

SDN control and monitoring of SDM/WDM and packet transport networks for 5G fronthaul/backhaul

R. Muñoz, J. M. Fàbrega, R. Vilalta, M. Svaluto Moreolo, R. Martínez, Ramon Casellas
 Centre Tecnològic de Telecomunicacions de Catalunya (CTTC/CERCA)
 Castelldefels (Barcelona), Spain
 raul.munoz@cttc.es

Abstract— This paper presents optical (SDM/WDM) and packet transport solutions for 5G fronthaul/backhaul and the hierarchical Transport SDN control and monitoring architecture. It dynamically provides multiple spectral-spatial super-channels and packet flows, and monitors the signal quality degradation of the optical super-channels and the aggregated packet traffic.

I. INTRODUCTION

Mobile transport networks can be traditionally sorted out as backhaul and fronthaul solutions. The mobile backhaul is the transport connection/network providing support to the backhaul interface between the base-band units (BBUs) and the mobile core (i.e., EPC). Mobile backhaul has low requirements for bandwidth and delay, and traditionally is deployed in packet-based network infrastructure (e.g. Ethernet, IP/MPLS). Instead, the mobile fronthaul is the transport connection/network supporting the fronthaul interface between the remote radio head (RRH) and the BBU. Mobile fronthaul has very strict requirements in terms of high-bandwidth and low-delay because it is required to transport the digitally sampled radio waveform from the RRH in the base stations to the central office (CO) where the pool of BBUs is located. The most widely used standard interface for the fronthaul is the common public radio interface (CPRI) and is deployed in C/DWDM links/networks, making use of optical transceivers with digital radio over fiber (DRoF) solutions. The main drawback of this approach is that the massive MIMO antenna deployments foreseen in 5G will require huge bandwidth resources [1].

Spatial Division Multiplexing (SDM) is the key technology to overcome the capacity crunch driven by 5G mobile communications. Even though the simplest way to make use of the spatial dimension is to deploy bundles of single mode fibers, the main target is exploiting the spatial dimensions of the optical fiber (i.e., modes and/or cores), having parallel propagation in the same fiber using multicore fibers, few mode fibers, or combining cores and modes in few-mode multicore fibers. The combination of SDM with flexi-grid DWDM enables to exploit the spectral and spatial dimensions in the fronthaul segment and to provide spectral-spatial super-channels (SSSCs). An SSSCh can be defined as the association of several flexi-grid DWDM channels that can be jointly allocated in different modes and/or cores (spatial) in order to create a (logical) channel with the desired capacity. SSSChs enables simplified switching, joint DSP with complexity reduction techniques. In order to introduce further flexibility, we propose a sliceable spectral-spatial transceiver (S-SST) to provide multiple independent SSSChs (slices).

On the other hand, 3GPP is proposing to reduce the bandwidth and latency requirements for 5G, while keeping most of the benefits of the C-RAN architectures, by performing a function split of the baseband processing in eight options. In this approach, the BBU functions are split into three logical entities; remote unit (RU), central unit (CU) and distributed unit (DU). It brings the introduction of the next generation fronthaul interface (NGFI) that is split into two network segments [2]. The fronthaul segment between the RU and DU is known as NGFI-I, and the network segment between the DU and the CU is the NGFI-II (also known as midhaul). This approach enables the packetization of the NGFI to provide more efficient network utilization in ultra-dense scenarios (enabling the use of statistical packet multiplexing).

This paper presents an integrated optical (SDM/WDM) and packet transport solutions for the 5G fronthaul/backhaul (Section. I) and the proposed hierarchical Transport SDN control and monitoring architecture (Section. II).

