

Design, control and management of a interconnecting link between medellin and bogota through a network of dwdm fiber optic of latest technology

¹Juan Manuel Sánchez Céspedes, ²Camilo Ramos Moyano, ¹Jhon Francined Herrera Cubides

¹Faculta de Ingeniería, Universidad Distrital "Francisco José de Caldas", Bogotá, Colombia,

Correo-e: jmsanchezc@udistrital.edu.co

jfherrerac@udistrital.edu.co

²Faculta de Ingeniería, Universidad Manuela Beltrá, Bogotá, Colombia,

Correo-e: camilo.ramos@docentes.umb.edu.co

Resumen— En este artículo se describe el diseño de una red de fibra óptica entre Bogotá y Medellín, cuyo objetivo principal es optimizar el ancho de banda por la tecnología DWDM. El diseño fue realizado con equipos de transmisión óptica OSN 6800 con la última tecnología, que puede manejar hasta 80 longitudes de onda. Además, esta red utiliza nodos de control y software de gestión de red a través de T2000, que se utiliza en la prestación de servicios en las redes ópticas reales. La contribución más importante de este artículo es su carácter práctico, ya que puede ser utilizado por los lectores como una herramienta para orientar el diseño de las redes ópticas para la transmisión de datos, el uso de dispositivos comerciales y los principales parámetros que se consideran en cualquier diseño.

Palabras clave— DWDM, Fibra Óptica, Gestión de Redes, Redes Ópticas.

Abstract— This paper describes the design of a fiber optic network between Bogotá and Medellín, whose main objective is to optimize the bandwidth by DWDM technology. The design was done with optical transmission equipment OSN 6800 with the latest technology, which can handle up to 80 wavelengths. Moreover, this network utilizes control nodes and network management software through T2000, which is used in the provision of services in the real optical networks. The most important contribution of this article is its practical character, because it can be used by the readers as a tool to guide the design of optical networks for data transmission, using commercial devices and the key parameters that are considered in any design.

Key Word — DWDM Fiber Optic, Network Management, Optical Network.

I. INTRODUCCIÓN

The analysis and design presented in the paper are very important for the people who work on areas related to Information Technologies and Communications, specifically for those working on fiber optic networks. The paper serves as a bridge or guide to develop and design fiber optic rings using commercial devices facilitating the design process of these types of networks. Using the process described in this paper, designers will save time and reduce errors, and in consequence they will optimize resources.

In this paper is shown a communication link by optical fiber, using DWDM technology in a ring topology. In the link the cities of Bogotá and Medellín are connected by two different paths for up and down traffic, giving redundancy. Careful design was conducted, detailed and mostly suited for each of sections link, based on the characteristics of the equipment and its components, in order to transmit data optimally.

The use of real, actual, and commercial equipment makes this design to be in the forefront, allowing executing the control and management of the network, using software T2000.

II. FIBER OPTIC RING

The network has a ring topology, with the end nodes Bogotá and Medellín, the network structure is found in Table 1.

CITY 1	CITY 2	DISTANCE
BOGOTÁ	GIRARDOT	136 Km
GIRARDOT	IBAGUÉ	77 Km
IBAGUÉ	PEREIRA	137 Km
PEREIRA	LA PINTADA	165 Km
LA PINTADA	MEDELLÍN	80 Km
MEDELLÍN	DORADAL	115 Km
DORADAL	GUADUAS	121 Km

GUADUAS	BOGOTÁ	164 Km
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Table 1. Cities which integrates the ring and the distances between them.

III. FIBER OPTIC RING

This network is bidirectional, allowing sending data in both directions of the ring. In some of these cities will be managed up and down traffic, others have only amplification points, therefore a summary of services offered in each city is presented in Table 2.

