Experimental Validation of Mobile Front-/Back-Haul Traffic Delivery with OFDM Transmission and Direct Detection in Elastic Metro/Access Networks using Sliceable Transceivers

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Abstract *A transparent and dynamic delivery of mobile front-/back-haul for converged metro/access elastic networking is experimentally demonstrated employing DD-OFDM S-BVTs. Testbed experiments show successful transmission after 60km, featuring up to 100Gb/s data rate.*

Introduction

5G services are conceived around the joint use of different heterogeneous resources (including transport, fixed and mobile), while combining networking and cloud functions. Precisely, for mobile networking, it is proposed to host 5G core functionalities in distributed data centres located at different local nodes (5G edge) and close to cell sites[1]. For example, these 5G edge nodes can contain virtual pools of baseband units (BBUs), with different functional splits, that are connected to a majority of remote radio units (RRUs) located in the cell sites. Thus, mobile front-/back-haul traffic is significantly decreased when compared to a centralized approach, reducing the associated CapEx and OpEx. Different radio access network (RAN) architectures can be envisioned for providing this connectivity. Interestingly, the overlay of mobile back-/front-haul over existing fixed optical metro/aggregation and access infrastructures constitutes a cost-effective approach. However, approaching such a converged architecture is challenging, as it has to cope with the needs of the network subscribers while supporting the new traffic.

The advent of elastic optical networking, enabled by the adoption of the flexible channel grid and programmable transceivers, opens the door to a truly dynamic management of optical networks[2,3]. This is especially interesting for achieving the pursued integration between optical metro/access and RAN. In fact, approaching this paradigm, specific channels can be set up according to the requirements of the services to deliver. Furthermore, elastic networking also enables to transparently set a RAN network over the optical metro/access. For example, a pool of BBUs would be located at a selected node of the metro network segment, while the RRUs could be scattered along one or multiple access trees, both interconnected by a suitable exchange node (EN). In this scheme a highly centric traffic pattern is expected, posing different requirements in terms of cost and data rate compared to typical transmission technologies for the transport/core networking.

In this paper, we propose to transparently and dynamically deliver mobile front-/back-haul in a converged metro/access environment, following the elastic networking paradigm in order to take advantage of the already deployed fibre infrastructure. In order to cope with that in a cost-effective way, we propose to use sliceable bandwidth variable transceivers (S-BVTs) based on OFDM employing direct detection (DD).

Network scheme and signal delivery

The network and signal delivery scheme is depicted in Fig.1. There, programmable S-BVTs are present at the 5G edge in order to concurrently serve different cell sites. At the other end of the network, each cell site has a programmable BVT. The (S-)BVTs can be remotely configured by the control plane, for an optimal management of the network resources[3, 4]. The parameters to be configured at each (S-)BVT include wavelength, spectral occupancy and modulation format/power per flow. So, the proposed (S-)BVTs deliver data flows with variable spectral occupancy and rate, according to the network and path conditions.

Among all the options for implementing the (S-)BVTs, those based on DD orthogonal frequency Division multiplexing (DD-OFDM) are the most attractive for cost-effectively coping with the flexibility requirements of elastic optical networks[4]. In fact, OFDM provides advanced spectrum manipulation capabilities, including arbitrary sub-carrier suppression and bit/power loading. Thanks to these features, DD-OFDM transceivers can be ad hoc configured for achieving a certain reach and/or coping with a targeted data rate adopting low complex optoelectronic subsystems[4].

In order to ensure full compatibility with the deployed optical metro and access networks, a specific wavelength plan is envisioned. In fact, legacy access standards (e.g. GEPON, GPON)

