

Sourceless colorless OCDMA-PONs

G. Cincotti¹, N. Kataoka², N. Wada² and Ken-ichi Kitayama³

1: Department of Applied Electronics, University Roma Tre, via della Vasca Navale 84, I-00146 Rome, Italy,
Phone: +(39)0657337399, Fax: +(39)0657337026, Email: g.cincotti@uniroma3.it

2: National Institute of Information and Communications Technology, 4-2-1, Koganei, Tokyo 184-8795, Japan.

3: Osaka University, 2-1 Yamadaoka, Suita, Osaka 565-0871, Japan.

Abstract

A new architecture for OCDMA-based PON systems is proposed, that allows contentionless, asynchronous access at 10Gb/s data rate, without using any laser source at the users' premises.

Introduction

As Fiber To The Home (FTTH) networks grow in terms of geographic reach, subscriber counts, and number of services offered, it becomes necessary to upgrade the systems, providing a larger dedicated bandwidth (100-Mb/s or more) to each user. Commercial Passive Optical Network (PON) systems have low CAPEX and OPEX costs, but the Time Division Multiplex Access (TDMA) technique requires ranging and burst control technologies, a complex algorithm for bandwidth management, clock synchronization, and fast optical signal detection. Among these shortcomings we could also add the fact that the network system is vulnerable to interference coming from rogue Optical Network Units (ONUs) and it works normally only while users do not violate the rules [1]. Furthermore, the information security of a broadcast-and-select network is unsatisfactory, and suitable electronics security algorithms should be applied to protect data confidentiality and integrity, which slow down the transmission speed.

Wavelength Division Multiple Access (WDMA) is considered a suitable method to upgrade PON systems, but it would not help in solving confidentiality problems. In addition, the lack of service and low-cost solutions, and the high-cost optical sources required in the ONUs have delayed its deployment [2].

During the last five years, Optical Code Division Multiple Access (OCDMA) systems have gained large research interest, since they provide another dimension for multiple contentionless access, beyond the time and frequency domains [3]. Upstream and downstream data are modulated according to a specific codeword assigned to each user, and all processes are implemented within the optical domain, without any Media Access Control (MAC) protocol or clock synchronization. Compared to WDMA-based systems, OCDMA-PONs make better use of the optical bandwidth, and they are more easy to reconfigure, enhancing system capacity and flexibility of the access network with respect to upgrades. In addition, OCDMA- and WDMA-based PON systems can be easily merged [4].

Recent field-trial experiments have demonstrated that OCDMA systems are extremely promising alternatives

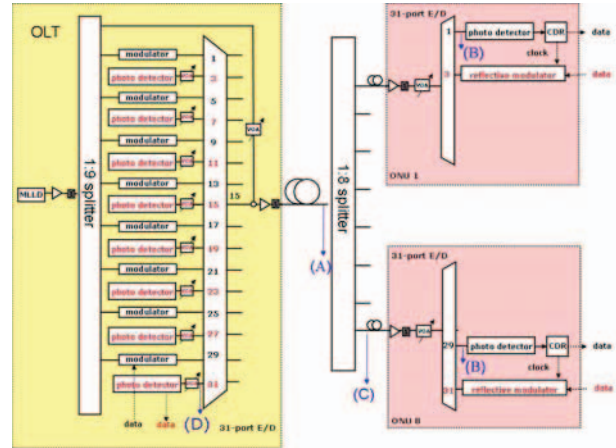


Fig. 1. Architecture of the OCDMA-PON system. In the downlink transmission (black color), optical signals at points (A) and (B) are shown in Fig. 2 and 3, respectively. In the uplink (red color), optical signals at points (C) and (D) are shown in Fig. 4 and 5, respectively.

for symmetric low-cost Gigabit access networks, with high spectral efficiency, good flexibility and enhanced security [5]. OCDMA-PON systems guarantee ultimate flexible bandwidth to each subscriber, with a high degree of information confidentiality. Full duplex asynchronous 10Gb/s transmission has been demonstrated in a OCDMA-PON with eight active users in downlink and four in uplink transmission [6].

In the present paper, we propose a novel simplified low-cost OCDMA-PON architecture that does not use any expensive laser source at the ONU, but only a reflective modulator, a single photodetector and Clock and Data Recovery (CDR), as shown in Fig. 1. At the Central Office (CO), the Optical Line Terminal (OLT) is composed of a single Mode Locked Laser Diode (MLLD), a 1:N splitter, N modulators and N photodetectors, where N is the number of active users

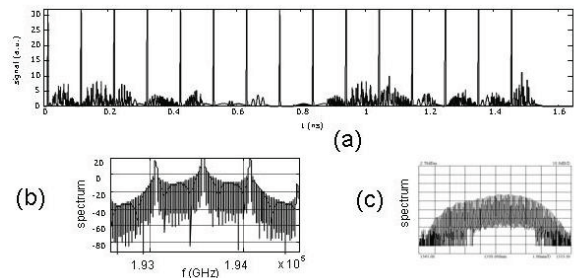


Fig. 2. [Point A of Fig. 1]: (a) 8-user OCDMA downlink transmission overlapped with the seed pulse train; (b) spectrum of the encoded signal from a single user; (c) spectrum of the seed pulse train.

