MULTI-LAYER NETWORK OPTIMIZATION

A PRAGMATIC APPROACH FOR DELIVERING BETTER QUALITY AT LOWER COST

APPLICATION NOTE

ABSTRACT

Multi-layer IP/optical networks are often under-optimized because the two networks have been built independently. In theory, multi-layer network optimization allows improvement of network quality and addresses the increasingly stringent requirements of transmission networks – such as huge traffic volume, service level agreements (SLAs) and high resiliency – while reducing the cost per transmitted bit. However, having the right features in the products is not enough. Indeed, multi-layer network optimization turns out to be a complex mathematical problem to solve. This paper explains the benefits of multi-layer network optimization. It illustrates through a use case how a pragmatic approach proposed by Alcatel-Lucent Professional Services and powered by Bell Labs algorithms provides a cost- and time-efficient implementation of multi-layer network optimization on a large scale network.

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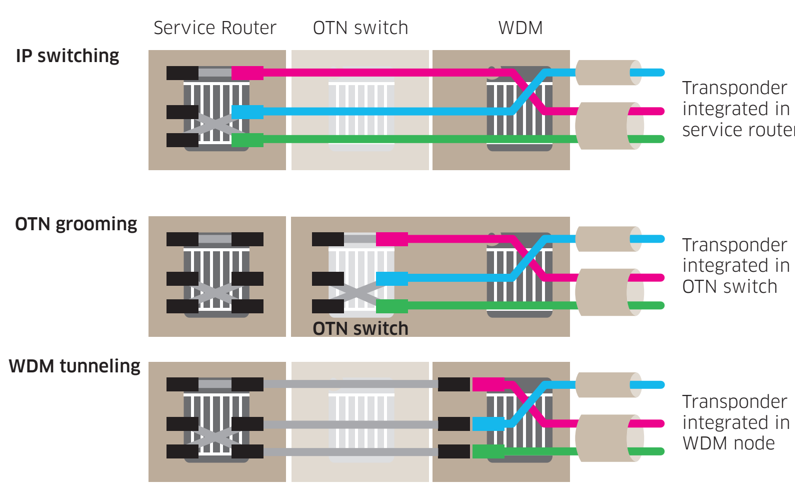
A COMPLEX MATHEMATICAL MODEL

Why is multi-layer network optimization needed?

For the last 20 years, optical networks have been deployed all over the world to satisfy the need for long-haul high capacity transport. IP networks on the other hand have undergone important developments along with the digitalization of communications. For historical reasons, these two types of network have been built independently, with their own data and control planes and their own over-engineering to provide high resiliency. However, the exponential growth in data traffic, higher SLAs and pressure on cost-per-transmitted-bit are now driving a technical and economical interest in converging IP and optical networks.

Multi-layer optimization consists of multiplexing and de-multiplexing IP traffic streams onto high capacity, high bandwidth optical trunks in order to improve bandwidth utilization, optimize network efficiency, reduce delay and minimize network cost. This operation, called traffic grooming, is performed by the transponder and can occur at the wavelength division multiplexing (WDM) layer (called WDM tunneling) or at the optical transport network (OTN) layer (called OTN grooming). Without grooming, the traffic is switched at the IP layer, which constitutes a third option, with the transponder located in the service router.

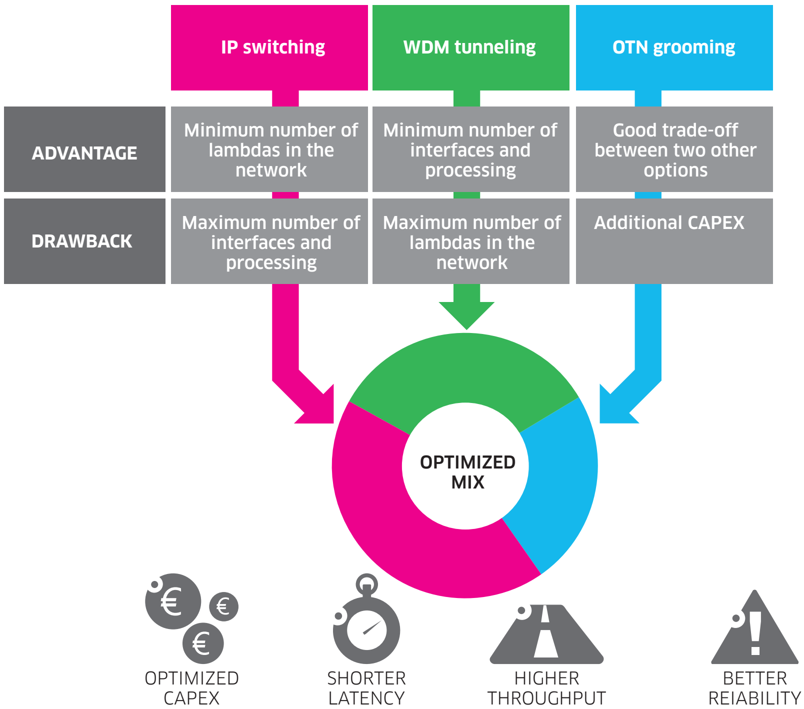
Figure 1. A multi-layer network consisting of WDM, OTN and IP layers



