Master's in Industrial Electronics and Computers Engineering

University of Minho

5S Drifter

Sensoring System for Surface Sea Streams

Integrative Project in Industrial Electronics and Computers

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Acronyms

UART Universal asynchronous receiver/transmitter

LTE Long-Term Evolution

ADC Analog to Digital Converter

IMU Inertial Measurement Unit

PCB Printed Circuit Board

CMEMS Center for Microeletromachanical Systems

STM32

DMA Direct Access Memory

IoT Internet of Things

GPS

JSON

DB Data Base

SST Sea Surface Temperature

HRSST High Resolution Sea Surface Temperature

ITC Inter Thread Comunication

Chapter 1

Project Plan

This chapter will briefly talk about the 5S Drifter project motivations as well their function as a product developed by the Minho's University under supervision by the professors Luis Gonçalves and Sérgio Lopes.

1.1 Introduction

Under the course unity of Integrative Project in Industrial Electronics and Computers the students must apply for professors projects in order to integrate unde their respective laboratories and start to undertand the pace demanded on the Master's final paper.

This project, given by the professor Luis Gonçalves and Sergio Lopes under the CMEMS laboratory, has the main porpouse to create a drifter for data aquisition. As a multi-themed project, this report will explore multiple areas, as the PCB design for hardware and firmware manufacture, software design under the idea to optimize the execution allowing for better performance. The main goal is to have the final product afloat at the end of the simester.

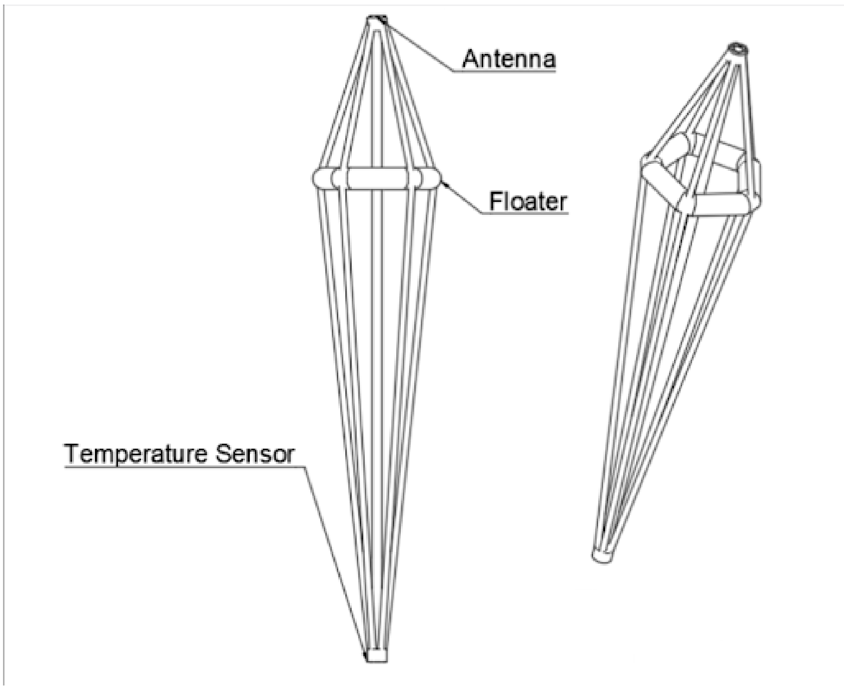

Figure 1.1: Draft Floater

1.1.1 Problem Statement

The ocean is one of the man the greatest mystery even before the written history. Humanity made the world ours over the water, from the Portuguese greatest discoveries, braving the raging ocean to the newest oil tanker demanding ever newer technology in order to tame the sea for safer and smoother sailing.

Nowadays, scientists believe only 20% to 26% of the ocean is discovered with the actual technology which means that humanity know as much about our so grate sky as our own seas. 5S ocean drifter is equipment made to acquire date from superficial sea streams and expand the oceanographic knowledge about it.

Better knowledge of the ocean lead to further development in diverse areas. Granting safety, security and efficiency.

5S, an acronym for Sensoring System for Surface Sea Streams is a low-cost, low-power solution to acquire said data with the focus to last autonomously for the longest time possible. The drifter has to attain its GPS coordinates in order to track its current and average velocity, alongside with the water temperature and an accelerometer information to gather information about the wave intensity. All this data will be stored locally and transmitted by a protocol, yet to be defined, with a JSON format in order to be received by a database that already is implemented.

Oceanograpy

The current in study will be the IPC (Iberian Poleward Current), a well documented by the Advanced Very High Resolution Radiometer (AVHRR) over the last two decades, is a narrow (25-40km) flow of water that follows the continent slope due to topography and/or water density commonly referred as a "slope-trapped tongue". Iberian as is "slope-trapped" at the continent going roughly near Portugal going along up to the bay of Biscay and Poleward, meaning that the current flows North. Being at their strongest in the winter, and weaker at the summer peak, the current is known to be significantly warmer and carrying more salinity due to the Mediterranean influence, over the Eastern North Atlantic Central Water (ENACW).

Transport

It isn't uncommon to see transport accidents being reported, and even worse, for it to be a gigantic problem. Some of these accidents are caused by poor mapping of sea conditions, tankers spilling oil, fishing vessels capsizing, leading to financial problems and even loss of life. Even when there are no accidents, poor knowledge of tides results in higher energy consumption when routes are set against the currents.

