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Multi-Band Power Allocation in AMOOFDM High data rate NG-PON downlink transmission direct modulation of linear laser

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Abstract: Multi-band power allocation for NG-PON downlink transmission is experimentally demonstrated when implementing AMOOFDM with direct modulation of a linear laser. Multi-user power and bit-allocation allows the users datarates to be balanced according to a target QoS.

OCIS codes: (060.2330) Fiber optics communications; (060.4080) Modulation

1. Introduction

Orthogonal frequency division multiplexing (OFDM) has been shown to be efficient for passive optical networks (PON) transmission using low-cost components through direct modulation of linear lasers [1]. In conjunction with bit-loading, adaptively modulated optical OFDM (AMOOFDM) takes into account the channel quality in order to maximize the datarate through quasi-optimal algorithms such as Levin-Campello algorithm [2]. Frequency multiplexing of different OFDM signals has been presented in [3].

A PON network is a shared network between different users in order to mutualise infrastructure effort and reduce deployment costs. Nowadays, PON technologies are using time division multiplexing (TDM) to share the optical channel. An OFDM-PON with a large bandwidth might induce a waste of resources, knowing that each user must be capable of demodulating the aggregated data streams comprised in a single bandwidth. Multi-band OFDM (MB-OFDM) offers one OFDM stream per user. At the transmitter side, all the user's streams are frequency multiplexed. At the receiver side, each user demodulates after filtering the signal intended to his use in a narrower bandwidth. This helps reduce drastically the modulation/demodulation required resources per user. The proposed study relies on an architecture with MB-OFDM in downstream PON transmissions. Each bandwidth carries an AMOOFDM signal dedicated to one user that is constructed through a Levin-Campello algorithm. This algorithm aims at maximizing the datarate under a bit error rate constraint and for a predefined power budget.

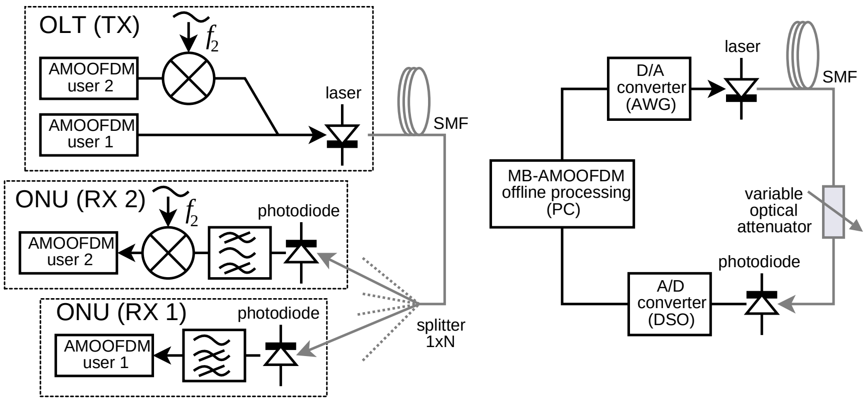
The topology of the network implies a difference in the channel quality for the different users sharing the PON. Moreover, the available transmission power has to be shared between the users and is limited by the characteristics of the transmitted optical source. In this paper, we show experimentally how the power distribution per user bandwidth impacts the delivered datarates. It gives an insight on the possibilities to control the QoS per user. The experimental results are shown in terms of balanced datarates curves with different power distributions between two users.

2. System description and Experimental setup

The aforementioned MB-OFDM downlink PON architecture is depicted in figure 1a for two users. The first distributed bandwidth that occupies the beginning of the spectrum carries a baseband AMOOFDM signal that is obtained through hermitian symmetry. The second distributed bandwidth is obtained through upconversion of a complex AMOOFDM signal around a frequency carrier denoted f_2. If more than two users share the PON, all the AMOOFDM signals will be upconverted except for the first baseband signal. Prior to signal upconversion, a digital-to-analog converter (DAC) helps convert each digital AMOOFDM signal to an analog signal. Filtering is used for each AMOOFDM signal in order to limit inter-band interference. The different signals are aggregated after upconversion which constructs a MB-OFDM signal that modulates directly the laser. In this paper, the used laser is a prototype developed by 3S Photonics which has 17 GHz bandwidth.

