Some open issues in multi-domain/multi-operator ASON/GMPLS networks

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ABSTRACT

Optical networks are composed by several domains each one controlled by different administrators/operators. Moreover, the bandwidth granularity of the domains may be different. In such a context, Label Switched Paths (LSP) provisioning in inter-domain/inter-operators network scenarios is actually a challenging problem, which has to be properly faced. In this paper, some open issues related to the end-to-end bandwidth provisioning are discussed and some solutions are highlighted. Among others, end-to-end recovery mechanisms for which the very limited information dissemination among domains affects their performances are discussed. Moreover, for multi-layer/multi-domain optical networks, the grooming problem jointly with the end-end services requirements is also taken in consideration.

Keywords: ASON, GMPLS, Multi-X networks.

1. INTRODUCTION

A communication network must be seen in its overall structure, which means to consider not just the transport layer (optical layer) but also the interworking between the transport layer and the client networks. In fact, the optical transport network is not isolated being connected to client networks (MPLS, SDH, IP, Ethernet, etc.). In the last years, in particular IP/MPLS networks have attracted the interest of many Network Operators.

ITU-T, IETF and OIF standardization bodies have recently provided architectural and protocol specifications to facilitate the interoperability amongst different network domains, technologies and vendor equipments. As defined in [1], a domain as any collection of network elements within a common sphere of address management or path computation responsibility.

In this context, the ASON architecture [2] introduces intelligence to the optical transport network by means of a control plane. The GMPLS protocol set [3] has arisen as the most accepted solution for implementing the control plane functionalities in ASON. Finally, OIF standardization work is devoted to the user-to-network interface (UNI), [4]) and the interface between different ASONs (E-NNI) [5], [6]. In particular, the OIF E-NNI routing specifications define for each domain a higher-level (hierarchical) OSPF instance that advertises selected resource information to each other domain in order to allow head domains to compute an inter-domain route.

Moreover, optical channels are able to carry 10 Gbit/s and beyond traffic flows. However, it is not usual to have such amounts of traffic between any pair of client nodes [7]. Wavelength capacity is thus wasted due to the mismatch between the bandwidth requirements of the client data flows and the optical channels capacity, leading to low wavelength bandwidth utilization and, from the network planning point of view, it increases the Capital Expenditure (CAPEX) of the transport network. In order to efficiently utilize this capacity, a number of independent lower-rate LSPs can be multiplexed into a single higher-order LSP (the so-called traffic grooming [8]) in order to meet network design goals such as hardware cost minimization. When the higher-order LSP is set up in the ASON domain is also called as λ-LSP.

On the other hand, the optimization of the utilization of network resources is very critical when failures occur in the network. Failures can occur at different layers composing the network architecture and thus it is crucial to decide at which layer the recovery is implemented. For example, lower layers could not be aware of failure occurred at the higher layers (i.e., client networks). To face failures, the resilience single-layer strategy (a single network layer has the responsibility for the recovery) is very simple from the implementation point of view. However it may not be able to efficiently recover the network from all kind of failures that can occur. Therefore, multi-layer resilience (various network layers can participate to the recovery actions) provides better performance in terms of protection.

Although a lot of effort has been done to standardize multi-domain/operator/layer (henceforth multi-X for short) aspects, there are still some open issues. In this paper, we explore some of these issues under scenarios such as the depicted in Fig. 1, where several access and transport networks, belonging to distinct operators, are interconnected.

This work has been partially funded by the Spanish Science Ministry through the project ENGINE (TEC2008-02634).

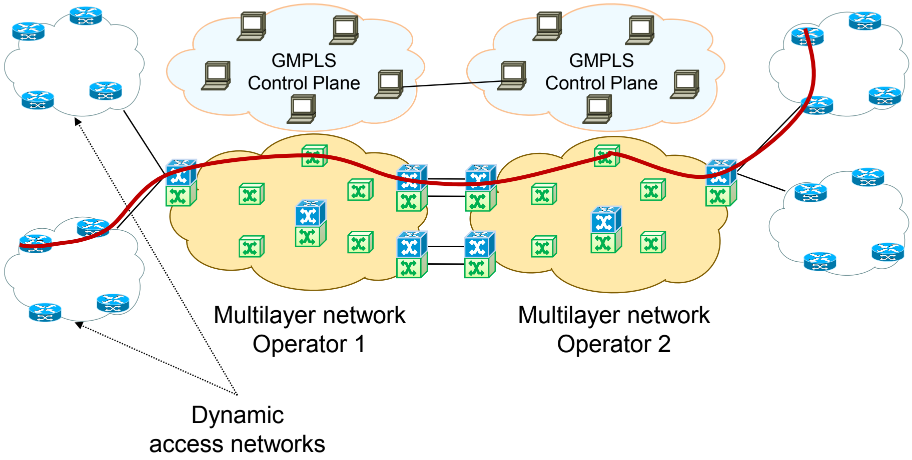

Fig. 1. Multi-domain and Multi-layer scenario.