A solution would be to create optimized shipping routes, minimizing accidents and improving energy efficiency while traversing the waves. Oil tankers could follow currents with lower fuel consumption. Fishing routes could become more efficient, as their target species may swim with the tides based on temperature and speed. This would ease the workload, making the activity less reactive and more predictable, aligning expected catch rates with reduced time and energy consumption.

A well-known example of a hazardous area is the Nazaré Canyon, where its unique shape creates enormous waves. Avoiding these waters is crucial for safer navigation.

Ecology

The IPC has an important part in their ecosystem, as it transports plankton transport, larval drift, and nutrient dynamics along the coast, essential components for the living fauna and flora.

Other way to see the importance of IPC looking after the ecology is the placement of wave energy converters, a growing field under the energy generation, is one of the main problems the technology faces. A good positioning improves the efficiency and reduces the costs of construction and maintenance.

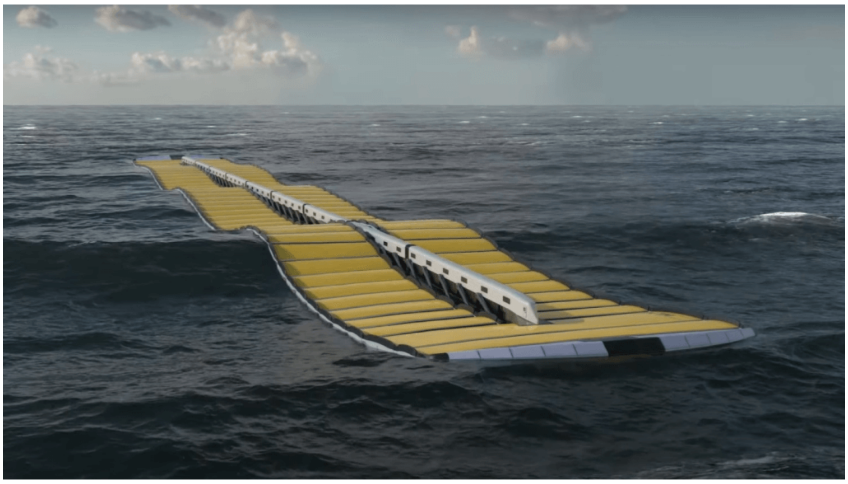

Figure 1.2: The Design of a Wave Energy Converter to Electricity

Nowadays, the field of renewable energy overseas is a hot topic, as the designs keep on changing and improving. As an example, the company Ocean Winds builds offshore wind farms over the world. Recently the company created the project WindFloat in Portugal as initiative to harvest the offshore winds in areas with depth greater than 40 meters, being around a few kilometers.

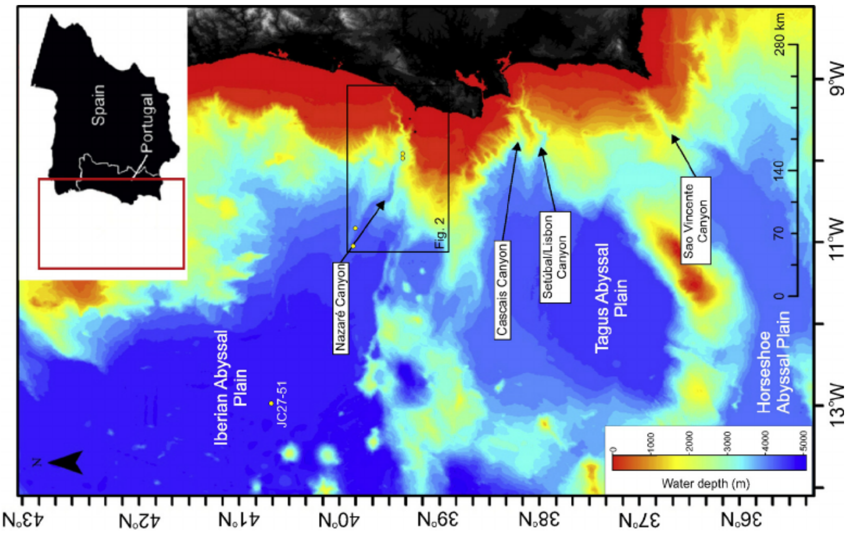

Figure 1.3: Depth Map of Portugal's Coast

Safety

As time passes one the important jobs of oceanography is the study of sediments of rocky structures at shore and their deposition. Data useful to determine the shore mineral composition and predict erosion areas or even weaker or stronger soil helping to plan coastal vulnerability and resilience.

The coast is a focus human attractor, being for sports, leisure, living and Industrial oportunities, and being so, good information around it prevent harm, and creates a safer environment.

1.1.2 Problem Statement Analysis

As a first step into solving this project, an initial construction of the demends is requested. Here will be presented, following the waterfall aprouch and UML standarts, the solutions to the individual problems presented by the project.

As stated, the floater has a series of data to acuare, format, and send in order to be considered concluded. The system will be divided in smaller and simpler packeges to solve each point then it will be assembled as a final product.

Equipment Objectives

The system, in order to acomplish said targets, must set the following topics

- Data aquisition
  - Power Source Level
    In order to alert a low batteries.
  - Wave intensity
    Measuring the force exercised by the water in the drifter
  - Position
    Track the movement of the water.
  - Temperature
    Measures the temperature directly.
- Wireless data transference
  As the floaters has no physical connections with the shore.
- Local data storage
  In case of lack of external communication.
- Autonomy
  The longer it survives, the more data it will gather.
- Resistant and buoyant shell
  The physical parts that support the system.

