A WDM-PON Architecture with Selective-Broadcast Overlay

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Abstract *We propose and demonstrate a novel WDM-PON architecture supporting both point-to-point service and selective broadcasting. For each WDM channel, the same light source is utilized to carry the two downstream services and the upstream re-modulated data.*

Introduction

Wavelength division multiplexed passive optical network (WDM-PON) is an attractive approach for optical broadband access. To realize more flexible networking functions, some efforts have been paid to provide both point-to-point data service as well as broadcast video/data service [1-3]. They could be transmitted via time division multiplexing, but complicated timing control was needed and the downstream bandwidth had to be shared. Another common approach was to use one or more additional light sources [1-2], which led to increase in cost and complexity of the wavelength routing.

In this paper, we propose a novel WDM-PON architecture which offers both kinds of services with the single light source. On the same wavelength channel, inverse-return-to-zero (IRZ) format is employed to carry the point-to-point data; while the differential-phase-shift keying (DPSK) broadcast data is superimposed onto it. No light source is needed at the ONU. The upstream data is re-modulated on the received downstream carrier, before being delivered back to the OLT, thus the ONU is colorless. Furthermore, by simple control in the transceivers at the OLT, the broadcast signal can be interrupted on any wavelength channel to achieve selective broadcast overlay.

Network Architecture

Fig. 1 depicts the WDM-PON architecture with selective-broadcast overlay. At the OLT, each point-to-point transceiver generates the downstream IRZ signals and receives the upstream re-modulated signals for the designated subscriber. The IRZ signal is generated by properly driving a Mach-Zehnder intensity modulator (IM) with a return-to-zero shaped data signal [3], which is generated by an electronic AND gate, driven by the point-to-point data and the clock signal, as shown in the inset in Fig. 1. The downstream IRZ signals from various transceivers are multiplexed, via an array waveguide grating (AWG) or other WDM multiplexers, before being optically-amplified to boost up the power level. The amplified signals are then fed into an optical phase modulator (PM), driven by the differentially pre-coded digital broadcast data. Since an IRZ signal carries finite optical power at both one and zero levels, the DPSK broadcast data can be successfully superimposed to all wavelength channels simultaneously. At the ONU, a portion of the received downstream signal power is tapped off for reception. The IRZ data can be simply detected by a photodiode, followed by an electrical inverting post-amplifier; while the DPSK broadcast data can be detected after demodulation. Part of the received downstream power is fed into an optical intensity modulator for upstream data re-modulation. The finite optical power in each bit of the downstream IRZ signal provides the light source for the upstream data in every bit slot. As the upstream bit rate (say 2.5 Gb/s) is usually lower than the downstream bit rate (say 10 Gb/s), no bit synchronization is required at the ONU.

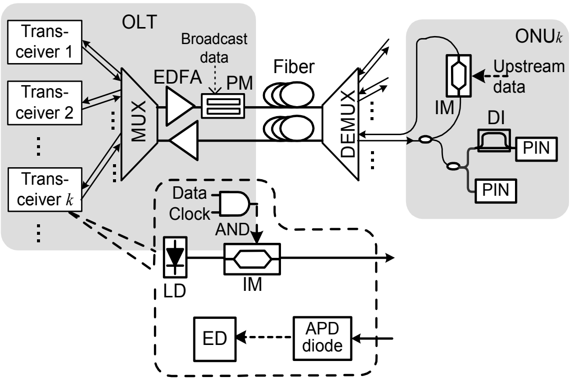

Fig. 1 WDM-PON Architecture with selective broadcast.

To disable the DPSK broadcast data for a particular wavelength channel, a simple electronic control circuit is employed at each transceiver at the OLT. The control circuit triggers the point-to-point data signal to bypass the electronic AND gate and directly drive the IM. Therefore, optical non-return-to-zero (NRZ) signal, instead of IRZ signal, is generated to carry the downstream point-to-point data. In this way, the DPSK broadcast data can be still modulated on the NRZ point-to-point signal, but it cannot be recovered at the ONU. Therefore, selective broadcasting is realized.

