ORCHESTRA- Optical performance monitoring enabling flexible networking

K. Christodoulopoulos[1], P. Soumplis[1], I. Sartzetakis[1], M. Quagliotti[2],A. Di Giglio[2], A. Pagano[2], N. Argyris[3], C. Spatharakis[3], S. Dris[3], H. Avramopoulos[3], JC. Antona[4], C. Delezoide[4], P. Jennevé[4], J. Pesic[4], Y. Pointurier[4], N. Sambo[5], F. Cugini[5], P. Castoldi[5], G. Bernini[6], F. Moscatelli[6] ,G. Carrozzo[6], E. Varvarigos[1]

1: Computer Technology Institute and Press – Diophantus, Patra, Greece, 2: Transport Innovation, Telecom Italia, Torino, Italy, 3: National Technical University of Athens, Zografou, Greece, 4: Nokia Bell Labs, Nozay, France , 5: Scuola Superiore Sant'Anna, Pisa, Italy, 6: Nextworks, Pisa, Italy

e-mail: manos@ceid.upatras.gr

***Abstract*— An optical network, like any system, has to be observable before it can become subject to optimization, and this is the main capability that ORCHESTRA introduces. ORCHESTRA's high observability will rely on information provided by the coherent transceivers that can be extended, almost for free, to operate as software defined optical performance monitors (soft-OPM). Novel digital signal processing (DSP) OPM algorithms will be developed and combined with a novel hierarchical monitoring plane, cross-layer optimization and active control functionalities. ORCHESTRA vision is to close the control loop, enabling true network dynamicity and unprecedented network capacity efficiency.**

***Keywords*— coherent receivers; optical performance monitors; hierarchical monitoring plane; cross-layer optimization; transmission margins**

I. Introduction

The continuous growth of IP traffic and the emerging of new services are leading to a huge increase of traffic volume, with high unpredictability and dynamicity. This motivates the design of a new truly flexible and programmable networking environment. The Wavelength Switched Optical Networks (WSONs) used today in core and metro networks are inflexible and designed with a large capacity overprovisioning factor. Moreover, optical connections are established taking into account gross margins and worst case assumptions regarding equipment aging and interference.

Elastic optical networks (EON) provide finer granularity and flexibility as a means to improve network capacity efficiency and enable dynamic network re-optimization. However, before an optical network can be subject to optimization, it first has to be observable. Current control and monitoring infrastructures cannot adequately support this in a cost-effective and scalable way. Coherent receivers have the ability to report a huge amount of data related to the physical layer; this data, however, are currently not fully exploited.

ORCHESTRA will rely on information provided by the coherent transceivers that can be extended, almost for free, to operate as software defined optical performance monitors (soft-OPMs). ORCHESTRA will leverage on a novel hierarchical monitoring infrastructure to efficiently use and correlate such information from multiple soft-OPMs and thus enable an accurate knowledge of the physical layer. This allows a fine, cross-layer optimization of connections, aiming to reduce capacity overprovisioning and transmission margins, and obtain savings in investment [1][2]. Moreover, higher physical layer observability can also increase network availability. Apart from enabling prediction and avoidance of link outages [3], soft failures such as increased noise due to ageing of equipment, or some sort of malfunctioning, or interference due to higher load, can be identified, and solved with appropriate control actions. ORCHESTRA vision is to close the control loop (Fig. 1), enabling dynamicity and unprecedented network efficiency.

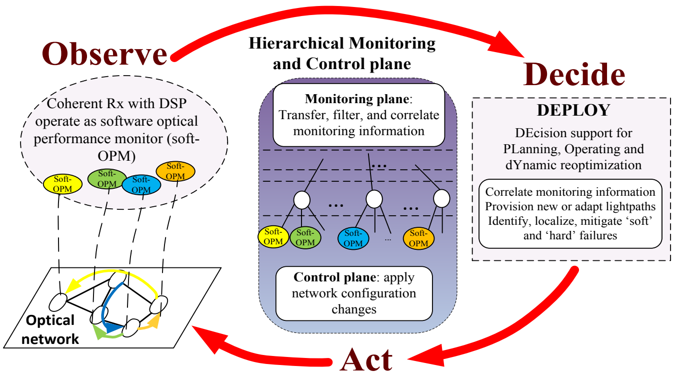

Fig. 1. ORCHESTRA observe-decide-act dynamic control cycle.

