POLITECNICO DI TORINO

Master degree thesis

ENGINEERING DESIGN OF A FIBER-TO-THE-HOME NETWORK IN THE CONTEXT OF PUBLIC INITIATIVE

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Summary

This thesis has been developed under the guidance of Philippe Garcia in the project office design of AXIANS Company in Nimes, France. Due to the increasing demand of network capacity in our society, the optical fiber deployment takes a preponderant role by allowing fast connectivity and quicker access to information.

Reading documents, scientific articles, reports and courses about FTTH networks have been the first stages before starting the project. This project is composed in multiple stages.

At first, the preparations of the study allow for an optical fiber network design to figure the total budget concerning the necessary expenditures and investment. It builds a business plan, takes decision concerning the interest of some areas compared to others, locates the main elements of the network such as the Central office (NRO) or the outdoor fiber optic cross connect cabinet (SRO). Furthermore, during this step, technicians or subcontractors go on the ground to effectuate (the letter box) survey.

Then, the preliminary design can start. It aims to give the most precise estimation of the network to be designed. Indeed, specific data are integrated, the engineering rules to be respected guide us in our system design, the generation of the fiber deployment is performed keeping in mind the necessity to optimize as far as possible the cost by restricting the used cable length.

To continue, the final design is the last stage before the building work for the project. This is where the technicians go on the ground to establish if the design done in the preliminaries is feasible (maybe an unavailable technical point or broken pipes) and return the information to the design office to see if the network can be changed and improved by rethinking other possible pathways.

Finally, the reflectometry study is performed to measure the length of the optical fiber links, to detect the events like a splice at the junction between two fibers, or the presence of a connector as well, to determinate the attenuation and visualize the variation and incidents along the fiber. This study allows also to evaluate the quality of the splices between optical fibers by estimating the loss values at each junction.

Acknowledgements

I would like to express at first my gratitude to Virgile Arene, the business executive of AXIANS, who welcomed me and gave me the opportunity to perform this thesis in the Vinci Energies group and to all the people who helped me during this thesis whether in the design office or on the ground.

My very warm thanks go to Mr. Philippe Garcia, my internship supervisor, who supervised me all along this thesis and has greatly contributed in growing as an engineer. Thanks for the enriching discussions and his knowledges in the design of the FTTH network shared with me. I also would like to express my gratitude to Nicolas Sireletti with whom I shared the office and who provided me assistance when I needed it. The great ambiance in which we worked will be an unforgettable memory.

Similarly, I thank the technicians on the ground for having explained me the functioning and the adjustment of an Optical Time Domain Reflectometer (OTDR), a big thanks to Olivier Vidal for giving me time to discuss about the reflectometry measurement realized in the design office, and also a thanks to the different project managers with whom I could talk about the way to carry out a project from start to finish.

Finally, a big thanks is for my parents and my sisters who always believed in me, without them I would never have been able to reach this important aim.

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Presentation of the company

a) VINICI ENERGIES

VINCI Energies is one of the four business segments, world's leading company in construction and concessions.
Created in 1899 by Alexandre Giros and Louis Loucheur, VINCI Energies is the leader in France and a major player in Europe in the field of energy and information and communication technology. In its lines of business (infrastructure, industry, tertiary sectors, telecommunications), VINCI Energies group develops local and global solutions, implementing by 1600 factories operating as a network in 52 countries, from all 5 continents, including 25 countries outside Europe.

In a world undergoing constant change, VINCI Energies focuses on connections, performance, energy efficiency and data to fast-track the rollout of new technologies and support two major changes: the digital transformation and the energy transition.

Keeping pace with market change, VINCI Energies supports its customers by offering increasingly innovative solutions and services, from design to implementation, operation and maintenance.

With their strong regional roots and agile organizational structure, VINCI Energies' 150 business units boost the reliability, safety and efficiency of energy, transport and communication infrastructure, factories and buildings.

VINCI Energies is grouped in five world brands: ACTEMIUM, AXIANS, CITEOS, OMEXOM, VINCI FACILITIES.

b) AXIANS: a brand of VINCI ENERGIES

Figure 1: Key figures of the AXIANS company

AXIANS is the VINCI Energies brand dedicated to Information and Communication Technology (ICT). With extensive Europe presence, AXIANS is a network of 210 companies in 15 countries (Figure 1).

Each AXIANS company is independent of others. There are 46 AXIANS companies in France taking care of their clients.

AXIANS offers a comprehensive range of ICT solutions to help its customers to achieve their goals, improve their performance, and services spanning from business applications and data analytics, enterprise networks and digital workspaces, datacenters and cloud services, telecommunications infrastructure and cybersecurity.

Living in a mode that is "always-on", and communicating within a society that never sleeps, Information and Communication solutions are vital for many human and business activities.

To make the world smarter (smart city, smart grid, smart building, smart factory), AXIANS embraces the business of its clients, as a means to contribute to the overall value creation. This is achieved by providing top-notch, scalable and sustainable solutions, with a human face and touch.

AXIANS Company will deploy over the coming years the fiber to the home (FTTH) in 9 French departments.

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c) Health/Safety, Sustainable development and Ethics section

1) Health and Safety at work: the programme of VINCI Energies

The health and safety policy aims to anticipate and prevent work-related risks, including psychosocial risks. It also involves ensuring the hygienic condition quality, safety, health and quality of life at work. Awareness, training and support campaigns are the various prevention measures. On the topic of occupational health, campaigns and studies concerns in particular addictions, the ergonomics of the working stations and musculoskeletal disorders. Many actions are carried out in the renewal of machinery and equipment and in the organization of work.

Risks of falling, risks associated with electricity or with handling, dangerous situations on the roads... Every day, the vigilance of each employee is necessary to avoid accidents at work and occupational diseases. VINCI Energies is committed to ensuring that everyone can carry out their daily tasks safely.

On the ground, the primary objective of “zero accident” translates into many actions:

- Personalized support for the new recruits, temporary workers or subcontractors
- Awareness promotion about respecting the wearing of personal protective equipment
- Risk assessment, dedicated trainings courses within the Vinci Energies Academy
- Communication actions to inform, initiate dialogue and promote the exchange of good practice, preventive actions by Zoé, a fictious character which allows to personify these safety messages.
- The “Vigiroute plan”: road traffic is a major risk requiring the development of a specific prevention policy. The Vigiroute plan has been implemented at European level to change our driving behavior.
- The VINCI Innovation Prize: Each year, VINCI recognizes the best ideas of its employees. Among the different categories, a Safety Award rewards inventions or development of devices to improve safety on worksites.
- An annual meeting dedicated to safety at work: To raise awareness and to address occupational safety and health issues, VINCI Energies is organizing the “Safety Week” (Figure 2). During the same week, all VINCI Energies employees meet to exchange in a small group on a common theme.

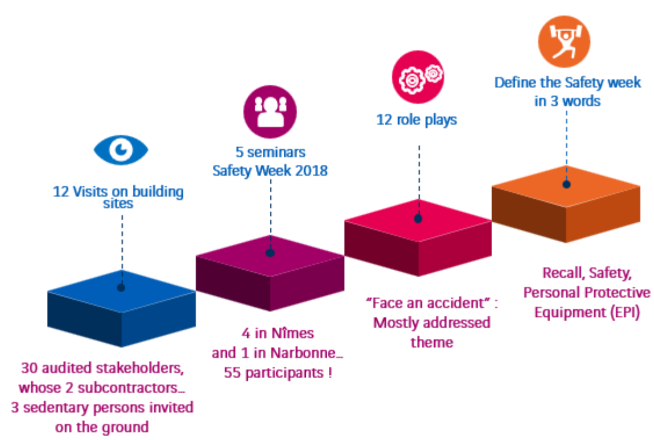


Figure 2: Safety week

2) Sustainable development

Since the achievements are in the public interest, Vinci group is pursuing a demanding and pragmatic sustainable development policy. This policy complies with two complementary principles. The first is to reduce the environmental impact of the projects and to optimize, over time, the socio-economic impact of activities on people and territories. The second is to imagine, in conjunction with all parties that have a stake in our activities, the most effective public utility solutions in a scarce economy. Its different companies develop offers that contribute to reducing the material quantities used during works and the energy consumption of works to preserve biodiversity.

Since 2007, VINCI has taken a proactive approach to reducing and controlling greenhouse gas emissions and is working to anticipate, monitor and comply with legislation in the most advanced countries on this subject. VINCI has seven facilities subjects to the "Plan National d'Allocation des Quotas" (PNAQ) and meets the Carbon Reduction Commitment (CRC) in the United Kingdom. These new regulations create opportunities for VINCI, whose companies now offer 'climate' solutions allowing to their customers to reduce their own greenhouse gas emissions.

VINCI is positioning itself as a central player to create or strengthen structures in the face of major climate events, ensure their sustainability and innovate to carry out these projects.

VINCI group introduced the « re-engineering » of its offers and its process in order to include solutions that provide environmental added value. It is a VINCI priority to develop the eco-design by integrating the life cycle analysis by empowering the different players in the value chain, from the conception to the project realization. It elaborates eco-comparison tools which allow to optimize the energy performance of buildings and to limit the structure environmental footprint.

Below are highlighted some figures showing the VINCI Group's commitment about the sustainable development:

- 30%: It corresponds to the reduction of greenhouse gas emissions over the 2009/2020 period.
- Since 2007, the whole of the greenhouse gas emissions is quantified according to the ISO 14064 standard.
- 48M€: The amount invested in 2014 in the R&D field.
- +200%: It refers to the augmentation of the amount of electricity purchasing from renewable sources between 2009 and 2014.
- Over the period 2009/2014, the greenhouse gas emissions have been reduced by 14.4%.

Furthermore, for the waste management, sensors are set up inside containers to indicate the fill rate, or some others can indicate the beginning of a fire. Monitoring solutions ensure the operation of the entire system.

3) Ethics and behaviours

Vinci group has been built around strong values, shaping the culture and guide the implemented actions:

- Guaranteeing equal opportunities for all

It is one of the VINCI's principles that it will not discriminate on any grounds in working relations. In the field of human resources management, and more broadly, relations between employees are based on confidence and mutual respect principles. The Group's companies pursue a proactive policy of managing equal opportunities, particularly in the areas of gender diversity, employment of the disabled, immigrants and seniors. They regularly audit their practices in this area in order to guide their improvement efforts. VINCI's senior managers are responsible for implementing this policy. They ensure that the principles are disseminated throughout the management chain.

- Treating people with respect

The VINCI group applies a fair and legal human resources policy. It prohibits any discrimination based on an illicit ground such as sex, age, morals, belonging to a race, ethnicity or nationality, handicaps, religious, political or trade union opinions or commitments. Any pressure, persecution of a moral or sexual nature or contrary to the law is prohibited.

Everyone respects the privacy laws of employees, including those governing computer files.

- Fight against corruption

The negotiation and execution of contracts must not give rise to behaviours or facts that can be described as passive or active corruption, or complicity in influence peddling or favouritism. No VINCI employee shall directly or indirectly grant benefits of any kind, by any means, in order to obtain or to maintain a commercial transaction or preferential treatment. In accordance with the « OCDE » convention on the fight against corruption of 17 December 1997, the corruption of public officials in all its forms is prohibited. Each employee will avoid dealing with third parties who may place him personally in a position of obligation and raise doubts about his integrity.

- Sanctions

It is recalled that these rules, which have been examined and approved by the VINCI executive committee are mandatory, and that no one within the Group can escape them, regardless of his hierarchical level.

Any possible violation of these rules by an employee would constitute a fault and could be penalized by his employer.

Such sanctions could include dismissal for fault and claims for damages.

Chapter 1

1 Introduction

1.1 What are optical fibers?

Optical fibers for communication system are generally made of very pure silica glass and composed by two main concentric sections: the core and the cladding.

The core: Thin glass center of the fiber where the light propagates and whose diameter is approximately 8-10 µm to get high performance fibers.

The cladding: Outer optical material surrounding the core that reflects the light back into the core and whose the diameter is 125 µm. Its refractive index is slightly lower than that of the core.

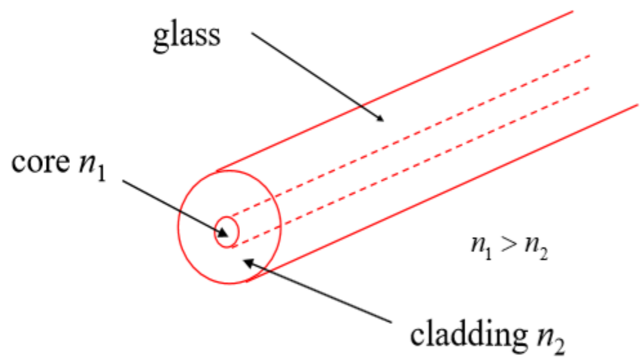


Figure 3 : Refractive index of an optical fiber

The refractive index n for a given material is a parameter which defines how a certain material interacts with a given electromagnetic field propagating within it. The light travels along the fiber with successive reflection between the core and the cladding. This is possible only if the core and the cladding are constituted of transparent material and the cladding refractive index is lower than the core refractive index (Figure 3). Furthermore, the light is sent with a certain angle, with respect to the axis, which has to be lower than the numerical aperture NA. The numerical aperture NA is expressed in function of the refractive index of the core and the cladding. (NA = $\sqrt{(n1^2 - n2^2)}$).

Buffer coating: Plastic coating that protects the fiber from damage and moisture.

Optical fibers are used to transmit light signals over long distances. Hundreds or thousands of these optical fibers are arranged in bundles in optical cables. The bundles are protected by the cable's outer covering, called a jacket (Figure 4).

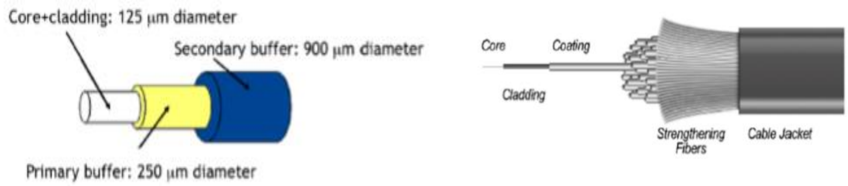


Figure 4 : Structure of an optical fiber cable

Optical fibers can be classified in two types with respect to the number of propagated modes.

- **Single-mode fibers (SMF):** They propagate only one mode, their core diameter is about 10 µm and transmit infrared laser light (wavelength from 1300 to 1550 nm).
- **Multi-mode fibers (MMF):** Larger diameter core (about 62.5 µm) and transmit infrared light (wavelength from 850 to 1300 nm).

1.2 What does Fiber-to-The-Home mean?

Fiber to the home (FTTH) is a fiber optic communication delivery form where the fiber extends from a central office to the boundary of a home living space or business office, replacing existing copper infrastructure such as telephone wires and coaxial cable. It is a new and fast-growing method of providing vastly higher bandwidth to consumers, and thereby allowing more robust video, internet and voice services.

The fact to connect homes directly to fiber optic cable allows wide improvements in the bandwidth that can be provided to consumers. Further, as cable modem and DSL providers are struggling to squeeze increments of higher bandwidth out of their technologies, ongoing improvements in fiber optic equipment are constantly increasing available bandwidth without having to change the fiber. That's why fiber networks are said to be "future proof".

Furthermore, the network architecture refers to the design of a communication network and provides a framework for the specification of the network from physical components to services.

The FTTH network allows a very high bitrate exceeding the limits of the ADSL. Indeed, it has also several advantages with respect to the copper:

- A reduced attenuation since light signals meet limited resistance, thus data can be transmitted further.
- Lighter, so easier to manipulate.
- Larger bandwidth.

The two most widely used topologies are the point-to-point (P2P) technology (Figure 5), with one optical fiber to supply just one subscriber and the passive optical network (PON) technology (Figure 6), with one optical fiber to supply multiple subscribers.

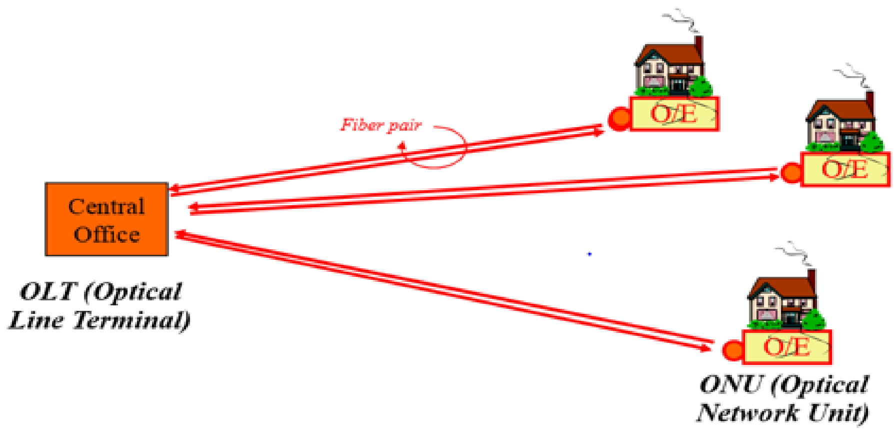


Figure 5: Point-to-Point (P2P) architecture [7]

For the P2P architecture, we have dedicated fiber pairs from the central office to the residential user.

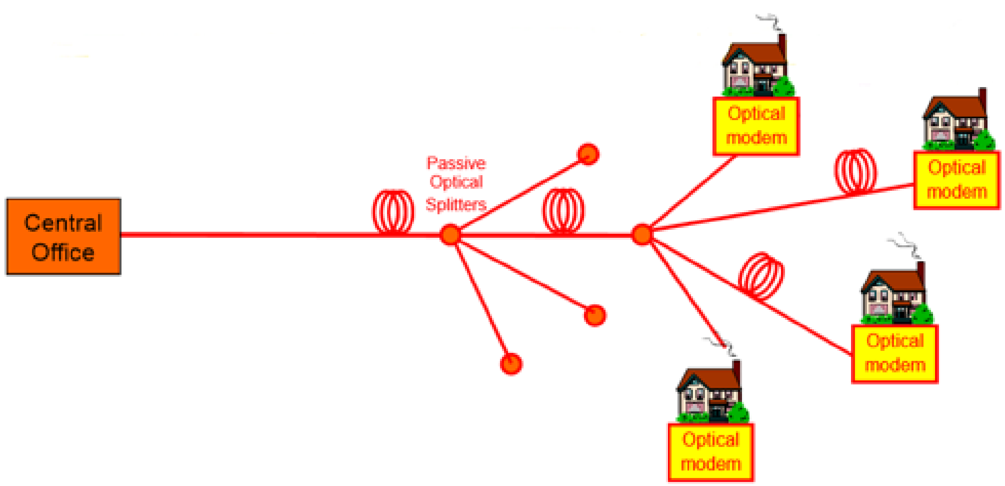


Figure 6: Passive Optical Network (PON) architecture [7]

The PON is an optical broadband access technology. It is a point to multipoint optical network that use passive optical components such as splitter, coupler and splicer. This is a passive optical network because there are no active components between the optical line termination (OLT) and the and the optical network units at the customer premises. The bandwidth is high, thus it allows to reach longer distances. Then, we have low cost equipment per subscriber. The optical splitter is used to reach N users

1.3 Where and how will the FTTH network be deployed?

A network is planned for an area with a high or a low population density, but design rules for these networks will differ greatly. Indeed, the question of area density is preponderant.

In a dense area, the provider will choose to gather more subscribers on a single aggregation point in order to get a relatively good filling of all aggregation points. However, in rural areas, distance between buildings and aggregation points may become a more important constraint in the design.

Furthermore, rural areas will have more options for placing cabinets, while urban areas spaces are quite limited, and thus more constraints are applied for cabinet placement.

The unit costs for deploying cables can differ significantly between urban and rural areas: in rural areas, one meter of trenching will be less expensive than similar trenching in urban areas. Additionally, more aerial deployments are used in rural areas. This will impact on the relationship between labor and material costs of both types of deployment, thus requiring a different set of design rules to be used for achieving minimal costs.

Equipment vendors have developed special deployment methods and cable types for urban versus rural deployments.

In rural area, the Passive Optical Network (PON) is preferable in terms of cost while in urban area with a higher population density, the Point-to-Point (P2P) architecture is preferable.

Optical cables allow, in each architecture, to connect the hardware locations such as the Central office containing the Optical Line Termination (OLT) up to the Optical Network Unit (ONU). The cable from the Central Office out to the first splitter location is considered as **feeder cable**. A feeder cable is able to serve several local convergence points (LCPs), as outdoor fiber optic cross connect cabinet, by dropping sufficient fibers at each LCP. To continue, the cable from the LCP to the terminal (Fiber Optic Distribution Box) that serves a home or living unit in a building is known as **distribution cable**. Then, the cables from the Fiber Optic Distribution Box, usually using single-fiber cables and make connections to individual homes or living units are called **drop cables**.

During this study, we will be focused mainly in the distribution part (D1 to D2), namely from outdoor fiber optic cross connect cabinet to the fiber optic distribution boxes using single-fiber cables which make connections to individual homes.

The Figure 7 shows the architecture of the FTTH network, and thus the deployment of the different cables from the Central office up to the different subscribers.

