A Novel Hybrid WDM/TDM-PON using Downlink DPSK and Uplink Remodulated OOK Signals Based on a Shared DI

Xiaofei Cheng (1), Yong-kee Yeo (1), Zhaowen Xu (2), Yixin Wang (1)

(1) Institute for Infocomm Research, A*STAR Singapore 138632 (Email: chengxf@i2r.a-star.edu.sg)
(2) Nanyang Technological University, Singapore 639798

Abstract *We propose a novel hybrid WDM/TDM-PON using downlink DPSK and uplink remodulated OOK signals based on a single shared delay interferometer (DI) at remote node. Experiments of 10-Gb/s downstream and 1.25-Gb/s upstream transmissions verify the proposed scheme.*

Introduction

Wavelength-division-multiplexed passive optical network (WDM-PON) has been demonstrated as a promising solution for future broadband optical access network. Recently, extensive attention has been paid to hybrid WDM/TDM passive optical network (WDM/TDM-PON) [1-6]. Hybrid WDM/TDM-PON combines the high bandwidth capacity of WDM-PON and the bandwidth efficiency of TDM-PON and is regarded as a smooth migration from TDM-PON to WDM-PON.

Downlink signal remodulation schemes in access networks have been proposed using either injection-locked Fabry-Perot laser diode (FPLD)[2,3] or injection-locked reflective semiconductor optical amplifier (RSOA)[4-6] as low-cost uplink transmitter. With injection-locked RSOA, the seeding light injected into the RSOA need not maintain its polarization state and requires relatively lower injection power. So, injection-locked RSOA as low-cost uplink transmitter has gained a lot of attention[4-6]. Downlink moduation format is also crucial for signal transmission performance in downlink signal remodulation schemes. A hybrid WDM/TDM-PON using downlink OOK signal was proposed[4]. However, extinction ratio (ER) of the downlink signal limits uplink transmission performance. A hybrid WDM/TDM-PON using downlink differential phase shift keying (DPSK) signal has been proposed[5,6]. In [5], a narrow band array waveguide grating (AWG) was used at remote node (RN) to demodulate downlink DPSK signals for both downlink data detection and uplink injection-locking. However, the downlink residual data causes downlink-to-uplink crosstalk and servely degrades the uplink transmission performance. In order to mitigate this crosstalk, a delay interferometer (DI) at each ONU is used [6] and the downlink DPSK signals are demodulated at ONU side. However, a dedicated DI has to be placed at each ONU and thus the cost of ONU will be very high.

In this paper, we propose a novel hybrid WDM/TDM-PON using downlink DPSK and uplink remodulated OOK signals based on a shared DI and an $N\times N$ cyclic arrayed waveguide grating (AWG). Our scheme mitigates the downlink-to-uplink crosstalk, thus improving the performance of uplink remodulated signals. Meanwhile, it replaces the dedicated DIs at each ONU with a shared DI at RN, thus allowing the ONU receiver to employ just a simple photodetector. Experiments of the 10-Gb/s downlink and 1.25-Gb/s uplink transmissions verify our proposed scheme.

Proposed Hybrid WDM/TDM-PON Architecture

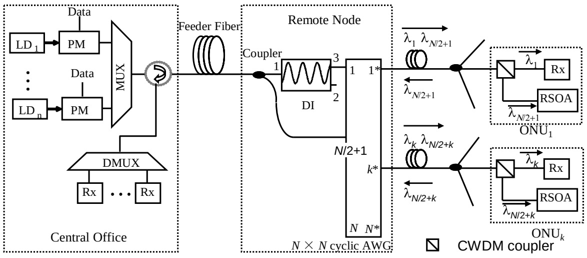

Fig. 1: Novel hybrid WDM/TDM-PON architecture

Fig.1 shows our proposed novel hybrid WDM/TDM-PON scheme. In central office (CO), downlink DPSK signal was generated using a phase modulator (PM). The downlink and uplink channels are multiplexed/demultiplexed by a 1xN multiplexer (MUX) and a demultiplexer (DMUX), respectively. A 3-port optical circulator is used to separate uplink and downlink channels. The multiplexed downlink DPSK signals are sent to remote node (RN) via a feeder fibre. The RN consists of a 1x2 optical coupler, a DI and an $N\times N$ cyclic AWG. The downlink DPSK signals are separated into two parts via the 3-dB optical coupler. One part is sent to the DI for downlink DPSK signals demodulation and the other part is sent to the $N\times N$ cyclic AWG directly for uplink injection-locking. The demodulated downlink wavelength channel, λ_k, and the downlink DPSK wavelength channel, $\lambda_{N/2+k}$, are then routed to the output port k^* of the AWG and distributed to the ONU$_k$ ($1\leq k\leq N$) via optical splitters and a distribution fibre. At ONU side, a CWDM coupler is used to separate these two wavelength channels. The demodulated downlink DPSK signal is sent to a receiver for downlink data detection. The other part is used as a seeding light to inject into an RSOA for uplink modulation.

