Flexible resource provisioning of polarization independent coherent PONs based on Non-Orthogonal Multiple Access and multiCAP modulation

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A combined Non-Orthogonal Multiple Access (NOMA) and multiband Carrierless Amplitude and Phase modulation (multiCAP) scheme is proposed for flexible resource provisioning in coherent Passive Optical Networks (PONs). While the proposed combination increases the data-rate and the number of users through the inclusion of NOMA and multiCAP, the coherent reception increases the range and splitting factor of the network through the optical power budget enhancement. The proposed system has been experimentally evaluated providing a 20 Gb/s aggregated data-rate per wavelength with 10G optoelectronics and applied in two main PON scenarios with four spectral configurations from full-band CAP to four-band multiCAP. The first PON scenario consists of an existing PON that network operator requires to increase the number of users, NOMA with full-band CAP or multiCAP can be introduced replacing one or more users of the existing PON by one or several new sub-networks and multiplex the sub-networks by NOMA. In the other PON scenario, several PONs can be nested sharing an initial splitter and achieving a larger number of users by the combination of NOMA and multiCAP. The proposed techniques are fully compatible with other multiplexing techniques such as DWDM that should be considered to achieve higher number of users.

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1. INTRODUCTION

The demand for data traffic on optical access networks is growing exponentially due to the appearance of new services requiring large bandwidths, which are added up to the high bandwidth services that telecommunication suppliers are already offering [1]. Therefore, high bandwidth connections require new access techniques able to increase the bit-rate and number of users per wavelength or their range to farther distances while presenting high flexibility in resource provisioning that permits the use of current network infrastructures and access technologies. All these requirements should be accomplished in a cost-effective way, without highly increasing the complexity of the receivers at the ONUs or their optoelectrical bandwidth requirements.

High data-rate demands require a migration to advanced and flexible multicarrier modulations such as Optical Frequency Division Multiplexing (OFDM) or Carrierless Amplitude and Phase (CAP). The main advantages of CAP are its potential high spectral efficiency per wavelength, lower peak-to-average power ratio (PAPR) and lower complexity implementation than OFDM [2], the feasibility of use more than 2 orthogonal dimensions in the modulation [3], and higher robustness in handling interferences [4]. A multiband approach of CAP signaling (multiCAP) can also be used, combining the advantages of CAP and Digital Multi-Tones (DMT) techniques, while it increases the flexibility of resource provisioning and, additionally, simplify the CAP filters [5]. This is due to the fact that the frequency bands covered by each pair of filters are narrowed down, as in DMT, and the use of different modulation orders and power in each band can be handled to accommodate respectively different bitrates and to compensate the losses of the link [6].

In a different perspective plane, Non-Orthogonal Multiple Access (NOMA) is a promising candidate to enhance both capacity and flexibility of the network combining the information of several users by constellation multiplexing [7]. This technique is fully compatible with frequency and time domain multiplexing and allows to share resources between users, increasing their number in the network. In wireless communications this technique may exploit the near-far effect, causing asymmetrical channel gains between the users [7] whereas in Free Space Optical (FSO) or Visible Light Communications (VLC) it has been proposed for backhauling [8] or enhancing the system capacity [9]. Meanwhile, in PONs and coherent PONs, NOMA can exploit and compensate the pre-post splitter position of users inside hierarchical PON architectures or the different user-to-OLT distances and introduce a new flexibility degree in the resource provisioning.

Finally, coherent detection in PONs provides a way to increase the available power budget (thus, the split level and range of the PON) without extra optical amplification such as in IM/DD schemes [10] and the spectral efficiency (enabling Ultra-Dense Wavelength Division Multiplexing (UDWDM) without complex optical tunable filters). However, coherent detection schemes are not commonly used in combination with NOMA and CAP modulation due to experimental issues such as phase noise and polarization dependence, which can be solved partly using polarization insensitive receivers [11].

