# OTN Network Based on DWDM Network Transport for CELEC EP – TRANSELECTRIC

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**Abstract— This paper presents the design process of a multiplexer network for national traffic CELEC EP - TRANSELECTRIC with technology OTN (Optical Transport Network), whose base is the current transport network with DWDM technology (Division Multiplexing Dense Wavelength), with the aim of optimizing the existing resources of the transportation network.**

**It provides a transport solution, which allows to combine the flexibility and management of SDH, with the transparency and the ability of DWDM, so that, in addition to providing large capacities of transmission DWDM, it permit the switching of different DWDM channels according to the needs of traffic.**

## INTRODUCTION

Today, technology is a dominant factor in telecommunications and major weakness that facing is the high demand for bandwidth, which has generated the need for technologies that can easily combine multiple networks and services, operating on a common infrastructure, so that the optical fiber is the transmission means most used in networks that require high bandwidth for data transmission due to the large capacity of bandwidth, immunity to interference, signal high security.

OTN technology emerges as a new generation of transport intended for optical fiber regional networks of the large transmission capabilities, allowing for bandwidth management integrated into the core of the transport network and switching different DWDM channels depending on the needs of traffic.

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## I. OPTICAL TRANSPORT NETWORK (OTN)

The OTN technology is currently a key component in the communications infrastructure is known as digital container due to their ability to attach of services in containers digital optical similar to the technology SDH, and applied directly on the wavelengths handled in DWDM technology.

OTN was designed with the aim of optimizing existing resources of a transport network, to provide support for DWDM optical networks, allowing transmissions handle multiple wavelengths on a single fiber to achieve higher transmission capacity, better performance transport, management and monitoring of optical channels carrying client signals. [1]

### *A. Features*

- It based architecture is a DWDM technology, where the payload is supported by a wavelength channels including management and supervision signaling to establish the network.
- OTN is known as a "digital wrapper" because of its ability to attach any service optical digital containers.
- OTN has similar hierarchy SDH technology with the difference that higher switching speeds handled as OTU1 (2.5 Gbps), OTU2 (10.70 Gbps), OTU3 (40Gbps).
- OTN technology is applied in regional or metropolitan networks that handle medium to large capacity traffic.
- Allows use ROADM equipment with higher switching directions DWDM technology.
- Both OTN and DWDM Grid work in the same frequency assigned by the ITU-T G. G94. Spectral grid of WDM applications.

### *B. OTN Architecture*

The OTN architecture allows multiservice transport packets based on the data traffic and management of each channel assigned to a given optical wavelength, this is done by adding a header (OH) to the client signal, which facilitates management and control information in addition to the use of error correction in the signal reception to this introduces two digital network layers as the ODU and OTU for the purpose of customer all signals corresponding to a channel optic. Figure 1. Shows the encapsulation of an OTN signal during the transport of client signal. [3]

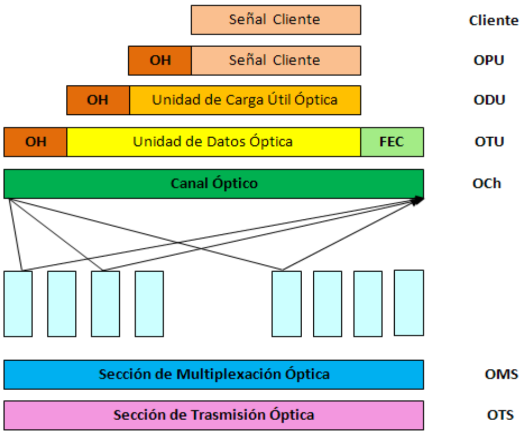


*Figure 1.* Encapsulation of OTN signal

For transporting a client signal in an OTN, it must undergo a process of encapsulation of headers (OH), in order to ensure end-to-end monitoring.

According to the recommendation G.872 of the ITU - T, an optical transport network is decomposed into separate network layers in which each may be divided so as to reflect the internal structure of the network layer. OTN network basically consists of three sections.

- Optical Transport Section (OTS)
- Optical Multiplex Section (OMS)
- Optical Channel (OCh)

- ***Optical Transport Section***

Provides transport of a multiplex section through an optical transmission path between access points. An optical transport section of order n supports a single copy of an optical multiplex section of the same order. The OTS defines a physical interface with parameters such as frequency, power level and signal / noise ratio.

- ***Optical Multiplex Section***

The network layer provides transport of optical channels through a multiplexing path between access points for interconnecting optical networks with multiple signal wavelengths, these capabilities allow interconnection support the operation and management of optical networks . Figure 2. Shows the process of multiplexing of an optical signal through the OTN technology.

