Integration of Planning and Control Plane in Packet Optical Multilayer Network

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Abstract: An integrated solution relying on a centralized management and a distributed control plane is presented for packet optical networks. Simulations results, based on realistic network, traffic and node modeling, show up to 42% CapEx saving.
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1. Introduction

Today transport networks need efficient solutions able to lower the cost-per-bit. This requires to optimize the resources and to maximize their sharing. In case of packet-opto networks the fulfilling of such requirement is challenging because it needs to conjugate two very different technologies and thus it is necessary to operate with efficient multi-layer path computation and to provide a dynamic configuration of the resources [1]. Due to the fact that Packet and Optical have very different features such as reconfiguration time, and bandwidth granularity of paths, a new architecture of PCE has been defined that conjugates the centralized operation proper of Management Plane (MP) with the real time operation proper of Control Plane (CP).This novel architecture, shown in Figure 1 is named Hybrid PCE and is based on the cooperation of a No Real Time PCE with one or more dynamic Real Time PCEs. The "No Real Time PCE" is in charge to compute paths for a forecast traffic matrix, and computes protection paths for the demands requiring pre-planned protection. It allows global optimization and has a computational time more relaxed than the real-time PCE. Virtual Network Topology Manager (VNTM) is in charge of receiving the configuration from the Non-Real-Time PCE and establishing such connections in the network. The Real Time PCE, instead, acts real time on a portion of the network to react to unpredicted events such as failure not predicted in advance such as on the fly restoration and multiple faults. Figure 1bsummarizesall the network items in a snapshot where each node contains a data plane entity, a GMPLS module as a CP "representative" inside the node, and a PCE module. In traditional networks, resiliency was provided using 1+1 protection schemes at optical layer and providing additional redundancy at packet layer: service providers needed to reserve up to 50% of their network capacity for full service recovery. With the current traffic growth, such a level of hardware redundancy cannot be maintained for economic considerations. The integration of GMPLS CP and MP enables an alternative and more efficient approach: rather than reserving dedicated and pre-computed alternative paths for each connection, CP can compute and configure restoration routes using a shared pool of excess capacity, also the coordination between the two layers allows to find correlated protection schemes, avoiding redundancies due to the knowledge of the resources of the two layers. In addition, traffic grooming can aggregate efficiently packet paths into optical path defining a virtual topology of lightpaths corresponding to the traffic matrix. In this paper we report an evaluation of the saving providing by the proposed architecture at design phase, carried out on operator network and traffic data, using a realistic model of the node, where we consider correlated protection mechanism. All this can be obtained as a migration step from the existing towards a highly integrated solution**.**

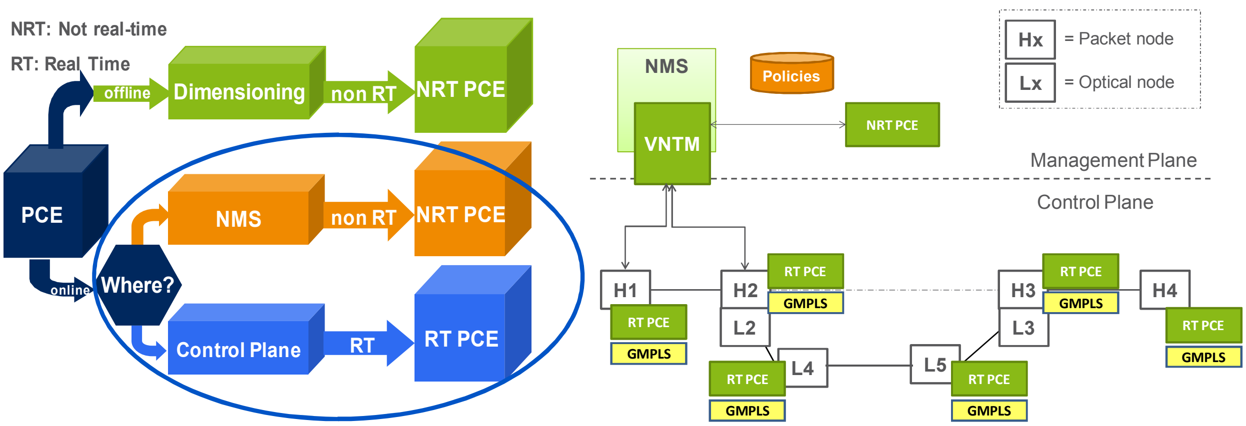
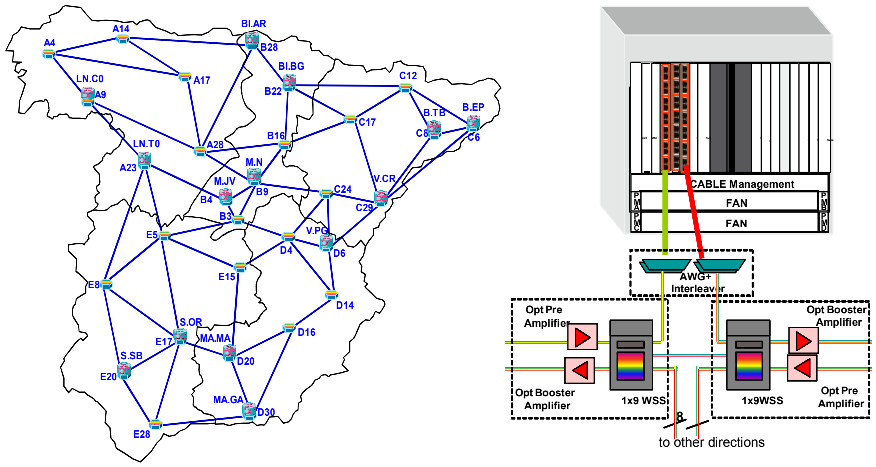