Experiment Setup

Fig. 2 shows our experimental setup. 10-Gb/s downlink DPSK signal was generated by externally modulating a continuous-wave (CW) light using a phase modulator (PM). The wavelength of downlink signal was 1550.12 nm. The pseudo-random bit

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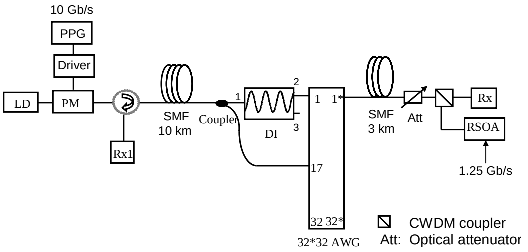
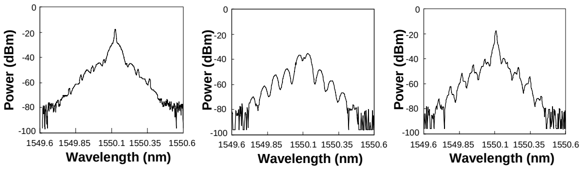


Fig. 2: Experiment setup

sequence with a word length of 2^{23}-1 used to drive the PM was provided by a pulse pattern generator (PPG). A commercial NEL 10-GHz DI and a 32×32 cyclic AWG with 100GHz channel spacing and a free spectral range (FSR) of 25.6 nm were used at the RN. Both the feeder fibre and the distribution fibre were single mode fibre (SMF) with lengths of 10 km and 3 km, respectively. An attenuator was used to emulate power loss of optical splitters in hybrid WDM/TDM-PON while a WDM coupler was employed to separate the downlink and uplink wavelength channels at the ONU side. A CIP RSOA with a 5-dBm optical saturation power and a 20-dB small signal gain at 500-mA bias current was used and was biased at 63.5 mA in our experiment. The uplink 1.25-Gb/s data was generated by another PPG with a word length of 2^{23}-1. To measure uplink transmission performance, the wavelength of the laser diode (LD) was set to 1562.92 nm. In this case, the seeding light of the RSOA was sent to the ONU via the feeder fibre, lower branch of the optical coupler and the distribution fibre. For comparison purpose, we also measured uplink transmission performance using a CW light as the seeding light (scheme I) and using the downlink demodulated DPSK signal as the seeding light (scheme II). The power of the seeding light injected into the RSOA was maintained at -8.5 dBm.

Results and Discussions

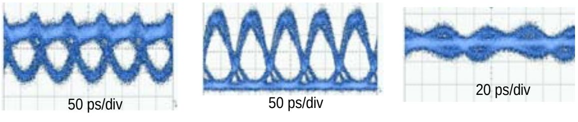
Fig. 3 shows the optical spectrum before the DI (port 1), before the Rx and after the DI (port 3) respectively. Fig. 3 shows that the demodulated DPSK signal has a narrower optical spectrum after the DI. It is beneficial to the downlink signal since it can tolerate larger accumulated chromatic dispersion.



(a) (b) (c)

Fig. 3: Measured optical spectrum (a) before the DI (b) before the Rx and (c) after the DI

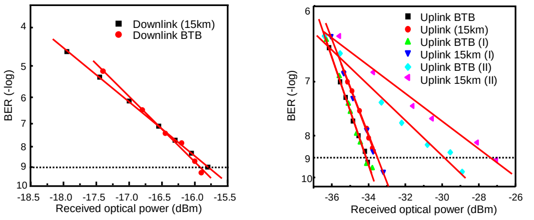
Fig. 4 shows measured eye diagrams. Fig. 4 (a) shows the eye diagram after DI (port 3) and Fig.4 (b) shows a clear eye diagram for downlink data detection. Fig. 4 (c) shows the eye diagram of the seeding light before injection into the RSOA for uplink modulation. The downlink DPSK seeding light still has amplitude fluctuation. This is due to the phase-to-amplitude conversion after 13-km fibre transmission.



(a) (b) (c)

Fig. 4: Measured downlink eye diagram (a) after DI (port 3) (b) before the Rx and (c) before RSOA

Fig.5 shows the measured BER curves of 10-Gb/s downlink and 1.25-Gb/s uplink transmissions. Receiver sensitivities (BER at 10^{-9}) of 10-Gb/s downlink signals for back to back (BTB) case and after 15-km transmission are -15.8 dBm and -15.9 dBm, respectively. Fig. 5 (b) shows that the receiver sensitivities for BTB case and after 13-km transmission in our scheme are -33.5 dBm and -34 dBm, respectively. The power penalty for uplink 1.25-Gb/s after 13-km transmission is 0.5 dB. Fig. 5 (b) shows that the transmission performance of our scheme is the same as the scheme I which uses a CW light as seeding light to inject into the RSOA for uplink modulation. The power penalty of the scheme II after 13-km transmission is 2.8 dB. Residual downlink data in scheme II severely degrades the uplink transmission performance. Our scheme improves uplink transmission performance.



(a) (b)

Fig. 5: Measure BER curves for (a) 10-Gb/s downlink signal and (b) 1.25-Gb/s uplink signal

Conclusions

We have proposed a novel hybrid WDM/TDM-PON architecture using downlink DPSK and uplink remodulated OOK signals based on a single shared delay interferometer (DI). The power penalties for downlink 10-Gb/s and uplink 1.25-Gb/s signals after 13km transmission at a BER of 10^{-9} are 0.1 dB and 0.5 dB, respectively. Our scheme mitigates the downlink-to-uplink crosstalk and improves uplink transmission performance, meanwhile maintains a cost-effective ONU by using a shared DI at RN.

References

1 G. Talli et al., J. Lightwave Technol., 24, 2827-2834 (2006)
2 L. Y. Chan et al., Electron. Lett., 38, 43 (2002)
3 Z. Xu et al., Proc. OFC'06, JThB72
4 F. Payoux et al., Proc. OFC'06 OTuC4 (2006)
5 N. Calabretta et al., Photon. Tech. Lett. 19(16), 1227 (2007).
6 C. H. Wang et al., Proc. OFC'09, JWA73 (2009).