In reality, most networks do not rely solely on one of these three architectures. Instead they are a mix resulting from successive network expansions, reconfigurations and local optimizations. However, what most networks have in common is a rather under-optimized configuration. Technically, multi-layer network optimization aims primarily to determine the right combination of options that will:

- Minimize the required number of lambdas and interfaces (and therefore the cost)
- Reduce the processing time for the whole network (and therefore the latency and throughput)
- Streamline the architecture (and therefore improve the reliability)

Figure 2. Multi-layer network optimization



A complex mathematical problem

While the principle might seem simple, its application is not. Two-layer network optimization has actually been a subject of interest due to its complexity and has been extensively studied in scientific research over the last decade. The benefits of this overlay network planning approach have been demonstrated but the implementation requires a solid mathematical model. The problem is often segmented into two NP-complete sub-problems, namely traffic grooming and routing on one side, and routing and resource assignment on the other side.

Providing an exact mathematical solution to these problems requires the resolution of mixed integer linear programming (MILP) equations. Although these equations consider simplified network models, they rarely scale over 15 nodes. Hence, the latest scientific papers tend to address the same mathematical problem but are differentiated from one another by the performance of their heuristics.

The lack of applicability of these heuristics to real networks comes from the mathematical formulation of the problem, which:

- Considers symmetric layers. Unfortunately in real networks, an optical cross-connect can be connected to no, one or multiple nodes, and some IP routers are directly connected to some others, for example when multi-homing provider edge routers.
- Focuses on minimizing capacity at the expense of the serviceability of the solution; one of the consequences of this approach being to split a traffic stream over multiple routes.

Though sharing similarities with the mathematical problem depicted in scientific literature, the one being considered in this paper is even more complex. It supports any topology and addresses the trade-off between the complexity of the solution and the resulting cost. Last but not least, the problem supports an additional layer, namely the OTN layer between IP and WDM. Research addressing all three layers first appeared in scientific publications in 2012.

A PRAGMATIC APPROACH

Despite its mathematical complexity, multi-layer network optimization is becoming a necessity to maintain the right SLAs in the network while containing costs. To that end, Alcatel-Lucent and Bell Labs have developed an algorithm that not only provides good optimization but is sufficiently fast and flexible to be executed on large scale networks.

An iterative process

The approach relies on a heuristic algorithm patented by Alcatel-Lucent's Bell Labs that works according to the following principles:

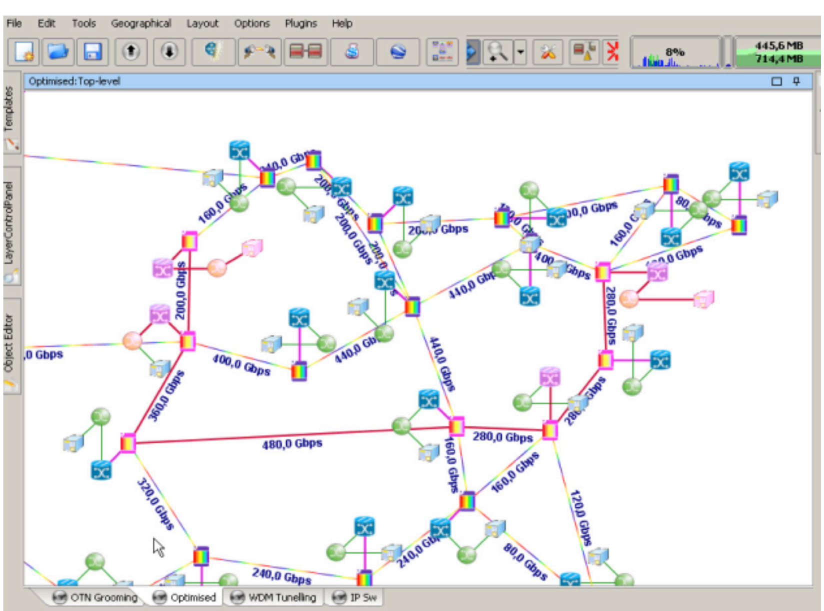
1. Route initial traffic demands
2. Compute a list of potential tunnels
3. Fill these tunnels with available traffic as best as possible
4. Compute for each potential tunnel the gain achieved by its creation
5. Elect the tunnel with the best gain and go back to step 2.

