Simultaneous Triple Data Transmissions on A Single Wavelength

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Abstract: *We propose and experimentally demonstrate a novel low-cost optical access network providing bidirectional data transmissions and a broadcast service simultaneously with a single wavelength. All these services are provided through the same fibre link.*

Introduction

Today, substantial research efforts have been placed on providing multiple data transmissions using a single wavelength[1-4] since it can significantly increase the wavelength utilization. For example, payload and label can be simultaneously modulated on one wavelength using orthogonal data formats[1,2]. The same method has also been reported in wavelength division multiplexed passive optical networks (WDM-PONs) to offer bidirectional transmissions[3,4] and broadcasting services[5].

Recently, we have proposed a WDM-PON to provide simultaneous downlink and uplink transmissions with a single wavelength[6]. In this scheme, the downlink and uplink data are carried on optical subcarriers and optical carriers, respectively. As a result, the modulation bandwidth of each downlink modulator has to be much larger than its data rate due to the subcarrier modulation.

In this report, we newly propose a novel low-cost WDM-PON architecture with simultaneous downlink, uplink and broadcast data transmissions on a single wavelength. Here the 10-Gb/s NRZ-OOK downlink data is modulated with a simple baseband modulator. The 1.25-Gb/s broadcasting data is carried on 20-GHz subcarriers and 1.25-Gb/s uplink data is remodulated on the broadcast signal with a reflective semiconductor optical amplifier. Only 0.3-dB power penalty is observed for downlink signal due to the crosstalk from broadcast.

Proposed WDM-PON Architecture

The proposed asymmetric WDM-PON architecture is shown in Fig. 1. At the central office (CO), the WDM light source is split into two parts. One part is used for individual downlink baseband data modulation. The other part is sent to a broadcast Mach-Zehnder modulator (MZM). A broadcast data mixed with a high frequency clock signal f_c is used to drive the broadcast MZM. The MZM is biased at null point to eliminate the optical carrier. For the purpose of uplink remodulation, the extinction ratio of broadcast signal is set to about 3 dB. The multichannel downlink signals and broadcast signals are then combined and amplified to be as the downstream light. Since the downlink data and broadcast data are separately modulated on optical carrier and subcarrier parts, the crosstalk between them[7] should be quite smaller than the previous scheme in [6].

The downstream light is sent to remote node (RN) via a piece of single mode fibre. At the RN, the downlink signal and broadcasting signal located at optical carriers and subcarriers, respectively, are separated by a interferometric filter (IF) with a free spectral range (FSR) of $2\times f_c$. The separated downlink signals and broadcasting signals are then launched into an N×N cyclic arrayed waveguide grating (AWG) from the input ports of 1 and (N/2+1). Due to the cyclic property of the AWG, a downlink signal appears at each output port together with a broadcasting signal, which is located at a wavelength with a distance of half of the AWG's FSR.

At each optical network unit (ONU), the downlink signal and broadcasting signal are separated with a coarse WDM coupler. The downlink signal is then detected with a baseband photodetector. While, the broadcasting light is split into two parts, one for data detection and the other for uplink modulation. A reflective semiconductor optical amplifier (RSOA) is used to erase the broadcasting data and remodulate the uplink data. The uplink signal is then sent back to the CO via the same fibre link and a circulator for uplink detection. As a result, each wavelength channel simultaneously carries three kinds of data, i.e. broadcast, downlink and uplink. This not only increases the wavelength utilization, but also eliminates the requirement of the light source in each ONU to reduce the deployment cost and facilitate the wavelength management and maintenance.

For the proposed scheme, the downlink is transparent to the data format. In this report, a 10-Gb/s non-return-to-zero (NRZ) signal was used as downlink signal. For both broadcasting and uplink signals, the bit rate was 1.25 Gb/s. A delay interferometer (DI) with an FSR of 40 GHz was used to separate the downlink and broadcasting signals. And a 32×32 AWG was employed for wavelength routing. The RSOA was biased with a current of 75

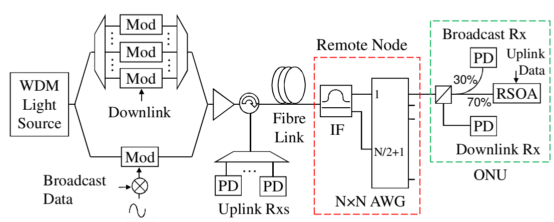

Fig. 1 Proposed WDM-PON architecture

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mA and its seeding power was about -8 dBm. The fibre link was 15-km single mode fibre.

