Elastic Optical Networking: An Operators Perspective

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Abstract *Although there is perhaps an acceptance that EON has benefits, there is a debate about whether a full flexgrid implementation is required to achieve those benefits. Current industry debate addressed in this paper relates to when is the most appropriate time for carriers to: (a) install flexgrid ready components, and (b) enable them and start using the technology.*

Introduction

The key flexgrid components are the liquid-crystal on silicon (LCoS) based wavelength selective switches (WSS's), which allow arbitrary spectrum demarcation, although they can be readily used in fixed grid mode, and the flexgrid capability can be software enabled (and paid for!) at a later date, when required. This is a useful alternative for carriers, who might only refresh their main transmission infrastructure every few years.

An alternative strategy is to continue with a fixed grid 50 GHz solution but use mixed line rates and higher modulation formats to carry demands. For high rates of 400 Gb/s and above, the fixed grid option requires the use of inverse multiplexing, in which the total rate is split into smaller chunks. For example, 400 Gb/s could be transmitted as 100 Gb/s, DP-QPSK in four, not necessarily adjacent fixed grid spectrum slots.

Rationale Behind Flexgrid WSS

It is commonly accepted though, that eliminating the arbitrary 50 GHz boundaries, allow a more efficient use of spectrum, and this results in an increase in network capacity. According to simulation studies shown in Figure 2 done over Telefonica network in Spain (Figure 1), fixed grid upgrades are required in 2019, whereas flexgrid can support traffic growth until 2024.

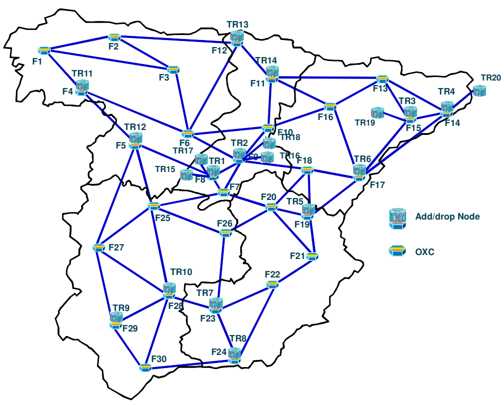

Fig. 1: Reference network based on Spanish national backbone

If current fixed grid networks have sufficient capacity until 2019, this suggests that although flexgrid is seen to have significant advantages, there isn't an immediate need for it, and so flexgrid ready components could be installed when carriers next refresh their DWDM capability.

On the other hand, the limitation on the maximum capacity which is able to be carried in a single lambda causes a dramatic increase in 100 Gbps optical channels in case the network grows following a WSON model. If the network is migrated to flexi-grid, the number of transponders is reduced.

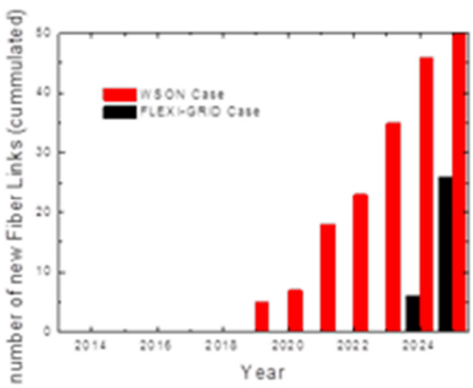

Fig. 2: Number of new Fiber Links WSON vs. flexgrid evolution models in Telefonica Spain reference network

Elastic transponders

Together with Flex WSS, the new concept of BVT (Bandwidth Variable Transponder) could considerably changing the landscape of optical networks. A BVT is capable to support multiple bit-rates and/or modulation formats so that the generated optical signals can be tailored, on-demand, according to the different bandwidth requirements depending on the selected rate, modulation format, path length, and required BER performance. A BVT will support super-channel by generating multiple sub-carriers. Furthermore, network flexibility could be significantly increased by adding multiflow capabilities to BVT according to a Sliceable-BVT (S-BVT) approach so that a single transponder could be used for multiple traffic flows to different destinations.

According to the simulation results done over Telefonica core network, S-BVTs could generate significant savings in terms of transponders and IP ports consumption. The number of cards is computed for each scenario with non-sliceable transponders and SBVT.

Figure 3 and Figure 4 presents percentage of total savings in the IP and optical layers. To allow the flexibility in the SBVT, an Ethernet switch is added in the architecture. To obtain the cost of the Ethernet ports, we have obtained the relation of an Ethernet port and an IP card in [5] and we have calculated its value in the relative cost unit of [4]. In light of the results, we can claim that the addition of SBVTs can achieve around 30% savings for the investment in the IP/MPLS cards and optical transponders, when using 400Gbps SBVTs.