Figure 1.Integrated Management and Control plane architecture.



Component	Cost SCU
IP/MPLS Router 16 slot Chassis	53,79
IP/MPLS Line Card 14x 10 GE / MPLS-TP	31.98
DWDM XFP Transceiver 10G, 750km/2000km	1
Amplifier (Amp_boost, Amp_pre)	0.8
AWG (48 channel)	0.9
Interleaver (96 channel)	0.5
WSS 1x9 (unidirectional + splitter and filter)	4
WSS 1x20	6

Figure 2.a) Spanish Backbone Network, b) Multi-Layer node architecture with 16 Slot IP/MPLS router and ROADM and c) CapEx Model

2. Network Scenario and Node Model Architectures

For this case study, the Spanish backbone network is used (Fig. 2a). The network has 14Multi-Layer (ML) nodes and 16 OXCs. The ML nodes are injecting the traffic to the network. The traffic matrix is created based on the aggregation of the traffic of Spanish regional networks in 2012. A 50% traffic increment per year is assumed. The ML nodes are composed by packet and optical layer (Fig. 2b). The node architectures used are based on the model defined in STRONGEST project [2], where different vendors have agreed on a generic node architecture for the packet and optical layer. The packet layer is based on IP/MPLS routers. The routers are based on a 16 slots line-card shelf with a capacity of 140 Gbit/s per slot (Fig. 2b). The router can be deployed in a single-chassis configuration with one line-card shelf or in a multi-chassis configuration. Traffic cards can accommodate up to 14 10 Gb Ethernet ports. Colored long reach tunable DWDM XFP are directly plugged in the line cards and interconnected to the DWDM system avoiding the need for dedicated transponders .The optical nodes are Reconfigurable Optical Add-Drop Modules (ROADM) based on WSS technology. Two different kinds of WSS have been taken into account 1x9 WSS and 1x20 WSS. Those allow to build a multi-degree ROADMs with a number of way respectively up to 8 and 19.Fig. 2bshows the ROADMs architecture. It is composed by a WSS module and a different Add-Drop (A/D) section for each way. The A/D sections are composed by 48 channels AWG Mux/DeMuxand an inter-leaver that allows having a system with up 96 channels. Such ROADM architecture is the currently deployed in production network, with direction-bound color-bound Add/Drop sections. This means that the optical layer is not fully flexible and to allow a change in the color or in the direction of the transponders a manual intervention is needed. In future work we will take into account CDC ROADMs architectures.