This heuristic algorithm has been defined to support any type of topology and to treat both IP over OTN and OTN over WDM optimization at the same time.

The Spider tool

The heuristic algorithm has been embedded in the Spider tool, a proprietary Alcatel-Lucent network modeling and architecture tool that generates an end-to-end network description of the access, transport and core networks. The Spider tool is vendor and product agnostic and includes a library of customizable telecom equipment. Beyond technical optimization, Spider provides a financial view with a multi-year business planning capability.

Figure 3. The Spider tool



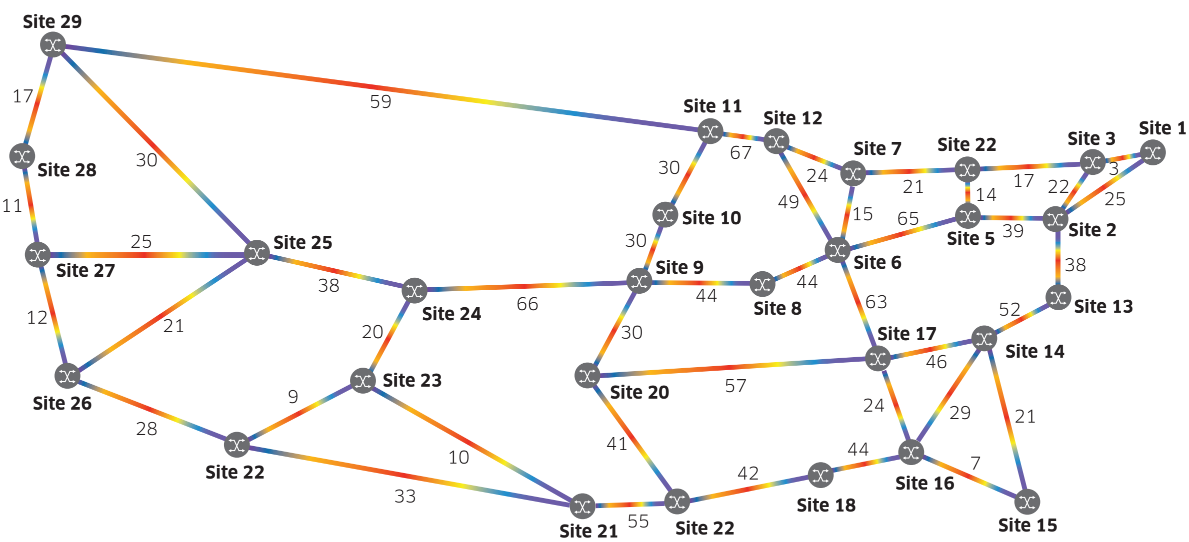
USE CASE

The following use case illustrates and quantifies the benefits of a multi-layer optimization performed by Alcatel-Lucent network professional services and is based on a realistic IP/optical transmission network. For the purpose of the exercise, four scenarios were created in the Spider tool:

- The first scenario implements WDM tunneling only, that is, the traffic is carried on dedicated lambdas between each pair of WDM nodes
- The second scenario sends all the traffic to the Ethernet level for switching
- The third scenario introduces OTN equipment systematically to allow grooming of the optical data units
- Finally, the fourth scenario presents the same network optimized by the algorithm.

Figure 4 represents the network architecture. Each symbolic interface between two sites is associated with a number representing the cumulative costs of the different interfaces.

