OFDM–IDMA for Uplink Transmission in Passive Optical Networks

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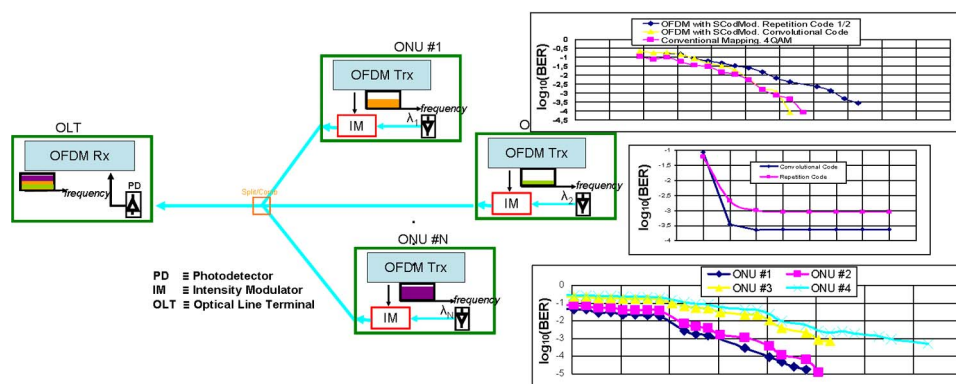
PD   ≡ Photodetector
IM   ≡ Intensity Modulator
OLT ≡ Optical Line Terminal

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Abstract: In this paper, we propose the orthogonal frequency-division multiplexing–interleaved division multiplexing access (OFDM–IDMA) technique for passive optical networks (PONs). We evaluate the performance of such systems and compare it with the already proposed OFDM-Access (OFDMA) technique by means of the bit error rate versus received power for two different coding schemes and different number of iterations. Results show that OFDM–IDMA technique with an unequal power allocation distribution among the different optical network units (ONUs) offers similar performance to OFDMA when used with a simple convolutional code at an aggregated rate of 4 and 8 Gbits/s. Dynamic bandwidth allocation can be easily implemented with this technique.

Index Terms: Orthogonal frequency-division multiplexing–Interleaved division multiplexing access (OFDM–IDMA), OFDM-access (OFDMA), passive optical networks (PONs), multiuser access medium technique.

1. Introduction

In recent years, there has been great interest in overcoming the bottleneck imposed by copper transmission links [1] due to the increasing demand on the quality of the communication services deployed by the end users, such as interactive games, high-definition TV, or voice over IP. This situation pushes the academic and industrial world to the search of advances on communication technologies and techniques which may offer higher systems performance.

Advances on digital signal processing (DSP) equipment during the last two decades have allowed the proposal of different techniques for the treatment of the optical channel impairments and the reduction of its consequent performance penalties [2], [3]. A paradigmatic case of an optical technology which has benefited from this progress is coherent optical communications [4]. DSP techniques have become a core part of the optical link designs, and it is not surprising that more advanced DSP techniques traditionally employed in wireless communications start to merge for their employment in optical communications as well [5].

Owing to the maturity of optical components and electronic circuits, optical-fiber links have become practical for use in access networks, and furthermore, passive optical networks (PONs) have become the preferred solution by the industry due to the high performance and low cost. Nowadays, next-generation PONs (NG-PONs) are intensively investigated worldwide and are envisioned to offer higher performance parameters, i.e., higher signal line rate per subscriber, increased split ratio and extended maximum reach. In such scenario, orthogonal frequency-division multiplexing (OFDM) is a promising modulation format, due to its high spectral efficiency, scalability, flexibility, robustness to linear system impairments, as well as because its generation and detection rely both on mature DSP techniques.

Current Ethernet-PONs and Gigabit-PONs employ time-division multiplexing access as medium access technique or wavelength-division multiplexing access (WDMA) may also be employed, where each optical network unit (ONU) is assigned to a different wavelength providing virtual point-to-point connectivity in a point-to-multipoint architecture with high transport capacity [6]. Another access approach based on OFDM, i.e., OFDM-Access (OFDMA), has been also proposed for PONs [7]. In this technique, each ONU transmits its data on a portion of the available electrical bandwidth, and taking advantage of the orthogonality between subcarriers, the data from different users or services are separated.

In this paper, for the first time to our knowledge, we propose and evaluate another technique for the separation of data from different ONUs in the upstream transmission: OFDM–Interleaved division multiplexing access (OFDM–IDMA). IDMA has been a candidate access technique for fourth-generation (4G) mobile communications offering salient features such as power and spectral efficiency. By employing a different interleaver for each user, a low-complexity iterative detector is able to separate the data from different users. OFDM–IDMA can be combined very easily with the superposition coded modulation (SCodMod) technique, allowing dynamic bandwidth allocation and quality-of-service policy [8].

This paper is organized as follows. In Section II, the basics for the understanding of OFDM–IDMA are explained. Section III presents the numerical results obtained for the evaluation of different aspects of OFDM–IDMA and compared with those obtained in OFDMA systems. Finally, the main contributions of this paper are summarized in Section IV.

2. Optical OFDM–IDMA Systems

2.1. Description of OFDM–IDMA Transmission Systems

Since 2005, optical OFDM (OOFDM) signal transmission has been proposed by several research groups for different communications scenarios, including optical access networks [9]. OFDM is a multicarrier multiplexing technique based on the mapping of a block of information complex symbols into a comb of subcarriers through an inverse Fast Fourier Transform (IFFT) [10]. In order to obtain a real-valued discrete signal at the IFFT output, the information symbols and their complex conjugated symbols are disposed in a Hermitian symmetry fashion. The digital signal is serialized, its amplitude excursion is limited by a hard clipper, and a cyclic prefix is added at the OFDM symbol in order to avoid intersymbol interference. The amplitude values of the discrete signal are quantized with a certain number of resolution bit and converted into an analog signal by a digital-to-analog converter (DAC). In the receiver, the reverse operations are carried out to obtain the received complex symbols after the computation of the Fast Fourier Transform (FFT). The linear channel effects can be easily compensated in the receiver in the frequency domain once an estimation of the channel transfer function is obtained. The uplink transmission part of a PON based on OOFDM is shown in Fig. 1. We can observe the OFDM transmitter structure in the ONUs and the OFDM receiver structure in the central office (CO).

