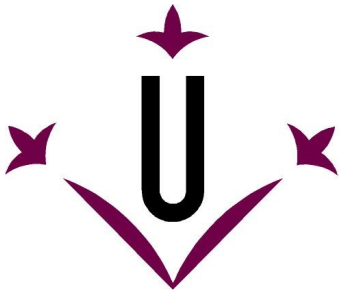

University of Lleida

Master's Degree in Informatics Engineering

Higher Polythecnic School

Engineering Book

Ubiquitous Computing and Embedded Systems

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1 Introduction

This document introduce the "**Wind Turbine Generator Farm**" (WTGF) project statement detailing the project requirements and the user stories related, since the aim is to concert the development process.

Hence, the purpose of this document is focused on describing the development of the project presenting the task distribution and the sprints made, but also, the suggestions related to the project that could improve it, and the situations/problems encountered with the proposed solutions.

In closing, there are the final project conclusions from the development team in charge of the project to remark their point of view.

2 Document structure

This section looks forward to narrating what is in each section of the document to help understand and facilitate the approach to the contents.

- **Project statement:** Introduction to the project, to set up the starting point for the whole project development.
- **Methodology:** Advance the methodology used during the development with some remarks because of the project.
- **Product Backlog Items (PBI):** The list including all the items present in the PBI, the final assigned score and their relation with the user stories.
- **Sprint Diary:** Detailed explanation for all the individual sprints during the project acting as a guideline of the process and the work done.
- **Final project conclusions:** Complete end of the line resulting from the development and over the realization of this document as well as from working with such embedded components and some contributions regarding personal opinion.

3 Project statement

The following is listed the starting point of the project:

- We work on developing embedded components able to manage and supervise machines.
- We have received a petition to design and evaluate a multi-purpose device including *Internet of Things* (IoT) capabilities.
- The main target is a **Wind Turbine Generator Farm** (WTGF).
- The engineering department has designed a prototype (Fig. 2).
- Our target is to evaluate the prototype and determine its weaknesses.
- The prototype is composed by multiple devices; the Supervision station (Data Consumer), the Data Producers and a MQTT Broker.

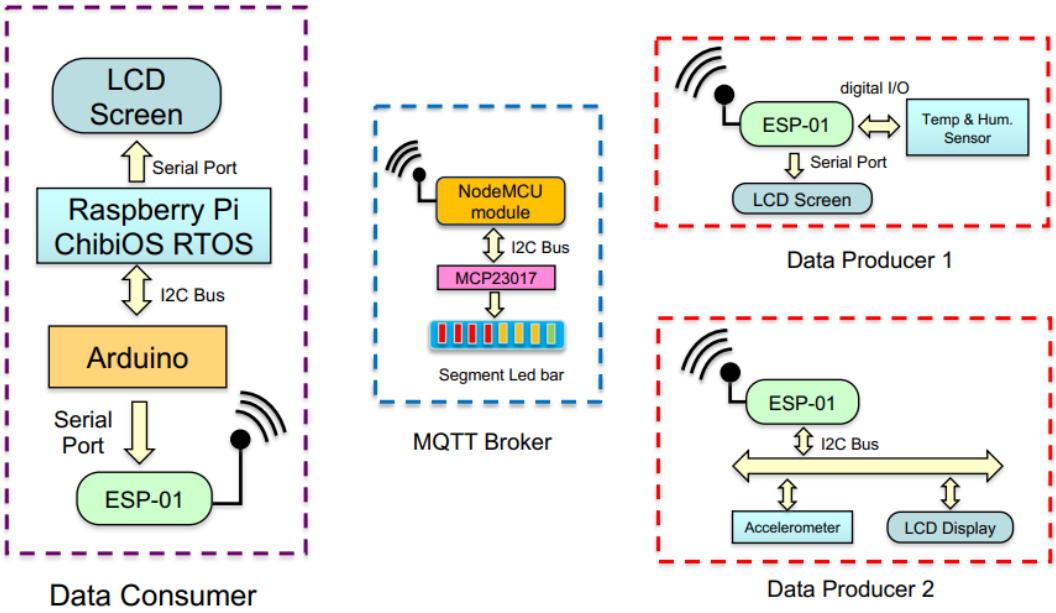

Figure 1: Electronic engineering department - WTGF Hardware Proposal

3.1 Project requirements

The following are the requirements presented:

- There is just only one Supervision station for the whole WTGF.
- All sensors are placed far from the Supervision station.
- Temperature and humidity sensors are placed near to the Rotor Hub.
- The Tower movement sensor is placed in the middle of the tower.
- Sensor measurements must be obtained in Real-Time.
- Sensors are controlled by the Data producers and they will show the current sensor readings.
- Whole WTGF data is transferred to the Supervision station through a MQTT Broker.
- The MQTT Broker will show graphically the current number of subscribers.
- The maintenance manager requires access to the last 24h that should be available graphically on the Supervision station.

3.2 User stories

The following are the features/goals to achieve:

- It is necessary to obtain the temperature and humidity at the top of the WTFG.
- It is necesssary to determine the WTFG tower movement.
- Sensor data must be must be sent to a Supervision station.
- MQTT Broker must show the current number of connections (percentatge).
- Maintenance manager requires graphically representation of the obtained sensor data, within the last 24h, in the Supervision station.

4 Methodology

At the project start-up, one of the main anchors that should be defined is the development methodology. In our case, as we were forming a group of engineers to work together, and because of the requirements, the Scrum methodology got the place.

Scrum is an agile development methodology, currently commonly widespread, based on an iterative and incremental processes. The primary objective of Scrum is to satisfy the customer's need through an environment of transparency in communication, collective responsability and continuous progress.

