Implementing PNNI Signaling in the Optical Control Plane

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Abstract: Introducing a control plane in optical networks is indispensable towards deploying new revenue generating services. While ASON/ASTN models constitute the definition of this control plane at the architectural level, the protocols that are intended to support ASON implementations are still under specification. Starting from ATM Forum’s PNNI, this paper focuses on adapting PNNI signaling so that it becomes aligned to ASON requirements. This adaptation can serve as a basis for implementing PNNI based signaling in the optical control plane. Apart from proposing a simple PNNI implementation, the issue of integrating an OTN making use of PNNI signaling with IP client networks is investigated.

Key-Words: PNNI, Signaling, Optical Networks, Control Plane

1. Introduction

During the last years optical carriers’ strategies are not confined to selling connectivity services; on the contrary they are targeting the deployment of services such as web hosting and VPNs, with a view to creating new revenue streams. Supporting such services hinges on the ability to incorporate new technologies, provision bandwidth in a flexible manner and supporting dynamic provisioning, while at the same time retaining the speed and reliability of conventional optical networks. To this end, it was realized that a control plane must be introduced between the management plane and the transport layer.

Efforts towards introducing this extra control layer, both from standard bodies and the industry, have resulted in protocols such as the Multi-Protocol Lambda Switching (MPLambdaS), the Generalized Multi-Protocol Label Switching (GMPLS), the Optical Network-to-Network interface (O-NNI), and the Optical Signaling and Routing Protocol (OSRP) [1]. Following these initiatives the ITU-T has defined the

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Automatic Switched Optical Network (ASON) [2], as a more specific case of the Automatically Switched Transport Network (ASTN). ASON and ASTN are protocol independent, since ITU-T has focused on defining the frameworks and then specifying the protocols.

Crucial components for ASONs are a signaling and a routing protocol. Most proposals regarding these protocols (including IETF and OIF standardization efforts) have focused on adapting and extending IP based control protocols. Relying on existing IP control protocols and mechanisms has the advantage of reusing work instead of reinventing everything from scratch. Apart from being compatible with current trends (e.g., [3]) applying IP mechanisms assists vendor interoperability and boosts the convergence between IP and optical standards [4]. Despite the strong presence of IP based mechanisms in optical control plane protocols (mainly within GMPLS [5]), we envisage that the suite of control mechanisms and protocols, which have been specified by the ATM Forum as part of the Private Network to Network Node Interface (PNNI) [6], could serve as the basis for an alternative suite of control plane mechanisms.

The process of developing a control plane comprises two major work areas: (a) the development of routing mechanisms, and (b) the production of a signaling protocol for switched connections. We do believe that ATM PNNI can provide the basis for devising a routing and a signaling protocol, that are appropriate for ASON networks. An ASON control plane based on PNNI protocols could be conveniently called O-PNNI based control plane [22]. Signaling for controlling optical networks is the topic of this paper. In particular, this contribution focuses on adapting PNNI signaling to ASON requirements by highlighting essential features of PNNI signaling that need to become aligned to ASON. It is emphasized that PNNI is appropriate for supporting ASON networks. It is no accident that the ITU-T is conducting work towards producing a specification for distributed call and connection management based on PNNI [7], [20]. However, that at the time of writing no relevant recommendation has been finalized. The present paper provides more extensive information on the PNNI signaling aspects for optical control planes illustrated in [22].

The paper is structured as follows: following this introductory section, section 2 provides the motivation for adapting PNNI signaling to ASON and provides a list of essential features that justify the PNNI/ASON compatibility. Section 3 illustrates solutions to PNNI signaling features that need adaptation. Section 4 defines the problem of PNNI signaling interworking with IP clients and how RSVP/ATM interworking proposals could help to alleviate this problem. Finally, section 5 includes a set of concluding remarks.

2. Motivation: PNNI/ASON Signaling compatibility

Having an alternative to OSPF/BGP routing and GMPLS signaling constitutes a sufficient motive towards studying and developing O-PNNI. Recent experiences related to GMPLS based control plane deployment for optical networks, boost the belief that PNNI might be more appropriate than GMPLS with respect to several control issues. This stems from the fact that packet switched networks (e.g., MPLS) differ significantly from circuit-switched networks (e.g., ASON).

As far as signalling is concerned GMPLS relies on RSVP-TE and CR-LDP [15]. RSVP-TE appears as the preferred protocol for establishing/releasing optical connections, but presents an important drawback. It is a “soft state“ protocol, which may allow control plane failures to impact established optical connections.
This is because the lack of refresh messages could result in LSP deletions. A “hard state” protocol is more appropriate for handling optical connections. Even though RSVP can be configured as a “hard state” (through very long timeout values), we believe that PNNI being “hard state” in nature could provide a more reliable and efficient signalling protocol.

