MHL 3000

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Glossary of Abbreviations (ACRONYMS)

3R	Re-sizing Re-shaping Re-timing
ADU	Add Drop Unit
ALS	Automatic Laser Shutdown
BER	Bit Error Rate
CBR	Constant Bit Rate
CCU	Channel Control Unit
CEU	Channel Equaliser Unit
DCC	Data Communications Channel
DCF	Dispersion Compensation Fibre
DCM	Dispersion Compensation Module
DCN	Data Communication Network
DMS	Dispersion Managed Soliton
DSA	Dual Stage Amplifier
DSF	Dispersion Shifted Fibre
DWDM	Dense Wavelength Division Multiplexing
EDFA	Erbium Doped Fibre Amplifier
EFEC	Extended Forward Error Correction
ELH	Extended Long Haul
EM	Element Manager
EMC	Electromagnetic Compatibility
EMF	Equipment Management Functions
EMS	Element Management System
EOW	Engineering Order Wire
FEC	Forward Error Correction
F-OADM	Fixed-Optical Add/Drop Multiplexer
GbE	Gigabit Ethernet
GCC0	General Communication Channel 0
GIU	Group Interleaver Unit
GMU	Group Mux Unit
ITU	International Telecommunication Union
ITU-T	Telecommunication Standardisation Sector of the ITU
LAN	Local Area Network
LH	Long Haul
LT/LCT	Local Craft Terminal
LTU	Line Termination Unit
M-OLT	Multiple-Optical Line Terminal
NE	Network Element
NNI	Network Node Interface
NRZ	Non Return-to-Zero
NZDSF	Non Zero Dispersion Shifted Fibre
OADM	Optical Add/Drop Multiplexer
O-E-O	Optical-Electrical-Optical
OCE	Optical Channel Extender
OCh	Optical Channel Signal
ODU	Optical Channel Data Unit
OLU	Optical Levelling Unit
ON	Optical Network
OOS	Optical transport module Overhead Signal
OPU	Optical channel Payload Unit

OSNC	Optical Sub-Network Connection
OSNR	Optical Signal to Noise Ratio
OSU	Optical Supervisory Unit
OTM	Optical Transport Module
OTN	Optical Transport Network
OTU	Optical channel Transport Unit
PDG	Polarisation Dependent Gain
PDL	Polarisation Dependent Loss
PMD	Polarisation Mode Dispersion
PMU	Power Monitor Unit
PSU	Power Supply Unit
Q Interface	Network Management Interface
QoS	Quality Of Service
R-OADM	Reconfigurable-Optical Add/Drop Multiplexer
RPU	Raman Pump Unit
Rx	Receiver
RZ	Return-to-Zero
S-OLT	SingleOptical Line Terminal
SDH	Synchronous Digital Hierarchy
SMF	Single Mode Fibre
SOH	Section Overhead
SRS	Stimulated Raman Scattering
SSA	Single Stage Amplifier
TDM	Time Division Multiplexing
TP	Transponder
Tx	Transmitter
UPSR	Unidirectional Path Switched Ring
UK	United Kingdom
ULH	Ultra Long Haul
VOA	Variable Optical Attenuator
WDM	Wavelength Division Multiplexing
XPM	Cross Phase Modulation

Foreword

The product information contained herein is independent by a product release an does not refer to a defined product release. The technical information and the estimated time scales provided in this document are offered, in good faith, as an indication of Marconi's intention to evolve its Optical Networks portfolio to meet the demands of the marketplace. Unless commercially agreed, the information contained herein should not to be taken as implying any commitment or obligation on the part of Marconi.

1 INTRODUCTION

1.1 Overview

Market Drive

Networks are continuously evolving: voice-centric traffic is being overtaken by data-centric traffic.

Increasing demand for Ethernet traffic over SDH networks has to be cost-optimised by introducing methods to reduce the SDH transport capacity needed, to align to the real data speed in the Ethernet network. For this purpose new standards for mapping and for capacity adjustment complement the toolbox of established technology to best utilise the SDH bandwidth for data transport capability.

In parallel with these developments in flexibility of the SDH layer, the WDM layer must also be flexible and scalable in terms of capacity, services and applications. Therefore it is vital to provide a multi-service transport platform that can scale from a low-cost low-capacity first-in system, to a high capacity platform, able to cover metropolitan, regional and national applications. Flexibility is vital in order to enable multiple services sharing the same hardware and software resources. Remote configurability is also important to allow traffic changes and variation without disruption of the existing traffic.

At the same time "intelligence" must be brought down to Network Element level, to allow optimal reconfiguration of transmission for variations of traffic conditions. Such intelligence reduces operation and maintenance costs.

Marconi Product Portfolio Solutions

Marconi solves this challenge with its Optical Multiservice portfolio, which is optimised to integrate network layers and to efficiently aggregate and transport multiple services, leading to a new generation of lean and flexible transport solutions. Marconi's latest photonic and electronic developments form the foundation of an integrated network architecture that significantly reduces the cost of owning and operating a network, providing full network transparency.

Marconi's Optical Multiservice portfolio consolidates network elements by increasing switching capacity and by integrating across vertical layersto simplify the optical network and improve network efficiency. While the optical plane provides a cost-optimised transport system, the electrical plane provides aggregation, intermediate grooming, selective wavelength regeneration and wavelength conversion. Unnecessary regeneration in the optical path is completely eliminated, providing a considerable cost saving compared to traditional transport architectures.

The flexibility of the solution for multiple applications enables adaptation to business needs, scaling with traffic requirements whilst also ensuring low first in cost. The common photonic platform has card types suitable for a range of applications, including direct Ethernet interfaces for multiple remote end user sites. At the far end of the network the original Ethernet signals are presented for customer use.
The Marconi's portfolio also enables operators to keep operational expenditures to a minimum optimising power consumption, space, spares management as well as simplifying and improving network control and maintenance.

The support of intelligent switching and ASTN control plane enables dynamic on the fly provisioning of services and restoration, allowing the introduction of new enhanced differentiated services.

MHL3000 – The DWDM platform

The MHL3000 has been designed to give flexibility and modularity addressing the low first-in cost, high integration.. Innovative technologies have been integrated and enhanced into a single, versatile DWDM platform delivering unique flexibility, best in class performance and operational synergies for optimised applications ranging from metro and regional to ultra long haul.

MHL3000 combines simplicity and modularity, improving operator business planning, offering low entry cost and minimal incremental investment as the network expands to accommodate new services, reducing the cost per bit per km all the way from the edge to the core. The system can be configured in an optimised way in metro and regional applications, while its powerful technology is resilient for distances up to 4000km, completely removing the need for regeneration. A pioneering multi-directional reconfigurable optical add-drop facility supports unique network transparency, increasing network connectivity and response to traffic needs.

MHL3000 provides a multiservice solution, transparently delivering data, SDH and wavelength services, through a wide range of wavelength translators and subrate aggregators at 2.5Gbit/s, 10Gbit/s and 40Gbit/s.

Close integration with the Marconi Optical Multiservice (OMS) portfolio and ASTN technology improves network efficiency and dynamics of optical networking, enhanced by full standardised Optical Transport Network functionality.

1.2 Main Features of MHL3000 platform

The main features supported by MHL3000 are:

- *Optimised multi-haul applications from the Edge to the Core*
- *80 channels operation, in service upgradeable to 160,*
- *High modularity and scalability*
- *Provides flexibility to cover Metro, short haul, long haul, extended long haul and ultra long haul in any ring or mesh topology*
- *Plug and Play architecture*
- *Flexible and 100% reconfigurable optical transparency*
- *Support of full standardised Optical Transport Network (OTN)*
- *Multiservice delivery: data, SDH and wavelength transport including bandwidth optimisation*
- *Enables high bit rates (40G) transmission implementing innovative technology*

- *Complete network resilience using various protection options*
- *Integration with Marconi Optical Multiservice (OMS) platforms; completely managed via Marconi Network Management System*

Optimised multi-haul application from the edge to the core

The MHL3000 merges simplicity and minimised up-front costs, driving down the cost per bit km of transport. Its modular building block design efficiently supports core as well metro access applications, reducing network complexity and cost of ownership.

- The latest transmission format and dispersion compensation technologies make MHL3000 capable of supporting *metro* applications. Unnecessary first in cost is completely removed, preserving upgrade to faster rates as soon as customer service take-up dictates.
- Highly versatile configuration options provide unique performance in core networking. The MHL3000 modular technology adapts to diverse spans characteristics – long, extended and ultralong haul – minimising entry as well as incremental investment and improving network connectivity.
- Direct access of customer located equipment to the photonic layer is guaranteed by means of fully managed compact customer premises configurations.

80 channels operation upgradeable to 160

Tailored entry cost scenarios, matching today's customer needs, can be rapidly and flexibly scaled to satisfy variable future traffic flows.

Core networks carrying 80 channels on a 50GHz grid over the C band can smoothly evolve to 160 channels exploiting the L band. The channels allocation is fully compliant with ITU-T G.694.1 recommendation.

High modularity and scalability

The system architecture is based on the use of three universal shelves, housing different mixes of all transmission units, which can be equipped in a fully flexible way according to traffic needs. Amplifier technology and different transmission formats allow system adaptability to network characteristics, striking a balance between entry cost and long term capacity demand.

Different multiplexing filters can be provided:

- Two offset groups of Mux/Demux exist for each band, each group comprising Multiplexer and Demultiplexer filters working with 40 channels in a 100 GHz grid.
- For a low initial channel count network, a modular approach is used, based on 8 channels Mux/Demux units.
- In a typical metro network, where the traffic grows in smaller steps, a modular approach based on 2 channel filters is implemented

Plug and Play architecture

To reduce commissioning time and to provide fast service provisioning, MHL3000 has introduced "intelligence" at the network element level, allowing full reconfiguration and transmission optimisation.

Traffic upgrades can be carried out without any need for manual intervention: all units once inserted, are immediately recognised and configured to pre-set values.

Dynamic channel power equalisation prevents disturbance to signals passing through respective nodes, simplifying network set up and reducing operational and maintenance costs.

Reconfigurable, flexible, optical transparency

Diverse optical add-drop modules deliver network flexibility and connectivity tailored to business needs.

- Fully reconfigurable optical add-drop (R-OADM) - with access to all channels provides 100% flexibility, allowing instant reaction to service requirements and support of new differentiated services.
- Fixed optical add-drop (F-OADM) – results in a lower cost solution, enabling up to 8 add/drop channels to be selected per line

- 2 channel add-drop filter – provides fine and scalable granularity for effective metro applications.

Network connectivity is further enhanced by multiple island connection options:
- Extended OADM is the natural evolution of R-OADM, delivering fully multidirectional transparent switching that enables network topologies to be smoothly upgraded from linear to mesh as required by changing business demands.
- Interconnection Node completely eliminates intermediate regeneration, via manual routing, minimising network investments

Optical Transport Network (OTN) standards full compliance

MHL3000 supports standardised (ITU-T/G.709) OTN functionality, which delivers:
- True end to end monitoring capability.
- Full signal transparency: SDH as well as Data traffic.
- Improved wavelength utilisation.
- Interoperability in multivendor environments, while preserving path continuity.
- Wavelength services in multi-carrier environments.

Multiservice platform

The MHL3000 delivers protocol-independent, carriers' global services, supporting SDH and Data, ranging from 125 Mbit/s to 40 Gbit/s, as well as SAN applications.
The supported services are listed below:

- SDHCBR
    - STM-4/CBR-622 Mbit/s
    - STM-16/CBR-2.5 Gbit/s
    - STM-64/CBR-10 Gbit/s
    - STM-256/CBR-40Gbit/s
- Ethernet
    - 1 Gigabit Ethernet
      10 Gigabit Ethernet (WAN/LAN-Phy)
      40 Gigabit Ethernet
- Video - 270 Mbit/s
- Fibre Channel - 1Gbit/s/2Gbit/s

The DWDM aggregate stream can be composed of any mixture of 2.5Gb/s, 10Gb/s and 40Gb/s wavelengths.
Transponders offer choices in technology, with Non-Return to Zero (NRZ), Return to Zero (RZ) and advance phase modulation transmission formats, which enables an operator to match the technology to the application both in metro and core networks thereby providing the most cost-effective solution for each particular configuration.

Bandwidth optimisation for lower bit rates

Lower bit rate aggregation options improve bandwidth utilisation, consistently reducing the cost per service.
Bandwidth optimisation is achieved via 2.5Gbit/s (4xSTM-1/STM-4), 10Gbit/s (4xSTM-16/ODU-1) and 40Gbit/s (4xSTM-64/ODU-2) muxponders as well as 2.5Gbit/s (2xGbE) and 10Gbit/s (8xGbE/FC) datamuxponders.

On the DWDM side the system features band-wide tuneable interfaces, simplifying network planning, reducing time to implement a service with more manageable inventory and maintenance procedures.
On the client side pluggable optics, such as SFP, provide flexibility in interface characteristic and card modularity, leaving the system open to the usage of the most up to date DWDM pluggable modules.

Network resilience

Full network resilience is provided through several forms of protection:

- 1+1 OSNC protection delivers protection on a per wavelength bases
- 1+1 Client port protection is offered when the client provides an MSP connection
- 1+1 Optical Line protection is used against fibre cut
- Optical path restoration is supported via Marconi Service On Network Manager.

High Integration with Marconi Optical Multiservice (OMS) platform; completely managed via Marconi Network Manager System

MHL3000 creates a flexible wavelength-routed overlay complementing the OMS family both in the edge as well as in the core, complemented with ASTN technology. The electrical core switch provides aggregation, intermediate grooming, selective wavelength regeneration and wavelength conversion. Integrated DWDM interfaces, feeding directly into the MHL3000 optical express plane, allow the cost of wavelength translation to be removed.

Marconi optical portfolio is managed by Marconi's proven, scalable, multi-technology management system, ServiceOn Optical. This provides centralised operation, efficient use of resources, speedy service deployment and fast, effective fault location.
ServiceOn Optical Element Manager (EM), provides Element Management Layer functions as described in relevant international standards.
ServiceOn Optical Network Manager (NM) provides Network Management Layer functions as described in relevant international standards, and provides support to Service / Business Layers.

2 Applications

2.1 Network Applications

Carriers need new optical transport solutions that can economically scale the network in at least four dimensions: bit-rate per channel, channel count, transmission distance and space/power consumption.

