

# DEPLOY Tool: Incrementally Planning Marginless Elastic Optical Networks

Aristotelis Kretsis<sup>1,2</sup>, Polizois Soumplis<sup>1</sup>, Kostas Christodoulopoulos<sup>1,2</sup>, and Emmanouel (Manos) Varvarigos<sup>1,3</sup>

<sup>1</sup> Department of Electrical and Computer Engineering, National Technical University of Athens, Greece

<sup>2</sup> Computer Technology Institute and Press - Diophantus, Patras, Greece

<sup>3</sup> Department of Electrical and Computer Systems Engineering, Monash University, Australia

Tel: (+30) 210 7724731, e-mail: vmanos@central.ntua.gr

## ABSTRACT

Currently, the hardware (equipment) and software (including planning and operation tools) are both provided by optical equipment vendors, leading to the so called vendor lock. We present DEPLOY, a tool for planning and operating optical networks that uses generic vendor-agnostic models. We demonstrate its capabilities through the use case of incrementally planning an optical network over multiple periods under evolving traffic and physical layer conditions. Using DEPLOY we can evaluate the benefits of planning with reduced as opposed to planning with end-of-life margins.

**Keywords:** elastic optical networks, planning tool, operation tool, multi-period planning, physical layer impairments, quality of transmission, ageing, interference, transmission margins, end-of-life.

## 1. INTRODUCTION

Optical equipment vendors develop and use in-house tools to plan and upgrade the core and metro networks for their telecom operator customers (e.g. Nokia's Network Planning and Optimization – NPO, Cyan Blue Plane Design – acquired by Ciena), Coriant TransNet, etc.). A vendor planning tool is specifically developed to include the equipment and features of the corresponding vendor and provides a complete set of functions to plan and analyse optical networks, including physical layer models, configuration scenarios, routing schemes, network recovery tests, and traffic load analysis. Most of the tools automate the purchase and the configuration of the vendor equipment. When the equipment is deployed the network management system (NMS)/ or the vendor controller is used to operate the network, including monitoring and failure identification and handling functions. Some more generic planning tools for various purposes also exist, such as Riverbed SteelCentral Network Planning and Configuration Management (NPCM) (formerly OPNET, acquired by Riverbed), Cariden MATE Design (acquired by Cisco), VPI OnePlan, WANDL IP/MPLSView (acquired by Juniper), and also several generic controllers, such as OpenDayLight and ONOS, have being developed.

However, in the majority of optical networks today the hardware (equipment) and the software (including the tools for both planning and operating and the related suites of protocols) are jointly provided by optical equipment vendors. The software offered by a vendor is able to design and operate only its equipment, and also the equipment of different vendors do not inter-operate, leading to vendor-specific domains that are isolated. This so called vendor-lock may break in the near futures, as optical equipment become more inter-operable and efforts on optical nodes – “white boxes” (e.g. YANG modeling) emerge [1]. Operators are pushing in this direction which can create a new market for both hardware but also software.

We present DEPLOY, a tool for planning and operating optical networks that uses generic equipment models. DEPLOY can be used as a standalone module to perform planning and what-if studies, and also as an advanced Path Computation Element (PCE) providing brain/logic functionality when operating the optical network. DEPLOY is an extension of Mantis tool firstly presented in [2] that has been developed by our team over several years to include various features and use cases. In this paper we use DEPLOY to incrementally plan an optical network over multiple periods under evolving traffic and physical layer conditions, a use case identified in ORCHESTRA Horizon 2020 project.

The key target in network design and operation is to provide the required services but avoid overprovisioning. Typically, in optical networks the connections are provisioned with *end-of-life (EOL) margins* [3]. High system margins are used to guarantee acceptable QoT under worst-case interference and pessimistic estimates for ageing and maintenance interventions expected after several years of network operation (e.g. 10 years). Also, a design margin is used to take into account the inaccuracies of the estimation model. The high margins translate to reduced optical reach estimates, requiring the deployment of more regenerators and more robust transponders than are strictly necessary at the time of installation. Reducing the margins can postpone the purchase of equipment until actually needed, or avoid the purchase, resulting in reduced cost [4][5].

DEPLOY, includes an advanced RSA algorithm that takes into account the actual physical layer performance to provision or reconfigure existing lightpaths with actual (just enough) margins, optimizing the placement and configuration of transponders and regenerators [6][7]. Accurate QoT estimation is crucial for this process [9][10][11]. Though DEPLOY web-based user interface (WUI) we can describe multi-period planning scenarios along with evolving traffic, physical layer and cost parameters. We execute the incremental planning algorithm

with reduced margins and then through the WUI we observe and analyse the detailed results. We can also describe, solve, analyse, and compare against multi-period planning with EOL margins scenarios. Thus, using DEPLOY we can showcase the benefits of planning with reduced as opposed to planning with EOL margins.

