



Universidad de Valladolid



**ESCUELA DE INGENIERÍAS
INDUSTRIALES**

UNIVERSIDAD DE VALLADOLID

ESCUELA DE INGENIERIAS INDUSTRIALES

Grado en Ingeniería Electrónica Industrial y Automática

IoT for small factories needs

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Resumen

El objetivo de este proyecto es comprobar si es viable integrar la tecnología del Internet de las Cosas (IoT), utilizada generalmente para la automatización de viviendas, en un entorno industrial para pequeñas empresas. Este enfoque puede ser una solución de bajo coste y efectiva para empresas con maquinaria antigua, mejorando la productividad y facilitando el mantenimiento sin tener que hacer modificaciones importantes en la instalación. Debido a la gran amplitud de este proyecto, el enfoque ha sido en investigar posibles soluciones tanto de hardware como de software ya utilizadas y realizar una instalación como prueba de concepto.

Palabras clave

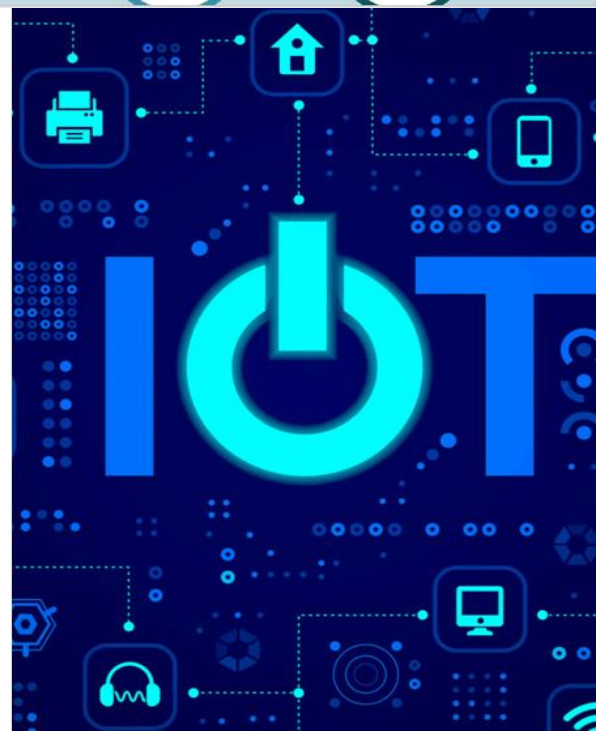
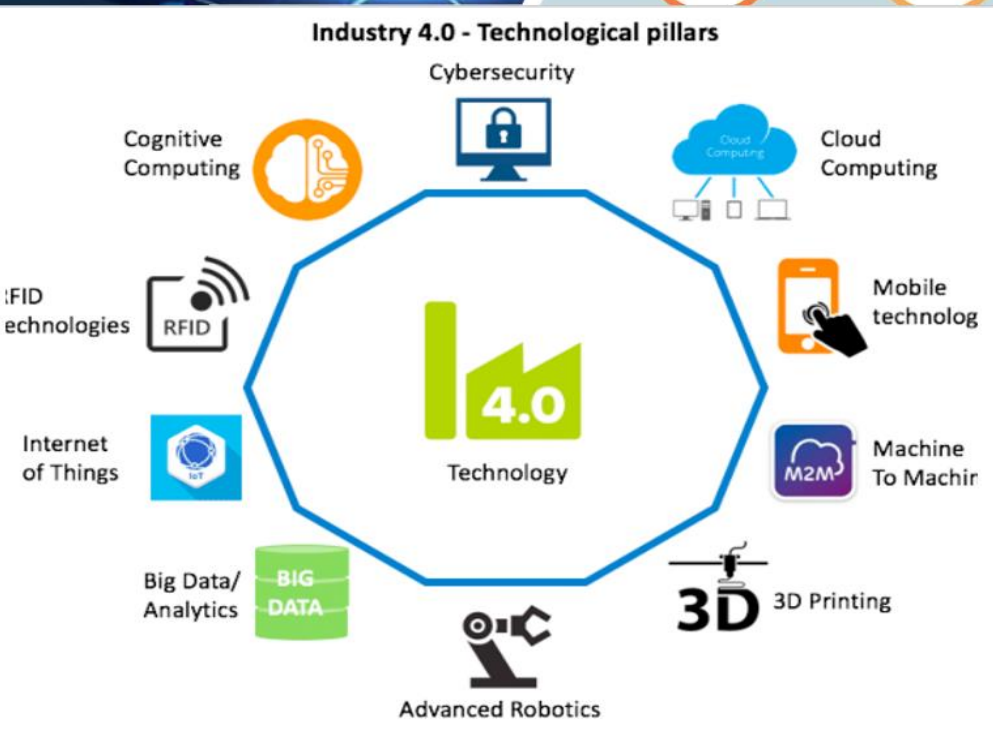
Internet de las Cosas, mantenimiento, pequeñas fábricas, sensores, automatización

Abstract

The goal of this project is to check if it is feasible to integrate the technology of Internet of Things (IoT), generally used for home automation, in an industrial environment for small factories. This approach may be a cost-effective solution for companies with old machinery, improving their productivity without important adjustments at the installation. Due to the wideness of this project, the focus has been on researching possible hardware and software solutions that are already in use and implement an installation as a proof of concept.

Keywords

Internet of Things, maintenance, small factories, sensors, automation



Final report: Internet Of Things for small factories

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Backgrounds:

What is a European Project Semester?

EPS is a student program available in 18 European universities in 12 countries throughout Europe to all students with at least two years of study. This program is focus on engineering students but still open to students from other fields. The purpose is to create a multidisciplinary and international environment comparable to working life in project teams. This environment allows all the stakeholders to improve their communication skills and intercultural competencies. This semester is composed of the project itself and other supporting courses, like Teambuilding, Project Management or cross culture discovery. Students work in groups of 3-6 with several field of study and nationality. At the end of the semester, a student will gain 30 ECTS, which represent a normal academic semester.

Novia University of Applied Sciences

The Novia University of Applied Sciences is a university that is located on the Finnish West coast of Vaasa with campuses that are located in four different cities in Finland. The university is the largest Swedish-Speaking University of Applied Sciences in Finland. There are about 4000 students studying at this school and about 300 staff members working. This university is specialised in training students in becoming experts and developers based on the requirements of working life.

What about us?

Our team is composed of 4 students representing 3 nationalities: Belgian, Spanish and French. This mix of culture and knowledges offers us a unique opportunity to develop our abilities and learn a lot from each other.

Fabien Jumel



Hello! I am Fabien Jumel, 22. Studying material engineering at ESI Reims, I'm of 4 years of university. This EPS internship is the opportunity to discover a new country and culture. Working in an international team and only in English is a very interesting challenge that I like!

Yoeri Reynaerts



My name is Yoeri Reynaerts, I am from Belgium. I study at the Artesis Plantijn University in Antwerp. The study I am following in my home country is Process-Automation. The reason I wanted to do this EPS project was because I wanted to push myself out of my comfort zone. Another reason is to learn new skills. Now that we got the Internet of Things project. I would like to learn more about IoT and expand my knowledge about it, because there is so much more to learn.

Álvaro García



Hello! I am Álvaro García, a student of Industrial Electronic and Automation Engineering at Valladolid, Spain. I applied for the EPS semester with the goal of doing my final thesis in a multicultural group, improve my English and learn new things about IoT, a field in which I am especially interested. And of course, meeting new people with different backgrounds and a new country and its culture.

Janik Swerts



Hey! My name is Janik Swerts, a student energy technology at the Thomas More university in Geel. I chose to complete my thesis and internship abroad by participating in the EPS program, this is an excellent opportunity to step out of my comfort zone and to meet new people. This project semester will also help me to improve my team skills and my English which will come in handy in my later career. The "Internet of Things" project is one that appeals strongly to me because I like to be involved with technology and because smart internet applications are gaining more and more popularity for both commercial as non commercial purposes.

Belbin test:

According to the team role theories there are several roles that can be taken up by the different members in a team. These different roles can be organizational, functional, personal and even skill full. A good and strong team should comply with different team roles that depends on the purpose of the project. By having each team member fill in the Belbin test, we can easily find out who is characterized by which roles. In this way we can check whether the team meets the necessary team roles and if there is too many overlap between the different members. This overlap should be avoided in order to create the healthiest possible group balance that leads to a healthy working atmosphere. When we now see to the Belbin results of our group we see that we are covering a large range of different roles. This leads to a good team dynamic, but we still have to keep in mind that we all have behaviours that can overlap at some point during the project (coordinators; shapers). All the team members should pay attention for this when we divide the tasks so that everyone can do what he likes the most and feel comfortable in the group.

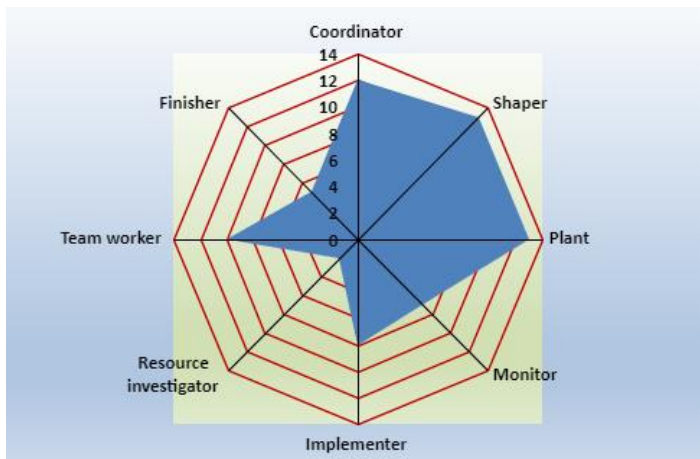


Figure 4 : Álvaro García Belbin results

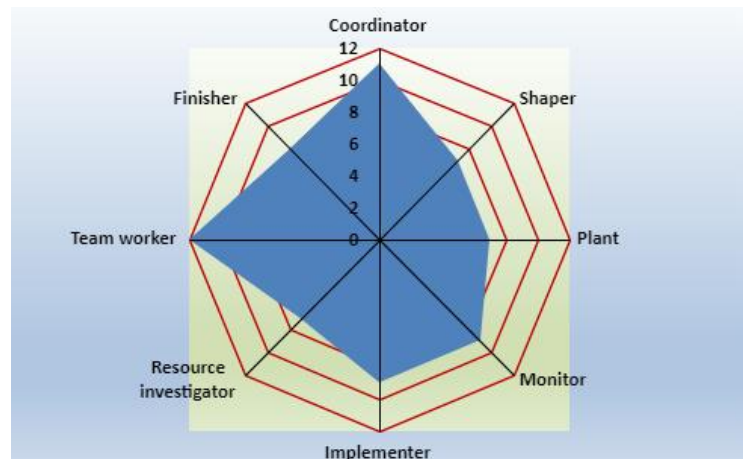


Figure 4: Janik Swerts Belbin results

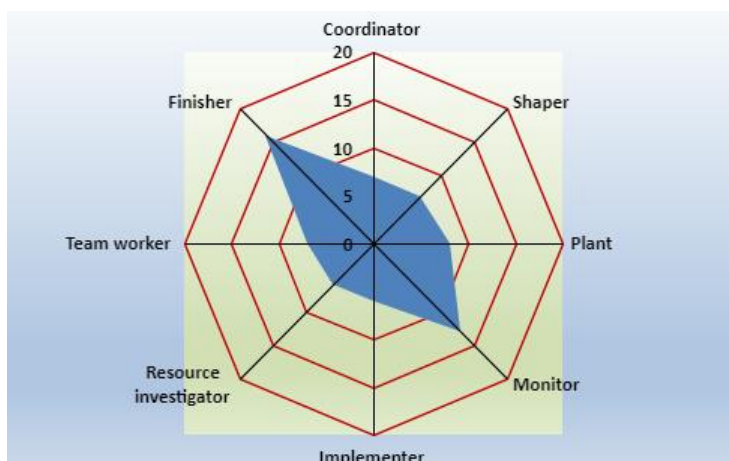


Figure 4: Yoeri Reynaerts Belbin results

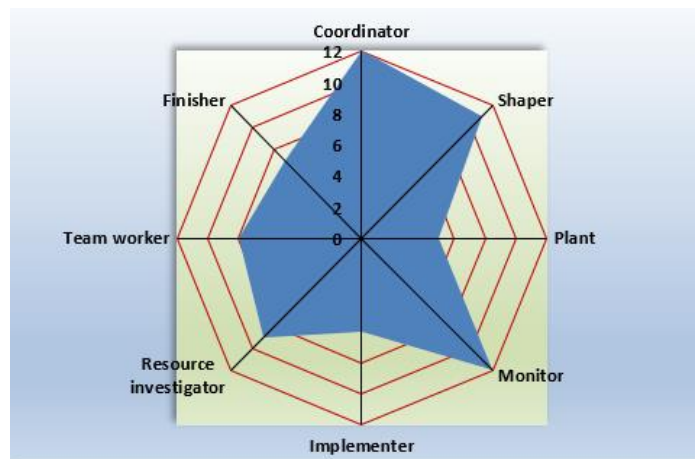


Figure 4: Fabien Jumel Belbin results

Mission and vision

On every project start, the team have to statute on the fundamental purpose, why the project has been developed and what the long-term objective is of the project.

The 'mission' is to find the best solution to implement Industry 4.0 in small factories.

The 'vision of the team' is to develop new connected tools and turnkey hardware which help small industrial structures in maintenance management to improve the productivity/profitability. The final delivery is an efficient and easy to set package adapted to different kind of machines.

Concepts linked to the project:

One of the biggest challenges of this project for each of us is to evolve into an unknown environment and field. Therefore, it seemed essential to deepen our knowledge and carry out research on the concepts surrounding this project before being able to focus completely on the realization of the project.

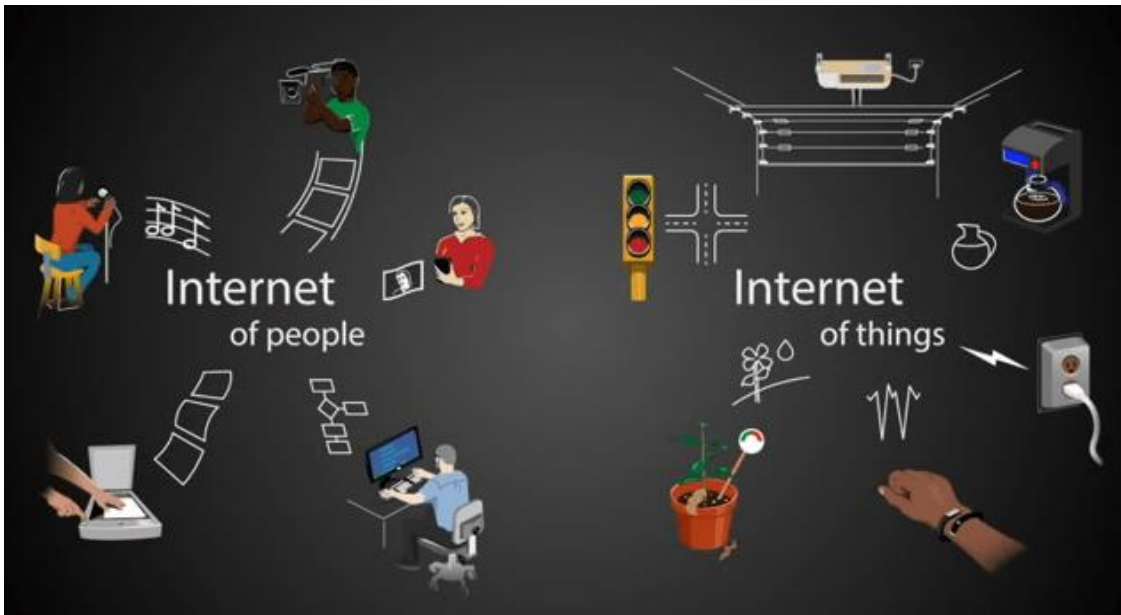
Internet of Things

When the internet was originally created the main goal was to provide people with information such as texts, videos, images etc. The internet was made by people and for people. Internet of Things or IoT can be considerate as the first major evolution of Internet.

The internet is around you every day and is has become a big part of our daily lives without most people even realizing it. IoT can be define as a giant network where objects communicate and share data with each other. The "things" in Internet of Things can refer to different type of devices from simple sensors to smartphones and wearables.

By combining smart connected devices with automated systems it is possible to gather information, analyse it and create actions to help someone/something perform a particular task, we can also use the gathered information to learn from certain processes to keep them improving. Internet of Things is about devices, data and networks.

In this way it is possible for components to share their information with other components without the need of human interaction. In order to let the things interact with each other we have to let them sense and communicate. With this we mean for example a light sensor, we have to make sure it can sense the amount of light in the environment but the sensor should also be able to transmit the measured value to the other connected devices.



Industry 4.0

Industry 4.0 is the digital transformation of manufacturing, production, related industries and value creation processes. Industry 4.0 is used interchangeably with the fourth industrial revolution and represents a new stage in the organization and control in the industrial value chain. The basis of industry 4.0 (smart machines) is formed by cyber-physical systems, they use modern control systems, have embedded software systems and dispose of an internet address to connect and be addressed throughout Internet of Things.

In this way, products and means of production get networked and can 'communicate' enabling new ways of production, value creation and real-time optimization. The cyber-physical systems have the capabilities needed for smart factories. These capabilities are the same as we know from the industrial Internet of Things like remote monitoring or track and trace.

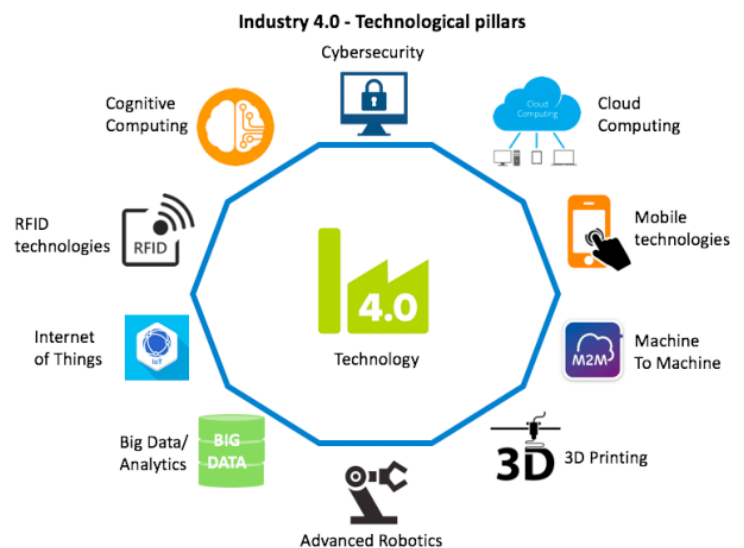


Figure 5: Industry 4.0 pillars

The goal of industry 4.0 is to enable autonomous decision-making processes, monitor assets and process in real-time, and to enable real time connected value creation networks through early involvement of stakeholders, and vertical and horizontal integration. These are a few key benefits of industry 4.0 to show why it is so important for factories to hop on this trend:

Real time data for a supply chain in a real time economy

Higher business continuity through advanced maintenance and monitoring possibilities

Better quality products: real time monitoring, IoT enabled quality improvement and cobots (advanced collaborative robots or robots that fit a collaboration between man and machine)

Better working conditions and sustainability

Personalization and customization for the customer

Improved agility

The development of innovative and new revenue models

As we can see, it is very important for companies and factories to move on to industry 4.0 and to the fourth industrial revolution as soon as possible to remain competitive. To fully equip a factory/production to industry 4.0 they need to do a fair amount of research and a lot of time, but by doing this the installation is ready to utilize all the benefits of IoT and industry 4.0.

M2M communication

Through the implementation of an IoT network in a factory environment we see that we are creating a machine to machine connection (M2M). Machine-to-machine communication is exactly as it sounds: two or more machines that are communicating with each other by a network. A machine to machine connection can be established in different ways. We can use for example a serial connection, a powerline connection or a wireless connection by using the Internet. By using wireless communication to establish a M2M connection it is much easier and there are more applications that can be connected in this way.

As businesses have realized the value of M2M, it has taken a new name, Internet of Things. IoT and M2M have quite a lot of similarities, they fundamentally change the way the world operates. IoT and M2M allows any sensor to communicate and because of this it is possible to monitor systems and automatically responding to changes in the environment. Because of this the need for a human to intercept in the process is reduced.

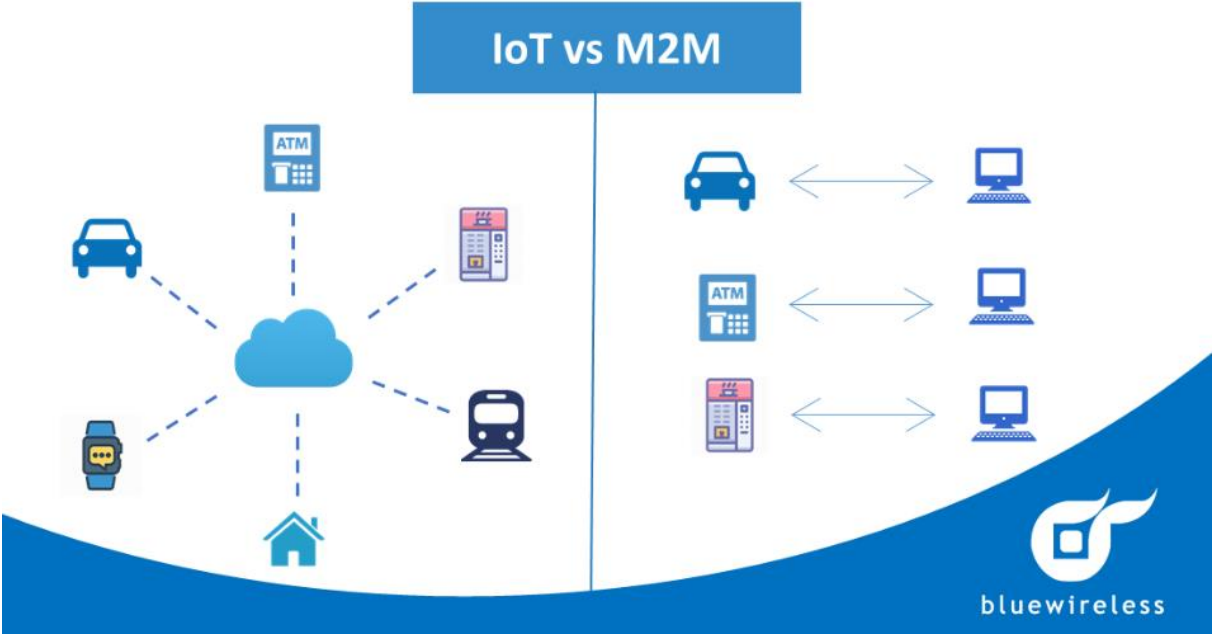


Figure 6: IoT / M2M comparison

Machine-to-machine communication makes the Internet of Things possible, M2M is one of the fastest growing types of connected device technologies on the market right now. This is because M2M technologies can connect millions of devices in a single network. These connected devices can go from vending machines up to medical equipment, vehicles and even buildings. Basically, anything that houses a sensor or control technologies can get connected to a wireless network.

These kind of networks sounds complex, but the idea is quite simple, M2M networks are quite similar to WLAN (Wireless Local Area Networks) and LAN (Local Area Networks) networks. But unlike LAN and WLAN is M2M networking exclusively to allow machines, sensors and controls to communicate. These devices feed information to a network and they collect information back from other devices in the same network. It is also possible for humans or an intelligent control unit to access the information and to intervene when something is wrong.

Condition based maintenance

Condition Based Maintenance (CBM) is a maintenance strategy that monitors the actual condition of an asset to decide when and what maintenance needs to be done. By using CBM, maintenance only needs to be done when necessary and the engineers know in advance which part needs to be replaced. Checking a machine for these indicators may include non-invasive measurements, visual inspection, performance data and scheduled tests.

Unlike planned maintenance, where maintenance is performed based upon predefined scheduled intervals, condition based maintenance is only performed when a decrease in the condition of the equipment has been observed. Compared with preventive maintenance, this increases the time between maintenance repairs, because maintenance is done when it is needed.

The goals of CBM are to spot upcoming equipment failure so maintenance can be proactively scheduled when its needed and not before. The asset conditions need to trigger maintenance within a long enough time before the failure so that there is enough time for the engineers to fix the problem before the asset fails. These are some advantages and disadvantages about CBM:

| Advantages of Condition Based Maintenance | Disadvantages of Condition Based Maintenance |
|--|--|
| CBM is performed while the asset is working, so the asset does not get disrupted | Condition monitoring test equipment is expensive to install, and the data costs money to analyse |
| Reduces the cost of asset failures | Cost to train staff to analyse the data and perform the work |
| Improves equipment reliability | Fatigue or uniform wear failures are not easily detected with CBM measurement tools |
| Minimizes unscheduled downtime due to catastrophic failure | Condition sensors may not survive in the operating environment |
| Minimizes time spent on maintenance | May require asset modifications to retrofit the system with sensors |
| Minimizes requirement for emergency spare parts | Unpredictable maintenance periods |
| Optimizes maintenance intervals (more optimal than manufacturer recommendations) | |
| Improves worker safety | |
| Reduces the change of collateral damage to the system | |

Overall Equipment Effectiveness

OEE (Overall Equipment Effectiveness) is the standard for measuring manufacturing productivity. This identifies itself as the percentage of manufacturing time that is truly productive. This means that they produce 100% quality (only good parts), 100% performance (so fast as possible) and 100% availability (so no down time). By measuring the OEE of a factory and the underlying losses, they will get insight on how to improve their manufacturing process.

The goal for factories is not only to measure their own OEE value, but to maximize their fully productive time. Above are some concerns that factories should focus on in order to improve the OEE and optimize production speed:

Get real time OEE data from machinery and correct quality deviation immediately

Identify problems that are reducing OEE and prioritize them

Perform preventive maintenance on these problems

The Overall Equipment Effectiveness factors

There are some factors that must be kept as high as possible in order to obtain the highest possible Overall Equipment Effectiveness score. These factors are:



Figure 7: Overall Equipment Effectiveness factors

- **Schedule loss:** it includes all the time that should be excluded from the OEE analyses because there is no intention of running the production line during this time (plant shutdown, lunchbreaks, or periods where there are no orders). OEE starts with Planned Production Time and scrutinizes all efficiency and productivity losses that occur within that time, the goal is to reduce these losses or eliminating them.

