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Water Leak Project

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1 Acknowledgment

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2 Introduction

Over the last decades, the issue of water loss, particularly in France, has reached a critical point. Key statistics underscore the urgency of implementing a water leak detection system in our homes in the coming years:

- As of 2023, an alarming 20% of water is currently lost due to water leaks within the country.
- The cumulative loss over the past 13 years totals a staggering 1.1 trillion cubic meters of water, equivalent to the annual consumption of 700,000 households.
- Even a minor water leak can result in costs ranging from 160 to 2800 euros per year.

These statistics go beyond numbers; they represent a tangible problem for both the economy and the environment. The substantial loss of water, both financially and environmentally, emphasizes the urgent need for action. Water, a precious resource, is being lost at an alarming rate through leaks, necessitating a comprehensive solution.

The implementation of a water leak detection system might soon become mandatory, given that 78% of current houses in France have already experienced the impact of water leaks. While this system may not entirely prevent leaks, it can significantly minimize the resulting damages.

3 Objectives

3.1 Context

The project aims to make a system that can quickly spot water leaks in homes and warn users early, however, making this happen faces challenges.

One challenge is figuring out how to combine advanced sensors and smart algorithms in a way that makes it easy for the system to find leaks fast. The main issue is to ensure the system works well in different homes and quickly catches any leaks.

Another challenge is making sure the system is accurate in detecting leaks without giving too many false alarms. Solving these problems is crucial to creating a strong solution that helps prevent water loss in houses.

3.2 Proposed solution and specification

The proposed solution for addressing water leaks involves developing an intelligent system equipped with advanced sensors and analytical algorithms. The system's primary goal is to provide early warnings to homeowners when a water leak is detected. To achieve this, the system will include a microprocessor managing detection algorithms, a database for storing data accessible to users and administrators, a Wi-Fi modem for transferring sensor data to the database, a generator for power, and a water flow sensor for gathering information about water usage. The chosen architecture aims to create a comprehensive solution that integrates into homes. This system is not only about detecting leaks; it is designed to minimize damages by identifying potential issues as early as possible.

3.3 Organisation

As for our way of working, we have implemented an agile method based on Scrum. This method is based on iterative and incremental processes and on the iteration of conception, programming and test.

We've developed small pieces of the project that bring value and validated them before moving on to the next. We've started by prioritizing the tasks to be done. Then by sprints of a two week period, we've set a list of objectives to complete.

At the end of each sprint, we would do a sprint retrospective where we would analyze and discuss the achieved work and start another sprint with new tasks or overflowing ones.

We have also had meetings with William Perez to discuss his needs, in order to discuss technical matters and get a more experienced perspective. We didn't hesitate to ask for help from other INSA's professors as well.

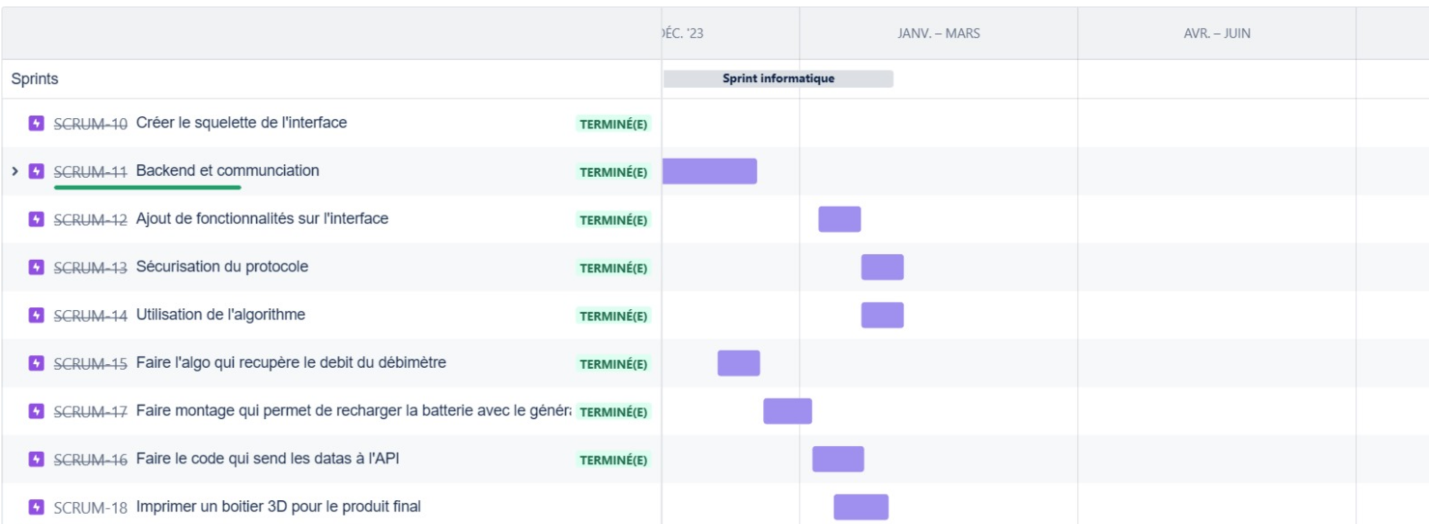

Figure 1: Organisation of the project

4 General design

To answer the problematic, we imagined a first architecture solution. We have to define an architecture that can respond to our problems, and provide a real solution.

