University of Minho
School of Engineering

António Sérgio da Costa Gomes

Fiber Networks Synoptics

january 2023

University of Minho
School of Engineering

António Sérgio da Costa Gomes

Fiber Networks Synoptics

Masters Dissertation
Master's in Informatics Engineering

Dissertation supervised by
António Costa
Helena Fernández

january 2023

Statement of Integrity

I hereby declare having conducted this academic work with integrity.

I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration.

I further declare that I have fully acknowledged the Code of Ethical Conduct of the University of Minho.

University of Minho, Braga, january 2023

António Sérgio da Costa Gomes

Contents

List of Figures

List of Tables

Acronyms

CAD Computer Aided Design. 6, 12, 13, 14, 17, 23, 24, 25

CO Optical Central, *(Central Ótica)*. 6

DSL Digital Subscriber Line. 2

DXF Drawing Exchange Format. v, 14, 15, 16, 24

FTTB Fiber To The Business. 14

FTTC Fiber To The Curb. 14

FTTH Fiber To The Home. 14

FTTN Fiber To The Neighborhood. 14

FTTO Fiber To The Office. 14

FTTP Fiber To The Premises. 14

FTTx Fiber To The x. 12, 14

GIS Geographic Information System. 12, 13

GNI Global Network Initiative. 12

GUI Graphical User Interface. 16, 24

HP Houses Passed. 10

ISP Internet Service Provider. 10, 18

JFO Optical Fusion Junction, *(Junta de Fusão Ótica)*. 7

JSO Optical Splitting Junction, *(Junta de Splitting Ótica)*. iv, 7, 8, 9, 10

JSON JavaScript Object Notation. 16

PDO Optical Distribution Point, *(Ponto de Distribuição Ótica)*. 7, 8, 9, 10

PON Passive Optical Network. 14

UML Unified Modelling Language. 24

Glossary

DWG 2D CAD format proprietary of Autodesk and generated by AutoCAD. 14

Java Java is an object oriented programming language.. 24

Proef Proef is a Portuguese company that aims at developing, implement and service turnkey integrated solutions in the areas of Telecom, Power, Cities and Corporate. In the telecommunications sector, Proef covers the entire operation from network planning to installation at the end customer's home.. 14, 20

Python Python is a generalized high level programming language.. 24, 25

synoptic Affording a general view of a whole. 13

Synoptics Map Logical or generalized representation of a network infrastructure devoid of geographical data for ease of consultation and improved readability. 2, 3, 15, 18, 19, 20, 21, 22, 25

Trace Map in the context of communications networks, a trace map is a graphical representation of network's physical layout and infrastructure along the path it is, was or will be built.. iv, v, 3, 5, 6, 7, 8, 10, 15, 17, 18, 20, 25

xlsx Microsoft Excel spreadsheet file format. 16, 23, 24

Part I

Introductory material

Chapter 1

Introduction

This chapter begins with a general description of the problem at hand and contextualising said problem within the business model to which it applies, followed by an overview of the document structure for the presentation of the suggested solution.

1.1 Context

In the past, the analogue telephone line was used to transport digital data[1] call a **Digital Subscriber Line** (**DSL**). With the explosion of technology and communications, costumer demands for faster and more resilient connection increases and so the **DSL** technology becomes obsolete and data begins being transported through coaxial television lines. This technology also was unable to cope with customer demands and so the fiber optical cable technology begins to replace it.

The creation and maintenance of network infrastructures is a highly complex task, requiring a strict project structure and wide array of auxiliary files. For this reason, such projects are divided in five sequential planning phases, each accomplishing a specific task spanning from planning the infrastructure to preparing the development phase.

Each project phase, and subsequently the project, is highly complex and time-consuming thus demanding time and resources as well as being subject to potential human error when performed manually by a company's employer. Delays and errors in a project's development can cause increased expenses during the implementation phase of the physical layer of a network infrastructure and, as a consequence, a loss in profit. Furthermore, the correction of a project's supporting documentation is imperative for the acquisition of adequate licensing permits legally mandated by the local governing bodies. Any delays or declines on obtaining such documentation can result in severe losses in time and revenue.

One such phase is the creation of network synoptics, given a physical network's layout as input. A network synoptics, or **Synoptics Map**, is an abstract representation of a network infrastructure, represented as a **Trace Map** or georeferenced map, that is used to simplify future consultation to the former and facilitate the optimization of allocated resources for each of said network's devices. Thus the creation of correct synoptics maps is crucial for proper resource allocation during the construction phase and later maintenance of a network. The conversion process from georeferenced map to **Synoptics Map** is highly complex and time consuming, often demanding the processing of large amounts of data and the creation of several project documents witch can be too large a task to be efficiently performed solely by employers.

The automation of project data acquisition and processing allows a significant reduction in the occurrence of errors as well as a significant reduction in time required for the project's completion, thus reducing costs and improving productivity within the company.

1.2 Objectives

The solution described in this document aims for the automation of the conversion process from trace maps into synoptics maps, whilst accommodating most of the client's needs in relation to software requirements as agreed between the client and the development team.

1.3 Document Structure

This dissertation is divided in the following chapters.

Introduction Defines the context and motivations of the dissertation and what it aims to achieve as it's final goal.

State of The Art Linguistic terminology inherent to the problem itself are explained, the structure and it's different components are defined and sources of information and technologies relevant to the problem are discussed.

The Problem and it's Challenges The main goals are defined and a solution is devised and proposed, aiming to fulfill the problem's main challenges.

Planned Schedule The development process for the dissertation and solution is defined.

Chapter 2

Current State of Fiber Network Projects Development

In this chapter, the problem is detailed and contextualized in the scope of network projects. Technical aspects relating trace maps and synoptics maps are defined, the background work and current solutions for the problem are presented along with their limitations and thus the current relevance for the relevance for a new solution is presented. Other technical aspects related with programming and data are analyzed and compared to support future technical decisions.

2.1 Problem's Nature and Motivation

Due to the highly complex nature of network infrastructures, in regards to dimension, fault tolerance and customer demands, their conceptualization process, from design to architecture to engineering, commands a rigorous project structure with aims to increase productivity, optimize the quality of service provided and minimize potential errors. In the context of Proef's [1] working environment, this structure is composed by four distinct projecting phases, each fulfilling different requirements and all being interconnected and dependant of other tasks. This notion of dependence can be observed in Figure 1.

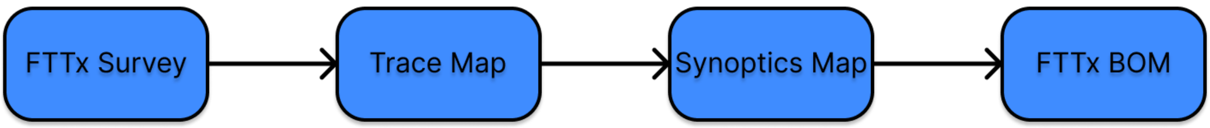


Figure 1: Project Chain for a Proef Telecom project.

Figure 1 shows the project structure as constituted by the following four distinct projecting phases:

1. **FTTx Survey**: Where data regarding customer needs, existing infrastructures and other relevant aspects of many target areas is gathered and stored in a processing-prone manner.

[1] https://proef.com/pt/sectores/telecom/

2. **Trace Map**: Given the information gathered through surveys, a map of the infrastructure is created including physical layout, existing infrastructures of relevance to the project, devices and equipment required and target end users.

3. **Synoptics Map**: A comprehensive representation of the infrastructure as a whole, thus being a logical diagram of the information depicted in the **Trace Map**.

4. **FTTx BOM**: Bill of Materials where all the required devices and equipment for the project's completion is determined.