With this goal in mind, taking maximum benefit from the full flexibility of the MHL3000, a single transmission platform can be deployed from the edge to the core of the network.

2.1.1 Core Network Applications

In a carrier's backbone network, traffic with different characteristics and needs usually overlaps on some of the routes. Express optical channels that need to cover distances of some thousands of kilometres, share the same routes as low bit-rate, short distance channels. In an efficient network the same nodes must effectively manage traffic with different needs in the most cost effective way, in terms of speed and reach.

MHL 3000 uses a range of optical cards (amplifiers, transponders, Raman pumps) to allow the platform to deliver Long Haul (LH), Extended Long Haul (ELH) and Ultra Long Haul (ULH) connections over a single optical backbone, as well as submarine ultra long links in which Marconi has proven experience.

Cost optimised EDFA amplifiers and conventional NRZ transponders have been implemented for LH applications. The introduction of very low noise figure amplifiers, over the same NRZ modulation technology, allows the system to be the ideal solution for **the** ELH (800km to 1500 km) market. ULH distances (1500km to 4000km) can be covered by combining the same low noise amplifiers with RZ modulation transponders.

Our extensive experience in Raman amplification makes Marconi able to cope with challenging single span distances typical of submarine links.

MHL3000 is extremely flexible in delivering the optical node configuration appropriate for any network scenario. From the terminal configuration for a typical Point to Point connection to the flexible and re-configurable OADM used in ring applications to the multi direction optical switch node that performs the central role in a fully meshed network scenario.

2.1.2 Metro Network Applications

Both point to point and ring network topologies are supported, as a stand-alone DWDM system with its own TDM aggregation capabilities, but also in conjunction with enhanced SDH/OTN and Marconi Ethernet switches. Network operators are given the possibility to support a wide variety of services within a unique platform and to transport them with the highest flexibility, adopting an easy to design and use philosophy. The carrier can select between straight wavelength services with point-to-point optical connections with no unnecessary intermediate optical/electrical/optical conversions, or any combination of network services, which can take full advantage of the electrical switch fabric in an OTN context.

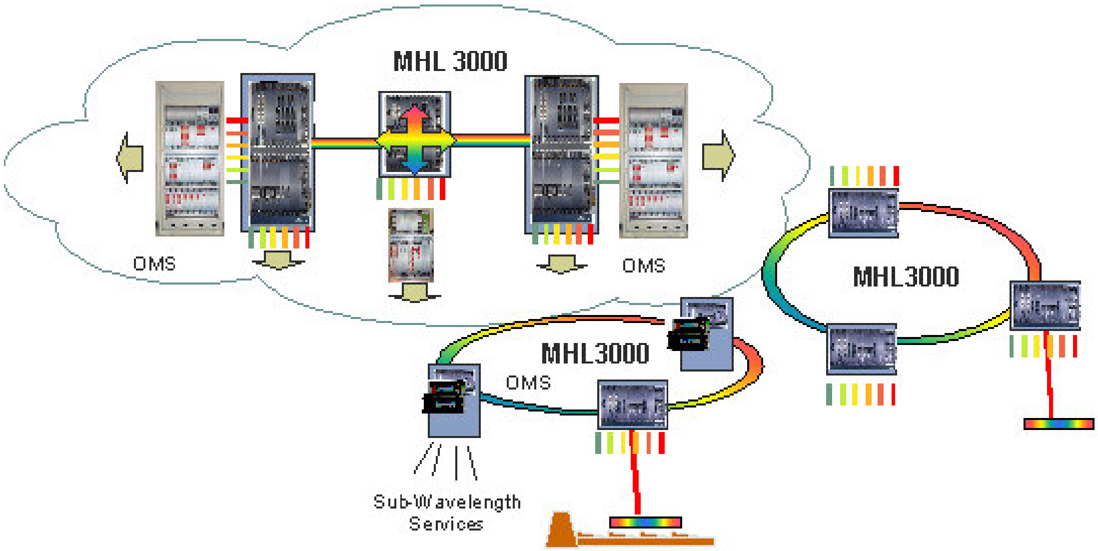


Figure 2.3-1 Network Application

2.2 Network Design and System Modelling

2.2.1 Network design procedure

The performance that can be achieved in a MHL3000 system varies depending on the network topology and application. Ring closure, insensitivity to add/drop channels, passive connections and chromatic dispersion compensation represent some of the major issues in the Metro environment. Whereas non linear effects, chromatic dispersion, PMD, multi-direction impairments and levelling are the key issues for core applications. Performance can also vary according to the type of fibre used such as SMF or NZDSF since these can have quite different characteristics. The MHL3000 modular structure allows network optimisation on a case-by-case basis.

The procedure for the link design of the majority of WDM links has been formalised as a process that takes as input the following parameters:

- Fibre physical parameters: length and type.
- Customer requirements and system design rules (ageing margins, connectors and so on).
- Maximum number of channels and types of interface in terminal and intermediate sites.
- Placement of terminal and add/drop sites.

and gives as outputs:

- Link feasibility (the capability to transmit with BER lower than 10^{-15} during all of the system life).

- Detailed amplifier and DCM allocation.

Span losses of up to 57 dB can be provisioned. Shorter spans can be grouped together to save amplifier sites. The presence of higher span loss can lead to the placement of additional regeneration sites. The applicability of MHL3000 solution in the Long, Extended or Ultra Long Haul space is mainly driven by the combined requirements of traffic matrix and distance between electrical regeneration to provide the most cost-effective solution. ELH/ULH solutions are applicable at least in case of more than 800 km from OTM to OTM and number of spans from 10 up to about 40.

LH solutions are optimised to provide transport of up to 40 channels over distances up to 800 km, allowing both fixed and reconfigurable add/drop capability. The transport of a reduced number of channels over longer distances is also an option.

System design is performed to guarantee an end of life BER of 10^{-15}.

All penalties are taken into account in the BER budget guaranteeing the working of the system from day one to the end of life:

- non-optimal dispersion management
- non-ideal filtering
- XPM
- PMD
- SRS
- PDL and PDG
- wavelength-dependent losses

Amplifier gain flatness is managed by means of proper levelling realised with active subsystems (pre-tilt, switch matrices and levelling filters). In this way, the power non-uniformity penalty can be reduced. When levelling devices are not present, solutions are designed to ensure that the received power is properly bounded in all operating conditions (span loss variation, system ageing). In this way, the worst-case in terms of received power is estimated and adopted for the modelling the receiver performance.

INTERplan the MHL3000 Network Design tool provides an end to end solution. In the first step the tool analyses the optical feasibility of the network providing the optical cards (Amplifiers, Dispersion Compensating Modules etc…) necessary to optimise the optical links. In the second step, the complete rack configuration of each Network Element is given graphically and the whole network bill of materials are provided. The end to end solution provided by the tool dramatically reduces the time from the design to the factory.

Generic tables are available to give rules of thumb for sample systems (equal amplifier spacing, generic fibres) and help to understand system performance and limitations under different conditions.

2.2.2 System modelling with MHL3000

The platform uses two different sets of amplifier cards: Long Haul (LH) and Extended Long Haul (ELH) variants. The former are suited for cost optimised Long Haul application, the latter are characterised by a lower noise figure and a higher output power for longer distances.

Two different modulation formats are used for 10Gbit/s networks: NRZ typical of Long haul and Extended Long Haul application, and RZ for Ultra Long Haul. At 40Gbit/s specific phase modulation format guarantees a narrower spectrum with respect to NRZ and RZ options, thus reducing the effects from chromatic dispersion and PMD constraints on the signal.

The picture below, shows the flexibility of the MHL3000 platform. With an appropriate selection of amplifier set and tributary card the optimised solution can be found for any network design:

- Long Haul links can be obtained with LH amplifiers and conventional NRZ transponders.

- Extended Long Haul application is flexible reached using NRZ transponders and ELH amplifiers.
- Ultra Long Haul distances can be covered joining the ELH amplifiers with RZ transponders.

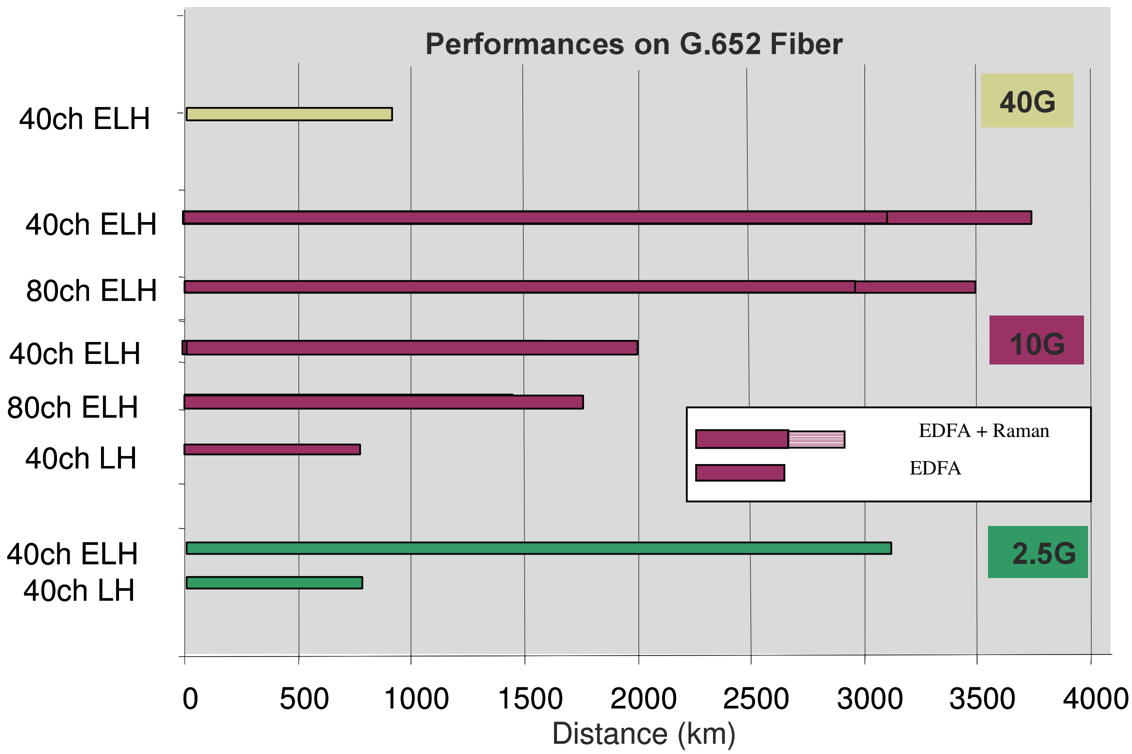


Figure 2.2-1 MHL3000 optical transmission performance

MHL3000 provides excellent performance in a single span festoon link of up to 68 dB of attenuation.

2.3 Supported services

The client signal is transported as a payload in the **Optical Channel (OCh)**, being mapped into an **Optical Transport Unit (OTU)**, independent of its protocol.

In accordance with the architecture defined in ITU-T G872, the transponder is therefore the **ONNI (Optical Network Node Interface)** for the DWDM transport platform.

The following client signals are supported by MHL3000:

- **STM-256** client signal can be directly connected to a MHL3000 40Gbit/s transponder
- **STM-64** client signal can be directly connected to a MHL3000 10Gbit/s transponder or to a ODU-3 Muxponder which maps four 10Gbit/s frames onto an ODU-3 frame.
- **STM-16** client signal can be directly connected to a MHL3000 2.5Gbit/s NRZ transponder and transported at that line rate. STM-16 client signal can alternatively be carried through the platform by means of an ODU-2 Muxponder, which will map the four 2.5Gbit/s frames into a single ODU-2 frame.

- **STM-4** client signal can be directly connected to a MHL3000 2.5Gbit/s NRZ transponder and transported at that line rate. Alternatively, it can be connected to a 2.5Gbit/s TDM multiplexer that maps four STM-4 signals into a “grey” STM-16 for presentation to a 2.5Gbit/s transponder.

- **10GbE** (IEEE 802.3ae WAN and LAN -Phy) client signal can be directly connected to a MHL3000 10Gbit/s transponder

- **1.25GbE** can be directly connected to a MHL3000 2.5G NRZ Transponder. Alternatively the GbE can be carried through the platform by means of a 2.5G Data muxponder, which maps 2 x 1.25Gbit/s Ethernet initially into a “grey” STM-16, or into a pluggable coloured DWDM interface in a second phase (by adding a DWDM SFP to existing card). In order to increase the transport efficiency the GbE signal can also be carried by means of a 10G Data Muxponder which maps 8x 1.25Gbit/s Ethernet into an ODU-2.
- **Fibre Channel** client interface can be directly connected to a MHL3000 2.5Gbit/s NRZ transponder or alternatively by means of 10Gbit/s Data Muxponder that maps 8 x FC into an ODU-2.
- Other **Constant Bit-Rate (CBR)** client signals, ranging from 125 Mbit/s to 2.7 Gbit/s, can be transparently transported with the bit-rate provisionable 3R regeneration functionality provided by Multi-rate 2.5Gbit/s transponders , using a pseudo ODU-1 frame.

3 PRODUCT OVERVIEW

3.1 MHL3000 Basic Architecture

The MHL3000 platform supports modular equipping based on the use of three generic shelf types as shown below. The shelves can be equipped with Line Termination Units (LTUs) to support the primary Network Element interfaces such as Q interface, rack alarms, overhead termination etc. These functions are only required once within a network element. They can also be used, without these LTUs, as extension shelves.

All units are plug-and-play, once inserted they are recognised and can be immediately configured from a local or remote terminal.