- **Availability:** these losses include any events that stop planned production for an appreciable length of time (several minutes long is enough for an operator to log a reason). Examples of things that create Availability loss includes unplanned stops (these stops can be equipment failure and material shortage), and planned stops (such as changeover time). Changeover time is also included in the OEE analysis because this time could be used for manufacturing. The remaining time after availability loss is subtracted is called Run Time.
- **Performance:** this can be anything that causes the manufacturing process to run at less than the maximum possible speed. Examples of things that create performance loss include machine wear, substandard materials, misfeeds and jams. The remaining time after performance loss is subtracted is called Net Run Time.
- **Quality:** this factor accounts for manufacturing parts that do not meet the quality standards. An example of quality loss can be scrap and parts that need to be reworked. OEE quality is similar to first pass yields, in that it defines good parts as parts that successfully pass through the manufacturing process the first time without needing any rework. The remaining time after quality loss is subtracted is called Fully Productive Time.

Project definition and planning

Project description

21st century's industrial world is composed of a large range of fields with a lot of variety into the size of factories. Performance, quality and cost-efficiency are today's success keys and Industry 4.0 rely on a big effectiveness toolbox based on Internet of Things and connectivity. For small structures it is hard to reach all these goals due to a lack of knowledges into this new tools and techniques.

The goal of this project is to try to demonstrate that simple home automation IoT stuff can be an efficient, easy and low-cost way for small factories to get into industry 4.0 and enhance their productivity to stay competitive. Our aim is to develop an IoT sensors-based tracking method solution to provide a follow-up of industrial machine performances and condition.

Organization of project team

The organization of the project team allows everyone to find their place but also to define the area of action of each in the overall of the project. The main objective of defining positions is to improve fluidity and coordination among team members to ensure the success of the project. The contribution of information from the Belbin test will also help to better understand each other's affinities and adjust responsibilities and tasks accordingly.

Tool: meeting; Technique: Belbin test

| <i>Name</i> | <i>Function (Feb-Mar)</i> | <i>Function (Apr-May)</i> | <i>Main work field</i> |
|----------------------------|-------------------------------|-------------------------------|---|
| <i>Alvaro Garcia</i> | | | Electronics Programming Automation |
| <i>Janik Swerts</i> | Secretary | Secretary | Data management User manual Programming |
| <i>Yoeri Reynaerts</i> | | | Process automation Electrical design |
| <i>Fabien Jumel</i> | Chairman | Chairman | Project management Materials Basics in design |

Environment definition

The aim is to define all stakeholders as well as the framework for the project's evolution. This is the first step in defining tasks and deliverables.

Result:

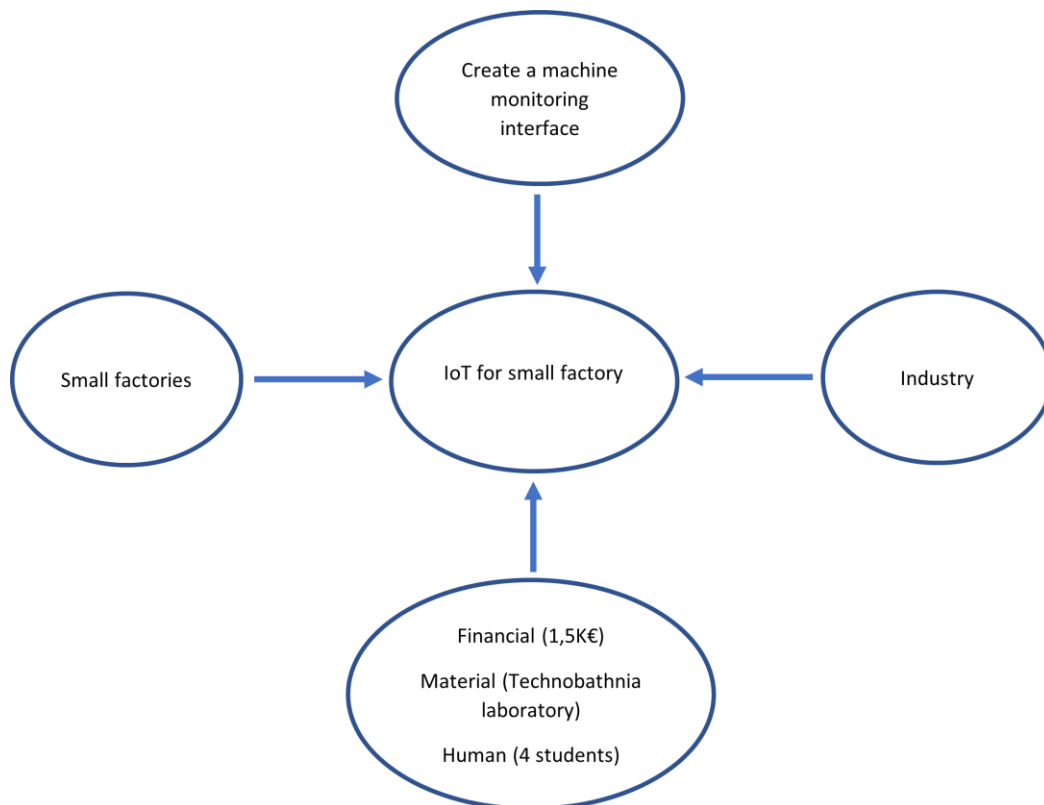


Figure 8: project environment analyses

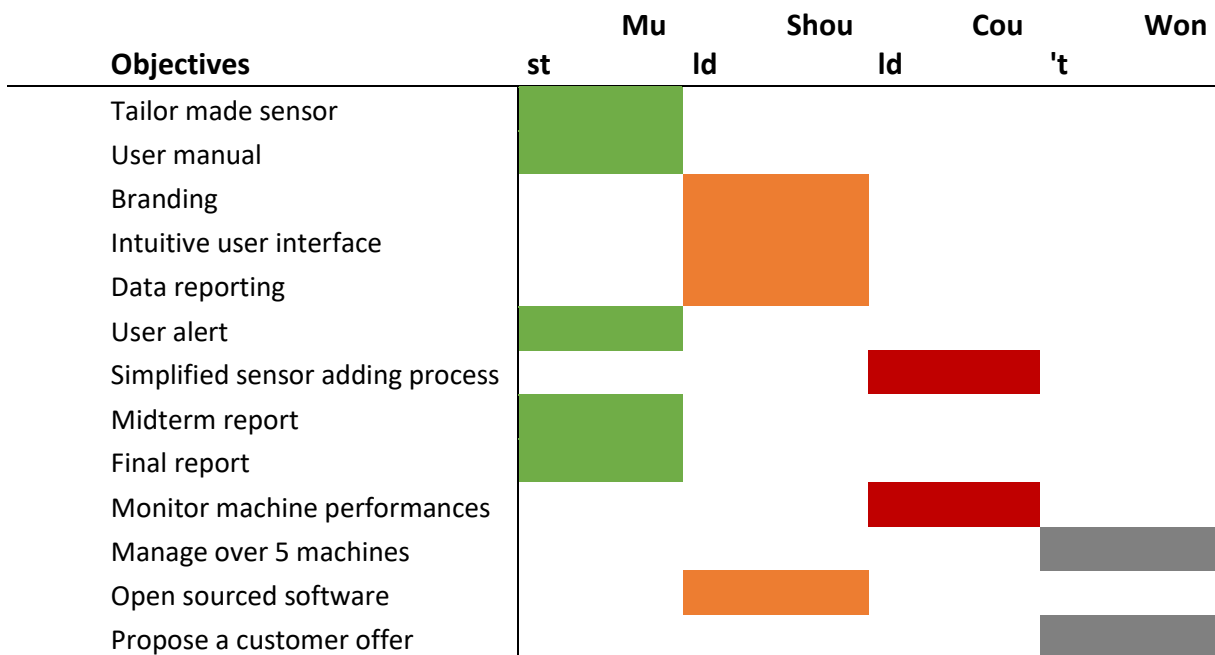
Stakeholders analyse

With this analyse the goal is to go deeper into the different stakeholders involved into the project. By defining degrees of interest and power for each one, the communication, information sharing, and the reporting can be adapted. Additionally, powerful stakeholders have to be included into decision-making process.

Inputs:

Tool: Microsoft Excel; Technique: MoSCoW

Result:



WBS

Inputs:

Based on the various information exchanged/collected during the first week, the overall objective of the project could be divided into easily measurable sub-deliverables and whose duration is also estimated. This division provides a clearer view of the project's limitations and also clarifies the expectations of each stakeholder.

Tools and techniques:

WBS provides a simple graphic overview of all the expectations and tasks associated with the project. We chose to divide the WBS into two: on the one hand all the elements directly related to the implementation of the project and on the other the indirect elements to ensure the follow-up of the project and the academic work. Direct spots are divided in chronological order to ensure simpler project tracking.

Tool: Adobe Illustrator; Technique: WBS

Outputs:

The result of the WBS is an exhaustive and clear list of all deliverables and the tasks that lead to them. All these tasks are accompanied by a precise description that will best adjust the estimate of working time.

Details in Appendix 1: tasks table

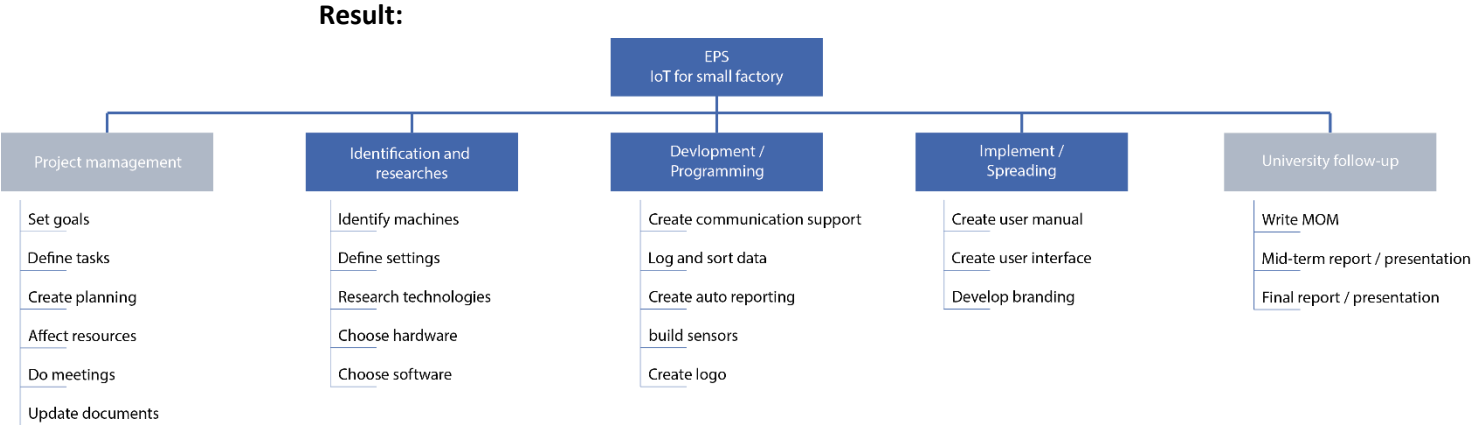


Figure 10: WBS

Risks and opportunities/changes analysis

Inputs:

In this case, everything is focus on preventing events. The main input is the list task which provide an overview of the project and will be the bases for this analysis.

Tools and techniques:

Brainstorming and meeting are the keys for a great analysis. The main goal is to figure out the problem and a way to handle it. Sorting by probability and importance factors allow to create and ranking and focus on the important points (except for risks, all of them must be taken into consideration).

Tool: Excel; Techniques: brainstorming, meeting

Outputs:

This study gives an overview of the project risks/opportunities and give the team a big advantage. By planning solutions and ways to take benefit of every situation the team can work more efficiently and be more reactive when a choice needs to be made.

Result:

| 1 (low) to 5 (high) | | | | | | | |
|--------------------------------------|-------------|------------|---|---|--|-----------------------------------|----------------|
| Risks | | | | | | | |
| Potential risks | Probability | Importance | Tasks list update | Preventive measure | Rescue measure | Rescue measure initialing event | Overall result |
| Delayed delivery | 3 | 3 | Add a note to "order stuff" task : "Check product availability" | Call the seller to ensure stock | Contact supplier to be delivered as soon as possible | Late on delivery | 9 |
| Team communication | 2 | 5 | Add a task "Weekly meeting" | Plan weekly meeting | Créer un document de suivi du travail journalier | More than 2 absence in a row | 10 |
| COVID 19 restriction | 4 | 2 | // | Keep alert about regulation | Home working | Gouvernemental announcement | 8 |
| Lack of knowledge | 4 | 5 | Add a task "Learning" | Enroll in additional classes | Learning on the internet | No lesson able | 20 |
| Implementation goes wrong | 2 | 5 | | Double check measure and data | Implement less sensors than plan | 1/3 late on this task | 10 |
| Erroneous estimation into planning | 4 | 4 | // | Add a security rate on uncertain tasks | Review objectives list | Late of more than 17% on the plan | 16 |
| Opportunities | | | | | | | |
| Potential opportunities | Probability | Interest | Tasks list update | Promoting measure | Opportunity measure | Initialing event | Overall result |
| Overestimated time | 2 | 5 | Add a task "communication with expert (for planning and development)" | // | Implementation without trouble | Good prevision, efficient work | 10 |
| Great reactivity and high commitment | 5 | 2 | // | Improve the cohesion between the different actors | Acceleration of the global project | Good communication from the team | 10 |
| Margin on budget | 3 | 5 | Add a task "Conduct a market study before choosing a supplier" | Partnership / advertisement proposal | Invest in more materials | expenses 20% below plan | 15 |

Figure 11: Table risks and opportunities

Human resource management

Inputs:

Once all the necessary tasks and knowledge have been defined the management of human resources to the objective of the distribution of work between the different actors of the project team. Not having the opportunity to adapt the demand as needed (definition of project teams without consideration of areas of expertise) the main objective here is to best distribute the work to be done according to the affinities and knowledge of each.

Tools and techniques:

A first draft of the task allocation was completed and refined with the entire project team during a meeting.

Tool: Microsoft Excel / Project; Technique: meeting / Belbin test

Outputs:

The roles and responsibilities of each are defined for all tasks. Combined with the planning the management of human resources will allow us to follow the progress of the project. This will also help to adjust the time allocation of tasks in order to spread the working time over the entire semester.

This may also allow us to confirm or not the sizing of the team (if working time exceeds the time available).

Result:

| Name | Start | Finish | Estimated Work |
|-----------------|-----------------|-----------------|----------------|
| Fabien Jumel | Thu 18/02/21 | Fri 28/05/21 | 249 hrs |
| Álvaro García | Thu 18/02/21 | Fri 28/05/21 | 181,8 hrs |
| Yoeri Reynaerts | Thu 18/02/21 | Fri 28/05/21 | 205,8 hrs |
| Janik Swerts | Thu 18/02/21 | Fri 28/05/21 | 250,8 hrs |

Details in Appendix 1: tasks table; Appendix 4: Project hours follow-up

Cost management

Inputs:

Based on the estimate of the overall working time induced by the project as well as research in order to estimate an average human cost per hour cost management is one of the key elements of the success of a project. It is important to add to the human cost the various material acquisitions necessary to carry out the project.

Tools and techniques:

Managing and tracking the cost of a project is a valuable indicator of the project's progress. In our case, all human cost assessments of the project were conducted using the MS Project.

Tool: MS Project, Excel; Technique: Cost follow-up % archived / overall costs

Outputs:

The rendering of this cost study is a curve that expresses the evolution of the estimated cost of the project according to the percentage of progress of the project.

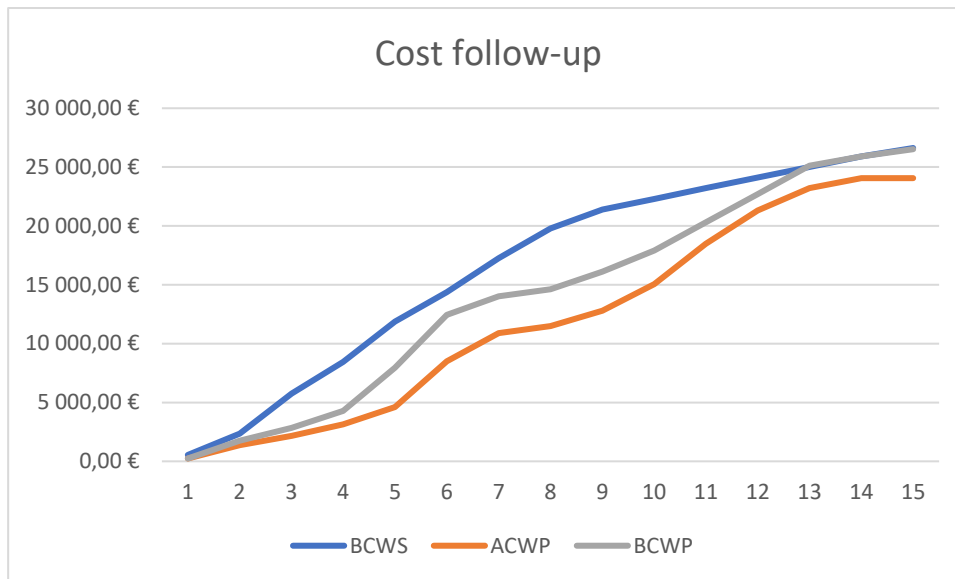


Figure 12: cost follow-up graphic

Analysis of the project's cost shows that the current cost is lower than expected. However, the variance in planning is zero (SV), the project is on time and completely ended. The final cost of the project is under the original forecast (CV).

Planning

Inputs:

The WBS and all the information that accompanies it (description of tasks / estimate of working time) make it possible to draw up a schedule for the project and define the critical path.

Tools and techniques:

We use 2 types of schedule the GANTT (bars) and PERT (arrows) charts. The PERT diagram provides a very graphic view of the schedule and makes it easy to identify the critical path.

Tools: MS Project; Techniques: GANTT/PERT charts + Critical Path Method

Outputs:

The planning resulting from this exercise serves as an element of performance monitoring but also as a guide to the entire project team. The MS Project software provides a graphic and simplified overview of the project. It also offers great modularity and makes it easy to evolve the different tasks.

Results:

Appendixes 2 and 3: PERT and GANTT charts

Quality management

Inputs:

Weekly hours, meeting reports and cost follow up provide a large range of information on which to base the quality analysis of the project.

Tools and techniques:

Tools for this analysis are Ishikawa diagram (causes – effect) and different graphics. The aim is to present an overview of the project through numbers and visual elements.

Tools: Excel, Word; Techniques: Ishikawa, meeting

Outputs:

The different graphics and indicators resulting of this analysis offer several ways to monitor, follow the project. They are used to describe alert thresholds and trigger action to correct the deviation. Those quality elements represent the health of the project.

Results:

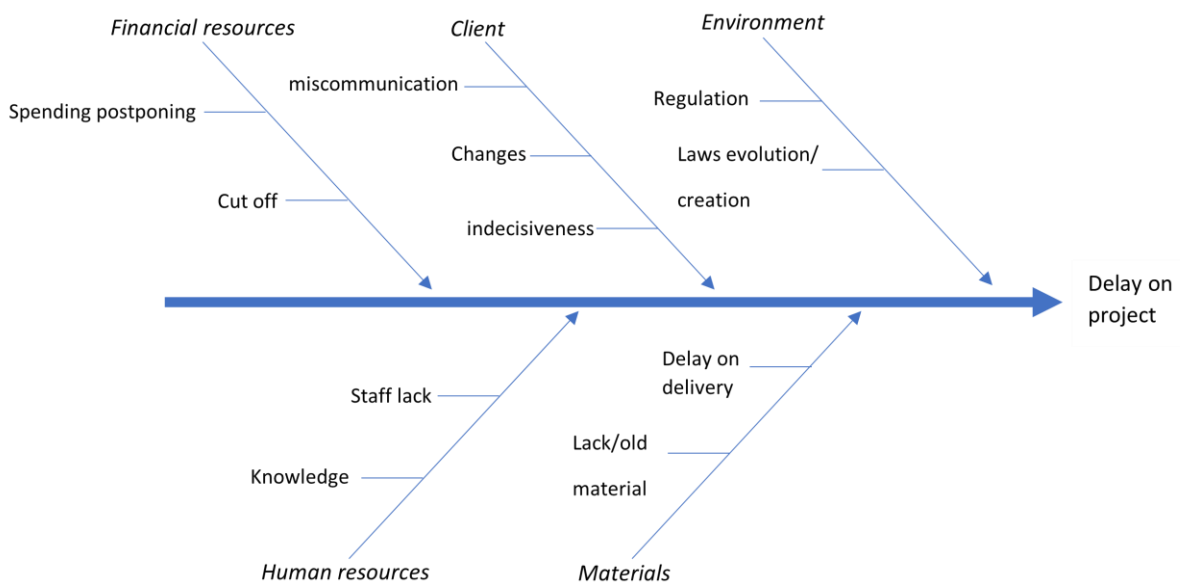


Figure 13: causes-effect diagram

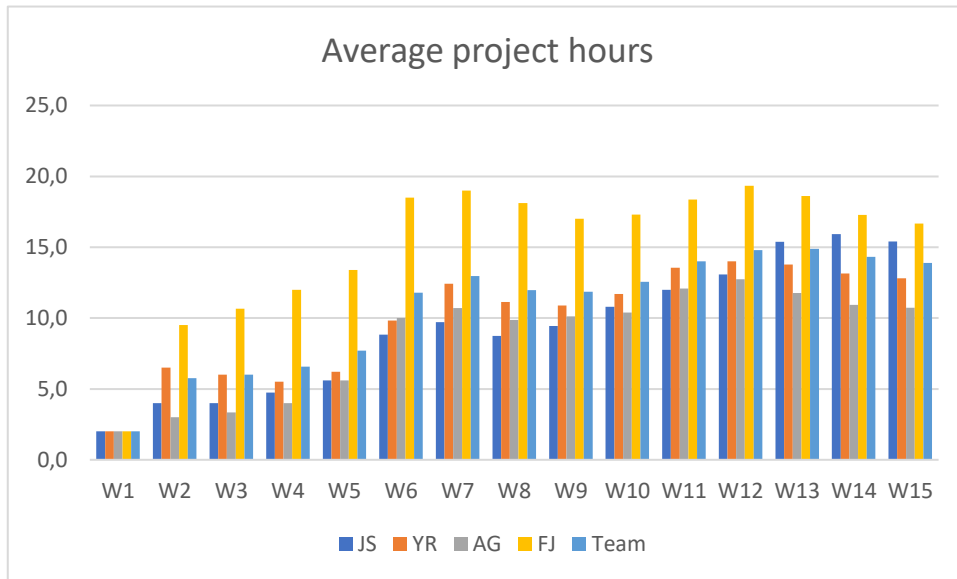


Figure 14: project hours follow-up

Details in Appendix 5: Weekly meeting report/agenda

Project initiation

Are home automation products suitable for industrial use?

Suitable applications for M2M and IoT

We can subdivide the application areas in which this technology can be set up into four large groups:

Manufacturing

Every manufacturing environment relies on technology to ensure that the costs are managed properly and that the production processes are executed efficiently. Automating manufacturing processes within such a fast-paced environment is expected to improve processes even more. In the manufacturing world could this involve highly automated equipment maintenance and safety procedures. When we clarify this with an example like: M2M tools allows a business owner to receive a notification when an important piece of a machine needs servicing, In this way, the person in charge of the installation is quickly warned and can schedule this maintenance to have as little production loss as possible.

Home appliances

M2M is expected to take home based IoT to the next level, there are a lot of manufacturers that are slowly unveiling smart home appliances to ensure a higher quality of life for occupants. For example, a washing machine that is capable to communicate M2M could send an alert to other smart devices once it is finished washing or drying. A smart refrigerator could automatically order groceries

from an online supermarket. There are a lot of other examples of home automation that can improve the quality of life.

Healthcare device management

Another big opportunity for M2M technology is in the realm of health care. With this technology hospitals can be able to automate processes to ensure the highest levels of treatment. This can be done using devices that can react faster than a human healthcare profession in an emergency. For instance, when a patient's vital signs drop below normal, an M2M-connected life support device could automatically administer oxygen and additional care until the healthcare profession arrives at the scene. With the use of M2M it is also possible to monitor patient at their home instead of in hospitals. There are cases where they can monitor the movement of an elderly person to detect if she falls and alert a healthcare worker as soon as possible.

Smart utility management

In the age of energy efficiency, automation will quickly become the new standard. We see this trend at the smart utility meters like energy and water. This smart measurement method is because of M2M, this helps energy companies to gather consumption data automatically and accurately, so they can make the bills for the customer. Smart meters can track how much energy a business or a household uses and can alert the energy company, this is even more important as utilities move towards a more dynamic pricing model, charging customers more for the energy that they use during peak times.

Home automation devices suitable for an industrial environment

One of the goals of this project is trying to implement IoT devices that are used in home automation systems in an industrial environment. Following there are the most used technologies/devices in home automation and possible use cases in a factory:

Lighting devices

This is one of the most common applications in home automation systems, with lots of smart light solutions available in the market. It is possible to control all the lights of your house through your smartphone, connected to smart switches that turn on/off the lights. It can also provide colour and brightness control of your bulbs.

Smart lighting products can help businesses monitor various premises and their environment, increase staff safety (including on-site traffic safety) and even deliver location-based services such as smart parking. Smart lights can optimize power consumption and give measurable return on investment.

Security and control

The devices used at some homes for surveillance and security, such as motion sensors, smart locks, cameras and alarms, can also be applied for factories. The suitability of this will depend on factors like factory location, value of the materials or critical processes.

Smart locks give small businesses increased convenience - with the ability to manage building access from any device - and security. Losing the keys can be a potentially major security risk, but with smart locks you and/or employees can control locks from phones or other devices.

Unique access codes allow small business owners to manage and track who enters a building – especially effective when used in conjunction with smart cameras and alarms.

Security cameras have been in operation for decades and are becoming more powerful and less expensive all the time. Today, connected cameras allow business owners to remotely monitor offices, warehouses, entrances and other areas. Unlike using expensive and voluminous servers or other storage devices, footage can be saved - often limitlessly - in the cloud. Connected cameras use Wi-Fi so no need of cables. Their reliance on Wi-Fi rather than cables does however mean they need a good wireless internet connection.

Virtual voice and audio assistants

Nowadays it is quite common to have a virtual assistant at your home that can complete tasks such as taking notes, setting reminders and delivering alerts. Virtual assistants have improved as artificial intelligence, machine learning and natural language processing (NLP) software develops. This list of functions is continuously growing and ranges from delivering audio search results to controlling remote security.

Apart from the productivity benefits for individuals, businesses are using voice assistants to offer better customer service and increase revenue by reducing the costs associated with a sale. Many businesses are integrating or optimizing their products and services for assistants such as Siri and Alexa to improve products and services or reach new audiences. Chatbots have been much lauded and continue to deliver efficiencies as well as valuable data to businesses.