Experimental Results and Discussions

The optical spectra of broadcast and downlink before and after combing have been shown in Fig.2(a). Although the broadcasting data and downlink data are modulated at the same light source, the mainly power of these two signals are located at different wavelength. In this experiment, the optical carrier to subcarrier ratio (OCSR) of broadcasting light was suppressed to nearly -20 dB. As a result, these two signals can be transmitted through the same fibre without significant crosstalk. After separating with the DI, the downlink and broadcasting signals are shown in Fig.2(b). Here, the OCSRs of broadcast and downlink are -14 dB and 22 dB, respectively.

The eye diagram of broadcasting signal is shown in Fig.3(a). The extinction ratio is about 3 dB. At each ONU, broadcasting signal is split by a 30:70 fibre coupler. The major power is launched into the RSOA as a seeding light. Due to the saturation effect of the RSOA, the data is removed as shown in Fig.3(b). The uplink eye diagram is also shown in Fig3(c). In most published work, the SOA is used to remodulate a data with lower bit rate on a signal with higher bit rate[3-4]. Our experimental result shows that the RSOA can also effectively remodulate the seeding light, even the data rate is same before and after remodulation.

The measured bit error rate (BER) performance is shown in Fig.4. Here, the back to back (BTB) receiver sensitivity with a BER of 10^{-9} for broadcast is -29.85 dBm. After downstream transmission, the receiver sensitivity is -28.7 dBm. To evaluate the effect of the crosstalk from the downlink signal, we also measured the BER curve without downlink signal. As shown in Fig.4, the power penalty introduced by the downlink

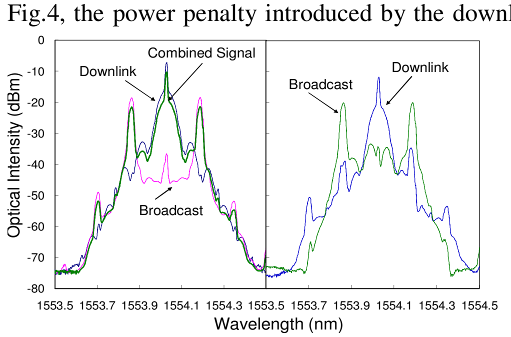

Fig.2 Optical spectra of broadcasting and downlink signal before combing (a), and after separating (b).

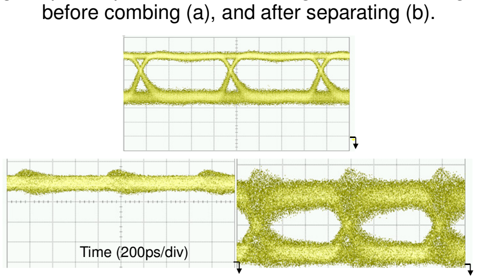

Fig. 3 Measured eye diagrams of broadcasting signal before erasing (a), after erasing (b), and uplink signal (c).

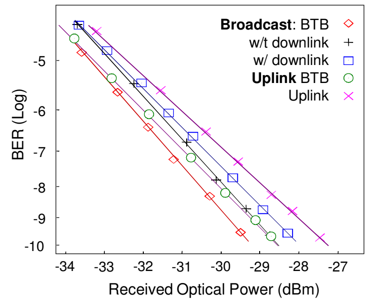

Fig.4 Measured BERs of broadcasting and uplink signals.

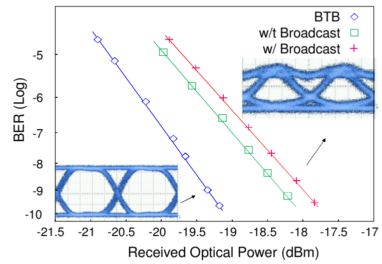

Fig. 5 Measured 10-Gb/s downlink BERs

signal is only about 0.45 dB. The authors believe that using an optical interleaver with flat top instead of a DI can further reduce this power penalty. Fig.4 also shows the BERs of the uplink signals. After remodulation, the BTB receiver sensitivity is -29.25 dBm. While after the upstream transmission, the receiver sensitivity becomes -28 dBm.

Fig.5 shows the measured 10-Gb/s downlink BERs. The receiver sensitivities for the case of BTB, uplink transmission without broadcasting signals and with broadcasting signals are -19.35 dBm, -18.3 dBm and -18 dBm, respectively. In this experiment, both broadcasting data and uplink data are carried on the optical subcarriers, while downlink data is carried on the optical carrier. As a result, the BER performance of the downlink is comparable with the case without broadcast and uplink remodulation. The power penalty introduced by the broadcasting signal is only 0.3 dB in this experiment. The eye diagrams of downlink are shown in the insets of Fig.5.

Conclusions

A novel WDM-PON architecture has been demonstrated, where all 10-Gb/s downlink data, 1.25-Gb/s uplink data and broadcasting data are carried on a single wavelength channel simultaneously. The power penalties of 0.45 dB and 0.3 dB have been observed for broadcasting and downlink signal, respectively, due to the crosstalk from each other.

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