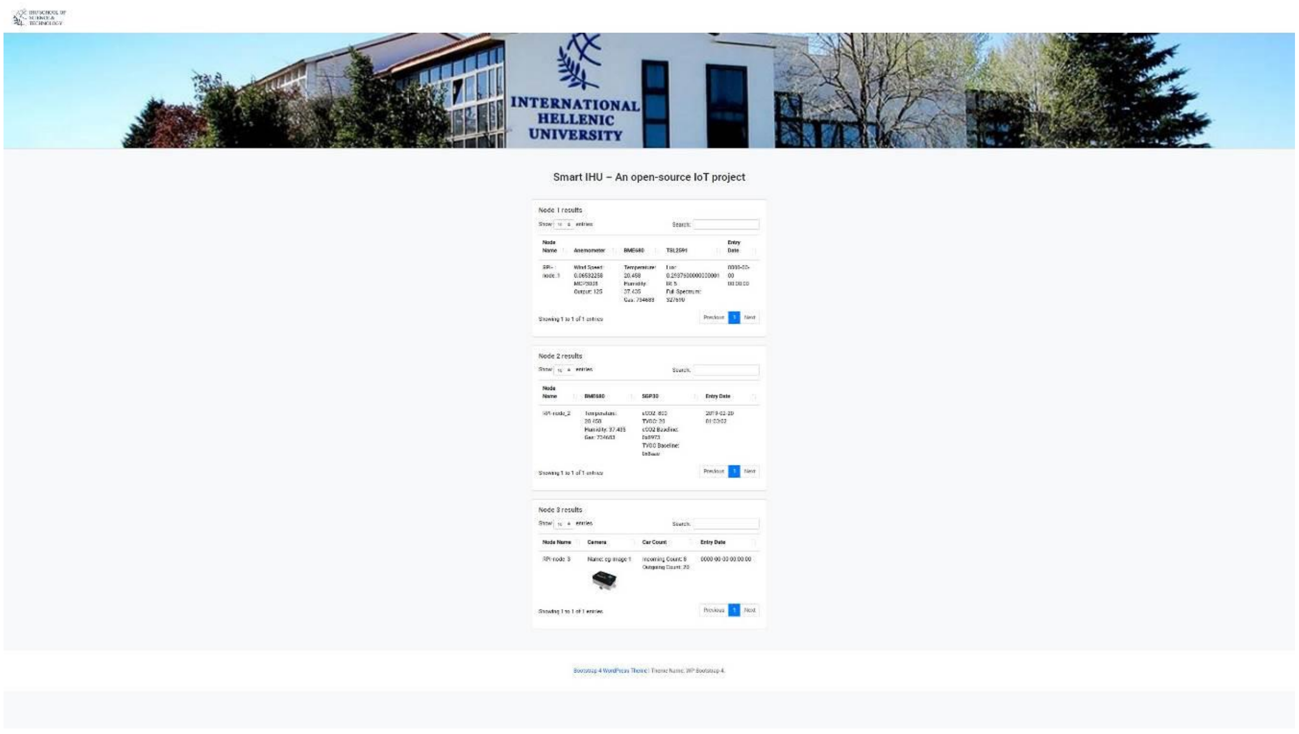
Picture 53: Sample model file – NodeOne.php

- The *v1* folder contains the controllers that expose the public APIs for data management of the nodes and use the models from the *models* folder.



```php
include( plugin_dir_path( __FILE__ ) . '../../models/NodeOne.php');
include_once 'Controller.php';

class NodeOneController extends Controller
{

    protected $base = 'nodeone';

    /**
     * Get a collection of items
     *
     * @return WP_Error|WP_REST_Response
     */
    public function index() {
        // Initialize object
        $node = new NodeOne();
        // Query properties
        $results = $node->index();
        $data = [];
        foreach( $results as $result ) {
            $data[] = [
                "id" => $result->id,
                "general_error_message" => $result->general_error_message,
                "general_error" => $result->general_error,
                "node_name" => $result->node_name,
                "readings" => $result->readings,
                "node_entry_date" => $result->node_entry_date,
                "anemometer" => json_decode($result->anemometer),
                "bme680" => json_decode($result->bme680),
                "tsl2591" => json_decode($result->tsl2591)
            ];
        }

        return new WP_REST_Response( $data, 200 );
    }

    public function store() {
        //Get user input and decode it.
        $data = json_decode(file_get_contents("php://input"));
        // Initialize object
        $node = new NodeOne();
        $node->setData($data);
        if ($node->store()) {
           return new WP_REST_Response($this->createResponseData($node), 200);
        }

        return new WP_REST_Response("Error", 400 );
    }

    //Used by store and update routes.
    private function createResponseData($node)
    {
        return [
            "id" => $node->id,
            "general_error_message" => $node->general_error_message,
            "general_error" => $node->general_error,
            "node_name" => $node->node_name,
            "readings" => $node->readings,
            "node_entry_date" => $node->node_entry_date,
            "anemometer" => $node->anemometer,
            "bme680" => $node->bme680,
            "tsl2591" => $node->tsl2591
        ];
    }
}
```

Picture 54: Sample controller file: NodeOneController.php



Smart IHU – An open-source IoT project

Node 1 results

Show 10 entries Search:

Node Name	Anemometer	BME680	TSL2591	Entry Date
RPi-node_1	Wind Speed: 0.06532258 MCP3008 Output: 125	Temperature: 20.458 Humidity: 37.435 Gas: 734683	Lux: 0.2937500000000001 IR: 5 Full Spectrum: 327680	0000-00-00 00:00:00

Showing 1 to 1 of 1 entries

Previous 1 Next

Node 2 results

Show 10 entries Search:

Node Name	BME680	SGP30	Entry Date
RPi-node_2	Temperature: 20.450 Humidity: 37.485 Gas: 734683	eCO2: 800 TVOC: 20 eCO2 Baseline: 0x8973 TVOC Baseline: 0x8aaa	2019-02-20 01:03:02

Showing 1 to 1 of 1 entries

Previous 1 Next

Node 3 results

Show 10 entries Search:

Node Name	Camera	Car Count	Entry Date
RPi-node_3	Name: cg-image 1	Incoming Count: 8 Outgoing Count: 20	0000-00-00 00:00:00

Showing 1 to 1 of 1 entries

Previous 1 Next

Bootstrap 4 WordPress Theme | Theme Name: WP Bootstrap 4.

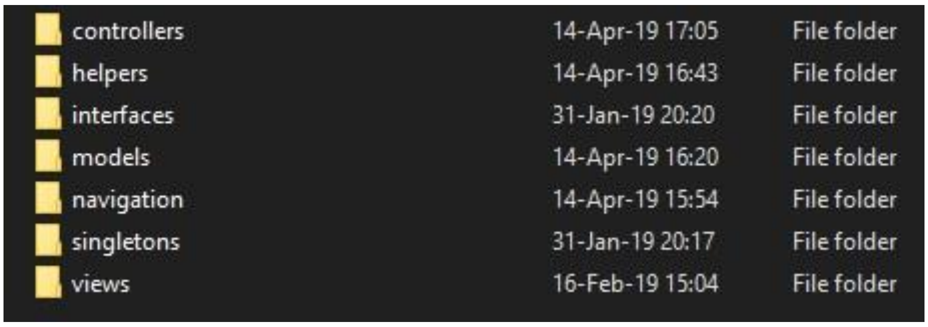
Picture 55: Live display of the node data

5 Mobile Development

This logic behind the mobile development of the Smart IHU app is very similar to the web-based Wordpress plugin. With the use of the GET endpoints, the data from every node is retrieved from the database in JSON format and is then converted into Java objects via the Gson library. The generated objects are then displayed on the frontend. This mobile app was developed with the use of Google's Android Studio. The coding language used is Java.

