Cost evaluation of the integration of IP/MPLS and WDM elements

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Abstract: Multi-layer integration is an important trend in the telecom industry as a cost-efficient alternative. From an incremental CapEx analysis, we aim to quantify the maximum cost savings that could be achieved by such integration.
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1. Introduction

Operators are migrating their core networks to an IP/MPLS over WSON architecture for scalability and granularity issues and to reduce the overhead of legacy architectures like SDH while providing the same services to the end users [1]. In this scenario, operators are concerned about the cost per bit in such multi-layer architecture.

Previous work [2] shows that operators can reduce the investment in equipment when efficiently using the information of both layers. With such information, the operator can reduce the transit traffic creating optical by-passes between two end points with a high traffic rate. Industry [3] is proposing the integration of colored transponders in the IP cards or even the integration of the photonic switching matrices in a single IP/MPLS/WSON node. This integration eliminates the necessity of some equipment due to such integration (grey interfaces), but the integrated cards with the colored transponders may be more expensive than the traditional IP cards.

This work analyses such integrated proposal in a realistic network scenario, comparing current separate node architecture with the new integrated solution.

2. Node architecture and network definition

Two multi-layer (ML) node architectures are evaluated in this paper (Fig. 1): (a) separate and (b) integrated. A separate ML node is composed by three levels: (1) IP/MPLS, (2) Transponders and (3) Photonic Switching. Levels 2 and 3 are commonly known as ROADM. The IP/MPLS level has a chassis, the IP/MPLS router line cards (including the forwarding card) with TX/RX Short Reach (SR) transceivers. These transceivers are connected to a transponders chassis (WDM Terminal) with grey interfaces. Such grey interfaces are connected to a colored transponder (i.e. WDM transponder), which transmits in a given wavelength. Once the wavelength is selected, the port is connected to the Optical Cross-Connect module (OXC) which contains the photonic switching matrix and the corresponding WSSs for the tributary side (TS), the optical conditioning (OC) and the line side (LS). A colorless and directionless OXC is assumed. The integrated ML node has the colored interfaces (Long Reach transceivers in the figure) in the IP/MPLS card, so the transponder level is not required. Level 3 elements are the same than the separate node model.

This study uses the Spanish backbone network [4]. This network has 20 ML nodes and 10 ROADMs. The ML nodes (i.e. nodes 4-17, 19, 20, 23, 24, 28 and 29 in [4]) are injecting the IP/MPLS traffic to the backbone network, while the ROADMs are just switching at the optical domain. A static traffic matrix is created aggregating the traffic of the Spanish regional networks with internal data of current traffic.

The cost model for this study is shown in Table 1. The SR transceivers cost (i.e. 0.4, 1 and 3.2 cost units for 40G, 100G and 400G transceivers respectively) is included both in the IP/MPLS line cards and the WDM transponders cost. The cost values are relative to the cost of a 10GbE transponder without transceiver [5]. The OXC cost has been computed according to the following expression: $OXC_{cost} = N\cdot(2\cdot WSS_{1x9} + 2\cdot Amp) + 2\cdot N\cdot AD(20)\cdot WSS_{1x20} + 2\cdot WSS_{9x9}$, being N the degree of the OXC and $AD(20)$ the number of wavelengths to be added/dropped with granularity of 20.

3. Methodology of the study

The goal of the study is to evaluate the yearly Capital Investments (CapEx) needed in the evolution of an already deployed IP backbone with a Photonic Switching infrastructure with two different strategies. In the first strategy the network keeps growing following the separate model. In the second one, an integrated approach is followed and only integrated cards are deployed. The reference point of the study (named as year 1) is the dimensioning of the Spanish backbone (both IP and Photonic Switching nodes) with a total traffic matrix of 1.4 Tbps obtained from internal Telefónica data. For the following periods of analysis, a traffic growth of 50% per year has been assumed.

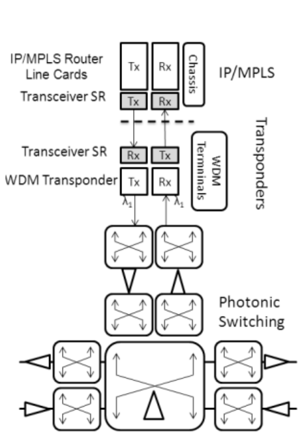


Fig. 1a. Separate architecture

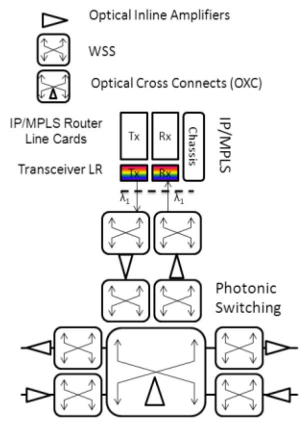


Fig. 1b. Integrated architecture

Table 1. Relative cost of the components [5]