Armed with information gathered by means of survey, the teams responsible for infrastructure design and project are then able to create a **Trace Map**, which displays the desired network layout and infrastructure over the geographic map of the area.

Trace maps are large and complex, making them impractical for consultation purposes, thus the need for an abstract representation of the same, known as a synoptics map, arises. This map constitutes a logical or abstract diagram of the networks represented on a **Trace Map**, devoid of all the added complexities derived from the geographical nature of a **Trace Map** and still containing all devices and connections of the network represented, all target end systems as well as potential customers and cable lines to be constructed on later stages.

Synoptics maps, in their condition of abstract diagrams of networks infrastructures, facilitate consultation both during construction an maintenance, allowing for easier comprehension of the existing connections and devices. This dissertation is targeted at the synoptics phase of the project structure, more particularly at the creation of synoptics maps from trace maps as shown in Figure 2.

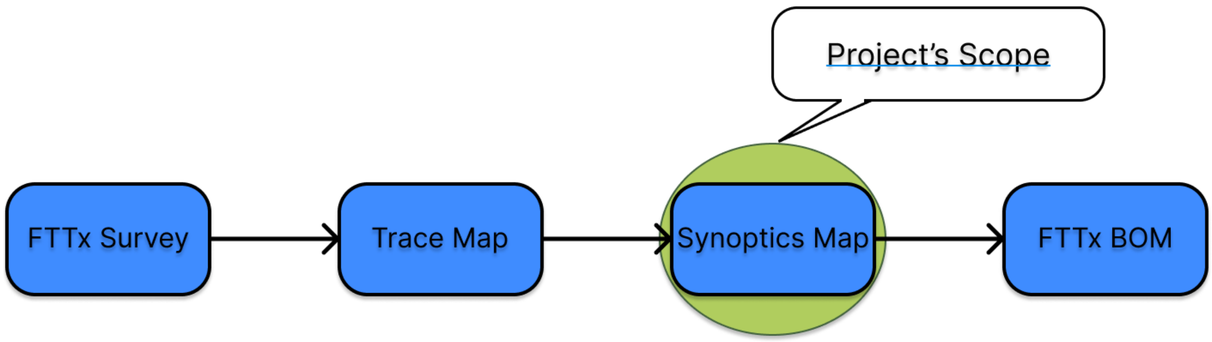


Figure 2: Scope of the proposed project.

A **Trace Map**, as shown in Figure 3 is a descriptive representations of a network's layout and infrastructure, drawn with the aid of a **Computer Aided Design** (**CAD**) tool. Figure 3 shows a **Trace Map**, in it's full scope, represented by a main line and multiple sub-networks, each with potentially distinct characteristics and necessities.

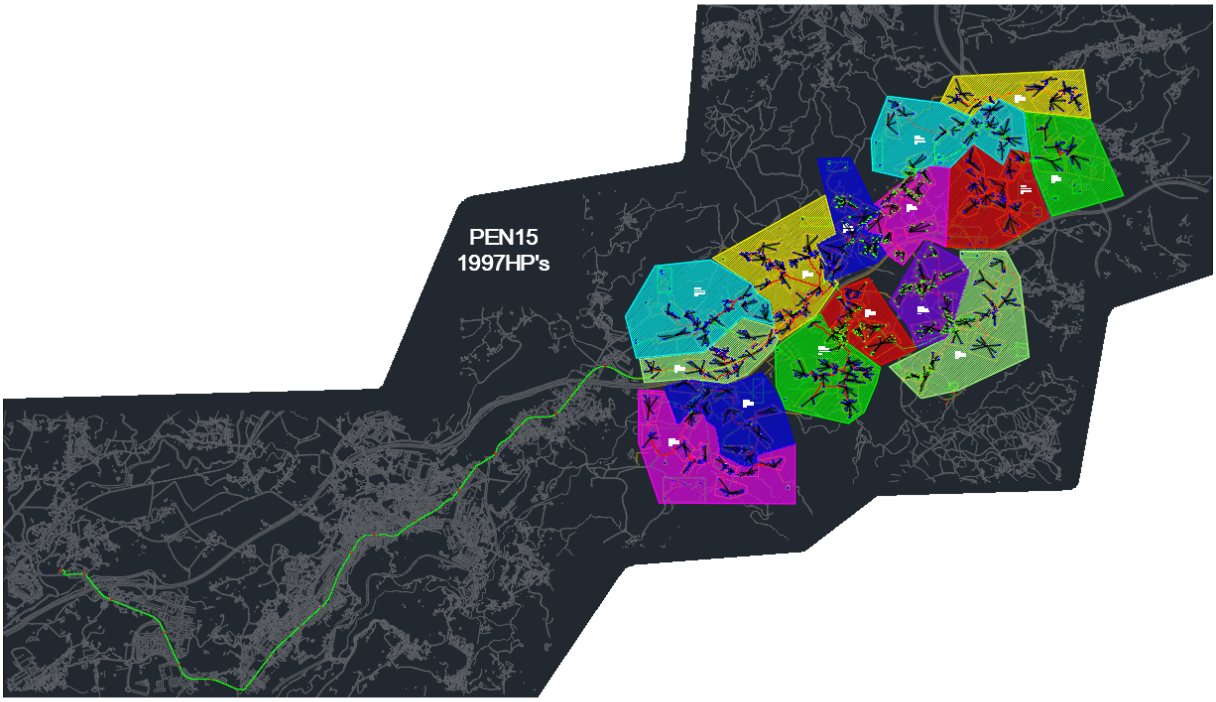
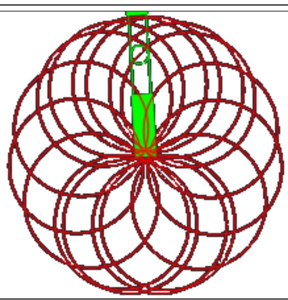
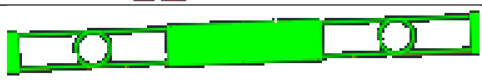


Figure 3: Full view of a **Trace Map**

Created by a conjunction of different block structures, each with different attributes and values, a **Trace Map** can be seen as a multitude of maps, from a primary map of the overall network layout and one sub-map for each sub-network attached to the main network. This consideration is imperative for the creation of synoptics maps. A trace map's constituting blocks are as seen below in Table 1.

Block Name	**Image**	**Description**
Optical Central *(Central Ótica,* **CO***)*		Central Hub from where multiple optical cables originate and data is distributed by them.
Vector Cables *(Cabos Vetores)* - ORAC		Optical cable for network signal distribution that passes through an underground conduit that may be purposefully built or a pre-existing structure.