5.1 Code Review

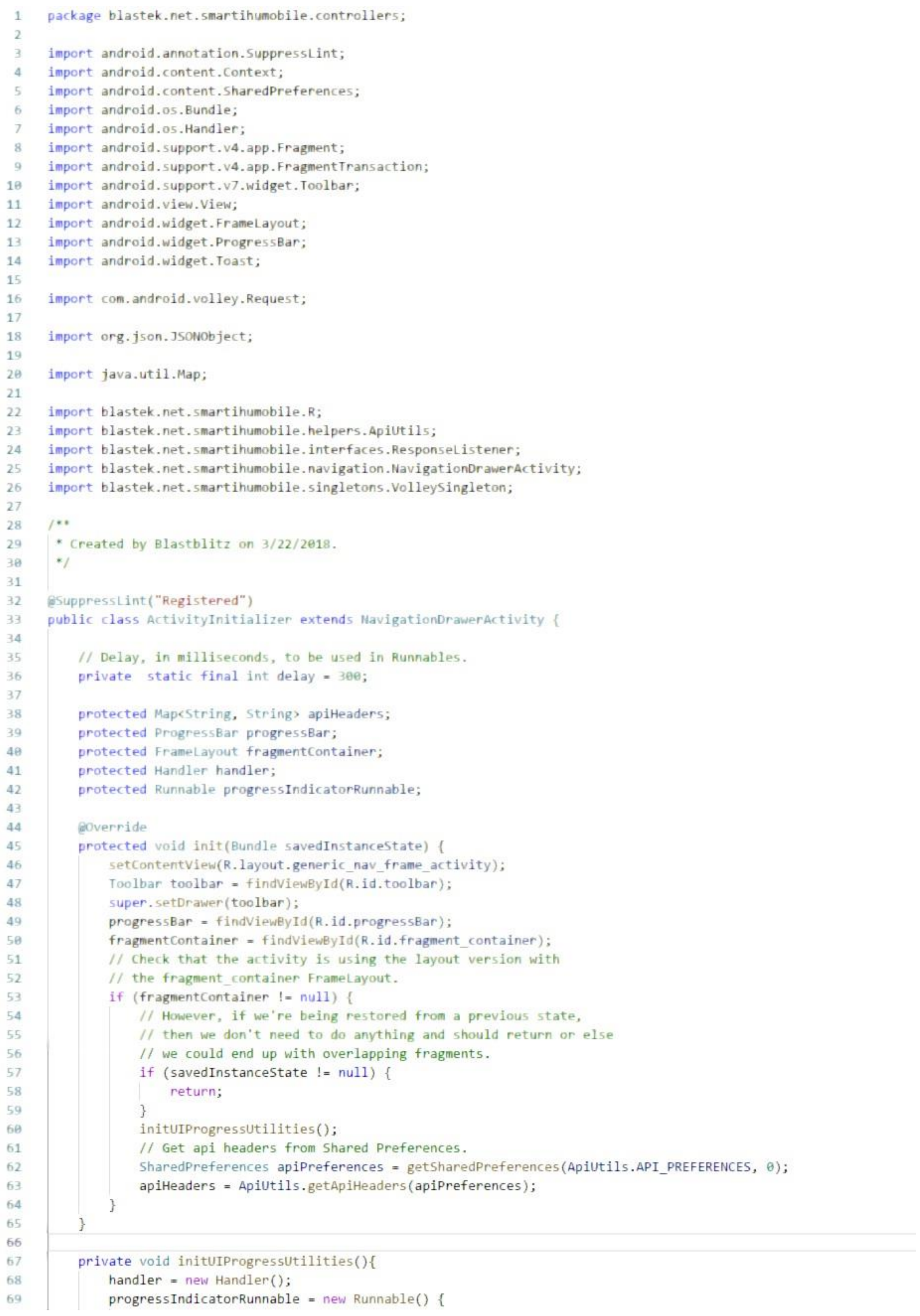
The main file structure of the mobile app is the following:



controllers	14-Apr-19 17:05	File folder
helpers	14-Apr-19 16:43	File folder
interfaces	31-Jan-19 20:20	File folder
models	14-Apr-19 16:20	File folder
navigation	14-Apr-19 15:54	File folder
singletons	31-Jan-19 20:17	File folder
views	16-Feb-19 15:04	File folder

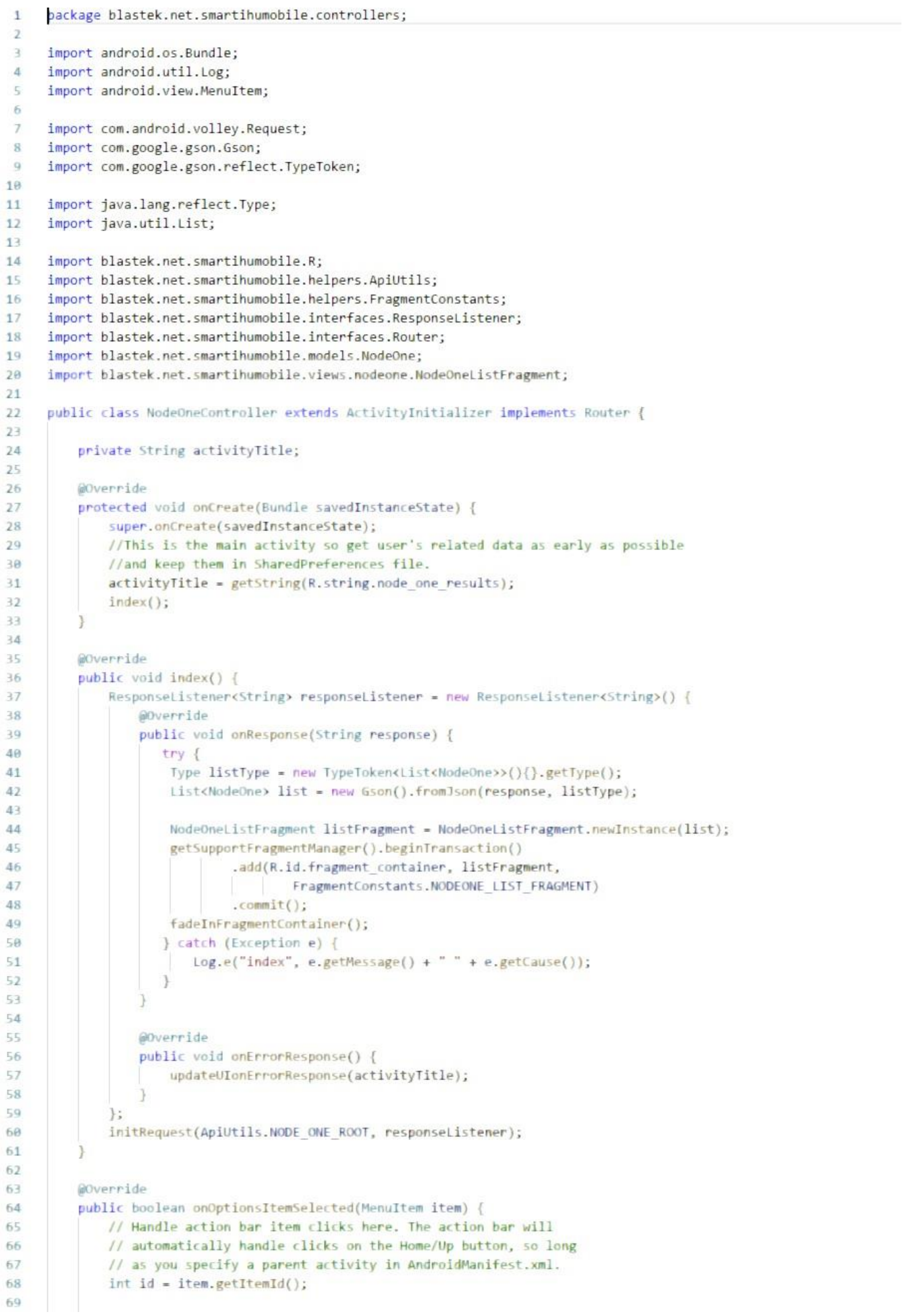
Picture 56: Mobile app file structure

- The *controllers* folder contain methods that call the API endpoints which are exposed by the Wordpress plugin. The controller files contain the *index()* method which calls the respective API which in turn returns the list of the nodes. The folder also contains the *ActivityInitializer*; a class which is extended by every controller and contains methods related to the User Interface and methods that initialize the requests.



```java
package blastek.net.smartihumobile.controllers;

import android.annotation.SuppressLint;
import android.content.Context;
import android.content.SharedPreferences;
import android.os.Bundle;
import android.os.Handler;
import android.support.v4.app.Fragment;
import android.support.v4.app.FragmentTransaction;
import android.support.v7.widget.Toolbar;
import android.view.View;
import android.widget.FrameLayout;
import android.widget.ProgressBar;
import android.widget.Toast;

import com.android.volley.Request;

import org.json.JSONObject;

import java.util.Map;

import blastek.net.smartihumobile.R;
import blastek.net.smartihumobile.helpers.ApiUtils;
import blastek.net.smartihumobile.interfaces.ResponseListener;
import blastek.net.smartihumobile.navigation.NavigationDrawerActivity;
import blastek.net.smartihumobile.singletons.VolleySingleton;

/**
 * Created by Blastblitz on 3/22/2018.
 */

@SuppressLint("Registered")
public class ActivityInitializer extends NavigationDrawerActivity {

    // Delay, in milliseconds, to be used in Runnables.
    private  static final int delay = 300;

    protected Map<String, String> apiHeaders;
    protected ProgressBar progressBar;
    protected FrameLayout fragmentContainer;
    protected Handler handler;
    protected Runnable progressIndicatorRunnable;

    @Override
    protected void init(Bundle savedInstanceState) {
        setContentView(R.layout.generic_nav_frame_activity);
        Toolbar toolbar = findViewById(R.id.toolbar);
        super.setDrawer(toolbar);
        progressBar = findViewById(R.id.progressBar);
        fragmentContainer = findViewById(R.id.fragment_container);
        // Check that the activity is using the layout version with
        // the fragment_container FrameLayout.
        if (fragmentContainer != null) {
            // However, if we're being restored from a previous state,
            // then we don't need to do anything and should return or else
            // we could end up with overlapping fragments.
            if (savedInstanceState != null) {
                return;
            }
            initUIProgressUtilities();
            // Get api headers from Shared Preferences.
            SharedPreferences apiPreferences = getSharedPreferences(ApiUtils.API_PREFERENCES, 0);
            apiHeaders = ApiUtils.getApiHeaders(apiPreferences);
        }
    }

    private void initUIProgressUtilities(){
        handler = new Handler();
        progressIndicatorRunnable = new Runnable() {
```