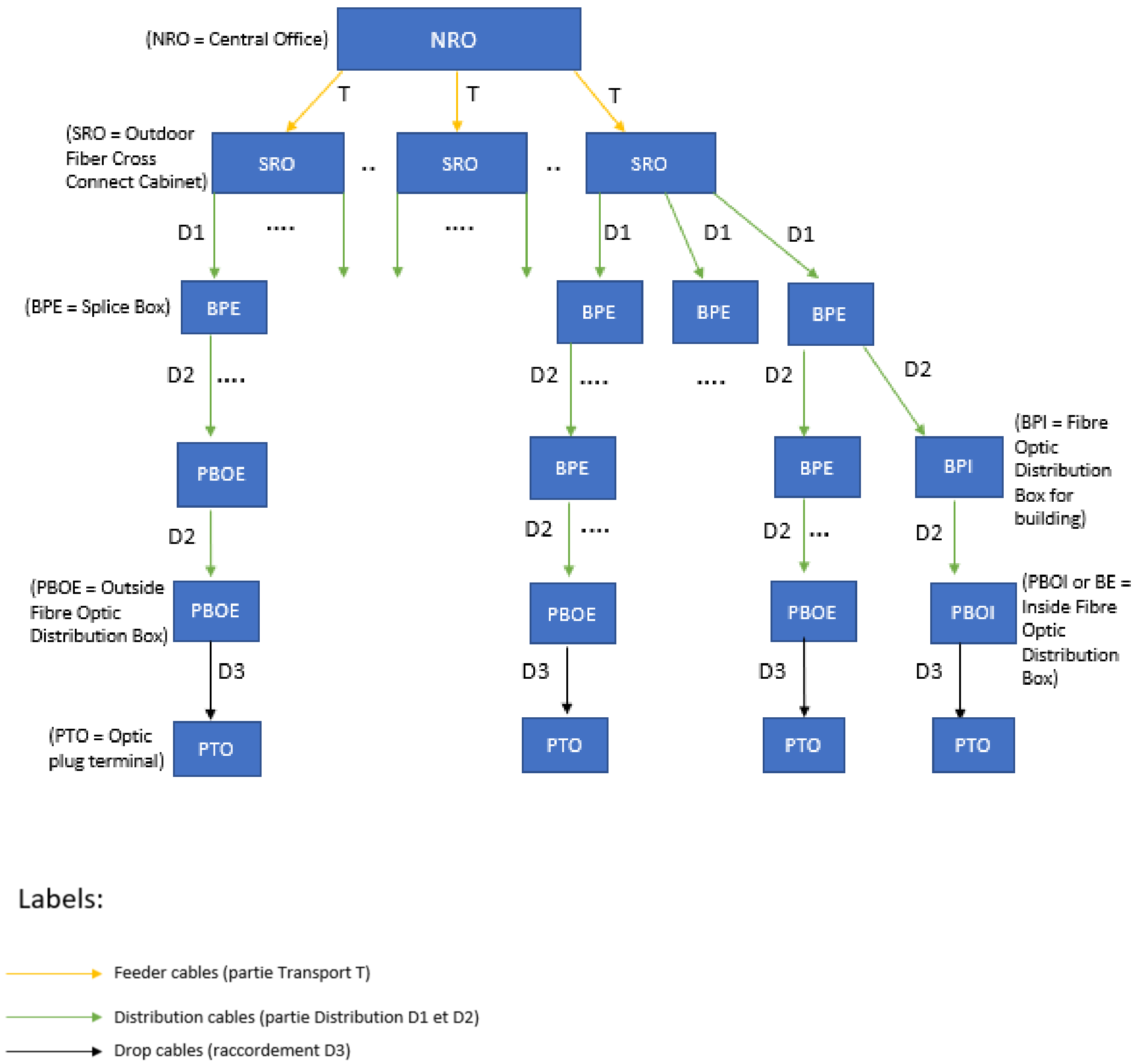


Figure 7: General architecture of the FTTH network

Generally, we have multiple Fiber Optic Distribution Boxes and Splice Boxes in series. Indeed, the Splice Boxes are used for different configurations such as dividing the cable in multiple sub cables smaller in size and in capacity for covering a larger geographic area. Both can be used for all types of distribution networks as for underground and aerial network, or installation on the facades. The only difference between these two kinds of boxes comes from the fact that fiber optic distribution boxes are directly linked to the subscribers to connect them to their own networks whereas splice boxes are inner components of the network that are connected to others splice box or Fiber Optic Distribution Boxes.

The Central office (NRO) (Figure 8) is a technical room containing the OLT and making the link between the national network and the subscribers' lines of a neighborhood or a city ([2] CREDO). The Outdoor Fiber Optic Cross Connect Cabinet (Figure 9) is allocated to a unique Central office. Generally, at this level, operators install their optical couplers necessary for the activation of the PON technologies.

Figure 8: Central office

Figure 9: Outdoor Fiber Optic Cross Connect Cabinet

The Splice Box (Figure 10) is the interface between the D1 and the D2. It can have multiple size depending on the area we have to connect. Mainly, we have one cable containing a huge number of optical fibers at the input (or two but it les usual) and at the output, this cable is divided in several smaller cables, with a reduced capacity, to service a more or less broad area. It can be settled in the underground room, on the poles or in some cases on the facades but aesthetically it is not the best way to deploy the fiber. Furthermore, it is necessary to have a permission of the owner. The cassettes inside the box hold the spliced fibers. It allows to optimize and to bring flexibility to the PON network.

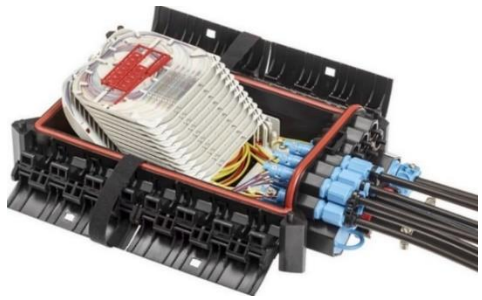


Figure 10: Splice box

The Outside Fiber Optic Distribution Box (Figure 11) is an intermediate equipment localized between the Central office and the optical network termination (ONT) to lead the fiber to the subscriber. It can be settled on the facades, on the poles or in underground room. It is allocated to a unique Outdoor Fiber Optic Cross Connect Cabinet.

Figure 11: Outside Fiber Optic Distribution Box

The Inside Fiber Optic Distribution Box (Figure 12) is based on the same principle in the sense that it allows to connect the subscriber. The use of this box is mandatory, it depends on the number of subscribers located at the same address (see the engineering rules in Table 6). If the number of subscribers at the same address is bigger than 7 (limit in the specifications imposed by the client), the use of Inside Fiber Optic Distribution Box is required. In the architecture of the FTTH network (as seen in Figure 7), the PBOI is preceded by a Fiber Optic Distribution Box for building (BPI).

Figure 12: Inside Fiber Optic Distribution Box

The Optic Plug Terminal (Figure 13), located in the premises (accommodations, companies, public sites), constitutes the termination point of the FTTH network and allows to connect the ONT of operators.

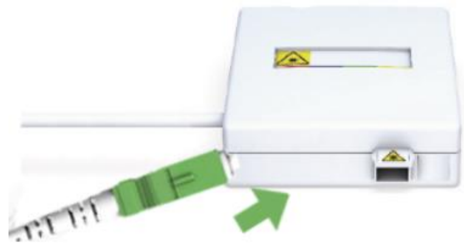


Figure 13: Optic Plug Terminal

1.4 Purpose and organization of the thesis

Nowadays, internet data traffic is continuously growing especially due to an increase of multimedia contents, services and applications available on the network. New generation networks must guarantee more capacity and at the same time they should be more flexible. Optical fibers are the best solution to provide huge capacity. The purpose of this study which will now be produced will allow to understand the way in which a project is implemented from the beginning to the end and the main stages in the deployment of the FTTH network to complete the project.

This thesis is divided into five chapters: Chapter 1 presents concepts of optical fiber cable networks, here FTTH networks and the possible architectures, Chapter 2 contains the input data, namely how data have been integrated using postgre SQL within the software, Chapter 3 deals with the network engineering, Chapter 4 concerns the reflectometry study and Chapter 5 is dedicated to conclusions.

1.5 Presentation of Qgis software

QGIS is a free and open-source cross platform desktop geographic information system software that supports viewing, editing, and analysis of geospatial data. It allows users to analyze and edit spatial information. We can add several data related to a region in QGIS. The data are added in the form of layers in this software. Depending on their features of data, several layers are added containing similar information. The layer files have the extension .shp. QGIS supports QGIS supports both raster and vector layers, vector data is stored as either point, line, or polygon features. QGIS integrates with other open-source GIS packages, including PostGIS, GRASS GIS, and MapServer. Plugins perform geoprocessing functions, which are similar to the standard tools found in ArcGIS, and interface with PostgreSQL/ PostGIS, SpatiaLite and MySQL databases.

Chapter 2

2 Input data

The department has at his disposal a geo-referenced database of habitations serving as a basis during the conception of the engineering scheme in order to determinate the base of premises which must be considered for the FTTH network.

This basis has been constituted by different means of cross-referencing data coming from several sources but cannot be considered as 100% reliable and exhaustive. Thus, it is necessary in the design phase to constitute a basis conform with reality on the ground and considering the possible evolution of the habitat, premises or professional sites.

To realize this basis, multiple actions will be led. Furthermore, several surveys will be done from the municipalities about the evolution of the residential and professional areas. Then, surveys are led in return of the letter boxes survey on specific sites needing further information.

2.1 Sources of data

2.1.1 Letter box surveys

The letter box surveys allow to know how many plugs have to be connected by counting the letter box number. Certain subcontractors are in charge to examine the ground in order to evaluate the possible number of subscribers.

During the picketing of the letter boxes survey, the identified premises will be geo-referenced and then certain data will be led:

- the number of premises per building
- the type of premise (individual residential, collective residential, professional)
- Energy existing adduction (above or underground)
- Telecom existing adduction (above or underground)

The identification of the premises is capital to realize the delimitation of the outdoor fiber optic cross connect cabinet area and for the modelling of the distribution network.

2.1.2 The itinerary

The itinerary identifies all copper cable network pathways which have been set up through years. It allows to decide the optical fiber cable network on the basis of the copper network. But, for this study and to start the preliminary design, a pre-study is done before to make a project costing. It is on the basis of this project costing, estimating the suitable portion of the whole itinerary that our design will be done.

2.2 Integration of the input data using postgre SQL

During the design of the project, it was necessary to rely on other projects already done to adapt it to our own project for completing the different tables as t_adresse table, t_suf table present in this chapter but also others as t_zbpo and t_ebp tables described in the chapter 3. Each table is composed of several fields to be informed. These fields are completed through SQL requests allowing to import input data and to perform the design through the Qgis software. Indeed, SQL is a standard language for accessing and manipulating databases. The first step during the study has been to get familiar with the table to be completed and the SQL.

Before discussing about the different tables, let's have a look on the Conceptual Data Modeling (Figure 14) performed below, summarizing the links between the tables by putting forward the primary key and some of the foreign keys of each table. Obviously, all the fields and tables are not informed in this figure

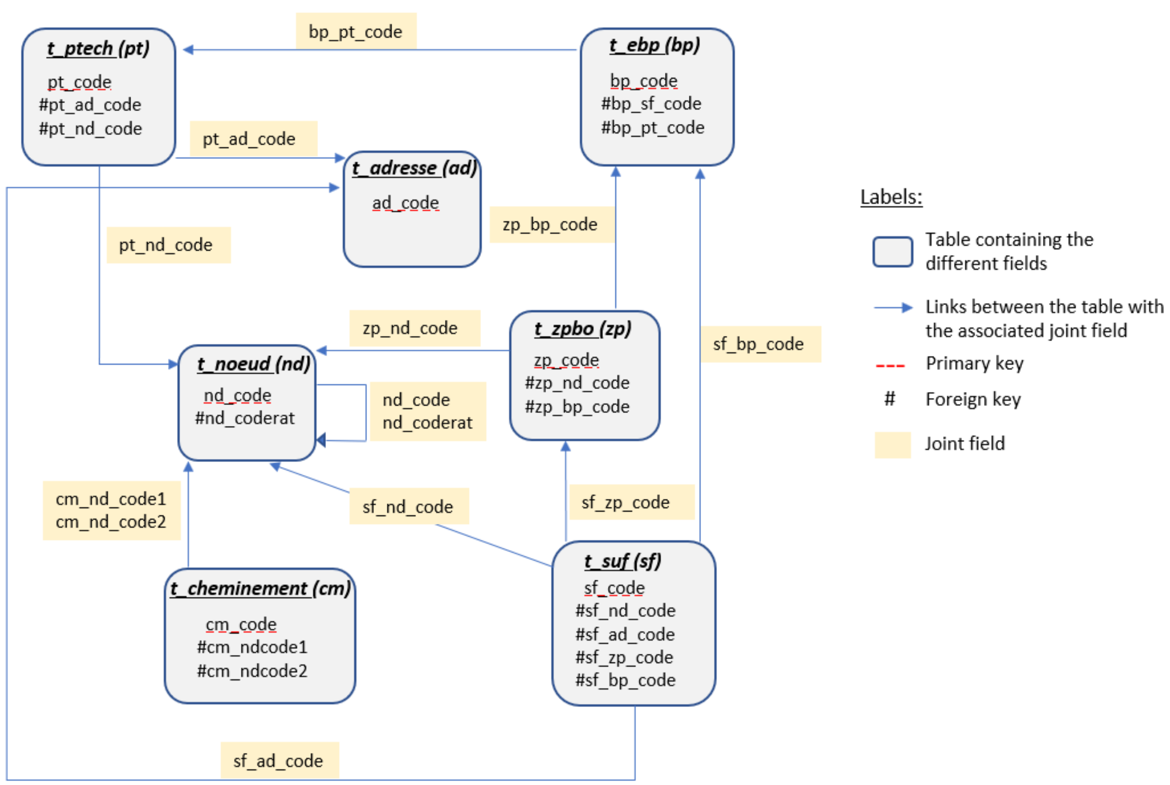


Figure 14: Conceptual Data Modeling

The **t_adresse table** allows to identify the address of the different subscribers (Figure 15). An address can contains multiple subscribers.

ad_itypeim: It corresponds to the type of habitation. When the number of plugs is below or equal to 4, it means that it is a Pavilion (P), and when the number of plugs is more than 4, it is a building (I). Thus, in the request, we dealt with 2 cases (more or less than 4) by summing the number of private accommodation (NBLOGEMENT) and professional accommodation (NBPROFESS). NBLOGEMENT and NBPROFESS are known input data provided by the letter boxes survey.

ad_nblhab: It corresponds to the number of premises at a given address. It takes the value 0 when there are no premises or the already known information contained in NBLOGEMENT provided during the pre-study.

ad_nbprhab: It refers to the number of plugs per private habitation. The fields "ad_nbprhab" and "ad_nblhab" are informed with the same request.

ad_nbprpro: It refers to the number of plugs per professional accommodation. It takes the value 0 when there are no plugs or the known information contained in NBPROFESS.

ad_zonenro: it refers to the code area covered by the Central office (NRO). Since the Central office is the same, the same identification code is taken.

ad_zonesro: it corresponds to the code identifying the area covered by the (SRO).

geom: it indicates the type of geometry. The function ST_GeometryN (geom,1) is used to return all the geometry of the field by informing only one value. If it is a "point" for example the function will display POINT with its geographical coordinates.

Table 1: t_adresse table

Fields	SQL request
ad_nomvoie	CONCAT (TYPE_VOIE, ' ', NOM_VOIE)
ad_numero	(case when NUMERO is null then '0' else NUMERO end)
ad_nblhab ad_nbprhab	(case when NBLOGEMENT is null then '0' else NBLOGEMENT end)
ad_nblpro ad_nbprpro	(case when NBPROFESS is null then '0' else NBPROFESS end)
ad_itypeim	(case when (case when NBLOGEMENT is null then '0' else NBLOGEMENT end) + (case when NBPROFESS is null then '0' else NBPROFESS end) >= 4 then 'I' when (case when NBLOGEMENT is null then '0' else NBLOGEMENT end) + (case when NBPROFESS is null then '0' else NBPROFESS end) < 4 then 'P' end)
geom	ST_GeometryN (geom,1)
ad_zonenro	ZN340034285503
ad_zonesro	ZN340034285525

Then, when the request is elaborated, it is possible to lay out every address on the Qgis software.

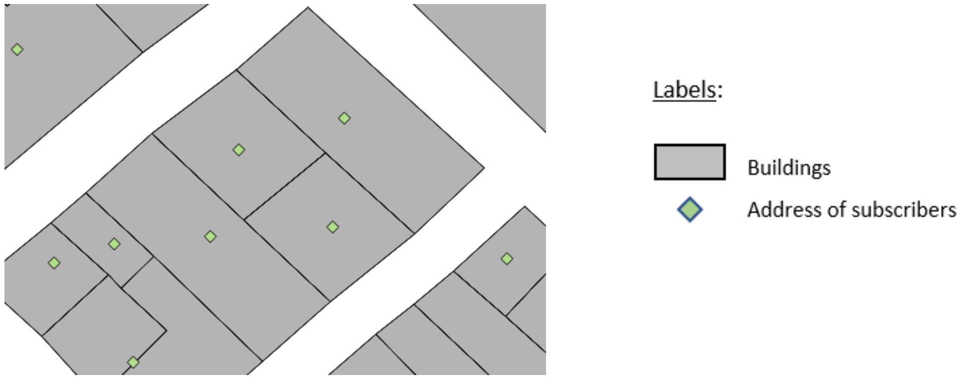


Figure 15: Display of the address of subscribers

In the figure 15, through the SQL request, we display the address of the different subscribers. Now, it is possible to locate each of them.

The **t_suf table** gives information about the subscribers. Each address is composed of one or multiple subscribers. Furthermore, the fields contribute to localize each subscriber, even those who are located at the same address. The table informs some fields such as sf_code, sf_ad_code, sf_zp_code (see the definitions below). The main part of them has been left at the value NULL since there are not mandatory at this step of the project. The function generates_series has been used to display all subscribers at a given address. This function allows to generate a set of data starting at some point, ending at another point, and optionally set the incrementing value. It works on two datatypes: integers and timestamps. Thus, **generate_series (0, ad_nbprhab-1)** used in the request, creates the potential number of subscribers at each address.

<u>sf_code</u>: Code proper to each subscriber which is automatically generated.

<u>sf_ad_code</u>: Unique identifier of the t_adresse table. Thus, every subscriber located at the same address has the same sf_ad_code. It takes the value of the field ad_code of the table t_adresse previously mentioned. The field sf_zp_code corresponds to the foreign key in the table t_suf referring to the table t_adressse by means of the primary key ad_code.

<u>sf_zp_code</u>: Identifier of the fiber optic distribution box area covering a part of the subscribers (see the table t_zpbo in the next part). Furthermore, sf_zp_code indicates the foreign key in the table t_suf referring to the table t_zpbo (described in the next part) by means of the primary key zp_code (field in the t_zbpo table).

<u>sf_bp_code</u>: It corresponds to the code of the fiber distribution box to which the subscriber is connected. Besides, sf_bp_code indicates the foreign key in the table t_suf referring to the table t_ebp by means of the primary key bp_code.

As indicated in the Figure 16, the number of subscribers per address is informed by summing the number of plugs in private accommodations and professional accommodations (ad_nbprhab + ad_nbprpro).

Figure 16: Display of the number of subscribers per address

The **t_ptech table** allows to identify every technical points of the territory being processed by informing fields such as pt_etiquet, pt_code or also pt_codeext. It can correspond to underground rooms, poles or facades. The type of technical point is specified in the fields pt_typephy and pt_nature by informing technical characteristics of the technical points as the length, the width, the lodging capacity of underground rooms in particular (see Table 19 in the appendix). The information to inform each field are provided in the Table 2.

pt_typephy: It refers to the type of technical point. 3 cases are considered: underground room ('C'), pole ('A'), façade ('F')).

pt_nature: It refers to the sizes of underground rooms. These sizes are indicated through terms used by France Telecom company (L1T, K1T etc..) as indicated in the appendix (Table 19).

pt_typelog: It corresponds to the part of the network where the optical fiber cables are deployed. The study in question concerns in particular the distribution network. Thus, we put the information 'T' (to make understand cable pulling ("Tirage de cable" in French).

pt_proptyp: It corresponds to the type of property. In this case, for this area which we deal with, we have only rental ("LOCATION" in French, hence "LOC" in the SQL request). Another case is possible in other areas, such as "CONSTRUCTION" if we have to build a new technical point (underground rooms).

pt_gest: It corresponds to the entity (identified here by a code) to which we can rent technical points to deploy the cables (example: Enedis or Orange company).

pt_codeext: Identifier of the technical point.

Table 2: t_ptech table

Fields	SQL requests
pt_prop	'OR34000000000392'
pt_gest	'OR34000000000395'
pt_typephy	(case when mode_pose = 'aerien' then 'A' when mode_pose = 'souterrain' then 'C' when mode_pose = 'facade' then 'F' end
pt_nature	(case when nature = '-' then 'IND' else nature end)
pt_proptyp	'LOC'
pt_typelog	'T'
geom	ST_GeometryN (geom,1)

Thus, it is possible now to display all the different technical points as underground rooms, facades and poles as shown in the figure 17.

