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# BULDING A RESILIENT OPTICAL TRANSPORT NETWORK (OTN) TRANSPORTING CRITICAL APPLICATIONS

**by**

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## SUMMARY

Facing the new challenges relating to the rapid growth of the electrical power network and the corresponding increase in information exchange across the power sector, the Brazilian power company CHESF has undertaken the implementation of a high capacity Optical Transport Network (OTN) that overlays its already deployed optical communication system constituting hence its core backbone. This project is the first Latin American Power Utility initiative to employ the ITU-T OTN technology for transporting both operational and administrative traffic through distinct networks. It can therefore serve as a benchmark for other Utilities planning the extension of their telecommunication infrastructure with similar requirements and constraints in the coming years.

The mentioned requirements and constraints comprise, but are not limited to, the capability of respecting the time imperatives of tightly coupled distributed applications such as protection relaying and fast remedial action schemes. Other essential attributes of an operational-grade telecom service include dependability, security, disaster survivability, path control and ease of maintenance. Multiple levels of ring resilience in the optical transport layer both at SDH and underlying OTN levels are incorporated into the system achieving automatic recovery in a few milliseconds.

The paper describes the implementation of the Optical Transport Network (OTN) in the operational environment of the electrical power company exploring technologies, architecture and structural design in order to meet service requirements for various applications such as Protection, SCADA and networking of substation automation (IEC61850) as well as less time sensitive supervision and monitoring applications or the transport of administrative data traffic of the company's enterprise network. Practical results obtained during the implementation of the network and deployed service restoration mechanisms are presented.

## KEYWORDS

Optical Transport Network, Telecommunication, Critical Applications, Power Utilities

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## 1. INTRODUCTION

The rapid development of the Brazilian national economy and the consequent challenges for the expansion of the electricity sector is producing the need for a substantial increase of information exchange across the electrical power delivery system.

Extensive information flow is to be expected between different stake-holders of the power sector (generation, transmission, distribution, energy market and consumption), as well as inside the perimeter of each individual actor. Some typical bandwidth consuming applications are as follows:

- between control platforms – database synchronization between control centers, available power resources and load information, trends and predictive data, grid monitoring information and stability margins,
- between operational platforms and HV substations – Scada, synchrophasor-based WAMS, primary asset monitoring, site surveillance and access control,
- between HV substations – Protection and Control in the digital substation context (IEC61850),
- between engineering or maintenance office and substation assets – remote diagnostics and remote setting of parameters
- between field worker in the substation and central platforms – remote access to network-wide data, asset documentation, and technical support

Moreover, the data exchange perimeter is extending to cover distributed energy generation and storage, energy consumers, other utilities, trading platforms, etc. which were not part of the power delivery scheme or at least not accessible for direct information exchange in the past.

On the other hand, the evolution of work practice in the utility office environment with intensified usage of integrated enterprise applications is exponentially increasing the corporate enterprise traffic rendering necessary the availability of substantially more bandwidth at the transport network.

The far larger panel of communication services associated to the operation and maintenance of the electro-energetic system over an extended perimeter and the increase of information volumes of previously existing applications largely impact the requirements and consequently lead to the necessity of a multi-annual plan for the extension of the telecommunication infrastructure.

Facing the described challenges, CHESF, the Brazilian electrical power transmission and generation company in the Northeast area of Brazil, decided to undertake the implementation of a new transport platform over its existing 9300 km optical fiber infrastructure to reinforce and complement the SDH network. The new transport platform was to provide extensive bandwidth growth capability to the enterprise network at the core without impacting the deterministic time behavior of the mission-critical operational applications. The network should further increase substantially the packet-switched traffic capability of the operational network allowing the deployment of new operational applications as described earlier.

In this way, secure, dependable and fault-tolerant communication system with controlled and deterministic behavior for critical communication requirements was to be integrated with a large capacity, scalable Enterprise communication network across the same fiber infrastructure.

This double requirement was fulfilled through the adoption of ITU-T Optical Transport Network (OTN) technology at 10Gbit/s (OTU-2) organized into regional rings. This technology brings the advantage to support long distances with high speeds without modification in the existing fibers. Packet-switched Gigabit Ethernet data traffic can be directly transported, besides transporting Time Division Multiplex (TDM) channels.

