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Investigation on wavelength re-modulated bi-directional passive optical network for different modulation formats

Simranjit Singh [a,*], Amit Kapoor [a], Gurpreet Kaur [a], R.S. Kaler [b], Rakesh Goyal [c]

[a] Department of Electronics and Communication Engineering, Punjabi University, Patiala, India
[b] Department of Electronics and Communication Engineering, Thapar University, Patiala, India
[c] Department of Electronics and Communication Engineering, Rayat and Bahra, Patiala, India

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ABSTRACT

In this paper, the cost effective bi-directional passive optical network architecture with wavelength remodulated scheme is investigated. To realize the cost-effective PON, remodulation scheme is used, in which the downstream optical signal is reused as a carrier for the upstream transmission as it eliminates the need for an extra laser source at optical network units. The performance of proposed passive optical network is analyzed and compared for various modulation formats such as Non Return to Zero (NRZ), Return to Zero (RZ) and On–Off Keying (OOK) with 64 optical networks units (ONUs) at different traffic speed for downlink and uplink, respectively. It has been observed that the most suitable data format for proposed PON network is NRZ. Further the proposed system performance is compared with the current state-of-the-art PON architectures.

1. Introduction

Passive optical networks (PONs) are emerging as the ultimate solution in the fiber-to-the-home (FTTH) environment. They can offer more bandwidth than copper-based solution. Current Ethernet PON and Gigabit PON have been widely deployed in many places around the world because of the low installation and maintenance cost [1,2]. Wavelength-division-multiplexing (WDM) transport systems that use different optical channels to carry combined signals would be quite useful for a fiber transport network providing multiple services [3]. There has been increasing attention in implementing next generation broadband network by using WDM-PON; it is because WDM-PON can provide large transmission capacity, network security and flexibility [4,5]. The tremendous growth of the high speed internet and data traffic has created an enormous demand for transmission bandwidth of dense wavelength division multiplexed optical communication systems and differential phase-shift keying is the current technology to achieve better performance even in cost-effective high-speed networks [6,7]. In PONs, a continuous light is distributed over a fiber link from the optical line terminal (OLT) to each optical network unit (ONU). At the ONU side, the continuous wave (CW) light is then modulated and transmitted back over the same fiber so in wavelength re-modulated scheme, a downstream optical signal is reused for upstream transmission. These configurations eliminate the need for an extra CW light source at ONU [8].

In the optical system the optical code pattern is the important factor for deciding the spectrum efficiency, transmission quality and dispersive tolerance of the system [9], so signal modulation format is a key issue in order to maximize optical transmission link capacity, system design and optimization have to take into account all the contributing facts, such as channel data rate, transmission distance, signal optical power, amplifier noise figure, channel wavelength spacing, optical amplifier spacing, fiber dispersion and non-linear parameters, dispersion management strategy, receiver bandwidth and so on [10,11]. One of the most important facts in the system, which affects the choices of all other system parameters, is the signal optical modulation format. The BER and *Q*-factor may be improved by choosing a proper line coding scheme which includes various modulation formats such as Non Return to Zero (NRZ), Return to Zero (RZ), On–Off Keying (OOK) and many more.

In literature, various works on the performance of PONs with various modulation formats has been reported. Kaler et al. [12] presented the comparative investigation and suitability of various data formats like NRZ Rectangular, NRZ Raised cosine, RZ Rectangular, RZ Raised cosine and RZ super Gaussian for optical transmission link at transmission distance of 50 km. Li et al. [13] employed separately different modulation modes of DPSK and OOK in the upstream

* Corresponding author.
E-mail address: simrankatron@gmail.com (S. Singh).

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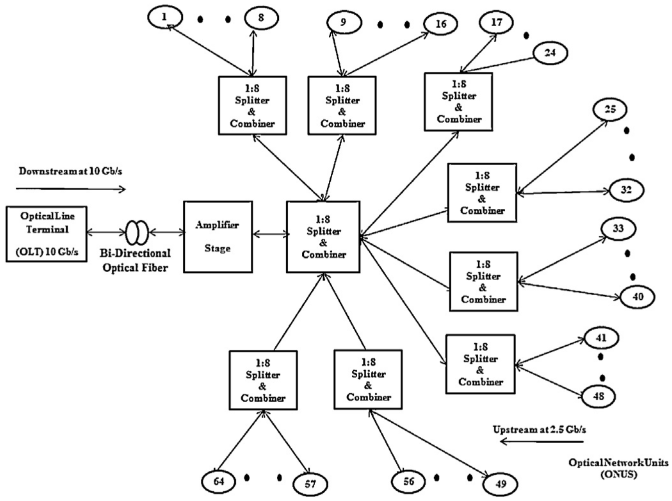

Fig. 1. System setup for bi-directional passive optical network architecture.