Heating, ventilation and air conditioning (HVAC)

Smart climate control is one of the most cost-efficient technology in the IoT domain. Temperature and humidity sensors provide information that trigger actions like turning on air conditioner when the temperature crosses its cut-off values. That helps to reduce energy consumption, which means large money savings with time.

IoT can monitor storage facilities to help businesses with temperature control and ensure perishables are monitored, flag issues when necessary and maintain compliance. It can also be very useful for processes where temperature and humidity control are key variables.

HVAC can all be monitored and controlled centrally and remotely for added convenience and to maximize energy efficiency. As the technology develops, some devices can even implement machine learning to increase efficiency and cost savings even further.

Protection sensors

Flood or water leak sensors are extremely useful to detect pipe leakages or excessive water consumption at sinks. Similarly, fire or smoke sensors are useful in kitchen areas. These sensors will instantly notify users and help them to take proactive measures, thereby preventing any further major kind of damage. The flood sensors can also be used in garden areas to stop the water sprinklers in case excess water has been poured.

Those sensors generally have a low cost and can avoid devastating events such a fire. So, every home or factory should include them as a protective measure.

Concerns about security

One of the most common fears for adopters is security and data protection. Below are some concerns that companies should consider when implementing IoT.

As more and more connected devices and IoT technologies emerge - from wearables to alarm systems and access management - it is important for small businesses to maintain security. All those networked devices can offer bad actors new entry points to business systems that can pose new vulnerabilities and threats. These threats only increase the need for small business owners to invest in high-quality endpoint security.

Data storage is one of the key points. New policies regarding user’s data privacy can lead to legal costly problems for the company. As businesses collect great amounts of data via IoT, they must take care not to suck up personal data without storing it securely and in accordance with international privacy standards. Setting clear policies on anonymizing user data, as well as data retention, can help limit potential problems. For some cases it can be interesting hiring third-party companies to take care of this.

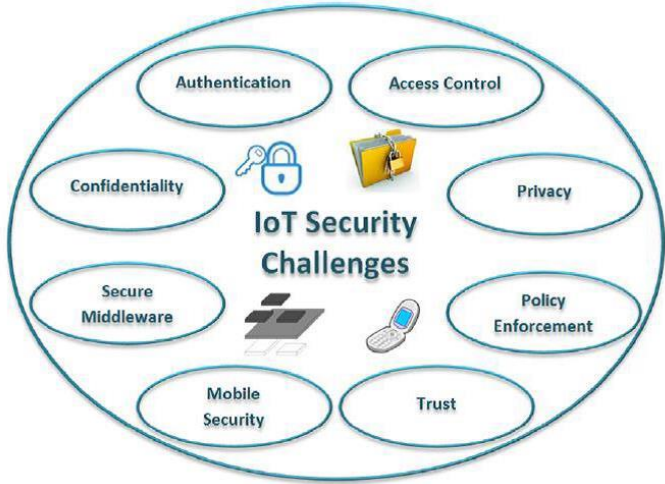


Figure 15: Common security challenges for IoT

Companies must be careful when purchasing IoT devices. Devices not updated can compromise all the network as most of them will eventually be hacked if they are not subjected to a verified update cycle. Therefore, it is important to look for trustable manufacturers who have proven to update their old products. If hackers can gain access to insecure devices, they can take down huge portions of the internet by simply hammering servers with relentless requests from thousands or millions of connected devices (DDoS, or distributed denial-of-service).

Smartphones are usually one of the main targets for hackers as an entry point often used to gain access to private data. Basic protection measures such as using secure passwords, storing them in a reliable place and being careful about the permissions set on apps can prevent major problems. In the end, companies should also think about how much automation they really need. Sometimes having everything connected and automated just makes the process more complicated and insecure and the benefits does not worth the potential risks.

Implementing IoT in small factories

Big factories are hopping on the IoT train seeing the opportunities that IoT can provide to their businesses. Healthcare, smart cities and big manufacturing industries have already taken advantage of this technology. IoT can help to create a technically driven environment for those companies. Figure indicates the evolution of the number of Internet of Things devices worldwide, we see that more and more smart devices are being added and that the Internet of Things network will continue to expand and increase in size.

IoT is profitable for factories to create faster development, optimize the production processes, cost control as well as increase the quality of their products, critical factors which impact Return on Investment. One of such fields is the manufacturing industries and Industrial Internet of Things has transformed it with things like big data, artificial intelligence and machine learning.

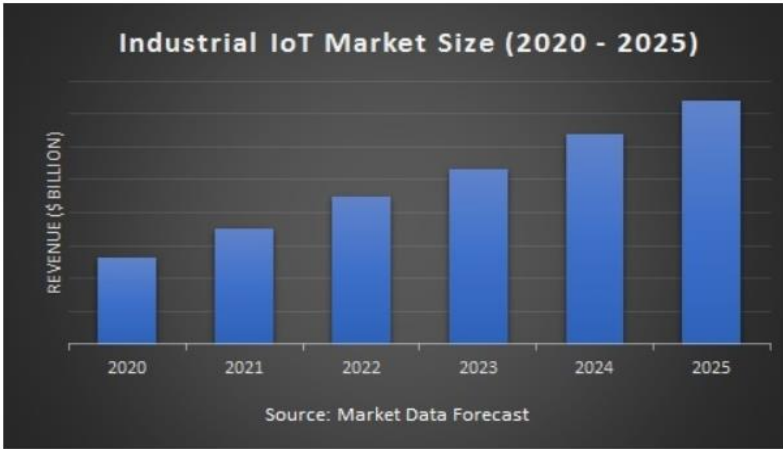


Figure 16: Rising IoT market share

However small companies are scared to make the transition to a IoT factory site because they think it is too expensive or they do not have the knowledge to change their factory to a smart factory. We see that there are more and more companies/factories that are making the transition to an Internet of Things environment, so it is extremely important for the small companies to participate in this upgrowing IoT trend in order to remain competitive with their direct competitors. In figure 16 is the fast growing IoT trend presented.

Key points for success:

Start small and try to scale over time.

Small companies should not try a broad adoption since the beginning, as it requires a larger investment and can cause confusion and compatibility issues. A gradual approach is more adequate, adding additional devices once they see the feasibility of this technology.

Considering, ideally, that small businesses will grow over time, owners should think about scalability. With that in mind, they should search solutions that will be compatible with devices that could be added in the future. Wrong planification will lead to bigger costs in future investments.

Focus on specific tasks and immediate needs.

Whenever a company is considering a new investment, it considers which are their most urgent/critical needs. For small companies with more restricted budgets, investments are time-sensitive, so owners should focus on areas with quick returns.

Once the goals are clear, companies should create a framework of how data will be coordinated and shared between devices. This also includes identifying which data is relevant and how this will affect to following decisions. If the project is too large, companies should consider the use of IoT platforms, which can directly provide all the maintenance and data collection and analysis needed. Each case should consider which solution is the most suitable for their needs.

Project execution

Before starting to create something, we have to figure out how we are going to work. There are 3 main points to settle on:

- Communication protocol
- Hardware and Software
- Sensors

All these choices will be the bases of the practical part. They must be refined well though to ensure a proper and smooth running of the project.

Communication protocols

To let the different IoT devices talk to each other we have to connect them with a communication network. We have a lot of different types of protocols that we can use for the communication between the different IoT components.

There are several IoT communication protocols available which are characterized by different capabilities, data rates, communication range, power usage and memory. They all have advantages and disadvantages so some of the communication protocols are suitable for use in small home appliances, while others are more suitable to use in a larger environment. It is our task to find out which protocols are the closest to our needs and which ones we want to use in our small industry environment.

To compare the different communication protocols with each other, we have all listed them up and added their most important technical parameters, then we gave each protocol point out of 5 on the different technical parameters to arrive at the most interesting protocols. By doing this we get a clear overview between the different options and we can draw technically substantiated conclusion

| Short range communication protocols | ZigBee | Wifi | Bluetooth | USB | Wireless | Z-wave | NFC |
|-------------------------------------|--|------------------|-----------------------------|-------|--------------|-----------------------|--------------------------|
| Data rate | 20, 40 and 250 Kbits/s | 11 and 54 Mbit/s | 1 Mbit/s | | 62,5 Kbits/s | 0,3 up to 50kbps | 100 up to 420kbps |
| score | 3 | 5 | 4 | | 2 | 2 | 3 |
| Range | 10-100 m | 50-100 m | 10 m | | 10 m | 30 m | 10cm |
| score | 5 | 5 | 2 | | 2 | 2 | 1 |
| Networking topology | Ad-hoc, P2P, star or mesh | Point to hub | Ad-hoc, very small networks | point | Point to | mesh network topology | single multi-hop network |
| Operating frequency | 868 MHz (Europe) ; 2,4 GHz (worldwide) | 5,4 and 5 GHz | 2,4 GHz | | 2,4 GHz | frequency can variate | 13,56MHz |
| Complexity score | Low | High | High | | Low | low | low |
| score | 5 | 2,5 | 2,5 | | 4 | 5 | 4 |
| Power consumption | Very low | High | Medium | | Low | low | low |
| score | 5 | 3 | 4 | | 5 | 5 | 5 |
| total score | 18 | 15,5 | 12,5 | | 13 | 14 | 13 |

ZigBee

- Zigbee standard 3.0 is based on IEEE802.15.4
- The Zigbee frequency is located on 2.4Ghz
- The range of the Zigbee protocol is 10 up till 100 meters
- The data rate of the Zigbee protocol is 250 kbps



Figure 17: ZigBee logo

Zigbee is one of the most used protocols in an IoT environment. It has significant advantages in complex systems: low power operation, high security protocol, robustness, high scalability and wireless control.

It is also suitable for industrial sites where there is a big need of low power components. The maximum number of nodes in a Zigbee network is 1024. Zigbee can transfer data with a range up to

200 meters and make use of the 128-bit AES encryption. Zigbee devices can also pass data through a mesh network, this can become very handy when we need to transfer data over a long distance because we can then use the intermediate components as a transceiver.

Wi-Fi

- This protocol is based on the standard IEEE (Institute of Electrical and Electronics Engineers) 802.11n
- The frequency used is 2,4GHz and 5GHz
- The range of this protocol is approximately 50 meters, but can expand up to 100 meters
- The data transfer speed is commonly 150-200 Mbps, but it depends on the channel frequency and number of antennas (the latest 802.11-ac standard can offer a speed from 500Mbps up to 1Gbps).



Figure 18: Wi-Fi logo

The Wi-Fi communication technology is a family of wireless network protocols. This type of connections are commonly used in Local Area networking and internet access. This communication protocol is capable of processing large amount of data so it is the go-to choice for many IoT developers.

The Wi-Fi protocol is mostly used in homes and small businesses because it offers a data rate of a few hundreds of megabits per second, which comes in handy to transfer large files. The main disadvantage for the most IoT applications is that it consumes too much power .

MQTT

- MQTT is an ISO/IEC 20922 standard protocol
- The data rate of the MQTT message protocol is around 256 mb in size



Figure 19: MQTT logo

MQTT (Message Queuing Telemetry Transport) is a lightweight message protocol that is often used for sending simple data flows from a sensor to an application. This protocol works on top of the TCP/IP network for sending reliable yet simple streams of data. The MQTT protocol comprises 3 key elements:

- subscriber
- publisher
- broker

It is often a good choice for a wireless network that experience occasional bandwidth constrains or unreliable connections.

Software

We will now figure out what kind of software and sensors based on these protocols we will use.

| <i>Hardware support</i> | | | | | | |
|-------------------------------|-----------------|--------------|-------------------|--------------|-----------------------|--------------------------|
| | <i>Price</i> | <i>Score</i> | <i>Complexity</i> | <i>score</i> | | |
| <i>IDE</i> | <i>Arduino</i> | free | 5 | High | 2 | |
| | <i>VS Code</i> | free | 5 | High | 3 | |
| <i>IO</i> | <i>Platform</i> | free | 5 | High | 3 | |
| | | | | | | |
| <i>Communication</i> | | | | | | |
| | <i>Price</i> | <i>Score</i> | <i>Complexity</i> | <i>score</i> | <i>code structure</i> | |
| <i>assistant</i> | <i>Node-Red</i> | free | 5 | Low | 5 | flow based |
| | <i>Home</i> | free | 5 | Low | 5 | simplified lines of code |
| | <i>VS Code</i> | free | 5 | High | 3 | lines of code |
| <i>Server / data services</i> | | | | | | |
| | <i>Price</i> | <i>Score</i> | <i>Complexity</i> | <i>score</i> | <i>Platform based</i> | |
| <i>mosquito</i> | <i>eclipse</i> | free | 5 | Low | 5 | locally |
| | <i>Google</i> | 3,50€/month | 3 | Low | 4 | cloud based |
| <i>lightsail</i> | <i>amazon</i> | 40,00€/TiB | 2 | Low | 4 | cloud based |
| | | | | | | |

Node-RED

Node-RED is the main programming tool in this project, it is used for directing the messages from the MQTT broker to the right client. The main reason that Node-RED is used is, because of the simple fact that the flow-based programming style is very easy to understand when you do not know anything about programming languages.

Flow-based programming

It is a way of describing an application's behaviour as a network of black-boxes, better known as a node in Node-RED. Each node has a well-defined purpose: it is given some data, then does

something with that data and then it passes that data further on. The network handles the flow of data between the nodes.

It is a model that lends itself to a visual representation and this makes it more accessible to a wider range of users. If you can break down a problem into discrete steps, they can look at a flow and get a sense of what it is doing, without having to understand the individual lines of code within each node.

Hardware

To compare the different sensors with each other, we have all listed them up and added their most important technical parameters. We also gave each sensor a point out of 5 on the different technical parameters to arrive at the most interesting sensors. By doing this we get a clear overview between the different options, so we can draw a technically substantiated conclusion.

| <i>Temperature sensors</i> | | | | | | | | | | |
|----------------------------|------------------------|-------------|----------------|--------------|--------------|--------------------------|----------------|----------------------------------|-------------|--------|
| | <i>Communi</i> | <i>s</i> | <i>Supply</i> | <i>s</i> | <i>Range</i> | <i>s</i> | <i>accur</i> | <i>s</i> | <i>T</i> | |
| | <i>cation protocol</i> | <i>core</i> | <i>voltage</i> | <i>core</i> | <i>core</i> | <i>core</i> | <i>acy</i> | <i>core</i> | <i>otal</i> | |
| B20 2 5 | DS18 | One-wire | 4 | 3 to 5.5V DC | 5 | -55 to 125°C | 4 | +/- 0.5°C (at -10 to 85°C) | 4 | 1 7 |
| | DHT2 | One-wire | 4 | 3 to 6V DC | 5 | -40 to 80°C | 2 | +/- 0.5°C (at -40 to 80°C) | 5 | 1 6 |
| | LM3 | Analog | 5 | 4 to 30 V DC | 3 | -55 to 150°C | 5 | +/- 0.5°C (at 25°C) | 2 | 1 5 |
| <i>Vibration sensors</i> | | | | | | | | | | |
| | <i>Communi</i> | <i>s</i> | <i>Supply</i> | <i>s</i> | <i>Range</i> | <i>s</i> | <i>Sens</i> | <i>s</i> | <i>T</i> | |
| | <i>cation protocol</i> | <i>core</i> | <i>voltage</i> | <i>core</i> | <i>core</i> | <i>core</i> | <i>itivity</i> | <i>core</i> | <i>otal</i> | |
| 335 | ADXL | I2C | 4 | 2 to 3.6V DC | 4 | X-axis 0.5 to 1600 Hz | 4 | +/- 2g | 4 | 1 6 |

| | | | | | | | | | | |
|---------------------------|------|------------------------|-------------|-----------------|--------------|-----------------|--------------|------|-------------|----------|
| -6050 | MPU | I2C | 4 | 2.3 to 3.3V | 3 | X-axis | 3 | +/- | 4 | 1 |
| | | | DC | | | 0.5 to 1000 Hz | | 2g | | 4 |
| A 7361 | MM | Analog | 5 | 3.3 to 5V DC | 5 | X-axis | 5 | +/- | 5 | 2 |
| | | | | | | 0.5 to 1500 Hz | | 1.5g | | 0 |
| <i>development sticks</i> | | | | | | | | | | |
| | | <i>Communi</i> | <i>s</i> | <i>Firmware</i> | <i>s</i> | <i>Certific</i> | <i>score</i> | | | <i>T</i> |
| | | <i>cation protocol</i> | <i>core</i> | <i>core</i> | <i>ation</i> | <i>exper</i> | | | <i>otal</i> | |
| ee 2 | Conb | Zigbee2 | 5 | coordinator | 4 | mental | 3 | | | 1 |
| | | MQTT | | | | | | | | 2 |
| 52RB | cc26 | Zigbee2 | 5 | coordinator | 5 | certifie | 5 | | | 1 |
| | | MQTT | | /router | d | | | | | 5 |

Home assistant:

Home assistant is described as a free open-source home automation system written in Python. It is a complete web user interface which can be hosted on a large range on hardware: Raspberry Pi, Asus Thinkerboard, Intel NUC operating under Linux, Windows, Mac OS. Working through add-ons and integrations, Home assistant offers great modularity and is suitable for many situations.



Figure 20: Home assistant

Integrations are one of the main features of Home Assistant, as they allow modular connection of devices and services using protocols like Wi-Fi, Zigbee and MQTT. All these elements are handled as entities in Home Assistant, which can trigger automations or used within scripts. Entities can be assigned to groups in order to be better organised. Automations, scripts and scenes can be created using Home Assistant interface or directly modifying YAML files using Add-ons like VS Code.

Home Assistant has a built-in dashboard called Lovelace. Its main features are that it is easy to use, with almost no programming knowledge required, and at the same time highly customizable. It gives the possibility of adding cards with different options that can represent the state of an entity or some specific data about it. It is also possible to add themes and upload tailor-made layouts.

According to the objective of the project (try to demonstrate the possibility to implement cheap automation system in small factories. Home assistant presents itself as an ideal solution. Ran on a Raspberry Pi 4 8GB RAM supplemented by an 64GB SD card and a CC2652RB it is allowing to work on 2 networks (ZigBee and WiFi) and offer enough performances to handle up to 10 sensors without facing any capacity problems. It is also providing the Node Red Add-on, hence there is no need of choosing between them.

Home assistant Add-ons

Add-ons are additional applications that the user can install through Home Assistant in order to further expand the functionalities. The Add-ons can be divided in two groups, the Official Home Assistant Add-ons and the third-party Add-ons. The official Add-ons are created and maintained by the Home Assistant team while the third-party Add-ons can be created by everyone.

In the following paragraphs the used Add-ons in this project will be discussed, what they are and what they do.

Eclipse mosquito

Eclipse mosquito is used for hosting a MQTT server on the home assistant system. This MQTT server allows communication with small IoT applications. That means that the home assistant system can receive and transmit information to the clients.

Zigbee2MQTT

Zigbee2MQTT is used to control Zigbee devices via MQTT. While the Add-on provides communication on software level, the home assistant system also need support on hardware level. The hardware support can be provided with a zigbee hub, in this project the CC2652RB usb stick was used.

ESPHOME

Esphome is used to manage and program ESP8266 and ESP32 based microcontrollers directly through the Home Assistant system. Due to its wide community of users the setup of a microcontroller is easy. It can even be stated so easy that there is no need for any programming experience.

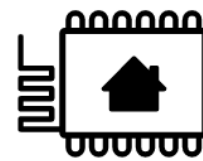


Figure 21 ESPHOME
logo

Samba share

Samba shares enables file sharing across different operating systems over a network. Meaning that the configurations files can be accessed from a computer in the same network as the Home Assistant system. By accessing the files modifications can be pushed through to the Home Assistant system and system recoveries can be accomplished.

File editor

File editor is a small web-app (you access it via web browser) that provides a filesystem-browser and text-editor to modify files on the machine the File editor is running on.

VS Code

Visual Studio Code allows editing the Home Assistant configuration from the web browser. Visual Studio Code runs as a remote server using code-server. Meaning that it can benefit from autocompletion and coding suggestions.



Figure 22 VS
Code logo

Node-RED

As we stated before at Hardware section, Node-RED is a flow based programming tool that allows to connect a wide range of different nodes, both from Home Assistant and different third party applications like Telegram. It is a good alternative to Home Assistant automations.

Influx DB

InfluxDB is a scalable time series database useful for storing events, metrics and real-time analytics. It is useful for recording high-volume sensor data. Chronograf and Kapacitor, Add-ons used for visualizing data and processing it, come preinstalled. Additionally, it can be used with Grafana for generating more complex charts and dashboards.

MotionEye

MotionEye is an open-source web-frontend, used to centralize the management and visualization of multiple types of cameras. This extension offers several possibilities: stream settings, motion detection, notification generation, flow redirection.



Figure 23: MotionEye logo

Sensors:

The objective of this part of the report is to look back at each of the sensors, how it works and its integration into Home Assistant.

ESP32-CAM

Presentation

The main use of this is to detect motion and get a live view of a place. In our case we use the ESP32-CAM to monitor the engine room as well as the usage of a 3D printer. The addition of an add-on into Home Assistant allows us also to perform motion detection.



Main characteristics:

- Brand: AI Thinker
- Module: ESP32S (WiFi, Bluetooth)
- Camera: OV2640 (up to 1600x1200p@15fps)
- Power supply: 3,3/5V
- Size: 40.5mm x 27mm x 4.5mm

Figure 24: ESP32 CAM

| + | - |
|---|--|
| <ul style="list-style-type: none"> • Size • Price • Easily settable • Support | <ul style="list-style-type: none"> • Stream quality • Power consumption (if portable) • No direct connector |

Preparation

As mentioned before, implement this sensor into our system is easy. The first part of the process consists in flashing the board through Arduino IDE, ESP Home or a similar software. The board has to be connected to a computer through an USB adapter. And the program that we uploaded

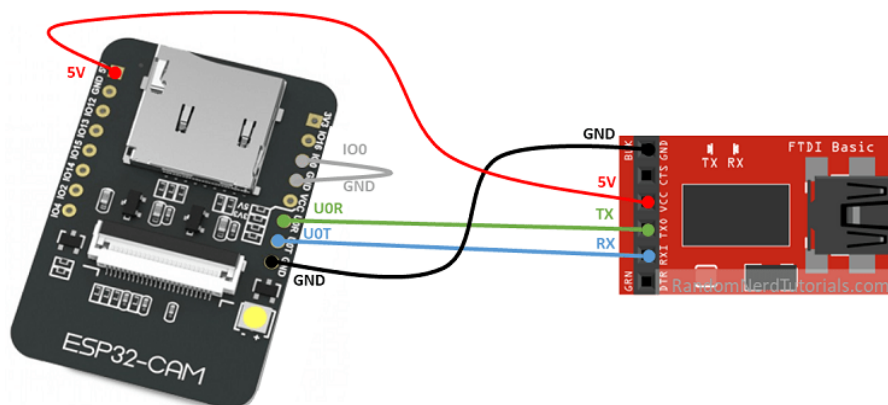


Figure 25: ESP32 connection schema

in the module can be found in the Appendix.

This program is composed of 2 different parts. The first part defines all the elements link to the network (SSID, password). An additional element is to define a static IP address for the

board, this fixed IP address helps to configure the camera in the software. The rest of the program focus on the configuration of the pins, camera, and stream settings.

The ESP32 CAM is now functional but must be integrated into Home Assistant. For this purpose, an add-on named Motion Eye is added to the system.

Implementation

Both Wi-Fi cameras are added through their IP address defined earlier. The motion detection module is activated and adjusted for tracking the 3D printer; notifications module is also used to generate a webhook¹ when motion is detected. For the second camera a stream link is created and will be used in Home Assistant dashboard to stream the engine room.

The webhook is included into a Home Assistant automation. This last step enables to link the motion detection with a visible element in the dashboard. An automation is defined by:

- **Trigger:** describe events which start the automation rule. This trigger can be a status of an element, a numeric value or a webhook.
In our case: Webhook.
- **Condition:** define of sub-elements which need to be considered into this automation. Those are generally a position, status, or number.
In our case: Is the indicator already on.
- **Action:** set changes that will be operated on the entities present in Home Assistant
In our case: turn on motion indicator.

The stream link generated is added as a source for a picture element into the dashboard.

Power supply:

3D printer: the camera can be plug on the USB-port of the printer through a splitter to keep a spot for transferring files to the printer.

Engine room: plugged on a wall socket or through a power bank.

¹ Webhooks are "user-defined HTTP callbacks". They are usually triggered by some event, such as pushing code to a repository or a comment being posted to a blog. When that event occurs, the source site makes an HTTP request to the URL configured for the webhook.

Case:

To improve aesthetics and offer a finished product the ESP32 CAM receive a special design case with the project logo on it. This case also works as a protection for the module and help to maintain the camera in a fixed position.

| PIECE | PRECISION | PRINTING TIME | WEIGHT | COST |
|-------|-----------|---------------|--------|--------|
| FRONT | 0,2mm | 44min | 7g | 0,175€ |
| BACK | 0,2mm | 17min | 3g | 0,075€ |
| PLATE | | | | |

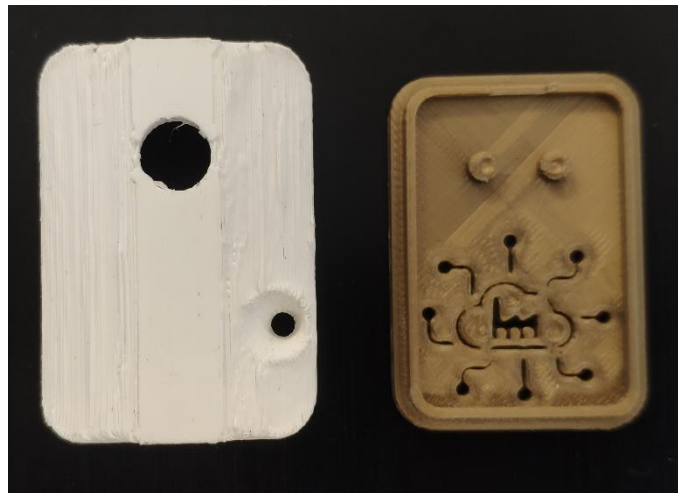
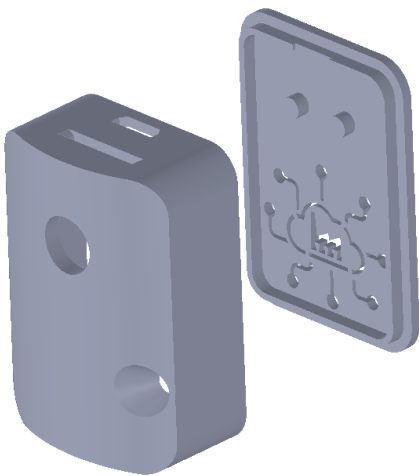


Figure 26: ESP32 CAM case

Aqara temperature and humidity

This sensor measures temperature, humidity, and atmospheric pressure. It is suitable for tracking these parameters at indoors environments, hence we decided that the engine's room would be a suitable place for it.



