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Automatic Switched Optical Network (ASON) Architecture and Its Related Protocols

Status of this Memo

1. Abstract

This draft describes an architecture for intelligent optical networks. This architecture is called the automatic switched optical networks (ASON). ASON is a client-server architecture with well-defined interfaces that allows clients to request services from the optical network (server). ASON architecture and its generic automatic switched transport networks (ASTN) has been an active study area both at T1X1 and ITU [2].

The protocols that run over ASON interfaces are not specified in [2]. The emerging of IP-based protocols, e.g. generalized MPLS [3], for the control of the optical layer makes it possible for the ASON architecture to benefit from the protocols design work that has been progressing at the IETF.

2. Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC-2119 [4].

3. Introduction

The existing transport networks provide SONET/SDH and WDM services whose connections are provisioned via network management protocols. This process is both slow (weeks to months) relative to the switching speed and costly to the network providers.

An automatic switched optical network (ASON) is an optical/transport network that has dynamic connection capability. It encompasses SONET/SDH, wavelength, and potentially fiber connection services in both OEO and all-opical networks. There are a number of added values related to such a capability:

- Traffic engineering of optical channels: Where bandwidth assignment is based on actual demand patterns.

- Mesh network topologies and restoration: Mesh network topologies can in general be engineered for better utilization for a given demand matrix. Ring topologies might not be as efficient due to the asymmetry of traffic patterns.

- Managed bandwidth to core IP network connectivity: A switched optical network can provide bandwidth and connectivity to an IP network in a dynamic manner compared to the relatively static service available today.

- Introduction of new optical services: The availability of switched optical networks will facilitate the introduction of new services at the optical layer. Those services include bandwidth on demand and optical virtual private networks (OVPN).

This draft describes the ASON architecture. ASON and its generic ASTN has been a topic of active discussion both at the T1X1 and ITU. The draft focuses on ASON control plane, its requirements, and related protocols.

4. ASON Architecture: An Overview

The ASON network architecture is shown in Figure 1. In this Figure all the components that can form part of ASON are shown. The architecture shown is intended to allow switching of optical network connections within the optical transport network under control of ASON signaling network.

There are three separate planes involved in the network:

- A transport plane (TP)
- A control plane (CP)
- A management plane (MP)

```
       +--------------------------+    +--------------+
       |   ASON Control Plane     |    |              |
       |                          |    |              |
   UNI |  +------+ I-NNI +------+ E-NNI|    +------+  |    +------+
   ------>| OCC  |-------| OCC  |-|----|----| OCC  |  | NMI|      |
       |  +------+       +------+ |    |    +------+  |<-->|      |
       |     ^              ^     |    |      ^       |    |      |
       +-----|--------------|-----+    +------|-------+    |      |
             | CCI          |                 |            |      |
       +-----|--------------|-----+    +------|-------+    |      |
       |     v              v     |    |      v       |    |      |
       |  +------+       +------+ |    |    +-----+   |<-->|      |
       |  | OXC  |       | OXC  | | PI |    | OXC |   | NMI+------+
       |  |      |-------|      |-----------|     |   |
       |  +------+       +------+ |    |    +-----+   |    Management
       | Transport Plane          |    |              |       Plane
       +--------------------------+    +--------------+

   OCC = Optical Network Controller        UNI = User Network Interface
   CCI = Connection Control Interface      OXC = Optical Cross Connect
   I-NNI = Internal Node to Node Interface
   E-NNI = External Node to Node Interface
   NMI = Network Management Interface
   PI = Physical Interface
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Figure 1: Automatic Switching Optical Network (ASON) Architecture

The transport plane contains the transport network elements (switches and links) that carry the entity that is switched, i.e. optical connections. End-to-end connections are setup within the transport plane under the control of the ASON control plane (CP). This draft is concerned with the CP part of the ASON architecture. Both the TP and MP are out of the scope of this draft.

ASON architecture belongs to client-server models or the overlay network models as defined in [5]. The salient feature of this model is the existence of well-recognized boundaries between client networks and provider domains. Client/provider separation is a direct recognition of today's networking realities where ownership of layer 3 and layer 1 equipment belongs to different organizations. This client/provider domain separation entails the running of different routing instants at each domain. Thus there is no need to share topology information between carriers and their clients.

5. ASON Control Plane: General Requirements

A well-designed control plane architecture should give service providers better control of their network, while providing faster and improved accuracy of circuit set-up. The control plane itself

should be reliable, scalable, and efficient. It should also be sufficiently generic to support different technologies and differing business needs and different partitions of functions by vendors (i.e., different packaging of the control plane components). In summary, the control plane architecture should:

- Be applicable to a variety of transport network technologies (e.g., SONET/SDH, OTN, PXC). In order to achieve this goal, it is essential that the architecture isolate technology dependent aspects from technology independent aspects, and address them separately.

- Be sufficiently flexible to accommodate a range of different network scenarios. This goal may be achieved by partitioning the control plane into distinct components. This, allows vendors and service providers to decide the location of these components, and also allows the service provider to decide the security and policy control of these components.

The ASON control plane can be divided into several components, namely, resource discovery, state information dissemination, path selection and path management components. These orthogonal functional components work together to complement each other and form an overall architecture. This approach is intended to avoid inappropriate focus upon certain functional components of the architecture, to the inadvertent exclusion of others, that could result in unnecessary dependencies and non-optimal solutions. The basic modules are described below.

5.1 Resource Discovery

Resource discovery is defined as the transaction that establishes the adjacencies of the port-pairs. Its basic function is address discovery, service discovery, data path connectivity discovery, verification, and management.   The role of the resource discovery module is to establish a complete map of physical connectivity including attributes, remote identifiers, and real-time status. The control procedure of this component could be generic, yet, its contents could be technology specific.

5.2 State Information Dissemination

State information dissemination is defined as the manner in which local physical resource information is disseminated throughout the network. First, the local physical resource map is summarized into logical link information according to link attributes. This information can then be distributed through the network piggybacked onto the control plane transport network IGP (Interior Gateway Protocol).

5.3 Path Selection

Transport network routing procedures typically utilize explicit routing, where path selection can be done either by operator, software scheduling tools in management systems. In a switched optical network, end-to-end optical channel connections are requested with certain constraints. Path selection for a connection request should employ constrained routing based algorithms that balance multiple objectives.

5.4 Path Management

Path management mainly deals with path operations such as connection setup, modification, deletion, query, auto-rerouting, and protection switching/restoration. Control messages could be conveyed through suitable signaling protocols.

Network topology information is typically only provided on a link (and typically not at a link-connection) basis. Link connections are not advertised in the topology dissemination component due to drawbacks with respect to lack of scalability. Therefore, the result of a path selection algorithm is also only at the link level. This implies that the local intelligence in the NE must decide upon the actual link connection that is used for that path.

6. ASON Control Plane: Interfaces and Protocols

The ASON CP as shown in Figure 1 defines a set of interfaces:

- User-Network Interface (UNI): UNI runs between the optical client and the network.

- Internal Node-to-Node Interface (I-NNI): I-NNI defines the interface between the signaling network elements, i.e. OCC within the switched optical network.

- External Node-to-Node Interface (E-NNI): E-NNI defines the interface between ASON control planes in different administration domains.

- Connection Control Interface (CCI): The CCI defines the interface between ASON signaling element, i.e. OCC and the transport network element, i.e. the cross connect.

The different ASON interfaces are described in the next few sections. Candidate protocols for use at the different interfaces are also discussed.

6.1 ASON User-Network Interface

ASON UNI allows ASON client to perform a number of functions including:

- Connection Create: Allows the clients to signal to the network to create a new connection with specified attributes. Those

attributes might include bandwidth, protection, restoration, and diversity.

- Connection Delete: Allows ASON clients to signal to the network the need to delete an already existing connection.

- Connection Modify: Allows ASON clients to signal to the network the need to modify one or more attribute for an already existing connection.

- Status Enquiry: Allows ASON clients to enquire the status of an already existing connection.

Other functions that might be performed at the ASON UNI are, client registration, address resolution, neighbor and service discovery. Those functions could be automated or manually configured between the network and its clients.

Client registration and address resolution are tightly coupled to the optical network address scheme. Requirements for optical network addresses and client names are outlined in [6]. In general the client name (or identification) domain and optical address domain are decoupled. The client id should be globally unique to allow for the establishment of end-to-end connections that encompass multiple administration domains. For security, it is required that the nodal addresses used for routing within an optical domain do not cross network boundaries. The notion of closed user groups should also be included in ASON addressing to allow for the offering of OVPN services.