Chapter 2

Analysis

In order to accomplish said objectives listed on the problem Statement Analysis, it is first needed to enlist the embedded system components, this will help to choose a STM32 model as well the modules for this task without any over and under dimensions.

- Microcontroller
  The STM32 CPU that will control the Embedded System.
- GNSS
  A module to acquire the world position in latitude and longitude.
- Mobile Communication
  The module with the ability to communicate wirelessly with MongoDB
- Power Source
  The set of batteries the system will relay on for energy. It is stipulated that the system must have the autonomy of at least 30 days.
- SD Card Slot
  Local long term memory in case of field transmission.
- Sensors:
  - IMU
    System physical acceleration and angle data.
  - Temperature Sensor
    Water Temperature data.
  - Power Source Level Sensor
    Voltage reading data.

As for the outer shell there are a few things to have in attention.

- The Antenna to floater distance, once the water interferes with the antenna signal.
- The float size, that needs to support all the weight and float, respecting the first topic.
- The drifter ballast, that will be the drifter core, located between the floater and the temperature sensor tip. It should be heavy so the drifter points up, but it shouldn't exceed the second topic demand
- The Floater volume, as it has to balance the hole eletronics and shell weight.

This creates a first view of the system as a block diagram. Indicating the physical connection between each component. This won't define the 5S architecture, but it will serve as an initial guide to build on.

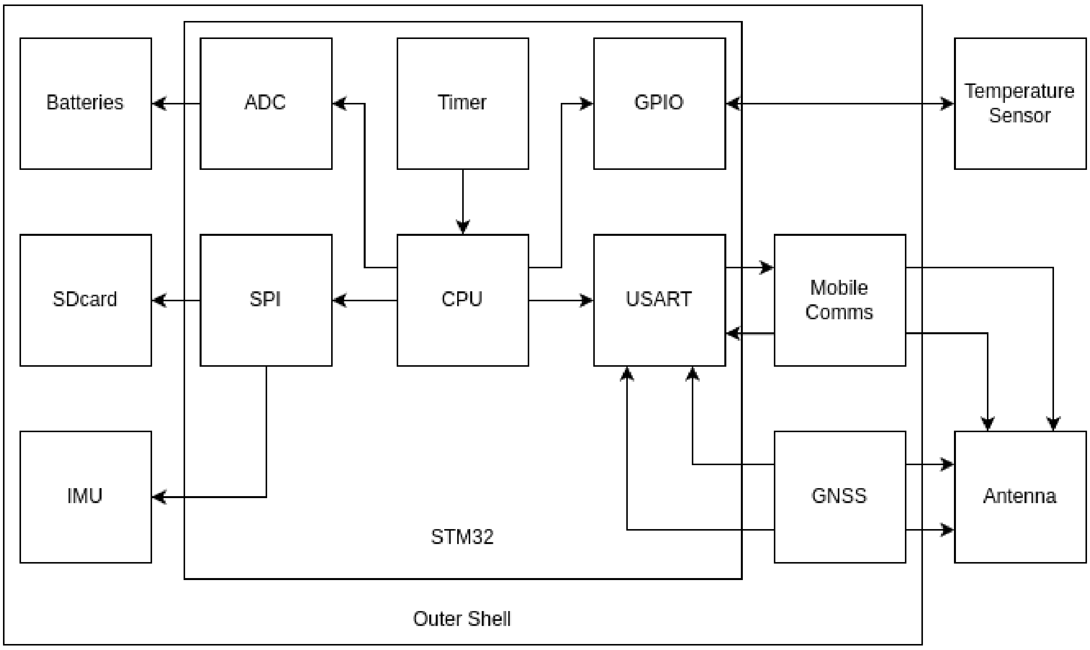

Figure 2.1: Block Diagram Initial Draft

The floater draft shows the initial concept of a drifter, as it has the above water antenna, a floater to counter balance the buoy weight, and the temperature sensor. Acording to the blockd diagram.

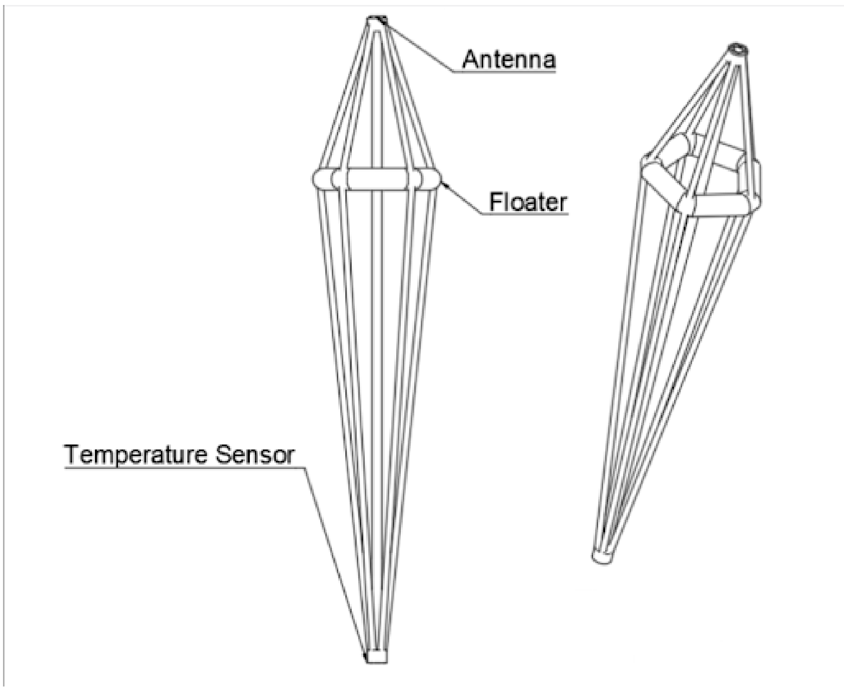

Figure 2.2: Floater Architecture Initial Draft

2.1 Requirements and Constraints

2.1.1 Requirements

- Search and selection of hardware components.
- Software design.
- PCB design.
- 5S outer shell 3D design.
- Actual product realization.
- Laboratory tests.

