

Using Self-management for Establishing Light Paths in Optical Networks: an Overview

Tiago Fioreze
University of Twente
Enschede, The Netherlands
Email: t.fioreze@ewi.utwente.nl

Aiko Pras
University of Twente
Enschede, The Netherlands
Email: a.pras@ewi.utwente.nl

Abstract—Current optical networks are generally composed of multi-service optical switches, which enable forwarding of data at multiple levels. Huge flows at the packet-level (IP-level) may be moved to the optical-level, which is faster than the packet-level. Such move could be beneficial since congested IP networks could be off-loaded, leaving more resources for other IP flows. At the same time, the flows switched at the optical-level would receive better Quality of Service (QoS). The transfer of those flows to the optical-level requires the creation of dedicated light paths to carry them. Currently, two approaches are used for that purpose: the first is based on conventional management techniques and the second is based on GMPLS signalling. In both approaches, the decision which IP flows will be moved to light paths is taken by managers. Therefore, only IP flows explicitly selected by such managers will take advantage of being transferred over light path connections. However, it may be that there are also other large IP flows, not known to the manager, that could potentially profit from being moved to the optical-level. The idea proposed in this paper is therefore to add self-management capabilities to the multi-service optical switches and make them responsible for identifying which IP flows should be moved to the optical level and establish and release light path connections for such flows.

I. INTRODUCTION

Optical networks are fast and reliable networks that allow huge amounts of data to be forwarded through optical switches. Modern optical networks are composed of multi-service optical switches, which means that they are capable of performing forwarding decisions at packet-level (network layer) as well as optical-level (physical layer).

Transferring those IP flows that put a heavy demand on IP level resources to the optical-domain can be advantageous, since this leaves more resources for the remaining IP flows, which will experience a better Quality of Service (QoS). At the same time, the flows that are now switched at the optical-level will also benefit and receive better QoS, in particular since delay will become smaller and constant (no more jitter).

In order to effectively carry flows, optical networks have to be properly configured. The current configuration process consists of setting up multi-service optical switches by defining which IP flows will be transferred to the optical-level and by establishing end-to-end light paths (i.e., optical connections). Two approaches are currently used for this optical network configuration process [1]: conventional management (i.e. centralized management) and GMPLS signalling.

A characteristic of the conventional management approach is that a centralized management entity (e.g., human manager or an automated management process) is in charge of

establishing light paths and deciding which IP flows will be moved to the optical level. In contrast, the GMPLS signalling approach is characterized by the fact that optical switches coordinate the creation of light paths among themselves. The decision which IP flows will be moved to the optical level can be taken by a centralized management entity, but as well by the entities responsible for the generation of the data flow.

The problem with these approaches is that the decision which IP flows will be moved to the optical level needs to be explicitly taken by (human) managers. As consequence, only those IP flows that are explicitly selected can benefit of the light path capabilities. IP flows that for some reason are not selected will not take advantage of being transferred over light path connections. These IP flows may still suffer from long delays and jitter commonly found in congested IP networks.

Our approach to solve this problem is to make the multi-service optical switches themselves responsible for identifying which IP flows will be moved to underlying light path connections. The optical switches will also automatically establish the required light paths and release them when they are no longer needed. Unlike the end-to-end optical connections, in our approach the optical connections are established in segments. The optical switches perform these tasks by using the cooperative management approach [2].

The ideas presented in this paper are developed within the context of the SURFnet Gigaport Next Generation (Gigaport-NG) Research on Networking (RoN) project [3]. It should be noted that our research has just started and conclusions based on actual experiments can not yet been drawn. The main objective of this paper is therefore to present and discuss new ideas about self-management in optical networks.

This paper is organized as follows. Section II presents the state of the art in configuring optical networks and discusses conventional management as well as GMPLS approaches. Section III focuses on self-management of optical networks and discusses the various phases that can be identified. Finally conclusions are provided in section IV.

II. CONFIGURATION APPROACHES FOR OPTICAL NETWORKS

The establishment of dedicated light paths and the definition of which IP flows will benefit from using optical switching can be in practice performed by two approaches: conventional management approach and GMPLS signalling approach.