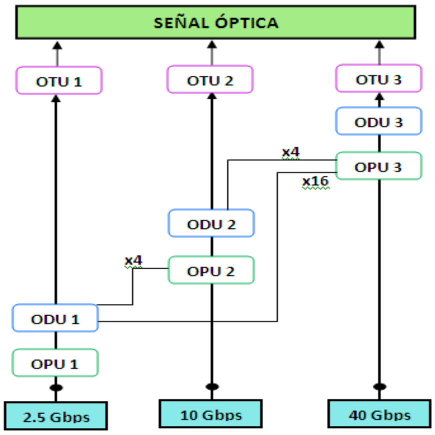


*Figura2.* OTN multiplexing

- ***Optical Channel***

As recommended in the ITU - T G.709 , a channel optical transport network is decomposed into two network layers, the unit of optical channel data (ODU), payload unit optical channel (OPU) and layers separate transport unit as the optical channel transport (OTU), where each layer separately may be divided so as to reflect the internal structure of the network layer. Figure 3.

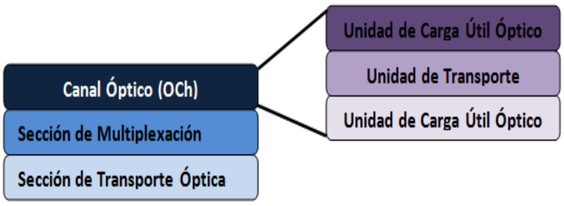


*Figura 3.* OCh Substructure

Furthermore, the optical channel is structured in layers OCh to bear network management, network connections between points transparent 3R regeneration of the OTN and monitoring features defined in the Recommendation G.872 of the ITU - T.

*C. Structure of frame*

The basic frame of an optical transport network contains multiple bytes addressed to specific operations such as the optical channel payload (OPU) containing all channels of the OTN frame, the data unit of the optical channel (ODU) which acts as level transport route OPU, optical transport unit (OTU) which provides the header section level for ODU and supplies the bytes for the communication channel (GCC0). Figure 4. Shows the division of bytes within a frame OTN. [2]

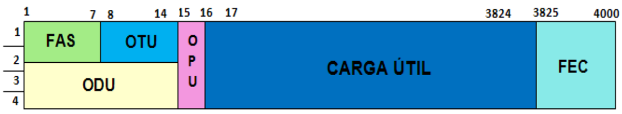


*Figure 4.* OTN Structure of frame

- **Optical channel data unit (ODU)**

It is responsible for end-to-end transport of digital client signals through the OTN, is formed as a block frame structure based on bytes with four rows and 3824 columns placed at the leading ends of the OPU.

- **Optical channel payload unit (OPU)**

This frame contains the payload and the header client signal (OH) for carrying in the OTN frame, the OPU is the basic unit of an OTN frame, which can support SDH signal of 2.5 Gbps, 40Gbps and 10Gbps .

- **Optical channel transport unit (OTU)**

The OTU adapts the ODU for the transport for connections of network of optical channel, is based on the ODU frame structure and extends with error correction (FEC) in the signal reception.

- **Forward error correction (FEC)**

Allows detection and correction of bit errors caused by faults in the physical transmission medium, in case of receiving a lower quality signal received errors are corrected by the FEC, improving the output BER signal also allows extend the distance of the optical signal without regeneration.

- ***Advantajes FEC***

The use of FEC in optical networks potentially improves the signal quality of an optical link offering several advantages:

- Reduced use of 3R regenerators (Regeneration, Reformation and Resynchronization) which allows to increase the distance between links.

*D. Settings OTN*

Within an optical transport network must consider several parameters that are critical for the development of the network and the speeds of the interfaces, attenuation, chromatic dispersion and signal amplification.

- **Bit rates and frame period OTN**

TABLE I.
BIT RATES AND FRAME PERIOD OTN

| BIT RATES OTN (K=1,2,3) | | |
|---|---|---|
| **OTUk** | **BIT RATES (Gbps)** | **FRAME PERIOD (µs)** |
| OTU1 | 2,666 | 48,971 |
| OTU2 | 10,709 | 12,191 |
| OTU3 | 43,018 | 3,035 |
| **ODUk** | **BIT RATES (Gbps)** | **FRAME PERIOD (µs)** |
| ODU1 | 2,498 | 48,971 |
| ODU2 | 10,037 | 12,191 |
| ODU3 | 40,319 | 3,035 |
| **OPUk** | **BIT RATES (Gbps)** | **FRAME PERIOD (µs)** |
| ODU1 | 2,498 | 48,971 |
| ODU2 | 10,037 | 12,191 |
| ODU3 | 40,319 | 3,035 |

- **OTN Interfaces**

As recommended by the ITU -T G.709, an optical transport network interfaces can have inter-domain and intra-domain information structure which is supported by the Optical Transport Module (OTM-n). Figure 5. Displays the types of interfaces that can exist in an OTN network.[2]