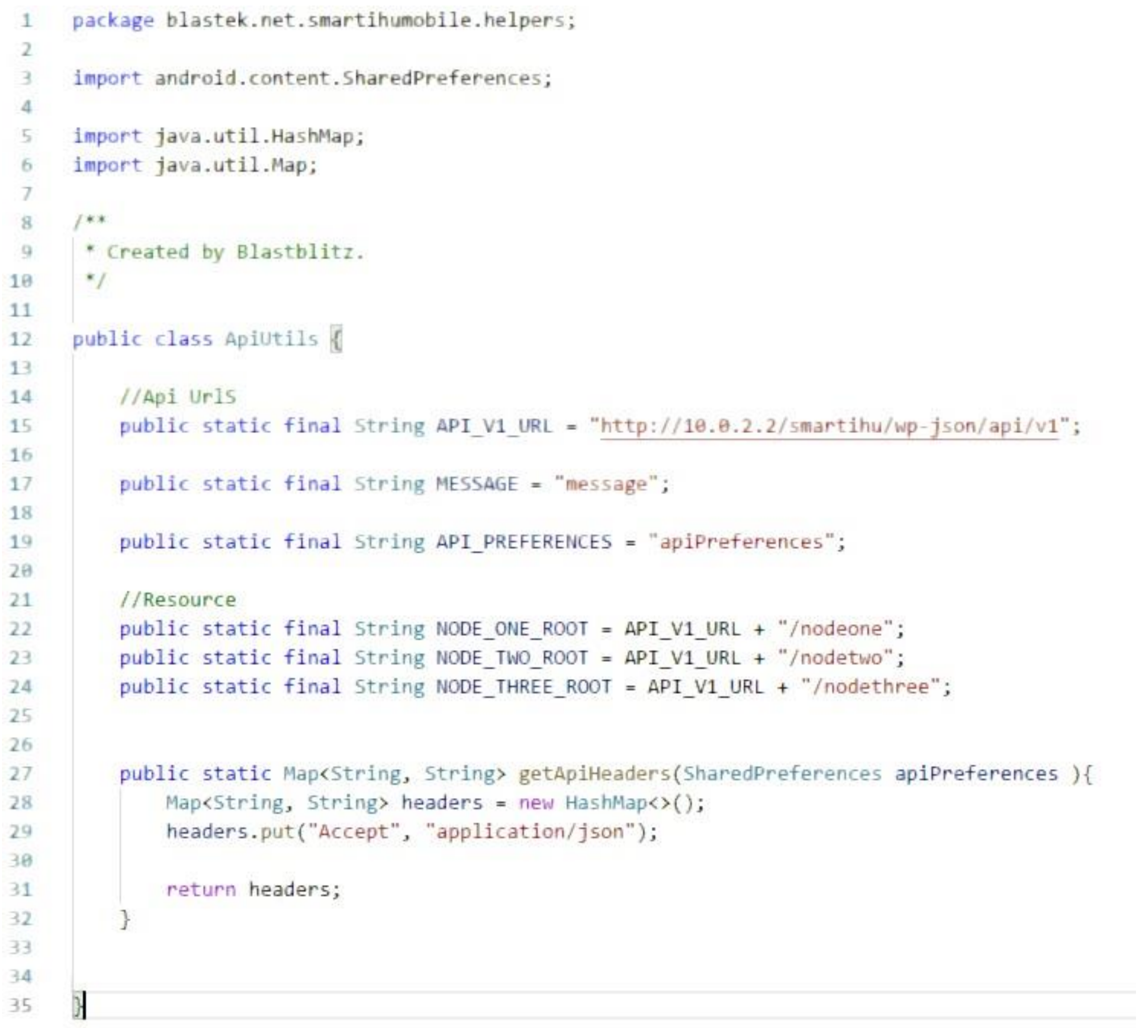
Picture 57: Sample picture of ActivityInitializer.java



```java
package blastek.net.smartihumobile.controllers;

import android.os.Bundle;
import android.util.Log;
import android.view.MenuItem;

import com.android.volley.Request;
import com.google.gson.Gson;
import com.google.gson.reflect.TypeToken;

import java.lang.reflect.Type;
import java.util.List;

import blastek.net.smartihumobile.R;
import blastek.net.smartihumobile.helpers.ApiUtils;
import blastek.net.smartihumobile.helpers.FragmentConstants;
import blastek.net.smartihumobile.interfaces.ResponseListener;
import blastek.net.smartihumobile.interfaces.Router;
import blastek.net.smartihumobile.models.NodeOne;
import blastek.net.smartihumobile.views.nodeone.NodeOneListFragment;

public class NodeOneController extends ActivityInitializer implements Router {

    private String activityTitle;

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        //This is the main activity so get user's related data as early as possible
        //and keep them in SharedPreferences file.
        activityTitle = getString(R.string.node_one_results);
        index();
    }

    @Override
    public void index() {
        ResponseListener<String> responseListener = new ResponseListener<String>() {
            @Override
            public void onResponse(String response) {
               try {
                Type listType = new TypeToken<List<NodeOne>>(){}.getType();
                List<NodeOne> list = new Gson().fromJson(response, listType);

                NodeOneListFragment listFragment = NodeOneListFragment.newInstance(list);
                getSupportFragmentManager().beginTransaction()
                        .add(R.id.fragment_container, listFragment,
                                FragmentConstants.NODEONE_LIST_FRAGMENT)
                        .commit();
                fadeInFragmentContainer();
               } catch (Exception e) {
                   Log.e("index", e.getMessage() + " " + e.getCause());
               }
            }

            @Override
            public void onErrorResponse() {
                updateUIonErrorResponse(activityTitle);
            }
        };
        initRequest(ApiUtils.NODE_ONE_ROOT, responseListener);
    }

    @Override
    public boolean onOptionsItemSelected(MenuItem item) {
        // Handle action bar item clicks here. The action bar will
        // automatically handle clicks on the Home/Up button, so long
        // as you specify a parent activity in AndroidManifest.xml.
        int id = item.getItemId();

```

Picture 58: Sample picture of NodeOneController.java

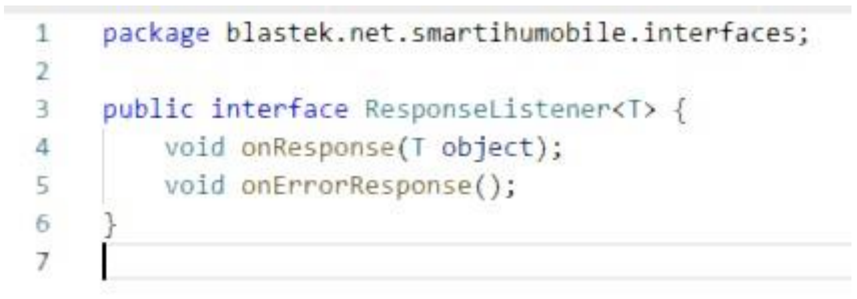
- The *helpers* folder contains classes with methods for the controllers, f.e. the *ApiUtils* class that contains the strings to the API endpoints and methods in order to set the headers for every request.



```java
package blastek.net.smartihumobile.helpers;

import android.content.SharedPreferences;

import java.util.HashMap;
import java.util.Map;

/**
 * Created by Blastblitz.
 */

public class ApiUtils {

    //Api Urls
    public static final String API_V1_URL = "http://10.0.2.2/smartihu/wp-json/api/v1";

    public static final String MESSAGE = "message";

    public static final String API_PREFERENCES = "apiPreferences";

    //Resource
    public static final String NODE_ONE_ROOT = API_V1_URL + "/nodeone";
    public static final String NODE_TWO_ROOT = API_V1_URL + "/nodetwo";
    public static final String NODE_THREE_ROOT = API_V1_URL + "/nodethree";


    public static Map<String, String> getApiHeaders(SharedPreferences apiPreferences ){
        Map<String, String> headers = new HashMap<>();
        headers.put("Accept", "application/json");

        return headers;
    }


}
```

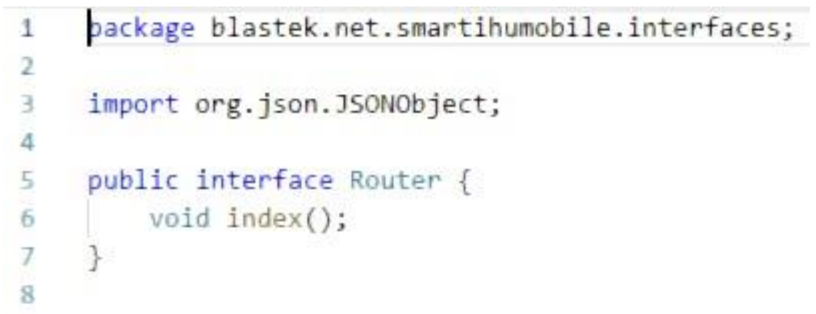
Picture 59: Sample helper file - ApiUtils.java

- The *interfaces* folder contains two interfaces which are implemented by the controllers.
    - The *ResponseListener* interface is executed at the end of the API requests
    - The *Router* interface contains an index() method for the service of the requests.



```java
package blastek.net.smartihumobile.interfaces;

public interface ResponseListener<T> {
    void onResponse(T object);
    void onErrorResponse();
}

