Optik 125 (2014) 5837–5841

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Performance evaluation of bi-directional passive optical networks in the scenario of triple play service

Simranjit Singh

Department of Electronics and Communication Engineering, Punjabi University, Patiala, India

ARTICLE INFO

Article history:
Received 18 October 2013
Accepted 30 May 2014

Keywords:
Bi-directional PON
FTTH
Triple play
ONU
Q-factor

ABSTRACT

In this paper, the performance of bi-directional passive optical network (BPON) has been evaluated and compared at different bit rates in the scenario of triple play service. The triple-play service is realized as a combination of data, voice and video signals. This architecture is investigated for symmetrical data traffic for uplink and downlink transmission and its performance is also evaluated in terms of *Q*-factor and eye height at different transmission distance. The *Q*-factor results show the acceptable performance at 10 Gbps data rate for downstream and upstream transmission, as it accommodates 128 optical network units (ONUs). Further the proposed system's performance is compared with the current state-of-the-art PON architectures.

1. Introduction

Since the Internet and broad-band access networks were introduced during the last decade, the communication industry has been experiencing dramatic changes. Network providers are facing the challenge of developing new business models through innovation of their existing network infrastructure. Triple-play service (TPS) is believed to be a promising business model for the network providers. Voice, data, and video services can be integrated in the form of TPS, which is delivered through a single network [1]. A rapid growth for huge bandwidth demanding services such as high-definition television (HDTV) is beginning to drive the development of broadband access network. The wavelength division multiplexed passive optical network (WDM-PON) is regarded as one of the most promising access network architecture in the future [2]. The tremendous growth of the high speed Internet and data traffic has created an enormous demand for transmission bandwidth of dense wavelength division multiplexed (DWDM) optical communication systems and Differential phase-shift keying (DPSK) is the current technology to achieve better performance even in cost-effective high-speed networks [3,4]. A passive optical network (PON) technology is now considered to be an effective solution to the last-mile problem and PON access architecture is the accepted choice of triple-play (voice, video, and data) service delivery from service providers to the end users in FTTH access networks [5]. Recently, due to the development of high speed and high capacity Internet, Video on demand, interactive gaming, and video conference etc., the requirement of broadband services is accelerated. Thus, passive optical network (PON) is regarded as the most promising candidate for fibre to the home (FTTH) access network because of its benefits of low cost, long transmission length, high capacity and bandwidth, and multi-service convergence [6,7].

In literature, various investigations have been done for high capacity PON with triple play services. Kocher et al. [8] evaluated and compared Gigabit ethernet PON link design for 56 subscribers at 20 km reach at 2 Gbps bit rate for triple play services. This investigation has been done for different values of data rate from a Central Office (CO) to the PON in terms of Bit Error Rate (BER). Malhotra et al. [9] investigated the performance of high capacity, long reach, and 32 channels FTTH downstream link employing triple play services on the performance metrics viz. eye-opening, BER and Q^2 dB. The Internet component was represented by a data with a speed of 2.5 Gbps for downstream link. Akanbi et al. [10] proposed a new bidirectional dense wavelength division multiplexing (DWDM) based passive optical network using optical carrier suppression and separation technique to generate both upstream and downstream wavelength channels from a single laser. They generated 32 DWDM channels and demonstrated error-free symmetric 10 Gbps data transmission over 20 km of single mode fibre using a wavelength pair. Kocher et al. [11] proposed and demonstrated FTTH architecture for both downstream and upstream channels and investigated the impact of different data rates on upstream and downstream data. The BER results show that the performance was good for 10 Gbps system for downstream transmission as it accommodated

E-mail address: simrankatron@gmail.com

http://dx.doi.org/10.1016/j.ijleo.2014.07.023
0030-4026/

64 ONUs. The reported results represented that with 10 Gbps of data rate the error-free performance can be achieved for a symmetrical PON over a 50 km of bidirectional fibre using 64 users. Son et al. [12] demonstrated an easily upgradable bi-directional PON for the simultaneous transmission of WDM channels and digital broadcast video signals. The proposed network could transmit 15 downstream and upstream channels at 2.5 Gbps and 155 Mbps of data rate, respectively. Goyal et al. [13] analyzed the performance and feasibility of a hybrid wavelength division multiplexing/time division multiplexing passive optical network PON system with 128 ONUs. In the proposed network, the triple play services (video, voice and data) were successfully transmitted to a distance of 28 km to all ONUs. The wavelengths in the range of 1480–1500 nm was used to transmit the data and voice component with 1.25 Gb/s and 1550–1560 nm was used for video signals with 0.8 Gbps.

Till now, the proposed PON were limited to lesser data rates ($\leq$2.5 Gbps) [8,9,12,13], and investigated at lesser transmission distance ($\leq$100 km) [8,10,11]. Moreover, the proposed networks were investigated in downlink transmission only [9,13] with less number of ONUs. In this paper, the previous work has been extended by investigating bidirectional PON link operating at data rate of 10 Gb/s in both directions utilizing 128 ONUs. This paper is organized into five sections. In Section 1, introduction to passive optical networks are described. In Section 2, the system setup for investigate the high capacity network with triple play service is described. In Section 3, results in terms of *Q*-factor and eye height for the proposed system have been reported. In Section 4, the comparison of important performance parameters of our proposed PON architecture with current state-of-the-art PON architectures is presented. Finally, the conclusion is made.

