A POLICY MANAGEMENT FRAMEWORK FOR GMPLS OPTICAL NETWORKS

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Abstract: This paper presents a policy-based management framework for GMPLS-enabled optical networks. First, the (Automatic Switched Optical Networks) and GMPLS (Generalized Multi-Protocol Label Switching) architecture are presented. We then present a framework based on an admission control protocol COPS (Common Open Policy Service) defined by the IETF (Internet Engineering Task Force) and on an Information Model based on the CIM (Common Information Model) model defined by DMTF (Distributed Management Task Force). This framework allows interworking between the policy and control plane, and provides a comprehensive policy provisioning setup for optical networks. An information model extended from CIM for managing dynamically configured optical networks is presented.

Key words: ASON, CIM, GMPLS, Optical Network Management, Policy Management Framework

1. INTRODUCTION

The Internet transport infrastructure is moving towards a model of high-speed routers interconnected by optical core networks. The architectural choices for the interaction between IP and optical network layers, specifically, the routing and signaling aspects, are maturing. At the same time, a consensus has emerged in the industry on utilizing IP-based protocols for the optical control plane. This poses new network design and management problems. The management needs to take into account the IP-centric control plane to support dynamic provisioning and restoration of the Optical high bandwidth services like lighthpath services. This control plane will provide an end-to-end provisioning within the optical network, including

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routing and signaling to the following types of devices: IP Routers, ATM switches and Frame Relay switches, etc. The management requirements are evolving to include faster, interoperable and dynamic provisioning of optical paths, a better integration with data networks, a more efficient use of network resource, a better support of transparent technologies, the ability to let service providers offer new services such as on-demand provisioning of optical paths.

Various standard organizations have proposed a control plane with signaling and routing functions for inter-domain networks. Driven by ANSI-T1X1.5 working group and the OIF (Optical Internetworking Forum), the ITU-T ASTN and ASON (Automatic Switched Transport/Optical Network) [1][2] describes the requirement and architecture of a control plane applicable to Optical Transport Networks defined in ITU-T Rec. G.805 [3] and Rec. G.872 [4]. ASON defines standard interfaces such as UNI (User-to-Network Interface) and NNI (Network-to-Network Interface) focused on signaling between Optical and User Network. The ASON standard also makes use of other ITU-T standards that help define the new intelligent optical networks [5]-[8].

In the IP world, the Internet Engineering Task Force (IETF) is currently defining a GMPLS (Generalized Multi-Protocol Label Switching) architecture [10]. GMPLS is a protocol suite [11] that uses advanced network signaling and routing mechanisms to automate set up of end-to-end connections for all types of network traffic: time-division-multiplexed, packet- or cell-based, wavebands, or wavelengths. GMPLS extends MPLS (Multi-Protocol Label Switching) to encompass SONET/SDH, PDH, G.709, WDM networks.

In this article, we propose a configurable mechanism based on Internet-based policy control framework which is required to regulate and control the information propagation across both types (public and private) of the UNI interface. The proposed framework is based on an admission control protocol COPS (Common Open Policy Service) defined by IETF and an Information Model based on the CIM (Common Information Model) model defined by DMTF (Distributed Management Task Force). This policy-based control can describe an admission control mechanism including authorization function to ensure that the requester is allowed to setup a connection between two endpoints. This authorization is required at public UNIs to provide more seamless interworking with IP-controlled devices. Paramount to the framework is an information model to manage the GMPLS-enabled optical paths.

The remainder of the document is organized as follows: Sections 2 describes the ASON and GMPLS architecture. Section 3 presents the Policy Control framework. Section 4 describes the extension to the UNI control plane interfaces to integrate with the policy framework. Section 5 describes the information model for managing GMPLS-enabled networks. Finally, we will draw concluding remarks.

2. ASON, GMPLS AND POLICY PLANE

2.1 ASON architecture

Currently, provisioning optical networks have no automated control. Lightpaths are set-up a priori and manually based on known or expected traffic conditions. ASON and GMPLS both define a control plane that allows the automatic set-up of optical paths. Therefore, as service providers introduce new network elements into their networks, add/remove facilities, or turn up new circuits, the control plane will automatically distribute and update the network with the new information.

The ITU-T ASON (Automatic Switched Optical Network) [2] control plane is composed of different components that provide specific functions including route determination and signaling. The ASON control plane defines a user-to-network interface (UNI) and a network-to-network interface (NNI). The UNI provides the connection between domains (e.g., user domain to service provider domain) for service requests, while the NNI provides the connection within a domain.