CITY	SERVICE	VALUE
BOGOTÁ	Final Traffic	136 Gbps
GIRARDOT	Optical Line Amplifier	23 dB
IBAGUÉ	intermediate traffic	30 Gbps
PEREIRA	intermediate traffic	35 Gbps
LA PINTADA	Optical Line Amplifier	23dB
MEDELLÍN	Final Traffic	136 Gbps
DORADAL	Optical Line Amplifier	23 dB
GUADUAS	intermediate traffic	23 Gbps

Table 2 Ring Nodes and services.

IV. DESCRIPTION OF THE OPTICAL EQUIPMENT

BWS1600 Huawei equipment, terminals and access points can added and removed services. These devices have the following features for managing DWDM:

- It is an equipment of high capacity and modular design, in which cards can be added as are needed for traffic. [1]
- Using the modular design, the BWS 1600G can be easily upgraded to manage 40, 80, 120 and 160 wavelengths for data transmission. [1]
- Working in the frequency bands C and L, can also be used to expand capacity by 20% to handle 192 wavelengths. Transmission System 10G / 40G (G = Gigahertz). [1]
- The BWS 1600G is the backbone of the DWDM optical transmission system, it offers 80/40 × 40G wavelength transmission capacity. [1]
- By connecting to 40G using Transponder implementation, the equipment BWS 1600G can satisfy the requirements of the operator in transmission and expansion capacity of the optical network. [1]
- Services allowed by the equipment are: Services multi-rate, multi-protocol access, capacity, and various modes of service convergence. [1]
- The BWS1600 handles services SDH / SONET at any bit rate, 1GE / 10GE / 40G data services, and other services with bit rate ranging from 34 Mbps to 2.7 Gbps. [1]

- The BWS1600 contains a unique clock signal transmission, which is used for bidirectional transmission of high accuracy. [1]

It has a full-band tunable transponder, by integrating different data management capabilities in one unit or rack, where the system maintenance can be improved, reducing operating expenses (OPEX) and capital expenditures (CAPEX). It performs protection to the carrier, as well as supporting the traditional 1 +1 protection, the service supports 1: N protection for transponder cards. This mechanism not only guarantees the security of the network, but also saves maintenance costs using standby. [1]

The network is normalized by the standard G.709 (Interfaces for the optical transport network), which is the standard of data communication over an optical network. [2]

The main component of the OTN (Optical Transport Network) is the optical channel OCH, which is defined in ITU-T G.872 standard, which is also structured as layer networks to support network management and supervisory functions as defined in ITU-T G.872. The optical channel with full functionality (OCh) or reduced functionality (OChr) provides transparent network connections between 3R regeneration points OTN. The transport unit completely or functionally standardized optical channel (OTUk / OTUkV) provides supervision and it conditions the signal for transportation between 3R regeneration points of the OTN. The unit of optical channel data (ODUk) provides oversight cascading (ODUKT), path monitoring end-to-end (ODUKP) and adaptation of client signals through the unit optical channel payload (OPUk, Optical Channel Payload Unit - k). The OPUk frame structure (k = 1,2,3) is shown in Figure 1. It is organized as a frame of block structure based on bytes with four rows and 3810 columns. [2] [3] [4]

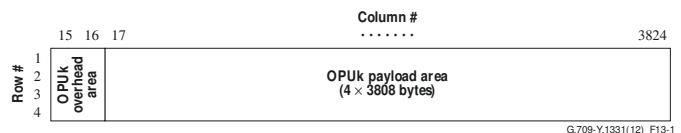


Figure 1 Plot of OPUks [2]

V. DESIGN LINK MEDELLIN – BOGOTA

A. Power Budget [5]

Firstly, locations and distances are established between these places, as is shown in table 1. The distance between nodes and the parameters of the link elements (Table 3), the power budget of each of the links is determined. [5].

$$L_R = \frac{P_T - S - (NC \times \alpha_C) + \alpha_E - MD}{\frac{\alpha_E}{L_C} + \alpha_{FO}} \quad \text{Equation (1)}$$

