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A WDM-PON Optical Multicast Overlay Scheme Using Inverse-RZ-Duobinary Signal

Zhixin Liu*, Yang Qiu, Jing Xu, Chun-Kit Chan and Lian-Kuan Chen

Department of Information Engineering, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong SAR, China.
Tel: +852-2609-8385, Fax: +852-2603-5032, Email:zxliu@cuhk.edu.hk

Abstract: We propose and demonstrate optical multicast overlay on WDM-PON employing bandwidth efficient Inverse-RZ-duobinary signal. Multicast overlay control is realized by tuning the bias at the point-to-point downstream modulator at the OLT.

OCSI codes: (060.2330) Fiber optics communications; (060.4080) Modulation; (130.6750) Systems

1. Introduction

Wavelength-division-multiplexed passive optical network (WDM-PON) is an attractive candidate solution to provide triple play services including video, data and voice [1]. In order to enable more flexible data delivery, a robust network architecture which can support simultaneous point-to-point (PtP) data as well as multicast data transmissions is highly desirable. Some schemes have been proposed [2-4]. Early work [2] realizes multicast overly by means of subcarrier multiplexing. However, such a technique required high-frequency electronic components at both the transmitter and receiver sides. Orthogonal modulation schemes in [3] demands Mach-Zehnder delay interferometer (MZDI) to demodulate the phase-shift keying multicast signal at the optical network unit (ONU) side. Another recent scheme [4] employs intensity format to transmit multicast and PtP data in one symbol, but the receiver sensitivity is low due to the small eye opening and 3-level detection.

In this paper, we employ optical Inverse-RZ-duobinary format to transmit both PtP and multicast data in a WDM-PON. Multicast control is realized by adjusting the bias of the PtP modulator. By combining the Inverse-RZ and duobinary coding together, the system can simultaneously transmit B Gbit/s PtP signal and B Gbit/s multicast signal with B GHz bandwidth. The dispersion tolerance can be improved due to the improved spectral efficiency. At the optical network unit (ONU), a single B GHz photo detector with two decision modules is required to receive PtP and multicast data, which provide the system with low-cost and colorless ONUs. 5-Gbit/s operations for all kinds of traffic have been experimentally demonstrated

2. WDM-PON with proposed optical multicast overlay

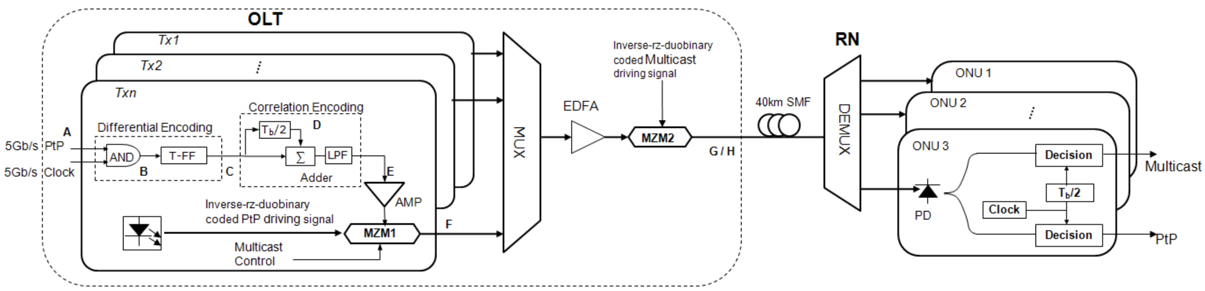

Fig.1 Schematic diagram of the proposed WDM-PON with proposed optical multicast overlay.

Fig. 1 depicts the architecture of the proposed WDM-PON. At the OLT side, wavelengths from different transmitters are firstly modulated with their respective Inverse-RZ-duobinary coded downstream PtP data. Then the downstream signals are multiplexed via an arrayed waveguide grating (AWG) and amplified before fed into the multicast transmitter (MZM2 in Fig.1), where the multicast data is modulated in Inverse-RZ-duobinary format. At the multicast transmitter, proper symbol synchronization is needed to superimpose the Inverse-RZ-duobinary coded multicast data onto the PtP signal in all wavelength channels. After 40-km transmission, both multicast and PtP data are received at the ONU, where a single photo-detector converts the optical signal into electric signal before being split and fed into two different paths for the recovery of PtP and multicast data respectively. The receiver requires only one photo-detector with bandwidth as the PtP bit rate, which saves the cost of ONU. The upstream transmission can take the form of any previous works like [2]. Therefore only downstream multicast scheme is considered in this paper.

