IoT waste management

Introduction

Waste management is a problem, in large parts of the world. Around the world exists different solutions that aim to make this easier, many of which are commercially available. In the capital of Brazil, Brasilia, there is still much to be gained in terms of better waste collection. This is still relevant, even though large improvements have already been made.

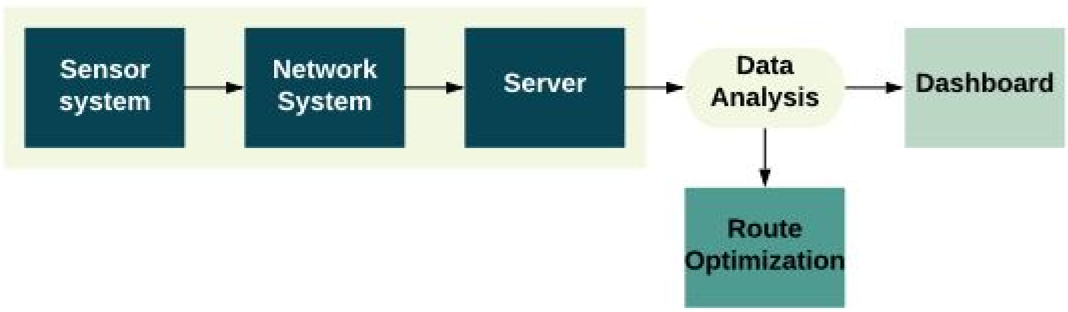
Recently, the largest dumpsite in South America – located in Brasilia, Brazil - was closed. Before the dumpsite was closed, around 1.000 waste pickers were working at the dumpsite by looking through the waste and finding either edible waste or waste they could sell. Whole families were working like this, both parents and children, hence, such development also shows that there, with some probability, still is a need to develop the infrastructure of the waste management in Brasilia.

Inside this context, a company called "*Green Ambiental*" located in Brasilia, manages collection of glass and correct destination of glass' waste. They are interested in having a system that makes collection of their different containers more effective, improving their business model by working directly to their collection process. Here lies the partnership provided by EPIC: students (our group proposing to design a viable solution), real-life problems and stakeholders.

Co-funded by the
Erasmus+ Programme
of the European Union

Initially, a problem with the way many countries handle their waste was examined.
Through discussions during the EPIC seminar in Hamburg it was found that a solution capable of providing data about the waste containers and the collection process could help companies optimise their waste collection routine.

The initial concept for such a system can be seen below, the idea is to place sensors on containers, these sensors should then be able to give an indication on how full each of the containers are at a given interval. The indication on how full the containers should be sent to a server through a gateway every 30 minutes.



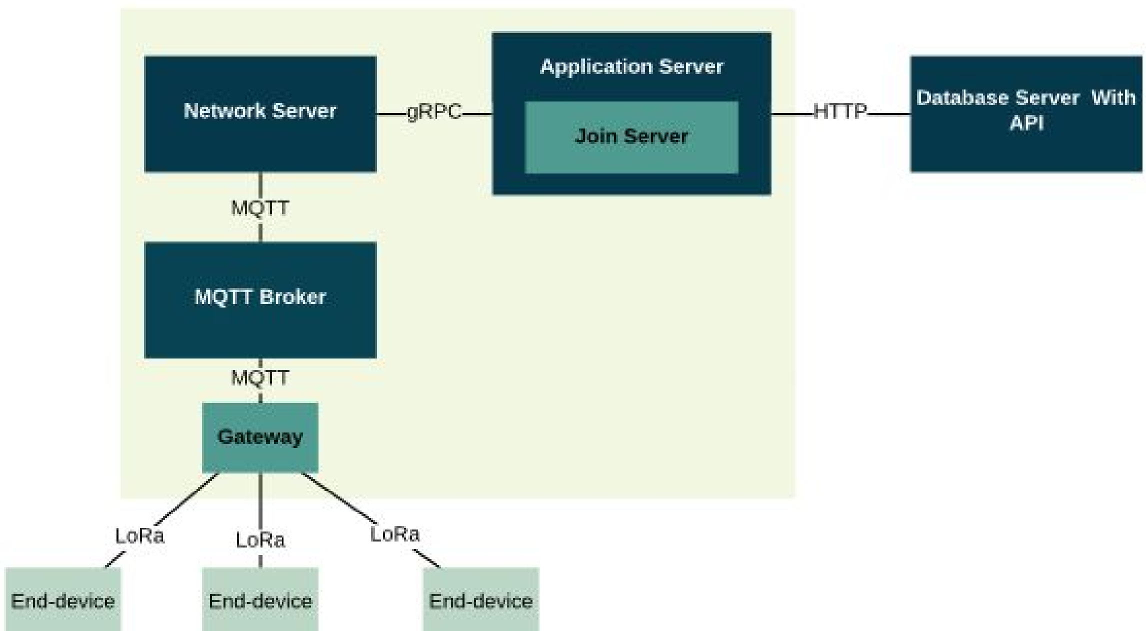
This data can then is analysed along with the information provided by the Route Optimization App, used to plan more efficient routes in terms of road use for the trucks considering distances and traffic. The goal is to ensure the company to work by emptying the waste containers, based on which containers are full. With this information a dashboard via *DataStudio* online report shows relevant information to the company can be made in order to clarify indicators, scenarios and provide useful data to develop future plan of actions and support company's strategy.