## 2. TOOL ARCHITECTURE

DEPLOY is a planning and operation tool, which is an extension of Mantis tool that started to be developed in 2010 and reached a stable phase in 2013 [1]. Since then the tool has continuously been upgraded/extended to include new use cases following the evolution of optical technologies and relevant research. DEPLOY can be used as a standalone module to perform planning and what-if studies, including joint IP and optical network planning, for single period and multi-periods, taking into account constant or evolving traffic and physical layer parameters. DEPLOY includes detailed models for optical components such as fixed or elastic optical transponders and regenerators, EDFA and fiber types, ROADMs, but also IP layer components such as modular IP routers and line cards. The optical layer is modelled with an extended version of the GN model [13] accounting for the evolution of physical layer with respect to ageing and/or equipment malfunctioning events.

DEPLOY can be also used in the operation phase of an IP and optical network as an advanced Path Computation Element (PCE) to dynamically compute paths for both IP (PCE layer 3) and optical (PCE layer 0) [8] separately but also jointly. In addition to the typical path computation function, DEPLOY handles some advanced operations such as QoT estimation, soft failure identification, localization and recovery [12].

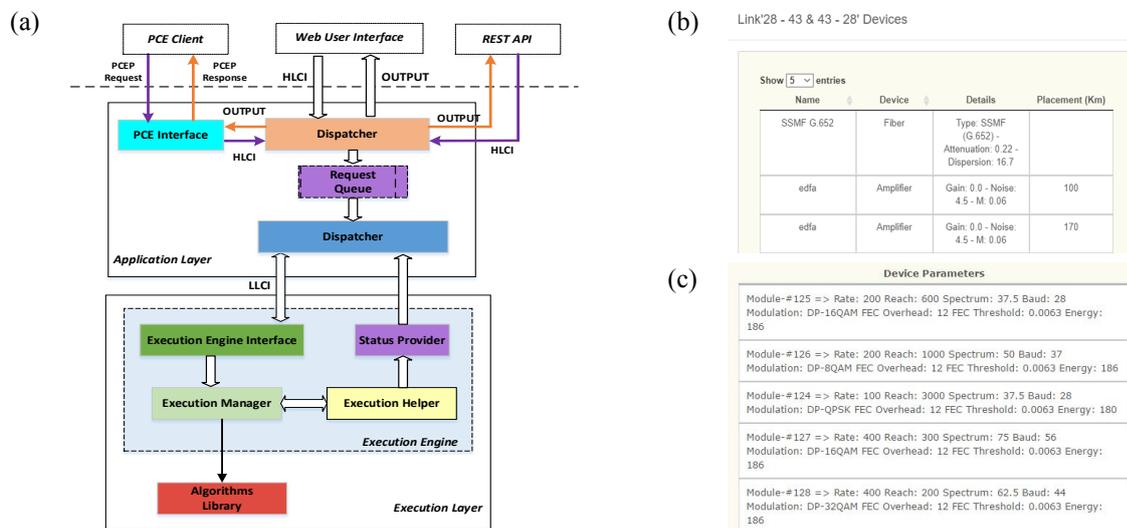


Figure 1: a) DEPLOY architecture and its main components; b) Definition of spans; c) Definition of an elastic transponder.

DEPLOY is organized in three layers: the access layer, the orchestration layer, the execution layer. Fig. 1a shows DEPLOY architecture and its main components. The access layer handles the interaction with the users through a web-based user interface (WUI) which provide easy access to all tool functionalities and supported operations. Furthermore, it exposes additional interfaces (PCEP and RESTful APIs) enabling external entities to request advanced PCE functions such as path computation, QoT estimation, soft failure localization and recovery. The application layer implements the application logic and orchestrates the execution of user requests, while coordinates also the required actions between the two other layers. The execution layer consists of the execution engine and the library of available network planning and operation algorithms. The execution engine receives requests, for starting or terminating scenarios executions, and is responsible for preparing the execution environment, monitor the scenarios' progress and the handles the final results or possible failures.

