A WDM-PON with 10-Gb/s Symmetric Bit-Rates and Multicast Overlay with Delay-based Multicast Control

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Abstract: We propose and experimentally demonstrate a WDM-PON with 10-Gb/s IRZ downstream point-to-point signals, 10-Gb/s DPSK downstream multicast signals, and 10-Gb/s NRZ upstream signals. The multicast control is achieved by simple electronic synchronization adjustment.

OCIS codes: (060.2330) Fiber optics communications; (060.4255) Networks, multicast.

1. Introduction

The wavelength-division-multiplexed passive optical network (WDM-PON) is a promising technology for the next-generation access networks. To realize more flexible network functions, several studies [1-5] have been carried out to simultaneously deliver both point-to-point data and broadcast/multicast data to subscribers. The multicast feature is more attractive, compared to broadcast, as it allows selective control of the connection for each user individually. Subcarrier multiplexing could be employed to transmit these services. However, such a solution required high-frequency (around 5-10 times the bit rate of the baseband signal) electronic components at the transmitter and/or receiver sides [1-3], which is not cost-effective and has limited transmission bit rate for the baseband signals (less than 1.5 Gb/s was demonstrated). Recently, two schemes were proposed to superimpose a 10-Gb/s multicast data stream on the conventional 10-Gb/s downstream point-to-point data service [4,5]. As the upstream transmission was realized by remodulating part of downstream NRZ using a high extinction ratio, the bit rate of the upstream signals was limited to 2.5-Gb/s [5]. With the surge of peer-to-peer applications, symmetric bit rates in both upstream and downstream are highly desirable for a future-proof PON system.

In this paper, we propose a novel scheme to realize 10-Gb/s symmetric uplink and downlink bit rates and 10-Gb/s multicast overlay with simplified control for multicast service. The multicast data encoded in DPSK format is superimposed onto all point-to-point data channels modulated in inverse return-to-zero (IRZ) format. By adjusting the synchronization of the DPDK/IRZ orthogonal modulation, simple and flexible multicast operation could be realized. It should be noted such synchronization control is also required in [3-5]. The upstream transmission can be realized by remodulating part of the downstream IRZ signal that has optical power in each bit. The scheme requires no adjustment on extinction ratio as in [3,4].

2. Proposed system architecture and multicast control

Fig. 1 shows the proposed WDM-PON architecture with symmetric bit rates and multicast overlay. At the OLT, the IRZ-shaped data signal is first generated via a commercial logic NAND gate and then used to drive an optical intensity modulator (IM) to generate the downstream point-to-point IRZ signal of each wavelength channel. All the downstream signals at the OLT are wavelength-multiplexed by an arrayed waveguide grating or its equivalent. The multiplexed signals are first amplified and then fed into an optical phase modulator (PM) which is driven by the precoded multicast data. By properly aligning the multicast DPSK data to the high-intensity level period in each IRZ bit at the PM, the multicast DPSK data can be properly demodulated and detected at the ONU. In contrast, by aligning the DPSK data to the IRZ dips, the multicast DPSK will suffer from excessive intensity fluctuation and thus cannot be properly demodulated at the ONU. In this way, multicast control can be achieved by the delay control of the multicast signal before being superimposed to the point-to-point IRZ signal. At an ONU, a portion of the received downstream signal power is tapped off for reception while the remaining is fed into an optical IM for upstream data remodulation, which can be regarded as NRZ/IRZ orthogonal modulation. Similar with the multicast transmission enabled case, proper synchronization of the NRZ/IRZ orthogonal modulation should be guaranteed to realize symmetric bit rate between the up- and downlinks.

