IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676, p-ISSN: 2320-3331, Volume 17, Issue 6 Ser. I (Nov. – Dec. 2022), PP 62-77
www.iosrjournals.org

Proposal for a capacity dimensioning tool for Mobile broadband capacity reservation in submarine optical links: Case of Cameroon.

DEUSSOM DJOMADJI Eric Michel [1,2], KABIENA Ivan Basile [3], TAKEMBO Clovis [1], BITHA OMGBA Junior [2], Michael EKONDE SONE[1]

[1]*Department of electrical and electronic engineering, College of Technology/ University of Buea, Cameroon*
[2]*Division of information and communications technology, National Advanced School of Post and Telecommunications, University of Yaoundé I, Cameroon.*
[3] *Department of Computer Engineering and telecommunications, National advanced school of Engineering, university of Douala, Cameroon*

Abstract: *It is clear that the dimensioning of current submarine links is carried out without taking into account the lifespan of a submarine optical cable, which leads to an increase in the capacity of the latter at each whenever the need arises regularly emanating from the saturation of the available bandwidth. This generates additional costs. This is the case observed for the submarine links established between the Cameroonian coast and Western countries. To avoid such inconveniences, the establishment of transoceanic links should be carried out based on the life cycle of a submarine optical cable.*

Materials and Methods*: In this study, the analysis was based on data consumption of subscribers which belongs to mobile and fixed telephony operators in Cameroon such as CAMTEL, ORANGE, MTN, and NEXTTEL during the period from 2013 to 2019 to predict the evolution of the said consumption over the next twenty-five years via the use of automatic learning methods using linear regression algorithm.*

Results*: the application of linear regression on all data consumption made it possible to estimate the variation in demand during the life cycle of a submarine cable with an accuracy of 84% with optimal values a = 116883587.46* and *b = -235279822125.09 for traffic to offer of a value of 34449.21 GBps, accentuated by a growth in demand of approximately 34.10% each year during the life cycle of the optical fiber under the sea.*

Conclusion*: The results obtained show that by carrying out a forecast of traffic demand based on the life cycle of an underwater optical fiber, we obtain a result that makes it possible to reduce the financial costs related to dimensioning and planning compared to a dimensioning that is based on the occasional demand for data traffic.*

Keywords*: submarine optical fiber, sizing, bandwidth, traffic, capacity*

Date of Submission: 22-11-2022 Date of Acceptance: 06-12-2022

I. Introduction

The Internet, which is an international telematic network, is the result of the interconnection of thousands of networks using a common communication protocol, intending to offer the possibility to its users of transmitting data, voice, images, and others, from one end of the planet to the other through satellite, coaxial and optical channels [1]. Today, it is clear that 80% of long-distance global traffic is carried out by optical fibers. Optical fiber has many advantages compared to other solutions like microwaves, it is more robust and very insensitive to electromagnetic interference. But above all, fiber optic among telecommunication technologies, which have been constantly improving over the past thirty years, make it possible to transmit information at very high speeds; which could not have been achieved without the development of manufacturing techniques to obtain this extremely transparent guiding medium [2]. To overcome the explosion in demand for bandwidth and broadband, characterized by the expansion of multimedia services such as VoIP, video, online games, and post-to-post applications, the need to connect the continents by appropriating the oceans through the use of submarine optical cables has thus been felt.

The establishment of these intercontinental links requires a preliminary study including the planning and sizing phases. The latter is defined by the ITU as: the choice of the size of the equipment of a network to satisfy the traffic circulating in the network, which must be able to take into account the aspect of the dynamic evolution of the traffic during the life cycle of the optical fiber transmission medium. The exponential demand for bandwidth for Internet provision has often proved to be excessive, given the increase in operators' subscriber base; thus, generating a considerable flow of traffic sometimes going as far as the saturation of the link. Taking into account strategic and economic issues, these transatlantic links, which benefit the coastal states of sub-Saharan Africa in general and those of Central Africa in particular, are often victims of the congestion of the said supports. These only take into account the occasional need for bandwidth and generate additional expenses when resizing the links as well as the terminal stations. The need to reduce these costs highlights the problem of sizing an optical link based on the specific bandwidth demand [3].

To avoid any inconvenience of congestion of the links and additional expenses, it would be essential to take into account the dynamic evolution of traffic during the life cycle of a submarine cable when dimensioning said links. The implementation of such a solution requires knowledge of the data traffic generated by subscribers in the past; to be able to make a future prediction of the evolutionary behaviour of traffic during the life cycle of a submarine optical cable (25 years), thanks to supervised learning methods; among which we find a statistical learning method called linear regression, used to predict a quantitative variable. In this paper, we will focus mostly on the traffic demand due to mobile broadband operators to show that it is very important to forecast the traffic demand by considering the whole life cycle of submarine cables [4].

II. Material And Methods

In this section, we present in detail all the different steps and methods to achieve this work. So first we will present all the processes necessary for the implementation of the power budget necessary for the deployment of the nodes of the link, then we will present the different stages related to the dimensioning of the capacity of the submarine optical links by putting in highlights the statistical approach used to make the prediction necessary for this dimensioning.

II.1. Power Budget Calculation Process

It is done by limiting the power budget during commissioning on the GROUND (Start of Life) before FEC (Forward Error Connection) which must be greater than or equal to the segment Q factor on the GROUND (before FEC). The approach for calculating the segment Q factor values is to calculate the segment Q factor SOL (Start of Life) / EOL (End of Life) before FEC, from the theoretical values of the SNR (Signal to Noise Ratio) SOL / EOL [5]. So, we can represent the algorithm for determining the power budget as follows:

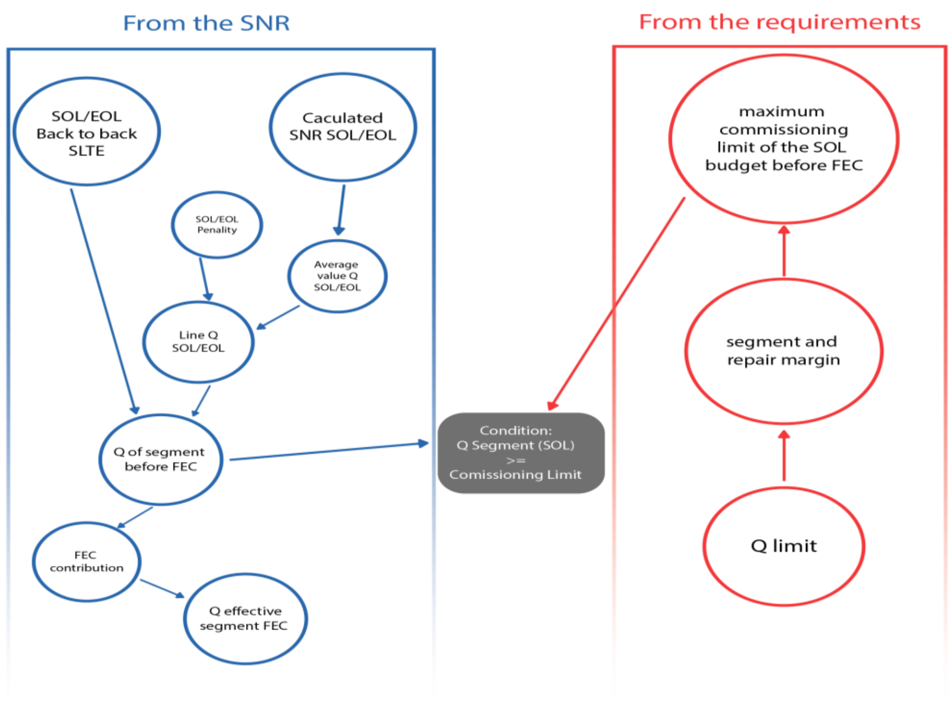

Figure1: SOL/EOL power budget calculation algorithm

II.1.1. Calculation made from the SNR

- **SNR SOL/EOL**

Each repeater in an optically amplified line contributes by adding noise to the system, and the noise in turn is amplified by subsequent repeaters. With each repeater compensating (almost exactly) for the loss of the