## 3. INCREMENTAL MULTI-PERIOD OPTICAL NETWORK PLANNING

To perform a multi-period planning study in DEPLOY, we first define the network scenario for the initial period, which consists of the i) topology, ii) link parameters, iii) node parameters, and iv) traffic. In DEPLOY we can create new topologies using the WUI or through uploading a file with specific format, specifying the id and basic features (e.g. length) of the links and the nodes. Topologies can be saved, loaded and modified. Various realistic topologies for National, and Continental size network are available. Then the topology is enhanced to include link and node parameters. DEPLOY models various equipment; key equipment for this use case are:

- Fiber types, with parameters of attenuation, dispersion, and nonlinear coefficients
- EDFAs, with parameters of gain, noise figure, saturation, and cost
- Transponders and regenerators, which can be fixed or elastic, supporting one or more transmission options, respectively. Each transmission option defines the baud-rate, modulation format, and FEC threshold and optionally the transmission reach (which is actually neglected when a specific physical layer model is used, as is the case here). Each transponder and regenerator has a specific cost.

The link parameters pertain to the descriptions of the spans (Fig. 1b). Each network link consists of one or more spans, and for each span we can select its length, fiber type and EDFA. We can set these parameters uniformly for all links or separately per link and span. The node parameters include the optical switch type (ROADM – DEPLOY currently supports 2 colorless-directionless-contentionless variations) and the transponders and regenerators (Fig. 1c). For planning studies we can select one or more transponders and regenerators as available to be used at each node and we can set constraints on each type or their total number. In operation studies we can set the number of existing/deployed transponders/regenerators per node.

We can create traffic with basic random processes for selecting the source-destination and capacity, or upload a file with a specific format. Realistic traffic profiles for the National and Continental topologies are available.

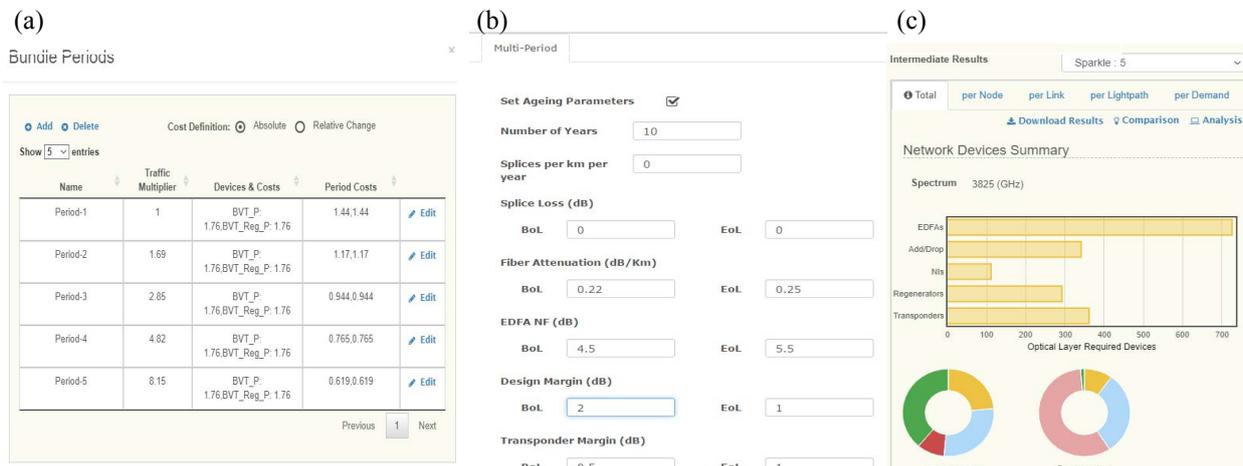


Figure 2: a) Description of periods (traffic and cost evolution); b) Definition of margins evolution; c) General tab with summary information for the components used at a specific period.

Once the above are selected, defining the scenario for the initial period, we can then extend it for multiple periods. For each period we can select the traffic, by generating, loading a new traffic profile, or defining a multiplier assuming a uniform increase of the initial traffic. We also need to define the equipment available at each period, mainly the transponders and regenerators. We can assume the availability of the same equipment and redefine their cost (to model the depreciation as time advances) or we can introduce new transponders/regenerators at any period (e.g. with better features such as higher baud rate, modulation format, etc., to model technology advances). Figure 2a shows an overview of the description of evolution of traffic (assuming uniform increase) and cost (assuming same transponders and regenerators) for 5 periods.

To study the effect of the physical layer over time we then introduce the margin parameters (Fig. 2b). We first specify the years that are studied. Previously we introduced the planning/upgrade period that can correspond to months or several years. To model the ageing of equipment (transponders) and certain parameters such as the fiber cuts, it is more obvious to consider the actual years. Then we give the begin of life - BOL (corresponding to the first planning period) and end of life - EOL (corresponding to the last planning period) values for varying parameters, i.e. the cuts per km per year, fiber attenuation, EDFA noise figure, and the transponder margin [6] [7]. We also set the design margin which we can assume that is constant or reduces as time advances [4][6]. This is currently passed as a parameter, but we intent to connect that to learning processes [9][10], that would reduce the design margin according to the established traffic/lightpaths at each period. Finally, we can select whether we model the actual or worst case interference [6][7]. The assumption is that the defined parameters evolve linearly from BOL to EOL values (note that some parameters evolve linearly in dB); we can avoid the linear evolution and specify a parameter value per year. Under the hood, DEPLOY models the physical layer with an extended GN model [13], which takes as input the evolution of the margin parameters. For example DEPLOY remembers the period a transponder was deployed and treats its related margin accordingly.