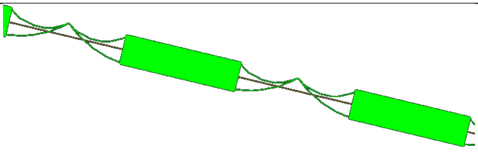
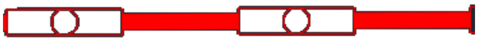
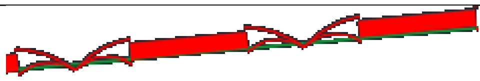
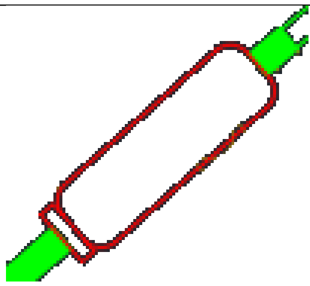
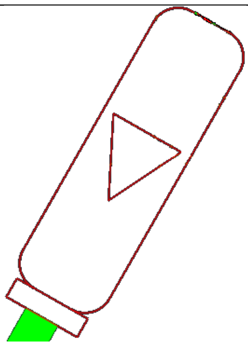
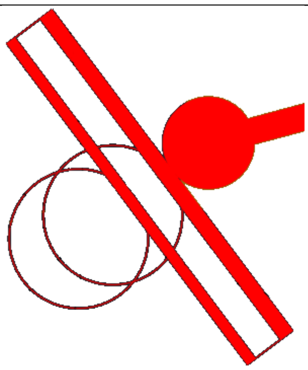
Primary Cables *(Cabos Primários)* - ORAP		Primary network optical cables for aerial distribution of network signal.
Secondary Cables *(Cabos Secundários)* - ORAC		Uderground optical distribution cables used to reach each individual sub-area.
Secondary Cables *(Cabos Secundários)* - ORAP		Aerial optical distribution cables used to reach each individual sub-area.
Optical Fusion Junction *(Junta de Fusão Ótica,* **JFO***)*		Device that allows the connection of two sequential optical cable ends to further extend a cable line after an optical cable coil has been fully used.
Optical Splitting Junction *(Junta de Splitting Ótica,* **JSO***)*		Device that allows the addition of new optical channels or fibers as well as the subdivision of a multi-fiber optical cable line in multiple distinct lines.
Optical Distribution Point *(Ponto de Distribuição ótica,* **PDO***)*		Optical PDO of distribution hub allows for multiple homes to have access to the secondary network and thus to the primary network as a consequence.

Table 1: Listing of block structures constituting a **Trace Map**.

A **Trace Map**'s internal structure appears subdivided in a primary network infrastructure followed by a multiplicity of secondary networks known as **JSO** zones, one for each sub-group of target costumers. A **JSO** zone must always begin and thus require a **JSO**1 type block as to redirect a portion of the primary cable's optical fibers for that area. Figure 4 displays such an area in the context of a **Trace Map**.

Figure 4: Trace map **JSO** zone.

JSO zones are numbered after the **JSO**1 type block's unique identifier located at the beginning of said area. Each area is composed by one or more secondary cable blocks, a multitude of PDO blocks, and a blue stamp block for each HP attached to each **PDO**1. Furthermore, reserve fibers can be represented here to be used in a later date in the necessity of new costumers being added to that **JSO** zone.

For every **JSO** zone in a **Trace Map**, a synoptics map is created. The main goal of a synopics map is to display all of the **PDO** in a **JSO** zone with all derivations, attributes and data regarding each **PDO**. Figure 5 shows the synoptics map of the same **JSO** zone described in figure 4.

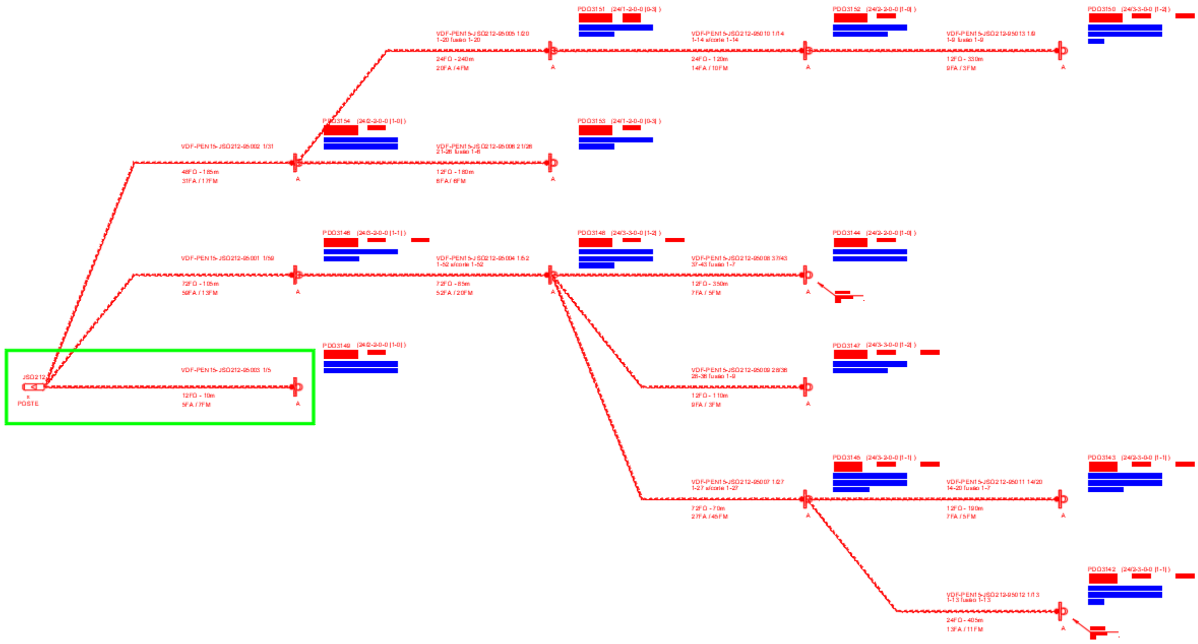


Figure 5: Synoptics Map of the same **JSO** zone.

As seen en figure 5, a synoptic diagram of a secondary network is rooted by a **JSO** type block, to which **PDO** type blocks are linked by an optical cable of a specific type. Each cable in the diagram must include an unique identifier referencing the **JSO** to which this belongs and a referencing number, technical data about it's physical structure such as number of optical fibers is such cable, total cable length or category of installation, being aerial cable, underground cable or others.

For referencing reasons, each **PDO** possesses a unique identifier and must include, as attributes, references to each input and output cables as well as technical details about the nature of the **PDO** equipment as defined by the following code referencing a letter to the respective equipment's manufacturer:

- **A** - R&M Venus
- **B** - arestel RG-FO 24
- **C** - arestel RG-FO 48
- **D** - arestel RG-FO 72
- **E** - arestel RG-FO 96
- **F** - Coyote LCC

Each synoptics map must also be accompanied by a link table and a configuration table, at least one for each synoptics map and, as a consequence, one for each **JSO** zone, as defined in the respective

Trace Map. A configuration table's purpose is to define the inner structure of a **JSO** by defining how many splitters are needed and how many fibers in each splitter must use in order to optimize the service provided to that splitter's target **PDO** and according to each **HP** those **PDO** feed. A link table, in the other hand, lists all cables arriving and departing the splitter and labels them according to a color scheme that associates a color to a cable's technical specification and defines the next node in that cable's sequence. This table must also include fibers that where not extended further and thus being saved as reserve fibers for future network expansion. A portion of such table can be seen in Figure 6 in which reserve fibers appear highlighted and in the first positions and the fibers currently in use, defined as fibers with an output and destination, appear next.