The idea of the architecture is the following:

- **A microprocessor**, that manages an algorithm that can detect a potential leak and processes data
- **A database**, that can store all the data, and is accessible at any moment by users and admins
- **A Wi-Fi** modem that can transfer data from the sensor to the chip to the database.
- **A generator** that we place in the pipe and creates energy for all the system
- **A sensor** that can collect information about the water flow

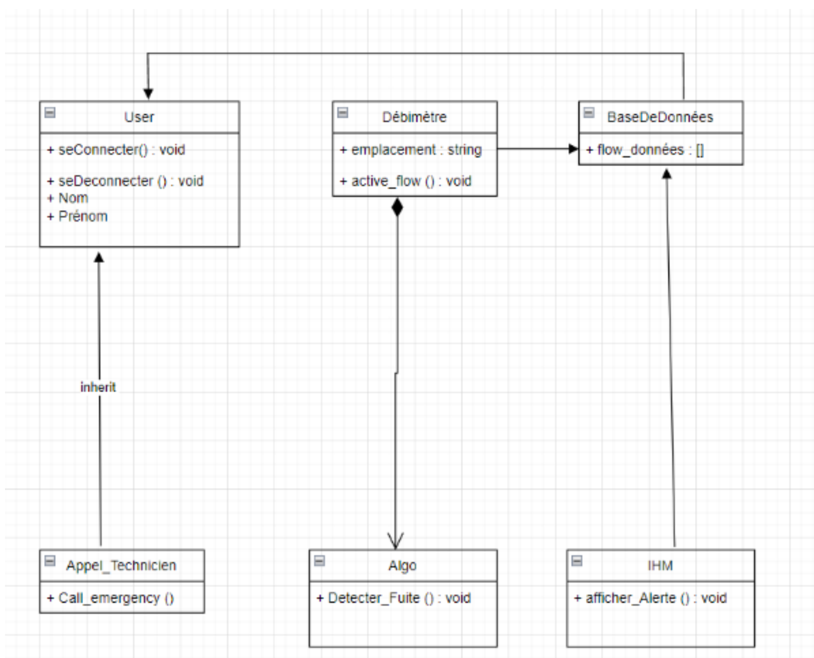

Figure 2: UML composition diagram

Foremost, we needed to determine which technology of communication to use for the communication between our system and the API. This is what we will see in the next part.

5 Communication technology study

To determine which protocol to use between the system and the gateway, we first reviewed all the following constraints :

- The system is located in an isolated area, in the entrance of the house in the basement.
- To ensure system autonomy, we focus on energy efficiency, optimizing power usage, and exploring energy harvesting.
- The system proposed must cost less than €100.
- We need a network that is secure enough so that the data cannot be intercepted by anyone. Because people with bad intentions could misuse it.

	Wi-Fi	Bluetooth
Range	Up to 100 FT	30 FT
Connectivity	Up to 10	One device
Bit Rate	600 Mbps	2.1 Mbps
Quality	Range	2.1 Mbps

Figure 3: Wi-Fi vs Bluetooth

Bluetooth and Wi-Fi are both wireless communication technologies, each with its own set of characteristics.

Bluetooth is known for short-range communication, typically within a range of about 10 meters. It's commonly used for connecting devices like headphones, speakers, and smartphones.

On the other hand, Wi-Fi provides a broader range, often reaching up to 100 meters or more, making it suitable for larger coverage areas.

In our project, we opted for Wi-Fi to send data from our system to the API. This decision was driven by the need for a more extended range, especially since our system will be located at the entrance of the house in the basement. Wi-Fi's larger coverage area aligns well with our project requirements, ensuring effective data transmission over a more significant distance.

6 Final Architecture

Finally, here is a diagram of our final architecture :