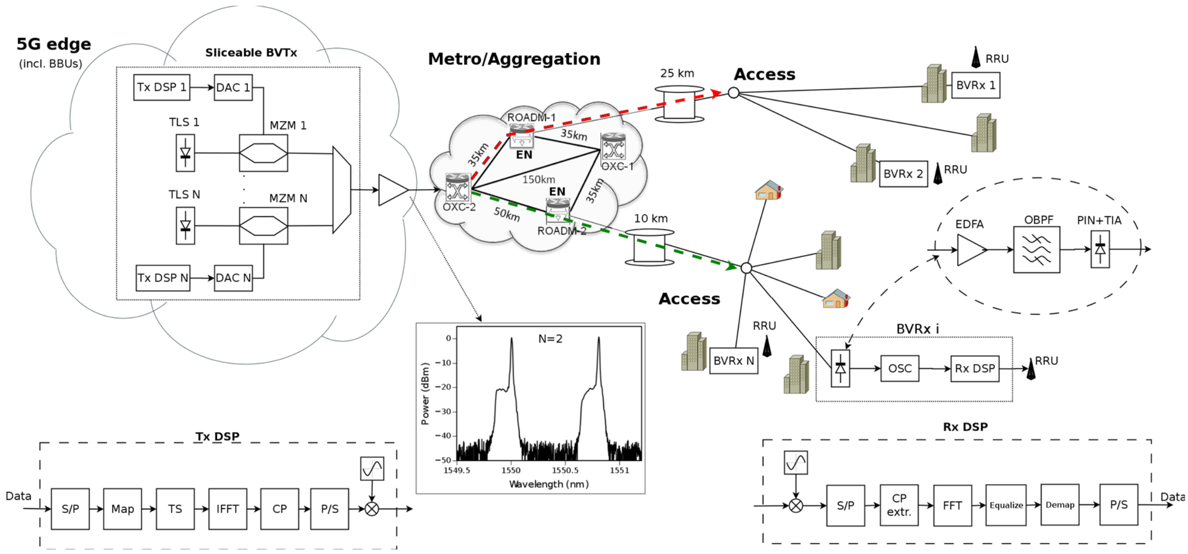

Fig. 1: Converged metro/access concept and experimental scheme for mobile front-/back-hauling.

use 1490nm for downstream; while late standards (10G-EPON and XGPON) recommend the range of 1575-1580nm also for downstream. Thus, the entire C-band is available for performing a wavelength overlay of channels in order to provide different additional services over the same access infrastructure.

At the ENs of the metro network, the mobile front-/back-haul signals are filtered out and transparently routed/dropped to their destination access tree. This fact does not pose any strict constraint, since commercial standard flexi-grid spectrum selective switches (SSS) and optical amplifiers typically operate at C-band. Also, each EN includes the corresponding optical line terminals and aggregation switches/units for delivering fixed access services to the network users across the corresponding access trees.

Regarding the dimension of traffic to support, it should be noted that the most bandwidth hungry service is mobile front-haul. In fact it may feature high bitrate variability, depending on the functional split adopted[5]. In case the split is set for full centralization of the base stations, the front-haul requires several tens of Gb/s and imposes a strict latency constraint. In order to relax these requirements, more functions can be decentralized and adopted by the RRUs, trading latency and data rate against flexibility. In fact, for transmitting up to 100km, 1ms minimum round trip delay should be expected. This requires a functional split at PHY2 or MAC-PHY level, relaxing the bitrate requirement[5].

Experimental setup

Fig. 1 shows the experimental setup for N=2 signal flows. The DSP and electrical up/downconversion at the transmitter/receiver are performed off-line, following the steps detailed in Fig.1. At the transmitter side, per each flow, randomly generated data are mapped into the corresponding constellation (ranging from BPSK up to 256 QAM). Adaptive bit/power loading is implemented using the rate adaptive version of the Levin-Campello algorithm[4]. Then, 4 training symbols are included every 100 OFDM frames. The resulting symbols feed an inverse fast Fourier transform (IFFT) of 512 subcarriers. Afterwards, a 2% cyclic prefix (CP) is added and the obtained OFDM symbols are serialized. The digital OFDM signal, fixed to be running at 20Gbaud, is clipped and upconverted to an intermediate frequency of 10GHz by mixing with a digital oscillator. The resulting signal is converted to the analogue domain by a digital to analogue converter (DAC) at 64GSa/s. This analogue signal is conditioned and injected to the corresponding Mach-Zehnder modulator (MZM) biased at the quadrature point and excited by a tuneable laser source (TLS). The flows resulting after each MZM are then aggregated using an LCoS reconfigurable optical SSS, configured to have 25GHz bandwidth per channel and slightly detuned in order to obtain an optical single sideband (SSB) signal. Two flows are generated, centred at 1550.12nm and 1550.92nm, as depicted in the inset of Fig.1.

