Modular Control Plane Implementation for Disaggregated Optical Transport Networks with Multi-band Support

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Abstract *This demo paper presents the B5G-OPEN control plane modular architecture designed to enable dynamic control of multi-band disaggregated optical networks through open-source software and standard interfaces. Such control plane will be demonstrated in a distributed testbed including real IPoWDM nodes, ROADMs and transponders. ©2023 The Author(s)*

Introduction

The recent evolution of transmission technology is driving the introduction of new solutions in optical networks such as: (i) multi-band operation, that allows to provision services using the several bands available in optical fibres, e.g., O-, E-, S-, C-, L-band; (ii) optical continuum, allowing to transparently cross different network segments and domains; (iii) coherent pluggable transceivers installed in the so-called IPoWDM packet-optical nodes that enable effective packet-level traffic aggregation at the edge of the optical domain[1].

The introduction of such solutions poses new requirements to the network control plane. For instance, multi-band operation not only means being able to map and exploit the devices' multi-band capabilities but also requires more accurate tools for the estimation of non-linear physical impairments[2]. On the other hand, the optical continuum requires the ability to setup connections in a transparent manner across multiple domains and network segments, and typically requires to extend SDN principles to networks composed of several technological layers[3],[4].

This work demonstrates the control plane architecture designed within the B5G-OPEN project to face the aforementioned requirements. Indeed, the proposed architecture relies on a modular organization where the inter-operation among control plane elements is guaranteed through open interfaces. This approach facilitates the scaling of the architecture towards complex multi-segment and multi-domain networks, and allows the seamless introduction of specialized element in the control plane, e.g., dedicated to path computation and estimation of physical impairments or dedicated to continuous collection of telemetry information, that could be used to feed AI algorithms facilitating the network automation[5].

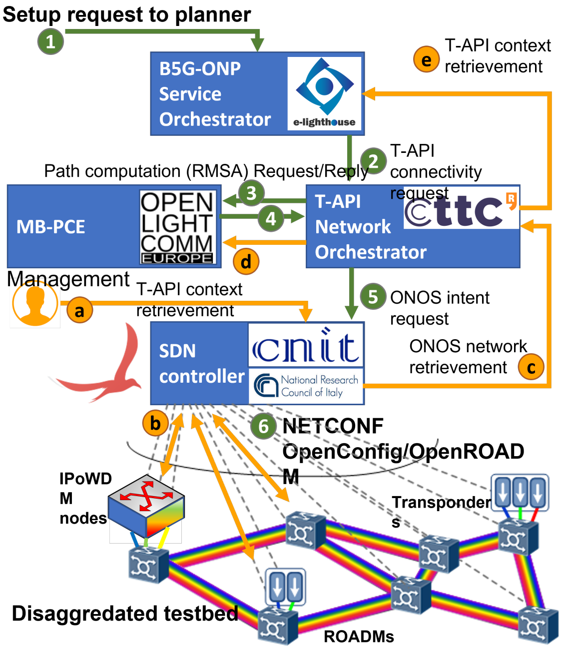


Fig. 1: Proposed control plane architecture and workflow for: the control plane initialization, steps (a-e); the activation of a new connectivity service, steps (1-6).

The demo leverages on two system-level novel contributions: i) implementation of a data information flow to transport device and fiber impairments description from the data layer, through the SDN controller, up to path computation and orchestration level; ii) extension of the OpenConfig model to properly map the supported operational modes to transponders and IPoWDM ports.

Demo Objectives

The primary objective of this demo is to showcase the integration of the multiple control plane modules developed withing the B5G-OPEN project, targeting the dynamic provisioning and release of connectivity services. More specifically, we aim to demonstrate the following key aspects:

- Implementation of a service orchestrator able to retrieve multiple domains information through T-API standards[6].
- Implementation of a T-API network orchestrator translating lower domains proprietary network descriptions in the standard T-API representation and requesting path computation to an externalized entity.
- Implementation of a dedicated path computation and physical impairment estimation element.
- Extension of the ONOS SDN controller[7] to support flex-grid, multi-band operation and exportation of physical parameters.
- Implementation of SDN agents based on extended OpenConfig and OpenROADM YANG models, for the control of ROADMs, IPoWDM nodes and transponders.

Data plane

The testbed is composed by 4 ROADMs, 4 transponders (one connected to each ROADM), and 2 IPoWDM nodes. All the ROADMs expose an OpenROADM model to the controller, two of them are implemented exploiting real devices (i.e., a Lumentum ROADM-20 and a Finisar Waveshaper), the others are emulated. Two transponders are implemented exploiting real devices, the others are emulated. The IPoWDM nodes are physical whiteboxes running the SONiC NOS[8]. All devices are deployed in the CNIT premises, except the two transponders that are located at CTTC premises.

