Why should telcos invest on open-source software for optical WDM disaggregation?

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***Abstract*—This work evaluates the impact of Open Source Software (OSS) deployment in the business models of optical WDM networks. OSS projects allow a large degree of network management automation, while providing large cost savings by enabling optical disaggregation architectures in Metropolitan Area Network (MAN) scenarios. We show that large network operators, above the threshold of a thousand Metro nodes, can have important CapEx-saving opportunities (above 20% expected) in addition to gain the other benefits of SDN-based architectures, namely faster service flexibility and operations agility.**

I. Introduction

Open Source Software (OSS) has proven itself both as a feasible de-facto standard for software (SW) development and successful business case. Indeed, OSS leverages from having a large community of software developers providing support and producing new updated software versions periodically, thus allowing companies avoid reinventing the wheel. As an example, Linux Red Hat accounts approximately 100 Million Lines Of Code (LOC), which shows the amount of developers and time devoted to the project.

Similarly, telecommunication operators (telcos) have begun to realize the opportunities provided by OSS in the context of disaggregation of their equipment at several networking layers (optical, packet switching, datacenter, etc). In particular, there is a great attention with the concept of optical disaggregation [1], [2], which involves "all the operational models in which telcos are actively involved in the design, assembly, testing and lifecycle management of the WDM transport systems (WDM-sys)" [1]. This implies that different optical functionalities, traditionally performed by different blades integrated in a single item of equipment, are now performed by different boxes. Furthermore, the introduction to the market of disaggregated optical hardware (HW) from some vendors or open communities like the Telecom Infra Project (TIP) [3], along with the rise of Software Defined Networking (SDN) initiatives like the Open-Source Network Operating System (ONOS) or Open DayLight (ODL) enables a wide range of disaggregation options in the WDM domain.

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Indeed, telcos are at present considering two main options for optical disaggregation, namely (1) an intermediate partially disaggregated vs (2) a fully disaggregated optical network [1]. Fig. 1 shows a classical aggregated optical WDM network, highlighting its two main WDM domains: the Analog WDM (A-WDM) and the Digital to WDM (DtoWDM). The DtoWDM part comprises the transponders (TP), muxponders (MP) and switchponders (SP) in charge of the adaptation of digital client signals to analogue "media channels" of the A-WDM domain, which includes the transport boxes of such analogue "media channels", namely ROADMs, Line Terminals (LT) and Optical Line Amplifiers (OLA).

In the aggregated legacy case, which shall be used as a benchmark, all costs related to the Network Elements (NEs), including HW, equipment SW and the system control and management SW are provided by the same vendor. An open and possibly standard North-Bound Interface (NBI) can be provided towards a high-level controller or orchestrator.

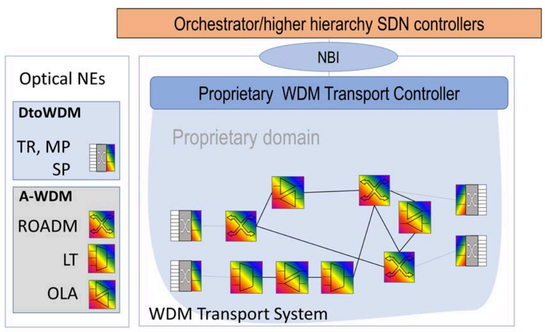

Fig. 1. Optical WDM transport architecture: Legacy benchmark, from [1].

The fully disaggregated option represents the case where both the Photonic NEs (P-NEs) and the A-WDM domains are composed of boxes provided by different vendors. To ensure data plane interoperability in this scenario, the interface between different boxes belonging to the A-WDM domain, here named Multi Wavelength Interface (MWI) should be compliant to a standard definition.

In the partially disaggregated model (or open line system),

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the A-WDM part is again provided by a single vendor, including its HW and SW; however, the P-NEs may be provided by different vendors.

II. Cost model

In a fully aggregated network, it is estimated that the bare-metal hardware cost itself of a product represents a percentage between 50% to 75% of the total cost of the Network Element [4]. The remaining cost typically belongs to the Operating System license and its software. Thus, in a disaggregated network model, telcos could potentially acquire optical equipment with large potential cost savings, then rely on open-source SW and further develop extra SW features (e.g. the SDN agents of each NE and the SDN controller) on top of existing mature OSS projects. Such SW extensions may be developed in-house or externally, opening new business opportunities to third parties. Indeed, existing OSS initiatives in the SDN context for WDM transport are gaining momentum and expected to reach maturity in the short to medium term.

