A Novel Multicast Overlay Scheme for WDM Passive Optical Networks using Optical Carrier Suppression Technique

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Abstract *A WDM-PON with simultaneous delivery of 10-Gb/s downstream unicast and upstream data as well as 10-Gb/s multicast data is proposed. Downstream multicast data is superimposed onto the subcarrier generated by optical carrier suppression technique.*

Introduction

The wavelength-division-multiplexed passive optical network (WDM-PON) is a promising approach to support optical broadband access. To enable more flexible data delivery, it is highly desirable to overlay the multicast data onto a WDM-PON with two-way unicast traffic. The control of multicast data could be achieved by adjusting the extinction ratio[1-3] of the downstream unicast amplitude-shift-keying (ASK) data, or switching the unicast ASK data format[4] between inverse-return-to-zero (IRZ) and non-return-to-zero (NRZ), both on which the multicast data, in differential phase-shift-keying (DPSK) format, was superimposed. However, the unicast data may suffer from system penalty due to its reduced extinction ratio. Besides, another approach[5] employed double-sideband DPSK format for the unicast data, while the central carrier was separated out to carry the multicast ASK data. However, it required an optical interleaver with steep and narrow passband.

In this paper, we propose and demonstrate a novel scheme for multicast overlay control in a two-way WDM-PON. It is based on the optical carrier suppression (OCS) technique[6] at the optical line terminal (OLT) so as to generate the subcarrier or sideband for multicast ASK data modulation. The downstream unicast data is modulated in DPSK format, which will be re-modulated with the upstream ASK data at the respective optical network unit (ONU). The control of the multicast transmission is achieved by simply setting the control clock signal at the OLT. Simultaneous 10-Gb/s operation for downstream and upstream unicast traffic as well as downstream multicast traffic is demonstrated with satisfactory performance.

WDM-PON with Proposed Multicast Overlay

Fig. 1 depicts a WDM-PON with N ONUs. At the OLT, the CW light from each transmitter is first modulated by a composite signal, which comprises a sinusoidal control clock signal and the downstream unicast NRZ data, via a Mach-Zehnder intensity modulator (IM), biased at its null transmission point. The peak-to-peak driving voltage (V_{pp}) of both the control clock and the unicast data should be twice of the half-wave voltage (V_π) of the IM. In this way, the optical central carrier is suppressed, while the two generated sidebands (subcarriers) are carrying the unicast data in DPSK format. This is also known as OCS-DPSK format. One of the generated subcarriers is then filtered off and reflected, via a fiber Bragg grating (FBG). The reflected subcarriers from all transmitters at the OLT are combined, via a WDM multiplexer, before being fed into a common IM for multicast ASK data

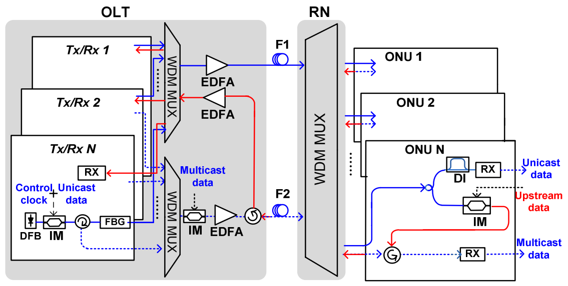

Fig. 1: A WDM-PON with proposed multicast overlay scheme. F1 & F2: fiber feeders, FBG: fiber Bragg grating, IM: optical intensity modulator, EDFA: Erbium doped fiber amplifier, DI: delay interferometer.

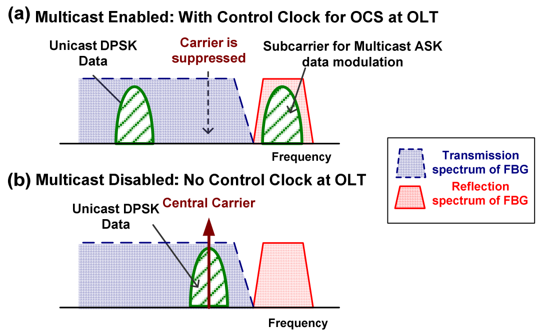

Fig. 2: Spectra of downstream carrier to illustrate the principle of multicast overlay control via optical carrier suppression (OCS).

modulation. The multicast composite signal is then delivered over the fiber feeder (*F2*) and demultiplexed at the remote node (RN) before being detected at their respective destined ONUs. On the other hand, the subcarrier at the transmission output port of the FBG is transmitted to the respective ONU, via the fiber feeder (*F1*), to deliver the unicast data. At the ONU, part of the received unicast DPSK data is demodulated, via an optical delay interferometer (DI), before direct detection. The rest of the downstream power is then fed into an IM for upstream ASK data modulation. The upstream signal is then transmitted, via the fiber feeder (*F2*), back to the respective receiver unit at the OLT. As the downstream unicast signal and the upstream signal are carried on different fiber feeders, while the upstream signal and the multicast signal are carried on different subcarriers, though on the same fiber feeder, the possible Rayleigh backscattering effect is much alleviated.

The control of multicast transmission for individual downstream channel is achieved by turning on or off the control clock signal at the respective transmitter at the OLT. When the control clock is present, the subcarrier for multicast data modulation is generated, hence multicast transmission is enabled. On the contrary, when the control clock is absent, the subcarrier is no longer generated, thus there is no optical power available to carry the multicast data and disables the multicast transmission. The multicast control of all transmitters is performed at the OLT only.

