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Performance investigation of optical multicast overlay system using orthogonal modulation format

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ABSTRACT

We proposed a bandwidth efficient wavelength division multiplexed-passive optical network (WDM-PON) to simultaneously transmit 60 Gb/s unicast and 10 Gb/s multicast services with 10 Gb/s upstream. The differential phase shift keying (DPSK) multicast signal is superimposed onto multiplexed non-return to zero/polarization shift keying (NRZ/PolSK) orthogonal modulated data signals. Upstream amplitude shift keying (ASK) signals formed without use of any additional light source and superimposed onto received unicast NRZ/PolSK signal before being transmitted back to optical line terminal (OLT). We also investigated the proposed WDM-PON system for variable optical input power, transmission distance of single mode fiber in multicast enable and disable mode. The measured Quality factor for all unicast and multicast signal is in acceptable range (>6). The original contribution of this paper is to propose a bandwidth efficient WDM-PON system that could be projected even in high speed scenario at reduced channel spacing and expected to be more technical viable due to use of optical orthogonal modulation formats.

1. Introduction

The demand for optical fibers with unlimited bandwidth has caused evolution of high capacity optical transmission system and modulation techniques over the past 15 years and this is still expanding over the time [1].

WDM-PON and optical orthogonal modulations techniques have better exploitation of the existing transmission infrastructure and are considered as promising technologies due to their large information carrying capacity, flexible scalability, enhanced security and protocol transparency as compared with time division multiplexing-passive optical network (TDM-PON) employed conventional modulation formats [2,3].

In literature, to realize more flexible optical network various schemes are proposed to provide both high speed unicast data service and multicast data/video services, such as TDM, dense wavelength division multiplexing (DWDM), sub-carrier multiplexing (SCM), WDM-PON and orthogonal modulation formats [4,5]. Several orthogonal modulation formats based on superimposing the multicast data onto unicast data to be one of the most cost-effective and bandwidth efficient schemes among other conventional schemes [6–9].

Various orthogonal modulation formats, such as amplitude shift keying/frequency shift keying (ASK/FSK), differential phase shift keying/non-return to zero (DPSK/NRZ), ASK/differential phase shift keying (ASK/DPSK), DPSK/dark return to zero (DPSK/DRZ) have attracted much attention because of its high spectral efficiency and capacity. These formats increase the transmission capacity and achieve the multi-bit-per-symbol optical transmission system [10]. Polarization shift keying (PolSK) is considered as one of the promising modulation techniques in future optical network, which deliver constant energy per bit and helpful to eliminate cross-talk between unicast data and multicast data signal [11].

In this paper, we proposed a WDM-PON employing NRZ/PolSK orthogonal modulated unicast signal at channel spacing of 100 GHz which supports simultaneously 60 Gb/s unicast and 10 Gb/s unicast upstream data delivery as well as 10 Gb/s multicast data delivery for transmission distance of 20 km. The DPSK multicast signal is superimposed onto multiplexed non-return to zero/polarization shift keying (NRZ/PolSK) orthogonal modulated data signals. The upstream ASK signal is generated without use of any additional light source and superimposed onto received unicast NRZ/PolSK signal before being transmitted back to optical line terminal (OLT). The proposed system is simple, involving low power and more compact spectrum. We further evaluated the performance of the proposed system in terms of quality factor, output power and power penalty.

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This paper is organized as follows: Section 1 introduced the WDM-PON and orthogonal modulation techniques and Section 2 describes the general discussion of optical multicast enable WDM-PON system description, followed by discussion of generation and detection of NRZ/PolSK signal in Sections 2.1 and 2.2, respectively. In Section 3, the results of WDM-PON system have been describes and in Section 4 the conclusions have been made.

2. Proposed multicast enabled WDM-PON architecture

Fig. 1 shows the proposed WDM-PON multicast overlay architecture employing NRZ/PolSK unicast data and DPSK multicast data with 8 ONUs. As shown in Fig. 1, at OLT side, the optical signals are generated from CW laser sources which are modulated as NRZ/PolSK orthogonal modulation and further transmitted over 20 km fiber link. The driving input power of all OLT laser sources (with line width of 10 MHz) is set to be 5 dBm. The generated orthogonal modulated signals from OLTs are then fed into WDM multiplexer where they are combined before the multicasting of DPSK data. The erbium doped fiber amplifier (EDFA) is used to compensate the linear loss occurring during propagation through optical link and noise figure of amplifier is kept at 4 dB [12–15].