previous section, the total accumulated noise is approximately equal to the noise of one repeater multiplied by the number of repeaters. [6]
As a result, there is a gradual increase in noise along the system, which leads to a decrease in the signal-to-noise ratio with distance. The optical SNR is approximately proportional to

$$\mathbf{P_{out}}\ /\ (\mathbf{k\,G})\ \approx\ \mathbf{P_{out}}\ /\ (\boldsymbol{\alpha}\mathbf{D}) \qquad \text{eq.1 [7]}$$

Where :

- Pout and G are the average repeater output power and gain (in linear units)
- k is the number of repeaters D is the total system length (in km), and α is the line fiber attenuation (in dB/km).

According to these formulas, the SNR decreases linearly with the number of amplifiers (at a constant gain) and exponentially with the spacing of the amplifiers (at a constant number of amplifiers). To obtain a good SNR at the end of the line, it is necessary to increase the input and output powers of the repeater.

➢ **Average value of the Q factor**

The theoretical definition of the Q factor shows that there is a relationship between the Q factor (which gives the transmission quality) and the SNR (signal-to-noise ratio). SNR can be measured using test equipment (i.e., an optical spectrum analyzer). In this case, it is possible to calculate the corresponding Q factor. If the SNR is not available (i.e., difficult to measure due to too small channel spacing), the BER measurement provides a corresponding Q factor (eq.7). These are the reasons why the Q factor is used for optical power budget calculation.

$$Q = \frac{\frac{2\mathrm{SNR}\ (1-\mathrm{ER})\sqrt{\frac{\mathrm{B_f}}{\mathrm{B_e}}}}{1+\mathrm{ER}}}{\sqrt{1+4\mathrm{ER}\,(\frac{\mathrm{SNR}}{1+\mathrm{ER}})}+\sqrt{1+4(\frac{\mathrm{SNR}}{1+\mathrm{ER}})}} \qquad \text{eq.2 [7]}$$

SNR: signal to noise ratio in Bf
ER: Transmitter extinction ratio =P(0)/P(1) ~ 0.1
Be: passband of the electrical filter
Bf: bandwidth of the optical filter

➢ **SOL/EOL penalties**

- Nonlinear effects: they are due to the variation of the optical intensity. Reducing the nonlinear effect is possible by increasing the effective area. This justifies the use of LCF (Large Core Fiber). The LCF is placed just after the repeaters to absorb the high power due to optical amplification. The optical intensity being a power density results in the following expression:

$$\text{optical intensity} = \frac{\text{optical power}}{\text{effective optical surface}} \qquad \text{eq.3 [7]}$$

- Dispersion effects: In the same medium, an optical signal made up of different wavelengths travels at different speeds. This phenomenon is called chromatic dispersion (CD). Along the fiber, the wavelengths (λ) contained in an optical pulse propagate at different speeds. Therefore, it induces pulse broadening along the length of the fiber.

Pulse widening (ΔT) is defined by:

$$\Delta\mathrm{T} = \mathrm{D} \times \mathrm{L} \times \sigma \qquad \text{eq.4 [8]}$$

It should therefore be noted that an increase in the transmitted bit rate would cause the received pulses to overlap, thus leading to the non-detection of the latter.

- The spectral width of the pulse (σ),
- The length of the fiber (L),
- The dispersion characteristics of the fiber (D).

➢ **The SOL/EOL line Q factor**

It gives the value of the line Q coming from the formula:

$$\mathrm{Q}_{\text{ligne (SOL/EOL)}} = \mathrm{Q}_{\text{mean (SOL\textbackslash EOl)}} - \text{penalités (SOL\textbackslash EOL)} \qquad \text{eq. 5 [8]}$$

➢ **SOL/EOL back-to-back SLTE Q**

Due to the non-infinite SNR and the imperfect electronic device of SLTE, the Q factor obtained when the transmitting terminal is directly connected to the receiving terminal is not infinite and is called the specified value.$\mathrm{Q_{TTE}}$

➢ **The segment Q factor before FEC**

Since the specified line Q factor and factor contribute to the overall system performance, the segment Q factor is derived from the back-to-back SOL/EOL and SOL/EOL line Q by the formula:$\mathrm{Q_{TTE}}\ \mathrm{Q_{SLTE}}$

$$\frac{1}{Q^2_{\text{segment}}} = \frac{1}{Q^2_{\text{line}}} + \frac{1}{Q^2_{\text{TTE BTB}}} \qquad \text{eq.6 [7][10-18]}$$

II.1.2. Calculation from system requirements

- **The limiting Q factor**

The factor should meet the condition that the BER should be <10-13 after FEC correction, which yields better performance than the minimum BER required using ITU-T Recs G.828/G8201/M2401.Q_{Limite}

- **Margin of repair**

It represents all the disturbances or degradations of the system that could be present in the system installed at the end of its life. It includes required repair margins, pump failures, and component and fiber aging. As these effects are interactive, they are grouped in the same row according to ITU G.977.

So, we have the following formulas:

$$\text{Marge}_{\text{réparation (EOL)}} = Q_{\text{segment SOL}} - Q_{\text{segment EOL}} \quad \text{eq. 7 [9] [10-18]}$$

$$\text{Marge}_{\text{segment (SOL)}} = \text{Marge}_{\text{réparation (EOL)}} + \text{Marge}_{\text{segment (EOL)}} \quad \text{eq. 8 [9] [10 - 18]}$$

Picture1: Repair and segment margins as a function of bond length **[5] [10-18]**

Link length (Km)	Repair margin (dB)	Segment margin (dB)
1000	1.8	1.1
2000	1.4	0.4
4000	1.1	0.3
8000	0.8	0

- Commissioning limit

This is the minimum performance to be demonstrated during the provisional acceptance of the system to be put in place. It is obtained according to the formula below:

$$\text{Commissioning limit} = \text{Marge}_{\text{réparation (SOL)}} + Q_{\text{limite}} \quad \text{eq.9 [9]}$$

The power budget at the end of the life cycle of the fiber achieved cannot be considered acceptable on the sole condition that

$$Q_{\text{segment (SOL)}} \geq \text{Commissioning limit} \quad \text{eq.10 [9]}$$

II.2. Link Capacity Sizing Process

II.2.1. Prediction

In order to highlight the existence of a significant linear relationship between two continuous quantitative characters X (years) and Y (annual consumption in Gbit), we can seek to formalize the average relationship that unites these two variables using of an equation$y = ax + b$, called the univariate regression line of Y against X. [19]

