ELASTIC NETWORKS MEAN:
Controlling your network in real time
 Quickly introducing new services and innovation
 Seamlessly operating in multi-vendor environments

VIVO DWDM network

ECI Telecom - Technical Concept for
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1. Introduction

1.1 About ECI

ECI Telecom is a leading global provider of intelligent infrastructure, offering platforms and solutions tailored to meet the escalating demands of tomorrow's services. Our comprehensive Comprehensive solution as part of SmartLight™ - Framework, defines ECI's total focus on optimal transition to Next-Generation Networks, through the unique combination of innovative and multi-functional segments like; P-OTS (Apollo) LightApps (Applications), LightControl (SDN controller) and LightSec (Cyber Security 'Hexagon' model).

ECI vision is Driving smart, communication beyond connectivity

The purpose of this document is to provide detailed information about the proposed solution for VIVO DWDM networks.

1.2 ECI P-OTS Offering

Apollo is a NG Flexible Packet-Optical Transport portfolio integrating Layer0 (pure DWDM photonics), Layer1 OTN switching (ODU-XC) technology, Layer2-MPLS-TP switching and Layer3 solution, providing a strong OAM model equally applicable to circuit and packet traffic, and offering an integrated multi-layer management view for Efficient Lowest TCO. The Apollo family offers a wide range of 10Gbps, 40Gbps (coherent) and 100Gbps (coherent) optical transceivers aggregated into 44/88/96 Fixed-grid DWDM channels or Fixed-grid DWDM spectral allocation based on Fix/Flex-grid ROADM links (with or without Mux/Demux filters).

In addition, ECI intends to support 400G and 1T transceivers as part of Apollo solution. The Apollo products include a range of platforms that span metro access, edge, and core/regional/long haul requirements.

Based on modular building blocks and a series of cost-optimized platforms, Apollo gives operators the option to implement several configurations:

- Pure photonic (DWDM Amplifiers, ROADMs, Transponders, etc.) – Apollo OPT96xx family.
- High Scale OTN switching (ODU-XC), Layer2 switching (MPLS-TP) and Layer3 – Apollo OPT99xx family.
- Cross Layer High scale LightSoft™ management System (can manage up to 20K NEs), LightControl™ (SDN Controller), LightApps™ (SDN Applications) and LightSec™ (Cyber Security 'Hexagon' model).

Passive optical components (a variety of Mux/Demux types, Splitter/Coupler types, DCF types, OSC filters and other filter types) can be installed either in Apollo platforms or in Artemis platforms.

Artemis platforms are totally passive chassis, used as a complementary solution to Apollo chassis in order to offload Apollo "active" slots into Artemis "passive" slots. Using Artemis together with Apollo achieves most cost-optimized optical solution.

Apollo offers operators significant future proofing, since networks can be designed and deployed gradually, minimizing initial investment to the current essentials, without a risk of stranding assets, without a risk of limiting future options due to initial deployment decisions, and without a risk of committing to a solution that will be less optimized for one type of traffic in favor of another.
The following charts summarized Apollo scalability and density.

**Figure 1: Apollo Portfolio - Summary chart**

For the given Models and Scenarios the Multidegree ROADMs, the best of breed EDFA amplifiers and Ultra Long Haul and Long Haul 100G transceivers together with High Capacity OPT9914/OPT9932 OTN switching (5.6T/16T) are the main building blocks today, while being ready for MPLS-TP services for future use cases.
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ECI's focus on providing practical solutions, part of our integrated SmartLight™ - Framework, offers a perfect fit for VIVO use cases, from network planning, consulting, installing, and commissioning, through to managed services – all in a one-stop shop.

Main benefits of ECI's Apollo solution for VIVO LH, Metro and ULH DWDM networks are as follows:

- **Improved protection and restoration mechanisms in an optical network level** when implementing OCH1+1 (two TRPs), **OLP (single TRP), WSON restoration or ASON restoration with ODU-XC**. Optical protection is based on Signal Degraded (Preformance Monitoring counters) and BER thresholds enables **sub 50msec switchover**.

- **Having a cost optimized OCH protection level** using a single transponder and OLP (Optical Line Protection) while keeping high performance and reliability as the OLP switch-over is based on fiber cut or channel loss.

- **LightPulse** – smart algorithm for equalization, operation and maintenance, providing real-time **OSNR, Non-linear, fiber loss** and other optical indications **from remote** (via LightSoft).

- **Real Ultra Long Haul 100G performances**, based on best in breed coherent transceivers, transmitting **elastic rate 2x100G, 2x150G and 2x200G according to traffic path OSNR**.

- **Superior Alien Lambda solution**, leveraging the new infrastructure for supporting existing install base from 3rd party vendors, or for Carriers-of-Carriers model.

- **End-to-end GUI friendly management**.

- **Future ready** – When upgrading a network to future rates, as 400Gbps and 1Tbps, it will require to replace an interface in the IP platform (in case of inherent DWDM transceivers in the IP platform), when differentiating the DWDM network from IP network, the operator can keep using the existing IP platforms install base (namely 100Gbps interfaces and base cards) and connect them to 4x100Gbps/10x100Gpbs combiners.
2. SmartLight™

ECI delivers SDN functionality as part of its comprehensive SmartLight™ framework, shown in the figure below. SmartLight™ incorporates an innovative model, featuring the required openness essential to the SDN concept, while benefiting from the technical maturity attained by years of rigorous field experience with its flagship LightSoft™ network management system.

Powering the physical delivery of SmartLight SDN transport applications across the network are ECI's proven Apollo and NPT families of packet-optical transport systems (P-OTS). Hundreds of customers worldwide have deployed Apollo and NPT for all types of transport applications including wireline, wireless/cellular, cable/MSO, wholesale, utilities, government entities, national research, and education networks, as well as for enterprise applications. Key features of Apollo and NPT that can power elastic and powerful SDN-defined transport applications are:

- Flexible multiservice multilayer transport (Ethernet, storage networking, video, cellular, and legacy TDM services) for lowest TCO
- Carrier-grade service assurance – providing protection, resilience, dynamic restoration, manageability, and security
- Modular and scalable architecture from the metro access through the regional core
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- From transparent services to encrypted services, and from n x 64 Kbps to 100G services
- True Packet Optical transport combining packet efficiency with transport grade availability and optics scalability
- DWDM-optimized routing flexibility through CDC ROADMs and flexible grid
- E2E unified multilayer management – for end-to-end visibility via an intuitive GUI-based NMS

The Apollo and NPT P-OTS network elements extend their configuration control to an SDN Controller using a variety of interfaces, with all capabilities eventually being accessible through the OpenFlow industry standard. The SDN Controller creates a virtualization layer for the NEs capabilities that, in turn, are extended to SDN applications. Under ECI's SmartLight framework, the world class LightSoft network management system expands to provide the SDN Controller. This is natural for LightSoft, as it already provides ubiquitous coverage of Apollo and NPT, and controls third-party NEs with a generic EMS.
3. Apollo Product Family

Apollo comprises a full product line, supporting several different chassis sizes for various network locations. The system installation is extremely cost-effective, and the system's modular architecture enables in-service system upgrades to support increasing number of channels. These upgrades can be performed by adding service cards or chassis to an existing site.

The Apollo product line supports number types of shelves.

- The 96xx family is used for implementing the photonic layer (ROADMs, Amplifiers, Muxponders, Transponders, L2/MPLS-TP on a blade), 9624 has option to be operated with 1T OTN switching.
- The Artemis family is used for hosting passive card (e.g. WDM Mux/Dmux. Splitters/Couplers, etc.)
- The 99xx family is used for implementing high capacity OTN-switching layer (5.6Tbps, 16Tbps) with L2/MPLS-TP and L3 feature set.

3.1 Apollo 96xx Platforms

3.1.1 OPT9624

The OPT9624 dimensions are sized for ETSI racks, with 674 mm height (15U), 492 mm width, and 271 mm depth.

It configured as pure WDM system with total capacity of up to 12Tbps per degree (24Tbps in the future).

The shelf includes two slots for controllers (working and standby) and 24 universal slots for optical service cards (Transponder/Combiners) and photonics modules (ROADM, amplifiers, passive filters). The system is fully redundant by power entry, main controller (RCP), fan units, fabrics, timing and management ports.

![Figure 4: OPT9624 Shelf View](image)

3.1.2 OPT9608
The OPT9608 dimensions are sized for 19" racks, with 221 mm height (5U), 443 mm width, and 253 mm depth. The OPT9608 is packet optical platform supporting standalone WDM system and Metro Packet-OTS on a blade.

Each shelf includes two controllers and eight universal slots for service and photonic cards. The same service and photonic cards are used in OPT9624, OPT9608 and OPT9603. The 9608 can be mounted in standard 19 inch and 21 inch ETSI and NA seismic racks. The platform includes:

- Two slots for redundant RCP main controller cards.
- Eight I/O slots for photonics and L1 services cards.
- Two slots for redundant power feed modules, using a DC power source. AC power source option is available by module connected at the rear of the cage.
- Fan Control Module (FCM) drawer with nine fans and built-in air filter. Air flow is directed horizontally from right to left.

![OPT9608 General Layout](image)

**Figure 5: OPT9608 General Layout**

### 3.1.3 OPT9603

The OPT9603 dimensions are sized for 19" racks, with 88 mm height (2U), 442 mm width, and 240 mm depth. The OPT9603 is packet optical platform supporting standalone WDM system and Metro Packet-OTS on a blade.

The 9603 can be mounted in standard 19 inch and 21 inch ETSI and NA seismic racks. The platform includes:

- One shelf controller (RCP)
- Fan Unit (FU). Fans are controlled by the shelf controller. Air flow is directed horizontally from right to left.
- Two modules for redundant PFMs, using a DC power source. The system supports also AC options.
- 3 universal I/O slot for service card.
Technical Concept

All universal I/O slots share the same photonic and L1 services cards as supported in OPT9608 and OPT9624.

Figure 6: OPT9603 General Layout

3.2 Apollo 96xx cards and modules

3.2.1 Layer 1 Service Cards

Each and every card below can be installed in OPT9603, OPT9608 and OPT9624.

AOC10B – dual 10G Add/Drop Multiplexer (ADM) on a Card with onboard ODU-XC.

This service card supports up to 16 client interfaces, which are multiplexed into the G.709 multiplexing structure and transmitted via two OTU-2 line interfaces. Any of the client interfaces can be configured to handle video signals, STM1/OC3, STM4/OC12, GbE, FC 1/2/4G, OTU-1, or STM-16/OC-48 signal. The card has integrated cross-connect capabilities (including ODUflex), providing more efficient utilization of the lambda. Any of the signals can be added or dropped at each site, while the rest of the traffic continues to the next site.

The AOC10 supports Sub-network Connection Protection (SNCP) mechanisms, allowing the system to select the better signal for each service that is transmitted over two paths.

The AOC10 can be configured to work as two independent multiplexers, or can be line protected by another client and line interface providing equipment and facility protection. Each service is protected by a path protection mechanism based on performance monitoring (PM).

The card provides Forward Error Correction (FEC) and Enhanced Forward Error Correction (EFEC) capabilities towards the line.

Figure 7: AOC10B card

AOC10_L2 – Four 10G Add/Drop Multiplexer (ADM) on a Card with onboard L2 switching.

This service card supports up to 16 GbE interfaces (can be configured as UNI or NNI), with MPLS-
Technical Concept

TP/Ethernet on board switching. Up to four 10GbE/OTU2e (SFP+ based) are supported, 10GbE can be configured as UNI or NNI.

The AoC10_L2 can be configured to work as independent card or as associated card.

In associated mode – two AoC10_L2 cards are associated (via OPT9608/OPT9624 backplane) with 20G internal connectivity.

The following are the main highlights of AoC10_L2:

- Single slot card
- 60G MPLS-TP on board Switch
- 16xGBE SFP clients plus 4x10GBE/OTU2e SFP+ uplinks
- T-SFP+ support in uplink
- Standalone card – no connectivity to centralized matrix
- 2x10GbE inter-card connectivity for protection and fan out (2 adjacent cards in 9608 and 9624)
- Supported at all shelves -9603, 9608 and 9624
- Interoperability with TR10_4/TR10_12/FIO10_5 OTU2/2e ports for backhauling purposes
- Interoperability with NPT products
- Services: P2P, MP2MP, VLAN transparency, P2P and P2MP MPLS based
- Classification: Untagged, tagged (C-VLAN, S-VLAN), 802.1p, DSCP
- MAC table: 64K onwards
- Ports: Equivalent to UNI, I-NNI, E-NNI, MPLS capabilities, Port mirroring
- QoS: Per CoS/Port strict priority queuing, ingress policing, MPLS queuing per LSP
- Redundancy: Sub 50msec protection: ERP or MSTP/RSTP, LAG, card protection
- OAM: 802.1ad (Link OAM), CFM (Service OAM), Y.1731
- In-band management: Over GCC, Over VLAN
- Management: LightSoft, STMS and CLI
- Timing (HW Ready): 1588v2 transparent clock, SyncE.
TR10_4 - 4 ports 10G Transponder

The 10 Gbps transponder maps two client signals to G.709 and transmits the colored signals towards the network. The transponder supports 10G LAN, STM-64/OC-192, OTU-2, and FC8/FC10 client signals that can be mapped to OTU-2, OTU-2e, and OTU-2f. Two 10 Gbps transponders are available in a single card. Each one can be configured independently for transponder or regenerator applications.

Each service in the TR10_4 can be configured to work independently with no protection, Y-protection, or equipment protection. The card supports FEC, EFEC (I.4 and I.7), and no FEC modes towards the line. In regenerator mode, EFEC is available for both line sides.

Apollo transponders comply with ITU-T standards for 50 GHz and 100 GHz multichannel spacing (DWDM) using fixed or tunable XFP transceivers. They support PM and GCC in-band management, with PM for client side signals in the signals' native layer (SDH/SONET and Ethernet).

The following figure shows a block diagram illustrating operation of the TR10_4 transponders.

![Figure 9: TR10_4 card](image)

TR10_4EN – Dual 10G encrypted Transponder

Single slot, dual 10G encrypted transponder, usable in any Apollo platform for uniform access-through-core solution supporting full set of XFP client service interfaces: 10GbE, STM64, OC192, FC10G, FC8G, OTU2 and OTU2e all services are wire speed, provides client service transparency with no added latency

Strongest multi-layer public key encryption:

- AES256-GCM key (highest level)
- Initialization Vector ensures no two messages are encrypted the same way
- Message Integrity Check ensures no message tampering

![Figure 10: TR10_4EN card](image)

CMR40B - 4x10G Combiner

The CMR40B is a multiservice combiner card that supports 4 x 10G LAN/STM-64/OC-192/OTU2/OTU2e aggregation to OTU-3e. The 10G clients are based on pluggable XFPs and the 40G line coherent transceiver is based on DP-DQPSK modulation format with tunable 88 channels DWDM line side transmitter.
CMR40B occupies double Apollo slot.

![Figure 11: CMR40B card](image)

**CMR100/CMR100L – 10x10G Combiner**

Apollo system supports 100G combiner Card (AKA Muxponder), based on state-of-the-art technology. The line transceiver is based on the Polarization Multiplexed Quad Phase Shift Keying (PM-QPSK) modulation format using coherent detection with extensive digital signal processing (DSP). It provides great capabilities to mitigate chromatic dispersion (CD) and PMD.

CMR100 supports a fully tunable 88 channels DWDM line side transmitter, line side receiver is wide band with tunable filter functionality (optimized solution for colorless networks) integrated with 10 client ports multiplexed to OTU-4 line. CMR100 Client rates can be one of the following:

- 10GbE, STM64, OC192, FC10G, FC8G, OTU2, OTU2e (FEX and EFEC i.7 supported in OTU2 (e) ports)

Any mixed and match of the above rates can be mapped (changed by software) and multiplexed into an OTU-4 and transported using a single 100G channel.

CMR100 occupies double Apollo slot.

![Figure 12: CMR100/CMR100L card](image)

**TR100 - 100G Transponder**

Apollo system supports 100G Transponder Card, based on state-of-the-art technology. The line transceiver is based on the Polarization Multiplexed Quad Phase Shift Keying (PM-QPSK) modulation format using coherent detection with extensive digital signal processing (DSP). It provides great capabilities to mitigate chromatic dispersion (CD) and PMD.

TR100 supports a fully tunable 88 channels DWDM line side transmitter, line side receiver is wide band with tunable filter functionality (optimized solution for colorless networks).

Client is based on CFP with SR10, LR10 and LR4 interfaces.

TR100 occupies double Apollo slot.
**Technical Concept**

**Figure 13: TR100 card**

**TR10_12 – 12 ports 10G Transponder**

TR10_12 is a single slot Apollo card, a dense 10Gbps transponder maps up to six client signals to G.709 and transmits the colored signals towards the network.

This transponder supports 10G LAN, STM-64/OC-192, OTU-2, and FC8/FC10/FC16 client signals that can be mapped to OTU-2, OTU-2e, and OTU-2f. Six 10Gbps transponders are available in a single card. Each one can be configured independently for transponder or regenerator applications.

Each service in the TR10_12 can be configured to work independently with no protection, Y-protection (beside FC16), or equipment protection. The card supports FEC, EFEC (I.4 and I.7), and no FEC modes towards the line. In regenerator mode, EFEC is available for both line sides.

Apollo transponders comply with ITU-T standards for 50 GHz and 100 GHz multichannel spacing (DWDM) using fixed or tunable SFP+ transceivers. They support PM and GCC in-band management, with PM for client side signals in the signals' native layer (SDH/SONET and Ethernet).

**Figure 14: TR10_12 card**

**CMR100M - Metro 10x10 Combiner**

CMR100M is a dual slot card, optimized to 100G Metro applications.

At the client level, CMR100M support variety of 10G rates plus 40GbE:

- Ten SFP+ chassis for: 10GbE, STM64, OC192, FC10G, FC8G, OTU2, OTU2e

- Two QSFP+ chassis supporting 40GbE each

Any mixed and match of the above rates can be mapped (changed by software) and multiplexed into an OTU-4 and transported using a single 100G channel.

At line side, CMR100M has CFP chassis. 100G line-side has two options:

- Coherent CFP transceiver (connecting to DWDM network)
- Non-Colored CFP – LR4, LR10, ER4, etc. (for point to point)
The Coherent CFP use Polarization Multiplexed Quad Phase Shift Keying (PM-QPSK) modulation format and coherent detection with extensive digital signal processing (DSP), which provides great capabilities to mitigate chromatic dispersion (CD) and PMD with fully 88 tunable DWDM channels support.

Figure 15: CMR100M card

TM100 - Metro 100G Transponder/Muxponder

TM100 is a single slot card, which can be operated (Software configured) in three modes. The line side is based on CFP transceiver (either DWDM Coherent or non-colored) and client/s are based on CFP2 pluggable.