Main characteristics:

- Brand: Aqara
- Wireless protocol: Zigbee
- Battery duration: 2 years
- Temperature range: -20°C ~ +50°C, ±0.3°C
- Size: 36 × 36 × 9 mm

Figure 25: Aqara temperature

Implementation

The first step, in order to receive data from the sensor, is to use an Aqara hub or a generic Zigbee stick, in our case Slaesh's CC2652RB. We choose the second option because it provides the possibility of connecting sensors from other brands different to Aqara, hence giving more flexibility to the project. The price is also lower. However, this solution requires to flash the Zigbee stick, which was a tricky process and took us more time than expected.

Once it is flashed the process of pairing the Zigbee sensor and the stick is quite easy when we follow the steps of the manufacturer. We use Zigbee2mqtt add-on for adding Zigbee devices to Home Assistant. It only requires pressing the button of the sensors a few times, while "Permit join" is enabled, until they are connected. The data is received by Home Assistant via MQTT using the Mosquitto broker.

Accelerometer and gyroscope MPU6050

The MPU6050 is a 3-axis accelerometer and 3-axis gyroscope sensor. The accelerometer measures the gravitational acceleration, and the gyroscope measures the rotational velocity. Additionally, this module also measures temperature. This sensor is ideal to determine the orientation of a moving object.

The first choice was the Aqara vibration sensor, but the data updates were not sent regularly, and we could not achieve the goal of tracking the motion state of a robot arm in real time. MPU6050 is more precise and suitable for this application. However, we lose one of the main advantages of the Aqara sensor, which was its reduced size and weight. One possible line of improvement for this sensor would be researching about light and small solutions for powering the device.

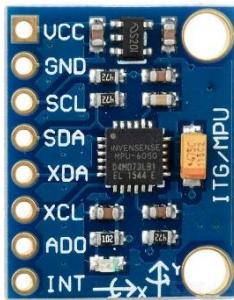


Figure 26:
MPU6050

Main characteristics:

- Brand: Greekcreit
- Module: Node MCU 32
- Power supply: 3,3/5V
- Gyro Range: ± 250 500 1000 2000 °/s
- Acceleration range: ± 2 ± 4 ± 8 ± 16 g
- Size: 2 x 1.6 x 0.1cm

Implementation

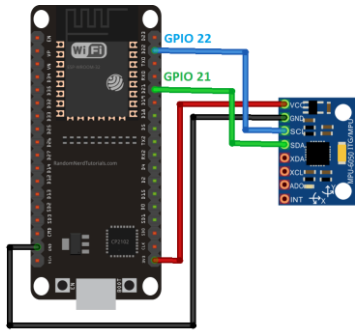


Figure 27: Connection diagram

The first step is installing the libraries and uploading the Arduino code to the ESP32 board. The wire connection diagram can be seen at Figure 26.

Once the data could be seen at Arduino's serial monitor and everything was working correctly, we soldered the pins, and we added the device to Home Assistant via ESPHome integration. As we stated before, ESPHome allows to easily program ESP8266 and ESP32 based microcontrollers, only writing YAML configuration files, while updates and compiling are all handled by ESPHome. Therefore, software configuration was quite simple.

DS18B20

The DS18B20 is a digital thermometer that provides a 9-bit to 12-bit Celsius temperature measurements. The DS18B20 communicates over a 1-Wire bus, that means the sensor requires only one data line for communication with a microprocessor. In addition, the DS18B20 can also be power directly from the data line and with that eliminating the need for an external power supply. Each DS18B20 has a unique 64-bit serial code, which allows multiple DS18B20s to function on the same 1-Wire bus.

Pin Diagram and Pin Description of DS18B20

The following image shows the Pin Diagram and the table next shows the pin description of DS18B20. There are two types of DS18B20 sensors a regular version and a waterproof version. The regular version can be seen on the left of the image where the waterproof version can be seen on the right.

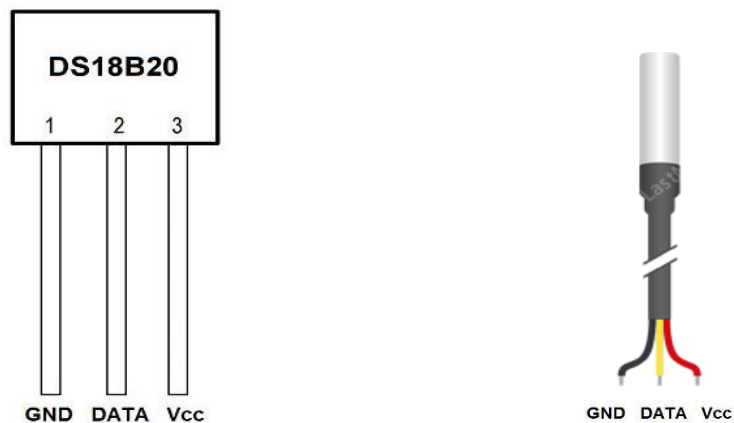


Figure 27 DS18B20

Table 1 Pins of DS18B20

| Pins of DS18B20 | | description |
|-----------------|--------|---|
| Name | colour | |
| GND | Black | Ground |
| DQ | Yellow | Input / Output Data. Must be pulled HIGH. |
| V _{DD} | Red | Power Supply |

Implementation

By wiring the DS18B20 sensor to an ESP32 microcontroller the temperature can be measured. The microcontroller will power and read the temperature of the sensors. After reading the temperature the value will be send to the Home Assistant system, where the value will be stored in a databank. In the image below the wiring diagram of the DS18B20 sensor to the ESP32 is shown.

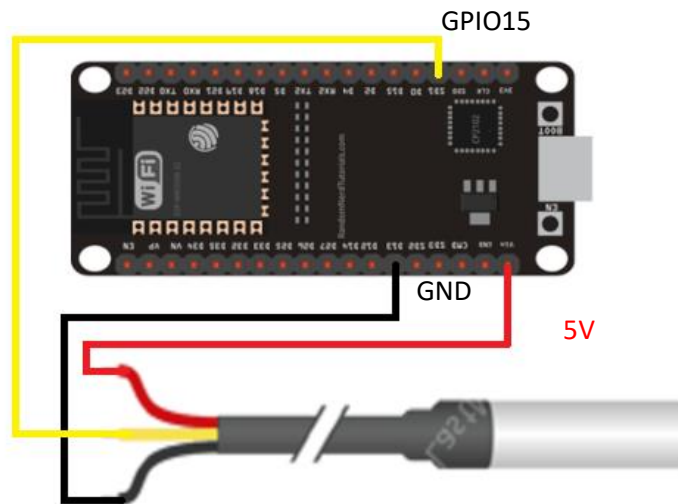


Figure 278 DS18B20 wiring diagram

Table 2 DS18B20 Connections to the ESP32

| Pins of DS18B20 | | | Pins of ESP32 | |
|-----------------|--------------|---|---------------|-----------------------------|
| Name | Description | | Name | Description |
| GND | Ground | ↔ | GND | Ground |
| DQ | Output | ↔ | GPIO15 | General input output pin 15 |
| V _{DD} | Power supply | ↔ | 5V | Power supply |

Smart plug

This sensor measures power consumption that is going through the plug. It is suitable for tracking the 3D-printer for movement or heating. The power consumption of a 3d printer in idle mode is very low in comparison to the printing mode.



Figure 28 hs110 smart plug

Main characteristics:

- Brand: TP-Link
- Wireless protocol: WiFi
- Voltage range: 100 - 240VAC
- Maximum load: 16A
- Size: 90 x 88 x 144 mm

Implementation

The first step, in order to receive data from the sensor, is to use Kasa app from the app/play store to configure the sensor to the network. This app will give the instructions on how to link the sensor to the network. Once linked to the network the app will reveal the IP address of the connected sensor. By linking this IP address to the home assistant system we can retrieve the measured values.

These measured values need to be analysed, this is done in node-RED. First there needs to be an update interval for the values in this case there was chosen for an interval of 5 seconds. So, every 5 seconds a difference in values can be seen. After the update interval there is also a value comparator, this comparator will check if the consumption is above a certain value. This value has been determined with tests on the 3D printers at Technobothnia and out of this test came the value 15 watts. When the power consumption of a 3D printer exceeds 15 Watts the printer can be evaluated as working/printing everything below 15 Watts can be evaluated as idle.

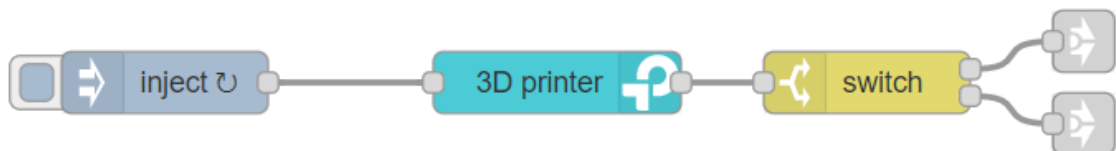


Figure 29 Smart plug Node-RED

In the image above is the node-RED flow of the 3D printer tracker visible. The inject node is used for the update interval and the switch node is used as comparator. The two grey nodes on the end are used to notify the system of the printer is printing or is idle.

CO₂ sensor MQ135

A subtask for the IoT project is that we will equip the engine room that is located in the basement of Technobothnia with a handmade measurement sensor box. We will implement in this box an MQ135 sensor that will measure the CO₂ pollution in the room. Next up we will make the values readable on the home assistant dashboard and we will also generate an alarm in the room itself to warn the people that are present in the room when the CO₂ level exceeds a certain concentration.

The components that we used for this task are:

- MQ-135 sensor (air quality sensor).
- 22kΩ resistor.
- ESP32-S VROOM module.
- Indicator LEDs (we will use red, green and yellow LEDs to indicate the current state of the CO₂ concentration).
- Piezo buzzer (to generate a sound alarm).
- 220Ω and 250Ω resistors.

The MQ-135 air quality sensor

The MQ-135 gas sensor is an air quality sensor that can be used to measure a wide variety of gasses, the sensor can measure gasses like:

- Carbon dioxide (CO₂).
- Carbon monoxide (CO).
- Alcohol.
- Ammonium (NH₄).
- Etc.

The operating voltage of the sensor chip ranges from 2,5 up to 5 Volt so we can choose if we want to connect the sensor to the 3,3 volt pin or the 5 Volt pin (because we only have a 3,3 Volt pin on the ESP32-S will we connect the sensor to this voltage). The MQ-135 sensor has a lower conductivity when it is surrounded by clean air. When the number of detectable gases increases around the sensor the conductivity of the gas sensor will also increase.

When we turn on the sensor after it has been inoperative for a certain period of time, we must let it heat up for about 5 minutes before the analog output of the sensor sends the right values out. This is because the sensor first has to heat up the air around the sensor so it can measure the right concentration of a certain gas in that heated air. This also means that these kinds of sensors are not very suitable for IoT devices because the heating procedure itself will take up quite a lot of energy. We can also not really work with an on/off interval since the heating process is relatively long (5 minutes) and we want to know the CO₂ values in a quick interval so we can warn people in time.

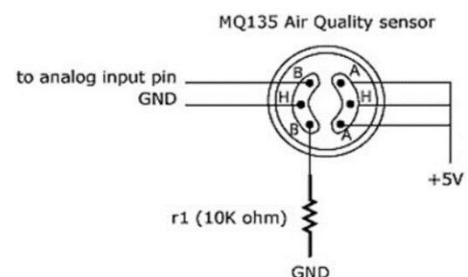


Figure 30 internals of the MQ135 sensor

The output of the air quality sensor is a signal output indicator instruction. The sensor has two different outputs, one analog and one digital output. by using the analog output signal it is possible to measure the concentration of a certain type of gas. When the gas concentration around the sensor increases, the output voltage of the sensor will also increase proportionally.

Characteristics of the MQ-135 sensor:

- Good sensitivity.
- Has a long lifespan and a low cost (€9).
- Has a good sensitivity for the different measurable gasses.
- Wide detecting scope.
- Heating up time between 2 and 5 minutes.

Preparing the MQ-135 sensor

Before we can connect the MQ-135 sensor we have to figure out how the internals of the sensors are located in order to understand the working of the sensor. Understanding the operation of the sensor can be done easily by consulting the circuit diagram of the sensor.

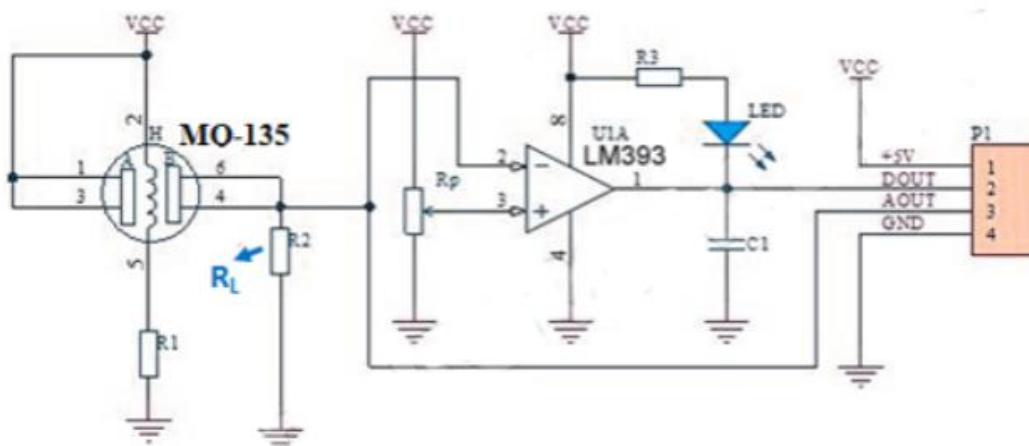


Figure 32 Electronics inside the MQ-135 sensor

In this diagram we see that the RL resistor plays an important role in making the sensor work. This resistance will change according to the amount of gas that the sensor detects. The resistor value can change from 10kΩ up to 47kΩ. In the datasheet we can find which value to use for R_{load} to get the most accurate measurement results, this value is 20kΩ. When we take a look at the backplate of the sensor we see that it already has a build in resistor of 1kΩ so we have to replace this resistor with one of 20kΩ.

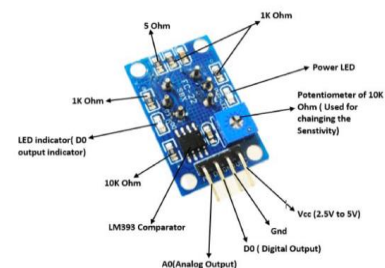


Figure 31 view of the backplate

SENSITIVITY ADJUSTMENT

Resistance value of MQ-135 is difference to various kinds and various concentration gases. So, When using this components, sensitivity adjustment is very necessary. we recommend that you calibrate the detector for 100ppm NH₃ or 50ppm Alcohol concentration in air and use value of Load resistancethat(R_L) about 20 KΩ(10KΩ to 47 KΩ).

When accurately measuring, the proper alarm point for the gas detector should be determined after considering the temperature and humidity influence.

Figure 33 sensitivity of the MQ-135

After the RL resistance value of the sensor is known we need to figure out what the R_0 value is. This R_0 value is the resistance value of the MQ-135 sensor when it is surrounded by clean air. In order to measure this value we need to make use of the **MQ135.h** Arduino library, another important thing to consider is that we should preheat the sensor for about 24 hours before we can use. This heat up period will ensure that we read in the correct R_0 value. The figure below shows how the sensor is connected to measure its R_0 value. Keep in mind that since the ESP WROOM-32 module is not integrated in the fritzing software, a similar board is used where the connections are in a different place but the pin numbers on the fritzing software and in real life do match each other.

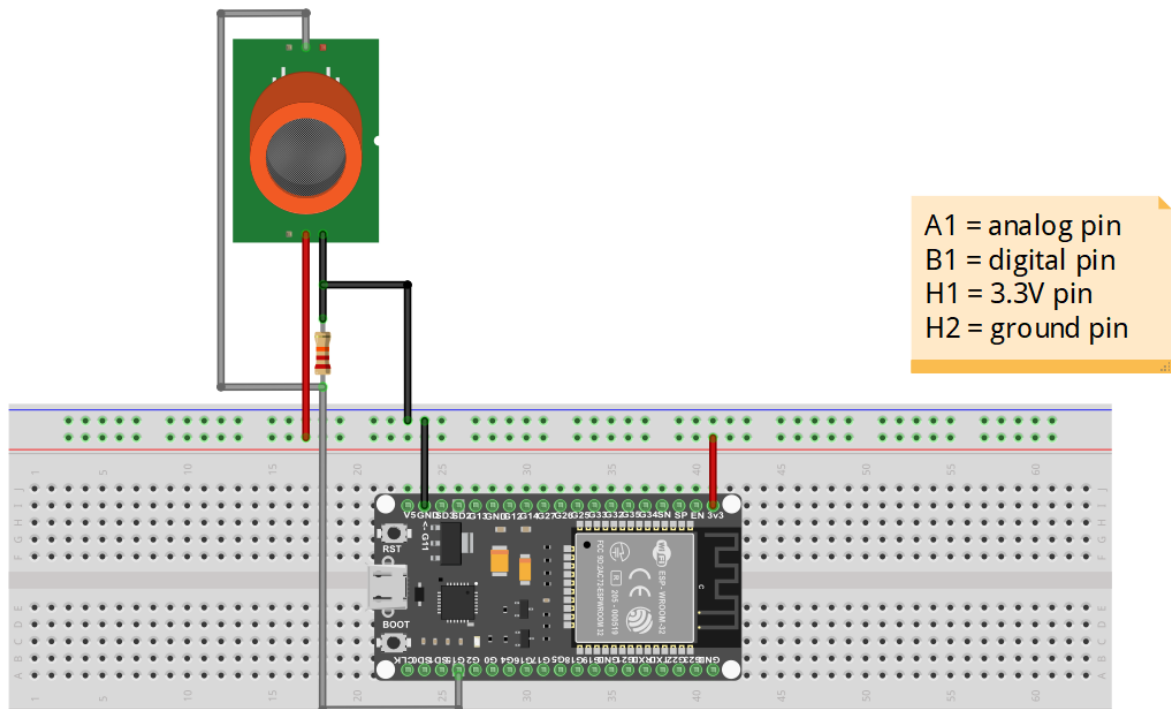


Figure 34 Connection diagram for MQ-135 sensor for the warm-up procedure

When we now open up the serial monitor we can see corresponding resistance value of the MQ135 sensor.

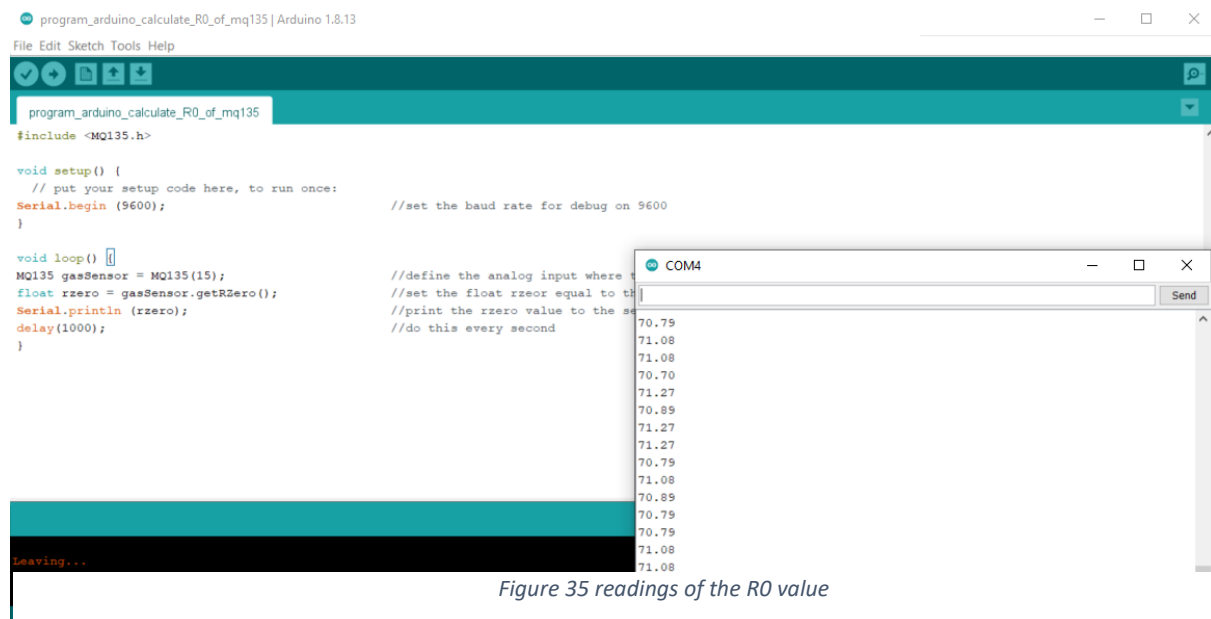


Figure 35 readings of the R_0 value

We both need the R_0 and the R_{load} value to adjust in the MQ-135 library, furthermore, we also need to know what the current co^2 pollution in the atmosphere is at this time this value can be googled. So the following values are:

- $R_{load} = 20k\Omega$
- $R_0 = 70,79$
- Atmosphere co^2 value = **411,29 PPM**

When we enter the correct values in the MQ-135 library the program will take these parameters into account and apply in the code of our project.

```

MQ135.h - Notepad
File Edit Format View Help
#include "Arduino.h"
#else
#include "WProgram.h"
#endif

// The load resistance on the board
#define RLOAD 22.0
// Calibration resistance at atmospheric CO2 level
#define RZERO 70.79
// Parameters for calculating ppm of CO2 from sensor resistance
#define PARA 116.6020682
#define PARB 2.769034857

// Parameters to model temperature and humidity dependence
#define CORA 0.00035
#define CORB 0.02718
#define CORC 1.39538
#define CORD 0.0018

// Atmospheric CO2 level for calibration purposes
#define ATMCO2 411.29
  
```

Figure 36 changing the MQ-135 library

Circuit diagram of the MQ-135 sensor

After we entered the correct parameters into the MQ-135 library we can start programming the code into the Arduino IDE software. The full circuit of the sensor box is explained in the paragraph below, as already said we will use the MQ-135 air quality sensor to measure the co^2 pollution of the air in the engine room, to visualise the concentration of the carbon dioxide we will use three LED's to indicate. We will also use a buzzer to give a signal to the people in the engine room when the co^2 value in the room is too high.

On the next page there are two images showing how the electrical connections are made between the components and the development board, as already mentioned before the module in Fritzing does not fully correspond to the applied ESP32-S module. The practical and the theoretical modules have the same connections but they are located on a different place on the board.

the connections of the components are as follows:

- The data pin of the buzzer is connected to GPIO27;
- The data pin of the red led is connected to GPIO14;
- The data pin of the yellow led is connected to GPIO13;
- The data pin of the green led is connected to GPIO25;
- The analog pin of the MQ-135 sensor is connected to GPIO15;
- The ground of the three LEDs and the buzzer are connected together to one of the ground pins on the module and the ground pin of the MQ-135 sensor is connected to the other ground pin on the ESP32-S module.

