NetXPTO - NetPlanner

16 de Novembro de 2017

Conteúdo

Capítulo 1

Introduction

LinkPlanner is devoted to the simulation of point-to-point links.

Capítulo 2

Simulator Structure

LinkPlanner is a signals open-source simulator.

The major entity is the system.

A system comprises a set of blocks.

The blocks interact with each other through signals.

2.1 System

2.2 Blocks

2.3 Signals

List of available signals:

- Signal

Capítulo 3

Development Cycle

The NetXPTO-LinkPlanner has been developed by several people using git as a version control system. The NetXPTO-LinkPlanner repository is located in the GitHub site http://github.com/netxpto/linkplanner. The more updated functional version of the software is in the branch master. Master should be considered a functional beta version of the software. Periodically new releases are delivered from the master branch under the branch name Release<Year><Month><Day>. The integration of the work of all people is performed by Armando Nolasco Pinto in the branch Develop. Each developer has is how branch with his/her name.

Capítulo 4

Case Studies

Student Name	:	Tiago Esteves
Starting Date	:	October 03, 2017
Goal	:	Implement the dimensioning of optical networks in the translucent transport mode.

4.1 Opaque with 1+1 Protection

In this case study we focus on the opaque case with 1 + 1 protection.

4.1.1 Physical Network Topology

Reference Network

As we can see in the figure, our reference network consists of 6 nodes and 8 Bidirectional links. The average length of the links was chosen so that the following calculations are more simplistic.

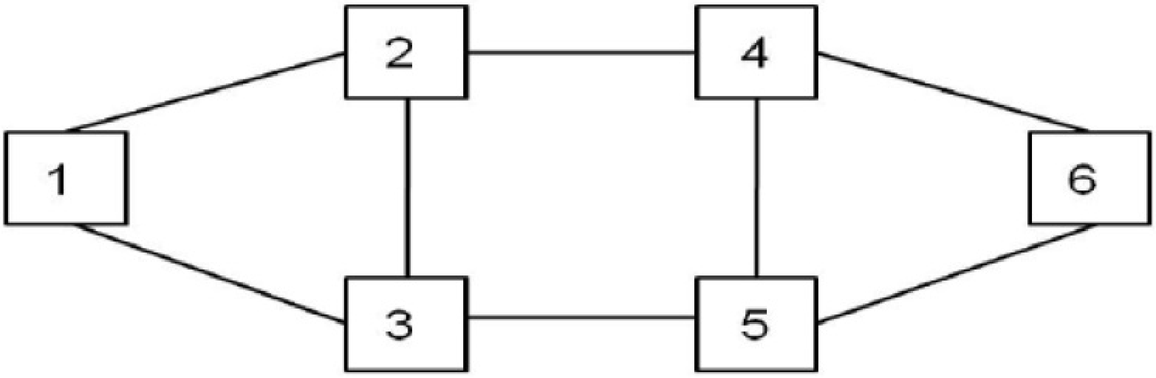

Figura 4.1: Physical Topology of the Reference Network.

The following table shows the values of the variables associated with this network.

Constant	Description	Value
N	Number of Nodes	6
L	Number of Bidirectional Links	8
$<\delta>$	Node out-degree	2,667
<len>	Mean Link Length (km)	500
<h>	Mean Number of Hops,for Working Paths	1,533
<h'>	Mean Number of Hops,for Backup Paths	2,467

Tabela 4.1: Table of reference network values

As we can see from table 4.5, to do all the calculations necessary for this project, let us know the value of the traffic used. This value is defined depending on the scenario used, as we can see:

- Low Traffic: **0.5 TBits/s**
- High Traffic: **5 TBits/s**

Realistic Network

The real network chosen for this work is the EON (European Optical Network). The way the nodes are arranged geographically can be seen from the following figure.