		Slots/ Ports	Relative Cost
IP/MPLS line cards 40GbE		10	35.98
IP/MPLS line cards 100GbE		4	40
IP/MPLS line cards 400GbE		1	37.48
IP single chassis		16	53.79
IP multi-chassis		32	285.92
WDM Transponder 40Gbps		1	6.4
WDM Transponder 100Gbps		1	16
WDM Transponder 400Gbps		1	20.2
WDM terminal (chassis)		40	3.4
Photonic Switch.	WSS_{1x20} - TS	20	6
	WSS_{9x9} - OC	9	48
	WSS_{1x9} - LS	9	4
	Amplification (Amp)		0.8

For each period of study, the full IP demand is routed through the IP backbone using a shortest path technique. As a result, the traffic load per each IP link is obtained. This load per link is carried with a set of lightpaths. Three mechanisms have been considered to map each link load into a set of lightpath demands to the Photonic Switching layer: i) **Same capacity (sameC)**: All lightpaths have the same speed (40Gbps, 100Gbps or 400Gbps); ii) **Max capacity (maxC)** maximizes the total lightpath utilization in terms of capacity and, in case that several combinations maximize the total capacity utilization, the combination that minimizes the number of requested lambdas is selected; iii) **Min lambdas (minL)** minimizes the total number of lightpaths. This way, the dimensioning of both the IP and the optical layers is achieved per period of study. For each network growth strategy (using a separate architecture as in Fig. 1a or following an integrated approach as in Fig. 1b) the total cost of the network nodes is computed using the cost model shown in Table 1. It is worth to mention that the switching nodes (i.e. ROADMs) only contain the Photonic Switching components (see Fig. 1), which are common for both the separate and integrated architectures (i.e. they have the same cost).

4. Numerical results

As the integrated cards are not a mature technology, its price is uncertain at the time of writing. For the numerical results, a sweep across a range of prices is done. The initial case for the simulations is the case where the integrated card cost is the price of the IP/MPLS card without SR (or gray) interfaces. We consider this point as the CR (Cost Relation) equal to 1. Specifically, the starting prices for the integrated cards are 31.98, 36 and 34.28 cost units (including the forwarding card) for 10x40G, 4x100G and 1x400G, respectively. Let us remark that this starting point is a lower cost threshold, because we are considering that integration would lead from the cost of an IP/MPLS card, two SR interfaces and a WDM transponder in the separate node to the cost of an IP/MPLS card in the integrated model. In order to find a less optimistic scenario, a cost relation of 1.15 and 1.3 (i.e. a cost increment of 15% and 30%, respectively, with respect to CR=1) for the integrated cards are assumed. Here, the results for CR=1.15 are not shown by lack of space.

We have carried out two similar analyses but from a different point of view. First, the total network cost is calculated for both node models considering increasing traffic matrices. These results show the yearly capital investments and cost savings in the Spanish backbone network, if an operator adopts an integrated model for all the nodes. Fig. 2 shows the CapEx investment in the core transport network for the two node models (relative units), all algorithms and CR=1 using the cost model of Table 1. As the price of the integrated solution is cheaper than the price of the IP/MPLS cards without gray interfaces, the separate node (dashed lines) is more expensive than the integrated node (solid lines).

The algorithm that achieves the lowest investment in network elements is the sameC 40-Gbit/s algorithm (Fig. 2). The reason is that the price per Gbit/s is cheaper in the 40-Gbit/s technology than in the 100-Gbit/s or 400-Gbit/s technology in STRONGEST CapEx model [5]. The cost of the network with minL and maxC algorithms lie within the envelope of the sameC 40-Gbit/s and 400-Gbit/s curves. The latter is the most expensive solution because the 400G ports are inefficiently filled, due to their coarse granularity. Fig. 3 depicts the CapEx savings comparing the separate and the integrated node. In light of the results, the algorithms which achieve the greatest savings are sameC 100-Gbit/s and sameC 40-Gbit/s algorithms. Although sameC 100Gbit/s algorithm achieves the highest savings, it is