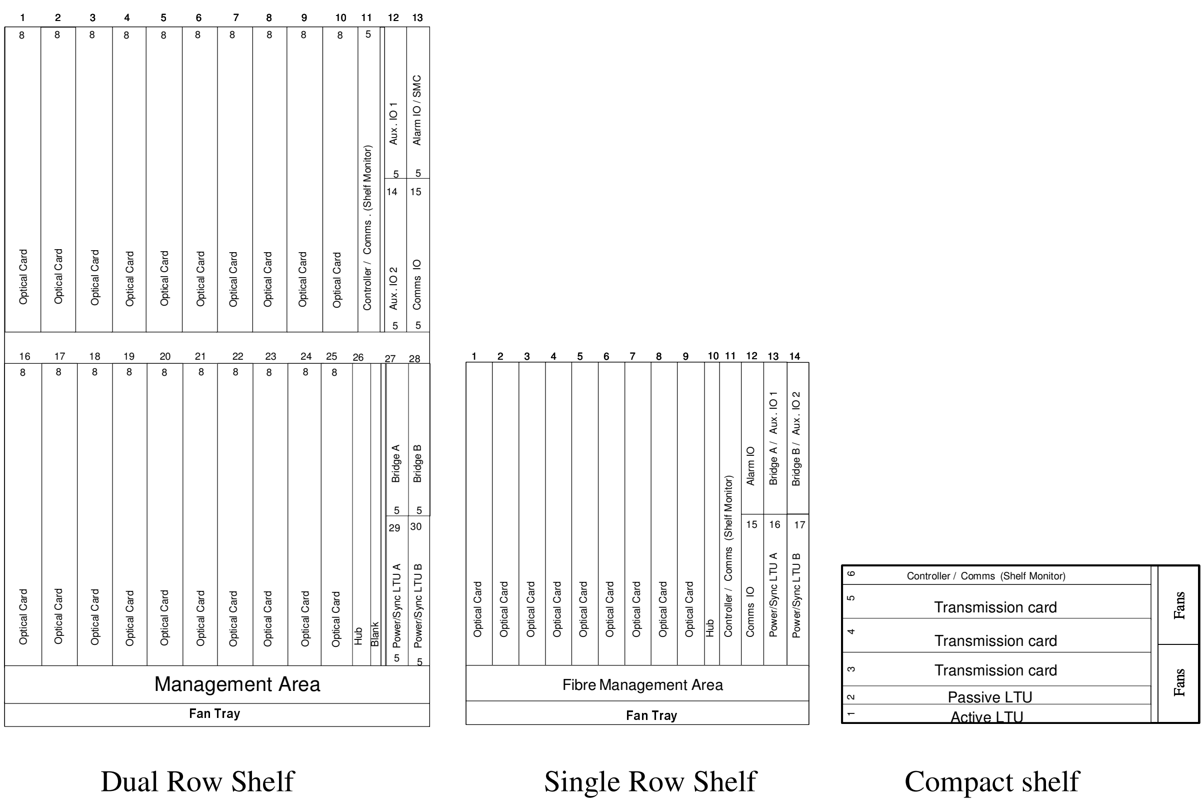


Figure 3.2-1 Generic shelf description

Based on a 1.6" pitch, the dual row, single row and compact shelves provide 20, 9 and 3 slot positions respectively, into which the various transmission units such as amplifiers, transponders and monitors can be fitted. Additional function specific slots are provided for the Network Element Controller, a Hub unit for intra-shelf communication and dual Bridge units for inter-shelf communication.

3.1.1 DCM Shelf

When Chromatic Dispersion needs to be compensated, Dispersion Compensating Modules (DCM) can be housed in dedicated shelves. Each DCM shelf can house two single height DCMs or one double height DCM.

3.2 Network Configurations

3.2.1 Core Network Configurations

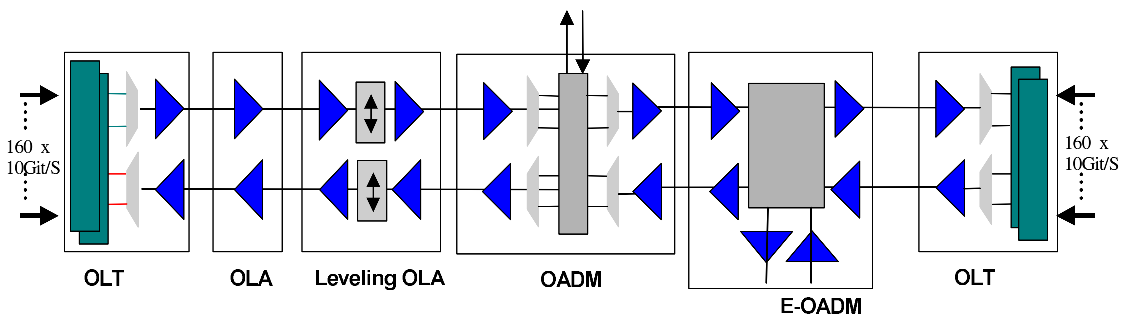


Figure 3.2.1-1 MHL3000 platform

Depending upon the application type (LH, ELH or ULH), the components of the MHL3000 platform can be configured as Optical Line Terminal, Optical Line Amplifier, Optical Add/Drop Multiplexer or multi direction optical switch.

3.2.1.1 Optical Line Terminal (OLT)

The Optical Line Terminal equipment, i.e. the start and end points where all optical channels are multiplexed/demultiplexed into the DWDM line signal, may be configured as:

- **Single Optical Line Terminal (S-OLT)** for point to point systems where all optical channels are multiplexed/demultiplexed into a single DWDM line.
-
- **Multiple Optical Line Terminal (M-OLT)** for interconnectivity where up to four DWDM lines are accessed in the same node. This node type simplifies O-SNC protection configuration in meshed network applications.
- **Optical Channel Extender (OCE)** can be used to connect individual signals to the DWDM network by multiple fibre connections in order to provide managed optical channels.

3.2.1.2 Optical Line Amplifier (OLA)

Optical Line Amplifier can be configured as:

- **Optical Line Amplifier**: Where two DWDM lines (East and West) are amplified in the same node. Its architecture can be based either on single stage unit, when no dispersion compensation is required, or on double stage unit thus providing inter-stage insertion loss to accomodate chromatic dispersion compensation modules.

- **Levelling Optical Line Amplifier**: To provide both amplification and channel equalisation functions within the same node.

3.2.1.3 Optical Add/Drop Multiplexer

The Add/Drop functionality, to give connectivity along the DWDM line without the need of complete demultiplexing/multiplexing of all optical channels, is provided in the terms of:

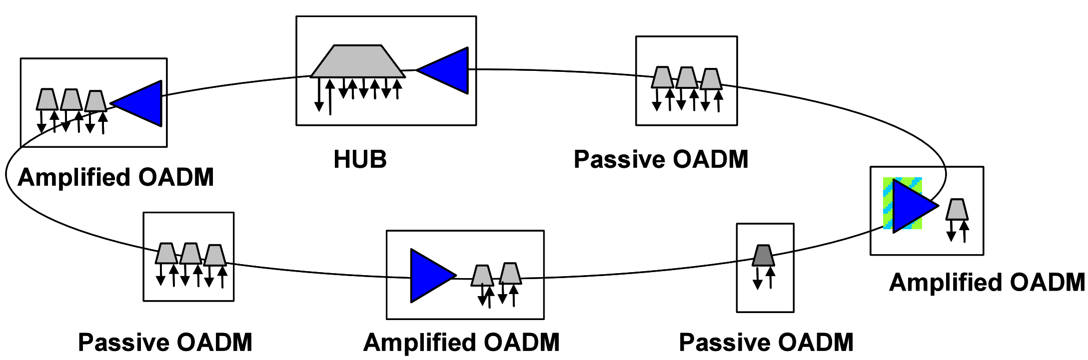
- **Fixed Optical Add-Drop Multiplexer (F-OADM):** Add/Drop channels can be selected in contiguous blocks of 2 from the aggregate wavelengths. The blocks can be cascaded accordingly to traffic growth. Any upgrade of added/dropped channel is not traffic affecting if the required add/drop filter unit is equipped from day one, or if the link is protected.
- **Re-configurable Optical Add-Drop Multiplexer (R-OADM):** Add/Drop channels can be selected from all wavelengths constituting the DWDM aggregate, in a flexible way.

To guarantee a fully optical meshed solution MHL3000 provides two network element options based on broadcast and select methodology.

- **Extended OADM:** Exploiting the combination of multi-way add/drop units and Channel Control Units the E-OADM is the ideal solution for fully configurable multidirectional optical switching. With a seamless upgrade from a bi-directional Re-configurable OADM it is possible to achieve a dynamic set-up of the light path allowing full traffic path diversity.

- **Inter-Connection Node (ICN):** Based on the insertion of an Optical Patch Panel between the demultiplexing and multiplexing stages the Inter-Connection Node allow multi-way direct re-routing, on a single channel basis.

3.2.2 Metro Network Configurations



MHL3000 can be employed in the following node configurations that can be used in point to point, un-amplified linear add/drop, un-amplified rings and amplified rings.

- **HUB node:** Terminates incoming traffic, performs grooming, aggregation and optical multiplexing/de-multiplexing functions.
- **OADM nodes:** Perform optical by-pass of incoming traffic, while terminating a reduced number of channels.

Depending on the network topology and traffic types MHL3000 can make use of passive, or amplified technologies or a mix of them.

- Passive node meets the need for a low cost solution typical of smaller metropolitan rings.
- Amplified nodes are optimised especially for high capacity and large metro core rings or long point-to-point connections.

3.3 Equipment configurations

3.3.1 Terminal Equipment Architecture

The Terminal Network Element is the origin of OChs carried through the transport platform.

The fundamental element of the terminal is the transponder or muxsponder card.

In the transmit direction, grey client signals are presented at the client interface of the transponder card. The transponder maps the client signal to the payload of a coloured optical channel, adding the optical channel overhead. FEC or Enhanced FEC code is added, according to the transponder type.

In the receiving direction the optical channel is presented to the receiver portion of the relevant transponder where it is first converted to electrical form. The FEC-corrected client signal is extracted and the optical channel overhead is terminated and processed. The client signal is presented at the client interface as an optical signal with the original bit rate and framing structure.

MHL3000 provides the following transponder or muxsponder card options:

- **2.5Gbit’s NRZ Extended Reach Transponder G.709, FEC, 50 GHz,**
- **2.5Gbit/s NRZ Multi-rate Transponder G.709, 50GHz, FEC, SFP client interface**
- **2.5Gbit/s NRZ Metro Multi-rate Transponder G.709, 100GHz, FEC, SFP client interface**
- **10Gbit/s NRZ Multirate Transponder G.709 FEC & E-FEC, 50GHz tuneable**
- **10Gbit/s RZ Transponder G.709 FEC & E-FEC, 50GHz tuneable,**
- **40Gbit/s Transponder E-FEC and client options**

- **10Gbit/s TDM Muxponder.** The Muxponder multiplexes 4 x STM16/ODU-1 (CBR 2.5G) into a 10Gbit/s signal. It offers total transparency to client signals, the basic concept of the aggregation being the realisation of an ODU2 frame where the bytes of the overheads of the 4 client Constant Bit Rate (CBR) 2.5Gbit/s streams are written without being terminated. SFP modules are used as client interfaces. The integrity of each client signal is completely preserved. The DWDM interface uses a tuneable laser.

- **2.5Gbit/s TDM and Data Multiplexer / Muxponder (2 channels GbE).** The TDM Multiplexer unit electrically multiplexes 4x STM-1 or STM-4 into a proprietary SDH-like signal at STM-16 bit rate. SDH tributary overheads are carried transparently. By careful mapping of the STM1/4 overhead into the STM16 frame, the overhead of the tributary signals is preserved. In addition, this multiplexing approach maintains the integrity of the B1 error counts for each individual tributary so that end-to-end performance monitoring is unaffected by the multiplexing process. The solution offers virtual transparency for the transported STM1/4 tributaries.

  The Data Muxponder electrically multiplexes 2 x Gigabit Ethernet signals into a contiguously concatenated VC-4-16c grey STM-16 aggregate signal. The aggregate signal can be routed through SDH networks that support VC-4-16c. SFP modules are used as client interfaces.

10Gbit/s Data Muxponder (8 channels GbE). The Gigabit Ethernet Muxponder maps up to 8 GbE/FC tributary signals into a 10.7Gbit/s ODU2 signal complete with E-FEC and G709 overhead. The ODU2 signal is then converted to a coloured optical channel for transport over the WDM system SFP modules are used as client interfaces. The DWDM interface uses a tuneable laser.

If the client signal is already coloured with a suitable wavelength and frame structure and can be set to the appropriate power then it will be interfaced directly to the optical multiplexer. If it cannot be set to the appropriate level then it is interfaced via a **Optical Levelling Unit** (OLU 8). An OLU 8 card allows control of the power level of up to 8 tributaries without altering the other optical or electrical characteristics of the signal.

Figure 3.3.1-1 illustrates the functional blocks of a Terminal Network Node typical of core applications. Only one band is shown in the figure and, the blocks are duplicated if a dual band terminal is used.

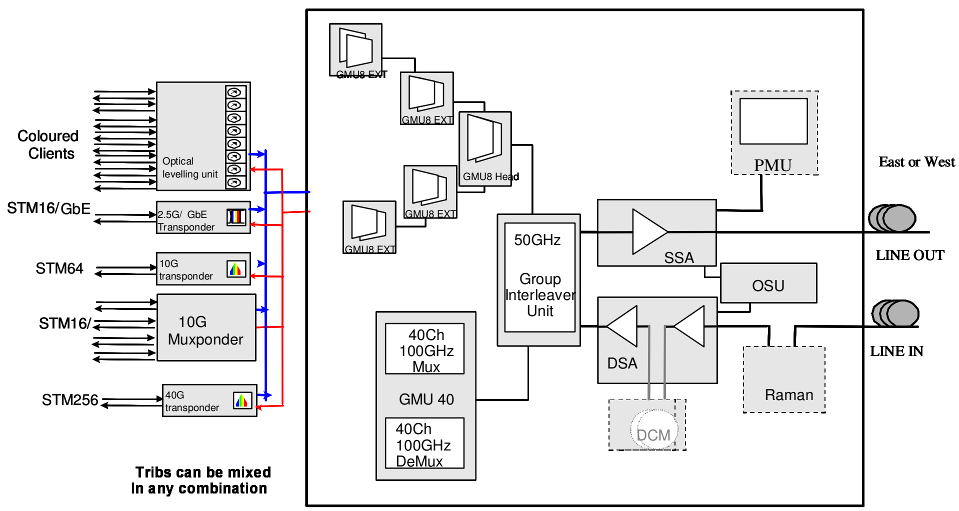


Figure 3.3.1-1 Terminal Core Network Element

The system supports the transmission of up to 80 client signals in each of two possible transmission bands, by assigning them a distinct wavelength and multiplexing them together onto the line.

Within each band, the optical channels are multiplexed either by means of 40 channel multiplexers, in case of high initial channel count, or by means of 8 an channels multiplexer, for a lower initial number of channels.