2.1.2 Constraints

- Limited Team
- The project must be presented for evaluation within deadline.
- The project has to be validated at the ocean.
- The pretended autonomy has to be of a mouth at minimum.

2.2 State of the art

Nowadays, there are a series of reasons in witch drifters are used. Usually, government departments, companies and universities with relations to oceanography, use drifter alike to research the local coast for the following reasons.

- Border Control
- Climate Modeling
- Traffic management
- Aquaculture management
- Public oceanographic research
- Marine spatial planning
- Defense and security

5S drifter aims for **Climate Modeling**, **Public oceanographic** or even **Traffic management** research as this project main objective. As the data for this project can be used, as stated in the Introduction, to model the environment in order to better the quality of said topics.

2.2.1 Copernicus Example

The Copernicus Marine Service, component of Copernicus Programme of the European Union, has developed the SVP-BRST, a drifter for temperature and depth measurement. Based on the SSP-B design, the updated version implements a HRSST in addition to the regular SST sensor, gathering the position with GNSS and transmitting the data using Iridium.

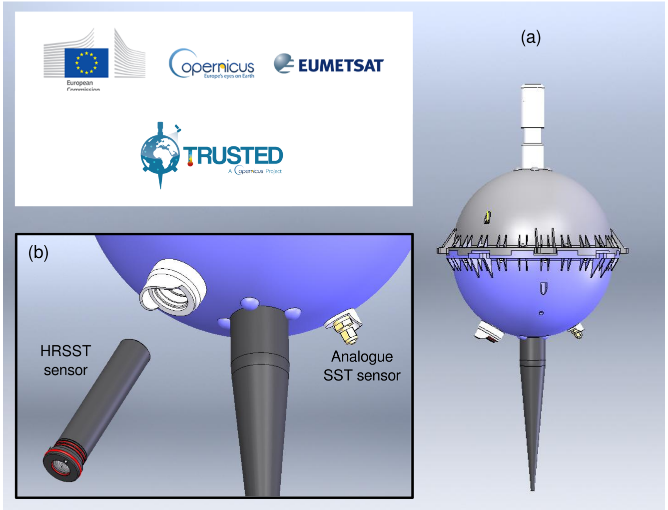

Figure 2.3: SVP-BRST Design

The image shows the SVP-BRST model. The (a) image shows the hole model with the antenna the buoyant part ad the weight to point the buoy up. As for the (b) image, shows the sensor's placement.

2.2.2 CMEMS Examples

The CMEMS lab at the University of Minho combines expertise in microsystems engineering with environmental research to develop innovative ocean monitoring technologies. One of its key areas involves the design and deployment of autonomous drifters to collect real-time data on sea surface conditions and currents.

SONDA

The project proposes a complementary system for atmospheric and oceanic monitoring using configurable probes launched by high-altitude balloons. These probes can measure environmental parameters from the stratosphere to the deep sea. After reaching the seafloor and collecting data (including acoustic imaging), the probe resurfaces and transmits the data via satellite. It then drifts until its material degrades. The system offers a low-cost, high-payload solution with limited positional accuracy.

NextSea

A new approach of monitoring coastal and estuarine relevant variables is presented. MEMS (Micro Electromechanical Systems), lab-on-chip and microelectronics are used to miniaturize and optimize main oceanic sampling. Beyond typical CTD (Conductivity, Temperature and Depth), other oceanic variables are also monitored. The system also samples type of phytoplankton and its concentration, pH, currents direction and intensity and turbidity.

2.3 System Architecture

Once studied what the system needs to follow, it is now needed to formulate a solution. Here it will be used UML diagrams to convey the solution in question, whiteout real specifications once this proposal works as a validation and organization to the problem as a formal language.

Block Diagram

As previsiosly stated, a block diagram is a formal representation of the system components and their connection. This one, shows how the peripherals communicate with the microcontroller STM32 as it considers connections with components outside the shell. Initialy, as a first analysis the communication protocol is't yet defined. However it will be used to narrow it down.

The diagram shows the SMT32 minimum peripherals: ADC, TIMER, GPIO, I2C / SPI, USART. However, as it discribes the hardware, it dosen't gives a good notion on the system software.

Some points to be considered are:

- The temperature sensor communicate using the GPIO, as waterproof sensors, usually, use a driver with specific comunication protocols.
- Mobile Comms is the protocol that will be used to send information to the database. Yet to be chosen.
- GNSS and Mobile Comms for now comunicate to the same Antenna, However it probably will use diferent atennas as different protocols require different frequencies to be used.
- The comunication to the SDcard, uses SPI with STM32 below 64 pins. As it dosent include SDMMC suporting FatFS.
- The batteris power the hole system. Even if not shown.
- Depending on the implementation, the timer block will be the Sysclock, as the a RTOS may use by defalt.