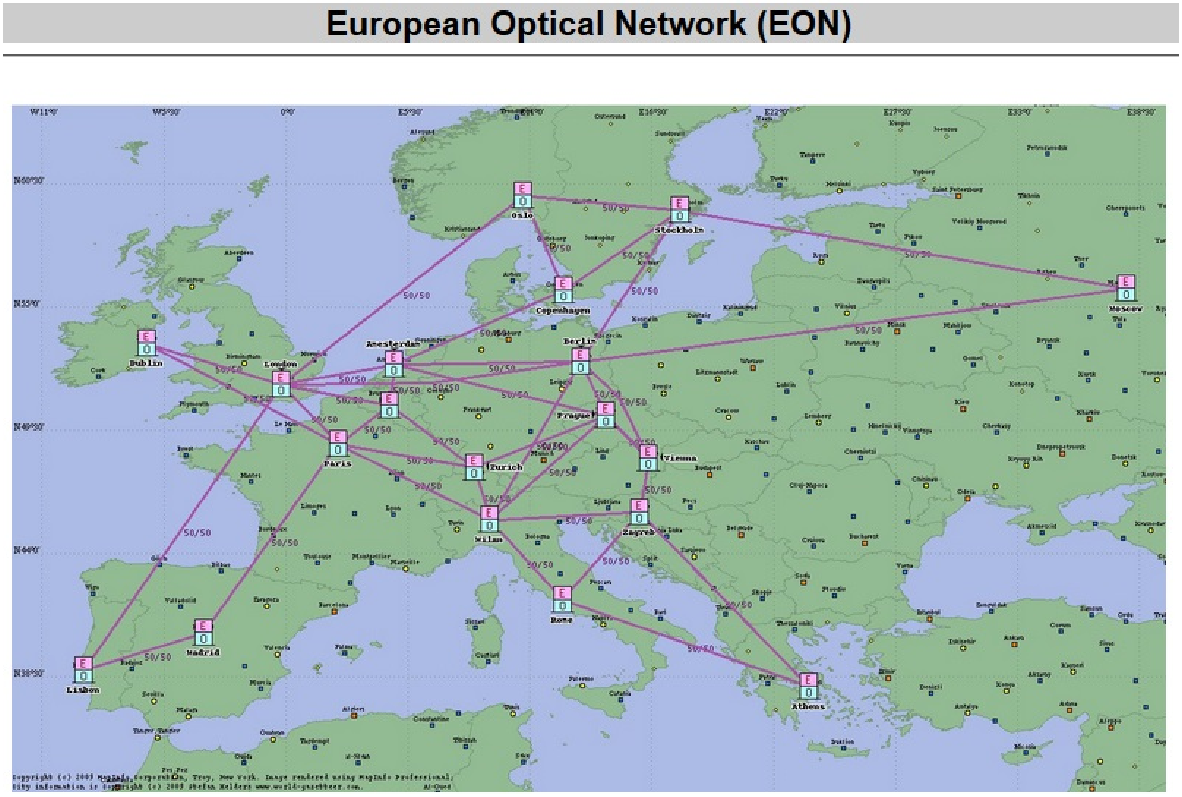

Figura 4.2: Physical Topology of the Realistic Network.

The table 4.6 shows the values of the variables associated with this network.

Constant	Description	Value
N	Number of Nodes	19
L	Number of Bidirectional Links	37
<δ>	Node out-degree	3,89
<len>	Mean Link Length (km)	753,76
<h>	Mean Number of Hops,for Working Paths	2,3
<h'>	Mean Number of Hops,for Backup Paths	3,2

Tabela 4.2: Table of realistic network values

Again, to make all the necessary calculations, only the value of the traffic used is missing. This value is set depending on the scenario used, as we can see:

- Low Traffic: **2 TBits/s**

- High Traffic: **20 TBits/s**

4.1.2 Dimensioning using ILP models

The objective function of following ILP is a minimization of the sum of two variables: total number of flows crossing link (i; j) for all demand pairs (o; d) and total number of optical channels in each link (i; j).

$$minimize \quad \sum_{(i,j)} \sum_{(o,d)} f_{ij}^{od} + \sum_{(i,j)} W_{ij} \tag{3.1}$$

$$subject\ to$$

$$\sum_{j \backslash \{o\}} f_{ij}^{od} = 2 \qquad \forall (o,d) : o < d \ , \forall i : i = o \tag{3.2}$$

$$\sum_{j \backslash \{o\}} f_{ij}^{od} = \sum_{j \backslash \{d\}} f_{ji}^{od} \qquad \forall (o,d) : o < d \ , \forall i : i \neq o, d \tag{3.3}$$

