Flexible Edge Nodes enabled by Hybrid Software Defined Optics & Networking

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Flexible Edge Nodes enabled by Hybrid Software Defined Optics & Networking

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Abstract: This paper presents our vision on flexible edge nodes for future networks and our efforts to combine software defined optics and software defined networking to optimize the overall performance and user experience.
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1. Introduction

The nature of optical networks has undergone a significant transformation in the last decade mainly because of an enormous traffic increase as a result of the rapid adoption of broadband connectivity and emergence of new bandwidth-hungry and Quality-of-Service (QoS) demanding applications and services. Photonic technologies are the dominant technologies to support and address such ever-increasing bandwidth demands – even mobile wireless networks rely on an optical network underneath to transport the data (mobile fibre backhaul). Capacity improvements in optical networks have been addressed by making use of wavelength division multiplexing (WDM) techniques to add ad-hoc new wavelength channels employing fixed modulation formats and bitrate serial interfaces. However, it is becoming evident that this growth model may not provide the projected future capacity – estimations suggest growth rates for fibre capacity of 20%, while conservative estimations on internet protocol (IP) type of traffic project increases in traffic of 30-40% a year [1]. Bridging the gap between infrastructure and traffic demands can only be achieved by a combination of increased spectral efficiencies and improved utilization of resources. Future optical networks – comprising the physical layer and the management layer – are hence envisioned as flexible or elastic, in order to accommodate more efficiently the shortage of bandwidth.

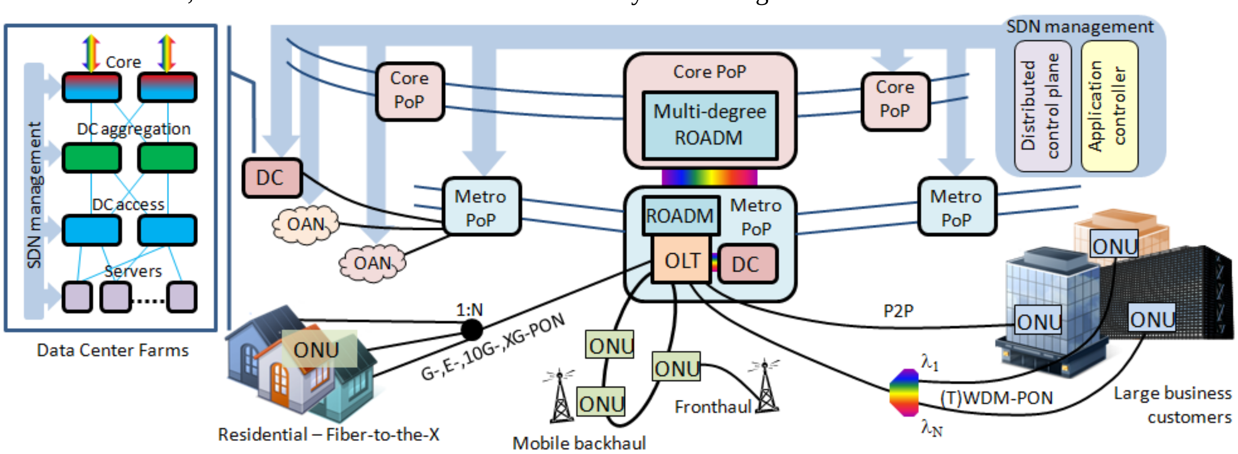

Fig. 1. Overall network architecture and vision. DC: data center, PoP: point of presence, OAN: optical access network, ROADM: reconfigurable optical add-drop multiplexer, ONU: optical network unit, OLT: optical line termination, P2P: peer to peer, (T)WDM-PON: (tunable) wavelength division multiplexing – passive optical network.

The physical layer has been for decades designed using a closed and step-by-step approach to upgrades. The utilization of resources has been usually limited to the functionalities provided by the transceivers, usually determined by their fixed data rate and bandwidth [2]. The driving technological concept we pursue is the utilization of software defined optics (SDO) to facilitate cross-layer optimization processes and reduce end-to-end latency, leveraging on advances in flexible optical transponders (able to operate at different bitrates) [3], malleable transmission schemes (such as orthogonal frequency division multiplexing or polybinary modulation) [3], and novel switching topologies and devices [4]. The idea is hence to perform switching across the network at a sub-wavelength granularity specifically at both the core and the access-core interconnection.