Address registration and resolution usually involves some kind of a directory service. The client uses the registration process to register his identification with the provider network for a particular user group or groups. Address resolution involves the process of translating client names to network addresses. Address resolution can be performed at clients, edge network element, or at every administrative boundary entry. It could involves authentication and policy look up to make sure that a client has the necessary credentials to join a user group.

ASON UNI realization requires the implementation of a signaling protocol with sufficient capabilities to satisfy UNI functions. Both LDP [7] and RSVP-TE [8] have been extended to be used the signaling protocol across the ASON UNI. The extensions involve the definition of the necessary TLVs or objects to be used for signaling connection attributes specific to the optical layer. New messages are also defined to allow for connection status enquiry. The Optical Internetworking Forum (OIF) has adopted both protocols in its UNI 1.0 specifications [9].

6.2 ASON Internal Node-to-Node Interface

The I-NNI defines the interface between adjacent optical connection controls (OCC) in the same network. There are two main aspects of I-NNI. Those are signaling and routing.

(Reword)
Path selection and setup through the optical network requires a signaling protocol. Transport networks typically utilize explicit routing, where path selection can be done either by operator or

software scheduling tools in management systems. IN ASON, end-to-end optical channels (connections) are requested with certain constraints. Path selection for a connection request should employ constrained routing algorithms that balance multiple objectives:

- Conform to constraints such as physical diversity, etc.

- Load balancing of network traffic to achieve the best utilization of network resources.

- Follow policy decisions on routing such as preferred routes.

To facilitate the automation of the optical connection setup, nodes in the optical network must have an updated view of its adjacencies and of the utilization levels at the various links of the network. This updated view is sometime referred to as state information.

State information dissemination is defined as the manner in which local physical resource information is disseminated throughout the network. First the local physical resource map is summarized into logical link information according to link attributes. This information can then be distributed to the different nodes in the network using the control plane transport network IGP.

ASON I-NNI could be based on two key protocols, IP and MPLS. Since MPLS employs the principle of separation between the control and the forward planes, its extension to support I-NNI signaling is feasible. Generalized MPLS [3] defines MPLS extensions to suit types of label switching other than the in-packet label. Those other types include, time slot switching, wavelength and waveband switching, and position switching between fibers. Both CR-LDP [10] and RSVP-TE [11] have been extended to allow for the request and the binding of generalized labels. With generalized MPLS, a label switched path (LSP) is established with the appropriate encoding type (e.g. SONET, wavelength, etc.). LSP establishment takes into account specific characteristics that belong to a particular technology.

MPLS traffic engineering requires the availability of routing protocols that are capable of summarizing link state information in their databases. Extensions to IP routing protocols, OSPF and IS-IS, in support of link state information for generalized MPLS are described in [12, 13].

6.3 ASON External Node-to-Node Interface

E-NNI is an inter-domain interface for use between ASON networks that are under different network administrations. It is similar to the UNI interface with some routing functions to allow for the exchange of reachability information between different domains. BGP is an IP based protocol that could be used to summarize reachability information between different ASON domains in the same manner as it has been in use today for IP networks.

6.4 ASON Connection Control Interface

CCI defines the interface between the ASON signaling element (OCC) and the transport network elements. Connection control information is passed over this interface to establish connections between the ports of the optical transport switch. The CCI is included as part of ASON control plane because it enables switches of various capacities and internal complexities to be part of an ASON node.

The protocol running across the CCI must support two essential functions:

- Adding and deletion of connections.

- Query of port status of the switch.

General Switch Management Protocol (GSMP) [14] fits CCI requirements. GSMP is a general-purpose protocol that allows a controller to establish and release connections across a switch. GSMP is well suited for network architectures that employs label swapping in the forwarding plane, e.g. ATM, FR, and MPLS. This property makes GSMP a good fit for generalized label as defined by generalized MPLS. GSMP extensions for generalized MPLS are yet to be worked out.

7. ASON CP Transport Network

In this section, we detail some architectural considerations for the makeup of the transport network that is used to transport the control plane information. For circuit based networks, the ability to have an independent transport network for message transportation is an important requirement.

The control network represents the transport infrastructure for control traffic, and can be either in-band or out-of-band. An implication of this is that the control plane may be supported by a different physical topology from that of the underlying ASON. There are fundamental requirements that control networks must satisfy in order to assure that control plane data can be transported in a reliable and efficient manner. In the event of control plane failure (for example, communications channel or control entity failure), while new connection operations will not be accepted, existing connections will not be dropped. Control network failure would still allow dissemination of the failure event to a management system for maintenance purposes. This implies a need for separate notifications and status codes for the control plane and ASON. Additional procedures may also be required for control plane failure recovery.

It is recognized that the inter-working of the control networks is the first step towards control plane inter-working. To maintain a certain level of ease, it's desirable to have a common control network for different domains/sub-networks or types of network.

Typically, control plane and transport functions may co-exist in a network element. However, this may not be true in the case of a third party control. This situation needs further study. Furthermore, addressing issues in the control plane vis- -vis the transport network is also for further study.

ASON CP transport network requirements includes:

- Control plane message transport should be secure. This requirement stems from the fact that the information exchanged over the control plane is service-provider specific and security is of utmost importance.

- Control message transport reliability has to be guaranteed in almost all situations, even during what might be considered catastrophic failure scenarios of the controlled network.

- The control traffic transport performance affects connection management performance. Connection service performance largely depends on its message transport. Time sensitive operations, such as protection switching, may need certain QoS guarantees. Furthermore, a certain level of survivability of the message transport should be provided in case of control network failure.

- The control network needs to be both upward and downward scalable in order for the control plane to be scalable. Downward scalability may be envisioned where the ASON network offers significant static connections, reducing the need for an extended control network.

Given the above requirements, it is critical that the maintenance of the control network itself not pose a problem to service providers. As a corollary this means that configuration-intensive operations should be avoided for the control network.

8. Security Considerations

This draft does not introduce any unknown security issues.

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