Programmable VCSEL-based Transceivers for Multi-terabit Capacity Networking

Michela Svaluto Moreolo, Laia Nadal, Josep M. Fabrega, Ricardo Martínez, Ramon Casellas
Centre Tecnològic de Telecomunicacions de Catalunya (CTTC/CERCA), Castelldefels, Spain
michela.svaluto@cttc.es

Abstract: Photonic transceivers adopting large-bandwidth vertical cavity surface emitting lasers (VCSELs) at long-wavelength, coherent detection and adaptive digital signal processing are presented as promising programmable architectures to provide multi-terabit capacity in future software-defined optical metro networks.

OCIS codes: (060.4510) Optical communications; (060.4250) Networks; (140.7260) Vertical cavity surface emitting lasers.

1. Introduction

With the advent of novel and more mature photonic technologies and the adoption of dense photonic integration, transceivers with advanced functionalities, like the sliceable bandwidth/bitrate variable transceiver (S-BVT), can be equipped with cost- and power-efficient devices with reduced footprint, integrated in the same photonic platform as pluggable units [1]. The programmability of the system and subsystems is crucial to fully exploit the transceiver features and enable software-defined networking (SDN) [2].

Vertical cavity surface emitting laser (VCSEL) technology at long-wavelength is emerging as promising alternative to external modulation for the design of programmable transceivers [3]. Particularly, short-cavity VCSELs provide large modulation bandwidth up to 20 GHz and have been demonstrated to be suitable for application at 100 Gb/s and beyond [4]. Thus, directly modulated (DM) VCSELs represent an attractive candidate for the design of novel high-capacity S-BVT architectures. By integrating multiple photonic modules and exploiting the spectral and spatial dimensions, aggregated flows supporting multi-terabit capacity can be provided. In order to extend the achievable reach, direct modulation can be combined with coherent (CO) detection [5,6]. In the framework of the EU H2020 PASSION project, programmable modular S-BVT architectures based on these concepts are proposed to address the challenges posed by future metro networks [7]. Actually, metropolitan area networks (MANs) are evolving faster and faster towards a very dense and dynamic scenario, requiring to support huge capacity and high-peak traffic demand at low cost [3].

In this work, we present the proposed architectures enabling multi-terabit capacity networking, showing that the envisioned solutions can promisingly address the technological challenges of MANs thanks to a suitable integration of modular and configurable VCSEL-based transceivers via an SDN controller.

2. Programmable modular system with SDN-enabled photonic transceivers

The envisioned (SDN-based) programmable optical system enabling spectrum and space aggregation/switching in the optical metro network is illustrated in Fig.1. The network nodes are equipped with modular S-BVTs being configured by an SDN controller, by means of dedicated control agents. Exploiting the modularity, the S-BVT is suitably sized to the metro network node type or the required hierarchy/aggregation level. For example, metro/core nodes can be equipped with more complex and higher capacity transceivers than metro/access nodes. In fact, the latter are closer to the user, aggregate less traffic and require being more cost-effective [3]. Furthermore, the S-BVT can grow-as-needed to achieve the target capacity/flexibility, also according to the evolution of the network.

At the transmitter (Tx) side of the S-BVT (S-BVTx), multiple modules based on large bandwidth VCSELs enable the generation of multiple flows, aggregated by a wavelength selective switch element or a simple passive multiplexer. As shown in Fig.1, the fundamental building block is a silicon-on-insulator (SOI) chip, integrating 4 submodules, each with 10 VCSELs, at operating wavelengths covering the C-band. At the receiver (Rx) side of the S-BVT (S-BVRx) multiple modules based on integrated CO-Rx are adopted. Sub-wavelength granularity and variable bandwidth adaptation (per flow) are enabled by adaptive digital signal processing (DSP) using multicarrier modulation with bit and power loading (BL/PL) algorithm, taking into account the signal-to-noise ratio (SNR) per subcarrier (up-left inset of Fig.1) [2]. Therefore, the flow is adapted to the required bandwidth, traffic demand and quality of transmission required by the established connection. Recent results have numerically demonstrated that 50 Gb/s capacity per 25 GHz bandwidth flow can be transmitted over hundreds of km, using discrete multitone (DMT) with single sideband (SSB) modulation and CO detection [5,6]. Therefore, a submodule would provide up to 500 Gb/s. The fundamental module (SOI chip), aggregating 40 flows (if all the VCSELs are enabled by the SDN controller), can provide up to 2 Tb/s capacity. Thus, with a super-module including 4 fundamental modules, the C-band is covered with 160 (25-GHz spaced) channels at 50 Gb/s, yielding a total capacity of 8 Tb/s. By considering the polarization dimension, the capacity is doubled to 16 Tb/s and including the spatial dimension (e.g. 7-core fiber or a bundle of 7 fibers) more than 100 Tb/s can be supported (see bottom insets of Fig.1). The peculiarities of the adopted technologies, such as the combination of DM with CO-Rx and the effect of chirp [6], or the limited tunability/flexibility of the laser sources, should be taken into account for the transceiver design. This is also particularly relevant for the S-BVT modeling and its programmability handled by the SDN controller [7]. Indeed, the SDN controller configures the transceiver according to a specific set of programmable parameters (e.g., JSON encoding for programming the receiver in Fig.1 up-right inset), being aware of the features, potentialities and limitations of the actual architecture, while computing and setting up an incoming multi-terabit connection request.