In this work, NOMA technique and multi-band Carrierless Amplitude and Phase (multiCAP) modulation are combined with coherent PONs in the downstream in order to allow flexible resource provisioning while at the same time increasing the data-rate through the inclusion of NOMA and the number of users and the range of the network through the increment in optical power budget given by the coherent receiver. NOMA-multiCAP has been successfully tested for radio-over-fiber links in W-band [12], and NOMA-CAP has been partly studied recently for PONs in our previous work [13]. In this work we demonstrate the capacity of the combination of NOMA and multiCAP to extend the flexible resource provisioning in a polarization insensitive coherent PON scenario. Polarization independent operation is a relevant claim and novelty of this work respect [13] and it has been obtained by the use of an ONU-side polarization insensitive receiver based on the Glance approach [11] avoiding complex polarization time coding techniques such as Alamouti coding [14]. Although this receiver has a sensitivity penalty of 3 dB compared to a polarization controlled heterodyne receiver, it is the simplest polarization insensitive approach and has been recently used as part of a quasicoherent receiver [15].

2. NOMA-MULTICAP ARCHITECTURE

A. Multi-band Carrierless Amplitude and Phase (multiCAP) modulation

Carrierless Amplitude and Phase (CAP) modulation transmits data over two orthogonal components, namely the in-phase (I) and quadrature (Q) components, as in QAM modulation. The main advantage of CAP is that it does not use carriers or oscillators and, therefore, it avoids the inherent transmitter and receiver synchronization complexity. In the case of CAP modulation, these two orthogonal components are obtained through two orthogonal filters with impulse responses that are the multiplication of a pulse shaper filter with two orthogonal sinusoidal waveforms [3]:

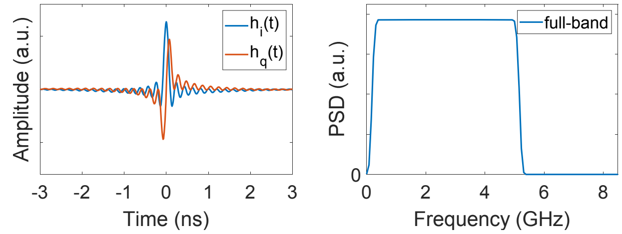

Fig. 1. Impulse response (a) and spectrum (b) of the orthogonal filters used in a 5 GBd full-band CAP modulation.

$$\begin{aligned} h_I(t) &= p(t)\cdot\cos(2\pi f_c t) \\ h_Q(t) &= p(t)\cdot\sin(2\pi f_c t) \end{aligned} \quad \textbf{(1)}$$

where $h_I(t)$ and $h_Q(t)$ are the impulse response of the orthogonal filters for the I and Q components, respectively, $p(t)$ is the pulse shaper and f_c is the central frequency of the CAP spectrum. In order to improve the spectral efficiency, a square root raised cosine (SRRC) function is usually employed as pulse shaper although other spectrally efficient filters can be used [16].

The impulse responses and the resulting spectrum of the filters for a 5 GBaud full-band CAP signal can be seen in Fig. 1, where the central frequency has been adjusted to minimize the used bandwidth. At the reception stage, the received signal is filtered with a pair of matched filters, extracting the signals at the same time minimizing the inter-symbol interference (ISI).

Multi-band CAP (multiCAP) technique slices the transmission spectrum into several bands and allows to correct the non-flat channel response and to achieve higher spectral efficiencies. It can be also used to increase the flexibility of the resource provisioning by assigning each band to a user or a group of users. MultiCAP bands are obtained through the generation of several pairs of orthogonal filters with different central frequencies f_{ci} [17]:

$$\begin{aligned} h_{Ii}(t) &= p(t)\cdot\cos(2\pi f_{ci} t) \\ h_{Qi}(t) &= p(t)\cdot\sin(2\pi f_{ci} t) \end{aligned} \quad \text{with } i\in[1,N] \quad \textbf{(2)}$$

where f_{ci} is the central frequency of the band i and N is the number of bands. These central frequencies can be obtained by:

$$\begin{aligned} f_{c1} &= R_{s1}\cdot\frac{1+\beta}{2}+f_{shift} \\ f_{ci} &= f_{ci-1}+\left(R_{s\,i-1}+R_{si}\right)\cdot\frac{1+\beta}{2} \quad \text{with } i\in[2,N] \end{aligned} \quad \textbf{(3)}$$

Where f_{shift} is an extra frequential shift of the first band respect 0 Hz, β is the rolloff factor of the SRRC pulse shaping filter that determines the excess bandwidth of the filter and R_{si} is the symbol-rate of band i. It is remarkable that multiCAP allows different symbol-rates in each

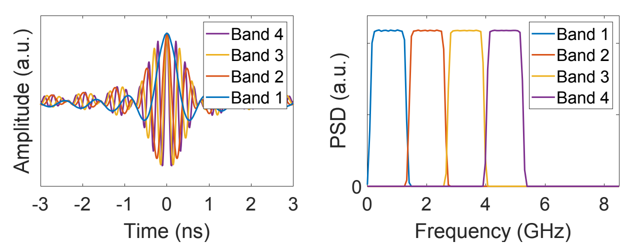

Fig. 2. Impulse response (a) and spectra (b) of the orthogonal filters used in multiCAP with four bands at 1.25 GBd each band.