IDMA is a nonorthogonal medium access technique proposed by Ping in [11]. The key issue of such technique is the employment of a coding stage and a user-dedicated interleaver. The information binary stream of a certain user is passed through an encoder introducing certain degree of redundancy. In the inset A) of Fig. 1, we can observe the block diagram of the involved signal processing. After the coding, the bits are related one to another and the coded sequence obtained would make sense for a decoding stage. The coded sequence is then randomly interleaved, and therefore the binary sequence has no sense anymore. This feature will be effectively used by the iterative detector at the receiver to cancel out the interference imposed by the rest of users. After interleaving, the binary stream is mapped into a block of quadrature phase-shift keying (QPSK) symbols, which are transmitted onto an OFDM signal. The OFDM signals of all users are summed up, and thus, a proper detection of the data sent by a determined user must deal with the interference imposed by the rest of users.
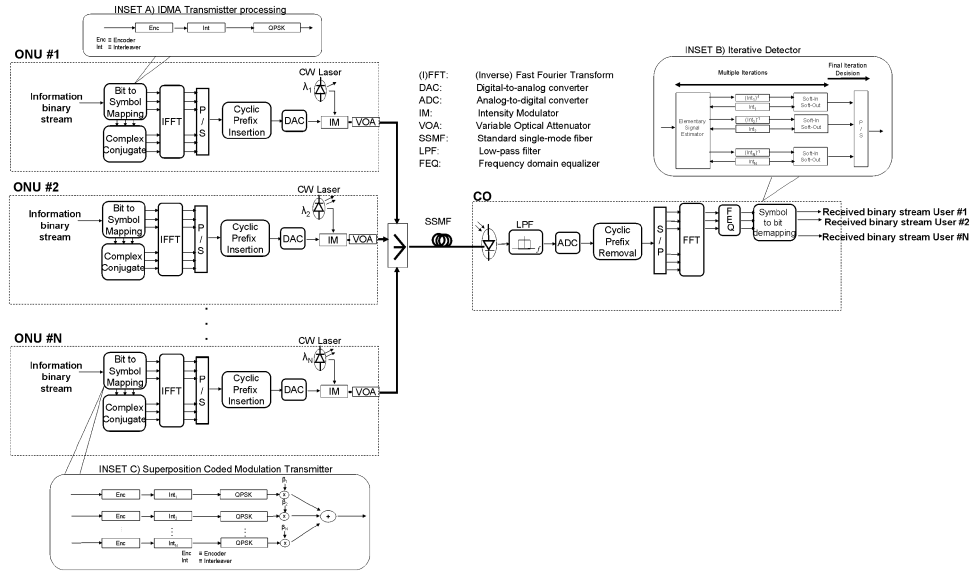
Fig. 1. Block diagram of an OOFDM system. Inset A) IDMA transmitter signal processing. Inset B) Iterative Gaussian-based detector. Inset C) Bit to symbol mapper based on superposition coded modulation.

IDMA offers a way to overcome this interference by using an iterative simple Gaussian-approximation-based detector: after the FFT at the receiver end of an OFDM system employing IDMA technique, the complex symbol on the jth subcarrier $S[j]$ can be expressed as

$$S[j] = \sum_{k=1}^{K} H_k[j] \cdot x_k[j] + N[j]$$

$$= H_{k'}[j] \cdot x_{k'}[j] + \sum_{\substack{k=1 \\ k \neq k'}}^{K} H_k[j] \cdot x_k[j] + N[j] \tag{1}$$

where K is the number of users, $H_k[j] \cdot$ is the channel transfer function on subcarrier j of user k, x_k is the complex information symbol, and $N[j]$ is the Fourier transform of the noise present in the system added to the information signal. When detecting the QPSK symbol from user k', the interference introduced by the rest of users plus the noise can be assumed to be Gaussian distributed. This is effectively exploited to design a simple and iterative detector, which is shown in the inset B) of Fig. 1. The mean and variance of the interference imposed by the rest of users is iteratively determined thanks to the combination of interleaving and de-interleaving stages and the soft-in soft-out (SISO) decoding stage. As the iterative detector runs, the interference is better characterized statistically, and it is more efficiently suppressed. The iterative detection process for the user k' consists of the next steps:

- The elementary signal estimator (ESE) determines the mean value of the information complex symbol $x_{k'}[j]$ and the mean and variance of the interference term (after passing through a maximum ratio combining equalizer) $I[j]$

$$I[j] = H_{k'}^*[j] \cdot x_{k'}[j] \left(\sum_{\substack{k=1 \\ k \neq k'}}^{K} H_k[j] \cdot x_k[j] + N[j] \right). \tag{2}$$

For such a purpose, the ESE needs the equalized version of $S[j]$ and the soft information provided by the interleaver as inputs. At the first iteration, this soft information is null.

- With the new values calculated in the previous step, finer values of the log-likelihood ratios (LLRs) of the bits [12] can be obtained by assuming a Gaussian distribution of the interference + noise term.
- These new LLR values are des-interleaved and are fed into a SISO. The SISO stage aims to provide more exact values of the soft values thanks to the redundancy introduced by the coding stage.
- Finally, the LLR values at the output of the SISO are interleaved and fed into the ESE again.

After a certain number of iterations, a hard decision is taken, and the received binary stream is compared with that transmitted for bit-error-rate computation. It is convenient to adopt a successive interference cancellation (SIC) (also referred as onion peeling) strategy by imposing different transmission power for each user: Those with higher power are detected correctly in the first iterations, in such a way the interference they introduce is cancelled and the users with lower power are detected without the interference effects introduced by the users with higher power.

