‘10Gb/s-40Gb/s Synergy’ Routing to Better Exploit Network Capacity

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Abstract. *We introduce a new routing method, 10-40 Gb/s synergy, that reduces the blocking probability of at least 15% against classical routing with both bit-rates. The transmission estimator enables better performance.*

Introduction

Current WDM transmission systems and optical switches make possible the transparent domain where optical paths can have many nodes and span thousands kilometres before detection. The major interest of transparent networks is twofold: the reduction of systematic optoelectronic (OEO) conversion in network nodes and also the ability to transport any type of channel with the same infrastructure whatever its modulation scheme and/or its modulation rate. Most deployed networks are designed to support 10 Gb/s transmission. On this infrastructure, operators will gradually introduce transponders (TSP) operating at 40 Gb/s to meet the increasing traffic requirement. So, the coexistence of channels with different bit rates is a hot topic for current network implementation.

Based on this observation, we propose to study *10-40 Gb/s synergy*. Previous publications have already demonstrated the reduction of blocking ratio by using these two bit rates simultaneously [1]. They supposed to have a traffic matrix per bit rate. Our study differs since we suppose to have only one traffic matrix and we show that the possibility to transmit a connection alternately on different bit rates according to the transmission performance can provide better resource exploitation. Further, we demonstrate the impact of the type of used physical impairment estimator on the required OEO devices.

Description of *10-40 Gb/s synergy*

As shown in [2], in the backbone network, 40% of the connections occurs between adjacent nodes. We assume this trend is likely to remain during the forthcoming years. Because of the reduced reach of the 40 Gb/s transmissions as compared to the 10 Gb/s ones, we consider the 40 Gb/s transmission technology for the connections between adjacent nodes, which are quite short [3].

A 40 Gb/s channel is the aggregation of up to four 10 Gb/s channels. *Synergy* consists in using available capacity on 40 Gb/s channels to transport a part of the 10 Gb/s connections that cannot reach destination transparently because of physical impairments or wavelength contention.

In figure 1 we present a schematic example of 10 Gb/s OEO saving when synergy is performed. A connection at 10 Gb/s between nodes *A-E* requires an OEO conversion in node *D*. In the dashed box we indicate the 40 Gb/s capacity availability on links belonging to *A-E* connection. Different combinations of 10-40 Gb/s transmissions are tested and the one requiring firstly the fewer number of 10 Gb/s TSP and then of 40 Gb/s TSP is chosen. In the depicted example, there are two equivalent solutions.

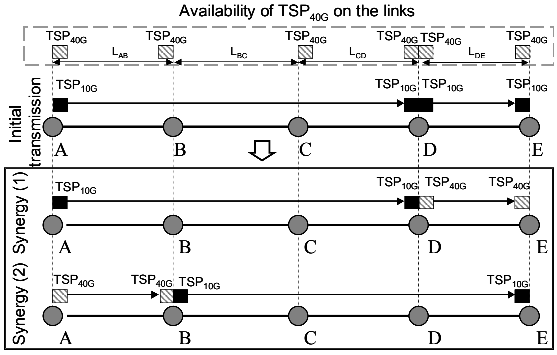

Figure 1: 10 Gb/s TSP savings with synergy.

Network assumptions

Presented results are obtained by dimensioning a European network with characteristics similar to [2]. Channel spacing is 50 GHz independently of the bit rate; NRZ modulation format is chosen for 10 Gb/s, while formats like Phase Shaped Binary Transmission (PSBT) may be adopted for 40 Gb/s.

The traffic matrix has 40% of demands between adjacent nodes (1 hop), 40% with maximum of 4 hops and remaining demands with more hops. Traffic matrices with different loads are considered, ranging from 500 to 1500 demands; they are not correlated, that is demands belonging to the matrix with load ‘*x-1*’ are not all present in the matrix with load ‘*x*’. Chosen loads require a network capacity greater than the one offered when only 10 Gb/s TSPs are installed, to justify the need of higher bit rate TSPs. When a 40 Gb/s channel is installed it takes the place of a 10 Gb/s one and we assume that the number of available 40 Gb/s channels is the same on all links.

Fibers contain up to 80 WDM channels.

Results and analysis

Firstly adjacent demands are routed, filling 40 Gb/s channels. If no more capacity on the 40 Gb/s TSPs is available, remaining demands are transported on 10 Gb/s. Then the 10 Gb/s routing is performed.