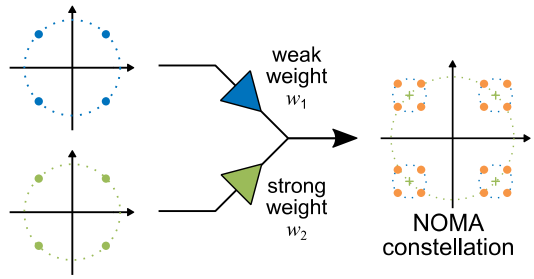

Fig. 3. Two users Non-Orthogonal Multiple Access constellation multiplexing, from [12].

band that can be interesting in a non-symmetrical downstream scenario. The limited spectral bandwidth of the SRRC allows to place the multiCAP bands close to each other without a relevant waste of bandwidth. An example of the multiCAP filters temporal and frequency responses are shown in Fig. 2, where four multiCAP bands of 1.25 GBd are used to transmit the same aggregated data-rate (5 GBd) as in Fig. 1.

B. Non-Orthogonal Multiple Access (NOMA)

NOMA uses constellation multiplexing of several users at the symbol level [12]. In this work, two users are multiplexed by this technique. The NOMA symbol (x_{NOMA}) is calculated by adding each user's symbol (x_1 and x_2) with different power or weight (w_1 and w_2):

$$x_{NOMA} = w_1 x_1 + w_2 x_2 \quad \textbf{(4)}$$

It is generally assumed that $w_2 > w_1$, so w_2 is considered the strong or far weight while w_1 is assumed to be the weak or near weight.

The resulting NOMA constellation for two users, each with a QAM4 modulation, is shown in Fig. 3. The weights are calculated in order to obtain the desired power ratio between users in the multiplexed signal, r_{power}:

$$r_{power} = 20\log_{10}\left(\frac{w_2}{w_1}\right) \quad \textbf{(5)}$$

This ratio can be dynamically adjusted to compensate changes in the requirements of the network such as variations in the user's data demand or balance between PONs.

At the receiver side, far (strong) user can demodulate his data directly meanwhile the near (weak) user needs to remove the interference of the far user previously to demodulate his data. This process is known as Successive Inference Cancellation (SIC) and is the main reason of the worse performance for near user than far user in NOMA [12].

C. Studied PON scenarios

Our NOMA-multiCAP over Coherent PON proposal uses constellation multiplexing of two users with two different power multiplexing levels to compensate their pre-post splitter position in the PON network. The power for the near user in the NOMA constellation is lower than the one for the far user. They are denoted as PON1 and PON2 user, respectively. We will study the performance in three different PON architectures as in [13], shown in Fig. 4. In the first one, Fig. 4(a), a new PON is added to an existing one and the users of each sub-network are NOMA multiplexed with users of the other sub-network. In the second architecture, Fig. 4(b), several PONs are added to the existing one. In the last scenario, Fig. 4(c), we study the integration of several PONs in a unique and bigger network with different user-to-OLT distances and sharing a common splitter. The migration between scenarios may be dynamic depending on user