In this way, we could define sprints and assure a quick an understandable communication to the customers/stakeholders, even doing two-week reports and progress presentations.

Although we must remark, as we were not full-time dedicated to this project, the daily-meetings were replaced by two-three days meetings. Thus, each team member reported the progress after a quite enough time.

Regarding the tasks that compose the product backlog item (PBI), they were defined and assigned by consensus of the whole development team. Moreover, the estimation story point for each item/task was calulated via **the Scrum Poker technique** through the next webpage https://scrumpoker.online/ where you can adapt anonymous sessions for each of the participants, thus, we assure a better task ponderation without influence obtaining approximate realistic story points.

Furthermore, we were using a Github repository to keep all the work done, but also, the Zenhub integated tool to manage the Scrum methodology.

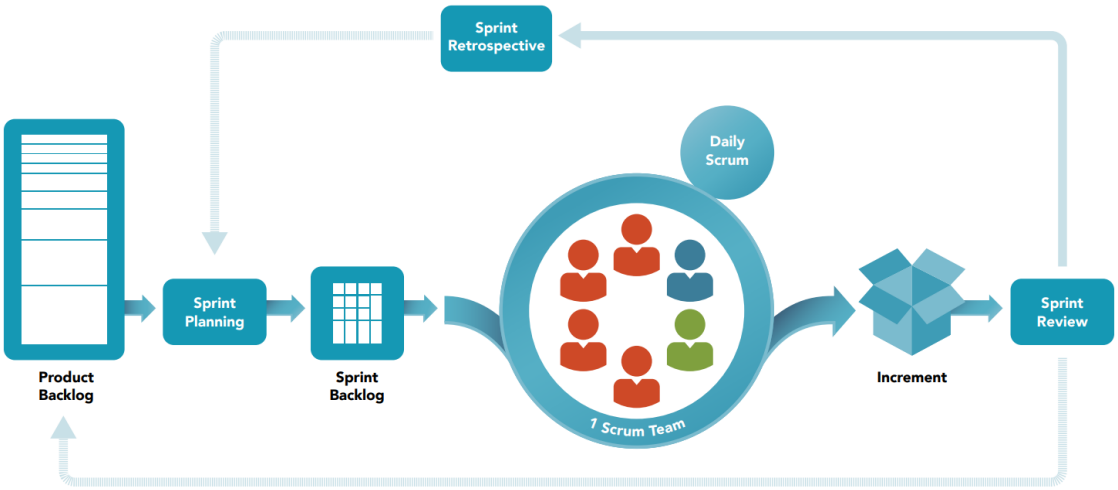

Figure 2: Scrum methodology

5 Product Backlog Items

The following is the final PBI of the project. For each task is specified the final assigned score, and the topic related to the user story.

You may see, at the beginning, lots of tasks related to "Learning" stuff as we needed to introduce ourselves to those components and environments to work with. Since then, there are more concrete ones focused on the development of the project.

Item	**Label**	**Story Point**
Revise Material	Good first issue	2
Read Documentation ESP-01	Learning	3
Read Documentation DHT11	Learning	3
Prepare Arduino Environment	Learning	3
First contact with electronic components	Learning	8
Read Documentation Accelerometer ADXL345	Learning	3
Read documentation MCP23017	Learning	3
Read documentation LCD Screen/Display	Learning	2
Read documentation I2C Bus Protocol	Learning	2
Prepare Raspberry Pi environment	Learning	3
Read documentation about NodeMCU module	Learning	3
Data Producer 1 development	Development	8
Data Producer 2 development	Development	8
Arduino interaction with ESP-01	Development	8
Install ChibiOS to Raspberry Pi	Development	3
Data log and Screen representation	Development	8

Table 1: Product Backlog 1/2

Item	Label	Story Point
Ultrasonic LED bar representation	Development	8
Connect Raspberry Pi to LCD Screen via serial port	Development	8
MQTT Broker development	Development	13
Arduino interaction with Raspberry Pi	Bug	8
Sprint 1 documentation	Documentation	8
Sprint 2 documentation	Documentation	8
Sprint 3 documentation	Documentation	8
Data Producer 1 documentation	Documentation	8
Data Producer 2 documentation	Documentation	8
MQTT Broker documentation	Documentation	5
Supervision Station documentation	Documentation	8
Test Supervision Station	Testing	13
Test MQTT Broker	Testing	8
Test Data Producer 1	Testing	5
Test Data Producer 2	Testing	8

Table 2: Product Backlog 2/2

Finally, there are **31 tasks**, getting a total of **194 story points** at the end of the project.

6 Sprint Diary

The purpose of this section is to illustrate the several sprints carried out during the development of the project. In kind, for all individual sprints are detailed:

a) Sprint definition - A short self-explaining sentence related to the user story that identify the sprint goal.

b) Backlog tasks assigned to the sprint.

c) Dedication time to each task (an estimation in hours for the whole team).

d) Percentatge of Sprint completion (or individual tasks).

e) Sprint Review - A short conclusion on the present Sprint, and if required the new PBI organitzation. It could also include any comment related to the team (problems, suggestions, tasks assignments, etc).

6.1 Sprint 1

6.1.1 Sprint Definition

This first sprint aimed to introduce the team to work with the hardware components and their corresponding software, how to program. Once the team is introduced to the hardware and software of the components, the worked user stories for this sprint were the following:

1. As a user I would like to know to obtain the temperature and humidity at the top of the Wind Turbine Generator.
   (a) **Acceptable Criteria**
      i. The Data Producer 1 uses ESP-01 to receive the data from the DHT11 sensor.
      ii. The ESP-01 sends the data obtained to the LCD Screen to visualize it.
   (b) **Related Task**
      i. Data Producer 1 Development.
2. As a user I would like to know the Wind Turbine Generator tower movement.
   (a) **Acceptable Criteria**
      i. Data Producer 2 uses ESP-01 to receive the data from the ADXL345 sensor.
      ii. The ESP-01 sends the data obtained to the LCD Display to visualize it.
   (b) **Related Task**
      i. Data Producer 2 Development.