Control plane

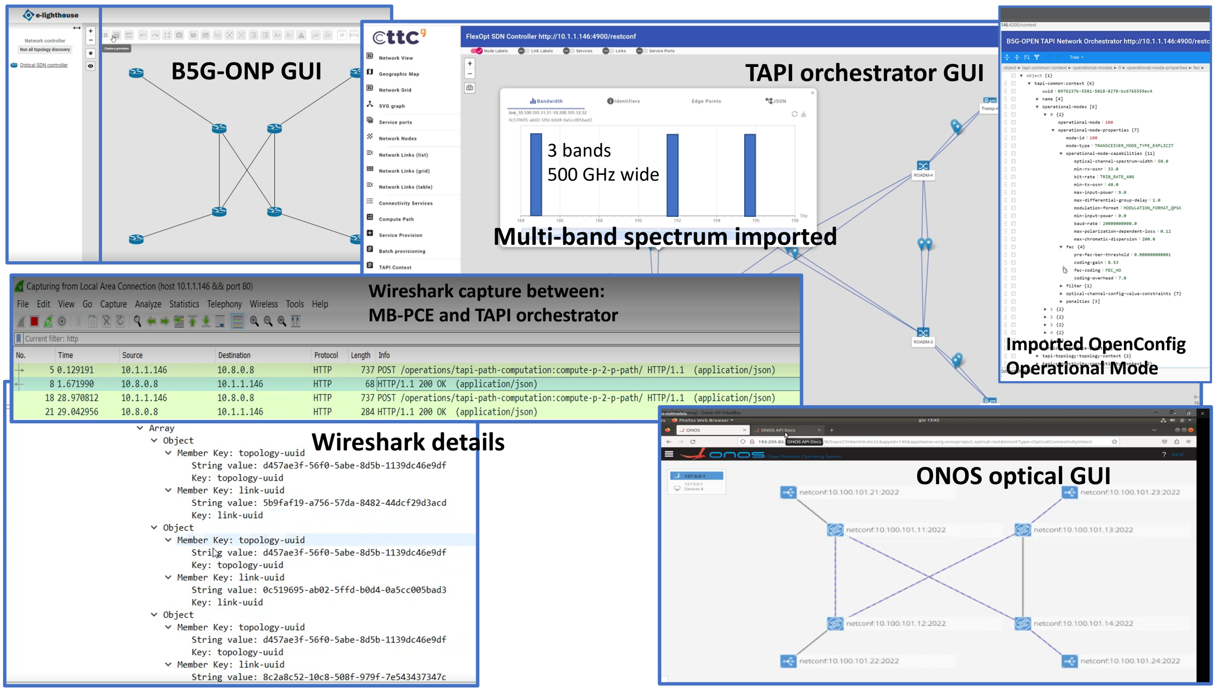
Fig. 1 showcases the proposed control plane architecture. The key elements are: the B5G-ONP service orchestrator, the T-API network orchestrator, the multi-band path computation element (MB-PCE), and the SDN controller.

The optical SDN controller is based on ONOS, version 3.0.0, which provides a solid base to control disaggregated optical networks[9]. The controller supports the following functions: (i) retrieval of key abstraction parameters of the data-plane sub-systems and distribution of them to the upper layers; (ii) to receive service configuration requests from the upper layers and translate them into a set of configuration messages using the appropriate format for each device. Several extensions are applied to the official ONOS distribution: (i) in the Southbound Interface (SBI), the OpenConfig drivers may now retrieve the description of the supported OpenConfig operational modes allowing to associate the operational mode to specific ports; (ii) the controller core is upgraded to support flex-grid and multi-band operation; (iii) the Northbound Interface (NBI) is upgraded with a set of REST APIs supporting seamless communication with the TAPI orchestrator, e.g., now it is possible to export the list of operational modes supported by a device and the status of each wavelength channel registered on a link.

The TAPI network orchestrator is a functional element of the architecture that is responsible for the following functions: i) providing a uniform, open and standard view and interface to higher control levels; ii) Compose a complete context to be consumed by the the B5G-ONP and additional consumers combining information retrieved from subsystems and sub-controllers (e.g., by the SDN controller); iii) Enable single entry point for provisioning connectivity services, including externalized path computation and iv) provide an event telemetry data source that reports events that happen asynchronously in the network.