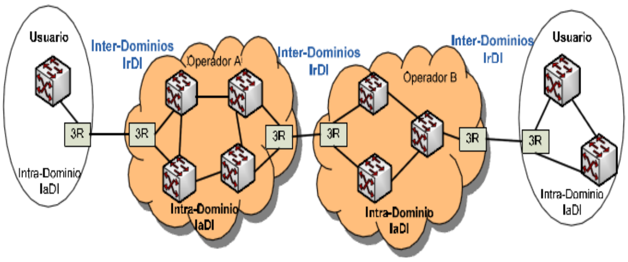


Figure 5. OTN Interfaces

- ***Inter - Domain Interface (IrDI)***

The interdomain interface defining the boundary between two administrative domains, this interface may be a single channel or multichannel processing 3R are defined at each end of the interface.

- ***Intra - Domain Interface (IaDI)***

The intradomain interface interfaces is defined as those that are within an administrative domain.

- **Frequency Grid**

Optical systems are based on the property of the optical fiber to transmit multiple wavelengths simultaneously without interfering with each other so that channeling plan uses a grid of frequencies used to denote the nominal frequency allowed to define core optical transport applications, according to the ITU-T G.694.1 recommendation for this application.

$$fn = fo + nDf$$

Where:

**fo:** Center frequency = 193100 GHz
**Df:** Channel Spacing (12,5 : 25 : 50 : 100) GHz
**n:** Integer (positive, negative, zero)

In both OTN and DWDM systems using C-band (1550nm), is replaced with a single lambda to 96 lambdas within recommendation ITU-T G.694.1.

*E. Advantaje OTN*

- It has the facility to work with DWDM and SDH equipment within banded or mesh networks.
- Transmits SDH services, without termination of the signal at each network element, the signal transport is transparent including the clock and byte header.
- Easily combine multiple networks and services on a common infrastructure entirely in the optical domain and transparent to the format and the speed of the signal carrying client, allowing you to create a multi-platform client.
- The OTN services offering are fully software programmable via a single line card, so that the protocols, connectivity and functionality can be reprogrammed remotely as they change services or customers.

## II. CURRENT SITUATION OF OPTICAL FIBER NETWORK CELEC EP – TRANSELECTRIC

CELEC EP through its TRANSELECTRIC Business Unit, is responsible for operating the National Transmission System (NTS), whose main objective is the electricity transmission and telecommunications, ensuring open access to transmission networks to customers. [4]

CELEC EP - TRANSELECTRIC is a of the leading telecommunications carrier which has a fiber optic network that extends high availability across the country, providing service capabilities that start from an E1 (2.048 Mbps) up capabilities an STM-64 (equivalent to 4032 E1's = 10 Gbps), which has allowed so far to meet the demand of bandwidth required by its customers.

### *A. Introduction*

The fiber optic network CELEC EP - TRANSELECTRIC has several optical links over the country, forming a robust fiber ring and high availability that allows carrier to provide service to most of service providers operators telecommunications within the country, the international connection is performed through TRANSNEXA company which operates exclusively in the fiber optic network stretched between Ecuador and Colombia.

The country's domestic routes have a capacity of STM-16 (network CELEC EP - TRANSELECTRIC) and the international departure both to Colombia as Peru is STM-64 (network TRANSNEXA).

It offers its services as a carrier of carriers in 16 provinces, five of the coast region, 8 and 3 sierra region of Ecuador, with its nodes and points of presence (PDP) in the substations of the national transmission grid SNT and central sites of the country.

### *B. Struture of the transport network*

CELEC EP - TRANSELECTRIC has a network of highly available transport whose nodes are distributed throughout the country.

- **SDH Network**

The SDH network consists of a ring structure with radial access multiplexers whose teams are distributed across the country, forming the optical transport network with links line STM-1, STM-4, STM-16, STM-64.

It has a core network which has links STM-16 and STM-64 line protection type (1 +1) and (1: N), for smaller capacity equipment with links to level E1 and Fast Ethernet.

- **DWDM Network**

The DWDM network consists of a central ring with two sub rings with access to interconnections Colombia and Peru, consists of OADM equipment and OLA, OADM multiplexers teams currently exist in the cities of Tulcán, Quito, Guayaquil, Machala and Milagro and transmission capacity on the network is 40 wavelengths with 40G capacity.

### *C. Equipment*

- **Huawei OptiX OSN 7500**

It is optical transmission equipment, mainly used in core networks for long distance links, supports links to STM-64 and carries technologies SDH, PDH, Ethernet and WDM can be implemented in the core network level.

