Extending Control for a Lite-Coherent Transceiver using TeraFlowSDN

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***Abstract*— This paper targets the necessary protocol extensions and their validation for SDN-control of lite-coherent transceivers with all-optical signal processing. The TeraFlowSDN controller is upgraded accordingly and shown to configure chromatic dispersion in an augmented terminal-device agent.**

***Keywords*— Lite COH TRX, SDN-Control, TeraFlowSDN, DSP**

I. Introduction

Optical transceivers exploit digital signal processing (DSP) performed by power-hungry electronic ASICs [1]. For "pluggable" transceivers (i.e., directly installed in routers), the current ZR+ standard targets low energy requirements (25W). However, additional energy savings can be achieved through all-optical signal processing [2–4] or DSP-free transceivers [5]. The PROTEUS-6G project [6] is targeting the development of a lite coherent transceiver (Lite-Coh TRX) featuring 0.8Tb/s per-λ achieving to deliver increased capacity at cell cites supporting the deployment of cell-free massive-MIMO on the wireless side. The all-optical-signal-processing (AOSP) eliminates the bandwidth-limited and power-hungry DSP used to compensate impairments such as chromatic dispersion and process IQ quadrature and orthogonal polarizations in conventional coherent TRXs, saving about 50% power in the new TRXs design.

It should be noted that the architecture of Lite-Coh TRX reflects into a change of paradigm for what concerns the transceiver configuration parameters: the linear dispersion compensation becomes a configuration parameter writeable

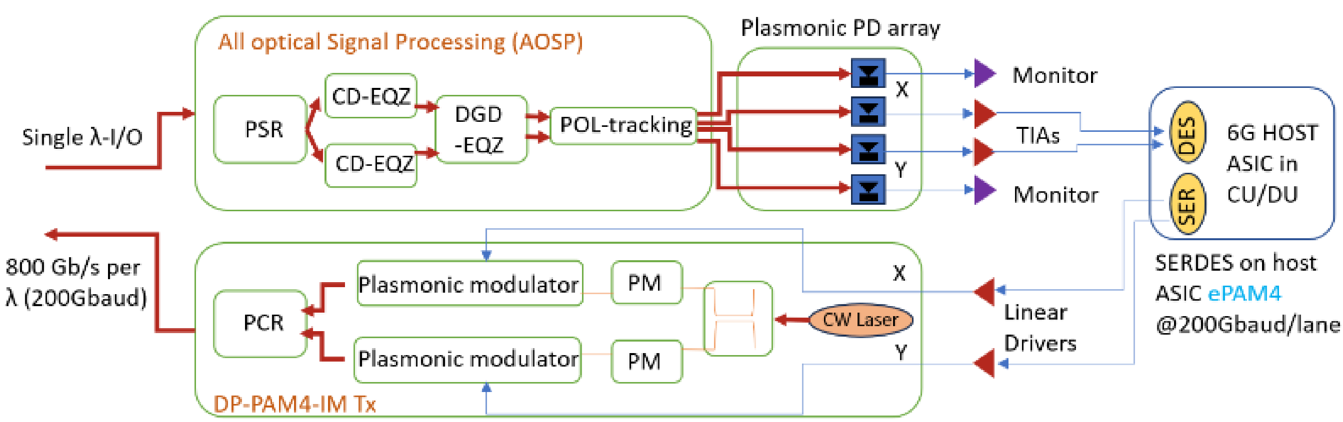

Fig. 1. Dual-POL (DP) PAM4 Intensity Modulated (IM) Direct-Detection (DD) TRX, DSP-free, based on Linear Drive Optics (LDO) enhanced by AOSP.

