



PROJETO FINAL DE GRADUAÇÃO

**NEIGHBORING MANAGEMENT TOOL FOR A  
MOBILE TELECOMMUNICATION NETWORK**

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Resumo.

O mundo das telecomunicações móveis está em constante evolução e é cada vez mais importante para a sociedade. Com isso, é importante o papel do engenheiro de telecomunicações para garantir uma conexão segura e cada vez com mais qualidade. O presente trabalho foi realizado na empresa Network Solutions Factory (NetSF), em Lyon, na França. A empresa atua na área de telecomunicações e presta serviços para operadoras de telefonia móvel. Estruturalmente dividida em equipes, a NetSF executa seus trabalhos principalmente na rede de acesso, planejando, otimizando e ligando diferentes estações rádio base de arquiteturas heterogêneas desde o 2G ao 5G.

O objetivo do trabalho foi o desenvolvimento de uma ferramenta para coleta, tratamento e registro de dados para automatização de vizinhança em redes móveis. Esse processo é muito importante para garantir uma boa qualidade de serviço e de experiência para os usuários da rede. Além disso, uma boa configuração de vizinhança em uma topologia móvel é crucial para não haver interrupções no serviço enquanto os usuários se deslocam, seja dentro de casa ou até mesmo em um trem de alta velocidade.

Os resultados obtidos por meio da implementação da ferramenta mostraram-se muito positivos. As principais melhorias obtidas foram nos quesitos de otimização de velocidade do processamento de dados, abrangência de mais operadoras, homogeneização de construtoras e estruturas de dados, tratamento de erros e sistema de logs. Os futuros trabalhos são continuar melhorando a velocidade de tratamento de dados por meio de ferramentas e estruturas de dados mais robustas e fazer o uso de métodos de inteligência artificial para a análise destes dados.

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## ABSTRACT

Resumo.

The world of mobile telecommunications is constantly. Thus, the role of the telecommunications engineer is important to ensure a secure connection with increasingly higher quality. The present work was held at the company Network Solutions Factory (NetSF), in Lyon, France. The company operates in the telecommunications area and provides services to mobile operators. Structurally divided into teams, NetSF performs its work mainly in the access network, planning, optimizing and linking different radio base stations of heterogeneous architectures from 2G to 5G.

The goal of this work was the development of a tool for collecting, processing and recording data for neighborhood automation in mobile networks. This process is very important to ensure a good quality of service and experience for network users. In addition, a good neighborhood configuration in a mobile topology is crucial for avoiding interruptions in service while users are on the move, whether indoors or even on a high-speed train.

The results obtained through the implementation of the tool were very positive. The main improvements obtained were in terms of data processing time optimization, coverage of more operators, homogenization of different construction companies and data structures, error handling and log system. Future works are to continue improving the speed of data processing through more robust tools and data structures and to make use of artificial intelligence methods for the analysis of these data.

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## **DEDICATÓRIA**

# 1 INTRODUCTION

This report presents a summary of the activities carried out during the end-of-studies stage. The internship was held at Network Solutions Factory between February and August 2021. During this period, the main objectives were to formalize the knowledge obtained during the years of study and experience what it is like to work in the telecommunications field. Among the objectives was also the elaboration of a final project, which was defined based on the company's needs.

The document is divided into different chapters. To help you understand the technical terms, Chapter 2 explains some of the content covered during the internship. Chapter 3 shows a detailed summary of the company and the tasks done. The final project developed is described in Chapter 4. Chapter 5 describes a little more about the work environment, based on an interview with an engineer who works at the company. Finally, Chapter 6 brings some perspectives for the future and a reflection on the internship experience.

## 2 IMPORTANT CONCEPTS

In this chapter, the concepts related to the work performed and the telecom network environment are briefly explained, thus enabling a better reading and understanding for all readers. Many of the concepts explained are shown in (1) and (2) in more depth.

### 2.1 MOBILE NETWORKS

**Site** It connects a set of radio transmitters/receivers with the other elements of the network (switches and routers). A site allows the creation of cells with different technologies (2G, 3G, 4G and 5G) (3). Each site has several different types of equipment such as controllers, monitoring systems, modulators, attenuators, amplifiers and filters. In addition to these, cables such as coax and fiber are also used for interconnecting equipment and antennas on a site.

**Cell** It is the elementary part of a cellular telecommunications network. A cell is a geographic region that receives a signal generated by an antenna located at a nearby site (2). Each cell has a certain frequency and specific technology. In addition, the same site can have several cells of the same technology or different technologies. Each cell differs in terms of its antenna pointing (azimuth and tilt), the channel used (ARFCN - Absolute Radio-Frequency Channel Number) and configuration parameters such as Scrambling Code (SC) and Primary Cell Identifier (PCI), for 3G and 4G respectively.

#### 2.1.1 2G

2G networks enabled the beginning of the use of digital communication, thus being able to provide new functionalities concerning 1G, such as sending text messages and calls with better quality. The 2G network allocated all the available frequency bands and made use of TDMA (Time-Division Multiple Access) to communicate with users. For it to work it was necessary to reuse frequencies, so there should be a planning of the frequencies used in each cell so that there would be no interference.

#### 2.1.2 3G

The technology used in 3G networks was what made the use of mobile internet possible. This technology uses WCDMA (Wide-Band Code-Division Multiple Access) to make it possible to connect several users at the same time using the same frequency.

### **2.1.3 4G**

With the arrival of 4G (LTE) it was possible to improve the use of mobile internet for multimedia applications that require more bandwidth. This technology uses OFDMA (Orthogonal Frequency-Division Multiple Access) to allocate resources to users. With 4G, a new way of voice calls has also emerged, VoLTE (Voice over LTE). Thus, calls that were previously based on a virtual circuit are now made in voice over IP, where a packet switching is responsible for guaranteeing the voice service to users.

### **2.1.4 5G**

5G is being implemented around the world and is highly anticipated due to the promises of high improvements in the quality of service and experience of the network. The network access part, radio, offers some improvements like beamforming, however it remains similar to 4G technology. On the other hand, the core of the network is modified to bring services closer to the users, thus decreasing latency and increasing the number of simultaneous users. This enables technologies such as the Internet of Things (IoT) and autonomous cars for example.

Due to the importance of technology, it is also worth mentioning that there are several geopolitical conflicts linked to 5G. These conflicts mainly involve the United States and China. As the Huawei company increasingly stands out in the field, Americans fear China will grow and that crucial data will be compromised using the Chinese company's technology. This conflict ends up influencing the choice of whether or not to use Huawei by other countries that fear the blocking of relations with the two largest world economies.