The ASON network can be viewed as made up of several control plane agents supporting dynamic call connection. The following is a list of the different ASON functions:

- **Survivability:** Survivability mechanisms is one aspect of the ASON network which may be realized by the transport network (e.g., mesh, ring or point-to-point protection) or by the ASON control plane function;

- **Link management:** These mechanisms provide link management for the service provider network;

- **Path computation:** It is responsible for the computation of end-to-end optical primary and backup paths;

- **Signaling :** Signaling mechanism provides for the communication of the ASON network, e.g., in setting up connection requests, **release, modification and maintenance of connections**. A signaling mechanism is needed for both UNI and NNI. OIF defined a **UNI 1.0 Signaling Specification** [9];

- **Routing:** Routing mechanism provides for automated route determination/calculation and route discovery through the service provider network. Example routing mechanisms currently used in other technologies include OSPF and BGP;

- **Topology Discovery:** Network connectivity provides the architecture of the service provider network by providing a topological view of the network via the discovery mechanism. The ASON routing mechanism will likely use this information for route calculations and link management;

- **Directory service & Name translation:** Directory service & name translation provides the ASON network with mapping of names and association of these names between layers (client-server layer) or domains (user-service provider domains).

For the purpose of managing connections within a layer network, the underlying transport plane resources are represented by a number of entities in the ASON

control plane. These transport resources are described using ITU-T Recommendation G.805 [3]. Entities managed include: Trails, subnetwork connections (SNC), Links, Trail Termination Point (TTP), Connection Termination points (CTP), etc. For the purpose of network management, the model presented in ITU-T Rec. M.3100 [12] is used.

2.2 GMPLS

Specified by the International Engineering Task Force (IETF), GMPLS (Generalized Multi-Protocol Label Switching) [10] [11] is a protocol suite that uses advanced network signaling and routing mechanisms to automate set up of end-to-end connections for all types of network traffic: time-division-multiplexed, packet- or cell-based, wavebands, or wavelengths. GMPLS has evolved from MPLS, the original IETF standard intended to enhance the forwarding performance and traffic engineering intelligence of packet-based networks. GMPLS will allow an entire infrastructure, extending from the access network to the core network, to utilize a common control plane. In a GMPLS-based network, it is possible to find and provision end-to-end paths that traverse different networks. For instance, a packet/cell LSP can be nested in a TDM LSP for transport over a Sonet network. The TDM LSP can similarly be nested in a wavelength-level LSP for transport over a wavelength network. This forwarding hierarchy of nested LSPs allows service providers to seamlessly send different types of traffic over varying network segments.

A GMPLS-based network can offer many capabilities: network resource discovery and routing control; dynamic provisioning and traffic engineering for end-to-end connections; bandwidth-on-demand for just-in-time service creation; and new quality of service-defined value-added services. A consequence of generalizing MPLS to encompass optical links is that a label is no longer an abstract identifier, but must now be able to map time slots, wavelengths, and physical resources such as ports on a switch. Some modifications and additions were required to the GMPLS routing and signaling protocols to adapt to the optical switch:

1. A new Link Management Protocol (LMP) designed to address issues related to link management in optical networks using photonic switches for controlling channel management and link information exchange between neighboring optical network elements;
2. Extensions in order to provide management applications with the topology of the optical network, optical NE capabilities, resource availability, etc.;
3. Enhancements to the dynamic routing protocols Intermediate to Intermediate System (IS-IS) and Open Shortest Path First (OSPF) routing protocols to advertise availability of optical resources;
4. Enhancements to the Resource Reservation Protocol (RSVP)/Constraint-based Routing Label-Distributed Protocol (CR-LDP) signaling protocols for traffic engineering purposes;

5. Scalability enhancements such as hierarchical LSP formation and link bundling;
6. Support for unnumbered links.

2.3 GMPLS/ASON control plane and the policy plane

Policies are needed to guide the ASON/GMPLS control functions. We will describe how the policy plane relates to the control plane and the management plane.

In the signaling function, a call admission control is one phase of the call set-up. Call admission control is a policy function invoked by an Originating role in a network and may involve cooperation with the Terminating role in the network. The Originating Call admission function is responsible for checking that a valid called user name and parameters has been provided. The service parameters are checked against a Service Level Specification. The Terminating Call admission function is responsible for checking that the called party is entitled to accept the call, based on the calling party and called party service contracts.

Route computation can be achieved by the control plane or by the management plane, using a centralized or decentralized approach. The policy plane may impact the routing used in both the management and the control plane. GMPLS policies can be used to define the conditions in resource utilization and in resource management strategy changes, as well as to perform decision-making on single or composite events notified internally or externally monitored. Optical paths may be dynamic but also can be permanent. The representation and the management of the permanent connections may be done in the management plane, outside the scope of the control plane. The management plane will then need to interact with the policy plane to exchange policy information.

