Hybrid SDN Orchestration in Multi-Layer Network with SONiC Packet-Optical Nodes and Coherent Pluggables

Davide Scano [1,2], Jordi Ortiz[3], Alessio Giorgetti [1,4], José Manuel Martínez[5], Andrea Sgambelluri[1,2], Emilio Riccardi [6], Filippo Cugini[1], Pablo Pavon[5,7]

1: CNIT, Pisa, Italy; 2: Scuola Superiore Sant'Anna, Pisa, Italy; 3: University Center of Defense at the Spanish Air Force Academy, San Javier, Spain; 4: IEIIT CNR, Pisa, Italy; 5: E-lighthouse Network Solutions; 6: TIM, Torino, Italy; 7: Technical University of Cartagena, Cartagena, Spain.

davide.scano@santannapisa.it

Abstract: This demo presents a comprehensive framework exploiting effective cooperation of packet-optical nodes, at the edge of packet and optical domains, managed by the BGP and OSPF protocols and a Hierarchical Control Architecture. The framework enables orchestrated provisioning and soft failure recovery across a multi-layer metro network. ©2023 The Author(s)

1. Overview

The recent evolution of transmission technology has driven the introduction of coherent pluggable transceivers as an attractive solution to tightly integrate packet aggregation and optical transport networks, in the so-called packet-optical nodes. In this context, whiteboxes have emerged as a cost-effective technology for building such packet-optical nodes, leveraging a clear separation between a, typically open-source, node operating system, and a programmable packet forwarding hardware. This approach has attracted the interest of the industry[1],[2], as a mean to avoid the vendor lock-in and opening the door to a pluggable-based integration of IP and optical network infrastructures. Whiteboxes are commonly based on programmable packet forwarding hardware, e.g., via open standards like P4 and permits programming a packet-node to behave as a Layer 2 (Ethernet) and/or Layer 3 (IP) packet switch.

Wire speed packet forwarding performances are achieved by already available commercial solutions, meaning billions of packets per second, for both Ethernet and IP forwarding at similar performances, driving the introduction of IP packet switching in contexts historically restricted to Layer 2 equipment. SONiC (Software for Open Networking in the Cloud) operating system emerged as a Linux based open-source solution for controlling packet-optical whiteboxes. SONiC has support for multiple vendors and ASICs integrating typical network functionality such as BGP. It is flexible and extensible, indeed in [3] some extension to the OS is made in order to demonstrate a workflow for controlling the packet-optical nodes in a multi-layer environment in a pure SDN approach. In this demo, we demonstrate the integration of two SONiC whiteboxes, optically connected via emulated coherent pluggable modules, and working as full-blown IP routers integrated in a potentially large-scale BGP/OSPF IP network. Two SDN controllers are in place, one for the IP and one for the optical part of the network. Note that this proposal is aligned with the control plane Dual SBI management of IPoWDM routers as proposed by Telecom Infra Project (TIP)[4], however in this demo the Optical SDN controller (OptC) not only receives information but also manages the packet-optical node transceivers configuration in order to relax the communication within the Hierarchical Controls Architecture. The commissioning of a new optical connection is demonstrated, driven by an orchestrator that instructs both SDN controllers. The SDN Packet Controller (PckC) configures the routing protocol daemons running on the node, while the optical SDN controller similarly handles the optical connectivity. Additionally, we are able to demonstrate multiple network recovery use cases, leveraging BGP/OSPF regular and well-known rerouting operation.

2. Innovation

This demo presents a variation of the workflow named 'Dual SBI management of IPoWDM routers' proposed by TIP in the MANTRA whitepaper [4], in this version of the workflow the OptC is in charge of configuring the optical domain, including the coherent pluggable, while the PckC configures the BGP and OSPF protocols instances running in the packet-optical nodes. The feasibility of this workflow is demonstrated providing connectivity and network recovery use cases.

3. OFC Relevance

This demo will showcase the framework inspired on the control plane Dual SBI management of IPoWDM routers as proposed by TIP. It enables effective orchestration among (i) coherent pluggable transceivers (ii) the SDN Hierarchical Controller Architecture, (iii) and BGP/OSPF routing. The framework enables the orchestration of coherent pluggable in a multi-layer metro network, in order to provide connectivity and handle soft failure. This demo is designed for the OFC audience, mainly telco and vendors, interested in the potential innovation capabilities driven by the orchestration of SDN Controllers for managing packet-optical node within multi-layer metro network.