The solution will transport IP-based corporate enterprise applications, and provide operational communications for grid-related mission-critical services, ensuring fast communication for protection and control between dispatch control centers, power grids and critical applications that require high levels of availability and controlled delay. The new data transmission system will optimize the management of the network in real time aligning operations and ensuring a continuous supply of energy.

## 2. CHESF TELECOMMUNICATION MASTER PLAN

CHESF Telecommunication Master Plan was an important reflection effort undertaken by the company in order to develop guidelines for the expansion and adaptation of the telecommunications system in the coming years, taking into account the particularities of the company in its core business role, generation and transmission of electrical power, as well as its importance and significance in the national context, corporate structure and expected evolutionary path.

Information traffic studies and volume estimations, crucial for the capacity planning of the different constituents of the network were conducted on the basis of CHESF's 2018 telecommunications network, as well its projection until 2023. Based on this study it was possible to elaborate the predicted traffic matrices across different CHESF localities and to identify suitable technologies and configurations for responding to the projected growth.

The traffic estimations were elaborated following objective criteria regarding the utilization of several systems, and the results also serve to help planning the implementation of various new systems, and provide necessary subsides to the engineering team, in the evaluation of the network's interconnection capacities throughout this Director Plan's horizon.

Considering the critical significance of the information flow through the network, the main guiding criteria in the plan was the need for total security in the telecommunications system.

Below are presented some of the measures to guarantee security to the new telecommunications platform:

- The carrier class equipment specification, with duplicated essential parts;
- The duplication of essential network elements and physical network support;
- The functional and geographical redundancy of servers and network controllers;
- The construction of rings;
- The diversity of communication possibilities;
- The communication survival, in case of network element failures.

Besides this basic requirement, other basic criteria also guided the communication networks, such as:

- Planning for the actual systems obsolescence in the 2018 horizon (the evolution of technology and the end of the equipment life cycle, imposing their replacement);

- Unification of personal corporate communication over IP and the integration of the communication services (voice, video, electronic mail, instant messages, identity portability, mobility and others) into one single network;
- Communication between different technology terminals (desk phones, wireless phones, smart phones, notebooks, notepads and similar);
- Availability of band in the presence points;
- Simplification of the IP network architecture;
- Use of modern technologies, although proved and available worldwide;
- Use of open technologies, allowing competition among vendors;
- Service quality throughout the network (low delays, band warranty);
- Control and management equipment security for the telecommunication network;
- Information security for the various systems who utilize the network;
- Isolated logic network, and safe for every service of application.

Based on these premises, a study of the existing networks at CHESF and its current and future services was done, and led to a needs forecast, which guided the planning of objectives for the new communications network at CHESF. In parallel, a study about the prospective markets, studies of adopted solutions in similar companies in Brazil and abroad, studies of the available technologies and equipment, as well as proposed solutions by the various manufacturers and vendors, currently acting in Brazil, through consultations, studies of technical materials, and several meetings along the upcoming months.

Based on these actions, the new communications network architecture of CHESF was designed as detailed below.

The Telecommunication Master Plan considered the transformation of the several systems in compliance with all requirements of Electric Sector and of the new services demands.

Some systems are listed below:

- Transport Network
- Synchronism
- Wide Area Network (WAN)
- Voice over IP ( VoIP)
- Unified Communications (UC)
- Video Surveillance
- Wireless Network (WiFi)
- Security
- Quality of Service

This paper will focus on the studies and results in the Transport Network.

## 3. PROJECT DESCRIPTION

### 3.1 Technologies

Based on the described studies, the new telecommunications transportation networks will utilize high capacity optical systems. In the high traffic regions, the transmission backbone will adopt the OTN (Optical Transport Network) technology, at 10 Gbit/s. This technology has the advantage to support long distances and high speeds, with no modification in the existing fibers and directly transports Gigabit Ethernet signals, besides transporting isochronic signals. For the lower traffic demand regions, the optic backbone will have a 2,5 Gbit/s. The IP charge will be transported through Carrier Ethernet services, over barring done with the NG-SDH (Next Generation SDH) techniques.