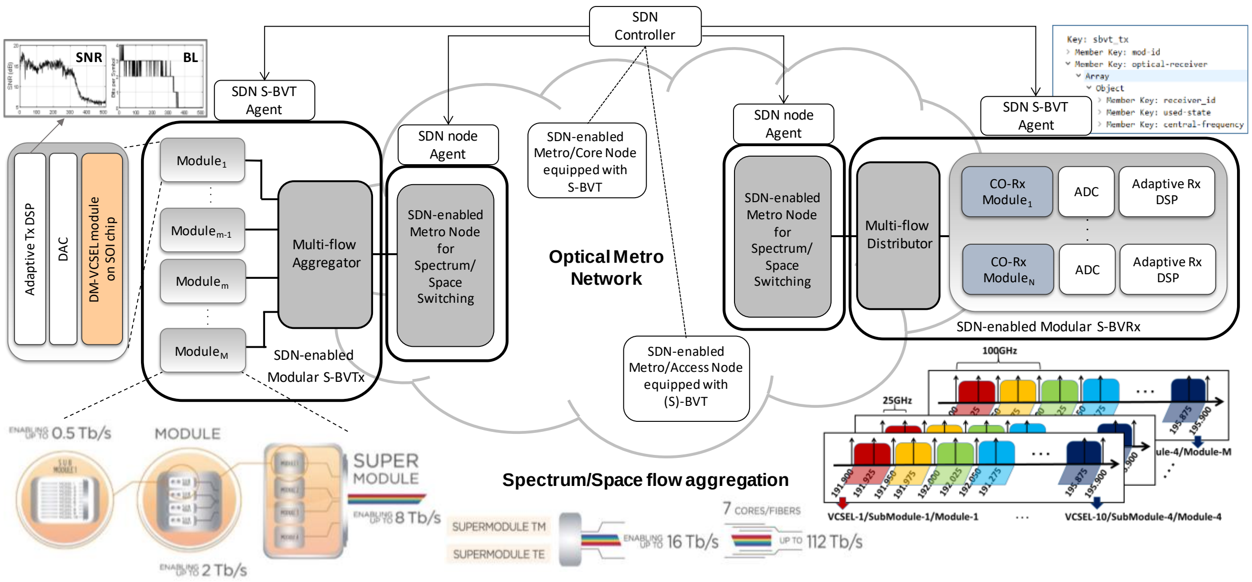

Fig. 1. Programmable optical system equipped with modular S-BVT architectures for multi-terabit capacity SDN in MANs.

3. Conclusions

VCSEL technology at long-wavelength is emerging as an attractive candidate for the design of programmable transceivers, which can find applications also in future MANs to support high-capacity and dynamic connections at low cost, power consumption and footprint. Particularly, within the PASSION project, these challenges are envisioned to be addressed adopting a modular S-BVT architecture based on large bandwidth VCSELs and CO-Rx. Aggregating multiple flows at 50 Gb/s, up to 8 Tb/s per polarization can be envisioned, exploiting the spectral resource, while over 100 Tb/s can be expected considering the spectral, polarization and spatial dimensions. Taking into account the programmable features and attributes of the proposed devices and transceiver architecture, the SDN controller allows automatically configuring them attaining an efficient usage of the network resources whilst exploiting the benefits and potentialities offered by the adopted optical network technologies.

This paper is part of a project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement PASSION No 780326. This work has been also partially supported by the Spanish AURORAS (RTI2018-099178-B-I00) project.

4. References

[1] A. D' Errico, G. Contestabile, "Next generation terabit transponder," in OFC 2016, W4B.4.
[2] M. Svaluto Moreolo et al., "SDN-Enabled Sliceable BVT Based on Multicarrier Technology for Multiflow Rate/Distance and Grid Adaptation," IEEE/OSA J. Lightwave Technol., **34**, 6, 1516-1522 (2016).
[3] M. Svaluto Moreolo, J. M. Fabrega, L. Nadal, F. J. Vilchez, "Exploring the Potential of VCSEL Technology for Agile and High Capacity Optical Metro Networks," in ONDM, Dublin, Ireland, 2018.
[4] C. Xie, et al., "Single VCSEL 100-Gb/s short reach system using discrete multi-tone modulation and direct detection," in OFC 2015, Tu2H.2.
[5] M. Svaluto Moreolo et al., "VCSEL-based sliceable bandwidth/bitrate variable transceivers," in SPIE-PWO, San Francisco, CA (USA), 2019.
[6] M. Rapisarda, et al. "Impact of Chirp in High-Capacity Optical Metro Networks Employing Directly-Modulated VCSELs," **5** (4), 51 (2018).
[7] http://www.passion-project.eu
[8] R. Martinez et al., "Proof-of-Concept validation of SDN-controlled VCSEL-based S-BVTs in flexi-grid optical metro networks," in OFC 2019, San Diego, CA (USA), March 2019.