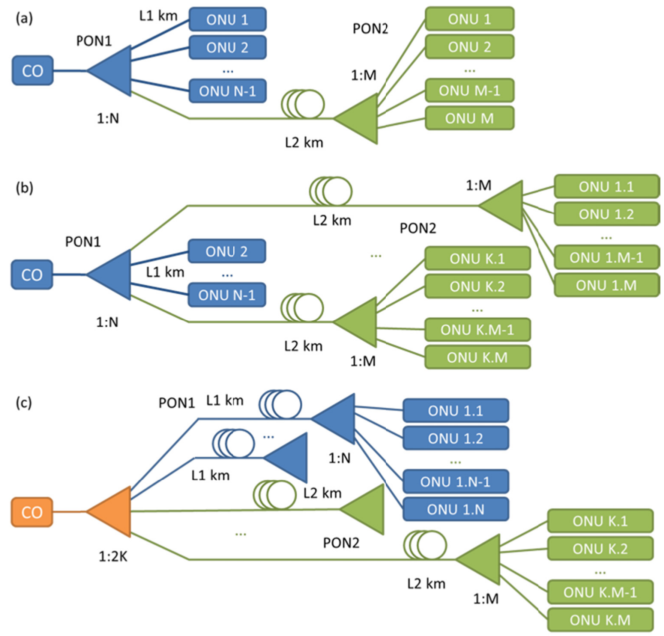

Fig. 4 Studied NOMA-CAP PON integration architectures: (a) 1×PON1 + 1×PON2; (b) 1×PON1+k×PON2, (c) k×PON1 + k×PON2, from [13].

demands and showcases the flexible resource provisioning that NOMA-multiCAP can provide to coherent PONs. It should be noted that we are restricting our analysis to optical power budget distribution, not taking into account other aspects as wavelength or TDMA planning for these architectures.

In this work four different spectral configurations have been evaluated: 2.5 GBd full-band CAP, 5 GBd full-band CAP, 2×2.5 GBd multiCAP and 4×1.25 GBd multiCAP. The first configuration, 2.5 GBd full-band CAP, provides an aggregated traffic of 10 Gb/s for two group of users or sub-networks [13]. The second one, 5 GBd full-band, can provide 10 Gb/s per sub-network multiplexed by NOMA and with an aggregated data-rate of 20 Gb/s. The two multiCAP scenarios enable the distribution of the previous aggregated data-rate (20 Gb/s) between two groups of sub-networks (2×2.5 GBd) with 10 Gb/s per band and 5 Gb/s per sub-network, or between four sub-networks (4×1.25 GBd) with 5 Gb/s per band and 2.5 Gb/s per sub-network.

3. EXPERIMENTAL SETUP

Fig. 5 shows the experimental setup for the evaluation of the NOMA-multiCAP medium access technique.

A. Transmitter

The first step in the digital transmitter corresponds to the mapping of each user data stream into a 4QAM symbol. Then, the NOMA symbols are obtained by constellation multiplexing of two different users' symbols, one of each sub-network PON1 and PON2. Users from PON2 have a stronger weight than users from PON1 to compensate the extra losses they bear to reach this sub-network. The NOMA symbols are up-sampled and filtered with the corresponding orthogonal filter of each band. Finally, these components are added obtaining the signal finally transmitted.

The CAP or multiCAP orthogonal filters, which follow either (1) or (2) respectively, employ a SRRC with a roll-off factor of 0.05 as pulse shaper and have a length of 20 symbols. These values represent a trade-off between complexity and performance. Lower roll-off factors and/or higher lengths will improve the performance but will also increase the cost and complexity of the digital signal processing.

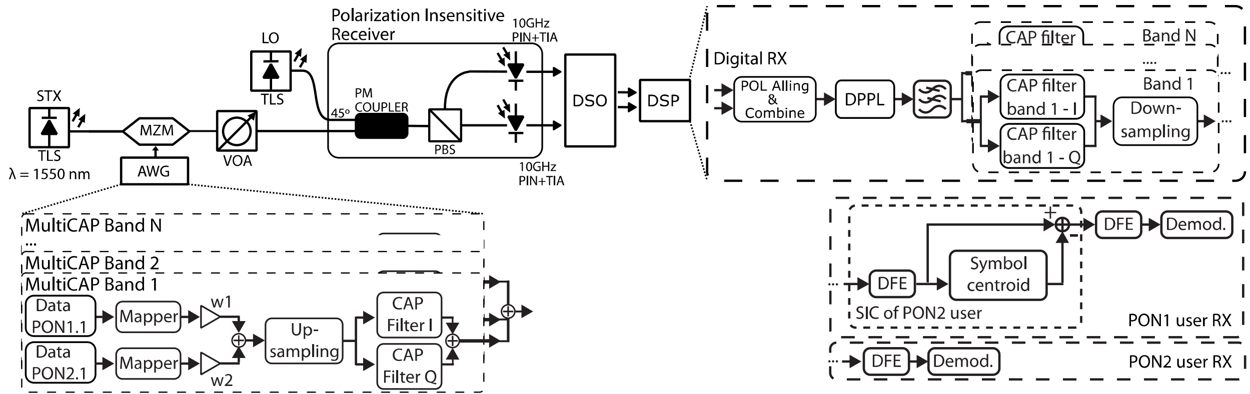

Fig. 5. Experimental setup.