A. Conventional Management

Network management systems are composed by managers and agents [4]. Managers consist of entities responsible for managing the network activity by ordering tasks (e.g. configuration or monitoring actions) for agents. Agents are entities in charge of performing the requested tasks. There may also be entities that can play a dual role, acting as both a manager and an agent, being therefore defined as dual-role entities.

The conventional management approach is defined by one centralized management entity (network manager or management system) that is in charge of managing the entire optical network. For the sake of simplicity the term network manager will be used to refer to the management entity from now on.

With regard to the configuration process, in this approach, the network manager is responsible for defining explicitly the IP flows that will benefit from being transferred over dedicated light paths. He or she can use management tools such as NetFlow in order to detect IP flows that are overloading the IP routing process in IP networks. Then, by analyzing the collected traffic samples, he or she creates the dedicated light path for those overloading IP flows.

The creation of dedicated light paths can be done by using management technologies such as CLI, SNMP and TL1. By using these technologies, network managers configure each optical switch along the connection path by passing to them the required connection parameters. The basic parameters consist of IP addresses (source and destination) of the benefited IP flows and also connection attributes (e.g., required bandwidth).

The conventional management approach has an important drawback concerning scalability [5]. When the number of managed devices increases and becomes greater than the management system is able to cope with, the management activities performed by the management system become overloaded. Adding new network tasks in this situation would therefore strain the system to its limits.

B. GMPLS Signaling

Generalized Multiprotocol Label Switching (GMPLS) architecture [6] aims to extend the characteristics of the MPLS architecture [7] to support peculiarities existing in today's optical networks. MPLS cannot be applied in modern optical networks because it was originally defined to be applied in packet-switching networks. Besides packet switching, GMPLS can also support three different types of switching: fiber, wavelength and TDM switching, which results in a greater number of labels supported by GMPLS. However, unlike in MPLS, in the GMPLS architecture the labels are no longer carried in the data, but they are defined in the optical switches.

With regard to the configuration process of the optical switches, GMPLS works similarly to MPLS by using signalling messages in order to establish light paths. However, GMPLS differs in the way that it is deployed in optical networks, influencing so that the manner that users or network managers require the establishment of light paths for benefited IP flows [8]. It can be deployed as two different operational models: peer and overlay model.

In the peer model, the topology of the core network is not hidden from users of the optical networks, which enables users to see the entire topology of the optical network and to choose the desired light path. Once the desired light path is chosen, users of the path have to communicate with their adjacent optical switches informing them about the desired light path, the IP addresses (source and destination) of the benefited IP flows and also inform the connection attributes. Once the optical switches receive this information, they start then the process of establishing the chosen light path by interacting with the other switches along the path.

Unlike peer model, in the overlay model the topology of the core network is not revealed to users of the optical network. As a result, users are not able to choose their desired light paths. Therefore to create a light path, the users have to inform their adjacent switches with only the source and destination IP addresses of the benefited IP flows and the connection attributes. Those adjacent switches then interact with the other switches to decide which light path will be chosen based on the connection parameters provided by the users.

Even though the GMPLS offers some autonomy for the optical network to decide the light paths to be created, in the GMPLS signalling approach, likewise the conventional management approach, the users or network managers of the optical network must still explicitly provide the information about the benefited IP flows. As a consequence, both approaches could not include some IP flows that could be eligible in using a dedicated light path, since they might not be detected or somehow by human operators; letting them so consuming resources in IP networks and suffering from long delays. In the next section we present our approach that envisages overcoming this limitation.

III. SELF-MANAGEMENT IN OPTICAL NETWORKS FOR LIGHT PATHS PROVISIONING

As previously presented, the current approaches used for establishing light paths trust on the explicit definition of network managers on which IP flows will be transferred to optical switching. As a result, eligible IP flows, i.e., those IP flows that consume many resources in IP networks, might not be detected by those network managers and therefore would not benefit from being transferred over a dedicated light path.

Our solution to overcome this issue has the principles of letting the optical switches in charge of detecting eligible IP flows and letting them also responsible for managing optical connections. Network managers are in charge of setting up configuration parameters in the optical switches by defining the self-management behaviour of these optical switches.

In addition, our solution envisages, at the end of long-term work developed in the Gigaport RoN project, including the self-management of optical switches located in different administrative domains. However, since this work is still in its first stage, the ideas to be presented in this section consider the self-management of optical switches in a single domain.