Generally speaking, the current optical fiber system is used at the limit of its capacity due to the lack of fibers available and, in some cases, the multiplex technique is adopted to carry several optical services over the same fiber through a DWDM (Dense Wavelength Division Multiplex).

In order to respond to this scenario, t is proposed to develop CHESF's long distance data network, using the *Metro/Carrier Ethernet* technology, with larger bandwidth characteristics, and capacity to provide this width in flexible increments, with an excellent support for voice, video and data conversion. This technology also presents low implementation costs, ease operation, advanced quality of service resources (QoS), protection and security. This layer will be transported by Carrier Ethernet services on buses based on NG-SDH technique (Next Generation SDH) or by Ethernet tunnels of OTN layer.

The planned network is expected to extend the Ethernet standard to the long distance metropolitan networks, using a flatter network topology, with use of more intense level 2 networks (Bridged Ethernet), allowing the latency reduction and costs. This network consists on a Multiservice Platform, based on Metro Ethernet technology, combined with IP/MPLS with TE (traffic engineering), split in 3 layers (Aggregation, Distribution and Access),

## 3.2 Network Topology

The basic system is composed of eight optical rings, as illustrated in Figure 1, seven 'real' rings and a "flat-ring", covering the various areas of activity of CHESF, making an integrated system with full provision of survival protection services, even in the presence of single faults in any part of the ring. All rings are organized in a way that at least two points of interconnections are done to another ting, ,except for the flat-ring between USB and GRB. The new backbone is based on a regional ring structure with OTN technology network elements to directly cover long distances in some sections, with optical carriers structured ODU-0 for flexibility to share the capacity of the new systems.

For the ring topology definition, it was considered all requirements for the implementation of ring protection (maximum number of nodes) and propagation delay.
The first phase of the project, purpose of this article, considers the implementation of northeast part of topology.

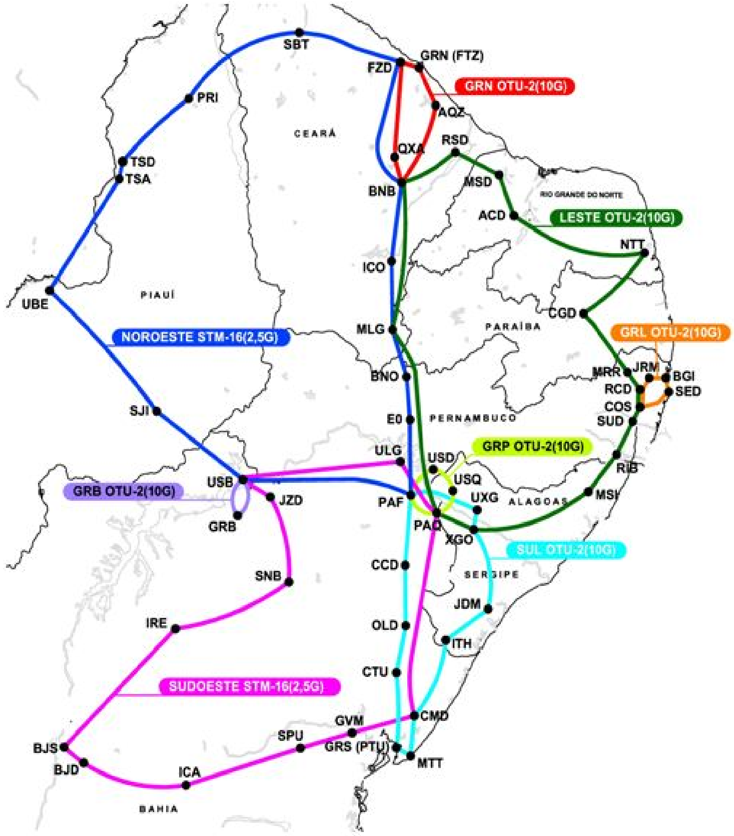


FIGURE 1 - Transport Network

<u>3.3 Description of Functional Aspects</u>

The transport network is designed to offer several types of protection. The use of rings and line protection according to the MS-SPRing procedure (Rec. ITU-T G.842, in the case of SDH) or ODUk-SPRing (Rec. ITU-T G.873.1 and G.873.2 in the case of OTN), offers high-level protection in the optical transport layer, compatible with the needs of the applications supported by the transport network. In both SDH layer and ODU layer, additional protection in accordance with the model SNC-P will be implemented depending of the criticality of the service.