The output signal of the digital transmitter is generated by a 80 GSa/s Arbitrary Waveform Generator (AWG) (Micram DAC10002) and drives a null-point biased Mach-Zehnder Modulator (MZM) (Avanex F10-0-13P) that modulates the light coming from a Tunable Laser Source (TLS) (ID-Photonics CoBriteDX4) at a wavelength of 1550 nm. The optical transmitted signal is a pure Double Side Band (DSB) modulation, instead of the common CAP signal based on Intensity Modulation (IM), to increase the power efficiency and the receiver sensitivity by reducing the power in the optical carrier and, consequently, the carrier-to-signal power ratio (CSPR).

B. Receiver

At the receiver side, the received signal is mixed with a +10 dBm local oscillator (LO) in a polarization insensitive coherent receiver [11, 15]. This receiver is based on a Polarization Maintaining (PM) coupler followed by a Polarization Beam Splitter (PBS) and two 10 Gbit/s PIN+TIA receivers (Nortel PP-10G). The local oscillator (LO) is a TLS (ID-Photonics CoBriteDX4), which polarization is fixed to 45° with respect to the PBS axis to ensure polarization insensitiveness. This design has a sensitivity penalty of 3 dB compared to a classical polarization controlled heterodyne receiver, such as the one used in [13]. The LO is shifted 6.0 GHz from the central wavelength of the received signal to use all the available bandwidth in the photo-receivers. The detected signals are digitalized by a 20 GHz Digital Storage Oscilloscope (DSO) at 80 GSa/s (Teledyne Lecroy Wavemaster 820Zi-B), and they are offline digitally processed. As can be seen in Fig. 6, where the spectra of the received signals for the four different spectral configurations are plotted, the signal presents a very low carrier-to-signal power ratio that improves the sensitivity by maximizing the DSO resolution. It should also be noticed that the photo-receivers response is not flat and the electrical signal power decreases, for the same received optical power, with the number of multiCAP bands. These two behaviors will affect the performance of the spectral configurations, as it will be shown later.

The first step in the digital receiver consists of the alignment and combination of the two digitalized signals that correspond to two orthogonal components in the polarization insensitive receiver. Then, a PLL is used for carrier recovery and baseband conversion of the combined signal. This baseband signal is passed through the CAP or multiCAP orthogonal filters and the NOMA symbol is extracted; this part is common to both users. PON1 users have to implement Successive Inference Cancellation (SIC) to remove the PON2 user data. The first step of the SIC is a decision feedback equalizer (DFE) with 30 forward and 20 backward taps. After that, the symbol centroid of the PON2 user data is assigned by the k-means algorithm and subtracted from the equalized symbol. After the SIC, a second DFE with the same parameters is applied again and PON1 user data is finally demapped. In the case of PON2 users, SIC is not required due to the lower optical power of the PON1 symbols compared to the PON2 ones. Therefore, DFE and demapping are performed directly to the symbols extracted after the orthogonal CAP or multiCAP filters.

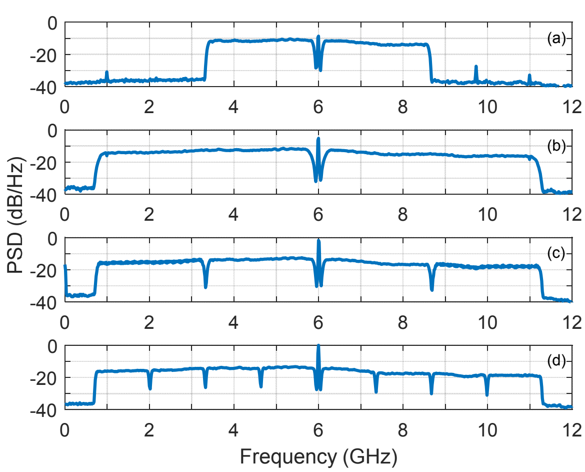

Fig. 6. Power Spectral Density of the received signal (with a received optical power of -25 dBm) for (a) 2.5 GBd full-band CAP, (b) 5 GBd full-band CAP, (c) 2×2.5 GBd multiCAP, (d) 4×1.25 GBd multiCAP.