Figure 16: TM100 card

- **TR100M - Metro 100G Transponder**
  TM100 assigned as TR100M is a single slot 100G transponder. With Coherent CFP at the line-side (up to 1500Km) and variety of CFP2 interfaces at the client-side.

- **MXP100E10 – 10x10GbE Muxponder**
  TM100 assigned as MXP100E is a single slot card with 10x10GbE clients mapped into 100G CFP line. 100G line-side has two options
    - Coherent CFP transceiver

" Figure 17: TM100 software modes"
### Technical Concept

- Non-Colored CFP – LR4, LR10, ER4, etc.

- **MXP100E40 – 2x40GbE Muxponder**
  
  TM100 assigned as MXP40E is a single slot card with 2x40GbE clients mapped into 100G CFP line. 100G line-side has two options
  
  - Coherent CFP transceiver
  - Non-Colored CFP – LR4, LR10, ER4, etc.

  The coherent CFP use Polarization Multiplexed Quad Phase Shift Keying (PM-QPSK) modulation format and coherent detection with extensive digital signal processing (DSP), which provides great capabilities to mitigate chromatic dispersion (CD) and PMD with fully 88 tunable DWDM channels supports at line side.

### 3.2.2 Photonics Modules

**ROADMs**

The ROADM is currently considered to be the technology of choice for carriers’ worldwide, adding flexibility and lowering total cost of ownership (TCO) for various network scenarios. Apollo supports 2D-ROADM, 4D-ROADM and 9D-ROADM for 100 GHz (44 channels) and 50Ghz spacing (88 channels).

Apollo's best-in-class WSS ROADM technology, together with fully tunable lasers and power equalization capabilities, introduces truly agile optical networking, providing up to 100Gbps wavelength connectivity in ring or mesh topology, with evolution to 400Gbps and 1Tbps super-channels using flex grid.

All ROADM flavors have WSS at the add side for restoration and superior alien lambda support, colorless, directionless and contention-less ROADM flavors are:

- **ROADM_9A** – 44 Channels (100GHz spacing), 9 degrees ROADM,
- **ROADM_9A50** – 88 Channels (50GHz spacing), 9 degrees ROADM
- **ROADM_4A** – 44 Channels (100GHz spacing), 4 degrees ROADM
- **ROADM_4A50** – 88 Channels (50GHz spacing), 4 degrees ROADM
- **ROADM_2A** – 44 Channels (100GHz spacing), 2 degrees ROADM
- **ROADM_2A50** – 88 Channels (50GHz spacing), 2 degrees ROADM,
- **ROADM9F** – 96 Channels (50GHz spacing) and Flex-grid spectrum, 9 degrees ROADM
- **ROADM4F** – 96 Channels (50GHz spacing) and Flex-grid spectrum, 9 degrees ROADM
- **ROADM20T** – 96 Channels (50GHz spacing) and Flex-grid spectrum, 20 degrees ROADM with Twin WSS.
Technical Concept


![Figure 18: ROADM_9A/9A50/9F/4A/4A_50/4F/2A/2A_50/20T/MxN front panel](image)

Amplifiers

Apollo system supports a variety of fix gain, variable gain, RAMAN and Hybrid EDFA-RAMAN amplifiers (as detailed below) to meet different network topologies and distance from access to core. The amplifiers are available for 100GHz, 50GHz and flexible spacing networks.

<table>
<thead>
<tr>
<th>Card</th>
<th># of slots</th>
<th>E/W</th>
<th>MSA</th>
<th>OSC SFP</th>
<th>OSC filter</th>
<th>Extended C-Band</th>
<th>Max Total Power [dBm]</th>
<th>Gain [dB]</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OA_PA</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>16</td>
<td>10-21</td>
<td>Fixed gain amplifier for metro applications.</td>
</tr>
<tr>
<td>OA_FB</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>20.5</td>
<td>14-22</td>
<td>High power fixed gain booster for long haul applications and ROADM sites.</td>
</tr>
<tr>
<td>OA_FHBS</td>
<td>1</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>22.5</td>
<td>15-24</td>
<td>Ultra high power fixed gain booster with integrated output OSC filter. Optimized for 88-channel ROADM sites.</td>
</tr>
<tr>
<td>OA_L</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>20.5</td>
<td>15-28</td>
<td>Variable gain amplifier without Mid Stage. Optimized for coherent network applications. For In-Line and ROADM sites after low/medium gain spans in Regional/LH applications.</td>
</tr>
<tr>
<td>OA_ML</td>
<td>1</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>20.5</td>
<td>15-28</td>
<td>High power dynamic variable gain multistage amplifier for regional/long haul applications. Optimized as a inline amplifier for short spans and as a pre-amp before ROADM sites.</td>
</tr>
<tr>
<td>Card</td>
<td># of slots</td>
<td>E/W</td>
<td>MSA</td>
<td>OSC SFP</td>
<td>OSC filter</td>
<td>Extended C-Band</td>
<td>Max Total Power [dBm]</td>
<td>Gain [dB]</td>
<td>Description</td>
</tr>
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<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>OA_M</td>
<td>1</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>20.5</td>
<td>25-37</td>
<td>High power dynamic variable gain multistage amplifier for regional/long haul applications. Optimized as an inline amplifier for long spans and as a pre-amp before ROADM sites.</td>
</tr>
<tr>
<td>OA_MHS</td>
<td>1</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>22.5</td>
<td>20-40</td>
<td>Ultra high power dynamic variable gain multistage amplifier for 88-channel regional/long haul applications. Mainly used as an inline amplifier.</td>
</tr>
<tr>
<td>OA_HRS</td>
<td>2 wide</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>28.5&lt;sup&gt;1&lt;/sup&gt;</td>
<td>10-20&lt;sup&gt;1&lt;/sup&gt;</td>
<td>High power 700 mW Raman amplifier for long haul multispans and undersea applications.</td>
</tr>
<tr>
<td>OA_EHRS</td>
<td>2 long</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>20.5&lt;sup&gt;1&lt;/sup&gt;</td>
<td>23-37&lt;sup&gt;1&lt;/sup&gt;</td>
<td>High power wide-gain hybrid EDFA/Raman (700mW) amplifier, optimized for DCF-less networks and low NF applications.</td>
</tr>
<tr>
<td>OA_LEHRS</td>
<td>2 long</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>20.5&lt;sup&gt;1&lt;/sup&gt;</td>
<td>15-28&lt;sup&gt;1&lt;/sup&gt;</td>
<td>High power low-gain hybrid EDFA/Raman (700mW) amplifier, optimized for DCF-less networks and low NF applications.</td>
</tr>
<tr>
<td>OA_LF</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>20.5</td>
<td>15-28</td>
<td>Variable gain amplifier without Mid Stage. Optimized for coherent network applications. For In-Line and ROADM sites after low/medium gain spans in Regional/LH applications. Extended C-band for 96ch and Flexed-Grid networks.</td>
</tr>
<tr>
<td>OA_HF</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>20.5</td>
<td>25-37</td>
<td>High power dynamic variable gain amplifier without Mid Stage for regional/long haul applications. Optimized as an inline amplifier for long spans and as a pre-amp before ROADM sites. Extended C-band for 96ch and Flexed-Grid networks.</td>
</tr>
<tr>
<td>Card</td>
<td># of slots</td>
<td>E/W</td>
<td>MSA</td>
<td>OSC SFP</td>
<td>OSC filter</td>
<td>Extended C-Band</td>
<td>Max Total Power [dBm]</td>
<td>Gain [dB]</td>
<td>Description</td>
</tr>
<tr>
<td>-------------</td>
<td>------------</td>
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<td>------------</td>
<td>-----------------</td>
<td>-----------------------</td>
<td>-----------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>OA_EHRSF</td>
<td>2 long</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>20.5¹</td>
<td>23-37¹</td>
<td>High power wide-gain hybrid EDFA/Raman (700mW) amplifier, optimized for DCF-less networks and low NF applications. Extended C-band for 96ch and Flexed-Grid networks.</td>
</tr>
<tr>
<td>OA_USPB</td>
<td>2 long</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>26</td>
<td>1-6</td>
<td>Dynamic gain Ultra high booster amplifier for LL links. Positioned after OA_FB or OA_M amplifiers.</td>
</tr>
<tr>
<td>OA_UHBRL</td>
<td>Ext shelf</td>
<td>+</td>
<td>-</td>
<td>Int</td>
<td>+</td>
<td>-</td>
<td>30</td>
<td>68¹</td>
<td>External shelves, combined with Dual High power booster (Multi-Mode) and Ultra high gain Raman (3W). can compensate up to 68dB single span insertion loss (w/o ILA), suitable for Coherent and Non-Coherent transmission.</td>
</tr>
</tbody>
</table>

¹ Depends on type of fiber. Actual gain is heavily dependent on splice quality and actual attenuation of fiber and can be drastically affected

Figure 19: For example - OA_FB EDFA and OA_EHRSF Hybrid EDFA/Raman amplifier cards

Passive cards

Different types of passive filters are available for fix network solutions. FOADMs and optical multiplexers are available in different configurations starting from single channel to full 44 and 88 channels.

Passive cards/modules can reside both in Apollo I/O slots (conceded as active slot) and Artemis slots (conceded as passive slot), however – Artemis is recommended as complementary platform for Apollo since it's saves Apollo "active slots" and make them free for photonic and services cards which require power feed and software configuration.
Technical Concept

Artemis is virtually managed by Apollo shelf as UME (Un Managed Element), so it's taking part of Apollo LIGHTPULSE algorithms.

3.3 Artemis Product Family

Apollo portfolio includes also passive boxes for passive cards. The passive cards could be installed either in the Apollo cages (OPT96xx) or in Artemis cages. Customer who wants to keep the slots in the OPT96xx for active type of cards could install the passive cards in one of the Artemis cages. The Artemis cage available in 3 sizes:

- Artemis 1 – 1RU size with 1 row (2 slots)
- Artemis 2 – with 2 rows (4 slots)
- Artemis 4 – with 4 rows (8 slots)

![Artemis General Layout](image)

Figure 20: Artemis General Layout

A wide range of CWDM and DWDM Mux/DeMux, OADMs, splitters/couplers, DCFs, and filters are available for use with the Artemis shelves. In addition Apollo passive cards are also supported in the Artemis.

The passive optical components are available in three different module sizes: Single slot, Double slot and Quad slot.

48 channels Mux/DeMux in 1U standalone passive cage and 96 channels Mux/DeMux in 2U standalone passive cage.

![Artemis cards – Examples](image)

Figure 21: Artemis cards – Examples

3.4 Apollo 99xx Platforms
3.4.1 OPT9932

The OPT9932 dimensions are sized for ETSI racks (600mmx300mm footprint), with 1970 mm height (full rack), 447 mm width, and 310 mm depth.

It can be configured as L1/OTN-Switching together L2/MPLS-TP and L3/IP-MPLS system with 16 Tbps total capacity.

The shelf includes:

- 32 universal slots for service cards xIO-01:xIO-32, 400Gbps each.
- 9 slots for central universal Fabric (7 + 1 or 2):

Figure 22: OPT9932 General Layout
Technical Concept

- 7 Fabric Modules, xFM-1:xFM-7
- 2 Routing Control Processor (active & standby controller) integrated with Fabric Module, xRCP-A:xRCP-B.

All the Fabrics Modules are switching traffic (8 actives in case of 7+1 or 9 actives in case of 7+2) and then there will be no traffic affection in case of 2 (or 1 in case of 7+1) Fabric Modules failure/s.

- 12 Power Feed Modules, with fully redundant power entry (Active & Standby), xPFM-A1:xPFM-B1 … xPFM-A6:xPFM-B6.

- Integrated Power Distribution Frame: each xPFM-A/B has a dedicated Circuit Breaker which connects the power feed from the communication room power suppliers to the specific xPFM-A/B

- 3 Fan Control Slots:
  - FCM-L – Fans for Lower part of the shelf (xIO-01:xIO-16) using xFCMH-32 an Horizontal Fan Control Module
  - FCM-M – Fans for Middle part of the shelf (Common cards area) using xFCMV-32 an Vertical Fan Control Module
  - FCM-U – Fans for Upper part of the shelf (xIO-17:xIO-32) using xFCMH-32 an Horizontal Fan Control Module

- Other common modules:
  - 2 xMIM (1 is optional), Management Interface Module (active and standby), at slots xMIM-R and xMIM=L, each has one Main Management Port plus 4 slave Managements ports (total 5 10/100/1000 Base-T) for up to five Multi-Shelf’s managed under the same IP address.

  XMIM redundancy enables redundant openflow connectivity to two SDN controllers.

- Timing and Alarm interfaces Module, xTAM, In/Out Timing connectors, In/Out Alarms connector, etc.
- (Optional) xTAM Extension Module, xTEM, an extension of xTAM with In/Out Alarms connector, a buzzer and system alarms LEDs.

3.4.2 OPT9914

The OPT9914 dimensions are sized for 19” unrestricted (300mm depth footprint) racks, with 974 mm height (22U), 447 mm width, and 310 mm depth.

It can be configured as L1/OTN-Switching together L2/MPLS-TP and L3/IP-MPLS system with 5.6 Tbps total capacity.

The shelf includes:

- 14 universal slots for service cards xIO-01:xIO-14, 400Gbps each.
- 4 slots for central universal Fabric (3 + 1 protection):
  - 2 Fabric Modules, xFM-1:xFM-2
  - 2 Routing Control Processor (active & standby controller) integrated with Fabric Module, xRCP-A and xRCP-B.
All the Fabrics Modules are switching traffic (actives) and then there will be no traffic affection in case of single Fabric Modules failure.

- 6 Power Feed Modules, with fully redundant power entry (1:1 protection), xPFM-A1:xPFM-B1 ... xPFM-A3:xPFM-B3
- 2 Fan Control Modules:
  - xFCM-L – Fans for Lower part of the shelf (xIO-01:xIO-14) using xFCMH-32 an Horizontal Fan Control Module
  - xFCM-M – Fans for Middle part of the shelf (Common cards area) using xFCMV-32 an Vertical Fan Control Module
- Other common modules:
  - 2 xMIM (1 is optional), Management Interface Module (active and standby), at slots xMIM-R and xMIM=L, each has one Main Management Port plus 4 slave Managements ports (total 5 10/100/1000 Base-T) for up to five Multi-Shelf’s managed under the same IP address.
  
  **xMIM redundancy enables redundant openflow connectivity to two SDN controllers.**
  - Timing and Alarm interfaces Module, xTAM, In/Out Timing connectors, In/Out Alarms connector, etc.

### 3.5 Apollo 99xx cards

#### 3.5.1 Layer 1 Service Cards

Each and every card below can be installed in OPT9932 and OPT9914 chassis.
single slot card for OPT99xx cages, supports any mix of low rate clients i/f connection to OPT99xx universal fabric, 32 SFP transceivers.

- STM1, STM4, STM16
- OC3, OC12, OC48
- Layer 1 GbE (optical and electrical)
- FC 1G, FC2G, FC4G
- Support ODU0, ODU1 and ODUflex FC4G cross-connections.
- SNCP and port protection

### 3.5.2 Hybrid Service Cards

Each and every card below can be installed in OPT9932 and OPT9914 chassis.

**HIO10_20 – Hybrid IO Multi Rate with 20 10G ports (with combination of 2 40G)**

Single slot card for OPT99xx cages supports any mix of the following client i/f connection to OPT99xx universal fabric, 20 SFP+ plus 2 QSFP+ pluggable transceivers, 10Gbps/40Gbps links for OTN switching L2/MPLS-TP (at phase-2_ and L3 (at phase-3 with new HW revision).

- Per port L1 and L2 mixing (L2/MPLS-TP will be supported at phase-2)
- OTU2
- OTU2e
- STM64
- OC192
- FC1200
- FC800
Technical Concept

- 10GE
- 2 QSFP+ transceiver supporting 40GE. When 40GE port is selected, four SFP+ ports will be inactive.
- Supports Port protection (IOP), SNCP protection.
- SyncE and 1588v2 support.
- GCC support.

**HIO100_2 – Hybrid IO Multi Rate with two 100G ports**

Single slot card for OPT99xx cages supports any mix of the following client i/f connection to OPT99xx universal fabric, 2 CFP pluggable transceivers, 100Gbps/40Gbps links for OTN switching, L2/MPLS-TP switching (Phase-2).

- Hybrid data and ODUk grooming capability Per low order ODUk/ODUflex L1 and L2 mixing (L2/MPLS-TP at phase 2).
- Two 100Gbps metro coherent CFPs for DWDM line
- Dual Rate ER4, LR4 and SR10 CFPs (OTU4/100GE) for Client connection (or dark fiber connection)
- OTU4/100GE interfaces
- Supports client’s port protection (IOP) and SNCP protection, ASON and WSON.
- GCC Support

**Figure 26: HIO100_2**

**HIO400 – Hybrid IO Multi Rate with two 100G/150G/200G ports**

Single slot card for OPT99xx cages supports any mix of the following adaptive DWDM Line rates i/f connection to OPT99xx universal fabric. HIO400 has two DWDM adaptive rate line ports (100Gbps/150Gbps/200Gbps) based on Coherent transmission with adaptive modulation and capable to 50GHz ITU-T Grid and Flex-Grid channels transmission. GCC, ASON and WSON are supported.

HIO400 is used for OTN switching, L2/MPLS-TP switching (Phase-2) and L3 routing (Phase-3) at line side with maximum 400Gbps capacity.

**Figure 27: HIO400**
HIO100_4 – Hybrid IO Multi Rate with four 100G ports

Single slot card for OPT99xx cages supports any mix of the following client i/f connection to OPT99xx universal fabric, 4 CFP2 pluggable transceivers, 100Gbps links for OTN switching, L2/MPLS-TP switching (Phase-2) and L3 routing (Phase-3).

- Hybrid data and ODUk grooming capability Per low order ODUk/ODUflex L1 and L2 mixing (L2/MPLS-TP at phase 2) and L3 routing (Phase-3).
- Four 100Gbps metro coherent CFPs for DWDM line
- Dual Rate ER4, LR4 and SR10 CFP2s (OTU4/100GE) for Client connection (or dark fiber connection)
- OTU4/100GE interfaces
- Supports client’s port protection (IOP) and SNCP protection, ASON and WSON.
- GCC Support

4. Beyond 100G & Spectral allocation

4.1 Modulations Overview

Polarization Multiplexed Quad Phase Shift Keying (PM-QPSK aka DP-4QAM/DP-QPSK) modulation format and coherent transmission is common practice for 100G carriers. One of the methods to cross the 100Gbps transmission is changing the modulation from 4QAM to 8QAM or 16QAM.

The following summarize the modulation formats ECI use.
DP-4QAM (aka PM-QPSK and DP-QPSK) modulation means:

- Symbol transmission rate = Baud Rate = 25Gbaud
- One symbol of QPSK “carry” Two bits of data → 25Gbaud represent 50Gbps
- Dual polarization → transmit double rate at the same time → 2 x 50Gbps = 100Gbps per DWDM wavelength.