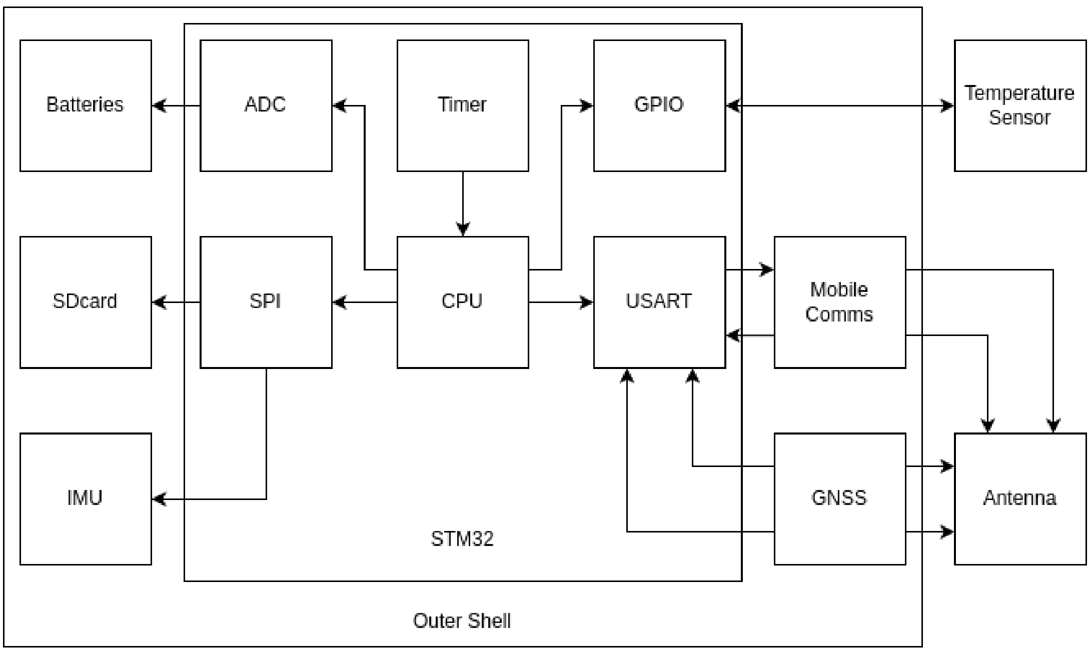

Figure 2.4: Block Diagram

Use Case

Now, for a software ilustration, UML offers a user case, a diagram that exemplifies the system interactions and stimuli.

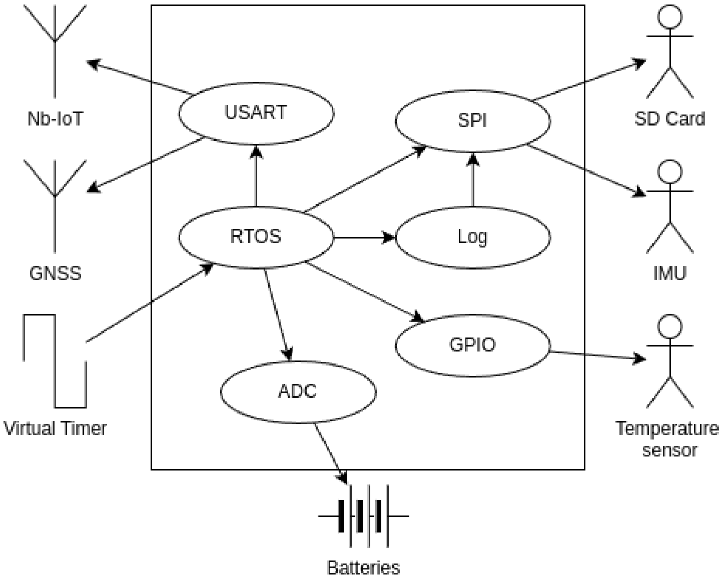

Figure 2.5: Use Case Diagram

Now it is introduced to one main component that will be explored further, an RTOS. As it is stimulated by the timer, it will actvate the peripherals in a organized form, allowing a fast and efficient use of energy. Other component is the Log, a virtual memory that will store temporaly the information, only storing localy, once per cicle, reducing the SDcard entries.

Sequence Diagram

Once the software and hardware are planed, now a time related diagram will show the blocks interactions as time passes.

First task sequence, a generic "Data Acquisition Task" shows the general behavior of a task focused to menage the sensors.

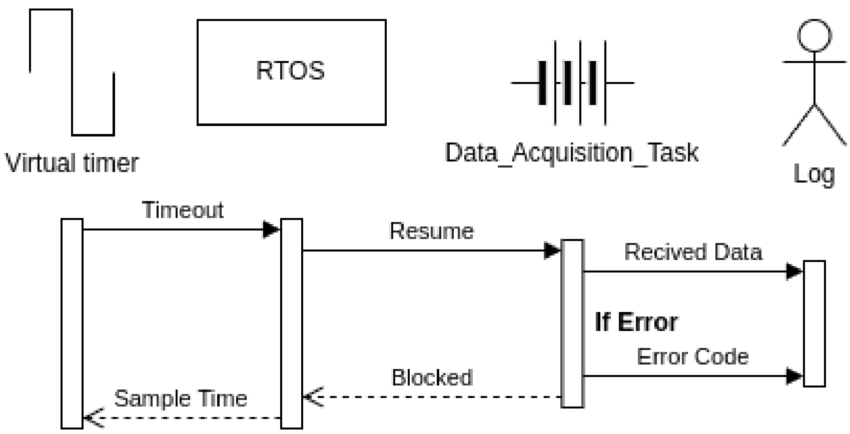

Figure 2.6: Sequence Diagram of Sensor Task

Next, the seconde task sequence, there will be 2 tasks with the behavior to get the GNSS information, store it on log, then call for the Mobile Comms task to send the stored memory to the Database. On the end, iniciating the SDcard storage.