## **2.2 RADIO OPTIMIZATION**

### **2.2.1 Antenna diagram patern**

Each antenna has a specific construction for a particular application and operates in a specific frequency band. Its different types and formats define some of its performance parameters, such as directivity, gain, polarization and bandwidth (4).

Another important parameter of an antenna is its emission diagram. This diagram is exemplified by Figure 2.1. It is possible to see the emission diagram for a specific antenna, commonly used in mobile telecommunications networks, (5).

In the image, it is possible to observe the horizontal and vertical planes of the antenna's emission diagram. Analyzing the graphs, differences can be seen in one of these axes and also in each operating band. The image also shows the main lobe of the antenna, which is the region where the antenna covers with up to 3dB of loss, equivalent to half the emitted power.

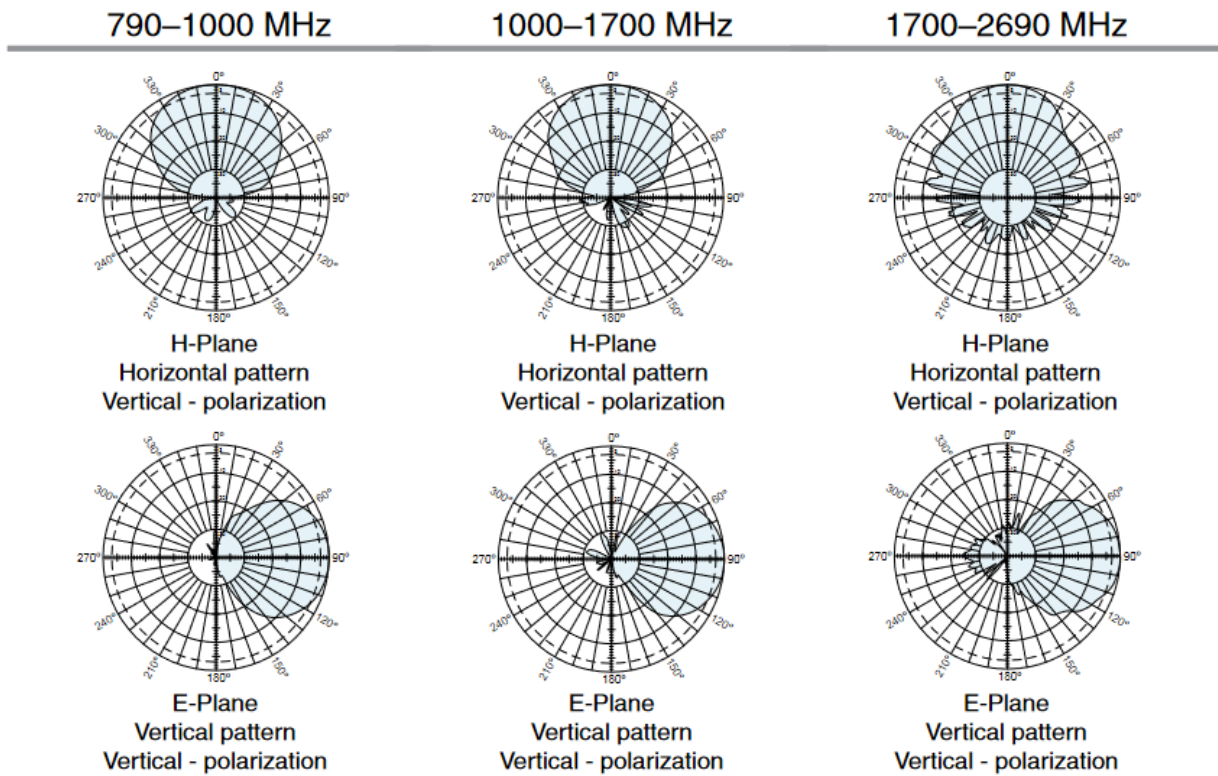


Figure 2.1: Antenna pattern diagram example

### 2.2.2 Tilt

Tilt is a parameter that defines the antenna’s coverage area, on the vertical axis. Considering an antenna emission diagram on the vertical axis, it is possible to select the area to be covered by varying the mechanical or electrical tilt of the antenna for a given cell.

Mechanical tilt is defined by the network designer and implemented in the installation of an antenna. The electrical tilt is also planned but can be easily changed from a distance to optimize a cell’s coverage area.

An example of tilt optimization is shown in Figure 2.2, where you can see 3 scenarios. The first shows a city that is completely covered by a cell. In the second scenario, the city grows and the operator must make an engineering and commercial choice to cover the new users who arrive in the city. Finally, the third scenario shows a possible choice where the company chooses to *uptilt*, covering new users. However, it is possible to see that some houses that were previously covered have lost coverage.

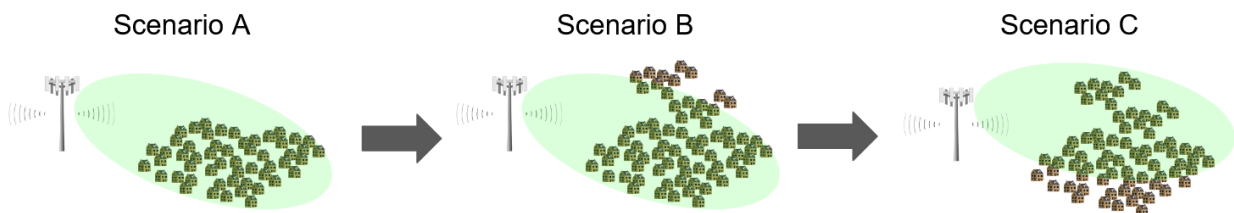


Figure 2.2: Tilt management example

This choice must be taken carefully so that old customers are not heavily impacted. There must be no degradation in the quality of service and access to the network for former users. Therefore, some possible solutions are to change the tilt of another cell to serve users who have lost coverage, to implement another cell that will cover the old users or to increase the power.

### 2.2.3 Handover

Handover (HO) is the process of cell switching by a user who is making use of network services while moves. A clear example is shown in Figure 2.3. In it, you can see a connected user who moves around in his vehicle while making a call. This user starts connected to cell A, during his way he performs a handover to cells B, C, D and finally E.