DP-8QAM modulation means:

- Symbol transmission rate = Baud Rate = 25Gbaud
- One symbol of QPSK “carry” Three bits of data → 25Gbaud represent 75Gbps
- Dual polarization → transmit double rate at the same time → 2 x 75Gbps = 150Gbps per DWDM wavelength.

DP-16QAM modulation means:

- Symbol transmission rate = Baud Rate = 25Gbaud
- One symbol of QPSK “carry” Four bits of data → 25Gbaud represent 100Gbps
- Dual polarization → transmit double rate at the same time → 2 x 100Gbps = 200Gbps per DWDM wavelength.

Each one of the modulations above might be transmitted over a Fixed-Grid (100GHz or 50GHz Spacing) or over a Flex-grid spectrum in order to increase the spectral efficiency.

4.2 400Gbps

According to the above section, the maximum bps rate per carrier is 200G (for commercial solutions as described at the above section). In order to cross 200Gbps transmission, a super-channel can be multiplexed and transmit n*100Gbps. ECI 400Gbps (2*200Gbps) solution will be available in two cards:

- HIO400 – a card for 99xx as described at Hybrid IO Multi Rate with two 100G/150G/200G section.
- TM400 – Transponder/Muxponder 400G as described in the next section.

4.2.1 TM400

The TM400 is a flex-grid and flex-rate transponder/muxponder designed for ultra-long haul, metro-long haul, and metro-regional network configurations. This software-configurable card can be used as:

- 10GE muxponder, fanout of 10, 20, 30, or 40 10GE SR clients
- 40GE muxponder, fanout of 2, 4, 6, or 8 40GE SR4 clients
- 100GE/OTU4 muxponder, with 2, 3, or 4 100GE/OTU4 ER4, LR4, or SR10 clients
- Dual 100GE ultra-long haul transponder
- Single 100G ultra-Long haul regenerator
- Combinations of two muxponder types: Nx10GE with Nx40GE, Nx10GE with Nx100GE, Nx40GE with Nx100GE
**Technical Concept**

- Combinations of ultra-long haul transponder with any one of the muxponder types (Nx10GE, Nx40GE, Nx100GE)

Note: 10 x 10GE fanout is implemented through patch cord fiber or patch panel fanout.

The TM400 provides 4 CFP2 client ports (100GE/OTU4; ER4/LR4/SR10), including fan out connections for multiple 40G or 10G clients. Up to 400G uplink is provided through 2 line ports, through one of the following configurations:

- 2 x 100G DP-4QAM (DP-QPSK) up to 5000 Km
- 2 x 150G DP-8QAM up to 1200 Km
- 2 x 200G DP-16QAM up to 800 Km
- 2 x 100G DP-4QAM (DP-QPSK) up to 5000 Km + 1 x 200G DP-16QAM up to 800 Km

Typical configuration options are illustrated in the following figure.

![Figure 31: TM400 card](image-url)
The TM400 card incorporates advanced technology for optimum performance, providing 25%SD-FEC for OSNR reach enhancement, Tx Nyquist spectral shaping base on TX DSP, and D/A manipulation for increased reach. The TM400 offers a unique capability of embedded OSNR measurements, providing integrated performance monitoring. With these cards, the transmit-receive NEs use integrated OSNR monitoring to optimize transmission rates based on the channel conditions. For example, shorter distances enable better usage of the lambda, with more bits transmitted per GHz. The range of adaptive rates supported by the TM400 are illustrated in the following figure.

The TM400 card is a genuine green technology, with less than 1W per 1G and ready for gridless networks with an ability to squeeze its 400G signal into a 75GHz bandwidth as well as tune the central frequency. The TM400 can be included in either fixed-grid or flex-grid networks. In fixed-grid networks the TM400 covers a total spectrum of 100GHz, including 2 channels of the 50GHz grid. In flex-grid networks the TM400 covers a 75GHz spectrum, working with 2 carriers in a super channel running over gridless ROADMs. Built-in line encryption will be included in future releases.

### 4.3 1Tbps

#### 4.3.1 About Tera Santa Consortium
The Tera Santa Consortium, supported by the Israeli Chief Science Officer, was founded in August 2010 with the aim of developing advanced optical network technologies, based on ultra-high capacity coherent links (1Tbps).

The Tera Santa Consortium comprises Israeli industry companies and academia.

The industry companies include component level companies (DSP, PICs), subsystem companies (transceiver/transponder), and system companies (platforms, network). ECI leads the Consortium whose members also include Orckit (aka Corrigent), Finisar Israel, Multiphy (a DSP startup), CivCom, Bezeq International, and Optiway.

The academia includes researchers from five universities (Technion, Hebrew University of Jerusalem, Ben-Gurion University, Bar-Ilan University and Tel-Aviv University), covering DSP algorithms, PIC and Photonic technologies, and optical network algorithms.

4.3.2 Consortuim goals

Development of the generic technology required for a cost-effective, high-density 1Tbps transceiver, based on coherent OFDM technology (transceiver and transponder), with a reach of 1,500-2,000 km. In addition to the 1Tbps transceiver, the consortium will develop generic technology for an add/drop transceiver, as described below, enabling adding and/or dropping partial traffic out of the 1Tbps channel.

Development of the generic technology required to provide network intelligence and automation capabilities that increase operational efficiency and reduce the operational costs of a packet-optical network. The coherent OFDM channels and the associated signal digital processing add new degrees of freedom at the channel level (adaptive modulation, adaptive impairment compensation), which can be leveraged at the network level to improve path computation and better utilize network resources.

A converged packet-optical network poses the challenge of vertical integration between the two layers (packet and optics) to best utilize network resources. This vertical integration and automation is useful in any operator process, including network planning, network configuration, network control/recovery, and network monitoring (with feedback to the network level).

Although research activity will be very intensive in the Consortium, it aspires to practical results, which will enable Consortium members to advance the generic technology towards application in commercial products. Demonstrating the generic technology, developed at both the channel and network level, as a general proof of the technology concept is a major and important step to showing that it is ‘real’ and can lead to commercial products. In Q1/2014, leading ECI customers received a demo of real-time implementation of 1Tbps OFDM transmission.

4.3.3 Addition or Dropping of Subchannel Capacity

Along a 1Tbps channel (up to 2000 km in length), it is reasonable to have intermediate network nodes that need to drop and/or add parts of the channel traffic, without affecting the rest of the traffic. It is true that such nodes can be equipped with a full 1Tbps transceiver, converting all the 1Tbps traffic from optical to electrical, performing the add/drop at the electrical level, and then converting the traffic back to optical
level. However, this method might be considered too expensive. Therefore, the Tera Santa Consortium is planning to enable a more efficient solution that will enable to adding/dropping of streams of 10Gbps net traffic (11.2Gbps gross traffic – OTU2) out of the 1Tbps stream. This will be done in conjunction with the optical and electrical levels. At the optical level, a very delicate and accurate filter will be used to cut (drop) a subchannel of 100Gbps out of the 1Tbps channel. The electrical level will process this subchannel to drop the received 10Gbps stream(s) and then add the transmitted 10Gbps streams instead of the dropped streams. Then, the filter will be used to add (overwrite) the new subchannel to the transit 1Tbps channel. An add/drop transceiver, based on an optical filter, a synchronization mechanism, and a 100G DSP power device, is also in the Tera Santa Consortium work plan.

The add/drop transceiver is primarily suited to Metro networks, where the traffic is aggregated out of many distributed nodes to create the 1Tbps channel. Expanding the use of 1Tbps channels to Metro networks is an attractive goal for the Consortium.

![Figure 34: Add/Drop Operation in OFDM Channel](image)

4.3.4 Channel Monitoring

A 1Tbps transceiver, based on digital processing technology, can provide continuous monitoring parameters, describing the channel condition and performance. This is one the advantageous side effects of the coherent technology. A 1Tbps channel might have many use cases. In some, it will cross 2000 km with many optical nodes—for example, ROADMs—along the way. The Consortium believes that it would be very useful to monitor the channel at these intermediate points to ascertain the channel conditions, impairments, and performance, without paying the cost of a 1Tbps transceiver. For that purpose, the Consortium is planning to design and demonstrate low-cost monitoring technology that enables monitoring of channel parameters at these intermediate points. In general, runtime distribution of the monitoring information between receiver and transmitter and between monitoring point and associated transmitter or receiver might enable dynamic DSP adaptation to improve performance.

4.3.5 Tera Santa 1Tbps transmission is field proven

1Tbps transmission was demonstrated successfully over ROADM Apollo network with live traffic. Further details described in the links below:

http://www.reuters.com/article/2014/04/16/eci-telecom-idUSnBw165010a+100+BSW20140416
4.4 Spectral Allocation

4.4.1 Fixed Grid Spectrum Allocation

Bandwidth demand in optical networks is dramatically growing and the forecast is that it will multiply itself 10x in several years. This speed poses technological and economic challenges for both vendors and operators. It is safe to assume that the expected life span of the 100 Gbps links that was introduced a couple of years ago, is limited. The optical networks industry is now examining other technologies that will answer the question: What's beyond the 100G links?

Lately, the optical networks community realized that due to the dramatic growth in demand for bandwidth, the expected life span of 100G links is limited, based on the understanding that the optical spectrum has become a scarce resource, and its optimal utilization is a mandatory consideration in any new standard. Adding more fibers for increased bandwidth in deployment and maintenance is very expensive, so the maximum use of spectrum on existing fibers has become a major challenge for the industry.

The ITU-T standards for DWDM channels that are currently widely used in optical networks define 50 GHz, or 100 GHz bandwidth for each channel, with the location of the channel centers also defined. This fixed bandwidth allocation per rate and condition can be inefficient and wasteful. With this legacy WDM approach, each link receives a 50/100 GHz constant spectrum bandwidth, regardless of the capacity (10G/40G/100G/200G) delivered over the link. In some cases, the 50/100 GHz spectrum is partially utilized, while in other cases-mainly for beyond 100 Gbps this spectrum is not sufficient.

As an answer to these problems many optical network companies are adopting a different approach that represents a move from the WDM fixed optical spectrum allocation to flexible (and optionally dynamic) spectrum allocation per rate and conditions. These new technologies include the Flexible grid (sometimes known in popular terms as Gridless) and the Super-Channel. ECI is developing new and future optical equipment that complies with the latest, most advanced Flexible grid technologies.

The ITU-T has defined a flexible grid in the most recent WDM wavelength grid specification, G.694.1. This standard defines wavelengths with 12.5 GHz granularity, with the ability to define an aggregate super channel spectral width of n x 12.5 GHz to accommodate any combination of optical carriers, modulations, and data rates.

We can assume that the next Ethernet data rates beyond 100 Gbps will be 400 Gbps and 1 Tbps. Flexible channel spacing will be required to accommodate these future bitrates that will occupy non-standard channel bandwidth and spacing. For example, a 400 Gbps channel will require about 75 GHz of spectrum.

The main enablers for a Flexible grid network include:
Flexible Spectrum WSS (Wavelength Selective Switches) - with the ability to define filters with varying bandwidths and center frequencies (not only on 50 GHz ITU Grid). This requires moving from current MEMs technology to advanced LCOS or DLP technologies.

Flexible OCM (Optical Channel Monitoring) - that can monitor the optical power within the non-standard ITU channels defined by the Flexible Spectrum WSS. These provide quick feedback to adjust the WSS filter equalization levels for maximum transmission.

Flexible Transceivers - that can be easily tuned to any required channel including non-ITU frequencies.

WSS are used in DWDM networks to enable remote control and automatic selection of wavelength routing. The WSS widely used in current networks are based on MEMS technology and are suitable for a fixed grid of 50 GHz or 100 GHz. Flexible grid operation requires installation of ECI’s Apollo flexible grid ROADMs, using LCOS and DLP technologies. Apollo’s coherent Layer 1 cards (TM400, TM100, CM100M, and FIO100M) have Flexible grid tuning capabilities. Networks based on these Flexible grid cards support variable channel bandwidth and spacing, providing a significant improvement in optical spectrum efficiency. Moving to Flexible grid configuration allows optical systems to dynamically select the best channel spacing, eliminating potentially wasted bandwidth. The following figure illustrates the spectrum efficiency of a Flexible grid network.

A Fixed-Grid spectral approach, allocates 50 GHz (or 100 GHz) slices of spectrum for all transmission rates regardless of bandwidth needs, this is a common practice of todays networks however considered as relatively Inefficient use of spectrum.

Figure 35: 50GHz Fixed-Grid vs. Flex-Grid: Single & Super-channel
5. Alien Lambda feels at home

As Alien Lambda behavior in DWDM network is one of the critical issues, which bothers IPoDWDM network designers. The following chapter provides a comprehensive Alien Lambda review.

While a colored interface in the routers seems to be cheaper at the first glance, there are many good reasons for a transponder as demarcation point:

- **Interoperability** - 100Gbps transceivers interoperability between different vendors is rare, using a dedicated optical transport network eliminates complicated interoperability between different IP platforms and different vendors. In addition,
  - 100Gbps signal Regeneration Optical-Electrical-Optical consumes high-end routers slots/space while it can be done with cost effective Optical transport system.
  - IP platforms are adjusted to high-end capacity and efficient port density using 100Gbps non-colored pluggable transceivers, such as CFP/ CFP2/ CFP 4 CPAK, CXP etc., while existing 100Gbps coherent LFF (large form factor) interfaces occupy valuable routers slots/space.
  - Having separated DWDM network (and keeping the DWDM transceivers at dedicated DWDM network), enables a better WSON restoring since WSON control plane can change the transceiver wavelength for finding restoration optical path.

- **Full differentiation** between Transport layer to Packet layer - usually simplifies services maintenances, fault management and alarm correlation while keeping the best of breed systems separated.

- When upgrading a network to future rates, as 400Gbps and 1Tbps, it will require a replacement of an interface in the IP platform (in case of inherent DWDM transceivers in the IP platform), when differentiating the DWDM network from IP network, the operator can keep using the existing IP platforms install base (namely 100Gbps interfaces and base cards) and connect them to 4x100Gbps/10x100Gbps combiners.

- **Best of breed** optical equipment from a supplier with optical core competence, in addition there is no routers vendor locks in.

ECI's Apollo system has superior support for alien wavelengths, including the following support:

- **Real time LIGHTPULSE (Optical Network Control Parameters) monitoring**
- **End to end optical trail management**
- **Viewing service route/s**
- **Variety of protection schemes**

Apollo system can support Alien transceivers simply by an Alien transceiver in the following manners:

1. Wavelengths detection at ROADM networks, using ROADM built in OCM (Optical Channel Monitoring).
2. Creating a “virtual Alien transceiver” at management system (embedded and EMS level) for enabling Alien Lambda LIGHTPULSE
3. Creating a “Virtual Alien card/module” at the NMS for presenting Un-Managed-Elements for presenting trails with non-ECI equipment.

5.1 Alien Lambda detection at ROADM networks
### Technical Concept

Each Apollo ROADM card has a built-in Optical Channel Monitoring (OCM) which detects all the wavelengths connected at the local node or wavelengths which received from other nodes. The OCM measures the power level per wavelength, Apollo system uses this information for generating alarms (like: low power per channel, high power per channel, missing carrier, etc.), sending indications to LIGHTPULSE algorithm (for equalization and Real Time Status).

#### 5.2 Creating a “virtual Alien transceiver”

The picture below is a snapshot of Alien Transceiver configuration window.

1. Input Signal Attributes (Alien Lambda Tx values)
   a. Dispersion
   b. PMD
   c. Spreading (If the signal can pass 50GHz filter or only 100GHz filter)
   d. Power
   e. Input OSNR
   f. Accumulated Nonlinearity
   g. PDL

2. Tolerance Attributes (Alien Lambda Rx – Thresholds values)
   a. Min Power Tolerance (aka sensitivity)
   b. Max Power Tolerance (aka overload)
   c. Min Dispersion Tolerance
   d. Max Dispersion Tolerance
   e. Min OSNR Tolerance
   f. Max PMD Tolerance
   g. Max ACC Nonlinearity
   h. Max PDL Tolerance

3. Misc attributes (parameters related both to Alien Lambda Tx and Rx)
   a. Spacing
   b. WDM Type (CWDM or DWDM)
   c. Rx Wavelength
   d. Tx Wavelength
   e. Multi Wavelength
5.3 Creating “virtual Alien Card/Module”

Un-Managed-Element is used to present non-ECI equipment under LightSoft in order to allowing Non-ECI equipment taking part in LightSoft trails, links and other functionalities. UME is available for creation in many rates; the user can choose the number of interfaces and select the required rate for each interface. The figures are example to one OTU4 interface UME and 100GbE UME.

Figure 36: Alien Transceiver configuration window

Figure 37: UME with OTUk interfaces
6. Protection and Restoration Mechanisms

6.1 Overview

Protection is of the utmost importance in the high-capacity traffic transmitted through WDM systems. Apollo’s high-level reliability is achieved through a comprehensive set of protection schemes implemented at different network levels. Protection schemes are provided per physical component as well as at Layer 0, Layer 1, and Layer 2/3 network levels.

Equipment redundancy is available for all units (common units, traffic units, I/O cards, fabrics, and network connections). Automatic protection switching is initiated by a robust internal built-in test (BIT) diagnostic system. Layer 0 protection includes optical line and WSS ROADM-based protection mechanisms.

Layer 1 protection mechanisms include various forms of line protection, SNC-N, DNI, and DRI protection schemes, protection based on the AoC card, and a complete range of OCH protection mechanisms.

Apollo also offers essential ASON GMPLS-based protection mechanisms.

Some of the Apollo protection mechanisms are introduced in this section.

6.2 Equipment Protection

Apollo provides the following protection schemes for common unit equipment:

- The fan units are protected 1:n.
- The power supply is protected 1+1.
- The main controller is protected 1:1.
6.3 OMSP 1:1 Protection

Apollo features a fiber protection scheme based on either signal power degradation or LOS, providing line protection for P2P optical links with minimal insertion loss (less than 3 dB). In the event of a fiber cut, the Optical Multiplexer Section Protection (OMSP) optical switch automatically switches traffic to the protection fiber. Protection can be configured to revert automatically to the main fiber upon repair. OMSP protection is generally used for fiber spanning in linear topologies. A pilot tone monitors the protection fiber.

This low-cost approach protects all DWDM channels simultaneously without hardware redundancy. The OMSP operates independently of data rates, protocols, or number of channels, and provides protection for future upgrades when additional DWDM channels are added to the network.

![Figure 39: OMSP protection](image)

6.4 OCH Protection

The OCH 1+1 protection scheme, based on LOS, provides separate protection for each channel.

In this mode only one line is used. Protective duplication is at the optical level and sent in two directions. The main advantage of OCH protection is that it requires only one transceiver instead of two.