II. SDM/WDM/PACKET-BASED FRONTHAUL/BACKHAUL NETWORK

Fig. 1 shows a general scheme for the hybrid SDM/WDM based DRoF fronthaul using S-SSTs. There, a central office is

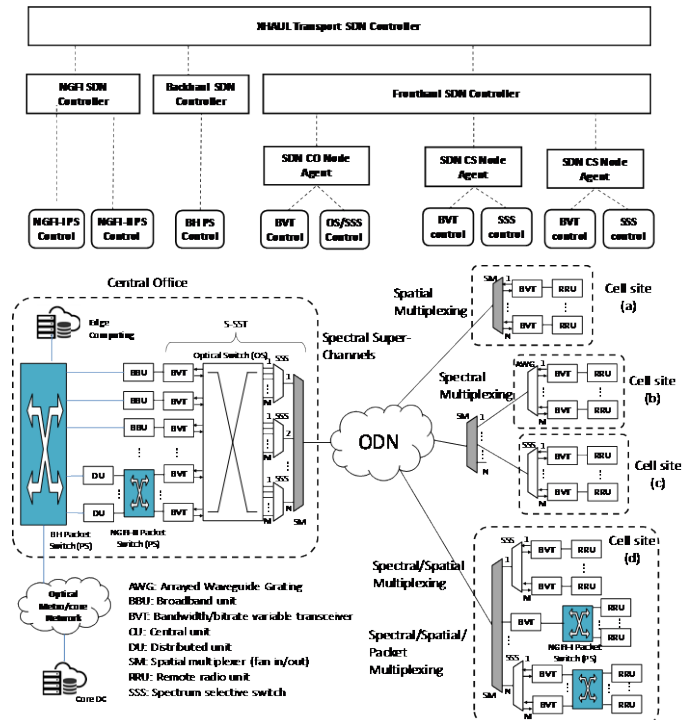


Figure 1: SDN-enabled SDM/WDM/Packet fronthaul/backhaul

attached to an optical metro/core in order to provide connectivity to the network edge. At the CO, a pool of BBUs is delivering the traffic to the corresponding bandwidth/bitrate variable transceivers (BVTs). Also a pool of DUs is envisioned to be connected to the corresponding packet switch whose outputs are connected to the BVTs. The BVTs can be remotely configured by the control plane, for an optimal management of the network resources [3]. In addition to the bitrate variability that can cope with a dynamic traffic variation (e.g., daily traffic variation), the BVTs also feature other benefits such as the capability to attain a specific capacity demand for a given connection [3]. The parameters to be configured at each BVT include wavelength, spectral occupancy, and modulation format/power. The inputs/outputs of each BVT are connected to an optical switch in order to perform the appropriate connections to each of the spectrum selective switches (SSSs), which are performing the wavelength division multiplexing/demultiplexing of M different signals into arbitrary portions of the spectrum according to the control plane indications. The main outputs of the SSSs are connected to the spatial multiplexers (SMs), which are the fan-in/out devices for SDM on N different fiber cores and/or modes.

The CO is delivering its data signals to the optical distribution network (ODN) in order to give connectivity to the different cell sites (CS) over a single fiber infrastructure. As for the cell sites, different options are envisioned.

A first cell site option (a) is a spatially multiplexed site. There, all the BVTs are tuned to use the very same wavelength while using different cores/modes either for scaling up the capacity or for implementing signal duplex. Therefore, a simplification of the BVT can be foreseen, as some wavelength dependent parts can be shared among them depending on the specific BVT design. For example, in the case of implementing external modulation, the laser sources can be shared between several BVTs in order to reduce the cost. The cell site options (b) and (c) correspond to the spectrally multiplexed site. In that case, a single core/mode is used while the multiplexing is exclusively performed in terms of wavelength. Therefore, a straightforward approach can be to employ fixed passive devices (b) to perform the wavelength multiplexing (e.g. AWGs) in order to keep the solution at low cost. Also active devices such as SSSs (c) can be employed, trading cost against flexibility. Please note that here a dual wavelength duplex is envisioned. Finally, a generic cell site option is depicted in (c). There either spatial and/or wavelength multiplexing is used in order to use all the available network resources. In this case it is also shown the eventual interconnection between BVTs and BBUs for a NGFI-like solution, even it could be also envisioned for all the cell sites options described before.