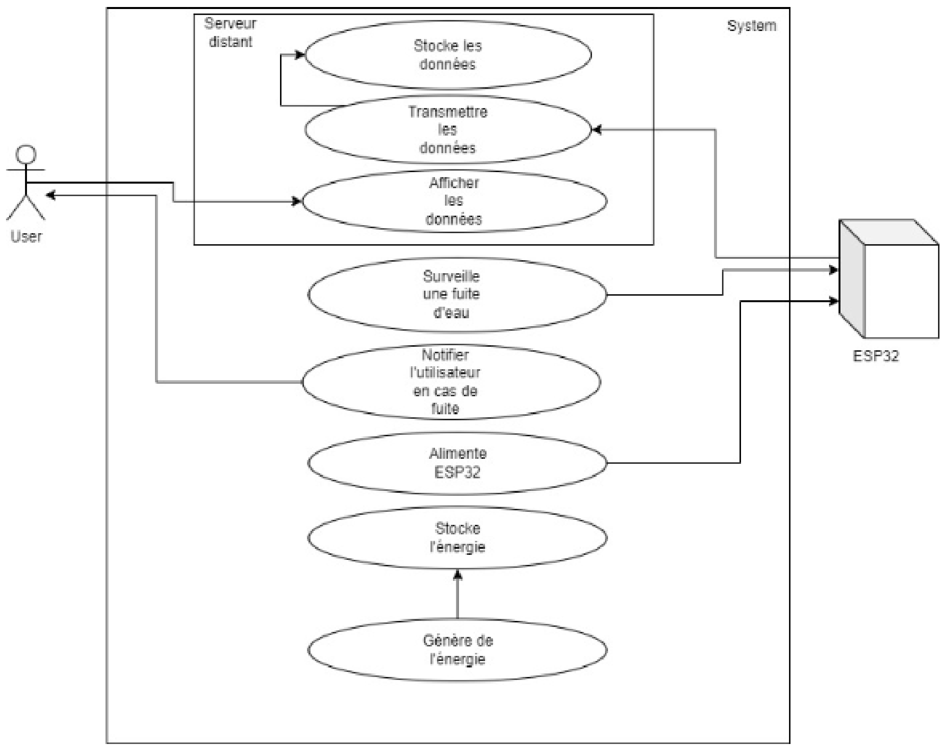

Figure 4: UML use case diagram

7 Water leak system

We employ an ESP32-C6, responsible for controlling all components with a single microcontroller.

The ESP32-C6 manages our energy management algorithm and continuously reads the sensor value. Then, It transmits this information to the API every 5 minutes.

Finally, the API's algorithm takes charge of water leak detection, alerting the system user to a potential water leak in the house's pipeline.

7.1 Choice of components

7.1.1 Sensor

We had limited options for the sensor due to budget constraints, choosing between the RS Pro module and the Kyro G3 module from Amazon.

Initially, we ordered from RS, but encountered issues as the sensor was non-functional. Consequently, we opted for the Kyro G3 module from Amazon.

7.1.2 ESP32-C6

We opted for the ESP32-C6-DevKitC-1-N8 microcontroller in our project for several reasons. This board is compatible with Wi-Fi technology. The ESP32-C6 provides a budget-friendly solution, which is essential considering the financial limitations of our project.

Finally, the ESP32-C6 proves to be a well-suited and economical choice for our smart water leak detection system.

7.1.3 Hydraulic Generator

To ensure the autonomy of our system, we integrated the Micro Hydraulic Generator DC 5V 12V. This hydraulic generator serves as a crucial component for providing a stable power source to our system.

With the ability to generate DC power in the range of 5V to 12V, it plays an important role in sustaining the operations of our smart water leak detection system, making it self-sufficient in terms of power supply.

7.1.4 Battery

We opted for the RS PRO 3.7V 2Ah Lithium Polymer Accumulator to power our ESP32-C6 board due to several compelling reasons : This lithium-polymer battery offers a balance between voltage and capacity, providing a stable power source suitable for our system's requirements. With a capacity of 2Ah, it ensures a prolonged operational life between charges, enhancing the autonomy of our smart water leak detection system.

7.1.5 Regulator Module

An oversight in our component selection led to the purchase of a 12V hydraulic generator instead of the required 5V for powering the ESP32-C6.

To rectify this, we procured the DollaTek DC-DC Power Module, a versatile regulator with adjustable output (5V, 12V, 24V) and a 3A current capacity. This module serves as a crucial intermediary, enabling us to convert the output from the 12V hydraulic generator to the 5V required by the ESP32-C6.

7.1.6 Battery charging

To facilitate battery charging within our system, we acquired the APKLVSR USB Type C Input Interface 5V 1A 18650 Lithium Battery Charger Module.

This module not only recharges the battery but it also has dual protection functions, ensuring the safety and longevity of the lithium battery.

8 Test phase

In this phase of the project we faced some difficulties, particularly in terms of practicality. Conducting tests involved the use of water containers to assess the functionality of the hydraulic generator while simultaneously managing electronic components and power sources on the same workspace.

In addition to that, when it comes to simulating real-world scenarios we faced some difficulties, as the available water pump from the GEI lab did not provide sufficient flow to drive the hydraulic generator effectively.

However, the flow meter was just needed to blow into itr to simulate water flow, and that was practical for both development and testing phases.