2. System setup

The system setup of bi-directional PON for 128 ONUs using single fibre based on circulator is shown in Fig. 1. Circulator is used to isolate optical signals of uplink and downlink, and hence to realize bidirectional transmission in single fibre. Uplinks are allocated to upload burst data from clients and downlinks are used to download multimedia data to clients, such as audio, video and data services. In the proposed architecture, triple play service is realized for 128 ONUs at different data rates and distances. By taking the quick look over different literature, it is evident that the term “triple play” service stands for three services: voice, internet and video. The combination of data, voice and video signals is realized at the central office [13].

OLT block which is the transmitter block consists of data/VOIP and video components as shown in Fig. 1. The data/VOIP signal is generated by using a continuous wave laser source which is tuned at 1550 nm wavelength as a downstream wavelength and laser source has input power of −3 dBm and 15 dB of extinction ratio. PRBS is used to generate the different data rates such as 2.5 Gbps, 5 Gbps and 10 Gbps as downstream traffic data. These bits are converted in to electrical pulses by using NRZ modulation format. For generation of video signals, Sine Generator is tuned at 10 GHz frequency and 0 phase is used with a carrier generator at 1 Gbps. To modulate the data an amplitude modulator with 1.7 GHz frequency is used. This signal is passed to the coupler for combining electrical signals with −3 dB loss. The data, voice and video signals are combined by MZM modulator with 30 dB extinction ratio and 5 dB insertion losses. A pre-amplifier SOA with 10 dB gain and 4 dB noise figure is used before transmitting the signal to the fibre. A circulator with 3 dB insertion loss is used to perform the bidirectional task. A delay element which is used in transmission is used to generate optical signal delay. A bidirectional fibre with different length is used to transmit the signal among 128 users. To distribute the signal among 128 users, a 1:128 bidirectional splitter with 1.5 dB insertion loss is used. To receive the data from different users as upstream data at OLT side, PIN photo diode with 1 A/W responsivity and 10 nA dark current is used with Bessel filter having 0.75× bit rate as a centre frequency.

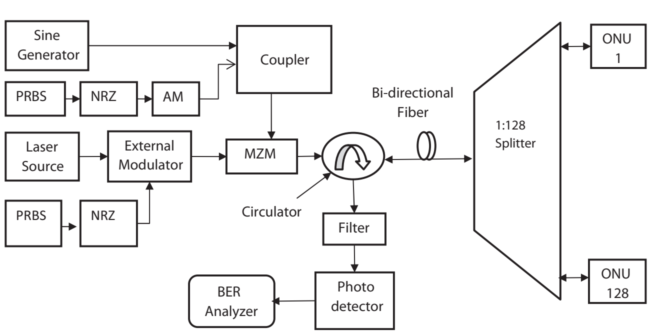

Fig. 1. System setup for bi-directional PON for triple play services.

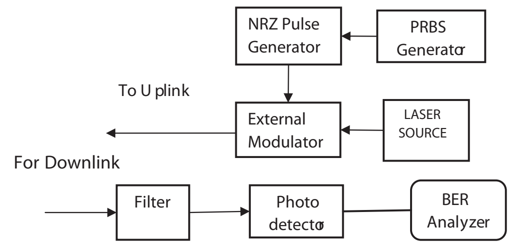

Fig. 2. Internal architecture of single optical network unit (ONU).

The internal architecture of ONU is shown in Fig. 2. To analyze the eye diagrams, it is necessary to convert optical signal into electrical so at the ONU side, the downlink signal is detected using PIN photo diode with 1 A/W responsivity and 10 nA dark current with Bessel filter whose centre frequency can be calculated as 0.75× bit rate. To generate uplink signals, PRBS is used to generate the different data rates such as 2.5 Gbps, 5 Gbps and 10 Gbps as upstream traffic data. A CW laser source tuned at 1300 nm wavelength and each channel has the input power of -3 dBm. The channel spacing between 128 users is 100 GHz. Further, line coding is performed by NRZ modulation format. The external modulator is used to transmit the data over bidirectional fibre as upstream data towards OLT.

3. Results and discussions

The most commonly parameters used for measuring the performance are *Q*-factor and Eye height. This *Q*-factor (which is unit less) can be converted in to *Q*-value by taking in to decibels. The graph for *Q*-factor versus number of users is shown in Fig. 3 at different data rates of 2.5 Gbps, 5 Gbps and 10 Gbps for downstream transmission. The acceptable *Q*-factor of 14.74, 10.43 and 5.91 is

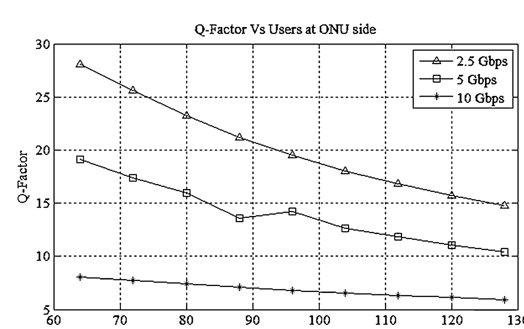

Fig. 3. *Q*-factor versus number of users for downlink at 40 km.