WDM-IDMA Solution for NG-PON2 Enabled by Coherent Technology and Colorless ONUs

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***Abstract*—We propose a novel hybrid solution for NG-PON2 combining wavelength-division multiplexing (WDM) and interleave-division multiple-access (IDMA). Results demonstrate the uplink transmission supporting more than 90 colorless ONUs at 1.25 Gb/s each over 100 km reach.**

I. Introduction

The explosive growth in the bandwidth demand pushes current passive optical networks (PONs) to their maximum capacity. Hence, introducing a new generation of PONs is inevitable. In the last few years, next generation PONs stage 2 (NG-PON2) has been introduced as the up-coming technology enabling a further bandwidth increase and able to solve the issues encountered in the 1G and 10G PON technologies [1]. According to NG-PON2 recommendation [2], operators' requirements are at least 40 Gb/s aggregate rate in uplink and downlink directions, 40 km reach, 1:64 split ratio, and at least 1 Gb/s access rate per optical network unit (ONU). Several solutions have been proposed in literature for NG-PON2, e.g., time-division multiplexing (TDM), wavelength-division multiplexing (WDM), orthogonal frequency-division multiplexing (OFDM), and hybrid time/wavelength-division multiplexing (TWDM) [3], [4]. Among these technologies, TWDM approach has been chosen as the primary solution to NG-PON2 [1], [2].

In this paper, we propose another possible solution for NG-PON2 demonstrating the uplink scenario using colorless ONUs. Our approach combines interleave-division multiple-access (IDMA) and WDM. Similar to TWDM-PON, different WDM channel pairs are used, but user separation on each channel is rendered using IDMA instead of TDM. We choose IDMA to replace TDM as it shows a superior performance over TDM in 10G PON systems in many aspects [5]. The proposed solution benefits from the coherent technology in the uplink direction, and uses colorless ONUs with tunable optical band pass filters (OBPFs) [6].

II. Proposed WDM-IDMA uplink architecture

The proposed uplink architecture of WDM-IDMA is shown in Fig. 1. First, the uplink carrier is generated at the optical line terminal (OLT), and then transmitted towards the ONUs through the feeder fiber. A bidirectional Erbium doped fiber amplifier (EDFA) for PON reaches exceeding 20 km is added to compensate for the additional losses. After the remote node (RN), each ONU selects its corresponding carrier using a tunable OBPF to achieve colorless operation. The carrier signal is then passed to the IDMA transmitter consisting of: spreading with repetition code, user specific interleaving, quadrature phase shift keying (QPSK) mapping, and optical carrier IQ modulation. Signals from different users are combined at the remote node and passed to the OLT through the feeder fiber. At the OLT side, an arrayed waveguide grating (AWG) separates the wavelengths and passes IDMA signals having the same wavelength to their corresponding IDMA receiver. The IDMA receiver consists of: QPSK coherent detection, electronic dispersion compensation, soft QPSK demodulation, and the iterative decoding. The iterative receiver is a turbo type receiver that is capable of decoding all signals simultaneously from the combined received signal of all users. The details of the iterative decoder are omitted here, but detailed in [5], [7].

III. Performance of the proposed WDM-IDMA PON

In this section, we report the performance of the proposed uplink scenario in Fig. 1 through a Matlab/Optisystem co-simulation. In our simulation, we use 16 chips common spreading sequence for all users on each wavelength carrier. The maximum chip rate is set to 10 Gchips/s per wavelength. Also, the local oscillator power at the OLT is set to 5 dBm and the iterative decoder iterations are set to 10 as in [7]. All noise effects are considered in our simulation (i.e., shot noise, thermal noise, and amplifier noise). The dispersion is electronically compensated before the iterative decoder. Finally, we consider $3.8\text{x}10^{-3}$ bit error rate (BER) forward error correction (FEC) threshold.

Fig. 2a shows the BER performance of a 64 users WDM-IDMA PON versus launch power for 20, 100, and 150 km reaches. It is observed that WDM-IDMA have a good performance at a relatively low launch power of nearly -13 dBm. Also, increasing the launch power ameliorates the BER performance till reaching high power levels, where the non-linearity contribution is not anymore negligible, and the BER performance is thus degraded. This explains the U-shaped trends of the curves. At 20 km PON reach, the launch power operating region, where the BER is below the FEC threshold, extends from -13 dBm to 1 dBm (i.e., 14 dB power range). Increasing PON reach to 100 km is translated to a decrease in the power range to 10 dB due to the added non-linear effects