In the case of 80 an channels system, two offset 100 GHz grids are combined by means of an *interleaver* that takes the two DWDM streams from each Mux group and superposes them in a common stream. The aggregate stream is then amplified prior to being launched into the line.

In the receive direction the DWDM signal is pre-amplified and then it fed into the *de-interleaver* filter which splits the 80 λ DWDM – 50 GHz signal into two signals of 40 λ that are de-multiplexed to feed the relevant transponders. An optional DCM compensates for chromatic dispersion on the line.

When the span exceeds a certain level of loss, Raman Amplification can be added to increase the span. Raman amplification is normally added to the traditional EDFA amplifiers; it operates by launching a high-energy wave counter-directional to the traffic stream, Raman scattering stimulated by the pumped wavelength then amplifies the active channels.

The Raman pumps are coupled to the line through special couplers contained in the main Line Interface. Due to the high power used with this kind of amplifier, an Automatic Laser Shutdown (ALS) mechanism is implemented.

A combined backward and forward Raman amplification scheme is implemented to achieve distances for single span, of up to 68dB, typical of submarine link.

Thanks to the use of general purpose shelves line cards (amplifiers, OSC) and tributary cards can be housed in the same shelf.

The picture below shows a single row shelf terminal housing amplifiers, OSC and a number of tributaries.

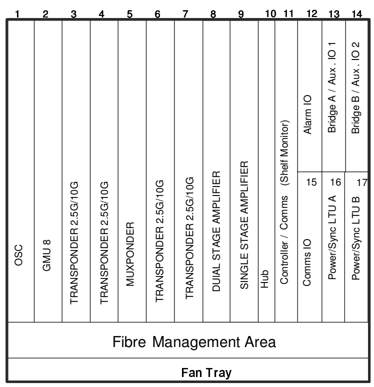


Figure 3.3.1-2 Terminal layout

In the case of a passive metro terminal all the above 9 slots are available for tributaries.

When the number of tributaries exceeds the capacity of the shelf, one or more extensions can be added.

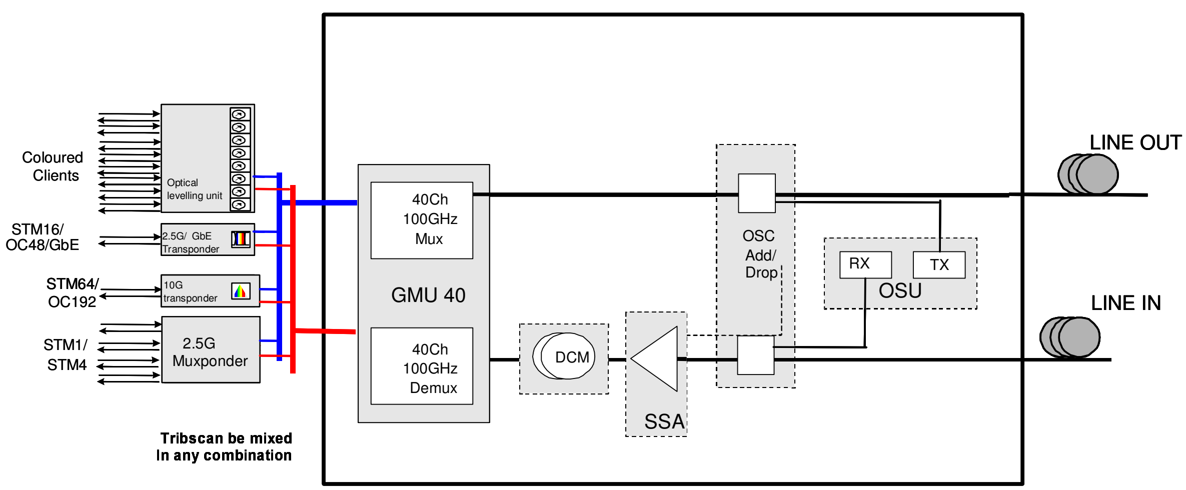


Figure 3.3.1-3 illustrates the functional blocks of a Terminal Metro Network Node.

Figure 3.3.1-3 Terminal Metro Network Element

In a metro configuration the system supports the transmission of up to 40 DWDM signals in the C-band. The channels, with frequencies separated by 100GHz, are presented to the input of a Group Multiplexer Unit (GMU-40) and multiplexed together.

An optional pre-amplifier is available for high span losses. The pre-amplifier includes a VOA and allows programmable attenuation to compensate for reduced attenuation in the line section (shorter spans). Utilising an enhanced Chromatic Dispersion tolerance transponder, DCMs could be removed for 10Gbit's transmission.

For relatively small numbers of channels the GMU-40s may be replaced by a number of 2 channel add/drop filters connected in series, thus reducing first in cost and at the same time allowing for upgrade in steps of 2 channels.There is an optional Optical Supervisory Channel (OSC) at 1510nm. The OSC provides management communication for nodes that are not connected to the DCC via transponders. The OSC also supports Aux and EOW. The OSC is inserted and extracted via OSC add/drop filters, in the case of pre-amplified nodes the OSC is extracted at the input of the amplifier.

3.3.2 Optical Channel Extender

The Optical Channel Extender (OCE) can be used to connect individual signals to the DWDM network by multiple fibre connections, in order to provide managed optical channels.

Traffic protection mechanisms, including SNCP and transponder card protection, are available to protect against both cable and equipment failure.

OCE is achieved by using additional transponders located at the client site connected in to the MHL3000. Depending on the distance between the customer premises and the DWDM terminal Network element, two possible implementations are available, as illustrated in the schemes below:

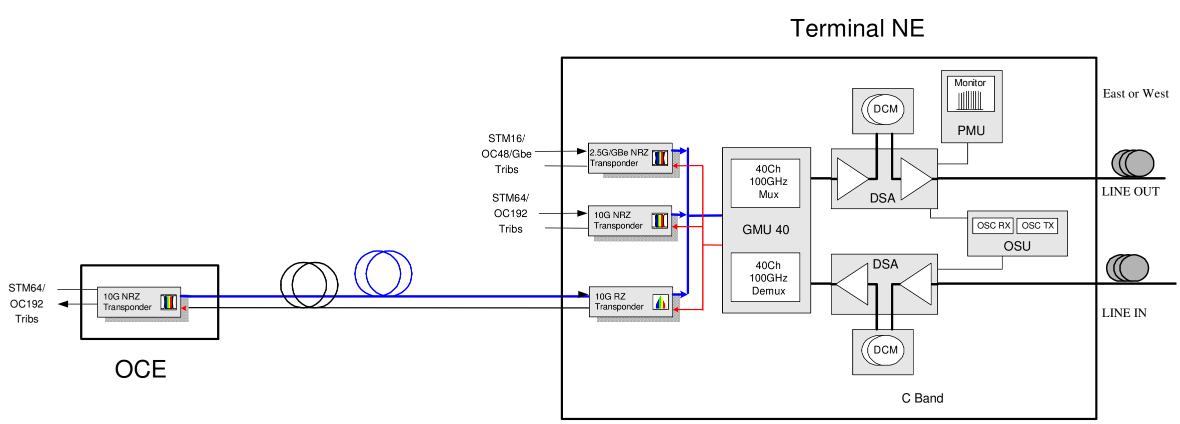


Figure 3.3.1-4 Asymmetric Optical Channel Extender

In the asymmetric case the remote transponder is connected directly to the client side of the local transponder.

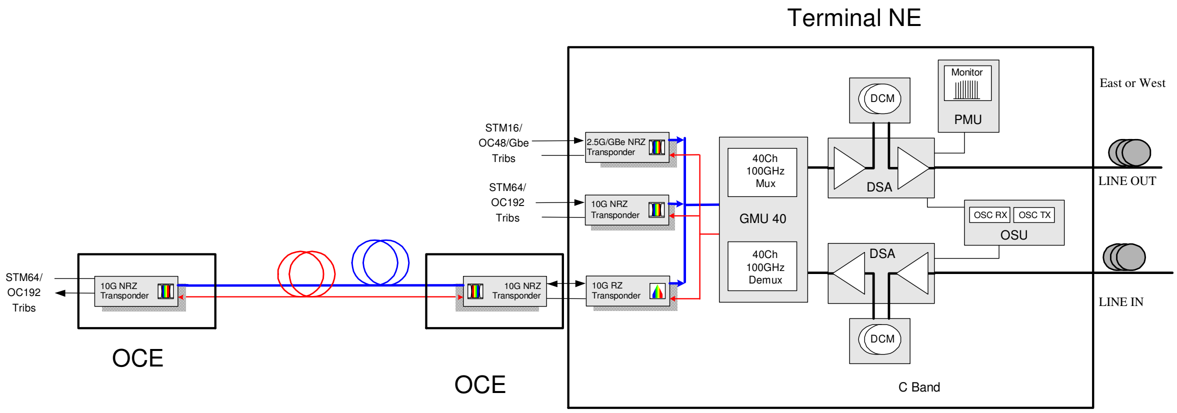


Figure 3.3.1-4 Symmetric Optical Channel Extender

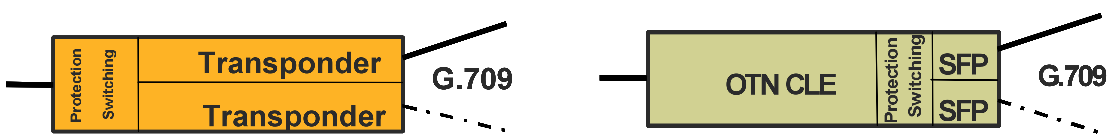
In the symmetric configuration the local OCE transponder is connected to the OCE transponder client site through coloured connection.

Remote management via DCC is provided by means of the GCC0 byte in the G.709 Digital Wrapper: in that way the DCC channels from the MHL3000 site to the Client site are directly handled from the transponders.

The transponders in the customer premises can be housed in a compact shelf or in a single slot shelf.

Traffic protection, against both cable and equipment failure, is implemented using the dual homing scheme at transponder level or at line-side SFP according to the topology.

The picture below shows the two mechanisms:



3.3.3 Amplifier Equipment Architecture

Rapid response to sudden traffic variation (loss of traffic channels due to failures) is fundamental to the system.

Gain ripple, Raman scattering, gain tilt with Raman amplifiers, fibre attenuation miss-match, transient control, all these effects contribute to channel power inequality and unbalance. Most of these effects cannot be predicted and they make the management of the transmission parameters a complex issue. In order to solve these issues two amplifier Network Element types have been conceived for the MHL3000, normal Line Amplifiers (for both core and metro) and Levelling Amplifiers (typical of core application).

Amplification is provided by a range of EDFA units, which caters for spans losses of up to 35dB.

EDFAs are optimised for their application: Reduced ripple and noise figure for ELH and ULH applications; a trade-off of functionality for cost effective LH applications.For amplified Metro applications an optimised lower gain EDFA is implemented.

All amplifier units incorporate advanced control circuitry for fast and accurate control of amplifier gain. The amplifiers respond automatically to changes in the number of channels without the need for manual intervention or realignment. Integrated Variable Optical Attenuators allow the amplifier units to automatically compensate for variations in span attenuation due to ageing and splicing.

3.3.3.1 Line Amplifiers

Line Amplifiers are used to amplify the composite WDM signal. The amplifier consists of two paths from West to East and from East to West. The Optical Supervisory Signal (OSC) is extracted and terminated within the amplifier node and re-inserted for onward transmission.

The EDFA unit can be single stage or a dual stage composed of a preamplifier stage and a booster stage.

The preamplifier stage is equipped with a built in VOA to compensate for variations in span attenuation. Depending on fibre type and number of spans, dispersion compensating elements and levelling components may appear in the mid-stage between the Preamplifier and Booster. The Booster amplifier boosts the signal in preparation for onward transmission.

Depending on span length and noise considerations, Raman amplification may also be configured.

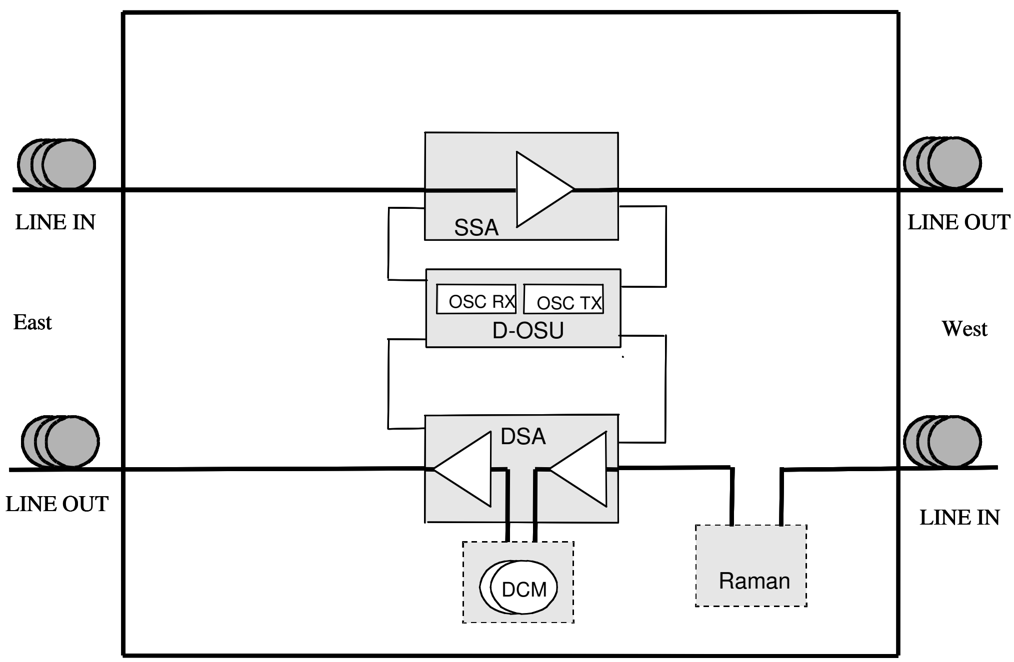


Figure 3.3.3.1-1 Core Line Amplifier Network Element

The picture below shows an amplifier node

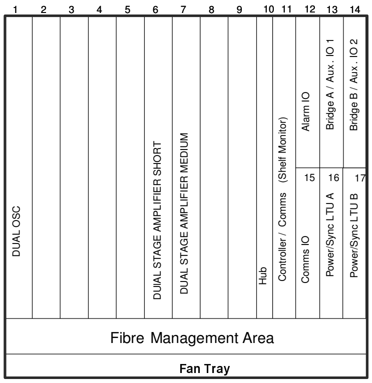


Figure 3.3.3.1-2 Core Line Amplifier layout

The metro EDFAs have been conceived to fulfil a closed Metro ring architecture. This consists of a ring optically closed with nodes providing OADM functionality. With the ring optically closed the portion of spectrum not involved in Add/Drop operation is free to re-circulate in the ring. This leads to ASE lasing in the higher gain spectral region. This ASE peak is exploited to optically stabilise the EDFA's gain in the ring making the system insensitive to channel add/drop operations.