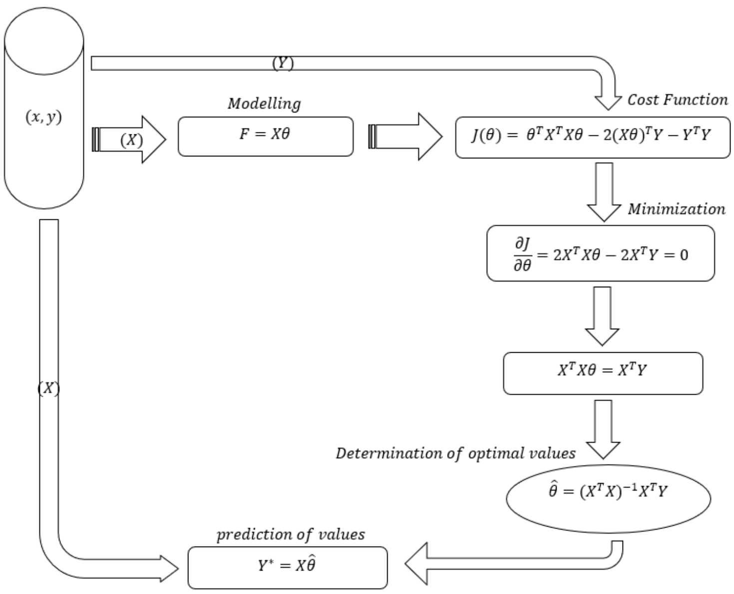

Figure2: linear regression algorithm

Model: f(x) = ax+b eq.11

Cost function: represents the average of the errors between the actual values and the predicted values belonging to the regression line [20][21]. Formulated by

$$J(a,b) = \frac{1}{2m}\sum_{i}^{m}(ax^{(i)} + b - y^{(i)})^2 \text{ eq.12}$$

It thus represents the root mean square error

Minimization algorithm: this is the gradient descent algorithm that will allow us to find the minimum of our cost function. It will initially be a question of determining the values of the gradients as well as that of the learning rate, and to arrive at optimal values of "a" and "b" the expressions of calculations should be the following:(α)

Gradients :

$$\frac{\partial J(a,b)}{\partial a} = \frac{1}{m}\sum_{i=1}^{m} x^{(i)}(ax^{(i)} + b - y^{(i)}) \quad \text{eq.13}$$

$$\frac{\partial J(a,b)}{\partial b} = \frac{1}{m}\sum_{i=1}^{m}(ax^{(i)} + b - y^{(i)}) \quad \text{eq.14}$$

For gradient descent

$$a = a - \alpha\frac{\partial J(a,b)}{\partial a} \text{ eq.15}$$

$$b = b - \alpha\frac{\partial J(a,b)}{\partial b} \quad \text{eq.16}$$

The set of optimal parameters obtained from the gradient descent algorithm for the implementation of the linear regression model will make it possible to predict the consumption of data at the end of the life cycle of the underwater optical fiber thanks to the following relationship:

$U_n = U_0(1 + f_p)^n$ [20]

U_n:Internet consumption in year n

U_0:Internet consumption of the current year

f_p :Internet consumption growth factor

n :Number of years of prediction

$U_0$is obtained by the following relationship:

$U_0 = \text{consommation moyenne/abonné} \times \text{Nombre abonné}$ **eq. 17** at year 0.

II.2.2 Capacity of end terminals

- **Speed offered**

The amount of traffic to flow during a unit of time is defined by dividing the traffic generated in the year by the number of seconds contained in a year:**n**

$$D_{offert} = \frac{U_n}{31536000}$$ eq.18 expressed in Gigabit/s

- **Number of channels to be multiplexed**

It emanates from the amount of information that can pass through a wavelength. Its calculation is characterized by the ratio between the bit rate to be offered and the bit rate provided by a wavelength according to the SDH multiplexing hierarchy:

$$N_{lien} = E\left[\frac{D_{offert}}{STM - N}\right] + 1 \quad \text{eq.19}$$

N_{lien} :Number of channels to be multiplexed

$STM - N$:Capacity of a link with N: (16;64;256)

- Total link capacity

The link being bilateral between the different stations, we obtain the following relationship:

$$C_{tot} = 2 \times N_{lien} \times STM - N(\text{Gbps}) \text{ eq.20}$$

II.3 Designing of the application

The purpose of this phase is to prepare and organize the implementation to respond to the planning for the establishment of an underwater optical link. We will therefore highlight the skeleton governing the operation of our tool through the class diagram.

II.3.1. Design

The class diagram represents one of the major aspects of object-oriented modeling. It is a diagram used in software engineering to present the classes and interfaces of systems as well as the different relationships between them [22]. This diagram is part of the static part of UML because it abstracts from temporal and dynamic aspects. Indeed, it shows the internal structure of a system from the point of view of the actors. Within the framework of our project, we used five (05) classes among which, one (01) devoted to the management of the users, one (01) intended for the management of the optical links and the three (03) last (Prediction, Balance_of_power, Bilan_de_dispersion) responsible for carrying out all the calculations necessary for dimensioning the connections.

- **The user class**: it is used to list all the information related to the individuals who can interact with the application. This information includes, among other things, the ID, surname, first name, email address, gender, password. This class therefore represents the users of the application.
- **The Optical_link class**: characterized by the ID, the names of the terminal stations (Point A/B) as well as their geographical coordinates (latitudes, longitudes), the length of the link, the type of fiber, the number of strands used and the capacity total bond; will have the role of providing the information necessary for the description of an underwater optical link.
- **The Power_balance_class**: it performs the role of calculations necessary for establishing the power budget from SOL to EOL including, among others, the following attributes: ID, mean Q (SOL/EOL), Wavelength tolerance (SOL/EOL), propagation impairment (SOL/EOL), design manufacturing (SOL/EOL), time varying (SOL/EOL), TTE Q (SOL/EOL), Q limit (SOL/EOL), ageing, segment margin (SOL/EOL) and commission limit.
- **The Balance_of_dispersion class**: its attributes are the ID, the output power, the signal to noise ratio, the bandwidth, the chromatic dispersion, the maximum length between the repeaters and as well as the number of repeaters necessary to establish the link. It makes it possible to carry out all the calculations necessary to determine the losses resulting from the nonlinear effects which can limit the optimal use of the bandwidth.
- **The prediction class**: used to make an estimate of the evolution of the traffic generated by the subscriber parks of the operators, it uses the linear regression algorithm in order to determine the reception capacity of the various terminal stations in terms of speed to be provided during the cycle of fiber optic life. Its attributes are the ID, the adjustment coefficient, the parameters (a_optimal, b_optimal), the growth rate, the EOL consumption, and the throughput offered.