4. RESULTS

The NOMA-multiCAP technique performance has been evaluated using bit error rate (BER) measurements for different NOMA power ratios, defined as in Eq. (5), and for the four spectral configurations. The sensitivity of the system is calculated as the received optical power at BER values of 3.8×10^{-3} and 1.32×10^{-2}, considered as the limits for standard Forward Error Corrections (FEC) with 7% and 25% of overhead (OH) respectively [18].

A. Full-band CAP

Figs. 7(a) to 7(d) show the computed BER values from the measurements as a function of the power ratio and received optical power for PON1 or PON2 users and for 2.5 or 5 GBd full-band CAP configurations. In the 2.5 GBd CAP scenario, according to Fig. 7(b), PON2 (far) users would prefer high NOMA power ratios since a sensitivity of at least –40.02 dBm will be always achieved with power ratios above 6 dB for a 7% FEC, as can also be seen in Fig. 7(e). If higher sensitivities are required, the power ratio can be increased, for example to 10 dB, where a sensitivity of –43.26 dBm for a PON2 user

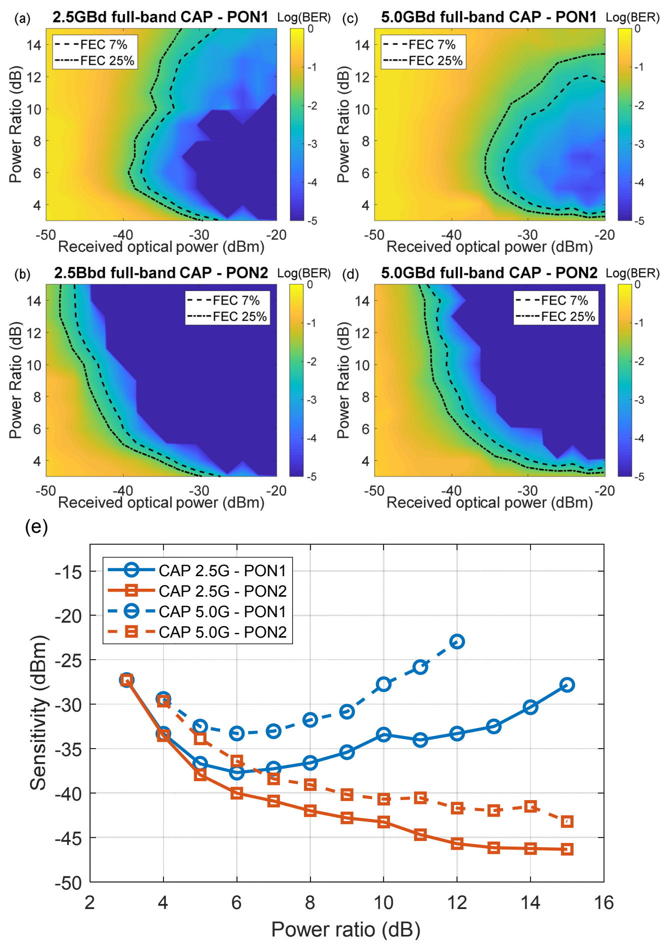

Fig. 7. BER and FEC limits for PON1 and PON2 users as a function of the power ratio and received power for 2.5 GBd (a-b), 5 GBd (c-d) full-band CAP and (e) sensitivities at the 7% FEC limit.

will be achieved at 2.5 GBd. On the other hand, PON1 user has an optimum power ratio around 6 dB, as is shown in Fig 7(a), where its sensitivity is –37.70 dBm. These results are about 3 dB better than the obtained in [13] due to a more optimized digital signal processing, improvements in the experimental setup and a slightly higher LO power. For example, the sensitivities obtained in [13] for the 6 dB power ratio were -37.0 dBm and -34.5 dBm for user 1 and 2, respectively, while now these values are -40.02 dBm and -37.70 dBm. If the NOMA power ratio decreases below 5 dB, PON2 user centroids cannot be correctly calculated by the SIC and therefore all these errors will be propagated to the PON1 user. If the power ratio increases, the PON2 user centroids will be calculated better but the PON1 user will have less power to be demodulated and its sensitivity will be degraded., as can be seen from Fig 7(e).