At the receiver side, the signal is detected by the PIN photodiode of each user ONU. Filtering around the dedicated user bandwidth helps recover the OFDM signal that will be downconverted. After analog to digital conversion, the signal is demodulated.

In order to investigate the power distribution scheme per user for this architecture, the experimental setup shown in figure 1.b is used. It aims to mimic the architecture shown in figure 1.a.



a. system architecture b. experimental setup

Fig. 1. MB-AMOOFDM downstream PON transmission architecture and experimental setup

Two AMOOFDM signals with a 6 GHz bandwidth are constructed and multiplexed using Matlab™. The first baseband AMOOFDM signal contains 128 subcarriers whereas the second upconverted AMOOFDM signal has 256 subcarriers. The FFT window size for both signals is then 256. The frequency carrier for the upconverted AMOOFDM signal is f_2 = 9 GHz. During the initialisation phase, QPSK constellations are used over all subcarriers as the channel probe. For data transmission, each subcarrier is modulated with constellation size up to 256-QAM. The resulting MB-AMOOFDM signal with a 12 GHz bandwidth is generated through an arbitrary wave generator (AWG) having 24 Gsample/s rate. This signal with a 2.6 Volts peak-to-peak amplitude modulates directly the aforementioned laser emitting at a wavelength of 1550nm with a 17 GHz electrical bandwidth. A 60mA bias current implies a 10 dBm optical power at the output of the laser. The optical signal is transmitted over an SMF fiber with respectively 17 ps/nm/km dispersion and 0.2 dB/km attenuation. An attenuator simulates the splitter loss in the PON network. At the receiver, a PIN photodiode with 35GHz bandwidth detects the optical signal. The electrical signal is captured and digitalized at 40 GSample/s with a digital sampling oscilloscope (DSO). At this stage, the signal is processed offline using Matlab™. The processing consists of recovering each AMOOFDM signal separately through filtering and downconversion for the second signal. The transmission performance is evaluated in terms of bit error rate (BER) using the error vector magnitude (EVM) for each subcarrier [4]. The EVM results during the initialization phase are used as inputs to the Levin-Campello bit and power loading algorithm. The performance results obtained after data transmission help ensure that the target error rate (10^{-4}) is reached. In conjunction with a coding scheme, a quasi error-free transmission is made possible [5].

3. Transmission performance results

The optical budget impact is not considered in this paper. The optical power is fixed at the receiver side to 3dBm using a variable optical attenuator, i.e. that the optical budget is fixed to 7 dB. The RF power budget dictated by the optimal configuration of the emitting laser is distributed among the two users of the system according to different ratios. This is carried out respectively for optical back-to-back, after 5 km and 10 km. The RF power of the aggregated signal is always constant. Figure 2 illustrates the performance results for a distance of 5 km when the RF power ratio is fixed to $\boldsymbol{P}_{\text{user2}} = 2\boldsymbol{P}_{\text{user1}}$. In this configuration, 23.16 Gbps is allocated for user 1 and 11.07 Gbps for user 2. The attained averaged bit error rate is 1.1×10^{-4} for user 1 and 2.1×10^{-4} for user 2.

Figure 3 shows the datarates obtained with different power distributions between user 1 and user 2 with an error rate target of 10^{-4}. Figure 3.a depicts the evolution of the datarates of user 1 and user 2 as well as the total rate according to the RF power $\boldsymbol{P}_{\text{user1}}$ attributed to user 1. The datarate for user 1 increases with $\boldsymbol{P}_{\text{user1}}$ while user 2 datarate decreases with $\boldsymbol{P}_{\text{user1}}$. The maximum aggregated datarates of both users are reported in table 1 for the different link distances. They are obtained in the three cases of link lengths for an equally distributed RF power between users 1 and 2.