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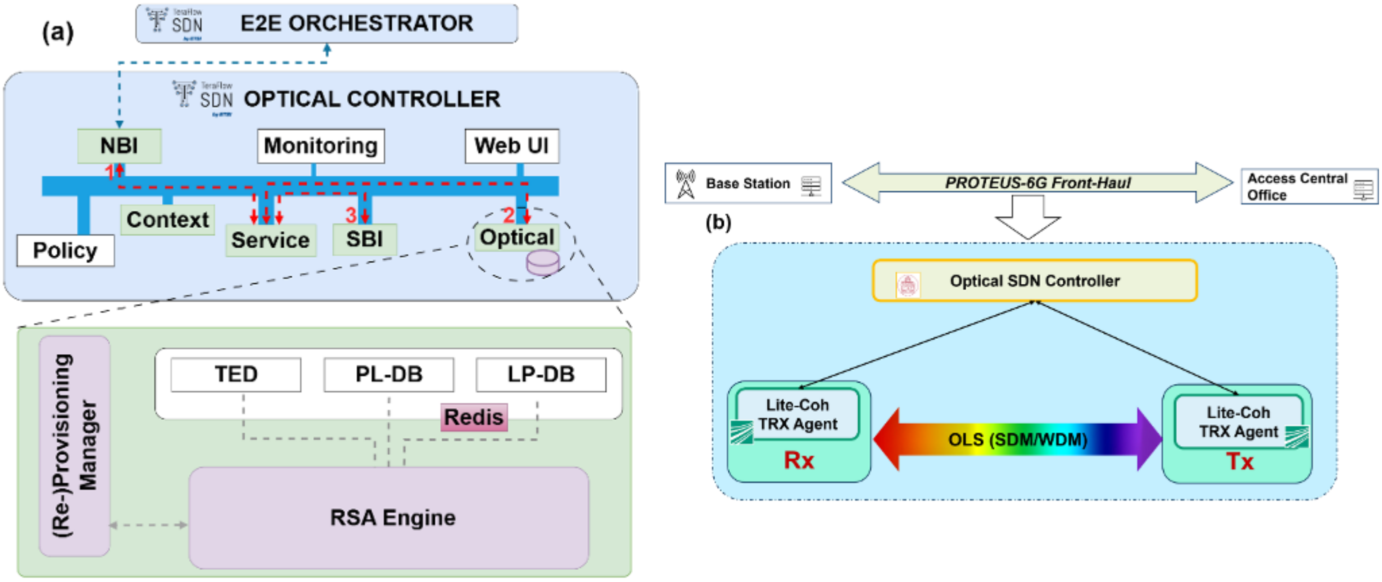

Fig. 2 (a) Optical controller architecture; (b) implementation environment comprising optical SDN controller and Lite-Coh TRX agents. The data plane hardware was emulated by their respective agents.

by an external entity such as a Software Defined Networking (SDN) controller and not the result of a transponder-self control loop. This drives implications at the control plane level and at the SDN controller.

Recently, the ETSI TeraFlowSDN controller has emerged as flexible, augmentable, and modular controller thanks to its cloud-native architecture based on isolated micro services (or control functionalities) [7]. Some implementations have been recently released in the ETSI repository or demonstrated in the context of optical networks [8–10].

In this paper, we present a TeraFlowSDN design, implementation, and demonstration targeting the control of optical networks including Lite-Coh TRXs supporting all-optical processing, achieving an end-to-end setup time of about 2 s.

II. PROPOSED ARCHITECUTRE

The proposed architecture enables SDN-controlled optical transmission by tightly coupling network-level decisions with physical-layer configuration. It consists of a Lite-COH transceiver, an SDN controller, and the optical line system as presented subsequently.

A. Lite COH Transceiver

The assumed Lite-Coh TRX is shown in Fig. 1 integrates an innovative AOSP photonic integrated circuit (PIC) on a low-loss silicon nitride platform for all-optical mitigation of chromatic dispersion (CD), differential group delay (DGD), and polarization demultiplexing (POL-demux) of the X/Y signals, cross-coupled during transmission.

After polarization separation via a polarization splitter-rotator (PCR), two modules of the PIC operate in series: an analogue optical equalizer (EQZ) and a polarization tracker. The tracker, built from alternating 2:2 couplers and push-pull phase modulators (PMs), acts as a tunable, all-optical 2×2 MIMO equalizer dynamically compensating state-of-polarization (SOP) changes. A key element – the chromatic dispersion equalizer (CD-EQZ) – is realized using eight cascaded all-pass silicon micro ring resonators (MRRs) [11] with a free spectral range of 200 GHz. The coupling coefficient K and phase shift $\Delta\varphi$ of each MRR must be tuned (thus, configured) to achieve the desired dispersion profile, with $\tau = -\frac{d\varphi}{d\omega}$ and $D = \frac{d\tau}{d\lambda}$. Together, the eight rings produce a near-linear group delay with

constant in-band dispersion and low ripple.

B. SDN control

As highlighted in the previous section, the Lite-Coh TRX requires the configuration of linear dispersion compensation, which is directly connected to the output of the routing and spectrum assignment (RSA) process.

Figure 2(a) presents the TeraFlowSDN-based Optical SDN controller which employs the distributed cloud-based microservice architecture. The TeraFlowSDN Optical controller consists of many key components including a North Bound Interface (NBI –, e.g. toward an orchestrator), a South Bound Interface (SBI –, toward data plane devices), the Service component (responsible to identify service parameters: source and destination nodes, and line rate) and the Optical component running RSA exploiting a set of databases – traffic engineering database (TED), physical layer database (PL-DB) storing physical layer information, and label switched path database (LP-DB) storing information on connections. After running RSA, the Optical component identifies the devices to be configured and the related configuration parameters values. Then, SBI translates the configuration parameters into the form of the adopted YANG model and finally acts the configuration of data plane devices by interfacing with the device agent (i.e., the local controller). For the Lite-Coh TRX we augmented the OpenConfig Terminal Device YANG model, as in Fig. 3(a): the `proteus6g-liteC` module introduces in the `OpenConfig-terminal-device` model specific extensions (e.g., chromatic dispersion to be compensated, polarization tracking, specific monitoring parameters of the Tx/Rx PICs), enabling seamless interaction with the Lite-Coh TRX agent via NETCONF protocol.