Where:

ACRONYMS	MEANING	DEVICE
P_T	Minimum transmit power	0dBm
	Maximum transmit power	2dBm
	Transmit Power (Booster)	19dB
S	Low sensitivity team	-22dBm
	Maximum sensitivity of equipment	-3dBm
NC	Number of connectors	2
MD	Design Margin	3dB
L_C	Fiber length reel	9,1km
α_C	Attenuation optical connectors	0,1dB
α_E	Optical attenuation splices	0,1dB
α_{FO}	Attenuation of the optical fiber	0,2dB

Table 3. Equipment data, fiber and other elements of the link [6]

First, is checked the minimum and maximum distance of the link for the chosen fiber (see Tables 1 and 3).

$$L_{Rmin.} = \frac{P_T - S - (NC \times \alpha_C) + \alpha_E - MD}{\frac{\alpha_E}{L_C} + \alpha_{FO}} \rightarrow L_R$$

$$= \frac{19 + 3 - (2 \times 0,1) + 0,1 - 3}{\frac{0,1}{9,1} + 0,2}$$

$$= 89,57km$$

$$L_{Rmax.} = \frac{P_T - S - (NC \times \alpha_C) + \alpha_E - MD}{\frac{\alpha_E}{L_C} + \alpha_{FO}} \rightarrow L_R$$

$$= \frac{19 + 22 - (2 \times 0,1) + 0,1 - 3}{\frac{0,1}{9,1} + 0,2}$$

$$= 179,6km$$

This result shows the maximum and minimum distance of the link with a booster amplifier to the output. It is necessary to calculate the signal power at the input of the device to determine whether the use of attenuators or preamplifiers is necessary.

1. Power Budget of the fiber optic ring western

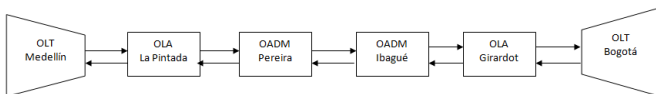


Figure 2 Block diagram of the optic ring western

• Section Medellín - La Pintada, distance 80 km.

$$P_{min} = P_{Tmin} + G_{Booster} - (NC \times \alpha_C) - (NE \times \alpha_E) - (\alpha_{FO} \times L_{TRAMO}) - MD$$

$$P_{min} = 0 + 19 - (2 \times 0,1) - (9 \times 0,1) - (0,2 \times 80) - 3 = -2,91 \text{ dBm}$$

$$P_{max} = P_{Tmax} + G_{Booster} - (NC \times \alpha_C) - (NE \times \alpha_E) - (\alpha_{FO} \times L_{TRAMO}) - MD$$

$$P_{max} = 2 + 19 - (2 \times 0,1) - (9 \times 0,1) - (0,2 \times 80) - 3 = -0,91 \text{ dBm}$$

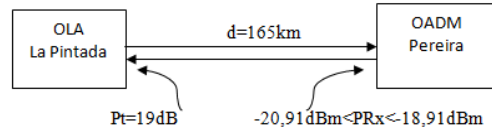


Figure 3. Input and Output powers, section Medellín-La Pintada

$$P_{min} = P_{Tmin} + G_{Booster} - (NC \times \alpha_C) - (NE \times \alpha_E) - (\alpha_{FO} \times L_{TRAMO}) - MD$$

$$P_{min} = 0 + 19 - (2 \times 0,1) - (16 \times 0,1) - (0,2 \times 137) - 3 = -15,01 \text{ dBm}$$

$$P_{max} = P_{Tmax} + G_{Booster} - (NC \times \alpha_C) - (NE \times \alpha_E) - (\alpha_{FO} \times L_{TRAMO}) - MD$$

$$P_{max} = 2 + 19 - (2 \times 0,1) - (16 \times 0,1) - (0,2 \times 137) - 3 = -13,01 \text{ dBm}$$

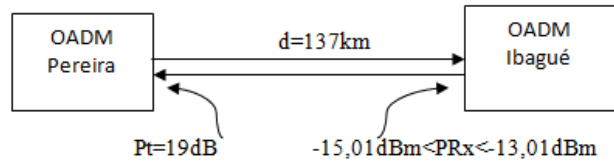


Figure 4. Input and Output powers, section La Pintada-Pereira.