INPUT						Nº Cassete	OUTPUT						
Etiqueta de Cabo	fibra source	Nº Tubo	cor tubo	fibra	cor fibra		Etiqueta de Cabo	fibra source	Nº tubo	cor tubo	fibra	cor fibra	Nó Destino
VDF-PEN15-95011 41/43 93/96 119/119	41-41	1	Branco	1-1	Branco	B-7	RESERVA						JSO212
VDF-PEN15-95011 41/43 93/96 119/119	42-42	1	Branco	2-2	Vermelho	B-7	RESERVA						JSO212
VDF-PEN15-95011 41/43 93/96 119/119	43-43	1	Branco	3-3	Verde	B-7	RESERVA						JSO212
VDF-PEN15-95011 41/43 93/96 119/119	119-119	1	Branco	4-4	Azul	B-7	RESERVA OP2						JSO212
VDF-PEN15-95011 41/43 93/96 119/119	93-93	1	Branco	5-5	Preto	A-1	S32_N1_1_I						JSO212
VDF-PEN15-95011 41/43 93/96 119/119	94-94	1	Branco	6-6	Amarelo	A-4	S32_N2_2_I						JSO212
VDF-PEN15-95011 41/43 93/96 119/119	95-95	1	Branco	7-7	Laranja	A-7	S8_3_I						JSO212
VDF-PEN15-95011 41/43 93/96 119/119	96-96	1	Branco	8-8	Cinzento	A-7	S8_4_I						JSO212
VDF-PEN15-95011 41/43 93/96 119/119		1-4		9-48		Fibras Mortas							JSO212
S32_N1_1_O_1-1				1-1		A-2	VDF-PEN15-JSO212-95001 1/59	1-1	1	Branco	1-1	Branco	PDO3146
S32_N1_1_O_2-2				2-2		A-2	VDF-PEN15-JSO212-95001 1/59	5-5	1	Branco	5-5	Preto	PDO3146
S32_N1_1_O_3-3				3-3		A-2	VDF-PEN15-JSO212-95001 1/59	7-7	1	Branco	7-7	Laranja	PDO3146
S32_N1_1_O_4-4				4-4		A-2	VDF-PEN15-JSO212-95001 1/59	8-8	1	Branco	8-8	Cinzento	PDO3146
S32_N1_1_O_5-5				5-5		A-2	VDF-PEN15-JSO212-95001 1/59	14-14	2	Vermelho	14-14	Vermelho	PDO3146
S32_N1_1_O_6-6				6-6		A-2	VDF-PEN15-JSO212-95001 1/59	15-15	2	Vermelho	15-15	Verde	PDO3146
S32_N1_1_O_7-7				7-7		A-2	VDF-PEN15-JSO212-95001 1/59	21-21	2	Vermelho	21-21	Castanho	PDO3146
S32_N1_1_O_8-8				8-8		A-2	VDF-PEN15-JSO212-95001 1/59	22-22	2	Vermelho	22-22	Violeta	PDO3146
S32_N1_1_O_9-9				9-9		A-2	VDF-PEN15-JSO212-95001 1/59	23-23	2	Vermelho	23-23	Rosa	PDO3146
S32_N1_1_O_10-10				10-10		A-2	VDF-PEN15-JSO212-95001 1/59	28-28	3	Verde	28-28	Azul	PDO3146
S32_N1_1_O_11-11				11-11		A-2	VDF-PEN15-JSO212-95001 1/59	29-29	3	Verde	29-29	Preto	PDO3146
S32_N1_1_O_12-12				12-12		A-2	VDF-PEN15-JSO212-95001 1/59	30-30	3	Verde	30-30	Amarelo	PDO3146
S32_N1_1_O_13-13				13-13		A-2	VDF-PEN15-JSO212-95001 1/59	37-37	4	Azul	37-37	Branco	PDO3146
S32_N1_1_O_14-14				14-14		A-2	VDF-PEN15-JSO212-95001 1/59	39-39	4	Azul	39-39	Verde	PDO3146
S32_N1_1_O_15-15				15-15		A-2	VDF-PEN15-JSO212-95001 1/59	40-40	4	Azul	40-40	Azul	PDO3146
S32_N1_1_O_16-16				16-16		A-2	VDF-PEN15-JSO212-95001 1/59	44-44	4	Azul	44-44	Cinzento	PDO3146
S32_N1_1_O_17-17				17-17		A-2	VDF-PEN15-JSO212-95001 1/59	45-45	4	Azul	45-45	Castanho	PDO3146
S32_N1_1_O_18-18				18-18		A-2	VDF-PEN15-JSO212-95001 1/59	46-46	4	Azul	46-46	Violeta	PDO3146

Figure 6: Portion of the link table for **JSO**212.

The structure of a link table, as seen in Figure 6, consists in a mapping of each fiber from input cables, defined by a unique identifier and described by their technical specifications, to the respective fibers in output cables, defined in similar way, with each different fiber defining rows and the technical specifications as columns, namely cable identifier, source, tube number, tuber coloring, fiber number, fiber color and destination.

2.2 Current Solutions and Their Limitations

Relating to network project solutions, a few commercial platforms exist and could be used to help and alleviate the overall workload related to networks structures projecting and maintenance. A total of five such solutions will be presented and analysed as to ascertain what necessities they cannot completely fulfill and other inherent issues regarding a lack of scalability when applied to large **Internet Service Provider** enterprises and issues regarding lack of adaptability to specific work models. Table 2 describes the main aspects of the aforementioned five applications and their applicability in the networks projects infrastructures.

Application	Enterprise	Description	Platforms
FiberCloud	**Weezie**	According to alternativeto.net [2] FiberCloud disposes of network layout tools and flexible network engineering design tools as well as network block edition, ata management and validation capabilities allowing for easy integration of client rules, adaptability to any project or infrastructure, reducing drawing time and increasing workflow.	Web app.
Kzavi GNI	**Softelnet**	According to [3]KSAVI GNI FTTH, Ksavi GNI is a fully featured fiber design tool for telecom operators, incentivized by the **GNI**, armed with geospatial network inventory based on **CAD** and **GIS** that allows for automation of inventory elements, generation of project documentation and network planning, design and management. It also contains a network operations manager for inventory and investment managment.	Web app.
COMSOF Fiber	**COMSOF**	According to comsof official website [4], COMSOFT Fiber is a **FTTx** network design software that strives to facilitate the design and planning phases of network structures through smart algorithms, preprogrammed rules and detailed budget tools.	Web app

[2] https://alternativeto.net/software/fibercloud/about/alternativeto.net

[3] https://ksavinetworkinventory.com/

[4] https://www.comsof.com/fiber

IQGeo	**IQGeo**	According to IQGeo Network Manager [5], IQGeo is a geospatial solution optimized for telecom network operators providing an open fiber network management software as well as accelarating the planning, design and maintenance.	Web and desktop app.
VETRO FiberMap	**VETRO**	According to VETRO FiberMap website [6], VETRO FiberMap is a web based application aimed at every stage of a network's lifecycle through customer queries and analytic tools for planning, ease of **GIS** workflows trough map viewer, attribute table, element detailing and integration libraries, workflow automation and deployment tools, as well as analytic tools for easy network management.	Web app.

Table 2: Software solutions for network desing, planning and management.

While the capabilities of the above-mentioned applications regarding designing, planning and managing networks are extensive, they still require the manual creation of network schemes and such other data structures thus still being liable to issues such as human error, impaired workflow in some stages of the projecting phase, and limitations in the supporting documentation created for each network. The geographical map of a network is highly complex and complete, thus being significantly unsuited for consultation and so the need for **synoptic** views of the network arises.

Considering the analysis of the technical characteristics of the solutions described as presented by the manufacturers on their web pages, the analysed solutions do not appear to be capable of automating the task of creating network diagrams and other consultation structures. Solutions currently used for network design derive from the adaptation or encapsulation of **CAD** based tools and other managing structures such as data tables, analytic tools, online surveys and management algorithms in an environment optimized for network design and planning, being subject to the previously mentioned limitations.

5 https://www.iqgeo.com/product/telecom-network-planning-design-workflow-management-software

6 https://vetrofibermap.com/products/fibermap/

2.3 Information Technologies

The aforementioned problem is, in it's nature, a **FTTH** problem, which is a sub-category of **FTTx**, the following being defined as a group of optical fiber network architectures, *x* being a generalized character representing each element, elements who vary on the distance to which the fiber endpoint comes to the costumer [2]. **FTTx** can be any of the following elements:

- **Fiber To The Business (FTTB),** "deployment of optical fibers from a central office switch to an directly to an enterprise" [2].
- **Fiber To The Curb (FTTC),** "deployment of fiber cables from a central office equipment to about 300m of a home or enterprise" [2].
- **Fiber To The Home (FTTH),** "deployment of optical fiber from a central office switch directly into a home" [2].
- **Fiber To The Neighborhood (FTTN),** "**Passive Optical Network** (**PON**) architecture in which optical fiber cables run to within about 1000m of homes and businesses being served by the network" [2].
- **Fiber To The Office (FTTO),** "an optical path is provided all the way to the premises of a business customer" [2].
- **Fiber To The Premises (FTTP),** "deployment of fiber optical cable to the doorstep of a home or business".