4. Demo content & implementation section

This demo envisions a scenario where connectivity through whiteboxes is initially granted and present therefore, the three controllers have already managed the service provisioning. At some point, resources to provide an enhancement to the existing connectivity are found at the optical level and/or removed, producing a service downgrade or shortage accordingly. When new resources at the optical level are available and aligned with the service provisioned then OptC manages the provisioning/reconfiguring of the lightpath while PckC reconfigures the routing daemons if needed. At this point, IP routing protocol convergence takes place and routing is modified accordingly, either taking profit of the new resources or rerouting the traffic through alternative paths on optical failures. The packet-optical nodes behave exactly as well-known distributed control routers following standard and interoperable protocols at the IP level but dynamically configured based on the underlying optical infrastructure that at the same time is repurposed optimally following a centralized control approach. Both layers, optical and packet, can be adjusted to the events from their counterpart thanks to the hierarchical controller architecture.

The demonstration will deploy an integrated environment including software and hardware components as illustrated in Fig. 1. In the multi-layer metro network, the packet-optical nodes are at edge of Networks N1, N2, N3; Two paths are available for connecting N1 and N3, one high-speed connection via the optical network or an alternative path that traverses N2.

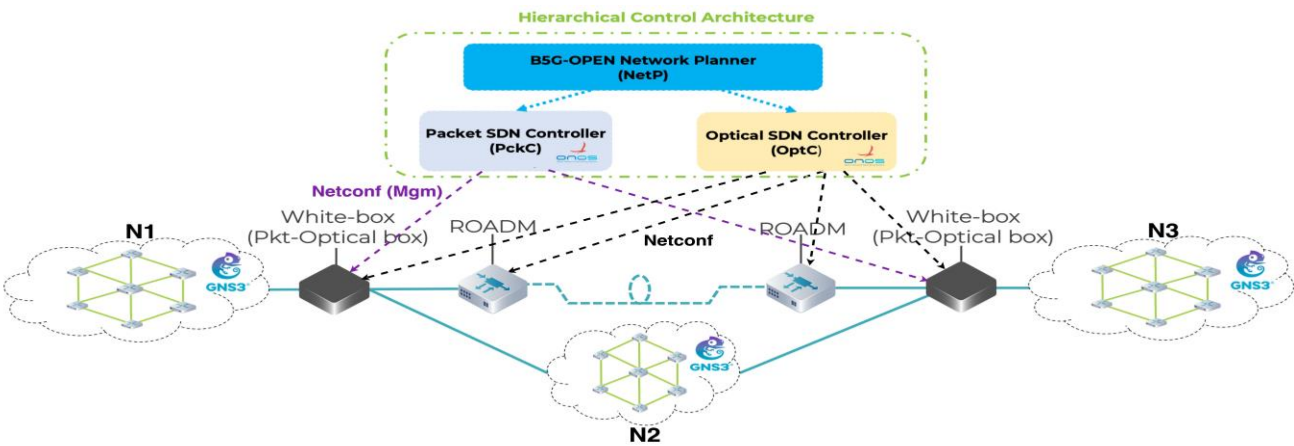

Fig. 1. Testbed topology.

The proposed framework is formed by the following components:

- **B5G-Open Network Planner(NetP):** This module oversees orchestrating the network wide resource allocation. Receives the user-initiated orders launching the workflow and interacts with the involved IP and optical SDN controllers Northbound Interfaces (NBIs).
- **SDN Controllers:** The PckC and the OptC are based on ONOS. In the PckC a NETCONF driver is developed for managing BGP/OSPF daemons deployed in the packet-optical node and a REST interface is employed for enabling communication among the NetP to the Optc and PckC.
- **Packet-Optical Node:** It runs an extended version of SONiC NOS where a NETCONF Agent is deployed. It implements Network Configuration Access Control Model (NCACM) solution, as detailed in RFC 8341. The NCACM has been conceived to restrict NETCONF access to specific operations and contents to OptC and PckC to manage the packet-optical nodes. The agent adopts OpenConfig YANG models for modeling BGP, OSPF and pluggables, those are filled via the communication with FRRouting and pmon container. The first one is in charge of deploying the BGP and OSPF protocols, the second can retrieve and configure the optical pluggable parameters via CMIS/C-CMIS interfaces.