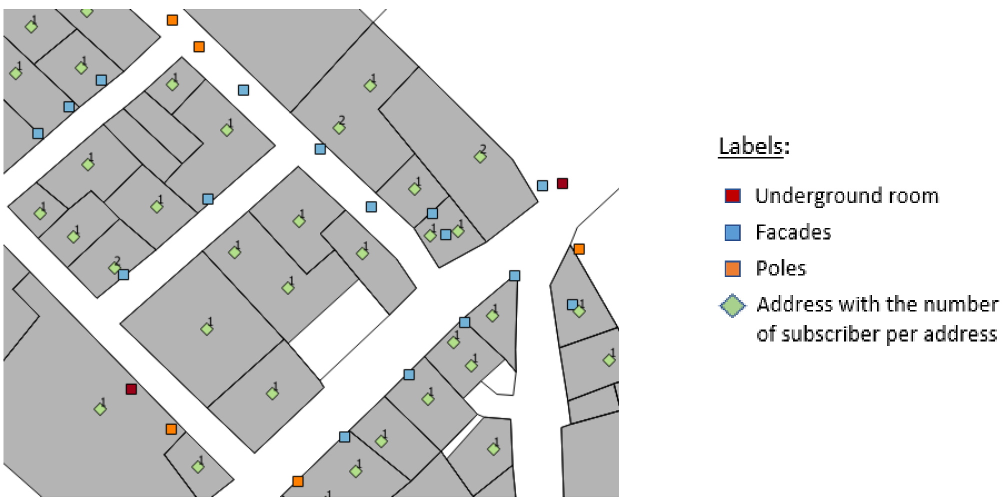


Figure 17: Positioning of the different technical points

The t_cheminement table indicates every authorized pathway of the cables. This is based on the itinerary previously described. Thus, it will be very useful when the deployment of the optical fiber will have to be done. This table informs some fields such as cm_avct, cm_typ_imp, cm_long through the request below (Table 3).

cm_r1_code: Name of the company handling the optical fiber network whose role is to assure the conception, the finance, the construction, the commercialization, the exploitation and the maintenance of the high-speed network into the territory of Hérault.

cm_long: It informs the length of the cable. The gem (geometry) field calculates automatically the value of the cable lengths based on the coordinate system (and the system of projection) of the cables.

cm_avct: It allows to indicate the progress of the works, by informing what already exists ('E') and what must be created ('C').

cm_typ_imp: Gives information about the type of implantation. It can correspond to civil engineering (GC) if we have to repair or replace existing pipes, or creating new underground rooms to set up new boxes and connect new subscribers. Our clients edit a template by listing all information and we use it to complete the fields. To respect the template, we have to convert a string character into a figure, hence the use in the request of :: integer.

cm_nature: Nature of the network. There is a distinction between electricity (ELE) and telecom (TEL) network

Table 3: t_cheminement table

Fields	SQL requests
cm_r1_code	'HERAULT THD'
cm_long	NULL
cm_avct	(case when mode_pose = 'GC' then 'C' else 'E' end)
cm_typ_imp	(case when mode_pose = 'GC' then 7 else mode_pose :: integer end)
cm_nature	(case when mode_pose = '1' then 'ELE' else 'TEL' end)
geom	ST_GeometryN (geom,1)

The t_cheminement table informs on the possible pathways used by the cables. This makes a connection between all technical points (Figure 18). There are differences between the name given to the different pathways, in particular for the cable pathways through facades and poles. The blue connections are called facade pathways and not aerial telecom because aerial telecom connection correspond to poles provided by the ENEDIS company and thus, the design office has to pay to use it, while when the optical fiber cables go through facades, an agreement with the homeowners is sufficient. The type of infrastructure is deducted from the technical point type.

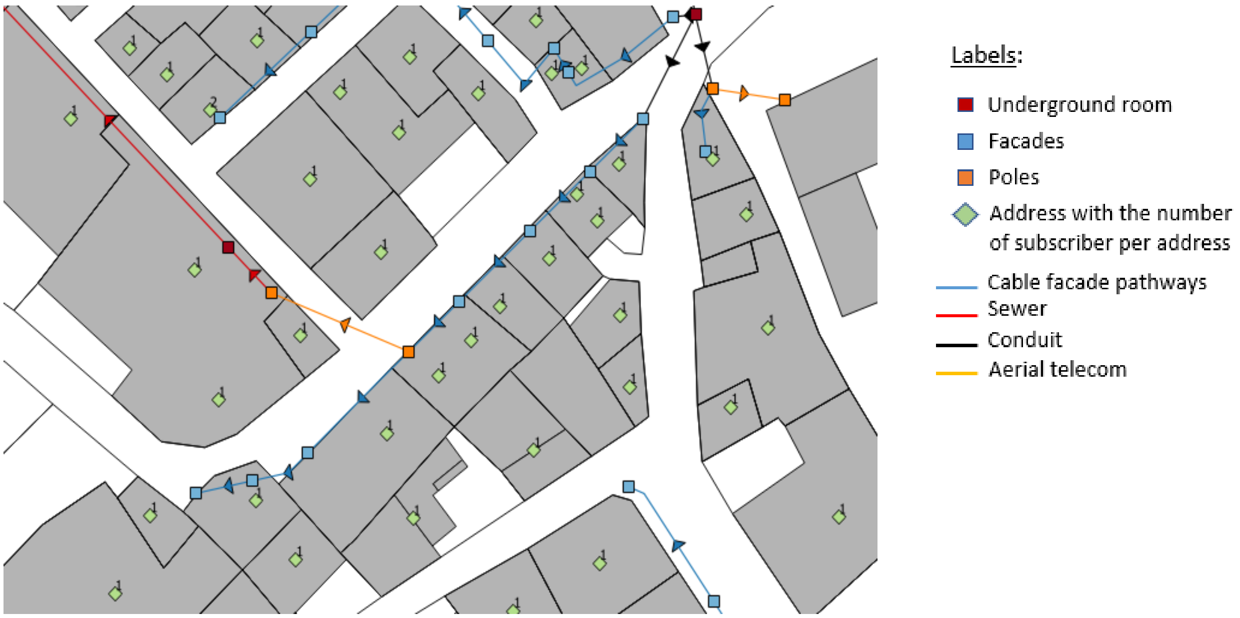


Figure 18: Cable pathways

My contribution at this stage has been to be able to get familiar with the database, SQL and to manipulate and integrate the data in order to lead the project up to the end. This part of the project is fundamental to begin the deployment of the optical fiber.

Chapter 3

3 Network engineering

3.1 Implementation of outside fiber optic distribution box areas and boxes

The t_zpbo table informs on the fiber optic distribution box area. It corresponds to the surface covered by the box located on the technical point and connecting a certain number of subscribers, limited to **4**. This limitation comes from the fact that each the fiber optic distribution box can receive one cable and transmit **a maximum of 6 optical fibers**, one fiber for each subscriber. But the design office imposed a maximum of 4 subscribers in order to have room of **30%** to respond in case of miscommunication of one of the fibers. All these requirements are specified in the specifications provided by our client and are informed in the appendix. The table contains some fields such as zp_code, zp_zs_code, zp_capamax, zp_bp_code.

zp_code: Unique code of each fiber optic distribution box area (automatically generated).

zp_zs_code: Code of the outdoor fiber optic cross connect cabinet proper to each fiber optic distribution box area. This code is the same for all areas of our project since there is only one outdoor fiber optic cross connect cabinet.

zp_capamax: capacity of the cable. The value 6 is affected.

zp_bp_code: Code proper to each fiber optic distribution box area referring to the box located on the technical point. Thus, zp_bp_code corresponds to the foreign key in the table t_zpbo referring to the table t_ebp (described in the next part) by means of the primary key bp_code in the table t_ebp.

The Figure 19 gives a sample of the entire outside fiber optic distribution box areas treated during the project to better understand how to the design is implemented.

The different fiber optic distribution box areas have been done manually by selecting, in each case, a certain number of subscribers. The next step of the design is to implement the PBOE in each area to connect the subscribers. The case in which the number of subscribers is bigger than 4 is rarely met, so it was handled manually by changing the code bp_etiquet to inform that a fiber optic distribution box for building (BPI) must be used.

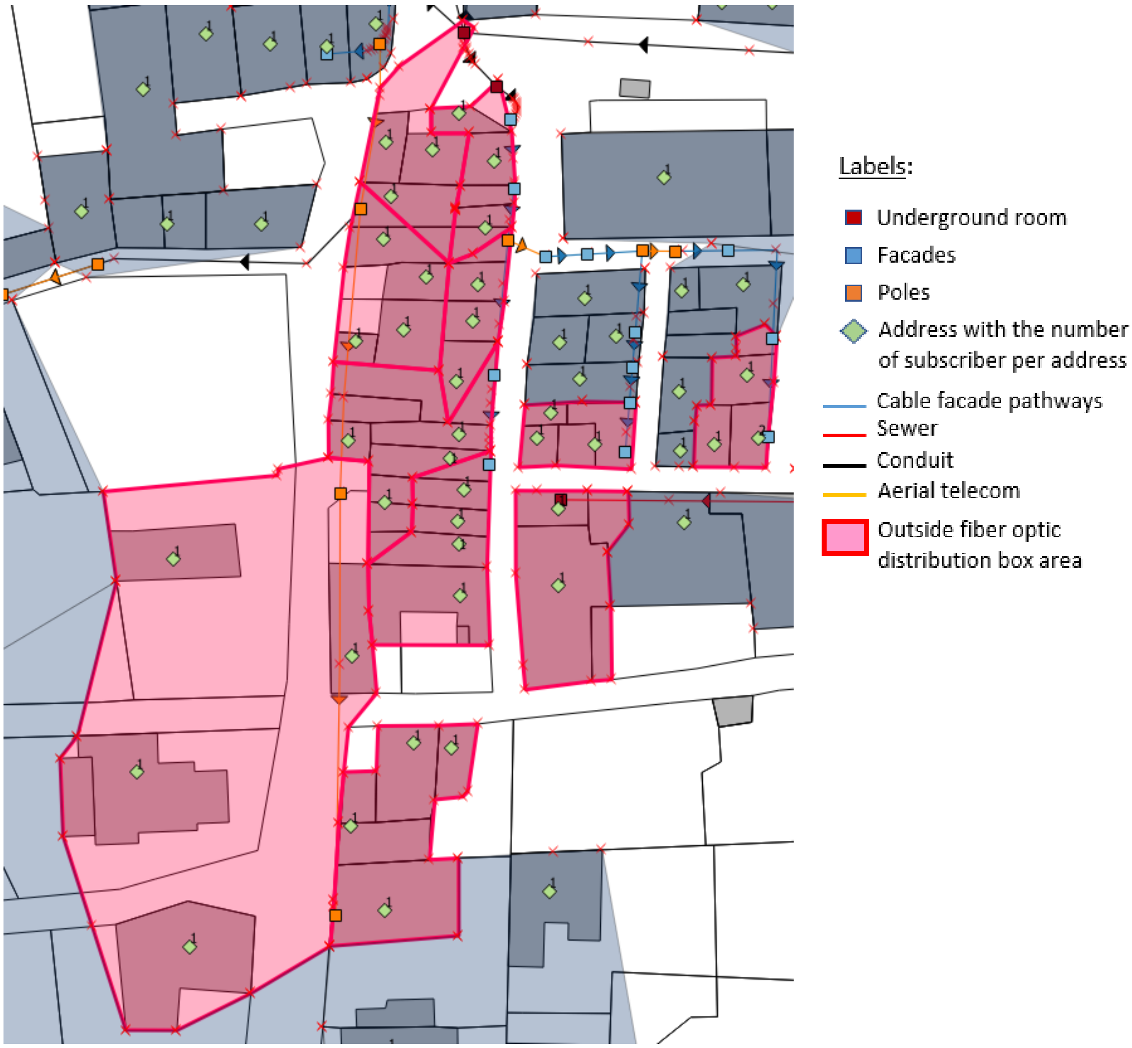


Figure 19: Implementation of the outside fiber optic distribution

The subscriber groups are delimited while meeting specific rules (see Figure 20). Indeed, if the group is composed of a site totaling 1 plug, thus this site is identified as long cable connection and it will be connected through the closer inside fiber optic distribution box (PBOE), at a distance greater than 100 linear meters.

If the group totals between 2 and 5 plugs, these plugs are "connectable upon request ".

Therefore, in the case of a validated opening line and considered by the delegatee, an **extension** of the network is built to relate to a fiber optic distribution box considered itself as "upon request" and located at a distance lower than 100 linear meters.

Furthermore, in a group with more than 1 plug, each plug must be at a distance lower than 100 linear meters to the closer plug of the same group.

When the group totals more than 5 plugs, it is called “IPE” (definition in the glossary). But in this study, the design office imposes a maximum number of 4 plugs, namely 4 subscribers in each fiber optic distribution box area.

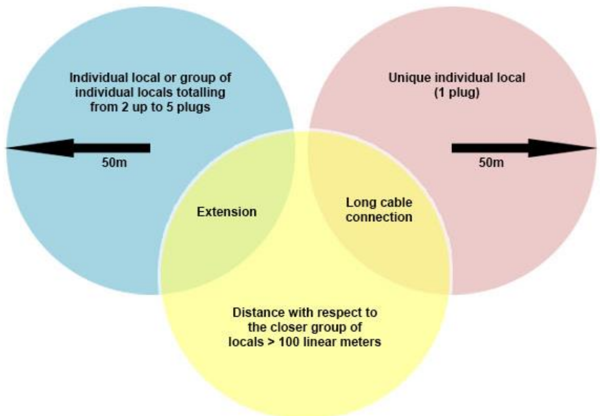


Figure 20: long cable connection and extension

The table t_ebp informs on the type of box which has to be set up within each technical point. There are different boxes present in the FTTH network and each of them have a specific rule in view to be able to connect every subscribers’ plugs. Indeed, the outside fiber optic distribution box (PBOE) gathers several types of boxes according to their capacities as shown in Table 17. Indeed, the outside fiber optic distribution box is in charge to connect the subscriber while the splice box split the cable in multiple cables. The fiber optic distribution box for building (BPI) which, as its name implies, allows to connect the areas where more than 4 subscribers are living. At this step, the SQL request (Table 4) allows to display only the outside fiber optic distribution box (PBOE). The splice box (BPE) will be added on the basis of need during the cabling part and the fiber optic distribution boxes for building (BPI) will be generated independently.

This table contains fields such as bp_code, bp_pt_code, bp_typelog, bp_rf_code.

<u>bp_code</u>: Unique code of the box generated automatically.

<u>bp_pt_code</u>: Code of the technical point where the box is set up. Thus, bp_pt_code corresponds to the foreign key in the table t_ebp referring to the table t_ptech by means of the primary key pt_code. Furthermore, this field takes the same value as pt_code.

<u>bp_typelog</u>: It corresponds to the type of boxes. For the moment, only the fiber optic distribution boxes (PBO) are considered as said previously.

<u>bp_rf_code</u>: It informs the reference code of the technical point where the box is located. Depending on the reference code, it is possible to know the nature of technical point such as underground room (indicated by letter C), or poles (indicated by the letter A) and facades (letter F), both being informed with the same reference code. Thereafter, the reference code for the splice boxes and the fiber optic distribution boxes for building (BPI) will be provided manually, progressively.

<u>bp-etiquet</u>: It indicate the etiquette of each box. The etiquettes are created by means of the functions concat and substring.

The equality **zp_nd_code = pt_nd_code,** allows to match, by means of the node (nd), each technical point with the corresponding fiber optic distribution box area, and thus, the box located on the technical point covering the given area. Furthermore, the node is a geometry allowing to achieve the correspondence between several geometries, here the fiber optic distribution box area (zp) and the technical point (pt).

Table 4: SQL request of the t_ebp table

Fields	SQL request
bp_typelog	'PBO'
bp_pt_code	pt_code
bp_rf_code	(case when pt_typephy = 'C' then 'RF340000000000124' when pt_typephy = 'A' then 'RF340000000000115' when pt_typephy = 'F' then 'RF340000000000115' end)
bp_etiquet	concat ('HT-BPE-',substr(pt_codeext,7,11),'-01')

In the Figure 21 is represented an outside fiber optic distribution box area with its corresponding PBOE located on the technical point, here a pole. Here, the PBOE in this area is in charge to connect 4 subscribers.

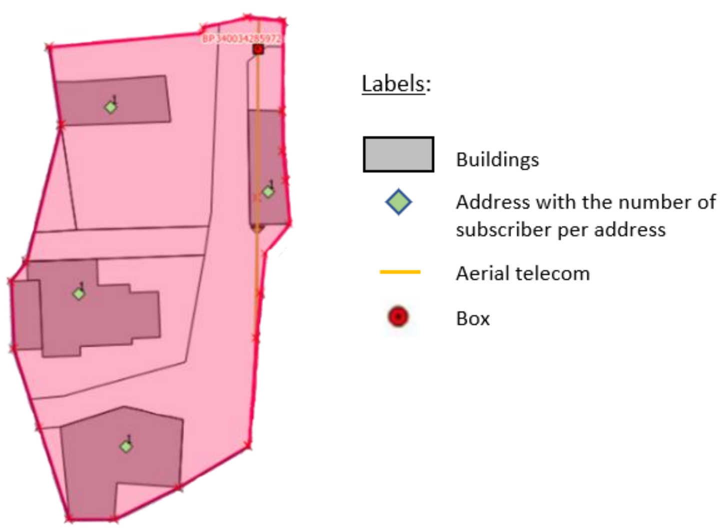


Figure 21: Outside fiber optic distribution box area with the corresponding

The node is a geometry allowing to achieve the correspondence between several geometries. The field nd_code indicate the code of the node. It is generated automatically. Then, the foreign key nd_coderat is the code proper to our network. It is a unique code informing the central office and the outdoor fiber optic cross connect cabinet from which the deployment of the optical cables starts. As it is notable, there is a self-join on this table. Indeed, this is due to the fact that the node can be used for an arrival and a departure, namely from a box up to the following box located on a technical point. Indeed, as it is informed in the Figure 14, two foreign keys (cm_ndcode1 and cm_ndcode2) of the t_cheminement table are in charge to indicate the arrival and the departure of the cable by appealing twice the primary key nd_code.

3.2 Dimensioning of the optical fiber cables

The values concerning the total capacity of the optical fiber cables are imposed by Covage company (Table 5). The total capacity of each cable must be a multiple of 6. The capacity of each tube in a given cable is represented by the number of optical fibers composing a tube of the cable itself. For example, modulo 6 means that each tube composing the cable is composed of 6 fibers (see figure 22).

It is authorized to use modulo 6 when the total capacity is included between 6 and 96-fiber cable, and the modulo 12 is imposed for a total capacity between 144 and 720-fiber cable. Thereafter, it will be important to make the difference between the total capacity and the used capacity of the cable. We note that the capacity of a given cable is **used capacity / total capacity.**

Table 5: Total capacity (number of fibers) authorized for cable

modulo 6	modulo 12
6	144
12	192
24	288
36	576
48	720
72	
96	

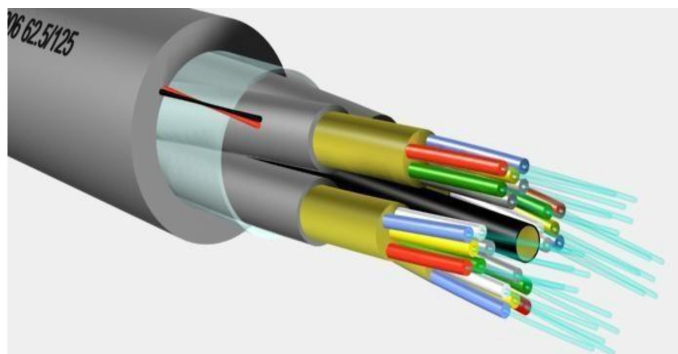


Figure 22: Example of a 24-fiber cable (modulo 6)

The engineering rules (Table 6) are requirements which we have to pay very special attention during the design of the FTTH network. Each of them must be respected to satisfy the client's requirements. In other cases, if these rules are not respected, softwares return an error report that must be treated before submitting the project to the client.

The implementation of boxes in every technical point is an important stage during the network design. Indeed, each technical point has a specific lodging capacity (Table 19 in the appendix) making available or not the technical point. In case of unavailability, we have to rethink the design while taking into account each engineering rule below.

Table 6: Engineering rules for the FTTH network design [5]

Rules imposed by the clients	Limitations
Maximum capacity for each aerial network cable (through poles or facades)	144 optical fibers
Maximum cable capacity at the input of outside fiber optic distribution box (PBOE)	96 optical fibers
Maximum number of cables going through the same pathway	3 cables
Maximum distance between the outside fiber optic distribution box and the beginning of the subscriber's private domain	The limitation is 50m of cable length, but during the network design, the client allowed us to take 100m as the crow flies
The corresponding box proper to each technical point based on the capacity of the entering cable and the number of possible splicing for this given box (BPE, PBOE, PBOI and BPI)	In underground room: **OFDC, TENIO T1, TENIO T2, GC02**-BD (specifications in appendix) For poles and facades: **FIST-BD, IDB-32**
Maximum number of subscribers connected through outside (PBOE), inside (PBOI) fiber optic distribution box and fiber optic distribution box for building (BPI)	Outside: max 4 subscribers (exceptionally up to 6 with the 30% of safety margin) Inside: from 8 up to 9 subscribers (above 9, another box in series in added) BPI: from 4 to 7 subscribers (from 4 subscribers this is considered as a building and not as an individual house)

Concerning the use of fiber optic distribution boxes for building (BPI), it concerns only the addresses containing 4 persons or more. Indeed, it is unsuitable to use in this case an outside fiber optic distribution box (PBOE) to serve such a number of subscribers present at the same address. Furthermore, when the number of subscribers is bigger than 7, an inside fiber optic distribution box (PBOI) must be added. Another PBOI is added in series, connected to the previous PBOI, in order to serve subscribers if their number overcomes 9 (etc..).