The same analysis has been performed in the full-band 5 GBd CAP scenario and, as can be seen in Figs. 7(c) and 7(d), the behavior is quite similar to the 2.5 GBd case but with a penalty of around 3.50 dB for PON2 users and 4 to 10 dB for PON1 users. For example, at the PON1 user optimum power ratio (6 dB), the sensitivities are –33.30 dBm and –36.39 dBm for PON1 and PON2 users, respectively. It is also remarkable that, in this case, NOMA power ratios over 12 dB (14 dB) will not work for PON1 because the BER is over the 7% (25%) FEC limit, as is depicted in Fig 7(e).

B. multiCAP

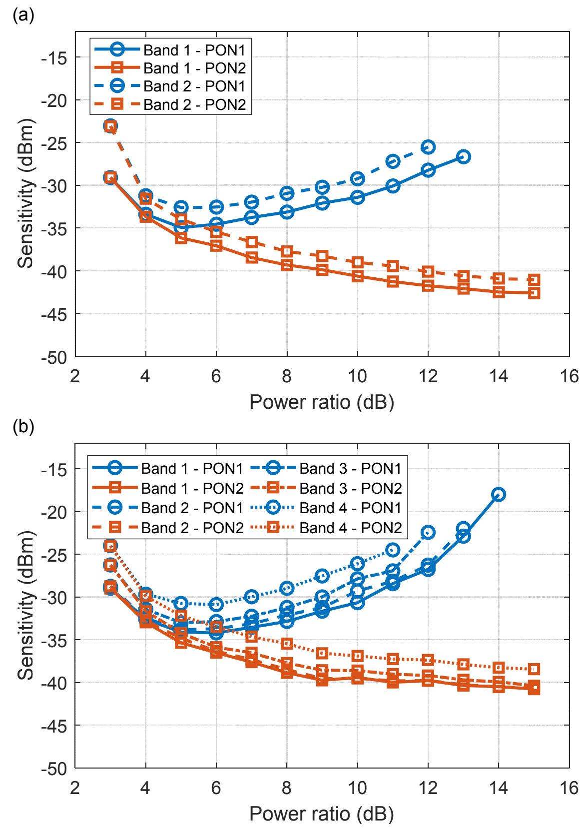

Fig. 8. Sensitivities at the 7% FEC limit for PON1 and PON2 users as a function of the power ratio and received power for two-band multiCAP (2×2.5 GBd) (a) and four-band multiCAP (4×1.25 GBd) (b).

In the multiCAP scenarios, according to Figs. 8(a) and (b), the behavior is similar between bands and the sensitivity values are close to the 5 GBd full-band CAP configuration. However, the sensitivity is degraded in higher bands. For example, in the 2-bands multiCAP configuration the sensitivity of PON1 and PON2 users in Band 2 are 2.24 dB and 1.78 dB worse than in Band 1, as can be seen in Fig. 8(a). In the four bands configuration, Fig. 8(b), the sensitivity penalty for PON1 user respect band 1 is 0.52, 1.69 and 3.85 dB for bands from 2 to 4. These penalties are also higher than the penalties for PON2 users that are 0.20 dB, 1.22 dB and 3.22 dB, as it also happens for the full-band CAP and two-band multiCAP scenarios due to the error propagation in the SIC. The increasing penalty with the number of bands is related to the jitter and symbol timing sensitivity of higher bands in multiCAP and to the non-flat response of the photo-receivers. These penalties could be compensated in a real deployment using power-loading technique.

5. FLEXIBLE PON RESOURCE PROVISIONING

The measured results show that the actual optimum power ratio has to be balanced depending on the PON deployment scenario to be implemented and in the users traffic demands. The NOMA-multiCAP technique permits to manage the network resources in a flexible way when needed. Thus, if the PON operator requires to increase the number of users, NOMA with full-band CAP can be introduced replacing one of the users of the PON1 by a new sub-network PON2 and multiplex the two sub-networks by NOMA. The use of multiCAP adds an extra degree of freedom to the operator in order to increase the number of users (by 2 or 4 times) or change and adapt the user data-rate to the scenario.