Such network architectures are complex and require extensive modelling before implementation, thus the need for modelling tools. For this, in the context of **Proef**'s work environment, **CAD** based tools are used and so network models are represented in 2D **CAD** files. From the multiple **CAD** file formats available two are of wider use, namely **DXF** and **DWG**, the first being an open source file format for the exchanging of data and the latter being a proprietary file format created and supported exclusively by Autodesk [7]. For this reason the **DXF** file format was chosen for the solution to be devised ahead.

Accordig to [3] there are six sections in a **DXF** file, they are heather, classes, blocks, tables, objects and entities. Among them, only entities section contains geometric information regarding any object drawn in the design file. Geometric information regarding each entity is stored after different **DXF** numbers or codes in the entities section.

[7] https://www.autodesk.com/

The processing of **Trace Map** files and the subsequent creation of **Synoptics Map** files require **DXF** processing capabilities and so require the use of **DXF** processing libraries.

Library	Language	Familiarity, %	Functionalities	Documentation	Support
JDXF [8]	Java [9]	50	Limited drawing operations	javadoc [10]	Consistent
libdxfrw [11]	C++ [12]	45	Unknown	Unknown	Limited
cadlib [13]	C++	50	Limited Processing	Online [14]	Consistent
ezdxf [15]	Python [16]	80	Cannot process comments	Online [17]	Consistent
sdxf [18]	Python	75	Cannot Read **DXF** files	Unknown	Limited

Table 3: **DXF** parsing libraries.

After careful analysis of the information contained in Table 3, python's **ezdxf** was chosen for being well documented, capable of all required tasks and properly supported for current and future versions of the **DXF** file format. Python also possesses well documented **xlsx** and **JSON** processing libraries which also will be imperative in the implementation phase. In relation to support for desktop application development and **GUI**, python does not include simple yet powerful capabilities thus the Java desktop application framework Swing was chosen for this task for being easy to use and possessing strong documentation and support.

8 https://jsevy.com/wordpress/index.php/java-and-android/jdxf-java-dxf-library/
9 https://www.java.com/en/
10 https://jsevy.com/java/jdxf/doc/index.htmljavadoc
11 https://sourceforge.net/p/libdxfrw/home/Home/libdxfrw
12 https://cplusplus.com/
13 https://www.codeproject.com/Articles/3398/CadLib-for-creating-DXF-Drawing-Interchange-Format
14 https://www.codeproject.com/Articles/3398/CadLib-for-creating-DXF-Drawing-Interchange-Format
15 https://pypi.org/project/ezdxf/
16 https://www.python.org/
17 https://ezdxf.readthedocs.io/en/stable/
18 https://pypi.org/project/SDXF/

Chapter 3

The problem and its challenges

This chapter describes the detailed aspects of the problem as shown in Section 2.1, "Problem's Nature and Motivation", by defining all relevant aspects that a solution must aim to solve and presents a structure for a software based solution, taking in consideration the data gathered in section "Information Technologies" as a knowledge base and support for technical decisions.

3.1 Purpose

In planning, construction and maintenance of network infrastructure, is imperative that numerous project files be created. Amidst such files, a **Trace Map** of the infrastructure's future layout in the desired terrain is created as well as multiple configuration tables. The **Trace Map** is created using **Computer Aided Design** (**CAD**) tools and it must be then converted to a logical representation of the same network infrastructure in a **CAD** diagram known as a Networks Synoptic map. This map is required for the acquisition of appropriate licensing and also for for future consultation of the network's devices, resources and existing connections for update or maintenance. The above interactions create the problem's domain model as seen in Figure 7 in which the problem's entities are defined and relationships between them are established.

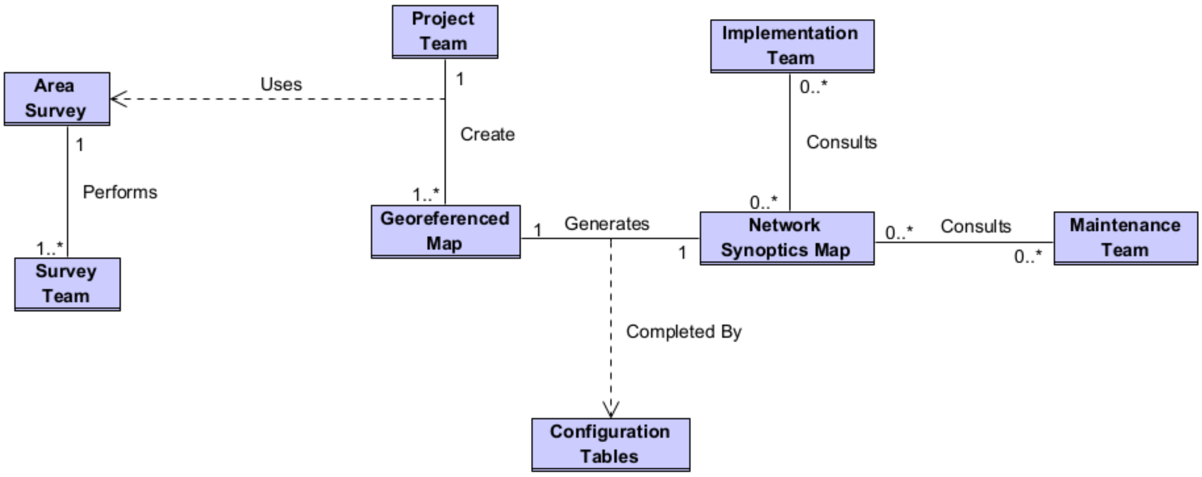


Figure 7: Domain Model for Fiber Networks Synoptics.

This conversion, from **Trace Map** to network **Synoptics Map**, is currently performed manually thus being being slow, time consuming and subject to human error.

3.2 Target Audience

An application for the automation of creation and update of Fiber Networks Synoptics maps is targeted and intended for numerous companies who are responsible for the projecting and/or construction of networks infrastructures as well as their update and maintenance. Target users are project designers with knowledge on networks for one or more **Internet Service Provider** (**ISP**).

3.3 Product Perspective and Functions

The manual creation of synotpics maps is a highly time consuming task and prone to human error thus the automation of Networks Synoptics maps creation allows to significantly reduce overall project time and drastically reduce human error while retaining the adaptability to changes in projects heuristics and adaptability to new customers as is the case with new **ISP**.