The way that our solution works is divided in phases: configuration, detection and management phases.

A. Configuration phase

In the configuration phase, network managers define how the optical switches should behave in order to detect IP flows and establish light paths. This phase is performed by setting up configuration parameters and it is the only phase in which network managers interact directly with optical switches.

Different parameters values can be defined along the optical network. Since an optical network may not be homogeneous in its topology, network managers can define different values for the same parameter at distinct parts of the managed optical network. Some examples of configuration parameters used in our approach are bandwidth consumed and flow duration.

The bandwidth consumed parameter defines after how much bandwidth consumed a flow can be considered eligible to be transferred over a light path. On its turn, the flow duration parameter is used for specifying after how much time a flow can be considered eligible. Both parameters can be used together. For instance, flows that have a short duration and generate sporadic big traffic may be discarded by defining values to those parameters..

Figure 1 shows the network manager defining different threshold values used for the optical switches to decide when to establish a dedicated light path.

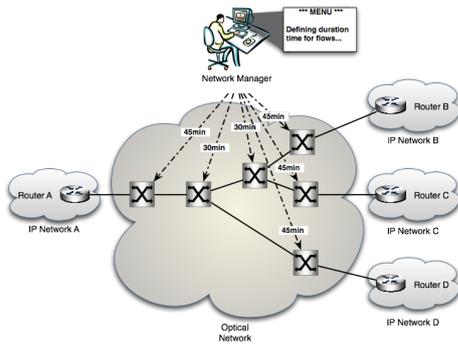


Fig. 1. Configuration Phase Example

B. Detection phase

In the detection phase, multi-service optical switches cooperatively work in order to detect when IP flows are entitled to be transferred over a light path and also when they are not entitled any more. The criteria used for taking these decisions is based on the parameters defined by network managers during the configuration phase.

The current monitoring process of flows is performed both by exporting (e.g. Netflow) and collecting (e.g. SNMP) approaches. In both approaches, the flow analysis is made by an external entity (human operator or monitoring station). In our approach, each optical switch is responsible itself for monitoring the IP flows that are passing through it and for taking actions (establishing or releasing light paths) when a threshold value (defined in the configuration phase) is reached. It is interesting to notice that, in our approach, the monitoring process will not concentrate only at the edge or core of an

optical network, but at the entire network. Figure 2 shows one example on how the detection phase would look like.

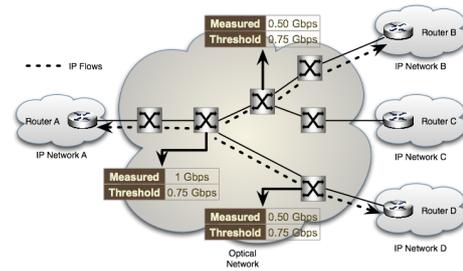


Fig. 2. Detection Phase Example

In order to avoid multiple light paths to be allocated for the same IP flows, the optical switches along the path of these flows have to cooperatively work. Peer-to-Peer (P2P) technologies seem to be the proper option to be used here. Besides its well-know file sharing feature (e.g. Napster and BitTorrent), P2P technologies can also provide means for real-time communication in medium or large-scale environments [9]. In addition, P2P technologies have also been investigated to be used in network management area [10].

In the cooperative work, each optical switch is responsible for monitoring the traffic passing through it and comparing the measured traffic with parameters values to check if some condition is satisfied. If an optical switch detects that some condition for establishing a light path was satisfied, it sends a message to its adjacent neighbours asking for the light path establishment. Its neighbours may accept or deny the request based on their own parameters values. Those neighbours that accept the request also send messages to its adjacent neighbours; except to that one they got the message. Optical switches that are located at the edge of the optical network do not send those messages to outside the network.

C. Management phase

In the management phase, light paths are established or tore-down depending on which condition is satisfied in the detection phase. The establishment of light paths is performed when a condition becomes true and the tearing-down process when a condition becomes false.

To create and release light paths between two adjacent optical switches (i.e., one path segment), the usage of the (Resource Reservation Protocol - Traffic Engineering) RSVP-TE [11] seems to be the most proper protocol for that. RSVP-TE is a signalling protocol used for establishing Label Switched Paths (LSPs) in MPLS and GMPLS networks.