The first user story corresponded to the work-block named Data Producer 1, which components related to were:

- ESP-01
- Temperature and humidity sensor (DHT11)
- LCD Screen

The second user story corresponded to the work-block named Data Producer 2, which components related to were:

- ESP-01
- I2C Bus
- Accelerometer (ADXL345)
- LCD Display

Therefore, the sprint goal for this sprint 1 was to have a working version of the Data Producer 1 and the Data Producer 2 of the project, once the team got introduced to work with such components.

6.1.2 Sprint Backlog tasks

Task	**Label**	**Story Point**
Revise Material	Good first issue	2
Read documentation ESP-01	Learning	3
Read documentation DHT11	Learning	3
Prepare Arduino environment	Learning	3
First contact with electronic components	Learning	8
Read documentation Accelerometer ADXL345	Learning	3
Data Producer 1 development	Enhancement	8
Data Producer 2 development	Enhancement	8
Sprint 1 documentation	Documentation	8
Read documentation LCD Screen/Display	Learning	3
Read documentation I2C Bus Protocol	Learning	3
Test Data Producer 1	Testing	5
Test Data Producer 2	Testing	8

The total story points for the Sprint 1 are **55 points**. We should remark this punctuation, as not having previous sprints, are not accurate to the amount of work the team could manage. Just an approximation.

6.1.3 Dedication time and completion percentage to each task

Task	**Completion (%)**	**Team dedication time (h)**
Revise Material	100	1
Read documentation ESP-01	100	2
Read documentation DHT11	100	2
Prepare Arduino environment	100	1
First contact with electronic components	100	4
Read documentation Accelerometer ADXL345	100	2
Data Producer 1 development	100	5
Data Producer 2 development	20	2
Sprint 1 documentation	100	3
Read documentation LCD Screen/Display	100	2
Read documentation I2C Bus Protocol	100	3
Test Data Producer 1	100	3

The total dedication time for this Sprint 1 is **30h**, which means that for 14 days that the sprint lasted, the team dedicated **2:15h per day** approximately.

6.1.4 Sprint Review

The team expected to get the two Data Producers as they are similar but it was realized that it was not as easy as expected when problems arise. The Data Producer 1 was done, just needed a quick clean of the code and integration with the broker, and for the Data Producer 2 needed more work on the I2C Bus.

Finally, the team finished this first sprint with **85% (47/55) of the tasks done**, which meant that needed to adjust the number of story points for the next sprint.

The team worked well together and the sprint advanced smoothly. Although everything was new to all of us, from working with Scrum to the chosen technologies, we were well integrated, everyone was very supportive and open to researching, learning, and even teaching if necessary.

Lastly, it is needed to adjust the next sprint amount of story points, so as to finish the remaining tasks/issues for the Data Producer Development, but also taking into account the hours approximatly the team will be able to work on the next sprint.