In a conventional OFDM system the complex symbols are the result of a bit-to-symbol mapping, using high QAM formats to increase the signal line rate by transmitting more bits into a single complex symbol. Another alternative highly compatible with IDMA is the employment of SCodMod, whose structure is shown in the inset C) of Fig. 1. It consists of dividing the original information binary stream into several segments and process each of them independently in a layer, from which a BPSK or a QPSK symbol is finally obtained. The transmitted complex symbol x is calculated as a linearly weighted

$$x = \sum_{n=1}^{N} \beta_n x_n \tag{3}$$

where N is the number of layers, β_n is the weight factor of the nth layer, and x_n is the symbol from the nth layer. Remark that, as in the case of IDMA, the interleaver is different for each layer, which assures that the coded bit sequence from a layer is not correlated to the coded bit sequence of another. The values of the weights $\beta_1, \beta_2, \ldots, \beta_N$ are chosen to make more efficient and fast the iterative detection at the receiver.

Although different types of code have been proposed for IDMA [13], [14], here we will employ a simple repetition code and a convolutional code with a low value of constraint length in order to make the system less complex. The coding process of a repetition code is very simple: an input bit is replicated $1/c_r$ times at the output, where c_r is the code rate, as depicted in Fig. 2(a). The SISO decoding of a repetition code is simply done by summing the calculated LLR values and subtracting the *a priori* information. A 1/2—convolutional coder with polynomial generators (7, 5) and a constraint length equals to 3 is shown in Fig. 2(b), together with its state diagram representation. The polynomial generators describe the connections to generate the output bit sequence (composed of two output streams in this case) and the constraint length is the number of bit delays. In the particular case of Fig. 2(b) the output connections are described by the vectors [1 1 1] and [1 0 1], which in octal nomenclature are 7 and 5. The state diagram aims to explain the coding process: Given a certain state of the coder, the input information bit determines the next state; this transition between states yields an output binary value, in this case given by two output bits (B0 and B1). Since a single input bit implies two output bits, the code rate is equal to 1/2. A repetition coder can be inserted after the convolutional coder in order to increase the number of bits of redundancy to better adapt the protection of the information and the signal line rate. The SISO algorithm of a convolutional coded sequence is done with the BCJR algorithm [15]. In order to simplify and obtain a reasonable performance, we use the log-map version [12]. A higher value of constraint length of the convolutional code means a higher number of possible states. This is translated into a higher coding gain of the convolutional code and, thus, better multiuser interference mitigation but into a higher complexity of the algorithm BCJR as well.

The combination of OFDM with IDMA was suggested in [16]–[18] and for wireless communications systems, showing as its main advantages its linear dependency of the number of operations of the iterative receiver with the number of users and its resilience to fading channels.
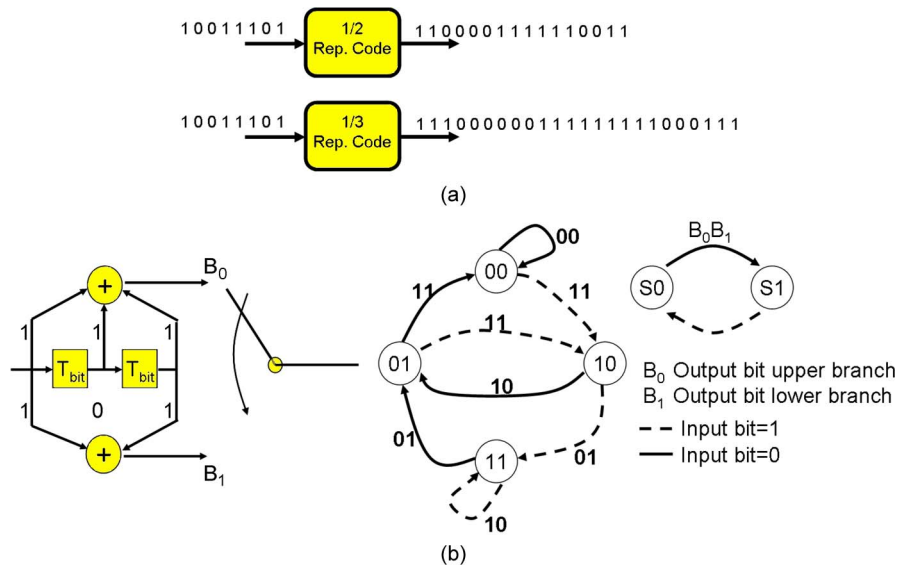
Fig. 2. Constituent codes. (a) 1/2 and 1/3 repetition code. (b) $(7, 5)_8$ convolutional code and state diagram representation.

In [19], OFDM–IDMA is compared with other approaches such as multicarrier CDMA (MC-CDMA) and OFDMA for uplink transmission in 4G mobile networks and it is shown that OFDM–IDMA takes advantage of the multiuser gain, allowing a more power efficient use as the number of users increases. The employment of IDMA as a medium access technique does not impose stringent modifications, since once the complex symbols have been generated, the subsequent processing is the same as in a normal OFDM transmitter. In the receiver, after FFT processing, the combined OFDM signal from all the users is iteratively detected with the Gaussian-approximation-based detector previously explained.

In contrast to OFDM–IDMA, OFDMA is an orthogonal access medium technique. Since, in OFDM signals, the subcarriers are orthogonal one to another, OFDMA systems exploit this aspect in a way that each user, and only that user, transmits onto certain subcarriers in such a way that capacity would be wasted if a given ONU is not fully using the assigned frequencies.

2.2. OFDM–IDMA in the Optical Domain

At the output of the DAC, the analog signal must be adapted to be transmitted through the optical fiber. The signal amplitude is scaled to obtain the peak-to-peak amplitude value and a dc offset is added to provide a linear response at the quadrature bias point of the Mach-Zehnder (MZ) modulator. In order to obtain an intensity modulation of the optical field coming from the CW laser, the MZ modulator is operated at quadrature. The optical signal is translated into an electrical signal by means of a square-law photodetector. At the electrical signal obtained, thermal and shot noises are added. The OFDM receiver performs the inverse operations at the transmitter: analog-to-digital conversion, cyclic prefix removal, serial to parallel conversion and an FFT of each block of received digital samples. After FFT, linear channel effects are compensated for using the estimated channel transfer function from the training symbols sent as preamble.