III. TRANSPORT SDN FOR THE FRONTHAUL/BACKHAUL NETWORK

A single SDN controller comprising the multiple and diverse technologies of the SDM/WDM/packet-based fronthaul and backhaul is not realistic. Traditionally, network operators fragment their networks into multiple administrative domains for scalability, modularity, and security purposes. We rely on a hierarchical Transport SDN control approach with different levels of hierarchy (parent/child architecture). In particular, we propose three child SDN controllers, one for the fronthaul segment, another for the NGFI-I segment, and the last for the backhaul segment, and a parent SDN controller on top acting as the Xhaul transport network orchestrator (or controller of controllers). It allows the control (e.g., E2E transport service provisioning, path computation, network topology and resource dissemination), at a higher, abstracted level, of the heterogeneous fronthaul and backhaul network technologies regardless of the specific control plane technology employed in

each domain through the use of the Transport API (TAPI) experimentally validated by the authors in [4]. This TAPI has to be properly extended in order to deal with the specific SDM transport technologies that are currently not covered. It is used as the northbound Interface (NBI) of the child SDN controller and as southbound Interface (SBI) of a parent SDN controller. Additionally, the parent SDN controller also uses the TAPI as NBI with the NFVO. It is worth to highlight the considered architecture can be applied recursively enabling the cascading of the SDN controllers.

The child SDN controllers for the backhaul and the NGFI network segments are based on packets networks using OpenFlow or P4 protocols as SBI to configure the packet switches. The packet SDN controllers have been extended to provision tagged packet flows and collect monitoring data from the packet switches in order to detect and prevent traffic congestion. The extended SDN controllers can define for each monitored link the maximum traffic bandwidth threshold and the time over threshold (ToT) allowed to avoid the generation of alarms for peak traffics above the bandwidth threshold. The SDN controller requests packet statistics on a periodic basis. A first IoT-aware SDN and cloud architecture that deploys IoT flow monitoring and traffic-congestion avoidance techniques has been experimentally validated in [5].

On the optical fronthaul segment side, the proposed solution is to deploy SDN node agents at the cell sites and another at the CO. The SDN agent's purpose is to map high-level operations coming from the child SDN controller into low-level, hardware-dependent operations using the proprietary protocols. This involves defining a configuration and monitoring data model for the DRoF transceivers, and the optical SDM/WDM aggregation elements, and agreeing on a protocol, with the corresponding message formats and encodings. We consider NETCONF protocol standardized by the IETF for network control and management. NETCONF relies on YANG as modelling language, used for defining the configurable parameters and state information in XML format. Thus, NETCONF and YANG provide a standard way to offer an open API for the child SDN controller's SBI. A first SDN-enabled sliceable SDM-WDM transceiver controlled with YANG/NETCONF has been experimentally validated over a 11-km 6-mode 19-core fiber in [6]. We have experimentally measured the BER of the optical channels of a slice in order to monitor the impact due to the provisioning of additional slices.

IV. CONCLUSIONS

The introduction of SDM combined with WDM and packet technologies, together with the control and monitoring systems, are key for the development of the 5G fronthaul and backhaul.

REFERENCES

- [1] Thomas Pfeiffer, Next Generation Mobile Fronthaul and Midhaul Architectures [Invited], *Journal of Optical Communications and Networks (JOCN)*, vol. 7, no. 11, pp. B38 - B45, November 2015.
- [2] Chih-Lin I, Han Li, Jouni Korhonen, Jinri Huang, Jinri Huang, RAN Revolution with NGFI (xhaul) for 5G, *Journal of Lightwave Technology*, DOI: 10.1109/JLT.2017.2764924
- [3] J. M. Fabrega, et al., Experimental Validation of a Converged Metro Architecture for Transparent Mobile Front-/Back-Haul Traffic Delivery Using SDN-Enabled Sliceable Bitrate Variable Transceivers, *Journal of Lightwave Technology*, vol. 36, no. 7, pp. 1429-1434, April (2018)
- [4] A. Mayoral, et al. "First experimental demonstration of distributed cloud and heterogeneous network orchestration with a common Transport API for E2E services with QoS." *Optical Fiber Conference (OFC) 2016*.
- [5] R. Muñoz, et al., IoT-aware Multi-layer Transport SDN and Cloud Architecture for Traffic Congestion Avoidance Through Dynamic Distribution of IoT Analytics, *ECOC 2017, Goteborg (Sweden)*
- [6] R. Muñoz, et al., SDN-enabled Sliceable Multi-dimensional (Spectral and Spatial) Transceiver Controlled with YANG/NETCONF, *Optical Fiber Communications (OFC)*, 11-15 March, San Diego (USA).