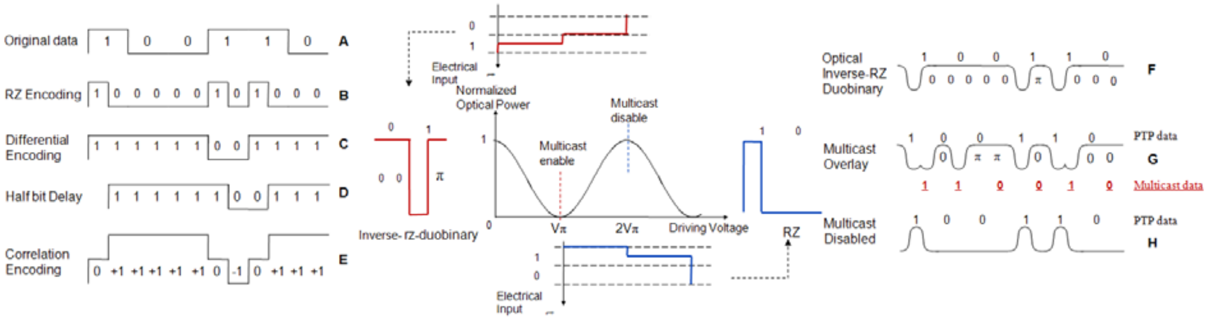

Fig.2 Illustration of the generation of Inverse-RZ-duobinary signal.

As depict in Fig. 1, the Inverse-RZ-duobinary transmitter contains differential encoding module and correlation encoding module. The differential encoding module in the transmitter contains an AND-gate followed by a toggle flip-flop circuit (T-FF) to implement RZ encoding using the original NRZ binary signal and its clock. The original NRZ signal is 5Gb/s pseudorandom binary sequence (PRBS) with a word length of 2^{15}-1. The original NRZ binary data and its corresponding RZ signal are shown as **A** and **B** in Fig. 2.

Correlation encoding is realized by adding half-bit period data delayed to the present data in order to transform differential encoded signals into three-level signals, "+1", "0," and "-1", which are illustrated as **C** and **E** in Fig. 2. Then a low-pass filter (LPF) with a bandwidth of 2.38 Gb/s after the correlation encoding, is used to further compress the bandwidth of three-level signals by trimming its high-frequency components. As a result, the filtered three-level signals have narrower bandwidth than the Inverse-RZ signals. Then the three-level electric signals are amplified to ~10V and modulated onto the optical carrier through an optical X-cut Mach-Zehnder modulator (MZM) with a V_π of 5.3 V. When multicast is enabled, the MZM is biased to guarantee level "0" at the transmission null point and level "+1" and "-1" at the transmission maximum points. Under this driving condition, the "+1" and "-1" levels in the duobinary signals have the same optical intensity but opposite phase after modulation. The optical Inverse-RZ-duobinary signal with duty cycle of 50% is shown as **F** in Fig. 2.

Fig. 2 **G** shows the signal with multicast overlay. Since the PtP information is only carried on the first half of each bit and there is always power at second half of each bit, the multicast data can be successfully superimposed onto the second half of PtP bits. The signal after the multicast overlaid is still duobinary. To disable the multicast signal for certain customer, the multicast controller only needs to shift the bias of level "0" of the corresponding transmitter to the transmission maximum point. Then the level "+1" and "-1" are at the transmission null points, the output of PtP modulator becomes RZ signal. In this case the second half of each bit is always null, the multicast signal cannot be superimposed onto the PtP signal, as depicted in Fig.2 **H**. When multicast is disabled, the data logic is also reversed. However, it can be easily rectified by simple digital processing.

At the receiver, the PtP data can be recovered by sampling the first half-bit of the superimposed signal while the multicast data can be restored by sampling the second half. Thus there is a $T_b/2$ delay between the sampling clocks, as is indicated in Fig. 1.

3. Results and discussion

The optical carrier has a center wavelength of 1551.42 nm, and it is launched into the transmission fiber after modulated by the multicast Inverse-RZ-duobinary signal. In the experiment, the launched optical power is kept below 0 dBm in order to avoid the influence of the fiber nonlinear effect.