SMF distance	Relative RF power		Datarate		
	user 1	user 2	user 1	user 2	Total
back-to-back	0.5	0.5	25.99 Gbps	10.74 Gbps	36.73 Gbps
5 km	0.5	0.5	26.07 Gbps	9.22 Gbps	35.29 Gbps
10 km	0.5	0.5	25.41 Gbps	5.29 Gbps	30.70 Gbps

Tab. 1. maximum aggregated datarates

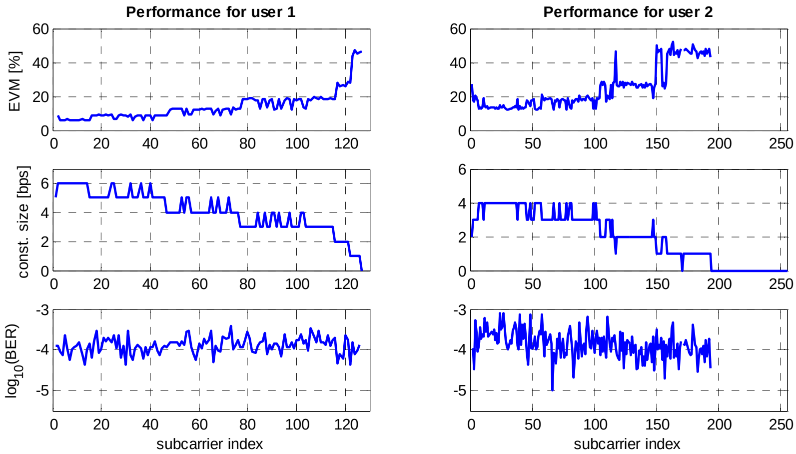


Fig. 2. performance results with $\boldsymbol{P}_{user2}= 2\boldsymbol{P}_{user1}$ for 5 km SMF and 7 dB optical budget

While an equal power results in this topology in the maximum aggregated datarate, user 2 datarate is much lower than user 1 datarate. Increasing the attributed power for user 2 allows the performance to be balanced. This is depicted in figure 3.b where the balanced datarates are reported for the three link lengths. Datarates of the same order for users 1 and 2 can be obtained. For instance, in the case of 5 km link, the datarates (17.16 Gbps, 12.42 Gbps) are obtained with a different power distribution than that for the maximum aggregated datarate power distribution. This system guarantees a better QoS for user 2 and allows for a more fair power distribution.

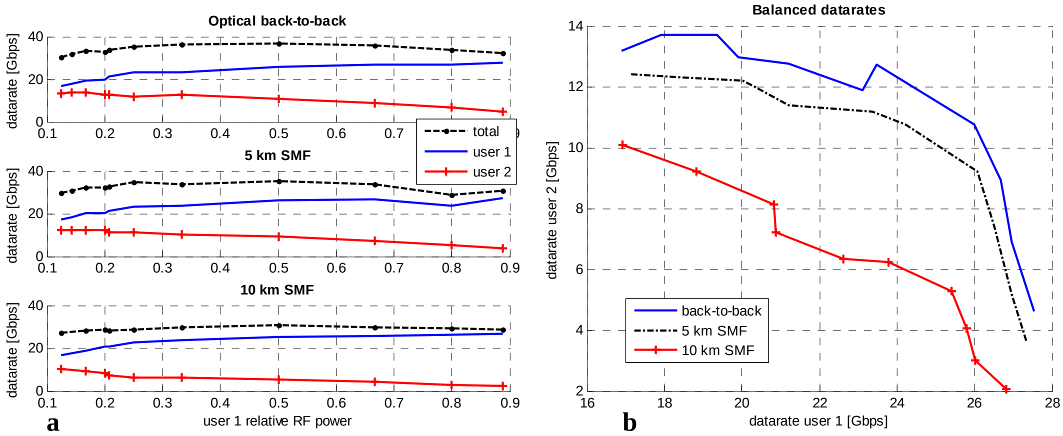


Fig. 3. performance for different RF power distributions and balanced datarates

5. Conclusion

Multi-band power distribution coupled with adaptively modulated OFDM is experimentally demonstrated. Two users having each 6 GHz bandwidth share the same channel. The maximum aggregated datarate is of 30.70 Gbps for 10 km SMF fiber. Power distribution between the two users makes flexible the possible allocated datarates. This proposed method can be employed to increase the fairness between users sharing the PON. It offers a new potentiality to control the QoS in optical MB-AMOOFDM.

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