The multi-band PCE (MB-PCE) is a dedicated element designed to complete computationally intensive operations. The MB-PCE consists of a routing engine that exploits a Physical Layer Impairment-aware Routing, Modulation and Spectral Assignment Algorithm (PLI-aware RMSA)[10] and it is equally applicable to both transparent and translucent paths[11]. The MB-PCE retrieves network topology from the TAPI network orchestrator. The PLI-aware RSA also gets as input the deployed optical transmission system parameters as well as the traffic components of the existing services. The physical layer modeling (also developed in the context of B5G-OPEN project[10]) estimates the impact of ASE accumulation, and the nonlinear propagation effects like the in-band FWM terms (XCI, SCI) and inter-band effects like SRS . Upon receiving a connectivity request, the PLI-aware RMSA assesses the performance of the candidate lightpath (that ought to be above a suitably chosen threshold) and it estimates the impact of this new lightpath on the already established ones. As soon as viable path is deduced, the MB-PCE returns the path in terms of links, number of frequency slots and selected transmission system parameters.

The B5G optical service orchestrator and planner (B5G-ONP) is the topmost component of the B5G-OPEN control plane that orchestrates IT and



```
Capturing from Local Area Connection (host 10.1.1.146 && port 80)
Current filter: http
No.  Time       Source      Destination  Protocol  Length  Info
  5  0.129191   10.1.1.146  10.8.0.8     HTTP      737 POST /operations/tapi-path-computation:compute-p-2-p-path/ HTTP/1.1  (application/json)
  8  1.671990   10.8.0.8    10.1.1.146   HTTP       68 HTTP/1.1 200 OK  (application/json)
 18  28.970812  10.1.1.146  10.8.0.8     HTTP      737 POST /operations/tapi-path-computation:compute-p-2-p-path/ HTTP/1.1  (application/json)
 21  29.042956  10.8.0.8    10.1.1.146   HTTP      284 HTTP/1.1 200 OK  (application/json)
```

```
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  Object
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      String value: d457ae3f-56f0-5abe-8d5b-1139dc46e9df
      Key: topology-uuid
    Member Key: link-uuid
      String value: 5b9faf19-a756-57da-8482-44dcf29d3acd
      Key: link-uuid
  Object
    Member Key: topology-uuid
      String value: d457ae3f-56f0-5abe-8d5b-1139dc46e9df
      Key: topology-uuid
    Member Key: link-uuid
      String value: 0c519695-ab02-5ffd-b0d4-0a5cc005bad3
      Key: link-uuid
  Object
    Member Key: topology-uuid
      String value: d457ae3f-56f0-5abe-8d5b-1139dc46e9df
      Key: topology-uuid
    Member Key: link-uuid
      String value: 8c2a8c52-10c8-508f-979f-7e543437347c
```

Fig. 2: A collection of screenshots of the four control plane elements involved in the demo, including a Wireshark capture.

network resources. This component provides design, optimisation and planning capabilities to deploy, manage and configure services and resources, facilitating integration with external entities. The key aspects of this module are: i) discover and assimilate the topology of underlying network segments and domains by exploiting the NBI of TAPI orchestrator (and other possible network controllers), allowing it to discern the availability of services and their inter-dependencies; ii) perform an intelligent analysis of available resources and interacts with the other elements of the control plane for network provisioning procedures; iii) display information through a friendly GUI, which offers an aesthetically pleasing layout, and intuitive, straightforward navigation.

Control plane workflow

The proposed demo will demonstrate two distinct phases as illustrated in Fig. 1: the control plane initialization and the setup/release of a number of connectivity services. The former procedure is illustrated in steps (a-e): the management layer provides the devices' location (step a), the device details discovery is then performed using NETCONF protocol by the SDN controller (step b); thus, the TAPI orchestrator can retrieve the network topology from the SDN controller (step c) and propagate it to the MB-PCE (step d) and to the B5G-ONP (step e). The latter procedure is illustrated in steps (1-6). A connectivity service is requested to the B5G-ONP (step 1), the request is forwarded to the TAPI orchestrator (step 2) that forwards it to the MB-PCE (step 3) which replies with the computed path (step 4). Thus, the TAPI orchestrator forwards the request, including computed path and selected network resources to the SDN controller (step 5) that properly configures each involved network element (step 6).

Demo Setup and Storyboard

The demo will be executed live through a remote connection to the integrated B5G-OPEN distributed testbed that includes software and hardware components deployed in four different locations. The testbed encompasses the following hardware: one or more servers in each of the four locations to run the software components. Two IPoWDM nodes and two ROADM at the CNIT lab in Pisa (Italy) and a transponder pair located at the CTTC lab in Barcelona (Spain). The demo will show dynamic activation and de-activation of several connectivity services. The proposed control workflow will be also described through dedicated slides. Moreover, a live connection to each control plane element will be available to show more details to the interested audience. On-site participation is planned with live interaction with the audience, providing feedback on architectural aspects as well as implementation solutions.

Acknowledgements

This work was supported by the EU Horizon 2020 Framework Programme under grant agreement no. 101016663 (B5G-OPEN).

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