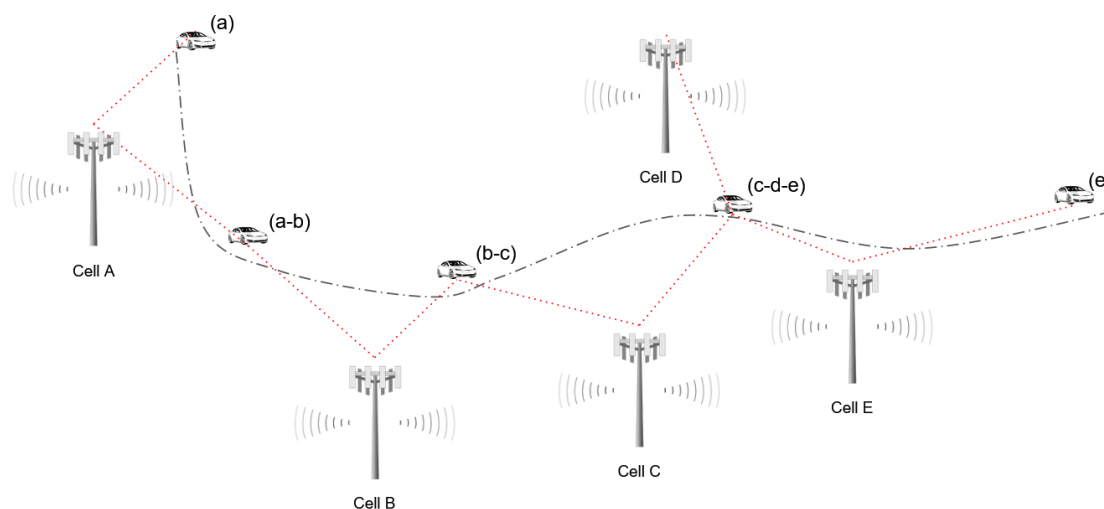


Figure 2.3: Handover example

In the image, it is also possible to see another important feature that emerged from 3G, where a user can connect to up to 3 cells simultaneously, thus facilitating the HOs and increasing the possibility of having a continuous call when moving. These HOs performed without the user having to disconnect from one cell before connecting to the other are one of the great improvements of 3G and are called Soft Handovers, SHO.

The cells to which the user is connected are present in an element called Active Set, which can reach up to 3. In addition, there is also the Monitored Set, which is a set of up to 31 cells that are constantly measured by the mobile device to verify the possibility of connection, changing it to the Active Set.

#### 2.2.3.1 Neighboring

The Monitored Set is composed of cells that are neighbors to those in the Active Set. This neighborhood relationships must be configured in each of the cells and a good configuration can improve the performance in the selection of neighbors and the HO process. The final project of the stage is related to the automation of the neighboring cells process.



**Note** Handover is different from roaming. When the user is in another country or region, where his origin operator does not cover, he can use the roaming to connect to the network of a partner operator. In addition, a roaming user will perform handovers if he start a call while moves.

### **2.2.4 Scrambling Code**

In 3G networks, cells emit all the time across space. Thus, there is a need for WCDMA (Wideband Code Division Multiple Access) to avoid interference and enable cell differentiation. In WCDMA the use of 2 codes is made, the Scrambling Code and the Spreading code. In general, both use the same theory for differentiating cells and users within a cell, respectively. An example of how WCDMA works and the use of orthogonal codes for identification is seen in (6).

As Spreading Code does not need planning by the engineer responsible for the network, it is usually not the focus, a deeper explanation can be seen in (7). However, Scrambling Code (SC) is a big problem for planning and optimizing 3G networks. This occurs because, in a given spatial region, the same SC must not be seen by a device or cell.

If there is an overlap of 2 cells with the same SC, there will be a great interference and the HO will also be affected because the user will not know how to differentiate the cells correctly. When this occurs it is common to say that there is a first-order SC clash. The SC clash can also occur when a cell is a neighbor of 2 cells with the same SC, even if these two cells do not overlap, which is called the second-order clash.

The big problem for the radio optimization engineer is that there is a limit of 512 SCs available on 3G networks. Furthermore, in some regions, such as on the border with other countries, it is common to have only half or even one-third of this value, in the case of a border with 2 other countries.

### **2.2.5 Swap**

Swap is a common process in telecommunications operators who want to change the constructor they use. In the case of Salt, the sites are currently being swapped from Nokia to Huawei. With this it is necessary to plan the sites to be replaced, to do a previous configuration, the replacement, monitoring to see if the process was done correctly and, finally, the optimization of the site that went through the swap.

### **2.2.6 Key Performance Indicator**

The KPIs (Key Performance Indicators) are data coming from counters present in the network sites. They can be used by the telecommunications engineer to analyze and improve the quality of service. Typically, KPIs can be seen at different granularity and scopes, such as for a cell, for a site, for a zone, or the entire network for example. Below are described some important KPIs.

#### 2.2.6.1 Call Setup Success Rate - CSSR

This KPI indicates the number of completed calls divided by the total number of call attempts. Which is important to verify that system users can make calls.

#### 2.2.6.2 Drop Call Rate - DCR

One of the things that most interferes in the quality of experience of a user is when their call is ended unintentionally. The DCR is the KPI responsible for accounting for these cases. It is the division of the number of calls that were terminated by the total number of calls.

#### 2.2.6.3 E-RAB Setup and Drop Rate

KPIs related to E-RAB have the function of showing the user's connection with the core of the network. The E-RAB is this connection and it's interesting to check its setup and drop success rate.

#### 2.2.6.4 Radio Bearer Setup and Drop Rate

Radio Bearer is the final part of the E-RAB, representing the radio link between the user mobile and the antenna in the site. It's also interesting to analyze your success and drop rates to detect problems in the radio side.

#### 2.2.6.5 Load KPIs

Charge related KPIs are also very important. They can indicate voice or data traffic, average throughput for users or the average number of users connected to a cell, for example. With the analysis of these KPIs it is possible to see overloaded cells and optimize them or even propose new solutions in the network design to solve this problem, such as the implementation of a new site or frequency.

#### 2.2.6.6 Handover KPIs

Finally, the handover process can also be monitored via KPIs. These can indicate the success rate of HO with a particular source or destination cell. There are different KPIs for analyzing different types of HO, such as inter-freq, intra-freq or Soft Handover, in 3G networks.

## 3 OVERVIEW: INTERNSHIP CONTEXT AND MISSIONS

In this chapter, an overview of the internship is presented, showing the tasks that were done during the 6 months of work. Some definitions, technologies and technical issues can be explained later, in Chapter 2, which can be consulted at all times for a better understanding of what is presented below.

### 3.1 PRESENTATION OF THE COMPANY

Network Solutions Factory (NetSF) is a company that is part of the NJJ holding, which also has several other companies in the telecommunications and technology market. By being within this environment, NetSF acts as the operations and management center of the mobile network of the NJJ group's telecom operators. Today the company has around 100 employees and is headquartered in Lyon, France (8).