The engineering of the network predicted a very high robustness against network failures. The first consideration was to structure the backbone in rings, which solve the problem of single system failures. The second was the duplication of essential network elements and physical network support (Figure 2). The third was the availability of the double provisioning of services by different routes, which solves the possibility of double faults or failures not duplicate products. The fourth was careful to carry the signals of stations that are not part of the backbone to two entry points, which allows you to configure alternative routes to ensure continuity of service in case of failure in the access network or on equipment .

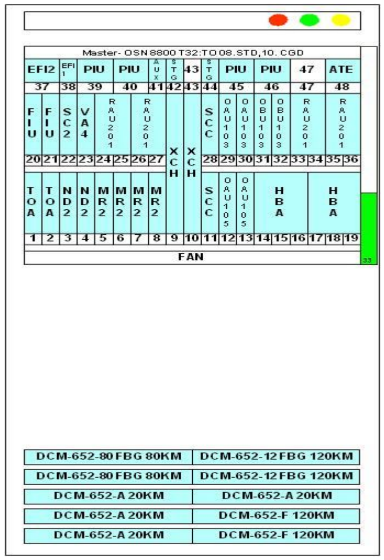

FIGURE 2 – Duplication of essential parts in the network elements

The most essential services such as teleprotection must be extraprotected against faults being connected to more than one network element connected to the backbone, for example an interface in packet service (*Carrier Ethernet*) and another in the deterministic service (SDH). The description of the main functional aspects of the equipment inthe system is shown below.

### 3.3.1 DWDM

The project chose to use multiplexers and de-multiplexers that support at least 08 (eight) wavelengths. This decision was made in consultation with DWDM equipment manufacturers who reported no significant difference in cost between systems sized to 8 channels when compare with systems sized to 4 channels. The use of DWDM with higher channel capacity is justified by the network scalability to add new nodes, preserving investments. In according with the protection requirements, two DWDM equipment will be used for each direction whenever the need of mux and demux of wavelengths is necessary.

### 3.3.2 OTN - 10 Gbit/s

The nodes that form the rings of 10 Gbit / s consist of Optical Add Drop Multiplexers & (OADM) of OTU-2 OTN hierarchy technology (Optical Transport Network) according to Rec. ITU-T G.709.

The OTN network elements operate with flexible transponders (multirate) with 8 inputs and 8 outputs, which map tributary signals in Ethernet (GE - Gigabit Ethernet ) or SDH standard (STM -1, STM-4 and STM-16) in the virtual tributary units of OTN line signal. The OTU-2 line signals of 10 Gbit / s capacity, have two levels of tributary units: tributary units of high order (HO, High Order) ODU-2 - these can be used completely (to receive STM-64 signals or 10GE, i.e. Ethernet 10 Gbit / s) - or be subdivided into 8 tributary units of lower order (LO Low Order) ODU-0, each of allows to carry tributary signals up to 1.25 Gbit / s (for example, GE or STM-4), or concatenated signals to nx 1.25 Gbit / sec (for example, STM-16 signals at 2 x concatenated ODU-0).

