Demonstration of control plane interoperability with integrated optical ports in multi-vendor scenarios

Victor Lopez(1), Zafar Ali(2), Stephan Neidlinger(3), Oscar González de Dios (1), Diane Patton(2) , Tomasz Remiszewski(3), Piotr Drózda(3), Juan Pedro Fernández-Palacios(1)

(1) Telefónica I+D, GCTO, C/ Don Ramón de la Cruz 84, Madrid, 28006, Spain, Email: vlopez@tid.es
(2) Cisco
(3) ADVA Optical Networking

Abstract *Integrated DWDM ports in routers reduce the CAPEX investment, but control plane complexity is increased as the IP router transponder becomes part of the optical domain. This work demonstrates the control plane interoperability between the IP and the optical vendors.*

Rational behind transponders integration and control plane support

Network operators have deployed networks based on IP/MPLS over WSON architectures in their core. This architecture enables cost reduction in comparison with the overhead of legacy architectures like SDH. Following this intention to reduce the network cost, the operators are assessing integrated transponders in packet nodes to deploy in backbone networks. Such colored transponders in the IP cards eliminate the necessity of gray interfaces between the router and the optical gear. Previous work[1] shows that operators can reduce the investment in equipment when doing such port integration.

There is a common agreement between operators that data plane integration is a key topic for the network evolution[2]. There are two leading use cases for port integration[2]: metro and core networks. Integrated colored interfaces can be used in metro networks because of the shorter distances and no restoration requirements Some core networks are very simple and do not need the deployment of ROADMs. For these scenarios, the only role of the optical network is to provide point-to-point links. However, large core networks already have GMPLS control plane deployed, which allows the network operators to have automated connection establishment and resilience capabilities. When the transponder is moved from the optical node into the IP node, part of the optical network (transponder) is owned by the IP vendor, while the ROADMS are controlled by an optical vendor. This scenario makes interoperability validation and alignment between vendors crucial.

For backbone core scenarios with control plane, the integration of the transponder must not limit the control plane capabilities, not only because automation and resilience is lost in the optical domain, but more important because of the network cost. The customers traffic has to be protected so in case of a failure in the IP or the optical network, the traffic loss is minimum. When there is no optical restoration, the amount of IP cards used for backup purposes is increased[3]. According to our previous findings[3], the number of IP ports saved thanks to the addition of optical restoration in Telefonica's Spanish backbone is 37% in 2017. Both arguments (automation and cost) increase the importance of this work.

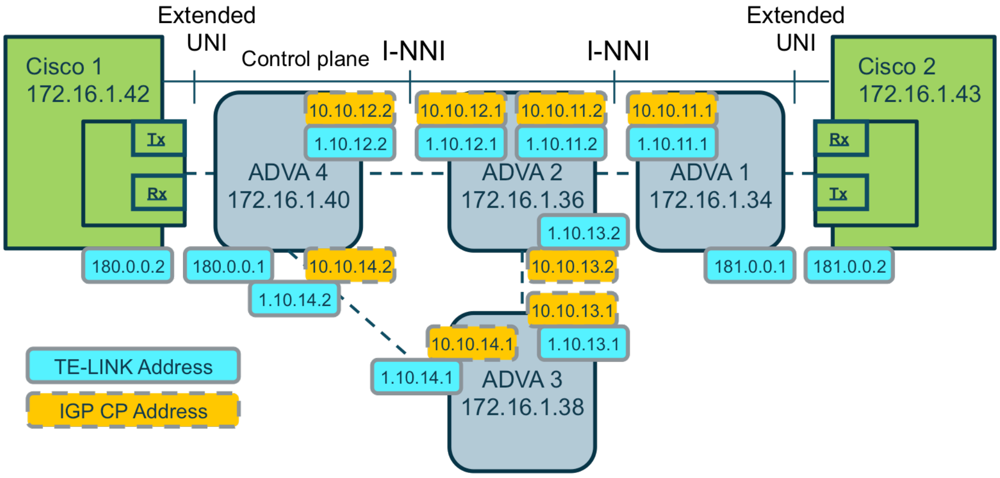


Fig. 1: Experimental set-up for demonstration with integrated ports

The paper outlines the control plane architecture for the integrated port case. Next, the control plane extensions required to support the integrated ports are presented. Finally, the experimental set-up is explained and the tests are shown.