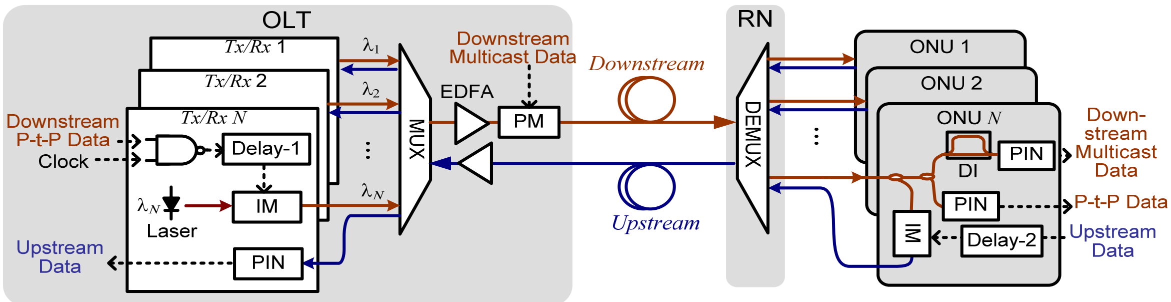

Fig. 1. Proposed WDM-PON architecture with symmetric bit rate and multicast overlay. P-t-P Data: point-to-point data.

3. Experimental demonstration

We have experimentally demonstrated the proposed WDM-PON architecture based on the setup shown in Fig. 1. At the OLT, a continuous-wave light source at 1547.8 nm was IRZ modulated by an IM with a 10-Gb/s 2^{31}-1 pseudorandom binary sequence (PRBS). The resultant output pulse width was 55 ps and was amplified by an erbium-doped fiber amplifier. Since only one channel was investigated, we did not use AWG in experiment, but an optical bandpass filter (OBF) with a 3-dB bandwidth of ~0.8nm and an insertion loss of 2.1 dB was used to emulate one channel of a 100-GHz AWG and to suppress the amplified spontaneous emission (ASE) noise. After power amplification and filtering, the WDM point-to-point signals were fed into a PM driven by a 10-Gb/s PRBS as the precoded broadcast data. Then the orthogonally modulated signal with an average power of 5 dBm was coupled into a 20-km dispersion-shifted fiber to emulate the downstream transmission link with dispersion compensation. For cost-effective purpose, we could place one common broadband dispersion-compensating module shared by all the downstream channels at the OLT to compensate the average dispersion experienced by all ONU's. At the ONU, the received downstream signal power was divided into three portions by two 3-dB optical power splitters. One quarter of the received downstream signal power was fed into a photodiode for IRZ detection. Another quarter was demodulated by a delay interferometer (DI) with a relative delay of 94.3 ps for DPSK detection. The remaining half of the power was fed into an optical IM, driven by a properly delayed 10-Gb/s 2^{31}-1 PRBS as the upstream data, before being transmitted back to the OLT, via another piece of 20-km dispersion-shifted fiber.

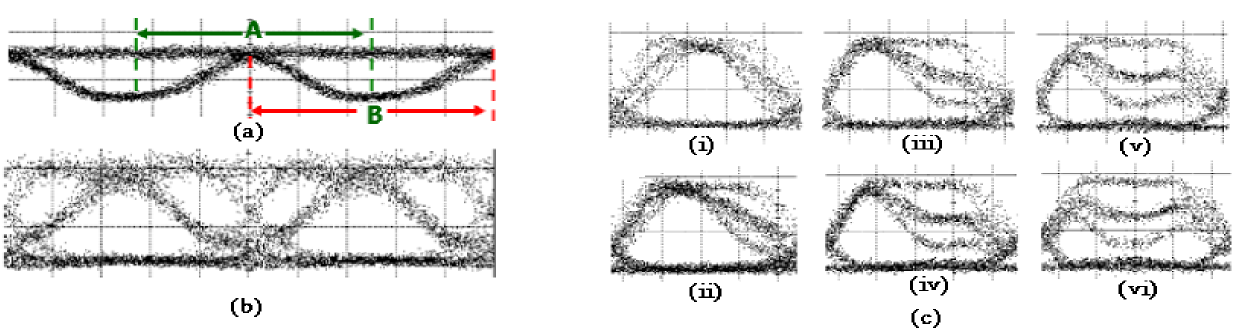

Fig. 2. Eye diagrams of (a) the detected 10-Gb/s downstream point-to-point data signal in IRZ format, (b) the detected upstream signal with proper delay at Delay-2, (c) (i) – (vi) the 10-Gb/s demodulated DPSK multicast signal with relative delay adjusted from 0 to 50 ps with a 10-ps step, Time scale: 20 ps/div.