In Fig. 3, we show schematically the structure of the uplink transmission part of a PON based on OFDM–IDMA (a), which is similar to that used in OFDMA PON (b), suggested by [20], since the objective of this paper is the evaluation of OFDM–IDMA as medium access technique. The ONUs employ different wavelengths for the upstream transmission in a tree-architecture, and the optical signals are synchronously summed up in a passive optical combiner. The generated optical signals are transmitted through 25 km of standard single mode fiber to reach the CO. The beats between
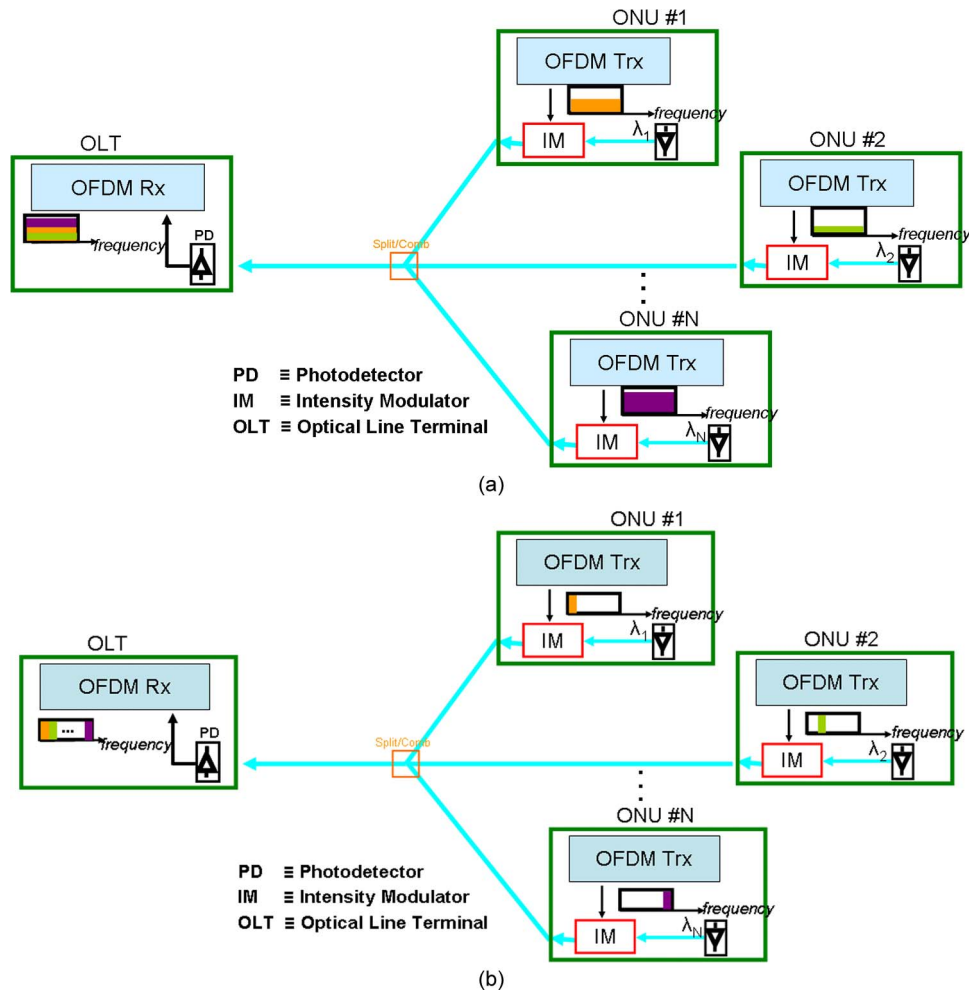
Fig. 3. Block diagrams. (a) OFDM–IDMA PON. (b) OFDMA PON.

different wavelengths during photodetection process generate high-frequency components which can be easily filtered. Finally, the CO performs the DSP needed to detect the data from different ONUs. As it can be observed, in an OFDM–IDMA PON all the ONUs share the same bandwidth, unlike the OFDMA-PON case, in which separation among ONU's signals must be preserved. Furthermore, the bandwidth shared by different ONUs in OFDM–IDMA could be easily employed to provide dynamic capacity allocation by changing the coding rate and/or the number of SCodMod layers employed. A variable optical attenuator is used at the output of the optical intensity modulator to adjust the transmitted power of each ONU.

3. Numerical Results

Matlab and VPI software packages have been used in order to perform numerical simulations to test the validity of the proposed OFDM–IDMA technique. A 5-GHz electrical bandwidth is used as a default value, which is divided into a total number of 512 subcarriers (including the null subcarrier at dc-frequency). The information and their corresponding complex conjugated values are fed into a 1024-IFFT. A cyclic prefix of 25% the duration of the original OFDM symbol is inserted and 13 dB of clipping ratio to limit the amplitude of the OFDM signal. Ten training symbols are sent as preamble in order to estimate the channel transfer function. Electrical square low-pass filters are used in the transmitter and in the receiver.
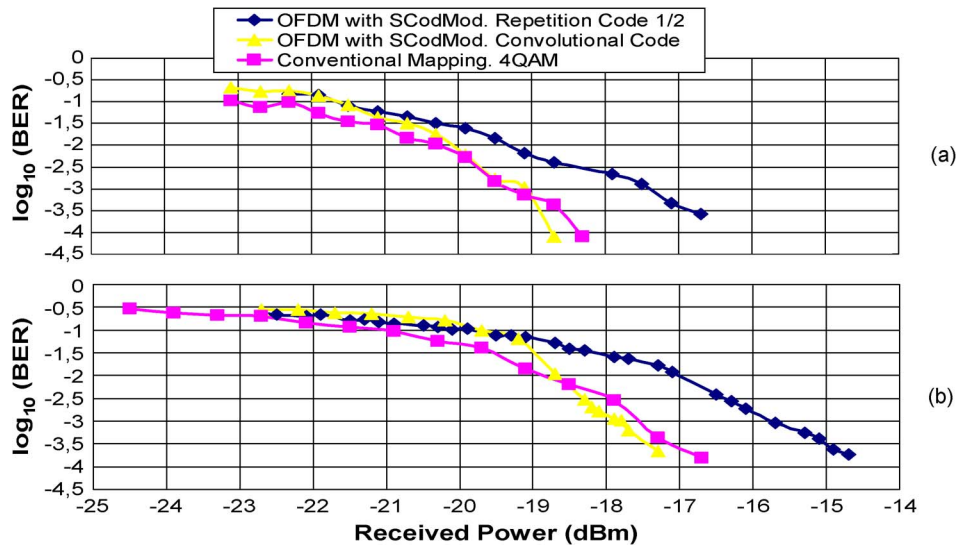
Fig. 4. BER versus the received power for two different superposition coded modulated systems and a conventionally QAM mapped system at (a) 4 Gbits/s and (b) 8 Gbits/s.