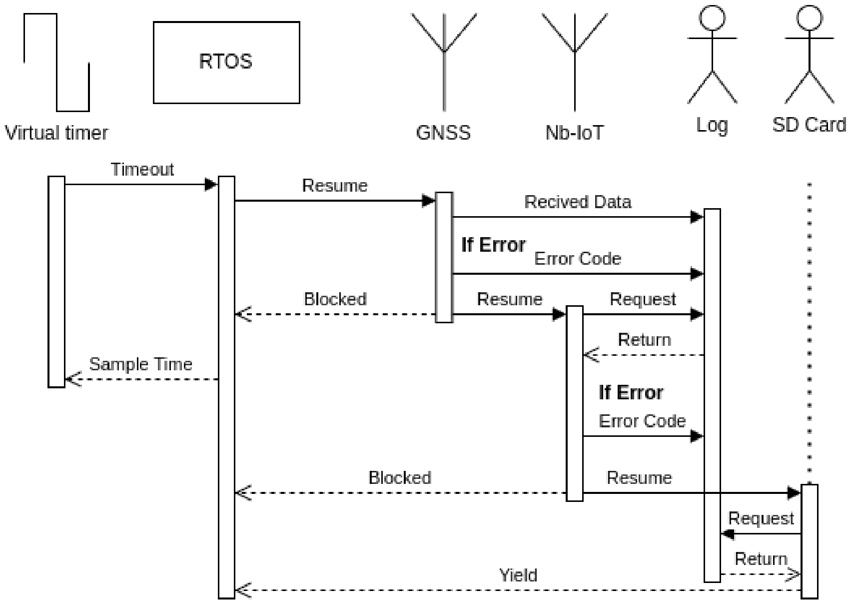

Figure 2.7: Sequence Diagram for Sending and Archive Task

Threads

Once this problem requires a list of taks to be executed, using a OS will allow a better project organization and performance with little to no impact in power consumption, even helping to menage the low power mode.

As the ST uC offers a variety of RTOS, the implementation will be acessible with good support due to the CMSIS v2 abstraction layer.

The division in Threads demands a separation in Priority levels, as the OS scheduler takes in consideration once both tasks are ready for execution.

Seting a task priority it must take in vision the resources the task will use, the time it will take to execute said behavior and the actual importance in matching it time constraints. In order to menage this level of complexity, the RTOS offers a set of tools for tasks control that will be used for its synchronization and comunication.

- High Priority Threads
  Tasks that will handle the outer communication as GNSS and the internet integration will take the higher priority once, as will be handled by a peripheral, its execution will be faster, only using the USART interface for AC transmission.

- Normal Priority Threads
  The only task here will be the one that has enough importance to be prioritized over the sensors but as the transmission beggins it should release the processor for the outer communication.

- Low Priority Threads
  Tasks that only has to measure the sensors having no problem to be removed from the CPU execution once their execution is, in their majority, asynchronous.

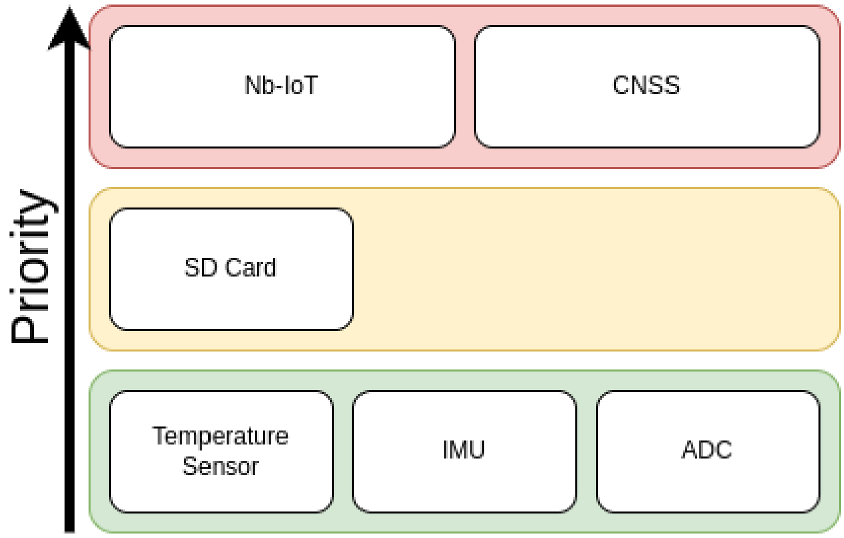

Figure 2.8: Thread Priority Stack

Other important perspective, is to emulate the task behavior with the priorities in action. Showing a repetion of X times a group of data aqcuisition tasks, then ending with the second task sequence. X yet to be defined as it first depends on the sample time.