3.Simulation Results

In order to evaluate the savings in terms of capital expenditure at design phase allowed by the Integrated Solution we have compared the total network cost in three different dimensioning approaches considering: a) traditional Single Layer (SL) Procedure; b) static ML optimization of the VNT exploiting optical bypass; c) the Integrated MP and CP solution using Correlated Protection. Case a) is used as benchmark and represents the dimensioning used in today backbone network known in literature as A/B-Plane Design. In such kind of design node redundancy is provided at IP/MPLS Level exploiting two disjoint topologies while link redundancy is provided by 1+1 protected optical links. Case b), denoted as Multilayer Design (ML), and adopts ML-PCE for planning without relying on CP. The VNT is traffic driven by our Multilayer Heuristics procedure that maximize the optical bypass and minimize the number of transponders by joint performing Grooming, Routing, Wavelength Assignment and Impairment Validation. Resiliency is still based on 1+1 link protection and on packet topology duplication. Finally case c) is based on Multilayer with Correlate Protection (ML-CP) dimensioning procedure that relies on the use of the “hybrid PCE” that guaranteesE2E path protection and dynamic restoration capabilities. It ensures two fully disjoint paths for each demand and allows saving in terms of required hardware providing the same level of resiliency.

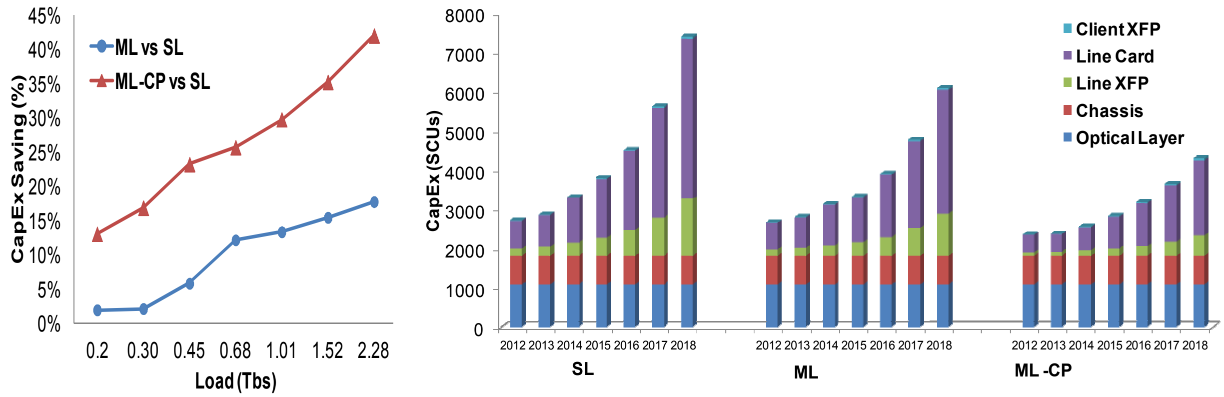


Figure 3.CapEx Saving percentage (a) and total cost per component for each design procedure (b).

A ML design heuristic that take into account the potentiality of such new architecture has been developed based on the ML-PCE presented in [3] The Heuristic takes as input the traffic matrix and the physical topology and as output gives the routed path for each traffic demand, the network dimensioning with the detailed node configuration and the Bill of Material (BOM) as number of shelves, line cards and transponders needed in each node to satisfy such traffic matrix and the related network cost. The heuristic maximizes the network offload but reducing the total cost of the network. To accomplish this, a sorting of the traffic matrix is done to evaluate a set of Candidate Lightpaths (LPs). From Candidate LPs, the VNT with the minimum set of lightpaths that guarantees the connectivity of the nodes is selected and are evaluated the number of transponders needed and route the traffic matrix. The PCE operates then on a transformed topology that allows jointly performing Grooming, Routing, Wavelength Assignment and Impairment Validation. In case of wavelength blocking, regenerators will be placed in order to accommodate all the traffic. While a blocked request exists the VNT will be re-evaluated by expanding the number of selected LPs from Candidate LPs.

In order to provide a fair cost evaluation we took as reference the ML cost model developed in the STRONGEST project [2]. We report in Fig. 1c the main cost figures elements used. Figure 3a reports CapEx savings of ML and ML-CP design procedures with respect to the SL one. It's worth noting that ML-CP outperforms ML by providing much higher savings (13% to 42% in ML-CP, 2% to 18% in ML). In fact ML-CP, relying on the Hybrid PCE architecture that takes advantages of the potentiality of intra-layer coordination allowed by CP and MP integration reduces the resource overbuilding proving E2E protected path without 1+1 duplication for each optical link. Thanks to this CP and MP integration, Hybrid-PCE achieves 24% savings in comparison with standard ML optimization. Finally, Figure 3b reports the total network cost per component versus the reference year for the three different design procedures. It is interesting to notice how as the traffic increases the cost becomes dominated by the line card cost (purple columns) and that ML-CP procedure minimizes such CapEx increase.

4. Acknowledgment

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