The choice of which incoming signal to process is based on LOS and not on signal degradation. OCH protection is available for 10G, 40G, and 100G transponders.

![Figure 40: OCH 1+1 protection](image)
6.5 WSS ROADM Restoration

ROADM configurations facilitate implementation of advanced protection schemes such as N+1 Path dynamic restoration and protection, 1+1 Forever protection and restoration in under-50 msec, and optical Dual Node Interface/Dual Ring Interface (DNI/DRI). This unique all-optical protection can handle and overcome multiple fiber cuts - ideal for mesh-based networks and topologies.

Apollo provides preplanned fixed protection against multiple fiber cuts or an NE failure along the main and protection routes by using WSS switching capabilities with a single transponder/combiner card. Additional protection against transponder/combiner failure requires a combination of both OCH 1+1 and WSS restoration.

When configuring WSS ROADM restoration, the client transponder/combiner connects via optical splitter to a ROADM WSS array with up to nine routing possibilities in the WSS add/drop node. Protection route(s) can be active at all times, so reducing the total restoration time as switching to protection only requires an update of the relevant ROADM port in the drop site.

6.5.1 N+1 Protection

The following illustrates a typical example of N+1 optical protection based on the WSS ROADM. This configuration includes one main route and two protection routes, segments of which can be used for restoration. For each working primary route, up to 15 secondary routes can be configured. All the routes are set automatically through the management system. If the primary working route fails, the system switches automatically to the Secondary 1 route. If the Secondary 1 route also fails, the Secondary 2 route is automatically activated. Protection routes can be kept active and dedicated to shorten restoration time.

![Figure 41: WSS ROADM N+1 protection](image)

6.5.2 1+1 Forever Protection
Optical 1+1 Forever protection is similar to OCH 1+1 protection with the added advantage of providing protection for more than one fiber cut. Optical 1+1 Forever protection is an extension of the traditional OCH 1+1 protection, where failure in the main or protection path results in sub-50 msec switching by the transponders. After this switching the failed path(s) are restored, returning the network to full OCH 1+1 protection. This enables continuing OCH 1+1 protection against multiple fiber cuts.

6.6 Client Traffic Protection

Client traffic protection protects against failures which occur in the connection between the network equipment (Apollo) and the client's equipment. Client traffic protection uses dual connectivity between the Apollo NE and the client's equipment, including two client entry ports in two distinct Apollo cards, two fiber connections, and two ports at the client's equipment.

In client traffic protection, the service is sent to two client ports on the egress side of the Apollo NE. On the ingress side, one of the client's entry ports is chosen. Protection switching criteria are based on incoming signal quality and module (SFP/XFP) extraction.

Input selection criteria depend on the client type.

6.7 Combined Network Traffic and Equipment Protection
Technical Concept

Equipment protection protects against card/module failures. The purpose of equipment protection is to allow service continuation in the event of failure or extraction of the service source/sink card or module/transceiver. By nature, equipment protection involves two adjacent cards protecting each other.

Port protection is activated on a per-service basis, using an external splitter/coupler to connect two Apollo client-side ports (one on each Apollo card) to the client’s equipment. A pair of cards assigned to protect at least one service, as described above, is considered a protection card pair. Note that on the same protection card pair, some services may have port protection while other services may be unprotected or protected with other types of protection, such as client traffic protection.

If PM on the main card does not indicate a problem, a message is sent through the backplane to the protection card to shut down its laser to the client, thereby ensuring transmission to the client from only one transponder/combiner (the main). Switching to the protection transponder/combiner occurs automatically when a failure is detected by the main transponder/combiner. Protection, based on ODU-0/1/2/3, is provided in less than 50 msec, and can be either revertive or non-revertive.

Figure 44: Combined network traffic (SNC-N) and equipment protection

6.8 ASON GMPLS-based Restoration

Transmission network traffic is shifting towards Ethernet-based services. Traffic patterns and protection requirements are changing, moving from dedicated to shared protection schemes. The Apollo family supports this evolution from ring protection to efficient mesh protection schemes, enabling more efficient utilization of bandwidth resources.

The Apollo family provides ASON architecture, capable of offering intelligent service in existing and new Apollo transport networks. This is achieved through a GMPLS control plane that enhances Apollo networks by adding restoration to the sub-50 msec protection schemes and automated service provisioning. The ASON architecture boosts network capabilities, thereby further reducing CAPEX and OPEX.

6.8.1 Faster and Safer Future
Key components of the Apollo management and control suite include automatic topology discovery, resource dissemination, point-and-click connection provisioning, user-initiated automatic setup, E2E performance management, and path protection and restoration across an OTN network.

The distributed dynamic routing capability enables rapid cost-effective creation of new nodes and increase in bandwidth, without the extensive offline operations usually required.

Apollo’s ASON architecture, compliant with ITU-T G.8080, is composed of three main layers or planes:

- **Transport plane**: Represents the switching equipment. The transport plane carries the client payload over a trail that consists of the connection endpoints plus any number of intermediate NEs along the trail.

- **Control plane**: Represents the processing engines within each Apollo RCP. The control plane software interoperates with the transport plane via a connection control interface (CCI). Control plane processors transmit management information over a dedicated DCN (inbound or outbound), connected through internal network-to-network interfaces (I-NNIs).

- **Management plane**: Represents the interface with client equipment. The management plane is implemented over the UNI where the connections that can be configured over other domains (such as other carriers, other layers, or third party equipment) are expanded. A dedicated management-to-network interface (MNI) is used between the control plane and the NMS.
6.8.2 Multiple Protection and Restoration Schemes

The unique value proposition of ASON for carriers is the ability to improve existing network resiliency by introducing the well-known restoration approach of IP networks. Service re-establishment in case of failure has been a key feature of transmission networks, which offer service protection in less than 50 msec.

Adding ASON to transmission networks brings added benefits without affecting the already superior performance of today’s network. With ASON restoration, the network itself monitors services and restores them in the event of failure. (The ASON control plane is capable of restoring services in case of multiple network failures.) Furthermore, the existing network capacity is utilized more efficiently by sharing protection resources.

Apollo architecture provides differentiated CoS. Supporting a range of protection schemes allows network planners to balance the time needed for protection switching against the amount of resources that must be dedicated to protection. For mission-critical services, Apollo provides distributed restoration mechanisms with 50 msec service recovery and dedicated protection. For less critical services, distributed shared mesh restoration schemes can be implemented. For efficient use of installed resources, pre-emptible services can be established using the protecting resources.

The Apollo control plane supports coexistence of multiple protection and restoration schemes. Supported combinations of protection and restoration schemes include:

- **1+1 protection**: Based on SNC-N path protection, with the network allocating a protection trail for each working trail. The protection trail is activated automatically in case of failure, restoring service in less than 50 msec.

- **1++ ("1+1 Forever")**: Similar to path protection with SNC-N, where a failed path is restored by the control plane and prepared for the next possible failure. A sub-50 msec restoration time is maintained for any number of failures as long as a restoration path can be found for the failed connection. This is an extension of the traditional 1+1 path protection, where failure in the main or protection path is followed by restoration of the failed path. Restoration continues to be performed in less than 50 msec. Note that this protection scheme consumes the most bandwidth as traffic is duplicated at all times.

- **1+R (Mesh/Shared Restoration)**: Reroute restoration (1+R), with dynamic restoration that enables shared protection with prioritization. This protection scheme is an extension of unprotected trails, where failure in the path results in restoration of the trail in a new path. The unused bandwidth may be used for low priority traffic at all times.
  
  In a variation of 1+R, preplanned shared protection enhances shared protection with prioritization. Preplanned priority reacts faster than dynamic restoration as the processing time is completed in advance.

- **Unprotected**.
The Apollo family offers WSON control plane architecture, which is capable of offering intelligent services in mesh transport networks over colorless, directionless and contentionless configuration. This is achieved by adding a GMPLS control plane that enhances Apollo networks by adding restoration to the sub-50 msec protection schemes for multiple failure (For optical 1++ services) and automated service provisioning. It also adds other capabilities that contribute to increased CAPEX and reduced OPEX. The Apollo control plane architecture, protocols, and functionalities are described below.

6.9 WSON GMPLS-based Restoration

The WSON–Apollo family solution is based on the “Add-On” concept that adds unique capabilities to existing and new networks. The Apollo provides seamless integration of Network Elements (NEs) to dynamic end-to-end WSON-based applications.

6.9.1 WSON–Apollo Family Portfolio

The WSON-Apollo family solution is based on the “Add-On” concept that adds unique capabilities to existing and new networks. The Apollo provides seamless integration of Network Elements (NEs) to dynamic end-to-end WSON-based applications.

6.9.2 Apollo Optical Control Plane Architecture

Apollo implements WSON-compliant network architecture (ITU-T G.8080). A high-level view of the WSON architecture in Apollo is shown in Figure 3. It is mainly composed of three layers or planes:

- Transport Plane
- Control Plane
- Management Plane.
Figure 46: WSON add-on

The Transport Plane represents the switching equipment. This carries the client payload between endpoints of a connection (trail) over any number of NEs. The management plane provides provisioning and operation (FCAPS) functions of NEs in the Transport Plane.

The control plane in Apollo networks is composed of a set of processing machines within each and every Apollo NE. The control plane uses various standard protocols that eventually implement the different roles of the WSON architecture. The control plane software interoperates with the transport plane via a CCI (Connection Control Interface), and control plane processors are interconnected with an I-NNI interface over a dedicated DCN (in- or outbound).

The following paragraphs describe each plane in more detail.

6.9.2.1. Transport Plane

Apollo offers state-of-the-art built in DWDM layers based on state of art ROADM modules with colorless, directionless, contentionless configurations (AKA CDC).

- Directionless switching enables the ROADM to automatically select the direction of the add/drop lambda without having to physically visit the site and connect the fiber to the required port.

- Colorless switching enables remote wavelength retuning of add/drop wavelengths, again, without the need visit the site. With this architecture, an add/drop port can be assigned to any wavelength and coupled to any direction(s) in a fully flexible fashion. The colorless feature is implemented utilizing the TFA card, drop configured for direct colorless operation.

- Contentionless switching means that two or more services can be transmitted from the site in different directions using the same wavelength channel.
The WDM cards can be added in any of Apollo slots in the same cage with or without the ODU-XC fabric and service cards. 10G, 40G and 100G channels are supported with 100GHz spacing (44 channels) and 50GHz spacing (88 channels) network design. Both mix network and pure coherent network are available.

The Apollo Transport Plane supports Automatic Discovery and DCN which are critical for the implementation of WSON architecture. Both compliant with WSON standards, explained in the following paragraphs.

6.9.2.2. Control Plane

The control plane in the Apollo is integrated in Apollo main controller, RCP.

Each Apollo shelf may be equipped with 2 RCP cards for 1:1 protection, preventing single point of failure.

6.9.2.3. Management Plane

LightSoft:

All ECI transmission equipment, including Apollo, is managed by a single management system, LightSoft. The LightSoft NMS features a unique multidimensional approach to managing today’s converged networks. LightSoft handles one physical layer and several technological layers, including SDH/SONET, Ethernet, OTN, and optical.

LightSoft offers on-demand service provisioning, pinpoint bandwidth allocation, and dramatic reductions in equipment and operating costs that multiple management systems often require. It does this by providing complete network management from a single platform, including configuration, fault management, performance management, administrative procedures, maintenance operations, and security control.

LightSoft simplifies provisioning and day-to-day monitoring of optical services. Information on light paths, wavelengths, channel availability, rates, is available from optical links and optical trail lists.

LightSoft provides fully automated optical trail provisioning, eliminating
operator intervention at the EMS level. Automatic trail provisioning is also vital in networks based on ROADMs and ODU cross-connect ASON and WSON lambda and sublambda levels that allow creation of complex mesh and ring network topologies.

NMS and STMS/LCT co-working with the Light Plan (ECI planning tool) for full plug and play atomization.

Figure 48: Plug and play life cycle

LightPlan:

The ECI LightPlan is a unified planning tool for Optical network planning process (from Traffic optimization, Optical design to site manager) and innovated plug and play process for green and brown field:

LightPlan TM:

- **Main purpose**
  - Optimizes traffic based on: traffic matrix, network topology, RWA and other constraints
  - Enables planning for very complex networks
  - OTN Traffic Grooming
  - OTN ASON & WSON

Figure 49: LightPlan – TM layer

LightPlan OM:
Main purpose

- Optical channel simulation
- Calculates optical signal level between origin and destination given specific optical topology, equipment, etc.
- Takes into consideration attenuation, dispersion, signal-to-noise ratio, etc.

**Figure 50:** LightPlan – OM layer

LightPlan SM:

Main purpose

- Slot and port assignment (automatically from other layers (TM and OM or manually)
- Spare parts calculation
- Accessories calculation

**Figure 51:** LightPlan – SM layer
6.9.3.1. Signalling Communications Network (SCN)

In a WSON-based network with a distributed control plan where each NE has its own WSON card, signaling communication between NEs is a critical issue. Moreover, when a failure occurs, no restoration is performed. High reliability is therefore required to always maintain “live” management connection between the NEs. The SCN is a data communication channel that enables communication between the control cards (RCP). Operators may implement the DCN both in-band and out-of-band, as follows:

- GCC over OTN links
- Optical Supervisory channel (OSC)
- In band over Ethernet links (for data cards)
- External DCN

The SC channel can be also defined as a combination of the above options.

6.9.3.2. Auto-Discovery

Auto-discovery in Apollo supports resource management and link management. The auto-discovery design complies with ITU-T G.7714 and ITU-T G.7714.1 standards. Various levels of auto-discovery are supported: self-discovery, topology discovery, and link bundling. These are described below.

6.9.3.2.1. Apollo Self-discovery

The NE Self-discovery process is handled at the transport layer, i.e., by Apollo shelves. Upon NE commissioning, the network element automatically detects installed circuit packs, software configuration, and initializes the circuit packs to default settings. The NE continuously monitors the state and attributes of its local facilities. It learns the local facility characteristics and port attributes, and reports them to the RCP control plane card, which updates topology database.

6.9.3.2.2. Network Topology Discovery

The control plane itself uses OSPF for the discovery of the control plane and network architecture. Each controller learns the network topology and builds its topology database. The routing mechanisms use this information in automated route computation. The objective is that each control plane instance holds a complete and identical view of the network topology and resources.

6.9.3.2.3. Link Bundling

The Apollo control plane bundles ports/facilities with the same link attributes into a single link bundle. Link Bundling provides an efficient way to distribute link information for multiple links at the same time instead of one at a time. This approach provides a scalable architecture for large networks.

6.9.3.3. Routing

Routing is responsible for network topology and resource discovery, and for automatic route computation. It complies with ITU-T G.7715 and ITU-T G.7715.1 standards.

A distributed link state routing protocol, OSPF-TE, is used for automatic discovery of the network topology and resources, and for maintaining a local topology database on each control plane instance. In particular, each RCP is responsible for discovering its neighboring NEs and the set of links that connects them. It then
advises the identities of its adjacent neighbors and the cost/weight of each link. This information is advertised among control plane instances by periodic exchange of link state packets. Thus, each RCP is armed with a dynamic map of the network topology and resources. Using this information, the RCP is capable of computing routes to any destination.

Both implicit and explicit path determination are supported at call creation. Implicit call is a call for which only the source and destination points are specified for its connection(s), along with other service attributes (i.e., rate, granularity, CoS, etc.).

Explicit routing refers to the cases for which the route is specified by the LightSoft NMS system, which in turn passes route specifications to the control plane. With explicit routing, no calculation is required from the control plane. An explicit call may still benefit from the dynamic connection management capabilities of the control plane by using precalculated mesh restoration.

6.9.3.4. Signaling

Signaling provides the underlying mechanisms for dynamic call and connection management. The signaling mechanisms handle connection requests, such as connection creation or restoration. The signaling design complies with ITU-T G.7713.2 and GMPLS RSVP-TE standards.

Once a route is determined by the RCP of the source node, signaling is used to set the connection. Label request messages are sent from source node to the destination node. The receipt of notification messages from the destination node to the source node are used by each RCP along the way to set the local cross-connect that services the entire connection end-to-end.

Two connection types may be supported:

- Soft Permanent Connections (SPC): the optical connection is requested by LightSoft (on behalf of client devices).
- Switched Connections (SC): the optical connection is requested directly by the client at the edge of the network.

6.9.3.5. Management and Operation

Apollo’s NMS system, LightSoft, works in conjunction with EMS-STMS to deliver a full FCAPS suite. LightSoft’s role is to ensure consistency between the network resources and the carrier’s internal database, in addition to other features related to fault reporting, accounting, performance monitoring, and security.

LightSoft provides Corba north- and southbound interfaces, it implements the MTNM architecture.

6.9.4 Protection and Restoration

The unique value proposition of WSON for carriers is the ability to improve existing network resiliency by introducing shared restoration approach. With WSON, the network itself monitors services and restores them in the event of failure. This approach of service re-establishment in case of failure has been the basic feature of transmission networks, which offer service protection in less than 50 msec (1st failure for 1+1 and 1+1+R and for the 2nd failure for optical 1++ services). OTN technology defined various shared and dedicated protection schemes. Over the years, these protection schemes have proven to be highly reliable. They have managed to achieve multi-vendor interoperability, and have paved the way to OTN technology becoming the most reliable transmission technology available.

This high reliability approach is achieved by allocating networking assets for protection. Linear protection schemes, such as OCH1+1, use a dedicated standby line. Path protection, which is suitable for mesh topologies, uses 50% of the overall network bandwidth by duplicating all traffic at its origin.
Adding WSON to the networks brings added benefits without affecting the already superior performance. With WSON, the control plane is capable of restoring services in case of multiple failures in the network. Furthermore, network capacity can be more efficiently utilized by sharing protection resources.

Differentiated classes of service are supported by Apollo architecture. Any compromise in protection schemes allows network planners to choose between the protection switching time and dedicated resources. For mission-critical services, Apollo provides distributed restoration mechanisms with 50 msec service recovery and dedicated protection. For less critical services, distributed shared mesh restoration schemes can be implemented.

The Apollo control plane supports multiple protection and restoration schemes, as follows:

- **Unprotected (Optical 1+0)**: One Main path only. No protection, no restoration
  
  *Traffic will lost after the 1st failure*

- **Optical 1+R**: One Main path. Restoration path is established upon failure in the Main path. The 2nd restoration path is established upon failure in the existing restoration path, and so on.
  
  Trail recovers within several seconds for any failure as long as a route is found from head-end to tail end.

- **Optical 1+1 path protection**: One Main path, and one Protection path. No restoration. The Main and Protection paths start and end in separate OTN ports. The Main and Protection paths may use different wavelengths or the same wavelength.
  