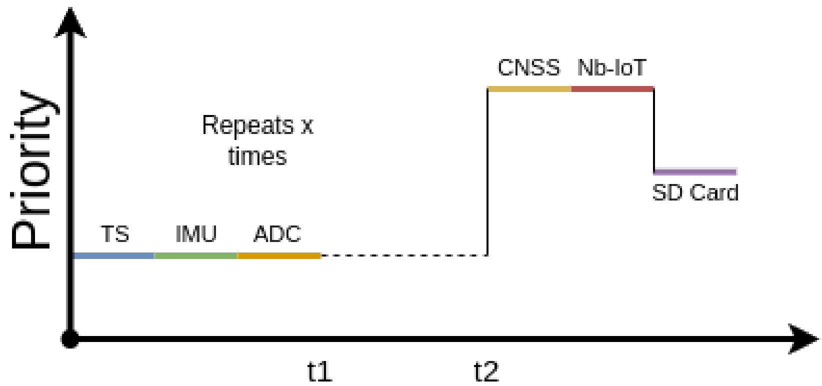

Figure 2.9: Thread Temporal Graph

Here up to t1 the system executes tasks, storing data, then entering low power mode untill the next sample. then, at the end of the last repetition, at t2, stating the second task sequence. Then after the SDcard task behavior ends, as so do the cicle.

Memory Abstraction (Log)

The final diagrams, are a exeption of UML diagrams, As it only builds a data structure and a simple interface to interact with it. Here the ideia is to allow memory to be acessible while written by the system, optmizing the RTOS ITCs options.

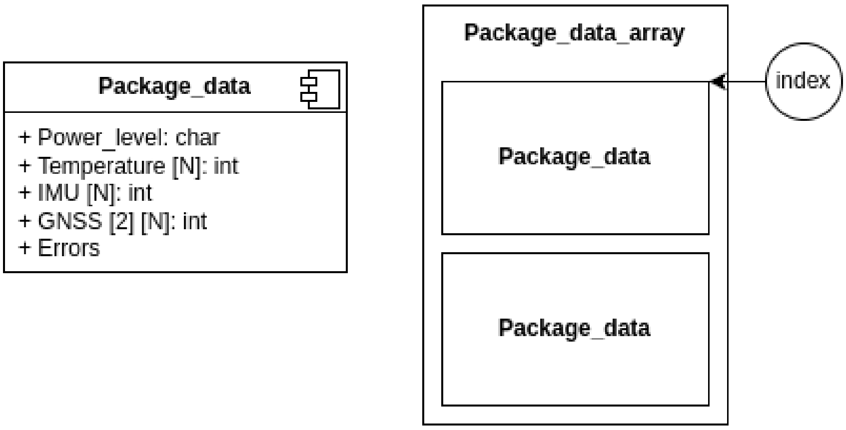

Figure 2.10: Package data structure

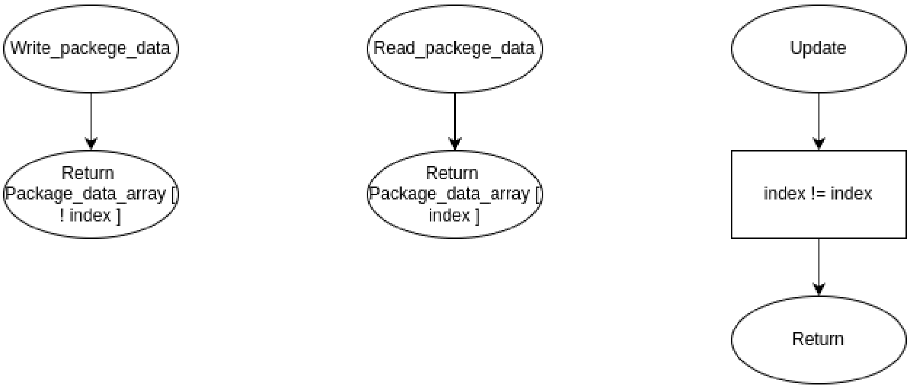

Figure 2.11: Memory Flowchart

Chapter 3

Design

Now, once planed "What" is the system, it is needed to plan the "How" the system will be build in the implementation fase. Here is explaned the components and the reason for it. As well for the instructions on the system construction and realisation.

3.1 Analysis Review

Taking in account the limited personal and time, some of what is specified in Analysis has the scope reduced as to accomplish acording to the requirements and constraints. Using as inspiration the Copernicus SVP-BRST and the CMEMS labs previous experience, the 5S can/ and will recall for used tecnology for easier design process.

The project then will be devided in three main parts; The Hardware, Software and the outer shell. Then, lately, it will be shown the softwares used to accomplish this project.

3.2 Hardware

This section elaborate on the system physical components, their connections and the reasons they ware chosen. It is important to remember that the main objective, even if it is not specified on the topic, is the lowpower functionalities. So the hability to consume less power is a favoring point.

3.2.1 Autonomy

Here will be discussed witch hardware is best sued for the task. The hardware will be evaluated by their autonomy, the communication protocol

As for the autonomy there are two main factors to consider, the batteries and the board consumption meaning that the whole system must consume, on average, 5mAH.

Batteries

Google sheets

Board Consumption

table

SIM7600 table 6 and 34 (pg 20 and) same voltage 2 SIM7020 peak 2A 20u in sleep mode 150mA

SIM7000 (GPS por NB-IoT e 2G fallback) Consome: 11mA

SIM7080G - Nb-IoT Quectel BG77

Quectel BG95-M3

GPS MAX-M10S

tele2

IMU BMI088 IMU Sensor accelerometer 15uA / and Gyroscope 2.7mA ISM330BX 0.19mA / 0.6mA activate BDU