• Section Pereira - Ibagué, distance 137km.

$$P_{min} = P_{Tmin} + G_{Booster} - (NC \times \alpha_C) - (NE \times \alpha_E) - (\alpha_{FO} \times L_{TRAMO}) - MD$$

$$P_{min} = 0 + 19 - (2 \times 0,1) - (16 \times 0,1) - (0,2 \times 137) - 3 = -15,01 \text{ dBm}$$

$$P_{max} = P_{Tmax} + G_{Booster} - (NC \times \alpha_C) - (NE \times \alpha_E) - (\alpha_{FO} \times L_{TRAMO}) - MD$$

$$P_{max} = 2 + 19 - (2 \times 0,1) - (16 \times 0,1) - (0,2 \times 137) - 3 = -13,01 \text{ dBm}$$

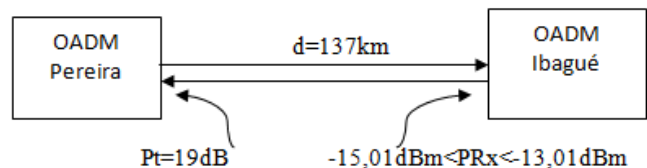


Figure 5. Input and Output powers, section Pereira Ibagué.

• Section Ibagué - Girardot, distance 77km.

$$P_{min} = P_{Tmin} + G_{Booster} - (NC \times \alpha_C) - (NE \times \alpha_E) - (\alpha_{FO} \times L_{TRAMO}) - MD$$

$$P_{min} = 0 + 19 - (2 \times 0,1) - (9 \times 0,1) - (0,2 \times 77) - 3 = -2,31 \text{ dBm}$$

$$P_{max} = P_{T_{max}} + G_{Booster} - (NC \times \alpha_C) - (NE \times \alpha_E) - (\alpha_{FO} \times L_{TRAMO}) - MD$$

$$P_{max} = 2 + 19 - (2 \times 0,1) - (9 \times 0,1) - (0,2 \times 77) - 3 = -0,31 \text{ dBm}$$

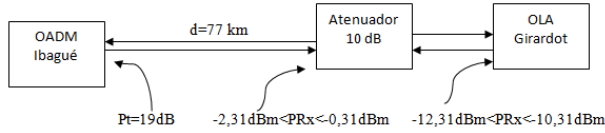


Figure 6. Input and Output powers, section Ibagué Girardot.

• Section Girardot-Bogotá, distance 136 km.

$$P_{min} = P_{T_{min}} + G_{Booster} - (NC \times \alpha_C) - (NE \times \alpha_E) - (\alpha_{FO} \times L_{TRAMO}) - MD$$

$$P_{min} = 0 + 19 - (2 \times 0,1) - (15 \times 0,1) - (0,2 \times 136) - 3 = -14,71 \text{ dBm}$$

$$P_{max} = P_{T_{max}} + G_{Booster} - (NC \times \alpha_C) - (NE \times \alpha_E) - (\alpha_{FO} \times L_{TRAMO}) - MD$$

$$P_{max} = 2 + 19 - (2 \times 0,1) - (19 \times 0,1) - (0,2 \times 164) - 3 = -12,71 \text{ dBm}$$

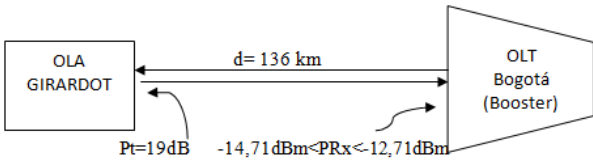


Figure 7. Input and Output powers, section Girardot Bogotá.