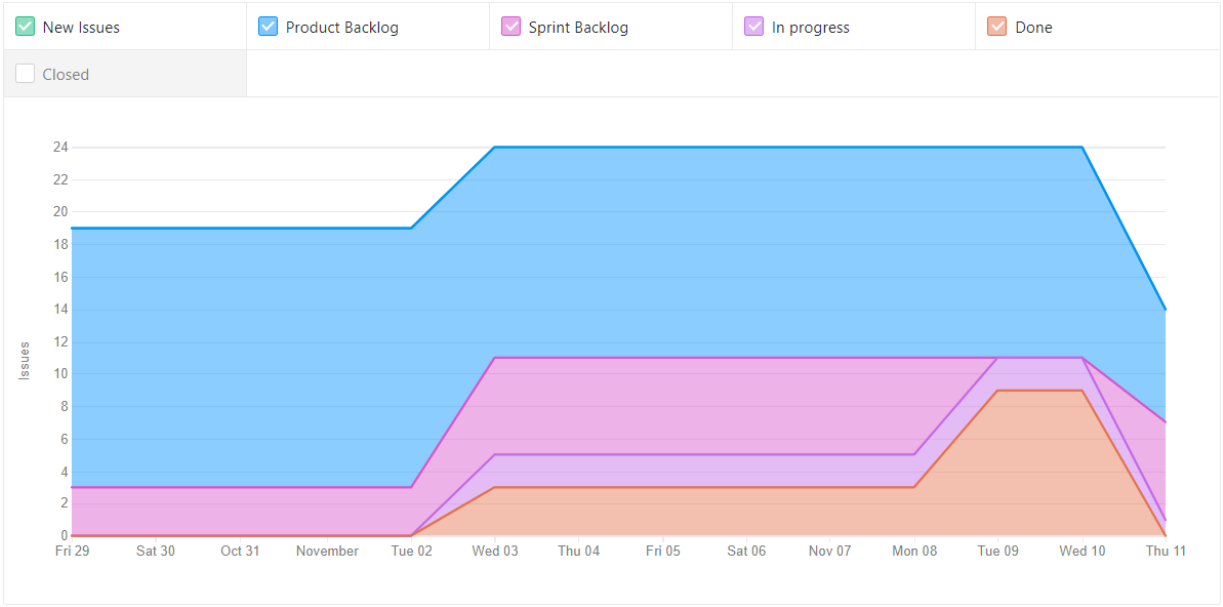

Figure 3: Sprint 1 - Cummulative-flow graph

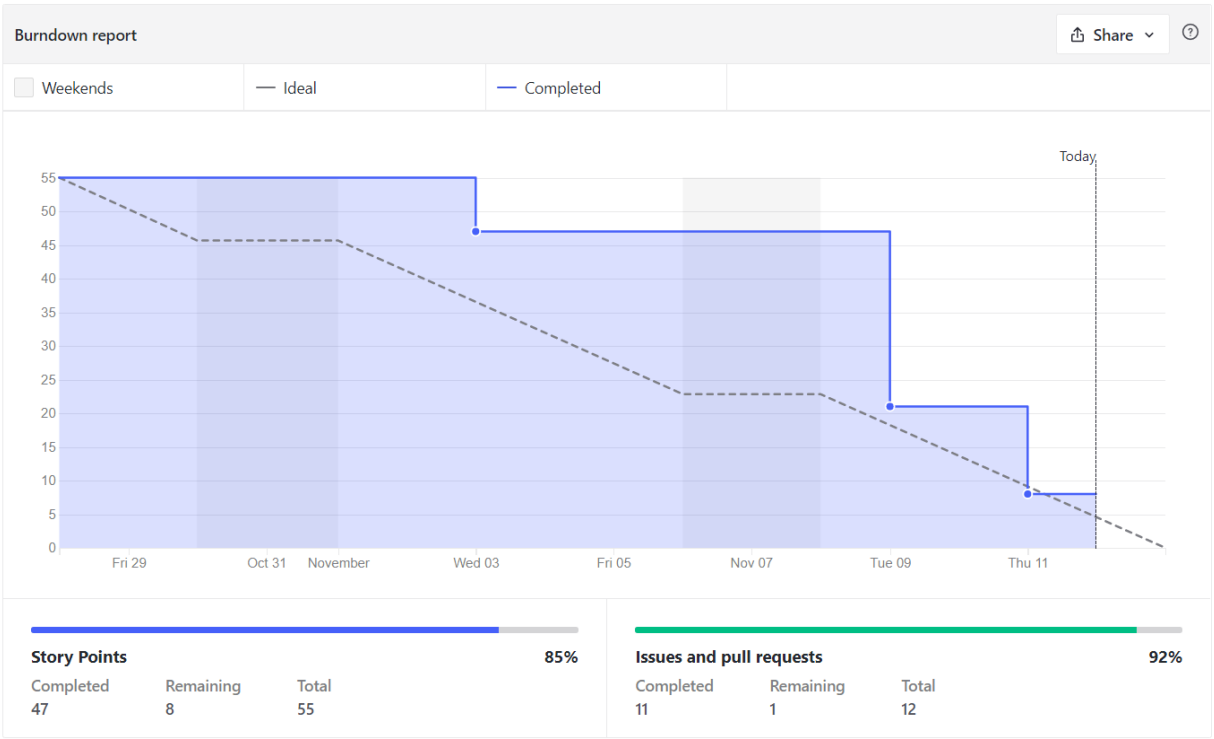

Figure 4: Sprint 1 - Burn-down graph

6.2 Sprint 2

6.2.1 Sprint Definition

The goal for this sprint was to finish the working version of the Data Producer 2 and having a working version of the MQTT Broker. The user stories that the team worked with during this sprint are the following:

6.2.2 User stories

1. As a user I would like to know the Wind Turbine Generator tower movement.
   (a) **Acceptable Criteria**
      i. Data Producer 2 uses ESP-01 to receive the data from the ADXL345 sensor.
      ii. The ESP-01 sends the data obtained to the LCD Display to visualize it.
   (b) **Related Task**
      i. Data Producer 2 Development.
2. As a broker I would like to show the current number of connections as a percentage.
   (a) **Acceptable Criteria**
      i. The MQTT Broker will receive data from Data Producer 1.
      ii. The MQTT Broker will receive data from Data Producer 2.
   (b) **Related Task**
      i. MQTT Broker Development.
3. As a broker I would like to send received sensor data to a Supervision Station.
   (a) **Acceptable Criteria**
      i. The MQTT Broker is able to subscribe to the correspondents topics provided by DP1 and DP2.
      ii. The MQTT Broker is able to publish the data received.
   (b) **Related Task**
      i. MQTT Broker Development.

The first user story corresponded to the work-block named Data Producer 2, which components related to were:

- ESP-01
- I2C Bus
- Accelerometer (ADXL345)
- LCD Display

The second and third user story corresponded to the work-block named MQTT Broker, which components related to were:

- NodeMCU module
- MCP23017
- Segment LED Bar

6.2.3 Sprint Backlog tasks

Task	Label	Story Point
Read documentation MCP23017	Learning	3
Test MQTT Broker	Testing	8
Test Data producer 2	Testing	8
Data producer 2 development	Enhancement	13
MQTT Broker development	Enhancement	13
Read Documentation about NodeMCU module	Learning	3
Documentation Sprint 2	Documentation	8
Data producer 2 documentation	Documentation	8
MQTT Broker documentation	Documentation	5

The total story points for the Sprint 2 were **69 points**.

6.2.4 Dedication time and completion percentage to each task

The total dedication time for the Sprint 2 was **35h**, which means that for 14 days that the sprint lasted, the team dedicated **2:30h per day** approx.