Initially, in 2015, NetSF started working for the engineering activities of Salt, formerly Orange Suisse. In 2018, it also started operating in other countries with the start of operations for Eir Ireland and Free Senegal. Finally, with the acquisition of part of Monaco Télécom by the NJJ group, NetSF also started to work for the operator Epic, present in Malta and Cyprus.

The company is divided into different groups that can work for a specific operator or for several operators at the same time. The teams are divided as follows:

- **Radio Optimization:** Its mission is to constantly optimize the quality of service for network users, be it 2G, 3G, 4G or 5G. It monitors network performance on a daily basis and detects specific problems that can be resolved. In addition, they are responsible to increase the Quality of Service. Therefore they can also propose and apply large-scale changes in the configuration of cells, aiming a gradual improvement that can be in coverage, energy consumption, latency, spectral efficiency, throughput, voice call success, among others. It also monitors user complaints and makes possible changes to improve the operator's user experience.
- **Radio planning:** Responsible for planning and designing the network, respecting the limits imposed, whether governmental (build-permit) or geographic (mountains, lakes, borders and large cities). Search for the best solutions for creating or updating sites.
- **Supervision:** Ensures operator availability, monitoring network elements 24/7. Detect incidents and track alarms that may impact usability and customer connection.
- **OSS:** Operates in the management of the information systems. This team is charged of solving user problems related to various technologies and tools.
- **Operations:** Manage operations on site and installation of equipment. This team install the equipment and make sure it works as expected.

- **Radio support:** Provides support for radio equipment from different manufacturers (Huawei, Nokia and Ericsson) to ensure the best levels of quality of service.
- **Transmission:** Makes communication between sites and connects clients, enabling communication. It works with various network equipment such as routers and switches. In addition, the team also work with the use of transmission technologies such as microwave and optical fiber. They are also divided in planning, support and operations.

## 3.2 INTERNSHIP DESCRIPTION

The final internship was in the radio optimization team for Salt. During the internship, several small projects were developed and it was possible to have contact with the work environment of a telecom engineer in the area of radio optimization. Furthermore, for the final project, some application development and data analysis tools were used, as will be shown in Chapter 4.

### 3.2.1 Salt.

Despite a challenging terrain and a very strict regulation on radiation levels and deployment of new sites, Switzerland is always present in the rankings as one of the best countries in the world of telecom (9). The country has 3 major operators, including Salt. This operator has more than 4000 sites, covering 99.3% of the population and is in constant development (10). Today its biggest challenges are related to the implementation and maintenance of 4G throughout all the territory, the arrival of 5G in large cities and the swap of Nokia sites to Huawei.

**Connect** The company's growth is evidenced annually by an important technical report that compares several operators in Germany, Austria, and Switzerland, called Connect. There are also reports with a granularity with quarterly measurements, where is possible to see what needs to be improved for the big test, that normally takes place during the month of October. Salt aims to continue improving each year and it's ranked as a very good operator despite being behind its competitors (Swisscom and Sunrise) (11).

Actually CONNECT is a german magazine that does this benchmark every year for Germany, Austria, and Switzerland. However the company that does this campaign, umlaut, is benchmarking operators in many countries in the world

## 3.3 MISSIONS

During the internship, it was possible to explore the universe of a telecommunications operator through the realization of different projects related to the radio part. The main works done are contained in the Gantt diagram shown in Figure 3.1.

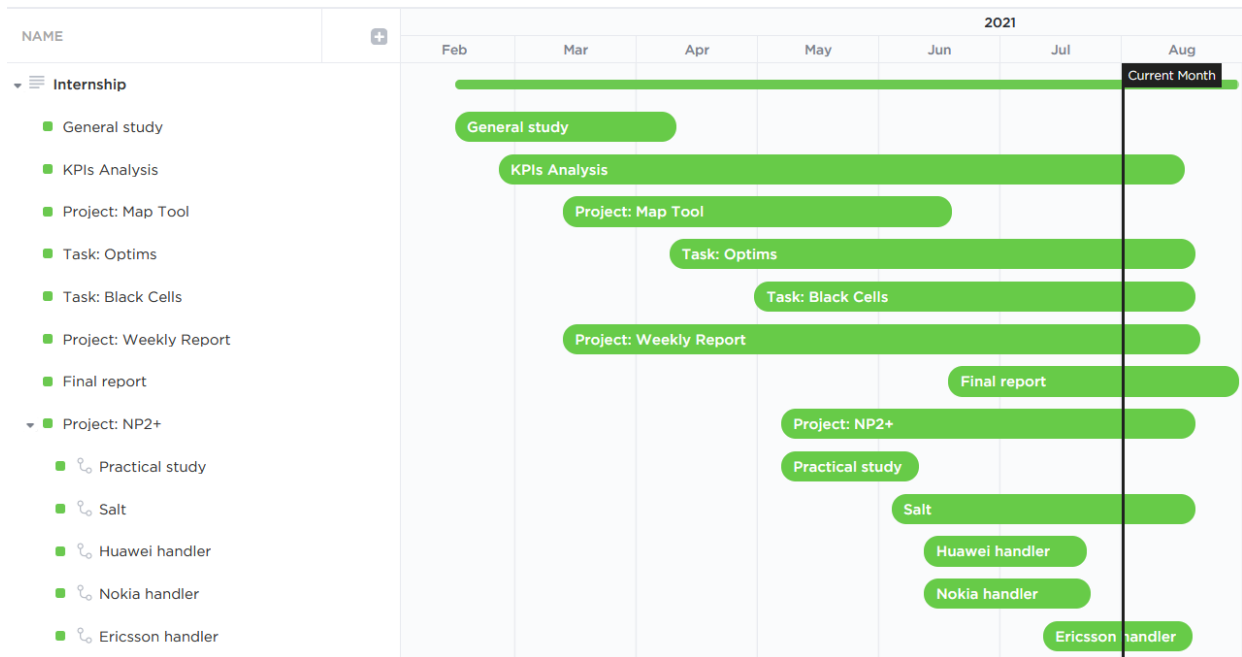


Figure 3.1: Gantt diagram with the projects and tasks done during the internship

### 3.3.1 General study

After arriving at the company, it was necessary to follow some courses about the technologies used in order to be more autonomous and secure to perform the daily tasks. First of all, it was given the support of a course on 2G, 3G and 4G networks, a basic subject for the work of a telecommunications engineer who works in the radio domain. The material to study was based on a slide presentation. During the study time, a document in  $\text{L}^{\text{T}}\text{E}^{\text{X}}$  was produced, which was shared to facilitate the training of new employees, considering that the previous document available was very good but not functional for dynamic and autonomous reading.

