Relationship between SMP, ASON, GMPLS and SDN

With the introduction of a control plane in optical networks, this white paper describes the relationships between different protocols and architectures.

Introduction

Traditional networks consist of two operating planes: the management plane and the transport or data plane. In this architecture, the data plane carries the user data. It consists of various network equipment, such as interface cards, switching equipment, and the fiber plant. Network operating information is managed by the management plane consisting of the Element Management System (EMS), the Network Management System (NMS) and the Operation Support System (OSS).

With the advent of optical networks, a third operating plane was added. The optical control plane sits between the management plane and the data plane and helps to move some network intelligence down to the Network Elements (NE). As a result of adding the optical control plane, the NEs have access to the overall topology of the network and available resources allowing the NEs to participate in the planning, establishment and maintaining network services for the end users..

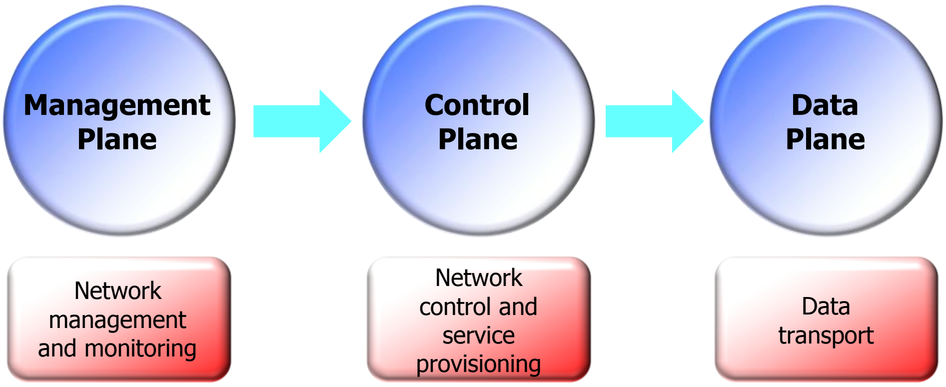

Figure 1: Operating planes for an optical transport network.

The control plane offers several benefits to the carriers. The control plane can provide much faster and less labor intensive service provisioning, therefore saving operating costs. It can also provide new revenue generating services, such as time-of-day service. Most of all, the control plane can provide efficient and cost effective network restoration.

Control Plane Applications

Most optical control plane applications focus mainly on the services that perform connection management for the transport plane for both the packet-based services and path-based services. The main functions of a control plane are:

- Routing control
- Resources discovery
- Connection management
- Connection restoration

Routing Control

The routing control function is responsible for selecting the combination of links to be used for a given connection, based on the network topology and routing criteria it is given. Common route selection criteria are things like: shortest path, lowest cost, fewest hops, and least congested. This function is triggered by a connection management function request and utilizes the network topology populated by resource discovery function.

Resource Discovery

The resource discovery function keeps track of the system resource availability such as bandwidth, multiplexing capability and ports. It is responsible for the discovery of neighboring nodes and the links connecting them, and the communication of this information to all relevant elements. It maintains the neighbor and link information and updates this in real time. This information enables all elements of the control plane to have an accurate topology map of the network to be used for connection management and routing control functions.

Connection Management

Connection management functions provide end-to-end service provisioning for different services as requested by the end users. The services include connection creation, modifications, status update, and tear down. Connections management functions often perform path computation based on parameters provided by the carriers. For example, path computation could establish a requested path based on the lowest cost. Other parameters could be bandwidth requirements, wavelength continuity, maximum allowable latency and optical characteristic allowable for the bit rates to be carried.

Path computation can also be used to calculate diverse routes needed for restoration.

Connection Restoration

Connection restoration function provides an additional level of protection to the network by establishing for each connection one or more pre-assigned backup resources. This pre-assigned path allows for quick restoration in case of a network failure.