In the proposed cost model, the amount of SW development in terms of number of lines of code (LOC) to develop all the extra features needed to reach the same functionalities as in a legacy benchmark network are quantified. It is assumed that SW developers may code an average of 4 LOC per hour, a number that includes all the software life cycle (i.e. requirements, design, coding, documentation, validation, operation and support). This 4 LOC/hour value is in line with [5], a past study conducted on hundreds of SW projects which concluded that the estimated range of software productivity ranges between 325 and 750 LOC per month.

Finally, integration costs for all options need also be included in the analysis as specified in the following section.

III. Evaluation

As a simple network scenario, we shall evaluate our models on Metro-like networks, whose features are inline with the reference topologies used in the EU H2020 project Metro-Haul [6], summarised in Table I. The table also shows the total cost of a Metro node, on average, in a legacy aggregated scenario and both disaggregated options. Cost values have been normalised to 1 CU = the cost of a 10G WDM Transponder.

As shown, we assume that the two disaggregated options benefit from 25% discount regarding DtoWDM HW cost, while the fully disaggregated case also benefits with an extra 40% discount for A-WDM HW (in aggregated A-WDM, the cost share of SW is estimated to be higher than in DtoWDM). In other words, while a MAN node in the legacy scenario may cost around 33 CUs, the cost for the partial and fully disaggregated nodes is 27.45 CU and 23.13 CU respectively. Clearly, important cost savings are achievable in disaggregated scenarios.

However, it is worth noting that in the legacy bench-mark case, equipment and system control and management SW is developed within the integrated solutions: equipment agent SW is included in the total cost of Table I while the system control and management SW cost is evaluated as a percentage of the entire equipment supply (5% has been applied in this study). For the disaggregated options, the cost of SW development needs to be provided separately and requires a different model with respect to the benchmark.

In disaggregated scenarios, the SW installed on equipment must rely on the availability of mature Open-Source SW projects, for instance SW developed within the framework of a standardization body like the Open-ROADM Multi-Source Agreement. However, in general, such OSS requires additional development for the customization required by the specific network implementation. The cost of SW customization is in this case shared between a limited number of items of equipment of the same telco. In such a case, we consider the cost of SW as 1 CU = 200 LOC (which is equal to the cost of a 10G Transponder as noted in Table I). We assume that SW agent development is needed for about 10 different O-NE requiring 50,000 LOC effort worst case per SW agent plus another 100,000 LOC for a professional-like SDN controller. This total SW cost is shared among all hardware nodes.

In the aggregated option, integration cost is modeled with a term that depends, less than linearly, on the number of deployed nodes. This is justified since telcos owning lots of metro nodes can require specific adaptations to some different contexts, each of them necessitating some additional integration effort. HW-SW integration of equipment is already provided lab by the mono-vendor before the supply shipping. In both disaggregated options, the integration cost is expected to be much higher than in the legacy case since the need for ensuring perfect internetworking between a large number of different components provided by multiple vendors is mandatory. The model in this case depends both on the volume of deployed equipment, as in the aggregated case, plus a term which depends on the square of the number of different pieces of equipment to be integrated (as all pieces must be verified with each other).

In an approximate assessment that neglects integration costs, a telco operator with N nodes would have a total cost of $33 \cdot N$ (CU) in a legacy aggregated architecture, while this cost can be down to $23.13N + 0.005L$ in a disaggregated architecture, i.e. savings in HW + cost of SW measured in L lines of code (LOC). Thus, a telco with N nodes willing to migrate to a disaggregated architecture is expected to achieve cost savings as long as the total cost in hardware (23.13 CU per node) and software (L LOC software which translates into $L/200$ CU) is smaller than the legacy benchmark solution (33 CU per node including everything). In other words:

$$23.13N + \frac{L}{200} < 33N$$

which implies that the total number of LOC invested in software has to satisfy: $L < 1974N$ to make the disaggregated architecture cost efficient.