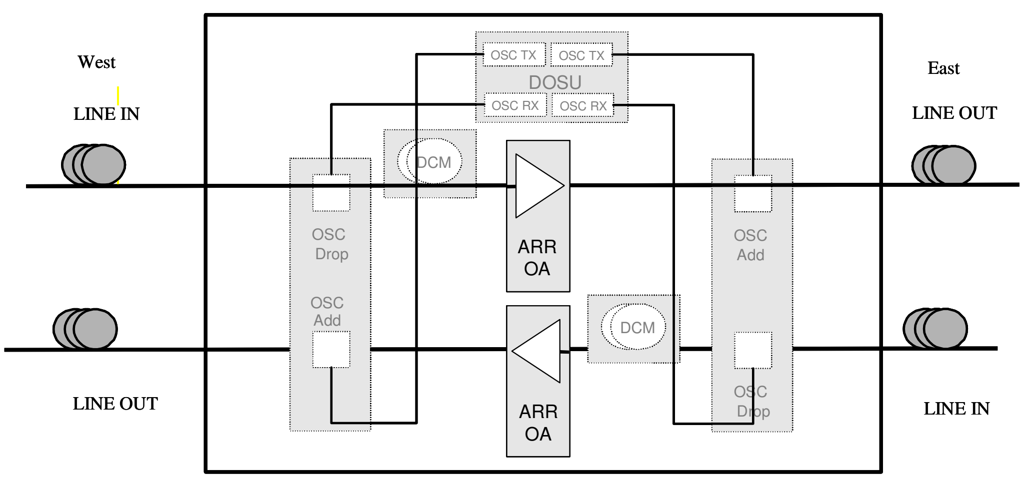


Figure 3.3.3.1-3 Metro Line Amplifier Network Element

Due to the reduced number of cards required the metro Amplifier can be housed in a three slot compact shelf.

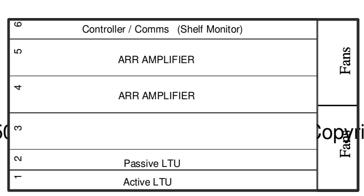


Figure 3.3.3.1-4 Metro Line Amplifier layout

3.3.3.2 Levelling Amplifiers

In a traditional DWDM core system, when cascading several amplifiers, the amplifier's gain tilt and gain variation (difference between the most amplified and the less amplified channel) can seriously limit the link overall performance. With only Line Amplifiers deployed in the link, margins and tolerancesare affected by the gain ripple of individual amplifiers.

The MHL3000 employs advanced dynamic channel power equalisation technology to ensure that the power levels of the optical channels remain consistent over the whole transmission path.

The levelling amplifier ensures all channels are at the desired power level, attenuating the most amplified to the intensity of the lowest power channel. This mechanism is completely automated and runs continuously allowing dynamic control of the transmission.

The approach to channel power equalisation implementation is based on the use of a Channel Equaliser Unit (CEU). The CEU uses control information from a Power Monitor Unit (PMU) to selectively adjust the power channels in order to restore the desired channel power profile. The solution is "all Optical" and requires no O-E-O conversion. Similarly, it is dynamic, responding automatically to variations in channel power.

The Power Monitor Unit at each equalising node is configured with the required Channel Power Profile. The PMU automatically adjusts this profile based on the actual number of channels in the system.

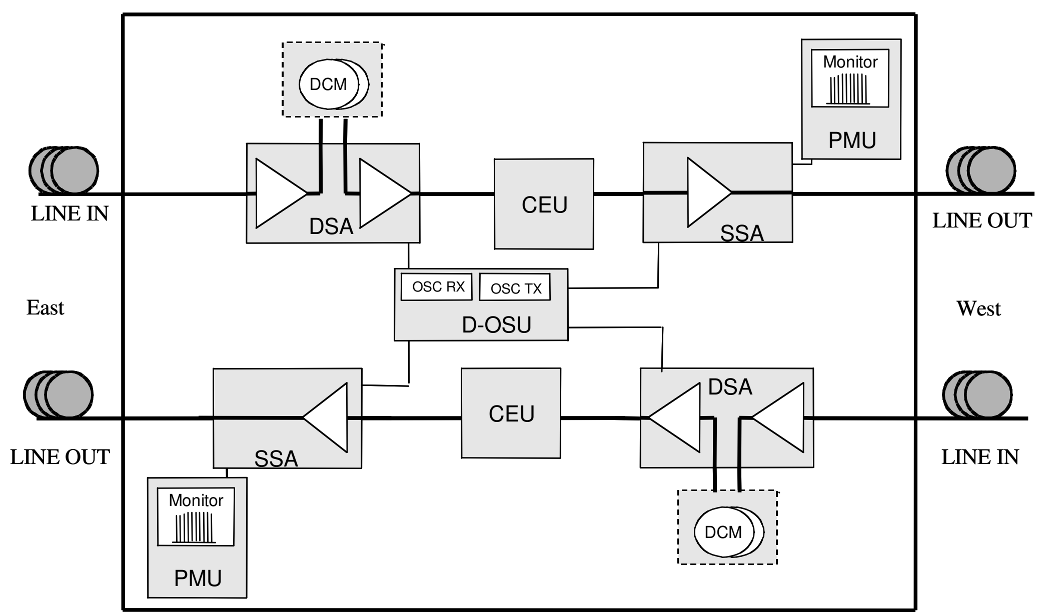


Figure 3.3.3.2-1 Levelling Amplifier Network Element

The increased number of amplifiers, the presence of the PMUs and CEUs may require a dual row shelf as shown in the picture below.

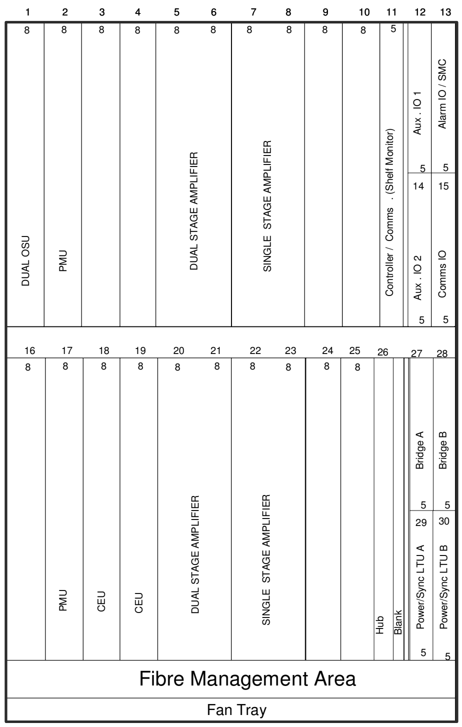


Figure 3.3.3.2-2 Levelling Amplifier layout

3.3.4 OADM Equipment Architecture

MHL3000 uses an extremely flexible approach to OADM functionality. The express traffic passing through the OADM does not need to be electrically regenerated avoiding the deployment of 3R regenerating cards for all channels. Depending on the amount of traffic added or dropped, on the application (core or metro) and on the requirement to remotely select the wavelength to be terminated, the equipment can perform either a fixed or re-configurable Add/Drop functions.

On a core network the fixed approach allows a set of 2/4 up to 8 channels to be accessed, via dedicated filters, resulting in the lowest cost solution. 2 or 4 channel filters can be cascaded to achieve a growing add/drop capability with low first in deployment.

The scheme below shows a typical fixed OADM implemented with the insertion a 4 channel fixed filter between two amplifier stages.

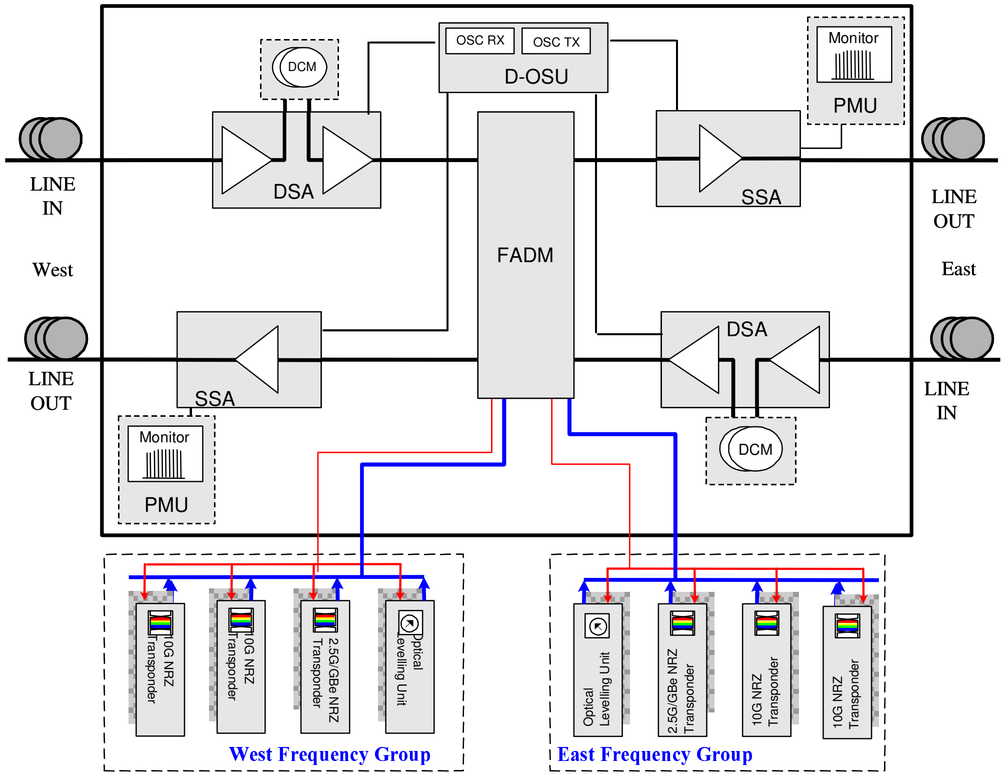


Figure 3.3.4-1 Fixed Add/Drop Network Element

For full channel access a more flexible and re-configurable approach is used. This gives access to any of the wavelengths contained in the DWDM stream allowing some channels to be terminated at the node. To achieve this, a Channel Control Unit is inserted into the optical path: this unit can separate the channels in an aggregate signal and selectively pass or block them.

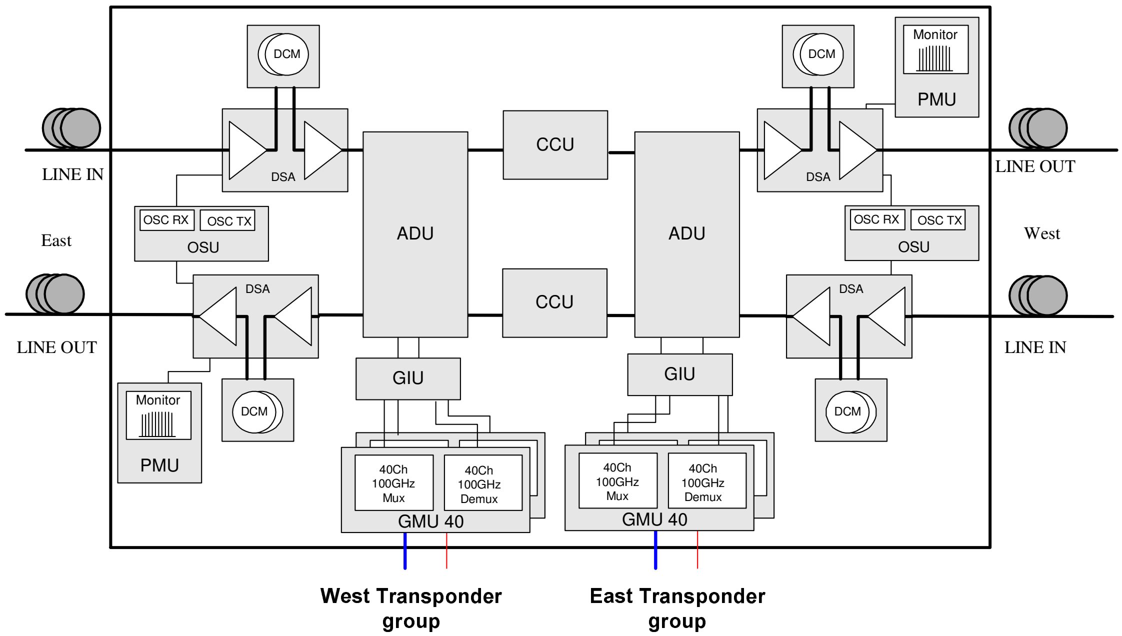


Figure 3.3.4-2 Optical Re-configurable Add/Drop Network Element

A key feature of the MHL3000 R-OADM is its flexibility that allows the traffic to be remotely configured and arranged without the need for on site intervention. In fact, provided that the necessary Network Node Interfaces (Transponders) are installed, one or more wavelengths can be immediately configured at the Drop/Insert and later redirected through the node, simply managing this operation from the remote management system.

To configure a channel from pass-through to drop, the specific hardware (transponder) must be equipped. A “connect” command specifying the channel number, the line port and the drop port is sent to the OADM Network Element via the management interface. This causes the Channel Controller to “block” the channel from propagating in both directions. Thereafter the add/drop transponder is activated and begins receiving. Its laser output level is also slowly ramped to match measured levels of the through channels. On the contrary when a dropped channel has to be configured as pass-through, a “connect” command is received from management system that unblocks the channels and switches off the transponder laser, allowing the wavelength to cross the OADM without being terminated.

A change in traffic that entails the sudden removal of some channels, dropped at an intermediate site, affects the whole transmission of the DWDM signal. MHL3000 R-OADM is equipped with an active control of the express traffic that adapts instantaneously the amplifier’s parameters to the wavelength count, thus never being affected by any degradation arising from a rapid reconfiguration.

The picture below shows a typical OADM layout.

