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A Novel WDM-OFDM-PON Architecture with Centralized Lightwave and PolSK-assisted Multicast Overlay

Lijia Zhang[1,2], Xiangjun Xin[1,2], Bo Liu[1,2], Kun Zhao[1], Chongxiu Yu[2]

1）School of Electronic Engineering, Beijing University of Posts and Telecommunications (BUPT), Beijing 100876, China
2）Key Laboratory of Information Photonics and Optical Communications (BUPT), Ministry of Education, Beijing 100876, China

Abstract: We experimentally demonstrate a novel WDM-OFDM-PON architecture with centralized lightwave sources and PolSK multicast overlay. The 10Gb/s P2P signals, 2.5Gb/s multicast signals and 2.5Gb/s upstream signals have been successfully transmitted over 25km fiber.

OCIS codes: (060.4250) Networks; (060.4510) Optical Communications.

1. Introduction

The wavelength division multiplexed passive optical network (WDM-PON) has been considered as a promising approach to meet the requirement of future access network due to its high data bandwidth, protocol transparency, enhanced security and flexible scalability [1-7]. In order to realize more flexible network, there are many schemes to provide both point-to-point data service and broadcast video/data service[1-4], such as time-division multiplexing (TDM), multi-light sources, sub-carrier multiplexing (SCM), and orthogonal modulation. Usually, the TDM is complicated because of the exact time control and communal downstream bandwidth. Using additional light sources has the simple configuration, but it causes significant increase in cost and complexity [2]. Orthogonal modulation scheme based on superimposing the multicast data onto point-to-point (P2P) data has many advantages and it is believed to be the most cost-effective scheme. Several orthogonal modulation schemes has been proposed, including NRZ multicast signal orthogonally modulated on the DPSK point-to-point signal, DPSK multicast signal orthogonally modulated on the inverse RZ point-to-point signal, and so on[3-4]. Optical orthogonal frequency-division multiplexing (OFDM) has recently gained much attention because of its high spectral efficiency and the resistance to various dispersions including chromatic dispersion [5-6]. PolSK is considered as one of the promising modulations formats in future network, which possesses constant energy per bit to eliminate the cross-talk between the point to point signal and multicast signal [7-8].

In this paper, we proposed a novel WDM-OFDM-PON architecture which simultaneously supports both P2P and multicast data transmission. We superimpose the 2.5Gb/s PolSK modulated broadcast overlay on the 10Gb/s 16QAM-OFDM modulated downstream P2P signal. At the optical network unit (ONU), the downstream signal is re-modulated by the 2.5Gb/s OOK upstream signal. We also studied the cross-talk between the P2P and multicast signal, which cause 1.5dB power penalty in this architecture, and can be removed by using a low-pass electrical filter.

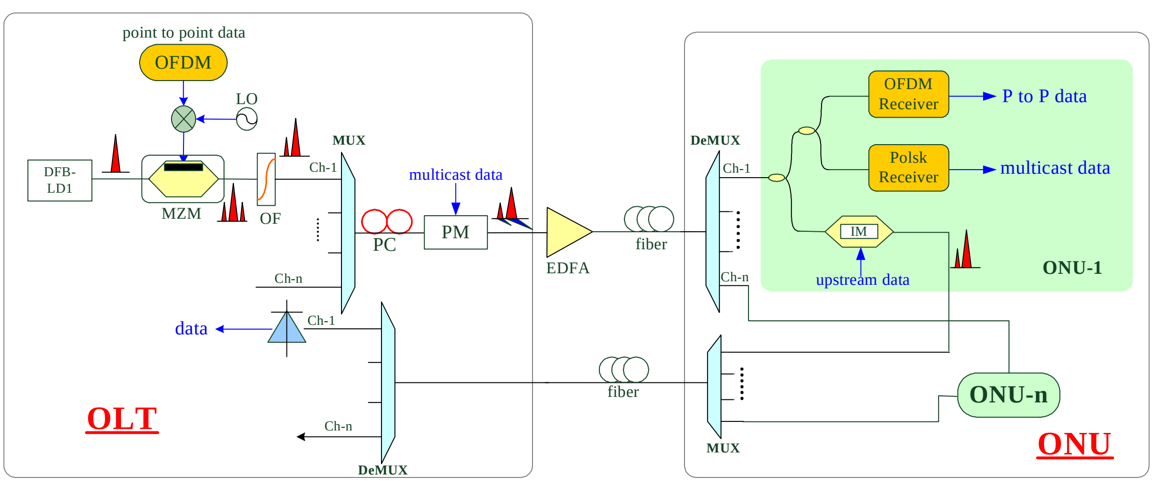

Fig.1. Principle of proposed WDM-OFDM-PON architecture with centralized and multicast overlay (LO: local oscillation; OF: optical filter; PC: polarization control)