### 3.3.2 KPI Analysis

The analysis of KPIs (Key Performance Indicators) was important to go further into the knowledge and start helping the radio optimization team in practice. In the beginning, important KPIs related to 3G were analyzed, such as CSSR and DCR, on Huawei and Nokia sites. Over time, it was also possible to analyze the important KPIs for 4G, such as E-RAB setup, E-RAB Drop Rate and Data RB setup. Every morning the first activity of the day was to check these important KPIs and a few others and compare the previous 2 days to see if there was any degradation in any specific site or area. Concepts related to this mission are explained in Chapter 2.

An example analysis is shown in Figure 3.2. In the figure you can see a strong degradation in the CSSR, which in this case was linked to a problem with the core IP network. It is possible to clearly see a degradation, where all the network was affected.

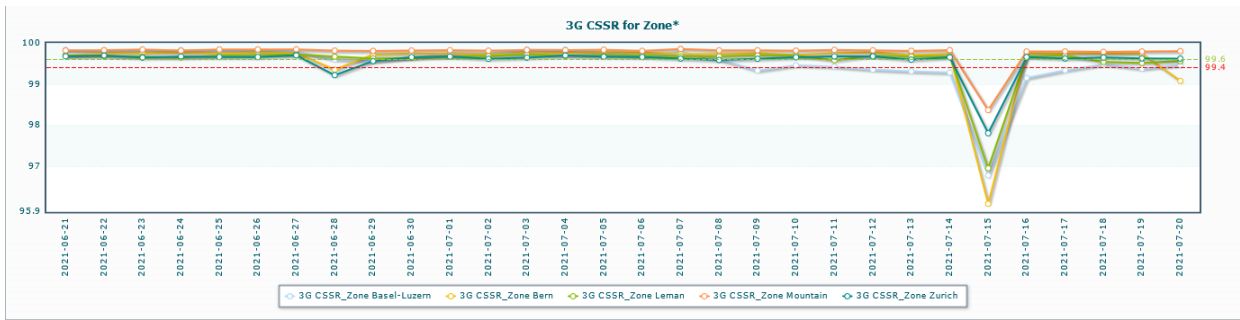


Figure 3.2: CSSR analysis

### 3.3.3 Project: Map Tool

The developed project aims to validate knowledge and propose another tool to the team. The application was made autonomously and can help in the selection of a new scrambling code in case of a clash. It works by showing the sites and cells on the map to have an overview of how the SCs are distributed in a given area, as shown in Figure 3.3.

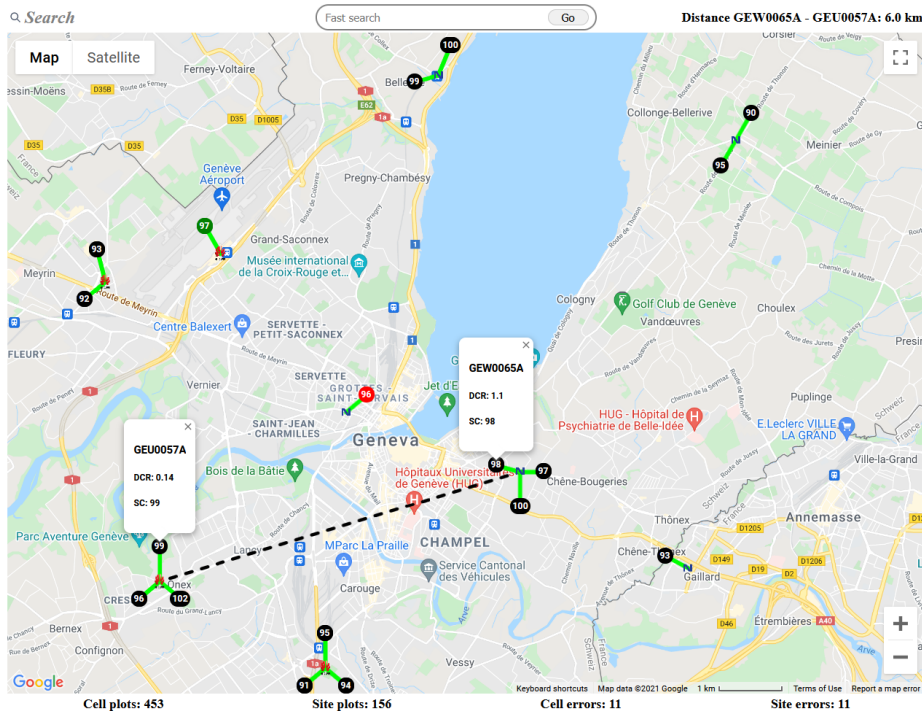


Figure 3.3: Project: Map Tool

#### Features

- Different ways to search: By cell, by site, by SC or by SC sequence. It is also possible to search for a set of the mentioned elements.
- Aggregation of different constructors: With the application, it is possible to visualize data from Nokia and Huawei sites on the same map.

- Distance measurement: By clicking on 2 cells the distance between them is automatically measured and shown in the upper right corner.
- DCR View: By clicking on a cell you can see an average of the previous days of its DCR.
- Site differentiation: For a better visualization, the outdoor, indoor and tunnel sites are differentiated by colors (black, green and red, respectively).
- Thread Selector: The number of threads used can be easily changed to adapt to different systems.

### Used tools

- Python: Language used for all part implementation of all computational part.
- Threads: A Python library was used in order to provide parallelism to the code and with that to improve the application's response speed incredibly.
- Flask: Framework used to link the web interface and code.
- Javascript: Used for Google API implementation.
- Google Maps API: Required to plot data and used due to its great documentation and security.
- Internal APIs: Used to query important information such as SC, site location and name, cell azimuth, among others.

### 3.3.4 Task: Optims

One of the main functions of an engineer who works in radio optimization is in fact the optimization of cells with different technologies (2G to 5G) and different builders (Huawei, Nokia and Ericsson). This task requires a little more knowledge as it actually involves users and can drastically affect the quality of service provided by the operator.

The optimizations made are related to the Nokia-Huawei swap, the addition of frequencies on sites and the implementation of new sites, most of the time Huawei. Each week it was possible to see that the optimizations were getting more interesting and the process to do them became more natural. Overall, optimizations were related to antenna tilt, power change, the addition of intra and inter-freq neighbors, concepts explained in Chapter 2. Furthermore, it was possible to learn about the configuration of some parameters and special features available on Nokia and Huawei sites.

