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Assessment of Economical Interest of Transparent Switching

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Abstract This paper evaluates the node cost reduction expected from introducing transparent switching into a pan-European network. The cost reduction is given as a function of the OXC/PXC cost ratio and the Maximum Transparency Length.

Introduction

In this paper, we evaluate the node cost reduction resulting from the introduction of transparent switching of wavelengths into a reference pan-European network and the expected traffic demand for the year 2005 [1,2]. The considered network is shown in Figure 1, and has link lengths between 250 and 1500 km.

Figure 1: pan-European Network

We examined this topology using two different node architectures. The first node architecture consists of a single opaque optical cross-connect (OXC). The network with all nodes of this type will be referred to as the *opaque network*. The second node architecture is an opaque OXC on top of a transparent photonic cross-connect (PXC). We will refer to this solution as the *hybrid network*.

In a network of the considered size we need to keep in mind that the light signal degrades due to nonlinear effects such as chromatic dispersion (CD) and polarisation mode dispersion (PMD) and needs 3R-regeneration (re-shaping, re-amplification, re-timing). The maximum distance light can travel without needing 3R is referred to as the *maximum transparency length (MTL)*. This MTL is dependent on the type of the optical fibre, the channel spacing, the bit rate of the signal and on some other physical design features. Today, on a typical 40 channel WDM

system with 10 Gbps per wavelength, a MTL of 1100 to 2800 km is possible [3], so that we can switch some wavelengths transparently through the PXC, and we will need some OXC ports to regenerate the wavelengths that need 3R. Since the price of a PXC will typically be lower than the price of an equally sized OXC, we can expect a change in the total node cost of a network when it is useful to introduce photonic switching.

Methodology and cost model

Precisely stated, the case study we performed comprised of the dimensioning of the reference network using a simulation tool [4], for the two considered node architectures. Several different MTL values were taken as an input, for the same traffic matrix. This yielded values for the number of opaque and transparent ports needed in every node. From these values, we suggested a linear or quadratic cost function for the price of the considered cross-connect, which leads to the following function for the cost of a PXC:

$$p^{\alpha}$$

The cost of an OXC is considered to be

$$bp^{\beta}$$

In these formulas, p represents the number of incoming ports, α and β can either be 1 or 2, and b is a parameter representing the OXC / PXC cost ratio. As there is no reason to think that an OXC and a PXC should depend differently on the number of ports, we only consider $\alpha = \beta$.

Figure 2: Opaque Node

Figure 3: Hybrid Node

In the opaque network case, all nodes consist of an OXC (see Figure 2), so the total network node cost becomes:

$$b \sum_i p_i^\alpha$$

For the hybrid network, it is a bit more difficult to determine the total node cost. When there are p wavelengths to be switched, and, say, P that need regeneration, the number of incoming (bidirectional) ports to the OXC is P , and the number of incoming (bidirectional) ports in the PXC is $p + P$. The latter is due to the fact that the P regenerated wavelengths pass the PXC twice. The total hybrid network node cost as a function of the ports thus becomes:

$$b \sum_i P_i^\alpha + \sum_i (p_i + P_i)^\alpha$$

Keeping the above calculations in mind, the total node cost ratio of the hybrid network versus the opaque network depends on the parameters b and α as shown in the formula below:

$$\frac{b \sum_i P_i^\alpha + \sum_i (p_i + P_i)^\alpha}{b \sum_i p_i^\alpha}$$

Note that we only considered the node cost of the network, because the link cost is equal in all cases, as long as the MTL is equal. This effect can be explained because, in the considered dimensioning tool, the optical links are dimensioned before any traffic is routed.

Simulation results

With a shrinking network diameter, or equivalently, a growing maximum transparency length, we expect the number of wavelengths that can be routed transparently in a certain node to increase and thus the hybrid solution to become more feasible. shows the total node cost ratio between the opaque and the hybrid solution for $\alpha = 1$ as a function of b for several MTL values. It can be noticed that the OXC / PXC cost ratio b to have a status quo in the network node cost decreases with increasing MTL.

Furthermore, when the MTL is smaller than the shortest two-hop route in the network (in our case around 500 km) the factor b becomes infinite due to the fact that no transparent routing is possible. The hybrid solution is economically infeasible, no matter how little the cost of an OXC.

It also shows that the profit that can be made flattens out with respect to the b value. This is expected, as the maximum profit that can be made is when every wavelength can be switched optically, thus when the network evolves to a fully transparent network. In this optimum case the node cost with respect to the node cost of a fully opaque network is $1/b$, which is indeed hyperbolic in nature (with respect to b), and

independent of α .

Figure 4: Normalized node cost vs. OXC / PXC ratio (b)

Conclusions

It can be deduced from the results shown in that in order to obtain a significant cost reduction (say, better than 15%) on the considered pan-European network with the introduction of transparent switching, two conditions should be fulfilled. First, the used fibres should support a transparent length of at least 1800 km. This excludes the networks based on large effective area fibre (with a transparent length limited to about 1300 km), but is compatible with SMF fibres (typical transparent length between 1800 and 2800 km) [3]. Second, the cost ratio between an opaque and a transparent switching matrix of at least 5 is required. This value should give a target for system designers. Moreover, for maximum transparency lengths of practical interest, the network cost reduction appears to have a maximum bound of 30%, even when the cost ratio is further increased. It has to be noted that to complete this study, the dependance of the transmission cost on the MTL should be taken into account.

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