2. Architecture

The principle of proposed architecture is illustrated in Fig.1. The optical line terminal (OLT) designed consists of N optical OFDM transmitters with N intensity modulators to generate optical OFDM signals for downstream transmission. Since the spectrum bandwidth of 16QAM-OFDM is narrow compared with on-off keying (OOK) modulation, a 10GHz LO source can be used to carry high-speed OFDM signal. An optical filter is used after the OFDM transmitter to generate single side band (SSB) 16QAM-OFDM signal for increasing the spectral efficiency and reducing the fading effect. After a MUX, the combined OFDM signals are sent for the multicast modulation. The combined signals are fed into a Polsk modulator, which is consisted of a polarization controller (PC) and a phase modulator (PM). Thus the multicast overlay is generated.

After fiber transmission, a DeMUX is used to separate the WDM channels and then deliver to different ONUs. In the ONU, the downstream signals are firstly passed through a 3dB coupler. One coupler output is used for upstream link, which is re-modulated by an OOK signal via a large extinction intensity modulator. The other output is divided again by another 3dB coupler. One is fed into the OFDM receiver. The OFDM receiver employs direct-detection optical OFDM scheme, which is insensitive to polarization dependent effect. The other is fed into the PolSK receiver, which consists of a polarization controller and polarization beam splitter (PBS) to convert the PolSK signal to OOK signal.

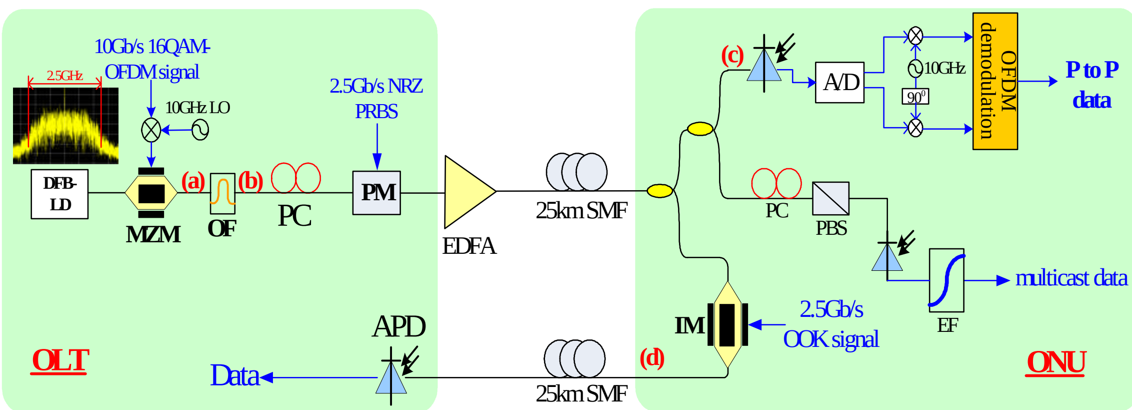

Fig.2 experimental setup of the proposed architecture (SMF: single mode fiber, EF: electrical filter; P-to-P: point to point; PBS: polarization beam splitter)

3. Experimental Setup and Results

The experiment setup is shown in Fig.2. In the OLT, a 1550.686nm DFB laser is employed as the optical source. The time domain OFDM signal is generated off-line with the parameter as: total size of FFT is 256 with 200 channel filled, 16QAM symbol mapping is used, 7 pilot sub-carriers are used for phase estimation, and the cyclic prefix is 1/16 symbol time. The analog signal is generated through a Tektronix Arbitrary Waveform Generator (AWG) and then mixes with a 10Gz LO source (Fig.2 insert shows the electrical spectrum). The MZM is driven by the 10Gb/s RF OFDM signal with 2V corresponding to half-wave voltage of 3.5V. Then the DSB signal is converted into SSB format through a tunable optical filter before entering the PM, where the Polsk multicast at 2.5Gb/s is encoded. A revolving PC is inserted before the PM to obtain the exactly required input state of polarization (SOP). After transmission, the downstream signal is split by a 3-dB optical coupler. One is for downstream signal receive, and the other is reused for OOK upstream. Fig.3(a)-(d) show the optical spectra at the corresponding points (a)-(d) in Fig.2, respectively. Another optical coupler is employed to split the downstream signal before receiver. One part is fed into a 20GHz PIN PD for O/E conversion and then sampled by a real time scope for offline processing. The measured BER curve and constellation are shown in Fig.4(a). For the other part, we obtain intensity detection of the PolSK multicast by a PBS that performs the conversion from polarization modulation to intensity modulation. The detected signal then passed through a 3.9GHz lowpass electrical filter to suppress the frequency components higher than the Polsk bit rate. The BER curve and eye diagram is presented in Fig.4(b).