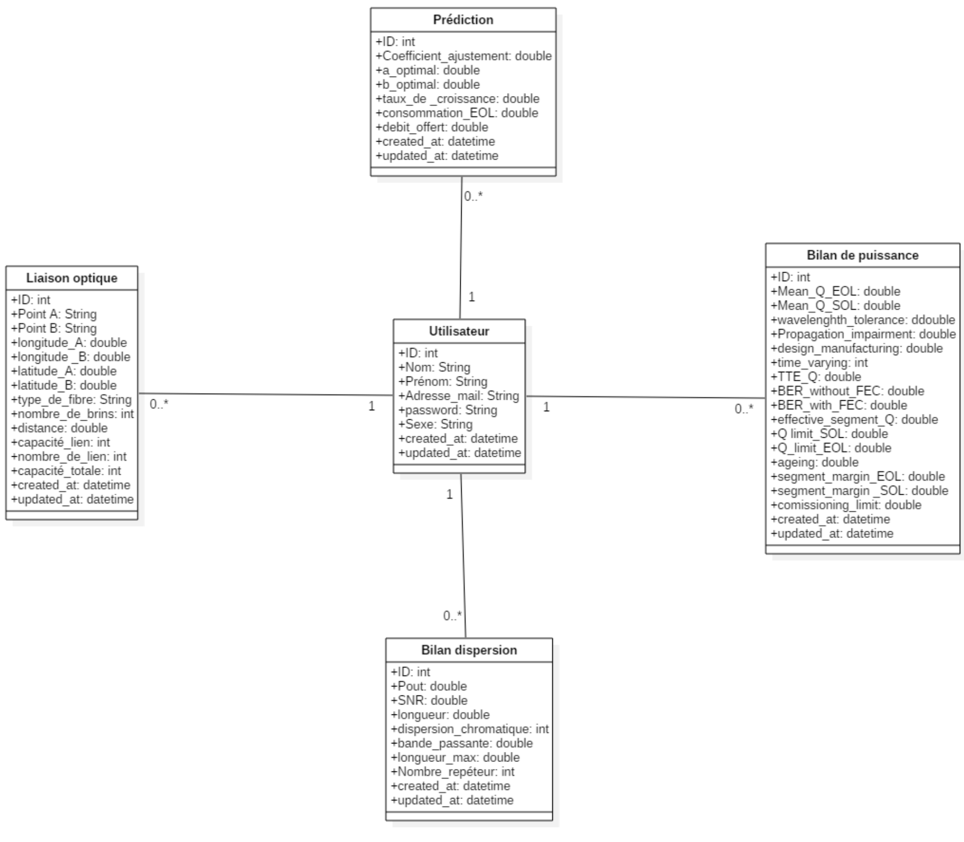

Figure 3: Class diagram

II.3.2. System Architecture

The success of the design stage of an application during the software lifecycle phase is highly dependent on the architectural design. Design on which our application is based.

This design consists of splitting the tasks of the application into different small parts in order to better organize and develop the software. It is based on the “divide and conquer” technique. Presenting as advantage:

- Sharing of the application developed by working groups;

- The possibility of reusing the components in other applications;
- Application portability.

In our case we will use, among other things, the MVC and the client-server architecture.

❖ **VMC**

MVC-based reasoning stipulates a separation between model, view, and controller. The view (equivalent to the client interface) uses the model (equivalent to the data) to generate its content. In the middle of the two, the controller (equivalent to the "service") will control all exchanges to remove errors and save data. This results in the following figure :

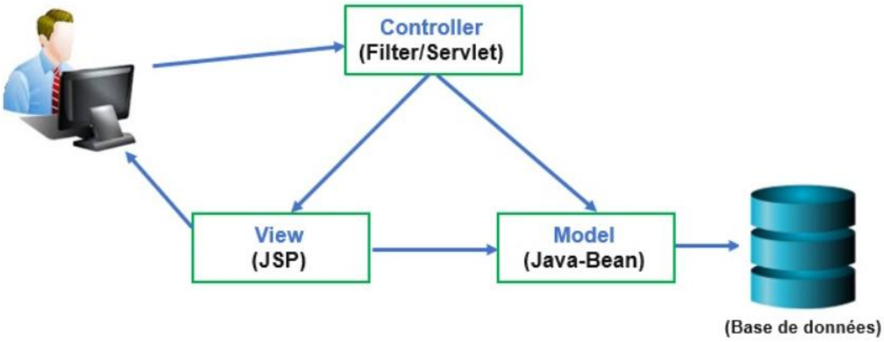

Figure 4: Modeling an MVC solution **[10]**

❖ **Client-server architecture**

The functioning of an application based on a client/server skeleton, results in all the requests sent by client machines to a server.

The latter allows the provision of services through programs having data such as files, a connection. These services are operated by programs, called client programs, running on client machines. We thus speak of FTP client, messaging client, etc.

The realization of the application gives rise to the presentation of the different interfaces, which is the subject of the following figures:

➢ **Home page**:

This is the first interface that opens when the application is launched. The user can access the other interfaces by clicking on the computer icon, however, with authentication.

Figure 5: home page

➢ **Login and authentication page**

This interface contains two functions which are authentication and account creation

- Authentication

This section contains the following fields:

- Username: referring to the user's email address;
- Password: representing the access key needed to fully authenticate a user account;

- Login: allows the authentication to be carried out by clicking on the button.

On this interface, the user must fill in the login and password fields to access the interfaces that allow him/her to perform the task he/she wants to accomplish. After filling in these fields, the user clicks on the "Login" button to authenticate. If the parameters entered are recognised by the system, a new interface will open, indicating authentication. However, if the system does not recognise the data, a dialogue box indicating invalid data will appear. Furthermore, if the user does not yet have an account, he/she will be asked to create one.

- Account creation

This section allows a new user to create an account in order to access the functionalities of the application, with the condition that all fields must be filled in.

After valid authentication of the user, the latter will be directly redirected to the user interface which gathers the various processing points of our tool.

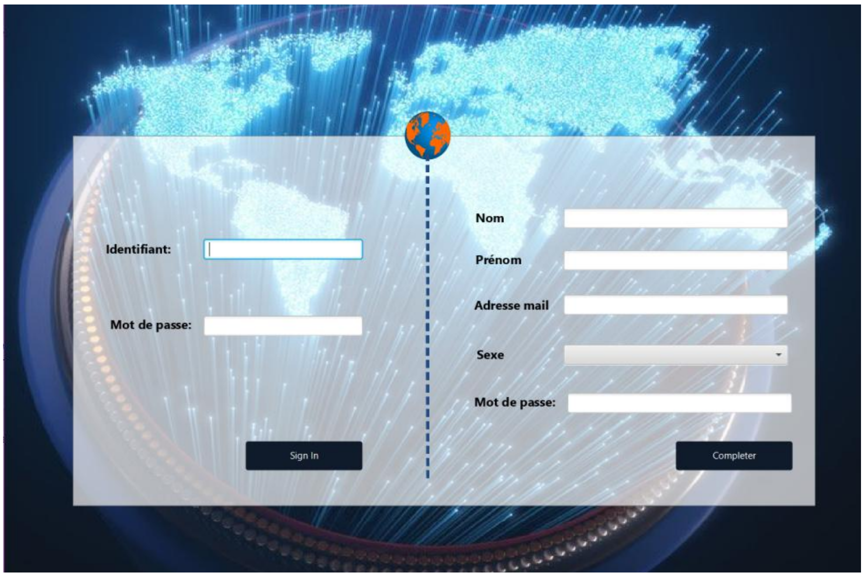

Figure 6: Authentication and account creation page

➢ **User interface**

The figure above shows the different treatment points necessary to achieve our objectives. The processing points identified are as follows:

- Optical links: to enter all the information required to identify the links to be created;
- Link budget: includes power budget calculation and quality evaluation functionalities;
- Traffic prediction: contains forecasting and linear regression functions;
- Link management: contains databases on users and the various links created.

