Perspectives of optical coding/decoding techniques in OCDMA networks

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Abstract: We review the research activities carried out during the past five years over OCDMA systems, that make a versatile use an innovative cost-effective multiport encoder/decoder to generate and process simultaneously optical codes.

OCIS codes: (060.2330) Fiber optics communication; (060.4230) Multiplexing; (999.9999) Optical code division multiple access

1. Introduction

The recent developments in optical code division multiple access (OCDMA) networks have been characterized by significant technological advances and the data bit rate, the spectral efficiency and the number of simultaneous users in laboratory experiments has exponentially increased during the last decade. Similar to Wavelength Division Multiplexing (WDM), OCDMA technology is an excellent solution to upgrade existing networks, allowing independent data rates and formats; furthermore, OCDMA systems have the additional advantages that they generally do not require multiple or tuneable laser sources, and the system bandwidth occupancy is independent from the number of simultaneous users, whereas adding WDM channels often requires an enlargement of the amplifiers bandwidth. In the access infrastructure, OCDMA-based passive optical networks (PON) have proven to be a suitable technology for next-generation access networks (NGAN), where a logical point-to-point (P2P) link is established by assigning a codeword to each end user.

In this paper, we review the main research results achieved during the last five years, using an innovative multiport encoder/decoder (E/D) that has the unique capability to generate and process a large number of optical codes.

2. OCDMA and hybrid WDM-OCDMA experiments

The information capacity of an OCDMA-based system, can be evaluated as [1]

$$C = N \cdot B\left[1-\log_2\left(1+e^{-SNR}\right)\right] \tag{1}$$

where N is the number of simultaneous users, B the data bit rate, and the signal to noise ratio (SNR) takes the multiple access interference (MAI) noise into account. In all the experiments, the user bit rate has been set to 10 Gb/s (10.71 Gb/s when the forward error control (FEC) has been used); the theoretical curve plotted in Fig. 1 represents the system capacity, when the SNR is the ratio between the auto- and cross-correlation signals.

In a first set of experiments, we used a 16-port E/D to encode/decode data signals from 12 asynchronous users, using FEC, with an aggregate capacity of 120 Gb/s, [2]. The same device has been used to transmit 8 users using differential phase shift keying (DPSK) modulation, with a total capacity of 80 Gb/s [3].

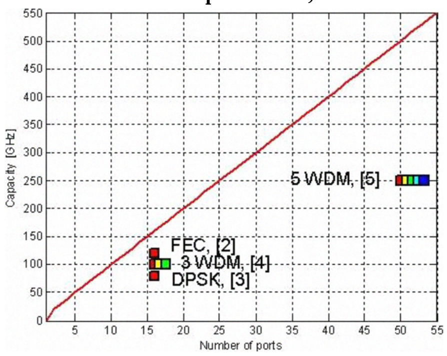

Fig. 1: OCDMA channel capacity

To further increase the link capacity, we made a combined use of WDM and OCDMA techniques: three OCDMA-encoded DPSK signals from 10 users have been multiplexed over three wavelength channels and transmitted in a truly asynchronous way, over a 100 km installed fiber [4]; the total capacity was 3 X 100 Gb/s, with 0.27 bit/s/Hz spectral efficiency. Later, the world-record overall transmission capacity of 1.24 Tb/s has been achieved using a 50-port E/D, in a field-trial experiment: 5 WDM wavelengths were used, each of them carrying a 25-user OCDMA asynchronous signal; the spectral efficiency was 0.41bit/s/Hz [5].

3. M-ary OCDMA systems

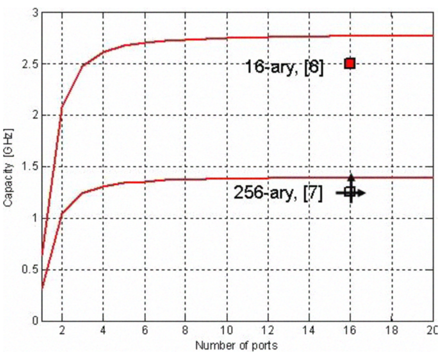

Fig. 2: M-ary OCDMA channel capacity

In a M-ary OCDMA transmission, a set of M codewords is assigned to a single user to encode blocks of $\log_2 M$ bits of a message; the upperbounds of the transmission capacity, evaluated according to the Shannon-Hartley formula, are plotted in Fig. 2, considering symbol rates of B=311.0 MHz and B=622.08 MHz, respectively. We have experimentally demonstrated a 2.5 Gbit/s, 16-ary OCDMA transmission over a 50 km fiber with true clock recovery [6]; the transmitter implements the cipher block chaining (CBC) encryption in the optical domain, and it has a very high degree of data confidentiality. In another set of experiments, we reduced the bit rate down to B=311.04 MHz, and used polarization multiplexing to transmit a 2 X 1.25Gbps 256-ary CDMA signal [7].

4. OCDMA-based PONs

The multiport encoder/decoder can be used in the optical line terminal (OLT) of a OCDMA-based PON central office; this configuration reduces the system costs, as a single device is used to multiplex/demultiplex both downlink and uplink streams. On the other hand, at the user's premise, is more convenient to use a fiber Bragg grating (FBG) E/D, that is compact, polarization independent and low cost for mass production, and presents code-length independent insertion loss. We have experimentally demonstrated a full-duplex asynchronous OCDMA transmission of 8 uplink and 8 downlink users at 10 Gb/s on the same wavelength, using both 16-port and FBG E/Ds [8].
On of the main challenge in the evolution of the NGAN is the development of 'sourceless' (without a laser source) and 'colorless' (non specific) optical ONUs. For first time, a full-duplex, asynchronous, 10-Gbps OCDMA system has been realized on the same wavelength, in a 'colorless' and 'sourceless' configuration, using a DPSK modulation and a 31-port E/D. In this case, the ONU is composed only of a DPSK receiver for the downstream signal, and a phase modulator that that re-modulates a 10 Gb/s seed pulse train transmitted from the OLT, to generate the uplink data stream.

4. Conclusions

We present a review of the recent research activities on OCDMA systems, that use a single multiport device to encode/decode data from asynchronous users.

Acknowledgments

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6. References

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