

Applying Intelligent Optical Networking Functionality in the Deployment of the Next-Generation Internet

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*Intelligent Optical Networks (IONs) are capable of automatically setting-up and tearing-down lightpaths. This offers the opportunity to dynamically reconfigure the logical IP network (i.e., the capacity and topology in the IP layer). IONs also enable the use of Multi-layer Traffic Engineering (MTE) to improve the Quality of Service (QoS) in IP-over-Optical networks. This paper discusses what is understood by MTE, how it works and what issues need to be resolved when developing a MTE strategy. The benefits of MTE are highlighted by means of two case studies.*¹

Introduction

In recent years, traffic has been growing explosively. Optical fiber and the deployment of Wavelength Division Multiplexing (WDM) have proven to be very cost-efficient in building the Optical Transport Network (OTN) and have opened tremendous amounts of capacity. By properly configuring the Optical Cross-Connects (OXC), a lightpath can be provisioned between any pair of nodes.

Not only is the traffic volume growing, the traffic pattern also fluctuates quite a lot due to the dominance of Internet traffic. Considering this high traffic dynamism, the ability to react timely to the traffic pattern variations becomes crucial. However, the current manual intervention by the operator takes a few weeks (even months) to respond to the demand for a new lightpath. In an IP-over-OTN scenario these lightpaths make up the links of the logical IP network topology. Therefore, the Intelligent Optical Network (ION) [1] has become a hot topic in today's research and will be the core of the next-generation optical network. ION replaces the manual intervention by a distributed control plane, which offers the ability to smartly and automatically manage the lightpaths (i.e., set-up or tear-down) based on the recent traffic situation.

Multi-layer traffic engineering

A well-known problem in today's optical networks is that the simple and straightforward routing strategies used, may lead to an unbalanced traffic load: some parts of the network are congested, while other parts are underused. Solving this problem is one of the goals of Traffic Engineering (TE). In general, spreading the traffic more evenly over the network will also significantly help in guaranteeing a certain level of Quality of Service (QoS) [2].

Traffic engineering could be applied in each layer separately (Single-layer Traffic Engineering (STE)). IP layer TE for example, should try to keep the traffic load in all links in the IP network reasonable low as a higher load typically implies a higher buffer delay and packet loss in the preceding router. IP layer TE thus helps to keep the end-to-end delay below a certain limit and decreases the chance that packets get lost. On the other hand, optical layer TE is used to reduce the blocking probability in optical

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networks with a limited number of wavelength channels per link. Sometimes STE cannot solve the service degradations (e.g., when the network is under-dimensioned). With an IP-over-ION however, it becomes feasible to dynamically reconfigure (e.g., upgrade) the logical IP network. Such decisions are called Multi-layer Traffic Engineering (MTE) decisions. Two different approaches can be identified in MTE: a proactive and a reactive one. A proactive strategy continuously optimizes the logical network, while a reactive strategy fixes the problem at the moment it is detected. Both MTE strategies involve three phases:

A. Monitoring/detection: Before any MTE action can be triggered, the traffic in the network should be monitored

B. Decision taking: Once the MTE is triggered, a decision should be taken on which action to take

C. Realization: Once the reconfiguration decision is made, it should be realized.

These phases will be discussed briefly in what follows; in [3] a more elaborated discussion of MTE concepts and issues is given.

A. When to reconfigure?

Deciding upon whether or not the logical network needs to be reconfigured should be based on monitoring the traffic in the network. One can, for example, choose to monitor the bit rate in each logical link during a certain observation window (phase 1 in Figure 1). Note that the triggering threshold should be reasonable, since too frequent triggers may affect the network stability.