To validate the optimizations a KPI analysis was done to verify that there was no degradation on the site and neither on the sites around it.

### 3.3.5 Project: Weekly Report

Every Monday, a meeting is held with the entire Salt optimization team, where problems from the previous week and what will be done in the current week are discussed. For this meeting, a report about

the network performance is required, which is called the Weekly Report. The report is presented at the meeting to support discussions on the network's problems. In the end some comments are added to be sent to Salt.

Before, the report was done manually and ended up without a fixed format each week. Moreover, there were also some errors in formulas and graphs, which could be questioned by Salt. For the Weekly Report, a manual file transfer was made from an FTP server, a change in the filenames and then it was possible to run an Access Macro to obtain a line of information that should be copied and pasted into another spreadsheet. All of this was automated and done directly just by running a Python script. In addition, some other counting tasks were also optimized.

Automation has greatly improved the time to get the report, which used to be around 1 hour and now less than 10 minutes. The issue of different formatting each week has been fixed and some information has been added during the period.

### **3.3.6 Final Report**

The final internship report also took some time and effort. The objective was to make a good report, which was simple to read, but without losing the learned content and the technical details involved.

The report was done using a template provided in L<sup>A</sup>T<sub>E</sub>X. However, some changes had to be made to have the report in English. Other small features were also added, such as a function that allows the creation of a bibliography and also an abstract in Portuguese.

### **3.3.7 Project: NP2+**

The final project of the internship involved an application that already existed for the company, called Neighbors Party 2 (NP2). This application allows you to automate some very massive and time-consuming tasks. With NP2 it is possible, for example, to make the neighborhood of 3G cells using an internal algorithm created by the company, which is based on cell configurations, current performance and data such as site location. It is also possible to audit some network configurations, comparing what is configured and operating on the network with what was planned by the radio planning team.



## 4 NEIGHBORING MANAGEMENT TOOL

In this chapter, the project will be explained, with a contextualization of the initial problem, a brief explanation of the necessities and a detailed explanation of the proposed solution to solve the problem. In the end, the results obtained from the use of the proposed solution and a comparison with the previous solution will also be shown.

### 4.1 INTRODUCTION

The radio optimization process is very important for the continuous improvement of the network's quality of service. Therefore, this process must be routine and many of the functions end up being repeated every day.

Some optimizations can be fast and simple, like a tilt change for example, explained in Chapter 2. However, some tasks require a lot of time, attention and analysis of several factors, such as the selection of neighbors present in the Monitoring Set of a 3G cell. This selection is important because a good choice can positively influence the success rate of handovers, intra or inter-freq.

The final project of the internship was defined based on the difficulty of managing the 3G cell neighboring. The company already had an application that worked only for the operator Salt and with the builders Nokia and Huawei.

When the application was created, it was not necessary to expand and generalize it to other operators and builders, so everything was done in an integrated way, the inputs, the actual application and the outputs. For the generalization of the tool, it was seen that the input standardization process was what would take the most time. That was noticed because each operator has its specific nomenclature for sites and cells, its engineering rules, its reference databases, in addition to the different constructors that provide exports of performance and configuration data in different formats.

Figure 4.1 shows a comparison of the tool's previous and current scenario. As mentioned, the tool that the company had made all data input, processing and output in a single system. With the internship project, the objective is to process the entries and register them in the database so that their treatment can be done equally in all operators. In this way, with the data standardized and correctly registered, the changes that are necessary in the core of the application are minimal. In addition, a module for handling Ericsson sites has been added.

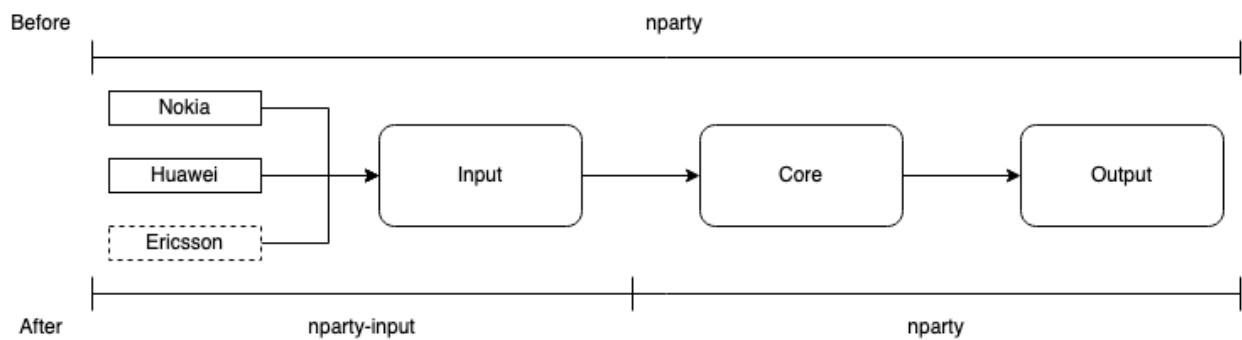


Figure 4.1: Comparison of the application Neighbors Party before and after the final project.

## 4.1.1 Input information

### 4.1.1.1 CM - Configuration Monitor

The data linked to the configuration is taken directly from the OSS of a builder. These data include various important information such as SC, cell ID, RNC ID, declared neighborhood relationships, etc. CM data is a reflection of what is actually implemented in the network. To obtain them, it is necessary to schedule a daily export of the necessary settings in OSS and direct this export to a server that can be accessed by the application.

### 4.1.1.2 PM - Performance Monitor

Performance data, on the other hand, are linked to the counters that monitor the quality of service of the cells. Some examples are the handover attempts and completion counters, which allow you to calculate the success rate of a flux between the source and target cell. Data is also obtained from scheduling an export in OSS.

### 4.1.1.3 Ref - Reference

Finally, the reference data is the data that was planned in the network design. In the reference data, it is possible to find, for example, the geographic coordinates of a site and the azimuth of each cell, important information for the neighborhood algorithm that runs in the core of the application. In addition, it is also possible to obtain SC which can be useful for a comparison audit of what was planned with what was implemented in the network, quickly locating errors in the implementation and can avoid an SC clash.

### 4.1.1.4 Database tables

The project database should not be modified for each operator, so it is important to standardize the input data so that they are registered in the correct format and there is no problem for the core of the application, NP2. The information is divided into the database following the structure shown in Figure 4.2. It is possible to see that 5 tables are used to store information about sites, cells, relationships and flux.