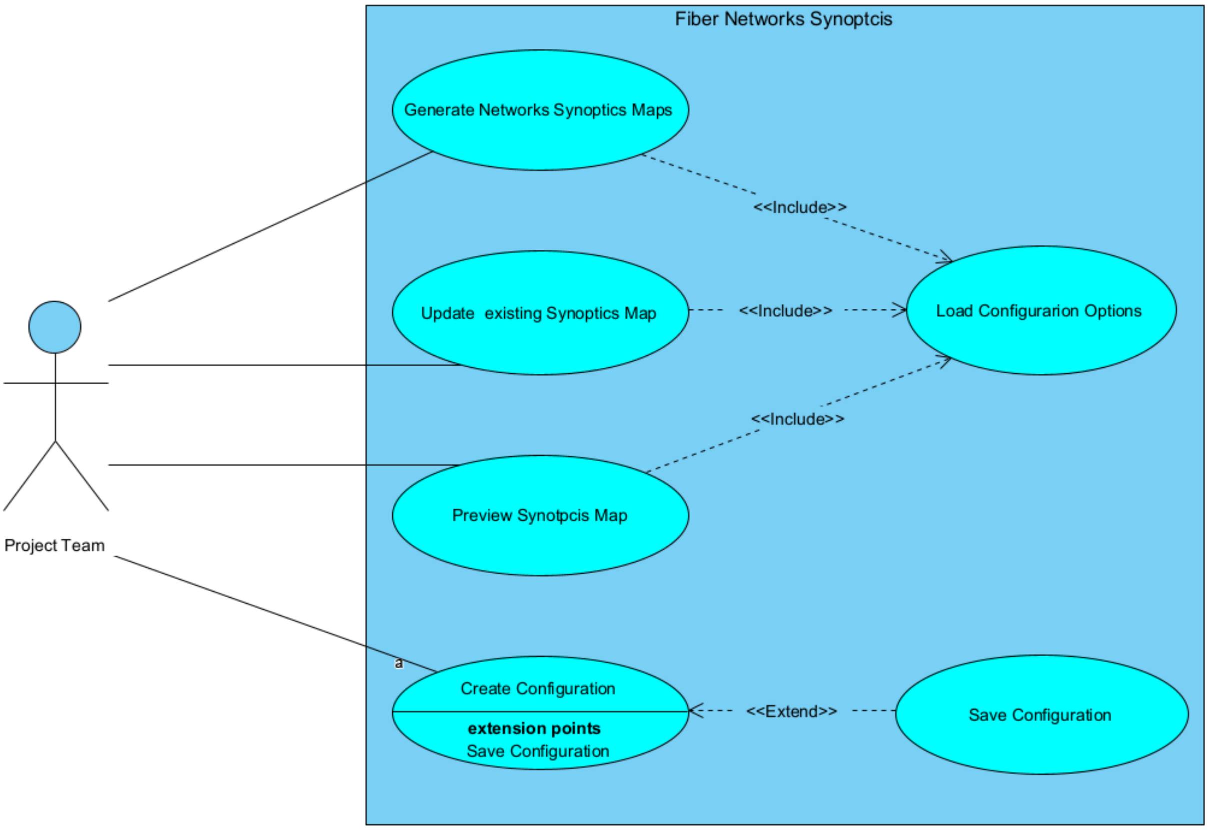


Figure 8: Use Case Diagram for Fiber Networks Synoptics.

As seen in Figure 8, a multitude of tasks can be performed,for different actions, with some tasks depending on, or using the result of other tasks. The use cases go as follows:

1. A new networks **Synoptics Map** of a specific georeferenced map can be generated, given a conversion settings configuration.

2. An Existing **Synoptics Map** can be updated, given a number of configuration tables pertaining to devices and connections represented on the **Synoptics Map**, given a conversion settings configuration.

3. The resulting **Synoptics Map** of a georeferenced map can be previewed for validation of the georeferenced map, given a conversion settings configuration.

4. Conversion settings configurations can be created and saved so the conversion process is dynamic and can adapt to possible changes in networks infrastructures creation procedures, changes in laws and regulations as well as being able to adapt to different *ISP*.

5. Configurations can be saved for further use, and loaded before a conversion is performed.

After careful analysis, the costumer requirements for a software based solution can be drawn and corroborated by both parties, namely the development team and the costumer enterprise, **Proef**. Such requirements were obtained through meetings and discussion with the interested party, direct observation of the current reality of the aforementioned problem faced by technicians in real cases, careful analysis of **Trace Map** CAD files and respective **Synoptics Map**. Considering the division of gathered requirements into two groups of requirements, namely functional requirements and non-functional requirements, Table 4 and Table 5 show the functional and non-functional requirements gathered in that specific order. Functional requirements pertain to functional or directly operational aspects of the intended solution, this are represented by an identifier, a validation method describing the method by which said requirement can be observed as being successfully satisfied by the solution and a validation entity describing who is responsible for that assessment. Such information appears condensed in the following table 4.

Num.	**Name**	**Description**	**Valid. Method**	**Valid. Entity**	**Pri.***
FR.01	Trace Map Loading	Must be possible to load a geo-referenced map in the form of a *.DWG* or *.DXF CAD* file.	Manual testing.	Proef	5
FR.02	Primary Synoptics Map Generation	Must be able to generate synoptics maps related to a loaded georeferenced map.	Direct comparison between synoptics maps obtained from the system and manually created ones for the same georeferenced maps.	Proef	5
FR.03	Secondary Synoptics Maps Generation	For each *JSO* type block on a georeferenced map, the application must be able to generate one secondary synoptics map.	Direct comparison between secondary synoptics maps generated by the application and manually created ones based on the same georeferenced map.	Proef	5
FR.04	Synoptics Map Update	System must be able to update a **Synoptics Map** with information from Microsoft Excel *.XLSX* files given by the user.	Direct comparison between synoptics maps updated by the system and manually updated ones.	Proef	3

FR.05	Synoptics Map Generation Preview	System must be able to create a preview of a **Synoptics Map** generation for a given georeferenced map.	Direct comparison between a preview and a map previously generated.	Dev. Team	2
FR.06	Conversion Rules Cofigurability	It must be possible to change the conversion rules for every conversion.	Comparing synoptics maps obtained from differently natured georeferenced maps and comparing the results to manually created ones.	Proef	3
FR.07	Changing Block Names	Must be possible to process different block names for similar structures for georeferenced maps.	Analysing the resulting conversions of different georeferenced maps.	Proef	4
FR.08	ISP Adaptability	System must be able to handle georeferenced maps and synoptics form different ISP.	Analysing the resulting conversions of different georeferenced maps.	Proef	5
FR.09	Configuration Table Generation	Create a configuration table for each *Splitting Junction* type block of a georeferenced map.	Exhaustive testing for each possible georeferenced map type.	Dev. Team	3
FR.10	Automated Link and Splitter allocation	Each configuration table, in *.XLSX* format, must be filled according to optimization rules and performance targets, given the base information of that specific *Splitting Junction* block.	Exhaustive testing for each possible georeferenced map type.	Dev. Team	2

FR.11	Link Table Generation	Upon the creation of all synoptics maps, for a given georeferenced map, a link table must be created containing information regarding the optical cables that arrive and depart each *Optical Splitting Junction*.	Exhaustive testing for each possible georeferenced map type.	Dev. Team	3

Table 4: Detailing of App Functional Requirements.

This application is going to be used by a wide array of people with differing skills and expertise, thus the need for a easy and friendly user interface arises. It is assumed that every user of this application has prior knowledge regarding trace maps and synoptics maps, as well as knowledge regarding network infrastructures projects. The description and targets for usability requirements appear represented in the following table 5.

Number	**Name**	**Description**	**Valid. Method**	**Valid. Entity**
NR.01	Synotpics Generation Usability	An unexperienced user must be able to generate a new **Synoptics Map** from any type of georeferenced map in under 3 minutes without the need for external guidance, other than the user's manual.	Acceptance testing	Proef
NR.02	Configuration File Editing Usability	A user with prior knowledge in networks infrastructures projects must be able to create a correct configuration file for a given *ISP* in under 10 minutes.	Acceptance Testing	Proef

NR.03	Synoptics Generation Performance	The functional requirement **2**, **3**, **9**, **10** and **11** must be all performed in under approximately 3 seconds after the generation begins.	System Testing	Dev. Team
NR.04	Configuration File Size	The size of configuration files must be less than 4 MB.	System Testing	Dev. Team

Table 5: Detailing of App Non-functional Requirements.