II. The ORCHESTRA Concept

The future of optical networks is coherent and elastic: operators are deploying an all-coherent, multi-format transport layer, leveraging DSP in powerful ASICs. This enables more robust transmission, allowing the shedding of redundant hardware and simplifying network design. ORCHESTRA will take advantage of the evolving trends and aggressively pursue the development of advanced DSP algorithms that will add real-time impairment measurement-capability to optical transceivers; potentially, every single transceiver in the network can be used as a soft-OPM. A key point is that monitoring functions come almost for free: the coherent receivers have already deployed ASICs for DSP. In addition to algorithms for measuring and mitigating dispersion effects (present in current receivers), ORCHESTRA will work on optical signal to noise ratio (OSNR), and take on the challenge of estimating non-linear effects and crosstalk.

The ORCHESTRA network will have a plethora of soft-OPMs to extract physical-layer information. But we can do even more: an OPM at a receiver provides aggregate measures over a path that usually spans several links. ORCHESTRA's ambitious objective is to correlate information from multiple soft-OPMs throughout the network [4][5], which opens up a multitude of possibilities such as: quality of transmission (QoT) estimation before lightpath establishment; detection, as well as anticipation, of 'hard' (total link failure) and 'soft' (QoT degradation) failures. Also, such methods make the gradual deployment of ORCHESTRA more appealing, since added value comes even from just a few OPMs.

ORCHESTRA will also develop a hierarchical control and monitoring infrastructure [6] capable of transferring and manipulating monitoring information while going beyond passive-monitoring operations by adding active-control functionality. ORCHESTRA monitoring plane will enable effective processing of monitoring information (filtering, correlation) and fault management, avoiding bottleneck issues related to centralized approaches. Active control functions will include the tuning of transmission parameters of flexible transceivers (changing modulation format, FEC, power, etc), the shift in spectrum or rerouting. Control actions will be examined at a local level for single connections, and then at higher hierarchy layers, to examine multi–connection actions, keeping complexity and intervention as low as possible, and avoiding overwhelming the central controller. The introduction of elastic networking has increased vastly the optimization dimensions, while new types of problems have emerged. ORCHESTRA will rely on the feedback from the soft-OPMs to develop true cross-layer optimization algorithms, targeting both dynamic but also offline (planning) use cases.

In the following table we list five classes of use cases where applying the ORCHESTRA concept can yield benefits:

Lightpaths provisioning with reduced margins: during the planning for an upgrade or the addition of new lightpaths, decisions on equipment purchase and (re-)configuration of lightpaths are taken. A planning tool estimates the QoT of existing or new lightpaths, typical using high margins to account for QoT model inaccuracies and avoid interventions during the network lifetime. ORCHESTRA proposes this planning process to be done with reduced margins, based on the actual network conditions as observed through the soft-OPMs. A preliminary study is presented in the following section.
Dynamic network adaptation: ORCHESTRA develops mechanisms to support dynamic network re-optimization based on the actual network and traffic conditions as opposed to the overprovision of the network resources. ORCHESTRA leverages the tunability of transceivers and accurate physical layer information to adapt them according to the network requirements and conditions.
Hard-/soft-failure localization and hard-failure prediction: It has been observed that a huge number of alarms are generated in Optical Transport Network (OTN), while alarm suppression mechanism are quite slow. ORCHESTRA's hierarchical monitoring plane provides an efficient and scalable infrastructure to filter and correlate alarms to suppress them and localize the failure. ORCHESTRA's advanced monitoring functions will also enable the localization and handling of soft-failures: QoT problems due e.g. to malfunctioning of equipment or equipment ageing or increased interference in a network operated with low margins. Finally, ORCHESTRA will examine how monitoring (e.g. states of polarization [3]) can help in predicting hard failures, as a means to increase the network availability.
Optimize transmission during network upgrade and maintenance tasks: Network upgrades and maintenance tasks are in most cases a gradual stepwise procedure; the network remains in operation but is vastly un-optimized. Through ORCHESTRA it is possible to optimize the network even during the upgrade/ maintenance processes.
Alien lightpaths support: Aliens are lightpaths for which we do not have knowledge on their transmission parameters. As such, they might cause soft-failures, e.g., use high launch power or be misaligned with filters, creating high crosstalk and nonlinear interference. It is also hard for aliens to obtain good QoT over an unknown domain. ORCHESTRA advanced monitoring and correlation functions can provide efficient solutions to QoT issues from the support of aliens.