$$\sum_{j \backslash \{d\}} f_{ji}^{od} = 2 \qquad \forall (o,d) : o < d \ , \forall i : i = d \tag{3.4}$$

$$\sum_{(o,d):o<d} (f_{ij}^{od} + f_{ji}^{od}) + \sum_{c \in C} (B(c) D_{cod} \leq 100 W_{ij} G_{ij} \qquad \forall (i,j) : i < j \tag{3.5}$$

$$W_{ij} \leq 80 \qquad \forall (i,j) : i < j \tag{3.6}$$

$$f_{ij}^{od}, f_{ji}^{od} \in \{0, 2\} \qquad \forall (i,j) : i < j, \forall (o,d) : o < d \tag{3.7}$$

$$W_{ij} \in \mathbb{N} \qquad \forall (i,j) : i < j \tag{3.8}$$

The objective function, to be minimized, is the expression(3.1). The flow conservation constraints are (3.2), (3.3) and (3.4). First constraint ensures that, for all demand pairs (o,d), it routes two flows of traffic for all bidirectional links (i,j) when "j"is not equal to the origin of the demand. Equation (3.4) is based on the same idea of (3.1), however applied in reverse direction. Assuming bidirectional traffic, so the number of flows in both directions of the link is the same (3.3). The inequality (3.5) is considered grooming constraint, so it means the total client traffic flows can not be greater than the capacity of optical channels on all links. Another important constraint (3.6) is the capacity of the optical channels which must be less or equal to 100 Gb/s or 80 ODU0. The number of flows per demand can be zero if there are no traffic demands or two if considering working and protection traffic (3.7). The last constraint is just needed to ensure the number optical of channels is a positive integer values greater than zero.

4.1.3 ILP Results

In this initial phase the results will be presented using ILP to calculate the CAPEX of the reference network. For this we will use the following calculation formulas:

We will also need a price list that we can see below.

$$C_C = C_L + C_N \qquad C_L = 2L\langle\gamma_0^{OLT}\rangle + 2L\langle\gamma_1^{OLT}\rangle\,\tau\,\langle w\rangle + L\langle n^R\rangle\langle c^R\rangle$$

Figura 4.3: First function is CAPEX cost, second is cost of the links

$$C_n = C_{EXC} + C_{OXC}$$

Figura 4.4: This function represent the cost of the nodes

Equipment	**Cost**
OLT without transponders	15000 €
Transponder	5000 €/Gb
Optical Amplifier	4000 €
EXC	10000 €
OXC	20000 €
EXC Port	1000 €/Gb/s
OXC Port	2500 €/porto

Figura 4.5: Table with costs

Finally we will calculate the CAPEX values for the various situations mentioned.

First we will present the scenario of low traffic and then in the case of a high of traffic. To know the value of CAPEX we will have to first calculate the value of the cost of the links and then the cost of the nodes.

First scenario:

Through the table, of auxiliary calculations and MatLab the value of the cost of the links is:

Cost link = 24 336 000 euros

Again, through the table, of auxiliary calculations and MatLab the value of the cost of the nodes is:

Cost node = 5 860 000 euros

Finally, for this scenario the cost of CAPEX is:

CAPEX = 30 196 000 euros

Second scenario:

Cost link = 191 336 000 euros

Cost node = 48 260 000 euros

CAPEX = 239 596 000 euros

4.1.4 Heuristics

4.2 Transparent with 1+1 Protection

In this case study we focus on the transparent case with 1 + 1 protection.

4.2.1 Physical Network Topology

Reference Network

As we can see in the figure, our reference network consists of 6 nodes and 8 Bidirectional links. The average length of the links was chosen so that the following calculations are more simplistic.