2. Power Budget eastern fiber optic ring

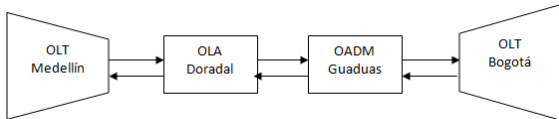


Figure 8. Block diagram eastern part of ring

• Section Medellín-Doradal, distance 164 km.

$$P_{min} = P_{T_{min}} + G_{Booster} - (NC \times \alpha_C) - (NE \times \alpha_E) - (\alpha_{FO} \times L_{TRAMO}) - MD$$

$$P_{min} = 0 + 19 - (2 \times 0,1) - (19 \times 0,1) - (0,2 \times 164) - 3 = -18,9 \text{ dBm}$$

$$P_{max} = P_{T_{max}} + G_{Booster} - (NC \times \alpha_C) - (NE \times \alpha_E) - (\alpha_{FO} \times L_{TRAMO}) - MD$$

$$P_{max} = 2 + 19 - (2 \times 0,1) - (19 \times 0,1) - (0,2 \times 164) - 3 = -16,9 \text{ dBm}$$

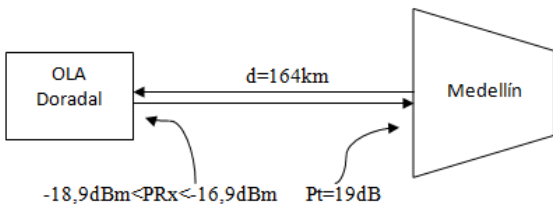


Figure 9. . Input and Output powers, first section

• Section Doradal-Guaduas, distance 121 km.

$$P_{min} = P_{T_{min}} + G_{Booster} - (NC \times \alpha_C) - (NE \times \alpha_E) - (\alpha_{FO} \times L_{TRAMO}) - MD$$

$$P_{min} = 0 + 19 - (2 \times 0,1) - (15 \times 0,1) - (0,2 \times 136) - 3 = - \text{dBm}$$

$$P_{max} = P_{T_{max}} + G_{Booster} - (NC \times \alpha_C) - (NE \times \alpha_E) - (\alpha_{FO} \times L_{TRAMO}) - MD$$

$$P_{max} = 2 + 19 - (2 \times 0,1) - (14 \times 0,1) - (0,2 \times 121) - 3 = -7,8 \text{ dBm}$$

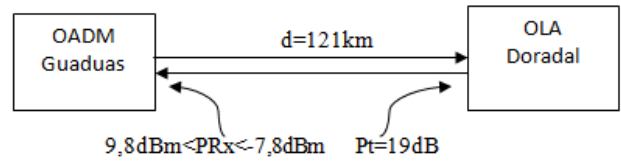


Figure 10. Input and Output powers equipment, first section

The values obtained for the OLA (Optical Line Amplifier) in Doradal, are within the values of the equipment, therefore using more amplifiers or attenuators are not necessary.

• Section Guaduas Bogotá, distance 115km.

$$P_{min} = P_{T_{min}} + G_{Booster} - (NC \times \alpha_C) - (NE \times \alpha_E) - (\alpha_{FO} \times L_{TRAMO}) - MD$$

$$P_{min} = 0 + 19 - (2 \times 0,1) - (12 \times 0,1) - (0,2 \times 105) - 3 = -8,5 \text{ dBm}$$

$$P_{max} = P_{T_{max}} + G_{Booster} - (NC \times \alpha_C) - (NE \times \alpha_E) - (\alpha_{FO} \times L_{TRAMO}) - MD$$

$$P_{max} = 2 + 19 - (2 \times 0,1) - (12 \times 0,1) - (0,2 \times 105) - 3 = -6,5 \text{ dBm}$$