3.4 Proposed Solution

An appropriate solution must satisfy the technician's necessities to the highest degree possible, one such necessity is often an intuitive yet complete user interface capable of performing all required tasks whilst allowing for anyone with prior knowledge of network design to be able to use most if not all of the application's capacities when devoid of special training. Figure 9 shows an example of such graphical user interface, previously discussed and agreed upon by both parties, namely the costumer enterprise and the development team. The left hand menu is targeted at the common and initial tasks of creating synoptics maps and respective tables. In here we can observe:

- **Trace Map:** File browser to load the trace map to be processed.
- **Destination:** File browser to select the directory to which the end result will be saved to.
- **Config File:** File browser to load the configuration file to be used in the processing and generating of **CAD** files.
- **Preview** button to display an initial render of the synoptics maps.
- **Generate** button to generate the synoptics **CAD** files and **xlsx** table files.

The right hand menu, as seen in Figure 9, is a configuration table allowing for consultation, editing and creation of configurations files to be used in the conversion process. Each block's structure can be defined beforehand by use of a simple nomenclature style in which the block name, unique identifier and attributes can be written in.

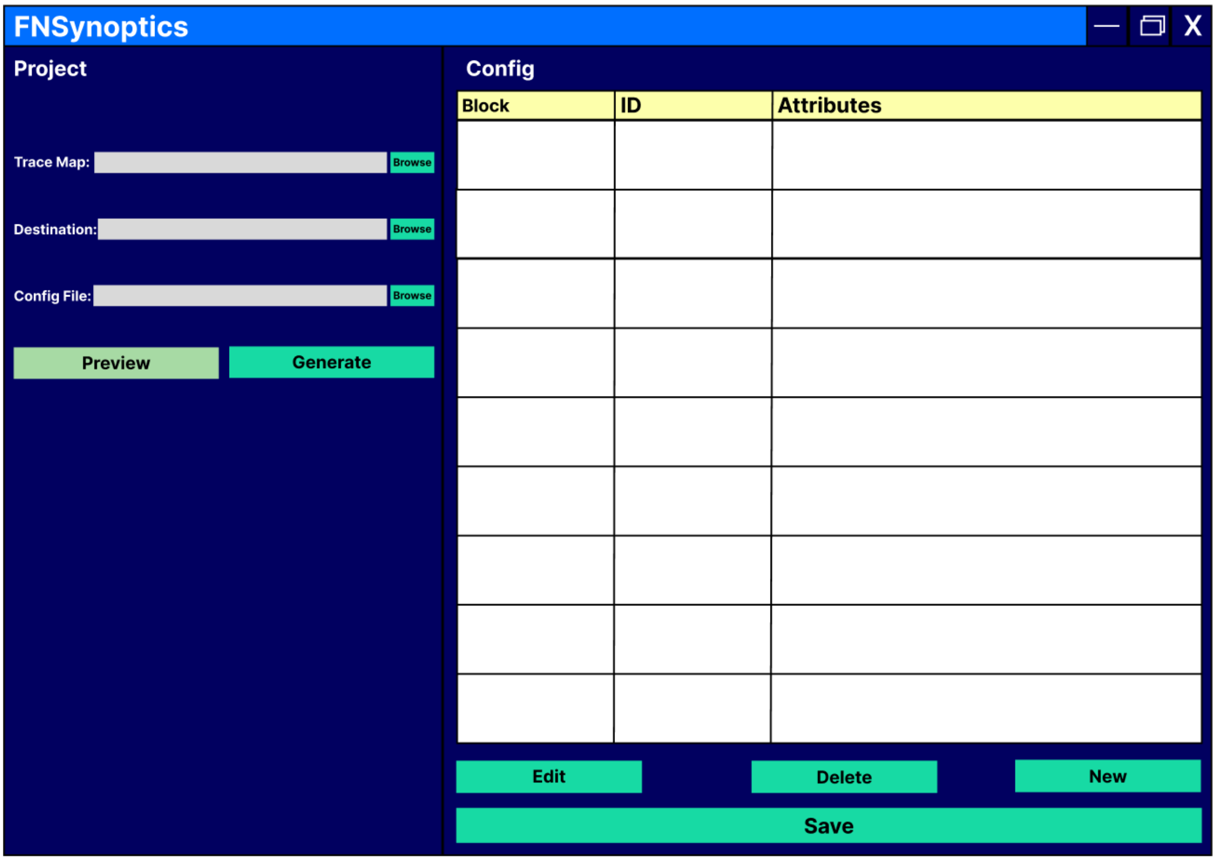


Figure 9: Mockup of GUI main menu

A software's architecture can be represented by use of many forms of diagrams and structures, for this effect a class diagram based in **UML** was chosen. In here the software's packages and most important classes can be represented, along with the main attributes and methods for each class and relationships between classes. In the case of this application and for reasons motioned in section 2.3, two distinct languages where chosen for the conception and thus two distinct software pieces must be developed, an application **GUI** package, written in **Java** and a processing and conversion package written in **Python**. The first is composed by the following **Java** classes as shown in figure 10:

- **GUI** class responsible for all the methods relating to the user interface.
- Config class responsible for creation and usage of configuration files.
- **CAD** Class responsible for loading and processing of **DXF** files, being trace maps or synoptics maps.
- Table Class responsible for the loading and processing of **xlsx** files., being link tables or configuration tables.

- Main class that brings the code structure together.

Most importantly, the processing logic package is responsible for most of the work and thus being more structured and complex. This package is defined by the following **Python** classes, as defined in figure 10.

- TraceMap class being an objectified representation of a **CAD Trace Map**, completed with methods for manipulation and processing of such data.
- Block class, used by TraceMap as a building block of trace maps, represents a generalized block with it's unique identifier, attributes and relations with other blocks.
- SynopticsMap class being an objectified representation of a **CAD Synoptics Map**, in similarity with trace maps.
- Table class, as an extention of ConfigTable and LinkTable classes, which defines a table's strucuter and manipulation methods.
- Main class that brings the code structure together.

