Policy-based Hybrid Hierarchical Optical Networks

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Abstract

This document presents provisioning strategies for emerging hybrid optical networks. The idea is to make use of policy-based management that guides the behavior of a network through high-level declarative directives. In this regard and in the context of hybrid optical networks, policy rules are employed as the main means to extend the functionality of the control system and to complement its role in order to achieve the service provisioning.

Keywords – *Hybrid Hierarchical Optical Networks, Network Management, Service Level Agreement, Service Provisioning, Policy-based Management*

1. Introduction and Background

The explosive growth of Internet data traffic has created a demand for capacity that doubles every year. Optical DWDM transmission has thus become a key technology to accommodate the continuing expansion of demand that keeps on fueling the growth of data traffic. Nonetheless, blindly augmenting transmission capacity is not the long-term solution. Therefore, in order to keep up with the incumbent challenges, next-generation optical carrier networks are expected to support the increasing load by employing advanced transmission (DWDM), and switching (hybrid optical cross-connects) technologies [1]. This huge increase of capacity challenges the switching equipments managing these wavelengths (separating, combining, adding, dropping, switching, and converting). It is in this context that emerging hybrid hierarchical optical cross-connects [2] become an attractive solution in next-generation optical networks. This is especially true since significant expenditure savings provided by hybrid technology, which replaces much expensive opto-electronic fabric with an all-optical one. This potential is augmented by the hierarchical technology merit (i.e., waveband switching), which further reduces capital expenditure since the same optical port can process multiple wavelengths simultaneously [2].

Before going any further, in this paper hybrid optical cross-connects are defined as being constituted of a transparent waveband switching stage and of a regenerative wavelength switching stage with a partial capacity with regard to the overall node throughput [3] (Figure 1). A waveband is formed by a set of wavelengths, and is either switched in the optical domain to another waveband or dynamically directed to the wavelength switching stage where electronic processing is performed.

In order to provision and manage optical services in hybrid optical networks, the management plane must operate in conjunction with the GMPLS control plane [4]. This latter might require, during the provisioning process, additional information to meet operators' expectations. The concept of Policy-based Network Management (PBM) [5] addresses that problem and offers solutions. In this paper, we expect to perform service provisioning using policy rules that are deduced from service agreements criteria.

However, since the policy approach is a very general one and has to solve a number of issues simultaneously, it is useful to examine its application to GMPLS-enabled hybrid optical networks [3], for which the internal topology abstraction consists of Traffic Engineering links (TE links) and the set of advertised Forwarding Adjacency (FA) [4, 6]. They form the topology perceived in the control plane which is constructed by the routing algorithm [7]. The virtual topology is used for path computation which is fulfilled by a Constraint-based Routing function (CBR) [8], via a Constraint Shortest Path First (CSPF) algorithm. The topology view will differ whether the computation of the explicit route is for a waveband-LSP (FA) or for a lambda-LSP (customer connection). Following the LSP nesting principle, and in the considered hybrid optical networks context, a waveband-LSP must be established before establishing the lambda-LSP to be nested in. Therefore, waveband coverage of the network is done before establishing the connections required by customers.

Next section provides an overview of the proposed policy control framework. While last section identifies the different policy rules put into action within the framework.

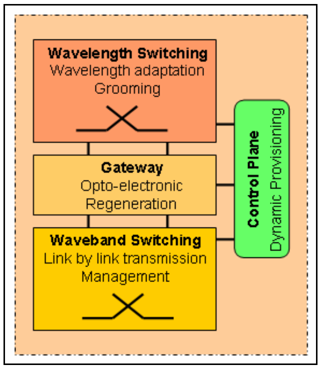

Figure 1. Hybrid optical cross-connect

2. Overall Policy based Framework

Figure 2 depicts the overall framework that has been retained for the purposes of controlling the network using policy rules. The rational behind this framework lies in the assignment of a unique identifier (SLA-Id) to the customer, once a service contract has been settled with the operator. The SLA id object is used by the management plane to index the different policy rules concerning a specific SLA.

First of all, clients may request a connection via the User to Network Interface (UNI), which entails a classical Call Admission Control (CAC) performed by the management plane. Besides the service request procedure, the second event that can be highlighted during the service provisioning process would be policy provisioning, where the management plane downloads the policy rules to the various nodes. However, in order to identify the group of policies associated to a specific SLA, the management plane employs the SLA-Id object conveyed in the UNI session request.

3. Policy Usage

The Optical SLA defined in [9] provides guidelines about client expectations regarding service fulfillment. As such, the different policy rules that can be used for this purpose may be inferred from the corresponding SLS parameters. In this section, we draw provisioning rules based on each of these parameters. However, some SLS parameters are omitted, like Service Boundary and Flow Identifier which doesn't generate policy rules on their own but participate in the formulation of policy rules derived from the other parameters.

Before going further, a policy rule is represented in the literature by the "IF Condition THEN Action" semantic, which is used from now on in the document [5].