In order to establish a dedicated light path the RSVP-TE uses two primary messages: Path and Resv. Optical switches, which first detect eligible IP flows, send Path messages to their adjacent optical switches that accepted to create a light path in the decision phase. The Path message is composed by the IP addresses of the sender and receiver switches and also by light path requirements. Once the receiver switches get the Path message, they check first if their IP addresses are listed in

it and, as well the light path requirements. If they can satisfy the requirements, they allocate the dedicated light path and send back a Resv message to the sender.

The establishment procedure of light paths is best described with the aid of examples. Figure 3 shows how the establishing of a dedicated light path would look like. The Path and Resv messages syntax are abstract for the sake of simplicity.

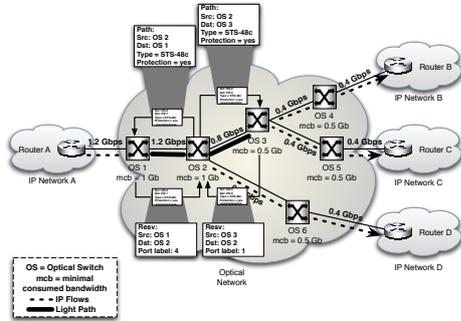


Fig. 3. Establishing procedure: the Exchange of Path and Resv Messages

In Figure 3 the OS 2 sends Path messages to those optical switches that accepted the light path establishment request: OS 1 and OS 3. In the Path messages, light path requirements and optical switches source and destination addresses are defined. After receiving the Path messages, OS 1 and 3 send Resv messages to OS 2, informing that the light path requirements were satisfied and that the light path was created.

In the releasing procedure the Path and Resv messages are used again, but with the object AdminStatus defined in the messages. In addition, the PathTear message is used as well. The object AdminStatus informs that a releasing procedure will take place and the PathTear message is used for tearing-down an established light path. An optical switch decides for tearing-down when IP flows are not using so much resources.

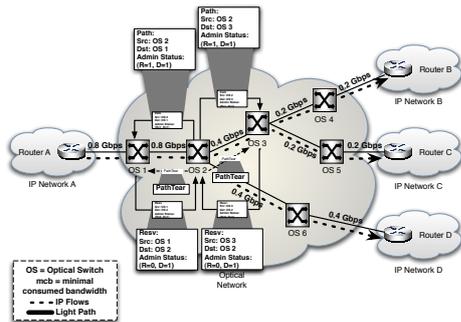


Fig. 4. Releasing procedure: the Exchange of Path and Resv Messages

In Figure 4, OS 2 detects that flows coming from Router A are consuming less bandwidth and it decides for releasing the dedicated light path. To do that, it sends Path messages to OS 1 and OS 3 with AdminStatus set as (R=1, D=1), which means a request for the optical switches to stay “aware” of a tearing-down procedure. OS 1 and OS 3 show awareness by

sending Resv messages back to OS 2 with AdminStatus set as (R=0, D=1). OS 2 then sends PathTear messages for releasing the light path. From this point on, flows coming from router A will be forwarded at IP-level in the optical network.

IV. CONCLUSION

In this paper we have presented a new approach for providing (establishing and releasing) light paths for IP flows that demand a great amount of routing resources in IP networks.

We have discussed two approaches that are currently used for providing light paths: conventional management and GMPLS signalling. In both approaches the light path is explicitly established and released by (human) managers or entities (end-users). Thus, only IP flows that are well-known to these managers/entities will benefit from being transferred over dedicated light paths. However, we believe that there are also other IP flows that could benefit from being moved to the optical-level, but which are not detected in these approaches.

Our solution to solve this problem is to make optical switches in charge of detecting such IP flows and to automatically provide dedicated light paths for them, without further interactions with network managers or end-users.

As future work we plan to investigate which configuration parameters are needed, and what will be the optimum values for these parameters. In addition, the decision which IP flows should be transferred over light paths should be further analysed. For this purpose we will define multiple scenarios, and evaluate each of them. Finally we intend to extend our solution to the multi-domain case and allow multiple optical networks to be involved in the provisioning of light paths.

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