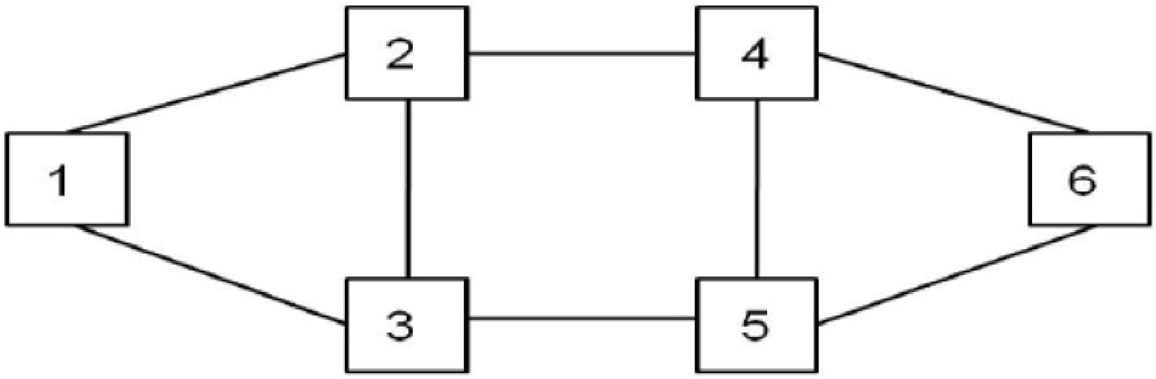

Figura 4.6: Physical Topology of the Reference Network.

The following table shows the values of the variables associated with this network.

Constant	Description	Value
N	Number of Nodes	6
L	Number of Bidirectional Links	8
<δ>	Node out-degree	2,667
<len>	Mean Link Length (km)	500
<h>	Mean Number of Hops,for Working Paths	1,533
<h'>	Mean Number of Hops,for Backup Paths	2,467

Tabela 4.3: Table of reference network values

As we can see from table 4.5, to do all the calculations necessary for this project, let us know the value of the traffic used. This value is defined depending on the scenario used, as we can see:

- Low Traffic: **0.5 TBits/s**
- High Traffic: **5 TBits/s**

Realistic Network

The real network chosen for this work is the EON (European Optical Network). The way the nodes are arranged geographically can be seen from the following figure.