Control plane architecture with integrated transponders

There are several multi-layer interoperability models like overlay and peer-to-peer. The Internet Engineering Task Force (IETF) is standardizing a GMPLS based overlay model. A related control plane architecture with integrated transponders is presented in Fig. 1. There are two main interfaces: User to Network Interface (UNI) and Internal Network to Network Interface (I-NNI). UNI specifies a client-server relationship between networks where client (IP/MPLS) and server (optical) layers are managed as separate domains [RFC4208]. On the other hand, I-NNI is the signaling between the optical nodes which are in the same domain. Moreover, the network elements connected via I-NNI are from the same vendor.

The UNI enables the IP/MPLS router to signal for a lightpath that will traverse the transport network. Note that the colored lightpath begins and ends in the IP/MPLS router (either in the colored transponder or the colored pluggable interface). The UNI boundary is established between IP/MPLS node and ROADM node as they are in different administrative domains. Control plane extensions to support the exchange of some optical information between the router and the optical node are discussed in the next section.

Control plane extensions

The DWDM network contains a host of information regarding the end-to-end transport network including circuit route paths, current frequency allocations as well as much other information. The packet layer, however, is aware of the underlying traffic requirements, (e.g. how much latency can be tolerated, what level of SLA does the traffic demand, how will traffic be protected, etc.). An architecture is needed where IP and Optical layers can complement and work with each other to form an optimized network

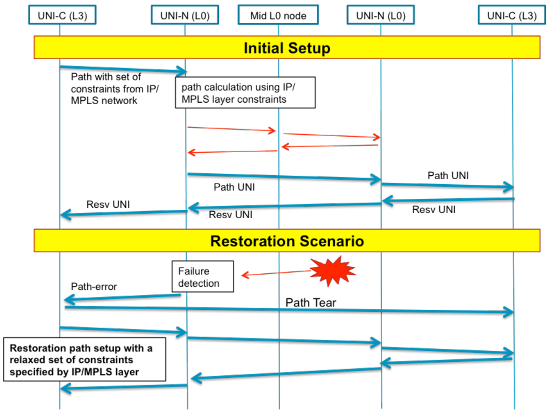


Fig. 2: Control plane process to set-up a path

GMPLS UNI defined in RFC4208 falls short of meeting the end goal outlined in this paper. What is needed is a tighter coupling between IP/MPLS and optical layers. Extended UNI described in this section is designed for this purpose. Extended UNI architecture is built on the Client Server model. Information sharing should be in the form of the client (Router Interface) to the Server (DWDM Network) and vice versa. Nonetheless, information sharing does not imply overburdening any of the layers with layer specific information that does not add value to the different layers such as OSNR, CD, PMD or Router Config files, IGP table, etc. Rather then overburdening with unnecessary information that may confuse or increase memory requirements, sharing only abstracted information that will improve network efficiencies is desired. Information sharing includes the following:

- IP/MPLS layer may specify the Shared Ling Risk Groups (SRLG).
- Diversity requirement from IP/MPLS layer to Optical layer may be specified[4].
- IP/MPLS layer Learns optical layer SRLG value identifying common L0 risks associated to the network, fiber duct, aerial fiber, regenerator, ROADM, etc.[5]
- IP/MPLS layer specifying the explicit Path and label values to be used by the optical layer IP/MPLS layer to optical layer (this information is typically computed by a multilayer planning tool) [RFC3209], [RFC3473], [RFC6205].
- Optical layer reporting TE metric attribute (e.g., latency) related to the optical trail[6].

Experimental set-up and validation

For this experimental validation, Cisco and ADVA Optical Networking equipment has been used in Telefonica R&D labs in Madrid, Spain. Regarding IP equipment, Cisco CRS3 routers are used with integrated 100 GigE Coherent DWDM interfaces. The optical layer is composed of four ADVA FSP 3000 optical nodes. Fig. 1 presents the data plane configuration and the addressing scheme for the nodes and the TE-Link configuration.