3.3 Splices in the case of boxes located on the same technical point

Splices are critical elements of an optical fiber network since they influence, to a large extent, not only the quality of connections but also their life expectancy. The splice must ensure a high level of quality and sustainability. A high-level splicing generally results in lower light loss. In this study, it is mainly used to join two different types of cable together, for example a 48- fiber cable to four 12 -fiber cables or a 24-fiber cable and two 12-fiber cables.

Let's see, through Figure 23 and Figure 24, an example of the different splices in the fiber optical network keeping in mind that the purpose of the design is to optimize the use of splices and the used cable length.

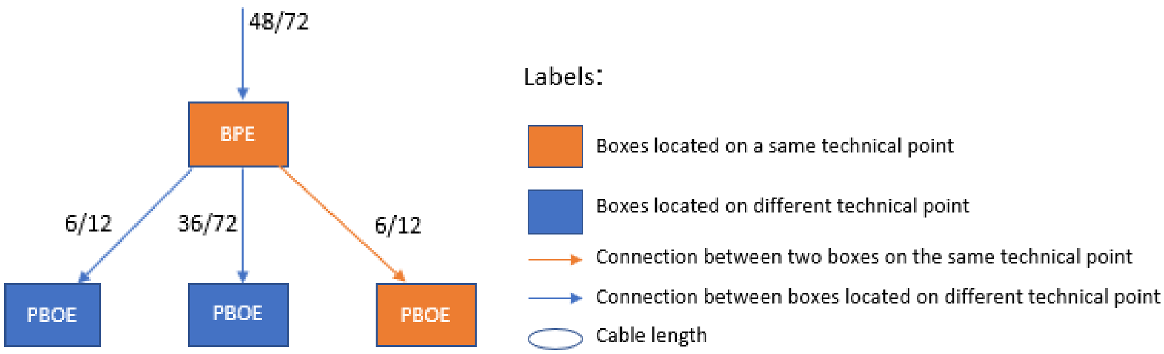


Figure 23: Calculation of the number of splices for a given cable deployment scheme

Here, we distinguish the boxes located on the same technical point and those which are not. Indeed, within the same technical point, we can set up several boxes.

The figure 23 shows a possible design of a part of the network. It is possible to see that at the input of the splice box, we have a 72-fiber cable, and the used capacity is 48 fibers. The splice box split the cable, at the output, into three cables, one cable with a 36/72 capacity which is the same as the input cable of the splice box (BPE) with a lower used capacity. The two other cables have been spliced from the cable 48/72 in the splice box to be connected to the outside fiber optic distribution boxes (PBOE). The PBOE are used to connect the subscribers. There are **30 splices** in this example**.** Indeed, 24 splices are done with the right and left cables (12 for each of them) and 6 splices for the outside fiber optic distribution box of the cable in the middle (36/72). The same scheme is described in the figure 24. The unique difference is the design of the optical fiber cable network. The same capacity is used at the input of the splice box. But, instead of dividing the cable in three different cables as previously seen in the figure 23, it is preferable to split it in two cables. The cable at left (6/12) is spliced in the splice box (BPE) to be connected to the next outside fiber optic distribution box. The subtlety for the right cable, making the difference with the deployment in the figure 23, is linked to the fact that the same cable (the one entering in the splice box) is utilized to connect the following outside fiber optic distribution boxes (PBOE). In this case, **24 splices** are implemented. Indeed, there are 12 splices only with the left cable (6/12) and then 12 splices at right. These calculations concerning the Figure 23 and Figure 24 has been done manually. They are a short example to better understand the idea of our thought and how we tried to optimize the cost during the design.

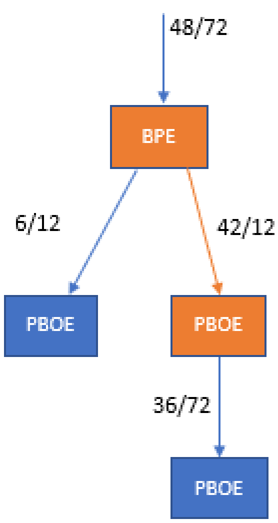


Figure 24: Calculation of the number of splices for an optimized way of cable deployment

3.4 Cost optimization of cable lengths used for the deployment

To better understand one of the methods implemented during the network design to optimize the cable length used for the deployment of the optical fiber cables, let's see an example through the figure 26 and the figure 25 described below.

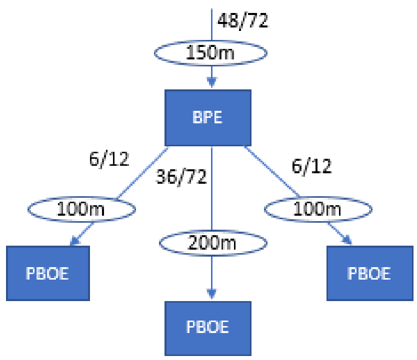


Figure 26: Calculation of the cable length cost for a given way of cable deployment

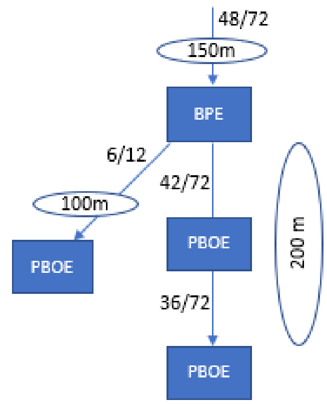


Figure 25: Calculation of the cable length cost for an optimized way of cable deployment

The two deployment methods implemented previously allow to connect the subscribers. However, the question of the cable pulling cost is one of the most important parameters and has to be considered during the design of the network. Indeed, as shown by the cost estimation document in the appendix and provided by the French company COVAGE, the cable pulling concerning cables having a capacity from 12 to 72 is 1 euro per linear meter. In the figure 20, from the BPE up to other boxes, 550 linear meters is deployed to connect all boxes, therefore the price is 550 euros. The figure 19 offers another method by using the same cable to connect multiple boxes, minimizing the cable length and avoiding the deployment of the cable twice when it could be deployed just one time. Here, the price is 450 euros, thus 100 euros less than the design seen in the figure 20. Here again, it corresponds to a manual optimization. This sample of our network allows to better understand the idea set up during the design.

That's this line of reasoning which has been applicated all along the FTTH network like the engineering rules (Table 6).

The difference of price will be much more important by implementing such methods for the design of the entire area which has to be connected. Furthermore, in case of deployment of aerial cable through facades or poles, a limitation of three cables is imposed by the French telecommunication company ORANGE and applied by COVAGE. Indeed, the design must consider some specific rules. Thus, using the same cable to connect several boxes allows to maintain a margin in order to respect this limitation.

A sample of the FTTH network is represented (Figure 27) to better understand how the optical fiber is deployed and linked to the different boxes so as to connect the subscribers. The engineering rules for the FTTH network design (Table 6) defined by the client appear through this design as the maximum number of subscribers connected through outside fiber optic distribution box, the maximum number of cables going through the same pathways (limited to three cables), the maximum cable capacity at the input of outside fiber optic distribution box (limited to 96 optical fibers) and the maximum capacity for each aerial network cable through poles and facades (limited to 144 optical fibers). These parameters forced us to think more about different strategies concerning the used pathways by cables, how to replace multiple cables with less cables while performing the same functions.

Figure 27: Sample of the FTTH network design (Scale: 1:1 120)

Figure 27 is zoom in. Three different pictures of this zoomed figure are informed below to clearly see how the design is elaborated (Figure 28, Figure 29 and Figure 30).

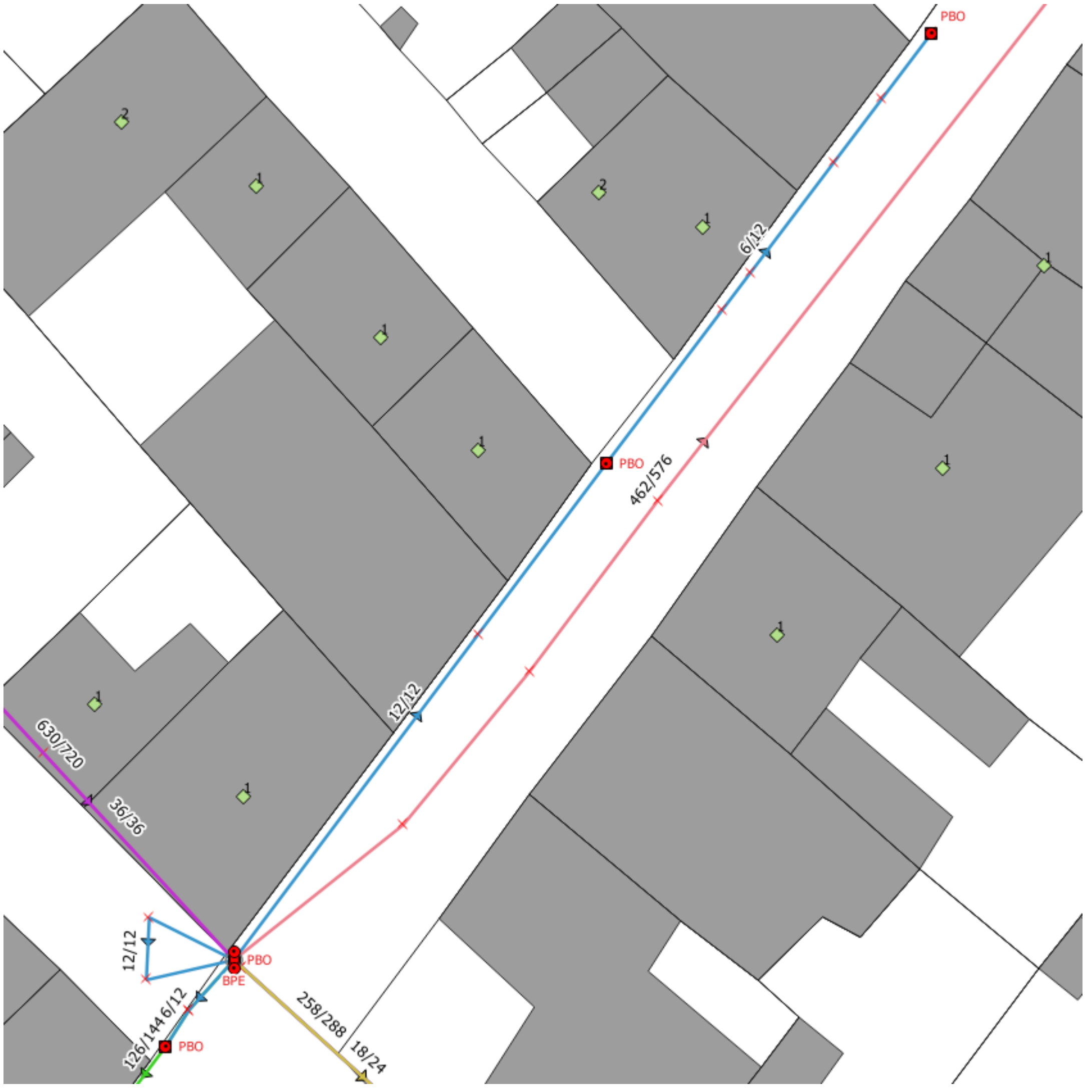


Figure 28: Sample of the FTTH network design 1 (Scale: 1: 560)

Figure 29: Sample of the FTTH network design 2 (Scale: 1: 560)

Figure 30: Sample of the FTTH network design 3 (Scale: 1: 560)

3.5 Final design of the network

Once the preliminary design has been realized, the second step of the study is to perform the final design to establish if the design performed in the preliminary design is feasible after the technicians or subcontractors went on the ground. All elements included at the end of this step of the design are definitively fixed.

First, it concerns the availability of the technical points, in particular underground rooms. To see if it is feasible (Figure 33) or not (Figure 34) and set up one more box within the different rooms, technicians take pictures and send it to the design office. The design office is in charge to analyze the situation, propose solutions and take a decision while respecting the client's requirements. Such a situation has been met during the design of the network, thus it was necessary to slightly modify the optical cable paths. The deployment is also modified when one of the engineering rules is not respected (Table 6).

Besides, other critical situations can be met as blocked discharge pipe. Such a problem would imply to find another cost-effective path or implement new pipes.

Furthermore, at this step of the design, new subscribers could be added to the network already designed. Indeed, these kinds of information is not known during the preliminary design. Indeed, this information is provided by the town hall. It concerns new housings, or housing under construction which now, must be considered and informed. Two strategies can be adopted to add the new subscribers.

It is whether possible to add a new outside fiber optic distribution box (PBOE) within a free and a close technical point to connect the new subscribers by respecting in the same way the rule of 100 meters between the box and the beginning of the subscribers 'property (Figure 31). In this case, since the box is located in a new outside fiber optic distribution box area (Zpbo), several fields must be informed, in particular the **zp_bp_code** field (it informs the foreign key in the table t_zpbo referring to the table t_ebp by means of the primary key bp_code) which indicates the area covered by the box in question.

The other strategy relies on finding optical cables with a sufficient available capacity, in other words optical cables with a good margin (Figure 32). Here both methods have been adopted. Indeed, for the new subscribers, we have found a cable with a good margin to add 1 subscriber but not all of them. To connect the rest, we put another outside fiber optic distribution box within an adequate size technical point (Figure 31) since a box was already set up. Thus, due to this addition of box, all cable capacities up to the outdoor fiber optic cross connect cabinet have been recalculated. When a new subscriber is connected to an outside fiber distribution box, we must inform multiple fields in the table t_suf in particular **sf_zp_code** (it corresponds to the foreign key in the table t_suf referring to the table t_zpbo by means of the primary key zp_code), **sf_bp_code** (it indicates the foreign key in the table t_suf referring to the table t_ebp by means of the primary key bp_code), and the field **cl_bpe_depart and cl_bpe_arrivee** corresponding to the codes of the box from where cable starts and finish. These two last fields can be informed manually or generated thanks to a developed plug-in the Qgis software.

Two SQL requests to update sf_bp_code and zp_bp_code are informed below to understand how this field have been filled after the multiple change from the preliminary design to the final design.

Figure 31: Addition of several subscribers after creating a new box (PBOE)

Figure 32: Addition of a subscriber within an existing box (PBOE

Figure 33: **Pictures of an available underground room**

Figure 34: **Pictures of an unavailable underground**

Let's look more closely these SQL requests to better understand the idea.

```
--* Request to inform the field sf_bp_code
UPDATE t013_mongs04_apd.t_suf sf -- update the t_suf table of the city Montagnac
SET     sf_bp_code = zp_bp_code      -- assign the value zp_bp_code to sf_bp_code
        sf_zp_code = zp_code         -- assign the value zp_code to sf_zp_code
FROM t013_mongs04_apd.t_zpbo zp   -- indicates the table where we can take the value zp_code and
                                     zp_bp_code
WHERE st_within (sf.geom, zp.geom)   -- the function st_within checks if the geometry of the suf and of
                                     the fiber optic distribution box area are superimposed
AND sf_bp_code is NULL;  -- Informs only the fields with the value NULL
```

```
--* Request to inform the field zp_bp_code
UPDATE t013_mongs04_apd.t_zpbo -- update the t_zpbo table of the city Montagnac
SET     zp_bp_code = bp_code        -- assign the value bp_code to zp_bp_code
FROM t013_mongs04_apd.t_ebp,     -- indicates the table where we can take the value bp_code (t_ebp)
        t013_mongs04_apd.t_ptech  -- To make the link between t_zpbo and t_ebp, we need t_ptech
WHERE bp_pt_code = pt_code  -- joining of tables
```

During this stage of the project, we had also to update multiple fields of the outdoor fiber optic cross connect cabinet table and also to perform a request to fill the number of splice cassettes inside the different types of boxes. These requests are informed in the appendix.

Chapter 4

4 Reflectometry

4.1 General principle of the reflectometry

The common schematic to all reflectometers, as shown in the Figure 35, is composed of three main elements: a transmitter, a directional coupler and a detector associated to a set of acquisition and signal processing and an observation system. The optical transmitter (laser diode), modulated at a few KHz through a pulse generator, delivers light pulses calibrated in duration and magnitude to the fiber being tested by means of the directional coupler. During the propagation, the light power of pulses undergoes an attenuation due to the absorption and diffusion losses within the core of the optical fiber.

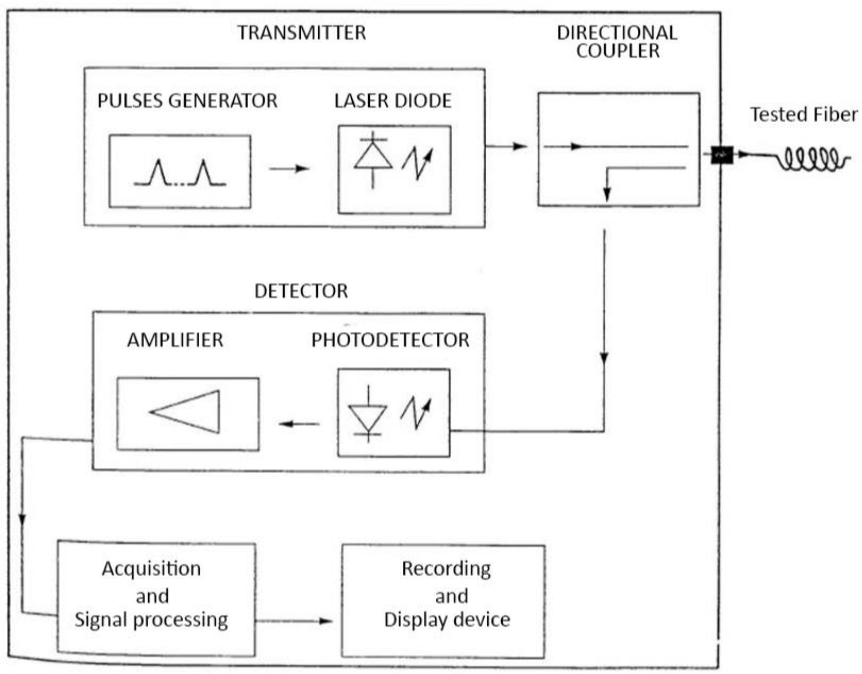


Figure 35: Principle of a reflectometer [3]

The directional coupler recovers the backscattered energy, itself attenuated during its propagation in the opposite direction, in order to guide it toward the photodetector. The photodetector allows to convert this optical signal in electrical signal which will be amplified to be adapted to the measure.

4.2 Basic principle of an OTDR reflectometer

The primary objectives of the reflectometry technology are to measure the lengths of the optical fiber links or the events, to determinate the attenuation and visualize the variation and incidents along the fiber. The measurement with the Optical Time Domain Reflectometer (OTDR) is frequently used to test the optical fiber transmission line. This is a method which allows to characterize simply the optical fiber from one of its ends and leads to the precise location of the cable faults, to the measurement of the fiber attenuation and to the differential losses between two chosen points of the fiber. Light pulses sufficiently brief and strong are injected in the fiber and reflected on the discontinuities such as on cracks, fiber ends, splicing, connectors or components of the fiber-optic link …). As the pulse travel along the fiber, a small portion of the pulse's energy returns to the OTDR's transmitter. Furthermore, the core of the fiber is constituted of molecules of silica and are also factors of the backscattered phenomenon. The time t separating the emission of the light pulse and the reception of the reflected signal gives the location of the default in the fiber. The height of the reflected pulse informs on the importance and the nature of the default. The measurement of the backscattered light by Rayleigh scattering towards the detector (Figure 36), even in the absence of reflective defects along the fiber, allows to know the fiber absorption in relation with the injected pulse wavelength. Indeed, as the light is scattered in all directions, some of it just happen to return back along the fiber towards the light source.

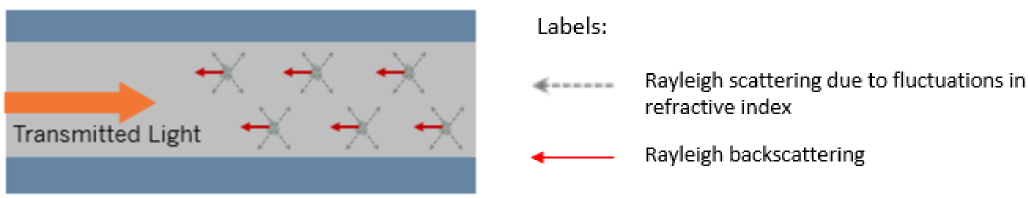


Figure 36: Backscattered light by Rayleigh scattering towards the detector ([11] Luna)

Theoretically, the measurements with the OTDR device are performed by injecting two different wavelengths on each side of the optical fiber cable and making the average of the obtained values (in dB) through the discontinuities (splices) for each corresponding wavelength. Once the curves for each wavelength is displayed, the comparison of their values at each splice allows to detect or not a possible defect. Normally, the values at the junctions between the fibers with λ=1550nm should be lower than those with λ=1310nm. If this is not the case, the client NGE authorize us a gap up to 0.05dB at each discontinuity of the two curves. A macro is in charge to perform this comparison for the different curves and to see if the obtained results satisfy the requirements of the clients. If not, we have to redo the splices until reaching suitable results. The method of measurement previously described is used only from the Central Office (NRO) up to the Outdoor fiber optic cross connect cabinet (SRO), namely for the feeder cable. Indeed, for the feeder cable, two different wavelengths are injected (λ=1310nm and λ=1550nm) in each direction. But, for the distribution cable, the client requires to utilize only the wavelength λ=1310nm, in only one propagation direction, even if it is less accurate. Thus, measurements obtained on the ground, concerning the distribution cable, are realized in this way.