Proposed Deliverables:

- Sensor system focused on containers - getting what container got the waste, when the container has been emptied and which container it was;
- Sensors for recyclable containers events (data collectors);
- Route optimization picking the best path for the truck on their journey to avoid empty containers and to ensure gas consumption reduction;
- Link between trucks localization and the sensor system;
- Platform to the client with analysis of all the data collected by the sensor system and the truck localization. Here we will present all indicators related to the project and results;
- Implementation of the platform with Green Ambiental (clients) via facilitations for the people who work there.

Design of Communication System

The group has implemented ChirpStack's network server, application server and join server. This is communicating with a server containing a database and software to provide an API which the route optimization and dashboard uses and the ChirpStack application uses to communicate when data is received.



The database server with API, connects to an online spreadsheet where data is analysed and translated into measurable indicators, those, are regularly updated according the indicators established. The presentation of this data occurs on an online report via *DataStudio* platform.

Implementation:

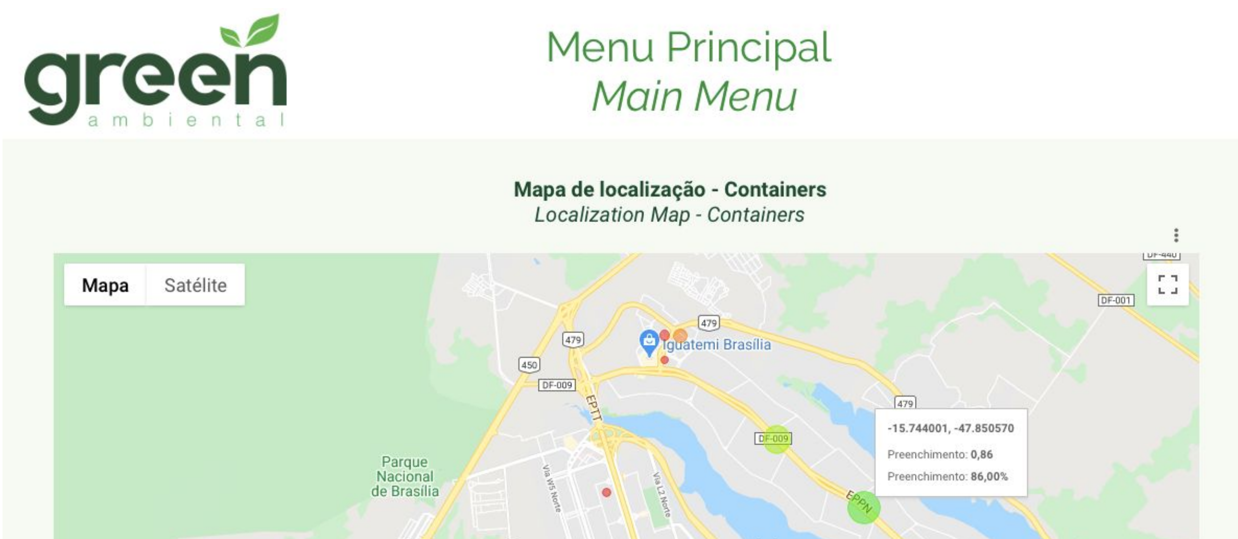
The picture shows the implemented devices.