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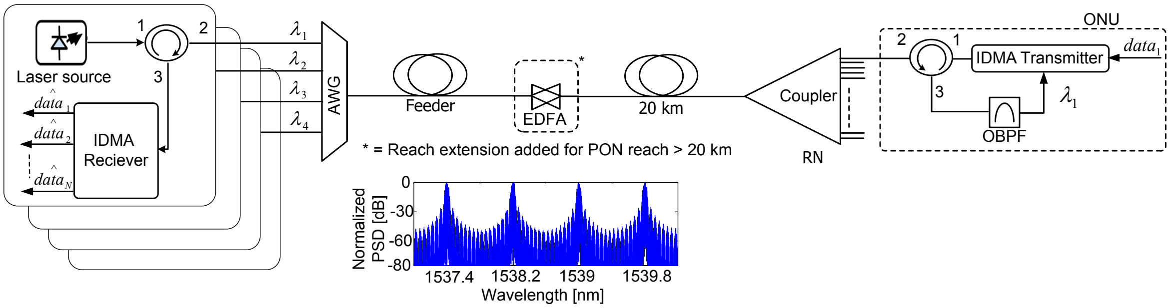
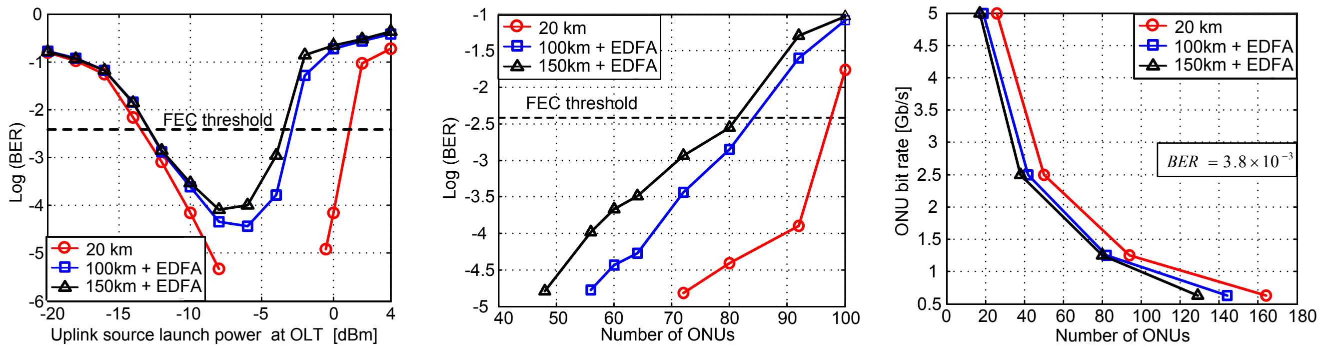


Fig. 1. Uplink architecture of the proposed WDM-IDMA PON. Normalized power spectral density (PSD) of the received signal is inset, where four wavelength carriers with 100 GHz separation are used.



(a) BER performance comparison for a 64 users WDM-IDMA PON over different PON reaches.

(b) BER versus the number of ONUs at −5 dBm launch power.

(c) ONU bit rate versus number of ONUs at −5 dBm launch power.

Fig. 2. Uplink performance of the proposed WDM-IDMA coherent PON.

of the increased 80 km in both directions and amplifier noise. Also, it is observed that there exists an optimal power point near −5 dBm for BER performance for the three PON reaches.

The BER performance versus number of ONUs accommodated at 1.25 Gb/s each is shown in Fig. 2b for different PON reaches. This figure shows the major advantage of WDM-IDMA over the TWDM technique, where the number of ONUs accommodated can be significantly increased at the same bit rate. For example, for a 64 split TWDM system the number of ONUs is limited to 64 ONUs at the same bit rate. On the other hand, for WDM-IDMA with 16 chips spreading code on each carrier (64 equivalent), the number of ONUs can reach more than 96 users at 1.25 Gb/s bit rate. Also, it is observed that increasing the PON reach corresponds to a decrease in the number of ONUs, however, this decrease is minimal compared to the gained PON reach. For example, increasing PON reach to 150 km, results in a decreased number of users to 81 users (i.e., 15 users less than 20 km reach scenario).

Fig. 2c outlines the trade off between increasing ONU bit rate and increasing number of ONUs. We vary the length of the spreading codes from 4 to 32 chips for each wavelength, either to accommodate more users (long spreading code) or to achieve higher bit rate (short spreading code). For example, WDM-IDMA can accommodate more than 160 ONUs over 20 km at 625 Mb/s, or achieve a 5 Gb/s rate and only limited to 26 ONUs.

IV. Conclusion

We present WDM-IDMA hybrid solution for NG-PON2 enabled by colorless ONUs and coherent technology. Performance of the proposed system is evaluated under different scenarios. Results reveal that WDM-IDMA can accommodate more than 80 users over 150 km reach at 1.25 Gb/s. These results are achieved while moving complexity to the OLT and employing colorless ONUs. Hence, WDM-IDMA can be considered as a promising candidate for long reach NG-PON2 with high capacity, high ONU bit rate, and low launch power.

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