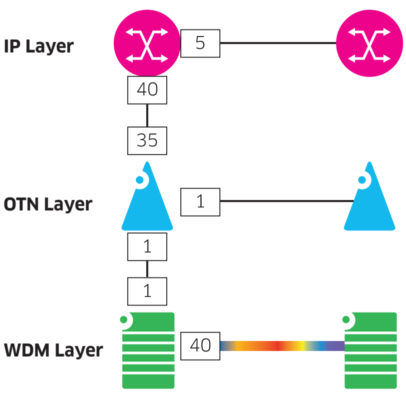
Figure 4. The network architecture used in the use case



Interface costs

The alternatives are compared from a CAPEX perspective in which each interface type is associated with a cost. Figure 5 shows an example of the normalized cost assumptions used for this study.

Figure 5. An example of the normalized cost assumptions used for the study



Equipment type	Interface type	Normalized cost
IP switch	Eth<->Eth	5
IP switch	Eth to OTN	40
OTN node	OTN to Eth	35
OTN node	OTN<->OTN	1
OTN node	OTN to WDM	1
WDM node	WDM to OTN	1
WDM node	WDM transponder	40

Optimization results

Figure 6 summarizes the output of the multi-layer network optimization. It shows, for each scenario, the required (normalized) CAPEX associated with each equipment type – IP routers, OTN nodes and WDM nodes. This CAPEX represents the cumulative costs of interfaces that are carried by the equipment.

Figure 6. A CAPEX summary of the multi-layer network optimization use case

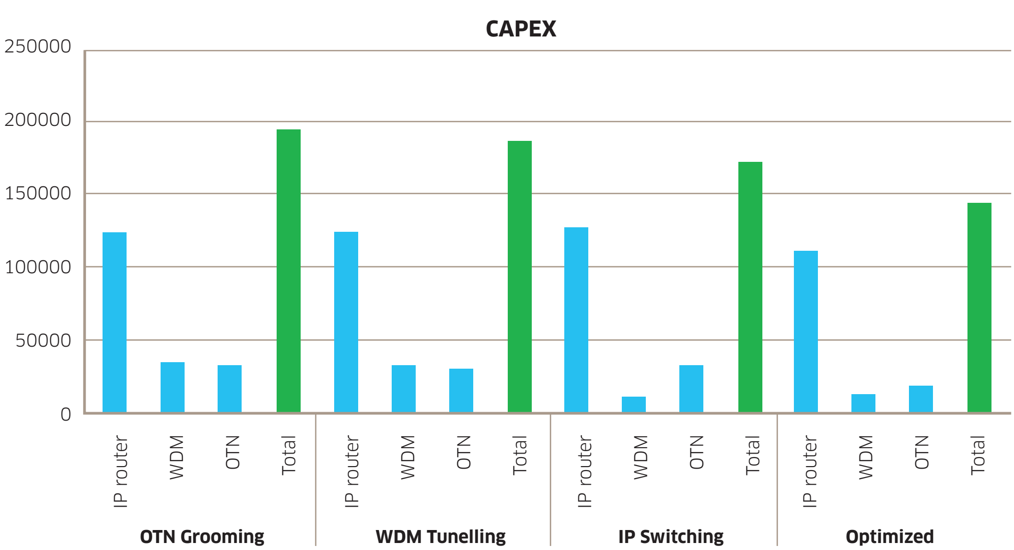


Table 1 indicates the savings, in percentage, of multi-layer network optimization compared to the other scenarios.

Table 1 Cost savings for multi-layer network optimization in comparison with other scenarios