- **Siemes Surpass HIT7070**

It's a team multiplexer ADM (Add / Drop Multiplexer) technology that can handle such as SDH, Ethernet, WDM. It has two operating centers, single and dual core called each of these layers handles tax systems of high and low order SDH, and have a switching unit for TDM and Packet. The TDM switching unit is designed to VC4, VC3, and VC12.

- **OptiX BWS 1600**

It's a team multiplexer for DWDM transmission systems and multi multialcance large capacity with a modular design that allows increased to 160 wavelengths in the same fiber, reaching a total of 1600Gbps way transmission on band C. Provides based ROADM wavelength multiplexing.

### *D. Traffic capacity*

Currently fiber optic network of CELEC EP - TRANSELECTRIC has extensive coverage, allowing you to offer their services to much of the country, providing transmission capabilities that start from an E1 (2.048 Mbps) up capabilities of an STM-64 (E1 equivalent to 4032's = 10 Gbps), for which possesses a SDH network and provide capabilities which allow DWDM according to customer requirements. See Table II.

TABLE II.

CURRENT TRAFFIC CAPACITY

| CURRENT TRAFFIC CAPACITY | | | | | | |
|---|---|---|---|---|---|---|
| **# PORTS/ NODES** | **STM64** | **STM16** | **STM-4** | **STM-1** | **10GBE** | **GBE** |
| **QUITO** | **2** | **18** | **9** | **17** | **4** | **14** |
| **GUAYAQUIL** | **2** | **10** | **6** | **10** | **1** | **8** |
| **CUENCA** | **-** | **5** | **3** | **7** | **-** | **4** |
| **TULCAN** | **1** | **-** | **-** | **-** | **1** | **-** |
| **MACHALA** | **1** | **3** | **3** | **-** | **-** | **2** |

For the dimensioning of the network traffic is considered both SDH and DWDM current major nodes in the network core, with interfaces GBE, 10GbE, STM-1, STM-4, STM-16, STM-64, is considered operational traffic, available and total of each team, thereby determining the teams that carry most traffic are those that are located at nodes QUITO (Ed. Transelectric), Guayaquil (Policentro), Cuenca (Zhoray) in the case of Quito and Guayaquil have both SDH and DWDM equipment with an available capacity of 64.61 and 46.05 Gbps Gbps respectively, in the case of Cuenca has only SDH equipment it currently provides capacity from the closest nodes counting the site with an available capacity of 0.78 Gbps, and for transport interconnection traffic between Colombia and Peru is considered the Tulcán nodes and Machala.

## III. OTN NETWORK DESIGN

The purpose of this design is supported in the current DWDM transport network, whose primary objective is to increase transmission capacity and efficiency in the transportation network of the company without losing bandwidth capabilities such as DWDM networks where the signal transmission is performed directly on the wavelength, without providing a switching speed flexible.

### *A. Selecting Nodes*

For the selection of the nodes of the network design, an evaluation of the current traffic capacity SDH and DWDM equipment that handle interfaces GBE, 10GbE, STM-1, STM-4, STM-16, STM-64, is considered the total installed capacity, operational and available equipment located in the cities of Quito, Guayaquil, Cuenca, Santo Domingo, Machala, Quevedo.

### *B. OTN Interfaces*

Below is the number of interfaces needed for the project. See Table III.

TABLE III.
DISTRIBUTION OF INTERFACES OTN

| DISTRIBUTION OF INTERFACES OTN | | | | | | |
|---|---|---|---|---|---|---|
| # PORTS/ NODES | STM64 | STM16 | STM4 | STM1 | 10GBE | GBE |
| QUITO | 4 | 55 | 35 | 65 | 6 | 20 |
| GUAYAQUIL | 4 | 55 | 30 | 50 | 2 | 16 |
| CUENCA | - | 25 | 15 | 35 | - | 8 |
| TULCAN | 2 | - | - | - | 2 | - |
| MACHALA | 4 | 15 | 10 | - | - | 4 |

### *C. Lambdas Distribution*

The transport of the required transmission capacity it is performed through the ring distributed lambdas OTN.

TABLE IV.
LAMBDAS DISTRIBUTION

| LAMBDAS DISTRIBUTION | | | | | |
|---|---|---|---|---|---|
| **NUMBER OF $\lambda$´s** | QUITO | GUAYAQUIL | CUENCA | MACHALA | TULCAN |
| | 14 $\lambda$ | 10 $\lambda$ | 4 $\lambda$ | 4 $\lambda$ | 2 $\lambda$ |

### *D. Matrix Crossconexion*

Once determines the nodes working OTN network determined the maximum traffic capacity gives each team must support OTN network, considering interfaces GBE, 10GbE, STM-1, STM-4, STM-16 and STM-64. See Table V.