```

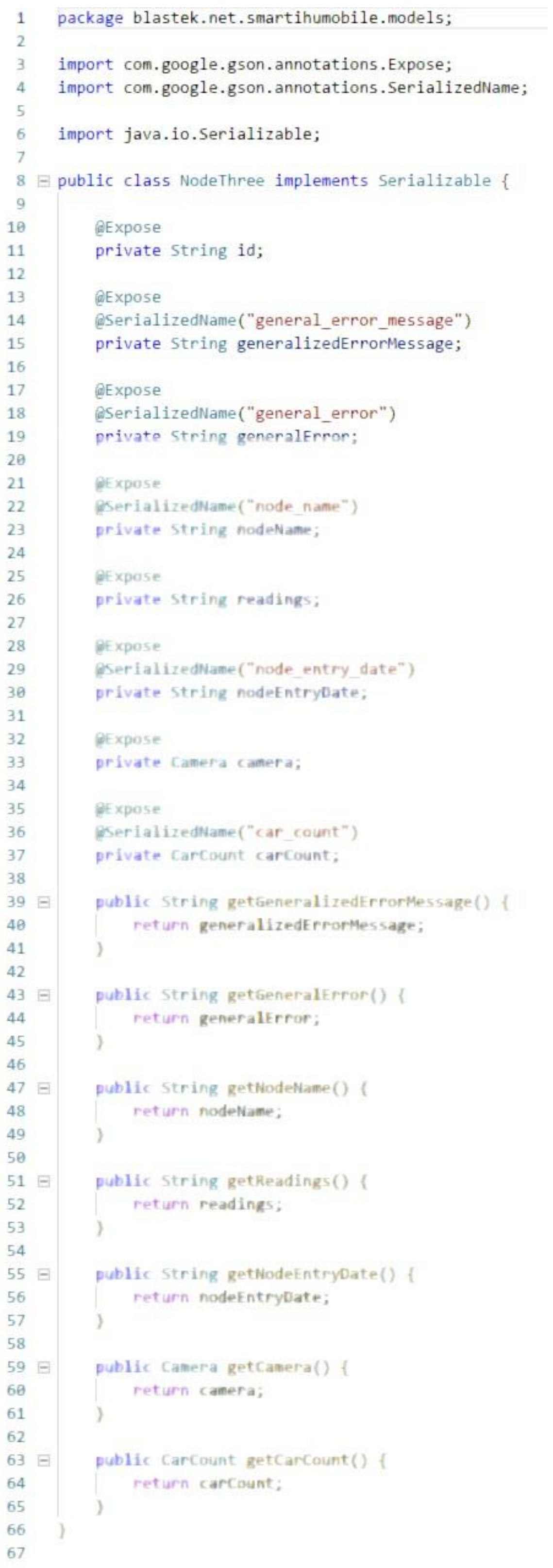
Picture 60: ResponseListener.java



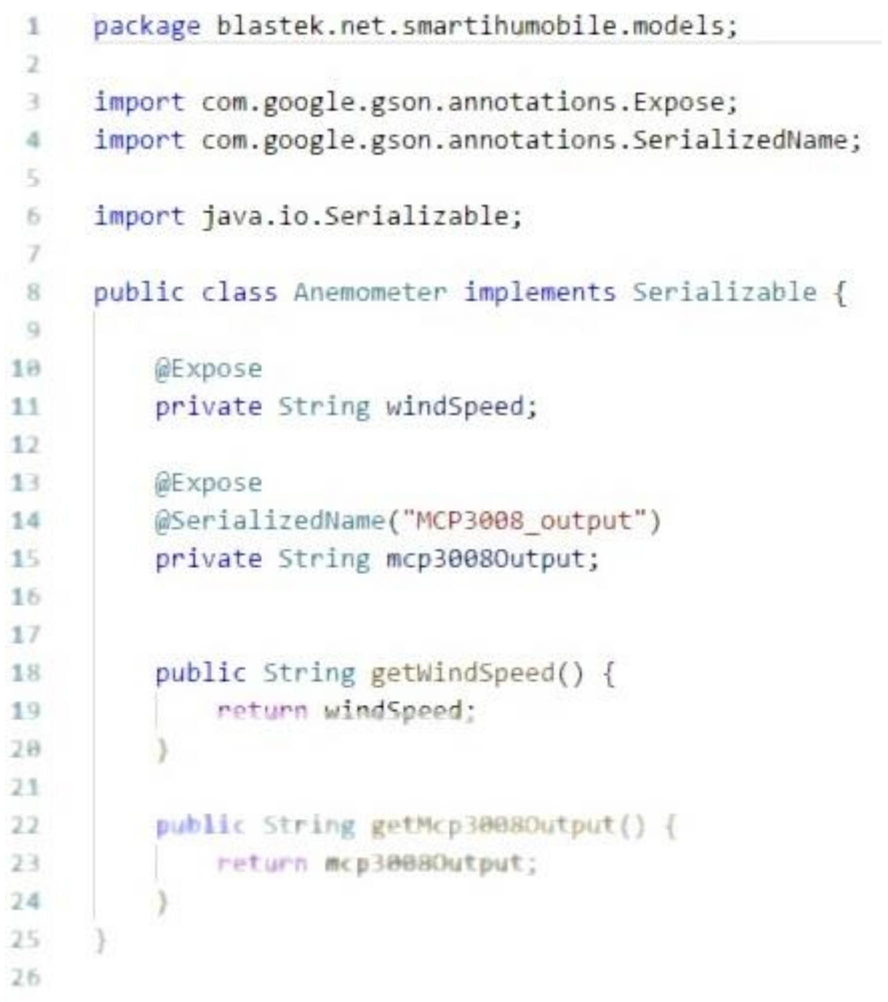
```java
package blastek.net.smartihumobile.interfaces;

import org.json.JSONObject;

public interface Router {
    void index();
}

```

Picture 61: Router.java

- The *models* folder contains the models of the nodes and the data fields for each node. The models have been created in a way that allows the data that have been returned from the APIs to be parsed by the Gson Library.


```java
package blastek.net.smartihumobile.models;

import com.google.gson.annotations.Expose;
import com.google.gson.annotations.SerializedName;

import java.io.Serializable;

public class NodeThree implements Serializable {

    @Expose
    private String id;

    @Expose
    @SerializedName("general_error_message")
    private String generalizedErrorMessage;

    @Expose
    @SerializedName("general_error")
    private String generalError;

    @Expose
    @SerializedName("node_name")
    private String nodeName;

    @Expose
    private String readings;

    @Expose
    @SerializedName("node_entry_date")
    private String nodeEntryDate;

    @Expose
    private Camera camera;

    @Expose
    @SerializedName("car_count")
    private CarCount carCount;

    public String getGeneralizedErrorMessage() {
        return generalizedErrorMessage;
    }

    public String getGeneralError() {
        return generalError;
    }

    public String getNodeName() {
        return nodeName;
    }

    public String getReadings() {
        return readings;
    }

    public String getNodeEntryDate() {
        return nodeEntryDate;
    }

    public Camera getCamera() {
        return camera;
    }

    public CarCount getCarCount() {
        return carCount;
    }
}
```

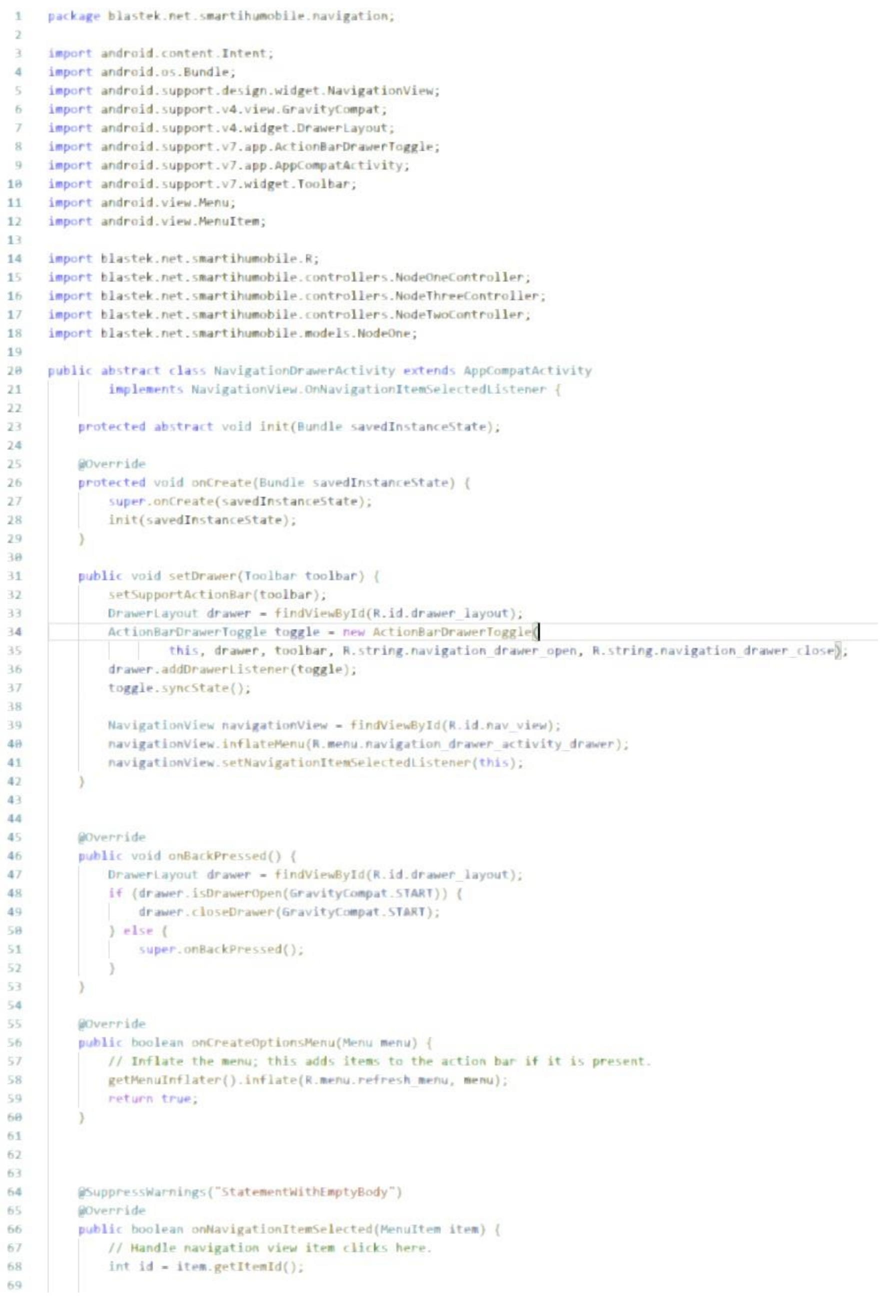
Picture 62: Sample NodeThree.java



```
package blastek.net.smartihumobile.models;

import com.google.gson.annotations.Expose;
import com.google.gson.annotations.SerializedName;

import java.io.Serializable;

public class Anemometer implements Serializable {

    @Expose
    private String windSpeed;

    @Expose
    @SerializedName("MCP3008_output")
    private String mcp3008Output;


    public String getWindSpeed() {
        return windSpeed;
    }

    public String getMcp3008Output() {
        return mcp3008Output;
    }
}