Experimental Results

We have demonstrated a two-channel experiment based on the setup shown in Fig. 1. CW light waves at 1546.9 nm and 1547.7 nm were IRZ (or NRZ) modulated by a 10-Gb/s 2^{31}-1 pseudo-random binary sequence (PRBS), with an extinction ratio of around 8 dB. After wavelength multiplexing and power amplification to 3 dBm, they were fed into a PM, driven by the decorrelated 10-Gbit/s PRBS as the broadcast data. The point-to-point and the broadcast signals were bit synchronized. Then the composite signal was coupled into a 20-km dispersion-shifted fiber (DSF) to emulate the downstream transmission link with proper dispersion compensation. At the ONU, a portion of the received downstream signal power was tapped off by a 3-dB optical power splitter, in which 80% was fed into a photodiode for IRZ detection and the rest was demodulated by a delay interferometer (DI) for DPSK detection. The other portion of the received downstream signal power was fed into an optical intensity modulator, driven by a 2.5-Gbit/s 2^{31}-1 PRBS as the upstream data, before being transmitted back to the OLT via another piece of 20-km DSF.

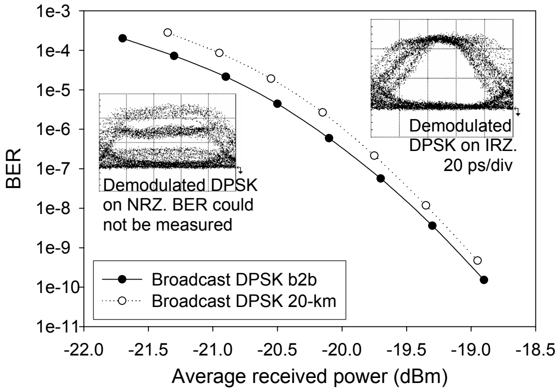

Fig. 2 BER of the downstream broadcast DPSK signal.

At the OLT, when the IRZ transmitter was enabled to produce IRZ signal, the superimposed DPSK broadcast data could be detected at the ONU. We have measured the bit error rate (BER) of the demodulated DPSK signal, as shown in Fig. 2. As the two channels had very similar performance, only the BER for the 1546.9-nm channel was shown. When the broadcasting was disabled, that is, when the transmitter was triggered to generated NRZ signal instead, the demodulated DPSK broadcast data at the ONU suffered from severe eye distortion and its BER could not be measured at the ONU.

Fig. 3 shows BER of the point-to-point IRZ or NRZ data. Negligible penalty was observed for both signals after transmission. For the upstream 2.5-Gb/s re-modulated signal, an APD photodiode was employed at the OLT for detection, followed by an electrical low-pass filter (ELPF) with a 3-dB bandwidth of 1.87 GHz. The ELPF could effectively alleviate the degradation caused by the downstream 10-Gb/s IRZ or NRZ signal. From the BER result in Fig. 4, the re-modulated upstream signal had better performance when the downstream signal was in IRZ format. This is attributed to the fact that the intensity variation of an IRZ signal was smaller than that of an NRZ signal. Such difference of the receiver sensitivities does not influence the normal operation of the system, as sufficient system margin has been designed for both cases.

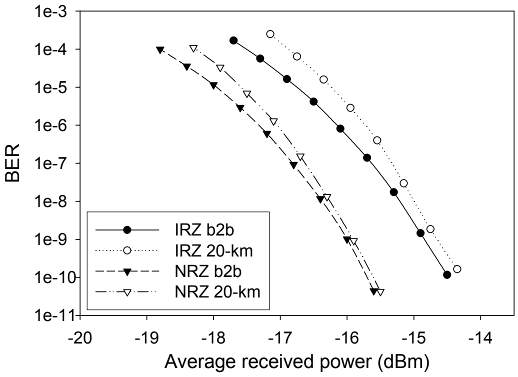

Fig. 3 BER of the downstream point-to-point signal.

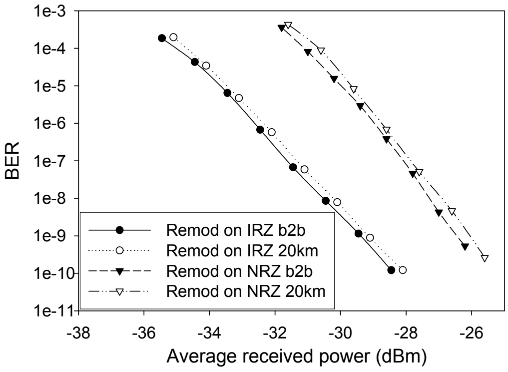

Fig.4 BER of the upstream re-modulated signal.

Summary

We have proposed a novel WDM-PON architecture to support selective-broadcast overlay. The DPSK broadcast data is superimposed on the IRZ point-to-point data, thus no additional light source is needed. The same light source can be re-modulated at the ONU to carry the upstream data. The project was supported in part by a research grant from Hong Kong RGC (Project No. CUHK4142/06E).

References

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