Task	Completion (%)	Team dedication time (h)
Read documentation MCP23017	100	2h
Test MQTT Broker	100	1h
Test Data producer 2	100	2h
Data producer 2 development	100	12h
MQTT Broker development	100	8h
Read Documentation about NodeMCU module	100	2h
Documentation Sprint 2	100	3h
Data producer 2 documentation	100	2h
MQTT Broker documentation	100	3h

6.2.5 Sprint Review

The goal for this sprint was to finish the Data Producer 2 module and the MQTT broker module. The team had a lot of difficulties throughout the sprint. Still, it was accomplished a working version of the Data Producer 2, retrieving and printing data from the accelerometer and a working version of the MQTT broker managing publications and subscriptions.

As a result, the team finished this second sprint with a **100% of tasks done**, which meant that it is likely to finish the project on time, since in the last sprint it will be worked on the third and last module of the project.

The team worked well together and the sprint advanced smoothly. From now on the team prepared the last issues and tasks to work on the last sprint and hope that the project will be finished by the end of the third sprint if problems will not arise.

Therefore, for the last sprint the team focused on configuring the environment of the Raspberry Pi and installing the ChibiOS, but also on the Arduino, at first, working on the interaction with the corresponding ESP-01, and finally, with the Raspberry PI. Finally, it is also needed to adjust all the components in order to work together following the project schema, and testing all the time if they work properly.