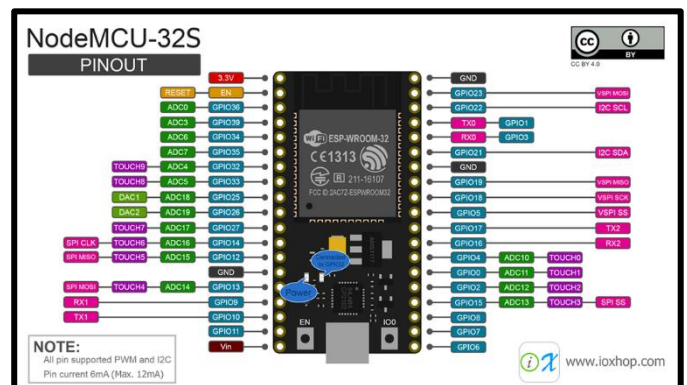


Figure 37 pin lay-out node MCU

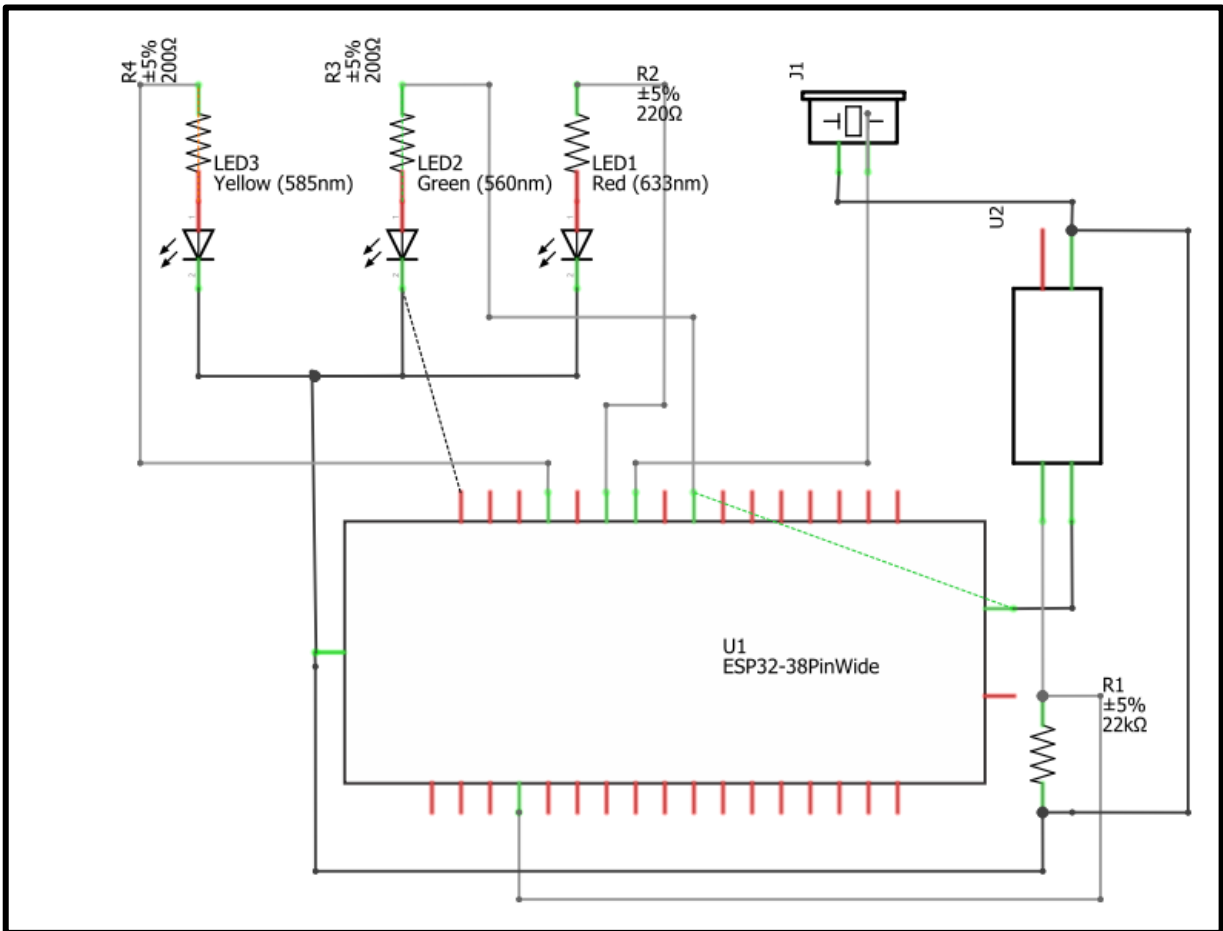
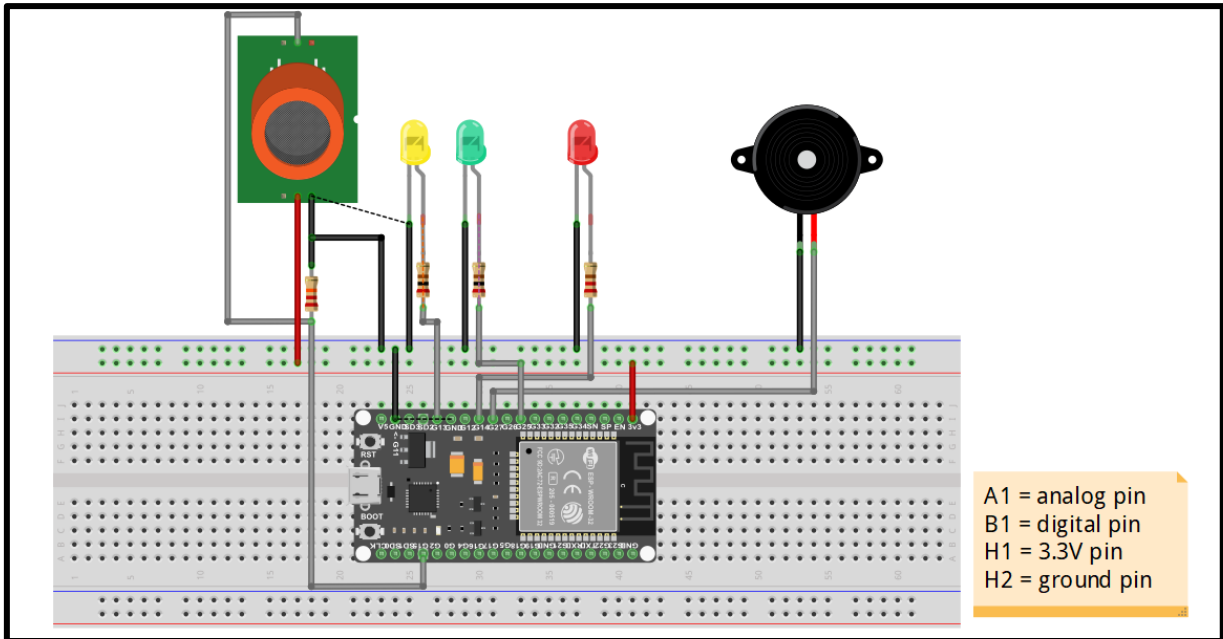


Figure 38 wiring diagram for the co² sensorbox

Arduino code for the MQ-135 sensor

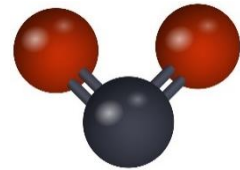
Since we are using home assistant it is possible to easily connect IoT sensors to the dashboard of home assistant using the ESPHome software that can be added by the add-on menu in home assistant. Unfortunately, this method is not possible to apply for the different air quality sensors that are currently on the market. This is because each air quality sensor can vary strongly from one another so there is no uniform way to calibrate the sensors.

Because of this we need to use the Arduino IDE software to program the MQ-135 sensor, this is in comparison with the ESP home software many times more complicated and cumbersome specially to make these values visible on a MQTT broker. The upside of programming it this way is that there are a lot of different possibilities and the program can be made to your own wishes. The full Arduino IDE code is given within a few pages

Levels of CO_2 concentration for human health

Because an excessive CO_2 concentration in the air can have a detrimental effect on the human body, we have to define certain limits between which the concentration is acceptable or no longer acceptable. Based on these predefined limits, we will also control the indication LED's and the buzzer.

So a brief introduction to what exactly CO_2 is and why we want to create air with a low CO_2 content. CO_2 or carbon dioxide is the fourth most abundant gas in the earth atmosphere, when CO_2 is at room temperature ($\pm 22^\circ\text{C}$) the gas is colourless, odourless and non-flammable, because the presence of CO_2 is very difficult for humans to sense it is important to take precautions against it in order to guarantee people's health.



CO_2 can be emitted in a variety of ways, for example, the normal cell function of humans and animals continuously emits CO_2 . Furthermore, CO_2 is mainly known as an unwanted gas that is produced during the burning process of fossil fuels. Exposure to carbon dioxide can cause a lot of adverse health effects on living organism. These health effects may include headaches, dizziness, restlessness, difficult breathing, sweating, increased heart rate, etc.

The CO_2 concentration with associated health problems are:

- 250 – 400 ppm: this is the normal outdoor air pollution.
- 400 – 1.000 ppm: this is the typical CO_2 pollution in occupied spaces with a good air exchange.
- 1.000 – 2.000 ppm: At this level of contamination, complaints may arise such as drowsiness and poor air quality.
- 2.000 – 5.000 ppm: this level of CO_2 pollution is associated with headaches, sleepiness, and stagnant, stale, stuffy air. Poor concentration, loss of attention, increased heart rate and slight nausea may also be present.
- 5.000 ppm: with such a high degree of pollution, other harmful gases may also be present in the room. It is also possible that toxicity and oxygen deprivation may occur.
- 40.000 ppm: this CO_2 concentration is immediately harmful due to oxygen deprivation.

Since we are going to implement the CO₂ sensor box in an engineroom we are going to choose to set the buzzer alarm to go off in time (CO₂ concentration above 2.000ppm), this way people have time enough to either turn on the ventilation or leave the room in time.

The table below shows at which CO₂ concentration which indicator will be activated and for how long.

| CO ₂ concentration | Indicators | duration |
|-------------------------------|---------------------------|--|
| Between 0 and 400 ppm | Green LED | 3 seconds on/3 seconds off |
| Between 400 and 1.000 ppm | Yellow LED | 3 seconds on/3 seconds off |
| Between 1.000 and 2.000 ppm | Red, green and yellow LED | 3 seconds on/3 seconds off |
| CO ₂ ppm > 2.000 | Buzzer and red LED | LED 3 seconds on/3 seconds off Buzzer 1 second on/5 seconds off |

Energy consumption of the sensor box

Since we are still in the process of making an IoT sensor it is certainly important to take the energy consumption of the sensor box into account. In the engineroom we do not have the possibility to use a socket to power the sensor box so therefore we need to work with a battery, we will make use of a powerbank in this project, since it can store many times more energy than a battery and it is easy to recharge.



A major disadvantage of the power bank is that it is fairly large and heavy, which greatly increases the size of the sensor box.

The powerbank we use is the Primo Powerbank 10,000 mAh. it is a portable charger that has 2 usb ports that can deliver a current of 2.1 and 1 ampere respectively and this at a voltage of 5 volts.

In the excel sheet below the energy consumption of the various components is calculated in order to determine how long the powerbank can power the sensorbox. For each component is listed what the voltage, current and working hours are per day and also the consumption in WH and Ah are calculated.

| component | voltage (V) | current (A) | hours/day (H) | effective hours** (H) | wattage (W) | consumption (Wh) | consumption (Ah) |
|---------------------------|-------------|-------------|---------------|-----------------------|-------------|------------------|------------------|
| LED red | 3,2 V | 0,015 A | 1 h | 0,5 h | 0,048 W | 0,024 Wh | 0,0075 Ah |
| LED yellow | 3 V | 0,015 A | 11,5 h | 5,75 h | 0,045 W | 0,25875 Wh | 0,08625 Ah |
| LED green | 3 V | 0,015 A | 11,5 h | 5,75 h | 0,045 W | 0,25875 Wh | 0,08625 Ah |
| MQ-135 sensor | 3,3 V | 0,15 A | 24 h | 12 h | 0,495 W | 5,94 Wh | 1,8 Ah |
| buzzer | 3,3 V | 0,09 A | 1 h | 0,5 h | 0,297 W | 0,1485 Wh | 0,045 Ah |
| resistor LED red | 1,8 V | 0,015 A | 1 h | 0,5 h | 0,027 W | 0,0135 Wh | 0,0075 Ah |
| resistor LED green/yellow | 2 V | 0,015 A | 23 h | 11,5 h | 0,03 W | 0,345 Wh | 0,1725 Ah |

| | |
|--------------------------|-----------|
| total consumption (Ah) | 2,205 Ah |
| total consumption (mAh) | 2205 mAh |
| powerbank capacity (mAh) | 10000 mAh |
| days | 5 days |

We see from the calculations of the energy consumption that the power bank can only power the sensor box for a maximum of 5 days. This is because, as mentioned earlier, the sensor an internal

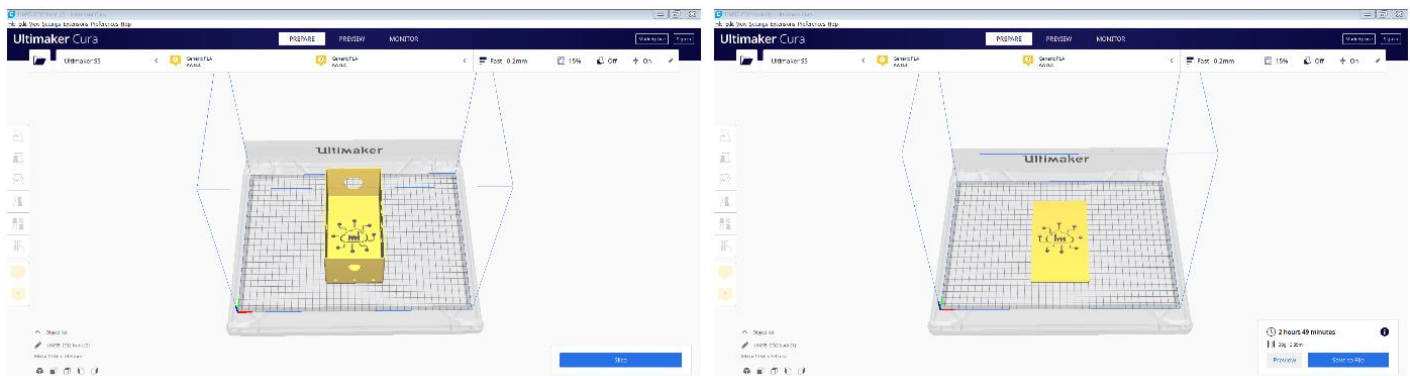
heating element has that heats up the air around the sensor in order to measure the CO_2 concentration. However, it is also not an option to measure the CO_2 level in intervals (such as one measurement and then nothing for a few minutes) since we cannot continuously monitor the air quality in this way and cannot warn the people in time.

Because we use led's we also have to take into account the maximum current that can flow through the led's to guarantee the longest possible life span. These calculations are also made and displayed in the excel sheet below

| resistor calculation | current (A) | voltage (V) | voltage drop led (V) | needed resistor (Ω) | used resistor (Ω) | power dissipation (W) |
|----------------------|-------------|-------------|----------------------|------------------------------|----------------------------|-----------------------|
| circuit red led | 0,015 A | 5 V | 1,8 V | 213,3333333 Ω | 250 Ω | 0,05625 W |
| circuit green led | 0,015 A | 5 V | 2 V | 200 Ω | 220 Ω | 0,0495 W |
| circuit yellow led | 0,015 A | 5 V | 2 V | 200 Ω | 220 Ω | 0,0495 W |

Sensor box case

To improve the aesthetics of the various components and to ensure that the entire sensor installation is nicely concealed, we have chosen to design a sensor box that ensures that the electronics are shielded from the engine installation. The 3D version of the box was first designed in SolidWorks and then implemented in the Ultimaker Cura software in order to obtain a 3D printed version.



| PIECE | PRECISION | PRINTING TIME | WEIGHT | MATERIAL |
|--------------------|-----------|----------------|--------|----------|
| CO_2 FRONT PLATE | 0,2mm | 8 hours 8 min | 93g | PLA |
| CO_2 BACK PLATE | 0,2mm | 2 hours 49 min | 30g | ABS |



Figure 39 co² sensorbox

Connecting the co² value to the MQTT broker

With the aforementioned programme, it is possible to read out the co² value from the MQ-135 sensor into the Arduino IDE sensor. Now it is still the intention to be able to send this value to the home assistant software in order to use it later in Node-Red. To do this we will use a MQTT (Message Queuing Telemetry Transport) broker. This broker can be added to the build in Add ons that supports home assistant. In the Arduino IDE program we now have to write some extra code to read out the measured value of the MQ-135 sensor.

To display the co² value on the dashboard, we first need to create an entity, for which we can use the standard integrated entity node in Node-Red. Further, we are going to create a short program in node red in which we are going to put the co² value in PPM on the dashboard and where we are also going to generate a telegram alarm message to warn about the high co² concentration.

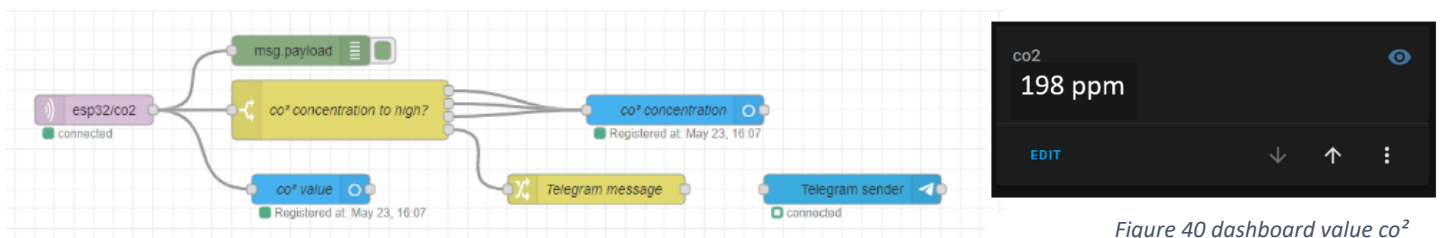


Figure 41 node red program for the co² value

Figure 40 dashboard value co² sensor

The total Arduino IDE programme now looks like this:

```
#define RLOAD 22.0 //the used resistor for the MQ-135 sensor
#include "MQ135.h" //include the MQ-135 library
#include <PubSubClient.h> //include the pubsubclient library
#include <WiFi.h> //include the wifi library
#define buzzer 27 //buzzer is connected to pin D27 on ESP board
#define redled 14 //red LED is connected to pin D14 on ESP board
#define yellowled 13 //yellow LED is connected to pin D13 on ESP board
#define greenled 25 //green LED is connected to pin D26 on ESP board

const char* ssid = "IoT_Project_Router_2.4GHz"; //add the SSID of the router
const char* password = "IoTProjectFUJA"; //add the wifi password in the code

const char* mqtt_server = "192.168.0.50"; //fill in the IP adress of the MQTT broker

WiFiClient espClient;
PubSubClient client(espClient);
long lastMsg = 0;
char msg[50];
int value = 0;

MQ135 gasSensor = MQ135(15); //the MQ-135 gassensor is connected to the analog pin 15 on ESP board
int val; //set the value in an integer
int sensorPin = 15; //we use pin 15 to connect the MQ-135 sensor
int sensorValue = 0; //set the sensor value to 0 integer

void setup() {
  Serial.begin(115200); //set the baud rate to 9600
  pinMode(sensorPin, INPUT); //set the sensorPin (MQ-135) as an input
  pinMode(buzzer, OUTPUT); //set the buzzer pin as an output
  pinMode(redled, OUTPUT); //set the redled pin as an output
  pinMode(greenled, OUTPUT); //set the greenled pin as an output
  pinMode(yellowled, OUTPUT); //set the yellowled pin as an output

  setup_wifi();
  client.setServer(mqtt_server, 1883);
  client.setCallback(callback);
}

void setup_wifi() {
  delay(10);
  // We start by connecting to a WiFi network
  Serial.println();
  Serial.print("Connecting to ");
  Serial.println(ssid);

  WiFi.begin(ssid, password);

  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }

  Serial.println("");
  Serial.println("WiFi connected");
  Serial.println("IP address: ");
  Serial.println(WiFi.localIP());
}

void callback(char* topic, byte* message, unsigned int length) {
  Serial.print("Message arrived on topic: ");
  Serial.print(topic);
  Serial.print(". Message: ");
  String messageCo2;

  for (int i = 0; i < length; i++) {
    Serial.print((char)message[i]);
    messageCo2 += (char)message[i];
  }
  Serial.println();

  // Feel free to add more if statements to control more GPIOs with MQTT

  // If a message is received on the topic esp32/output, you check if the message is either "on" or "off".
  // Changes the output state according to the message
  if (String(topic) == "esp32/output") {
    Serial.print("Changing output to ");
    if (messageCo2 == "on"){
      Serial.println("on");
    }
  }
}
```

```

    else if(messageCo2 == "off"){
        Serial.println("off");
    }
}
}

void reconnect() {
// Loop until we're reconnected
while (!client.connected()) {
    Serial.print("Attempting MQTT connection...");
    // Attempt to connect
    if (client.connect("ESP8266Client")) {
        Serial.println("connected");
        // Subscribe
        client.subscribe("esp32/output");
    } else {
        Serial.print("failed, rc=");
        Serial.print(client.state());
        Serial.println(" try again in 5 seconds");
        // Wait 5 seconds before retrying
        delay(5000);
    }
}
}

void loop() {

    val = analogRead(A15); //read in the analog value of pin 15
    Serial.print ("raw = "); //print the raw in the serial monitor
    Serial.println (val); //print in the value into the serial monitor
    // float zero = gasSensor.getRZero();
    // Serial.print ("zzero: ");
    //Serial.println (zero);
    float co2 = gasSensor.getPPM(); //get the co2 value in ppm
    Serial.print ("ppm: "); //print in the text "ppm"
    Serial.print ("CO2"); //print the text co2 into the serial monitor
    Serial.print (" (PPM)"); //print the text PPM into the serial monitor
    Serial.print (co2); //print in the ppm value of the sensor into the serial monitor
    delay(2000); //delay for 2 seconds

}

if (!client.connected()) {
    reconnect();
}
client.loop();

long now = millis();
if (now - lastMsg > 5000) {
    lastMsg = now;

    char Co2String[8];
    dtostrf(co2, 1, 2, Co2String);
    Serial.print("carbondioxide: ");
    Serial.println(Co2String);
    client.publish("esp32/co2", Co2String);

    // Convert the value to a char array
    char carbondioxideString[8];
    dtostrf(co2, 1, 2, carbondioxideString);
    Serial.print("carbondioxide: ");
    Serial.println(Co2String);
    client.publish("esp32/co2", Co2String);

if (co2<400 && co2>0){ //when the co2 parts per million is below 400 then (typical outdoor co2 concentration)
    digitalWrite (buzzer, LOW); //set the buzzer output pin to low
    digitalWrite (redled, LOW); //set the redled output pin to low
    digitalWrite (yellowled, LOW); //set the yellowled output pin to low
    digitalWrite (greenled, HIGH); //set the greenled output pin to high
    delay(3000); //wait for 3 seconds
    digitalWrite (greenled, LOW); //set the greenled back to low
    delay(3000); //wait for 3 seconds
}

else if (co2>400 && co2<1000){ //when the co2 parts per million is between 400 and 1000ppm then (typical level of co2 in occupied spaces with good air exchange)
    digitalWrite (buzzer, LOW); //set the buzzer output pin to low
    digitalWrite (redled, LOW); //set the redled output pin to low
    digitalWrite (yellowled, HIGH); //set the yellowled output pin to high
    digitalWrite (greenled, LOW); //set the greenled output pin to low
    delay (3000); //wait for 3 seconds
    digitalWrite (yellowled, LOW); //set the yellowled output pin to low
    delay (3000); //wait for 3 seconds
}

delay (3000); //wait for 3 seconds
digitalWrite (yellowled, LOW); //set the yellowled output pin to low
delay (3000); //wait for 3 seconds
}

else if (co2 >1000 && co2<2000){ //when the co2 PPM value is between 1000 and 2000 then (level associated with complaints of drowsiness and poor air)
    digitalWrite (buzzer, LOW); //set the buzzer output pin to low
    digitalWrite (redled, HIGH); //set the redled output pin to high
    digitalWrite (yellowled, HIGH); //set the yellowled output pin to high
    digitalWrite (greenled, HIGH); //set the greenled output pin to high
    delay (3000); //wait for 3 seconds
    digitalWrite (redled, LOW); //set the redled output pin to low
    digitalWrite (yellowled, LOW); //set the yellowled output pin to low
    digitalWrite (greenled, LOW); //set the greenled output pin to low
    delay (3000); //wait for 3 seconds
}

else if (co2> 2000){ //when the co2 PPM value is greater then 2000 then (alarm the co2 concentration in the air is to high and not healthy)
    digitalWrite (buzzer, HIGH); //set the buzzer output pin to high
    digitalWrite (redled, HIGH); //set the redled output pin to high
    digitalWrite (yellowled, LOW); //set the yellowled output pin to low
    digitalWrite (greenled, LOW); //set the greenled output pin to low
    delay (1000); //wait for 1 second
    digitalWrite (buzzer, LOW); //set the buzzer output pin to low
    digitalWrite (redled, HIGH); //set the redled output pin to high
    digitalWrite (yellowled, LOW); //set the yellowled output pin to low
    digitalWrite (greenled, LOW); //set the greenled output pin to low
    delay (2000); //wait for 2 seconds
    digitalWrite (buzzer, LOW); //set the buzzer output pin to low
    digitalWrite (redled, LOW); //set the redled output pin to high
    digitalWrite (yellowled, LOW); //set the yellowled output pin to low
    digitalWrite (greenled, LOW); //set the greenled output pin to low
    delay(3000); //wait for 3 seconds
}
}

```

Branding:

To add sense to our project and add value to our creation developing branding around the product is essential. In our case we focus on very simple elements such as a logo, name and a website.

Logo and name:

Logo and name give a visual identity to the project. The goal for both is to be easy to recognize and remember. They also must transmit a message and be a reflect of our objective and our product.

The logo must include a common representation of industry but also technology. Our strategy was to let everyone works on ideas/design and vote for the most appropriate solution during a meeting.

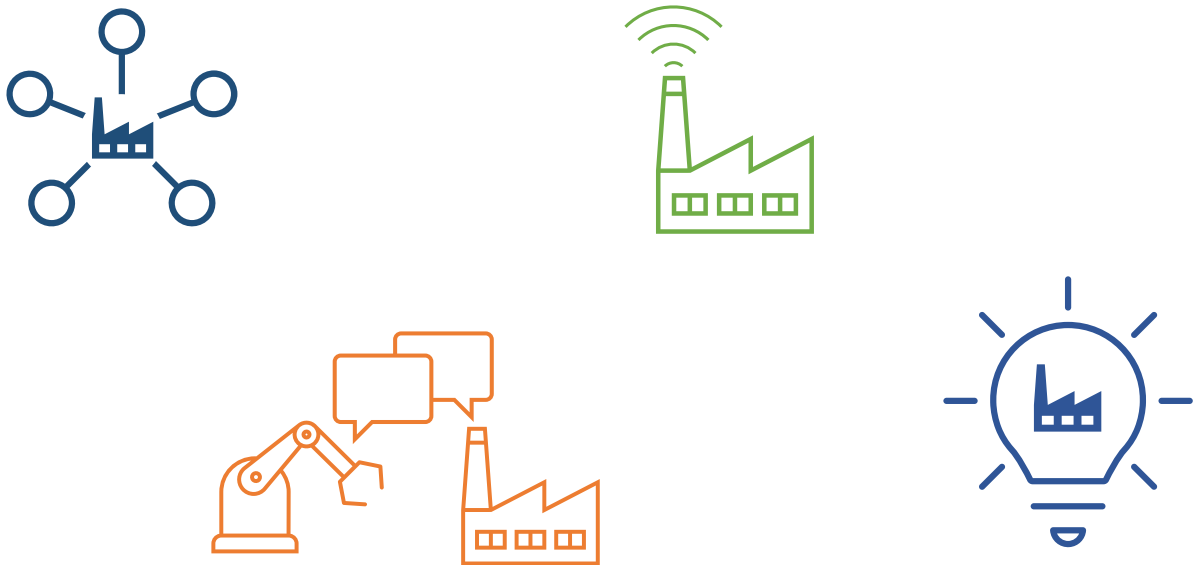


Figure 42: Logo proposals

The chosen solution (right) is a combination of a classic vision of industry (the factory) and the cloud and network representing the future. Deep blue color is seen as a evidence of firmness and strength, it's also a regular color in technologies and industry field.



Figure 43: selected logo

The name of our project is also a perfect reflect of the theme of our project “IoT small factories” as a wink to IoT we decide to name our project “Industry of Tomorrow”.

Website:

To offer more visibility to the project a dedicated website has been created. On this website you will find 2 pages, a homepage with a quick presentation of the project and key elements and on the second page there is a quick overview of the team members.