PNNI possesses many features that are perfectly in line with ASON. From an architectural point of view, PNNI has been designed for operation in an environment of ATM switches, which feature a Connection Controller (CC) component and an associated Connection Controller Interface (CCI) that are compatible with those recommended for ASON and are depicted in figure 1.

![Figure 1: ASON Connection Controller component (G.8080)](image)

Also that the process of call/connection establishment, release and modification as specified in the PNNI (apart from [6], see also [12-14]) satisfies a large set of ASON requirements, for example:

9. Connection routing so that a single call controller can monitor them
10. Call Release to be initiated by any call controller
11. Security features at the UNI
12. Support for CoS
13. Protection and restoration mechanisms
14. Support for crankback capabilities
15. Existing calls not distorted in the case of failures in the signaling network
16. Access to the status of existing connections upon signaling failures
17. Support for ASON call and connection states are supported.

This indicative list makes evident the signalling compatibility between PNNI and ASON.

3. Implementing ASON Signalling based on PNNI

Towards adapting PNNI signalling we rely on conventional PNNI signalling flows and introduce new messages based on standard PNNI message formats. Connection setup in PNNI relies on a Source Routing mechanism that provides/specifies the path to the connection destination based on the source’s current view of the network. The signaling information flow in PNNI is compatible to that required by ASON.

All PNNI signaling messages have a similar format consisting of four common information elements: (a) a Protocol discriminator, (b) a Call reference, (c) a message type, (d) the message’s length, which is used for parsing the last variable part of the message according to the message type. It should be noted that it is quite easy to devise/specify/construct and implement new or enhanced messages by appropriate interventions in the variable part of the signaling message. A simplified call setup/release message exchange in the scope of the PNNI, is depicted in fig. 2.

There are also signaling messages for point to multipoint call and connection control [6]. Having this set of PNNI mechanisms
and messages at hand, we address ASON/ASTN signaling requirements not directly supported by PNNI [7-8]:

![Diagram](image)

**Figure 2: PNNI signaling messages exchange during call setup and release**

**Support for out-of-band signalling**

PNNI uses in-band signalling where the signalling information is distinguished from the data traffic by using the VPI and VCI identifiers (values 5 and 0 respectively). As separated control and data planes are recommended for ASONs, we suggest providing interface identification information to the O-PNNI signalling. Our suggestion is based on the recommendation G.7713.1, which provides the protocol specifications for the distributed call and connection management based on PNNI/Q2931. We consider two possible options:

- A first option is adding a new information element (i.e. Interface Identifier) in the signalling messages. This element should include an interface identifier and a node identifier used by the source node to identify a data channel.

- A second option consists in using a Generic Identifier Transport Element (defined Q.2931). This element is used to carry identifiers between two users. The network may process and examine its contents. Depending on the identifier type, its purpose and structure are defined either in the Q.2931 specification or in other standards. The number of instances of this information element in a message is limited to three. We suggest carrying the interface information related with the data channel, in the Generic Identifier transport Element. Moreover, we suggest adding two instances: an interface identifier and a node identifier.

**Support for layer networks (i.e. SDH, OTN, PDH)**

PNNI supports ATM connections, and deals with manipulation of parameters at the ATM layer. On the other hand O-PNNI constitutes a control plane for optical networks that should be independent of the transport optical layer (e.g., SDH, OTN, PDH). According to [2] ASON may be applied to layer networks. Thus O-PNNI signaling messages should encompass information declaring the transport layer. Such information must be carried in the setup message to allow call and connection controller to become aware of the transport layer of the target connection. Given that ATM layer parameters at the are not the sole option, it is imperative that the ATM traffic descriptor field of the PNNI SETUP message is altered to encode the target transport layer type and its associated parameters.

**End-to-end message acknowledgements**

The flow of PNNI signaling messages does not support end to end acknowledgement of SETUP and CONNECT messages. In the scope of an ASON it is recommended that Call Controllers cater for end to end acknowledgements of these messages. Such an end to end operation is a key prerequisite for a robust and reliable control plane. Since PNNI signaling messages do not include a CONNECT_ACKNOWLEDGE and a SETUP_ACKNOWLEDGE message, two new messages should be included in the O-PNNI signaling (Table 1). The format of the new messages, can be derived from the Q.2931 CONNECT_ACKNOWLEDGE message.
[9], with an appropriate message type. Due to the global significance of these messages it is imperative that they contain the SNP/Endpoint reference so that they can reach its final destination. We also suggest that the CONNECT_ACKNOWLEDGE message with local significance specified in Q.2931 is retained and used in the O-PNNI control plane, since hop by hop acknowledgements are important for time critical restoration tasks.