  Trail recovers within less than 50ms for the 1st failure and traffic lost after the 2nd failure (on the protected path)

- **Optical 1+1+R**: One Main path, and one Protection path. With restoration. As in 1+1, the Main and Protection paths start and end in separate OTN ports. The Main and Protection paths may use different wavelengths or the same wavelength.
  
  - No restoration action is taken upon 1st failure of the Main or Protection paths.
  - Restoration path is established upon failure in both the Main and Protection paths.
  - Another restoration path is established upon additional failure in the active restoration path, and so on.
  
  Trail recovers within less than 50ms for the 1st failure, from the 2nd failure recovers within several seconds for any failure as long as a route is found from the head-end to tail end.

- **Optical 1++ ("1+1 forever")**: One Main path, and one Protection path. With restoration. As in 1+1, the Main and Protection paths start and end in separate OTN ports. The Main and Protection paths may use different wavelengths or the same wavelength.
  
  - Restoration path is established upon failure in either the Main or Protection paths.
  - Another restoration path is established upon additional failure in one of the active paths (the current paths on which there were no failed links), and so on.
  
  *Trail recovers always within less than 50ms as long as a route is found from the head-end to tail end.*

- **re-route restoration (dynamic restoration)**. Dynamic Restoration enables shared protection with prioritization. This protection scheme is an extension of unprotected trails where failure in the path results in restoration of the trail in a new path.

### 6.9.5 Path Computation
The protection and restoration capabilities of links and the Shared Risk Link Groups (SRLG) associated with links can also be advertised by the routing protocols. Based on the Physical layer, SRLG constrains the information and capabilities provided by the GMPLS routing and signaling protocols. The path computation algorithm CSPF (Constrained Shortest Path First) can select disjointed paths based on link, node, or SRLG diversity.

6.10  IP/DWDM interworking architectures

As IP has become the dominant layer in the communication networks, efficiently and effectively transporting IP traffic in a DWDM network is an important task. See below the description for IP over DWDM networking architectures.

- IP networks act as client layer where dynamic DWDM networks (CDC + control plane) behave as the physical transport network
- A DWDM network has its own network control plane and management system, which could be centralised or distributed.

There are two alternatives to interface between IP client and WDM server:

**User to network interface (UNI) (Model A)-**

Instead of relying on the NMS providing the interface, the IP control plane can directly talk to WDM control plane through optical UNI. The end-to-end DWDM service can be set up dynamically, which requires the WDM edge node to be capable of signaling and reserving bandwidth.

**WDM network management system (NMS) (Model B) -**

IP clients request services from the WDM NMS(Via 3rd management system COP ), which sits above the WDM transport and control layers. Hence, there is no direct interaction between IP control and DWDM control plane.

![Interworking models](image)

**Figure 52: Interworking models**

Under the above 2 models all WSON capabilities should be workable (Protection, restoration inside the DWDM network and between the IP client and the client in the DWDM NE, PCE ,CDC etc)

ECI plan to support the above 2 models
Model A

Will comply with http://datatracker.ietf.org/doc/draft-beeram-ccamp-gmpls-eni/?include_text=1 - response to description of information that would be exchanged between CP in the optical and IP domains

Model B

NMS + MTNM

7. Management system

7.1 LightSoft

LightSoft is ECI’s state-of-the-art field-proven, multi-dimensional, multi-technology and fully scalable NMS (network management system). It provides crystal-clear management control of the physical, data, and optical layers. LightSoft makes navigation between the physical and service layers transparent. You can easily perform all monitoring, maintenance and management operations via the GUI or standard CORBA interfaces. The layered architecture concept provides comprehensive control of all equipment in your network. Among its powerful set of features we may mention:

- Totally GUI-based management system
- Multilayer topology views
- Fast and flexible fault management
- End-to-end trail, tunnel and service definition
- Complete network scalability
- Simple operation and fast learning
- Multiple users and configuration operators
- Full end-to-end operations, administration, and management (OAM) of Ethernet links and MPLS tunnels
- Integration in TMN environments
- Convenient simple network management across different networks
- Comprehensive security
- Fail-safe database backup
- Comprehensive configuration, maintenance, and PM tools
- Sophisticated resource domain partitioning (RDP) and customer network management (CNM).
7.1.1 Architecture of ECI’s Network Manager – NMS Concept

The network management concept provides three main building blocks: LightSoft at the NML (network management layer), managing the EMSs (element management systems) and providing the single point of integration towards OSS via its northbound interface; the STMS at the EML (element management layer), integrated under LightSoft via a CORBA MTNM TMF-814 interface and directly managing the Apollo OPT96xx product lines.

7.1.2 Multilayer Management

ECI Telecoms’ management concept is designed with a layered architecture in accordance with ITU-T recommendation M.3010. Separate management layers make up this management structure. The lowest, the Network Element Layer (NEL), constitutes the embedded agent software of the network elements. The second layer, the Element Management Layer (EML) controls many individual network elements, while the third layer, Network Management Layer (NML), controls all the main network management functions.
7.1.3 Managed Elements vs. Functional Nodes

Lightsoft™ offers operators a clear distinction between the network elements (or managed elements that make up the network, and the logical or functional nodes (FNs) that these managed elements (MEs) represent. While an ME represents a piece of equipment (typically a shelf), an FN represents a functional element of the network, such as its ports. This unique distinction offered by the Lightsoft™ enables true multidimensional network management by allowing operators to focus on the managed elements when creating and deleting NEs, and to focus separately on the different technology oriented ports available (for example Optical, Data or SDH/SONET) when managing trails an services.

Whenever an ME is added to the network at the physical layer of Lightsoft™, an FN is projected automatically into the relevant technology layer, depending on the ports contained in the shelf of the ME. If the ME contains ports that belong to multiple technologies (as is the case with Apollo shelves), FNs are created at each technology layer containing only those ports relevant to that layer.
7.1.4 Client/Server Architecture

The Lightsoft™ implements advanced client/server software architecture to support a large number of processes. Lightsoft™ server can run on a single or multiple Sun workstation/s and multiple Lightsoft™ clients may be installed and operated. Each Lightsoft™ client has the ability to configure and manage the network. This distributed architecture allows you to divide large, complex networks among multiple operators. Each of these operators has the tools and ability to open Lightsoft™ sessions and manage parts or the entire network simultaneously.

7.1.5 System Redundancy

Lightsoft™ uses a protection scheme called RDR Remote Database Replication) to provide full network management backup capabilities. RDR employs duplicate management hardware, with one station serving as the active site (primary server) and the other station serving as the standby site (backup server and mirror). One standby site can act as a backup for multiple stations (1:n) running Lightsoft™ and various EMSs.

All of the active site's databases (both NMS and EMS) are periodically duplicated and transmitted over a direct link to the standby site. The user can configure the frequency of the database replication. In addition, the Database Signature feature intelligently updates the standby site with all NE configuration data that has changed since the last replication.

In the event of a failure in the active site, the RDR enables the operator to quickly switch over to the password-protected standby site and resume management of the network within minutes. When the
primary server is restored, the operator can initiate a replication back from the standby site in order to preserve any configuration changes that were made while the primary server was down.

A client workstation can be connected over the same LAN to both the active and standby sites, so that when switching from one site to the other, the client operator can always initiate a client session on the station presently managing the network.

7.1.6 DWDM Trails

OTN technology offers a range of rates up to 100 Gbps. In ECI equipment, OTN interfaces are supported through the following types of ports:

- **Optical Transmission Section (OTS)** ports for equipment with more than one wavelength supporting OMS and OCH interfaces. Used, for example, in amplifiers or DCF cards, or in OADM or Mux/DeMux cards for channelization purposes.

- **Optical Channel ports (OCHP)**, for single-wavelength OCH interfaces.

- **Optical Transport Unit (OTU)** ports, for port rates ranging from OTU1 to OTU4, for comparable ODUk interfaces ranging from ODU1 to ODU4. Also supported are the overclocked ODU2e, ODU2f, and ODU3e rates. OTUs are used, for example, in OTU2 ports in TR10_4 cards, or for ODU interfaces multiplexed to an OTUk port in an AoC10 or FiO10_5 card. Also used for ECI’s proprietary ODU0s interface for ports with interface rates under 2.5G, and in OTU2x for interoperability with the XDM AoC.

In a typical optical network, components are configured into a hierarchy of OMS, OCH, ODU, and LP trails, as illustrated in the following figure.

![Figure 56: Hierarchy of optical trails](image)

LightSoft supports Optical Multiplex Section (OMS) trails, optical trails between multiplexing devices (MDs). They can be uni- or bidirectional. They behave as server trails that carry multiple OCH trails in fixed groups - typically DWDM - 16, 32, 40, 44, 80, or 88 channels, and CWDM - 4 or 8 channels. Amplifiers may be included in the path of an OMS trail. Multiple OMSs, connected in tandem, cause alarms to be reported only with respect to the directly associated OMS trail segments and not at other segments along the path.

LightSoft simplifies provisioning and day-to-day monitoring of optical services. Information on light paths, wavelengths, channel availability, rates, is available from optical links and optical trail lists.

LightSoft provides fully automated optical trail provisioning, eliminating operator intervention at the EMS level. Automatic trail provisioning is also vital in networks based on ROADM and ODU cross-connect that allow creation of complex mesh and ring network topologies at the lambda and sublambda levels.

The following features are especially valuable:

- **UME – Un Managed Element for each mapping level (including OCH)** provide a clear and easy way to create OCH optical trail for Alien Lambda Transceiver.
### Technical Concept

- Point-and-click functionality for optical trail creation and activation of optical services for all types of trails, including OMS, OCH, ODU, LightPath (LP), EoS over optics, protected and unprotected, P2P, and P2MP (drop-and-continue).

- Top-down trails provisioning beginning at the NMS level with LightSoft (creating trails) and automatically continuing down to the EMS (implementing details).

- Rapid trail creation, with a choice of either:
  - Fully automatic pathfinding, where you specify the endpoints and LightSoft chooses the optimal path for both main and protection segments.
  - Fully manual, where you specify the exact trail path and LightSoft completes the trail provisioning tasks.
  - Combination, where you specify the trail endpoints and specific segments of the path and LightSoft automatically completes the rest of the path route and provisioning.

- GCT split single-card LEs on technology layers (such as the optical layer) directly opening the internal card view.

- Utilization tables showing the state of the channels through a DWDM or CWDM OMS trail, helping you decide which channel to utilize.

- Availability maps and tables and sophisticated maintenance tools enhance trail provisioning and management.

- Optical network control parameters (LIGHTPULSEs) are utilized by APOLLO platforms to enable proper gain setting and power equalization along the entire network. LIGHTPULSEs are a set of optical parameters generated independently at a terminal or ROADM node, and are transmitted periodically through the entire network, from one optical card to the next and from one node to the next, following the actual optical transmission direction.

- OSNR Weight, estimated OSNR value assigned per OMS trail, calculated internally by LightSoft, based on the physical signal parameters. Higher OSNR values correlate with better signal quality. Assigning a greater priority to OSNR Weight values means that PathFinder gives these values greater importance when provisioning an OCH trail. OSNR levels can be displayed in LightSoft on demand for any existing Apollo trail or link.

You can automatically acquire all OMS, ODU, OCH, LP, and EoS trails in a single optical trail discovery operation. This is especially useful when the system is first installed. Optical trails can also be provisioned by the OSS via NBI.

### 7.1.7 Optical Trail Provisioning and Management

Different optical components may require specific network management capabilities. LightSoft provides all the tools necessary for effective network design, configuration, and management of all components. For example:

- LightSoft utilizes specific payload objects (SPOs) when supporting trails using the multiprotocol AoC or OMCM cards. LightSoft also supports P2MP LightPaths for AoC and OMCM25 cards.

- If a lambda (line port) is connected to a multiplexer or ROADM, LightSoft provides enhanced validation, preventing mistakes during link creation.

- LightSoft displays the reason why an optical trail is classified as a Flex trail, allowing you to detect and correct it. Flex trails are non-classified trails with non-standard trail patterns.
Route selection for optical trails can be fully automatic using LightSoft’s Pathfinder algorithm, fully manual using LightSoft’s GUI, or partially automated. Pathfinder selects the optimal main path based on the minimum hops criterion. You can apply route constraints, such as segments that must be included. This algorithm takes into consideration lambda switching within the topology.

For maximum protective value, Pathfinder selects protection path routes that offer the maximum diversity from the main traffic paths, as illustrated in the following example.

LightSoft verifies the correctness of the endpoints and user-selected trails. Parameters such as Forward Error Correction (FEC) and line code are checked, significantly reducing the chance of configuration errors.

Once a path is selected, optical XCs are automatically provisioned on the NEs along the trail. LightSoft provides a table with a list of available frequencies across multiple OMS trails, making it simple to select the frequency used at trail endpoints.

Creating and editing optical trails in single and bulk operations is possible using the XML file import feature.
Technical Concept

To enable proper gain setting and power equalization along the entire network, Apollo utilizes optical network control parameters (LIGHTPULSES), a set of optical parameters transmitted periodically. They are generated independently at a terminal or ROADM node, and are transmitted through the entire network.

LIGHTPULSE enables LS operator to check the OSNR level of an optical trail during its creation and select a different path if so indicated.

7.1.8 LightPath Trail Availability Maps

LightSoft includes enhanced availability maps for OCH via LightPath. These maps show resource availability, ensuring that link capacity suits the required services.

First check the area in which you wish to create a new trail to verify that the links have enough capacity. The following figure shows a simple availability map for a network fragment after a traffic segment was added.

![Availability map after additional trails added](image)

Network availability information can be exported to external applications in CSV format using a command line.

7.1.9 LightSoft Northbound Interfaces

Smooth integration of ECI’s Management Systems into Operations Support Systems (OSS), using rich standard northbound interfaces is a key advantage of our proposed solution.

OSS integration is typically performed using the LightSoft northbound interface as a single interface for the entire ECI sub-network, including all network technologies (OTN, MPLS, Ethernet and TDM).

Existing LightSoft northbound interfaces include:
**Technical Concept**

- MTNM TMF-814 compliant CORBA Northbound Interface supporting fault management, inventory, topology, performance, security, provisioning. MTNM TMF-814 is LightSoft’s native northbound interface.

- MTNM TMF-854 compliant MTOSI V1.0 Web Services XML/SOAP supporting fault management, inventory, topology, security, provisioning. The MTOSI northbound interface is provided by ECI’s MTOSI Gateway software which acts as an adaptor, translating LightSoft’s native MTNM TMF-814 CORBA interface to MTOSI and vice versa.

- SNMP V3.5 interface for fault management. The SNMP northbound interface is provided by ECI’s SNMP Gateway software which acts as an adaptor, translating LightSoft’s native MTNM TMF-814 CORBA interface to SNMP.

- Read-only SQL Interface to LightSoft DB

- ASCII file interfaces for alarms

- ASCII file interfaces for Performance Monitoring (from the EMS level)

- XML files interfaces for Trails, Tunnels and Services (import and export)

ECI is a member of the TM Forum and plays an active role in defining the MTNM and MTOSI standards, enabling us to fully align our interfaces with any developments in the standards. We have a proven track record of dozens of successful integrations with various OSS systems, both commercial off-the-shelf products and proprietary systems developed by ECI’s customers.

### 7.2 STMS

The ShadeTree Management System (STMS) is the enhanced EMS for the Apollo product line (OPT96xx, SR96xx and SR97xx). Some of its salient advantages include:

- Alarms and events collected and presented in real time, with a history database maintained for future reference

- A rich set of provisioning, monitoring and management capabilities at the NE level

![Figure 60: STMS GUI view](image-url)
7.3 Apollo LightPulse

7.3.1 Introduction

Network architects and network operators know what an ideal optical network should include. Modern dynamic mesh optical networks require Real Time Optical Calibration based on changes in the network; optical amplifiers should automatically set their gain to the desired value, and ROADMs should automatically equalize the power of all channels passing through.

In addition network operators know that a healthy network is crucial in order to meet highest SLAs. Healthy network means, 24/7 optical impairments analysis.

There are few key parameters that an operator shall gather in order to have a real optical analysis: OSNR, received and transmit power (both composite and per channel), chromatic dispersion (less relevant for Coherent networks), Non-Linear level/penalty, etc.

7.3.2 OSNR and Non-Linear challenge

Optical Signal to Noise Ratio (OSNR) is the most important parameter for analyzing a Digital Line Section (DLS) – an end to end wavelength route.

OSNR measure is a known challenge for Coherent channels and ROADM networks. In a glance, the following are the main (but not the only) challenges:

- ROADMs cause noise shaping ➔ Equipment Measurement System (OSA or OSA card) leads to under-estimation of the noise level.
- Coherent signals are closely spaced and overlap ➔ Equipment Measurement System (OSA card) leads to over-estimation of the noise level.

In addition, Non-Linear phenomena’s are not measurable – so what is the right way to evaluate it?

7.3.3 LightPulse building blocks

LightPulse is a software algorithm which runs in each one of the Apollo network elements (NEs) controller (RCP). The LightPulse is signaling and communicating the optical values between all the active optical components (like Optical Transceivers, ROADMs, and Amplifiers).

LightPulse make sure the optical network is balanced and healthy, it set the optical gain of each amplifier; equalize the optical channels running through each ROADM, raise alarms in case of fiber span loss changes (when |Site_A_Tx – Site_B_Rx| cross a configurable threshold (e.g. 0.5dB), raise
alarms in case the OSNR drops and cross threshold or when a Non-linear status at a specific DLS becomes a worry, etc.

But how it’s done? How do we get OSNR levels and Non-Linear and many other optical parameters?

Plug & Play

After the optical network design stage, one of the outputs of the LightPlan planning tool (ECI’s optical networks design tool) is “Fiber connectivity” XML file.

The XML file is imported through the management system via Element Managements System (EMS) and/or Local Craft (LCT) to each NE. This is a plug & play process which configure the NE name, NE IP address, Cards/Modules/Plugables assignments and set fiber connectivity’s configuration.

Fiber Connectivity

In reality each optical object (e.g. optical transmitter, optical receiver, optical amplifier, Mux, Demux, OAADM, ROADM, DCF, etc.) is connected to another optical object with an optical fiber patch cord, then two sites are connected with a pair of fibers between the sites (usually a booster amplifier at Site_A and pre-amplifier at Site_B.

- Internal Fiber connectivity – is a software configuration describing an optical patch chord connection between two optical objects in the same NW. optical patch chord insertion loss is by default 0dB, the user can configure an attenuators value (in dB) attached into an optical port/object, as sometimes external attenuators are required.
Technical Concept

- External Fiber connectivity – is a software configuration describing optical fiber pair connectivity between two sites or between two NEs. Fiber connectivity between sites also considering three pre-requisites parameters (configured manually or imported from the XML file):
  - Fiber Type (e.g. G.652, G.655, etc.)
  - Fiber Distance (e.g. 100Km)
  - Fiber Attenuation (e.g. 25dB)

Both External and Internal Fiber connectivity can be configured manually via CLI/LCT/EMS or can be imported from XML file generated from LightPlan planning tool via LCT/EMS.