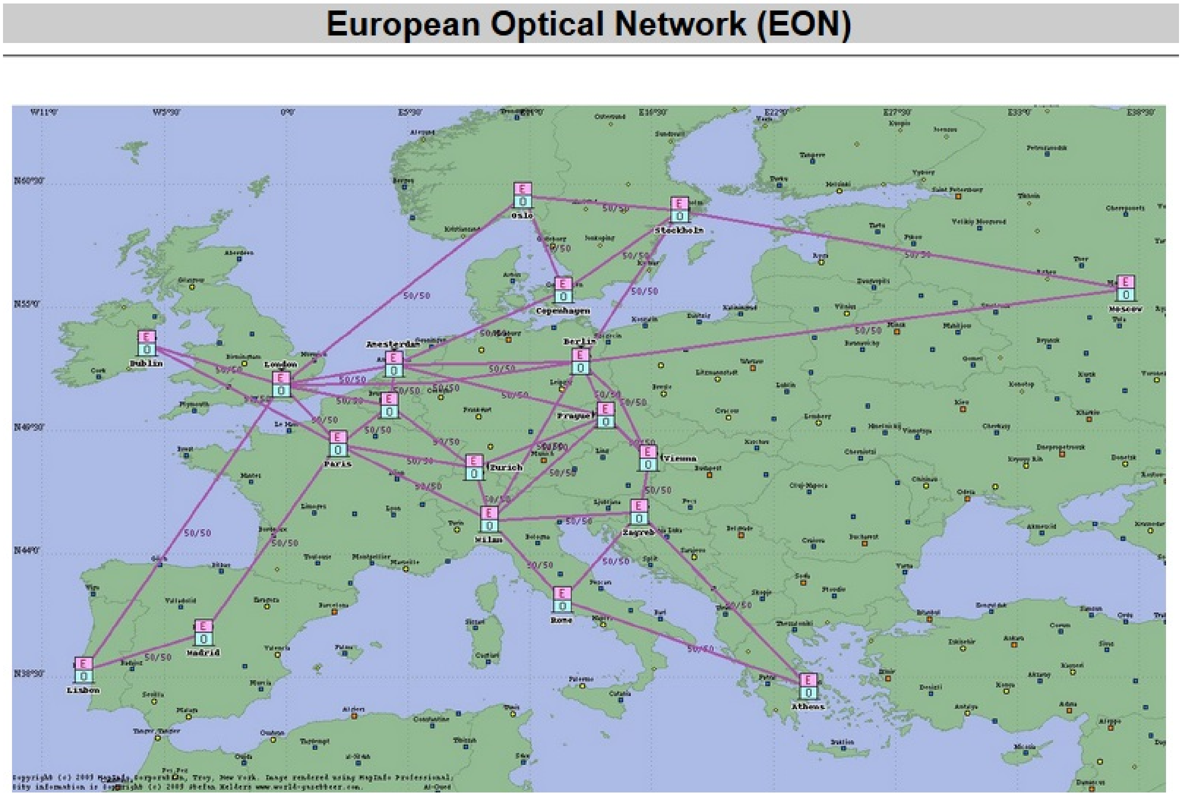

Figura 4.7: Physical Topology of the Realistic Network.

The table 4.6 shows the values of the variables associated with this network.

Constant	Description	Value
N	Number of Nodes	19
L	Number of Bidirectional Links	37
<δ>	Node out-degree	3,89
<len>	Mean Link Length (km)	753,76
<h>	Mean Number of Hops,for Working Paths	2,3
<h'>	Mean Number of Hops,for Backup Paths	3,2

Tabela 4.4: Table of realistic network values

Again, to make all the necessary calculations, only the value of the traffic used is missing. This value is set depending on the scenario used, as we can see:

- Low Traffic: **2 TBits/s**

- High Traffic: **20 TBits/s**

4.2.2 Dimensioning using ILP models

The optimization model suggested for transparent transport mode with dedicated path protection intends to minimize the total number of flows crossing link (i; j) for all demand pairs (o; d). The mathematical model described below also minimizes the total number of optical channels between each demand end nodes Wod, instead of minimizing the number of optical link-by-link channels as in the previous model.

$$minimize \quad \sum_{(i,j)} \sum_{(o,d)} f_{ij}^{od} + \sum_{(o,d)} W_{od} \tag{3.9}$$

$$subject\ to$$

$$\sum_{j \backslash \{o\}} f_{ij}^{od} = 2 \qquad \forall (o,d) : o < d, \forall i : i = o \tag{3.10}$$

$$\sum_{j \backslash \{o\}} f_{ij}^{od} = \sum_{j \backslash \{d\}} f_{ji}^{od} \qquad \forall (o,d) : o < d \ , \forall i : i \neq o, d \tag{3.11}$$

$$\sum_{j \backslash \{d\}} f_{ji}^{od} = 2 \qquad \forall (o,d) : o < d, \forall i : i = d \tag{3.12}$$

$$\sum_{(o,d):o<d} (f_{ij}^{od} + f_{ji}^{od}) x W_{od} \leq 80 G_{ij} \qquad \forall (i,j) : i < j \tag{3.13}$$

$$f_{ij}^{od}, f_{ji}^{od} \in \{0, 2\} \qquad \forall (i,j) : i < j, \forall (o,d) : o < d \tag{3.14}$$

$$W_{od} \in \mathbb{N} \qquad \forall (o,d) : o < d \tag{3.15}$$

The objective function, to be minimized, is the expression(3.9). The flow conservation is performed by equations (3.10), (3.11) and (3.12) and share the same mathematical description of opaque model. The inequality (3.13) answers capacity constraint problem. Then, total flows times the traffic of the demands must be less or equal to the capacity of network links. The grooming of this model can be done before routing since the traffic is aggregated just for demands between the same nodes, thus not depending on the routes. Last two constraints define the total number of flows must be zero if there is no demand, or two for a demand with traffic protection, and the number of optical channels must be a counting number.

4.2.3 ILP Results

In this initial phase the results will be presented using ILP to calculate the CAPEX of the reference network. For this we will use the following calculation formulas:

We will also need a price list that we can see below.

Finally we will calculate the CAPEX values for the various situations mentioned.