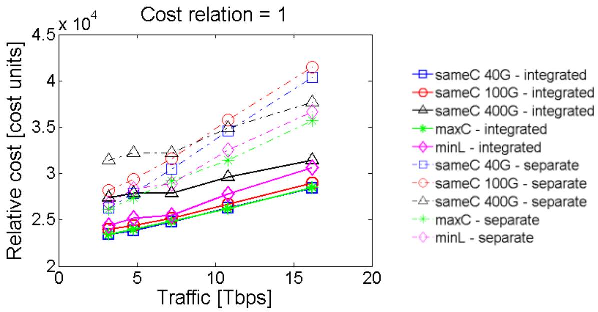
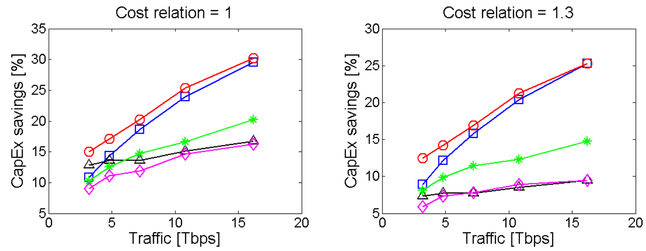


Fig. 2. Relative cost of the integrated (solid lines) and separate (dash lines) node solutions. Cost values 2014 (CR=1)



a) CR=1 b) CR=1.3

Fig. 3. CapEx savings of the integrated model. Cost values 2014

more expensive than sameC 40-Gbit/s (Fig. 2). So, the best algorithm is the sameC 40-Gbit/s which results in savings of up 30% (CR=1) and 25% (CR=1.3) for a traffic matrix of 16.2 Tbps (expected traffic in 2018).

For the second study, an incremental cost analysis is performed for CR=1 (Fig. 4) and CR=1.3 (Fig. 5) just focusing on IP/MPLS line cards, WDM transponders and WDM terminals. The sameC 40-Gbit/s algorithm is used since it achieves the best results. We have computed the required investment and the cost distribution per element (left y-axis) by both solutions with respect to the cost of these components in the year 1 (i.e. 1.4 Tbps) and the associated cost savings (right y-axis) taking the total cost of the separate solution in year 1 as reference.

The proposed integration could lead to cost savings around 40% for CR=1 (Fig. 4) and 35% for CR=1.3 (Fig. 5) for a traffic matrix of 16.2 Tbps (i.e. year 7 in our analysis). Let us remark that these savings are related just to the investment of IP/MPLS line cards, WDM transponders and WDM terminals.

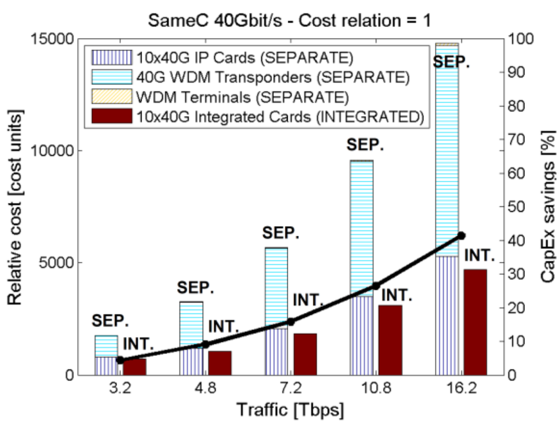


Fig. 4. Incremental CapEx analysis of the separate and the integrated model with respect to 2012 (CR = 1)

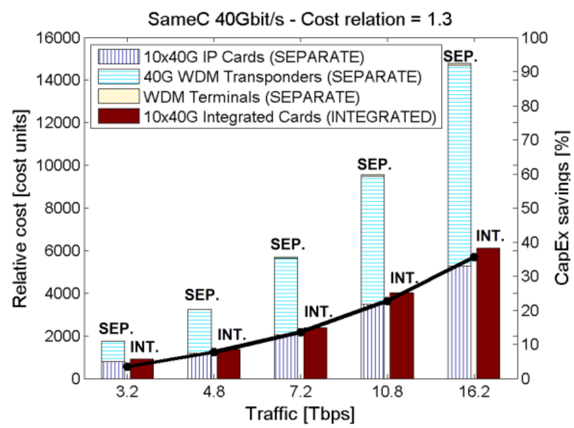


Fig. 5. Incremental CapEx analysis of the separate and the integrated model with respect to 2012 (CR = 1.3)

5. Conclusions

The integration of colored transponders in the IP cards could lead to CapEx reduction up to 40% if such integrated transponders have a similar price (or, at most, a 30% increase) than separated components. This study does not consider other cost related to the integration, such as organizational changes or multi-layer control plane coordination which are mandatory for this evolution. Finally, let us remark that these integrated transponders must be interoperable at the optical domain in multi-vendor scenario to motivate its deployment.

6. Acknowledgements

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