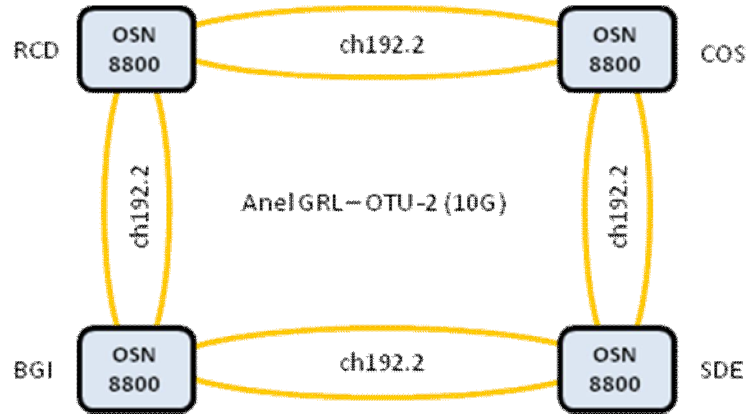


FIGURE 3 – Headquarter Metropolitan Ring

5.3.3 SDH

In some casesof 2.5 Gbit / s rings , the distances are too long to overcome and as there are stretches with DWDM lnks, the SDH signals that constitute the STM-16 rings may be mapped into tributariesof first hierarchy (OTU-1) or even second hierarchy (OTU-2) according to Rec. ITU-T G.709. Rings of 2.5 Gbit / s will consist of multiplexers ADM (add drop multiplexers &) next-generation STM-16 and will be used for the transport of legacy TDM signals and signs.

The NG-SDH cards will support Carrier Ethernet services and should meet the tributary Ethernet signals up to 1 Gbit / s, with supports VCAT (virtual concatenation of VC-12 tributaries, VC-3 and VC-4) and LCAS.

## 5.4 Description of the Network Protection

For a high level protection, in the optic transport layer, the ring configuration allows the implementation of line protection, according to the MS-SPRing (Figure 4) or ODU-SPRing protocols, over two fibers. In the SDH trajectory layer, and even in the ODU trajectory layer, and additional protection according to the SNC-P model may be implemented. Regarding the transportation services of statistics signals (Ethernet), protections may be implemented, foreseeing an automatic recovery of the services, in tens of milliseconds, similar to the SDH protection, using the new functions of the Ethernet layer. Naturally, the normal router topology protections, including the fast protections in the range of tens of milliseconds, will also be implemented.

The spatial reuse is a strong influence of the shared protection rings. A connection that does not have overlapping sections with others non-overlapping connection can be routed in the same period of time or time slot therefore, at the same capability, but in different sections of the ring. Thus, the protection time slots can be shared among connections that do not have overlapping sections in a SPRing. In a SNCP ring, for each connection is assigned a dedicated protection, because the source copies the sign in both directions of the ring, and the destination node chooses the best of the two received copies (instead of closing the traffic loop, as in the cases SPRing).

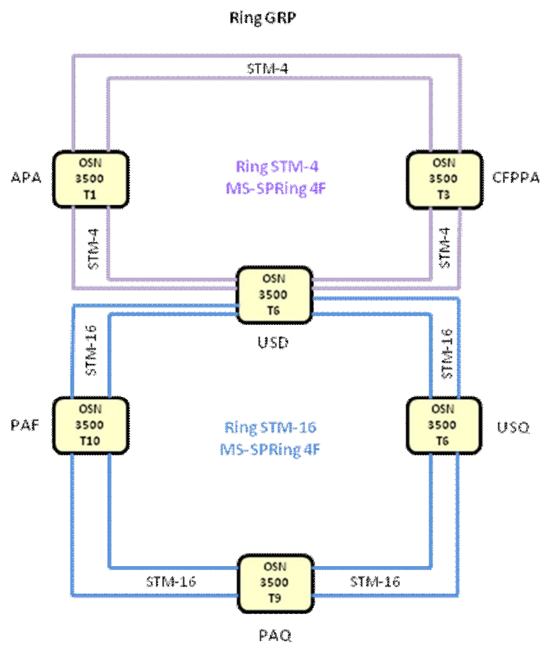


FIGURE 4 – Ring Protection

In a configuration of two fibers, only two different fibers connect the nodes in the ring between them, each one carrying active capacity 50% and 50% reserve/protection capacity. This means that for a Och-SPRing ring with two fiber configuration is only capable of carrying a maximum of N / 2 protected bidirectional ODUk (i.e. four of the eight ODU-0 in case of a ring OTU-2 with 10 Gbit/s) in each span (span).

## 3. REQUIREMENT FOR CRITICAL APPLICATIONS

A transport network must be able to support the business requirements for carriers and the demand for new oriented service from all segments of the market and the demand are huge. Utilities are protecting their critical systems and data deploying new high-bandwidth applications to increase productivity, but they are encountering numerous challenges along with the expectation of increasing amounts of bandwidth with the lowest possible latency for all demand access to cloud computing, virtualization, business continuity and disaster recovery.