The first we will present the low traffic and then the high of traffic. To know the value of CAPEX we will have to first calculate the value of the cost of the links and then the cost of the nodes.

$$C_C = C_L + C_N \qquad C_L = 2L\langle\gamma_0^{OLT}\rangle + 2L\langle\gamma_1^{OLT}\rangle\,\tau\,\langle w\rangle + L\langle n^R\rangle\langle c^R\rangle$$

Figura 4.8: First function is CAPEX cost, second is cost of the links

$$C_n = C_{EXC} + C_{OXC}$$

Figura 4.9: This function represent the cost of the nodes

Equipment	Cost
OLT without transponders	15000 €
Transponder	5000 €/Gb
Optical Amplifier	4000 €
EXC	10000 €
OXC	20000 €
EXC Port	1000 €/Gb/s
OXC Port	2500 €/porto

Figura 4.10: Table with costs

First scenario:

Through the table, of auxiliary calculations and MatLab the value of the cost of the links is:

Cost link = 44 336 000 euros

Again, through the table, of auxiliary calculations and MatLab the value of the cost of the nodes is:

Cost node = 2 515 000 euros

Finally, for this scenario the cost of CAPEX is:

CAPEX = 46 851 000 euros

Second scenario:

Cost link = 391 336 000 euros

Cost node = 21 445 000 euros

CAPEX = 412 781 000 euros

4.2.4 Heuristics

4.3 Translucent with 1+1 Protection

In this case study we focus on the translucent case with 1 + 1 protection.

4.3.1 Physical Network Topology

Reference Network

As we can see in the figure, our reference network consists of 6 nodes and 8 Bidirectional links. The average length of the links was chosen so that the following calculations are more simplistic.

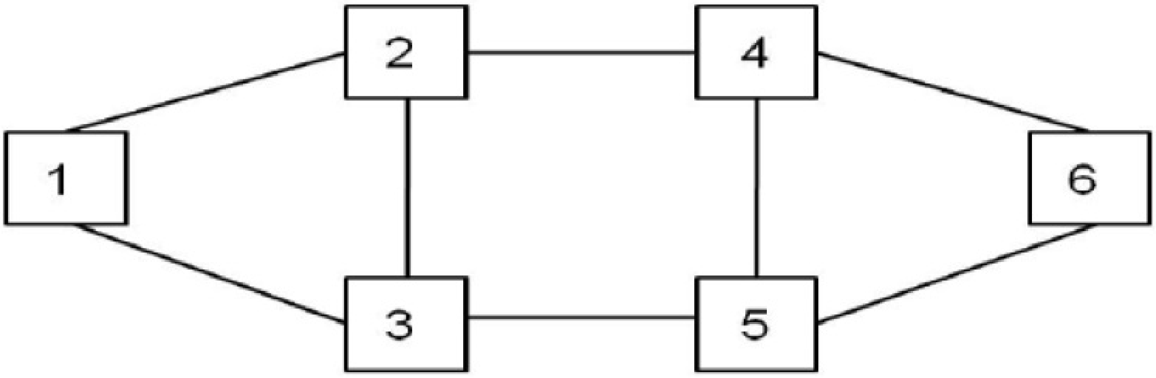

Figura 4.11: Physical Topology of the Reference Network.

The following table shows the values of the variables associated with this network.

Constant	Description	Value
N	Number of Nodes	6
L	Number of Bidirectional Links	8
<δ>	Node out-degree	2,667
<len>	Mean Link Length (km)	500
<h>	Mean Number of Hops,for Working Paths	1,533
<h'>	Mean Number of Hops,for Backup Paths	2,467

Tabela 4.5: Table of reference network values

As we can see from table 4.5, to do all the calculations necessary for this project, let us know the value of the traffic used. This value is defined depending on the scenario used, as we can see:

- Low Traffic: **0.5 TBits/s**
- High Traffic: **5 TBits/s**

Realistic Network

The real network chosen for this work is the EON (European Optical Network). The way the nodes are arranged geographically can be seen from the following figure.