The CW lasers are modeled as ideal sources with zero linewidth and no laser phase noise. The Mach–Zehnder intensity modulator has a half-wave voltage of 5 V and an extinction ratio of 25 dB. Once the optical signals have been obtained, its power is adjusted by a variable optical attenuator. The standard single-mode fiber is simulated using the split-step method. This method provides accurate results provided that a sufficiently low value of step is employed. The effects of loss, chromatic dispersion, and the power dependence of refractive index are included in the SMF model. The N_{ONU} to 1 power splitter/coupler used is also an ideal one. A single PIN photodiode detects the transmitted signal at the OLT, where thermal and shot noises and low-pass filtering effects have been considered in the model. Finally, the electrical signal is passed to an OFDM receiver, the information signal is processed and the received and detected binary stream is compared with that transmitted for BER computation.

3.1. SCodMod and Conventional Mapping

Fig. 4 shows the system performance obtained when conventional 4QAM (de)mapping, SCodMod using repetition code, and SCodMod with a convolutional code at which a repetition code is added to adapt the signal line rate by introducing more redundant bits into the coded sequence. The convolutional code employed is a nonrecursive systematic convolutional code with polynomial generators (7, 5), as shown in Fig. 2. For the information transmission in the systems with SCodMod, the binary stream is separated and passed through two layers with different weight values. The BER is calculated for the aggregated data of the two layers. The net signal line rate is approximately 4 Gbits/s in Fig. 4(a) and 8 Gbits/s in Fig. 4(b). These two different signal line rates are obtained by changing the code rate of the coding stage. The number of iterations in the iterative detector is 8.

The SCodMod scheme with repetition code clearly presents a penalty with respect to the SCodMod scheme with a convolutional code and the conventional mapped scheme for both signal line rates. This is due to the fact that the coding gain introduced by the simple repetition code is not sufficiently high to compensate for the Gaussian distributed multiuser interference assumption made by the iterative detector, and thus the multiuser interference is not efficiently suppressed. In order to achieve a BER equals to 10^{-3}, it needs a received power of approximately -17.5 dBm at 4 Gbits/s and -15.7 dB at 8 Gbits/s.
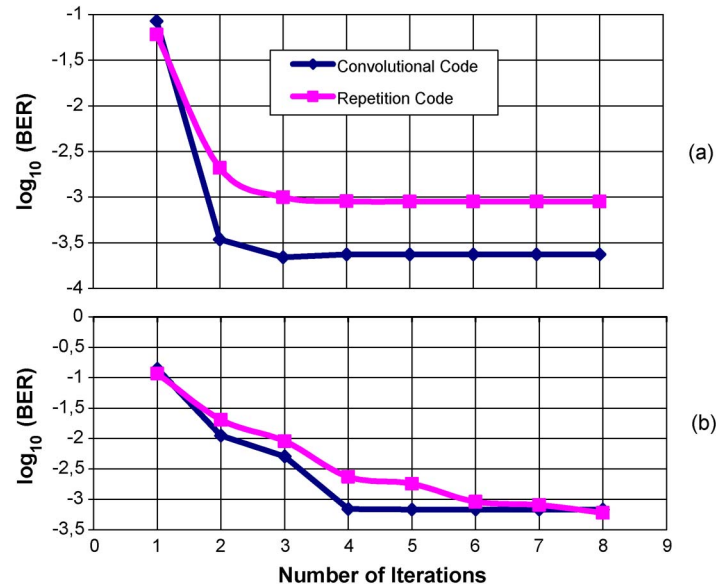
Fig. 5. BER versus the number of iterations. (a) Repetition coded system ($P_{rx} = -17.4$ dBm, SLR $= 4$ Gbits/s) and convolutional $+$ repetition coded system ($P_{rx} = -19.1$ dBm, SLR $= 4$ Gbits/s). (b) Repetition coded system ($P_{rx} = -15.7$ dBm, SLR $= 8$ Gbits/s) and convolutional $+$ repetition coded system with a receiver power of ($P_{rx} = -17.7$ dBm, SLR $= 8$ Gbits/s).

The superposition code scheme with a convolutional code and the conventional mapped scheme require similar received power to achieve a BER of 10^{-3}. Specifically, both schemes require a received power of -19.1 dBm at 4 Gbits/s, while at 8 Gbits/s the SCodMod convolutional coded scheme requires -17.7 dBm and the conventional mapped scheme requires approximately -17.6 dBm. The coding gain introduced by the convolutional code is the key factor for such difference in the effectiveness for the multiuser interference cancellation.

Aside from the dependence on the code employed, the performance in the uplink transmission in a PON based on OFDM–IDMA depends significantly on the number of iterations run by the multiuser detection. As mentioned before, the number of iterations for obtaining the results above has been fixed at 8. In Fig. 5, we can observe the dependence of the BER on the number of iterations for the two SCodMod systems at 4 Gbits/s (a) and 8 Gbits/s (b). Different values of received power have been set for each curve in order to guarantee BER values lower than 10^{-3}. We can observe that for all the cases shown, a BER lower than 10^{-3} is achieved for a number of iterations lower than 8. In particular, for the SCodMod with repetition code the number of iterations needed is 4 with a received power equals to -17.4 dBm at 4 Gbits/s, and 6 with and a received power equals to -15.7 dBm at 8 Gbits/s. In the case a combination of a convolutional code and a repetition code is employed, the number of iterations needed is 3 and 4 for signal line rates equal to 4 Gbits/s and 8 Gbits/s and received powers equal to -19.1 dBm and -17.7 dBm, respectively. A stopping criteria such those used in turbo decoding may be adopted in the IDMA system in order to get computational costs savings.