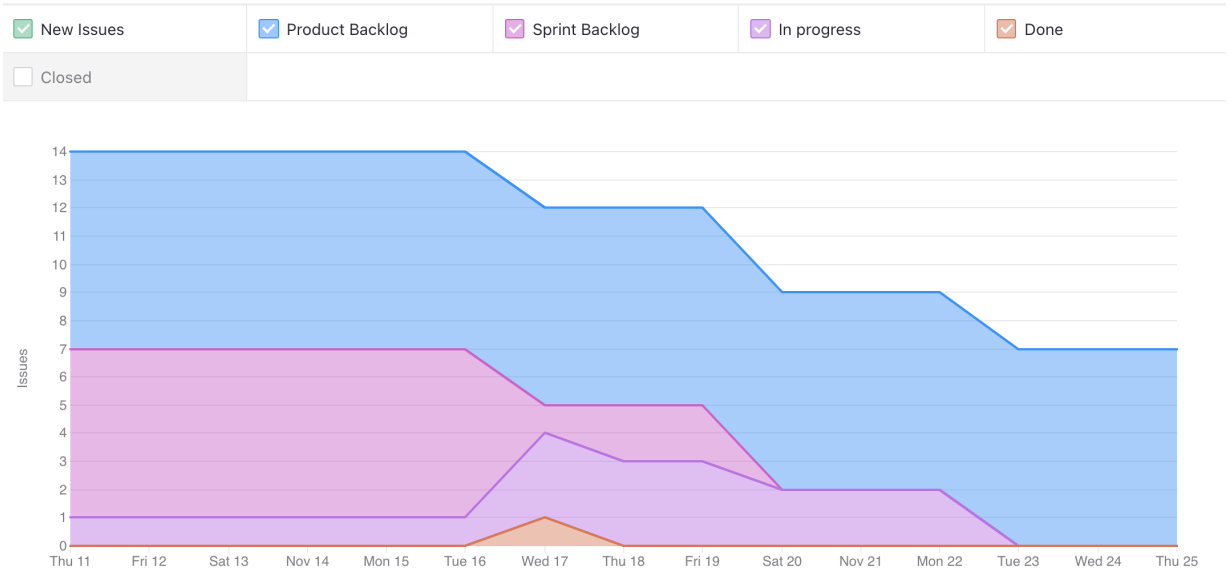

Figure 5: Sprint 2 - Cummulative-flow graph

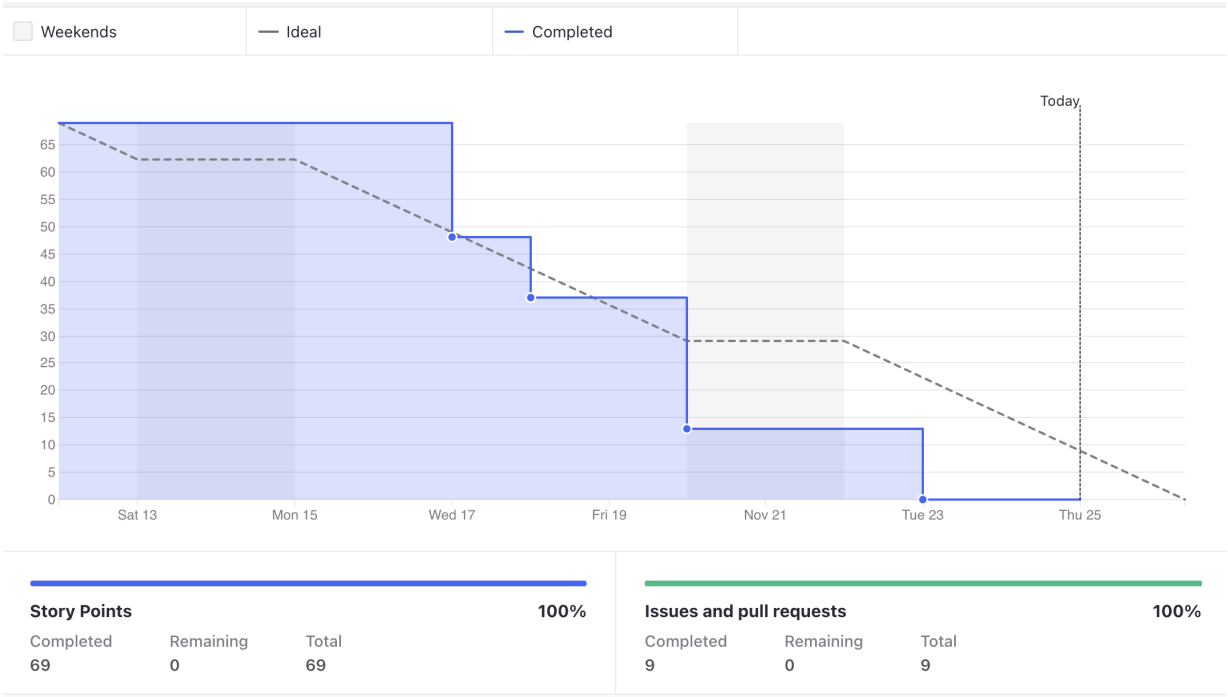

Figure 6: Sprint 2 - Burn-down graph

6.3 Sprint 3

6.3.1 Sprint Definition

The goal for this sprint was to have a working version of the Supervision Station, which corresponds to the Data Consumer module of the project. The user story that the team worked during this sprint is the following:

6.3.2 User stories

1. As a Maintenance manager I would like to represent graphically the obtained sensor data, within the last 24h, in the Supervision Station.
   (a) **Acceptable Criteria:**
      i. The Arduino UNO connects to the ESP-01 in order to get the data produced by the Data Producers
      ii. The Raspberry Pi connects to the LCD Screen in order to represent the data from the Data Producers
      iii. The Arduino UNO and the Raspberry Pi are linked by an I2C Bus where the Raspberry Pi will be the master and the Arduino UNO will be the slave.
      iv. The ESP-01 receives the data obtained from the MQTT Broker, which has the data from Data Producer 1 and Data Producer 2.
      v. We can see the data provided by the MQTT Broker.
   (b) **Related Task:**
      i. Supervision Station Development.

The user story corresponds to the work-block named Data Consumer, which components related to are the following:

- ESP-01
- Arduino UNO
- Raspberry Pi
- LCD Screen

6.3.3 Sprint Backlog tasks

For this sprint, the total story points is **86 points**. This may seem too much compared to the previous sprints, but they wanted to get focused on all task related to the Supervision Station as the last step to conclude the project.

In this way, for the last sprint we expected to finish the remaining tasks if any, and work on the integration of all project parts.

Task	**Label**	**Story Point**
Prepare Raspberry Pi environment	Learning	3
Install ChibiOS to Raspberry Pi	Enhancement	2
Arduino interaction with R.Pi	Enhancement	13
Connect Raspberry Pi to LCD Screen via serial port	Enhancement	8
Arduino interaction with ESP-01	Enhancement	8
Test Supervision Station	Testing	13
Data Consumer: Data log and Screen representation	Enhancement	13
Sprint 3 documentation	Documentation	13
Supervision Station documentation	Documentation	13

6.3.4 Dedication time and completion percentage to each task

Task	**Completion (%)**	**Team dedication time (h)**
Prepare Raspberry Pi Environment	100	1h
Install ChibiOS to Raspberry Pi	100	1h
Arduino interaction with R.Pi	80	3h
Connect Raspberry Pi to LCD Screen via serial port	100	2h
Arduino interaction with ESP-01	50	2h
Test Supervision Station	80	5h
Data Consumer: Data log and Screen representation	70	4h
Sprint 3 documentation	100	3h
Supervision Station documentation	25	1h

The total dedication time for the Sprint 3 was **22 hours**.

The dedication time to this sprint was not as much compared to the others as it can be observed. About **1.5 hours per day**. Basically, due to some issues encountered which slowed-down the development, and a short vacation period in mid-sprint.

On the other hand, the main purpose of the sprint was accomplished, as the team got a working version of the Data Consumer, but waiting to test it all.

6.3.5 Sprint Review

The main reasons why the team slowed down the development were that they got issues with some failing wires when treating with the SDA connection between the Raspberry Pi and the Arduino when building the component schema for the I2C bus. And also, with the LCD Screen, the one needed for multiple testing because they couldn't work properly on it since it was failing. Thus, implying not being able to work fairly on the graphics representation, nor even see the values received from the Arduino.

Hence, it can be observed the "Arduino interaction with R.Pi" task and the "Test Supervision Station" task are not completely finished, specifying a symbolic 80 percent.

In this way, the team should work on finishing and testing the graphics representation on the LCD Screen. Moreover, remained to conclude the Arduino interaction with the ESP to get dynamically the data (this corresponds to the project parts integration), because it could not be dedicated so much time due to the mentioned problems above.