The management layer grew initially based on the notion of autonomous systems, meaning that networks could scale organically and maintain traffic performance by exchanging partial need-to-know information. Topology and control systems evolved intimately. However, with the advent of elastic cloud architectures and dynamic resources allocation systems, it becomes apparent that network control (learning and forwarding decisions) and network topology need to be decoupled. The current technological concept in the field of traffic engineering and network management is software defined networking (SDN), which enables globally aware centralized or distributed software controllers to drive the network hardware in order to create an easily programmable identity based overlay on top of the traditional IP core [5]. Figure 1 shows a general overview of an optical network, comprising the core, metro and access network. Each section of the network interconnects with the other through points of presence (PoP). We take a holistic approach to optical network development, understanding that the development of a specific section of the network affects all design and operations in other sections.

2. Reconfigurable Flexible Edge Nodes for Core-Access Interconnection

Figure 2 shows our vision of future reconfigurable flexible edge nodes for core-access interconnection. These nodes consist of a bench of flexible transceivers capable of operating at multiples of 1.25Gbps. 1.25G is considered nowadays the smallest granularity in terms of bitrate in the core network. It is in turn convenient because the most deployed passive optical networks – GPON and EPON – use 1.25Gbit/s as baseline. The design, parameterization and demonstration of this flexible transceiver belong to the core of our goals. Figure 2 also shows a large number of heterogeneous access networks (AN), service or applications are directly connected to the Edge Node. The access networks (ANs) do not necessarily share the access infrastructure; quite on the contrary, current heterogeneous ANs are a mix of technologies. These ANs may operate on different legacy optical access ((X)GPON, (10G)-EPON, point-to-point Ethernet), emerging optical access technologies (e.g. OFDMA-PON), special purpose applications (e.g. cloud computing, data centers), mobile backhauling, or copper-based access (xDSL). Regardless the capacity of each access technology to be capable to interact with it, the Edge Node sees each access network, service or application as a "black box" with specific service layer agreements (SLAs) and requirements in terms of bandwidth and QoS. The transceivers must also interact with the core segment, and for this reason, adaptability to optical transport networks' technologies is a must. Figure 1 also shows an overview of a possible physical implementation of the Flexible Transceiver. The receiver side will be based on coherent detection of the optical signal and further processing using digital signal processing (DSP) methods – a highly flexible and reconfigurable receiver can be build around a digital coherent transponder. The transmitter will be based on yet another DSP block performing forward error correction (FEC), pre-coding and pre-processing of the signal (in order to enhance its transmission properties) and a tunable laser source for full reconfigurability on the wavelength channel; this enhancement, in the context of SDO, can be done dynamically/adaptively, according to traffic conditions and service requirements (beyond manually pre-configuring/reconfiguring the optics).