```

Picture 63: Anemometer.java

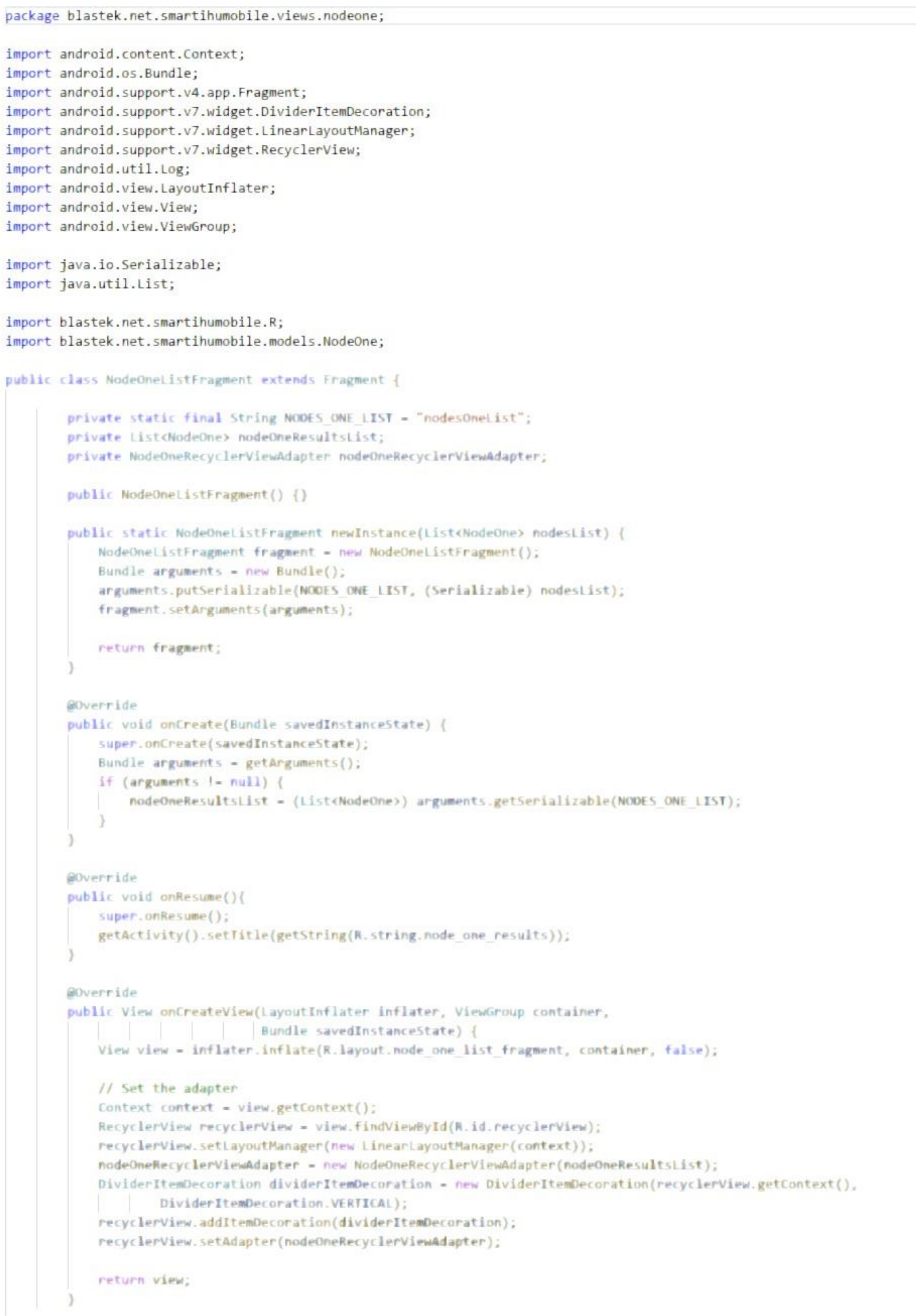
- The *navigation* folder contains a class that creates the navigation drawer.



```java
package blastek.net.smartihumobile.navigation;

import android.content.Intent;
import android.os.Bundle;
import android.support.design.widget.NavigationView;
import android.support.v4.view.GravityCompat;
import android.support.v4.widget.DrawerLayout;
import android.support.v7.app.ActionBarDrawerToggle;
import android.support.v7.app.AppCompatActivity;
import android.support.v7.widget.Toolbar;
import android.view.Menu;
import android.view.MenuItem;

import blastek.net.smartihumobile.R;
import blastek.net.smartihumobile.controllers.NodeOneController;
import blastek.net.smartihumobile.controllers.NodeThreeController;
import blastek.net.smartihumobile.controllers.NodeTwoController;
import blastek.net.smartihumobile.models.NodeOne;

public abstract class NavigationDrawerActivity extends AppCompatActivity
        implements NavigationView.OnNavigationItemSelectedListener {

    protected abstract void init(Bundle savedInstanceState);

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        init(savedInstanceState);
    }

    public void setDrawer(Toolbar toolbar) {
        setSupportActionBar(toolbar);
        DrawerLayout drawer = findViewById(R.id.drawer_layout);
        ActionBarDrawerToggle toggle = new ActionBarDrawerToggle(
                this, drawer, toolbar, R.string.navigation_drawer_open, R.string.navigation_drawer_close);
        drawer.addDrawerListener(toggle);
        toggle.syncState();

        NavigationView navigationView = findViewById(R.id.nav_view);
        navigationView.inflateMenu(R.menu.navigation_drawer_activity_drawer);
        navigationView.setNavigationItemSelectedListener(this);
    }


    @Override
    public void onBackPressed() {
        DrawerLayout drawer = findViewById(R.id.drawer_layout);
        if (drawer.isDrawerOpen(GravityCompat.START)) {
            drawer.closeDrawer(GravityCompat.START);
        } else {
            super.onBackPressed();
        }
    }

    @Override
    public boolean onCreateOptionsMenu(Menu menu) {
        // Inflate the menu; this adds items to the action bar if it is present.
        getMenuInflater().inflate(R.menu.refresh_menu, menu);
        return true;
    }



    @SuppressWarnings("StatementWithEmptyBody")
    @Override
    public boolean onNavigationItemSelected(MenuItem item) {
        // Handle navigation view item clicks here.
        int id = item.getItemId();

