Optical Node Disaggregation Management and Interoperability

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Abstract: This work gives a high-level overview of the maturity and open issues of the disaggregation approach as applied to WDM transport network eco-system.

1. Introduction and Context

The introduction of the Software Defined Networking (SDN) and disaggregation paradigms in optical WDM transport networks requires the availability of two basic technologies compliant to appropriate standards [1]: (i) Disaggregated optical devices in the form of whiteboxes (Optical Xponders including single and multi-client optical transceivers with or without digital switching capabilities, Optical Line Amplifier, and ROADM) and/or Open Line Systems (OLS); (ii) A special implementation of SDN controllers capable of managing the specific characteristics of the optical layer (e.g. optical power control, spectrum management, transmission degradation calculation, etc.) using standard protocols and models.

The disaggregation of optical networks can bring advantages especially on two aspects, both related to the possibility of having different manufacturers' equipment and management systems into the network: potential savings on investments as recently discussed in [2]; and the ability to quickly introduce the most innovative technological solutions, especially on optical transponders reducing at the same time vendor lock-in. However, this intrinsically multi-vendor eco-system requires a high level of standardization both in terms of architecture and implementation (protocols, optical specifications), otherwise the advantages mentioned above would be far exceeded by prohibitive integration and operating costs needed to guarantee both network operation and service quality at least comparable to that of today solutions. Furthermore, the optical SDN ecosystem should be complemented with a pool of SW tools for agnostic planning, design, automatic node configuration and bill of material generation, thus promoting and enabling automation of the whole WDM network lifecycle.

The maturity of the optical SDN eco-system and its open issues from a telecommunication operator (telco) viewpoint are sketched in next sections where we first briefly introduce the key elements in the open optical SDN eco-system and then perform a gap analysis highlighting some critical topics that still need more development efforts.

2. Optical SDN Eco-System

Two main options for optical WDM transport systems disaggregation are considered so far, namely an intermediate Partially Disaggregated (PD) versus a Fully Disaggregated (FD) optical network. Without entering in detail here (please refer to [1] for an in-depth discussion) both options grounds on whiteboxes for Xponders Network Elements (NEs) with HW, equipment SW and network-wide control SW separated and potentially provided by different vendors. While FD extends the disaggregation paradigm to the Analog WDM (A-WDM) domain including ROADM and OLA equipment, in PD the A-WDM is a mono-vendor OLS. In both cases the full system is complemented by a SDN domain controllers and SW modules for all management and Operation Administration and Maintenance (OAM) functions.

The so called optical whiteboxes eco-system consists of suitable disaggregated HW, open interoperability and modeling standards, and open source reference implementations of SW modules. It includes the following items:

• Optical whiteboxes: are the fundamental NE sub-systems of the optical layer in the form of HW boxes that can be managed using the NETCONF protocol and conform to standard YANG models. To ensure physical interoperability, these elements must also comply with appropriate optical layer standards (e.g. OpenROADM [3], OpenConfig [4], which are the two prominent standards for FD and PD respectively). Many of these whiteboxes sub-systems may be needed to build a network node (e.g. a full ROADM node composed by several degrees and add-drop elements).

• Optical node controllers or agents: these SW elements are necessary to control the low-level functions of the whiteboxes present in a node and to expose the high-level functionalities to the optical layer controller (e.g. using OpenROADM models). This application SW complement witheboxes HW in creating a full functional NE.

• Optical domain SDN controller and management sub-systems. It controls all the nodes and network functions through the NETCONF/REST protocols and YANG models, provides the operator with the OAM functionalities and exposes digital network services to the upper level of control (e.g. an orchestrator). Paramount examples of open source implementation of controllers specifically dedicated to the optical domain are the ODTN [5] and the TransportPCE [6] projects.

• Open source SW modules for design and planning. These SW modules provide to telco the additional capabilities for controlling the entire life cycle of an WDM disaggregated network form the initial planning and design up to its full operation stage (see for example [7]).

3. Requirements and Gap Analysis

The high-level requirements for the two main disaggregation models introduced in the previous section are reported here subdivided into 5 categories: physical requirements, Northbound and Southbound interfaces of the optical SDN controller, optical control functions and OAM requirements. Here all the Network Elements belong only to the whitebox or OLS categories; application SW aboard NEs or in the control and management systems are full carrier-grade version developed starting from open source initiatives in line with the techno-economic evaluation of [2].

Table 1. High level requirements for the two disaggregation architectures

Disaggregation level	Physical requirements	SDN Controller SB interface (to HW)	SDN control optical functions	SDN Controller NB interface (to service orchestrator)	OAM requirements
Fully disaggregated	Specification of optical signals at subsystems interface (e.g. ROADM-Xponder). Specifications of digital services (FEC, framing, mod. ....).	YANG models of optical subsystems. Standard YANG models of network nodes. NETCONF protocol.	Routing and Spectrum allocation. Power management. Protection&OAM.	Standard NorthBound interface exposing DIGITAL services to a service orchestrator.	All OAM functions available today in DWDM-ROADM systems.
Partially disaggregated	Specification of optical signals at Xponders-OLS interface. Specifications of digital services (FEC, framing, mod. ....).	OLS standard NB interface exposing ANALOG services to the Controller. Standard YANG models of Xponders. NETCONF protocol.	Routing and Spectrum allocation. Power management (maybe devoted to OLS controller). Xponder Protection& OAM.	Standard NorthBound interface exposing DIGITAL services to a service orchestrator.	All OAM functions available today in DWDM-ROADM systems.