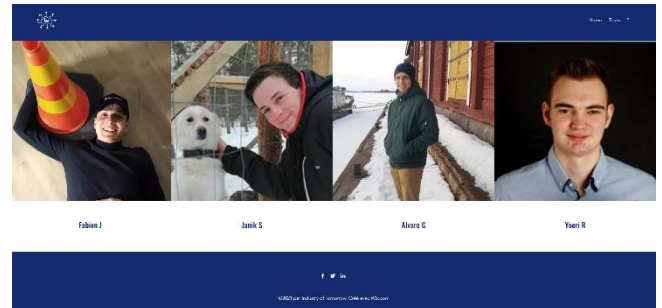
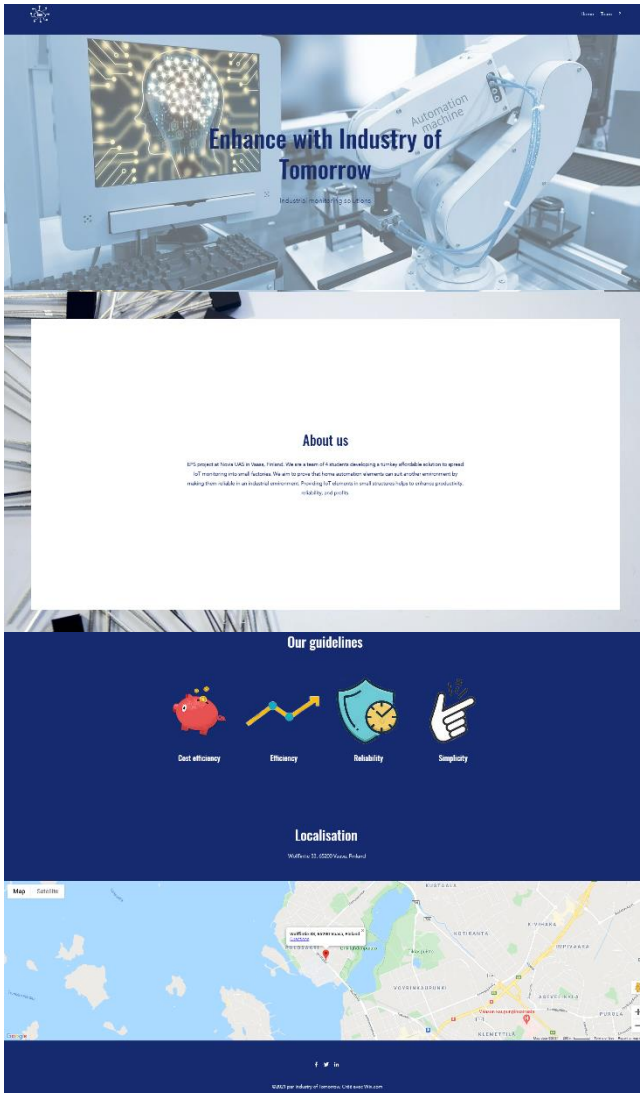


Figure 44: Website overview

Auto report

An important goal of this project is generating automatic reports as a proof of concept. The reports are a useful tool for quickly checking some statistics about the day, such as maximum and minimum temperatures or machine's usage time. We established daily frequency as it is the most suitable rate considering the type of data received.

The working principle is reading the data stored at InfluxDB databases, using Node-RED for processing and structuring this data and finally sending the report to Telegram. It exists the possibility of creating more tailor-made solutions using add-ons like Jupyter Lab or Home Assistant templates, but we preferred to keep it simple as we did not need a complex report. Anyway, this solution is also very flexible and can be used as a base for more detailed reports.

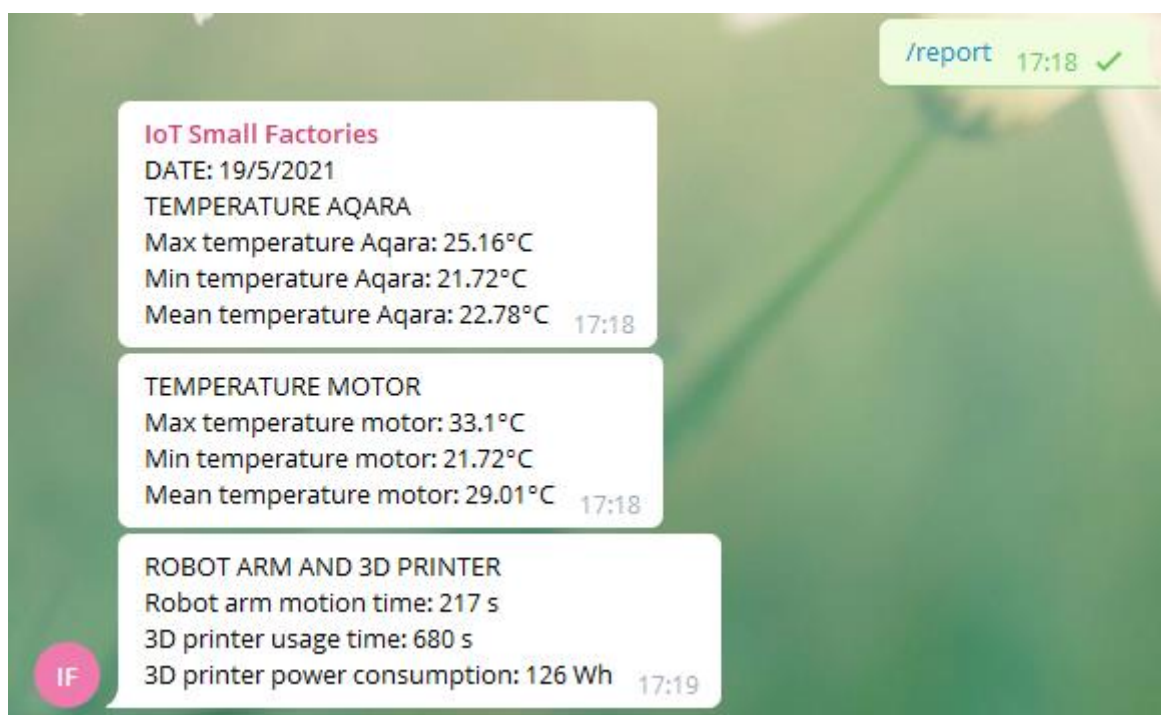


Figure 28: Example of report obtained using the command "/report" directly form Telegram

Temperature of the Aqara temperature sensor and the Dallas sensor, respectively. This data can be accessed using queries sent to Influx DB, in which it can be specified time range (in our case one day), data series or functions like mean or maximum values. The report is structured in 3 sections. The first 2 are the minimum, maximum and mean

The third part of the report is tracking the usage time of the robot arm and 3D printer, as well as power consumption. The robot arm usage time is measured using a counter node of the motion messages received from the accelerometer at the robot arm, with a rate of one per second. 3D printer usage time is tracked in a similar way, checking when the power consumption measured by the Kasa plug is over a minimum threshold. This data is reset every day after the report is sent at the time established, in our case 20:00.

Once the data is obtained, Node-RED process it and generate formatted messages, as we can see in the figure above.

These messages are sent by a bot to a Telegram group, in which you can see the reports and alerts directly at your phone, without the need of being at the laboratory or connected to the same network. It is also possible to request a report whenever you want sending a message “/report” from your phone.

The code used can be found at Appendix 2.

Alerts

Firing alarms and instantly sending messages to Telegram when some parameters are out of their desirable working range is another interesting feature that we have implemented in Node-RED. These are some examples of possible alarms that are set:

- Low battery of Aqara sensors when it is below 20% of its maximum capacity.
- High or low room and motor temperature.
- High CO₂ level.

The code used can be found at Appendix 2.

Project analysis:

The objective here is to go back over all the work done and its management. The analysis of the project allows us to learn from the actions taken and to improve the management of future projects. This type of feedback can also serve as a knowledge support for other teams.

Observations:

| Positive points | Negative points |
|---|--|
| <ul style="list-style-type: none">- Communication- Team spirit- Work splitting- Commitment- open-mindedness and strength of proposal- On time work | <ul style="list-style-type: none">- Work regularity- Time to get into the project- Lack of time- Limited access to school |

The lessons learned from this project are numerous and of diverse types. We all get new knowledge out of our main study field, learn how to work in group on a “long term” project and how to handle a situation of diversity / international mixing.

What next?

According to our initial plan we tick most of the objectives: research about technologies, material definition and requirements, developing solutions to demonstrate the feasibility of the project, implement it in a similar environment as industry. The coming work might be focus on reliability, power supply solution and developing a larger network. It still many interesting challenges to face and solve!

Appendix

Appendix 1: tasks table

| Notes | Task Name | Description | Duration | Resource Names | Estimated cost |
|-------|-----------------------------|---|----------|---|----------------|
| A | Project presentation | Project presentation by the supervisor | 0 days | | |
| AA | Meet team | First meeting with the team. Main goal is to learn to know each other | 1 day | Álvaro García[25%];Fabien Jumel[25%];Janik Swerts[25%];Yoeri Reynaerts[25%] | 180,00 € |
| AB | Goals definition | Define vision, mission | 5 days | Álvaro García[25%];Fabien Jumel[25%];Janik Swerts[25%];Yoeri Reynaerts[25%] | 900,00 € |
| AC | Structure project team | Split responsibilities and roles during meeting and through the whole project | 2 days | Álvaro García[25%];Fabien Jumel[25%];Janik Swerts[25%];Yoeri Reynaerts[25%] | 360,00 € |
| | Environment analysis | Define all the limits all the project, budget, people... | 7 days | Álvaro García[25%];Fabien Jumel[25%];Janik Swerts[25%];Yoeri Reynaerts[25%] | 1 260,00 € |
| BA | Project initiation | | | | - |
| BB | Collect information | Collect information about the concept behind the project | 8 days | Álvaro García[25%];Fabien Jumel[25%];Janik | 1 440,00 € |

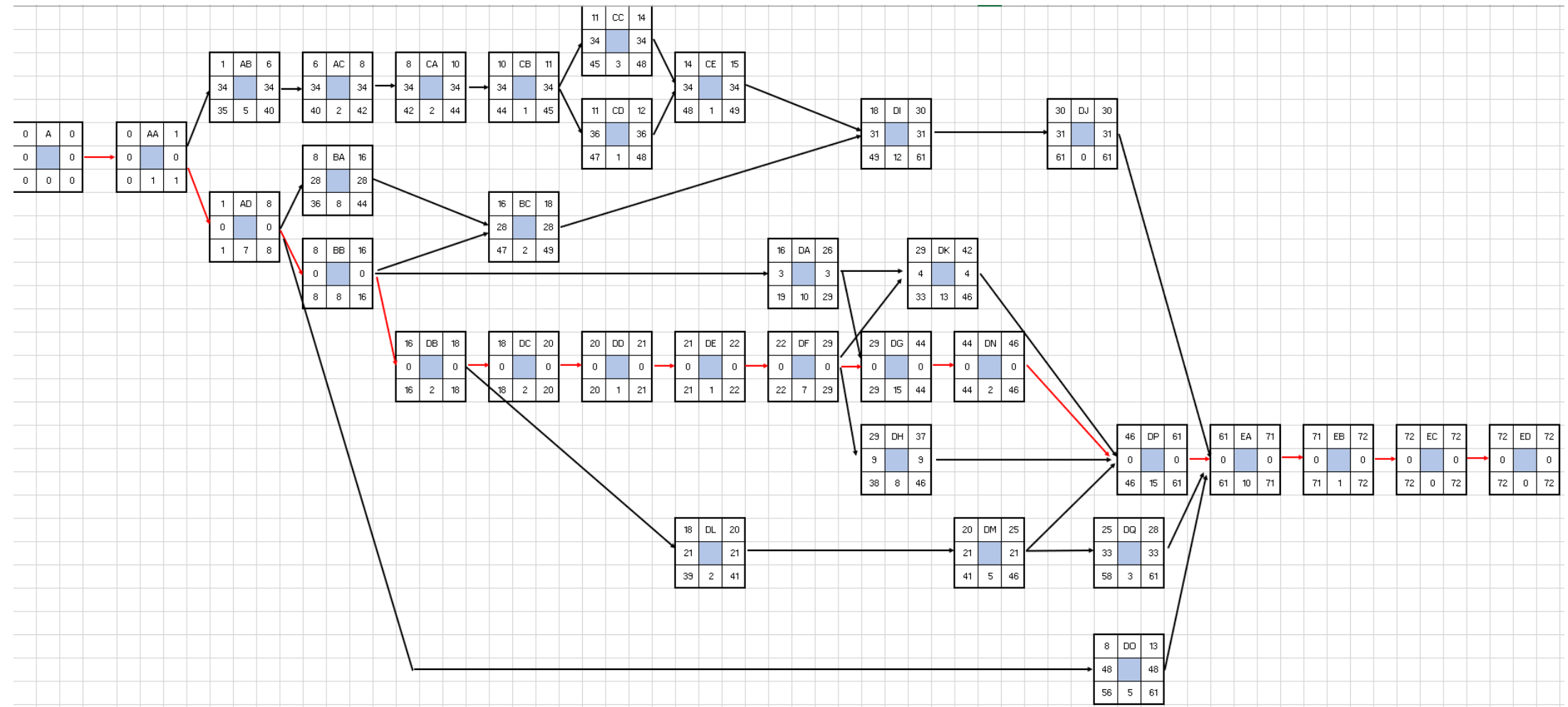
| | | | | | |
|----|--------------------------------|---|---------|---|------------|
| | | | | Swerts[25%];Yoeri Reynaerts[25%] | |
| BC | Feasibility study | Study information about IoT and home automation | 8 days | Álvaro García[25%];Fabien Jumel[25%];Janik Swerts[25%];Yoeri Reynaerts[25%] | 1 440,00 € |
| | Identify opportunities / risks | Foresee and define solutions to facilitate the project | 2 days | Fabien Jumel[50%];Janik Swerts[50%] | 360,00 € |
| CA | Project planning | | | | - |
| CB | WBS | Define and draw WBS | 2 days | Fabien Jumel | 360,00 € |
| CC | Tasks definition | Write a description for all tasks | 1 day | Fabien Jumel | 180,00 € |
| CD | Create planning | Establish the panning | 3 days | Fabien Jumel | 540,00 € |
| CE | Human resource allocation | Split the resources according to the needs | 1 day | Fabien Jumel | 180,00 € |
| DA | Cost management | Conduct a study to define global project cost | 1 day | Fabien Jumel | 180,00 € |
| DB | Project execution | | | | - |
| DC | IoT learning | Follow specific classes and learn information from the internet to get required knowledge | 10 days | Álvaro García[33%];Janik Swerts[33%];Yoeri Reynaerts[33%] | 1 782,00 € |
| DD | Choose machines | According to the research and the available machines in the laboratory define which one will be part of the project | 2 days | Álvaro García[25%];Fabien Jumel[25%];Janik Swerts[25%];Yoeri Reynaerts[25%] | 360,00 € |
| DE | Select settings | According to condition based maintenance and previous choices define the setting to monitor | 2 days | Álvaro García[25%];Fabien Jumel[25%];Janik | 360,00 € |

| | | | | | |
|----|---------------------------|---|---------|---|------------|
| | | | | Swerts[25%];Yoeri Reynaerts[25%] | |
| DF | Define hardware/software | Create a list with various possibilities for each need | 1 day | Álvaro García[25%];Fabien Jumel[25%];Janik Swerts[25%];Yoeri Reynaerts[25%] | 180,00 € |
| DG | Order stuff | According to collected information, choose stuff and pass an order | 1 day | Yoeri Reynaerts | 180,00 € |
| DH | Stuff delivery | | 6 days | | |
| DI | Communication programming | Develop the program which manage the communication between all the elements | 15 days | Yoeri Reynaerts[50%];Janik Swerts[50%] | 2 700,00 € |
| DJ | Build sensor | Build a tailor made sensor with the stuff previously order | 16 days | Janik Swerts[25%];Álvaro García[25%];Fabien Jumel[25%];Yoeri Reynaerts[25%] | 2 880,00 € |
| DK | Write report | midterm | 12 days | Janik Swerts[25%];Álvaro García[25%];Fabien Jumel[25%];Yoeri Reynaerts[25%] | 2 160,00 € |
| DL | Midterm presentation | | 0 days | Álvaro García[25%];Fabien Jumel[25%];Janik Swerts[25%];Yoeri Reynaerts[25%] | |
| DM | Develop data management | Develop the data storage and sorting in order to keep the useful one | 10 days | Álvaro García[50%];Janik Swerts[50%] | 1 800,00 € |

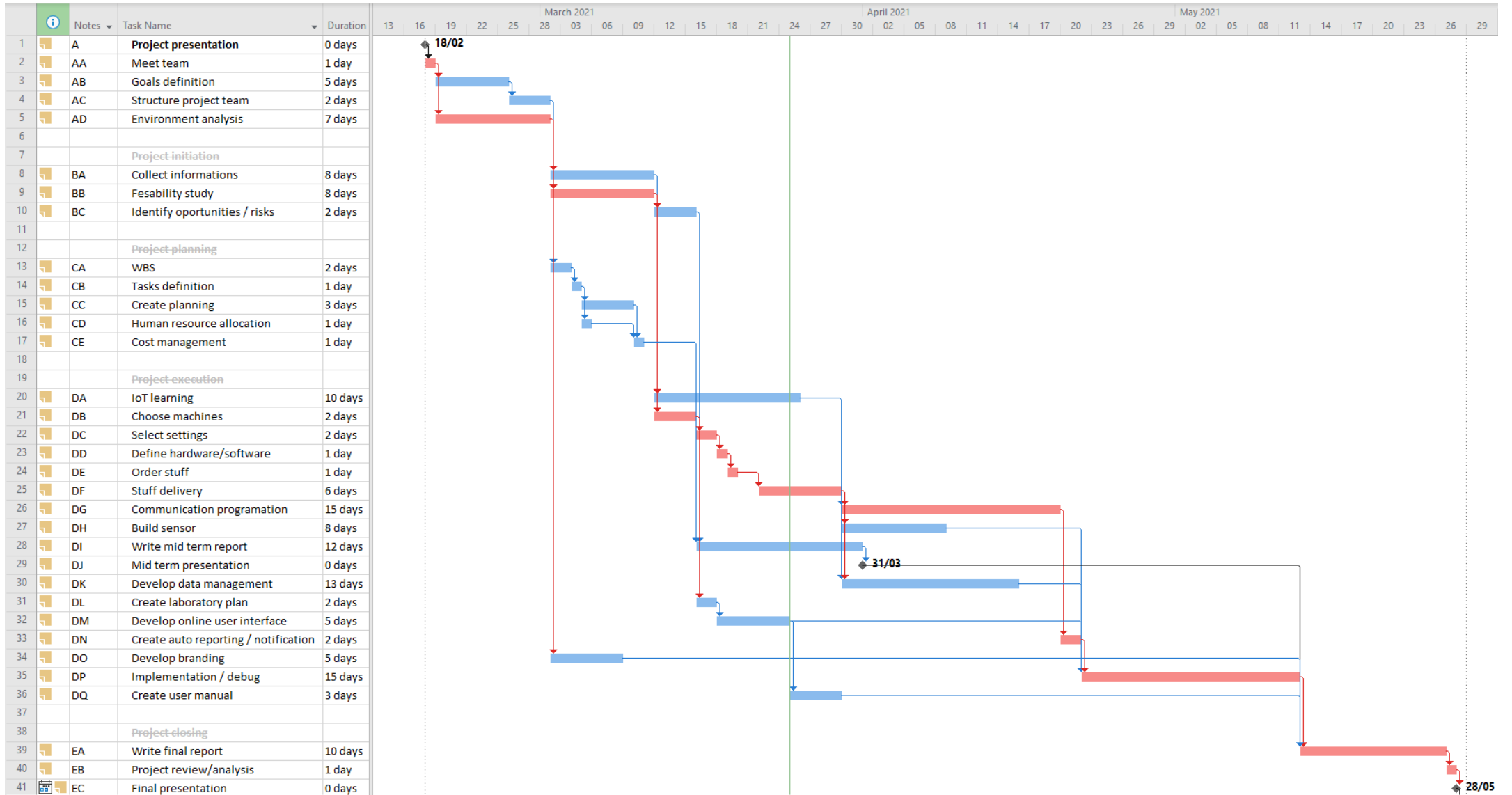
| | | | | | |
|----|--------------------------------------|--|---------|---|------------|
| DN | Create laboratory plan | Create a plan of the laboratory | 2 days | Fabien Jumel | 360,00 € |
| DO | Develop online user interface | Develop an easy and graphic user interface | 5 days | Janik Swerts | 900,00 € |
| DP | Create auto reporting / notification | Set limits and create a system to alert the owner in case of failure | 2 days | Álvaro García | 360,00 € |
| DQ | Develop branding | Develop some basic branding around the project (logo, goal, leaflet) | 7 days | Fabien Jumel | 1 260,00 € |
| | Implementation / debug | Implement all the project into the laboratory | 15 days | Álvaro García[25%];Fabien Jumel[25%];Janik Swerts[25%];Yoeri Reynaerts[25%] | 2 700,00 € |
| EA | Create user manual | Create a manual to instruct user on how the product works | 10 days | Álvaro García[33%];Fabien Jumel[33%];Yoeri Reynaerts[33%] | 1 782,00 € |
| EB | Project closing | | | | - |
| EC | Write final report | | 10 days | Álvaro García[25%];Fabien Jumel[25%];Janik Swerts[25%];Yoeri Reynaerts[25%] | 1 800,00 € |
| ED | Project review/analysis | Do a review of the whole project and figure out the pros/cons | 1 day | Álvaro García[25%];Fabien Jumel[25%];Janik Swerts[25%];Yoeri Reynaerts[25%] | 180,00 € |
| | Final presentation | | 0 days | Álvaro García[25%];Fabien Jumel[25%];Janik | |

| | | | | |
|--------------------|--|--------|---|--|
| | | | Swerts[25%];Yoeri Reynaerts[25%] | |
| Inform coordinator | Share what are the next steps into the project, what left to do or improve | 0 days | Álvaro García[25%];Fabien Jumel[25%];Janik Swerts[25%];Yoeri Reynaerts[25%] | |

Appendix 2: PERT or arrow chart



Appendix 3: GANTT or bars chart



Appendix 4: Project hours follow-up

| W1 | | | | |
|-----------|---|--------|--|----|
| | F | 1 | | |
| J | | 8-févr | Project presentation | 2 |
| | A | 1 | | |
| G | | 8-févr | Project presentation | 2 |
| | Y | 1 | | |
| R | | 8-févr | Project presentation | 2 |
| | J | 1 | | |
| S | | 8-févr | project presentation | 2 |
| W2 | | | | |
| | F | 2 | | |
| J | | 4-févr | PM tasks | 8 |
| | F | 2 | | |
| J | | 4-févr | Hard/soft ware research | 8 |
| | F | 2 | | 0 |
| J | | 3-févr | Weekly meeting | ,5 |
| | A | 2 | | 0 |
| G | | 3-févr | Weekly meeting | ,5 |
| | A | 2 | | |
| G | | 2-févr | Software research | 3 |
| | Y | 2 | | 0 |
| R | | 3-févr | Weekly meeting | ,5 |
| | Y | 2 | | |
| R | | 0-févr | research tailormade sensors | 6 |
| | Y | 2 | | |
| R | | 1-févr | research DIY sensors | 4 |
| | J | 2 | | |
| S | | 1-févr | research sensors/communication protocol | 2 |
| | J | 2 | | 0 |
| S | | 0-févr | weekly meeting | ,5 |
| | J | 2 | | |
| S | | 3-févr | reserach sensors | 3 |
| W3 | | | | |
| | F | 0 | | 1 |
| J | | 3-mars | Research / Information about programation | 0 |
| | F | 0 | | |
| J | | 4-mars | Weekly meeting | 1 |
| | F | 0 | | |
| J | | 4-mars | Weekly documents | 2 |
| | A | 0 | | |
| G | | 6-mars | Software and project architecture research | 4 |
| | Y | 0 | | |
| R | | 3-mars | software and protocol research | 4 |
| | Y | 0 | | 0 |
| R | | 4-mars | Weekly meeting | ,5 |
| | J | 4 | | 0 |
| S | | -mrt | weekly meeting | ,5 |
| | J | 6 | | |
| S | | -mrt | node red programation | 3 |

| W4 | | | | |
|-----------|---|--------|--|----|
| | F | 0 | | |
| J | | 9-mars | sensor research / information and learning | 6 |
| | F | 1 | | |
| J | | 0-mars | sensor research / information and learning | 6 |
| | F | 1 | | |
| J | | 2-mars | Weekly meeting (school) | 2 |
| | F | 1 | | 1 |
| J | | 2-mars | Weekly document | ,5 |
| | A | 1 | | |
| G | | 1-mars | Node Red tasks and sensor research | 4 |
| | A | 1 | | |
| G | | 3-mars | Software compatibility | 2 |
| | Y | 0 | | |
| R | | 9-mars | Weekly meeting (school) | 2 |
| | Y | 1 | | |
| R | | 1-mars | Node-RED | 2 |
| | J | 1 | | |
| S | | 2-mrt | node-red | 3 |
| | J | 1 | | |
| S | | 3-mrt | weekly meeting (school) | 2 |
| | J | 1 | | |
| S | | 1-mrt | node red tasks and research server | 2 |
| W5 | | | | |
| | F | 1 | | 2 |
| J | | 6-mars | WBS update | ,5 |
| | F | 1 | | |
| J | | 6-mars | Tasks list update | 3 |
| | F | 1 | | 1 |
| J | | 6-mars | document creation | ,5 |
| | F | 1 | | |
| J | | 6-mars | Plan Technobothnia | 3 |
| | F | 1 | | |
| J | | 7-mars | Project planning | 3 |
| | F | 1 | | |
| J | | 9-mars | Project planning | 4 |
| | J | 1 | | |
| S | | 9-mrt | timeline Mid term report | 4 |
| | F | 1 | | |
| J | | 8-mars | Weekly meeting | 1 |
| | F | 1 | | |
| J | | 9-mars | Weekly documents | 1 |
| | A | 1 | | |
| G | | 6-mars | Node Red | 3 |
| | A | 1 | | |
| G | | 8-mars | Node Red | 4 |
| | A | 2 | | |
| G | | 1-mars | Node Red | 4 |
| | A | 1 | | |
| G | | 8-mars | Weekly meeting | 1 |

| | | | | |
|-----------|---|--------|---|----|
| R | Y | 1 | | 1 |
| | | 5-mars | Ordering sensors and mcu's | ,5 |
| R | Y | 1 | | |
| | | 6-mars | Node Red | 6 |
| R | Y | 1 | | |
| | | 8-mars | Weekly meeting | 1 |
| S | J | 1 | | |
| | | 5-mrt | weekly meeting | 1 |
| S | J | 1 | | |
| | | 7-mrt | research about the different components | 4 |
| W6 | | | | |
| J | F | 2 | | |
| | | 2-mars | Planning MS Project | 1 |
| J | F | 2 | | |
| | | 2-mars | Human resource management | 2 |
| J | F | 2 | | |
| | | 2-mars | Cost analysis | 2 |
| J | F | 2 | | |
| | | 2-mars | Mid term report | 3 |
| J | F | 2 | | |
| | | 3-mars | MoSCoW | 2 |
| J | F | 2 | | |
| | | 3-mars | mid term report | 6 |
| J | F | 2 | | |
| | | 4-mars | mid term report | 5 |
| J | F | 2 | | |
| | | 5-mars | mid term report | 6 |
| J | F | 2 | | |
| | | 6-mars | mid term report | 5 |
| J | F | 2 | | |
| | | 6-mars | weekly meeting | 1 |
| G | A | 2 | | |
| | | 3-mars | Mid term report | 4 |
| G | A | 2 | | |
| | | 4-mars | Node Red tasks | 4 |
| G | A | 2 | | |
| | | 5-mars | Mid term report | 6 |
| G | A | 2 | | |
| | | 6-mars | Node Red tasks | 2 |
| G | A | 2 | | |
| | | 6-mars | Mid term report | 3 |
| R | Y | 2 | | |
| | | 3-mars | Mid term report | 3 |
| R | Y | 2 | | |
| | | 4-mars | Mid term report | 3 |
| R | Y | 2 | | |
| | | 5-mars | Mid term report | 6 |
| R | Y | 2 | | |
| | | 6-mars | Mid term report | 6 |
| S | J | 2 | | |
| | | 3-mrt | mid term report | 6 |