To support these new services, carriers are faced with a difficult balance. On one side, costs escalate with increasing capacity and operations complexity. On the other side, revenues lag behind increasing traffic and costs. Faced with this cost/revenue dilemma, service providers must transform their networks to reduce the traffic transport "cost per bit," while maintaining and even increasing service quality. Packet-Optical Transport allows service providers to fully leverage their existing SDH/SONET network infrastructure and operations as they migrate their networks from circuit-optimized to packet-optimized transport. Emerging products and standards can enable this network transformation and maintain profitable services.

Customers are demanding extremely resilient networks to support their mission-critical applications. Backup and security strategies for high availability require a geographically dispersed implementation and since it's not only high capacity that is needed, more bandwidth is also required, these services increase the network complexity and increase the challenges when trying to construct a reliable, next generation and high-bandwidth network and the effort of the network operations with requirements such as Service Level agreements with precise Quality of Service on behavior and measurements, distance, reliability, high performance in terms of high throughput, low latency and low packet loss, extremely high network resilience and high network security associated with smart grids by encryption are also critical.

The new IP and Storage Area Network (SAN) services are emerging on a large scale and establishing new requirements for communication networks but important factors are driving the need for optical networks and the reasons for this migrating are described below:

- Scalability: Both in the number of services supported, such as Ethernet LAN (E-LAN) and Ethernet line (E-line), and of bandwidth. The key factor is its ability to vary bandwidth on demand as business needs change.
- Protection: Carrier Ethernet should offer end-to-end, 30-ms network-wide restoration capability in the event of link or node failure to avoid massive implications due to the fiber capacity increase and allowing service providers to support traditional TDM traffic.
- Hard QoS: This fundamentally changes how Ethernet is delivered. Service providers must deliver committed information rate (CIR) and extended information rate (EIR), allowing Carrier Ethernet to underwrite their SLAs. Only then can service providers guarantee services with confidence.
- TDM support: Provided through native support of TDM on the packet-optical system or using TDM circuit emulation (CES) for pure packet transport.
- Fiber Capacity: Providers needed more capacity between two sites. WDM provider many virtual fibers on a single physical fiber using different frequency and in that way send many signals in one fiber.
- Services management: Carrier-grade service provisioning and OAM. The transport network must also be monitored carefully for overloading and degraded services.

Important critical applications such as the relay protection have extremely strict security standards and require comprehensive protection strategies. The benefits that made SONET a robust optical transport technology, including a standardized mapping of client signals, enhanced performance monitoring at multiple layers, comprehensive fault detection and isolation, and embedded communications channels, must be present in all WDM networks and stablish the need for OTN Standards.

## 4. OPTICAL TRANSPORT NETWORK TECHNOLOGY DESCRIPTION

According to recommendation ITU-T G.709 and ITU-T G.872, the OTN (Optical Transport Network) architecture concept was developed to build upon the Synchronous Digital Hierarchy (SDH) and Dense Wavelength-Division Multiplexing (DWDM) experience to provide functions of transport, bit rate efficiency, add-drop multiplexing, routing, supervision, management and resiliency at high capacity. The OTN/DWDM technology allows multiplex and demultiplex up to 80 channels into a single optical fiber, through one or more optical paths, taking into account the same network management features available on SDH technology with less overhead and more management features. It supports different network topologies such as ring, linear, mesh, etc beside a transparent transport of any client traffic under optical or electrical domain.

Known as “digital wrapper”, the OTN is capable to encapsulate different type of services such as Ethernet, SDH/SONET, digital video, IP/VPN and VPLS regardless of their native protocol into an optical transport unit (OTU) frame. The OTN technology has no impose limits on switching rates, making it very flexible in bandwidth and allowing a transparent client signals transportation. Existing protocols on client side may be encapsulated in a single entity with a few numbers of headers and better efficiency.