As far as physical requirements are concerned, it is necessary to define the power levels and the optical spectrum of the signals at the interface points between the different whiteboxes in the FD case, and between Xponder and OLS in the PD case. Furthermore, the models of digital transport services that are exposed to the orchestrator must be defined. About the Southbound interface of the SDN controller, in the FD case standard YANG models are required for all optical whiteboxes, while in the PD case standard models are enough for the services offered by the OLS and for the Xponders. The NETCONF protocol is the standard of reference in both cases. If telemetry is required often an additional APIs could be specified. The optical control and management functions are different in the two cases: in the FD case the SDN controller must provide all the optical power control functions, Routing and Spectrum Allocation, protection, OAM, etc. In the PD case, many of these functions can be delegated to the OLS controller, while the SDN controller remains responsible for coordinating these functions between OLS and Xponders. The Northbound interface requirements are identical in both cases: it is a standard interface that exposes transport services to the higher control level. Finally, the OAM requirements are also identical: in both cases all the functionalities necessary for the correct management of the DWDM layer are required: digital and optical performance monitoring, alarms, configuration of un/protected optical channels, network and service inventory, etc. Of course, in the PD case, a part of these functions can be referred to the OLS controller. Planning and design tools are included in this last category.

Table 2 reports the comparison between the above identified requirements and the maturity of the available technologies. The columns of Table 2 correspond to those in the table of requirements (Table 1) but are divided into two parts: the one on the left refers to the standards, the one on the right refers to the availability of HW or SW (either commercial or Open Source). The meaning of the colors is obvious: green means wide commercial availability or consolidated standard, yellow means prototype or standard demonstrations at the initial state, red means unavailability of HW / SW and/or standard. For the FD architecture we see that there are three critical issues. First, the limited whiteboxes options available so far for the A-WDM domain. Then the lack of complete standards and implementations for optical control functions: the TransportPCE project is probably the most advanced in this field, but some essential features are not yet available (e.g. the calculation of transmission degradation: integration of GNPy with SDN controllers is still ongoing [8]).

Finally, complete OAM features are not provided by any Open Source platform or manufacturer. In any case, the strength of the FD architecture is represented by the OpenROADM standard which satisfies both the physical and the Southbound and Northbound interfaces requirements for the controller. On the other hand, for the PD architecture, we see that there are no serious concerns: the OpenConfig and ONF T-API standards represent solid bases for the development of partially disaggregated optical networks. It should be noted, however, that there is still no standard implementation of optical control functions in the line system that today are still proprietary. The same problem also occurs for the OAM and planning functions and the design tools that are still proprietary.

Table 2. Summary of the comparison between requirements and available technologies

Disaggregation level	Physical requirements		SDN Controller SB interface (to HW)		SDN control optical functions		SDN Controller NB interface (to service orchestrator)		OAM requirements
Fully disaggregated	Standard OpenROADM	HW missing	Standard OpenROADM	Prototypes	Standard missing	TransportP CE	OpenROADM	Prototypes	Limited open source functions
Partially disaggregated	Standard OPENCONFIG	HW available	Standard OPENCONFIG	Prototypes	Proprietary solutions	OLS cont.	Standard ONF TAPI	Prototypes	Proprietary OAM from OLS controller

4. Discussion and Conclusion

The results of the "gap analysis" allow us to draw the following conclusions. Considering the limited commercial availability of optical whiteboxes for WDM transport systems and the still limited functionalities of optical SDN controllers, a completely disaggregated optical network is still far from a concrete feasibility. In fact, even within the framework of OpenROADM, the most advanced standard in this field, to date a multi-vendor disaggregated optical network has been demonstrated only in the laboratory environment. The most feasible optical disaggregation scenario today is that of partial disaggregation in which a mono-vendor OLS is equipped with a proprietary control system with widely available Xponder devices from several vendors and a common higher-level optical domain controller form an independent provider or developed in-house by the telco. A multivendor environment in the analog layer is also possible as the network could be partitioned in “vendor domains” in which mono-vendor OLSs are deployed: internetworking could be realized through the digital layer by border transponders. Open source controllers are slowly progressing with the development of specific optical level functions and in the near future could become the root of carrier-grade products. As all SW sub-systems for network control, design and planning should be integrated in the multi-vendor eco-system, agnostic solutions and interworking among SW modules and NEs should be granted by open standardized APIs, open common SBIs and suitable MSAs. As expected, partial disaggregation reduces the complexity of integration and the need for agnostic SW tools, as the problem is restricted to design and plan a sub-network inside each OLS vendor-domain. Of course, this is achieved at the cost of an uncomplete elimination of vendor lock-in.

To conclude our analysis, it is worth mention another partial disaggregation scenario that seems very promising, namely the generation of WDM optical channels directly in the routers/switches using new pluggable (coherent) transceivers. This architecture allows, with the elimination of transponders, a considerable simplification of the data plane and drastically reduces the complexity of optical transport while making SDN control simpler. The challenges of this approach are very similar to those of partial disaggregation, but the full eco-system is still in a nascent state and significant research and demonstration work is still needed.

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7. References

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