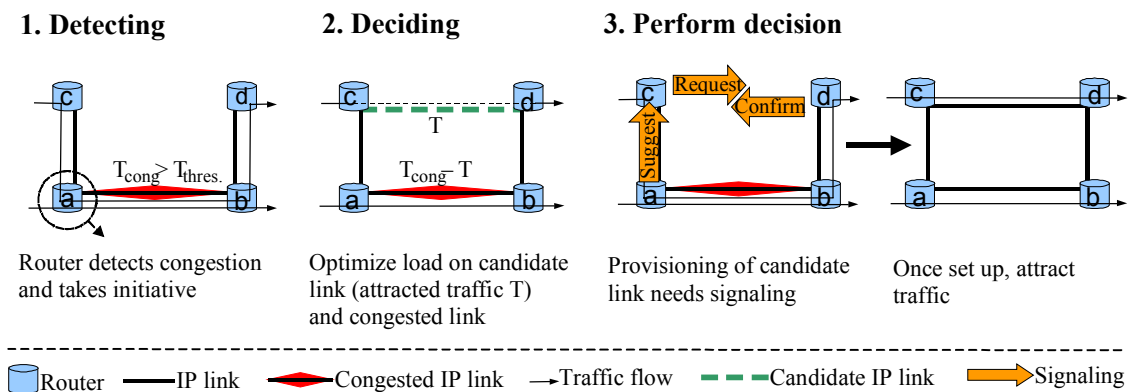


Figure 1: The three phases in multi-layer traffic engineering

B. What to reconfigure?

The goal of the decision taking process is to decide which new logical link should be set up in order to achieve a logical network suited to carry the traffic injected into the network (i.e., a fair trade-off between capacity usage and QoS). However, only deciding where to install the new logical link is not sufficient, also a decision on how and which traffic flows to attract over the newly established links is needed. An example of a reactive strategy is depicted in phase 2 of Figure 1. In this example, the reconfiguration decision is made taking into account the traffic load information. The goal is to decrease the traffic along the congested link and attract traffic on the newly established link (spread the traffic more evenly).

C. How to perform the decided reconfiguration?

Once the reconfiguration decision has been taken, one should act accordingly (see phase 3 of Figure 1). Several practical solutions exist for this purpose, but all need signaling

protocols to establish the lightpaths. A single integrated control plane for both the IP and optical layer allows the most intelligent solution.

Case studies

The goal of this section is to present two case studies that illustrate and confirm the benefits of MTE. In case study 1 a reactive MTE strategy is simulated. Case study 2 discusses the design of a proactive MTE strategy. In [4] and [5] we have focused on multilayer network recovery, which is a part of the overall MTE and progressively gains importance.

Case study 1: Simulation of a reactive MTE strategy

Input for this case study is a realistic backbone network with a realistic traffic forecast. To illustrate the benefits of MTE however, we let the traffic demand grow from 80% to 180% of this original traffic demand forecast, in steps of 20% every 30 seconds. Two situations are then compared. In the static situation the network is only dimensioned to carry the original traffic forecast and the traffic changes occur significantly faster than that capacity can be (manually) provisioned to the logical IP network. In the second, dynamic case the optical layer is an ION and MTE is applied.

Figure 2 shows that in the dynamic case the logical IP network always suits the offered traffic, as the packet loss ratio (PLR) stays low over the studied time interval. In the static case however, the PLR starts to increase once the traffic volume exceeds the original traffic forecast at second 60. The dynamic case also only uses physical resources (wavelength channels) when they are really needed. In the static case the number of used wavelength channels stays constant, while in the dynamic case at first fewer wavelengths are needed but then the number of wavelengths needed starts to increase in order to be able to keep the low PLR.

