Optics Communications 355 (2015) 296–300

Contents lists available at ScienceDirect

Optics Communications

journal homepage: www.elsevier.com/locate/optcom

In-band simultaneous transmission of baseband and broadcast signals in wavelength reused bidirectional passive optical network

Pallab K. Choudhury *

Department of Electronics and Communication Engineering, Khulna University of Engineering & Technology (KUET), Khulna 9203, Bangladesh

ARTICLE INFO

Article history:
Received 7 May 2015
Received in revised form
22 June 2015
Accepted 23 June 2015
Available online 9 July 2015

Keywords:
Passive optical network (PON)
Reflective semiconductor optical amplifier
Rayleigh backscattering
Line coding
Non return to zero (NRZ)

ABSTRACT

Reflective semiconductor optical amplifier (RSOA) based bidirectional wavelength division multiplexing passive optical network (WDM-PON) is proposed and analyzed for broadcasting services along with conventional baseband signal. The downstream baseband signal is spectrally shaped for in-band transmission of broadcast signal, which ensures effective utilization of transmission bandwidth. The modulated downstream optical signal is further reused for upstream data modulation and transmitted over the same fiber with suppressed re-modulation and rayleigh backscattering noises. The proposed WDM-PON is successfully demonstrated for 10 Gb/s downstream baseband signal, 100 Mb/s 16-QAM (quadrature amplitude modulation) in-band broadcast signal and wavelength reused 1.25 Gb/s upstream signal. Error free operation for both the baseband signals as well as low value of error vector magnitude (EVM) for broadcast data are simultaneously achieved in acceptable receiver sensitivity.

1. Introduction

For future broadband access, wavelength division multiplexing passive optical network (WDM-PON) is regarded as the ultimate solution that ensures large bandwidth, wavelength independency, easy upgradability and excellent network security [1,2]. To meet the growing bandwidth demand from diverse services such as IPTV, video-on-demand and multimedia broadcast, a converge WDM-PON with both baseband and broadcast data has been attracted much attention in recent years [3,4].

Several approaches have been proposed to deliver the broadcast data over the WDM-PON, which can be classified either by using separate wavelength for broadcast services or by sharing a single wavelength for both baseband and broadcast data traffic. The proposed architectures for converge WDM-PON utilize the broadband light sources along with cyclic property of array waveguide grating (AWG) at remote node [4–8]. The broadband light sources are mainly based on Fabry–Pérot laser diode [4,5], mutually injected Fabry–Pérot laser diode [6], amplified spontaneous emission (ASE) source from erbium doped fiber amplifier (EDFA) [7], and semiconductor optical amplifier (SOA) [8]. Multiple AWGs are also used at remote node based on the different data service channels [9],[10]. However, those approaches limit the use of WDM channels due to the dedicated wavelength for broadcast service of each optical network unit (ONU). Moreover, system transmission performance is significantly degraded by relative intensity noise (RIN) of incoherent light sources. A different approach is reported in [11,12], where a single wavelength can be shared by both the baseband and broadcast data. The proposed system utilizes the subcarrier multiplexing (SCM) signal for broadcast service and finally, combined with baseband data to modulate a single optical source. The use of single wavelength for both the services results in effective utilization of WDM channels to meet future bandwidth demand.

For the deployment of practical low cost WDM-PONs, the desirable approach is the use of 'colorless/wavelength independent' ONUs for loopback transmission system with centralized seeding light source [13,14]. In recent years, there have been number of demonstrations for single fiber bi-directional WDM-PONs with colorless ONUs. Among them, ONU based on reflective semiconductor optical amplifier (RSOA) is appeared as a potential candidate for real transmission scenario [15,16]. In fact, RSOA itself is a key device in this architecture due to its properties of optical gain, wide optical bandwidth and integration capability. In this architecture, the downstream (DS) signal is transmitted from central office (CO), propagated over the fiber, reflected and remodulated by the upstream (US) data and finally, sent back to the CO for detection.

In this paper, a wavelength reuse RSOA based bidirectional WDM-PON is proposed for the transmission of both baseband and broadcast data in single wavelength. Broadcasting signals are

* Fax: +88 041774403.
E-mail addresses: pallab@ece.kuet.ac.bd, pallab_eee@yahoo.com

http://dx.doi.org/10.1016/j.optcom.2015.06.078
0030-4018/

generated at different radio frequencies (RF) to meet the diverse applications in both residential and commercial networks. Since the broadcast signals are transmitted within the same bandwidth of baseband data, the proposed system does not require additional bandwidth dedicated for broadcast service, however, the bandwidth of the baseband signal has increased by 25% due to the overheads included in line coding scheme. Moreover, wavelength reuse RSOA based architecture ensures maximum utilization of available wavelengths and simplifies the 'colorless' operation of upstream/downstream transmission. For downstream transmission, a hybrid signal is generated with 10 Gb/s baseband data and 100 Mb/s broadcast signals centered in 2.5 GHz and 5 GHz frequencies. The downstream wavelength is further re-modulated with upstream data of 1.25 Gb/s. The system performance is analyzed in terms of bit error ratio (BER) and error vector magnitude (EVM) for baseband and broadcast signals respectively. Error free operation for both the DS/US baseband signals as well as low value of error vector magnitude for broadcast data are simultaneously achieved in acceptable receiver sensitivity.