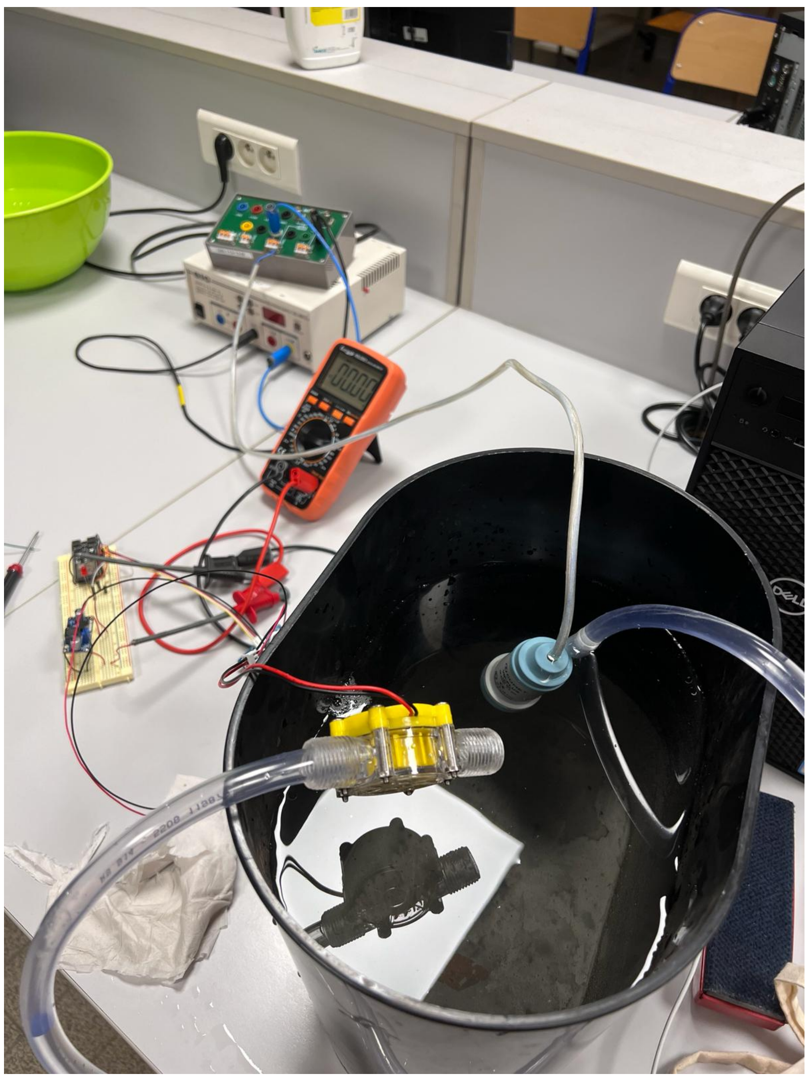

Figure 5: Test phase

9 Implementation

Because of our specialities (Automation Electronics/Computer Sciences and Networks) we decided to split the tasks in two parts:

- Electronics, this part will consist in dimensioning and choosing the electronic components, wiring the system, and programming the ESP32 (Microcontroller) to allow communication between it and the sensor and make the system autonomous with the generator.
- The Computer science part consists principally in the “back end” of the project. Our goal is to create an algorithm that can detect the water leaks, to create a database which stores all data, and a user interface .

For the computer science part we decided of this plan :

- Create a database
- Make a web interface that can communicate using an API with the database
- Create all the “user” features for the algorithm
- Make a functional algorithm

9.1 Hardware Part

During this project phase, the hardware domain was expertly managed by two SE students. Our initial step involved procuring essential components, namely the flow meter, hydraulic generator, and ESP32-C6 microcontroller, sourced from RS.

Upon receiving these components, our attention shifted to the ESP32 board, a pivotal component in our setup. Setting up the board was a very important process, requiring the installation of various dependencies and libraries to ensure its proper functioning. This phase was essential for a robust foundation of the project.

With the ESP32 operational, we started the visualization of our system's architecture. This step allowed us to do the conception and the integration of the various components and anticipate

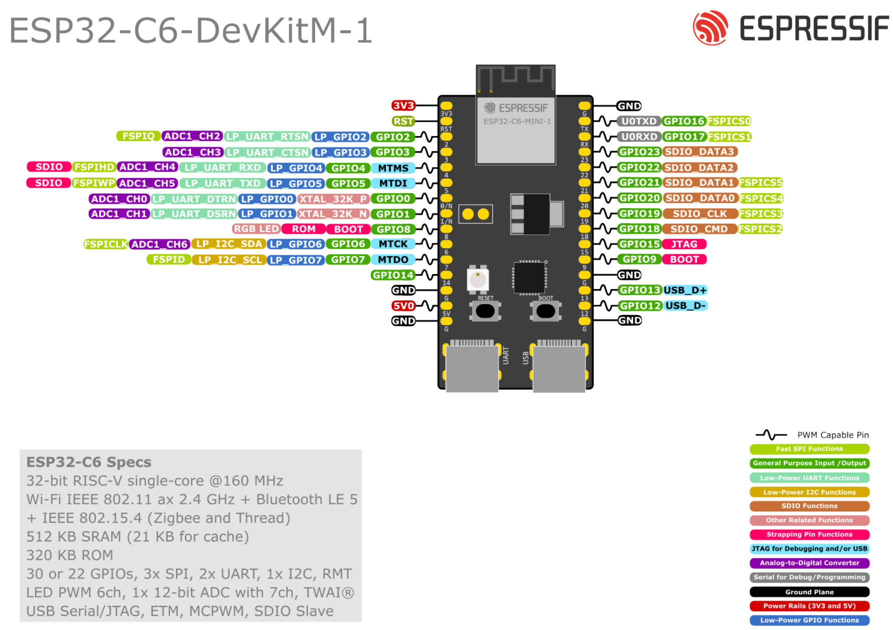

Figure 6: ESP32-C6

their interactions. However, we had a problem when the initially acquired flow meter from RS was non-functional. To resolve this, we took another one from Amazon.

Figure 7: Components

Then, we developed the code responsible for processing the sensor data acquired from the flow meter. This data was then transmitted to our API, marking a critical milestone in our project.

