Experimental validation of MTU-BRAS connectivity with DMT transmission and coherent detection in flexgrid metro networks using sliceable transceivers

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Abstract: Simple and cost-effective DMT transmission in combination with shared coherent detection is proposed for evolutionary flexgrid metro/regional networks. Network testbed experiments show successful 10Gb/s connections from MTUs to the sliceable transceiver at the virtual BRAS farm, covering up to 150km.

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1. Introduction

The advent of elastic optical networks and the advance of transmission techniques in terms of capacity and flexibility has led to undertake new goals and challenges, enabling the creation of sliceable superchannels as well as the reduction of channel width for low bit rate connections. This granularity becomes especially interesting for an aggregation network, where the adoption of flexgrid technologies improves spectrum utilization and network efficiency, while reducing CapEx investment. Thus, an evolutionary approach for the metro/regional network segment has been also envisioned and novel scenario proposals have been considered [1].

As main network operators are expanding their photonic mesh to the regional networks, it has been proposed to extend the aggregation network reach (typically confined in a metropolitan area) and centralize IP edge functionalities in virtual BRAS (broadband remote access server) farms hosted in distributed data centers. This implies the creation of a conveniently dimensioned pool of virtual BRASes co-located with IP core transit routers in the same data center to further reduce the cost. In this scenario, the traffic pattern is expected to be also highly centric, with a majority of low bit rate connections from multi-tenant units (MTUs) to the virtual BRASes. Thus, the requirements are substantially different in terms of cost and data rate compared to transmission technologies for core networks. However, flexgrid technologies offer interesting features to be suitably adopted, such as the ability of concurrently serving multiple destinations, as for the Sliceable Bandwidth Variable Transceiver (S-BVT) through the individual control of its carriers [2]. Thus, a possible solution to give service to several MTUs is to use S-BVT(s) at the BRAS farm, which should be both cost-effective and robust against transmission impairments, in order to support multiple low bit rate connections over regional optical paths.

In previous works [2-3], we proposed cost-effective S-BVT architectures based on orthogonal frequency division multiplexing (OFDM), using direct detection (DD), and capable to serve up to 5 or 6 MTUs with a single optoelectronic block. So, at the MTU bandwidth variable receiver (BVRx), a simple DD is required.

Likewise, here we propose a simple and cost-effective scheme based on optical discrete multitone (DMT) for the transmitter at the MTU, while leaving the downstream communication between BRAS and MTUs as in [2-3]. As chromatic dispersion can severely affect DMT systems, introducing power fading effect and reducing the maximum achievable reach, it must be properly compensated. Thus, in order to cover the topology requirements, defined in our previous study [2], we propose to combine DMT transmission with shared coherent reception at the S-BVRx located at the BRAS.

2. System architecture

The proposed upstream transmission system architecture is shown in Fig. 1. The idea is to transmit an amplitude modulation in order to keep a simple transmitter at the MTU. For a more efficient and flexible use of the spectrum, DMT is used as modulation format. After transmission, the amplitude modulated signal is recovered at the BRAS receiver by means of a phase diversity coherent front-end, enabling the detection of the full optical field.

The digital signal processing (DSP) block at each MTU transmitter takes the common steps of DMT signal generation, depicted in the inset of Fig. 1. This includes data parallelization (S/P), data mapping, inverse Fourier transform (iFFT), cyclic prefix (CP) addition, and serialization (P/S). Next, the resulting signal is converted into the analog domain by means of a digital to analog converter (DAC) and driven to a Mach-Zehnder modulator (MZM),