and downstream link, after the comparison with different modulation formats in the downstream including the codes of NRZ, RZ and Inverse Return-to-Zero (IRZ), the symmetric rate of 10 Gbps with 20 km transmission was realized without the dispersion compensation. Goyal et al. [14] analyzed the performance of a hybrid WDM/TDM PON system and compared the proposed hybrid PON for suitability of various modulation formats for different distance. It had been observed that the most suitable data format for hybrid PON network was NRZ Rectangular. Feng et al. [15] proposed a novel architecture for WDM-PON with centralized light-wave and investigated that the power penalty of the downstream was very small, while the power penalty of the upstream was large. They have also shown that with the decrease of launch power, the power penalty of the upstream can be reduced, at the cost of shortening the transmission distance. Kashyap et al. [16] observed the performance evaluation of Ethernet PON in the absence and presence of dispersion compensation techniques (DCT) and concluded that using DCT transmission speed as well as transmission distance of EPON system can be increased. Hwan et al. [17] reported T-ECL based WDM-PON in which 25 wavelength channels were transmitted up to a distance of 20 km. Urban et al. [18] transmitted only two 1.25-Gbps wavelength channels through single-mode fiber up to a distance of 26 km.

Till now, the proposed PON were investigated at lesser transmission distance (≤50 km) [12–18] and limited to lesser data rate [16,18]. Moreover most of the proposed networks were investigated in downlink transmission only [12,16]. In this paper, we extend the previous work by investigating the different modulation formats such as NRZ, RZ, and OOK for bi-directional passive optical network at different transmission distance and reduce the complexity of the system by using the re-modulation technique instead of costly RSOA. This paper is organized into five sections. In Section 1, introduction to passive optical networks and different modulation formats pulses are described. In Section 2, the system setup for investigates the effects of modulation formats in re-modulated bi-directional PON. In Section 3, results have been reported for the BER, *Q*-factor and received power in terms of distance. 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 FTTH using bi-direction PON architecture is shown in Fig. 1. It consists of an OLT and number of ONUs. To

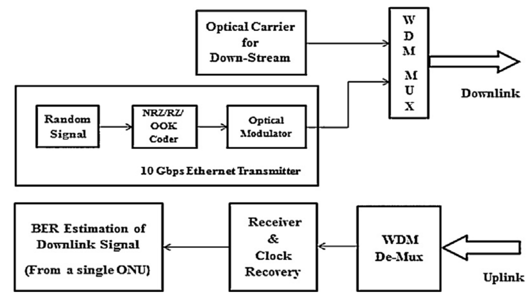

Fig. 2. Internal architecture for optical line terminal (OLT).

implement a point to multipoint architecture a fiber distribution is used between single OLT to multiple ONUs. Eight passive elements 1:8 splitters and combiners with coupling factor of 0.50 are used to establish connection between a central office to different users. Semiconductor optical amplifier with 10 dB gain is used as a booster amplifier. In this paper, the proposed PON architecture has been investigated for different lengths from a central office to the ONUs in terms of BER, *Q*-factor, and received power under with different modulation formats. The wavelength is tuned at 1490 nm for downlink and 1310 nm for uplink with 10 Gbps and 2.5 Gbps data rate for downstream and upstream respectively.

OLT is a device which consists of transmitter to transmit the data to different ONUs and receiver to detect the information from different ONUs. The internal architecture of OLT is shown in Fig. 2. Transmitter section consists of random data source, electrical driver, laser source and modulator as shown in Fig. 2. CW laser source with 100 MHz line width and electrical sine wave generator is used which superimposed and produced modulated signal for downstream signal. Pseudo random data source generate bit pattern and provide necessary bit rate of 10 Gbps then this sequence is converted into electrical pulses using different electrical coders such as NRZ, RZ and OOK. Mach–Zehnder optical modulator is used to provide modulated output and then 2:1 mux with 3 dB insertion loss is used for multiplexing.

OLT receiver section consists of PIN photodiode, clock recovery circuit and Bessel filter. The different signals coming from different ONUs are demultiplexed by using 1:2 de-mux with power attenuation of 3 dB for attenuator then passed through the Bessel filter. To detect the information from ONUs a coherent detection techniques is used. PIN photodiode with 1 A/W responsivity, zero ampere dark current, and thermal noise of $10^{-11}\ \mathrm{A}/\sqrt{\mathrm{Hz}}$ is used to convert optical signal into electrical signal. The clock recovery module is used which determines the time delay between the incoming signal and the original signal hence provides synchronization. The performances of various modulation formats used in transmitter section on bi-directional PON can be observed by plotting the graph for BER, *Q*-factor at OLT side with transmission distance.

ONU lies at subscriber end in PON architecture which provides many kinds of broadband services such as VoIP, HDTV, video conferences, etc. It consists of a transmitter to send the data to OLT at 2.5 Gbps and receiver to detect the data from OLT as shown in Fig. 3. ONU transmitter consists of PRBS, NRZ, RZ and OOK electrical drives and optical modulator. PRBS generates the data rate of 2.5 Gbps as upstream data and passes to different driver which convert it into different electrical coded signal for each input bit. The AM optical modulator with 0.9 modulation index modulates this electrical coded signal with carrier signal taken from downlink signal. In ONU receiver, first signal from OLT is demultiplexed by 1:2 demultiplexers with power attenuation of 0 dB for attenuator. One output of de-mux is connected to the AM optical modulator as shown in Fig. 3, so we are reusing the downstream optical signal for the upstream transmission, which is known as the remodulation