| | | | | | |
|-----------|---|---|--------|------------------------------------|---|
| S | J | 2 | 6-mrt | mid term report | 5 |
| S | J | 2 | 5-mrt | mid term report | 5 |
| S | J | 2 | 5-mrt | mid term report | 5 |
| S | J | 2 | 5-mrt | mid term report | 4 |
| J | F | 2 | 7-mars | Cost analysis | 4 |
| J | F | 2 | 8-mars | Mid term report | 7 |
| G | A | 2 | 7-mars | Mid term report | 6 |
| G | A | 2 | 8-mars | Mid term report | 7 |
| R | Y | 2 | 7-mars | Mid term report | 5 |
| R | Y | 2 | 8-mars | Mid term report | 5 |
| W7 | | | | | |
| J | F | 2 | 9-mars | Mid term presentation | 7 |
| J | F | 3 | 0-mars | Mid term presentation | 8 |
| J | F | 3 | 1-mars | Mid term presentation (all groups) | 4 |
| J | F | 0 | 1-avr | weekly meeting | 2 |
| J | F | 0 | 2-avr | Documents | 1 |
| G | A | 2 | 9-mars | Mid term presentation | 4 |
| G | A | 3 | 0-mars | Mid term presentation | 5 |
| G | A | 3 | 1-mars | Mid term presentation (all groups) | 5 |
| G | A | 0 | 1-avr | weekly meeting | 1 |
| R | Y | 2 | 9-mars | Mid term presentation | 7 |
| R | Y | 3 | 0-mars | Mid term presentation | 6 |
| R | Y | 3 | 1-mars | Mid term presentation (all groups) | 4 |
| R | Y | 0 | 1-avr | weekly meeting | 2 |
| R | Y | 0 | 2-avr | MQTT on Rpi OS | 2 |
| R | Y | 0 | 2-avr | Wemos DS18b20 Temp sensor | 4 |

| | | | | | |
|-----------|---|--------|--|--|---|
| R | Y | 0 | | | |
| | | 3-avr | Wemos wireless communication | | 3 |
| S | J | 3 | | | |
| | | 0-mrt | presentation mid term | | 5 |
| S | J | 2 | | | |
| | | 9-mrt | presentation mid term | | 2 |
| S | J | 3 | | | |
| | | 0-mars | preparing the mid term presentation | | 4 |
| S | J | 3 | | | |
| | | 1-mars | presenting project mid term project | | 4 |
| W8 | | | | | |
| J | F | 0 | | | |
| | | 8-avr | Weekly meeting | | 2 |
| J | F | 0 | | | |
| | | 8-avr | Documents | | 1 |
| J | F | 1 | | | |
| | | 1-avr | Stakeholders analyse | | 3 |
| J | F | 0 | | | |
| | | 9-avr | Camera/motion research | | 6 |
| S | J | 0 | | | |
| | | 9-avr | router settings | | 2 |
| G | A | 0 | | | |
| | | 6-avr | Router research and purchase | | 3 |
| G | A | 0 | | | |
| | | 8-avr | Weekly meeting | | 1 |
| R | Y | 0 | | | |
| | | 8-avr | Weekly meeting | | 2 |
| W9 | | | | | |
| J | F | 1 | | | |
| | | 2-avr | Logo research | | 2 |
| J | F | 1 | | | |
| | | 3-avr | Market analyse research | | 2 |
| J | F | 1 | | | |
| | | 4-avr | Weekly meeting | | 1 |
| J | F | 1 | | | |
| | | 6-avr | Sensors research | | 2 |
| J | F | 1 | | | |
| | | 4-avr | Weekly documents | | 1 |
| S | J | 1 | | | |
| | | 2-avr | information about camera movement and smart socket | | 4 |
| S | J | 1 | | | |
| | | 3-avr | look up information about camera/led display | | 4 |
| S | J | 1 | | | |
| | | 4-avr | information about the pollution sensor arduino | | 6 |
| S | J | 1 | | | |
| | | 4-avr | weekly meeting | | 1 |
| G | A | 1 | | | |
| | | 4-avr | weekly meeting | | 1 |
| G | A | 1 | | | |
| | | 5-avr | Sensors research | | 3 |

| | | | | |
|------------|---|-------|---|---|
| G | A | 1 | | |
| | | 6-avr | Node-Red | 5 |
| G | A | 1 | | |
| | | 7-avr | Zigbee2mqtt | 3 |
| R | Y | 1 | | |
| | | 4-avr | weekly meeting | 1 |
| R | Y | 1 | | |
| | | 5-avr | CO2 sensor research | 3 |
| R | Y | 1 | | |
| | | 7-avr | Home assistant research possibilities | 5 |
| W10 | | | | |
| J | F | 1 | | |
| | | 9-avr | Learning sensors | 2 |
| J | F | 2 | | |
| | | 0-avr | Documents | 2 |
| J | F | 2 | | |
| | | 1-avr | Meeting + CAD | 6 |
| J | F | 2 | | |
| | | 1-avr | Meeting documents | 1 |
| J | F | 2 | | |
| | | 2-avr | Case printing | 6 |
| J | F | 2 | | |
| | | 3-avr | research case ESP CAM + Aqara sensors | 3 |
| S | J | 1 | | |
| | | 9-avr | information about the cam | 5 |
| S | J | 2 | | |
| | | 0-avr | information about air quality sensor | 6 |
| S | J | 2 | | |
| | | 0-avr | adapt the sensor table list | 2 |
| S | J | 2 | | |
| | | 1-avr | weekly meeting | 1 |
| S | J | 2 | | |
| | | 1-avr | set up the raspberry pi + home assistant | 3 |
| S | J | 2 | | |
| | | 2-avr | 3D print the raspberry pi case | 2 |
| S | J | 2 | | |
| | | 2-avr | implement the sensors in the home automation software | 4 |
| G | A | 1 | | |
| | | 9-avr | Pairing Zigbee sensors | 6 |
| G | A | 2 | | |
| | | 0-avr | Order sensors | 1 |
| G | A | 2 | | |
| | | 1-avr | weekly meeting | 1 |
| G | A | 2 | | |
| | | 1-avr | Zigbee, MQTT and home assistant | 5 |
| R | Y | 2 | | |
| | | 1-avr | weekly meeting | 1 |
| R | Y | 2 | | |
| | | 1-avr | set up the raspberry pi + home assistant | 5 |
| R | Y | 2 | | |
| | | 1-avr | implement the sensors in the home automation software | 2 |

| | | | | | |
|------------|---|-------|---|--|---|
| R | Y | 2 | | | |
| | | 2-avr | implement the sensors in the home automation software | | 6 |
| R | Y | 2 | | | |
| | | 5-avr | installing Ha floorplan | | 2 |
| R | Y | 2 | | | |
| | | 5-avr | installing hacs | | 2 |
| R | Y | 2 | | | |
| | | 2-avr | Case printing | | 1 |
| W11 | | | | | |
| J | F | 2 | | | |
| | | 6-avr | Layout/home assistant | | 4 |
| J | F | 2 | | | |
| | | 7-avr | Home assistant/IP setting | | 4 |
| S | J | 2 | | | |
| | | 6-avr | try to set up open VPN | | 5 |
| S | J | 2 | | | |
| | | 7-avr | gathering info about floorplan in home assistant | | 6 |
| S | J | 2 | | | |
| | | 8-avr | information about esp8266/MQ135 | | 6 |
| S | J | 2 | | | |
| | | 9-avr | setting up air quality sensor | | 6 |
| J | F | 2 | | | |
| | | 8-avr | Research | | 3 |
| J | F | 2 | | | |
| | | 9-avr | Pi case/ cam | | 8 |
| J | F | 3 | | | |
| | | 0-avr | cam/motion detection | | 5 |
| J | F | 0 | | | |
| | | 2-mai | cam/motion detection (indicator + Webhook) | | 5 |
| G | A | 2 | | | |
| | | 6-avr | Flashing Zigbee stick | | 7 |
| G | A | 2 | | | |
| | | 7-avr | Remote connection and static IP | | 6 |
| G | A | 2 | | | |
| | | 8-avr | Data storage | | 4 |
| G | A | 2 | | | |
| | | 9-avr | Telegram | | 8 |
| G | A | 3 | | | |
| | | 0-avr | Configure MPU6050 | | 4 |
| R | Y | 2 | | | |
| | | 6-avr | Flashing Zigbee stick | | 7 |
| R | Y | 2 | | | |
| | | 7-avr | Remote connection and static IP | | 5 |
| R | Y | 2 | | | |
| | | 6-avr | Re configure Home assistant | | 2 |
| R | Y | 2 | | | |
| | | 8-avr | Home assistant | | 6 |
| R | Y | 2 | | | |
| | | 9-avr | weekly meeting+ Home assistant | | 6 |
| R | Y | 3 | | | |
| | | 0-avr | Configure MPU6050 | | 2 |

| | | | | | |
|------------|---|-------|--|--|----|
| R | Y | 3 | | | |
| | | 0-avr | ESPHOME | | 4 |
| | J | 2 | | | 0 |
| S | | 9-avr | weekly meeting | | ,5 |
| W12 | | | | | |
| J | F | 0 | | | |
| | | 3-mai | CAD | | 4 |
| J | F | 0 | | | |
| | | 4-mai | Cam (stream/detection) | | 6 |
| J | F | 0 | | | |
| | | 5-mai | CAD + printing | | 6 |
| J | J | 0 | | | |
| S | | 4-mai | read in the co ² value | | 5 |
| S | J | 0 | | | |
| | | 3-mai | figure out how to connect the MQ135 to esp32 node mcu | | 7 |
| S | J | 0 | | | |
| | | 5-mai | searching on how to publish air quality sensor to MQTT | | 6 |
| G | A | 0 | | | |
| | | 3-mai | Auto report software research | | 2 |
| G | A | 0 | | | |
| | | 4-mai | Auto report | | 6 |
| G | A | 0 | | | |
| | | 5-mai | Telegram and Node-Red | | 3 |
| G | A | 0 | | | |
| | | 6-mai | Telegram and Node-Red | | 4 |
| J | F | 0 | | | |
| | | 6-mai | PM + website | | 4 |
| J | J | 0 | | | |
| S | | 6-mai | programming connection MQTT to Arduino IDE | | 4 |
| S | J | 0 | | | |
| | | 7-mai | calculating dimensions of co ² sensor case+estimated energy consumption | | 3 |
| G | A | 0 | | | |
| | | 7-mai | Auto report and weekly meeting | | 5 |
| J | F | 0 | | | |
| | | 7-mai | Layout + meeting + report | | 4 |
| J | F | 0 | | | 5 |
| J | | 9-mai | Report design | | ,5 |
| R | Y | 0 | | | |
| | | 3-mai | Home assistant | | 4 |
| R | Y | 0 | | | 8 |
| R | | 7-mai | meeting + Technobotnia | | ,5 |
| R | Y | 0 | | | |
| | | 8-mai | final report | | 6 |
| W13 | | | | | |
| S | J | 1 | | | 3 |
| | | 0-mai | soldering the co ² sensor with the other components | | ,5 |
| S | J | 1 | | | 2 |
| | | 0-mai | printing the backplate of the co ² sensor box | | ,5 |
| S | J | 1 | | | |
| | | 0-mai | writing on the end term report | | 1 |

| | | | | | |
|------------|---|-------|--|--|----|
| J | F | 1 | | | |
| J | | 0-mai | Final report | | 4 |
| J | F | 1 | | | |
| J | | 1-mai | Final report | | 5 |
| S | J | 1 | | | |
| S | | 1-mai | writing co ² sensor for end report | | 1 |
| S | J | 1 | | | |
| S | | 1-mai | rewriting the code for co ² sensor | | 3 |
| S | J | 1 | | | |
| S | | 1-mai | resoldering the co ² sensor | | 4 |
| J | F | 1 | | | |
| J | | 2-mai | Meeting | | 1 |
| S | J | 1 | | | |
| S | | 2-mai | meeting | | 1 |
| S | J | 1 | | | |
| S | | 3-mai | printing the front plate of the co ² sensor | | 4 |
| S | J | 1 | | | |
| S | | 3-mai | trying to get the co ² sensor to work | | 5 |
| S | J | 1 | | | |
| S | | 4-mai | fixing the co ² sensor + connect it to mqtt | | 5 |
| S | J | 1 | | | |
| S | | 4-mai | writing for the end report about co ² sensor | | 1 |
| S | J | 1 | | | |
| S | | 5-mai | connecting co ² sensor to MQTT | | 5 |
| S | J | 1 | | | |
| S | | 6-mai | connecting co ² sensor to MQTT | | 2 |
| S | J | 1 | | | |
| S | | 6-mai | writing the co ² sensor part for final report | | 5 |
| R | Y | 1 | | | |
| R | | 2-mai | meeting + final report | | 3 |
| R | Y | 1 | | | |
| R | | 4-mai | Final report | | 4 |
| R | Y | 1 | | | |
| R | | 6-mai | Final report | | 4 |
| G | A | 1 | | | |
| G | | 2-mai | meeting + auto report | | 3 |
| G | A | 1 | | | |
| G | | 3-mai | Final report | | 4 |
| G | A | 1 | | | |
| G | | 4-mai | Final report | | 2 |
| W14 | | | | | |
| S | J | 1 | | | |
| S | | 7-mai | soldering the MQ-135 sensor to the led buzzer, etc, | | 3 |
| S | J | 1 | | | |
| S | | 7-mai | writing on the end term report in general | | 5 |
| R | Y | 1 | | | |
| R | | 8-mai | final report + inner meeting what needs to be done | | ,5 |
| R | Y | 1 | | | |
| R | | 8-mai | final report | | 2 |
| S | J | 1 | | | |
| S | | 8-mai | final report co ² sensor part | | 4 |

| | | | | | |
|------------|---|-------|---|--|---|
| S | J | 1 | | | |
| S | J | 9-mai | 1 | shooting the demonstration video | 4 |
| S | J | 9-mai | 1 | editing and merge the video parts together | 4 |
| S | J | 2 | | | |
| S | J | 0-mai | 2 | editing and merge the video parts together | 3 |
| S | J | 2 | | | |
| S | J | 0-mai | 2 | final report | |
| J | F | 2 | | | |
| J | A | 1 | | | |
| J | A | 1-mai | 2 | final report | 5 |
| G | A | 1 | | | |
| G | A | 7-mai | 1 | Final report | 5 |
| G | A | 1 | | | |
| G | A | 8-mai | 1 | Final report | 4 |
| G | A | 1 | | | |
| G | A | 9-mai | 1 | Videos | 6 |
| G | A | 2 | | | |
| G | A | 0-mai | 2 | Final report | 2 |
| G | A | 2 | | | |
| G | A | 1-mai | 2 | Final report | 3 |
| G | A | 2 | | | |
| G | A | 2-mai | 2 | Final report | 4 |
| W15 | | | | | |
| S | J | 2 | | | |
| S | J | 5-mai | 2 | Presentation | 8 |
| G | A | 2 | | | |
| G | A | 5-mai | 2 | Presentation | 8 |
| R | Y | 2 | | | |
| R | Y | 5-mai | 2 | Presentation | 8 |
| J | F | 2 | | | |
| J | F | 5-mai | 2 | Presentation | 8 |

Appendix 5: Weekly meeting report/agenda

Weekly meeting

Date of meeting | Time 04/03/2021 | 10:00 | Place: Technobotnia

Chairman Fabien Jumel Present: Yoeri Revnaerts
 Secretary Janik Swerts Absent: Alvaro Garcia
 Tobias Ekfors

TOPICS ON THE AGENDA

Software / Hardware
 Machine / setting choice

WORK FOLLOW UP

| Task(s) | Person in charge | Time spend |
|---|------------------|------------|
| Sensors researches Information about tailor made sensors (Arduino, dallas) and commercial ones (Agar, Xiaomi) | JS, AG, YR, FJ | // |
| Hardware researches Programming (Red Node), Home automation (Domoticz) | JS, AG, YR, FJ | // |
| Setting choice We will work on temperature, vibrations, air pressure and motion | JS, AG, YR, FJ | // |

ISSUES / DECISIONS

At least one of the sensors used will be tailor made

MEETING ISSUES

//

COMING WORK

| Task(s) | Person in charge | Estimated time |
|--|------------------|----------------|
| Sensors researches and choice Create a table with all information about potential sensors. (price, features, software...) | JS, AG, YR, FJ | 7 days |

NEXT MEETING

Fri 12/03/21 at 10:00 (place have to be define)

REMARK(S)

It is important to identify at least 2 way of working for each type of sensor.

Weekly meeting

Date of meeting | Time 12/03/2021 | 10:00 | Place: Online

Chairman Fabien Jumel Present: Yoeri Revnaerts
 Secretary Janik Swerts Absent: Tobias Ekfors
 Alvaro Garcia

TOPICS ON THE AGENDA

Sensors choice/order

WORK FOLLOW UP

| Task(s) | Person in charge | Time spend |
|--|------------------|------------|
| Sensors table Creation of a table with all information related with sensors/materials | JS, AG, YR, FJ | // |

ISSUES / DECISIONS

[Slaesh](#)'s CC2652RB will be the receiver/transmitter despite Con Bee 2 (less stable)

MEETING ISSUES

//

COMING WORK

| Task(s) | Person in charge | Estimated time |
|---|------------------|----------------|
| Order Order all the closed sensors | JS, AG, YR, FJ | 7 days |

NEXT MEETING

Thu 18/03/21 at 8:30 online

REMARK(S)

//

Weekly meeting

Date of meeting | Time 18/03/2021 | 8:30 | Place: Online

| | | | |
|-----------|--------------|-----------------|---------|
| Chairman | Fabien Jumel | Present: | Absent: |
| Secretary | Janik Swerts | Yoeri Reynaerts | |
| | | Tobias Ekfors | |
| | | Alvaro Garcia | |

TOPICS ON THE AGENDA

Sensors order

WORK FOLLOW UP

| Task(s) | Person in charge | Time spend |
|---|------------------|------------|
| Sensors order <i>All the material have been ordered</i> | YR | // |
| PM update <i>Lpdate of WBS, task list, planning</i> | FJ | // |
| Technobothnia plan <i>Creation of Technobothnia plan</i> | FJ | // |

ISSUES / DECISIONS

//

MEETING ISSUES

//

COMMING WORK

| Task(s) | Person in charge | Estimated time |
|-------------------------------------|------------------|----------------|
| Mid term report <i>Redaction</i> | JS, AG, YR, FJ | 12 days |

NEXT MEETING

Fri 26/03/21 at 10:00 school

REMARK(S)

//

Weekly meeting

Date of meeting | Time 26/03/2021 | 10:00 | Place: Technobothnia

| | | | |
|-----------|--------------|-----------------|---------|
| Chairman | Fabien Jumel | Present: | Absent: |
| Secretary | Janik Swerts | Yoeri Reynaerts | |
| | | Tobias Ekfors | |
| | | Alvaro Garcia | |

TOPICS ON THE AGENDA

Mid term report

WORK FOLLOW UP

| Task(s) | Person in charge | Time spent |
|---|------------------|------------|
| Mid term report <i>Writing/comment</i> | YR, FJ, AG, JS | 30h |

ISSUES / DECISIONS

// |

MEETING ISSUES

//

COMMING WORK

| Task(s) | Person in charge | Estimated time |
|--|------------------|----------------|
| Mid term report/presentation <i>Redaction</i> | JS, AG, YR, FJ | |

NEXT MEETING

Thu 01/04/21 at 14:15 school

REMARK(S)

//

Weekly meeting

Date of meeting | Time 01/04/2021 | 14:15 | Place: [Technobothnia](#)

Chairman Fabien Jumel
Secretary Janik Swerts

Present: Yoeri Reynaerts
Tobias Ekfors
Alvaro Garcia (Teams)

Absent:

TOPICS ON THE AGENDA

Feedback on midterm report/presentation

WORK FOLLOW UP

| <u>Task(s)</u> | <u>Person in charge</u> | <u>Time spent</u> |
|-----------------------|-------------------------|-------------------|
| Mid term presentation | YR, FJ, AG, JS | 30h |

ISSUES / DECISIONS

Router:

Buy a router dedicated to the [project](#)

MEETING ISSUES

Stuff update :

Delivered : Raspberry pi, micro [sd](#) card, micro [sd](#) card converter to [usb](#), esp32 model, [aquara](#) vibration sensor

Pending : [zigbee](#) to [mqtt](#) hub, backorder of esp32 [aquara](#) temperature sensor

Monitor 3D printer

Follow energy consumption, use camera and motion analyze.

COMING WORK

| <u>Task(s)</u> | <u>Person in charge</u> | <u>Estimated time</u> |
|--|-------------------------|-------------------------|
| Programming <i>Read value from the temperature sensor, start config</i> | AG, YR | 10 days |
| Router <i>Find a router and order it</i> | JS | 2h |

NEXT MEETING

Thu 08/04/21 at 10:00 school

REMARK(S)

//

Weekly meeting

Date of meeting | Time 07/04/2021 | 10:00 | Place: [Technobothnia](#)

Chairman Fabien Jumel
Secretary Janik Swerts

Present: Yoeri Reynaerts
Tobias Ekfors
Alvaro Garcia (Teams)

Absent:

TOPICS ON THE AGENDA

Programming progress + tailor made sensor

WORK FOLLOW UP

| <u>Task(s)</u> | <u>Person in charge</u> | <u>Time spent</u> |
|----------------|-------------------------|-------------------|
| Programming | YR, AG, JS | 8h |
| Router order | AG | 2h |

ISSUES / DECISIONS

//

MEETING ISSUES

Still waiting for ZigBee stick

COMING WORK

| <u>Task(s)</u> | <u>Person in charge</u> | <u>Estimated time</u> |
|--|-------------------------|-----------------------|
| Programming | AG, YR | |
| Router <i>Network configuration</i> | JS | 2h |
| PM update/branding <i>Stakeholders analyze + start develop branding</i> | FJ | 10h |

NEXT MEETING

Thu 14/04/21 at 12:15 school

REMARK(S)

//

Weekly meeting

Date of meeting | Time 14/04/2021 | 12:15 | Place: [Technobothnia](#)

Chairman Fabien Jumel
Secretary Janik Swerts

Present: Yoeri Reynaerts
Tobias Ekfors
Alvaro Garcia

Absent:

TOPICS ON THE AGENDA

Programming progress + sensors

WORK FOLLOW UP

| <u>Task(s)</u> | <u>Person in charge</u> | <u>Time spent</u> |
|----------------|-------------------------|-------------------|
| Research | YR, AG, JS, FJ | 8h |
| PM tasks | FJ | 4h |

ISSUES / DECISIONS

Order element for camera + CO2 sensor

MEETING ISSUES

Still waiting for ZigBee stick

COMING WORK

| <u>Task(s)</u> | <u>Person in charge</u> | <u>Estimated time</u> |
|--|-------------------------|-----------------------|
| Programming | AG, YR | |
| Order <i>Network configuration</i> | JS | 2h |
| Branding <i>Market analyze + logo</i> | FJ | 10h |

NEXT MEETING

Thu 21/04/21 at 4:00 school /teams

REMARK(S)

//

Weekly meeting

Date of meeting | Time 21/04/2021 | 15:45 | Place: [Technobothnia](#)

Chairman Fabien Jumel
Secretary Janik Swerts

Present: Yoeri Reynaerts
Tobias Ekfors
Alvaro Garcia

Absent:

TOPICS ON THE AGENDA

Order new sensors + developping

WORK FOLLOW UP

| <u>Task(s)</u> | <u>Person in charge</u> | <u>Time spent</u> |
|--|-------------------------|-------------------|
| Research <i>CO2 sensors, Home assistant integration</i> | YR, AG, JS, FJ | // |
| Logos + <u>researches</u> | FJ | // |

ISSUES / DECISIONS

//

MEETING ISSUES

Still waiting for ZigBee stick

COMING WORK

| <u>Task(s)</u> | <u>Person in charge</u> | <u>Estimated time</u> |
|-----------------------------------|-------------------------|-----------------------|
| Home assistant + data management | AG, YR, JS | // |
| Design <i>Case prototyping</i> | FJ, YR, JS | // |

NEXT MEETING

REMARK(S)

//

Weekly meeting

Date of meeting | Time 28/04/2021 | 12:15 | Place: Technobothnia

| | | | |
|-----------|--------------|------------------------|---------|
| Chairman | Fabien Jumel | Present: | Absent: |
| Secretary | Janik Swerts | <u>Yoeri Revnaerts</u> | |
| | | <u>Tobias Ekfors</u> | |
| | | Alvaro Garcia | |

TOPICS ON THE AGENDA

Implementation

WORK FOLLOW UP

Worked hours have been recorded in an separate document that can be found in the project folder

| <u>Task(s)</u> | <u>Person in charge</u> | <u>Time spent</u> |
|----------------|-------------------------|-------------------|
| Home assistant | YR, AG, <u>JS,FJ</u> | // |

ISSUES / DECISIONS

//

MEETING ISSUES

//

COMING WORK

| <u>Task(s)</u> | <u>Person in charge</u> | <u>Estimated time</u> |
|----------------------------------|-------------------------|-----------------------|
| Home assistant + data management | AG, YR, <u>JS,FJ</u> | // |

NEXT MEETING

REMARK(S)

//

1. Opening the meeting

07/05/21

Alvaro Garcia, Janik Swerts, Yoeri, Fabian and Tobias are in place.

2. Approval of last week's MoM (to go through and check that everything decided on has been done)

Last weeks minutes of meeting was approved by everyone.

3. Time follow up for each team member. (Hours worked and on which task.)

Worked hours have been logged into a separate excel document.