**Note** Each of the tables contains information that can come from CM, PM or Ref data.

- `lesvoisines_site`: This table is the basis for the others, it contains the name of the site and its builder. When deleting a site, all cells linked to this site must be deleted, the inverse is not valid since you can delete only 1 cell from the site without this action interfering with the others.
- `lesvoisines_cell`: Contains cell information such as general parameters (geographical coordinates, azimuth, number of declared relations, frequency band and technology) and cell technology-specific parameters (2G, 3G, 4G or 5G).
- `lesvoisines_extcell`: It has a very similar structure to `lesvoisines_cell`, however, it is simpler. It is also divided into general parameters and cell technology-specific parameters. It stores the cells of other operators, which are used by the operator in question through the RAN sharing process, explained in (12).
- `lesvoisines_relation`: Inside this table are the relations declared in all cells of the network. Declared items have some specific parameters but generally contain the source cell, destination cell and relation type.
- `lesvoisines_flux`: Keeps the flux data, which comes from PM, described previously. Therefore, in this table are the success rates for each handover flux between 2 cells specified by the parameters `cellID` and `RNC`.

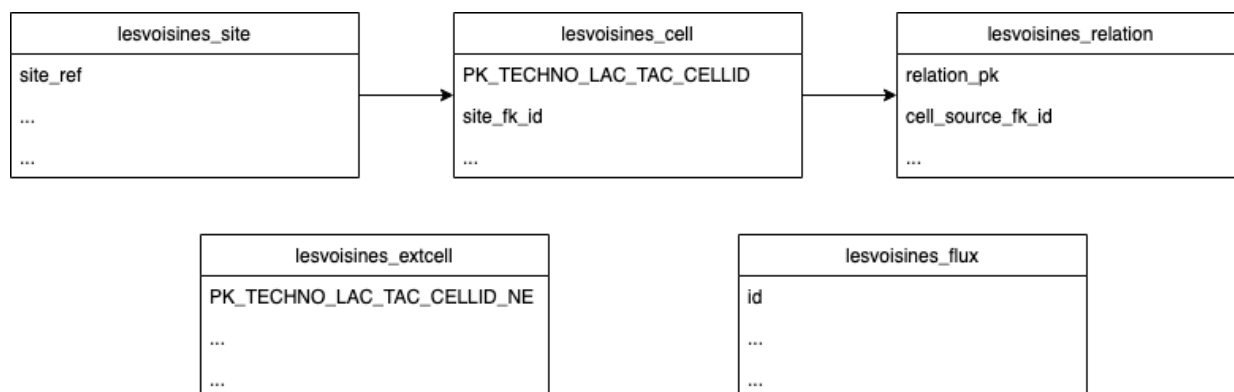


Figure 4.2: Database structure.

## 4.2 NPARTY-INPUT

The application has already been initially implemented in Python and using the Django framework. To maintain the standard and be able to facilitate future maintenance, the choice of Python for the implementation of the application proposed in the stage project, called `nparty-input` (NPIn) was continued. However, the use of Django was abandoned to make NPIn more modular and easier to run. The project structure is seen in Figure 4.3.

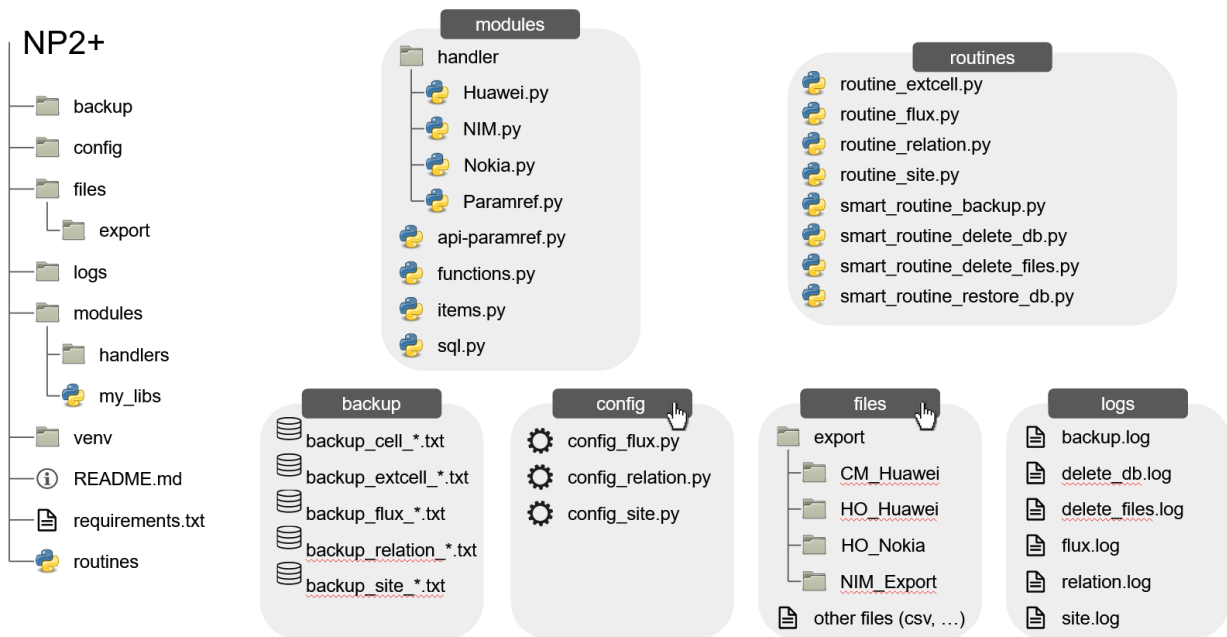


Figure 4.3: Project schema

## 4.2.1 Structure description

### 4.2.1.1 backup

Directory created for daily backup storage. Important for a possible restoration of data from an earlier date in the event of an application crash. There is a file for each of the database tables.

### 4.2.1.2 config

Contains configuration files. The objective is only to change the configuration files present in this directory when using the code in a different operator. Inside this, there are 3 configuration files, one for flux, one for relationship and one for site, which defines the important information that will be used in each of the routines, explained later. Some of the information are parameters such as the builders that must be imported, the MNC (Mobile Network Code) and MCC (Mobile Country Code) of the operator in question, the data for accessing the reference database and the location of the PM and CM files.

### 4.2.1.3 files

Inside this directory are the exports mentioned above, containing the PM and CM data.

### 4.2.1.4 logs

Used to store log files, important for maintenance and to understand any failure that occurred in the execution of daily routines. There is a log for each of the routines.

#### 4.2.1.5 modules

This directory contains the core of the input application. In it, there is a sub-directory, handlers, where the classes responsible for handling the data of each one of the constructors are. Within this sub-directory, it is also possible to see the files that contain the NIM and Paramref classes, which are used to obtain the reference data. Within Nokia, Huawei and Ericsson handlers, there are the same classes responsible for handling sites and cells, flux and relationships.