TABLE V.
CROSSCONEXION MATRIX OTN

| CROSSCONEXION MATRIX OTN | |
|---|---|
| **Team OTN** | **Capacity (Tbps)** |
| TULCAN | 0,12 |
| QUITO | 1 |
| GUAYAQUIL | 1 |
| MACHALA | 0,22 |
| CUENCA | 0,20 |

Based on the traffic requirements is determined that the transmission network will grow approximately 57.86 Gbps per year in the case of Quito node is the node that support greater network capacity by determining that the year 2017 could be occupy approximately 416.56 Gbps total capacity OTN equipment whereas the maximum capacity that must support the equipment is 1Tbps allowing OTN demonstrate that meet requirements allow traffic required by the present application. See Table VI.

TABLE VI.
INITIAL CAPACITY AND PROJECTED FOR RED OTN

| TRANSMISSION CAPACITY OTN | | | | | |
|---|---|---|---|---|---|
| NODES / ITEM | QUITO | GYE | CUENCA | MACHALA | TULCAN |
| INITIAL CAPACITY (Gbps) | 81,49 | 68,28 | 19,44 | 23,40 | 20 |
| CAPACITY OTN (Gbps) | 289,32 | 202,40 | 85,24 | 87,72 | 40 |
| ANNUAL GROWTH(Gbps) | 57,86 | 40,48 | 17,04 | 17,54 | 8 |

### E. *Optical Budget*

For the network design is considered the total attenuation, dispersion and amplification binding, these parameters are calculated based on the recommendations specified by standards ITU - T G.655 and G.652.

Below is the optical budget needed for project implementation which specifies the type of fiber, distance, stretch total attenuation, chromatic dispersion per link required compensating amount per link and maximum distance without amplification each way. See Table VII.

TABLA VII.
OPTICAL BUDGET

| PRESUPUESTO ÓPTICO | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **SITE A** | **SITE B** | **TIPE FIBER** | **DISTANCE (km)** | **TOTAL ATTENUATION BY SECTION (dB)** | **DISPERSION CHROMATIC (ps/nm)** | **DISPERSION COMPENSATORS** | **MAX DISTANCE WITHOUT AMPLIFICATION (km)** | **AMPLIFICATION FOR CHANNEL (dB)** |
| TULCAN | POMASQUI | G.652 | 146 | 44,05 | 1022 | 2 | 163 | 75 |
| POMASQUI | QUITO | G.652 + G.655 | 25 | 8,37 | 175 | 1 | 31 | 39 |
| QUITO | TOTORAS | G.652 + G.655 | 141 | 42,57 | 987 | 2 | 165 | 74 |
| TOTORAS | RIOBAMBA | G.652 | 44 | 13,90 | 308 | 1 | 51 | 45 |
| RIOBAMBA | ZHORAY | G.652 | 148 | 44,70 | 1036 | 2 | 165 | 76 |
| ZHORAY | MILAGRO | G.652 | 126 | 17,77 | 399 | 1 | 66 | 49 |
| MILAGRO | GUAYAQUIL | G.652 | 72 | 38,15 | 882 | 2 | 141 | 69 |
| MILAGRO | MACHALA | G.652 | 135 | 22,20 | 504 | 1 | 82 | 53 |
| GUAYAQUIL | QUEVEDO | G.652 | 168 | 40,82 | 945 | 2 | 157 | 72 |
| QUEVEDO | STO. DOMINGO | G.652 | 108 | 50,60 | 1176 | 2 | 187 | 82 |
| STO. DOMINGO | STA. ROSA | G.655 | 84 | 32,90 | 756 | 1 | 122 | 64 |
| STA. ROSA | QUITO | G.652 + G.655 | 26 | 25,80 | 588 | 2 | 96 | 57 |
| ZHORAY | CUENCA | G.652 | 57 | 8,65 | 182 | 1 | 32 | 40 |

For the design of the network is taken as reference the currently installed DWDM network with capacity up to STM-64 (10Gbps), the system will use the existing infrastructure OTN in TRANSELECTRIC substations.