III. Preliminary Results on Cost Benefits

We compare the cost of a network over 5 periods (10 years) for provision lightpath with: (i) End-of-life (EOL), and (ii) begin-of-life (BOL) margins, which is the ORCHESTRA approach. In the study we assumed the SPARKLE Pan-European topology and traffic 100 Gbps between all nodes that does not increase over time. We assumed 100 km spans, 100 G PM-QPSK transceivers (TR) with soft FEC, and we calculated the acceptable reach (changes every period) using the GN model [7]. We assumed a span margin of 3dB at BOL and 4 dB at EOL, fiber attenuation of 0.22 at BOL and 0.24 dB/km at EOL, span budget of 25 dB at BOL and 28 dB at EOL, and worst case interference (all channels active). The cost of a period was calculated by adding the cost of the TRs, regenerators (REG), optical line amplifiers (OLA), optical switches (WSS used for add/drop and lines). The following relative costs (in C.U. - Cost Units) were assumed: 100 G TR=1, 100 G REG=2, REG displacement= 0.15, OLA=0.15, line WSS =0.3, A/D WSS: 0.4, fiber rental=0.004 C.U./year.

Fig. 1 presents the accumulated cost, for the EOL and BOL cases. In the EOL case, the cost of all equipment is paid upfront, at period 1, and does not change (except for fiber rental), since no new equipment is added at latter periods. The accumulated cost for BOL is calculated assuming 10% depreciation of equipment per year. The savings obtained vary with time and at the end of the examined 5 periods were observed to be 13.7%, and can rise to 22% assuming 3% interest rate/year on saved money. Note that in this study, we did not take into account the reduction of interference margins, which early results show that the have additive effect, and thus the savings enabled by ORCHESTRA will be even higher.

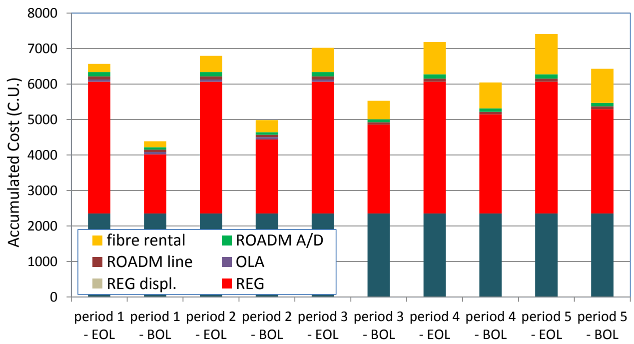

Fig. 1. Accumulated cost for planning with End-of-life (EOL) and Begin-of-life (BOL) margins – the ORCHESTRA approach.

Acknowledgment

This work was supported by the EC through the Horizon 2020 ORCHESTRA project (grant agreement: 645360).

References

[1] J. Auge,"Can we use Flexible Transponders to Reduce Margins?" OFC 2013
[2] Y. Pointurier, "Design of low-margin optical networks" OFC 2016.
[3] J. Pesic, et. al., "Proactive Restoration of Optical Links Based on the Classification of Events", ONDM, 2011.
[4] I. Sartzetakis, et al. "Estimating QoT of Unestablished Lightpaths", OFC 2016.
[5] N. Sambo, et. al., "Lightpath Establishment Assisted by Offline QoT Estimation in Transparent Optical Networks", IEEE/OSA JLT, 2010.
[6] N. Sambo, et. al., "Monitoring plane architecture and OAM Handler", IEEE/OSA JLT, 2016.
[7] P. Poggiolini "The GN Model of Non-Linear Propagation in Uncompensated Coherent Optical Systems", IEEE/OSA JLT. 2012.