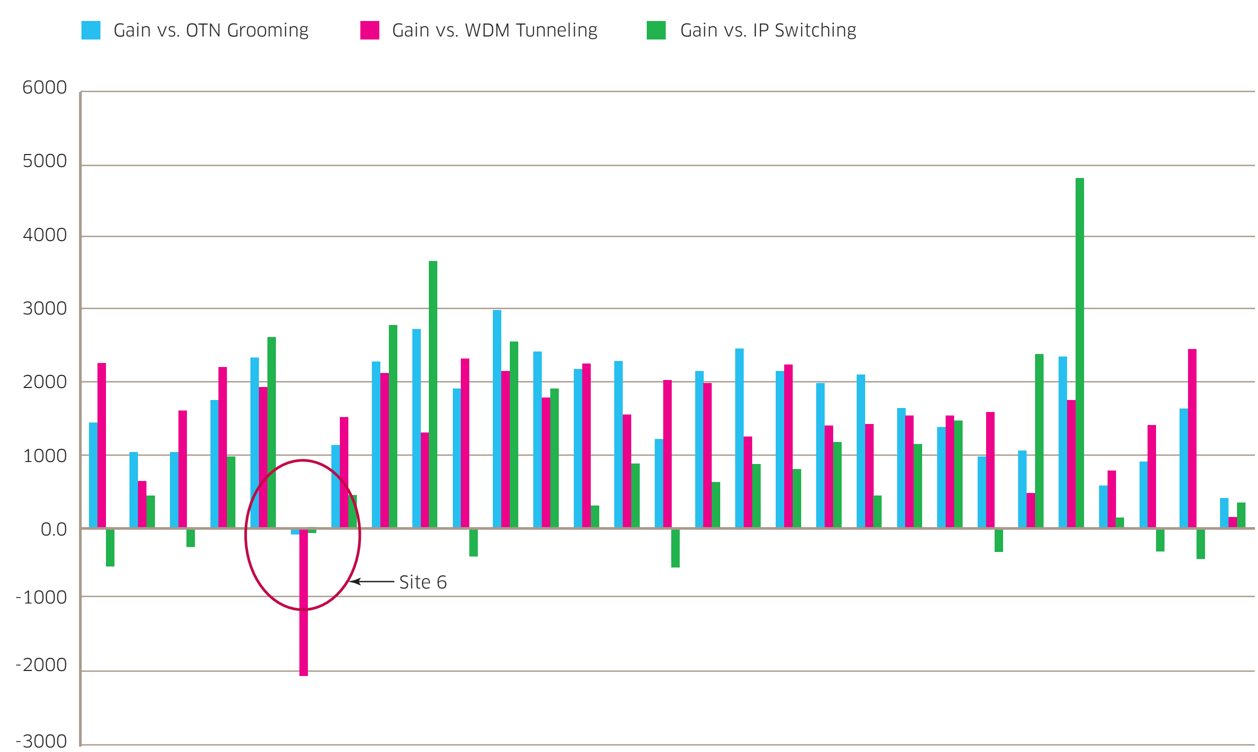
	PERCENTAGE OF COST SAVINGS GAINED
Compared to pure IP switching optimization	~16%
Compared to pure WDM tunnelling optimization	~23%
Compared to pure OTN grooming	~25%

These results show significant savings in the total CAPEX, from 16% when compared to optimizing IP switching only, up to 25% when compared optimizing OTN grooming only. These numbers cannot be directly applied to a real network as most networks usually have a mix of the three options rather than a single one. However, the potential gains are sufficiently high to advocate multi-layer network optimization, especially given the high investments that transmission networks require.

Total network optimization is not simply the sum of local site optimizations

A closer look at the results of multi-layer network optimization across individual sites reveals another interesting finding. Although multi-layer optimization reduces the CAPEX for most sites, the CAPEX for some sites may actually be increased. Figure 7 shows the detailed CAPEX gains obtained by multi-layer network optimization per site compared to other scenarios. On some sites, multi-layer optimization increased the CAPEX compared to the other options. Site 6 is an interesting example, as the multi-layer optimization has the highest CAPEX of the four scenarios.

Figure 7. The detailed CAPEX gains per site compared to other scenarios



CONCLUSION

Transmission networks represent a large investment for service providers. Implementing multi-layer network optimization can be fully justified given the significant savings that can potentially be achieved. However, the problem is complex, so multi-layer network optimization needs to be conducted across large parts of the network covering the majority of sites to ensure that the maximum level of optimization is reached. The study shows that although multi-layer network optimization reduces the overall costs across the network as a whole, it may increase the cost for some sites locally.

Efficient multi-layer network optimization requires a network-wide approach. To address this challenge, Alcatel-Lucent has developed a multi-layer network optimization service. This service, based on Bell Labs research, the Spider modeling tool and delivered by experienced network professionals, provides a pragmatic approach to solving the complex mathematical problems of network optimization.

ABOUT ALCATEL-LUCENT PROFESSIONAL SERVICES

Alcatel-Lucent is a long-trusted partner of service providers and has been involved with most of the large backbone network deployments worldwide. It has industry-leading expertise in the specific issues faced by service providers with large optical and IP networks.

For more information, please see www.alcatel-lucent.com/content/professional-services

ACRONYMS

CAPEX	capital expenditures
IP	Internet Protocol
MILP	mixed integer linear programming
OTN	Optical Transport Network
SLA	Service Level Agreement
WDM	Wavelength Division Multiplexing

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