The performance monitoring of the whole multiservice traffic is done by its enhanced OAM with added development that enables more efficient mapping of and support for data signals which includes framing conventions, nonintrusive performance monitoring, error control, rate adaption, multiplexing mechanisms, ring protection, and network restoration mechanisms operating on a wavelength basis. Its major feature is called FEC (forward error correction) allowing a theoretical improvement in reach/capacity of the Signal-to-Noise Ratio (SNR) by 6.2 dB. This improvement can be used to enhance the optical systems in the following areas:

- Increase the reach of optical systems by increasing span length or increasing the number of spans.
- Increase the number of DWDM channels in a DWDM system which is limited by the output power of the amplifiers by decreasing the power per channel and increasing the number of channels
- The increased power budget can ease the introduction of transparent optical network elements, which can’t be introduced without a penalty (e.g attenuation). These elements include Optical Add-Drop Multiplexers (OADMs), Photonic Cross Connects (PXCs), splitters, etc., which are fundamental for the evolution from today’s point-to-point links to transparent, meshed optical networks with sufficient functionality.

The multiplexing structure and terminology of OTN frame format is defined in Figure 5.

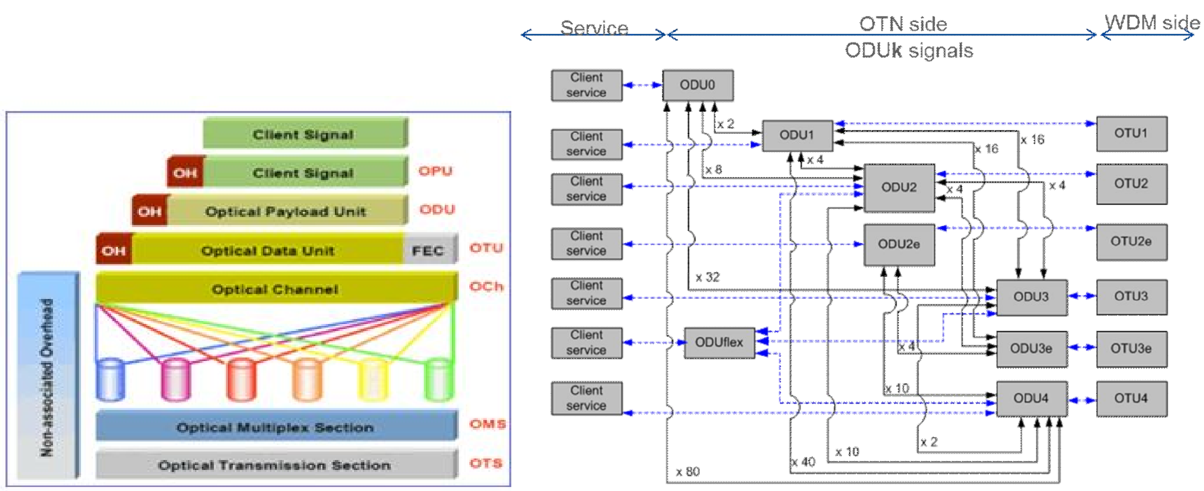


FIGURE 5 – Multiplexing structure and terminology of OTN frame

At a basic level, G.709 OTN defines a frame format that "wraps" data packets, in a format quite similar to that of a SONET frame. There are six distinct layers to this format.

- OPU: Optical Channel Payload Unit. This contains the encapsulated client data, and a header describing the type of that data.
- ODU: Optical Data Unit. This level adds optical path-level monitoring, alarm indication signals and automatic protection switching.
- OTU: Optical Transport Unit. This represents a physical optical port (such as OTU2, 10Gbps), and adds performance monitoring (for the optical layer) and the FEC (Forward Error Correction).

- OCh: Optical Channel. This represents an end-to-end optical path.
- OMS: Optical Multiplex Section. This deals with fixed wavelength DWDM (Dense Wavelength Division Multiplexing) between OADMs (Optical Add Drop Multiplexer) and transport the non-associated overhead.
- OTS: Optical Transport Section. This deals with fixed wavelength DWDM between nodes.