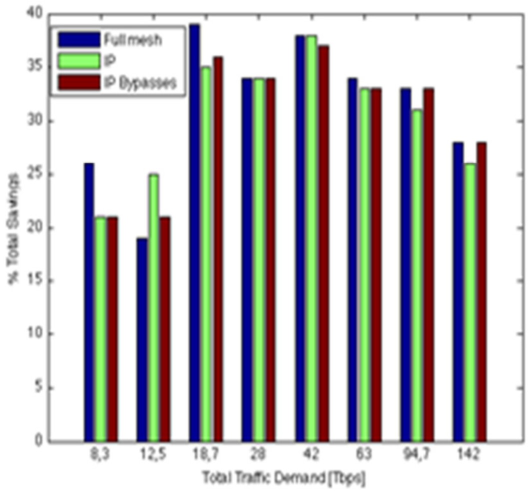

Fig. 3: Percentage of total savings by using SBVTs 400Gb/s versus non-sliceable transponders.

When the capacity of the SBVTs is 1Tbps, this savings are even higher reaching 35%.

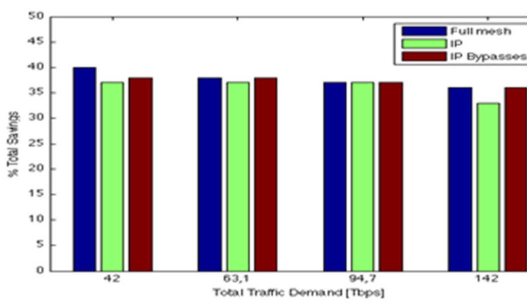

Fig. 4: Percentage of total savings by using SBVTs 1Tb/s versus non-sliceable transponders

Furthermore, as represented in Figure 5, S-BVTs can save large amounts of transponders compared to fixed BVTs. This plots the number of transponders vs the number of transmit routers for a 4.2Tb/s Telefonica future core network and where the parameter 'f' determines the number of slices from a single S-BVT.

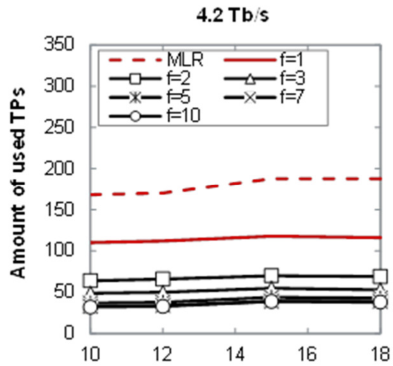

Fig. 5: S-BVT savings on transponders in Telefonica reference core network

Elastic data center interconnection

Transponders capacity is underutilized due to traffic fluctuations along the day. Free capacity could be utilized to supply deterministic traffic (e.g., updates, backup…) between data centers.

The user traffic fluctuation is known. The behavior of this traffic is characterized in Figure 6.

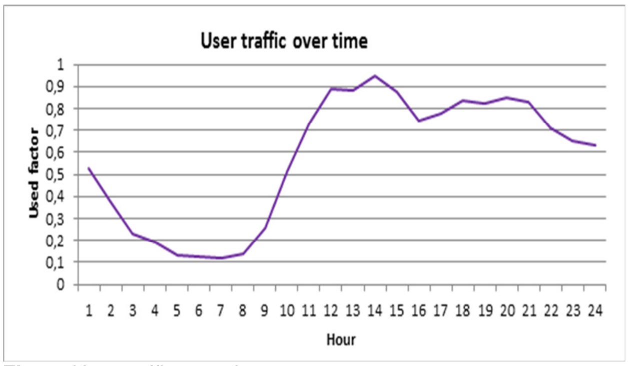

Fig. 6: User traffic over time

Two different scenarios for data center interconnection are considered. The first scenario is based on 400 Gb/s SBVTs with granularity equals to 40 Gb/s (10 carriers per transponders) over time. The second scenario makes use of fixed transponders with 40 Gb/s, 100 Gb/s and 400 Gb/s of capacity. According to the simulations results shown in Figure 7 done over Telefonica reference Network (Figure 1), SBVT based transport networks can provide more free capacity than traditional DWDM networks for inter datacenter deterministic traffic.

