Experimental Characterization of Back-Scattering Interference Limits for Fronthaul employing Bitrate Variable Transceivers based on OFDM and Direct Detection

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Abstract: We experimentally assess the impact of back-scattering when featuring DD-OFDM bidirectional transmission over a single fiber. Results show that different functional split options can be supported for signal/scattering ratios $> 16\text{dB}$ and received optical power around -24dBm .

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1. Introduction

In 5G, a high capacity demand is required together with a dynamic network management. In fact, a large number of antenna elements over small cells are envisioned for increasing the data rate per end user [1]. Therefore, the 5G network paradigm is expected to have a segment close to the end user supported by wireless communications, while optical fiber links serve the corresponding radio access network (RAN) which demands very high capacity [1].

A popular solution is the so-called centralized RAN (C-RAN) featuring digital fronthaul [2]. There, a pool of broadband units (BBUs) implementing all radio signal generation and further digitization is placed in a central office (CO), while simple remote radio units (RRUs) are scattered at the other end of the RAN (see Fig. 1a). This solution entails a high capacity and strict latency requirement [1]. Typical capacities are higher than 10Gb/s and maximum transmission latencies are less than hundreds of μs , limiting the transmission distance to less than 25km of standard single mode fiber (SSMF) [1]. In order to relax these strict requirements, 3GPP is proposing to perform a function split of the baseband processing with eight different options [3]. In fact, the BBU functions are split into two logical entities: central unit (CU, e.g. located at the CO) and distributed unit (DU, e.g. located at the RRU). The split options under consideration in 3GPP can be categorized as high layer (options 2 and 3), medium layer (options 5 and 6), and low layer (options 7 and 8), all of them with different latency and capacity requirements [3].

Since C-RAN deployment should be covered at an affordable cost, a suitable solution can be the reuse of already deployed fiber infrastructure in the residential access, as suggested in [1]. In this sense, NGPON2 has included the point to point (PtP) wavelength division multiplexed (WDM) scheme in order to allow a WDM overlay of additional services (including C-RAN) together with fixed access [4].

Regarding optical transmission technologies, bandwidth/bitrate variable transceivers (BVTs) can be employed for such a C-RAN deployment, providing the required flexible connectivity and scalable capacity [5]. This also enables a transparent connection to the metro/aggregation segment as suggested in [5]. A very dense WDM scheme is proposed with BVTs based on orthogonal frequency division multiplexing (OFDM) and direct detection (DD). Therefore, the capacity of the transceivers can be configured (e.g. by an SDN controller) according to the network condition, including transmission impairments and the suitable functional split option. Interestingly, OFDM features adaptive modulation of its subcarriers, so the depth of modulation can be adapted to the channel spectral response. Furthermore, the BVTs are a fundamental building block of the so-called sliceable BVT (S-BVT), where different WDM traffic flows are generated/detected in order to either serve the same site or concurrently serve different locations [6]. Since capacity is expected to be further increasing, and OFDM-based (S-)BVTs can adapt the transmission to the channel response, a highly dense WDM deployment can be approached for C-RAN when envisioning a bidirectional transmission over a single fiber using the same wavelength for upstream and downstream.

This paper presents an experimental assessment of single fiber bidirectional transmission of DD-OFDM BVTs over 25km of SSMF employing the same wavelength for upstream and downstream. Taking advantage of the OFDM adaptive modulation, we explore its capacity limits in terms of sensitivity and optical signal to interferent back-scattering ratio (SIR) level due to the counter-propagating signal. Results show that low layer functional split options can be supported for SIR values above 16dB and covering a power budget of 20dB .

2. Experimental setup

The experimental setup is shown in Fig. 1b. The digital signal processing (DSP) and electrical up/down-conversion at the transmitter of each transmitted signal is performed off-line, following the steps are detailed in [6] (insets of

Fig. 2. (a) Sample spectrum of transmitted signal. (b) Capacity vs received power with no back-scattering and (e) the corresponding BER. (c) Capacity as function of the SIR and received power after 25 km SSMF, and (f) the corresponding BER. (d) Back-scattered spectra at different SIR.

the maximum capacity attained is 41.1Gb/s for the B2B and 36.4Gb/s after propagating through 25km of optical fiber. Therefore, the maximum functional split supported in this case is option 7a, which needs a maximum of 22.2Gb/s [3]. Such split option can be supported down to -24 dBm of received power, where B2B and transmission after 25km feature a capacity around 25Gb/s. The lower power measured is -30 dBm, where both configurations feature a capacity slightly higher than 5Gb/s. In this case, the maximum functional split supported is option 5, requiring up to 4Gb/s.

Next, the signal coming from MZM 2 is activated and the interference effect from back-scattering is characterized. Results are shown in Fig.2c. In Fig.2c we can see that SIR is limiting the performance also in terms of capacity. In fact, option 7a of functional split can be supported for SIR values >16 dB and power values around -24 dBm, similar to the results reported in B2B and 25km with no back-scattering. For SIR values below 16dB, the capacity decreases and a worst case for supporting split option 7a is found at 14dB SIR and -20 dBm received power. At -30 dBm of received power, capacity is slightly higher than 5Gb/s for all SIR values, supporting the functional split option 5.

The split option requiring higher capacity is option 8, asking for 157.3Gb/s. So, a sliceable BVT configuration with at least 7 flows (wavelengths) is needed to meet this requirement at SIR values >16 dB and -24 dBm received power.

4. Conclusions

The impact of back-scattering when featuring DD-OFDM bidirectional transmission over a single fiber is assessed for different functional split options. Low layer options (up to 7a) can be easily served with a single BVT. Thus, BVTs based on DD-OFDM is a promising solution for serving different sites when featuring a flexible functional split.

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References

1. B. Skubic et al. "Optical transport solutions for 5G fixed wireless access," Journal of Optical Communications and Networking, vol. **9**, no. 9, p. D10 (2017)
2. T. Pfeiffer, "Next Generation Mobile Fronthaul and Midhaul Architectures," Journal of Optical Communications and Networking, vol. **7**, no. 11, p. B38 (2015)
3. 3GPP TR 38.801 V14.0.0 "Technical Specification Group Radio Access Network; Study on new radio access technology: Radio access architecture and interfaces" (2017)
4. D. Nasset, "NG-PON2 Technology and Standards," J. Lightwave Technol., Vol. **33**, no. 5, p. 1136 (2015).
5. 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," J. Lightwave Technol., Vol. **36**, no. 7, p. 1429 (2018).
6. M. Svaluto Moreolo et al., "SDN-enabled Sliceable BVT Based on Multicarrier Technology for Multi-Flow Rate/Distance and Grid Adaptation," J. Lightwave Technol., Vol. **34**, no. 8, p. 1516 (2016).
7. ITU-T recommendation G.975.1 (2004).