3.2. OFDM–IDMA-Based Uplink Transmission in PONs

Fig. 6 shows the system performance in the uplink transmission of a PON with 2 ONUs based on OFDM–IDMA and OFDMA. As before, for the OFDM–IDMA system, two different plots have been obtained for the cases in which a repetition code and a combination of a convolutional and repetition codes is used. The output power at each ONU has been optimized to obtain a reasonable global performance of the PON. From these plots, we can observe that the scheme based on OFDM–IDMA with a 1/4-repetition code [see Fig. 6(a)] presents the worst performance and it needs a received power equals to -17.2 dBm to assure a BER lower than 10^{-3} for both ONUs. The
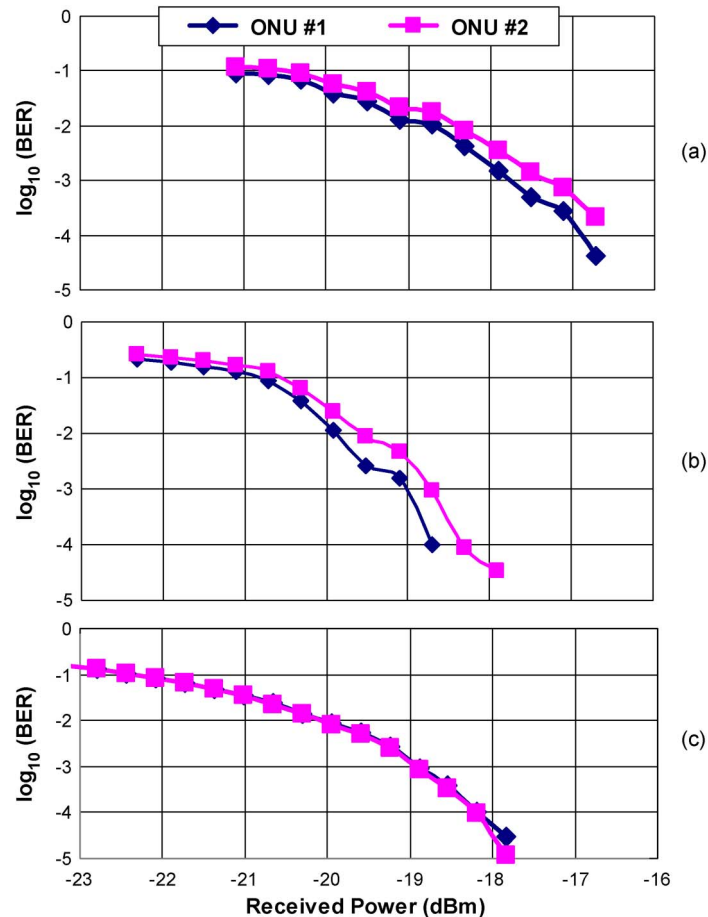
Fig. 6. BER versus the received power for the uplink transmission in a PON with 2 ONUs. (a) OFDM–IDMA with a 1/4 repetition code. (b) OFDM–IDMA with 1/2 convolutional code+ 1/2 repetition code. (c) OFDMA based uplink transmission with 4QAM.

difference in performance between the two ONUs is due to the different values of transmitted power assigned to the two ONUs in order to exploit the SIC principle in the iterative detector. The same can be observed for the OFDM–IDMA-based scheme with a convolutional code [see Fig. 6(b)]. Although the complexity of the system with repetition code is lower than that with a convolutional code, it presents a penalty of approximately 1.5 dB. OFDMA [see Fig. 6(c)] and OFDM–IDMA with convolutional + repetition coding presents similar performances, but due to the unequal power allocation policy, the curve which corresponds to the ONU #2 is shifted 0.3–0.4 dB toward higher received powers with respect to the ONU #1. For a total received power of -18.6 dBm, OFDM–IDMA with convolutional coding allows a BER of 10^{-3} for ONU #2 and a BER of around 10^{-4} for ONU #1. In OFDMA, the two curves are almost identical, since the noise and modeled channel impairments affect equally both ONUs. In order to guarantee a BER lower than 10^{-3} a received power of -18.9 dBm is needed.