```

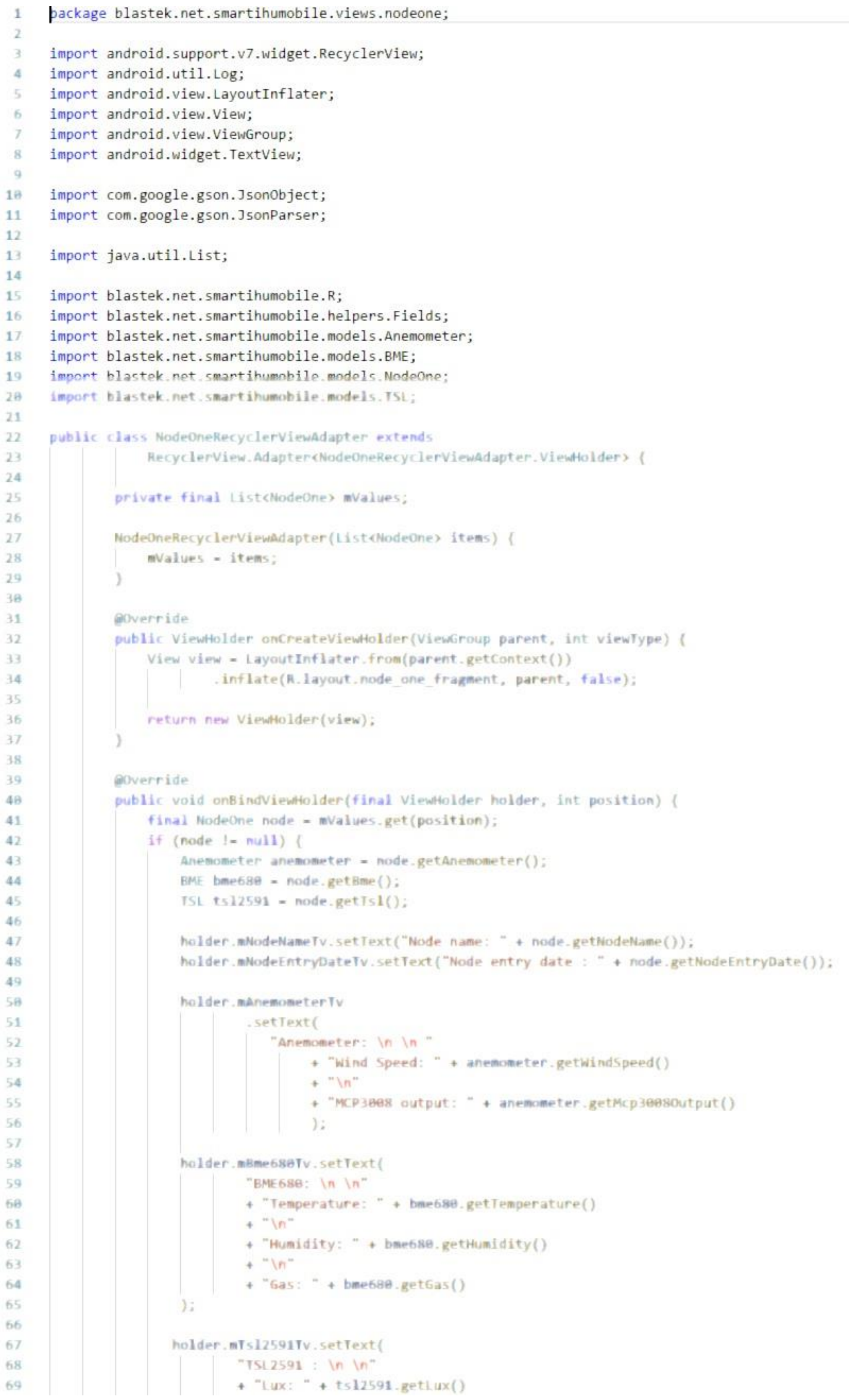
Picture 64: NavigationDrawer.java

- The *singletons* folder contains the VolleySingleton class which is the implementation of the Volley Library for HTTP requests. It was deemed preferable to use the Singleton pattern in order to have a single Volley instance for the whole application.
- Finally, the views folder contains classes that extend the fragment() class and contain methods for the projection of the nodes in lists with the use of RecycleViewAdapter().



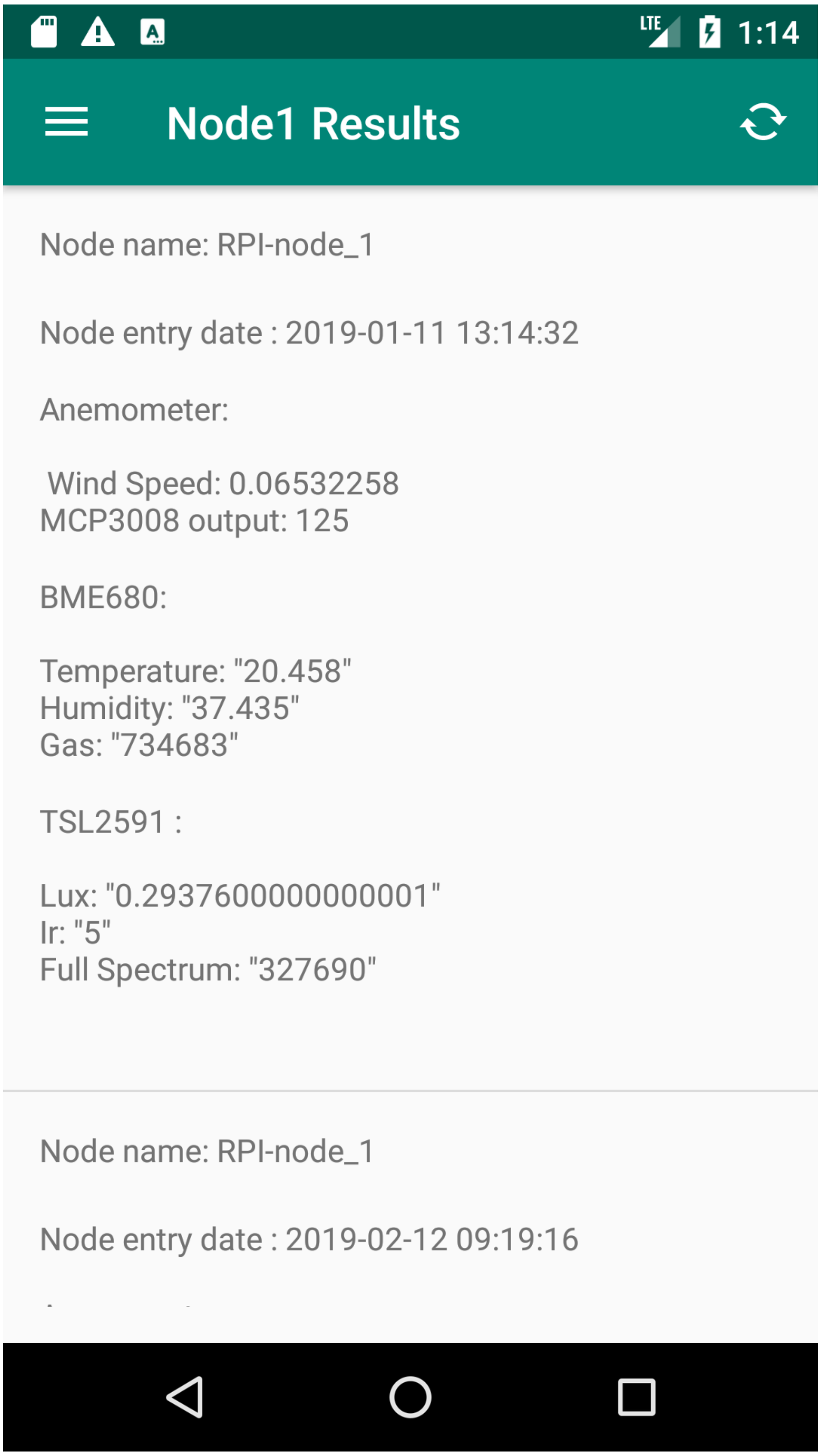
```java
package blastek.net.smartihumobile.views.nodeone;

import android.content.Context;
import android.os.Bundle;
import android.support.v4.app.Fragment;
import android.support.v7.widget.DividerItemDecoration;
import android.support.v7.widget.LinearLayoutManager;
import android.support.v7.widget.RecyclerView;
import android.util.Log;
import android.view.LayoutInflater;
import android.view.View;
import android.view.ViewGroup;

import java.io.Serializable;
import java.util.List;

import blastek.net.smartihumobile.R;
import blastek.net.smartihumobile.models.NodeOne;

public class NodeOneListFragment extends Fragment {

        private static final String NODES_ONE_LIST = "nodesOneList";
        private List<NodeOne> nodeOneResultsList;
        private NodeOneRecyclerViewAdapter nodeOneRecyclerViewAdapter;

        public NodeOneListFragment() {}

        public static NodeOneListFragment newInstance(List<NodeOne> nodesList) {
            NodeOneListFragment fragment = new NodeOneListFragment();
            Bundle arguments = new Bundle();
            arguments.putSerializable(NODES_ONE_LIST, (Serializable) nodesList);
            fragment.setArguments(arguments);

            return fragment;
        }

        @Override
        public void onCreate(Bundle savedInstanceState) {
            super.onCreate(savedInstanceState);
            Bundle arguments = getArguments();
            if (arguments != null) {
                nodeOneResultsList = (List<NodeOne>) arguments.getSerializable(NODES_ONE_LIST);
            }
        }

        @Override
        public void onResume(){
            super.onResume();
            getActivity().setTitle(getString(R.string.node_one_results));
        }

        @Override
        public View onCreateView(LayoutInflater inflater, ViewGroup container,
                                 Bundle savedInstanceState) {
            View view = inflater.inflate(R.layout.node_one_list_fragment, container, false);

            // Set the adapter
            Context context = view.getContext();
            RecyclerView recyclerView = view.findViewById(R.id.recyclerView);
            recyclerView.setLayoutManager(new LinearLayoutManager(context));
            nodeOneRecyclerViewAdapter = new NodeOneRecyclerViewAdapter(nodeOneResultsList);
            DividerItemDecoration dividerItemDecoration = new DividerItemDecoration(recyclerView.getContext(),
                    DividerItemDecoration.VERTICAL);
            recyclerView.addItemDecoration(dividerItemDecoration);
            recyclerView.setAdapter(nodeOneRecyclerViewAdapter);

            return view;
        }
```

Picture 65: Sample NodeOneListFragment.java



```java
package blastek.net.smartihumobile.views.nodeone;

import android.support.v7.widget.RecyclerView;
import android.util.Log;
import android.view.LayoutInflater;
import android.view.View;
import android.view.ViewGroup;
import android.widget.TextView;

import com.google.gson.JsonObject;
import com.google.gson.JsonParser;

import java.util.List;

import blastek.net.smartihumobile.R;
import blastek.net.smartihumobile.helpers.Fields;
import blastek.net.smartihumobile.models.Anemometer;
import blastek.net.smartihumobile.models.BME;
import blastek.net.smartihumobile.models.NodeOne;
import blastek.net.smartihumobile.models.TSL;

public class NodeOneRecyclerViewAdapter extends
        RecyclerView.Adapter<NodeOneRecyclerViewAdapter.ViewHolder> {

    private final List<NodeOne> mValues;

    NodeOneRecyclerViewAdapter(List<NodeOne> items) {
        mValues = items;
    }

    @Override
    public ViewHolder onCreateViewHolder(ViewGroup parent, int viewType) {
        View view = LayoutInflater.from(parent.getContext())
                .inflate(R.layout.node_one_fragment, parent, false);

        return new ViewHolder(view);
    }

    @Override
    public void onBindViewHolder(final ViewHolder holder, int position) {
        final NodeOne node = mValues.get(position);
        if (node != null) {
            Anemometer anemometer = node.getAnemometer();
            BME bme680 = node.getBme();
            TSL tsl2591 = node.getTsl();

            holder.mNodeNameTv.setText("Node name: " + node.getNodeName());
            holder.mNodeEntryDateTv.setText("Node entry date : " + node.getNodeEntryDate());

            holder.mAnemometerTv
                    .setText(
                       "Anemometer: \n \n "
                            + "Wind Speed: " + anemometer.getWindSpeed()
                            + "\n"
                            + "MCP3008 output: " + anemometer.getMcp3008Output()
                            );

            holder.mBme680Tv.setText(
                    "BME680: \n \n"
                    + "Temperature: " + bme680.getTemperature()
                    + "\n"
                    + "Humidity: " + bme680.getHumidity()
                    + "\n"
                    + "Gas: " + bme680.getGas()
            );

           holder.mTsl2591Tv.setText(
                   "TSL2591 : \n \n"
                   + "Lux: " + tsl2591.getLux()
```