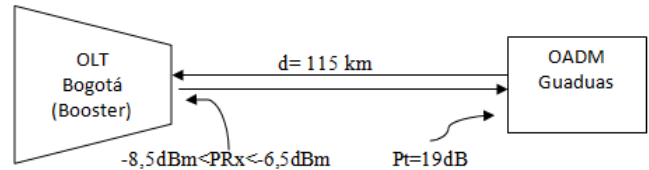


Figure 11. Input and Output powers equipment, first section

Looking at the results of the minimum and maximum power seen from the entrance of the OADM (Optical Add / Drop Multiplexer) in Guaduas, can be concluded that using these values, the link is going to work properly in terms of power transmission and reception.

VI. NETWORK CONTROL

The network is divided into 3 sections for the connection between the cities of Medellín and Bogotá, on the east side of

the ring: The first is from Medellin to Doradal, where it has available security and power to install equipment OLA. The next section is from Doradal to Guaduas, where it also has safety equipment and energy equipment with OADM configuration. And the end is from Guaduas and Bogota. The path is a total distance of about 400 Km. the laying of the fibers is located beside the main road between the two cities.

These are the main points or towns where the laying of the external optical fiber is performed: Bogotá - Mosquera-Shanker - Madrid - Alto Tribune - Alban -Villeta - Guaduas - Alto de la Mona - Honda - Dorada - Puerto Salgar - Freeport- Puerto Triunfo - Doradal - Rio Claro -Cocorna - Sanctuary - Marinilla - Rionegro and Medellín.

The west side of the ring consists of five sections between the two cities and are as follows: the first from Medellin to the town of La Pintada, where it has available security and power to install equipment OLA. Then from the town La Pintada to the city of Pereira, where it has the infrastructure to install the equipment of OADM. The next section is from the city of Pereira to the city of Ibague, where sufficient conditions are obtained to install the equipment of OADM. Then from the city of Ibague to Girardot, where the equipment of OLA was installed and finally between Girardot and Bogotá.



Figure 12. General diagram of the system. (Adaption of www.google.es/maps)

The laying of fiber is installed next to the main road described in the figure 12.

The main OTM (Optical Terminal Multiplexer) system is in Medellin, which has a handling capacity of 127 Gbps and maintains the flow of traffic between the cities of Medellin and Bogota. There is an OADM in Doradal (Antioquia) and two in the cities of Pereira and Ibague, in which it is raised and lowered traffic as configured. It has three OLA located in

the municipalities of Guaduas, Girardot (Cundinamarca) and another in the town of La Pintada (Antioquia). [6]

Table 4 summarizes the cards used for the management of services between these cities as well as the location where the system becomes.

Card	Description	Capacity	Location
LBE	Transmit – Recive line wavelength conversion borrard for 10GE (LAN)	10,71 Gb/s	OTM Bogotá OTM Medellín OADM Pereira OADM Guaduas
LWM	Multi-Rate optical wavelength conversion borrard	2,5 Gb/s	OTM Bogotá OTM Medellín OADM Pereira
LDG	2 x Gigabit Ethernet unit	2,5 Gb/s	OTM Bogotá OTM Medellín OADM Pereira
ELOG	8 x Gigabit Ethernet Multiplex Optical Board	8 Gb/s	OTM Bogotá OTM Medellín OADM Pereira OADM Guaduas
LWF	STM-64 Transmit-recvie conversion unit with FEC/AFEC function	10,71 Gb/s	OTM Bogotá OTM Medellín
LWC	STM-16 line wavelength conversion unit	2,67 Gb/s	OTM Bogotá OTM Medellín OADM Guaduas

Table 4. Summary cards used equipment

The configuration of the rack provision shown in Medellin.