TABLE I
NOMA-multiCAP coherent PON Results

Configuration	Power Ratio	PON1 Power Budget	PON1 Reach (L1)	PON1 Splitting Ratio (N)	PON1 # users	PON2 Power Budget	PON2 Reach (L2)	PON2 Splitting Ratio (N)	PON2 # users	Total users
PON1 + PON2	8 dB	33.99 dB	40 km	32	31	40.74 dB	40 km	16	16	47
	11 dB	30.21 dB	40 km	32	31	42.44 dB	40 km	32	32	63
	11 dB	30.21 dB	40 km	64	63	42.44 dB	20 km	32	32	95
PON1 + 2×PON2	11 dB	30.21 dB	40 km	64	62	42.44 dB	20 km	32 (×2)	32 (×2)	126
16×PON1 + 16×PON2	10 dB	32.24 dB	20 km	8	8 (×16)	42.02 dB	70 km	8	8 (×16)	256
	6.5 dB	35.26 dB	40 km	8	8 (×16)	39.04 dB	40 km	16	16 (×16)	384

In each configuration, different PONs architectures can be implemented by selecting different power ratios. It should be noted that the analysis is made only for the downstream leaving the upstream solution open for future works. For the sake of simplicity, we have chosen the two-band multiCAP configuration with 20 Gb/s aggregated bit rate, but similar analysis can be made for the other full-band CAP or multiCAP configurations. Table I shows the results for the three different PONs scenarios shown in Fig. 4. For this table, optical power budgets have been calculated using measured receiver sensitivities for different optical power ratios at 7% FEC and an optical emitted power of +3 dBm.

First, the data corresponding to the configuration in Fig. 4(a) is presented, PON1+PON2, for two different optical power ratios, where a new PON (PON2) is deployed from one of the branches of an existing PON1. The NOMA-multiCAP technique can be applied in this scenario to include a strong user that will be used for the new PON2. For a NOMA power ratio of 8 dB, the power budgets obtained by the measured sensitivities and optical emitted power are 33.99 dB for the PON1 users and 40.74 dB for the farther, PON2 users. The power budget for PON1 users can be used to achieve different reach lengths and splitting ratios. We have chosen 40 km and a splitting ratio of 32 users, but other options may be chosen. With this configuration, if a new PON needs to be multiplexed using NOMA its power budget would be 40.74 dB. For a same reach length of 40 km, the maximum achievable splitting ratio would be 16 for a number of 47 total users, but it might be higher if we chose a shorter reach length L2. The number of users may keep growing using higher power ratios, as can be seen from the table. However, for higher optical power ratios the optical power budget of PON1 decreases and it may limit the network size.

If the network operator needs to continue increasing the size of the PON, a greater number of PON1 users can be replaced for new PONs, increasing the total number of users. As can be seen in Table 1, the number of users can be increased up to 126 by including 2 new PON2 connected to two branches of the original PON1. In this case, the users of the PONs are not only multiplexed by NOMA but also by multiCAP, allocating a PON2 sub-network in each multiCAP band. It should also be noted that in this case L2 reach is shorter than the L1 one. But despite to be 'nearer' than PON1 users, they have a double splitting and from a sensitivity point of view they receive much less power than PON 1 users.

As final scenario, several PON1 and PON2 can be nested achieving a larger number of users. For example, given the optical power budgets obtained for this case, up to 32 different PONs can be deployed from one OLT, obtaining a number of 256 possible users, 16 of them will be near (20 km) PON1s, while the rest will be far (70 km) PON2s. For these long reaches additional extra digital processing such as chromatic dispersion correction may be included [19] although it is not strictly necessary in our case due to the narrow bandwidth of the transmitted signal (10 GHz) and the multiCAP bands. If both PONs types have the same reach, the splitting ratio can be increased in PON2 and provide services up to 384 users for a lower NOMA power ratio. In this case, other multiplexing techniques such as DWDM-PON should be considered to achieve the optimum bit rate for these users.

6. CONCLUSION

Non-Orthogonal Multiple Access (NOMA) and multiband Carrierless Amplitude Phase modulation (multiCAP) in combination with coherent Passive Optical Access Networks (PON) have been proposed and evaluated in two main PON scenarios and four spectral configurations. The proposed combination increases at the same time the data-rate and the number of users through the inclusion of NOMA and multiCAP, and the reach and splitting factor of the network through the increment in optical power budget given by the coherent receiver. Based on experimental receiver sensitivities with an aggregated data-rate of 20 Gb/s, NOMA-CAP enables flexible resource provisioning for the downstream of future generation PON architectures. The proposed techniques are fully compatible with other multiplexing techniques such as DWDM that should be considered to achieve higher number of users.

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