Picture 66: Sample NodeOneRecyclerViewAdapter.java



1:14

Node1 Results

Node name: RPI-node_1

Node entry date : 2019-01-11 13:14:32

Anemometer:

Wind Speed: 0.06532258
MCP3008 output: 125

BME680:

Temperature: "20.458"
Humidity: "37.435"
Gas: "734683"

TSL2591 :

Lux: "0.29376000000000001"
Ir: "5"
Full Spectrum: "327690"

Node name: RPI-node_1

Node entry date : 2019-02-12 09:19:16

Picture 67: Sample picture of Node1 results in the mobile app

6 Inspirational Projects

The idea behind this project was conceived earlier this year, but it didn't come out of nowhere. There are currently many other IoT projects that are being developed in a larger scale and are playing a crucial role to the betterment of the lives of citizens around the world. The writer of this dissertation also works as a developer in one. It is only fair that honorable mention is made to some of the projects that kicked this project into life, proved inspiring and ultimately helped in its completion.

6.1 DUT – "Smart University Campus"

The Democritus University of Thrace in cooperation with COSMOTE was the first university in Greece to launch a "Smart University Campus" located in Xanthi[30]. The project makes use of the Narrow-Band Internet of Things (NB-IoT). It is considered a pilot program that takes full advantage of the capabilities of NB-IoT technology, thus managing to promote solutions via smart applications around the campus.

Picture 68: DUT – The first Greek "Smart University Campus"

More specifically, the following solutions were implemented:

- Air Quality Monitoring: special sensors for air quality measurement were installed; the measurements include real-time temperature, humidity, pressure, various gases and particles. They also enable optimal design and implementation of appropriate actions for the reduction of atmospheric pollution.

- Smart Tank Fuel Management: This application makes use of a gas oil level meter which has been installed in order to prevent over-consumption, fuel theft and valuation of invoices. The application is based on the solution provided by the Greek company Fuelics and is being implemented in cooperation with Ericsson.
- Water Quality Measurement: Ensures the quality of drinking water at the campus and is being implemented in collaboration with Greek company Wings.
- Smart Lighting: makes use of NB-IoT technology in order to provide assistance with light adaption depending on the season and time of day in order to drastically reduce power consumption.

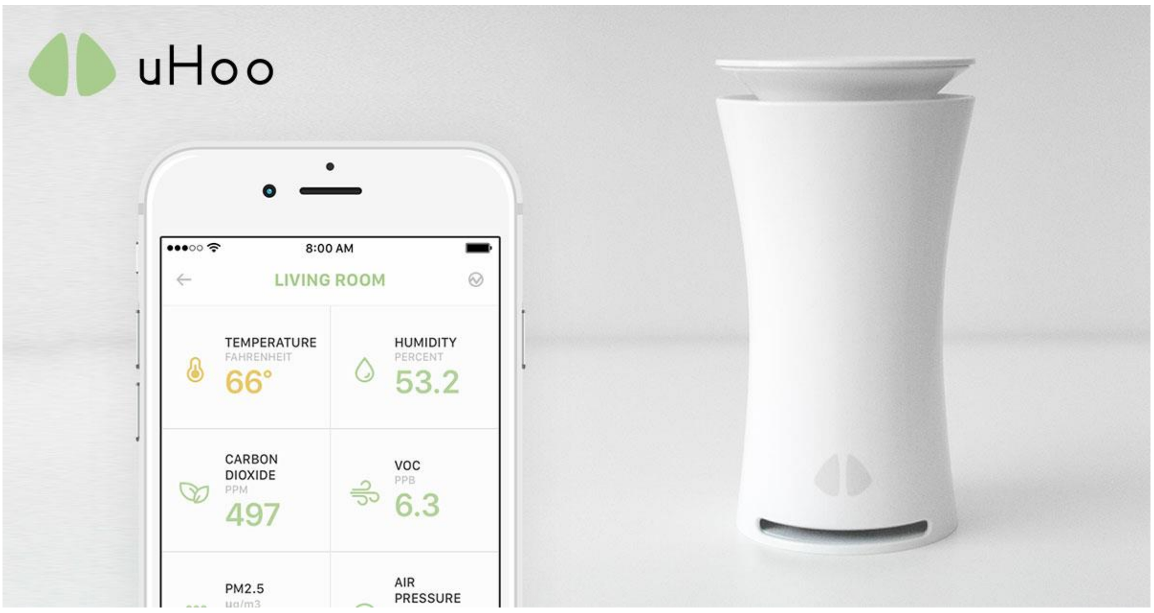
The use of the NB-IoT technology provides an easier and more-cost effective interconnection between network devices as no special equipment is required. This technology also offers better indoor coverage since it makes use of a mobile telephony network and is considered to be superior to other IoT technologies in terms of quality and safety.

6.2 The ICARUS Project

ICARUS is a project funded from the European Union’s Horizon 2020 Research and Innovation programme[31]. Its main objective is to develop integrated tools and strategies for urban impact assessment in support of air quality and climate change governance in EU Member States leading to the design and implementation of appropriate abatement strategies to improve the air quality and reduce the carbon footprint in European cities. The project will develop detailed policies and measures for air pollution and climate control for the short and medium term (until ca. 2030). For the long term perspective (2050 and beyond) ICARUS will develop visions of green cities and explore pathways on how to start realizing these visions.

The ICARUS project boasts a detailed webpage where the whole scope of the project is explained in detailed, along with deliverables, newsletters, news and events, as well as a forum where citizens and scientists alike may discuss ongoing research or concerns regarding environmental issues.

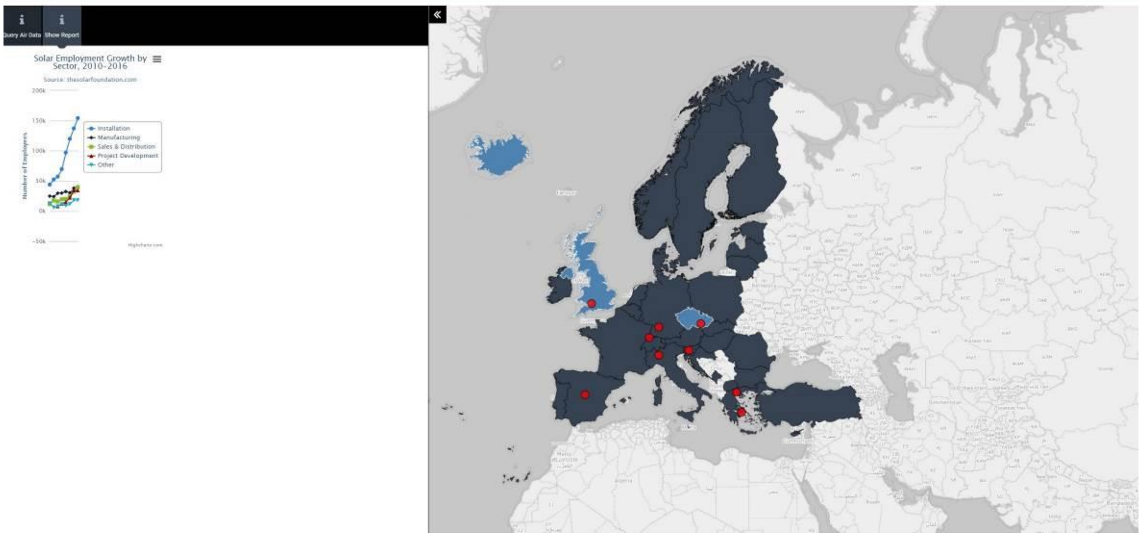
The ICARUS project has held campaigns in most of Europe’s major cities, where volunteers make use of sensors in their households and their every-day life in order to measure environmental data that will assist in improving the environmental conditions in the long run. Namely, every household that participated in a campaign made use of a uHoo household sensor, while every volunteer used a Garmin vivosmart watch every day for a week while performing their daily routine. Data gathered by the sensors is exported via a data portal developed by UPCOM and then is made available to scientists for further analysis.



Picture 69: Sample picture of the uHoo household sensor and the uHoo app

Picture 70: Sample picture of a Garmin vivosmart used in the ICARUS project

ICARUS will also deliver a Decision Support System (DSS), a web-based, flexible and interactive platform aimed at assisting stakeholders in the selection, application and evaluation of the available datasets and tools for urban impact assessment in support of air quality and climate change governance at different spatial and temporal scales and taking into account the specific regulatory context.