The transmission system will provide user interfaces required at the following stations: Tulcán, Quito, Guayaquil, Machala and Cuenca. For traffic between Colombia and Peru have taken the equipment located at nodes respectively Tulcán and Machala. See Figure. 6. The substations where the equipment would be installed are:

- Tulcán: Node Tulcán Transelectric
- Quito: Node Transelectric
- Guayaquil: Node Policentro Transelectric
- Machala: Node Machala Transelectric
- Cuenca: Node Cuenca Transelectric

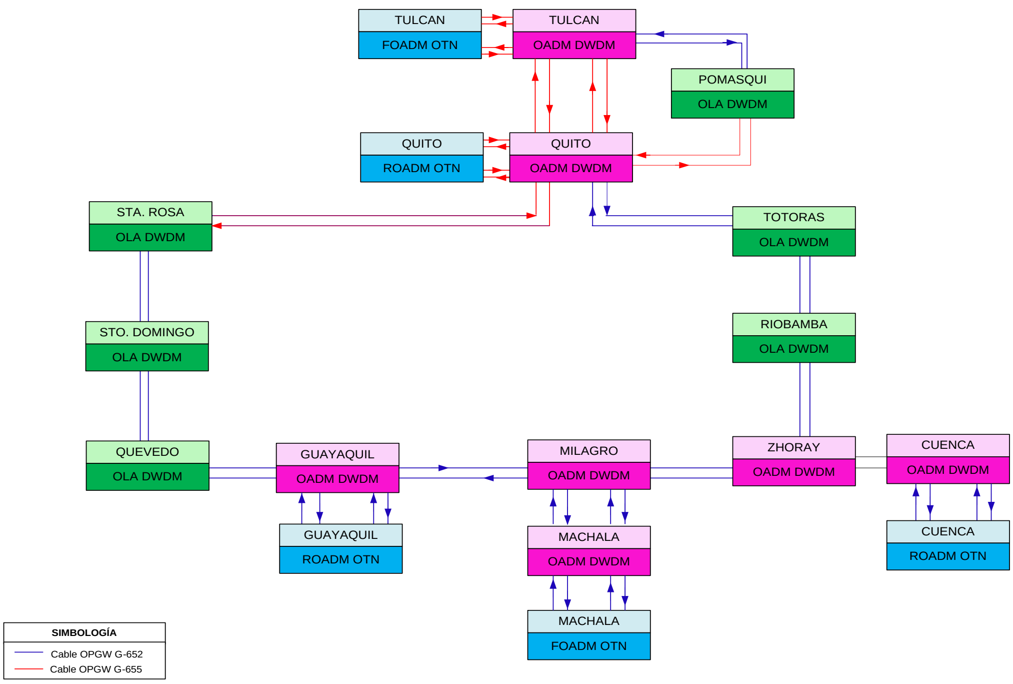


Figura 6. OTN Network Design

### *E. Network Protection*

The proposed design has been dimensioned with redundancy to prevent single points of failure exist in the network, as shown in Figure 37. It has established a working path and a protection path for each link and thereby provide security for the entire route WDM signal by transmitting the signal twice through transponders equipment using line 1 +1 protection, for this is used to route one working fiber and 1 fiber protection path in case of failure, wire breakage or degradation of the optical signal, traffic will be switched automatically to the path protection, response time switching path must be less than 50ms. See Figure 7.

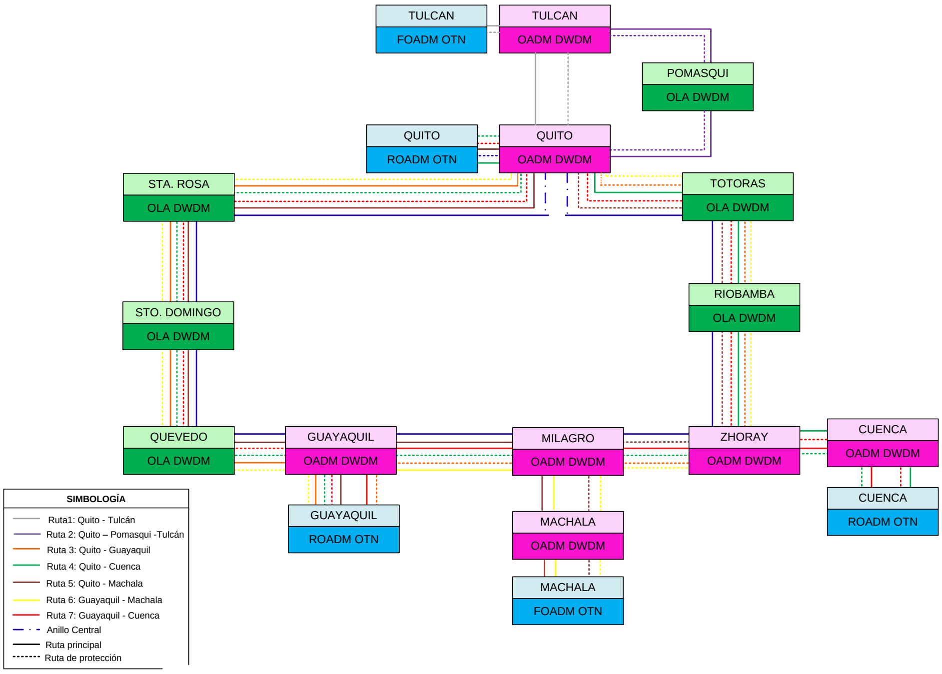


Figura 7. OTN protections

The stages are defined as working routes and protection are detailed in Table VIII.