Inter-node Connectivity and Network Topology

As result of Intra-node fiber connectivity is created per each site and network topology connectivity between the sites, is created. These connectivity’s and topologies are loaded into Light Soft Network Management System. Then optical trails (OMS, OCH and Lightpaths) are easily created.

Optical measures

Each active optical object has measuring point, measuring composite (or per channel) power via photo-diodes (or OCM) in real time. Meaning, each Transceiver has Tx and Rx measures, each amplifier has Input and Output composite signals measures, each ROADM has Line In/Line Out composite signals measures and Optical Channel Monitoring (OCM) which measure power per channel (power level of each wavelength).

In addition – each transceiver indicate the ITU-T wavelength it’s transmitting.

7.3.4 Alien Lambda

LightPulse can consider also Alien Lambdas just as an Apollo Lambda.

The network operator can configure* a “virtual transceiver” for each Alien Lambda with the following signal attributes and tolerance values according the Alien Lambda transceivers performance. For example: Tx power; Rx power; Dispersion; PMD; etc,

*Subject to “Alien Lambda” License (per port).
7.3.5 LightPulse benefits

Real Time (and automatic) Optical Calibration

LightPulse algorithm is using the above info and communication between the Network Element in order to calibrate the optical network: Amplifiers gain, ROADM channels equalization, etc.
**Technical Concept**

The network operator gets real time information in regards to each optical port like: Total power, power per channel, number of channels running through this port, wavelengths running through the port, accumulated dispersion, OSNR, PMD, Distance and Non-Liner indication (accumulated power).

In addition, the network operator can retrieve the above info per Lightsoft (NMS) optical trail (OMS or OCH); the network operator can view the optical objects among each optical trail and get the Real Time optical impairments performance monitoring.

### Real Time Port Status

![Real Time Port Status Diagram]

<table>
<thead>
<tr>
<th>Output Port Status Table</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total power</strong></td>
</tr>
<tr>
<td><strong>power per channel (average)</strong></td>
</tr>
<tr>
<td><strong>Number of channels</strong></td>
</tr>
<tr>
<td><strong>Transmitted Channels</strong></td>
</tr>
<tr>
<td><strong>Channel type</strong></td>
</tr>
<tr>
<td><strong>Accumulated dispersion</strong></td>
</tr>
<tr>
<td><strong>OSNR</strong></td>
</tr>
<tr>
<td><strong>PMD</strong></td>
</tr>
<tr>
<td><strong>Travelled Distance</strong></td>
</tr>
<tr>
<td><strong>NL</strong></td>
</tr>
</tbody>
</table>

**Figure 64: LightPulse - Real Time Port Status**

**Auto Diagnostic**

**Intra-node loss**

An alarm would be generated in case of internal patch cord failure when \(|P_{out} - P_{in}| > [X]dB\); \(X\) is a configured value.

**Inter-node loss**

An alarm would be generated in case of fiber pair between two sites has a failure/degradation when \(|P_{out} - P_{in}| > Y[dB]\); \(Y\) is a configured value.

**Performance analysis**

An alarm would be generated in case of optical receiver crossed a threshold tolerance of the specific receiver; for example: actual OSNR < OSNR threshold; Actual Rx power < Rx power threshold; Non-Linear > Non-Linear threshold.
Enhanced WSON restoration

The WSON control plane considers the optical values of alternative restoration paths. WSON networks use LightPulse data to calculate an optically validated restoration path, OSNR values at the endpoints are crucial to ensure that restored services will actually be able to maintain the highest SLA.

Enhanced optical path finder

LightSoft Pathfinder Enables End-to-End Route Selection for Optical Trail

LightSoft Pathfinder finds a trail candidate using ‘traditional’ criteria (e.g. distance, cost, etc.) or “OSNR weight” criterion

LightSoft Pathfinder also calculates protected path trail “OSNR weight”

Then, the network operator decides whether to accept the trail, or recalculate it.

7.3.6 OSNR Accuracy

LightPulse is the answer for the OSNR measurement challenge! The OSNR indications are accurate and have no influence from ROADM noise shaping and 100G/200G signal shapes.
LightPulse accuracy vs. measured OSNR values are reasonable, with $< 1\text{dB}$ deviation. Taking into account that OSA has its own deviation, LightPulse is gives an accurate indication.

![Figure 66: LightPulse – OSNR accuracy](image)

### 7.3.7 Summary

With Apollo, 'should' becomes 'does'. Apollo provides enhanced APC together with OSNR, power, dispersion, and even non-linear indicators in real time!

LightPulse overcome the OSNR measurement challenge, LightPulse enable prompt and accurate OSNR measured from remote via LightSoft NMS, Saving Optical Spectrum Analyzers CAPEX and Field engineers plus site traveling OPEX.

LightPulse indicate the Non-Linear status in each DLS/optical route.

LightPulse help to keep healthy optical network with highest SLA and lowest costs.

### 8. LightApps

LightApps encompasses the following capabilities:

- A set of initial turnkey SDN applications, including:
  - LIGHTCONNECT for bandwidth-on-demand
  - LIGHITIME for scheduled services
  - LIGHTACTION for event-driven network automation
  - LIGHTINSIGHT for network analytics
- Future applications, including:
  - LIGHTSAVER (Power Optimization)
8.1 LIGHTCONNECT

LightConnect bandwidth-on-demand provides simple, fast, and ad-hoc allocation of transport connections, as needed. It leverages network elasticity to allow customers to use network resources for burst applications rather than rely on over-provisioning.

Using a pre-defined template to hide complexity, a user specifies Point A, Point B, Bandwidth C, Time D, and Profile E (e.g. desired QoS). The application makes use of LightSoft’s “Path Finder” capabilities to create paths for both point-to-point and mesh topologies, and to eliminate them when no longer needed. The created paths are provisioned automatically across all relevant layers (OTN, Packet, and WDM) to achieve the most optimized configuration.

LightApps enables further customization of the LightConnect application through REST APIs. The figure above illustrates an example of Bandwidth on Demand (BWoD). A content consumer has a full-time connection to Data Center 2 via the purple path. This consumer requires a data backup at Data Center 1, and requests a short-term link between the two data centers. The BWoD application establishes a temporary connection between DC1 and DC2, represented by the orange path, and temporarily re-routes a portion of the primary path as shown with the thick dotted red path. After the backup is complete, the paths are restored to their original state so that only the purple path remains.
8.2 LIGHTTIME

Many services are required only at certain times and for predictable durations. For example, during daylight hours, business users generate most of the network traffic, while there is far less in residential areas. In the evening, this pattern is reversed. LightTime provides time-based solutions to schedule network services in advance. The benefits are better network utilization, congestion avoidance, and potential incremental service revenues due to higher traffic throughput.

Using pre-defined templates to hide complexity, users schedule services based on time of day, duration, and frequency, and the resources required. The figure below shows an example of bandwidth allocation serving business and residential areas, based on time-of-day.

LightTime can also supplement the BWoD application. For instance, using the example shown, connectivity between the two data centers can be scheduled to occur every night at 2:00 AM for one hour.

![LightTime Diagram](image)

**Figure 68: LightTime**

8.3 LIGHTACTION

Network automation provides network reconfiguration where the trigger is a network-based event, rather than an external request. The purpose of the application is to give the user flexibility to create any event-driven set of actions. The user creates rules/macros, based on events, that translate into changes in the network.

The basic sequence is Event → Policy → Action, which translates into a predefined network reconfiguration. Sequences can be chained or even made conditional, to handle complex situations. Similar to the other applications, LightAction uses predefined templates to hide complexity, as shown below.
8.4 LIGHTINSIGHT

The LightInsight application provides consolidated and analytical views of network use and performance. It advises how to make most efficient use of the network, to better plan for growth and how to evolve the network to deal with traffic surges and possible failures.

Operationally, it gathers information from network management systems and the OpenNet layer, and consolidates this in a data warehouse, which becomes the basis for recognizing network patterns and making network predictions. The LightInsight application then provides web clients for five content areas that reach into and organize this data, each with a dashboard and list of reports, as follows:

- **Network Inventory**
  - Summarizes inventory and recent changes (additions and removals)
  - Highlights trends of growth, decline, and change to guide capital investments
  - Shows availability and occupation of card, ports, and bandwidth
- **Network Health**
  - Summarizes alarm and failure views, as per the inventory
  - Provides proactive detection of potential failures to avoid service interruptions
- **Network SLA**
  - Monitors performance and bandwidth utilization against SLAs
  - Guides how to add or change network resources to meet current and future SLA guarantees
  - Create predictions of actual traffic use per time period, geography, and service types, that can be used for data/optics multilayer optimization
- **Security**
  - Summarizes security reports for user management and alerts for abnormal cases
  - Provides proactive detection of security weaknesses and intrusion threats

Below is an example of a LightInsight dashboard, showing network inventory per technology type.
ECI's SDN solution is based on the SmartLight framework. This integrates the robust Apollo and NPT packet-optical transport systems with the LightSoft NMS, creating an OpenNet network virtualization layer. Riding on OpenNet, SmartLight already provides four valuable turnkey SDN applications called 'LightApps', which expose OpenNet via northbound interfaces (such as REST) for further customization of these applications and creation of new ones.

SmartLight's SDN solutions are open, simple, automatic and secure, as summarized in the table below, providing customers with SDN automation without losing network control.

<table>
<thead>
<tr>
<th>OPEN</th>
<th>SIMPLE</th>
<th>AUTOMATIC</th>
</tr>
</thead>
</table>
| • Open northbound interfaces (REST-based) for OSS & Network applications | • Point-and-click end-to-end service creation via:  
  ▪ LightSoft - Mature large scale network management  
  ▪ LightApps - SDN based Network applications  
  ▪ Smooth migration to NFV and SDN Network | Network programming w/o losing network control:  
  ▪ BWoD - Dynamics BW for Apps and customer demand  
  ▪ Scheduled services with guaranteed SLAs  
  ▪ Event-triggered automation  
  ▪ Automatic power optimization  
  ▪ Automatic congestion control  
  ▪ Centralized data and optical restoration |
| • OpenFlow control over elastic NEs | | |
| • Real multi-vendor management | | |
9. LightControl – SDN controller

9.1 Introduction

Modern communication networks consist of a logical topology overlaid on an optical physical infrastructure. Distinguishing between the logical and physical networks is crucial to flexibility and efficiency. However, this distinction gives rise to important cross-layer optimization issues, such as how to improve end-to-end network efficiency, reduce network costs, and guarantee smooth restoration following a failure in the physical network.

In a typical scenario, the logical topology created in the IP/data layer operates on top of the physical optical infrastructure. Each layer operates independently with minimum or no interaction between the layers. For example, path computation software for each network layer has access to a topology map only of its layer, resulting in multiple restricted views of the network. Technologies such as GMPLS have been proposed for a number of years to achieve multi-layer convergence, but have never been widely deployed across layers in operational networks.

The problem of coordination between layers does not disappear even when those layers are integrated inside the same device. Usually such a multi-layer device inherits for each layer the traditional behavior and control plane attributes. Thus, for example, an event in the data plane, such as signaling and congestion, will create a response in this layer alone.

ECI's carrier-class Multi-layer SDN Controller, LightControl, is designed to address the problem of coordination between layers using a centralized, programmable, control plane that both replaces and complements a distributed network equipment-based control plane. This new architecture enables unprecedented real-time control of network resources for greater levels of efficiency, responsiveness, advanced applications, and survivability. LightControl is also designed to support SDN based eco-systems through standard interfaces including abstraction and virtualization.
9.2 LightControl description

LightControl is Carrier-grade controller for wide area networks.

The following is a high level description of the product features:

- **Centralized integrated multi-layer control plane for packet-optical networking and optimization**
  - Consolidates the functionality of WSON, ASON, IGP... control protocols for unified provisioning, service restoration and network optimization

- **Real-time and programmable control logic**
  
  Programmability is a key feature of LightControl. It opens the control plane to fast time to market new services introduction, innovation and enables the customization of the network according to specific setup or scenario. E.g. Based on one or more external information resources such as Analytics, Forecast, Orchestration directives the routing in a network is automatically adapted to optimize resource utilization. Another example is Offline tools that can calculate failure recovery order that is than fed into LightControl logic and influence its behavior. In case of network failure, restoration and recovery will be performed as planned offline.

- **Transparent Interoperability with non-SDN domains over standard protocols processing information such as: topology, routing information and signaling.**

- **Standard interfaces**
  - Southbound interface towards NEs over OpenFlow protocol.
  - Northbound interface, including virtualization and abstraction, towards Applications and Eco-system orchestrations such as Data centers, Hybrid cloud and NFVi
  - East, West interfaces towards peer controllers

- **Carrier grade and scalable solution**

SDN Control Plane for multi-layer network elements, such as implemented in LightControl, provides a framework for integration of topology, resource and policy information across layers. Such integration is the basis for common control for all layers that simultaneously offer services and benefits never achieved before such as:

- Ability to share optical resources dynamically between services based on indications such as congestion and load level in the data layer
- Ability to allocate optical capacity based on data layer signaling
- Automated turn-up of new express links at lower layers to alleviate congestion at higher layers
- Ability to offer a tiered traffic restoration model based on technologies such as MPLS protection in data layer and optical restoration at the optical layers
- Periodic multi-layer re-optimization of service paths
- 1: N protection of interfaces

9.3 Benefits of LightControl
Technical Concept

Traditional system
In a distributed control environment each layer has its own independent control plane which is generally not coordinated with the control of the other layers. This leads to the following drawbacks:

- Long provisioning cycle
- Inefficient use of resources
- Higher service deployments costs
- Lack of on-demand, application-driven connectivity – especially in the optical layer
- Giving-up the optical dynamicity that can be used to increase service velocity, and reduce both CAPEX and OPEX

Breaking through the layering walls – the Benefits
LightControl with its multi-layer processing and support of standard interfaces is breaking through the layering borders solving the above drawbacks:

- Better time to market and application-driven connectivity is achieved through support of standard interfaces for service creation via signaling or APIs. Process Automation reduces OPEX and ensures error-free (human) operation.
- Holistic multi-layer provisioning, restoration and optimization view ensure much efficient use of resources while improving CAPEX utilization. E.g. integrated restoration approach allows less spares at each layer.
- The ability to share optical resources dynamically between services based on indications such as congestion, load level in the data layer or signaling allow the optical network operator to offer new services and accommodate demands based on actual use rather than peak utilization.
- Centralized control plane ensures faster stabilization after failures as there is no need for hold-off timers to regulate the recovery process in each layer and there is no Cranckback process.

The above benefits are summarized in the figure below:

![Figure 71: LightControl summary of OPEX & CAPEX benefits](image-url)
ECI's Cyber Security Card/Appliance is a new Network Function Virtualization (NFV) platform designed to operate over ECI based portfolio, or as a standalone solution for third party equipment based networks, respectively. The Distributed (D-NFV) approach replaces traditional purpose-built equipment with a generic, yet robust "generic box".

This enables the equipment from ECI products line to be furnished with generic x86 based engines, to be remotely configured and to run a variety of applications. ECI's holistic 'Hexagon' model provides the most suitable security means, a central point of real time views, and control for a total unified IT/operational networks cyber security solution.

Figure 72: ECI's Holistic Cyber Security 'Hexagon' model

10.1 Firewall

The firewall controls incoming and outgoing network traffic, based on an applied set of rules. Simultaneously, it creates a barrier between a trusted secure network and a non-trusted network. This provides a multilayer protection firewall suite, including five security gates, between the public and private networks. Each security gate supports intelligent security technologies suited to a specific layer including MacSec capabilities, IPSec, NAT, header analysis, user identification, data validation, state full session management, IP/Port/User based ACL, integrated application and URL awareness. This offering is part of our latest announcement with cooperation with Checkpoint. The solution is based on Checkpoint Next Generation Threat Prevention solution with the multi-layered security protections.

10.2 Encryption

Delivers data confidentiality and integrity for sensitive data in motion in shared environments, preventing one tenant from monitoring the network traffic or attacking the virtual servers of another tenant. Furthermore, it allows the data owner or a trusted third party to control the encryption keys without having to share the encryption keys to the infrastructure provider.

ECI has encryption solution at each of the following levels:

- Layer-1 – AES256 encryption for OTN frames.
- Layer-2 – AES256 encryption for layer-2 Ethernet frames.
- Layer-3 – IPsec protocol for layer-3 IP packets encryption


10.3 Front-end Perimeter

The Front-end Perimeter is a dual-node patented approach for securing the network from the less secure network to a secure one, eliminates the need to, deploy reverse-proxy solutions and to maintain incoming firewall ports. This improves the security of the networks and simplifies network configuration, thereby reducing operation, administration, and management costs.

The solution has two-tier deployment architecture, comprising an external and internal node. The external node serves as a front-end to all services published. This node ensures that only legitimate session data can traverse the internal network. It operates without opening any ports within the external firewall. The role of the internal node is to deliver the session data to the internal network from the external node, scan it using various application level security techniques, and then pass it on to the destination application server.

10.4 DDOS Protection

This is a real-time, behavioral-based attack mitigation device that protects the organization infrastructure against network and application downtime, application vulnerability exploitation, malware spread, network anomalies, information theft and other emerging cyber-attacks. The solution provides world-class security including distributed denial of service (DDoS) mitigation and SSL-based protection to fully protect applications and networks against known and emerging network security threats such denial of service attacks, DDoS attacks, Internet pipe saturation, attacks on login pages, attacks behind CDNs, and SSL-based flood attacks, using:

- Dedicated hardware that protects without affecting legitimate traffic
- A full set of security modules
- Accuracy of inline or out-of-path (OOP) deployment
- Centralized attack management, monitoring, and reporting

10.5 SCADA DPI

This is a fast and optimized pattern match mechanism that provides: state-full awareness, deep per-packet inspection, quick ID of existence of common signatures within the packet, matching to signatures based on set of rules, ability to load any rule/signature on run time without affecting traffic, dynamically updated signatures, focus on MODBUS, DNP3, BACnet and additional SCADA protocols.

SCADA DPI quickly filters out the vast majority of traffic that is clearly harmless (looking for simple signatures at a low CPU cost). Traffic marked as suspicious (common attack signature found) is forwarded for further analysis. SCADA searches deeper in the packet and keeps track of the connection to increase the level of certainty and reduce false positives.

10.6 Network Anomaly Detection

This breach detection and remediation solution comprises one or more network appliances (physical and/or virtual) together with software modules. They passively connect to the primary network switches of your internal network and proactively find compromised endpoints and stolen credentials, and flag and remediate them.

The solution works in a three-step iterative process to identify and mitigate attacks:

- **Detect** - The appliance passively monitors traffic in the enterprise network using deep packet inspection and profiles the behavior of each user/endpoint in the network. Without requiring any
configuration or signatures, the appliance detects subtle behavior deviations of users and endpoints from their past behavior and peers in the organization.