2. Operating principle

The proposed RSOA based WDM-PON is shown in Fig. 1(a), which utilizes single wavelength for the in-band transmission of baseband and broadcast data and is further re-used in upstream direction. The DS baseband data is spectrally shaped with multiple null frequencies that are used to provide free spectral bands for the in-band transmission of broadcast data. Such spectral shaped signal can be generated by arranging the incoming PRBS serial data stream into number of parallel streams, each of which is encoded separately by using standard 8b10b line coding. The resulting coded parallel streams are then converted back to a single serial stream before transmission. The 8b10b line coding was invented by IBM corporation and popularly used in fiber channel as well as Gigabit-Ethernet (GbE). Due to its DC-balanced property, the aforementioned line coding can significantly reduce the frequency components near DC part compare to PRBS coded data stream [17].

Fig. 1(b) shows the architecture of the encoder that produces a signal with multiple in-band notches, further details of such encoding process is also reported in [18,19]. In order to create a spectral null at a desired frequency, the encoder should ensure a finite value of running digital sum (RDS) at that frequency. For 8b10b line coding scheme, the RDS is bounded at DC with the values of −2, 0, 2 and thus, provides sufficient DC suppression. Fig. 1(c) shows the power spectral density (PSD) of normal PRBS and 8b10b coded sequence that indicates sufficient DC-suppression in 8b10b coded sequence compared to PRBS data and further extended to certain frequency range for a given data rate. Thus, by interleaving n parallel 8b10b coded streams, the RDS is bounded at B/n (Hz) frequencies to produce spectral nulls as shown in Fig. 1(b), where the B is the data rate of PRBS serial data stream. Furthermore, these spectral notches have sufficient bandwidth to accommodate multiple in-band broadcast channels for overlay transmission on baseband signal. Therefore, simultaneous in-band downstream transmission of both baseband and broadcast data is possible in the proposed architecture, which improves the overall bandwidth utilization for future system up-gradation. Finally, this in-band composite signal is used for optical modulation by using an external modulator and transmitted over the single mode fiber in downstream direction.

At ONU, a portion of the downstream optical signal is received by a single photodiode (PD) to recover the data for both baseband and broadcast signals. Another portion is used as a seeding source for RSOA to re-modulate the DS wavelength with upstream baseband signal. However, such wavelength reuse architecture based on RSOA suffers from re-modulation noise, which needs to be minimized for proper operation of the uplink channel. As reported in [20,21], such noise can be suppressed by minimizing the

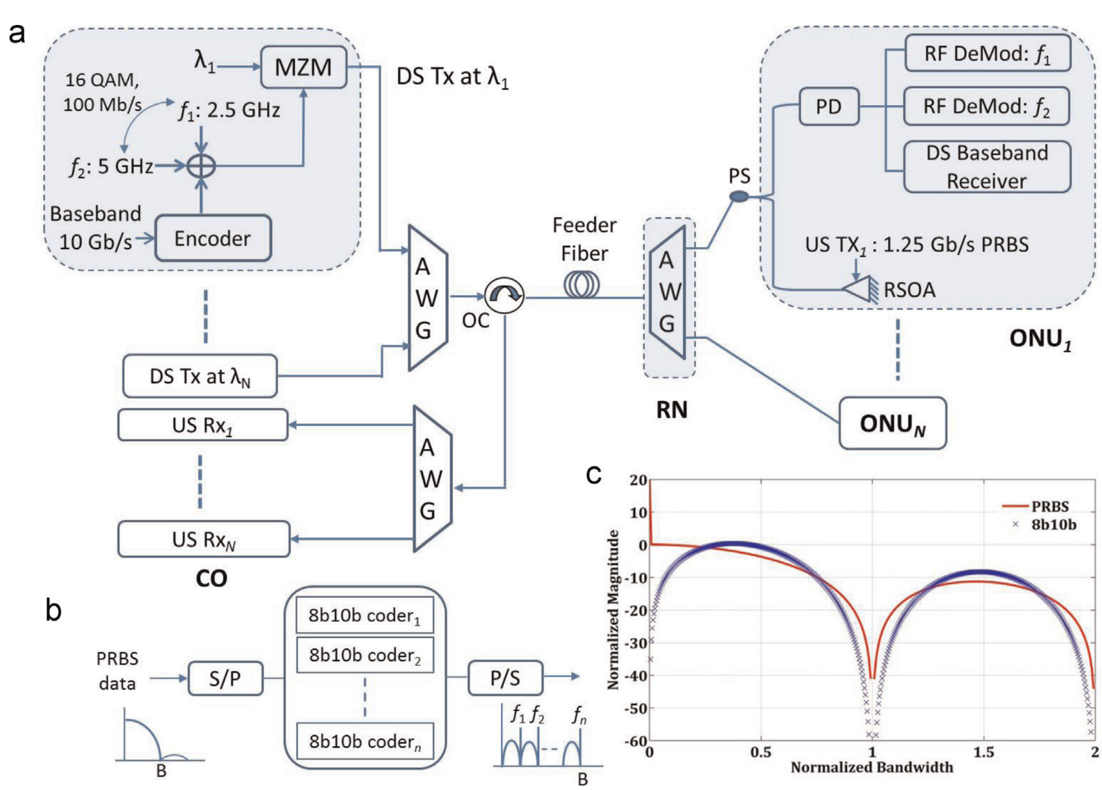

Fig.1. (a) Proposed architecture of broadcast overlay wavelength reused WDM-PON. (b) Interleaved system with 8b10b encoder for spectrally shaped baseband signal. (c) Power Spectral Density of PRBS and 8b10b coded signal.