Co-funded by the Erasmus+ Programme of the European Union

Gateway (left) and a Sensor Node (right).

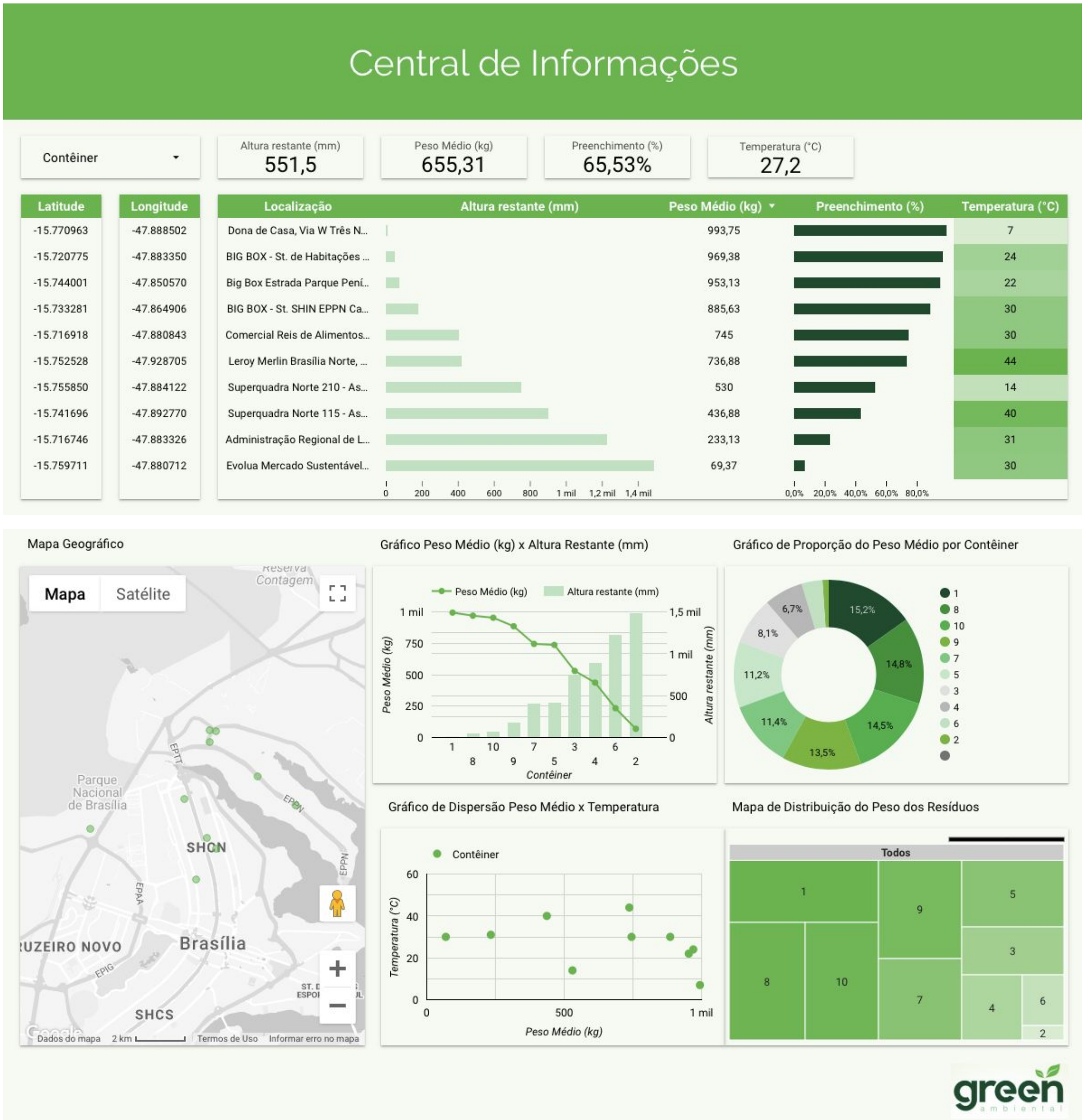
Those devices are supposed to be installed, when possible due to COVID-19 crisis, inside the waste containers to provide the information about that unit. Our project's full implementation relies on when we will be able to install the devices and provide the client real information regarding their business, once this done, the team will have resources to design a guide on recommendations to the client's business model improvement and/or changes based on the results observed using the parameters measured.