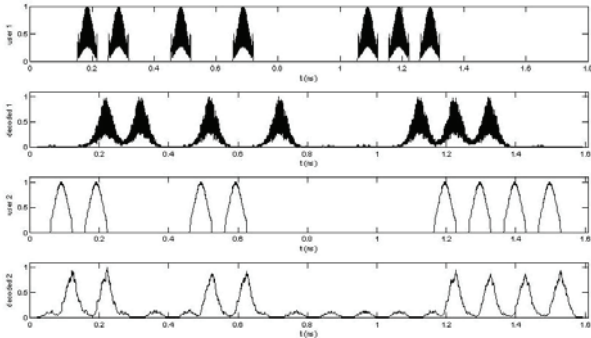


Fig. 3. [Point B of Fig. 1]: Encoded and decoded downstream signals at two ONUs.

($N=8$ in Fig. 1). Two codes (i.e. two outputs of a multiport encoder/decoder (E/D)) are assigned to each user, for downstream and the upstream transmission, respectively. For the downstream link, the output from the MLLD is distributed over 8 users, and is independently modulated at 10 Gb/s; data from each user is sent to different inputs of the multiport E/D. In this numerical simulation, we used a 31-port E/D that is able to generate/process simultaneously 31 different optical codes; however, to guarantee sufficient orthogonality among the codes, only the odd ports of the E/D have been used for the uplink and downlink transmission of $N=8$ users. A pulse train at 10 GHz repetition rate is transmitted at the same time, overlapping with the OCDMA downlink signal, that will be used at the ONUs for the uplink transmission.

Each user in the OLT transmits asynchronously with respect to all the others users and the pulse train; the ratio between the amplitudes of the seed pulse and the encoded signal is a key design parameter, that can be tuned using a Variable Optical Attenuator (VOA) in the CO. We note that the VOAs at each ONU are used to compensate different length reach, but do not affect the value of this parameter.

At each ONU, we obtain the autocorrelation signal at the E/D outputs that have been used to encode data in the OLT; the downstream signal is correctly detected, because the autocorrelation signal can be easily distinguished from the crosscorrelation signals and the codes generated by the seed pulse train, as shown in Fig. 3. Since a single MLLD is used to generate both the downstream OCDMA signal and the pulse train, the clock extracted by the CDR at the ONU in the downlink is also used to time the upstream transmission. At the E/D outputs that have not been used for the downstream signal, we obtain a crosscorrelation signal, which is very small, and the codes generated by the pulse train. This signal is data modulated for the upstream transmission, by using a reflective modulator, and it is sent back to the E/D. Finally the upstream signals from all the ONUs are combined together by the splitter and sent back to the CO, where they are decoded by the multiport E/D and photodetected. The upstream signal encoded at two ONUs and decoded at the OLT are shown in Fig. 4 and 5, respectively, and we observe that the multiple access

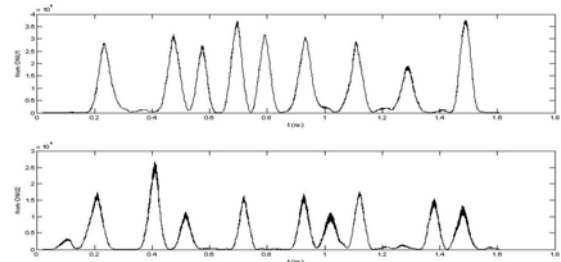


Fig. 4. [Point C of Fig. 1]: Encoded upstream signals at two ONUs.

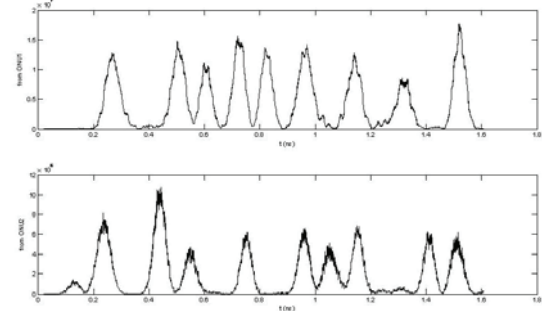


Fig. 5. [Point D of Fig. 1]: Decoded upstream signals at the OLT.

interference (MAI) noise is very small both in the downlink and the uplink signal. The key parameters of the proposed scheme are the ratio between the auto- and cross-correlation peaks and the code length that corresponds to the number of device ports. The latter parameter allows us to distinguish the autocorrelation signals from the codes generated at the ONUs.

Conclusions

We have proposed a novel efficient low-cost PON system based on optical codes that allows subscribers to asynchronously access the network, at high bit rates. The main advantage with respect to other OCDMA-based systems is that the proposed scheme does not require any source at the ONU, reducing equipment cost. In addition, the ONU receivers are identical (colorless), which is one of the key requirements from network operators.

Acknowledgment

The work described in this paper was carried out with the support of the BONE-project ("Building the Future Optical Network in Europe"), a Network of Excellence funded by the European Commission through the 7th ICT-Framework Programme.

References

1. J. Prat et al., *Fiber-to-the-Home Technologies*. Boston, MA: Kluwer, 2002.
2. A. Banerjee et al., *J. Opt. Netw.*, 4 (2005), pp. 737.
3. S. Galli et al., *IEEE OFC (2005) Anaheim US*.
4. X. Wang et al., *IEEE OFC (2007) Anaheim US*, postdeadline.
5. N. Kataoka et al., *J. Lightwave Technol.*, 27, (2009), pp. 299.
6. N. Kataoka, et al., *Conference on Optical Network Design and Modelling (ONDM) (2009)*, Braunschweig, Germany.