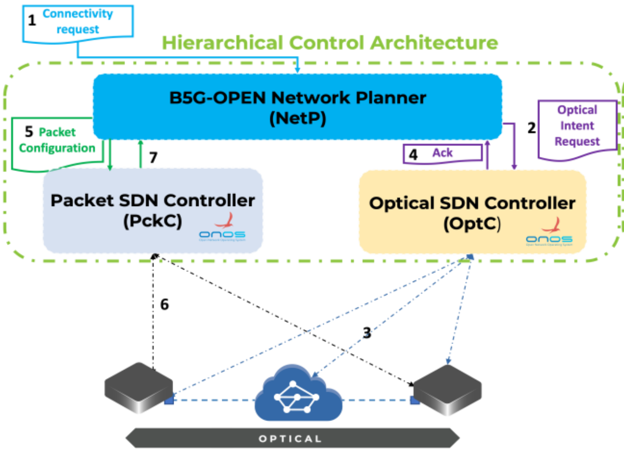

Fig. 3. Provisioning Workflow.

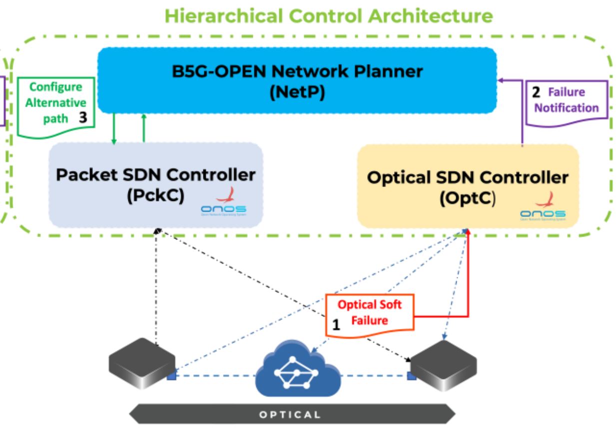

Fig. 4. Soft Failure Recovery Wrokflow

Fig.3. displays the provisioning workflow (step 1), the NetP receives a connectivity request. The NetP sends a request to Optc for establishing a lightpath between the two optical nodes (step 2). The OptC is aware of pluggable supported features (e.g., supported modulation formats, FECs, operational modes) and it performs impairment-aware optical path computation (step 3). Once the lightpath is configured Optc sends notification to NetP (step 4), at this point packet level configuration is sent (step 5) producing specific protocol configuration (OSPF for this demo) which is relayed via NETCONF to the Packet-Optical Node (step 6). Protocol convergence implying topology detection and reconfiguration takes place at the Packet-Optical Nodes and continuously analyzed in the NetP (step 7). In Fig.4. the recovery workflow is presented, after the soft failure detection affecting the lightpath provisioned through the optical pluggable modules, a NETCONF notification is sent to OptC (step 1). Then a failure notification is sent to NetP (step 2), it has to reroute traffic to another interface of the packet-optical nodes, while the OptC is handling the optical soft failure. In (step 3) an alternative packet level communication alternative is found, even though through a lower quality channel which might imply even traversing other autonomous systems, and PckC is informed about the need to update the packet level configurations. In this case other ports might be added to the Packet-Optical Nodes configuration or simply monitor that the failback mechanism provided by the routing algorithm behave as expected, if not, again reconfiguration of the Packet-Optical Node routing protocol is requested by the NetP to the PckC.

The demo will be remotely executed on the CNIT testbed located in Pisa, Italy. The testbed encompasses: disaggregated metro optical network resources (ROADMs, 100G transponders, etc.), two Nvidia/Mellanox switches that act as packet-optical nodes, and two DELL servers were GNS3 network emulator is run to provide networking context to the experiments and the SDN Architecture. The demo will show dynamic orchestration of packet-optical nodes in a multi-layer metro network, exploiting provisioning and soft failure of network resources efficiently coordinated by the proposed framework. On-site participation is expected with live interaction with the audience, providing feedback on both implementation details as well as architectural aspects. Discussions will also cover challenges and open issues for the efficient orchestration of packet-optical nodes in metro networks.

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