To continue, the distance d travelled in the tested fiber in the case of the OTDR method is determined in function of the time of the incident pulse in the fiber through the formula ([1] Boldyreva) :

$$d = (c_{vacuum} * t)/2n_{fiber} \quad (4.1)$$

where: t is the elapsed time between the emission and the reception of the pulse reflected by the event to be detected

c_{vacuum} is the speed of the light in free space

n_{fiber} is the group index of the fiber

d is the distance travelled in the tested fiber

4.3 Calibration of an OTDR measurement

There are important parameters to be considered and adjusted before buying a reflectometer and doing measurements.

The dynamic range allows to determinate the optical losses that the OTDR is able to analyze, namely the total fiber length which can be measured. The wider the dynamic range, the higher **the distance which can be analyzed by the OTDR** ([9] Kumar). An insufficient dynamic range does not allow to measure the complete optical fiber length and thus affects the precision of measurement loss, attenuation and of the farthest connector.

There is always at least one dead zone in every fiber connected to the OTDR. The existence of **dead zones** is an important drawback for OTDR. Thus, it is important to minimize the effects of dead zones wherever possible. The dead zone is caused by reflecting events as connectors, splices located along the fiber. They prevent the OTDR to measure with good precision the attenuation for short lengths and differentiating not-too-distant event. Furthermore, dead zones are influenced by the pulse width. Indeed, the shortest pulse width, the shortest the dead zones. The pulse width is actually the time during which the laser is on. As we know, time is converted into distance so that the pulse width has a length. If the pulse is too short, it loses its energy before the fiber end. This results in an inability to reach the end of the fiber. Therefore, it is not possible to measure the complete link since the returned end of fiber distance is much shorter than the actual length of the fiber.

The event (or reflective) **dead zone** is the minimum distance between the beginning of one reflective event and the point where a consecutive reflective event can be detected. If an event is located in the dead zone of the previous event, it will neither be detected nor correctly measured. The norm for this specification varies from 1 to 5 meters. The following schemes shows two examples of an OTDR with an event dead zone of 1m (Figure 37) and of 3m (Figure 38).

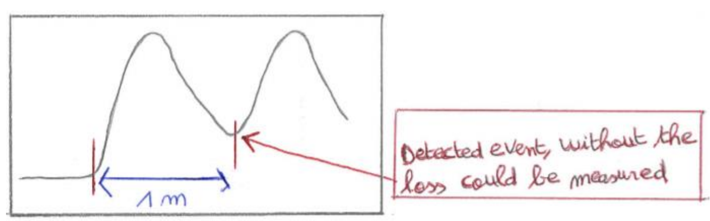


Figure 37: OTDR with an event dead zone of 1m

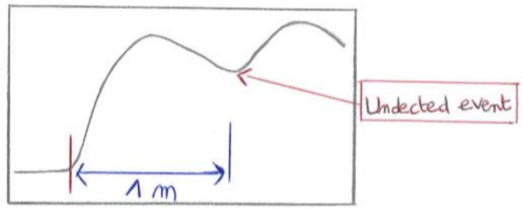


Figure 38: OTDR with an event dead zone of 3m

The attenuation (or non-reflective) **dead zone** is the minimum distance, after a reflective event, for the OTDR to measure a loss due to a reflective or a non-reflective event. The shorter the attenuation dead zone, the better the results. The norm for this specification varies from 3 to 10 meters. The following schemes shows two examples of an OTDR with attenuation dead zone of 10m (Figure 39) and of 3m (Figure 40).

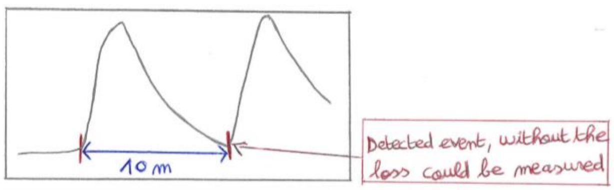


Figure 39: OTDR with an attenuation dead zone of 10m

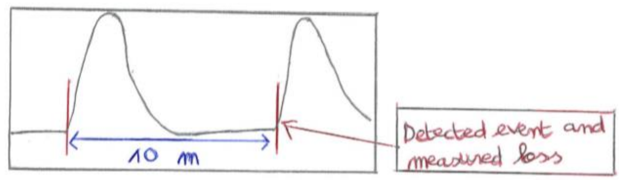


Figure 40: OTDR with an attenuation dead zone of 3m

The sampling resolution for an OTDR is defined as the minimum distance between two consecutive sampling points acquired by the instrument. This parameter is crucial since it determinates the distance and the OTDR location capability concerning the breakage or cracks in the fiber.

4.4 Reflectometry measurements for one optical fiber in the distribution network

To realize these measurements, going on the ground to utilize the reflectometer was necessary to concretely see how the measurement traces are performed.
For the distribution network part, as said before, only the wavelength λ=1310nm is injected in only one direction. The distance 0m correspond to the end of the input coil which is utilized to minimize imprecision of the measurement due to the dead zone and to represent the beginning of the tested fiber. Indeed, the coils allow to leave the dead zone and to characterize the input and output connectors. To properly choose the coils, the coils' connectors and those present in the tested network must be of the same nature (single-mode). Here, the measurements are performed for single-mode fibers (SMF).

4.4.1 Event threshold values for the reflectance, losses and slope through the OTDR trace

The trace of the OTDR informs the different events which can occur between the moment where the light enters in the fiber up to the end. Events like losses or gains due to the splices, the Fresnel reflectance peak originating from connectors, the noise floor at the end of the output coil and the corresponding slope values between two events are directly identified on the trace. The threshold values imposed by our client for every event are specified in the Table 7 below.

Table 7: Threshold values for events in the OTDR trace

Characterization of the OTDR trace	Threshold value
Splice loss (dB)	≤ 0.15
Reflectance at level of connectors (dB)	≤ - 50
Loss at level of connectors (dB)	≤ 0.5
Slope (dB/km)	≤ 0.35

4.4.2 Reflectance testing by OTDR

Reflectance (called also “back reflection” or “optical return loss”) of a connection is the amount of light that is reflected back up the fiber toward the source by light reflections off the interface of the polished end surface of the mated connectors and air. The reflectance is defined as the ratio between the reflected power Pr and the incident power Pi (4.3). It is also called Fresnel reflection (Figure 41) and is caused by the light going through the change in index of refraction at the interface between the fiber and air. These sudden changes in density occur at the level of connectors and at fiber breaks.

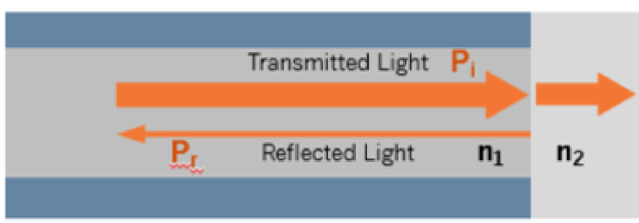


Figure 41: Fresnel reflectance ([11] Luna)

Generally, connectors will show reflectance peaks on OTDR traces, mechanical splices may show reflectance peaks and fusion splices will show no reflectance. In this study, there are only fusion splices to bring the optical fibers together and hold them, thus making the transmission of the optical signal through the join possible. The measurements performed on the ground, in particular for the specific fiber we decided to deal with, show a reflectance peak value of -70.15dB at the input connector, linking the input coil and the tested fiber (Figure 42) thus according to the Table 7, this obtained value is suitable with respect to the threshold value -50dB. We could also observe a loss (0.148dB) at the junction located at 2829m (Figure 45), a gain at 3508m (see Figure 44) and the slope value between two splices (Figure 51 in the appendix). The noise floor at the junction between the end of the output coil and the air is equal to -41.48 dB (see Figure 52 in the appendix).
The calculation of the reflectance value is given by the following formula:

$$\text{Reflectance R (dB)} = 10 * \log_{10} \frac{\text{Reflected power}}{\text{Incident power}} \quad (4.2)$$

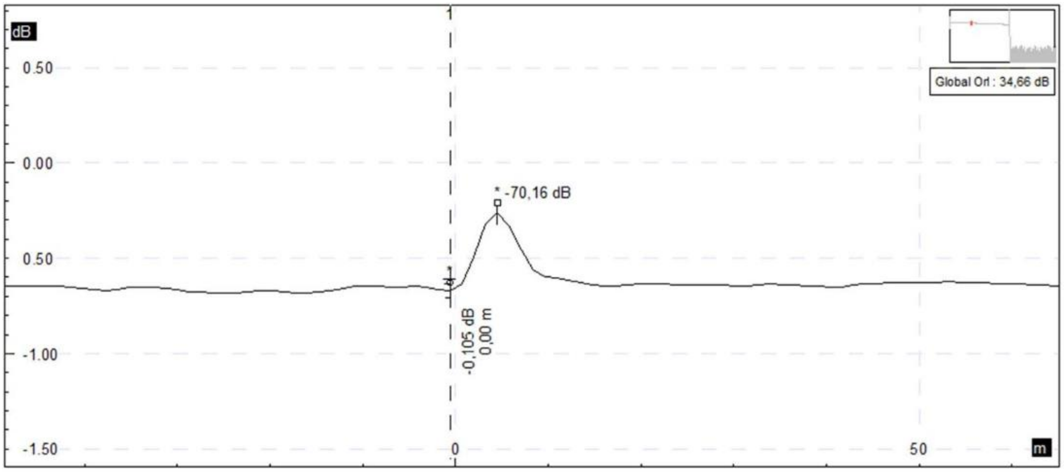


Figure 42: **Fresnel reflectance at the input of one optical fiber**

4.4.3 Measurement of the fusion splice loss

At first, the splice loss corresponds to the part of the optical power which is not transmitted through the splice. The total loss at the fusion splice is translated by the following equation:

$$\alpha_{splice}(dB) = 10 * \log_{10} \frac{P_{in}}{P_{trans}} \tag{4.3}$$

where P_{in} is the total power incident on the fusion splice and P_{trans} is the portion of the optical power transmitted across the fusion splice.

Since $P_{in} > P_{trans}$, the splice loss (4.4) is always a positive number. The important advantage of fusion splice is the relatively small amount of optical power reflected ([18] Thollabandi). Besides, the splice loss is computed from the bi-directional average of the two uni-directional OTDR measurements as shown by the equation (4.5). Furthermore, the maximum apparent splice loss seen by uni-directional OTDR measurement [15] can be calculated with equation (4.6). The measurements realized on the ground shows that the splice loss at the junction between two fibers can be a positive number (Figure 44), but it can be also a negative number and thus interpreted as a gain (Figure 45 in the appendix). Thus, it is interesting to try to explain how such a gain can appear in the OTDR trace.

4.4.3.1 OTDR backscatter behavior for spliced fibers with different mode field diameter

The mode field diameter (MFD) corresponds to the section of the fiber where the most of the light energy travels (Figure 43). It gives the effective width of the field distribution inside the optical fiber. Related to the diameter of the fiber core, generally, MFD is greater than the physical diameter of the fiber core which means that some optical power is always guided by the fiber cladding.
In telecoms, the core diameter is around 9 µm. For the FTTH network, two specific fibers can be used such as G.657 fibers (mostly used for FTTH network) and G.652 fibers compatible with the previous one.
The G.657 fibers are the new bending-loss insensitive single-mode optical fibers ([8] ITU). These fibers are coming into widespread use in all the access network. Today, G.652 fibers are more used. G.657 and G.652 fibers are compatible and thus it is possible to meet on the ground a G.657 connected with a G.652. The G.657 fibers, throughout their first deployment surprised with the observation of "gains" during the reflectometry measurements. It comes to the fact that, as mentioned previously, the mode field diameters MFD are slightly different and it influences on the Rayleigh backscattering (known phenomenon obtained by doing the measurement on each side in accordance with the IEC standard).
One of the largest suppliers of optical fiber is the ACOME company. We wondered about what will happen when a splice concerns two fibers of the same nature or if the splice is performed between two different fibers like a G.657 with a G.652 fiber ([14] Gerard Paris). We assume that this is certainly due to a MFD difference. The higher the MFD mismatch between two fibers, the higher the calculated loss.

The backscattering capture fraction B(λ, z) of an optical fiber, one of the parameters of the backscatter power P(z) (4.7) ([12] Ohashi), is inversely proportional to the MFD. In fact, the greater the difference in MFD between two spliced fibers, the greater the variance in backscatter. The backscatter capture fraction B(z) describes the proportion of light energy that is scattered by the structure of the glass at points z along fiber which is captured by the fiber in the return direction. Therefore, B(λ, z) describes factors related to fiber design, which include the core geometry, the refractive properties of the core and cladding (i.e. index profile) and material composition (glass and dopants).

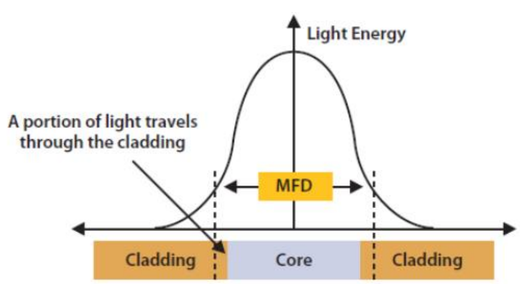


Figure 43: The MFD of single-mode fiber

Thus, when two fibers of dissimilar MFD are spliced together, measurable differences in the OTDR backscattered signal will occur. When measuring from a fiber with a larger MFD to one with a smaller MFD, the OTDR measurement will result in a "gainer" ([10] Littlejohn)
Inversely, when the measurement is performed from a smaller MFD to a larger MFD, the measure will result in an "exaggerated loss". To continue, the higher the MFD mismatch, the higher the loss values.

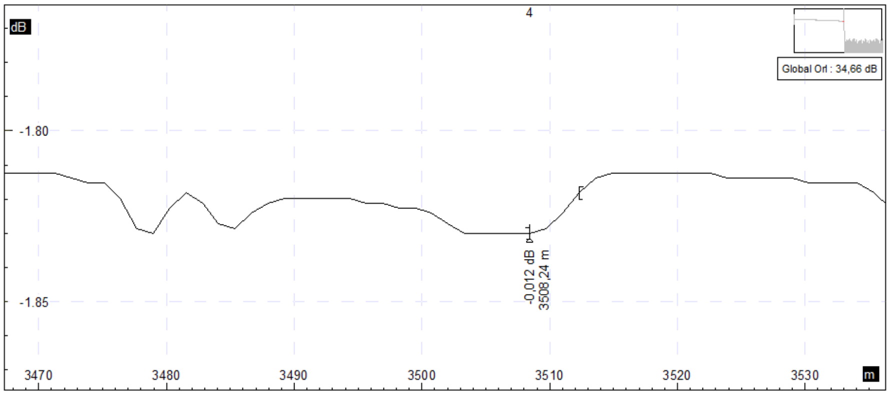


Figure 44: Gain (value in dB > 0) at the junction between two fibers

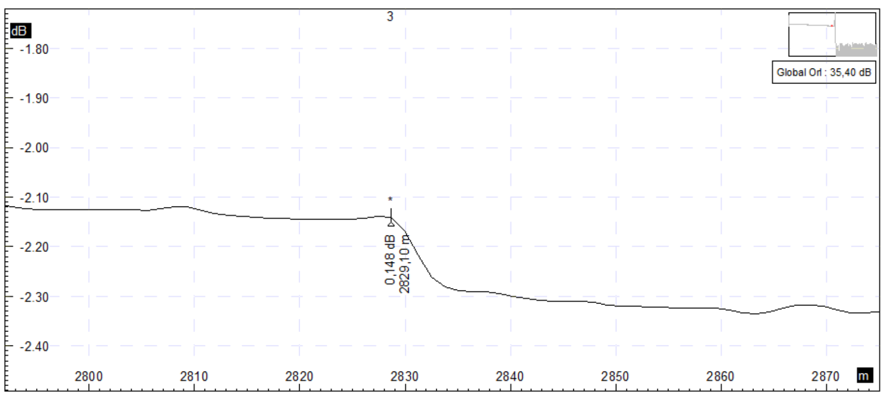


Figure 45: Loss (value in dB < 0) at the junction between two fibers

$$\text{Uni-directional OTDR Loss (dB)} = 10 * \log_{10}\frac{\text{MFD}_{B/A}}{\text{MFD}_{A/B}} \quad (4.4)$$

$$\text{Maximum Loss}_{\text{OTDR Error}}\text{(dB)} = \left|10 * \log_{10}\frac{\text{MFD}_{\max}}{\text{MFD}_{\min}}\right| \quad (4.5)$$

$$P(z) = P_0 * \alpha_s(z) * B(\lambda,z) * \exp\left[-2\int_0^z \gamma(x)dx\right] \quad (4.6)$$

where P_0 (watts) is the input power, $\alpha_s(z)$ the local scattering coefficient which is non-dimensional quantities expressed relative to the scattering coefficient of 1 m^{-1}, $\gamma(z)$ the local attenuation coefficient (dB/km) and B(z) the backscattering capture fraction (dimensionless). With conventional SMF, the variation in the local scattering coefficient $\alpha_s(z)$ is negligible compared to the MFD.
The backscattering power (4.9) encompass the real power P_{real} (4.8), namely the power presents in each point of the fiber, composed of the input power and a function ($\exp\left[-2\int_0^z \gamma(x)dx\right]$) to translate the

attenuation along the fiber. But the technique used by the reflectometer allows to determine only the backscatter power of the different events in the fiber.

$$P_{real}(z) = P_0 * \exp\left[-2\int_0^z \gamma(x)dx\right] \tag{4.7}$$

$$P_{back}(z) = P_{real} * \alpha_s(z) * B(z) = P(z) \tag{4.8}$$

To confirm the theory telling that a MFD difference between two spliced fibers creates the apparition of the gain and the loss, we spliced a SMF (around 9 µm) to a MMF (around 52 µm) and a MMF to a SMF in series with a coil at the input and the output of the network (Figure 46) to perform measurements.

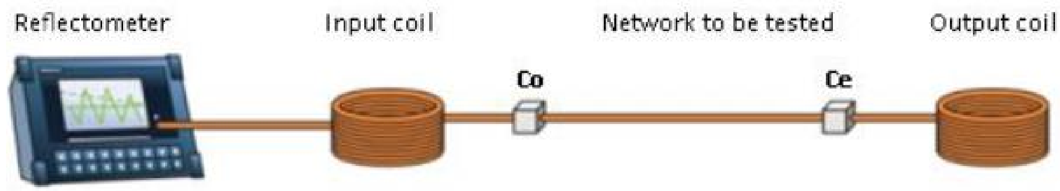


Figure 46: Illustration of the reflectometry measurement method

This type of configuration is unlikely, if ever, to emerge in a FTTH network which is a public communication network. However, this configuration can appear through a private network such as in a company for example. Furthermore, to realize this measurement, two different wavelengths have been emitted, λ=1310nm and λ=1550nm. A reflectometer for single-mode fiber has been used through a single mode network including a multi-mode section. The obtained traces for the different wavelengths are informed in the appendix. Furthermore, for this experiment, we don't pay attention to the threshold values imposed by the client. The aim here consists of having a response to our hypothesis.
The tables below indicate the obtained values for the reflectance, splices and the slopes for each section.
At λ=1310nm (Figure 53 in the appendix), the obtained reflectance at the joining between the input coil and the SMF is rather high **(-47.23dB),** above the threshold -50dB. Generally, to respect the threshold value, cleaning the connector or replacing it can be the possible solutions since the presence of dirt is the main cause of the problems in the optical networks [16]. Furthermore, it is noticeable that the loss obtained **(0.64dB)** within the connector at the input of the network joining the input coil to the single mode fiber (Table 8) is rather higher than the threshold imposed by the client which is **0.5dB**. Otherwise, due to the MFD difference between the two types of fibers (SMF and MMF), from the input to the end of the network, the splice measurements display a loss of 1.73dB at the first splice (Table 8) then a gain at the following splice **(-0.11dB).** In the opposite direction (EO) (Figure 46), the obtained value is **1.74dB**, making a splice average for both directions of 0.81 dB. Besides, concerning the slope values (Table 9), excepted for the slope 2 where the obtained slope is not significant, the other values are in accordance with the threshold imposed by the client. Then the macro allows to display the OTDR trace of the superposition of the 2 directions of light propagation to compute the average for λ=1310nm (Figure 55)**.**

Table 8: Splices and Connectors (dB) at λ=1310nm

Connector O			Splice N° 1			Splice N° 2			Connector E		
OE	EO	Average	OE	EO	Average	OE	EO	Average	OE	EO	Average
0,64	0,47	***0,56***	1,73	0,05	***0,89***	-0,11	1,74	***0,81***	0,11	0,05	**0,08**

Table 9: Slope (dB/km) at λ=1310nm

Slope N° 1			Slope N° 2			Slope N° 3		
OE	EO	Average	OE	EO	Average	OE	EO	Average
0,34	0,36	0,35	0,57	0,70	*0,64*	0,33	0,35	0,34

At λ=1550nm, at the distance 2717m, from the MMF to the SMF, a gain is noticeable (**-0.24dB)** (Table 10). But we can also observe a reflectance at this junction (Figure 56), which is abnormal. A splice should not present a reflectance. This is probably due to the fact that our splice has not been well performed. Otherwise, the values at the different splices, in each direction, allow to observe the gain and the loss that we were looking for during this experiment. The slope values (Table 11), in this case too, are in accordance with the threshold imposed by the client (<0.35dB/km). The OTDR trace from the end up to the source (EO) (Figure 57) allows to perform the average of both propagation directions of light (see Figure 58).