Fig. 7 shows the system performance of a PON with 4 ONUs when a repetition code and a recursive systematic convolutional code with polynomial generators (7, 5) and for different number of iterations. The performance obtained by an OFDMA-PON which employs 16QAM is also shown for the sake of comparison. The net signal line rate is approximately 4 Gbits/s. We can observe that the higher the number of iterations, the better the system performance obtained for both constituent codes. For example, for the ONU #1 with repetition-coded OFDM–IDMA, a received power equals to -13 dBm is needed for a BER of 10^{-3} with eight iterations, while a received power equals to -13.9 dBm is needed when 14 iterations are performed. Similarly, with a convolutional-coded OFDM–IDMA
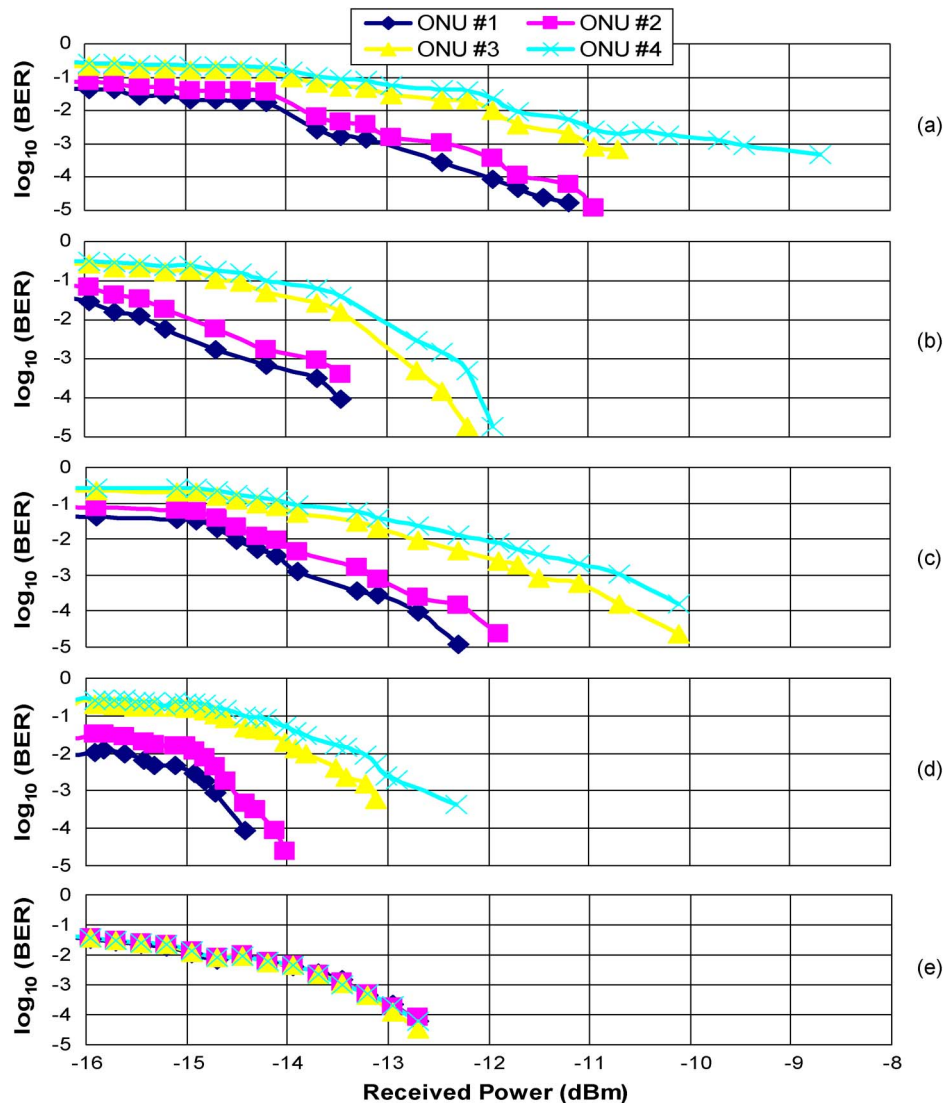
Fig. 7. BER versus the received power for the uplink transmission in a PON with 4 ONUs. (a) OFDM–IDMA with a 1/4 repetition code and 8 iterations. (b) OFDM–IDMA with 1/2 convolutional code+ 1/2 repetition code and eight iterations. (c) OFDM–IDMA with a 1/4 repetition code and 14 iterations. (d) OFDM–IDMA with 1/2 convolutional code+ 1/2 repetition code and 14 iterations. (e) OFDMA based uplink transmission with 16QAM.

PON, for the ONU #1, a received power equals to -14.25 dBm is needed to achieve a BER of 10^{-3} with 8 iterations, while a received power of -14.7 dBm is needed with 14 iterations. As expected, the performance obtained with a convolutional code is better than that achieved with a repetition code. For example, for ONU #3 and using eight iterations, a received power of -10.95 dBm is needed for a BER of 10^{-3}, while a received power of -12.5 dBm is needed when employing the considered convolutional code.

The different performance of ONUs with different powers is clear, due to the noise present in the system and the error propagation in the iterative detection. This fact would imply that the maximum distance between the OLT and the ONUs in a PON with OFDM–IDMA-based upstream transmission would be limited by the ONU with lowest power. Furthermore, this effect can be used to implement selective QoS policies in these systems. Unlike OFDM–IDMA based systems, in an OFDMA-based PON the performance of all the ONUs is similar. We can observe from Fig. 7(e)
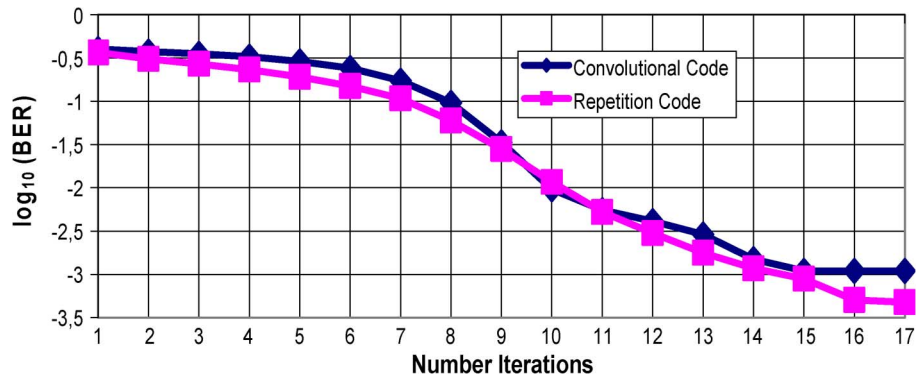
Fig. 8. BER versus the number of iterations for a repetition coded system ($P_{rx} = -10.7$ dBm) and a convolutional + repetition coded system ($P_{rx} = -12.7$ dBm) at SLR = 4 Gbits/s.
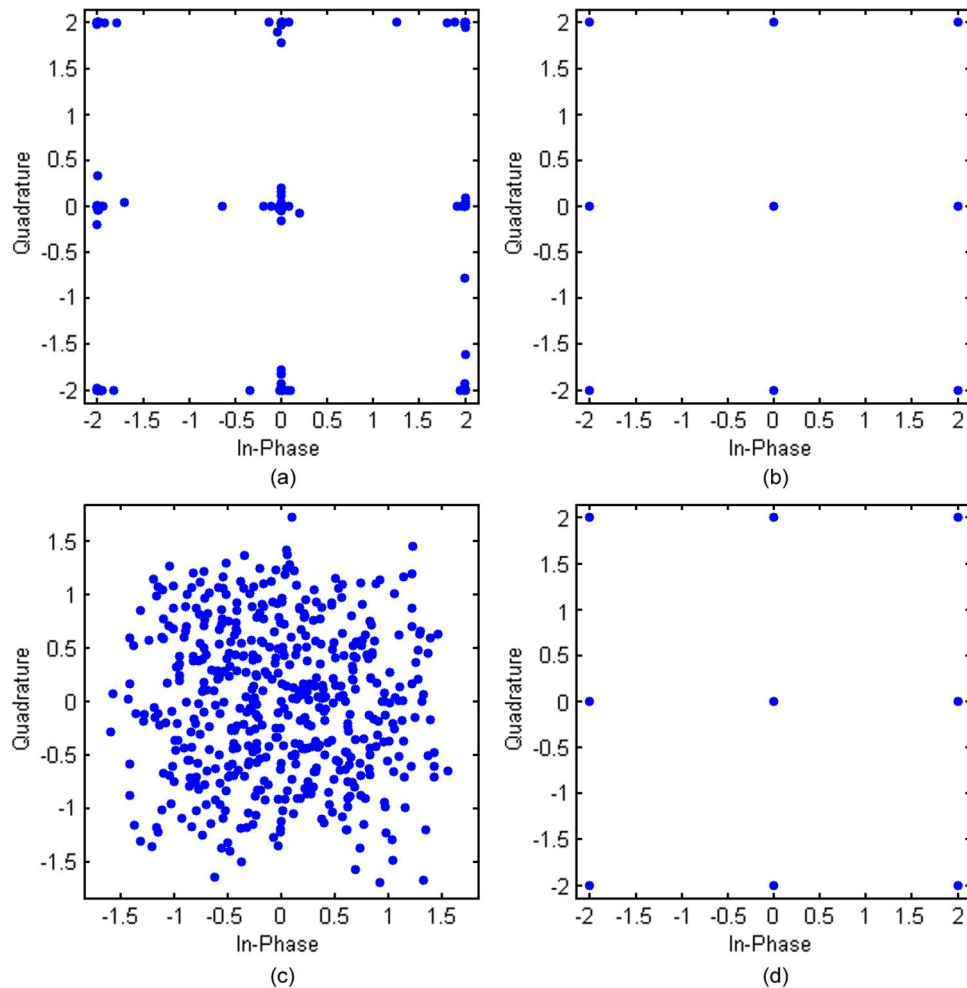