The re-configurable OADM layout require a dual row shelf as a core network element housing optical line cards (amplifiers, add/drop unit, CCUs OSC) and tributaries. The network element can be expanded with extension shelves equipped with tributaries to reach the maximum configuration.

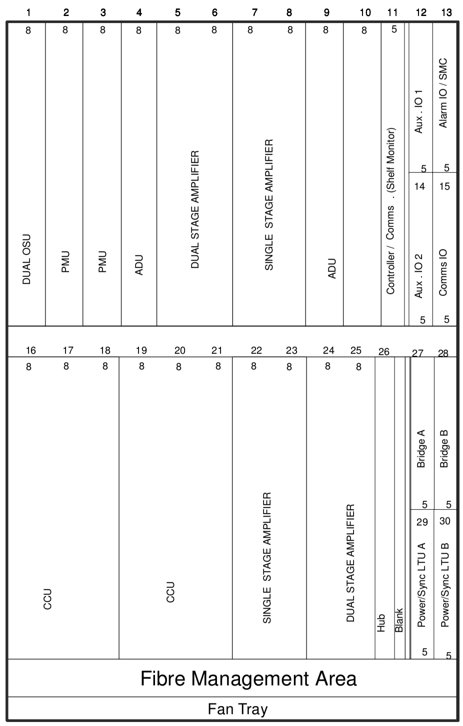


Figure 3.3.4-3 Re-configurable Add/Drop layout

In the metro environment , a serial or parallel approach can be followed dependent on the number of channels to be dropped.

The picture below describes a general Metro OADM node.

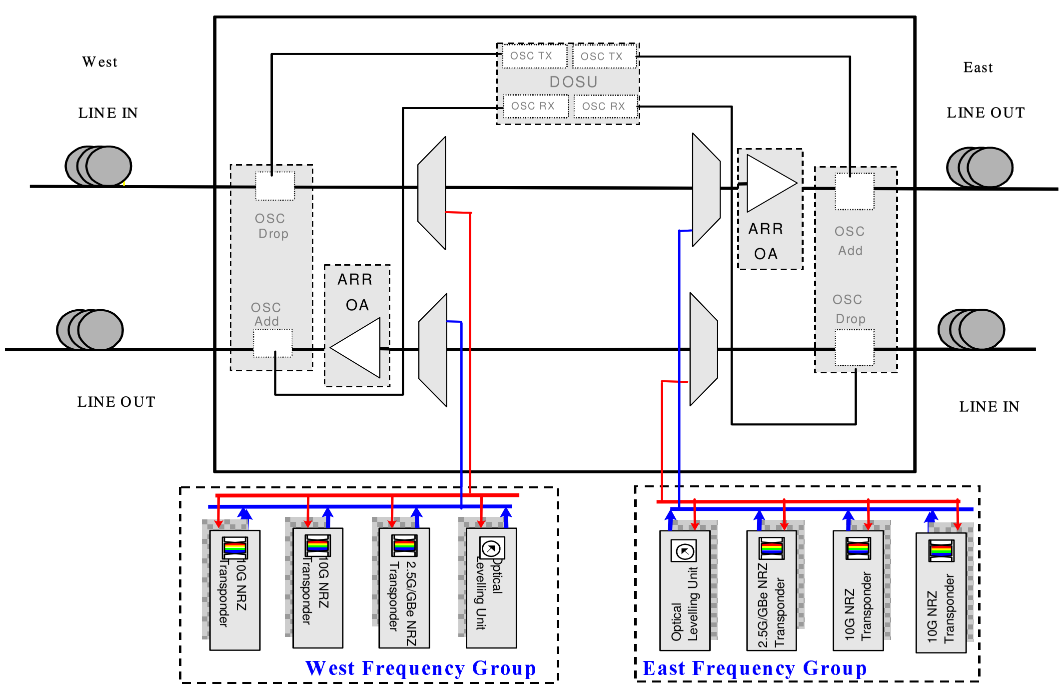


Figure 3.3.4-4 Generic metro Add/Drop Network Element

In case of high initial channel count the parallel scheme is implemented by means of two GMU_40 cards in back to back configuration that are able to simultaneously access to all the channels in the aggregate stream. Pass through traffic is managed via an optical patch-cord.

For a low channel count, a series of 2 channel filters can replace the 40 channel group mux units. The filters allow fixed add/drop of two adjacent channels in a 100GHz grid.

For metro configurations, the OSC at 1510nm is optional. The OSC provides management communication for nodes that are not connected to the DCC via transponders. The OSC also supports Aux and EOW. The OSC is inserted and extracted via OSC add/drop filters. The Dual OSU is a single card and provides OSC for both West and East lines in the same card.

In the usual metro case carrying a few channels a passive OADM layout is shown below.

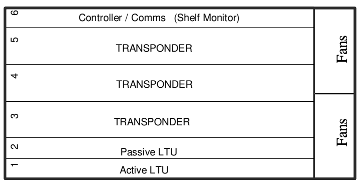


Figure 3.3.4-5 Metro Add/Drop layout

2 channels filters are housed in dedicated trays at bottom of the rack.

3.3.5 Optical switch equipment architecture

To guarantee a fully optical meshed solution MHL3000 provides two network element options.

Inter-Connection Node offers the possibility to achieve the interconnection of 4 DWDM sections, coming from different networks, and realise re-routing on a per wavelength basis.

Extended R-OADM represents a network evolution of R-OADM for fully multidirectional non-blocking switching. By using a combination of a multi-way add/drop unit and a Channel Control Unit a R-OADM at day one can be seamlessly expanded up to 4 directions.

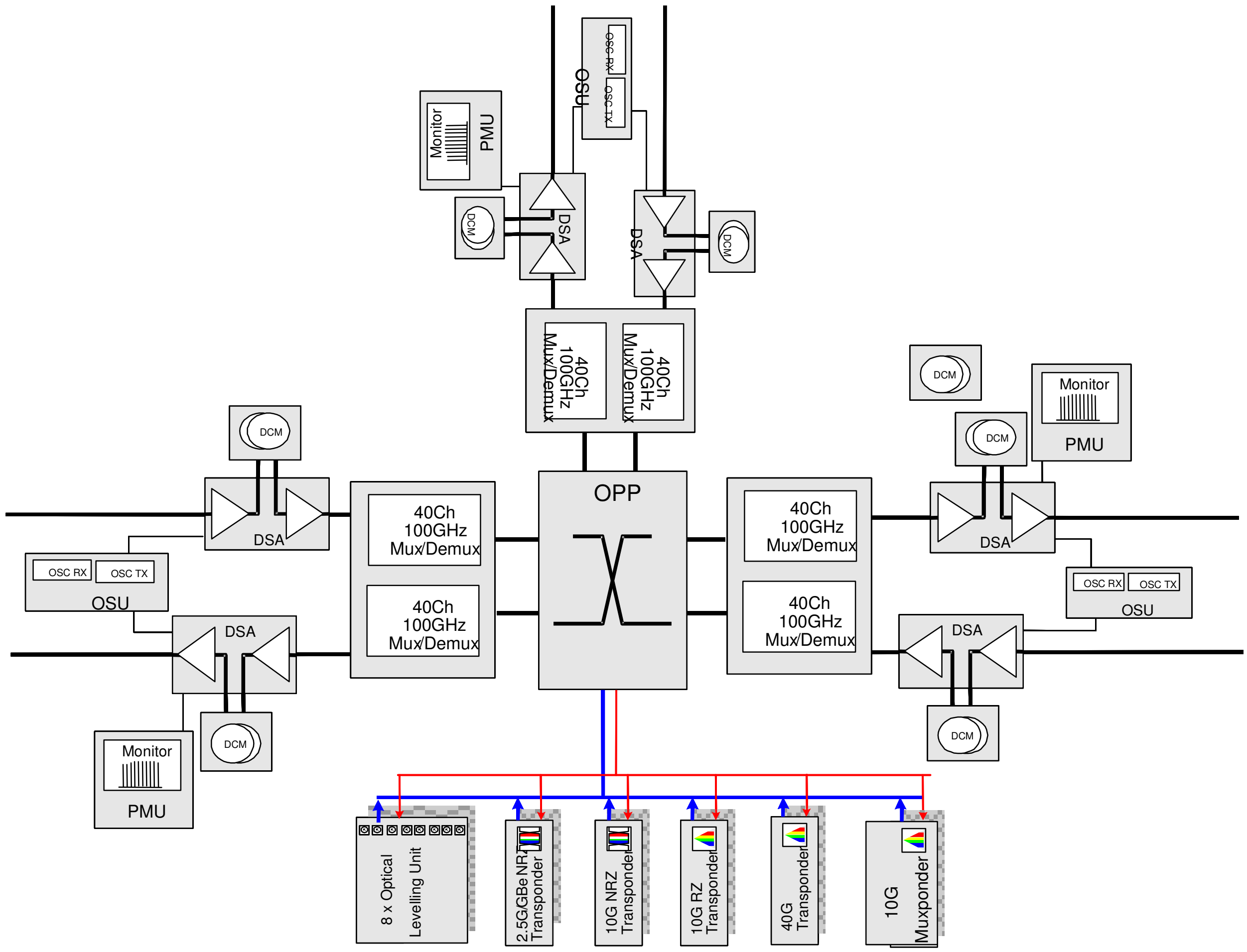


Figure 3.3.5-1 3-way Optical Inter-Change Node

The multi-way connectivity is obtained by inserting an Optical Patch panel (OPP) between the de-multiplexing and multiplexing stage. Pass through traffic is routed and levelled through the use of patch cords and Optical levelling Units.

A dual row shelf is used to house all the optical line cards (Amplifiers, OSC, demultiplexer, PMUs)

Tributaries can be inserted in extension shelves.

The picture below shows an example of 2-way ICN equipped with 14 tributary cards.

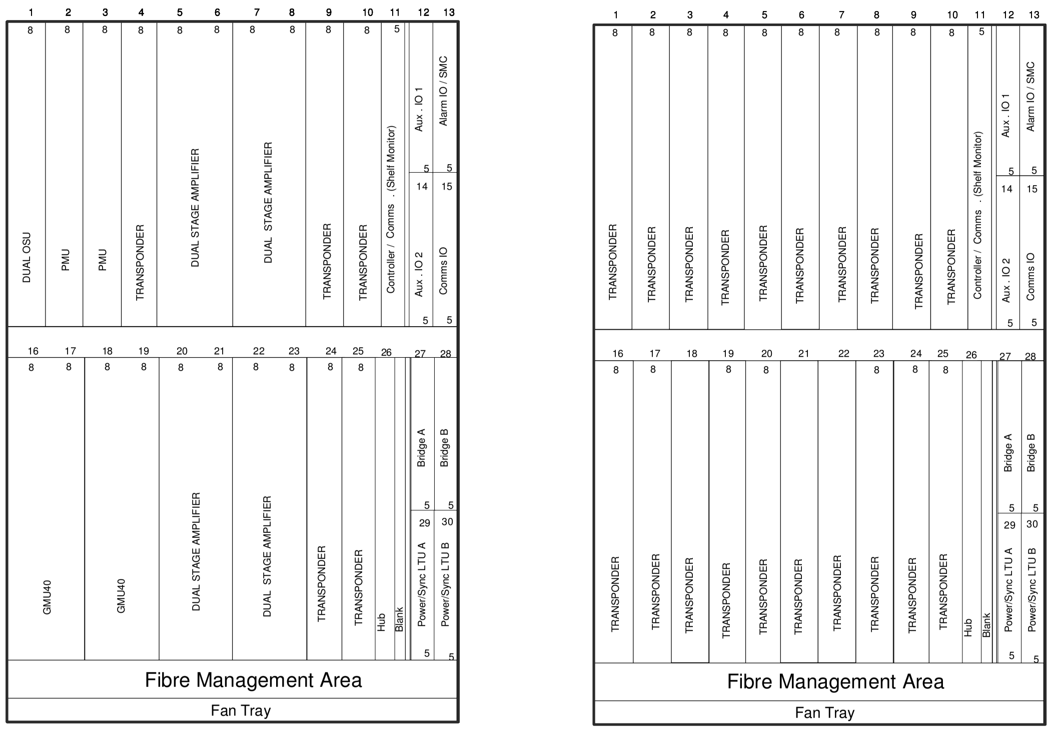


Figure 3.3.5-2 Inter-Change Node layout

4 PROTECTION SCHEMES

When the DWDM systems transport SDH-structured traffic the photonic layer does not need to incorporate any protection mechanisms as the traffic protection mechanisms can be integrated in the SDH layer.

ATM and IP, on the contrary, rely on the transport layer for protection and restoration and, in particular, when this type of traffic data is carried directly on the photonic layer, the latter must ensure protection.

The MHL3000 can implement 1+1 Optical Sub-Network Connection Protection (OSNCP) with transponder protection (inter-card) or port protection (client port), both in ring and linear applications. The protection mechanism can be single-ended or dual-ended, and can be revertive or non-revertive.

For metropolitan/regional applications, where the traffic requires only to be protected only against fibre breaks, the system can provide a Line Protection mechanism via a Line Switch Unit.

4.1 Inter-card 1+1 OSNC Protection

Single channel protection can be realised through optical sub-network protection in both ring and linear applications. Providing transponder redundancy against card failure further enhances service availability of individual channels offered by the OSNCP mechanism. The switching criteria are based on Signal Fail or Signal Degrade conditions detected at transponder level of the Optical channel termination or non-intrusive monitoring.

The following block diagram shows the inter-working of two transponders to provide card protection. Both transponders are active and send the same client signal split in the transmit direction by an external passive splitter/coupler.

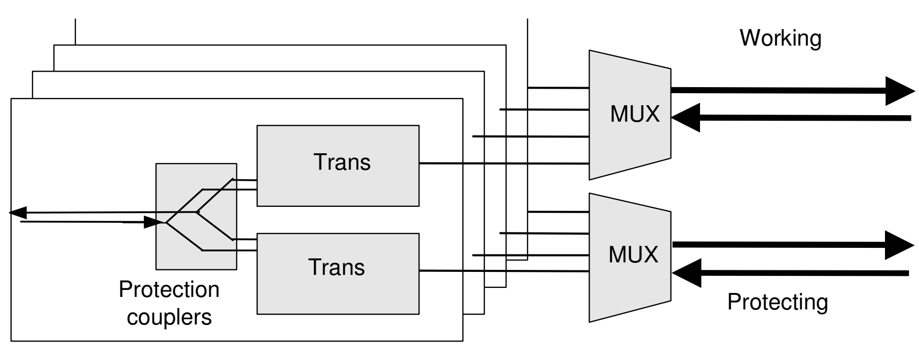


Figure 4.1-1 Inter Card 1+1 SNCP Architecture

Both transponders receive a wavelength carrying the same traffic. Bytes are processed in both transponders but only one (working transponder) has its client line active toward the tributary. In the case of Loss Of Signal (LOS) detection or Signal Degrade (SD) the change round is achieved by switching off the working transponder client transmit and activating the protection transponder client transmit.