Theoretically, the values obtained at the connector and at the different splices with the wavelength **λ=1550nm** should be lower than those obtained with **λ=1310nm**. If it is not the case, the client authorized a margin of 0.05dB. This comparison is indispensable to notice if there are some constraints within the optical fibers. With respect to the results achieved, it is notable that an incoherence can be seen at the input connector (Connector O) where the average achieved for λ=1550nm (0.87 dB) is higher than the average for λ=1310nm (0.56dB). This incoherence could occur when the optical fiber is not correctly curled up. This is due more to an installation problem of the fiber than to the fiber itself.

Table 10: Splices and Connectors (dB) at λ=1550nm

Connector O			Splice N° 1			Splice N° 2			Connector E		
OE	EO	Average	OE	EO	Average	OE	EO	Average	OE	EO	Average
0,95	**0,78**	***0,87***	**1,58**	**-0,15**	***0,72***	**-0,24**	**1,63**	***0,70***	**0,07**	**0,06**	**0,07**

Table 11: Slope (dB/km) at λ=1550nm

Slope N° 1			Slope N° 2			Slope N° 3		
OE	EO	Average	OE	EO	Average	OE	EO	Average
0,24	0,24	0,24	0,32	0,41	*0,37*	0,19	0,20	0,20

Fiber attenuation assumes different values depending on the central wavelength (frequency) and three optical windows can be recognized around the lowest attenuations. In Figure 47, spectral occupation for each of them is indicated according to the wavelength:

- 1st window around 980nm
- 2nd window around 1300nm, it is also called O-band
- 3rd window between 1530 and 1570nm, called C-band

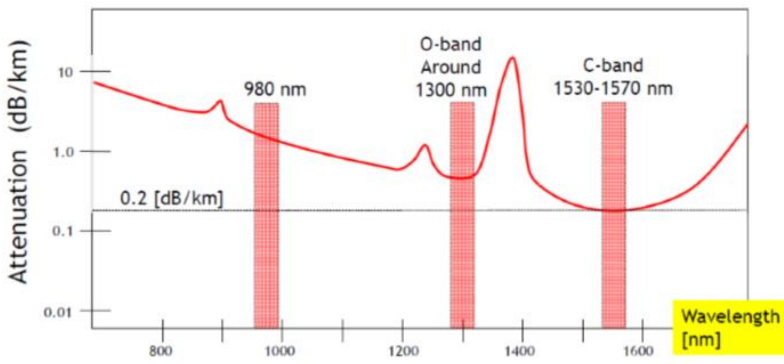


Figure 47: Fiber attenuation (dB/km) as a function of wavelength (nm) [6]

4.4.3.2 OTDR backscatter behavior for spliced fibers with different attenuations sharing the same MFD specifications

When the OTDR looks at the returning signal to calculate loss based on the declining amount of light it sees coming back, it is notable that the light scattered is not a constant. It is a function of the attenuation of the fiber and the diameter of the core of the fiber. Higher attenuation fiber has more attenuation because the glass in its core scatters more light.

If both fibers are identical (Figure 48), the backscattering will be the same on both sides of the joint ([17] FOA). Thus, the OTDR measure the actual splice loss. We assume that the local scattering coefficient $\alpha_s(z)$ is the same on both sides, thus the slopes before and after the splice is identical. The measured loss corresponds by definition to the actual loss plus a loss of error, and is, in this case similar.

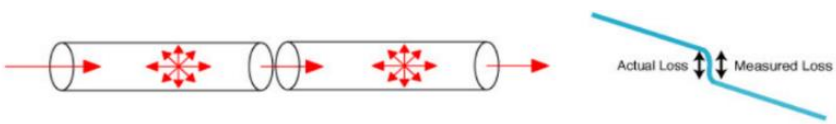


Figure 48: Splicing between two identical fibers

However, if the fibers are different in terms of attenuation, the backscatter coefficients will cause a different percentage of light to be sent back to the OTDR. In the case where the first fiber has more attenuation than the one after the connection (Figure 49), the percentage of light from the OTDR test pulse will go down, so the measured loss on the OTDR will include the actual loss plus a loss error caused by the lower backscatter level, making the displayed loss greater than it actually is.

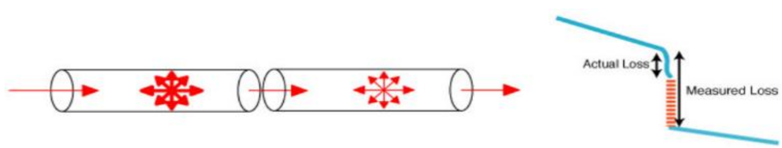


Figure 49: Splicing between two fibers with different attenuation 1

By looking at the opposite situation (Figure 50), from a low attenuation fiber to a high attenuation fiber, we find the backscatter goes up, making the measured loss seem less than it actually is. When splicing dissimilar fiber types, larger changes in uni-directional OTDR backscatter are to be expected as a result of differences that may exist in the intrinsic glass properties of the fibers being spliced together [4]. These can be due to differences in fiber manufacturing processes depending on the manufacturer (Table 12 in the appendix), glass composition, or differences in the fiber refractive index profile design (Figure 60 in the appendix). For example, splicing conventional G.652 to ultra-low loss technologies such as SMF-28® ULL fiber, results in larger "gainers" and "exaggerated losses" due to glass composition and fiber design differences although they share the same MFD specifications.

Figure 50: Splicing between two fibers with different attenuation 2

CHAPTER 5

5 CONCLUSIONS

The progress made in telecommunications sector are so great and rapid that transmission system structures is all undergoing changes. The purpose of this thesis was to bring a project to fruition, starting with the network design of given areas and then studying the reflectometry part.
Through this work, we have come to deal with one preliminary designs (APS) and multiple final designs (APD) allowing to know in much broader way how the project is treated as a whole since each study is different, unique and has its proper constraints requiring a certain reflection.
Concerning the preliminary design, once the technical points, fiber distribution boxes, address and the different subscribers has been informed, the part requesting the most creativity is the laying cable from the outdoor fiber optic cross connect cabinet up to the fiber optic distribution boxes because there are several ways to deploy the optical fiber cables. We tried to optimize this design in order to limit the costs but there is certainly a better optimized model.
The time between the end of the preliminary design and the start of the final design study can last one month or more since the technicians or subcontractors have to go on the ground to notice if the cable deployment is feasible. In the meantime, we decided to treat a new project with a preliminary design already performed. For this reason, we had to adapt to the new project by discussing with the person who realized it so as to clearly understand the way he proceeded the preliminary design. The different final designs treated during the whole project allow to analyze the problems which can occur on the ground and rethink a new design to, at the same time, satisfy the requirements of the clients and connect all subscribers. The approach concerning these two stages which we had to deal with is rather different since contrary to the preliminary design where we have to create a circuit for the cable deployment up to the subscribers, the final design leans on the reality and the constraints of the ground.

Throughout this thesis, I could attend meetings with the clients and follow the evolution of the different projects. During these meetings, I could propose solutions to the different constraints met on the ground and plan the duration of the project's realization.
The reflectometry part was not expected at the beginning of this thesis. It was interesting to do a study because it allows to adjust the last parameters to validate our project. After receiving the measurements realized on the ground and noticed the apparition of gains in the trace, it looked interesting to explain the reasons since the presence of losses at the splice between two fibers was obvious for me, but not the presence of gains. We have seen that a mode field diameter difference is the main factor explaining the losses and gains depending on the propagation direction of light. Because of lack of resources, I could not hold of the technical characteristics of the different types of fibers met on the ground like the MFD or the supplier names, always with the aim to explain the gains and losses apparition. After splicing a single-mode fiber (SMF) and a multi-mode fiber (MMF) in the design office, we could validate our hypothesis. Indeed, our measurements, performed by making the average of both direction propagations contrary to measurements realized on the ground due to the client's requirements, gave us significant results.
Finally, this business experience offered me a good preparation for my professional integration strengthens my aim to be a telecommunications engineer.

APPENDIX

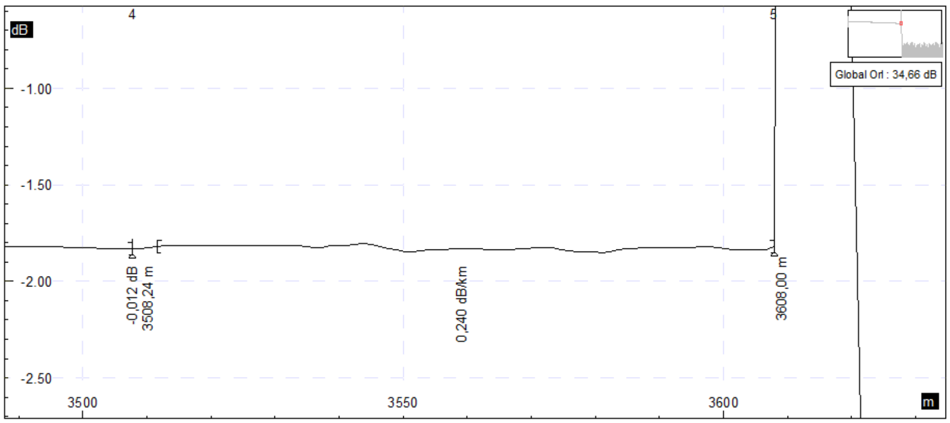


Figure 51: Slope (in dB/km) between two events

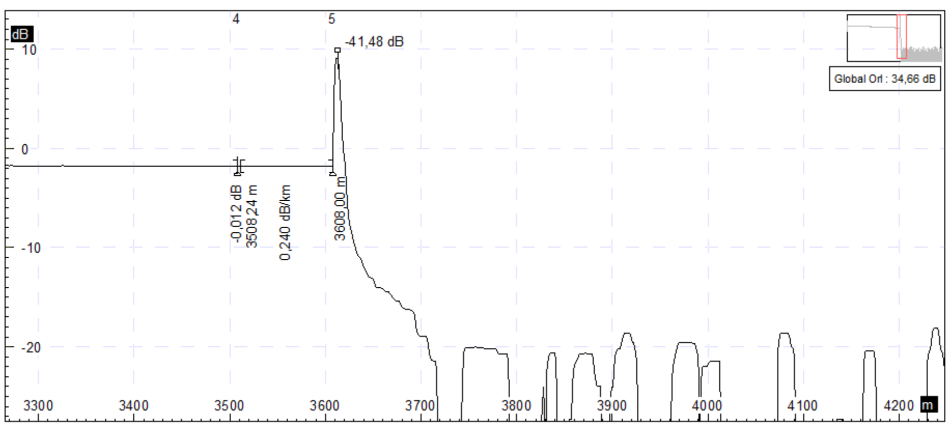
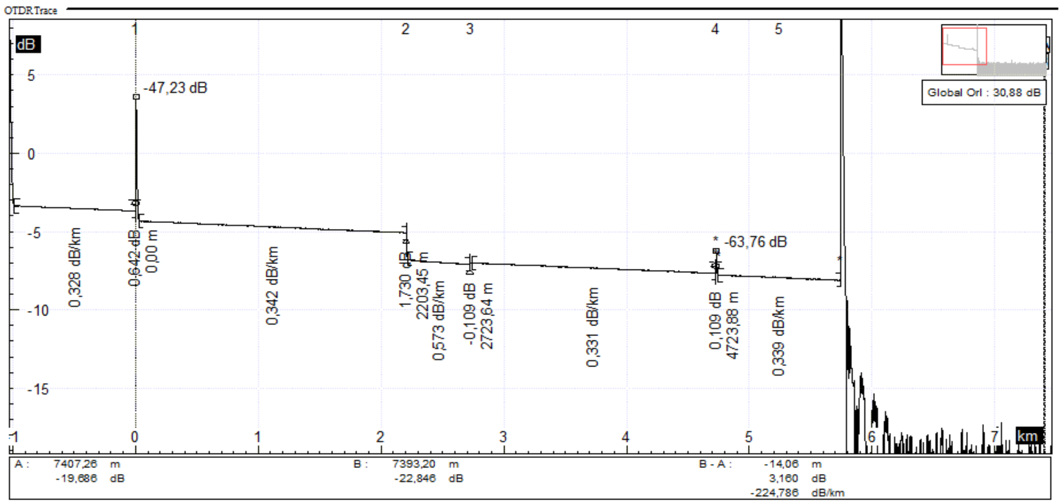


Figure 52: Noise floor at the end of the network



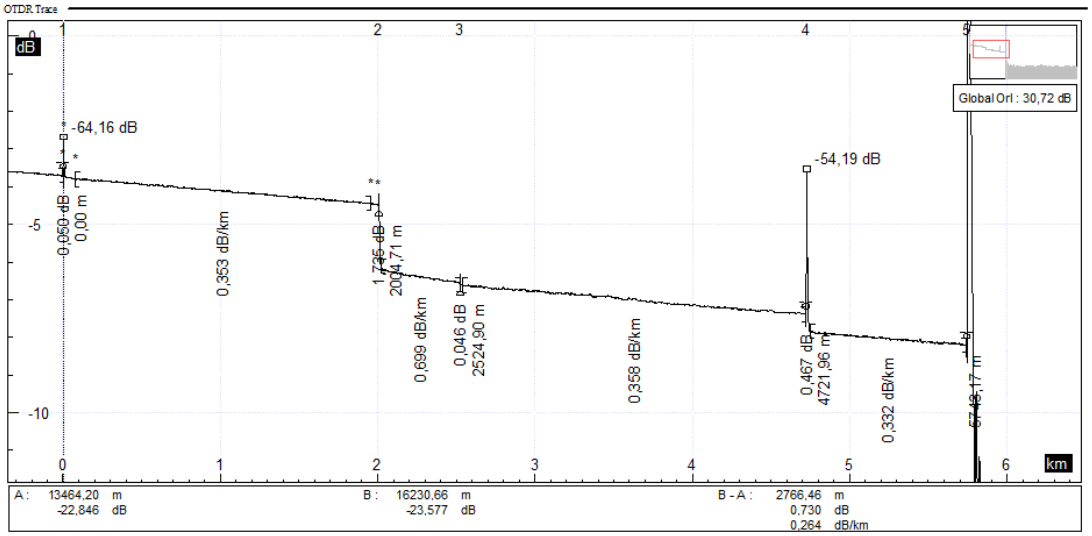
Table

	Event (5)	Distance (m)	Loss (dB)	Reflectance (dB)	Slope (dB/km)	Rel. Dist. (m)	Section loss (dB)	Total loss (OTDR) (dB)
1		0,00	0,642	-47,23	0,328	1026,96	0,337	
2		2203,45	1,730		0,342	2203,45	0,753	1,395
3		2723,64	-0,109		0,573	520,19	0,298	3,424
4		4723,88	0,109	-63,76	0,331	2000,24	0,662	4,086
5		5739,97			0,339	-10,86	0,345	

Figure 53: OTDR trace from the source up to the end (OE) for λ=1310nm

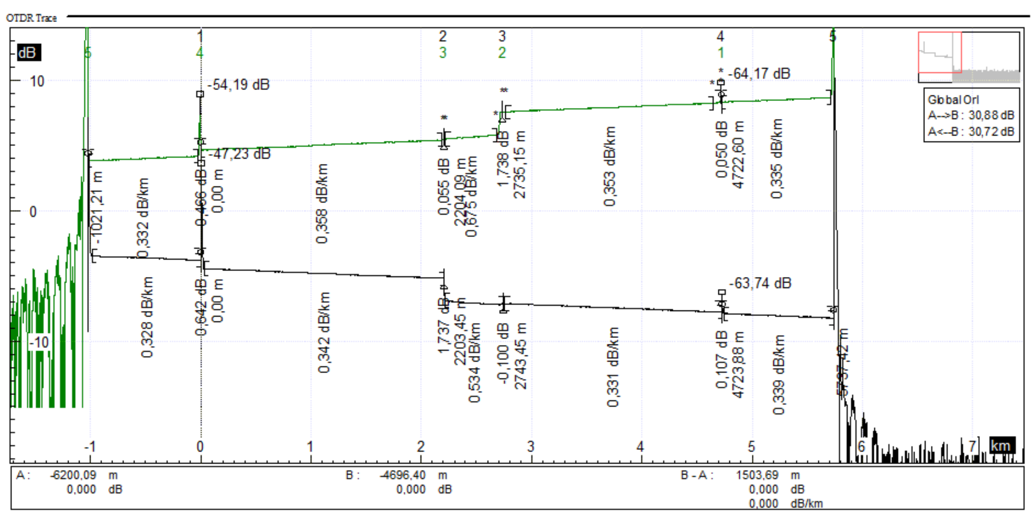
This are the results of our simulation between a SMF 1 and a MMF and this MMF with another SMF 2 in order to see what happens at the junctions when the light propagates. These measurements are independent of the requirements of the clients which imposed us to perform the measures only in one direction. Thus, we didn't care about the threshold that we had to pay attention. Here, through the Figure 56 and Figure 59, we performed the average of both directions with different values of the wavelength (λ=1310nm and λ=1550nm) to realize the comparison and notice if there are contradictions or not.

In Figure 56, for λ=1310nm, we notice a loss (1.730 dB) at the junction between the SMF 1 and the MMF (at 2202.45m) and a negative value at 2723.64 m between the MMF and the SMF 2 which is in accordance with our theory concerning the difference of mode field diameter. In Figure 55, the light propagates in the opposite direction. So, the event 2 at 2004.71m correponds to the junction between SMF 2 and the MMF and the event 3 at 2524.90m corresponds to the splice between the MMF and the SMF1. At this splice, we should get a negative value but here we obained 0.046 dB, which is a very low value, so we can consider this value as null. Then, we performed similar measurements with λ=1550nm.



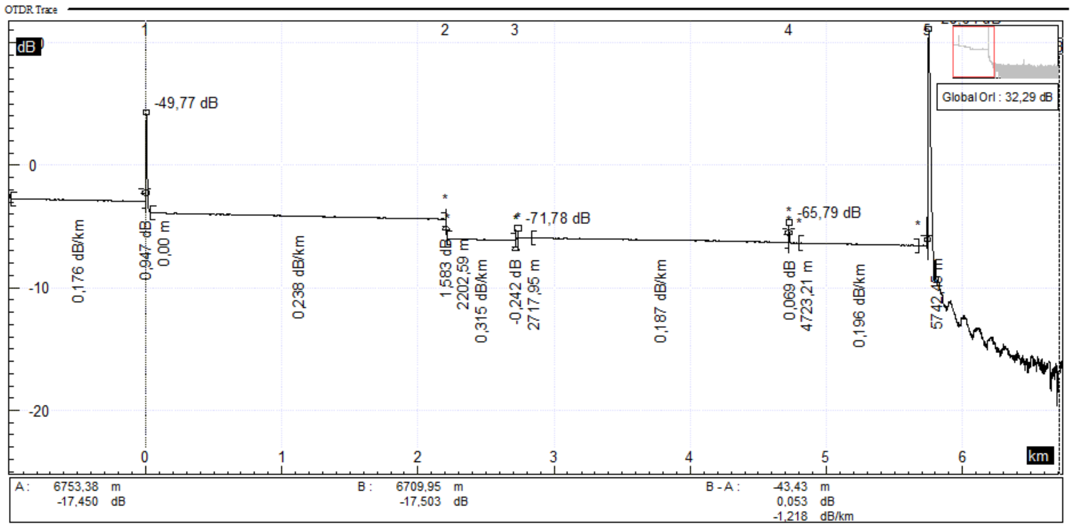
	Event (5)	Distance (m)	Loss (dB)	Reflectance (dB)	Slope (dB/km)	Rel. Dist. (m)	Section loss (dB)	Total loss (OTDR) (dB)
1		0,00	0,050	-64,16	0,334	1023,76	0,342	
2		2004,71	1,735		0,353	2004,71	0,708	0,758
3		2524,90	0,046		0,699	520,19	0,364	2,856
4		4721,96	0,467	-54,19	0,358	2197,06	0,786	4,155
5		5743,17			0,332	1021,21	0,339	

Figure 54: OTDR trace from the end up to the source (EO) for λ=1310nm



Direction A-->B (5)	Direction A<--B (5)	Distance (m)	Loss (dB)	Loss (dB)	Average (dB)	Slope (dB/km)	Slope (dB/km)	Average (dB/km)	Reflectance (dB)	Reflectance (dB)
	5	-1021,21								
1 ✖	4	0,00	0,642	0,466	✖ 0,554	0,328	0,332	0,330	✖ -47,23	-54,19
2 ✖	3*	2203,45	1,737	0,055	✖ 0,896	0,342	0,358	0,350		
3 ✖	2*	2743,45	-0,100	1,738	✖ 0,819	0,534	0,675	✖ 0,604		
4	1*	4723,88	0,107	0,050	0,079	0,331	0,353	0,342	-63,74	-64,17
5		5737,42				0,339	0,335	0,337		