Picture 71: Sample picture of the ICARUS DSS platform

Finally, the ICARUS project is currently developing a mobile application, the ICARUS UCT (User-Centric-Tools), essentially a platform where every user may register daily activities such as walking, jogging, running, driving their car, as well as track activities like recycling, waste management or other tasks that are related to environmental awareness.

The proposed integrated system deployment and application in several cities across Europe is expected to have a positive impact on local society and the economy contributing to lower the health costs associated to environmental burden.

7 Conclusions

The final chapter of this dissertation aims to provide some insight on the project and its impact on the author, his colleagues and the campus. It describes the reasons why this project was undertaken, the process, the journey, the impact the data can have, as well as the problems that arose along the way, or even before it even started.

7.1 The Internet of Things

After this journey has come to its end, it is the author’s belief that the Internet of Things already has a significant impact on the world and ultimately, it is the future. From households to offices, from small towns to large cities, from manufacturing to transportation, from healthcare to the environment, from agriculture to energy, the technology of the Internet of Things has found its way into everyone’s daily life. As of today, billions of devices are connected to the internet and keep producing data that can be used to change the lives of every citizen across the world for the better. This technology was used for this project with the aim of producing environmental data that will help better the lives of every guest, student, staff and faculty that spends a good portion of their day in the International Hellenic University.

7.2 The Nodes and the Network

The setup of the nodes and the sensor network proved to be a unique experience. The hands-on approach on this part of the project helped the author gain good knowledge of how the sensors and the network operate. It also went a long way to show how a cheap and affordable product like the Raspberry Pi can prove to be a powerful asset when used correctly.

7.3 Environmental Data

The data gathered in this project will be of immense value for the IHU for a variety of reasons. Firstly, it can determine the environmental conditions around the campus area;

that way the administration can take steps to improve indoor conditions based on the data of the classroom sensor. The weather station provides the university with meteorological data as well as environmental quality data which can be used by the IHU itself in other projects, or can be provided to stakeholders of other projects for scientific research.

7.4 Development

The development of this project, web and mobile, has assisted the author in various way. Web development helped him gain a better understanding of the Bootstrap4 theme, while the plugin development proved quite challenging. The greatest benefit was gained from the mobile development since the author had no prior experience in the specific field.

7.5 Problems and hindrances

From the author’s point of view, the most serious of problems occurred with the arrival of the sensor parts. Due to the fact that the majority of these parts are manufactured abroad and for bureaucratic reasons regarding their order, the amount of time lost on this process took a huge toll in the time it took for the project to complete. Another problem that occurred was the fact that the sensors appear to be quite fragile. Several of them arrived damaged and were thus deemed inoperable which resulted in more delays and time lost.

7.6 The future of the project

The project still appears to have a lot of potential. From the author's view, every aspect of it can be expanded and improved. The network will benefit from the addition of more sensors that can enhance its effectiveness and the impact it has on the campus grounds. Network security can be enhanced in order to prevent any malicious attempts to exploit the nodes. The webpage can be enriched with more sections and attract even more visitors who can gain a better understanding of the value of the Internet of Things as a technology. The mobile application can be improved as well, with an iOS version being the next step.

Bibliography

[1] A. Gabbai, "SMITHSONIAN MAGAZINE," January 2015. [Online]. Available: https://www.smithsonianmag.com/innovation/kevin-ashton-describes-the-internet-of-things-180953749/. [Accessed 9 December 2018].

[2] S. Greengard, The Internet of Things, Cambridge: MA: MIT Press, 2015.

[3] P. Waher, Learning the Internet of Things, Birmingham - Mumbai: PACKT Publishing, 2015.

[4] S. V. K. S. Divya Sharma, "Network Topologies in Wireless Sensor Networks: A Review," *International Journal of Electronics & Communication Technology,* vol. 4, no. Spl - 3, p. 5, 2013.

[5] R. P. FOUNDATION, "Raspberry Pi 3 Model B+," Aardman and Studiocanal SAS, Cambridge, UK, 2019.

[6] W. L. -. M. Services, "Stevenson Screen," WeatherOnline, London, UK, 2018.

[7] Adafruit, "ADAFRUIT PERMA-PROTO FULL-SIZED BREADBOARD PCB," Adafruit, [Online]. Available: https://www.adafruit.com/product/590. [Accessed 9

December 2018].

[8] Adafruit, "ADAFRUIT PERMA-PROTO HALF-SIZED BREADBOARD PCB," Adafruit, [Online]. Available: https://www.adafruit.com/product/571. [Accessed 9 December 2018].

[9] Adafruit, "ADAFRUIT TSL2591 HIGH DYNAMIC RANGE DIGITAL LIGHT SENSOR," [Online]. Available: https://www.adafruit.com/product/1980. [Accessed 9 December 2018].

[10] Adafruit, "RGB LCD SHIELD KIT W/ 16X2 CHARACTER DISPLAY," [Online]. Available: https://www.adafruit.com/product/714. [Accessed 9 December 2018].

[11] Adafruit, "LOCK-STYLE SOLENOID - 12VDC," [Online]. Available: https://www.adafruit.com/product/1512. [Accessed 9 December 2018].

[12] Adafruit, "ANEMOMETER WIND SPEED SENSOR W/ANALOG VOLTAGE OUTPUT," [Online]. Available: https://www.adafruit.com/product/1733. [Accessed 9 December 2018].

[13] Adafruit, "ADAFRUIT BME680 - TEMPERATURE, HUMIDITY, PRESSURE AND GAS SENSOR," [Online]. Available: https://www.adafruit.com/product/3660. [Accessed 9 December 2018].

[14] Espruino, "MFRC522 NFC/RFID module," [Online]. Available: https://www.espruino.com/MFRC522. [Accessed 9 December 2018].

[15] Adafruit, "ADAFRUIT SGP30 AIR QUALITY SENSOR BREAKOUT - VOC AND ECO2," [Online]. Available: https://www.adafruit.com/product/3709. [Accessed 9 December 2018].

[16] Adafruit, "ADAFRUIT PERMA-PROTO QUARTER-SIZED BREADBOARD PCB," [Online]. Available: https://www.adafruit.com/product/589. [Accessed 9 Decemberr 2018].

[17] Adafruit, "WEATHERPROOF TTL SERIAL JPEG CAMERA WITH NTSC VIDEO AND IR LEDS," [Online]. Available: https://www.adafruit.com/product/613. [Accessed 9 December 2018].

[18] https://www.adafruit.com/product/164, "IR DISTANCE SENSOR INCLUDES

CABLE (10CM-80CM)," [Online]. Available: https://www.adafruit.com/product/164. [Accessed 9 December 2018].

[19] Adafruit, "PIR Motion Sensor - An overview," [Online]. Available: https://learn.adafruit.com/pir-passive-infrared-proximity-motion-sensor/overview. [Accessed 9 December 2018].

[20] Adafruit, "ADAFRUIT PERMA-PROTO HAT FOR PI MINI KIT," [Online]. Available: https://www.adafruit.com/product/2310. [Accessed 9 December 2018].

[21] J. B. C. B. J. J. I. K. Benjamin Mako Hill, The Official Ubuntu Book: Introducing Ubuntu, Prentice Hall, 2006.

[22] G. B, "What is Apache? An In-Depth Overview of Apache Web Server," Hostinger, 18 January 2018. [Online]. Available: https://www.hostinger.com/tutorials/what-is-apache. [Accessed 29 March 2019].

[23] S. Morris, "Everything you need to know about PHP," Skillcrush, Inc., 25 October 2018. [Online]. Available: https://skillcrush.com/2012/04/11/php/. [Accessed 08 October 2019].

[24] O. Corporation, "What is MySQL?," 04 October 2019. [Online]. Available: https://dev.mysql.com/doc/refman/8.0/en/what-is-mysql.html. [Accessed 8 October 2019].

[25] S. Gordiyenko, "Website Development Process," XB Software Blog, 14 December 2015. [Online]. Available: https://xbsoftware.com/blog/website-development-process-full-guide/. [Accessed 9 October 2019].

[26] edureka, "Everything you Need to Know About PHPStorm," edureka!, 19 September 2019. [Online]. Available: https://www.edureka.co/blog/phpstorm. [Accessed 9 October 2019].

[27] p. team, "Bringing MySQL to the web," phpMyAdmin team, 9 September 2019. [Online]. Available: https://docs.phpmyadmin.net/en/latest/. [Accessed 9 October 2019].

[28] P. Ganesan, " What is XAMPP," WPBlogX, 16 October 2017. [Online]. Available: https://www.wpblogx.com/what-is-xampp/. [Accessed 9 October 2019].

[29] G. B., "What is WordPress? An Overview of the World’s Most Popular CMS,"

hostinger.com, 18 January 2019. [Online]. Available: https://www.hostinger.com/tutorials/what-is-wordpress. [Accessed 9 October 2019].

[30] COSMOTE, "Democritus University of Thrace: The first “smart university campus” in Greece using NBIoT technology," COSMOTE, 9 August 2018. [Online]. Available: https://www.cosmote.gr/cs/business/en/new_dimokriteio.html.

[31] EnveLab, "ICARUS - Integrated Climate forcing and Air pollution Reduction in Urban Systems," HORIZON EU 2016-2020, 9 January 2016. [Online]. Available: http://www.enve-lab.eu/index.php/work/icarus/. [Accessed 9 October 2019].

Appendix A

Project tools

- PHPStorm
- XAMPP
- phpMyAdmin
- Wordpress
- Google Android Studio