Once we specify the periods and the evolution of margins we select the algorithm (currently the heuristic of [6]) and execute the scenario. Depending on the topology, traffic, number of periods, etc., the scenario can run from few minutes to hours, which is considered acceptable for planning studies of this type. Once the execution finishes we can observe through DEPLOY WUI the detailed results.

First of all we can view for each period some global metrics such as the number of equipment used, the total (accumulated up to this period) cost, the total spectrum used, etc. (Fig. 2c). For each period we can select each node and view the transponders and regenerators used. We can also select each link and view the lightpaths that cross that link, and we can also select a lightpath and view its path, the used transponder and transmission parameters and also the QoT details (Fig. 3a). We can also perform a multi-period analysis, where we can track how each traffic demand was served: what transponders and regenerators were used at each period and the related QoT metrics. For example in Fig. 3b we view a demand that was installed at period 1 and was initially

served with a single transponder/lightpath. Since we planned the network with reduced margins, the QoT of the lightpath was acceptable when the lightpath was provisioned. The QoT deteriorated and at some point at period 5 the QoT become unacceptable and we installed a regenerator.

Following similar steps we can also perform a multi-period planning with EOL margins study. We set the BOL margin parameters equal to the related EOL parameters and use the same algorithm to plan the network over the multiple periods. As previous, detailed results for each period are provided through the WUI. In Fig. 3c we observe the evolution of the same demand of Fig. 3b, but provisioned with EOL margins. We observe that we installed from period 1 a regenerator so that the 2 lightpaths (transponder to regenerator, and regenerator to transponder) reach the last period (EOL) with acceptable QoT. Finally, we can use DEPLOY to create graphs comparing the two scenarios were we can observe the benefits of planning with reduced margins [6] [7].

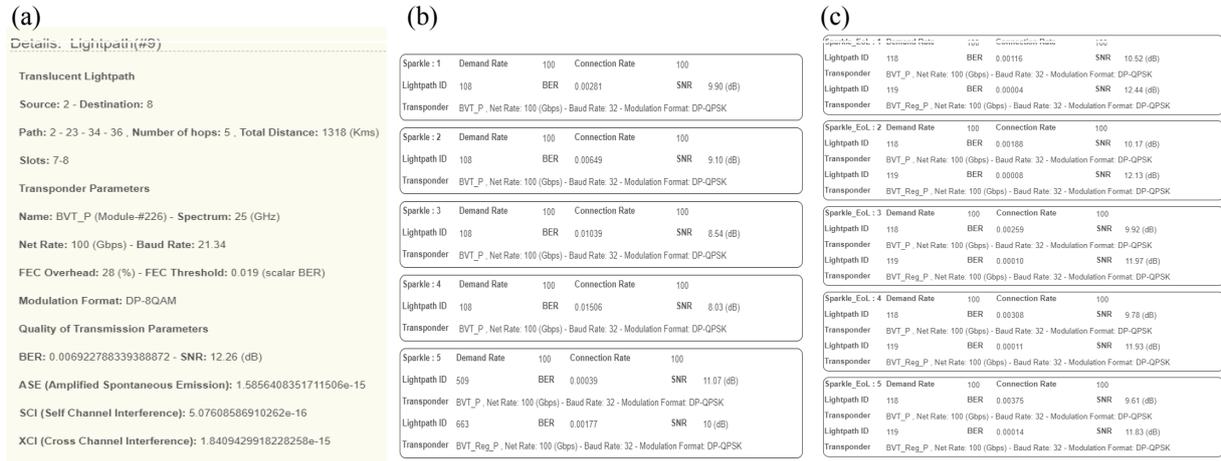


Figure 3: a) Details for a specific lightpath at a specific period; b) Evolution of a demand over the examined periods when provisioned with reduced; c) With EOL margins.

## 4. CONCLUSIONS

We presented DEPLOY, a tool for planning and operating optical networks that uses generic vendor-agnostic equipment models. We described the steps in DEPLOY for defining a multi-period planning scenario with evolving traffic and physical layer conditions. Using DEPLOY we can evaluate the benefits of multi-period planning with reduced margins as opposed to planning with end-of-life margins.

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