TABLE VIII.
ROUTES OF WORK AND PROTECTIONS OTN

| ROUTES OF WORK AND PROTECTIONS OTN | | | |
|---|---|---|---|
| **ROUTES OF WORK** | **DISTANCE (km)** | **ROUTES OF PROTECCTION** | **DISTANCE (km)** |
| Quito - Tulcán | 171 | Quito - Pomasqui - Tulcán | 171 |
| Quito - Guayaquil | 386 | Guayaquil - Milagro - Zhoray - Quito | 531 |
| Quito - Cuenca | 390 | Quito - Guayaquil - Milagro - Zhoray - Cuenca | 641 |
| Quito - Machala | 593 | Quito - Zhoray - Milagro - Machala | 594 |
| Guayaquil - Machala | 207 | Guayaquil - Quito - Zhoray - Milagro - Machala | 980 |
| Guayaquil - Cuenca | 255 | Guayaquil - Quito - Zhoray - Cuenca | 776 |

### *F. Network Management*

The management system is based on ITU-T Recommendation M.3010 (Administration of a telecommunications network) which aims to improve the availability and performance of the system components, the management network is composed of a small LAN consisting of a server is the brain which houses management management platform, this system must be able to monitor and manage all network elements and should allow the gradual growth of the network and connect additional network equipment if necessary. [5]

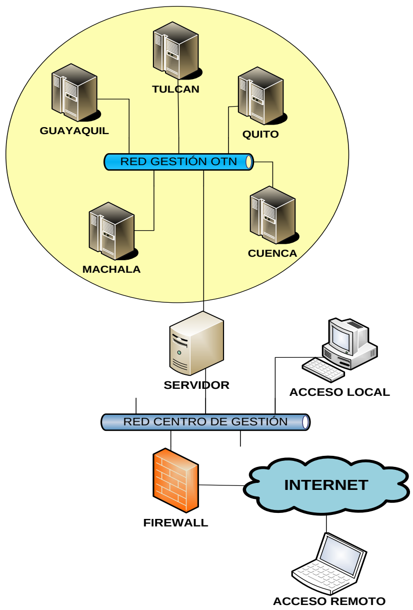


*Figura 8.* Diagram of the management network OTN

As shown in Figure 8, all OTN network elements are connected to an Ethernet network, allowing you to stay connected to the network management center (Quito).

If you request information from one computer exclusively OTN multiplexer are connected by local management daughter card, each team owns a computer.

In the management center will be a server that shows all the activities implemented as: status information, alarm, and use of the equipment capacity.

Note that the management software must be provided by the company that makes the sale and installation of equipment and that since OTN equipment manufactured by high-capacity each specific providers such network must have a management network.

## IV. ECONOMIC FEASIBILITY STUDY

### A. *Initial Investment*

Implementation costs OTN network proposal include the estimated costs of equipment and management system that are necessary for the implementation and operation of OTN transport system, resulting in an estimated investment of the project as shown in the table IX.

TABLE IX
INITIAL INVESTMENT AND EQUIPMENT

| INITIAL INVESTMENT AND EQUIPMENT | | | | |
|---|---|---|---|---|
| **PARAMETER** | **NODE** | **TIPE OF TEAM** | **UNIT COST (Usd)** | **TOTAL COST (Usd)** |
| **TEAM OTN** | | | | |
| OTN optical transmission system | 2 | FOADM | 486,363.63 | 972,727.27 |
| | 3 | ROADM | 486,363.63 | 1459,090.91 |
| Stock Parts | 5 | PARTS | 103,969.09 | 519,845.47 |
| Management Software and Hardware | 1 | GESTIÓN | 20544,06 | 20544,06 |
| **TEAM DWDM** | | | | |
| DWDM optical transmission system | 1 | ACTUALIZACION DE OLA A OADM | 123,370.53 | 123,370.53 |
| | 1 | OADM | 319,554.28 | 319,554.28 |
| Stock parts | 1 | REPUESTOS | 46,933.72 | 46,933.72 |
| **NODE OF AMPLIFICATION** | | | | |
| TEAM DWDM | 6 | OLA | 86,654.95 | 519,929.71 |
| **ISTALATION** | | | | |
| INSTALACIÓN DEL SISTEMA (Usd) | **266,515.14** | | | |
| **INVERSIÓN TOTAL (Usd)** | 4268,511.09 | | | |

The cost of equipment is taken as an average value from three OEMs with OTN technology, considered as potential suppliers for this project because the actual values are reserved exclusively for each manufacturer for direct customers, so driving in values this economic study are estimates.