. When the multicast was enabled, the synchronization of the DPSK/IRZ orthogonal modulation should be carefully adjusted via Delay-1 at OLT as shown in Fig. 1, such that each bit of the DPSK data could be superimposed right in the middle of two adjacent IRZ pulses as denoted by 'A' in Fig. 2(a), in which the longest period of high intensity level resides. The superimposed DPSK multicast data was detected at the ONU, which showed a clear eye diagram as Fig. 2(c)(i). The uplink data was measured with the eye-diagram shown in Fig. 2(b). To show the effect of relative delay on multicast control using electronic delay circuit (Delay-1), the eye diagrams for different relative delays are depicted in Fig. 2(c)(i)-(vi), and the increasing degradation by the delay adjustment was shown clearly. When the synchronization of the DPSK was detuned by 50 ps to the period 'B' in Fig. 2(a), the superimposed DPSK multicast data could not be detected successfully at the ONU. The performance of downstream point-to-point signals, downstream multicast signals, and upstream signals depended on both the extinction ratio and the duty cycle of the IRZ signal. Tradeoff should be considered when choosing these two values, which were around 4.5 dB and 50%, respectively, in this experiment.

The BER measurement results are shown in Fig. 3. After 20-km transmission, for the downstream point-to-point and multicast enabled signals, negligible power penalty was observed. For the upstream signals, less than 0.5-dB power penalty, mainly due to the degraded waveform, was observed. When multicast was disabled, the multicast DPSK signal suffered from an error floor.

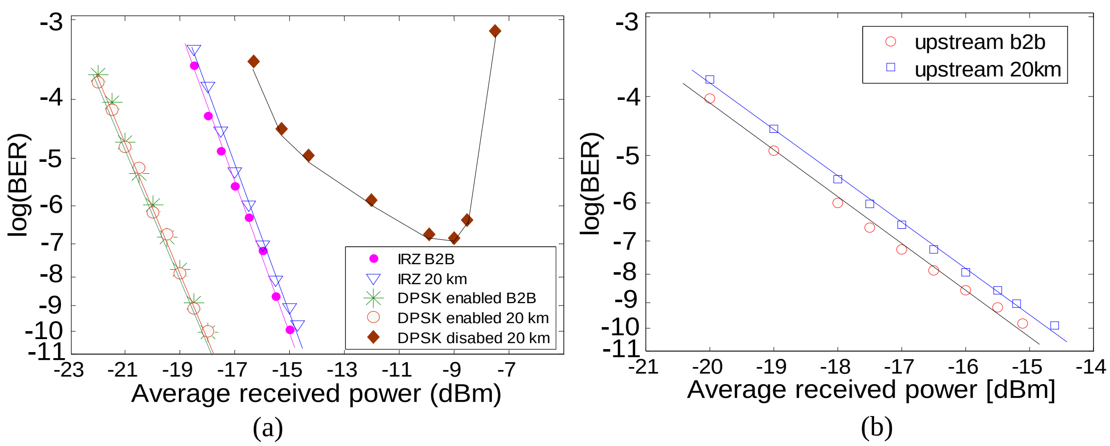

Fig. 3. BER curves: (a) downstream point-to-point signals and multicast signals ; (b) upstream signals.

4. Conclusions

We propose a novel WDM-PON architecture to provide symmetric bit rates and multicast overlay based on DPSK/IRZ, NRZ/IRZ orthogonal modulation and synchronization control. Experimental demonstration of downstream point-to-point signals, downstream multicast signals, and upstream signals, all at 10 Gb/s, are achieved with the power penalties less than 0.5 dB for all signals after 20-km transmission. This work is supported in part by RGC GRF CUHK411006 and RGC GRF CUHK4105/08E

5. References

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