The optical signal resulting from the transmitter is injected into the ADRENALINE testbed, whose simplified scheme is depicted in Fig.1. It is a 4-node photonic mesh network with amplified links of different lengths, ranging from 35km to 150km. The feeder section of the access trees, attached to selected ENs, is composed of different fibre spools (10km, and 25km). The power delivered to each tree is set

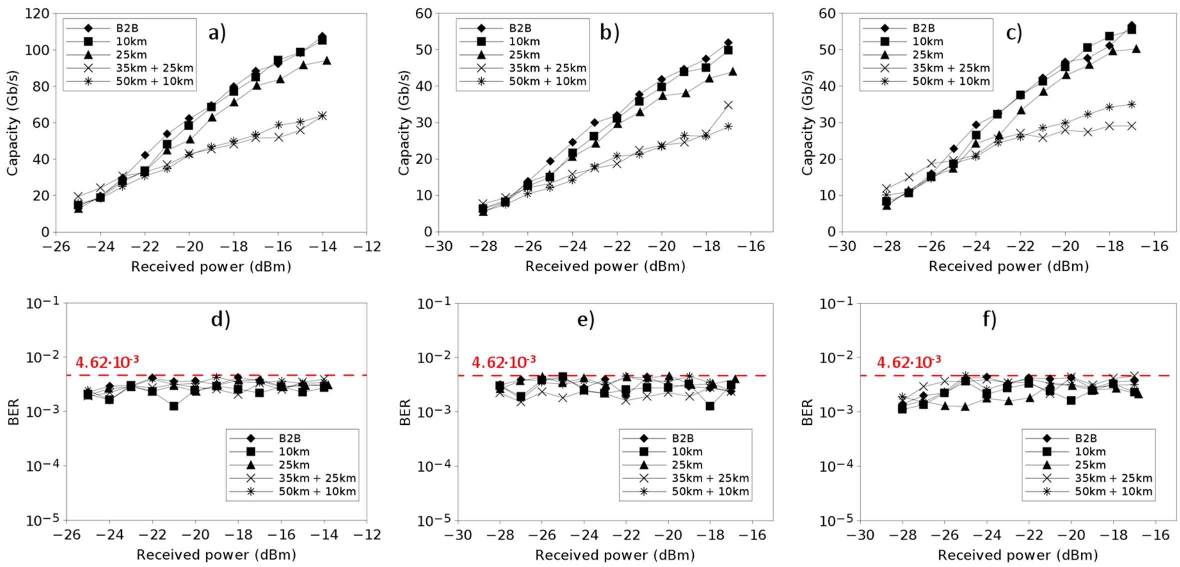

Fig. 2: Experimental results in terms of maximum capacity (a, b, c) and BER (d, e, f) versus received power for the cases of detecting both the two flows (a, d), and single slice individually, (b, e) and (c, f), respectively.

to +5dBm. Then, a variable optical attenuator is used to emulate the power splitters.

At the receiver, the incoming signal is filtered out and photodetected. Finally, in order to emulate a high bandwidth avalanche photodiode in the set-up, a combination of gain-stabilized EDFA, optical band pass filter (OBPF) and PIN diode is calibrated to obtain a -28dBm sensitivity at 10^{-3} BER for on-off keying transmission at 10.7Gb/s. The detected current is then digitized by a real-time oscilloscope (OSC) running at 100GSa/s. The baseband OFDM signal is recovered after downconversion and afterwards off-line demodulated, equalized and demapped.

Results

Fig.2 shows the sensitivity measurements for the different cases analysed, assuming a BER threshold of $4.62\cdot10^{-3}$ for a 7% FEC overhead[6].

First, a back to back (B2B) configuration is tested, featuring a maximum aggregated gross capacity of 105.2Gb/s at -14dBm of input power. At -17dBm (which corresponds to a 20 dB power budget for the transmitted power, including a 3dB margin), the maximum aggregated capacity is 88.4Gb/s. In this case, each slice when individually transmitted is featuring slightly above 50Gb/s. Next, the impact of the access trees is assessed after 10km and 25km of fibre. Fig.2 shows that these configurations are well aligned with the B2B case, with power penalties of less than 1dB for all the analysed cases.

For proving the proposed sliceable functionality, the different flows are transmitted over the optical mesh network of the ADRENALINE testbed, through two different lightpaths of 35km and 50km. Next those paths continue through the different access segments to cope with a total distance of 60km. In this case, we observe a capacity penalty of less than 42% with respect to the B2B at -17dBm, achieving beyond 50Gb/s when detecting both flows. When detecting the slices individually, their maximum capacity ranges between 28.9Gb/s and 34.8Gb/s for the same power.

Conclusions

A transparent delivery of mobile front-/back-haul for converged metro/access elastic networking has been experimentally demonstrated with DD-OFDM S-BVTs. Results show successful beyond 50Gb/s connections from BBUs to the RRUs, when serving different paths, covering distances up to 60km. Thus, it is a promising solution for serving the multiple endpoints employing S-BVT(s) at the 5G-edge nodes.

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