<table>
<thead>
<tr>
<th>Message</th>
<th>Direction</th>
<th>Significance</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONNECT ACK</td>
<td>P→S</td>
<td>Global</td>
<td>Indicates that the calling party has received the called's party CONNECT message (i.e. the connection has been established and calling party is in the Active state (NN10))</td>
</tr>
<tr>
<td>SETUP ACK</td>
<td>S→P</td>
<td>Global</td>
<td>Indicates that called party has received the call/connection request and has therefore entered the Call Initiated phase (NN1) (i.e. called party has not responded to the request yet)</td>
</tr>
</tbody>
</table>

(*) S: Succeeding Party, P: Proceeding Party

Table 1 End to end acknowledge messages in O-PNNI

Alarm suppression (connection release)
G.8080 suggests that ASON provides capabilities for distinguishing changes in the state of connections due to management or control plane actions and from network failures. Moreover it is recommended that alarms regarding these states are appropriately generated and/or and suppressed. RSVP-TE tackles these requirements through handling of Administrative Status Information [10]. PNNI does not include a mechanism for directly suppressing alarms during connection release. A possible solution is to make use of the NOTIFY message that is present in the PNNI signaling. NOTIFY messages are used to convey information with respect to the call or connection. The introduction of a new Notification indicator code, signifying the suppression of all alarms for a given call/connection could suffice for alarm suppression.

UNI, E-NNI and I-NNI attributes
UNI, E-NNI and I-NNI Setup messages contain various attributes. All of these can be directly encapsulated in the scope of PNNI SETUP message. Nevertheless, special provisions should be made to encode appropriately the CoS/GoS fields specified in [11], and match them with respective parameters.

Adaptation of UNI, E-NNI, I-NNI messages
The contents of UNI, E-NNI and I-NNI signalling messages specified in [11] should be appropriately encapsulated in PNNI signalling messages. Again PNNI messages provide placeholders for all attributes of these messages, except for the CallSetupConfirm message, as the later is specified in all three interfaces (UNI, E-NNI, I-NNI). Following the process outlined in the development of end-to-end acknowledgements we could define SETUP_CONFIRM messages, so that O-PNNI becomes aligned to [11].

Apart from the above adaptations and enhancements of PNNI signalling, O-PNNI demands that all return codes and messages recommended by ITU-T for ASON are supported (e.g., Call setup error code indicating error causes). Thus, PNNI need to be enhanced to include additional indicators in existing signalling fields.
4. Integration with Client Networks

In studying the signaling interworking between ASON and client networks, we assume a signaled overlay model. This is because the O-PNNI network is likely to be totally decoupled from the different client (sub)networks. The use of a peer-to-peer model for interworking between IP client networks and ASON would require an unjustified signaling adaptation overhead.

**ATM Client Networks**

The interworking between ATM signaling and O-PNNI is quite straightforward. This is because O-PNNI signalling messages are derived from Q.2931 signaling [9]. When an ATM signaling message (e.g., a SETUP message) arrives at the boundary between the client network and the ASON core, the parameters can be directly mapped to the corresponding O-PNNI (i.e., SETUP) message. According to the overlay model the calling and called party information in the O-PNNI message will be determined by the source and the destination addresses of the source’s message. In particular, it is necessary to consult routing information so that a route between the ingress and egress points of the ASON network is determined, along with the addresses of the ingress and egress points.

**MPLS/GMPLS/IP Client networks**

This interworking case is more challenging, since RSVP-TE messages have a totally different structure from O-PNNI messages. In this case a special internetworking signalling unit (IWU) is required to perform the mapping between UNI and NNI signalling protocols. From an implementation perspective this unit can be either attached (i.e., software modules in an attached workstation) or embedded to the border O-PNNI capable OXC node (Figure 3).
issues become much more complicated when it comes to supporting multicasting and heterogeneous reservations [19]. Dynamic QoS and transitions of receivers can be efficiently supported by using the O-PNNI ‘MODIFY’ signaling messages in response to RSVP-TE refresh requests. A rather detailed mapping of Guaranteed Service and Controlled Load Service traffic parameters to ATM traffic descriptors (provided in [18]) could be used in cases where CoS information is conveyed.

5. Conclusions and work in progress

This paper has underlined the compatibility between ASON and PNNI signaling, and identified points that need adaptation/customization towards a PNNI implementation for the optical control plane. It has been shown that PNNI can act as a signaling protocol for ASONs. Moreover, hints for supporting integration with IP client networks have been provided. Towards justifying our claims we are currently building a simulation engine (on top of the NS2 simulator), which simulates a network following the G.8080 architecture and making use of PNNI signaling.

6. Acknowledgements

A major part of this work was conducted in the scope of the EC funded LION project (IST-1999-11387). The authors acknowledge valuable help and contributions from their project partners, as well as from the EC.

7. References

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