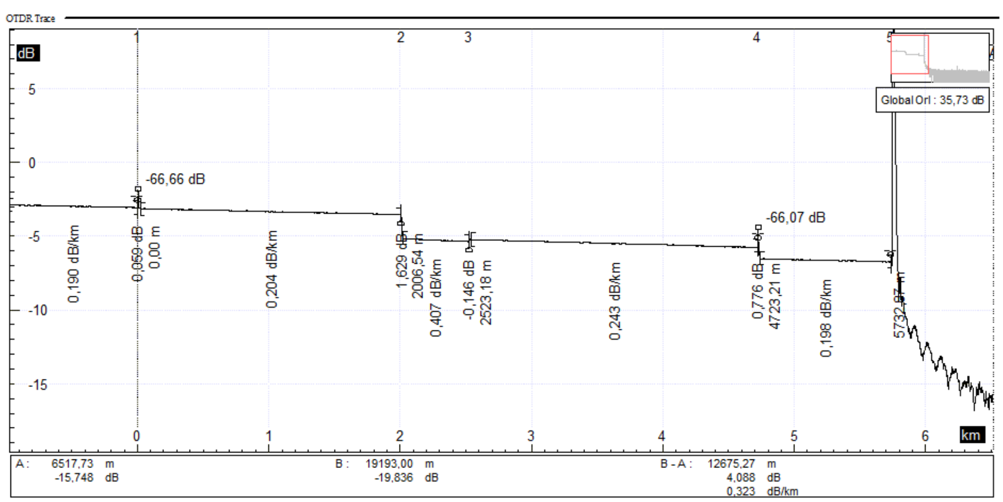
Figure 55: OTDR trace of the superposition of the 2 directions of light propagation for λ=1310nm



Table

	Event (5)	Distance (m)	Loss (dB)	Reflectance (dB)	Slope (dB/km)	Rel. Dist. (m)	Section loss (dB)	Total loss (OTDR) (dB)
1		0,00	0,947	-49,77	0,176	1026,90	0,180	
2		2202,59	1,583		0,238	2202,59	0,523	1,470
3		2717,95	-0,242	-71,78	0,315	515,36	0,162	3,215
4		4723,21	0,069	-65,79	0,187	2005,26	0,376	3,418
5		5742,45		-28,61	0,196	1019,23	0,200	

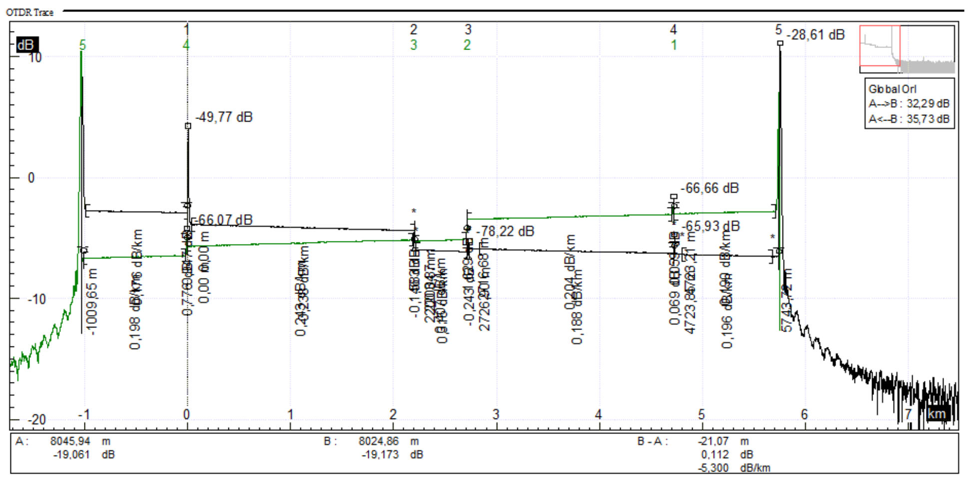
Figure 56: OTDR trace from the source up to the end (OE) for λ=1550nm



Table

	Event (5)	Distance (m)	Loss (dB)	Reflectance (dB)	Slope (dB/km)	Rel. Dist. (m)	Section loss (dB)	Total loss (OTDR) (dB)
1		0,00	0,059	-66,66	0,190	1023,06	0,194	
2		2006,54	1,629		0,204	2006,54	0,409	0,468
3		2523,18	-0,146		0,407	516,64	0,210	2,307
4		4723,21	0,776	-66,07	0,243	2200,04	0,536	3,473
5		5732,87			0,198	1009,65	0,200	

Figure 57: OTDR trace from the end up to the source (EO) for λ=1550nm



Table

Direction A-->B (5)	Direction A<--B (5)	Distance (m)	Loss (dB)	Loss (dB)	Average (dB)	Slope (dB/km)	Slope (dB/km)	Average (dB/km)	Reflectance (dB)	Reflectance (dB)
	5	-1009,65								
1	4	0,00	0,947	0,776	× 0,861	0,176	0,198	0,187	-49,77	-66,07
2*	3	2203,87	1,583	-0,146	× 0,719	0,238	0,243	0,241		
3*	2	2726,90	-0,243	1,629	× 0,693	0,315	0,407	0,361	-78,22	
4*	1	4723,85	0,069	0,059	0,064	0,188	0,204	0,196	-65,93	-66,66
5		5743,72				0,196	0,190	0,193	-28,61	

Figure 58: OTDR trace of the superposition of the 2 directions of light propagation for λ=1550nm

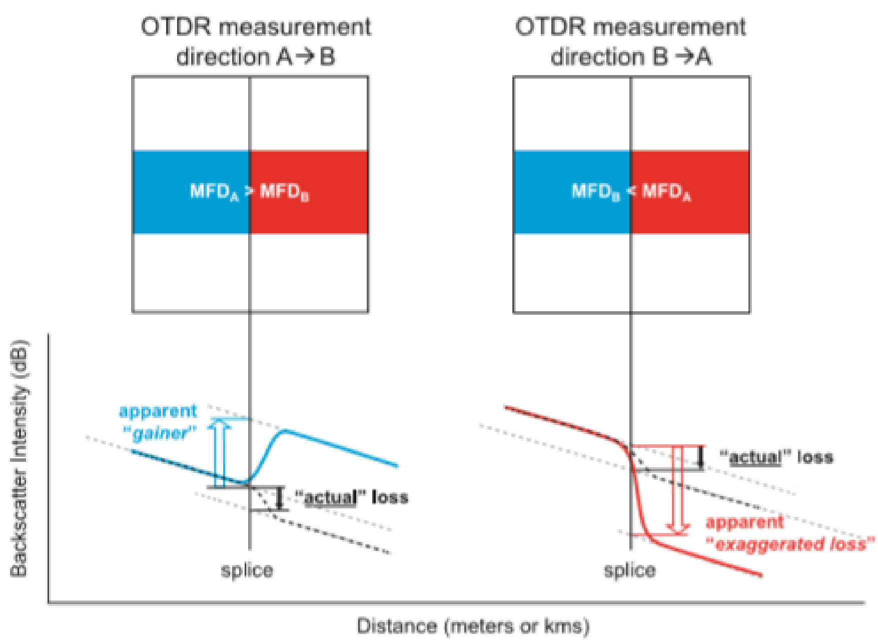


Figure 59: Illustration of OTDR backscatter trace behavior at splice location between fibers of different MFD [4]

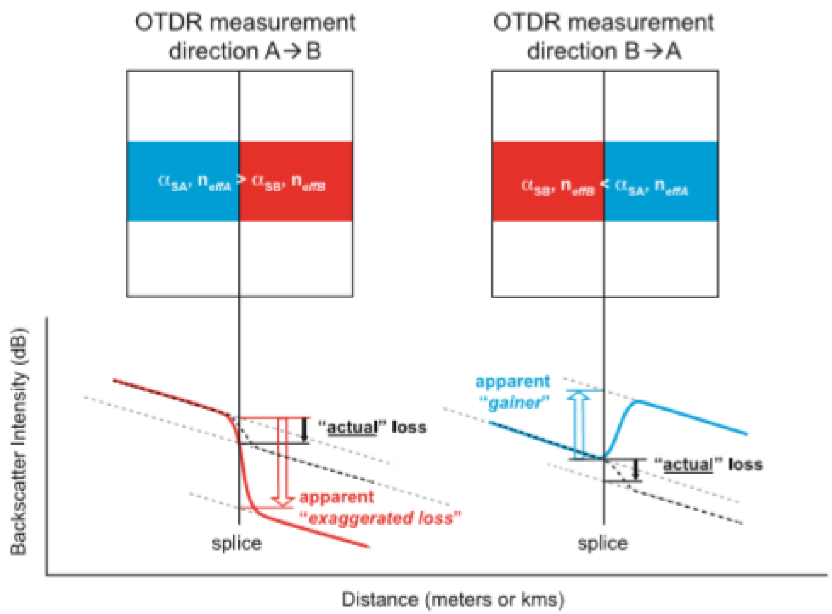


Figure 60: Illustration of OTDR backscatter trace behavior at splice location between heterogeneous splice junctions with different optical fibers properties as scattering coefficient αs and group refractive index, neff [4]

Table 12: Splicing compatibility between fibers [14]

Soudeuse Fujikura 50S Mode automatic				
A	B	Perte A=>B	Perte B=>A	Perte Moy
G657 ACOME	G657 ACOME	0,04	0,06	0,05
G657 ACOME	G657 ACOME	0,04	0,00	0,02
G657 ACOME	G657 ACOME	0,08	0,01	0,05
G657 ACOME	G657 Autres	0,16	-0,08	0,04
G657 ACOME	G657 Autres	0,19	-0,09	0,05
G657 ACOME	G657 Autres	0,20	-0,05	0,08
G657 ACOME	G652 ACOME	0,18	-0,13	0,03
G657 ACOME	G652 ACOME	0,21	-0,13	0,04
G657 ACOME	G652 ACOME	0,20	-0,15	0,03
G657 ACOME	G652 Autres	0,29	-0,23	0,03
G657 ACOME	G652 Autres	0,36	-0,18	0,09
G657 ACOME	G652 Autres	0,29	-0,24	0,03
G657 ACOME	G657 Autres	-0,14	0,23	0,05
G657 ACOME	G657 Autres	-0,15	0,22	0,04
G657 ACOME	G657 Autres	-0,16	0,22	0,03

Table 13: Price per linear meter of optical cables [5]

Désignation	U	prix cibles
Câblage	-	
Déroulage de câbles fibre optique Ø 12 à Ø 72 dans les fourreaux Orange par tirage & ou portage	ml	1,00
Déroulage de câbles fibre optique Ø 96 à Ø 144 dans les fourreaux Orange par tirage & ou portage	ml	1,05
Déroulage de câbles fibre optique Ø 288 dans les fourreaux Orange par tirage & ou portage	ml	1,10
Déroulage de câbles fibre optique Ø > 288 dans les fourreaux Orange par tirage & ou portage	ml	1,16
Déroulage de câbles fibre optique sur poteaux Orange ou électriques B.T. yc armements	ml	2,41
Déroulage de câbles fibre optique sur façade	ml	6,64
Portage de câbles fibre dans les fourreaux GC neuf	ml	0,50
Fourniture et pose de poteaux Télécom tout type	U	332,00
Modification de support télécom (offre iBLO, changement, renforcement) forfait au poteau	U	240,70
Sous tubage Rigide	ml	2,32
Sous tubage souple	ml	2,08

Table 14: Price for a box installation on a technical point and for cables runs [5]

Désignation	U	Prix cibles
Optique		
Prépa. et racco. d'un câble 12 fo y compris pose de la boite joint droit	U	165,84
Prépa. et racco. d'un câble 24 fo y compris pose de la boite joint droit	U	219,54
Prépa. et racco. d'un câble 36 fo y compris pose de la boite joint droit	U	272,03
Prépa. et racco. d'un câble 48 fo y compris pose de la boite joint droit	U	378,22
Prépa. et racco. d'un câble 72 fo y compris pose de la boite joint droit	U	484,41
Prépa. et racco. d'un câble 96 fo y compris pose de la boite joint droit	U	572,70
Prépa. et racco. d'un câble 144 fo y compris pose de la boite joint droit	U	696,79
Prépa. et racco. d'un câble 288 fo y compris pose de la boite joint droit	U	1333,91
Prépa. et racco. d'un câble 432 fo y compris pose de la boite joint droit	U	1971,04
Prépa. et racco. d'un câble 576 fo y compris pose de la boite joint droit	U	2529,43
Prépa. d'un câble 12 fo y compris pose de la boite joint blanc	U	119,31
Prépa. d'un câble 36 fo y compris pose de la boite joint blanc	U	131,24
Prépa. d'un câble 48 fo y compris pose de la boite joint blanc	U	155,11
Prépa. d'un câble 72 fo y compris pose de la boite joint blanc	U	178,97
Prépa. d'un câble 96 fo y compris pose de la boite joint blanc	U	226,69
Prépa. d'un câble 144 fo y compris pose de la boite joint blanc	U	369,87
Prépa. d'un câble 288 fo y compris pose de la boite joint blanc	U	477,25
Prépa. d'un câble 432 fo y compris pose de la boite joint blanc	U	553,61
Prépa. d'un câble 576 fo y compris pose de la boite joint blanc	U	656,22
Pose d'un PBO en sous-terrain	U	143,18
Pose d'un PBO en aérien	U	209,99
Pose d'un PBO en façade	U	209,99
Mesure optique au PBO en desserte	U	66,82

Table 15: Engineering rule concerning the maximum number of subscribers through PBOE located on poles or facades [5]

COVAGE	Covage Networks	Version du doc v3A
	Règle ingénierie FTTH v3A - VF3A	Page 15 sur 24

4.2 PBO Aérien : PBO Commscope (FIST-BD)

La règle ci-dessous s'appuie sur :

Ce PBO est dimensionné pour accueillir jusqu'à 8 câbles clients maximum.

Il est compatible avec les câbles de distribution dont les caractéristiques sont :

Micro module 6 Fo – câble jusqu'à 96 Fo maximum.

Les PBO sont installé sur le domaine public à proximité direct des logements de sorte qu'il y a maximum 50 mètre de linéaire entre la limite du domaine privée et du domaine public de l'usager final.

Ci-dessous un exemple d'ingénierie pour ce PBO avec 30% de surcapacité :

	Nombre de clients Ab initio	Nombre de fibre nécessaires avec surcapacité	Nombre FO (modulo 6)
PBO	1	2	6
	2	3	6
	3	4	6
	4	6	6
	5	7	12
	6	8	12

Règle d'ingénierie du BPO Souterrain :

De 2 à 8 clients maximum

Calcul du Nb de clients Ab Initio : Arrondi inférieur de 8 / 1.XX

(XX étant le % de surcapacité du projet, soit 30%).

Câble de distribution admis :

Micro Module 6 Fo : câble jusqu'à 96 Fo maximum.

Attention : Afin de ne pas générer de surcapacité de câble trop importante il est préférable, dès que possible, de limiter le nombre de client par PBO à 4 pour ne réserver qu'un tube de 6 Fo dans le cas d'une surcapacité à 30%

COVAGE	Date : 22/07/2019

Table 16: Engineering rule concerning the maximum number of subscribers through PBOE located in underground room [5]

	Covage Networks	Version du doc v3A
COVAGE	Règle ingénierie FTTH v3A - VF3A	Page 14 sur 24

4 Dimensionnement des Points de Branchement Optique (PBO)

4.1 PBO Souterrain : PBO Commscope (OFMC)

La règle ci-dessous s'appuie sur :

Ce PBO est dimensionné pour accueillir jusqu'à 8 câbles clients maximum.

Il est compatible avec les câbles de distribution dont les caractéristiques sont :

Micro module 6 Fo – câble jusqu'à 96 Fo maximum.

Les PBO sont installés sur le domaine public à proximité directe des logements de sorte qu'il y a maximum 50 mètres de linéaire entre la limite du domaine privée et du domaine public de l'usager final.

Ci-dessous un exemple d'ingénierie pour ce PBO avec 30% de surcapacité :

	Nombre de clients Ab initio	Nombre de fibre nécessaires avec surcapacité	Nombre FO (modulo 6)
PBO	1	2	6
	2	3	6
	3	4	6
	4	6	6
	5	7	12
	6	8	12

Règle d'ingénierie du BPO Souterrain :

De 2 à 8 clients maximum

Calcul du Nb de clients Ab Initio : Arrondi inférieur de 8 / 1.XX

(XX étant le % de surcapacité du projet, soit 30%).

Câble de distribution admis :

Micro Module 6 Fo : câble jusqu'à 96 Fo maximum.

Attention : Afin de ne pas générer de surcapacité de câble trop importante il est préférable, dès que possible, de limiter le nombre de client par PBO à 4 pour ne réserver qu'un tube de 6 Fo dans le cas d'une surcapacité à 30%

COVAGE	Date : 22/07/2019

Table 17: Technical characteristics of the different types of PBOE [5]

	Covage Networks	Version du doc v3A
	Règle ingénierie FTTH v3A - VF3A	Page 17 sur 24

6 Matériels Référencés et caractéristiques techniques

6.1 Les PBO

Les boites qualifiées dans les règles d'ingénierie sont listées ci-dessous.

Sont mentionnées les caractéristiques suivantes :

- La référence des boites et leurs fabricants ;
- Le nombre d'épissures maximum acceptable par produit ;
- La capacité maximum du câble en passage acceptée par la boite ;
- Le nombre de câbles en dérivation maximum admissible ;
- Le nombre de câbles client maximum admissible ;
- Le type de boite et son volume pour la location des infrastructures d'Orange ;
- Le nombre et le type de cassette acceptable par le boitier.

Chaque tube réservé dans un PBO sera coupé et stocké dans les cassettes prévues à cet effet.

Version du doc v01.A
Date: 23/06/16
Document: 4 - Materiel reference

Type de PBO reference:

Boites	Epissure Max	Passage Max	Dérivation Max	Raccordement Max	Classification Orange		Nbr de cassette
OFMC (Commscope)	48	96(m6)	0	8x 1fo	µ Manchon	<à 2 dm3	1 x 24 fo
FIST-BD (Commscope)	48	96(m6)	0	8x 1fo	Aérien		1 x 12 fo

COVAGE	Date : 22/07/2019

Table 18: Technical characteristics of the different types of splicing boxes located on poles and facades [5]

COVAGE	Covage Networks	Version du doc v3A
	Règle ingénierie FTTH v3A - VF3A	Page 21 sur 24

6.5 Les BPE pour l'aérien et façade

Une BPE ne pourra mutualiser des liens faisant partie du réseau de transport et des liens faisant partie du réseau de distribution. Aussi, un BPE du réseau de transport ou de distribution ne pourra recevoir de raccordements clients finals.

L'usage des BPE devra être limité aux cas suivant :

- Réalisation d'une dérivation ;
- Réalisation d'un joint droit.

Les boites qualifiées dans les règles d'ingénierie sont listées ci-dessous.

Sont mentionnées les caractéristiques suivantes :

- La référence des boites et leurs fabricants ;
- Le nombre d'épissures maximum acceptable par produit ;
- La capacité maximum du câble en passage acceptée par la boite ;
- Le nombre de câbles en dérivation maximum admissible ;
- Le nombre de câbles client maximum admissible ;
- Le type de boite et son volume pour la location des infrastructures d'Orange ;
- Le nombre et le type de cassette acceptable par le boitier.

COVAGE — Version du doc v01.B
Date: 03/02/17
Document: 5 - Materiel reference

Type de BPE Aérien - reference:

Boites	Epissure Max	Passage Max	Dérivation Max	Raccordement Max	Classification Orange		Nbr de cassette
FIST-BD (Commscope)	48	144 (m6)	1	0	Aérien	Façade	4 x 12 fo
IDB-32 (Commscope)	120	144 (m6)	2	0	Aérien	Façade	5 x 24 fo

Table 19: Lodging capacity of the different underground rooms [5]

COVAGE	Covage Networks	Version du doc v3A
	Règle ingénierie FTTH v3A - VF3A	Page 20 sur 24

6.4 Règle d'hébergement des BPE dans les chambres de Génie Civil

Nombre maximum de BPE admissible par type de chambre (lorsque la chambre est libre de tout équipement).

