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SDN Control of Packet-Optical Edge Network Nodes

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***Abstract*— This paper presents and discusses two candidate solutions to efficiently control packet-optical nodes equipped with coherent pluggable modules. The first one is based on join management by two SDN controllers of the nodes, while the second solution relies on hierarchy of controllers.**

Keywords—Coherent pluggable modules, Software Defined Networking, SONiC

I. Introduction

The off-the-shelf availability of cost-effective coherent pluggable transceivers is driving the removal of transponders as standalone network elements in transport optical networks. Pluggable modules can be directly equipped within packet switching elements [1-3]. This way, packet nodes become part of the optical transport network, directly connected to reconfigurable optical add drop multiplexers (ROADM). This guarantees significant benefits in terms of CAPEX, power consumption and space occupation in central offices. Examples of such pluggable modules include Digital Coherent Optics (DCO) transceivers with CFP2 or QSFP-DD form factors which are already commercially available with rates up to 400 Gbps and configurable transmission parameters [4]. Of particular interest is the latter form factor, which directly fits the packet white boxes designed for data center markets. A further benefit of packet nodes equipped with coherent pluggables is the tight integration between packet-based aggregation networks and optical transport networks, guaranteeing effective traffic engineering solutions while simplifying the network management. A typical use case exploits a single packet switch for both intra-data centre (DC) traffic aggregation and, relying on coherent pluggables, inter-DC communication. A further interesting use case refers to edge infrastructures, where packet-optical nodes need to (i) aggregate access traffic, (ii) interface edge computing resources, and (iii) provide, via embedded coherent pluggable modules, high-rate interconnection to the cloud.

However, controlling and managing packet-optical nodes requires a complete operating system that is much more complex than the traditional NETCONF/YANG software agents employed in standalone transponders [5]. SONiC (Software for Open Networking in the Cloud) is an open-source network operating system already deployed in production intra-DC networks and it is also considered a strong candidate to control packet-optical nodes. However, some operational extensions are needed to fill the current architectural gaps. For example, SONiC does not natively support NETCONF and it does not encompass the needed software components to operate on coherent pluggable transceivers. Work is ongoing within TIP [6] to provide Transponder Abstraction Interface (TAI), enabling abstracted control of pluggable transceivers. Another gap to be filled is the coordination between packet and optical parameters on the same node, which are often provided by two different SDN controllers. Indeed, in traditional control plane architectures, packet-related configurations are typically enforced by an SDN Controller dedicated to the packet domain (i.e., PckC), while optical parameters are configured by a different SDN controller dedicated to the optical domain (i.e., OptC) [7-9].

II. Control Plane for packet-optical nodes

Two main approaches can be considered to efficiently support packet-optical box.

A. Coordinated packet-optical control

In the work in [7], we presented a coordinated control where both PckC and OptC have access to the packet-optical box (Fig 1-left). The solution relies on the NETCONF Access Control Model (NCACM) solution detailed in RFC 8341. That is, the packet-optical node participates in the coordination process by applying restricted rights to access the pluggables. Specifically, OptC is provided with writing rights on the optical parameters and read-only rights on packet parameters. Vice versa, the PckC is provided with writing rights on packet parameters and read-only rights on optical parameters (see Fig. 2, 3). Using this approach, no inter-Controller communication is needed for configuring the pluggables. However, the packet-optical node takes an active role in the configuration workflow and has to interact with two controllers. This approach may introduce significant management/maintenance issues especially in case of differentiated firmware and software updates at the node or at the controller level. Furthermore, such solution may generate complex workflows for coordinating actions across the entire packet-optical network. Fig. 4 shows an example of complex workflow upon soft-failure (see [7] for details). In this case, the overall measured time is in the order of 2.5 seconds, with around 2 seconds required by the data plane configuration implemented in SONiC, while around 0.5 seconds are due to the control plane operations.

B. Hierarchical packet-optical control

In the work in [8], we investigated a hierarchical control where only the PckC has access to the packet-optical box (Fig 1-right). Coordination between PckC and OptC is guaranteed by the presence of a hierarchical SDN Controller (HrC), "Parent SDN Controller" in figure.

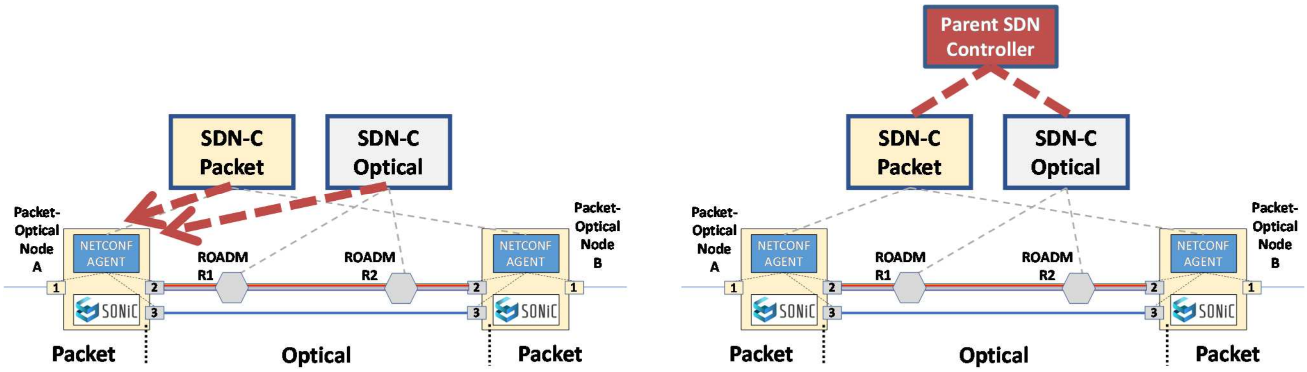

Fig. 1: Coordinated packet-optical control (left); Hierarchical packet-optical control (right)