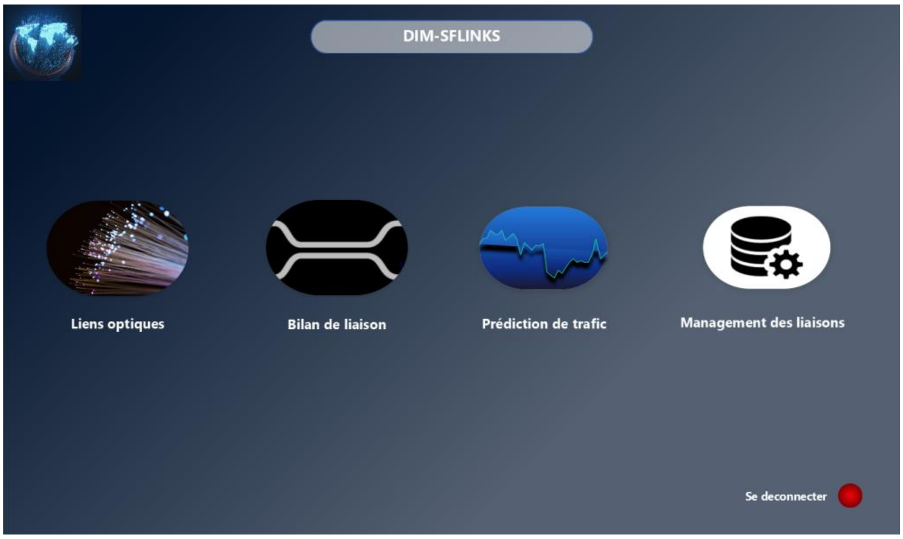

Figure 7: user interface

➢ **Optical link interface**

This interface allows the user to enter all the parameters required to describe an optical link and to locate the various nodes. The latter require in particular a set of calculations beforehand.

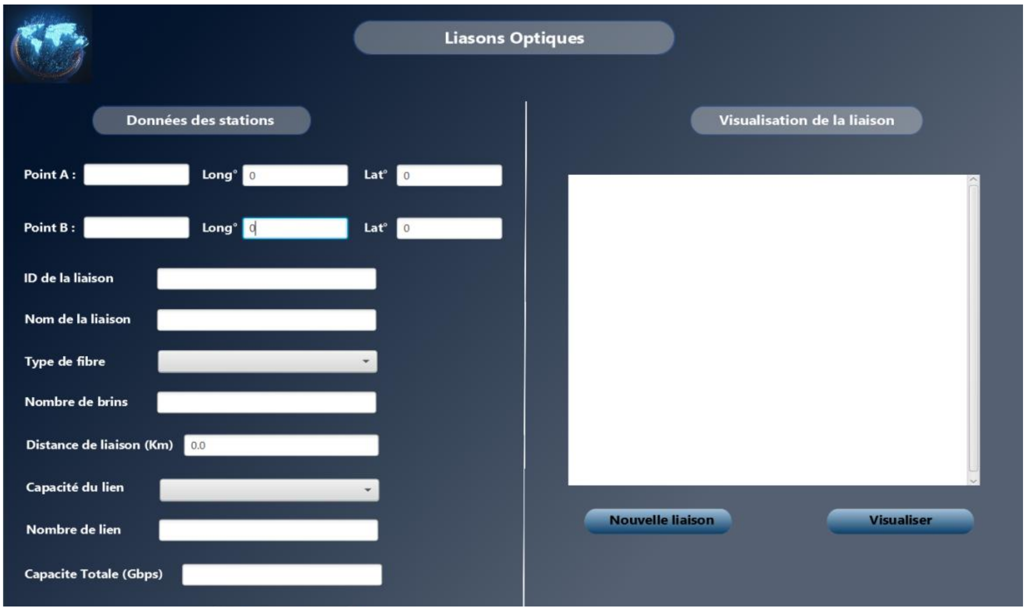

Figure 8: Optical Link interface

The latter is subdivided into two sections, namely the link assessment and the quality assessment.

Link review

Figure 9: link review

It lists all the calculations necessary to establish a power budget according to the life cycle of an optical cable. The power balance part records all the parameters linked to the quality factor of the link (SOL/EOL), namely:

- Mean Q-factor;
- Line Q value;
- Q TTE back to back;
- Segment Q value;

- Aging;
- Segment margin;
- Commissioning limit.

The dispersion balance part makes it possible, among other things, to be able to determine the quantity of repeaters to be used, as well as the distance separating two of them. We find there as a parameter:

- Output power;
- SNR;
- Chromatic dispersion;
- Bandwidth

Quality assessment

Figure 10: quality assessment

The figure above allows to visualize the behaviors of the quality of the link according to the BER and the SNR, in order to know the interval in which the quality factor must be located for the link to be considered as being reliable or good.

- **traffic prediction interface**

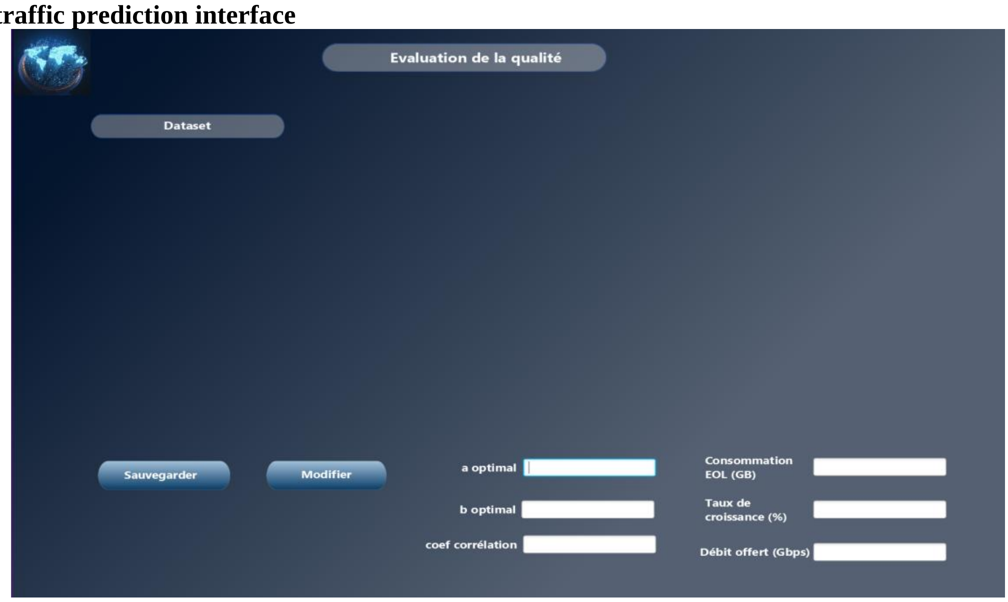

Figure 11: traffic prediction interface

The prediction interface will provide the results of the linear regression, highlighting the following results
- The parameters of the optimal coefficients of the regression line;
- The goodness of fit;
- EOL consumption;
- The growth rate;
- The throughput to be offered.