BMI270

Unix Steptime

final list IMU 9DOF GY-85 - ITG3205 + ADXL345 + HMC5883L

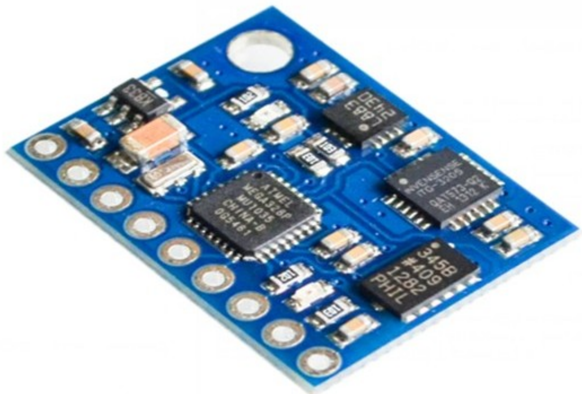

Figure 3.1: Memory Flowchart

SIM7000E Arduino NB-IoT/LTE/GPRS/GPS Expansion Shield

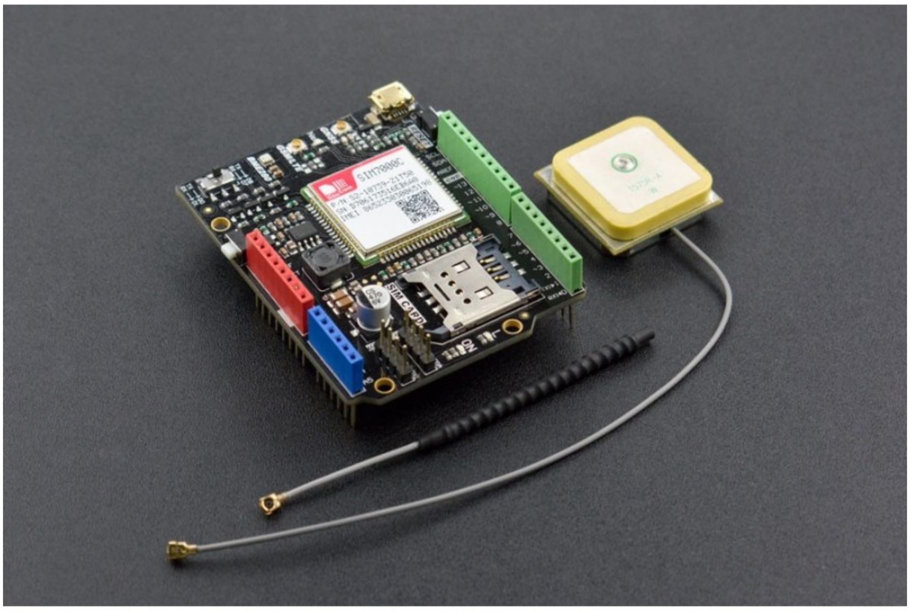

Figure 3.2: Memory Flowchart

SENSOR DE TEMPERATURA À PROVA DE ÁGUA (DS18B20) 1M

Figure 3.3: Memory Flowchart

Cartão micro SDHC 32GB Adata Class 10 UHS-I com adaptador INF01016

Figure 3.4: Memory Flowchart

Módulo leitor de cartões micro SD

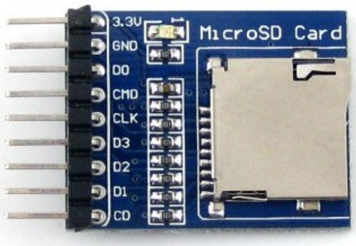

Figure 3.5: Memory Flowchart

Battery Holder for 4x 18650 with wires

Figure 3.6: Memory Flowchart

PILHA LI-ION 18650 3,7V 2000MAH

Figure 3.7: Memory Flowchart

Possible solar energy solar penel AEM10941 SM111K06L

3.3 Hardware Specification

3.3.1 SDCard

3.3.2 STM32

STM32L010K4T6 microcontroler ADC UART SPI ONEWire

3.3.3 BMI088 IMU Sensor

gyroscope and acelerometer

3.3.4 Temperature

DS18B20

3.4 Software

3.4.1 Communication protocol

factors to consider chip distance bitrate availability table EVKITST87M01-1 nb-iot SIM7600 2g 3g 4g LTE CAT4

Portugal	2G	3G	4G	5G	LTE	NB-IoT
Meo	V	V	V	–	–	–
Nos	V	V	–	–	–	–
Vodafone	V	–	V	V	V	–

simbase chip availability
europe coast 2g 4g

3.5 Shell

2.5 dB Antenna should be at least 10 cm form water

3.5.1 Conclusion

3.6 Case Construction

Diagram

The hardware configurations, as idicated on the datasheet should follow the leading steps.

As for the UART communication, the list of commads are listed on the datasheet. As for better flow, here are listed the commadsused along the project and their functionalities.

3.7 Tools and COTS

3.7.1 Tools

3.7.2 COTS

GPS and 4G module

Inkscape

draw.io

STM32 CUBEmx

LaTeX

3.8 Software Specification

3.9 Theorical Concepts

Chapter 4

Implementation

4.1 Hardware and Shell

4.2 Software

4.2.1 Project Sections

4.2.2 Task Behavior

separar funções do IMU e GNSS para não atrapalhar um ao outro.

4.2.3 DataBase Comunication

Mongo db
JASON

Chapter 5

Conclusion

5.1 Gantt Diagram

5.2 Bibliografy

The secondary ageostrophic circulation in the Iberian Poleward Current along the Cantabrian Sea (Bay of Biscay) Atmospheric modes influence on Iberian Poleward Current variability

5.3 Special Greatings

At last it's important to add the support from the CMEMS labs personal as well of the professor Tiago Matos for his support with hardware decisions and previous knowledge from similar projects.