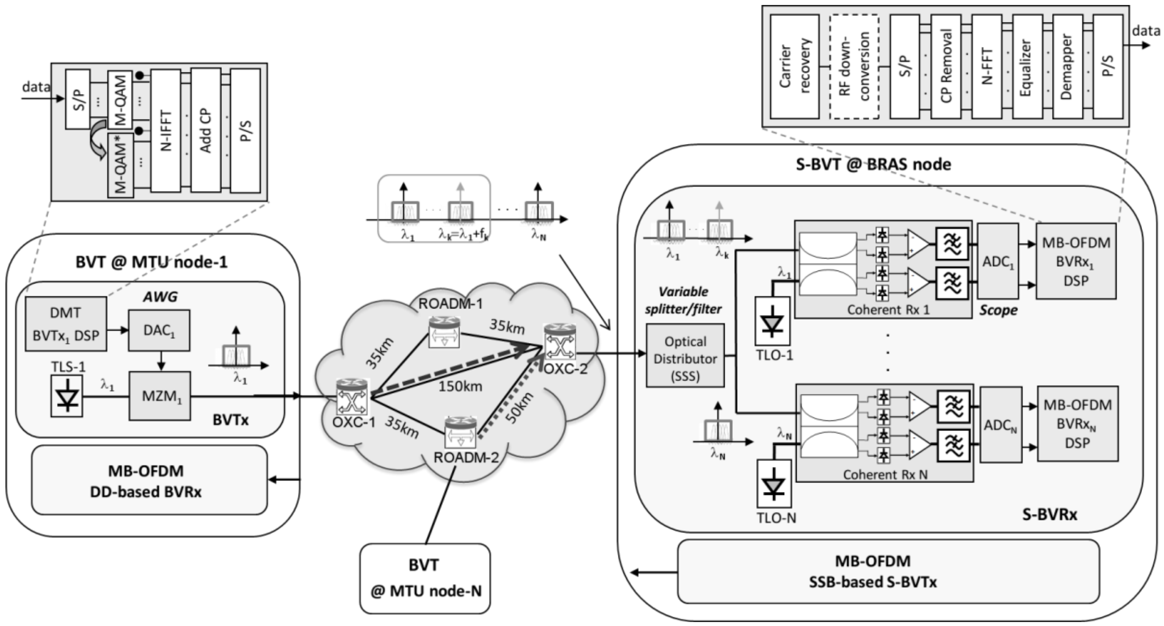

Figure 1. BVT schematic and experimental set-up. Inset DSP blocks correspond to a single MTU.

excited by a tunable laser source (TLS). Alternatively, a DML implementing intensity modulation can also be used, as demonstrated in [4] for distances up to 60km, leaving an even more cost-effective implementation.

In the flexgrid network the optical flows generated by each MTU are conveniently aggregated and directed towards the corresponding network node, that hosts the pool of BRASes.

At the BRAS S-BVT, a spectrum selective switch (SSS) distributes the slices of the received flow (aggregating the traffic from several MTUs) to a bank of bandwidth variable coherent receivers (BVCo-Rxs), whose number (N) determines the S-BVT total capacity. Furthermore, similarly to the connections between the BRASes and the MTUs, demonstrated in [2], also in the proposed architecture different MTUs can be served by a single optoelectronic block at the BRAS S-BVRx. In fact as shown in Fig. 1, closely spaced MTU channels can be received by using a single local oscillator at the BVCo-Rx and further digitally processed by the corresponding multi-band OFDM (MB-OFDM) signal processing block. There, a preliminary digital radio frequency (RF) down-conversion step per each MTU connection/channel, followed by the proper demodulation DSP, is required, enabling a fine tuning over the spectrum. Multiple parallel DSP modules are used for detecting multiple MTU signals/connections (in Fig. 1 only one DSP block is represented) sharing the same optoelectronic block. Thus, the cost of a complex coherent receiver can be shared among several MTUs. The maximum number of MTU connections supported by the same BVCo-Rx depends on the components bandwidth.

Each of the DSP modules at the receiver side consists of a first carrier recovery block, in order to properly lock to the desired optical source, followed by an RF down-conversion module, used for channels with carrier adjacent to the tunable local oscillator (TLO) carrier (e.g. in Fig. 1, λ_k with respect to λ_1). Next, the common steps for OFDM demodulation are performed, including the cyclic prefix removal, the FFT calculation, further equalization and symbol demapping. This is also shown in the inset of Fig. 1.

3. Experiments and results

In order to show the feasibility of such transceivers, we analyze MTU connections at 10Gb/s. Variable bandwidth occupancy can be considered according to the adopted bit loading scheme for distance-adaptive purpose. In our implementation, we assume that the MTU signal should fit within a 12.5GHz channel according to the flexible grid. Specifically, we consider uniform 4QAM loading for a net 10Gb/s connection. The overhead consists of 7% FEC, for a 10^{-3} target bit error ratio (BER), and 13%, due to training symbols (4 over 64 frames), cyclic prefix (5%) and a minimum guard band (4 DMT subcarriers over 256) for allowing synchronization with the optical carrier. This results in a total electrical bandwidth of 6.1GHz (21% of total overhead). In the experimental set-up, the digital DMT signal is generated offline using Python code and converted to the analog domain by means of an arbitrary waveform generator (AWG) running at 20GSa/s. A sample of the signal spectrum at the AWG output is shown in Fig. 2(b), where the guard band and the total signal bandwidth can be clearly identified. The optical DMT signal is generated by using a MZM, biased near the null point for amplitude modulation, and driven by an external cavity laser centered at 1550.12nm and featuring a linewidth of 100kHz.