Resource Management

Resource management is the function of controlling the utilization of resources based on network design parameters. It includes the formation of the Traffic Engineering (TE) database, based on the network topology and the real-time utilization of each link and node. The database makes it possible for the routing control function use the existing utilization of a link as criteria for routing. Resource management, in addition to maintaining an accurate record or utilization, typically includes the ability to reserve capacity for a particular purpose (such as capacity reserved for protection of active connections) or connection that is not yet active (such as a new customer circuit to be turned up at a certain time).

Control Plane Standards

When intelligent optical networks first arrived on the market, every implementation utilized different control plane architectures, to support varying functions, using proprietary protocols. Due to the fact that network operators typically included equipment from multiple suppliers (either by design or acquisition) and suppliers wanted to sell standards based products globally, work was started to standardize the optical control plane. There were parallel efforts in multiple standards development organizations and forums, but the International Telecommunication Union – Telecommunications Sector (ITU-T) first defined a clear architecture and a standardized set of functions for an optical network. The optical network with an active control plane between was labeled an Automatically Switched Optical Network (ASON) and the ASON architecture was defined in ITU-T Recommendation G.8080/Y.1304 (referred to as G.ASON when it was a draft). ASON is a standardized network architecture and set of functions for automated resource and connection management within the network, driven by dynamic signaling between users and ASON network elements. Though the acronym ASON implies applicability to optical networks, it is general enough for application to any network layer where connections (static or virtual) are used.

Implementers of the ASON control planes chose to re-use existing protocols from the Internet Engineering Task Force (IETF) for the control plane messages and agreed to a protocol based on Multi-Protocol Label Switching (MPLS). The IETF defined Generalized Multi-Protocol Label Switching (GMPLS) in RFC3473 to satisfy the requirements of those building ASON based control planes. This standard is a generalized signaling extension to MPLS. This extends the concept of a label to include implicit values defined by the medium that is being provisioned. It can be used to work with SONET/SDH/OTN equipment as well as with Wavelength Division Multiplexing (WDM) systems.

Automatically Switched Optical Network (ASON)

ASON is a control plane architecture allowing a policy driven control of a SDH or optical network using signaling between NEs and between users and NEs of a network. Its objective is to provide automated control functions for network resources and connections. The main objectives of an ASON network are:

- Automated end-to-end provisioning
- Automated re-routing for protection and restoration
- Dynamic setup of connections
- Enable different levels of quality of services

ASON/GMPLS Control Plane

GMPLS is the protocol defined to support a control plane based on the ASON architecture. Specific capabilities that fit under the ASON architecture are defined for GMPLS. The fundamental service provided by an ASON/GMPLS control plane is dynamic end-to-end connection provisioning. The operators need only to specify the connection parameters and send them to the ingress node. The network control plane can then determine the best optical paths across the network according to the parameters and signal the adjacent nodes to establish the connection.

ASON/GMPLS will also function well in today's multi- layers optical networks. It can be used for traffic grooming on edge nodes when applied across a two-layer network. For example, consider an optical wavelength routed in an optical network and an "optoelectronic" multiplexed layer over it. When a transparent light path connects in the optical layer (operating strictly at wavelength granularity) two physically adjacent or distant nodes, these nodes will seem adjacent to the multiplexing layer. The multiplexing layer can then multiplex the different traffic streams into a single wavelength-based light path. It can also de-multiplex different traffic streams from a single light path. At a multiplexing node, some of the de-multiplexed traffic can also be re-multiplexed into different light paths using a GMPLS-based control plane.

GMPLS includes the definition of several forms of labels – the generalized labels suitable to be used with wavelength-based optical networks. These objects include the generalized label request, the generalized label, the explicit label control, and the protection flag. The generalized label can be used to represent time slots, wavelengths, wave bands, or space-division multiplexed positions.

In order to set up a light path, GMPLS uses a signaling protocol to exchange control information among the nodes in the network, to distribute labels, and to reserve resources along the path. Signaling protocol to be used for the GMPLS control plane includes Resource Reservation Protocol (RSVP). RSVP can be used to reserve a single wavelength for a light path if the wavelength is known in advance. Open Shortest Path First (OSPF) can be used over GMPLS as a routing protocol to keep track of link states and select link as requested by users, management plane, or triggered by control plane functions.