The CRS3 100GigE Coherent DWDM interfaces are directly connected to FSP 3000 client ports and are using DP-QPSK modulation format.

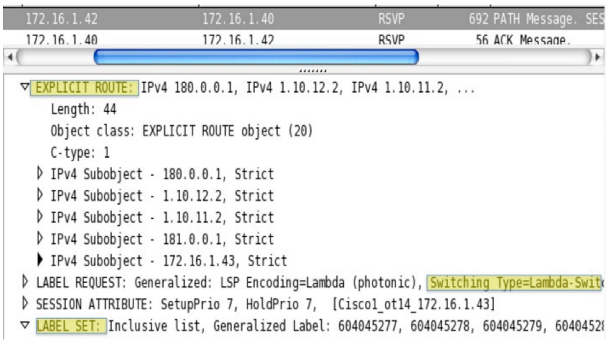
CRS-3 DWDM signals are transported in FSP 3000 network as an external wavelength service (sometimes also called “alien wavelength”). Such optical services start and end on client ports of wavelength filter modules in DWDM terminal nodes or colorless modules in ROADMs. External channel profiles need to be provisioned containing a set of parameters like data rate, FEC, line coding, launch power, TX OSNR, RX required OSNR. We deployed several optical nodes in order to investigate various networking scenarios: optical terminal multiplexers, fixed and remotely configurable optical add-drop multiplexers (FOADM, ROADM).

Data plane interoperability was tested initially to verify connectivity. Coherent 100 GigE signals were sent between CRS3 nodes via FSP 3000 external wavelength service and this test was successful and torn down.

To dynamically establish a path using the colored interfaces, a path message was sent from CRS3 egress node (172.16.1.42) to FSP 3000 ingress node (172.16.1.40), as shown in Fig. 4. The Explicit Route Object (ERO) information is encoded using the TE-Links with the whole path sequence, from router to router (Fig. 3). The LABEL REQUEST sub-object identifies the switching type required “Lambda-switch”. Moreover, the LABEL SET field shows which are the possible wavelengths that are supported by the integrated transponder.

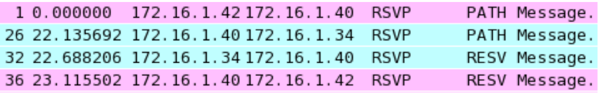
Next, the PATH messages are sent between the FSP 3000s to the egress optical node (172.16.1.34), as shown in Fig. 4 and Fig. 5. The egress FSP 3000 (172.16.1.34) then sends a PATH to the tail CRS3 (172.16.1.43) as per Fig. 5.

As described in Fig. 2, the tail CRS3 (172.16.1.43) responds by sending RESV message to egress FSP 3000 (172.16.1.34). This message is seen in Fig. 5. The RESV messages then get sent hop by hop in the optical domain, and sent from the ingress FSP 3000 back to Head End CRS3 (172.16.1.42). After this, the CRS3 100GbE interfaces came up.



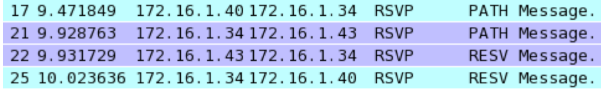
```
172.16.1.42          172.16.1.40          RSVP     692 PATH Message. SES
172.16.1.40          172.16.1.42          RSVP      56 ACK Message.

▽ EXPLICIT ROUTE: IPv4 180.0.0.1, IPv4 1.10.12.2, IPv4 1.10.11.2, ...
    Length: 44
    Object class: EXPLICIT ROUTE object (20)
    C-type: 1
  ▷ IPv4 Subobject - 180.0.0.1, Strict
  ▷ IPv4 Subobject - 1.10.12.2, Strict
  ▷ IPv4 Subobject - 1.10.11.2, Strict
  ▷ IPv4 Subobject - 181.0.0.1, Strict
  ▶ IPv4 Subobject - 172.16.1.43, Strict
▷ LABEL REQUEST: Generalized: LSP Encoding=Lambda (photonic), Switching Type=Lambda-Swit
▷ SESSION ATTRIBUTE: SetupPrio 7, HoldPrio 7,  [Cisco1_ot14_172.16.1.43]
▽ LABEL SET: Inclusive list, Generalized Label: 604045277, 604045278, 604045279, 6040452
```