III. Result

All the results obtained were collected following the simulation of a planning of the SAIL link between the towns of Kribi and Fortaleza. Our dataset comes from the directory of the INS and the national observatories of ART which is presented as follows:

Picture2: DATA Traffic **[23][24]**

<table>
<tr><th>DATA TRAFFIC in GB</th><th>2013</th><th>2014</th><th>2015</th><th>2016</th><th>2017</th><th>2018</th><th>2019</th></tr>
<tr><td>CAMTEL</td><td>91057493</td><td>90426202</td><td>40319859</td><td>481870080</td><td>370 516 472</td><td>565 866 982</td><td>623217370</td></tr>
<tr><td>MTN</td><td rowspan="2">1371420</td><td rowspan="3">4607312</td><td rowspan="3">18440717</td><td>12870221</td><td>22325966</td><td>38070000</td><td>67065165</td></tr>
<tr><td>ORANGE</td><td>14167890</td><td>8154000</td><td>11329000</td><td>17719000</td></tr>
<tr><td>VIETTEL</td><td>/</td><td>3978500</td><td>3942000</td><td>14195733</td><td>2291351</td></tr>
<tr><td>TOTALMobile</td><td>1371420</td><td>4607312</td><td>18440717</td><td>31016611</td><td>34421966</td><td>63594733</td><td>87075516</td></tr>
<tr><td>GRAND TOTAL</td><td>920428913</td><td>95 033 514</td><td>58,760,576</td><td>512886691</td><td>404938438</td><td>629461715</td><td>710292886</td></tr>
</table>

Thus, allowing us to obtain the regression and consumption curves in the future 25 years as illustrated below:

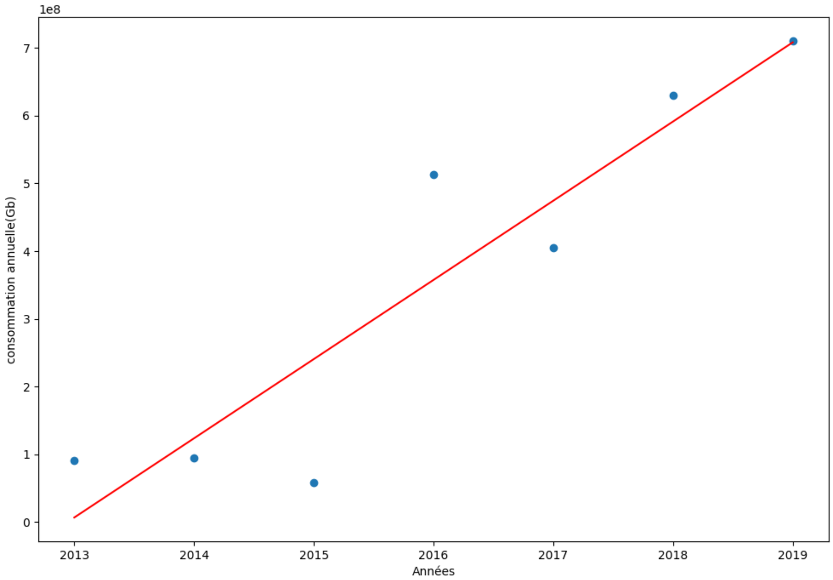

figure12: linear regression line of annual consumption as a function of years

Thanks to the gradient descent algorithm used via the statistical method of linear regression, we can observe that the optimal coefficients necessary for a better adjustment are a* = 116883587.46 and b* = -235279822125.09 thus allowing to achieve a goodness of fit of 0.84. The latter reflects the fact that we can predict up to 84% of subscribers' internet consumption depending on the year. Thus, we can predict to evaluate the evolution of the data traffic generated by the various parks of subscribers of operators taking into account the lifespan of a submarine cable. This leads us to obtain the following graph :

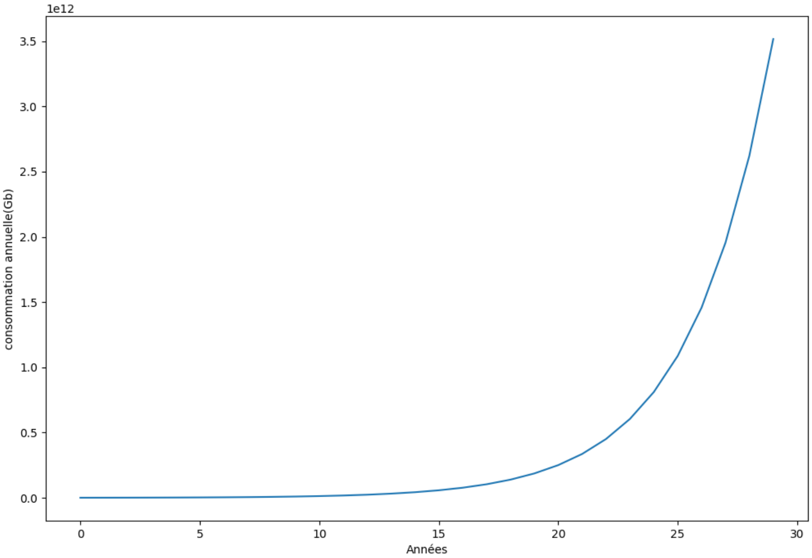

Figure13: prediction of consumption of the data at EOL

We can therefore note down the consumption at the end of the life cycle (25th year) of, characterized by an average annual growth of , thus leading to obtaining the throughput to be offered when setting up the optical link at a height of .$1{,}08639 \times 10^{12}$ GB34,10%34449,21 GBps

figure14: Result of the power budget calculation

Taking into account the distance between the different stations, the operation of a submarine link is based on the condition that the value of "Segment Q Value" should be greater than or equal to the "Commissioning limit". Such is the case observed in this simulation where these last two values are equal. It, therefore, follows that it will be necessary to inject a power of and to respect a maximum distance between the repeaters if it is desired to make said link operate correctly.18 dBm50 Km

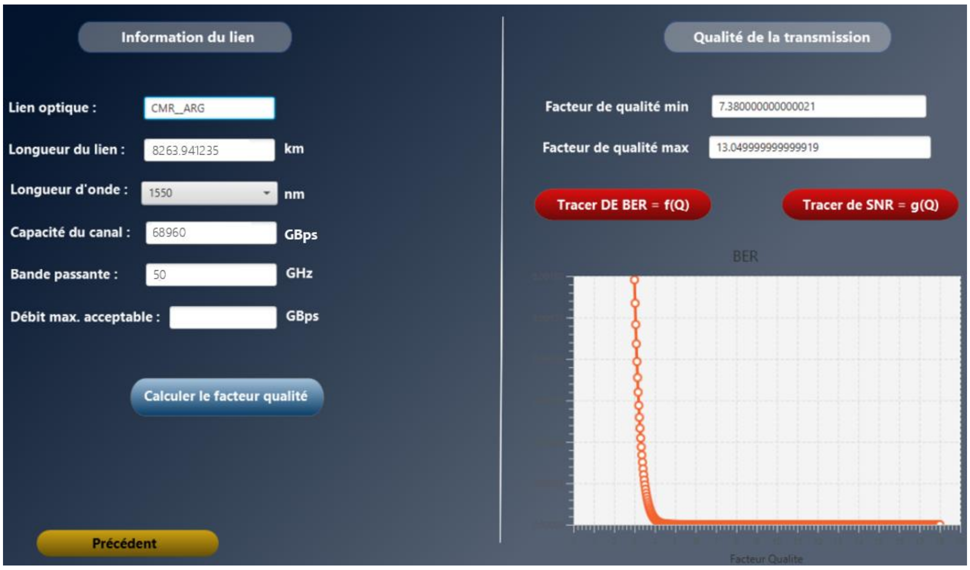

figure15: Result of the estimation of the quality factor

The quality evaluation shows here that the quality factor should be in the interval [7.38;13.04] for the link to be considered good. It can therefore be seen through the graph generated by the plot of BER as a function of Q that the BER will be almost zero if the quality factor is high. This reflects a minimization of errors during data transmission.

figure16: assessment of the optical link establishment

The total capacity of the link is that of 68960 GBps thus involving a fiber of (11) eleven strands for an SDH multiplexing hierarchy capable of multiplexing 862 channels per fiber.
The distribution of the flow forecast can therefore be carried out as follows:

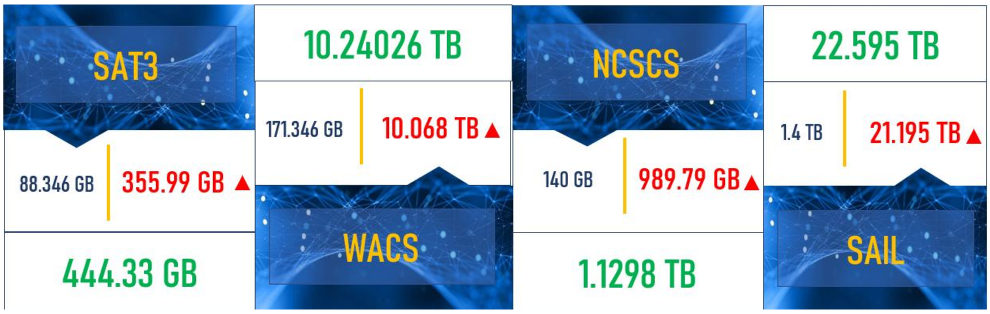

Figure17: distribution of traffic according to submarine optical links

Optical links

The set of preceding calculations lead to the following result through which we can visualize the future link to be established as well as the set of data related to the capacity and the geographic position of landing stations.

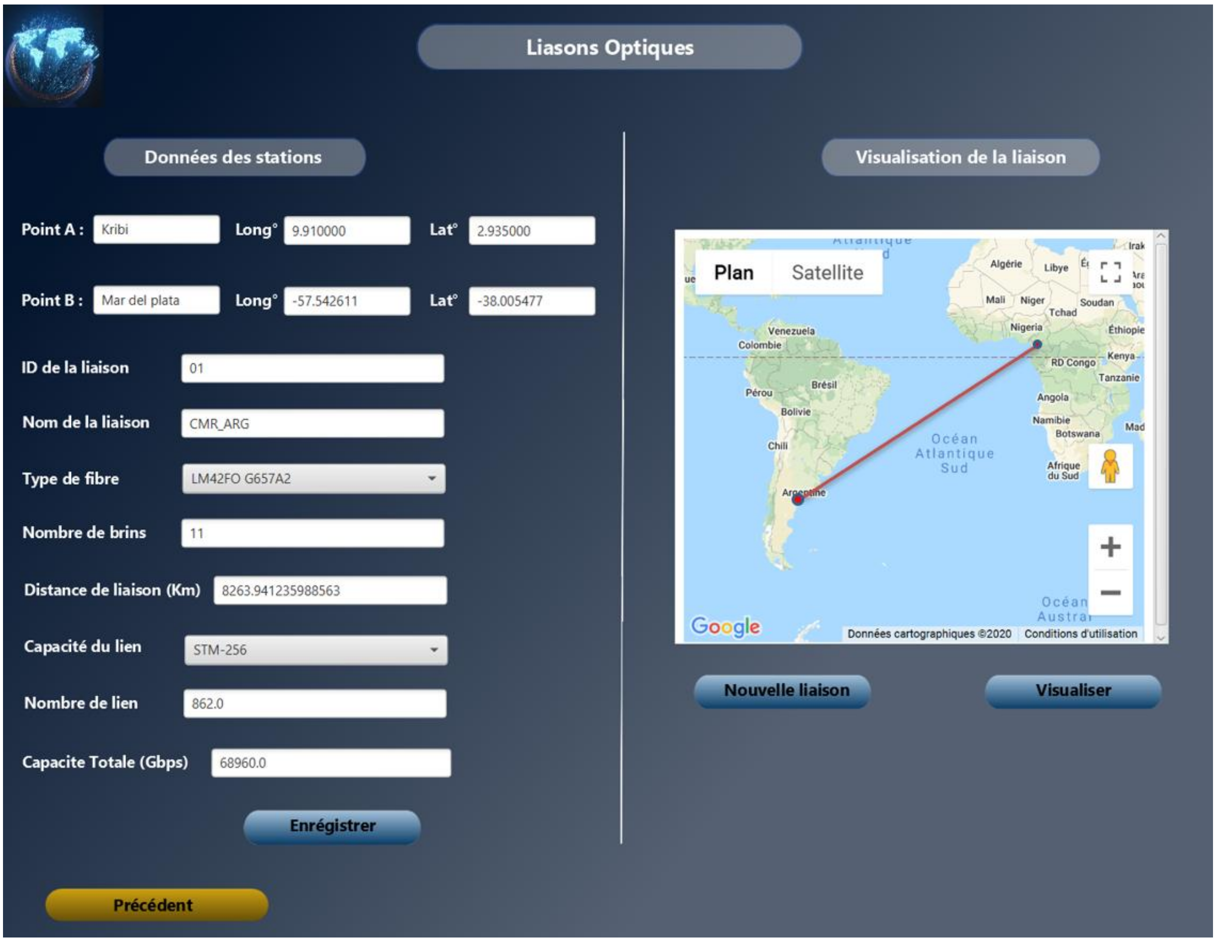

Figure 18: link results after calculations

After having carried out all the calculations necessary for the dimensioning of the optical links, the various results resulting from these as well as the user data are listed in a database as illustrated in figure 19.

On this paper, we have highlighted our theoretical study of the dimensioning process through a practical application on a real case. This practical study was provided by the present proposed dimensioning tool. We finally carried out some tests to verify the functionality of the tool.