- **Illuminate** - An agentless endpoint analysis module, further investigates traffic anomalies, automatically scans suspected endpoints and collects host level indicators to identify the origin of suspicious activities. This unique combination of network-centric detection and endpoint analysis, augmented by cloud-based threat intelligence, provides your security team with actionable incidents with an extremely low false positive rate.

- **Remediate** - Detailed alerts with actionable information are generated for each breached endpoint, enabling efficient triage and remediation. The solution purposely keeps the number of alarms (and false positives) to a low, manageable number, so that breaches can be mitigated practically and quickly by IT security practitioners. This can be executed early in the attack life cycle, before any real damage can be done.
11. VIVO DWDM optical network solution description

11.1 Optical design by LightPlan-OM

LP-OM (Optical Module) is ECI’s tool for designing Optical networks, includes Long Haul and multi-drgree ROADM support.

The LP-OM taking in account all network information: fibers type and characteristics, distances, topology, CD, PMD and all optical phenomenon. LP-OM Output guarantees network performance.

11.1.1 Network Topology

As for the requested network/s, all the fiber information and site connectivity is inserted into the LP-OM:

![Network Topology Diagram]

**Figure 73: requested network (ROUTE TO QUOTE #6 - VIVO DWDM network)**

The attenuations mentioned in the RFP were taken into account for the optical simulation.

This implementation is of course an example and can be re-adapted to VIVO’s future requirements.

In total up to 88 channels are supported, at 50GHz spacing with the option for operating gridless over the suggested Twin WSS ROADMs.

The optical design performed through our optical design tool (LightPlan OM) shows that, according to specific traffic/demands requirements, With or without regeneration.

The network designed according to the specified fiber parameters provided in the RFP (Routes to quote 1 to 6):

- In order to achieve the requirements, the network designed based on: ROADM_20T – 1x20 TWIN WSS ROADMs, 50GHz spacing, Flexgrid ready.
Technical Concept

Number of ROADM_20T per site is according to the number the site degrees (connections to other sites)

- **MxN-Collector** – based on TWIN WSS (50GHz, Flexgrid ready), while M are the ports towards ROADM degrees and N are Colorless ports towards 100G/200G optical transceivers. M+N=20.

Number of MxN collectors is usually two – enabling Colorless-Directionless- contentionless and full redundancy

- **OLP** – Optical Line Protection, smart way to protect 100G traffic with a cost of single line transceiver. Based on optical splitter at the transmitting side and Optical switch at the receiving site

- **Several types of Amplifiers for optimized network performance according to the specific fiber characteristics:**
  - **OA_LF** – Variable gain amplifier 20.5 dBm without Mid Stage. Optimized for coherent network applications operating over the extended C-band. For Booster, In-Line, and Preamp sites in short span network applications.
  - **OA_HF** – Variable gain amplifier 20.5 dBm without Mid Stage. Optimized for coherent network applications operating over the extended C-band. For In-Line and Preamp sites in long span network applications.
  - **OA_FHBS** – Fixed Gain High Power Booster; 22.5 dBm. Optimized for Terminal and ROADM sites. E/W configuration. Includes built-in OSC filters.
  - **OA_HRS** – High power (700 mW) backward Raman amplifier for long multi-span and single span applications. E/W configuration. Includes built-in OSC filters.
  - **OA_EHRS** – 20.5 dBm EDFA/(High power) Raman amplifier. Optimized for both high gain spans in coherent network applications. E/W configuration. Includes built-in OSC filters and OSC SFP.
  - **OA_USPBF** – Fixed Gain Extended C band Very High Power Booster; 26 dBm. To be used after 20 dBm amplifiers before long spans. E/W configuration. Includes built-in OSC filters.
  - **OA_UHBR** – Ultra High Power Dual Booster transmission and Ultra High Gain, 3W Backward Raman.
Figure 74: ROADM node with 3 degrees and redundant MxN CDC collector
11.2 Site design by LightPlan-SM

The LP-SM (Site Manager) module is connected to LP-OM module and optical layer is translated to components. The tool supports planning of the management systems, accessories and spare parts. The LP-SM automatically produces a project book for all sites and configurations. Reports include:

- Bill of Materials
- Installation
- Power consumption
- Heat dissipation

For each site, graphical view of the following: rack, chasis, slot, port.
11.2.1 ROADM node

The below figure examples a (2Deg ROADM) site view:

Figure 76: Example of a 2 degree ROADM node with 100G Transponders and 5.6T OTN switching shelf (Route #6).

In this site, there are two shelves, OPT9624 and OPT9914.

OPT9624 installed with 100G transponders, ROADMs, collectors and amplifiers.

The passive Artemis chassis accommodates the C/T filter for the optical supervisory channel.

OPT9914 installed with HIO400 (2x100G, 2x150G, 2x200G elastic line ports with backplane connectivity), and one HIO10_20 (twenty Multi-rate 10G clients plus two 40GE clients).

The following rack and NE accessories can be optional: AC power rectifier (when needed), xRAP (power distribution panel), fiber guides and fiber spooler.

Both shelves are suitable to 19” rack.
11.3 Management scheme

LightSoft NMS (server and client) and EMS-STMS are installed on the production x86 server. Duplication of LightSoft and STMS can be installed on a backup x86 server. A 10Mbps connection is required between the production and the DRP servers for the database replication transfer.

The communication between the network and the management is via GW-NE that is connected to the EMS-STMS.

NOTE: For the present offer, backup Server has not been included
12. Apollo References

Following are some of our references

12.1 DFN – Germany

ECI TELECOM ENABLES MULTI-TERABIT NETWORK FOR GERMAN RESEARCH NETWORK

-- New network will benefit students, professors and scientists, who depend on seamless and powerful connection to global science networks for increased collaboration--

PETACH TIKVAH, ISRAEL – May 16, 2012 – ECI Telecom, a global provider of next-generation network solutions, will supply the German Research Network - Deutsches Forschungsnetz e.V. (DFN-Verein) – with the Apollo family of Optimized Multi-Layer Transport (OMLT) platforms, to upgrade their X-WIN research network. With the Apollo OMLT, X-WIN will be a multi-terabit network, able to provide DFN members with the fastest available services ever. The Apollo OMLT is part of ECI’s 1Net packet-optical transport solutions, and brings increased capacity, flexibility and reliability for advanced data traffic services.

HIGHLIGHTS:

• More than 750 universities and research institutes use X-WIN to connect to global research networks and the internet in general. DFN offers these universities and institutes specialized services such as voice over IP, videoconferencing, roaming, and public key infrastructure for digital certification.

• X-WIN, spanning more than 11,000 km of dark fiber with up to 40Gbit/s connections, is one of the largest and most powerful research networks worldwide. With the new multi-terabit technology provided by Apollo, DFN will be able to provide for today’s and the future’s research and science needs in Germany.

• ECI was selected after a rigorous tender process, in which key criteria was highest transmission capacity and the flexibility to enable new connections with short lead times.

• Since its founding in 1961, ECI has provided leading service providers and network operators with the most innovative and advanced networking solutions in the market. ECI has been present in the German market since 1984.

THE SOLUTION
ECI will deploy the Apollo OMLT in all 69 locations of the X-WIN network. To guarantee a smooth transition, without interruption of services, the network will be upgraded in the shortest period of time possible. Since academic facilities are usually connected to the X-WIN via two independent links, the upgrade will not affect most of the 2.5 million students, professors and scientists using this network.

EXECUTIVE PERSPECTIVES
“With the new Apollo OMLT, X-WIN will become a multi-terabit network. Complemented by the highly flexible management of Apollo, X-WIN then is well prepared for the coming data challenges of science
and research, such as connecting computing and storage facilities or enabling data-intensive experiments in high-energy physics, biology, or medicine.”

Dr. Stefan Piger, DFN Association

“As a leading worldwide research association, DFN must have the most advanced network to support its members, one that is able to provide not only today’s services, but also those in the future. The Apollo OMLT is a cost-effective solution that gives DFN the flexibility to add services as the needs arise, without unnecessary investments or added complexity.”

Jehonathan Neuberger, Managing Director, ECI Telecom GmbH

RESOURCES
OMLT for Dummies and other resources
What is the OMLT? (Video)

SOCIAL MEDIA LINKS
Become a fan of ECI Telecom on Facebook
Follow ECI Telecom news updates on Twitter
High-resolution graphics are available for download at Flickr

ABOUT DEUTSCHES FORSCHUNGSNETZ E.V. (DFN-VEREIN)

Science itself organizes the German National Research and Education Network (DFN), the communications network for science and research in Germany. DFN connects universities and research institutions and has become an integral part of the European and worldwide community of R&E networks. Through several high-capacity peerings, DFN is connected with the common Internet. DFN offers a wide range of customized services for collaboration and communication in the R&E communities. The service portfolio is constantly being enhanced and complemented by innovative applications which are developed through projects and piloting ventures. DFN supports its users conducting training events, workshops and conferences. Moreover, DFN promotes various competence centres which provide advice in operational and technical matters as well as in legal affairs. The association to promote a German education and research network, DFN-Veren, organizes DFN and guarantees its further development and usage. DFN-Verein is an acknowledged non-profit association. For more information, visit www.dfn.de.

ABOUT ECI TELECOM

ECI Telecom delivers innovative communications platforms to carriers and service providers worldwide. ECI provides efficient platforms and solutions that enable customers to rapidly deploy cost-effective, revenue-generating services. Founded in 1961, Israel-based ECI has consistently delivered customer-focused networking solutions to the world’s largest carriers. The Company is also a market leader in
12.2 RCS RDS Romania

ECI TELECOM ENABLES 100G CHANNELS IN ROMANIA, THE FIRST IN THE REGION

-- The project, with leading cable operator and internet provider RCS & RDS, enables advanced, bandwidth-hungry applications in the country --

PETACH TIKVAH, ISRAEL – September 24, 2012 – ECI Telecom, a global provider of next-generation network solutions, and RCS & RDS, the leading cable operator in Romania, announced today the deployment of 100G channels over its existing network, with ECI’s next-generation Optimized Multi-Layer Transport (OMLT) platforms, Apollo. The Apollo OMLT is part of ECI’s 1Net framework for addressing our customers’ challenges in their day-to-day operations and going forward. By deploying Apollo, RCS & RDS has future-proofed its network to support advanced and bandwidth-hungry services and applications.

HIGHLIGHTS:

• With more than four million subscribers, RCS & RDS is the largest Romanian cable and internet provider, offering quad-play services (voice, data, video and mobile services).

• The new capabilities increased RCS & RDS network capacity by tenfold, by upgrading from 10G to 100G channels.

• The 100G channels cover about 700Km, from Oradea to Bucharest, with minimal changes in the network.

• The new 100G channels are delivered with the Apollo line of OMLT platforms. Managed by ECI’s LightSoft® Network Management System, the deployment simplifies operations and reduces training and personnel expenses for RCS & RDS.

• ECI has worked with RCS & RDS for more than ten years, supplying them with multiservice provisioning and optical equipment. The company has an extensive network of installed XDM® and BG® platforms.

THE SOLUTION

RCS & RDS deployed the Apollo line of Optimized Multi-Layer Transport (OMLT) platforms, part of ECI’s 1Net framework of equipment, services and solutions. The 100G DWDM network connects core routers between Oradea to Bucharest over the Apollo transport solution. RCS & RDS will be the first provider to offer 100G bandwidth in the country. By using the Apollo over the XDM network, the company saves significant capex and opex expenses as both platforms share the same Network Management System, LightSoft.
EXECUTIVE PERSPECTIVES

"With minimal changes to its existing infrastructure, RCS & RDS increased tenfold the available bandwidth to its customers. This new 100G network enables the company to remain competitive and offer the latest next-generation services and applications to its customers, without major investments in capex or opex."

Yoav Gazelle, Head of Sales & Marketing for Europe & Americas, ECI Telecom

"The ability to implement 100G in our current network is a confirmation of our continuous effort to invest in cutting-edge communications solutions. For more than 10 years, ECI has been an innovative and experienced strategic partner that helped us provide our customers with exceptional services. The move to 100G will enable RCS & RDS to better meet the needs of its customer base by quickly reacting to current and future bandwidth demands and reliably offering the highest capacity services available on the market today, as well as the ability to approach new markets."

Valentin Popoviciu, Development Manager, RCS & RDS

RESOURCES
- OMLT for Dummies and other resources
- What is the OMLT? (Video)
- www.rcs-rds.ro

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- High-resolution graphics are available for download at Flickr

ABOUT RCS & RDS

RCS & RDS is one of the leading telecommunications operators in Southeastern Europe, providing services in Romania, Hungary, Czech Republic, Slovakia, Croatia, Serbia, Spain and Italy. In Romania, it is the largest cable and satellite television company and is a leading provider of Internet services. The company is the only full telecommunications services provider offering, among other services, mobile and fixed telephone. The operator owns several TV channels – including Digi Sport, present in several countries (Romania, Hungary and Slovakia), Digi Film and several music channels – and holds a news channel.

With an experience of over 18 years in providing telecommunications solutions, RCS & RDS has developed its own infrastructure on optical fiber support and offers to its customers complete telecommunications services at the best prices.
MTS DEPLOYS ECI TELECOM’S APOLLO 100G SOLUTION IN RUSSIA

-- By extending the existing DWDM network, MTS brings to market more bandwidth and services to the customer --

PETACH TIKVAH, ISRAEL – January 29, 2013 – ECI Telecom, a global provider of next-generation network solutions, today announced that MTS, the leading mobile operator in Russia, has deployed ECI’S Apollo Optimized Multi-Layer Transport (OMLT) platforms to extend the existing ECI’s DWDM backbone, enabling all advanced services, including 100G.

HIGHLIGHTS:

• Mobile TeleSystems (MTS) is the leading telecommunications group in Russia, Eastern Europe and Central Asia, offering mobile and fixed voice, broadband, pay TV as well as content and entertainment services in one of the world’s fastest growing regions.

• The project links Moscow and Saint Petersburg. With more than 1,000 km, it has been operational since 2003, with both 2.5G and 10G. By adding Apollo OMLT shelves with 100G cards in add/drop points, MTS can leverage the already installed XDM shelves, saving time and money while enabling new services.

• The Apollo OMLT is part of ECI’s JNet framework for addressing our customers’ challenges in their day-to-day operation and strategic directions. Both Apollo and the XDM are managed by ECI’s LightSoft® Network Management System, enabling end-to-end provisioning, simplified operations and faster time to market.

THE SOLUTION

ECI’s platforms bring a cost-effective and advanced core solution for MTS’ backbone network. MTS has deployed the Apollo OPT3624 to expand its cross-country DWDM backbone based on ECI optical platforms. The new Apollo DWDM network will enable MTS to provide advanced high capacity, long reach 100G services. It includes connection between core routers with 100G link.

EXECUTIVE PERSPECTIVES

“We are facing the challenge to provide our customers quality and high-speed data exchange while its volume grows every year. According to our forecast the penetration of smartphones in our network will reach 60% by the end of 2015; launches of LTE networks in Russian regions will force the mobile traffic growth; implementation of fixed line internet and its usage growth will increase the volume of data traffic in our backbones at 6-10 times. At the moment the volume of everyday traffic exchange between Moscow and Saint Petersburg is over 1 Petabyte and we are building the high-performance system of
backbone lines sequentially enhancing its capacity to supply the demand in data exchange in long-term perspective.”

Andrey Ushatskiy, Vice-president, Group CTO, MTS

“With about 100 million mobile subscribers, MTS is able to edge ahead with 100G capabilities in one of the main telecom links in the country. The Russian market faces one of the fiercest competition today in the world, and by leveraging the deployed XDM network, MTS can migrate to advanced services more cost-effectively and with faster time to market.”

Boris Mirkin, Head of Russia and CIS Business Unit, ECI Telecom

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ABOUT ECI TELECOM

ECI Telecom delivers innovative communications platforms to carriers and service providers worldwide. ECI provides efficient platforms and solutions that enable customers to rapidly deploy cost-effective, revenue-generating services. Founded in 1961, Israel-based ECI has consistently delivered customer-focused networking solutions to the world’s largest carriers. The Company is also a market leader in many emerging markets. ECI provides scalable broadband access, transport and data networking infrastructure that provides the foundation for the communications of tomorrow, including next-generation voice, IPTV, mobility and other business solutions. For more information, please visit www.ecitele.com.

ABOUT MTS

Mobile TeleSystems OJSC ("MTS") is the leading telecommunications group in Russia, Eastern Europe and Central Asia, offering mobile and fixed voice, broadband, pay TV as well as content and entertainment services in one of the world’s fastest growing regions. Including its subsidiaries, the Group services about 100 million mobile subscribers. The Group has been awarded GSM licenses in Russia, Ukraine, Uzbekistan, Armenia and Belarus, a region that boasts a total population of more than 230 million. Since June 2000, MTS' Level 3 ADRs have been listed on the New York Stock Exchange (ticker symbol MBT). Additional information about the MTS Group can be found at www.mtsgsm.com.

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ISRAELI ELECTRIC CORPORATION SELECTS ECI TELECOM’S APOLLO FAMILY FOR ADVANCED TRANSPORT NETWORK

--Under the scope of the Apollo OMLT deployment, IEC and ECI successfully trial 100G speeds to maximize the capacity of the network--

PETACH TIKVAH, ISRAEL – March 28, 2012 – ECI Telecom, a global provider of next-generation network solutions, announced today that the Israeli Electric Corporation (IEC) has selected the Apollo family of Optimized Multi-Layer Transport (OMLT) platforms, part of ECI’s 1Net packet-optical transport solutions, for its network connectivity needs. The Apollo OMLT brings increased capacity, flexibility and reliability for advanced data traffic services. As part of this deployment, the IEC ran a successful pilot of the platform’s 100G capabilities.

Highlights:

- The IEC is deploying the Apollo OMLT to cope with its increasing capacity and communications needs.
- During the 100G Apollo pilot, the IEC tested the platform’s ability to transmit 100 Gbit/s on a single wavelength. The pilot, considered a technological breakthrough for the IEC, introduced advanced capabilities in the company’s transmission network, increasing capacity by more than tenfold.
- Apollo’s 100G capabilities will allow the company to implement broadband services across the board, through optimized utilization of existing resources.