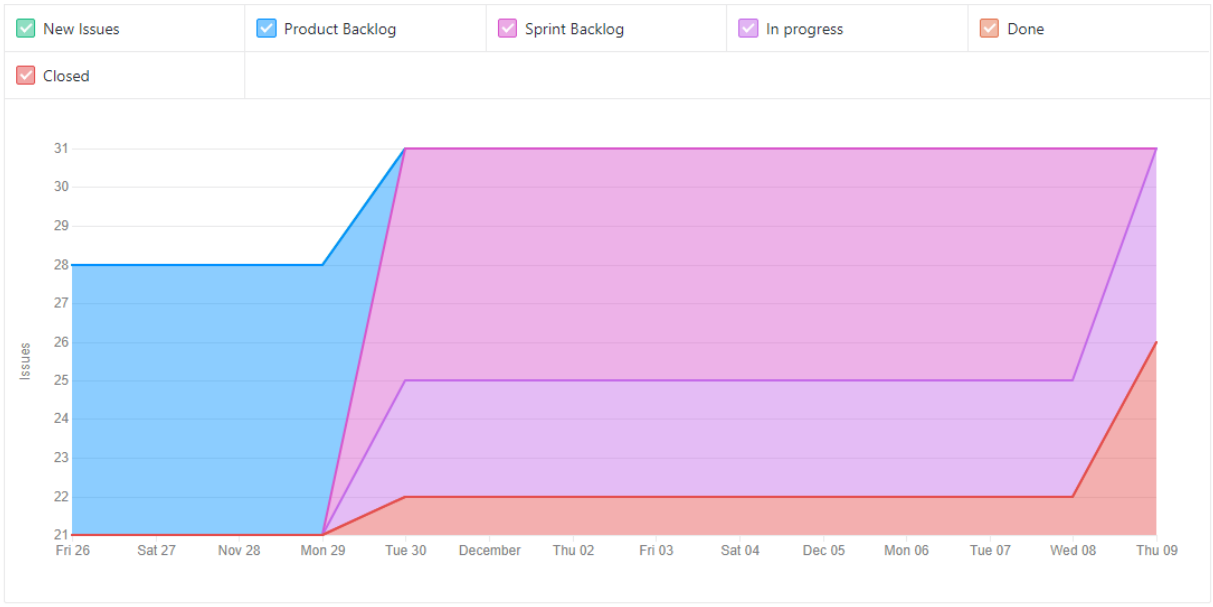

Figure 7: Sprint 3 - Cummulative-flow graph

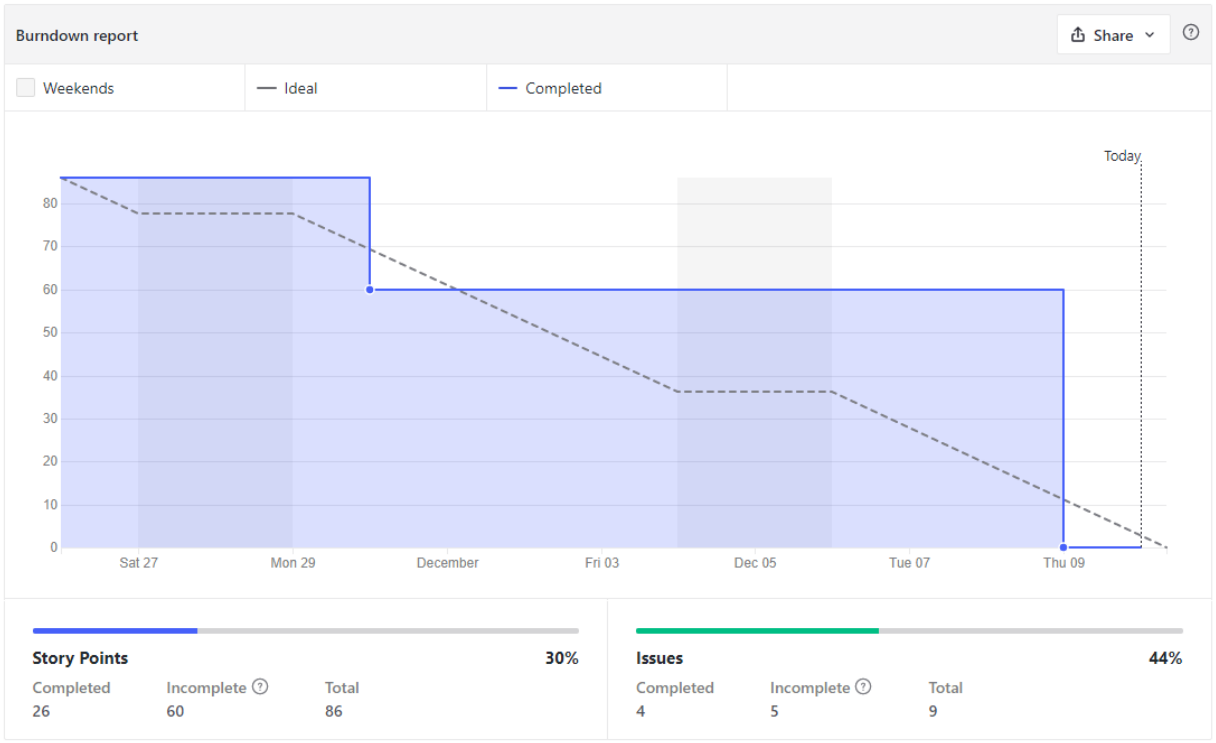

Figure 8: Sprint 3 - Burn-down graph

From now on the team shall prepare the last issues and tasks to work on the last sprint and they thought that if they keep working as they have done, the project will be finished in time.

Although, the team must got focused on solving the issues encountered on this sprint to finish the remaining tasks and test them all. Mainly the Raspberry Pi and Arduino interaction. And finally, test the whole project parts integration, and carried out the final project documentation.

7 Project Flow

This section illustrates the whole project flow, and the currently issues state.