Next picture shows part of final product.



Online report's main menu, presenting one container's fulfillment percentage

Co-funded by the
Erasmus+ Programme
of the European Union



Full dashboard overview

The final dashboard presents firstly, the filter for specifying the range. By choosing one the region where an amount is located, the user receives the sum of weight, fulfillment percentage, the temperature measured and height found on that region. The exactly locations are presented next, along with an overview on metrics by unit on that region.

The geographic maps present a shaded area of greater or lesser intensity according to the degree of filling of the containers found.

Co-funded by the
Erasmus+ Programme
of the European Union

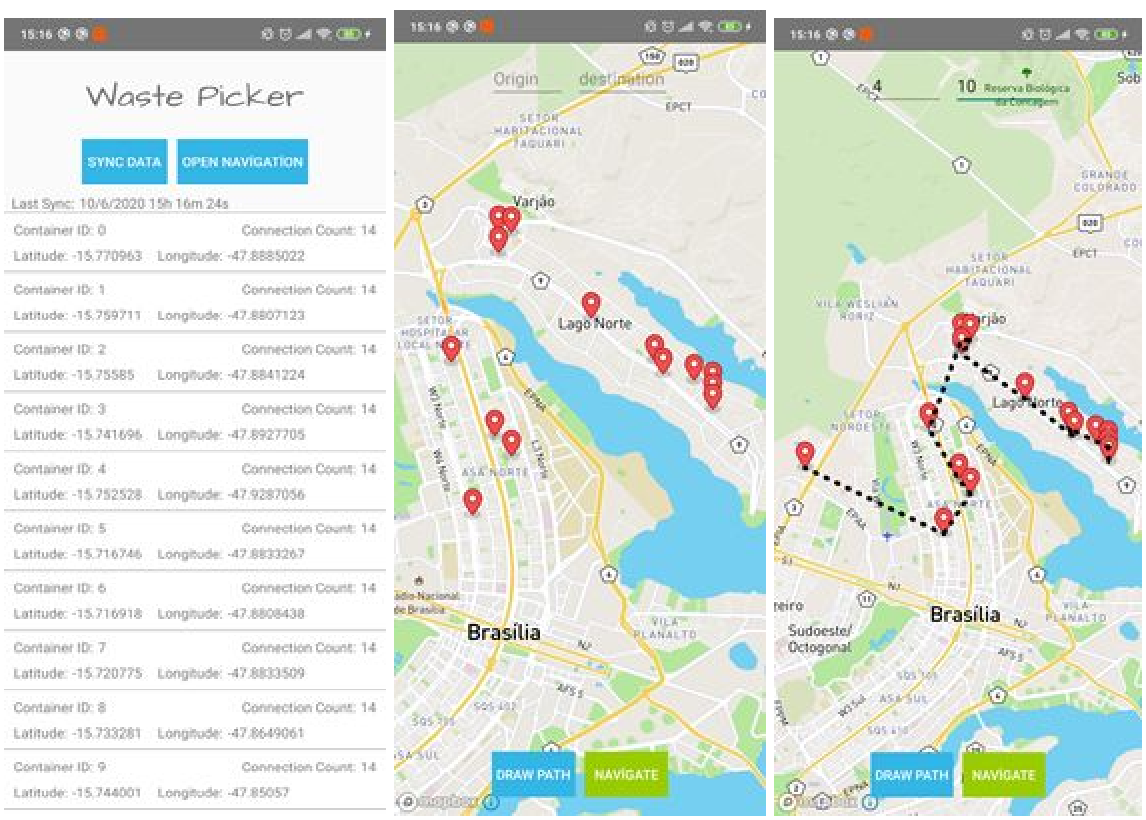
A graph of combination of rows and columns shows the average weight versus the remaining filling height of the containers in the specified region. In sequence, there is a graph showing the proportion of weight distribution between the units considered.