Caractéristiques des Chambres				Nb Protections d'Épissure maxi selon règle					longueur maxi par Câble Optique en présence de Manchon ou PEO (m)
Type Chb	Longueur Int. (L, M, K, P)	Largeur Int. (L, M, K, P)	Hauteur Int. (L, M, K, P)	µ Manchon (< à 2 dm³)	Manchon (< à 6 dm³)	PEO (< à 10 dm³)	PEO (< à 30 dm³)	PEO (< à 40 dm³)	
L1T	520	380	600	2	0	0	0	0	2
A2/1/2 L4 T	885	520	600	3	2	1	0	0	3
A1/A3/L2T	1160	380	600	3	2	1	0	0	4
L3T	1380	520	600	4	3	1	1	0	4
A4/D1/L4T	1870	520	600	4	4	2	1	1	5
B1/L5T	1790	880	1200	4	4	3	2	1	6
B2/L6T	2420	880	1200	4	4	4	3	2	7
M1	1870	1050	950	4	4	4	4	2	7
M2	3060	1050	950	4	4	4	4	3	8
D2/M3	2370	1050	950	4	4	4	4	3	7
K1C	750	750	750	4	4	1	0	0	3
K2C	1500	750	750	4	4	2	1	0	5
K3C	2250	750	750	4	4	4	2	1	6
C1/D3/P1	2640	1270	1850	4	4	4	4	4	10
C2/D4/P2	3520	1400	1850	4	4	4	4	4	12
E1/P3	4270	1760	1850	4	4	4	4	4	14
C3/P4	5020	1760	1850	4	4	4	4	4	15
E2/E3/P5	4270	1760	2250	4	4	4	4	4	15
E4/P6	5280	2250	2250	4	4	4	4	4	17

COVAGE	Date : 22/07/2019

Table 20: Types of splicing boxes located inside underground room in function of their volume [5]

	Covage Networks	Version du doc v3A
COVAGE	Règle ingénierie FTTH v3A - VF3A	Page 19 sur 24

6.3 Dénomination Orange des BPE qualifiés pour le Génie Civil :

Chaque BPE correspond à une dénomination de boite qui permet de se positionner dans le tableau précédent (µ Manchon, Manchon, PEO)

COVAGE

Version du doc v01.D
Date: 22/06/16
Document: 4 - Materiel reference

Type de BPE en fonction de son volume:			
Produit:	**Fabricant:**	**Volume:**	**Type de boîte:**
OFMC	Commscope	< à 2 dm3	µ Manchon
OFDC	Commscope	< à 6 dm3	Manchon
TENIO T1	Commscope	< à 6 dm3	Manchon
TENIO T2	Commscope	< à 10 dm3	PEO
FIST-GCO2-FC	Commscope	< à 10 dm3	PEO
FIST-GCO2-BC	Commscope	< à 30 dm3	PEO
FIST-GCO2-BD	Commscope	< à 30 dm3	PEO
FIST-GCO2-BE	Commscope	< à 30 dm3	PEO
FIST-GCO2-BF	Commscope	< à 30 dm3	PEO

COVAGE	Date : 22/07/2019

Table 21: Technical characteristics of the different fiber optic distribution Boxes for building (BPI) [5]

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6.6 Les Equipements en logements collectifs

6.6.1 Les Boitiers de Pied d'Immeuble (BPI)

Une BPI ne pourra mutualiser des liens faisant partie du réseau de transport et des liens faisant partie du réseau de distribution. Aussi, un BPI du réseau de distribution ne pourra recevoir de raccordements clients finals.

L'usage des BPI devra être limité aux cas suivant :

- Réalisation d'une dérivation.
- Réalisation d'un joint droit.

Les boites qualifiées dans les règles d'ingénierie sont listées ci-dessous.

Sont mentionnées les caractéristiques suivantes :

- La référence des boites et leurs fabricants ;
- Le nombre d'épissures maximum acceptable par produit ;
- La capacité maximum du câble en passage acceptée par la boite ;
- Le nombre de câbles en dérivation maximum admissible ;
- Le nombre de câbles client maximum admissible ;
- Le type de boite et son volume pour la location des infrastructures d'Orange ;
- Le nombre et le type de cassette acceptable par le boitier.

COVAGE

Version du doc v01.B
Date: 07/02/17
Document: 5 - Materiel reference

Type de BPI Immeuble - reference:

Boites	Epissure Max	Passage Max	Dérivation Max	Raccordement Max	Nbr de cassette
FIST-BD (Commscope)	48	144 (m6)	1	0	4 x 12 fo
IDB-32 (Commscope)	120	144 (m6)	2	0	5 x 24 fo
PBO Taille 2 (3M)	144	144 (m6)	2	0	12 x 12 fo

COVAGE	Date : 22/07/2019

SQL request to inform the outdoor fiber optic cross connect cabinet's fields

```
UPDATE t013_mongs04_apd.t_zsro
SET
zs_code = (
        CASE
                When zs_code NOT LIKE 'ZS34002_______' Then 'ER' || zs_code
                Else zs_code
        END),

zs_nd_code = (
        CASE
                When zs_nd_code <> (SELECT st_nd_code FROM t013_mongs04_apd.t_sitetech WHERE st_typephy = 'ADR' AND st_typelog = 'SRO')
                Then (SELECT st_nd_code FROM t013_mongs04_apd.t_sitetech WHERE st_typephy = 'ADR' AND st_typelog = 'SRO')
                Else zs_nd_code
        END),


zs_zn_code = (SELECT zn_code FROM t013_mongs04_apd.t_znro),
zs_r1_code = 'HERAULT THD',
zs_r2_code = (SELECT st_codeext FROM t013_mongs04_apd.t_sitetech WHERE st_typephy = 'SHE' AND st_typelog = 'NRO'), --NRO
zs_r3_code = (SELECT st_codeext FROM t013_mongs04_apd.t_sitetech WHERE st_typephy = 'ADR' AND st_typelog = 'SRO'), --SRO

zs_r4_code = (
        CASE
                When zs_r4_code IS NOT NULL AND zs_r4_code LIKE '____' Then zs_r4_code
                Else ((SELECT EXTRACT(YEAR FROM (SELECT localtimestamp::TIMESTAMP)))::TEXT)
        END),


zs_refpm = (SELECT st_codeext FROM t013_mongs04_apd.t_sitetech WHERE st_typephy = 'ADR' AND st_typelog = 'SRO'), --SRO

zs_etatpm =  ( --concerne l'état d'avancement du SRO à discuter avec le BE
        CASE
                When (
                                SELECT st_statut
                                FROM t013_mongs04_apd.t_sitetech
                                WHERE st_typephy = 'ADR' AND st_typelog = 'SRO') = 'REC'
                        AND ((
                                SELECT st_avct
                                FROM t013_mongs04_apd.t_sitetech
                                WHERE st_typephy = 'ADR' AND st_typelog = 'SRO') = 'E'
                        OR (
                                SELECT st_avct
                                FROM t013_mongs04_apd.t_sitetech
                                WHERE st_typephy = 'ADR' AND st_typelog = 'SRO') = 'T'
                        OR (
                                SELECT st_avct
                                FROM t013_mongs04_apd.t_sitetech
                                WHERE st_typephy = 'ADR' AND st_typelog = 'SRO') = 'S')
                        AND (
                                SELECT st_datemes
                                FROM t013_mongs04_apd.t_sitetech
                                WHERE st_typephy = 'ADR' AND st_typelog = 'SRO') IS NOT NULL
                Then 'DP' --DEPLOYE
```

```
			When (
					SELECT st_statut
					FROM t013_mongs04_apd.t_sitetech
					WHERE st_typephy = 'ADR' AND st_typelog = 'SRO') = 'PRO'
				AND ((
					SELECT st_avct
					FROM t013_mongs04_apd.t_sitetech
					WHERE st_typephy = 'ADR' AND st_typelog = 'SRO') = 'C'
				OR (
					SELECT st_avct
					FROM t013_mongs04_apd.t_sitetech
					WHERE st_typephy = 'ADR' AND st_typelog = 'SRO') = 'E')
				AND (
					SELECT st_datemes
					FROM t013_mongs04_apd.t_sitetech
					WHERE st_typephy = 'ADR' AND st_typelog = 'SRO') IS NULL
			Then 'EC' --EN COURS DE DEPLOIEMENT
			/*APS*/
			When (
					SELECT st_statut
					FROM t013_mongs04_apd.t_sitetech
					WHERE st_typephy = 'ADR' AND st_typelog = 'SRO') = 'AVP'
				AND (
					SELECT st_avct
					FROM t013_mongs04_apd.t_sitetech
					WHERE st_typephy = 'ADR' AND st_typelog = 'SRO') = 'C'
				AND (
					SELECT st_datemes
					FROM t013_mongs04_apd.t_sitetech
					WHERE st_typephy = 'ADR' AND st_typelog = 'SRO') IS NULL
			Then 'PL' --PLANIFIE
			Else 'EC'
		END),


zs_capamax = (
		CASE
			When ((SELECT count(*) FROM t013_mongs04_apd.t_suf) < 461)
			AND ((SELECT SUM(ad_nblhab + ad_nblpro) FROM t013_mongs04_apd.t_adresse) < 461 )
			AND ((SELECT SUM(ad_nbprhab + ad_nbprpro) FROM t013_mongs04_apd.t_adresse) < 461)
			Then 460
			When ((SELECT count(*) FROM t013_mongs04_apd.t_suf) > 460)
			AND ((SELECT SUM(ad_nblhab + ad_nblpro) FROM t013_mongs04_apd.t_adresse) > 460 )
			AND ((SELECT SUM(ad_nbprhab + ad_nbprpro) FROM t013_mongs04_apd.t_adresse) > 460)
			Then 800
			Else NULL
		END),

zs_ad_code = (
		CASE
			When zs_ad_code != (SELECT st_ad_code FROM t013_mongs04_apd.t_sitetech WHERE st_typephy = 'ADR' AND st_typelog = 'SRO')
			Then (SELECT st_ad_code FROM t013_mongs04_apd.t_sitetech WHERE st_typephy = 'ADR' AND st_typelog = 'SRO')
			Else zs_ad_code
		END),



zs_nblogmt = (SELECT count(*) FROM t013_mongs04_apd.t_suf),

zs_actif = (--permet d'indiquer s'il y a de l'électricité au PM
		SELECT lt_elec
		FROM t013_mongs04_apd.t_sitetech
		INNER JOIN t013_mongs04_apd.t_ltech ON lt_st_code = st_code
		WHERE st_typephy = 'ADR'),

zs_creadat = (
		CASE
			When zs_creadat IS NOT NULL Then zs_creadat
			Else current_date
		END),
```

SQL request to inform the number of splice cassettes inside the different types of boxes

```
UPDATE t013_mongs04_apd.t_ebp
SET
bp_ca_nb = (
        CASE
                WHEN bp_rf_code = 'RF34000000000113' AND (bp_typelog = 'PBO' OR bp_typelog = 'BPE')
                        THEN 4
                WHEN bp_rf_code = 'RF34000000000114' AND bp_typelog = 'BPE'
                        THEN 12
                WHEN bp_rf_code = 'RF34000000000115' AND (bp_typelog = 'PBO' OR bp_typelog = 'BPE')
                        THEN 1
                WHEN bp_rf_code = 'RF34000000000116' AND (bp_typelog = 'PBO' OR bp_typelog = 'BPE')
                        THEN 12
                WHEN bp_rf_code = 'RF34000000000117' AND bp_typelog = 'BPE'
                        THEN 24
                WHEN bp_rf_code = 'RF34000000000118' AND bp_typelog = 'BPE'
                        THEN 56
                WHEN bp_rf_code = 'RF34000000000119' AND bp_typelog = 'BPE'
                        THEN 80
                WHEN bp_rf_code = 'RF34000000000120' AND (bp_typelog = 'PBO' OR bp_typelog = 'BPE')
                        THEN 1
                WHEN bp_rf_code = 'RF34000000000121' AND bp_typelog = 'BPE'
                        THEN 56
                WHEN bp_rf_code = 'RF34000000000122' AND bp_typelog = 'BPE'
                        THEN 80
                WHEN bp_rf_code = 'RF34000000000123' AND bp_typelog = 'BPE'
                        THEN 12
                WHEN bp_rf_code = 'RF34000000000124' AND bp_typelog = 'PBO'
                        THEN 1
                WHEN bp_rf_code = 'RF34000000000125' AND bp_typelog = 'BPE'
                        THEN 2
                WHEN bp_rf_code = 'RF34000000000126' AND bp_typelog = 'BPE'
                        THEN 12
                WHEN bp_rf_code = 'RF34000000000127' AND (bp_typelog = 'PBO' OR bp_typelog = 'BPE')
                        THEN 4
                WHEN bp_rf_code = 'RF34000000000128' AND bp_typelog = 'BPE'
                        THEN 12
                WHEN bp_rf_code = 'RF34000000000129' AND (bp_typelog = 'PBO' OR bp_typelog = 'BPE')
                        THEN 4
                WHEN bp_rf_code = 'RF340025999704' AND bp_typelog = 'PTO'
                        THEN 1
                ELSE 0
        END )
```

Glossary

NRO : Noeud de raccordement optique (Central office)

SRO : Sous répartiteur optique (Outdoor fiber optic cross connect cabinet)

BPE : Boitier de protection d'épissure (Splice box)

BPI : Boitier pour immeuble (fiber optic distribution box for building)

PBOE : Point de branchement optique extérieure (Outside fiber optic distribution box)

PBOI ou BE : Point de branchement optique intérieure ou boitier d'étage (Inside fiber optic distribution box)

PTO : Point de terminaison optique (Optic plug terminal)

ONT: Optical network termination

SUF (Site Utilisateur Finale): It corresponds to a site which must be connected

OPTICAL FIBER: Transmission support of signals in the form of pulses of light. The optical fiber is very fine constituted of silica or flexible plastic.

COIL (Bobine amorce): It corresponds to the fiber length used to perform a measurement before and after the cable to be measured. It allows to avoid the dead zone (glare) due to the light created by the reflectometer power.

BANDWIDTH (Bande passante): The optical fiber bandwidth is defined as the maximum transmission frequency (MHz) for which the transmitted signal is subjected to fading (of 3dB). The wider the bandwidth, the higher the capacity to support high-speed transmissions. It is expressed in MHz.km or in GHz.km. It depends on the transmission wavelength and other physical parameters of the fiber (the core diameter, materials…).

FIBER CORE: Central part of the optical fiber, generally in silica in which the optical signal and data propagate. It can be of different size according the type of fiber. (ex: 9 µm for the monomode fiber, 50 or 62.5 µm for the multimode fiber).

DECIBEL or dB: Unit of measure of the optical power (dB=10log (power ratio)).

SPLICE: Junction of two fibers called strands (« brin » in French) to form a connection. The splice can be realized by fusion splicing or mechanical splicing of the two fibers (welding machine).

CLADDING (Gaine optique): Silica cladding of 125 µm recovering the core of the fiber allowing to have a low refractive index.

G657 FIBER: Developed to meet the technical and financial requirements of the operators, the G657 fiber is characterized by multiple advantages: a low bend radius, flexibility and ease of installation, very useful to realize the cabling, in particular inside buildings.

G652D FIBER: The standard monomode fiber is the G652 optical fiber, this norm evolved in several variants. The G652D fiber is the best-performing version and the most common.

OUTDOOR FIBER OPTIC CROSS CONNECT CABINET'S AREA (ZAPM= Zone arrière du point de mutualisation): Geographical area constituted of the set of buildings linked to the outdoor fiber optic cross connect cabinet.

MODES: Different pathways that light beams can performed within the fiber.

PON (Passive Optical Network)**:** Passive optical network characterized by a point to multipoint architecture (several subscribers share the same fiber and there is no active equipment between the central office and the subscribers). There are different types of PON, such as the GPON and the EPON.

P2P (Point to Point): For this type of architecture, there is a continuous and non-shared fiber from the central office (NRO) and the subscriber. It has the particularity to provide at the end of each network termination a dedicated fiber.

SINGLE-MODE FIBER: Optical fiber in which there is only one light beam (also called mode). Indeed, their core very fine authorized just one mode of propagation, as much direct as possible, namely in the axis of the fiber. It is used for long distances and/or for high-speed network. Multiple types of single-mode fiber exist such as the G652D, G657, G655 fibers.

MULTI-MODE FIBER: Optical fiber in which there are multiple light beam (mode). It is characterized by a core diameter between 50 and 62.5µm. It is used for the cabling of private networks and thus with shorter distance. Multiple types of multi-mode fiber exist such as OM1, OM2 and the OM3 fiber.

SPLICE CASSETTE (Cassette d'épissure): Element of a box (as BPE and PBOE) allowing to host a defined number of spliced fibers, with the possibility to curl up the fiber (storage in case of fiber supplement need).

IPE: Informations Préalables Enrichies

t_sitetech (st): It corresponds to the table of the technical site (see Table 22).

t_ltech (lt): It corresponds to the table of the wiring closet (see Table 23).

t_zsro (zs): It correspond to the table of the outdoor fiber optic cross connect cabinet (see Table 24)

Table 22: Definition of the t_sitetech table's fields

Fields of the table t_sitetech (st)	Definition
st_statut	It indicates the progress of the works. At the APS stage, we put "AVP" for preliminary draft (Avant Projet in French), at the APD stage, we put "PRO" for project underway (Projet in French).
st_typephy	It informs the physical type of the technical site (shelter, outdoor fiber optic cross connect cabinet or building). We put "ADR" for the outdoor fiber optic cross connect cabinet (SRO) or "SHE" for the Central office (NRO).
st_datemes	It corresponds to the in-service date of the technical site.
st_avct	It allows, during the study phase, to distinguish what already exists and what it is in creation.
st_typelog	It represents the type of the site (NRO, SRO, CLIENT).

Table 23: Definition of the t_ltech table's fields

Fields of the table t_ltech (lt)	Definition
lt_st_code	Unique identifier contained in the table t_sitetech. It corresponds to the foreign key in the table t_ltech referring to the table t_sitetech by means of the primary key st_code (field in the table t_sitetech).
lt_elec	It indicates the presence of a power supply within the wiring closet. We put "0" for the site without power supply and "1" with a power supply.

Table 24: Definition of the t_zsro table's fields

Fields of the table t_zsro (zs)	Definition
zs_code	Unique code identifying the outdoor fiber optic cross connect cabinet (generated automatically).
zs_nd_code	It indicates the location of the outdoor fiber optic cross connect cabinet through its node.
zs_r1_code	It indicates the name of the company handling the optical fiber network whose role is to assure the conception, the finance, the construction, the commercialization, the exploitation and the maintenance of the high-speed network into the territory of Hérault. To inform this field, we put "HERAULT THD".
zs_r2_code	It corresponds to the unique identifier of the Central office to which the outdoor fiber optic cross connect cabinet is linked (identifier: HT-TEC-00C43)
zs_r3_code	It corresponds to the unique identifier of outdoor fiber optic cross connect cabinet (SRO), informed on the ground (exemple: HT-TEC-0267W)
zs_r4_code	The r4_code is used to inform the year of deployment of the outdoor fiber optic cross connect cabinet's area (ZAPM in french).
zs_refpm	Reference of the outdoor fiber optic cross connect cabinet. This reference is mandatory as soon as the "SRO" is in process.
zs_etatpm	It indicates the progress of the works for the installation of the SRO. It takes the value "EC" when it is in progress ("en cours" in French) or "DE" when it is 100 % deployed.
zs_capamax	Maximum capacity of the outdoor fiber optic cross connect cabinet.
zs_ad_code	Address code of the outdoor fiber optic cross connect cabinet.
zs_nblogmt	It corresponds to the total number of housing located within the outdoor fiber optic cross connect cabinet.
zs_actif	It informs if there is electricity in the outdoor fiber optic cross connect cabinet to allow to a commercial operator if he can store the active equipment.
zs_creadat	It indicates the creation date.

The fields of the three different tables described previously (t_zsro, t_ltech, t_sitetech) allow to clearly understand the SQL request to inform the outdoor fiber optic cross connect cabinet's fields (see in the appendix). Each field met in the SQL request is put forward with its proper definition through the previous tables

Bibliography

[1] Boldyreva, E. (2016). *Mesures reparties par reflectometrie frequentielle sur fibre optique.* Retrieved from http://oatao.univ-toulouse.fr/18709/1/Boldyreva_Ekaterina.pdf

[2] Cercle de Réflexion et d'Etude pour le Développement de l'Optique. (2017). *Technologies et Composants du Réseau d'Accès.*

[3] Chireux, N. (2015). *Mesure sur les Fibres optiques.* Retrieved from https://www.chireux.fr/mp/TIPE/ADS/Fibre%20Optique.pdf

[4] Corning. (March 2014). *Guidance for OTDR Assessment of Fusion Spliced Single-mode Fibers.*

[5] COVAGE. (2019). *Regle ingenierie FTTH.*

[6] Gaudino, R. (2016). *Course of "Optical and Wireless Communications".* Politecnico di Torino.

[7] Gaudino, R. (November 2018). *Course of "Current trends in Optical Access Networks".* Politecnico di Torino.

[8] ITU. (2016). *Characteristics of a bending-loss insensitive single-mode optical fibre and cable.*

[9] Kumar, P. (2017, December 6th). *Optical Time Domain Reflectometer.*

[10] LITTLEJOHN, C. (2002, September 1st). *Lightwave.* Retrieved from Impact of MFD mismatch on OTDR splice loss measurements: https://www.lightwaveonline.com/test/network-test/article/16647931/impact-of-mfd-mismatch-on-otdr-splice-loss-measurements

[11] LUNA. (September 2018). *Optical Backscatter Reflectometry (OBR)-Overview and Applications.*

[12] Ohashi, M. (2013). *Fiber Measurement technique Based on OTDR* .

[13] *Optical Fiber Splice Loss.* (2016). Retrieved from FOSCO: https://www.fiberoptics4sale.com/blogs/archive-posts/95039494-optical-fiber-splice-loss

[14] Paris, G. (February 2008). *Evolution des fibres optiques monomodes pour le marché télécom.* Cercle de Réflexion et d'Etude pour le Développement de l'Optique.

[15] Prysmian Group. (March 2010). *Single-Mode Fiber: Splicing and OTDR splice measurements.*

[16] Richard, G. (2014). *Détection et analyse des événements optiques dans les réseaux FTTx.*

[17] The Fiber Optic Association FOA. (2013). *Optical Time Domain Refelctometer.* Retrieved from https://www.thefoa.org/tech/ref/testing/OTDR/OTDR.html

[18] Thollabandi, M. (2013). *Optical Fiber Splice Loss.*