4. Status follow up. What is working what is the status of the project now.

- Home assistant
 - Server is up and running. Work still need to be done
 - Layout, interface and floor map needs a little bit work
 - Reporting is working. Needs still more features
 - Notifications working if something alarming happens (e.g. CO2 level rises)
 - Zigbee communication is working
 - Aqara (zigbee) vibration sensor works, but is not suitable for this project because the sensor doesn't update regularly
 - Aqara (zigbee) temperature sensor is working and can be used in engine room to track temperature
 - Dallas DS18B20 sensor is working with ESP32 and integrated to Home Assistant and can be used for electric motors
 - CO2 sensor is almost working. Integration to Home Assistant is still to be done. Will be used for engine room
 - ESP32-cameras are working and integrated to Home Assistant
 - One is used for video streaming inside engine room
 - The other is used for motion detection. Still a little bit work to do. Will be used for 3D printer
 - HS110 remote plug with power measuring. This will be used for 3D printers to determine based on power consumption when the machine is being used
 - Accelerometer MPU6050 is connected to ESP32 and working perfectly.
5. work to be done and other plans for the coming week
- Print some cases for sensors
6. Final Report
- Writing of final report has been started
 - Report need to be given 23.5 at latest
 - Presentation date 26.5
7. Specific issues about the project to decide or inform about
8. other issues

Refund recipe will be

9. next meeting, date and time

Wednesday 12.5 at 12 O'clock

10. closing the meeting

Appendix 6: Node-RED code

Next sections include Node-RED code used to generate the auto report and alerts, in json format. It can be uploaded to Node-RED using the "Import" feature.

6.1. Robot arm time usage calculation (MPU6050)

```
{{"id":"506943f0.a6076c","type":"tab","label":"Accelerometer","disabled":false,"info":
""},{{"id":"d9323db4.96d53","type":"counter","z":"506943f0.a6076c","name":"","init":"0","step
":"1","lower":"","upper":"","mode":"increment","outputs":2,"x":880,"y":360,"wires":[["1f407a
1f.1eb5a6","b09a499b.f34738"],[]]},{{"id":"1f407a1f.1eb5a6","type":"debug","z":"506943f0.a6
076c","name":"","active":false,"tosidebar":true,"console":false,"tostatus":false,"complete":"p
ayload","targetType":"msg","statusVal":"","statusType":"auto","x":1070,"y":420,"wires":[]},{i
d":"eaa9b659.cc7bd8","type":"function","z":"506943f0.a6076c","name":"","func":"if
(msg.payload[\"sensor.mpu6050_gyro_x\"] >= -3 | msg.payload[\"sensor.mpu6050_gyro_x\"]
<= -4)\nreturn msg;\nif (msg.payload[\"sensor.mpu6050_gyro_y\"] >= -2 |
msg.payload[\"sensor.mpu6050_gyro_y\"] <= -3.5)\nreturn msg;\nif
(msg.payload[\"sensor.mpu6050_gyro_z\"] >= 0 | msg.payload[\"sensor.mpu6050_gyro_z\"]
<= -1)\nreturn
msg;","outputs":1,"noerr":0,"initialize":"","finalize":"","libs":[],"x":720,"y":360,"wires":[["d932
3db4.96d53","a5b93495.6ec428","4c61fbe2.0a8764","c5098ac.c4b5378"]],{"id":"59acbe1.e1
6004","type":"join","z":"506943f0.a6076c","name":"","mode":"custom","build":"object","prop
erty":"payload","propertyType":"msg","key":"topic","joiner":"\\n","joinerType":"str","accumul
ate":false,"timeout":"","count":"3","reduceRight":false,"reduceExp":"","reduceInit":"","reduce
InitType":"","reduceFixup":"","x":550,"y":360,"wires":[["eaa9b659.cc7bd8"]],{"id":"a5b93495.
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sole":false,"tostatus":false,"complete":"true","targetType":"full","statusVal":"","statusType":"
auto","x":870,"y":420,"wires":[]},{{"id":"8675951.8184d68","type":"poll-
state","z":"506943f0.a6076c","name":"","server":"3e545835.277878","version":1,"exposeToH
omeAssistant":false,"haConfig":[{"property":"name","value":""},{property":"icon","value":""}]
,"updateinterval":"1","updateIntervalUnits":"seconds","outputinitially":false,"outputonchange
d":false,"entity_id":"sensor.mpu6050_gyro_x","state_type":"num","halt_if":"","halt_if_type":"
str","halt_if_compare":"is_not","outputs":1,"x":300,"y":300,"wires":[["59acbe1.e16004"]],{"id
":"eb12528d.adc0f","type":"poll-
state","z":"506943f0.a6076c","name":"","server":"3e545835.277878","version":1,"exposeToH
omeAssistant":false,"haConfig":[{"property":"name","value":""},{property":"icon","value":""}]
,"updateinterval":"1","updateIntervalUnits":"seconds","outputinitially":false,"outputonchange
d":false,"entity_id":"sensor.mpu6050_gyro_y","state_type":"num","halt_if":"","halt_if_type":"
str","halt_if_compare":"is_not","outputs":1,"x":300,"y":360,"wires":[["59acbe1.e16004"]],{"id
":"9469f8ee.a49b68","type":"poll-
state","z":"506943f0.a6076c","name":"","server":"3e545835.277878","version":1,"exposeToH
omeAssistant":false,"haConfig":[{"property":"name","value":""},{property":"icon","value":""}]
,"updateinterval":"1","updateIntervalUnits":"seconds","outputinitially":false,"outputonchange
d":false,"entity_id":"sensor.mpu6050_gyro_z","state_type":"num","halt_if":"","halt_if_type":"
str","halt_if_compare":"is_not","outputs":1,"x":300,"y":420,"wires":[["59acbe1.e16004"]],{"id
":"e9227f2c.cab32","type":"inject","z":"506943f0.a6076c","name":"Reset
counter","props":{"p":"reset","v":"true","vt":"bool"},"repeat":"","crontab":"01 20 * *
```

```

*, "once":false, "onceDelay":0.1, "topic": "", "x":680, "y":280, "wires": [{"d9323db4.96d53"}], {"id":
:"b09a499b.f34738", "type": "change", "z": "506943f0.a6076c", "name": "", "rules": [{"t": "set", "p":
"time_gyro", "pt": "global", "to": "payload", "tot": "msg"}], "action": "", "property": "", "from": "", "to":
"", "reg": false, "x":1120, "y":360, "wires": [{"id": "c5098ac.c4b5378", "type": "api-call-
service", "z": "506943f0.a6076c", "name": "", "server": "3e545835.277878", "version":1, "debugen
abled":false, "service_domain": "virtual", "service": "turn_on", "entityId": "binary_sensor.virtual_a
rm_move", "data": "", "dataType": "jsonata", "mergecontext": "", "output_location": "", "output_lo
cation_type": "none", "mustacheAltTags": false, "x":990, "y":200, "wires": [{"id": "4c61fbe2.0a8
764", "type": "trigger", "z": "506943f0.a6076c", "name": "Watchdog", "op1": "", "op2": "No data
received", "op1type": "nul", "op2type": "str", "duration": "2", "extend": true, "overrideDelay": false,
"units": "s", "reset": "", "bytopic": "all", "topic": "topic", "outputs":1, "x":940, "y":260, "wires": [{"54b
3da29.b07ef4"}], {"id": "54b3da29.b07ef4", "type": "api-call-
service", "z": "506943f0.a6076c", "name": "", "server": "3e545835.277878", "version":1, "debugen
abled":false, "service_domain": "virtual", "service": "turn_off", "entityId": "binary_sensor.virtual_
arm_move", "data": "", "dataType": "jsonata", "mergecontext": "", "output_location": "", "output_l
ocation_type": "none", "mustacheAltTags": false, "x":1130, "y":260, "wires": [{"id": "3e545835.
277878", "type": "server", "name": "Home Assistant", "addon": true}}

```

6.2. 3D printer time usage calculation (Kasa plug)

```

{"id": "1439d4b5.e748fb", "type": "tab", "label": "Smart
plug", "disabled": false, "info": "", {"id": "ba67d52c.c6bbf8", "type": "function", "z": "1439d4b5.e74
8fb", "name": "", "func": "let Power = parseFloat(msg.payload.power);\nlet PowerIdle = 15\nlet c;
//Counter\n\nif (Power <= PowerIdle) {\n  msg.payload = \"idle\\n\\n\"}\nelse {\n  c =
global.get(\"time_3D\");\n  c = c + 5;\n  global.set(\"time_3D\",c);\n  msg.payload = \"in
use\\n\\n\";\n}\n\nreturn
msg;\", \"outputs\":1, \"noerr\":0, \"initialize\": \"\", \"finalize\": \"\", \"libs\": [], \"x\":640, \"y\":220, \"wires\": [{id":
:"b14711f4.81ecf", "type": "kasa", "z": "1439d4b5.e748fb", "name": "3D_Printer
HS110(EU)", "device": "192.168.0.101", "interval": 60000, "eventInterval": "5000", "payload": "get
MeterInfo", "payloadType": "info", "debug": false, "x":430, "y":220, "wires": [{"ba67d52c.c6bbf8", "
5dbf1779.824548", "d9f3f3ad.02892", "297d7938.8e97c6"}], {"id": "6f814fb5.99e0c", "type": "de
bug", "z": "1439d4b5.e748fb", "name": "", "active": false, "tosidebar": true, "console": false, "tostatu
s": false, "complete": "payload", "targetType": "msg", "statusVal": "", "statusType": "auto", "x":810, "
y":220, "wires": [{"id": "8544aa79.75a1e8", "type": "inject", "z": "1439d4b5.e748fb", "name": "", "
props": [{"p": "payload"}, {"p": "topic", "vt": "str"}], "repeat": "5", "crontab": "", "once": true, "onceDe
lay": 0.1, "topic": "", "payload": "getMeterInfo", "payloadType": "str", "x":180, "y":220, "wires": [{"b1
4711f4.81ecf"}], {"id": "13aa3997.92f3f6", "type": "inject", "z": "1439d4b5.e748fb", "name": "Rese
t everyday", "props": [{"p": "reset", "v": "true", "vt": "bool"}], "repeat": "", "crontab": "01 20 * *
*", "once": false, "onceDelay": 0.1, "topic": "", "x":330, "y":360, "wires": [{"8a60ce24.24e81"}], {"id":
:"8a60ce24.24e81", "type": "change", "z": "1439d4b5.e748fb", "name": "", "rules": [{"t": "set", "p": "t
ime_3D", "pt": "global", "to": "0", "tot": "num"}], "action": "", "property": "", "from": "", "to": "", "reg": f
alse, "x":540, "y":360, "wires": [{"id": "3ebf0bb5.979eb4", "type": "inject", "z": "1439d4b5.e748f
b", "name": "Init
variable", "props": [{"p": "payload"}, {"p": "topic", "vt": "str"}], "repeat": "", "crontab": "", "once": true
, "onceDelay": 0.1, "topic": "", "payload": "", "payloadType": "date", "x":350, "y":400, "wires": [{"8a60
ce24.24e81"}], {"id": "5dbf1779.824548", "type": "debug", "z": "1439d4b5.e748fb", "name": "", "ac

```

```

tive":false,"tosidebar":true,"console":false,"tostatus":false,"complete":"payload","targetType"
:"msg","statusVal":"","statusType":"auto","x":510,"y":80,"wires":[]},{id:"9f0be950.d6cad8",
type:"inject","z":"1439d4b5.e748fb","name":"","props":[{"p":"payload"}],"repeat":"","cronTa
b":"01                20                *                *
*","once":false,"onceDelay":0.1,"topic":"","payload":"eraseStats","payloadType":"str","x":170,
"y":260,"wires":[{"b14711f4.81ecf"}]},{id:"d9f3f3ad.02892","type":"change","z":"1439d4b5.
e748fb","name":"","rules":[{"t":"set","p":"wh","pt":"global","to":"payload.total_wh","tot":"ms
g"}],"action":"","property":"","from":"","to":"","reg":false,"x":650,"y":280,"wires":[]},{id:"e
3ab09a1.026c48","type":"api-call-
service","z":"1439d4b5.e748fb","name":"","server":"3e545835.277878","version":1,"debugen
abled":false,"service_domain":"virtual","service":"turn_on","entityId":"binary_sensor.virtual_
plug_print","data":"","dataType":"jsonata","mergecontext":"","output_location":"","output_lo
cation_type":"none","mustacheAltTags":false,"x":910,"y":80,"wires":[]},{id:"2cb323a.ba41
4dc","type":"api-call-
service","z":"1439d4b5.e748fb","name":"","server":"3e545835.277878","version":1,"debugen
abled":false,"service_domain":"virtual","service":"turn_off","entityId":"binary_sensor.virtual_
plug_print","data":"","dataType":"jsonata","mergecontext":"","output_location":"","output_lo
cation_type":"none","mustacheAltTags":false,"x":910,"y":140,"wires":[]},{id:"297d7938.8e
97c6","type":"switch","z":"1439d4b5.e748fb","name":"","property":"payload.power","propert
yType":"msg","rules":[{"t":"gte","v":"15","vt":"num"}],"checkall":
"true","repair":false,"outputs":2,"x":710,"y":100,"wires":[{"e3ab09a1.026c48"},["2cb323a.ba4
14dc","6f814fb5.99e0c"]],{"id":"3e545835.277878","type":"server","name":"Home
Assistant","addon":true}}

```

6.3. Auto report

```

[{"id":"9cf79844.811da8","type":"tab","label":"Autoreport","disabled":false,"info":"","{
id":"b3c7a533.481a68","type":"influxdb
in","z":"9cf79844.811da8","influxdb":"76e662b4.4266ac","name":"Temperature Aqara last
24h","query":"SELECT      mean(\"temperature\")      AS      \"mean_temperature\",
max(\"temperature\")      AS      \"max_temperature\",      min(\"temperature\")      AS
\"min_temperature\" FROM \"homeassistant\".\"autogen\".\"%\" WHERE time > now()-24h
AND
                                time
                                <
now()","rawOutput":false,"precision":"","retentionPolicy":"","org":"organisation","x":580,"y":
820,"wires":[{"129bd2a.a379a2d","23113da4.d07232"}]},{id":"debc464b.d338b8","type":"infl
uxdb in","z":"9cf79844.811da8","influxdb":"76e662b4.4266ac","name":"Temperature motor
last 24h","query":"SELECT mean(\"value\") AS \"mean_value\", max(\"value\") AS
\"max_value\", min(\"value\") AS \"min_value\" FROM \"homeassistant\".\"autogen\".\"C\"
WHERE
time
>
now()-24h
AND
time
<
now()","rawOutput":false,"precision":"","retentionPolicy":"","org":"organisation","x":580,"y":
880,"wires":[{"129bd2a.a379a2d"}]},{id":"f3c13842.38ff48","type":"function","z":"9cf79844.8
11da8","name":"Report temp Aqara","func":"let date = new Date();\nndate = date.getDate() +
\"/\n\" + (date.getMonth()+1) + \"/\n\" + date.getFullYear();\nvar report = \"DATE: \"+ date +

```

```

\\nTEMPERATURE AQARA\\n" +\\n"Max temperature Aqara: \" +
msg.payload.temp_aqara[0].max_temperature + \"%C\" +\\n\"\\nMin temperature Aqara: \" +
msg.payload.temp_aqara[0].min_temperature + \"%C\" +\\n\"\\nMean temperature Aqara: \" +
msg.payload.temp_aqara[0].mean_temperature.toFixed(2) + \"%C\";nglobal.set
(\"Report_Aq\",report);nmsg = {payload: report, topic: \"weather report\"};nreturn
msg;,\"outputs\":1,\"noerr\":0,\"initialize\":\"\",\"finalize\":\"\",\"libs\":[],\"x\":990,\"y\":800,\"wires\":[[\"66d0
9559.5c477c\",\"51d53567.752d9c\"]],{\"id\":\"129bd2a.a379a2d\",\"type\":\"join\",\"z\":\"9cf79844.811
da8\",\"name\":\"\",\"mode\":\"custom\",\"build\":\"object\",\"property\":\"payload\",\"propertyType\":\"msg
\",\"key\":\"topic\",\"joiner\":\"\\n\",\"joinerType\":\"str\",\"accumulate\":false,\"timeout\":\"\",\"count\":\"2\",\"r
educeRight\":false,\"reduceExp\":\"\",\"reduceInit\":\"\",\"reduceInitType\":\"\",\"reduceFixup\":\"\",\"x\":790
,\"y\":860,\"wires\":[[\"f3c13842.38ff48\",\"6d183255.36c36c\",\"7c8c1b1d.370024\"]],{\"id\":\"23113da
4.d07232\",\"type\":\"debug\",\"z\":\"9cf79844.811da8\",\"name\":\"\",\"active\":true,\"tosidebar\":true,\"co
nsole\":false,\"tostatus\":false,\"complete\":\"payload\",\"targetType\":\"msg\",\"statusVal\":\"\",\"statusTy
pe\":\"auto\",\"x\":950,\"y\":720,\"wires\":[]},{\"id\":\"e9a04197.47ffd\",\"type\":\"telegram
sender\",\"z\":\"9cf79844.811da8\",\"name\":\"\",\"bot\":\"5a024ad4.82e5f4\",\"haserroroutput\":false,\"o
utputs\":1,\"x\":1630,\"y\":860,\"wires\":[]},{\"id\":\"66d09559.5c477c\",\"type\":\"change\",\"z\":\"9cf7984
4.811da8\",\"name\":\"Telegram
message\",\"rules\":[{\"t\":\"delete\",\"p\":\"payload\",\"pt\":\"msg\"},{\"t\":\"set\",\"p\":\"payload.chatId\",\"pt\":
\"msg\",\"to\":\"-
585212061\",\"tot\":\"num\"},{\"t\":\"set\",\"p\":\"payload.content\",\"pt\":\"msg\",\"to\":\"Report_Aq\",\"tot\":
\"global\"},{\"t\":\"set\",\"p\":\"payload.type\",\"pt\":\"msg\",\"to\":\"message\",\"tot\":\"str\"}],\"action\":\"\",\"prop
erty\":\"\",\"from\":\"\",\"to\":\"\",\"reg\":false,\"x\":1230,\"y\":800,\"wires\":[[\"e9a04197.47ffd\"]],{\"id\":\"6d1
83255.36c36c\",\"type\":\"function\",\"z\":\"9cf79844.811da8\",\"name\":\"Report
temp
motor\",\"func\":\"var report = \\\"TEMPERATURE MOTOR\\n\\n\" +\\n\"Max temperature motor: \" +
msg.payload.temp_motor[0].max_value + \"%C\" +\\n\"\\nMin temperature motor: \" +
msg.payload.temp_motor[0].min_value + \"%C\" +\\n\"\\nMean temperature motor: \" +
msg.payload.temp_motor[0].mean_value.toFixed(2) + \"%C\";nglobal.set
(\"Report_Mo\",report);nmsg = {payload: report, topic: \"weather report\"};nreturn
msg;,\"outputs\":1,\"noerr\":0,\"initialize\":\"\",\"finalize\":\"\",\"libs\":[],\"x\":990,\"y\":860,\"wires\":[[\"6e55
656b.e8542c\"]],{\"id\":\"6e55656b.e8542c\",\"type\":\"change\",\"z\":\"9cf79844.811da8\",\"name\":\"Te
legram
message\",\"rules\":[{\"t\":\"delete\",\"p\":\"payload\",\"pt\":\"msg\"},{\"t\":\"set\",\"p\":\"payload.chatId\",\"pt\":
\"msg\",\"to\":\"-
585212061\",\"tot\":\"num\"},{\"t\":\"set\",\"p\":\"payload.content\",\"pt\":\"msg\",\"to\":\"Report_Mo\",\"tot\":
\"global\"},{\"t\":\"set\",\"p\":\"payload.type\",\"pt\":\"msg\",\"to\":\"message\",\"tot\":\"str\"}],\"action\":\"\",\"pro
perty\":\"\",\"from\":\"\",\"to\":\"\",\"reg\":false,\"x\":1230,\"y\":860,\"wires\":[[\"aaf2c7db.5a54d8\"]],{\"id\":\"a
af2c7db.5a54d8\",\"type\":\"delay\",\"z\":\"9cf79844.811da8\",\"name\":\"\",\"pauseType\":\"delay\",\"time
out\":\"25\",\"timeoutUnits\":\"milliseconds\",\"rate\":\"1\",\"nbRateUnits\":\"1\",\"rateUnits\":\"second\",\"ra
ndomFirst\":\"1\",\"randomLast\":\"5\",\"randomUnits\":\"seconds\",\"drop\":false,\"x\":1410,\"y\":860,\"wir
es\":[[\"e9a04197.47ffd\"]],{\"id\":\"a71a7f39.ae629\",\"type\":\"change\",\"z\":\"9cf79844.811da8\",\"na
me\":\"temp_aqara\",\"rules\":[{\"t\":\"set\",\"p\":\"topic\",\"pt\":\"msg\",\"to\":\"temp_aqara\",\"tot\":\"str\"}],\"a
ction\":\"\",\"property\":\"\",\"from\":\"\",\"to\":\"\",\"reg\":false,\"x\":350,\"y\":820,\"wires\":[[\"b3c7a533.481a6
8\"]],{\"id\":\"7e3a3ab8.823974\",\"type\":\"change\",\"z\":\"9cf79844.811da8\",\"name\":\"temp_motor\",
\"rules\":[{\"t\":\"set\",\"p\":\"topic\",\"pt\":\"msg\",\"to\":\"temp_motor\",\"tot\":\"str\"}],\"action\":\"\",\"property
\":\"\",\"from\":\"\",\"to\":\"\",\"reg\":false,\"x\":350,\"y\":880,\"wires\":[[\"debc464b.d338b8\"]],{\"id\":\"5b81b

```

```

Of4.93efd","type":"inject","z":"9cf79844.811da8","name":"","props":{"p":"payload"},"p":"top
ic","vt":"str"},"repeat":"","crontab":"00          20          *          *
*","once":false,"onceDelay":0.1,"topic":"","payload":"","payloadType":"date","x":130,"y":880,
"wires":[["a71a7f39.ae629","7e3a3ab8.823974"]],{"id":"a15b411.f7ec9c","type":"telegram
command","z":"9cf79844.811da8","name":"","command":"report","bot":"5a024ad4.82e5f4","
strict":false,"hasresponse":true,"useregex":false,"removeregexcommand":false,"outputs":2,"x
":150,"y":820,"wires":[["a71a7f39.ae629","7e3a3ab8.823974"],[]],{"id":"7c8c1b1d.370024","t
ype":"function","z":"9cf79844.811da8","name":"Report time","func":"var report = `ROBOT
ARM AND 3D PRINTER` +`n`nRobot arm motion time: ` + global.get(`time_gyro`) + ` s`
+`n`n3D printer usage time: ` + global.get(`time_3D`) + ` s` +`n`n3D printer power
consumption: ` + global.get(`wh`) + ` Wh`;nglobal.set (`Report_3D`,report);nmsg =
{payload:      report,      topic:      `weather      report`;nreturn
msg;","outputs":1,"noerr":0,"initialize":"","finalize":"","libs":[],"x":970,"y":920,"wires":[["4ce2
29.1aef2dd8"]],{"id":"4ce229.1aef2dd8","type":"change","z":"9cf79844.811da8","name":"Tel
egram
message","rules":{"t":"delete","p":"payload","pt":"msg"},"t":"set","p":"payload.content","pt
":"msg","to":"Report_3D","tot":"global"},"t":"set","p":"payload.type","pt":"msg","to":"messa
ge","tot":"str"},"t":"set","p":"payload.chatid","pt":"msg","to":"-
585212061","tot":"str"},"action":"","property":"","from":"","to":"","reg":false,"x":1230,"y":92
0,"wires":[["e1ad9f12.769b5"]],{"id":"e1ad9f12.769b5","type":"delay","z":"9cf79844.811da8
","name":"","pauseType":"delay","timeout":"50","timeoutUnits":"milliseconds","rate":"1","nbR
ateUnits":"1","rateUnits":"second","randomFirst":"1","randomLast":"5","randomUnits":"seco
nds","drop":false,"x":1410,"y":920,"wires":[["e9a04197.47ffd"]],{"id":"51d53567.752d9c","ty
pe":"debug","z":"9cf79844.811da8","name":"","active":false,"tosidebar":true,"console":false,"
tostatus":false,"complete":"payload","targetType":"msg","statusVal":"","statusType":"auto","x
":1130,"y":720,"wires":[],{"id":"76e662b4.4266ac","type":"influxdb","hostname":"127.0.0.1",
"port":"8086","protocol":"http","database":"homeassistant","name":"homeassistant","usetls"
:false,"tls":"","influxdbVersion":"1.x","url":"http://localhost:8086","rejectUnauthorized":true},
{"id":"5a024ad4.82e5f4","type":"telegram
bot","botname":"IoTsmallfactoryBot","usernames":"","chatids":"-
585212061","baseapiurl":"","updatemode":"polling","pollinterval":"300","usesocks":false,"soc
kshost":"","socksport":"6667","socksusername":"anonymous","sockspassword":"","bothost":"
","botpath":"","localbotport":"8443","publicbotport":"8443","privatekey":"","certificate":"","u
seselfsignedcertificate":false,"sslterminated":false,"verboseLogging":false}]

```

6.4. Alerts

```

{"id":"4ae90896.12f348","type":"tab","label":"Alarms","disabled":false,"info":"","id"
:"5955a40f.8b95cc","type":"trigger-state","z":"4ae90896.12f348","name":"Low battery Aqara
Vibration
","server":"3e545835.277878","exposeToHomeAssistant":false,"haConfig":{"property":"name
","value":"","property":"icon","value":""},"entityid":"sensor.0x00158d000323232c_battery",
"entityidfiltertype":"exact","debugenabled":false,"constraints":{"targetType":"this_entity","ta
rgetValue":"","propertyType":"current_state","comparatorType":"<=","comparatorValueDatat
ype":"num","comparatorValue":"20","propertyValue":"new_state.state"},"outputs":2,"custo
moutputs":[],"outputinitially":false,"state_type":"num","x":240,"y":240,"wires":[["ffe056cf.22c

```



```

0e8"],[]],{"id":"e3f7dbcc.8b9a28","type":"telegram
sender","z":"4ae90896.12f348","name":"","bot":"5a024ad4.82e5f4","haserroroutput":false,"o
utputs":1,"x":1030,"y":420,"wires":[[]]},{id:"e7a6e0b9.dfb6","type":"change","z":"4ae9089
6.12f348","name":"Telegram
message","rules":[{"t":"delete","p":"payload","pt":"msg"},{"t":"set","p":"payload.chatId","pt":
"msg","to":"1035051020","tot":"num"},{"t":"set","p":"payload.content","pt":"msg","to":"Low
battery
Aqara
Vibration
","tot":"str"},{"t":"set","p":"payload.type","pt":"msg","to":"message","tot":"str"}],"action":"","
property":"","from":"","to":"","reg":false,"x":670,"y":240,"wires":["e3f7dbcc.8b9a28"]},{id":
"afdabf4c.c156e","type":"trigger-state","z":"4ae90896.12f348","name":"Low battery Aqara
Temperature","server":"3e545835.277878","exposeToHomeAssistant":false,"haConfig":{"pro
perty":"name","value":"","property":"icon","value":""},"entityid":"sensor.0x00158d00054ac
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