Techno-economical optimizations in optical backbone networks

K. Casier, S. Verbrugge, L. Depré, P. Audenaert, D. Colle, M. Pickavet, P. Demeester

Supervisor(s): D. Colle, M. Pickavet

Abstract When planning how to roll out a new network or extend an existing one, the operator has several possibilities for minimizing the costs. A first approach is to optimize the introduction time of new switching equipment (e.g., OXC) in the network, considering the estimated traffic-growth and evolution of the equipment-cost. We study the costs of a network-wide migration of introducing OXCs at a single point in time, as well as a so-called island-based migration in which the OXCs are introduced gradually. Another approach is to find the most economical way to realize the bandwidth in the network. There is the possibility to lease dark fiber on a per year basis or to acquire fiber via an IRU (Indefeasible Right of Use) for a longer period. We compare the total cost for dark fiber with the cost for leased wavelengths. In the case-studies, we use a planning period of multiple years.

Keywords techno-economical evaluation, OXC, dark fiber

I. INTRODUCTION

During the past years the internet traffic has known an important growth, which is still going on [1]. For an operator it is a challenge to handle this increasing traffic in the most cost-effective manner. In order to make well-considered decisions, long-term network planning and techno-economical evaluation of the various alternative solutions are necessary.

In the current optical backbone networks, the wavelength division multiplexing (WDM) technique has opened vast amounts of bandwidth. Switching all traffic on the IP-layer places a considerable burden on the IP-routers, leading to increasing costs for this IP-layer. Optical cross-connects (OXCs) enable the switching of huge amounts of traffic on the optical layer and reduce the IP-layer costs. However since OXCs are still very expensive today, it will be important to find the optimal introduction time. The operator also has several possibilities for realizing the necessary bandwidth over the network. The bandwidth can be provided by leasing dark fibers or leasing wavelengths. As an alternative to leasing dark fiber, an Indefeasible Right of Use (IRU) for a longer time period can be negotiated.

Section II studies the costs of introducing OXCs in the network and proposes an optimized migration path for introducing these OXCs.

Section III studies the costs of several alternatives for providing the bandwidth in the network.

II. INTRODUCING OXCS

A. Link-by-link versus end-to-end grooming

In the traditional link-by-link grooming approach, all traffic is switched in the IP-routers and wavelengths are filled as efficiently as possible. This saves in the amount of wavelengths used in the network, but requires more interface cards in the IP-layer. In the end-to-end grooming approach, a wavelength is dedicated to traffic originating from a single source-destination pair. This allows to bypass the IP-routers optically, but with a less efficiently used optical line capacity. End-to-end grooming is only possible if OXCs are present in the network.

In case of low traffic volume, the link-by-link grooming approach results in a more cost-efficient solution. At a certain traffic volume, the expenses of introducing OXCs in the network are compensated by the expenses in the IP-layer when using the link-by-link grooming approach. For an even larger traffic volume, the end-to-end grooming approach results in a more cost-efficient solution.

B. Migration paths

Network expansion is a typical dynamic and uncertain problem. Both the traffic over the network and the costs of the equipment are varying in time. Within our simulations we used a traffic as estimated by the forecast models first proposed by Vaughn and Wagner [2] (annual growth of 10% for voice traffic, 34% for transaction data traffic and 100% for IP traffic). We used the cost figures (decreasing over time) suggested by [3] and used the realistic backbone topologies as defined by [4].

We have identified the following migration paths towards OXC-introduction:
- Network-wide migration in which the OXCs are introduced at a certain point in time and end-to-end grooming is used from this point onwards.
- Island-based migration in which the OXCs are introduced gradually in the network. If a certain node gets too heavily loaded, we install an OXC in that node and it becomes an end-to-end grooming island.

In Figure 1 we compare the net present value (NPV) of the expenses necessary for the new equipment in these two scenarios to the scenario of not introducing OXCs in the network (link-by-link). We see that, for all considered planning intervals, the island based migration is the most cost-effective solution. A network-wide migration in 2010 is also a better solution than expanding the network using link-by-link grooming. By 2012, network expansion based on link-by-link is even the worst of the considered options.
III. OPTIMIZING BANDWIDTH COSTS

A. Description of the scenarios

We considered the following possible scenarios for realizing the bandwidth in the optical network by lighting up dark fibers:

- Acquire dark fiber for some longer period via an IRU. In this case there is a single upfront payment of the total cost in the first year. Some telecommunication operators additionally charge a smaller yearly fee for the maintenance of the whole cable.

- Lease dark fiber on a per year basis. In this scenario you have to pay a yearly fee for the fiber, including the maintenance for the fiber cable. Some telecommunication operators additionally charge you a one time installation cost in the first year. The yearly fee varies conform the duration of the lease contract (a contract for a longer period will give a lower yearly fee).

If you don’t want to lease a whole fiber and light it up yourself, there is also the possibility to lease some wavelengths. Here you also have to pay a yearly fee. A small installation cost in the first year might also be charged.

B. Comparison of the scenarios

To compare the cost of the different scenarios we considered a small network topology with 15 nodes. We calculated the cumulative cost of the different scenarios for a longer period. The results are shown in Figure 2. As a time period in this figure we chose 15 years as this is the most commonly used time period to have an IRU on dark fiber.

The cost calculations in case of an IRU are based on a contract for 15 years and in case of leased dark fiber and leased wavelengths on a contract for 5 years. The leased wavelength scenario is indicated on the figure with ‘WL’, and is split up in two cost considerations. In the first scenario, we considered only one wavelength (10G) on each link of the network, while in the second scenario we considered 4 wavelengths (4*10G) on each link accommodating larger traffic volumes.

It is clear that if you look at a longer period (more than 5 years) it is more interesting to acquire dark fiber via an IRU. In this scenario you have a big cost in the first year and a small extra cost over the other years. If only a shorter period is considered (4-5 years), leased dark fiber can be more interesting. It can also be an alternative if it is not possible to pay the whole amount of the IRU in the first year.

Leasing wavelengths is clearly the most expensive solution for transporting large traffic volumes, exceeding the cost of an IRU in the second year. Cost figures for this scenario are only given up to year 9, since they become irrelevant high afterwards. Leased wavelengths are only interesting for small amounts of traffic and for a short time-period (7-8 years).

IV. CONCLUSIONS

We have shown that introducing optical crossconnects in all nodes of the network becomes more cost-effective by 2010 considering an annual IP-traffic growth of 100% on a European level. A timely introduction of OXCs (island-based grooming) allows for an even larger cost-reduction and leads to a cheaper overall solution.

We have shown that an IRU on dark fiber is most interesting to realize an optical network, when transporting large amounts of traffic for a long period. Considering shorter periods, leasing dark fiber for transporting large amounts of traffic and leasing wavelengths for transporting a smaller traffic volume are the cheapest solutions.

REFERENCES