Experiments and Results

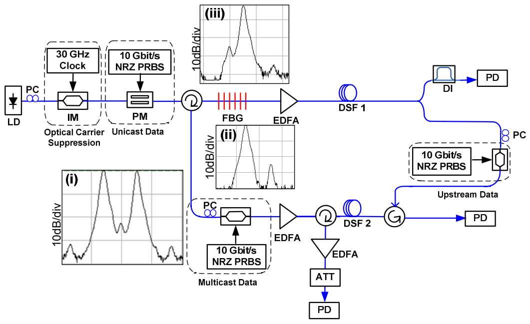

Fig. 3: Experimental setup. DSF: dispersion shifted fiber, PM: optical phase modulator, ATT: optical attenuator. Insets show the (i) output spectrum of the PM; (ii) reflected spectrum of FBG; (iii) transmitted spectrum of FBG. Horizontal scale: 0.42nm/div.

Fig. 3 shows the experimental setup for the proposed scheme. A CW light at 1536.41 nm was first fed into a 40-Gb/s optical IM, driven by a 30-GHz clock to perform OCS and create two sub-carriers, λ_{sub1} at 1536.17 nm and λ_{sub2} at 1536.65 nm. The two sub-carriers were then phase modulated by a 10-Gbit/s 2^{31}-1 pseudorandom binary sequence (PRBS) unicast data via an optical phase modulator (PM), to generate OCS-DPSK signal. This procedure of OCS-DPSK signal generation could be simplified with a single IM, as suggested in Fig. 1, but a broadband electrical combiner was needed. The OCS-DPSK signal, with a carrier suppression ratio of about 25 dB, as shown in Fig. 3 inset (i), was fed into an FBG with a reflection FWHM passband of 0.38 nm and a reflectivity of 99%, so as to separate the two subcarriers. The sub-carrier λ_{sub1} , as shown in Fig. 3 inset (ii), was reflected into an IM, where it was intensity modulated by the 10-Gbit/s 2^{31}-1 PRBS multicast NRZ data and amplified to about 3 dBm before being fed into a piece of 20-km fiber feeder (DSF2). Dispersion-shifted fiber (DSF) was employed to emulate dispersion compensated links for the fiber feeders. At the transmission output port of the FBG, λ_{sub2}, as shown in Fig. 3 inset (iii), was amplified to about 5 dBm and delivered the downstream unicast DPSK data to the ONU, via another piece of 20-km fiber feeder (DSF1). At the ONU, the multicast data was directly detected. In addition, half of the received unicast DPSK signal power on λ_{sub2} is fed into an optical DI for demodulation and detection; while the other half was re-used as the upstream carrier, which was then intensity modulated with the 10-Gb/s 2^{31}-1 PRBS upstream NRZ data. The upstream ASK signal was then sent back to the OLT, via DSF2, before it was separated from the downstream signal and detected.

Fig. 4 shows the measured BER performances when the multicast was enabled by turning on the control clock signal to generate the subcarrier for the multicast modulation. Less than 0.5-dB penalty was observed for the unicast, the multicast and the upstream data after transmission, showing receiver sensitivity improvements by about 5 dB and 3 dB, for unicast and multicast transmissions, respectively, as compared with the previously reported approach[1].

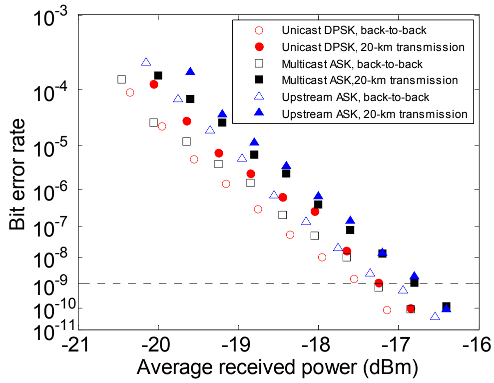

Fig. 4: BER measurements when multicast is enabled.

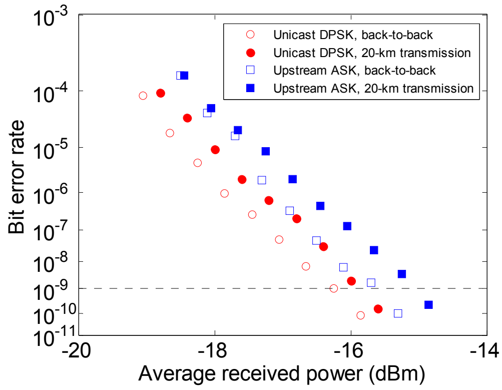

Fig. 5: BER measurements when multicast is disabled.

Fig. 5 shows the BER performances when the multicast was disabled by turning off the control clock signal. The receiver sensitivities for downstream unicast and upstream signals were degraded by 1.2 dB and 1.6 dB, respectively, after transmission, as compared with the multicast-enabled case. This could be attributed to the non-ideal reflection passband of the FBG, which induced excessive filtering to the central carrier when the control clock was absent. This could be alleviated by employing a FBG with steeper edges in its reflective passband.

Summary

We have proposed and experimentally investigated a novel multicast overlay scheme for WDM-PONs. It is based on optical carrier suppression technique to generate the subcarrier for the multicast data modulation. Simultaneous 10-Gb/s transmissions of the downstream unicast and multicast data, as well as the upstream data have been demonstrated with satisfactory system performance. This project was partially supported by Hong Kong RGC General Research Fund (Project No. CUHK4105/08E).

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