4.2 1+1 Client Port Protection

The MHL3000 provides 1+1 Client Port Protection for clients originating below the optical layer. It is provisioned by means of a pair of transponders (single path).

1+1 Client Port Protection provides a means of protecting a pair of client signals against failure of the components of a SNC in a network of MHL3000 NEs. It includes parts of the originating/terminating NE(up to and including the Transponding Channel Units) as well as optical components, interconnecting fibres and other NEs in the network.

Client port protection is effectively provided for the client signals from the point they enter the NE to the point where they exit the optical network.

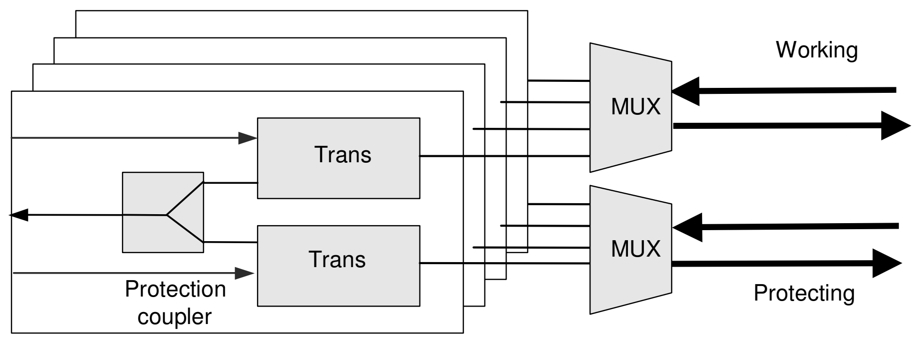


Figure 4.2-1 1+1 Client Port Protection Architecture

4.3 1+1 Line Protection

In point to point systems, especially for metropolitan applications, when traffic only needs to be be protected against fibre breaks, the system can be configured to support Line Protection mechanism. This is achieved by configuring the system with a dedicated unit, the Line Switch Unit (LSU), which provides 1+1 unidirectional protection switching. The Line Switch Unit provides a broadcast function at the source and a switch function at the sink, continuously monitoring the protected path.

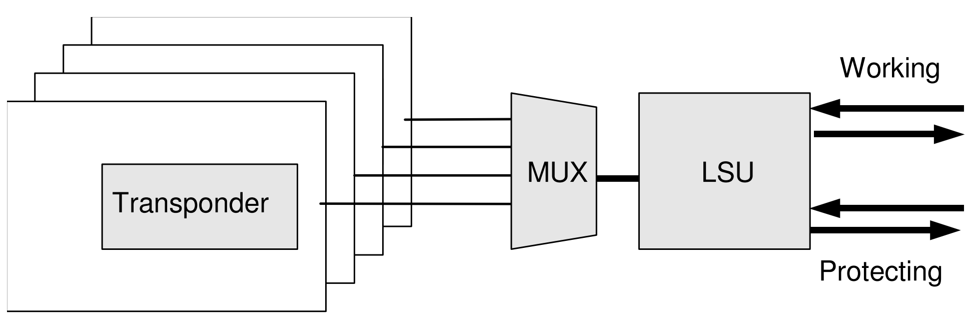


Figure 4.3-1 1+1 Line Protection Architecture

5 NETWORK MANAGEMENT

The network management structure consists of both the Network Management System (NMS) and the Element Management System (EMS).

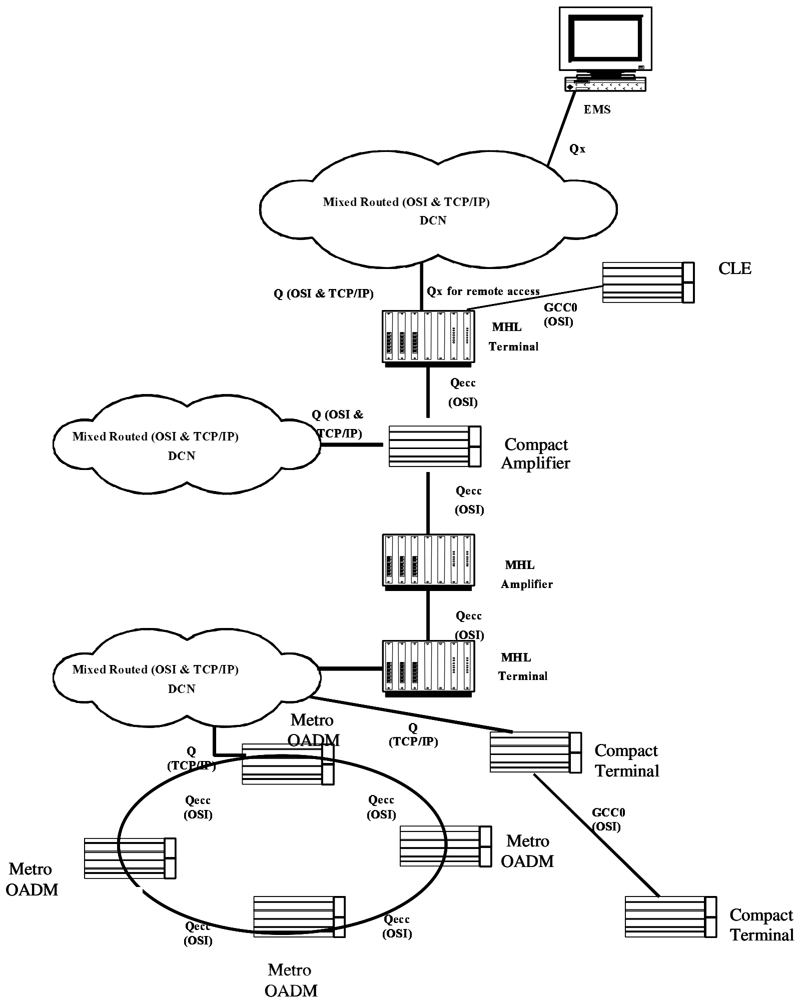


Figure 5.1 Digital Communication Channel Architecture

Marconi Network Management System (NMS) provides the network management functions defined in the ITU Telecommunications Management Network (TMN) model: Fault, Configuration, Administration, Performance and Security.

The system provides a standards-based Qx interface for integration within a multi-technology environment and a set of proprietary interfaces to export specific data, e.g. to allow the integration with third-party operational and billing management systems. The NMS is designed to flexibly scale and manage thousands of network nodes with no distinction between Access, SDH or DWDM nodes, thus allowing smooth migration of the networks and integration of new products into existing backbones.

The Element Management System for MHL3000 is the Marconi ServiceOn Optical Element Manager system; it is designed to grant full access and management of the network elements. It allows equipment handling on an individual basis.

Marconi Network Management Software called ServiceOn Optical Network Management System is designed to provide the network management functions defined in the ITU Telecommunication Management Network (TMN) model. The NMS software is designed to flexibly scale and manage thousands of network nodes, thus providing a comprehensive topological view and global management features.

Management of the MHL3000 family by the relevant EMS can be achieved by:

Direct connection of the EMS via a standard Qx interface over Ethernet LAN.

Connection of the equipment’s Qx interface over a remote LAN connected itself to the network management system by means of routers and dedicated links.

Network Elements can communicate with each other by means of the Data Communication Channels contained in the OSC via a Q_{ecc} interface.

5.1 Multi-User Security Features

Marconi's EMS and NMS security features are based on the security mechanisms of the host operating system (HP-UX) that, working in its “Trusted Mode” can comply with the highest security levels. This mechanism is enforced with a set of user profiles (actions allowed) and domains (set of resources where actions can be executed) that allow the system administration to flexibly handle the system security.

5.2 Management Access

The MHL3000 supports management access via a 10BaseT Ethernet port for central management access and an RS232-C interface for local craft access. The Network Management System manages the NE remotely using the Ethernet interface. Redundancy is provided within the Communication card by two 10BaseT and RS232-C interfaces.

6 GENERAL TECHNICAL SPECIFICATIONS

6.1 Mechanical structure

The single shelf structure is composed of a metal chassis that can house units of different size and weight according to the specific function.

Shelf dimensions are:

Shelf Types	**Dimension** (HxDxW mm^3)
Compact	200x280x440
Single row	930x280x495
Double row	500x280x495
Filter tray	119x265x481
DCM tray	100x280x495

Shelves are compliant for installation in European standard rack - ETS 300 119-3 (2200 x 600 x 300mm racks) or in ANSI 23" American racking cabinet.

The footprint of a 300 mm deep ETSI single-rack is (0.6 x 0.3) m^2 = 0.18 m^2 = 278.5 in^2.

Racks are accessed only from the front, to allow them to be placed back to back or back to the wall. No doors are included in the rack. Closed cabinets can be provided on specific request.

6.2 Physical Interfaces

The optical interfaces of a MHL3000, both single channel and multi-channel, are all compliant to the principal standards accepted worldwide.

The following table outlines the main section Interfaces.

Parameter	**Value**
Fibre type	ITU-T G652, G653, G655
Connectors	SC/PC on WDM cards, LC/PC on tribs cards, MT on GMU-40, OLU-8
Wavelength grid/spacing	ITU-T G.694.1: 100/50 GHz
FEC /E-FEC	Standard FEC based on Reed Solomon (255/239) ITU-T G709 and proprietary Extended FEC with increased gain.
Optical Supervisory Channel	1510 nm , 2Mbit/s

Fully compliant physical interfaces: ITU-T G.957/G.691 IEEE802.3	S-1.1, S-4.1, I16, S-16.1, L-16.1, L-16.2, I-64.2r, S-64.2, VSR 2000 3R2 1000BASE-SX and 1000BASE-LX on SMF
Client signal supported	STM-1 STM-4, ATM 622, CBR622Mbit/s STM-16, ATM 2488, CBR2.5Gbit/s STM-64, CBR10Gbit/s STM-256, CBR40Gbit/s ESCON (*) FICON (*) 1G FiberChannel (*) 2G FiberChannel (*) 1 Gigabit Ethernet 10 Gigabit Ethernet WAN and LAN-Phy 270Mbit/s DVB ASI Any signal with frequency from 125Mbit/s to 2.5Gbit/s bit-rate

(*) Buffer credit functionality required for extended distances, need to be provided via external equipment.

6.2.1 Electrical Interfaces

The Power Supply Unit (PSU) operates from nominal battery voltages of –48V and –60V (-38.4V to –72V). Input circuit characteristics are compliant to ETS 300 132.

6.2.2 Control and Communication (Management) Interface

The Communication and Control Unit provides the complete microprocessor-based management system for MHL3000 equipment, supporting both Equipment Management Functions (EMF) and Management Communications Functions (MCF). The Communication and Control Unit supports the ‘F’ interface for Local Terminal access and the ‘Qx’ Ethernet interface for NMS access, in both ‘gateway’ NE applications and ‘Qecc non-gateway’ interface.

This unit supports the high level control of the equipment, and provides the access to DCC of the OSC allowing management traffic to be directly connected to the equipment via an Ethernet interface, and transported to other nodes.

6.2.3 Auxiliary Functions

The Auxiliary functions provide a configurable access to selected OH bytes of the terminated OSC signal. Installation of the appropriate physical interface unit accommodates Engineer Order Wire facilities (EOW) or digital port interfaces for customised auxiliary data channel transport (two 64 kbit/s channels).

The EOW and Aux channel support are incorporated into the dual OSU unit. In conjunction with the controller and the line termination cards, the OSU supports DCC communication, Engineers Order Wire functions (selective call, additional call, omnibus call and to PSTN network), G.703 data channels, V11 Aux options and a number of internal control channels.

6.2.4 Network to Network I/F - Optical Supervisory Channel (OSC)

The Optical Supervisory Channel is the overhead of the Optical Transport Section (OTS). It is an extra band wavelength at 1510 nm carrying a 32 Byte frame (2 Mbit/s) based on the structure defined by the ITU-T standard G704.

Among the bytes assigned to transport of information, the OSC carries management information through OMS_DCC & OTS_DCC. Some bytes are also reserved for Auxiliary data (2x64kb/s), and Engineering Order Wire (2x64kbit/s).

OSC is also used to transmit alarm information and consequently in locating failures. If a card in a node fails, the alarm is written on the DCC of the OSC with the corresponding address of the "Smallest Replaceable Unit" that has failed. The information is propagated through the network carried by the DCC until it reaches the gateway to the EMS.

Finally when the Raman Amplifier is implemented in the system, the OSC is used to drive ALS and pump reactivation in case of line failure.

6.3 General Standards

The MHL3000 shelves conforms to the following European specifications:

	ETSI
EMC	ETS-300-386 Class A
SAFETY	EN 60950 / IEC 60950
OPTICAL SAFETY	IEC 60825 Safety of Information Technology equipment
ENVIRONMENTAL	
In Use	ETS-300-019 part 1-3 class 3.1E for terminal and OADM. ETSI 300-019-1-3 Class 3.2 for line amplifier
Storage	ETS-300-019 part 1-1 class 1.2
Transport	ETS-300-019 part 1-2 class 2.3
DC POWER SUPPLY	ETS-300-132-2

EARTHING & BONDING	ETS-300-253
ACOUSTIC NOISE	ETS-300-753

7 SYSTEM LAYOUT

The small footprint is one of the MHL3000 system's benefits.

This section shows some composition layouts of the main complete configurations.

7.1 Terminal layout

Fig. 7.1-1 shows the terminal configuration for an 80 channels fully provisioned equipment.

The first 8 channels can be housed in the first dual row core shelf; the node is expanded by the addition of further dual row shelves each equipped with transponders and secondary 8 channel mux/demux (or alternatively with a 40 channel mux/demux in the first shelf).

The primary core shelf contains the following units:

- Operation and Maintenance units
- OSU
- Amplifiers
- Monitoring units
- Transponders
- Mux/Demux

The extension shelves contain:

- Transponders
- Mux/Demux

For a system of up to 24 channels a single rack is sufficient.