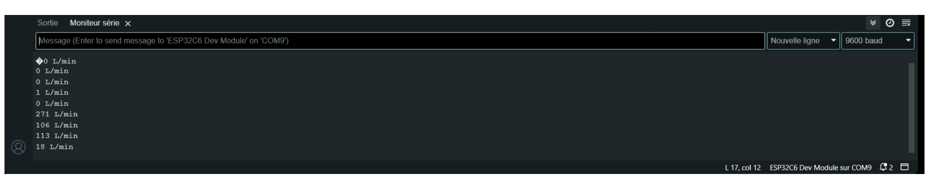

Figure 8: Flow Sensor Data

After that, we focused on the power supply aspects of our system. The hydraulic generator generated a DC output of 12V. To align this with the ESP32-C6's requirements, we added a voltage regulator to achieve a stable 5V supply.

Knowing the importance of autonomy in our system, we integrated a LiPo battery into our system. We opted for a LiPo battery charging module, allowing simultaneous charging and usage.

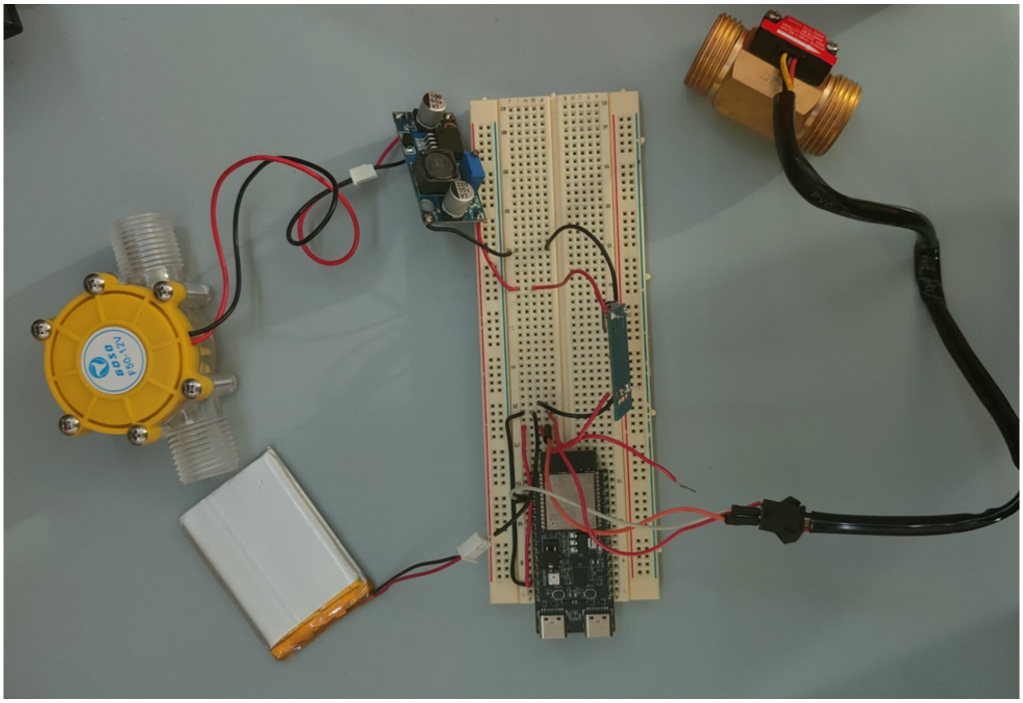

Figure 9: water leak detection system

Even though we faced initial challenges in this project, our teamwork and problem solving skills helped us to drive this phase successfully.

This can only reflect the strength of our team, showing our ability to overcome obstacles and reach project milestones

9.2 Software part : Web Application

Now that we have a working sensor ready to send data, we need somewhere to store it and process it. Moreover, as we have to limit what the ESP32-C6 has to do in order to not use too much energy, we chose to do it on the cloud and do all the storing and processing there. That is why we setted up a virtual machine on a remote server to run all our components from the API to the database.

But, why did we choose to do a web API for our project ? Well because it answered several of our needs. Firstly it is easily usable by both the ESP32 to send data and by the website to display information to the user. Also in terms of security, it can be easily used over https, making communications end to end encrypted so no one can intercept data.

9.2.1 Database

For the database, we created 3 tables. A first one, a table of users, where we can store usernames and hashed passwords. A second one in which we can find the information about the composition of the home of the user and finally a last one with water consumption data. Here are the description of the different tables :

```
mysql> DESCRIBE users;
+---------------+--------------+------+-----+---------+----------------+
| Field         | Type         | Null | Key | Default | Extra          |
+---------------+--------------+------+-----+---------+----------------+
| user_id       | int          | NO   | PRI | NULL    | auto_increment |
| username      | varchar(255) | NO   | UNI | NULL    |                |
| password_hash | varchar(256) | NO   |     | NULL    |                |
| usertoken     | varchar(512) | YES  |     | NULL    |                |
+---------------+--------------+------+-----+---------+----------------+
4 rows in set (0.00 sec)
```