GMPLS also uses the Link Management Protocol (LMP) to communicate proper cross-connect information between the network elements. LMP runs between adjacent systems for link provisioning and fault isolation.

In addition to the service-related advantages of using a control plane, the most important function of a control plane is to provide efficient and cost effective restoration for optical networks. In view of the current implementation of 40G and 100G systems, restoration become even most critical for future optical networks.

The efficient ASON/GMPLS based control plane incorporated with the management plane will not only provide new and better network functions but will also help the carriers explore new revenue streams as well as save network and operations costs.

Relationship between GMPLS, ASON and SMP

As explained earlier, ASON is a control plane architecture and a list of functions with GMPLS being the protocol used to implement those control plane functions. The ASON control plane performs many tasks in addition to protection and restoration. It uses a set of protocols, including GMPLS, to achieve the functions. ASON and GMPLS both can be used for control planes in packet and circuit networks.

Per the name, Shared Mesh Protection (SMP) is an attempt to define a standardized architecture with the primary function of sharing protection capacity in a meshed network. It works in the data plane and is independent on the management and control planes. It only provides protection and restoration functions, depending on pre-assigned protection resources. Its only relationship with the management plane rests with the notification functions, so network operators can be notified of a network failure and subsequent restoration. The simplicity of this architecture allows for faster and more reliable restoration. The activation of the process is initiated locally at the node using either Signal Fail (SF) or Signal Degrade (SD) parameters. It is not initiated by the control plane or the management plane. SMP is a protection mechanism designed for meshed network just like the SONET/SDH ring protection mechanism commonly used prior to the introduction of ASON and GMPLS. Technology-specific SMP is a more refined architecture designed specifically for a particular technology.

SDN and ASON/GMPLS

Software-Defined Networking (SDN) is a network architecture based on a signaling protocol (typically OpenFlow) with the primary purpose of automatically controlling a network for efficient utilization of network capacity and resources. It was created to reduce the amount of wasted network capacity and resources in a packet network, by automatically allocating them where they are needed. The primary SDN function is in many ways similar to the traffic engineering and capacity planning functions traditionally done for optical networks, where more static connections are the norm. The possibility of applying SDN across network layers based on physical connections and not the virtual connections that exist at the data layers is still being explored. The use of SDN for optical networks (either for TDM layers like SDH/SONET/OTN or optical layers) may help operators look for available resources and assign protection resources in the real time basis. While SDN could also be used to provision services, the linking of the functions in SDN and ASON/GMPLS, might assure efficient assignment of protection resources. For example, SDN may require the use of the discovery capability from either the ASON or GMPLS control plane. Indeed, the combination of the SDN and ASON/GMPLS functions might provide the operators with the most efficient optical network.

Conclusion

Thought often presented as competing technologies, SMP- and ASON/GMPS-based protection/restoration are two different approaches, playing at different levels.

GMPLS is the protocol defined to support a control plane based on the ASON architecture. The fundamental service provided by an ASON/GMPLS control plane is dynamic end-to-end connection provisioning.

SMP operation does not require ASON/GMPS technology:

- All ODUk paths are pre-provisioned/ pre-defined (this can be done by NMS, SDN, or ASON/GMPLS);
- SMP signaling is based on APS bytes in the ODUk overhead and does not rely on ASON/GMPLS routing;
- SMP-based protection switching is faster than restoration based on ASON/GMPS.

Depending on operators' requirements (spanning from hardware resources to switching time and global network availability), there is no one-size-fits-all solution or approach. As exposed above, the combination of the SDN and ASON/GMPLS functions, with mechanisms implemented in specific network layer on a per need basis, might provide the operators with the most efficient optical network.

Note: In another white paper, entitled "Shared Mesh Protection: What It Is and Where It Fits", Xtera describes the Shared Mesh Protection (SMP) architecture leading to faster protection switching than restoration based on ASON/GMPS protocols.

Maximizing Network Capacity, Reach and Value

Over land, under sea, worldwide

Edition Date: March 2014
Version: 1.0