III. Experimental demonstration

The testbed shown in Fig. 2(b) has been considered to validate the software implementation in an emulation

```
module: proteus6g-litec
  augment /oc-platform:components/oc-platform:component/
                                oc-opt-term:optical-channel/oc-opt-term:config:
      +--rw chromatic-dispersion?   decimal64
      +--rw pol-tracking-enabled?   boolean
  augment /oc-platform:components/oc-platform:component/
                                oc-opt-term:optical-channel/oc-opt-term:state:
      +--ro pol-tracking-enabled?                     boolean
      +--ro num-degrees-of-freedom?                   int32
      +--ro rate-of-change-per-degree-of-freedom* [index]
      |  +--ro index    uint8
      |  +--ro rate?    decimal64
      +--ro tx-pic
      |  +--ro pilot-bias
      |  |  +--ro xi?   decimal64
      |  |  +--ro yi?   decimal64
      |  +--ro pilot-frequency
      |     +--ro xi?   decimal64
      |     +--ro yi?   decimal64
      +--ro rx-pic
              +--ro bias-voltages
              |   +--ro xip?   decimal64
              |   +--ro xin?   decimal64
              |   +--ro yip?   decimal64
              |   +--ro yin?   decimal64
              +--ro photo-currents
                      +--ro xip?   decimal64
                      +--ro xin?   decimal64
                      +--ro yip?   decimal64
                      +--ro yin?   decimal64
```
(a)


```
<config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
   <components xmlns="http://openconfig.net/yang/platform">
      <component>
        <name>channel-1</name>
         <config><name>channel-1</name></config>
           <optical-channel xmlns="http://openconfig.net/yang/terminal-device">
             <config>
                <target-output-power>1.0</target-output-power>
                <frequency>1934000000</frequency>
                <operational-mode>1</operational-mode>
                <chromatic-dispersion xmlns="http://proteus6g.eu/ns
                                /litec">340.0</chromatic-dispersion>
             </config>
           </optical-channel>
      </component>
   </components>
   <terminal-device xmlns="http://openconfig.net/yang/terminal-device">
      <logical-channels>
        <channel>
          <index>1</index>
          <config>
                <index>1</index>
                <admin-state>ENABLED</admin-state>
          </config>
        </channel>
      </logical-channels>
   </terminal-device>
</config>
```

(b)

Fig. 3. (a) YANG model describing the Lite-Coh TRX; (b) NETCONF edit-config message for Lite-Coh TRX configuration

environment, where the plane was emulated through NETCONF servers and Lite-Coh TRX configuration parameters. In this setup, the chromatic dispersion compensation is dynamically determined based on the accumulated dispersion in the optical line system. During the RSA process, the Optical SDN controller orchestrates spatial division multiplexing (SDM) and wavelength division multiplexing (WDM) resources across reconfigurable optical add/drop multiplexer (ROADM) nodes. Then, it computes the chromatic dispersion to be compensated, alongside other channel-specific parameters such as frequency slot, modulation format, symbol rate, and coding.

The resulting configuration parameters are transferred to the SBI, which encodes them into NETCONF-compliant augmented OpenConfig messages, as shown in Fig. 3(b). In the example shown, TeraFlowSDN configures the Lite-Coh TRX to compensate for 340 *ps/nm* over a distance of 20 *km*.

The TRX agent reads the configuration parameters in the NETCONF server. The agent uses a CD-EQZ-PIC specific predefined look up table to translate the required chromatic dispersion CD_{OLS} accumulated over the optical line system (OLS) into corresponding set-voltages of the actual Lite-Coh PIC hardware, so that $-CD_{OLS}$ is achieved for compensation.

The overall control plane provisioning time – starting from the service request at the NBI up to the completion of NETCONF message processing at the Lite-Coh TXR agents – is approximately 2.1 *s*. Of this, the RSA computation contributes about 1–5 *ms*, while NETCONF communication with data-plane nodes accounts for 200–300 *ms* on average.

IV. Conclusion

We presented TeraFlowSDN controller designed and implemented for controlling Lite-Coh TRXs supporting all-optical processing and configurable linear dispersion compensation through an extended OpenConfig YANG model and NETCONF interface in an emulation-based validation with hardware demonstration as future work. We demonstrated successful configuration of the Lite-Coh TRX agent and OLS with a complete end-to-end setup time of approximately 2s, confirming the feasibility of dynamic, SDN-driven control for next-generation coherent-lite systems.

Acknowledgment

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