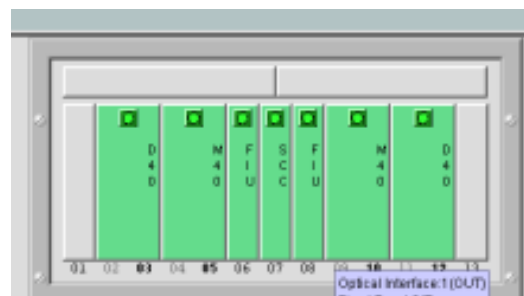


Figure 13. OTM main rack.

In Figure 13 the main sub rack configuration is shown, which has the following cards:

Card	Function	Description
OAU	Booster amplifier card depending	Optical amplifier unit

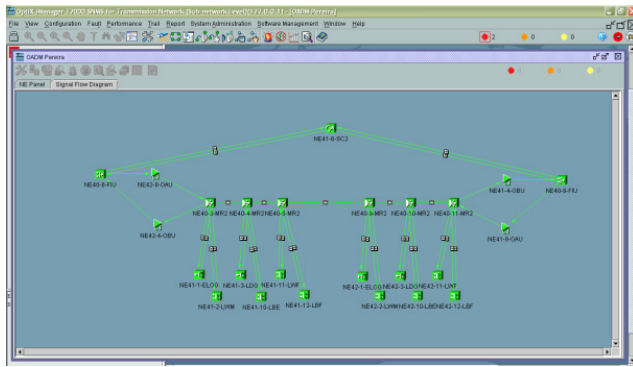


Figure 18 Internal Configuration of the OADM equipment.

The difference between the OADM found in different cities, are the transponders used for each point. The other points of the network are the OLA and these are found in the towns of La Pintada, Girardot and La Dorada. Below is shown the main rack:

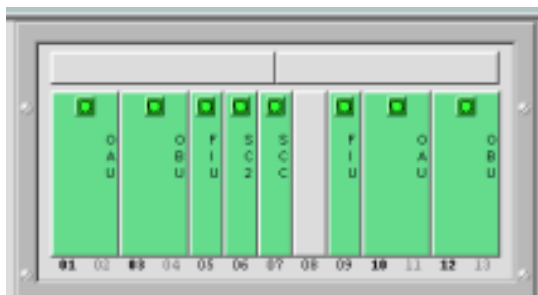


Figure 19. Main Rack OLA

The following is the internal diagram at these points:

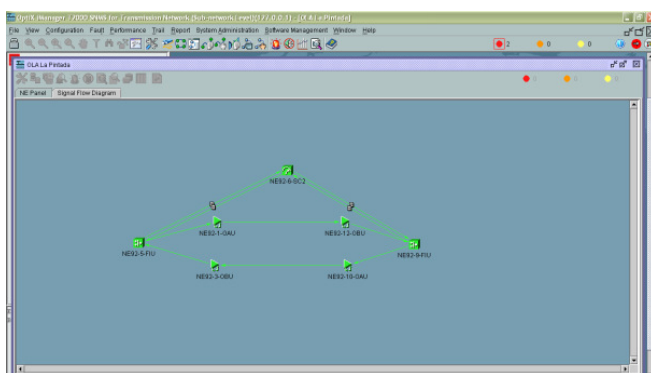
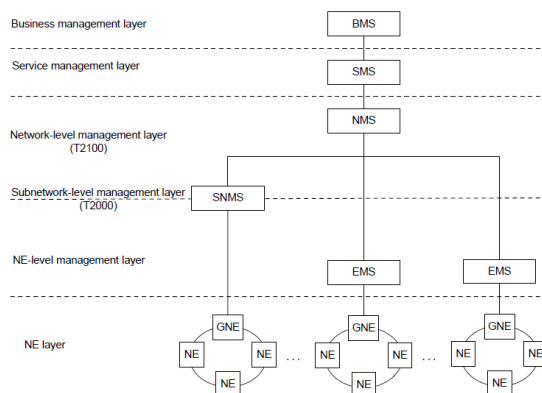