The policy plane play a key role in the realization of the different control plane and management functions.

3. POLICY CONTROL FRAMEWORK

In this section, we will present the policy control framework which is based on [13]. Policy Control is composed of two key elements: the mechanisms of exchanging policy information and an information model that describes those policies.

3.1 Extending the control plane with Policy Control

The control plane needs a policy plane to decide whether or not a service request can be granted to a requesting device. Policies are defined by a set of rules to administer, manage, and control access to network resources. A policy consists in an event-condition-action chain that impacts decisions taken or actions performed

within the GMPLS/ASON control plane and the management plane. Policy Control can provide connection control admission, constraining the lightpath establishment based on the service level parameter constraints: bandwidth, QoS or time. When the policy server receives a request from the optical device, it gathers all the necessary information to formulate a decision and returns a response. During the UNI or NNI session set-up, policy-based information (service level, contract information) is exchanged and authorized between the clients and the service provider.

Connection Path computation can be achieved by the control plane or by the management plane. The policy control functions will guide the routing used in both the management and the control plane. Integrated Traffic engineering allows optimizing the bandwidth utilization and performance. It may be achieved through a central off-line traffic engineering tool or using a decentralized approach through load balancing or LSP (Label Switched Path) rearrangements. The representation and the management of the permanent connections may be done in the management plane, outside the scope of the control plane. The management plane will then need to interact with the policy plane to exchange policy information.

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The policy can bridge the gap between the automatic signaling approach and a more static approach provided by the management plane. Policies are needed to guide the control functions or the management functions and to provision the optical network effectively..

3.2 Policy Framework

The proposed framework is based on the IETF Common Open Policy Service (COPS) protocol [14]. COPS supports policy-based call acceptance, user access authentication and authorization, usage-based accounting, etc. COPS is a simple client-server protocol specification designed for communicating policy information within a policy management system. The built-in reliability and security features of the COPS protocol ensure its applicability to robust services-provisioning scenarios.

The primary policy management architectural components are the policy decision point (PDP), policy enforcement points (PEPs), and the policy repository, typically

stored in a directory. To make its decisions, the PDP taps the repository for the rules and conditions established by the network manager and decides based on current network conditions, how traffic and access rights should be enforced. Once the PDP has made a decision on how to treat network traffic, it communicates this behavior to the PEPs (routers, switches, and gateways) via COPS. The PEP corresponds to the Port in the GMPLS model. The PDP can be done within the Port, though it may be distributed to a different system.

An optical network is a collection of optical sub-networks constituted by Optical Network Element (ONE), such as Optical Cross-Connect (OCX), Photonic Cross-Connect (PXC), Optical Add/Drop multiplexers (OADM) which are interconnected in a general mesh topology. The edge device can be different types of network element such as IP Routers, ATM switches, etc.

Figure 1 shows the GMPLS/ASON Architecture with the Control Plane, the Management Plane and the Policy Plane.

Figure 1. Control Plane architecture with Policy plane

The Optical Connection Controller (OCC) will have the ability to establish, close and maintain the end-to-end Optical Link connection in real-time between two Edge Devices. The OCC will exchange thru signaling protocol information about the Optical Link Connection. When routing an optical path, OCC have to dynamically distribute and propagate the network information among all the routing entities. Each routing entity can compute the best path from one point to another. OCC uses a resource/service discovery protocol to determine the available services and identify connection state information. Management Plane describes the functions related to the management of network element, networking layers, and network services. An Optical Connection will traverse two UNI interfaces and zero or more NNI interfaces. The optical connection can be either unidirectional or bi-directional and can be PDH, SDH, digitalWrapper, etc.

The policy framework components are the Policy Server (corresponding to PDP)

which communicates with Edge devices or ONEs (corresponding to the Policy Enforcement Point or PEP) via the COPS protocol. Different policy servers may share the information through directory services. LDAPv3 (Lightweight Directory Access Protocol) [15] is the most commonly used approach.

3.3 COPS

The policy control plane will be responsible for performing decision making on simple or composite events. The control plane needs a policy control to decide whether or not a service request can be granted to a requesting device. In the case of the ONE Interface, decisions should apply to connection request actions received from the client. We propose to add the PEP to the optical control plane functions (see figure 2). When the policy server receives a request from the ONE, it gathers all the necessary information to formulate a decision and returns a response.