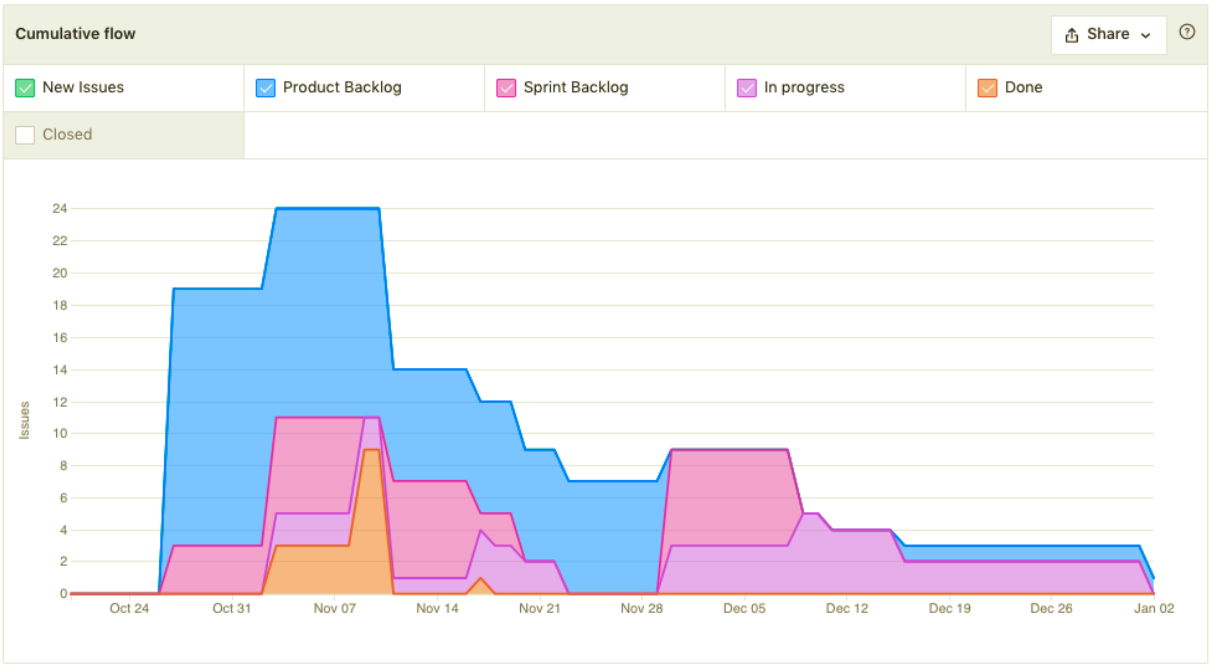

Figure 9: Whole project flow

Here in the whole project cummulative-flow you may see how the product backlog is changing over the time, as well as the sprint because of the development process. The project progressed well as seen multiple product backlog redefinitions, also the corresponding sprint task assignation, and its work done represented as descending in progress lines.

Issues in pipeline	December 30th, 2021	December 31st, 2021	January 1st	January 2nd
New Issues	0	0	0	0
Product Backlog	1	1	1	1
Sprint Backlog	0	0	0	0
In progress	2	2	2	0
Done	0	0	0	0
Closed	28	28	28	30

Figure 10: Final project task table report

Even though, there is one last issue in the product backlog which corresponds to “Arduino interaction with R.PI”. The one meant a problem for us, due to the impossibility to carry out the communication thourgh an I2C Bus amonb these components. There is more specific criteria in the technical documentation you may find in the github repository.

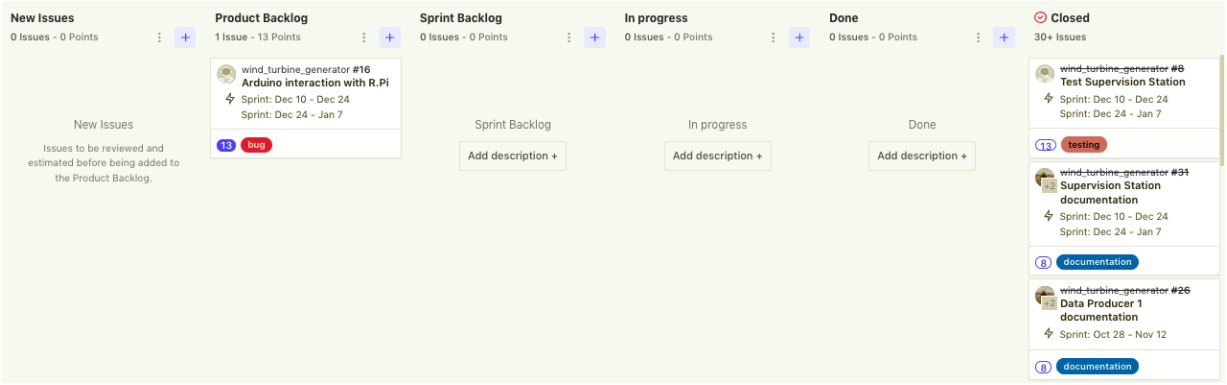

Figure 11: Final project board view

Overall, the project got its final face even encountering a few problems, thus, having one issue in the product backlog. But, as the main objective was to evaluate the optimum solution to the presented user stories, this last issue doesn’t meant that much as there is a better solution proposal done. See technical documentation.

8 Final Project Conclusions

As the development team of this project, we would like to write down some suggestions, conclusions, improvements regarding the development process, regarding the proposed solutions and our personal opinion as regards the subject's project.

We think that this kind of project is ideal to get started with micro-controllers and learn about embedded systems, the concept of IoT and the ubiquitous computing. Furthermore, it is perfect to hone our technical skills regarding electronics and programming. Along with the IoT concept, this project allows you to further your network management. Besides, the fact that you can obtain and transfer data from remote sensors very interesting.

Despite these advantages, the inconveniences that we have learnt from this kind of project is that you need to work patiently and very careful and meticulous, because although your code would execute fine, the components might be worn away or broken and the module you are working will fail.

As regards the components used for this project, we propose that, in future projects of the subject, they shall be replaced by state-of-the-art ones, so as to diminish the possible problems that future students might encounter.

To conclude, we would just like to point out that we really liked the way the project was approached. That is, we were presented with a statement to analyze and propose a functional solution, but with total freedom to decide whether the initially proposed scheme was optimal or not, also being able to adapt the solution to the problems that can be found. In our case, due to certain problems and schema analysis considerations of the initial solution, we were able to propose the best way to carry out the project.