Fig. 3: Sub-Object detailed information in the initial PATH message



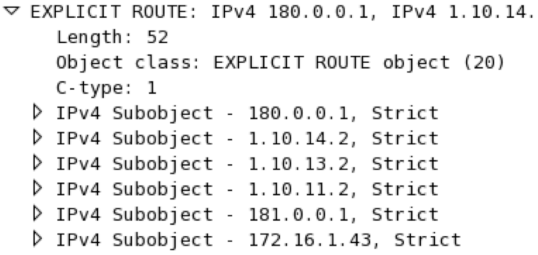
```
 1 0.000000  172.16.1.42 172.16.1.40  RSVP    PATH Message.
26 22.135692 172.16.1.40 172.16.1.34  RSVP    PATH Message.
32 22.688206 172.16.1.34 172.16.1.40  RSVP    RESV Message.
36 23.115502 172.16.1.40 172.16.1.42  RSVP    RESV Message.
```

Fig. 4: PATH-RESV message exchange in ADVA 4



```
17 9.471849  172.16.1.40 172.16.1.34  RSVP    PATH Message.
21 9.928763  172.16.1.34 172.16.1.43  RSVP    PATH Message.
22 9.931729  172.16.1.43 172.16.1.34  RSVP    RESV Message.
25 10.023636 172.16.1.34 172.16.1.40  RSVP    RESV Message.
```

Fig. 5: PATH-RESV message exchange in ADVA 1



```
▽ EXPLICIT ROUTE: IPv4 180.0.0.1, IPv4 1.10.14.
    Length: 52
    Object class: EXPLICIT ROUTE object (20)
    C-type: 1
  ▷ IPv4 Subobject - 180.0.0.1, Strict
  ▷ IPv4 Subobject - 1.10.14.2, Strict
  ▷ IPv4 Subobject - 1.10.13.2, Strict
  ▷ IPv4 Subobject - 1.10.11.2, Strict
  ▷ IPv4 Subobject - 181.0.0.1, Strict
  ▷ IPv4 Subobject - 172.16.1.43, Strict
```

Fig. 6: PATH-RESV message exchange in ADVA 1

The restoration scenario is similar, but the triggering starts from a PathErr message. If the failure happens between ADVA 4 and 2, the path for restoration uses a different ERO (via ADVA 3 node), as shown in Fig. 6. Further, at times it might be impossible to form the circuit, as no route or no lambda is available from the optical network a PathErr is sent from the FSP 3000 to the CRS3.

Conclusions

This work demonstrates control plane communication is possible for integrated optical transponder scenarios in multi-vendor environments. This demonstration allows taking advantage of the CAPEX savings of port integration and optical resilience while still allowing the advantages of control plane connectivity.

References

[1] R. Duque, et al: Cost evaluation of the integration of IP/MPLS and WDM elements, in Proc. OFC, NM3F.3, (2013).

[2] White Paper: IP and Optical Convergence: Use Cases and Technical Requirements.

[3] O. Gerstel, et al. “Multi-Layer Capacity Planning for IP-Optical Networks”, IEEE ComMag, January (2014).

[4] Z. Ali, et al, “ RSVP-TE Path Diversity using Exclude Route”, draft-ietf-ccamp-lsp-diversity-03.

[5] F. Zhang, O. Gonzalez de Dios, et al, “RSVP-TE Extensions for Collecting SRLG Information”, draft-ietf-ccamp-rsvp-te-srlg-collect-04.

[6] Z. Ali, et al. “RSVP-TE extension for recording TE Metric of a Label Switched Path”, draft-ietf-ccamp-te-metric-recording-03.txt.