Figure 2. Extending the ONE functions

The UNI and NNI signaling operations are logically divided into three steps: set-up session, set-up link and set-up link connection. The session set-up is needed to exchange the policy-based information between the clients and the service providers. During link set-up, characteristic information are exchanged from the A-end to the Z-end. Information is exchanged on topological relationship and capacity availability from A-end to Z-end. After link establishment, link connections setup is established between A-end and Z-end users. We propose to map the establishment of the session to the COPS connection. For the UNI Interface, a session is established by the exchange of message SessionUtoN. During the session setup, admission, verification, service level, contract information is exchanged and authorized.

Two approaches for mapping the Session Setup with the COPS connection are possible. In the first approach, some of the equipment in place may not interoperate with a policy server. In such cases, the policy server must translate the policy decision to a protocol that each device can understand. In this case, the ONE uses the Session Setup to exchange session templates. The ONE will then use COPS connection to accept the connection. Therefore, when PEPs open communications with PDP servers, their initial Client-Open messages have the client-type set to

indicate a signaled client. If the PDP supports this client-type, it responds with a Client-Accept message or otherwise with a Client-Close message. In the second approach, the edge device acts as COPS Client with the Providers PDP. Then the UNI session Setup is performed. The Client Specific info object is used to specify the requested resources.

Separation between the policy plane and the control plane allows flexibility in approaches used for admission control or other type of policy-based actions

4. INFORMATION MODEL

4.1 Common Information Model (CIM) and PCIM

The proposed information model is based on the CIM (Common Information Model) model [16] developed by the DTMF (Distributed Management Task Force). CIM supplies a set of classes that provide a conceptual framework within which it is possible to organize the available information about the managed environment. The CIM specification provides a complete meta-model based on Unified Modeling Language (UML) for defining how management information should be presented and structured. The policy information model used is PCIM [17]. Other models have been presented: [18] present the design of an information model for ASON.

4.2 Extending the information model

GMPLS uses the following basic concepts (same concepts defined in MPLS):

- The Label Switched Path (LSP) defines the hops (Label Switch Routers or LSRs) that packets travel through. The LSP provides information about the path.
- The Tunnel has all the additional properties required to control the setup of a tunnel such as setup and holding priorities. The Tunnel may use one or more LSPs. Two types of LSPs are used: the primary LSP used to carry the real traffic and the backup LSPs established when the primary fails.
- The labels used in GMPLS need to identify the entities that are to be switched in the optical network. This includes the support of: Digital Carrier Hierarchy, SONET and SDH Hierarchy, PDH labels, G.709 labels, Lambdas and Fibers.

A white paper has been written on a MPLS CIM Network model [19].

Figure 3 shows the CIM extensions that defines the tunnels and LSPs. The GMPLSTunnel has association to itself since a Tunnel might be bi-directional. The traffic going into a particular tunnel is controlled via filtering policies. GMPLSTunnelHop can be used for describing the computed or the desired paths. A Tunnel has two different associations with an LSP. One defines the LSPs assigned for that particular Tunnel (primary and backup). Segments correspond to GMPLS labels.

Figure 5. Optical Network connection model

The CIM model was extended to include policy information. The IETF Policy Core Information Model (PCIM) [17] is a joint effort of the IETF Policy Working Group and the DMTF Service Level Agreement WG. The policy information model defines management abstractions: profiles, policies, devices, protocols, and services. This model represents the policy information carried between the Edge Device and the optical network so it can be handled by the Policy Control Plane. GMPLS classes can be associated with the PCIM Policy classes to enable the control admission capabilities and other policy related functions.

5. CONCLUSION

The ASON control plane can make use of GMPLS-related protocols and their extensions for the optical networks currently being defined by the IETF. GMPLS will provide the necessary bridges between the IP and photonic layers to allow for interoperable and scalable parallel growth in the IP and photonic dimensions. GMPLS provides the ability to automate many of the network functions that are operationally complex, ultimately making the optical network intelligent.

Policy management plays a critical role in establishing the new GMPLS-capable networks for admission control and for other type of policy services [20]. It is difficult to provide a automation: some control is required by the network administrator. The presented framework based on IETF COPS and CIM extensions is a foundation for an optical policy plane. A separation of the policy plane allows coping with the different functions at the control and management plane. We defined an information model for managing GMPLS-enabled optical networks, The IETF GMPLS optical extended MIBs (Management Information Base) are currently been proposed [21] [22]. This will have an impact on the mapping between the IETF MIBs and the extended CIM model proposed in this paper.

The policy plane can also facilitate the establishment of different strategies for different domains. Each domain may have different rules represented by policies. The Connection Admission Control is facilitated by a Policy Plane that contains the different policies for the different domains.

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