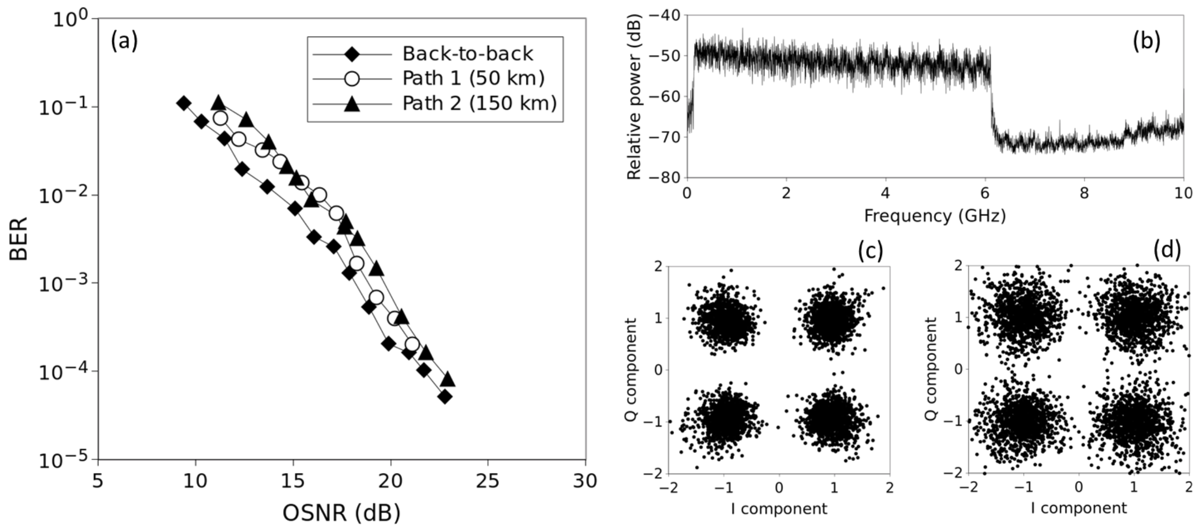

Figure 2. (a) OSNR requirement for the analyzed paths, reported in Fig. 1. (b) Electrical spectrum of the transmitted signal before modulation. (c)-(d) received constellations for path 1 at 10^{-4} BER (c) and 10^{-3} BER (d).

For the back-to-back assessment, a single 10Gb/s MTU optical signal with 0.5dBm output power is detected by a single optoelectronic block of the S-BVRx at the BRAS. After passing by an ASE optical filter, the signal is mixed with a TLO in a 90° degree hybrid. The same optical source is used at the transmitter and as local oscillator at the receiver side. The optical signal is then converted to electrical by using a couple of balanced photodetectors and subsequently captured by a real-time oscilloscope running at 100GSa/s, which is used for analog-to-digital conversion (ADC). The offline DSP consists of a first module for carrier recovery, followed by DMT demodulation, one-tap equalization and demapping. Results for this configuration are shown in Fig. 2(a); where it can be observed that the required OSNR for a 10^{-3} BER is 18.3dB.

For proving the BRAS sliceable functionality, two 10Gb/s MTU connections are transmitted over the optical mesh network of the ADRENALINE testbed, through two different lightpaths of 50km (path 1) and 150km (path 2) as depicted in Fig.1. No inline dispersion compensation is adopted and the signals are received at the same node (BRAS node) by an S-BVT using coherent detection. An optical filter is used (as SSS) to suitably select the portion of the spectrum to be detected by the coherent receiver, which uses, as TLO, the optical laser source at the related optical DMT transmitter. Results are shown in Fig. 2(a) for both paths. At 10^{-3} BER, the required OSNR for path 1 (50 km) is 19.0dB, 0.7dB away from the back-to-back result, while path 2 (150 km) requires an OSNR of 19.9 dB, 1.6dB away from the back-to-back case, showing a high robustness against the accumulated dispersion. Also the difference between the required OSNR for path 1 and path 2 is only 0.9dB.

4. Conclusion

Cost-effective MTU-BRAS connectivity concept based on simple DMT transmission combined with shared coherent reception has been proposed and experimentally assessed for a flexgrid metro/regional scenario with centralized IP edge functionalities in virtual BRAS farms equipped with S-BVT. Results show successful 10Gb/s net connections from MTUs to the virtual BRASes, when serving different paths and covering distances up to 150km. Thus, the proposed architecture for upstream communication, combined with the one previously proposed and assessed for downstream [2], offers a promising solution for serving the multiple endpoints using S-BVT(s) at the BRASes according to the topology requirements.

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