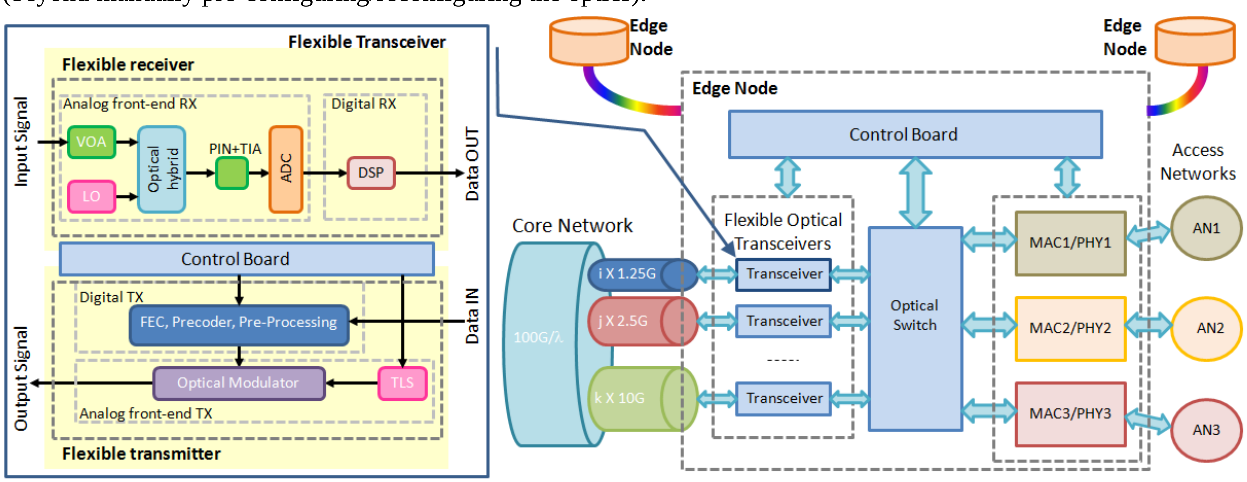

Fig. 2. Edge node architecture and detail of the flexible transceiver topology. VOA: variable optical attenuator, LO: local oscillator, ADC: analog-digital converter, TLS: tunable laser source, AN: access network.

The whole Edge Node is controlled by a control system, comprising the hardware control and the management plane and integrating SDN extensions to effectively utilize all variable parameters of the SDO devices.

3. Reconfigurable Coherent Remote Access Units for Mobile Backhauling

The development of access networks have been fueled by the need for wireless systems, which are normally layered on top of optical networks. This trend will continue, and is not facing the challenge of new optical fiber backhauling solutions of wireless base station. The requirements emphasis is on low cost, low power consumption and heterogeneous technology integration; furthermore, since capacity is key, migration toward higher frequency bands such as the W- or the E-band is foreseen. Figure 3 shows the topology of a reconfigurable coherent remote access unit (RAU), which can effectively bridge a flexible edge node with an access network (AN) using SDN friendly photonic blocks [6].

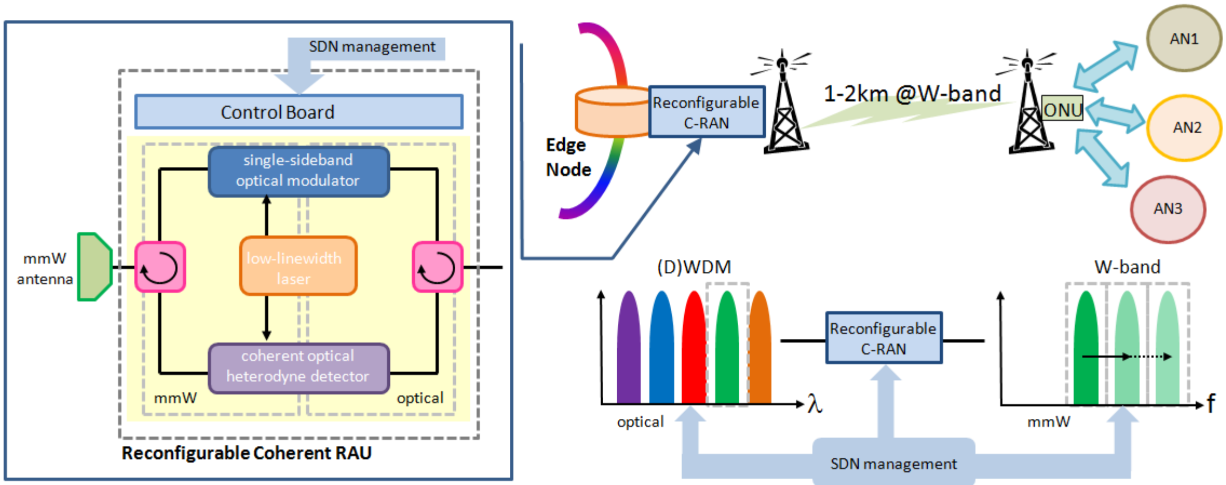

Fig. 3. Topology of a reconfigurable coherent RAU. C-RAN: coherent remote access unit, (D)WDM: (dense) wavelength division multiplexing.

These reconfigurable C-RAN units can be integrated together with the flexible edge nodes and managed in liaison, effectively creating networks that span over different transmission media.

4. Conclusions

In this presentation, we will provide an overview of our activities aiming at integrating SDN management capabilities with SDO devices and subsystems. The multidisciplinary nature of this research field requires co-design among different areas such as traffic and network engineering, digital signal processing, photonics and system integration. Unless we tackle future optical network systems as a whole, flexibility, cost and energy management may become issues hindering the development of other activities on top of telecommunication infrastructure.

5. Acknowledgements

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