Figure 2 depicts the evolution of blocking probability when introducing 40 Gb/s TSPs with and without synergy. These results are related to the

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characteristics of considered traffic matrices. Continuous line represents the scenario where only 10 Gb/s TSPs are installed (reference); empty symbols stand for results without synergy when only five and ten TSPs at 40 Gb/s are available on each link. In this case, the increase of TSP bit rate induces an increase of capacity only for adjacent connections, while for longer ones it yields a reduction as they are transported on 10 Gb/s channels, which number decreases with the 40 Gb/s channel increase. This explains the raise of blocking probability with the increase of 40 Gb/s TSPs. For low traffic, the introduced 40 Gb/s TSPs give more capacity for adjacent demands than required. Comparing total blocking probability with the reference case, we observe a greater blocking because in no-synergy case there are more blocked non-adjacent demands than additional routed adjacent compared to the reference. Increasing the load, the 40 Gb/s capacity is better filled, and this trend turns over. Considering synergy scenario with five and ten 40 Gb/s TSPs, the increase of the whole capacity is proportional to the number of 40 Gb/s TSPs as all the connections, adjacent and not, can use them. This explains the lower blocking for all traffic loads as compared to both the reference and no synergy. We conclude that the introduction of 40Gb/s channels performs better with synergy.

Advantages related to performance estimator

[4] shows the interests of fine performance estimators (Quality of Transmission estimator, QoT) compared to rougher ones (e.g., Maximum Reach, MR). Their main difference is the wavelength performance discrimination. Using the physical assumptions as in [4], the system MR is 2500 km.

Now we investigate the interest of the QoT estimator in a synergy context. As the main difference between the dimensioning with MR and QoT estimators is the total number of required regenerators (available fiber capacity is estimator independent, so blocking probability is the same in both cases), we depict in figure 3 just the difference of required 10 Gb/s TSP normalized by MR values. Fluctuations are related to the traffic matrices decorrelation between different loads. The required 40 Gb/s TSP number is unchanged. Positive values mean that 10 Gb/s TSPs are more numerous when MR is performed. We observe that for most cases, the use of QoT enables a reduction on the number of 10 Gb/s TSPs.

Conclusions

The introduction of 40 Gb/s channel capacity automatically increases the link capacity and reduces blocking probability. In this paper we propose a new method to consider the gradual introduction of 40 Gb/s channels. Our approach considered the synergy between 10 and 40 Gb/s devices in transparent networks. Hence, we propose to transmit the demand on 10 Gb/s and pass to 40 Gb/s if regeneration is required and if the capacity is available on a 40 Gb/s transponder. The proposed synergy enables a reduction of blocking probability compared to the absence of 40 Gb/s devices of at least 30% and 50% for the availability of five and ten 40 Gb/s TSPs, respectively. This reduction is of 15% and 40% when compared to no synergy case. A further conclusion of this paper is that for various optical network scenarii featuring 40 Gb/s transmission resources, the QoT estimator of connection feasibility is helpful to optimize the global resource utilization.

References

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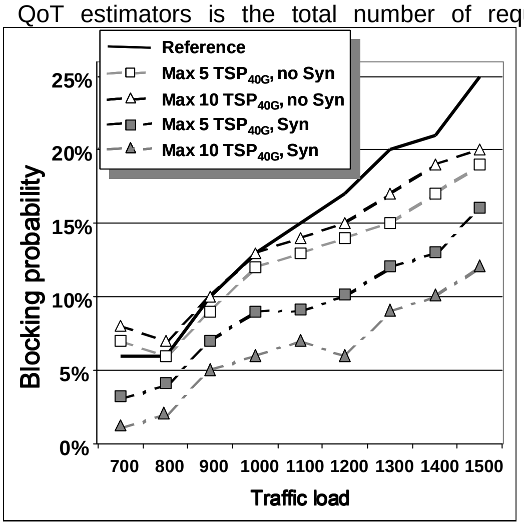

Figure 2: Blocking probability comparison with only 0, 5 and 10 TSPs at 40 Gb/s installed, w/wo synergy.

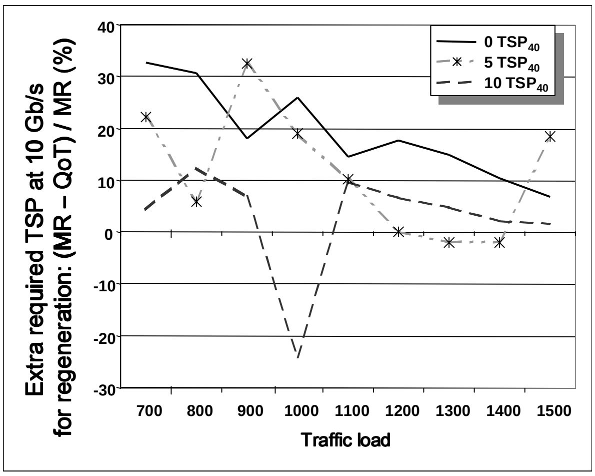

Figure 3: Comparison of the number of savings on 10 Gb/s TSPs required by QoT and MR estimators.