### B. *Receipts of project*

To determine the revenue generated by the project first determine the annual value to be raised in a year by a lambda (10GbE), whereas CELEC EP - TRANSELECTRIC $ 17.22 monthly charge for E1 (155Mbps), it should be noted that this amount is an estimate and that the actual company policy this information cannot be made public. See Table X.

TABLE X.
*COSTS BY SERVICE*

| COSTS BY SERVICE | | |
|---|---|---|
| **TIPE OF INTERFACE** | **MENSUAL COST (Usd)** | **ANNUAL COST (Usd)** |
| E1 | 17,22 | 206,64 |
| STM-1 | 1084,86 | 13.018,32 |
| STM-4 | 4339,44 | 52.073,28 |
| STM-16 | 17.357,76 | 208.293,12 |
| 10GBE | 69.431,04 | 833.172,48 |

Whereas the implementation of the project requires 34 lambdas 10GbE and annual income is $ 833,172.48 lambda is determined that the total annual income will be $ 33,263,032.32.

### C. *Expenditures Project*

It is considered as expenses of the project's direct and indirect costs to generate the implementation thereof as are the power consumption of the equipment, network maintenance, cost of optical fiber, labor both administrative and technical, so that to determine the expenses that generate this project will take approximately 60% of total investment which will be considered each year as revenues to be generated in the project's achieved gradually within five years of *screening.*

### D. *Net Flow*

It is considered net flow to profit or gain received from an investment after being discounted expenditures of net income that is generated by such a project. See XI.

The following table details the economic feasibility of the project, with indicators such as VAN, TIR, TMAR.

TABLE XI

I. ECONOMIC FEASIBILITY STUDY

| ECONOMIC FEASIBILITY STUDY “OTN PROJECT” | | | | | | |
|---|---|---|---|---|---|---|
| **Detalle/Año** | **0** | **1** | **2** | **3** | **4** | **5** |
| Investment ($) | 4.268.511,09 | | | | | |
| Growth (%) | | 20% | 40% | 60% | 80% | 100% |
| Income (34 lambdas) ($) | | 5.665.572,86 | 11.331.145,73 | 16.996.718,59 | 22.662.291,46 | 28.327.864,32 |
| Expenses (60% operating cost) | | 3.399.343,72 | 6.798.687,44 | 10.198.031,16 | 13.597.374,87 | 16.996.718,59 |
| Net Flow ($) | - 4.268.511,09 | 2.266.229,15 | 4.532.458,29 | 6.798.687,44 | 9.064.916,58 | 11.331.145,73 |
| **VAN** | **23.148.109,39** | | | | | |
| **TMAR** | **16,15%** | | | | | |
| **TIR** | **84%** | | | | | |

TMAR= 16,15%

TIR > TMAR

For this economic feasibility study of the value obtained TIR is 84%, meaning that this value is the maximum rate of return that the project will generate, therefore the project as is feasible considering the TIR was applied a discount rate of 16.15%.

- *Time for payback*

The payback period of the investment indicates the time required to recover the capital invested and the shorter is the recovery time will increase economic profit.

Considering that the project investment is 4268.511,09 can analyze the payback period of the investment would approximately 1 year, 5 months and 8 days.

## V. CONCLUSIONS

- OTN technology is a key point in the telecommunications infrastructure for regional networks. The large increase in telecommunications services is possible due to the great development of technologies and optical networks, where OTN allows increased bandwidth over existing networks.

- OTN technology reduces the use of regenerators as equipment has major limits its amplification and signal dispersion, allowing increasing the distance between the optical links.

- OTN uses nine automatic switching directions, allowing the reception of signals of a larger number of multiplexers equipment.

- To implement OTN network equipment must be upgraded at node OLA Zhoray a team - a DWDM OADM - DWDM as it handles incoming signals from 3 different sites additionally equipment must be located at node OADM Cuenca DWDM multiplexing signals from node Zhoray and to work together with the OTN ROADM equipment located in the same node.

## VI. RECOMMENDATIONS

- For optical network security protections are recommended both as network routing, since no network is without its faults either human or technical, so that in case of failure the network must be able to switch as soon possible to another channel where information is transported to its destination in a manner imperceptible to the client.

- For the evaluation of equipment is recommended to consider the complete compatibility of installed equipment and network management and network DWDM OTN management in a single proposal, additionally if teams use multiplexers cards supervision, management and control must be available 1 +1 protection and in the event that the computer has oversight functions, distributed management and control, protections must be for all the cards that make up the team multiplexer.

- increasing the capacity transmission systems not solve the problem of bandwidth long term, it is recommended to operate normally the first three years of the implementation of the network and then seek a new alternative network enable them to continue to lead the telecommunications market in the country.

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