2. MULTI-DOMAIN SCENARIOS

Currently, the IETF is defining signaling and routing mechanisms and extensions to allow LSP set up and maintenance across multiple domains. Also, it is defining abstract link and LSP properties needed for link and LSP protection, specifying signaling mechanisms for LSP protection, diverse routing and fast LSP restoration, thus ensuring that multi-domain LSP protection and restoration functions are achievable using the defined signaling and routing, either separately or in combination.

Specifically, [9] focuses on the route computation aspects and defines a method for establishing inter-domain LSPs, where each node in charge of computing a section of an inter-domain TE LSP path. When the visibility of an end-to-end complete LSP spanning multiple domains is not available at the source node, one approach consists of using a per-domain route computation technique during LSP set up to determine the inter-domain TE LSP as it traverses multiple domains. This technique is based on using sets of loose and strict hops. However, when the objective is to get an end-to-end constraint-based shortest route across multiple domains, then a mechanism using one or more distributed PCEs [1] could be used to compute the shortest route across different domains. Path Computation Clients (PCC) may make requests to a PCE for paths to be computed.

However, after a failure affects an inter-domain LSP some specific information related with the failure must be send across different domains if that LSP need to be rerouted. As an example, Fig. 2 shows two connected ASON/GMPLS domains where an inter-domain LSP between OXC_A in the network operator 1 domain and OXC_3 in the network operator 2 domain has been set up.

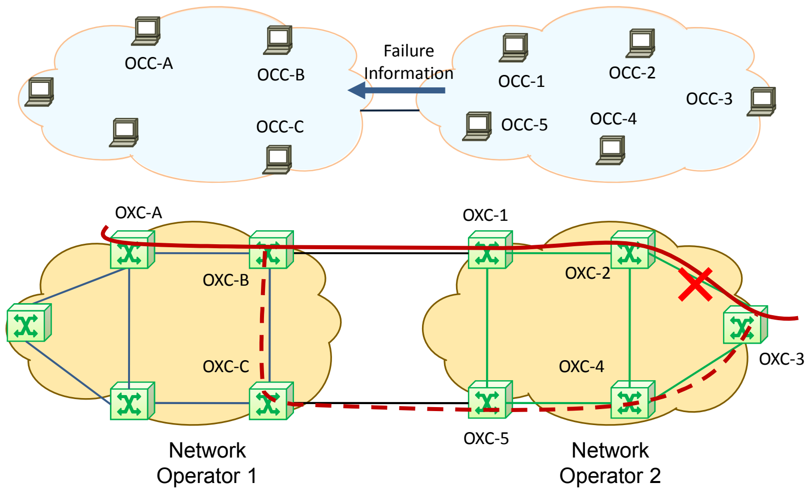

Fig. 2. Multi-domain recovery

If the link OXC_2-OXC_3 fails, a failure notification is sent to upstream and downstream OCC nodes in the LSP route, giving them the opportunity to reroute that LSP. In Fig. 2, OCC-1 receives that notification. If no alternative route is found to restore the LSP, which is a normal situation in networks without wavelength converters, OCC_1 must forward the failure notification upstream to the neighbor domain. In such a case, some information belonging to the domain 2 is needed to be sent to the domain 1 in order to exclude those resources in failure and those resources without enough resources to reroute the LSP. In Fig. 2, the notification must include the failed link OXC_2-OXC_3, and OXC_1 local data-links with wavelength the one currently used by the LSP.

Including that information, the OCC_B can compute a new route for the LSP excluding those resources. OCC_B has to add those excluded resources in a XRO object in the RSVP Path message [10]. Upon the reception of the Path message at OCC_5, the new route segment in the domain 2 is computed excluding those resources in the incoming XRO, giving a result the new route depicted in Fig. 2.

Another open issue is traffic differentiation in multi-domain scenarios. The massive use of the Internet and multimedia applications highly increases the traffic to be carried by optical networks. Typically, the Internet traffic is not considered as a critical service and the revenues obtained from carrying this traffic are, in general, low. Nevertheless, business data traffic, requiring much less capacity than Internet traffic, is usually associated with strict SLAs. SLA breaches turn into revenue losses for carriers. In between, carrying telephonic traffic provides regular revenues with less strict service requirements. Therefore, it is important for network operators to implement some classes of service policy to differentiate traffic. Although several proposals providing intra-domain traffic differentiation can be found in the literature, in the best of our knowledge, there are any for the inter-domain.