Figure 10: users tables

Information about the home composition table :

```
mysql> DESCRIBE informations_menage;
+-----------------------------+--------------+------+-----+---------+----------------+
| Field                       | Type         | Null | Key | Default | Extra          |
+-----------------------------+--------------+------+-----+---------+----------------+
| id                          | int          | NO   | PRI | NULL    | auto_increment |
| nb_personnes_foyer          | int          | YES  |     | NULL    |                |
| nb_douches_semaine          | int          | YES  |     | NULL    |                |
| duree_douches               | int          | YES  |     | NULL    |                |
| lave_vaiselle_par_semaine   | int          | YES  |     | NULL    |                |
| machine_a_laver_par_semaine | int          | YES  |     | NULL    |                |
| chasses_d_eau_par_jour      | int          | YES  |     | NULL    |                |
| bain_frequence              | int          | YES  |     | NULL    |                |
| user                        | varchar(255) | YES  | UNI | NULL    |                |
+-----------------------------+--------------+------+-----+---------+----------------+
9 rows in set (0.00 sec)
```

Figure 11: home composition tables

And lastly the table with water consumption data :

```
mysql> DESCRIBE water_consumption;
+------------+----------+------+-----+---------+----------------+
| Field      | Type     | Null | Key | Default | Extra          |
+------------+----------+------+-----+---------+----------------+
| id         | int      | NO   | PRI | NULL    | auto_increment |
| date_heure | datetime | YES  |     | NULL    |                |
| water      | float    | YES  |     | NULL    |                |
+------------+----------+------+-----+---------+----------------+
```

Figure 12: water consumption data

9.2.2 API

Our API architecture relies on microservices. One service, the `login_API`, acts as a Gateway for both the ESP32 and the user (through the web interface) to interact with the API. All requests must go through it to make sure people are authenticated before retrieving any sort of data.

The `login_API` is publicly accessible via a URL: `https://api.vigileak.obrulez.fr/`. It is responsible for serving the web pages and forwarding requests to other services. Here is how our micro service architecture is organized :

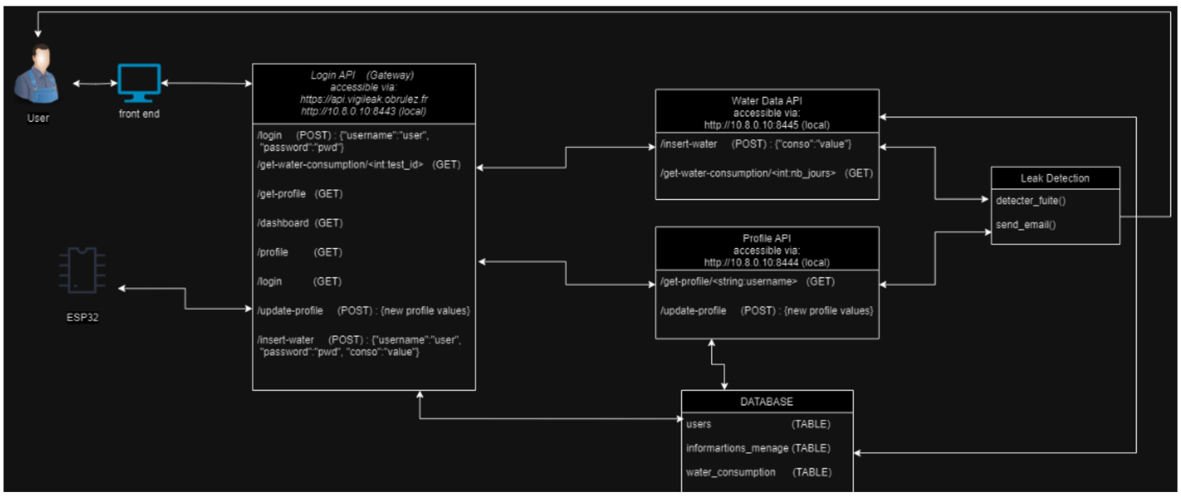

Figure 13: micro service architecture

As you can see, apart from the login API we have other services. The profile API which is responsible for updating and retrieving information about the composition of the home of a user.

A WaterData API whose role is to handle both the insertion of data about water consumption and the retrieving of said data to display it on the user interface and also make it accessible for our last service, the leak detection service. This one retrieves both water consumption data and information about the home of the user to compute them and detect leaks thanks to it.

If a leak is detected, an email is sent to the user. Leaks can be detected in two situations. A first one is when you have a non zero consumption over a long period of time, in our case we setted it to three hours. A second one, when the consumption over a week is substantially higher than the estimated consumption from the user data.

You will be able to find the code of our API on the following github repository : https://github.com/Solaumein/

9.2.3 User interface

Now, we also needed a user interface for the user to update its personal data.

It is in the form of a website served by our API. You can find three main parts on it. A login page, a home page, the dashboard where you can see your consumption over the last day. Finally A last page for the user's profile. On it, he can see its personal information and update them.

Here are what those pages look like.