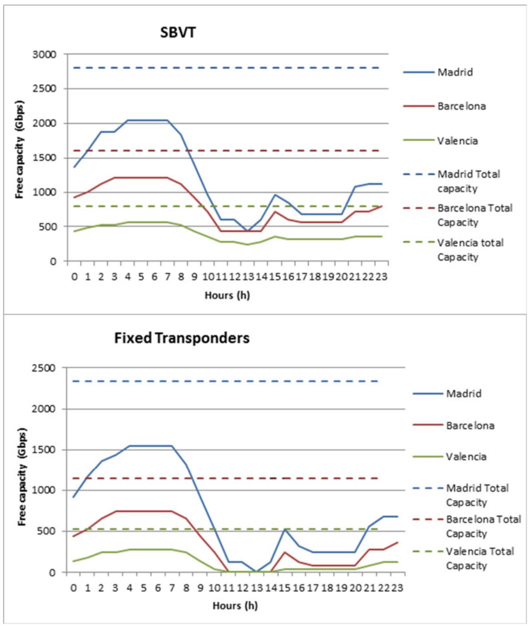

Fig. 5: Free transport capacity to for data centers deterministic traffic.

Besides in SBVT case it is possible to use free capacity even when the user traffic is maximum which happens between 10 and 15 hours, meanwhile traditional transponders have not free capacity in this time interval.

The discontinuous lines mark the total capacity in each datacenter meanwhile the continuous ones indicate the free capacity which can be used for data centers traffic exchange along the hours of the day. The area between the total capacity and free capacity is the capacity used for users' Internet traffic.

Conclusions

The study has compared the evolution of a national level optical transport network based on the current Fixed grid WSON approach and the newly proposed Flexi-grid approach. The results show that a network based on Flexgrid could extends the lifetime of the network 5 years with respect the legacy WSON. Results also show that current WSON capacity will not be exhausted until 2019. Even though in the next years capacity in terms of spectrum is not yet an issue, and thus migrating to flexi-grid just because of the lack of spectrum makes is not urgent, a key driver to migrate to flexi-grid is the demand of high speed channels and the availability of cost effective 400Gbs and 1Tbps transponders

SBVT enables transmitting from one point to multiple destinations, changing the traffic rate to each destination and the number of destinations on demand. Although there are not commercial implementations, there are some architecture proposals, which shows its feasibility.

In this paper we present results of the target cost of 400 Gb/s and 1 Tb/s Sliceable Bandwidth Variable Transponders to reduce in a 30% transponders cost in a core network scenario. In light of the results, savings of 30% in transponder cost are possible using 400Gb/s and 1Tb/s interfaces. We assume that operators would like to migrate their infrastructure to use SBVTs, if 30% savings are possible as demonstrated with the target cost estimations for SBVTs done in this work.

SBVT could also provide some capacity optimization for data center interconnection. It is possible to take advantage of S-BVTs deployed for user traffic in order to supply deterministic traffic between data centers when user traffic volume is lower. Moreover, on the basis of the results obtained it is possible to conclude that SBVTs offer more free capacity to data centers traffic than traditional fixed transponders.

Acknowledgements

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References

[1] C. Mas, "Expenditures Study for Network Operators," in Transparent Optical Networks, Nottingham, England, 2006.

[2] M. Pióro and D. Medhi, Routing, Flow and Capacity Design in Communication and Computer Networks, Morgan Kaufmann, 2004.

[3] D. FP7-STRONGEST project, Efficient and optimized network architecture: Requirements and reference scenarios", Available at http://www.ict-strongest.eu.

[4] F. Rambach, B. Konrad, L. Dembeck, U. Gebhard, M. Gunkel, M. S. L. Quagliotti and V. Lopez, "A multilayer cost model for metro/core networks," IEEE/OSA Journal of Optical Communications and Networking, vol. 5, no. 3, pp. 210-225, March 2013.

[5] R. Huelsermann, M. Gunkel, C. Meusburger and D. A. Schupke, "Cost modeling and evaluation of capital expenditures in optical multilayer networks," Journal of Optical Communications and Networking, vol. 7, no. 9, p. 814–883, Sept. 2008.

[6] V. López, B. de la Cruz, O. González de Dios, O. Gerstel, N. Amaya, G. Zervas, D. Simeonidou and J. Fernandez-Palacios, "Finding the Target Cost for Sliceable Bandwidth Variable Transponders," Journal of Optical Communications and Networking, vol. 6, no. 5, pp. 476-485, 2014.