3. MULTI-LAYER SCENARIOS

A network may comprise multiple layers. These layers may represent separations of technologies, separation of data plane switching granularity levels, or a distinction between client and server networking roles. In this multi-layer network, LSPs in lower layers are used to carry higher-layer LSPs. Extensions of the current protocols in order to achieve interworking between MPLS and GMPLS networks are currently being studied within the IETF.

The network topology formed by lower-layer LSPs, and advertised as TE links in the higher layer, is called a virtual network topology [11]. It is important to optimize network resource utilization globally, taking into account all layers, rather than optimizing resource utilization at each layer independently allowing better network efficiency to be achieved; this is called inter-layer traffic engineering. This includes mechanisms allowing the computation of end-to-end paths across layers, and mechanisms for control and management of the virtual topology by setting up and releasing LSPs in the lower layers. PCE can also provide a suitable mechanism for resolving inter-layer path computation issues. In [12], PCE protocol extensions for inter-layer traffic engineering are presented.

Moreover, the localization of nodes with grooming capabilities highly impact over the λ-LSP length, and thus over number of the expensive Opto-Electronic (O/E) ports to be equipped in the network. Therefore, network planning tools able to decide the optimal placement of grooming capable nodes, thus reducing CAPEX, are needed.

Regarding recovery, both network technologies, MPLS and GMPLS, provide intra-domain recovery mechanisms able to recover LSPs from failures over resources strictly in that domain. For example, in MPLS fast reroute [13] mechanisms can be used to recover MPLS LSPs from failures in that network; whereas a wider variety of mechanisms have been proposed to be used in ASON GMPLS networks. In [14], an analysis to evaluate, compare, and contrast the GMPLS capabilities with the recovery mechanisms currently proposed at the IETF is provided. Recently, [15] provides RSVP-TE extensions in support to the end-to-end LSP recovery in GMPLS networks. However, when the resource in failure is the border node, in our case the OBN1 in Fig. 3, it is not clear how the different layers have to become coordinated and which domain has to provide the recovery mechanism. This case can be extended to a more general case in which when the optical layer cannot provide the needed recovery after the detection of an intra-domain failure, communicates this event to the client layer to provide recover in the client layer.

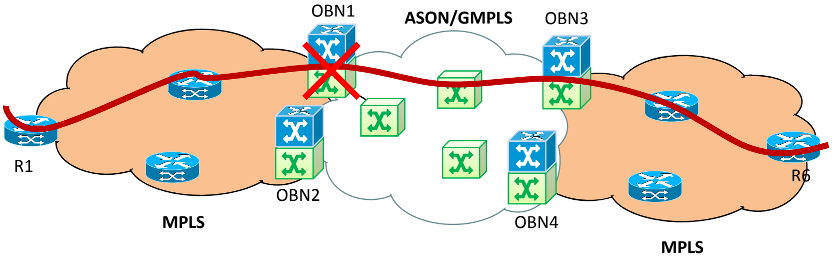

Fig. 3. Border Node failure in a multi-layer scenario.

Therefore, extensions for the intra-domain protection mechanisms to the multi-layer and multi-domain scenario must be studied.

4. MULTI-DOMAIN/MULTI-LAYER

Current control plane solutions do not provide the adequate functionalities and Traffic Engineering (TE) capabilities to fully support recent and innovative optical technologies. Network TE is a powerful mean for guaranteeing the requested Quality of Services (QoS) to the users while maximizing the overall network resource utilization. TE has a strong impact in both CAPEX and Operational Expenditure (OPEX) and, as a consequence, on the cost of advanced network services to end-users. So far, TE has been rarely adopted by Network Operators in single-domain and single system vendor optical networks because of the intrinsic complexity of the current TE mechanisms and procedures. In addition, because of the limited availability of effective solutions, TE is practically unavailable in multi-domain multi-vendor networks. Finally, TE is completely unsupported in multi-domain/operator/layer transparent optical networks because of the complete lack of TE procedures

The design of multi-layer strategies to efficiently utilize the available bandwidth in the optical domain (multi/layer traffic engineering, MLTE) and interworking strategies to optimize the network reconfiguration in case of failures occurred in the network infrastructure (multi-layer protection) is thus needed.

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