Figure 20. Diagram of the anterior internal rack OLA

VII. NETWORK MANAGEMENT [7] [8]

Figure 21. General diagram of the management plane. [7]



A property program of fabricator does the management of the optical network. It is the T2000, which provides a wealth of solutions for all transmission networks from access to transport equipment. Through this program you can create several layers of management, with more than one management system level through a standard external interface to facilitate the layers of senior management, control, monitoring for large networks transmission. In the following chart is shown the general scheme where can be applied the management system:

This program can manage SDH, DWDM, MPLS, ASON, SONET and PDH transmission systems. The T2000 provides all management functions in the layer network element (NE), some of the features presented by this layer are: fault management, performance management, configuration management, security management, communication management, topology management. [7] [8]

The main functions of management layer are: Search End-to-end fiber optic lines, flowchart fiber management, subnet search for wavelength and management of isolated nodes. [7] [8]

Can be performed alarm monitoring and can be configured by the user: Setting alarms for various functions, automation alarm acknowledgment, automatically synchronization of alarms, analyze the correlation of alarms which can suppress rootless alarms or chained to others changing the severity of them, therefore can be found major faults more quickly, automatically change the status of alarms and keep a record of them; alarm filtering. [7] [8]

On a DWDM optical network can be set: The transponder, service multiplexing, the optical amplifier, the optical stabilization, among others. [7] [8]

In an OADM station, a user can perform ADM settings for:

- GE Services with FC LQG.
- Support for the protection of WXCP with work and the protection of cross-connections configured on the NE or final element.
- The T2000 allows to configure electrical connections to control the flow of services in the electrical layer, and dynamically converge and are divided the services of sub-wavelength or grooming. Thus, networking and survivability of network is enhanced.
- Configuring Cross-optic connection to dynamically create connections Och.
- Manage Connections of optical interconnections for various network basis elements, including the creation, activation, deactivation, removal and consultation. [7] [8]

VIII. CONCLUSIONS

1. In the design of a real fiber optic network, in addition to the study of power between transmitter and receiver, it is necessary to check the internal powers of the equipment in each of its nodes. And each node consists of different cards which can introduce attenuations at certain wavelengths especially in modern optical transmission equipment, which can be fixed from the management plane, because the optical multiplexer have variable attenuators in each of the wavelengths of work.
2. Transmission to deliver different wavelengths (in the case DWDM) with different power levels, it produces a big problem by generating non-linear disturbances in the transmission, which are cumulative, leading to increased intermodulation and intersymbol interference, degrading communication and in some cases interrupting entirely. For that reason the equipment performance in the inner layers the compensation to minimize these drawbacks.
3. The use of a fiber optic two-way network introduces redundancy, producing a backup communication. Therefore, if at any time one path were interrupted, the control plane would enter to find a new route for information.
4. In some sections of the network are necessary additional attenuators at the input of the optical receiver, because the received power saturates the receiver and these attenuators allow the reception to suitable levels.
5. Optical equipment used for real allows multiplexing up to 80 different wavelengths, having a handling traffic for each length of maximum 10 Gbps.
6. This equipment allows grooming, which can build a solid and efficient transportation network.
7. The T2000 is a software package of the Chinese company Huawei, which allows control and management of the network from the core; This software connects to an already implemented network which solve problems without going into the field, reducing costs and time to control network.
8. The use of the ROADM function in the T2000 allows the user to add / drop passing through a configuration of the optical channels. The equipment WDM uses Wavelength Dynamic Control (DWC) and Wave Selective Switch (WSS) to implement the feature of reconfiguration optical add / drop multiplexing.
9. The DWC is applicable to normal nodes in a chain or a ring network. The WSS is applicable to cross-connect nodes in a ring.
10. Overall through this management program allows to manage a whole advanced form of DWDM optical network, as well as making settings, including management services for any operator optical network.
- 11.

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