A graph of the temperature proportion. Finally, a map of the distribution of the weight of the waste is presented, corroborating the proposal to facilitate the choice of the appropriate equipment / vehicle for the collection of that region.

Route Optimization System

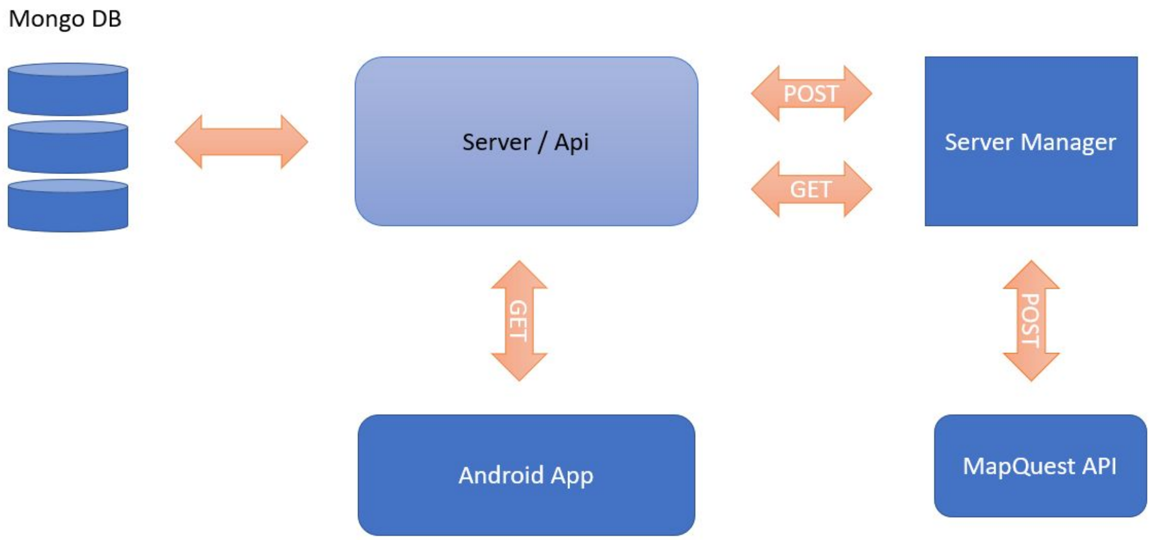
Route optimizer is supposed to show locations of containers and draw shortest possible route to reduce overall gas consumption. System can be categorized into three parts which are Mobile App, Server and Database.

Server responsible to maintain database and provide data that related containers when mobile app requests.Mobile App, can store latest data and sync data by requesting from Server by Api endpoints. Following screenshots represents demo of Mobile App.



Shortest possible route is calculated using both Simulated Annealing and Genetic Algorithm. For high end 2018 Android devices it takes 1 to 2 seconds to draw route for 15 static containers.

Following image represent hierarchy diagram of system.



System has two extra elements which are Server Manager and MapQuest Api. Server manager is responsible to fill Database with road distance information of containers respect to each others. When a new container is added to system Server manager has to fetch all the real world distance from MapQuest Api and give Server which will update database.

Currently system is incapable to navigate driver. Source of the problem is MapBox itself which is used to show map. Unfortunately, an internal error occurs when Android App request a route that includes multiple waypoints from MapBox engine. Google Maps can be used for future development however, it brings huge leap at cost. Related problem can be accessed from here.

Project's Results:

The testing of the system performance shows that the system is able to send measurements at a distance of 5 km which means that the intended gateway placements will work quite well as the radius was set to 3 km. The comparison of the measured values to the simulated also showed that the simulation is quite accurate, meaning that if the simulation of the deployment area is as accurate the system will have great coverage and it should be possible to send measurements from all containers. The tests also showed that no packet loss was seen when using SF12.

Also, the application and analysis of data presented proves to be viable for escalation to other regions beyond the area defined for study and able to simulate a reasonable economy on resources - such human as with equipment.

All in all it can be concluded that a communication system for providing information about the level of waste in containers over long distances has been successfully built. A thorough documentation can be seen in Appendix A: "**LoRa Communication in Waste Collection**",, Appendix B: "**International Collaboration Project: a Pilot on Route Optimization Utilizing Fullness Sensors on Waste Containers** " and Appendix C: "..."