Fig. 9. Constellations of the detected information complex symbols in an OFDM–IDMA based scheme with a convolutional + repetition code. (a) From ONU #1 after six iterations. (b) From ONU #1 after 14 iterations. (c) From ONU #4 after six iterations. (d) From ONU #4 after 14 iterations.

that a received power of -13.35 dBm is needed to achieve a BER of 10^{-3}. Comparing both OFDM–IDMA and OFDMA systems, just the OFDM–IDMA scheme employing the convolutional code may present advantages with respect to the OFDMA scheme in terms of power budget. For both values

of number of iterations, the two ONUs with higher power achieve a BER of 10^{-3} improvement, which can be as high as 1.2 dBm if we consider the ONU #1 with 14 iterations. Nevertheless, the two ONUs with lowest assigned transmission powers present power penalties, which can reach a value of 1.25 dBm when considering the ONU #4 and eight iterations.

During the iterative detection in an OFDM–IDMA system, the ONU with the lowest value of transmitted power is the last one to achieve a BER of 10^{-3}. Fig. 8 shows the evolution of the BER of the ONU with the lowest value of transmitted power. Due to a higher multiuser interference power we can observe that the number of iterations at which the iterative detector converges to a BER 10^{-3} is approximately 14 for both coding schemes. In Fig. 9, the constellations of the received complex symbols after six and 14 iterations for the convolutional+repetition coded scheme and ONU #1 (highest transmitted power) and ONU #4 (lowest transmitted power). The theoretical constellations are determined by (3), that is, the constellations represent the linearly combined symbol x. After six iterations, the detected complex symbols transmitted by the ONU #1 are concentrated around their theoretical values, unlike those which correspond to ONU #4 which are rather dispersed. After 14 iterations, the complex symbols from both ONUs have adopted values around their theoretical values and which will hardly change after more iterations. A reduction in the number of operations of the overall iterative detector may thus come from the evaluation of the LLR values in the iterative process, in such a way the data from the ONUs (and layers) with higher powers is decided to be correctly detected before the maximum number of iterations is achieved. This reduction in the number of operations is very appropriate for an optical communication system, where high data rates are achieved and the data processing speed is a critical factor.

4. Conclusion

In this paper, we have proposed OFDM–IDMA as an alternative medium access technique for PONs, which rely on DSP for the mitigation of the multiuser interference. Different constituent codes have been tested and the studied $(7,5)_8$ convolutional coded OFDM–IDMA system has been proved to achieve higher performance than obtained with repetition coded system due to the higher coding gain. We have also studied the dependence of the BER with the number of iterations and observed that the computational complexity of the iterative detector may be reduced by dynamically limiting the number of iterations when a satisfactory performance has been obtained. Although the complexity of the decoding of a convolutional code is higher than that for a repetition code, we have also observed that it achieves the same system performance with lower values of received power and number of iterations. Besides, this reduction into the number of iterations yields a reduction of the global computational cost of the receiver, which is within the reasonable limits of currently available processing technology. More advanced codes than convolutional ones are envisioned to be a good alternative for its employment in OFDM–IDMA based systems to achieve better system performance and/or faster convergence to the required system performance. Due to its higher coding gain, low density parity check codes are a good alternative to achieve high values of split ratios (i.e., number of simultaneous ONUs) with low values of iterations and will be subject of further work. We also point out it may be interesting to take advantage of the unequal power distribution required in OFDM–IDMA for selective QoS policies. In comparison with OFDMA and in terms of power budget, a similar global performance is obtained only when a combination of convolutional and repetition code is employed. Furthermore, OFDM–IDMA allows the sharing of certain frequency by several ONUs for dynamic bandwidth allocation purposes.

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