The data rate transmission capacity is defined by OTU hierarchy with the following approximate rates (Table 1):

| SIGNAL | Approximate data rate (Gbit/s) | APPLICATIONS |
|---|---|---|
| OTU1 | 2.66 | Transports SONET OC-3/12/48 or SDH STM-1/4/16 signal, FC-100/200, GbE, GPON |
| OTU2 | 10.70 | Transports an OC-192/STM-64 or wide area network (WAN) physical layer (PHY) for 10 Gigabit Ethernet (10GBASE-W) |
| OTU2e | 11.09 | Transports a 10 Gigabit Ethernet local area network (LAN) PHY coming from IP/Ethernet switches and routers at full line rate (10.3 Gbit/s). |
| OTU2f | 11.32 | Transports a 10 Fibre Channel. |
| OTU3 | 43.01 | Transports an OC-768/STM-256 signal or a 40 Gigabit Ethernet signal |
| OTU3e2 | 44.58 | Transports up to four OTU2e signals |
| OTU4 | 112 | Transports a 100 Gigabit Ethernet signal |

Table 1: OTN Approximate data rates

## 5. IMPLEMENTATION & TEST RESULTS

### 5.1 Proof of concept

The proof of concept was held in October 2013 at manufacturer's premises in China. The topology was based on the same equipment model of the project simulating a network with three OTN rings and one DWDM link.

To perform the tests, a logical ring was simulated for all OTN paths, making three OTN rings with ODUk-SPRing protection and one logical SDH ring in STM-16 with MS-Spring protection through ODU-0 of OTN between the following locations: RCD-BGI-COS-RCD

SDH tests:

- Equipment protection: power supply, controller cards , cross-connect and synchronization
- Network protection: MS-Spring/SNCP switching time and synchronization
- Ethernet services: LCAS, Vlan, QinQ
- Optical interfaces: Optical power, sensibility and jitter output

OTN/DWDM tests:

- Equipment protection: power supply, controller cards and cross-connect
- Network protection: ODUk SNCP and ODUk Spring switching time
- Ethernet services: LCAS, Vlan, QinQ, VCAT and QoS
- Optical interfaces: Optical power, sensibility and jitter output, FEC and OSNR threshold
- OSC & APE function and capacity of 8 DWDM channels
- Multi-rate service card
- ODUk Cross-connect ODUK and 10G line card aggregation

Management Test:

- Resource management, alarms, performance and reporting

Different tests on both systems were performed simulating several outages to analyze the behavior of the services and its resilience. At the end, equipment was accepted.

### 5.2 Factory test

The factory test took place between October and December 2014 taking into account function and system tests of SDH, OTN, DWDM and management system with successful results. The goal of the tests was to certificate and ensure the proper functioning of the characteristics and technical features of the equipment involved in the Transport Layer solution.

A big ring with SDH equipment was built and through this topology all protection and system tests were conducted.

OTN/DWDM equipment was tested per ring and due to the first implementation of this new technology, many difficulties in the execution of the tests were faced, in which manufacturer's support was required. Different tests were performed such as sensitivity and optical power tests, SNR, services aggregation, protection at the hardware and line level, FEC function, wavelengths in DWDM and also tests on optical amplification module, pre-amplification, Raman and chromatic dispersion compensation using fiber optic coils.

5.3 First Ring Commissioning

The first ring (Figure 4) was commissioned in March 2015 involving the location of Recife II (RCD), COS, Bongi (BGI), Joairam (JRM) and Sede (SDE) with successful results after functional and system tests on SDH and OTN equipment.

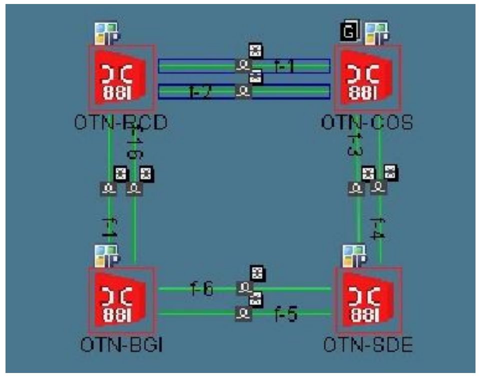


Figure 4 – First Ring commissioning

## 6. CONCLUSION

The optical transport network was foreseen and planned based on optical rings topologies. This network layer intends to cover several working areas of the company to carry critical and non-critical services creating an integrated system with survival protection and transport of transparent services. The information transmitted over the OTN layer will not suffer any impact, even under different failure conditions, due to the high level of resilience.

OTN technology has proved to be a good solution for high capacity data transmission of corporate applications and also critical services respecting their specific requirements of bandwidth, scalability, latency, protection, supervision and maintenance.

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