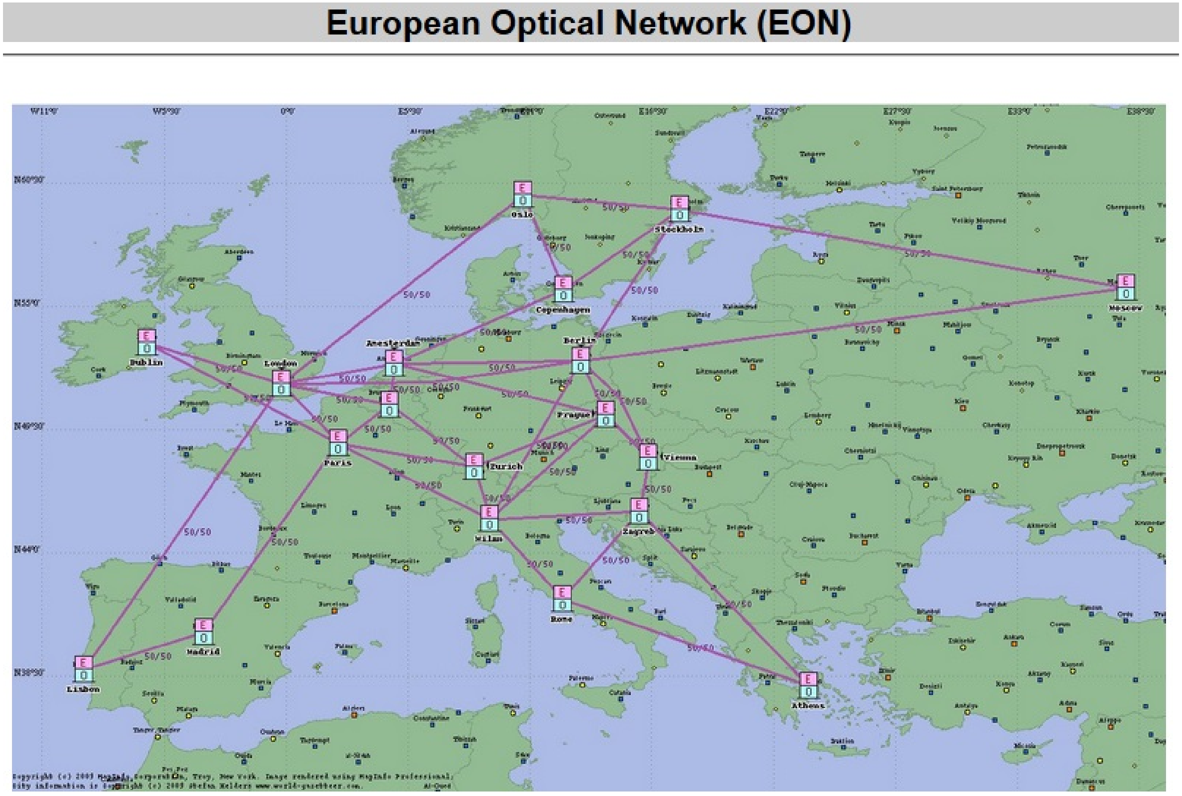

Figura 4.12: Physical Topology of the Realistic Network.

The table 4.6 shows the values of the variables associated with this network.

Constant	Description	Value
N	Number of Nodes	19
L	Number of Bidirectional Links	37
$<\delta>$	Node out-degree	3,89
<len>	Mean Link Length (km)	753,76
<h>	Mean Number of Hops,for Working Paths	2,3
<h'>	Mean Number of Hops,for Backup Paths	3,2

Tabela 4.6: Table of realistic network values

Again, to make all the necessary calculations, only the value of the traffic used is missing. This value is set depending on the scenario used, as we can see:

- Low Traffic: **2 TBits/s**

- High Traffic: **20 TBits/s**

4.3.2 Dimensioning using ILP models

4.3.3 ILP Results

In this initial phase the results will be presented using ILP to calculate the CAPEX of the reference network. For this we will use the following calculation formulas:

$$C_C = C_L + C_N \qquad C_L = 2L\langle\gamma_0^{OLT}\rangle + 2L\langle\gamma_1^{OLT}\rangle\,\tau\,\langle w\rangle + L\langle n^R\rangle\langle c^R\rangle$$

Figura 4.13: First function is CAPEX cost, second is cost of the links

$$C_n = C_{EXC} + C_{OXC}$$

Figura 4.14: This function represent the cost of the nodes

We will also need a price list that we can see below.

Equipment	Cost
OLT without transponders	15000 €
Transponder	5000 €/Gb
Optical Amplifier	4000 €
EXC	10000 €
OXC	20000 €
EXC Port	1000 €/Gb/s
OXC Port	2500 €/porto

Figura 4.15: Table with costs

Finally we will calculate the CAPEX values for the various situations mentioned.

4.3.4 Heuristics

Capítulo 5

Attachments