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- <rule-list>
    <name>packet</name>
    <group>pck</group>
  - <rule>
      <name>vlan</name>
      <module-name>vlan</module-name>
      <path>/switched-vlans</path>
      <access-operations>read create update delete</access-operations>
      <action>permit</action>
    </rule>
  - <rule>
      <name>terminal-device</name>
      <module-name>*</module-name>
      <path>/terminal-device</path>
      <access-operations>create update delete</access-operations>
      <action>deny</action>
    </rule>
  - <rule>
      <name>components</name>
      <module-name>*</module-name>
      <path>/components</path>
      <access-operations>create update delete</access-operations>
      <action>deny</action>
    </rule>
</rule-list>
```


Fig. 2: Example of coordinated control through NCACM

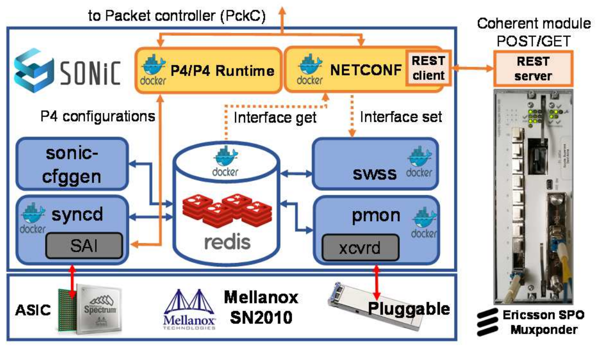

Fig. 3: Proof-of-concept implementation of packet optical box

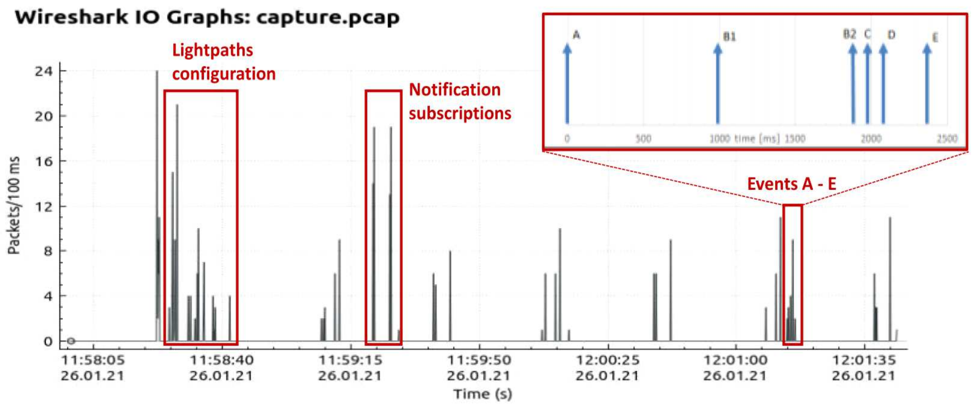

Fig. 4: Example of NETCONF message exchange between the agent and the SDN Controller in the case of coordinated packet-optical control [7]

During network initialization, both packet and optical topologies are pushed by the respective controllers to the HrC . In this phase, the PckC provides the HrC with type and features (e.g., supported operational modes) of the pluggable modules equipped within the packet-optical boxes. Also, the associations between the pluggables modules used in the

packet-optical nodes and the ROADM add/drop interfaces are pushed to HrC.

This data is classified as quasi-static information since determined by manual intervention and can be therefore initialized through specific configuration (i.e., POST commands on the REST APIs).

After network initialization, when a layer 2/3 connectivity request arrives, the HrC first identifies the pair of pluggable modules to be interconnected through the optical network.

Then, the HrC requests (e.g., through Open Transport API, T-API) the OptC to perform impairment-aware optical path computation between the identified pair of pluggables. The OptC computes the suitable configuration for pluggable modules as well as traversed optical path. This step, typically, is not executed inside the SDN controller, but exploiting external tools specifically developed with this target, e.g., GNPy. At this stage, the OptC enforces the configuration through NETCONF, driving the set-up of all traversed ROADMs. Once the path is successfully established, the OptC replies to the HrC informing about the available connectivity as well as on the selected configuration of pluggable modules.

The latter information is passed to the PckC for the actual configuration. As final step, the PckC informs the HrC about the successful configuration.

This approach based on hierarchical control has the potential to simplify the workflows among controllers compared to the coordinated solution, however it might introduce additional delay and may determine scalability issues at the hierarchical controller.

III. Discussion and future work on Packet-Optical nodes for edge networking

In this paper, we summarized the two candidate solutions to control packet-optical nodes in the interconnection towards a remote data center. Additional studies are required to assess specific pros and drawbacks, for example in the context of recovery scenario, e.g., performance alarm notifications.

The use of coherent pluggables inside packet-optical nodes is opening some issue concerning operation of the device. In particular, release change in the device operating system impacts both optical and packet control and therefore adds complexity to the overall network operations.

Furthermore, specific work is needed to efficiently support within packet-optical nodes and their operating system new types of pluggable modules, such as pluggable OLT (e.g., TiBit) or point-to-multipoint solutions based on digital subcarrier multiplexing (Open XR).

Further evolution of packet-optical nodes at the edge may be driven by the introduction of programmable packet forwarding ASICs, e.g., based on P4 technology [9].

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