International Collaboration:

Regarding the group interaction, during the seminar in Germany all groups received instructions and materials in order to support the planning of work for the next months. A few presentations were also part of the schedule, from outside groups and teachers. Those presentations worked as catalysors to create the feeling of commitment and challenge, but also, as good manuals of good-practices and tips on how to work as a team, and to divide workload.

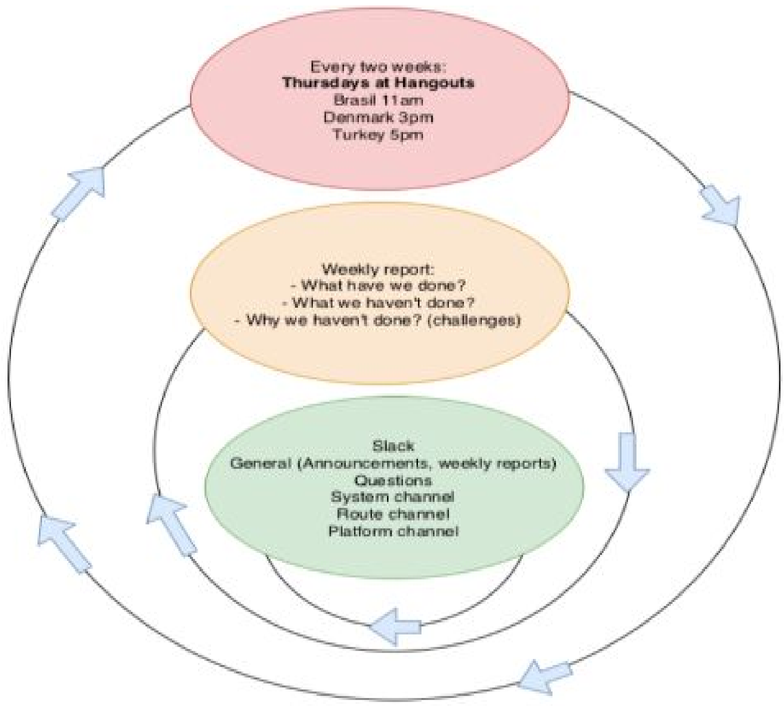
Within our group, specifically, previous Brazilian-Danish collaborations had already happened and failed. For that reason, all members were apprehensive about next steps and feeling the need to ensure good results from this project. Amid warm group discussions, sometimes our cultural differences stood in the way. The language barrier usually presented as a stepback on fluid communication and for that reason the members choose, when needed, to discuss in their own language and find a joint answer to present to the rest of the group in english. This strategy worked well when several opinions could be misunderstood if not fully explained. Also, the presence of teachers during decision making processes helped to guide the team with a second opinion and wide experience. The insights provided were very good in the sense of agreeing with deliverables and clarifying expectations.

Considering the solution needs to be developed by different member in different countries, the communication and plans needed to be established beforehand. The division's presented next.

Country	Responsibilities
Brasil	Raise solution requirements with client, point of contact with the client, developing analysis of data provided by system and defining the final delivery format (for client) and defining monitoring process
Denmark	Developing the sensors system (defining and setting all technical and structural requirements), point of contact with university and project supervisors
Turkey	Developing route optimization system/app

	(defining and setting all technical and structural requirements)

The communication plan defined is a cyclic periodic updated among all teams, using a consistent unique platform for each type of information: ***Slack*** and ***Google Meets***. All kinds of project related information must be stored on the Slack channel on an explanatory thread so all channel member can be aware and comment or react, if needed. Regarding the meetings, during the Hamburg seminar the group realised it would be necessary to establish a strong routine, considering time zones, and frequency due to previous international collaboration failing by lack of consistency in interest and prioritisation, mentioned before. The system defined to communication is presented next.



Even with COVID-19 crisis, the project kept virtually among members from the same country and, as planned, with the rest of the team following the communication agreement. We were provided with frequently professor's supervision and will work together to re plan the implementation phase until a safe environment is guaranteed. A great work has been developed by the team and the results are attending the expectations.