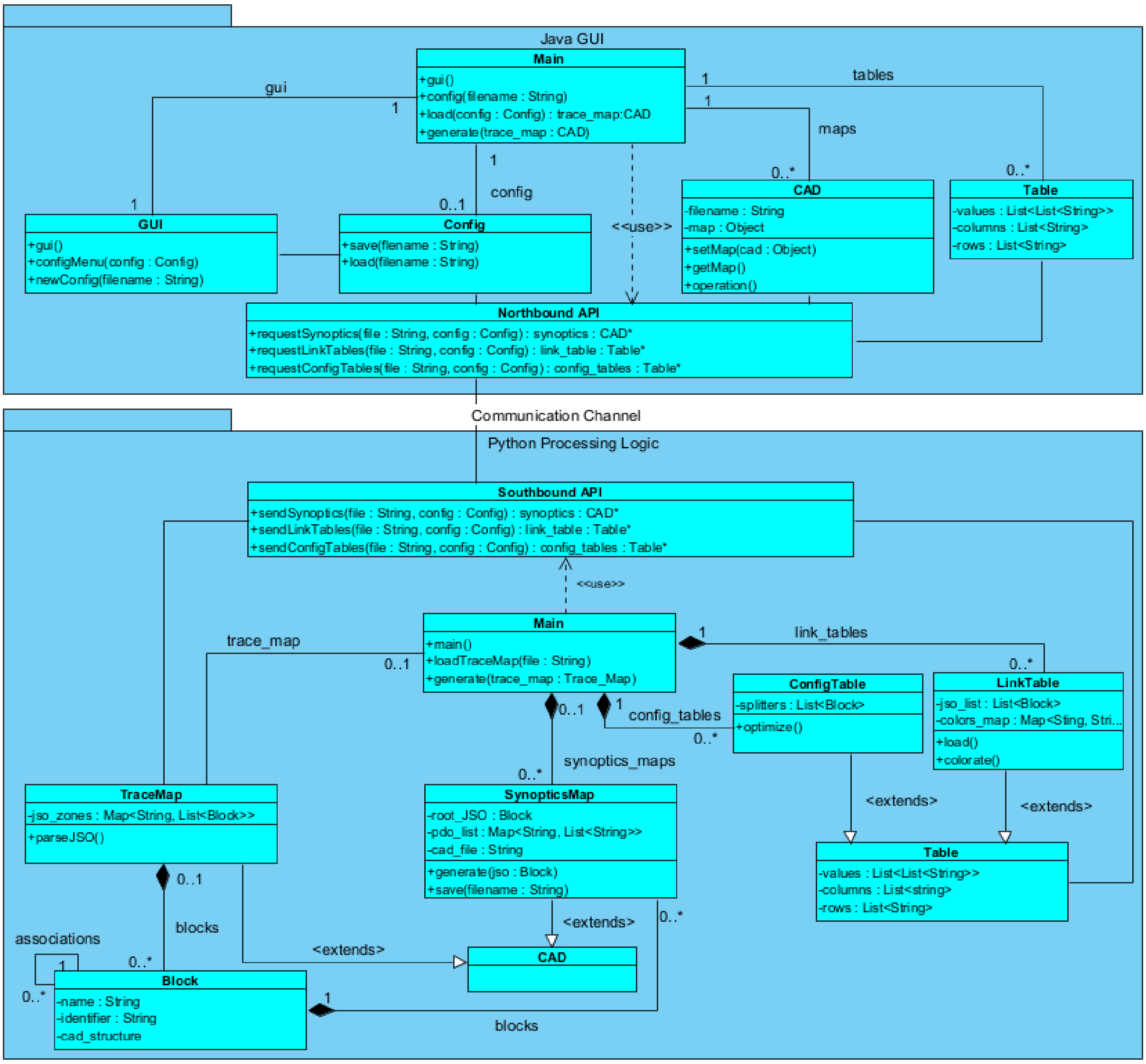


Figure 10: Class and package definition for GUI and Logic modules.

Chapter 4

Planned Schedule

4.1 Activities

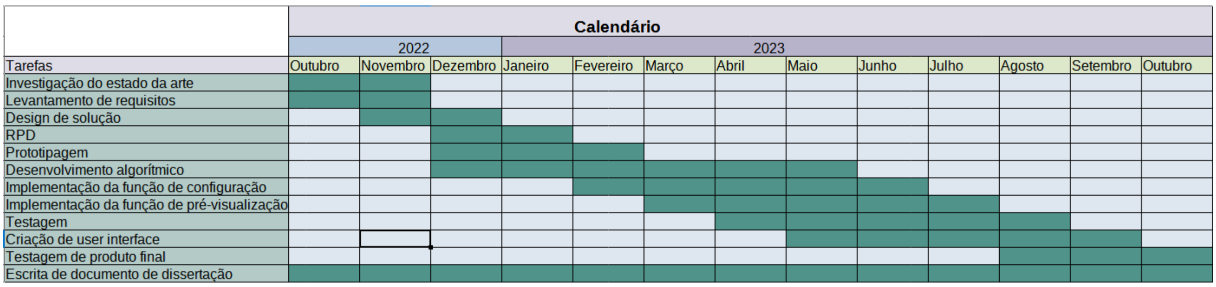


Figure 11: Planned Schedule by month.

Tabela de Tarefas			
Tarefa	**Descrição**	**Resultado**	**Prazo**
Investigação do estado da arte	Compreensão dos diversos aspetos relevantes ao problema assim como investigação de ferramentas para a resolução do mesmo.	Capítulo 2 do documento de dissertação.	11/2022
Levantamento de requisitos	Diálogos com diversos elementos da empresa para recolha de informação relevante aos diversos aspetos a que a solução deve responder.	Documento de requisitos da aplicação.	11/2022
Design de solução	Criação de Modelos representativos da solução a ser implementada e maquetes do interface da mesma.	Modelos de arquitetura da solução e mockups do interface gráfico, a serem apresentados à entidade requisitante da aplicação.	12/2022
PRD	Escrita e apresentação do documento RPD.	Documento de RPD abordando vários aspectos como descrição do problema, estado da arte, importância do trabalho a desenvolver, entre outros.	01/2023
Prototipagem	Desenvolvimento de algoritmos de teste dos conceitos relevantes à solução para corroboração da solução, familiarização de ferramentas e para efeitos de consulta futura.	Packages de algoritmos de implementação de funções à implementação das diversas tarefas como processamento de ficheiros .DXF/DWG, conversão de blocos de traçado em blocos de sinóticos, entre outras.	02/2023
Desenvolvimento algoritmico	Desenvolvimento dos diversos aspectos da aplicação relevantes ao processamento de mapas georeferenciados e posterior geração de mapas de sinóticos e folhas de cálculo de suporte necessárias à análise de sinóticos.	Versão inicial da aplicação munida de algoritmos que permitem satizfazer os requisitos funcionais de maior prioridade, nomeadamente a criação de sinóticos de rede e respetivas folhas de cálculo de suporte.	05/2023
Requisito de configuração	Implementação de função de configuração capaz de modificar os algoritmos de conversão de mapas consoante regras definidas pelo utilizador da aplicação, atravéz de ficheiros de configuração editáveis na aplicação.	Versão evoluida da solução capaz de suportar a possíbilidade do utilizador modificar o processo de geração de sinóticos e tabelas para que este possa ser aplicado a várias operadoras.	06/2023
Requisito de pre-visualização	Implementação da função de pré-visualização.	Evolução da solução aonde nesta é possível a pré-visualização de resultados de uma conversão.	07/2023
Testagem	Testagem dos algoritmos de conversão e outros aspectos funcionais da solução.	Versão melhorada do algoritmo, capaz de satizfazer os requisitos funcionais para os casos de maior prioridade e importância.	08/2023
Criação de user interface	Desenvolvimento do interface de utilizador segundo os modelos e maquetes previamente apresentados.	Versão da aplicação capaz de satizfazer os requisitos funcionais e não funcionais de maior prioridade, previamente definidos com a entidade requisitante da aplicação.	09/2023
Testagem de produto final	Testagem do interface de utilizador e outros requisitos funcionais e não funcionais de maior prioridade.	Versão final da aplicação, incluindo documentação e manual de utilização.	10/2023

Figure 12: Description of each task in planned schedule.

Tabela de Milestones		
Milestone	**Descrição**	**Prazo**
Aprovação do documento de requisitos.	Aprovação do documento de requisitos por parte da entidade requisitante.	11/2022
Aprovação do RPD	Apresentação e aprovação do documento RPD.	01/2023
Processamento de CAD	Algoritmos de conversão de .DWG para .DXF, conversão de traçados em sinóticos primários e secundários e tabelas auxiliares.	03/2023
Requisitos funcionais principais.	Algoritmos de geração de sinóticos e tabelas completos e funcionalidade de configuração do processo de conversão completo.	05/2023
Outros requisitos funcionais.	Funcionalidades adicionais, como a pré-visualização de resultados de conversão, implementadas.	07/2023
Documento de Dissertação.	Finalização do documento de dissertação.	09/2023
Produto final	Produto final, com os requisitos principais implementados e testados e com interface de utilizador, devidamente testado.	10/2023

Figure 13: List of main milestones in the project's development.

Bibliography

[1] James Farmer et al. *FTTx Networks: Technology Implementation and Operation*. Morgan Kaufmann, 2016 (cit. on p. 2).

[2] Gerd Keiser. *FTTX concepts and applications*. John Wiley & Sons, 2006 (cit. on p. 14).

[3] Nafis Ahmad and AFM Anwarul Haque. “Manufacturing feature recognition of parts using DXF files”. In: *4th international conference on mechanical engineering*. Vol. 6. 2001, pp. 111–115 (cit. on p. 14).