For example, a telco with $N = 1000$ nodes willing to migrate to a disaggregated option will have cost savings as long as the SW development accounts for less than approximately 2 Million LOC, which is a very large SW project. It is

Equipment	Units per node	Unitary Cost	Legacy Cost/node	Partial Disagg Cost/node	Fully disagg Cost/node
A-WDM parameters					(40% disc)
Average degree of nodes (MD-ROADM)	2.8	2.5			
Average A/D units per node (LT)	1.2	3.1			
Average OLA amplifiers per link	0.05	1.3	10.8 CU	10.8 CU	6.48 CU
DtoWDM parameters				(25% disc)	(25% disc)
Average 10G Transponder per node	4	1			
Average 10x10G Muxponder per node	1.5	7.6			
Average 100G Transponder per node	1	6.8	22.2 CU	16.65 CU	16.65 CU
Total Cost per Node			33.0 CU	27.45 CU	23.13 CU

TABLE I
HARDWARE COST PER NODE IN BOTH LEGACY AND DISAGGREGATED SCENARIOS

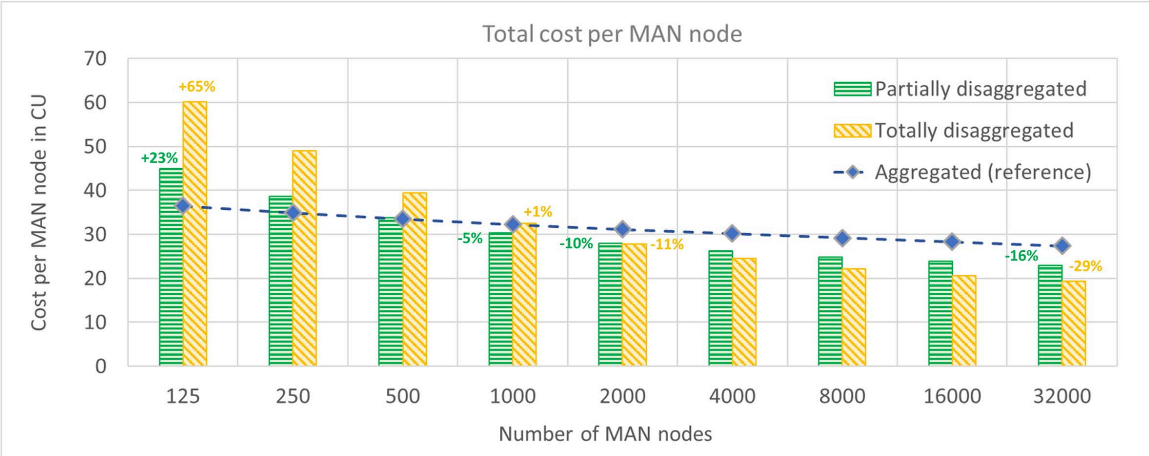

Fig. 2. Cost per node evolution with number of MAN nodes (3% of discount at every equipment volume doubling is assumed for all architectures)

worth remarking that telcos typically deploy one Metro node per 15000 customers, thus large network operators may have several thousand Metro nodes in their networks (obviously not all in a single MAN, but distributed between many MANs).

Fig. 2 shows the results of a cost evaluation use case which includes all costs contributions for the three architectures. The total cost per node for a number of owned node from 125 (small telco operating in a single city or in a region) to 32,000 MAN nodes (very large, continental or global operators). As shown in Fig. 2 (left), disaggregated options are far more expensive when the number of nodes ranges a couple of hundreds only, but this trend reverses for telcos with some thousands of nodes, reaching nearly 15-30% potential discount at 32,000 nodes.

IV. Discussion

In conclusion, this work has shown that telcos have a business opportunity by migrating their optical WDM systems to disaggregated models based on Open-Source SW projects, where the operator will deploy optical whiteboxes with pre-installed open-source SW. Still the operators will require to invest on OSS and require its customization plus some added extra functionality to meet their particular needs and system requirements. We foresee SDN-based solutions both as a requirement and enabler for optical disaggregation in the near future. Hence, adopting the disaggregation paradigm in the optical WDM layer is expected to provide significant benefits in terms of cost savings but also as a means to provide telcos with further flexibility and agile operations and management.

Acknowledgements

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