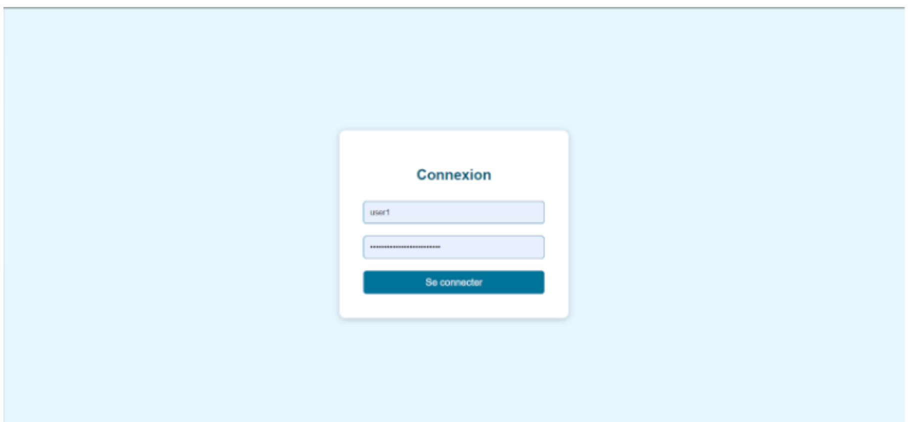

Figure 14: login page

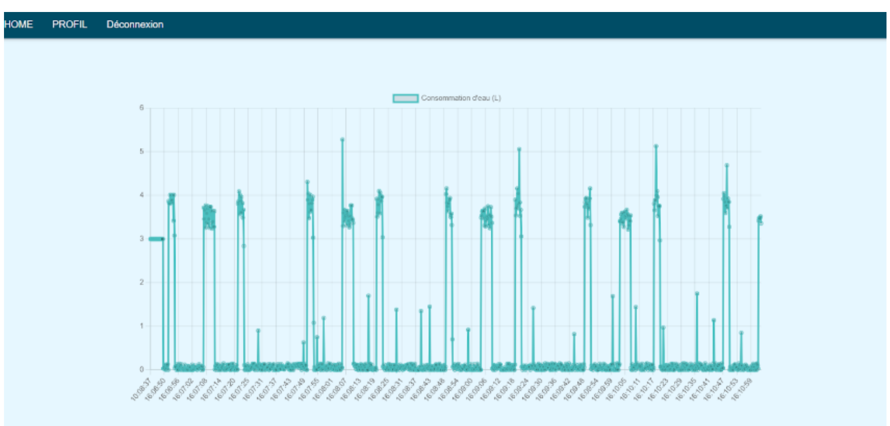

Figure 15: dashboard

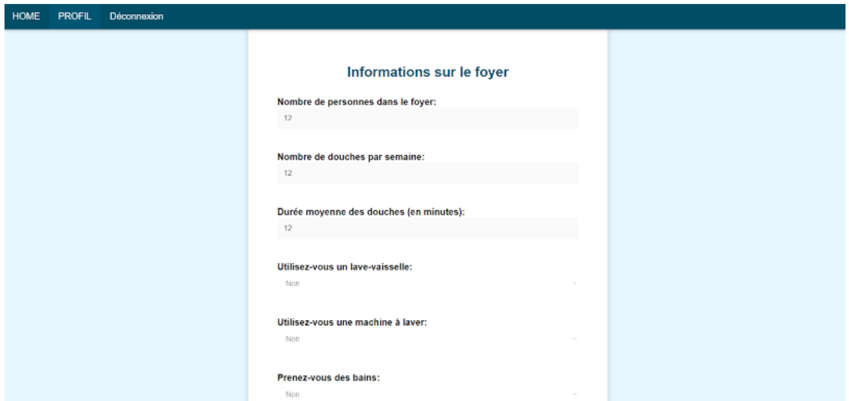

Figure 16: profile

10 Security

For the security part of our system we used the EBIOS Risk Manager methodology. This methodology is for assessing and managing informatics risks. Ebios Risk Manager has been developed by ANSSI (Agence Nationale de Sécurité des Systèmes d'Information) and means the expression of needs and identification of security objectives. The main part of EBIOS Risk Manager lies in its structured approach to identify and analyze an information environment. It allows organizations to understand the cybersecurity necessities, identify threats and vulnerabilities and understand the operations needed. The methodology is designed to be adapted to various types of organizations.

EBIOS involves several key steps :

- Context Establishment: Understanding the organization's environment, objectives, and constraints.
- Risk Identification: Identifying potential threats and vulnerabilities that could affect the organization's digital assets
- Risk Analysis: Assessing the likelihood and impact of identified risks.
- Risk Treatment: Developing strategies to manage, mitigate, or accept risks.
- Action Plan and Monitoring: Implementing risk treatment plans and monitoring the effectiveness of risk management efforts over time.

Context Establishment

- Project Overview: A device designed to detect water leaks in house implementing it at the water inlet. It collects water consumption data and communicates it to users via a website interface.
- Target Users: Homeowners or renters interested in monitoring water usage and preventing water damage.
- Technical Environment: The device connects to home water systems (water inlet) and communicates the data through the WiFi gateway to a server where data is stored and processed. Users access this data through a web interface.

Risk Identification

- Physical Risks: Damage to the device from environmental factors, malfunction.
- Cyber Risks: Unauthorized access to the device or website, data interception during transmission, malware, and system vulnerabilities.
- Data Risks: Loss, corruption, or unauthorized access to water consumption data, which may include personal information about users.
- Operational Risks: Device failure leading to undetected leaks, website downtime, or inaccurate water usage reporting.
- Compliance Risks: Non-compliance with data protection laws like GDPR (General Data Protection Regulation).