The experimental eye diagrams and simulated spectra of both PtP Inverse-RZ-duobinary signal and the overlay of multicast signal are provided in Fig. 3. The simulated spectra show that the bandwidth of the 5Gb/s PtP Inverse-RZ-duobinary signal is ~5GHz with its carrier suppressed (Fig.3 (g)). After multicast overlay, two eyes can be seen in each symbol. PtP and multicast data can be recovered by sampling these two eyes. There is also a slightly increase in the bandwidth after the multicast overlay (Fig.3 (h)). It may mainly caused by the residual power at pulse transition. When multicast is disabled, the signal after multicast modulator is RZ like (Fig.3 (f)), but the carrier and clock frequencies are suppressed (Fig.3 (h)).

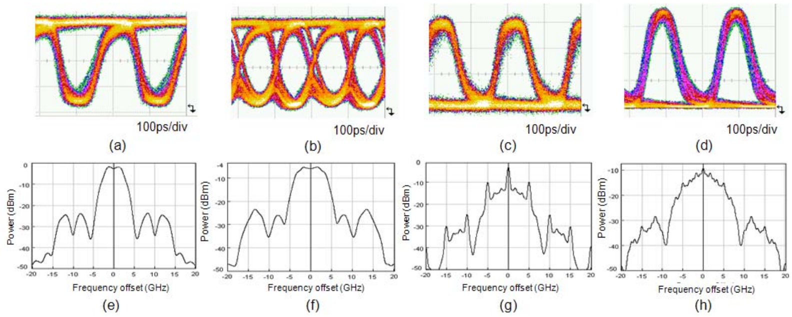

Fig.3 Eye diagrams and spectra. (a) and (e) are eyes and spectra at F in Fig.1 when multicast is enabled. (b) and (f) are eyes and spectra at G in Fig.1 when multicast is enabled. (c) and (g) are eyes and spectra at F in Fig.1when multicast is disabled. (d) and (f) are eyes and spectra at G in Fig.1 when multicast is disabled.

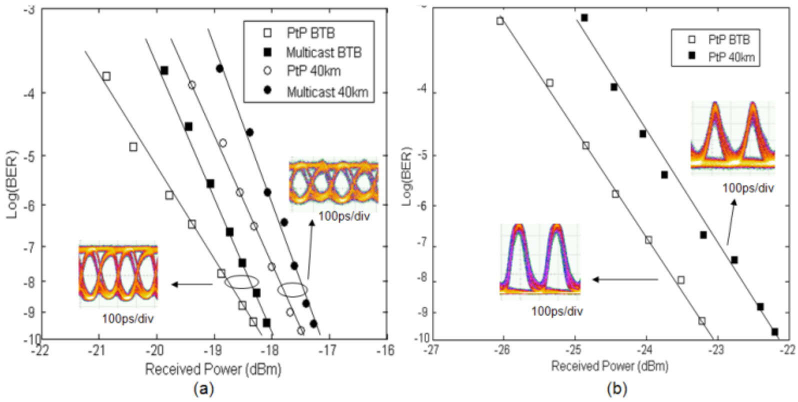

Fig.4 BER curves. (a) BER curves of PtP and multicast signals when multicast is enabled, (b) BER curves of PtP signal when multicast is disabled

The bit-error-rate (BER) results of the PtP and multicast signals are shown in Fig. 4 (a) and Fig.3 (b). When multicast is enabled, the receiver sensitivities (at the BER of 10^{-9}) for the PtP data and multicast data are -18.43 dBm and -18.12 dBm, having 0.83-dB and 0.90-dB power penalties after 40 km transmission respectively. Since half-bit of time-slot is used to detect both point-to-point and multicast signals, the signal is less tolerant to time jittering. When multicast is disabled, the back-to-back sensitivity at BER of 10^{-9} for PtP data is -23.31 dBm with about 1 dB power penalty after transmission.

4. Summary

We proposed and experimentally demonstrated a WDM-PON with optical multicast overlay by using Inverse-RZ-duobinary signal. Multicast control can be easily achieved by tuning bias of the downstream PtP modulator. Satisfactory transmission performances of the PtP and multicast signals have been achieved, which provide sufficient power budget for the system. This project was partially supported by RGC GRF No. CUHK4105/08E.

5. Reference

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