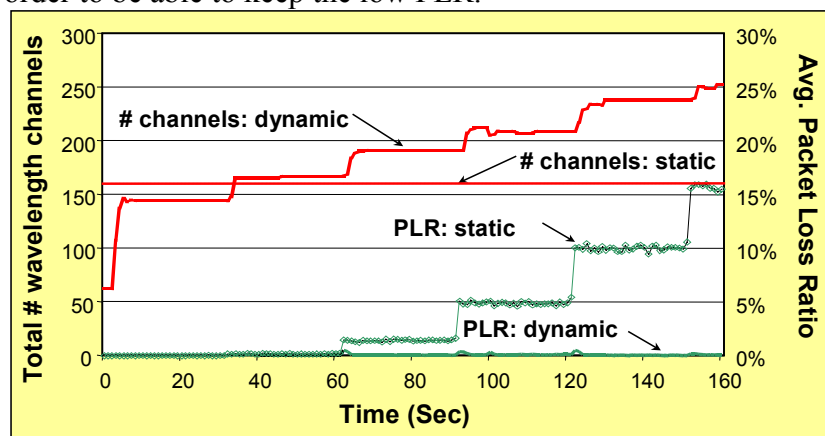


Figure 2: Packet loss ratio and wavelength usage in the static and dynamic case

Case study 2: Design of a proactive MTE strategy

Figure 3 shows the methodology we developed for a proactive MTE strategy (continuous optimization of the IP network routing to suit the current traffic pattern). The most challenging part of this methodology is the development of an appropriate cost function.

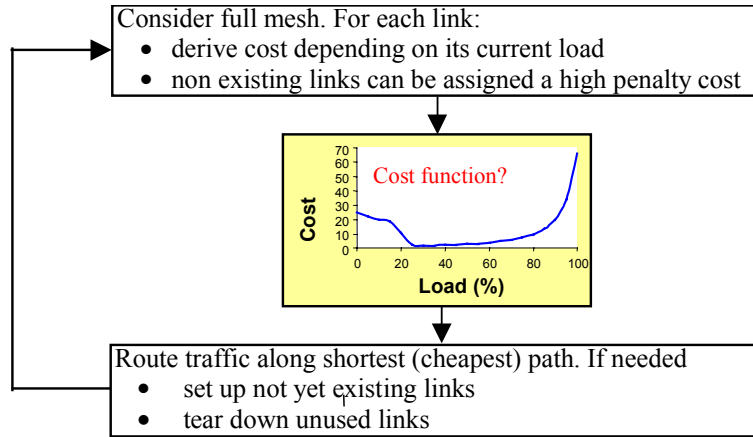


Figure 3: Proactive MTE strategy

The first, intuitive idea was to use a parabolic cost function. Figure 4 illustrates however that a cost function that differs from a truly parabolic one by (1) an elevated plateau for very lightly loaded links, (2) a quite wide plateau with almost zero cost for reasonable loaded links and (3) a very high cost for heavily loaded links gives the best results. Such a cost function locks the load (utilization) of the links in a reasonable range as both highly and lightly loaded links are penalized with a high cost.

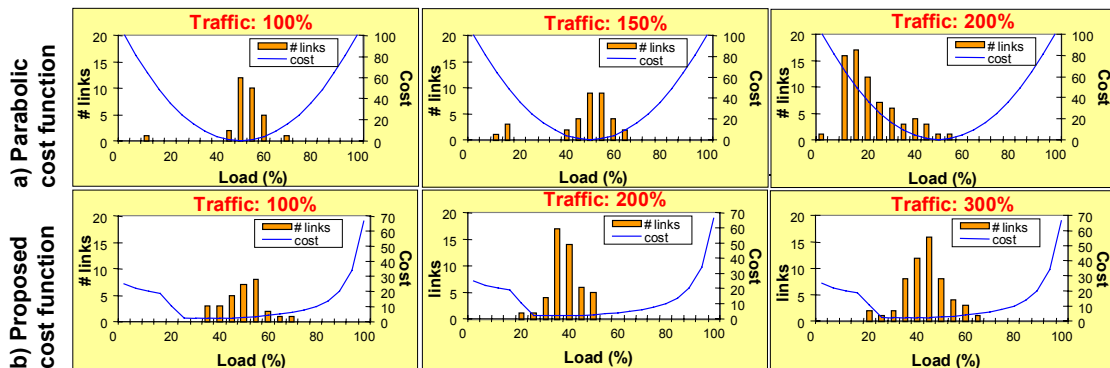


Figure 4: Shape of the cost function

We have also found that the height of the elevated plateau for light loads should be sufficiently high compared to the values for the ideal load range and that the plateau for the ideal load range should be wide enough.

Conclusions

In this paper the concept of multi-layer traffic engineering has been introduced and discussed. After explaining the operational aspects of such MTE schemes, two case studies illustrated the benefits of applying MTE schemes.

References

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