Risk Analysis and Evaluation

- Prioritize Risks: Prioritize risks such as data breaches, device malfunction, or legal non-compliance (GDPR).
- Impact Analysis: Assess the potential impact of each risk on users, the company's reputation, and financial costs.

Risk Treatment

- Mitigation: Stay informed about relevant data protection laws (like GDPR) and ensure compliance through regular legal consultations and audits.
- Avoidance: Design the system with privacy by design principles, ensuring it meets legal standards from the beginning.

Action plan

- We did several actions to ensure the security for the Innovative project. First, an important thing to know is that there are principally 2 places where we can intercept data. Between the ESP32 and the server, and between the database and the user interface (website).

  We chose a protocol of communication for those 2 places, because we use an API, all the data passing through these ways are encrypted with the protocol HTTPS. Even if an attacker intercepts data, he cannot understand the payloads because of the encryption. The infrastructure is accessible by only one gateway that can do only some actions.

  We can contact the gateway only with the correct username/password. The rest of the interface is not available, but it can only be made available by having previously given the correct information (username/password). To prevent the user from being able to retrieve information that they are not supposed to access, the server only gives them the rest of the user interface if the user has the connection cookie with the token. To explain it more clearly, when you log correctly into the interface, you get a connection token, and in every communication you have with the server, it verifies if the token is correct, then gives you the interface.

  Moreover, when you want to retrieve data for example from the Profile API, you cannot contact it directly. You have to go through the loginAPI and if you are entitled to this request, it will forward it to the said service.
  All the ports of the servers are closed, the system respects the minimum security because it hasn't (for the moment) been pwned even if in less than a month, more than 120 000 login attempts have been detected.

11 Opportunities for improvement

In this section we will enumerate what we could have done with more time. We still have ideas to improve our product and we hope that new students will keep on working on it.

11.1 Security analysis

11.1.1 Attack Scenarios

- Unauthorized Access: We can have some attacks with threats gaining unauthorized access to the system, manipulating or disrupting its functionality.
- Data Interception: we can have some attacks with threat intercepting the transmission of data from the house to the API.
- Tampering with Sensors: we can have some attacks with threats that might tamper with the sensors, providing false data or causing malfunctions.

11.1.2 Security Measures

- Implement sensor tamper detection mechanisms to promptly identify any unauthorized interference, alerting relevant personnel in case of any irregularities.
- Conduct regular security audits to proactively rectify any possible system vulnerabilities.

11.1.3 Contingency Planning

- Data Backup: This measure will help us against incidents and facilitate data recovery.
- Emergency Shutdown: This measure will help us to avoid potential threats and prevent unauthorized access.

The implementation of these security measures, and the user awareness initiatives, is very important for ensuring the reliability of the water leak detection system in our clients houses.

11.1.4 Areas for improvement

We are currently using a LiPo battery, charged simultaneously with its usage to power the ESP32-C6; this approach presents potential risks to the battery's life. Future iterations of the system could explore more sophisticated battery management solutions, such as separate charging and discharging cycles or alternative power sources. This enhancement would not only extend the battery life but also enhance the overall reliability of the system.

11.2 Possibles added functionalities/improvement

Once the development of the project is finished, we can now take the time to imagine how we could improve our system.

11.2.1 Artificial Intelligence

As an improvement, we can imagine using Artificial Intelligence to detect the leak. For that we would need to "commercialize" or distribute the system as a beta to create a dataset adapted and then we could train a model to detect leaks using consumption data.

11.2.2 Automatic actions

The system can for the moment send an email to the user when a leak is detected by the system. The problem of being informed of a leak is interesting, but if you are on holiday, or just not near from home, you can't do anything about it, so we could imagine an extension of the system that would cut the water coming into the apartment to prevent water damages.

11.2.3 Intelligent house

Let's imagine an intelligent house, with our system. We could expand the system for all the objects that have a link with water, with AI we could (as the Linky counter in France) deduce with the water consumption, what is the user doing (taking a bath, washing dishes, etc..). With this information, we could adapt some usings in the house, to give a simple example, if we see that the user takes in general showers of 10 minutes, then the water heater only works for a certain quantity of water to reduce electric consumption.

11.2.4 Localize the leak

Because of the price of a flow meter, we decided to use only one sensor in our prototype, but let's imagine we would create a system less cheap, we could place sensors in every water outlet of the house to localize where the leak is.

12 Conclusion

In conclusion, the Water Leak Detection project is the most important one we have worked on during the PTP training. The goal was to use all the skills acquired during our engineering training, and more particularly during the year of PTP, to answer in an innovative way to a problem of society.

This challenges the imagination, and leads to a great reflection on the technologies that can be used to carry out the project. We asked ourselves a lot of questions related to security, energy consumption, algorithmic complexity, aligning with the awareness cultivated through our courses at INSA.

The collective feeling towards this project is very positive. It was really interesting to work on this project, as it aims at fixing a current societal problem. We are very aware of ecology and environmental protection at INSA, which is an essential thing if we want to save our planet. So, working for such an important topic was very encouraging and motivating.

There is still room for improvement but we feel that we could have a final product in the end. That is why we hope that students next year will keep on improving it and test it in real conditions.