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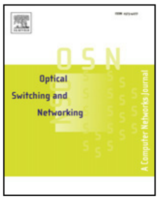

Is multilayer networking feasible?

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ABSTRACT

IP traffic has been growing every year, bringing the need for deploying an IP backbone interconnected by links provided by the transport network. Thus, network operators have had traditionally divided their core network in two, the IP network and the transport network. Network planning and engineering tasks have been performed independently in both domains. Traditionally, the transport network has been quite inflexible, and changes have often required a long time to occur. However, recent developments in the control plane allow flexibility in the transport network, making it possible to set up and tear down circuits on demand. In this light, multilayer traffic engineering has been proposed to jointly manage both IP and transport layers, with the aim of optimizing the use of resources. This paper aims to describe the rationale behind multilayer traffic engineering, demonstrate its feasibility and quantify its advantages in terms of cost effectiveness. Also, this work takes a look at the different choices in performing the multilayer operation, in terms of control plane implementation and equipment integration. Finally, the paper presents a report on multilayer traffic engineer experimentation which proves its feasibility and show a preliminary techno-economic case study of the multilayer operation.

1. Introduction

Traditionally, different networks have been used for different services. According to it, each transport network has been specifically designed in order to fulfill the survivability and QoS requirements of specific applications. For example, while NG-SDH networks were designed to support real time traffic with strict requirements in terms of delay and availability, packet transport technologies were initially used to support best-effort Internet traffic. However, current network trends foresee an evolution towards a unique multiservice IP backbone network able to support any kind of service over the same underlying infrastructure. Main drivers for a unique transport network are the CAPEX [1] and OPEX savings achieved by simplifying the transport network infrastructure. However, this evolution also presents important technical challenges since a huge amount of traffic should be transported over a single IP network while QoS and survivability requirements of each service should still be fulfilled in the most cost-effective way.

In that respect, the evolution towards a unique IP backbone together with new traffic demands imply an increase in the switching capacity of the IP backbone routers. Such a capacity increase strongly impacts on the total network costs since long distance ports for IP routers are really expensive for switching speeds beyond 10 Gbps. However, all optical end-to-end transport at switching speeds of 10 to 40 Gbps are very cheap in comparison with IP equipment. Cost models developed in IST NOBEL Project [2], IST MUPBED [3] or other studies like [4] support this fact. Therefore, scalability and efficiency of the IP core

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could be highly improved by means of high capacity transit traffic offloading over a reconfigurable optical mesh [5].

The paper is organized as follows. First, we describe the evolution of the transport and IP networks, presenting the motivation for performing the joint operation of IP and transport layers. Next, we explain the different choices in the control plane and equipment integration. Next, we present a prototype initially developed within the IST NOBEL Project [6], and further expanded in Telefónica I+D. Finally we present a case study of the CAPEX savings when a multilayer solution in the operator's network is implemented.

2. Evolution of IP and transport networks

Current IP backbones are often based on hierarchical architectures and high speed point-to-point links between IP routers. This architecture presents scalability problems, mainly due to the increase of pass-through traffic, which still needs to be processed at the IP layer. This solution thus reduces to long-distance high-speed ports. Still, such long distance ports for IP routers are quite expensive for switching speeds beyond 10 Gbps.

With the advent of optical networking, optical switches are available in the network, giving the possibility to establish direct connections (light-paths) between any two end points. With them, the network architecture has changed to high capacity IP routers connected to optical switches (ROADMs). In this new architecture, traffic can be groomed and sent over a direct light-path, bypassing the intermediate nodes. Additionally, switching 10-Gbps traffic at the optical layer is much cheaper than at the IP layer. The next upgrade is to provide the operator's network with wavelength switching capabilities that help IP routers to cope with the new demands. However, still the establishment of all-optical circuits is not provided on demand.

In light of this, the last step is to provide inter-layer flexibility by adding a control layer between the IP router and the optical switch leading to multi-layer capable routers, where, on demand, traffic can be sent either over the IP layer or the optical layer (either through an already existing light-path or a newly created one). Note that this approach is evolutionary since the IP routers are kept on the network, and new demand is absorbed by the optical layer (see Fig. 1).

2.1. Migration of functions from IP to transport plane

Thus, with the appraisal of IP over Intelligent Optical Networks (ION), the number of technical alternatives for providing resilience and Traffic Engineering capabilities to the network has increased. While in pure IP networks, all the network engineering mechanisms are exclusively done at the IP layer, in IP over ION both Traffic Engineering and resilience mechanisms can be carried out either at the IP/MPLS or optical layer. Furthermore, such resilience and traffic engineering could be executed on an independent or coordinated way. Next section describes the main technical alternatives for such multilayer networking.

3. Multilayer networking

As seen in the previous chapter, the multilayer operation is justified by the need of offloading traffic from IP routers and switching it at lower layers, allowing it to increase the supported traffic without investing in new IP equipment. The question now turns as to how to implement the multilayer operation. One of the first choices is by using the control plane. The control plane is the key element to offer the flexibility and self-operation of the network (dynamic provisioning, restoration, reconfiguration), and can be either integrated or separated. This is reviewed in the following subsections.

The current approach in the transport network is to have a control plane implemented just on the IP/MPLS network. The control over the WDM layer is restricted to link status monitoring. In terms of routing and addressing, IP/MPLS are the only active technologies, so that all traffic is forwarded by means of IP routing tables or MPLS LSPs.

3.1. Integrated control plane

The main goal of multilayer traffic engineering is to optimize global resources usage and to reduce network management complexity. This is possible only by taking into account information available at all layers. For this reason, an integrated control plane with multilayer traffic engineering is the only way to achieve such optimization.

A feasible approach for an integrated control plane is to follow the peer model from the GMPLS architecture, in which each node has a unique vision of the whole multilayer network. This way, optical and IP/MPLS equipment are interconnected at the control plane level by means of signaling and routing adjacencies, existing only one integrated instance of routing and signaling protocols.

There are two options in terms of network equipment implementation:

(a) Both layers are integrated in a single node, with a control module running a single instance of the common control plane. In this case, the existence of a network with dual-layer integrated technologies is supposed, and generally from a single vendor.
(b) There are different network elements with different switching capabilities and different control modules, but participating in the same control plane instance, and therefore with peering relationships to each other. In this case, the support for different vendors at each layer would depend on the full support of the standards by each of them.

In this case, the border routers would be in charge of the end-to-end path computing, and would initiate the signaling process throughout the integrated transport network.

However, a unified control plane has also several drawbacks. On one hand it requires more computational resources than separate control planes. First, a common control plane has to control more elements than a single-layer control plane, which implies bigger databases and a less scalable solution in general. Second, route calculation algorithms and traffic engineering mechanisms