At receiver side, the overlaid signals passed through the 3 dB coupler, optical demultiplexer, Mach–Zehnder interferometer (MZI), PIN detector, filter and applied to BER analyzer. The values of dark current and responsivity of PIN detector is set to be 10 nA and 1 A/W, respectively. Data signal for unicast and multicast are delivered to the respective ONU, where the modulated multicast data is separated from unicast by 3 dB coupler and multicast DPSK data is demodulated by using Mach–Zehnder interferometer (MZI) with delay of 2 s. The demodulation of unicast NRZ/PolSK orthogonal modulated signals is explained in Section 2.2. The remaining power is then fed into MZM modulator for upstream ASK data modulation. The upstream ASK signal is then transmitted through SMF of length 20 km and received back to the respective OLT. The system is simulated by varying extinction ratio of NRZ, input power to light source and variable transmission distance to visualize the graphs and results such as optical spectra, eye diagram, BER and quality factor measurement.

2.1. NRZ/PolSK transmitter

Fig. 2 shows the schematic diagram of single transmitter for generation of NRZ/PolSK orthogonal modulated signal having data rate of 60 Gb/s. In transmitter, a continuous wave laser with line width of 10 MHz, input power of 5 dBm is fed to LiNb Mach–Zehnder modulator works on push–pull mode and electrical driven by data1 (NRZ modulation format) having extinction ratio >20 dBm. Generated NRZ modulated signal directly launched to polarization controller at 45° phase angle for polarization shift keying (PolSK) signal generation. Polarization modulator (PolM) consists of polarization beam splitter (PBS), polarization beam combiner (PBC) and phase modulator. The phase modulator3 (PM3) placed between PBS and PBC which is driven by data2 as shown in Fig. 2. At output of PolM the NRZ/PolSK orthogonal modulated signal can be observed. It is observed that the eye diagrams detected at the output port of MZM and PBC are not the same, large eye openings detected at NRZ signal and after PolSK signal eye opening will be reduced due to insertion of more data bits from data2. These eye diagrams have been observed at single channel transmitter only.

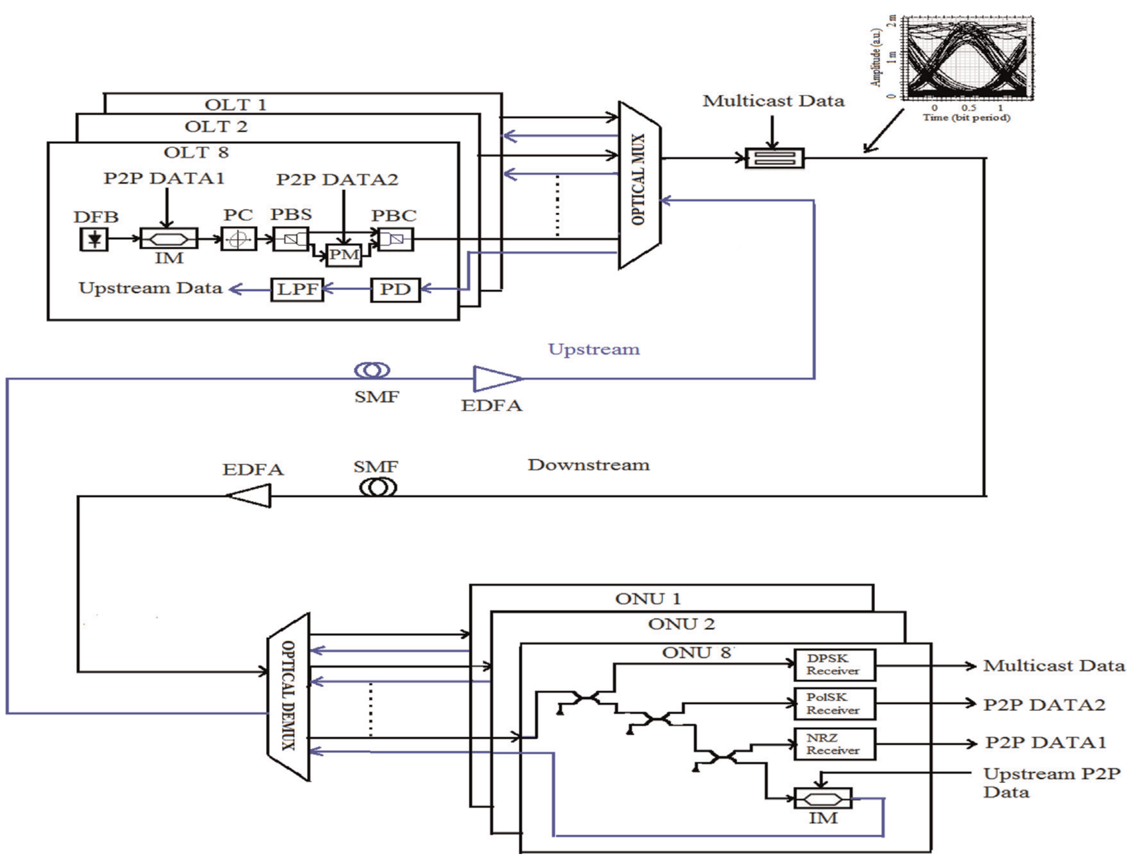

Fig. 1. Architecture of proposed multicast overlay schemes for WDM-PON.