The node can grow up to the maximum capacity with the addition of further racks as depicted in the picture below.

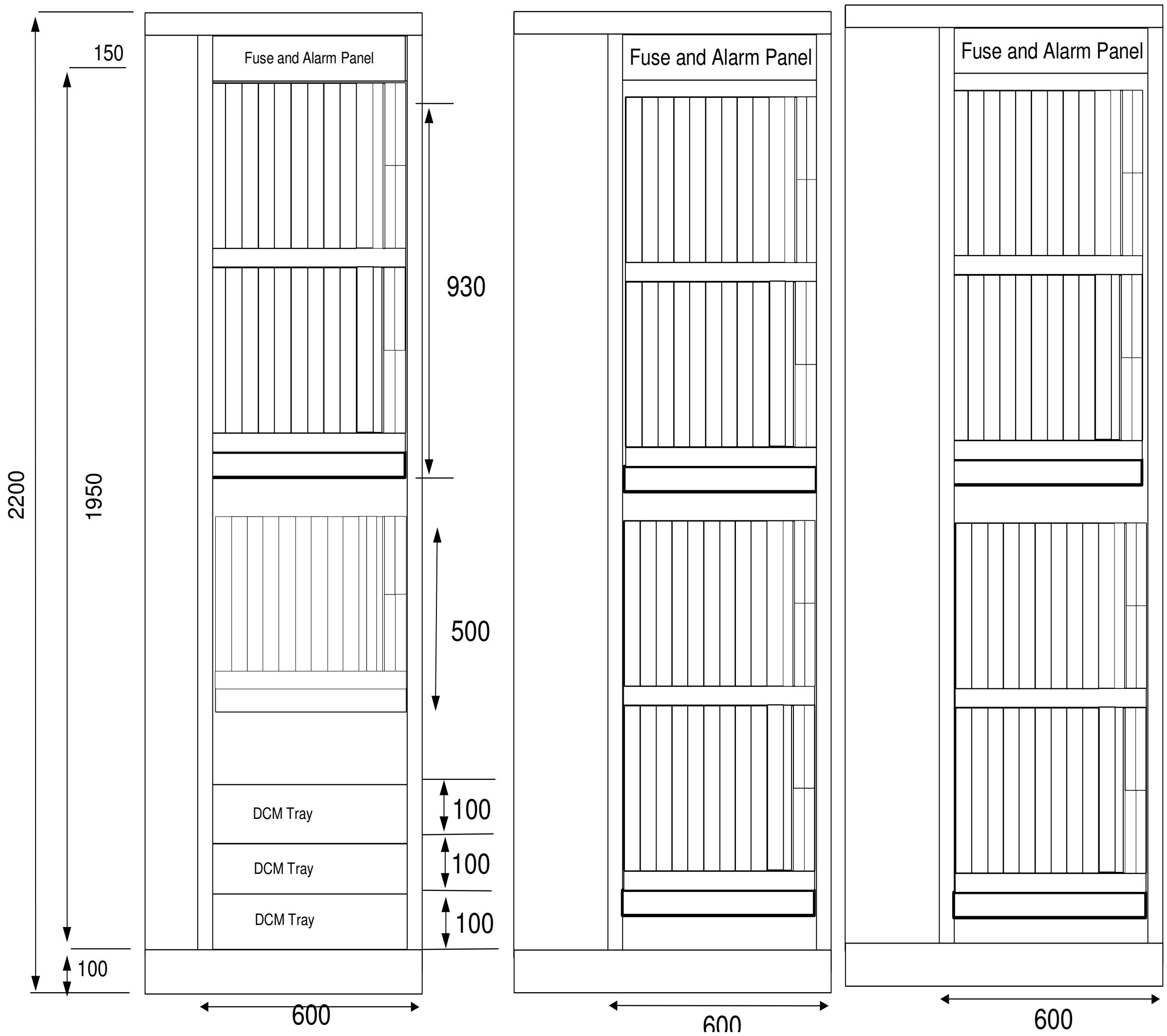


Figure 7.1-1 Rack Layout for 80 Channel Terminal

In case of low traffic count a compact terminal network element can be composed by means of a stack of compact shelves; a total of 12 clients may be supported in a single rack.

7.2 Amplifier layout

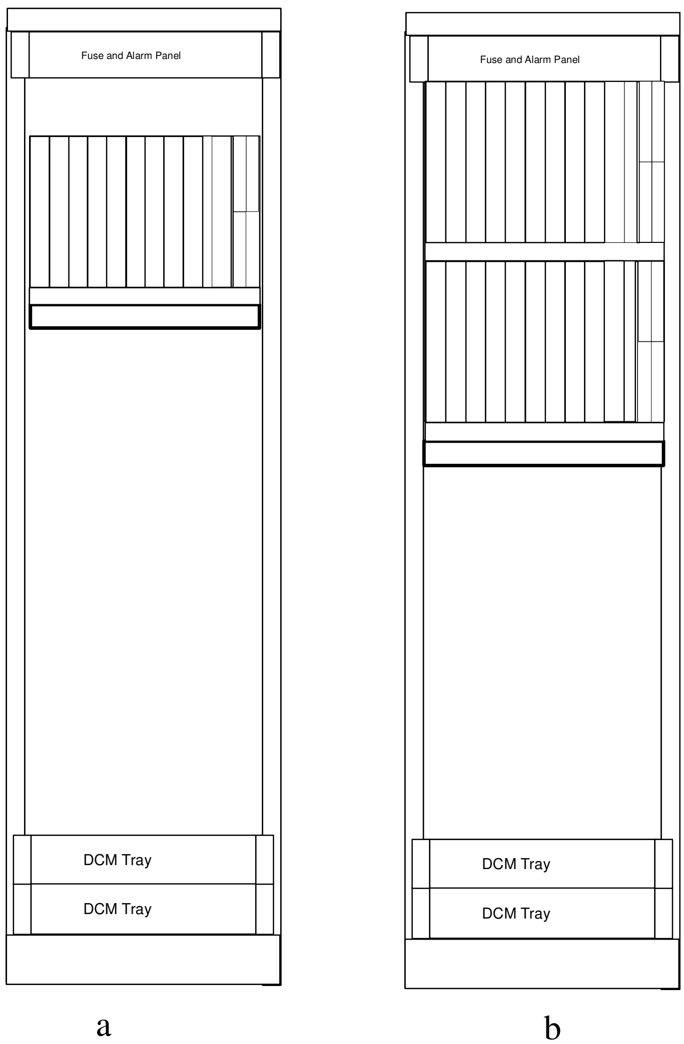
The Amplifier system layout is shown in Fig. 7.2-1

For an optical line amplifier without Raman a primary single row core shelf is sufficient. This contains:

- Operation and Maintenance units
- OSU

- Amplifiers

In case of ELH/ULH line amplifier with Raman a primary dual row core shelf, in place of a single row, is necessary.



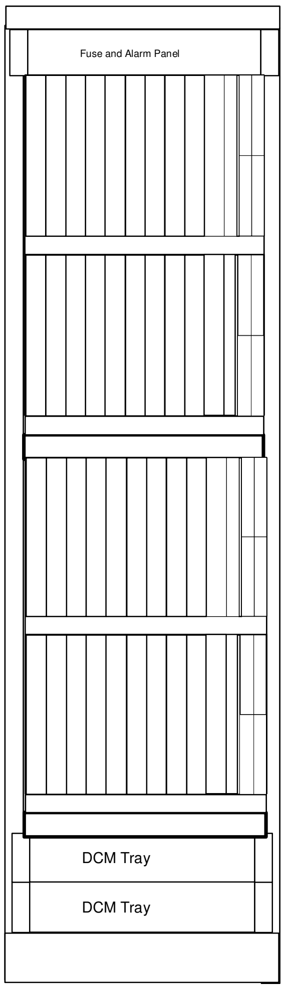
For a levelling amplifier the following units need to be added to the primary core shelf:

- Additional amplifier to compensate for the insertion loss of the levelling units
- Levelling Unit
- Monitoring Unit

Figure 7.2-1 a) Rack Layout for a in line amplifier, b) rack layout for a levelling amplifier

7.3 OADM layout

The rack layout of the core OADM system up to 12 channels per direction is shown in Fig. 7.3-1



For the Fixed OADM the Primary core dual row shelf contains:

- Operation and maintenance units
- OSU
- Amplifiers
- Monitoring unit (optional)
- ADD/DROP unit

Figure 7.3-1 a) Rack Layout for an OADM up to 12 channels per directions

A reconfigurable OADM can have full channels access. A Channel Control Unit is used in place of the fixed ADD/DROP unit and as many extension shelves as necessary to house transponders.

The footprint of each individual rack is 0.18 m^2. The space required for a node of every configuration can be computed using this footprint.

In the case of a Metro OADM with very low channel count a compact OADM network element can be composed.

If a stack of Compact shelves is used, a total of 12 Clients may be supported in a single rack.

8 FUNCTIONAL SPECIFICATIONS

8.1 Modulation techniques

The transponder represents the NNI for the DWDM transport platform (Optical Transport Network). The client signal, transported like a payload in the OCh (Optical Channel), is mapped into an Optical Transport Unit, independently of its protocol.

Transponders can have different DWDM modulation format accordingly with the specific application.

Non Return to Zero (NRZ) is the modulation format typically used in the LH/ELH application. The client signal bits are applied to the whole bit time slot and the resulting signal drives the laser modulation. This modulation technique provides an optimum solution for the most common network applications giving a good balance between overall costs and achieved performance.

The MHL3000 achieves Ultra Long Haul transmission by the application of RZ technology to the transmitted data and dispersion map, to carefully balance the non-linearities and the dispersion.

As the transmission bit rate increases, so do the technical challenges of ensuring error free propagation. Impairments due to chromatic and polarization mode dispersion increase drastically at line rates above 10Gbit/s. Additionally due to the larger optical bandwidth a conventional 40Gbit/s channel occupying 50GHz wavelength spacing is difficult to achieve.
To overcome these limitations, a novel spectrally compressed modulation format is employed for 40Gbit/s transmission which is based on multi-level phase coding. In combination with advanced electronic signal processing, the novel modulation format exhibits a much larger tolerance against chromatic and polarisation mode dispersion than an equivalent NRZ/RZ signal. Together with the narrower spectral width, these features allow MHL3000 40 Gbit/s signals to be transmitted using the same wavelength spacing and dispersion map as lower bit rate 10 Gbit/s and 2.5 Gbit/s NRZ signals.

8.2 Analogue monitoring

MHL3000 provides facilities to the Element Manager System and Local Controller to display, collect and storage the input and output power as well as the temperature of all the optical units.

In addition to the instantaneous display and user reset facilities, MHL3000 can also provide historical records for all analogue monitored entities as follow:

- 1 current 15min record and 16 recent 15min records,
- 1 current 24hr record and 1 recent 24hr record,
- 1 'All Time' record.

By using the PMU, is possible to monitor frequency, power and OSNR on a per channel basis thus allowing a real time re-calibration and amplifier power setting procedure.

8.3 ITU-T G.709 Overhead standard technology

The MHL3000 system implements ITU-T G709 conformant wrapping function which adds overhead data and Forward Error Correction (FEC) information to the client signal to provide an Optical Channel (OCh) signal.

The overhead information transported within the OCh supports the monitoring and control of optical channels within the context of the Optical Transport Network (OTN):

STM-N, IP, ATM and Ethernet signals are mapped/wrapped into OCh frames (called ODU – OCh Data Unit)

OPUk layer performs the mapping of the client signal into the ODUk

ODUk layer allows end-to-end path monitoring:

- Performance Monitoring
- Connectivity Supervision
- Maintenance Signals

The OTUk layer provides FEC encoding/decoding (and FEC enabling/disabling). Reed-Solomon FEC standardised in G.975.

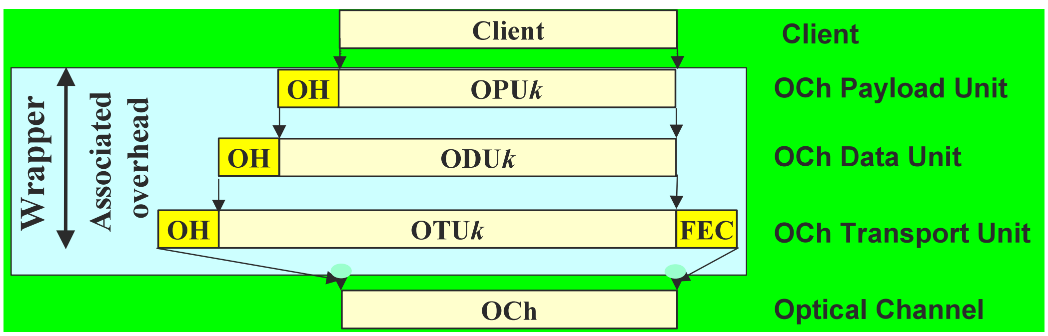


Figure 8.3.1 Wrapping layers

8.3.1 OTN Performance monitoring

Performance Monitoring can be carried out at the following layers of a signal transported in an OTN network:

- OTUk and ODUk Termination or Monitoring based on PM overhead bytes information

  The transponders provide a post FEC error detection mechanism using the ‘ODUk PM Error Detection Code (BIP-8)’, and ‘OTUk PM Error Detection Code (BIP-8)’ defined in “Interface for the optical transport network (OTN)”. This enable the system to monitor the performance of an end to end OTUk trail and ODUk path. Both Near End and Far End performance monitoring can be enabled.

- SDH/SONET Regeneration Section (RS) Monitoring

The transponders provide an error detection mechanism based on the unobtrusive monitoring of the RS B1 Byte

Block Error Monitoring via the DWDM OTU and ODU, and via the SDH / SONET RS allows the following primitive counts to be processed and presented to the user according to principles based on "ETSI EN 300 417-7-1 V1.1.1"

- Errored Seconds (ES)
- Severely Errored Seconds (SES)
- UnAvailable Seconds (UAS)
- UnAvailable Time (UAT) Logs
- Severely Errored Period (SEP) Logs
- 15min / 24hr Records

Performance data produced by NE are available to the EM and to the LT (Local Terminal). The user is able to obtain sufficient information for the following long-term Grade of Service parameters:

- Availability
- BBER (Background Block Error Ratio)
- ESR (Errored Second Ratio)
- SESR (Severely Errored Second Ratio)

End of Document