EXECUTIVE PERSPECTIVES

“This 100G trial represented a technological leapfrog for the IEC, as we are able to expand and provide next-generation broadband services over the most advanced optical infrastructure. With ECI’s Apollo OMLT, we are better able to cope with our increasing needs for capacity and to respond to our organizational and our customers’ demands for more bandwidth and services. The success of the trial has further emphasized the high quality of the IEC fiber optic network and its ability to transport new high end capacity services without any changes to the existing infrastructure.”
Yosi Shneek, VP for Information Systems and Communication, IEC

“By deploying this technology, the IEC will contribute to a marked increase in efficiency and a noted improvement in the telecommunications capabilities we are able to provide our customers, bringing Israel to the forefront of communications technology.”
Nava Trinczer, Deputy VP for Information Systems and Communication, and Manager for the Communication and Electronics Unit, IEC

“100G technology is at the forefront of the telecom market today, and only very few operators are deploying it at the moment. The IEC belongs to a select group of providers who have embarked on a quantum leap in terms of capacity and the ability to support advanced services and the constant traffic
growth rate. “We are proud to deploy Israel’s first 100G optical network.”
Oren Marmur, Head of Optical Networking & CESR Lines of Business, ECI Telecom

RESOURCES

Apollo Brochure
What is the OMLT? (Video)
ECI Apollo: Defining the Next-Generation of Optimized Multi-Layer Transport (White Paper)

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ABOUT THE ISRAELI ELECTRIC CORPORATION

The IEC is the sole integrated electric utility in the State of Israel and generates, transmits and distributes substantially all the electricity used in Israel. 99% of the Company is owned by the Government. Installed capacity: 12,700 MW (430 MW self-generation/private), peak demand 11,530 MW 10,950) (19/8/2010) MW by IEC), annual budget approximately 20 billion NIS. IEC is one of the biggest industrial companies in Israel totaling approximately 12,500 employees and serving approximately 2.6 million customers. The fiber network managed by the Communication and Electronics Unit in the Information Systems & Communication division provides all the communication needs of IEC including the operation and control systems, IT and telephony covering hundreds of IEC’s premises all over Israel. For more information, please visit http://www.iec.co.il/EN/IR/Pages/default.aspx.

ABOUT ECI TELECOM

ECI Telecom delivers innovative communications platforms to carriers and service providers worldwide. ECI provides efficient platforms and solutions that enable customers to rapidly deploy cost-effective, revenue-generating services. Founded in 1961, Israel-based ECI has consistently delivered customer-focused networking solutions to the world’s largest carriers. The Company is also a market leader in many emerging markets and has focused solutions for utilities. ECI provides scalable broadband access, transport and data networking infrastructure that provides the foundation for the communications of tomorrow, including next-generation voice, IPTV, mobility and other business solutions. For more information, please visit www.ecitel.com.

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12.5  TMC award
ECI TELECOM RECEIVES “2011 COMMUNICATIONS SOLUTIONS PRODUCT OF THE YEAR” AWARD

Apollo Optimized Multi-Layer Transport (OMLT) platform recognized for exceptional innovation in true convergence of optical and packet layers

PETACH TIKVAH, ISRAEL — September 05, 2012 — ECI Telecom, a global provider of next-generation network solutions, announced today that IMC, a global, integrated media company, has named its Apollo Optimized Multi-Layer Transport (OMLT) platform as a recipient of a 2011 Communications Solutions Product of the Year Award.

HIGHLIGHTS

- The latest addition to the 1Net framework for addressing our customers’ challenges and opportunities, the Apollo family of OMLTs provides a fully integrated, next-generation multi-layer packet-transport optical system, simplifying operations and increasing return on investment.
- Apollo’s unified approach to multi-layered network architecture simultaneously reduces infrastructure costs and simplifies the introduction of new services with a single management system for all network layers.
- Its modularity allows operators to deploy the OMLT as an optical system, carrier Ethernet switch/router (CESR) or as an integrated solution. With Apollo, operators can time their circuit-to-packet network upgrade path more easily to meet current needs without risk of stranding assets as a result of future upgrades.
- Several leading tier-1 operators around the globe are already deploying the Apollo OMLT. Recently, the German Research Network - Deutsches Forschungsnetz e.V. (DFN-Verein) and the Israeli Electric Corporation (IEC) have been announced as customers benefiting from the high level of adaptability offered along with the operational savings associated with the single box design.
- The Communications Solutions Product of the Year Award recognizes the vision, leadership, and thoroughness that are characteristics of the prestigious award. The most innovative products and services brought to the market from March 2011 through March 2012 were chosen as winners of the Communications Solutions Product of the Year Award.

The 2011 Communications Solutions Product of the Year Award winners are published on the INTERNET TELEPHONY and Customer Interaction Solutions websites.

EXECUTIVE PERSPECTIVES

“ECI was chosen to receive a 2011 Product of the Year Award for creating outstanding advancements in communications. The Apollo OMLT has proven benefits for its customers and provides ROI for the companies that use it. Congratulations to the entire team at ECI. I look forward to more innovative solutions from the company in the coming year.”
We are pleased to receive a Product of the Year award from TMCnet. This recognition reaffirms the value proposition that many of our customers have already realized: Apollo’s innovative modular design couples the scalability, performance, cost and operational capabilities of optical networks with the adaptability, cost effectiveness and flexible service creation aspects of packet networks.

Oren Marmur, Head of Optical Networking & CESR Lines of Business, ECI Telecom

RESOURCES
OMLT for Dummies and other resources
What is the OMLT? (Video)

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ABOUT TMC
TMC is celebrating its 40th anniversary as a global, integrated media company that helps clients build communities in print, in person, and online. TMC publishes the Customer Interaction Solutions, Internet Telephony, Next Gen Mobility, and Cloud Computing magazines. TMC is the producer of ITEXPO, the world’s leading B2B communications event. TMCnet.com, which is read by two million unique visitors each month, is the leading source of news and articles for the communications and technology industries. In addition, TMC runs multiple industry events: Cloud Communications Expo; Cloud4SM Expo; CVx (ChannelVision Expo); DevCon5; HTML5 Summit; LatinComm Conference & Expo; M2M Evolution Conference & Expo; Mobility Tech Conference & Expo; MSPAlliance MSPWorld; StartupCamp; Video World Conference & Expo and more. For more information about TMC, visit www.tmcnet.com.

PRESS CONTACT
Sandra Welke, Corporate Communications
13. Apollo Technical Advantages

13.1 High density solution

ECI Apollo supports a variety of service cards providing the densest systems in the market. All of the cards are designed to support multiple rate and protocol services to reduce the number of I/O types and spare part required in each site.

In addition, most of the transceivers, for Metro and Regional/LH, are pluggable to provide the customer pay as you grow option. In addition the transceivers are available with tunable functionality to enable developing dynamic network from access to core.

13.2 LightPulse

The LightPulse enables the following network functionalities:

- Power/gain control in EDFA, ROADM, and FOADM cards.
- Real-time diagnostics.
- Span/connection loss diagnostics.
- Performance diagnostics, including channel OSNR, dispersion, polarization mode dispersion (PMD), and nonlinear phase.
- Performance verification for a preinstalled trail.

13.3 Superior solution for alien wavelengths on the ITU-T DWDM grid.

ECI’s Apollo system has superior support for alien wavelengths (Different vendors which working according to ITU-T DWDM grid), including LightPulse support). The meaning is that Apollo user can create an Alien Transponder (or other transceiver) with its own technical specification as results, the Alien wavelength services get:

- Real time LightPulse monitoring.
- End to end trail management.
- Viewing service route/s
- Creating 1+N protection at ROADM level, etc.

13.4 End-to-End OTN transparency

ECI’s full OTN-compliant solution enables operators to optimally reduce CAPEX and OPEX. An excellent example is the implementation of E-FEC in OTN, reducing the number of regenerations and thereby reducing CAPEX. OTN also reduces OPEX for operators, primarily via advanced Performance Monitoring (PM) capabilities.

Major features and benefits of ECI’s OTN capabilities include:

- Direct mapping to ODUk.
- OTN Multiplexing of SDH/Sonet, Storage and Ethernet into OTUk, while enabling each client to maintain its own timing source. Thus, the customer can provide private service lines to different customers from the same card using the same lambda, without compromising the timing source of any of the clients.
### Technical Concept

- Third party interoperability by using ODU mapping and OTU framing.
- Full commonality of the all platforms data cards and modules allowing delivery of seamless integration of metro-access to metro-core solutions while eliminating back-to-back terminals.
- Full interoperability from access to long haul.
- Optimized OPEX reduction by using a universal architecture.

13.5 A Single Optimized Solution for any reach

Apollo system incorporates built-in low-noise amplifiers, a large variety of long-range transponders, dispersion compensation equipment, and high capacity links with up to 44/88/48/96 (or up to 120 carriers with Flex-grid) channels per link. ECI provides a comprehensive range of 2.5G/10G/40G/100G/150G/200G G.709 OTN channel tunable transponders and combiners with GFEC/EFEC, LiNbO3 transmitters, advanced modulation techniques, advanced single-stage and dynamic variable-gain mid-stage EDFA amplifiers, plus optional high-power RAMAN and ROPA amplifiers.

13.6 Capacity ready for the future

Apollo system already supports the high capacity 40G/100G interfaces. Our platform is designed, in terms of backplane support and modulation technique, to support the upcoming 200G optical channels handling 400G and 1T super-channels.

The system supports 100G PM-QPSK interface cards (standalone Transponders/Muxponders and connected to fabric cards) uniquely enabling co-existing of 10G/40G/100G/150G/200G channels on a single link, enabling smooth upgrade and transparent scalability.

13.7 Scalable, L2/MPLS Switching and Layer3 IP

Residential customer expectations are very different today from what they were only a few years ago. Today’s residential customers demand the power and simplicity of triple play service, including HSI, VoIP, uni-cast VoD using Layer 2 MPLS-TP and Layer3 VPN.

The need for data connectivity across the WAN/MAN for business customers is continuously on the rise. Enterprises with geographically distributed offices seek to expand their Ethernet-based LANs to connect remote branches to their headquarters, and their business to the Internet.

The typical L2VPNs offers MEF compliant services - point-to-point (VPWS/E-Line) services, point-to-multipoint (E-Tree) and multipoint-to-multipoint services (VPLS/E-LAN), both with Ethernet customer interfaces and MPLS switching infrastructure. VPLS establishes a full mesh of MPLS label switched paths (LSPs) or tunnels between the PE (Provider Edge) sites. The Ethernet payload is encapsulated with MPLS tags and switched along the L2 network, allowing uni-cast and multicast services. To scale the number of nodes of the VPLS network, Hierarchical VPLS (H-VPLS) may be required, allowing partial mesh LSPs and less multicast replication points.

13.8 Scalable, Universal ODU/MPLS Fabric

As traffic demands increase, the core of networks are evolving from static architectures, which is less-efficient, to the dynamic next-generation architectures based on OXC and Control plane GMPLS-based.
Apollo provides Universal fabric that supports up to 16 Tbps (scalable to multi-tera) ODU cross connects/L2/MPLS/L3 switching (frame agnostic). Any slot can allocate either L1 service card, L2/MPLS-TP (Phase 2) and L3 VPN (phase 3).

TDM and Ethernet services are mapped to OTN and cross-connect through the system providing grooming, end to end provisioning and restoration based on ASON/GMPLS.

The unique cross-connect capability allows cross-connections of ODUk, non-blocking up to the full fabric capacity.

The unique Fabric architecture provides smooth migration from network that is based mainly on TDM services to next generation network which is based mainly on IP/Ethernet services. The L1 and L2/L3 service cards may be plugged-in to any of the service slots in the system which provides full flexibility when configure the system according to each site requirements.

13.9 Reconfigurable Optics, from Access to Core

ROADM is currently considered the technology of choice for carrier’s worldwide, adding flexibility and lowering total cost of ownership (TCO) for various network scenarios.

As traffic demands grow, networks become complex, even at the metro layer. Today's operators require flexible capabilities all the way from the metro to the core and cost-effective ROADMs for each segment. Apollo provides an access-to-core solution based on a variety of photonic modules and ROADMs.

Apollo' best-in-class WSS ROADM technology, together with fully tunable lasers and power equalization capabilities, introduces true agile optical networking, providing 100Gbps/150Gbps/200Gbps wavelength connectivity in ring or mesh topology, 100GHz spacing (44/48 channels), native 50GHz spacing (88/96 channels) and Flex-grid spectrum (up to 120 channels). The system supports variety of amplifiers and ROADMs that meets each network segment requirements such as 2D-ROADM and Multi-degree ROADM.

13.10 Control Plane Architecture

Transmission network traffic is shifting towards Ethernet-based services. Traffic patterns and protection requirements are changing, presenting a change from dedicated to shared protection schemes. The APOLLO family supports this evolution from ring protection to efficient mesh protection schemes, making more efficient use of bandwidth resources.

The Apollo family offers Automatic and Wavelength Switched Optical Network (ASON/WSON) control plane architecture, capable of offering intelligent services in existing and new Apollo transport networks. This is achieved by supplying a GMPLS control plane that enhances Apollo networks by adding restoration to the sub 50msec protection schemes and automated service provisioning. It further boosts network capabilities that contribute to reduced CAPEX and OPEX.

The key components of the Apollo management and control suite include automatic topology discovery, resource dissemination, point-and-click connection provisioning, automatic user-initiated setup, end-to-end performance management across an OTN circuit, and network-wide End-to-End path protection and restoration.

This distributed dynamic routing capability allows for rapid cost-effective creation of new nodes and additional bandwidth, without the extensive offline operations usually required.
The new ASON capabilities offer additional types of protection schemes in order to increase network survivability, including the 1++ SNCP-based protection for very high CoS services and 1+R (unprotected-based) protection for low CoS services. These options are available at the sub-lambda level as well as on wavelength level. WSON enable to protect the service without the need to terminate the service in each and every node, thus, reducing the network cost significantly.

13.11 Ease of Operation Reducing Network OPEX

ECI’s optical solution simplifies the planning, installing, operating, and maintenance networks that were previously considered fairly complex.

Starting with ECI’s unique planning tool that makes it possible to quickly design and optimize the most efficient networks based on network demand and span information. There is no need any more to redefine traffic demands. The comprehensive planning tool enables bandwidth optimization, optical link design optimization/verification, and shelf layout - simplifying installation and reducing CAPEX. These capabilities make it possible to quickly design the most efficient networks based on demand and span information.

Network design including system, cards and services definition are downloaded from the planning tool to each network element reducing significantly network provisioning.

Activating services, rerouting wavelengths, finding and optimizing network resources can be performed faster than ever, greatly accelerating time to revenue.

Enhanced Automatic Power Control (APC) ensures network robustness by automatically adjusting to changes in optical power due to variations in span loss and/or the number of active channels, and providing comprehensive information on network status. In addition to reducing OPEX, APC can potentially increase revenue by improving the reliability of services and response to customer demand.

13.12 Transparent Transport of Services

In the current telecommunications marketplace where infrastructure is often costly, many customers lease services from CoCs rather than build their own transmission network. Customers demand far more than simple, rigid, point-to-point services; they require multiple services, bitrates, and protocols in their Points Of Presence (POPs), as well as convergence of all services over a single leased transmission pipe. In addition, major customers seeking higher quality services are shifting from monitored leased lines, which cannot be managed directly, to fully managed Customer Managed Networks (CMNs).

Apollo enables operators to lease a wide variety of TDM, Ethernet, and even full wavelength services. It supports transparent connectivity, including the timing clock and overhead bytes.

Managed by the innovative LightSoft® Network Manager, Apollo enables CoCs to offer CMN services with transmission resources. This includes virtual topology views and service provisioning. CMN clients have complete visibility of their networks and are able to monitor, control, and maintain it in real time, thereby responding to dynamic market requirements quickly and efficiently.
13.13 Unified Management System

All ECI transmission equipment, including Apollo, is managed by a single management system - LightSoft. LightSoft network management system features a unique multidimensional approach to managing today's converged networks. LightSoft handles one physical layer and several technological layers, including SDH/SONET, Ethernet, OTN and optical. This creates a graphic interface that provides users with a comprehensive view of the entire network, while allowing customization of individual technology-centric views.

End-to-end trails for the optical layer and the service layer are supported across the products, allowing trails to be set that start at the Apollo transponder and terminate at XDM. LightSoft also supports top-down trail provisioning reducing the time for provisioning new services.

13.14 Design for “Green” Machine

Saving power is becoming a major concern for most operators around the world. The needed aim of sustainable design is to produce products and services in a way that reduces use of non-renewable resources, minimizes environmental impact, and relates people with the natural environment.

The fact that the Apollo platform is a converged platform speaks for itself by reducing space, power, interfaces, and additional requirements that not only save in TCO, but are environmentally friendlier.

Apollo is design to minimized power consumption and reduces the customer OPEX. All the hardware components as well as the software architecture were developed with the intention to reduce the power consumption to the minimum as possible.

13.15 SDN suit (controller and Applications)

A LightControl is Carrier-grade controller for wide area networks.

SDN Control Plane for multi-layer network elements, such as implemented in LightControl, provides a framework for integration of topology, resource and policy information across layers. Such integration is the basis for common control for all layers that simultaneously offer services and benefits never achieved before

LightApps delivers all the benefits of SDN today on your current LightSoft-managed infrastructure, but also runs with LightControl - SDN controller. The LightApps suite supports migration to an SDN environment the easy way, skillfully leveraging your current investment!

13.16 Cyber Security suit

ECI's holistic 'Hexagon' model provides the most suitable security means, a central point of real time views, and control for a total unified IT/operational networks cyber security solution to include: Firewall, Encryption (Layer1/Layer2/Layer3), Front-end Perimeter, DDOS Protection, DPI and Network Anomaly detection.
14. Apollo's Unique Value Proposition

ECI's Apollo offers operators and carriers a solution that is ideally suited to meet the challenges presented by today's fast-changing market. The Apollo family features the advanced functionality necessary to provide customers with numerous advantages and benefits, including:

- Comprehensive solution as part of SmartLight™ Framework, including Converged Packet-Optical Transport (Apollo and NPT), LightApps™ (SDN Applications), LightControl™ (SDN controller) and LightSec™ (Cyber Security 'Hexagon' model).
- Market Highest 10Gbps and 100Gbps port density
- Smooth migration from 10Gbps interfaces/services to 40Gbps and 100G interfaces/services based on the exact same HW (TM100 and TM400 cards).
- High Capacity Universal fabric (ODU/Layer2/Layer3) providing smooth migration from existing to NG networks. 9914 – 5.6Tbps, 9932 – 16Tbps.
- LightPulse – built-in OSNR and Non-Linearity indications from remote, in real time, per optical path (and per port) via NMS.
- Variety of spectrum capacity: 16/44/48/88/96 and up to 128 carriers (with Flex-grid) per link.
- 400Gbps today and 1Tbps future proof.
- GMPLS-based control plane across different network layers.
- E2E service trail across lambdas, OTN, and service layers, as well as across ECI families (XDM®, Apollo, BGF).
- Plug-and-play user-friendly technology, simple to design, install and maintain.
- Full product line that meets the requirements of each POP in the network, from access to core.
- Strong OAM capabilities and great service flexibility through enhanced OTN offering and Ethernet OAM.
- Green design enabling low power consumption.
- Recognizing and processing alien lambdas from third party routers.