#### 4.2.1.6 routines

Routines are codes that will be executed daily to obtain the necessary information and update each of the database tables. There are also routines for deleting the database, deleting old files, making a backup and restoring the database based on a backup.

**Note** In addition to the mentioned directories, it is also possible to observe some extra files and directories. The *venv* directory has the necessary information to manage the virtual environment, which is important to isolate the application and avoid library conflicts with other applications. The *requirements.txt* contains the libraries and versions that must be installed for NPin to work. Finally, it's possible to see also the *README.md* file, where you can find instructions for installing and using the application, as well as a brief description and the developers contact.

### 4.3 RESULTS

With the project, it was possible to import information to the operator Salt. Compared to the current import system, the new one is more modularized and simpler for maintenance and error handling. The log system created also helps you to easily check if there were any errors in the import. In addition, the database backup and restoration routines were important on days where there were failures to obtain the necessary CM, PM or reference files.

Due to technical limitations it was not possible to test the program for other operators, as there was no virtual machine available. However, some tests of the Ericsson module were done and proved to be satisfactory. What is necessary for the use of the developed application, NPin, was passed on to the other developers of the team, who will be able to continue supporting any failures.

## 5 JOB INTERVIEW

The following interview was conducted with José Franceschi, a young engineer who works at the company. Despite his young age, José already has good experience in the area as he started working right after he graduated from the university. He went through several interesting situations, such as doing an exchange and living far from his home country, Venezuela. The collaborator was chosen for the interview because we have several points in common, such as the continent of origin, the economic and social situation of the country of origin. Below are the answers to some questions related to experience in Network Solutions Factory, the life far from the country of origin and the work of a radio optimization engineer, a position that José holds in the company.

### 5.0.0.1 Why the telecommunications area?

**José** - I studied telecommunications engineering and during my bachelor's degree I really liked the signal related classes so I tried to focus on this area. Luckily, I could find a job directly related to this topic.

### 5.0.0.2 Why France?

**José** - France is a great country for international students (In my opinion in TOP 3 of Europe). I was looking for opportunities abroad and after doing some research I decided to come to France. This beautiful country and its people gave me the opportunity to have an amazing studying experience abroad, learn a new language, make new friends and work in the area I like. I recommend it, come to France !

### 5.0.0.3 How was your formation?

**José** - My formation in France was great because it introduced me many topics (current and future) in the area of telecom, it also allowed me to discover new areas and share ideas with very smart people from around the world. The formation was top class, overall I recommend it. The university is called EURECOM in case you want to check it out.

### 5.0.0.4 What are your routine tasks as a radio optimization engineer?

**José** - There are a wide variety of tasks but in simple words, the main objective is to optimize the network with means to work hard to improve the mobile communications (2G/3G/4G/5G) user experience in certain areas and work on projects that will enhance this in the future.

### 5.0.0.5 What are the advantages of living outside the country of origin?

- Multicultural environment.

- Different culture exposure : this has many advantages particularly in architecture, art, way of thinking, food, etc.
- Europe is great because given its size you can visit many countries and discover new cultures just by traveling a couple of hours.

#### 5.0.0.6 What are the disadvantages of living outside the country of origin?

- Family and friends are far.
- Local food : certain foods and spices are quite hard to find.

#### 5.0.0.7 What areas do you think could grow in the future? Is the telecommunications among these areas?

**José** - I expect the following areas to grow: Health, data science, Virtual reality technology, etc. Telecom as well, particularly with 5G, the Telecom industry might evolve:

5G will bring out a lot of opportunities in the future not only in terms of speed but given all the user cases this tech has on paper, I strongly think new market opportunities will be created, new jobs and new ways to do things.

# 6 CONCLUSION, PERSPECTIVES AND CAREER PLAN

## 6.1 FUTURE WORKS AND PROJECTS FOR THE ENTERPRISE

Despite being new, NetSF has already been able to gain market share. The company has good professionals and growth potential, as in approximately 5 years it has multiplied the number of employees by 10. To help with growth, it is also worth leaving some possible suggestions for future work.

- Use of artificial intelligence techniques for optimization, as seen in competitors in the country itself (Swisscom) (13).
- Task automation.
- Creation of more applications that facilitate the routine of optimization and planning engineers.
- Extension and testing of the proposed input module for all operators.
- Improved NPin logging and administration system.
- Improved NPin execution time, using threading or modifying the code structure, for example.

**Note** Some of the suggestions are already in progress. However, it is worth noting that these are important projects for the company, which can help all operators at the same time.

## 6.2 EXPERIENCE AND PERSONAL GOALS

During the internship, in the radio optimization team for Salt, it was possible to obtain new knowledge in the field of telecommunications, as presented in the report. Due to the company's constant search for positive results, it was also possible to improve some soft skills, such as autonomy (always seeking to propose new solutions that can help), the willingness to learn (always being open to new lessons) and teamwork (trying as much as possible to help all teams in different projects). In addition, language skills were also explored and improved in a multicultural environment, with people from different countries, with documents and constant meetings in French and English, improving the ability to communicate in these languages.

Even with the very compromised health situation due to the Covid-19 pandemic, it was possible to follow the internship in person during almost the entire period between February and August. With the presence in the company and the work, it was possible to observe some differences between this internship and some previous experiences in Brazil. It was clear the European technological evolution compared to what exists in Brazil. This can be seen as a negative point but also as an opportunity to stay ahead of the market.



The learning acquired with the internship is immeasurable. In addition, the experience of having an exchange program was also very good and constructive. The opportunity to experience a new culture, different places and people was very enriching.

Despite the difficulties and challenges faced during this period, new career plans also emerged. Today, I have the opportunity to stay a few more months at the company before returning to Brazil to complete my graduation, an internship agreement was signed with the company and my home university (UnB) so that I could continue the work a little longer in France. When I return, in December, I must continue my studies and take some subjects to obtain my graduation in Brazil, in May of next year. So I'll be available for the job market and I'll try to return to France, either for a job, or to study M2 and get a diploma recognized in the country. On a more distant plane, I hope to be able to help the world market in the telecommunications area.

### **6.3 CONCLUSION**

The works that were proposed at the beginning of the internship could be carried out. Many tasks were done autonomously, which can further empower and increase the skills acquired in the internship period. It was possible to know the work environment and practice the language skills. With the completion of the final project, it was possible to put into practice several contents learned in the years of study in France and also in Brazil.

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