Traffic Conformance and Excess Treatment. These two parameters are correlated: the first parameter, Traffic Conformance, describes the profile to which must agree the client's traffic in order to be classified as in-profile; otherwise it is considered as out-of-profile. In the latter case, the second parameter, i.e. Excess Treatment, determines what to do with the out-of-profile traffic. Excess traffic may be shaped, or degraded. In the optical domain, shaping is done through Optical-Electronic-Optical (OEO) regeneration of the optical signal; while degrading means further transmission across the network without regeneration.

- IF ((optical client) AND (time within Service Schedule) AND (traffic profile = Traffic Conformance)) THEN further transmit signal into the optical network
- IF ((optical client) AND (time within Service Schedule) AND (traffic profile ≠ Traffic Conformance) AND (Excess Treatment = shaping)) THEN cross-connect to electronic stage (regeneration of optical signal)
- IF ((optical client) AND (time within Service Schedule) AND (traffic profile ≠ Traffic Conformance) AND (Excess Treatment = degrading)) THEN further transmit the signal

Service Schedule. This parameter indicates when the service is available by indicating the start and end date and time related to the service. From this parameter can be inferred policy rules that activate or tear down services. For lambda LSP clients, service activation means the setup of a new lambda LSP; while this would not be the case for under lambda clients.

- IF ((optical client) AND (Current time/date approaches start time/date)) THEN Create LSP

Connection Setup Time. This parameter specifies how long it will take for a service connection to be established once it has been negotiated and requested. As a result, a service such as Bandwidth on Demand (BoD) [9] must be treated in a special way in order to meet its stringent connection setup time constraints (in the order of minutes). Under these conditions, the operator can consider to privilege the use of existing FAs when dealing with a BoD service in an attempt to avoid the lengthy process of creating a new FA during service provisioning.

- IF ((Service is BoD) AND (Connection Setup Time < threshold)) THEN Privilege the use of existing FA's

Service Performance Guarantees. The Service Performance Guarantees parameters concern the selection of the path taken by an LSP. For a lambda LSP, two SLS parameters were identified: Delay, Throughput. The role of the constraints induced by these parameters would be to prune from the virtual topology, over which the path

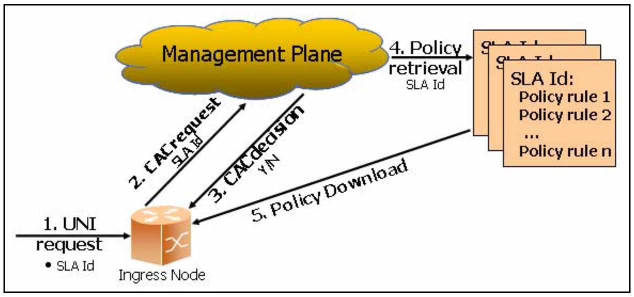

Figure 2. Overall policy control framework

computation is performed, the links that do not meet the service exigencies.

- IF ((FA's bandwidth < SLS' bandwidth) OR (FA's delay > SLS' delay)) THEN prune the designated FA from virtual topology during path computation process

Routing Stability. The routing stability determines how often optical traffic trunks can be rerouted. An important policy rule induced from this parameter is more related to traffic engineering actions: periodically, a network operator reroutes clients' traffic in an attempt to optimize network resource usage.

- IF ((LSP load < threshold) AND (elapsed time = value) AND (Number of rerouting done so far < Routing Stability)) THEN reroute traffic and delete LSP

Route Differentiation. This parameter places two important routing constraints on the operator: the establishment of LSP that do not share the same links or nodes (SRLG) [10] and the exclusion of links situated in a certain region or territory from being associated to the LSP route of a specific client. For the second constraint, the coloring concept [8, 11] is used on the links (FA) of the virtual topology. The links are provided a certain color ("restricted" for instance) by the management plane.

- IF (Route differentiation is "(link, node) diff") THEN Remove previous connections' links and nodes from the virtual topology
- IF (FA is colored as restricted) THEN prune it from virtual topology

Confidentiality. A total confidentiality associated with a certain connection request indicates an end-to-end transparent (not regenerated) connection. A lower confidentiality level called partial transparency has been envisioned though the O-SLA, in this case grooming with other clients is avoided. This goal can be reached using the coloring concept that can be used to hide an LSP to other clients.

- IF (LSP requires complete transparency) THEN find a waveband from source to destination, if it doesn't exist create a new one
- IF (Partial confidentiality) THEN either don't declare LSP or color as restricted the established LSP

4. Conclusion

The problem we have identified is pertaining to service provisioning in GMPLS-enabled hybrid optical networks. Policy rules induced from service level agreements have been defined in this paper as a possible means to complement the provisioning process with intelligent directives ensuring the right enforcement of a service.

The possibility of conflict among the different policy rules defined through this document is always under study and a future work will present different conflict cases with possible solutions in this regard.

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