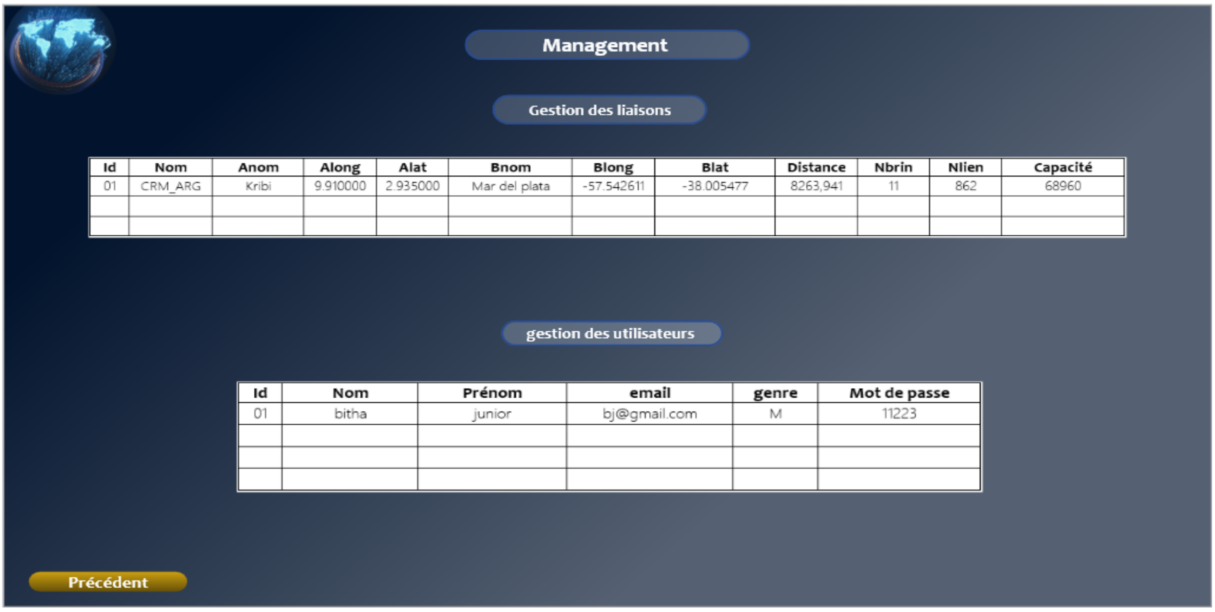

Figure 19: Users database and links

IV. Conclusion

The implementation of future submarine optical links should be based on taking into account the evolution of data demand according to the life cycle of a submarine optical cable to limit the additional expenses related to the study phases and the installation of new cables to expand the capacity of the existing ones. Long-distance telecommunications networks have always tried to meet the increasingly pressing needs of subscribers, mainly in terms of data services. However, the ad hoc nature of the dimensioning of these submarine optical networks affects the provision of data services with respect to the rapid evolution of said services and the exponential demand for bandwidth from subscribers, thus causing congestion problems in these networks and generating additional costs with a view to increasing their capacity. Faced with this situation, the modelling of a dimensioning of submarine optical links based on the evolving nature of services and the exponential demand for Internet-related services during the life cycle of said fibre appears to be the appropriate solution whose implementation will incur minimal long-term costs. It is in this context that this article is based on the study of the submarine optical network in order to propose an adequate tool for sizing submarine optical links with a application to the Central African sub-region. To this end, we have detailed the process of sizing an submarine optical network as well as the operation of the software tool that we have developed and presented. With the deployment of 5G in the sub Saharan region especially in central African region, the demand in terms of data and mobile data will increase faster than before and the capacity of the submarine links should be able to fulfil all the requirements and subscribers demand. This justifies the need of capacity design accounting the traffic evolution with respect to the time.

References

[1]. Niels Brügger, Gerard Goggin, Ian Milligan & Valérie Schafer (2017) Introduction: Internet histories, Internet Histories, 1:1-2, 1-7, DOI: 10.1080/24701475.2017.1317128. https://doi.org/10.1080/24701475.2017.1317128

[2]. M. BENCHEKROUN, "Etude et Dimensionnement d'une boucle NGWDM sur le réseau IAM," Marakhech, 2016.

[3]. "DSP for 100 1 Gb/s, Optical Fiber Communication Conference and Exposition and the National Fiber Optic Engineers Conference (OFC/NFOEC)". Patent paper OW1E.1, 17 Mars 2013.

[4]. W. P. A. O. A. e. P. D. Van Parys, "« Quantifying the benefits of selective wavelength regeneration in ultra-long-haul WDM networks »," In Optical Fiber Communication , 2001.

[5]. J. CHESNOY, "les technologies des câbles sous-marins du 21e sièc l," 2016. [Online]. Available: dx.doi.org/10.1051/photon/20168334. [Accessed 18 Octobre 2020].

[6]. G. Agrawal, " Fiber-Optic Communication Systems," New York, N.Y. : John Wiley & Sons, 1997., p. pp. 172 .

[7]. ALCATEL SUBMARINE NETWORKS, Introduction to Repeatered Submarine Networks - training manual, Paris: ASN, 2017.

[8]. J. CHESNOY, Undersea Fiber Communications Systems second edition, Paris: ELSEVIER, 2016.

[9]. A. MARKOV, "Summary of Undersea Fiber Optic Network Technology and Systems," TerreMark worlwide Inc.

[10]. Gabriel Charlet and Pascal Pecci, Alcatel-Lucent Submarine Networks, Ultra-long haul submarine transmission, chapter in books (Undersea Fiber Communication Systems, Second Edition by Chesnoy, © 2016 Elsevier Ltd. All rights reserved) pages 200-202.

[11]. Leroy JB, Marmier P, Laval C, Gautheron O. 2000 32310 Gbit/s transmission over 8000 km using hybrid Raman-Erbium doped fiber optical amplifiers. In: proceedings of OFC 2000, Baltimore, paperTuJ4.

[12]. Bergano NS, Davidson CR. Circulating loop transmission experiments for the study of long-haul transmission systems using erbium doped fiber amplifiers. J. Lightwave Technol. 1995;13:879.

[13]. Vareille G, Pitel F, Uhel R, Bassier G, Collet J-P, Bourret G, et al. 1999. 340 Gbit/s (34310 Gbit/s, 50 GHz spacing DWDM) Straight Line Transmission over 6380 km with Full System Implementation Assessment. In: Proceedings of OFC'99, San Diego, CA, paper PD18.
[14]. Leroy JB, Marmier P, Le Flao C. 2001. Optimum fiber for 1 Tbit/s transoceanic transmission system. In: Proceedings of SubOptic 2001, Kyoto, paper T3.2.5.
[15]. Tsuritani T, Yamada Y, Agata A, Takeda N, Edagawa N, Suzuki M. 2000. 1 Tbit/s (100310.7 Gbit/s) transpacific transmission over 7750 km using single-stage 980 nmpumped C-band optical repeaters without Forward Error Correction. In: Proceedings of OECC2000, paper 11A2-3.
[16]. Davidson CR, Chen CJ, Nissov M, Pilipetskii A, Ramanujam N, Kidorf HD, et al. 2000. 1800 Gbit/s transmission of one hundred and eighty 10 Gbit/s WDM channels over 7000 km using full EDFA C-band. In: Proceedings of OFC 2000, Baltimore, paper PD 25.
[17]. Bakshi B, Areny MF, Vaa M, Golovshenko EA, Duff D, Li H, et al. 2001. 1 Tbit/s (101310 Gbit/s) transmission over transpacific distance using 28 nm C-band EDFAs. In: Proceedings of OFC 2001, Anaheim, paper PD21
[18]. Bertran-Pardo O, Renaudier J, Tran P, Mardoyan H, Brindel P, Ghazisaeidi A, et al. Submarine transmissions with spectral efficiency higher than 3 b/s/Hz using Nyquist pulse-shaped channels, OFC 2013, Paper OTu2B.1.
[19]. T. M. Mitchell, "Machine Learning," New York,, McGraw-Hill, 1997.
[20]. G. Bonaccorso, "Machine Learning Algorithms - Popular algorithms for data science and machine learning," no. Available: https://www.packt.co, p. page 404.
[21]. Deussom Eric and Tonye Emmanuel « Optimisation du modèle d'Okumura Hata par larégression linéaire. Application à la ville de Yaoundé au Cameroun », IOSR Journal ofElectronics and Communication Engineering (IOSR-JECE) e-ISSN: 2278-2834,p-ISSN:2278-8735.Volume 10, Issue 6, Ver. I (Nov - Dec .2015), PP 63-72.
[22]. L. AUDIBERT, "diagramme de classe," [Online]. Available: https://laurentaudibert.developpez.com/Cours-UML/?page=diagramme-classe. [Accessed 16 Novembre 2020].
[23]. Agence de Régulation des Télécommunications, "Observatoire annuel 2017 du marché des communications électroniques," Yaoundé, 2018.
[24]. Agence de Régulation des Télécommunications, "Observatoire annuel 2019 du marché des communications électroniques," Yaoundé, 2020.

DEUSSOM DJOMADJI Eric Michel, et. al. "Proposal for a capacity dimensioning tool for Mobile broadband capacity reservation in submarine optical links: Case of Cameroon." *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)*, 17(6), 2022, pp. 62-77.