For the upstream link, the OFDM/Polsk signal is re-modulated to OOK by an IM at 2.5Gb/s with a PRBS of length 2^{31}-1. After 25-km transmission, a 5GHz commercial APD is used for directly detection. The eye diagrams and BER curve is illustrated in Fig.3(e). The power penalty is less than 0.1dB at the BER of 10^{-9}.

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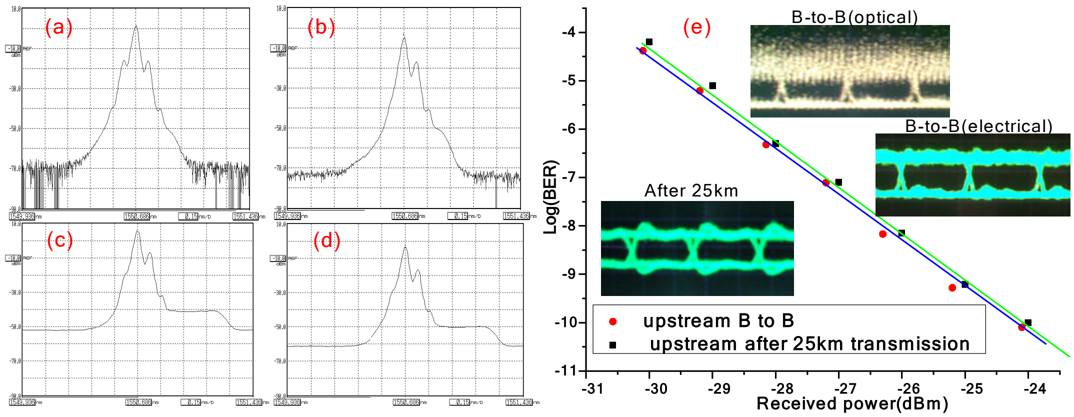

Fig.3 (a)-(d): optical spectra at the corresponding measured points in Fig.2; (e): BER curve and eye diagrams of the upstream signal (resolution: 200ps/div).

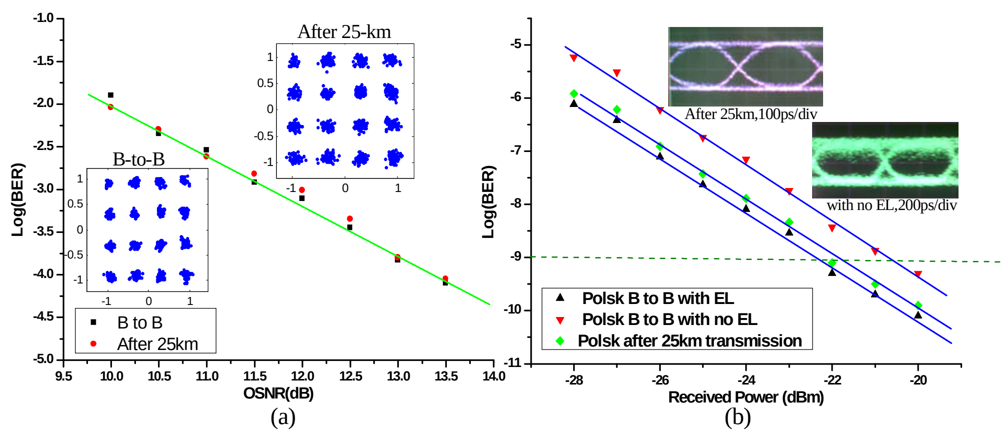

Fig.4: Measured BER curves and corresponding constellations and eye diagrams of downstream signals with and without transmission.

4. Conclusion

We have proposed and demonstrated a novel WDM-OFDM-PON architecture with centralized lightwave sources and PolSK multicast overlay. The downstream 10Gb/s 16QAM-OFDM modulated P2P signal and 2.5Gb/s PolSK modulated multicast signal have been transmitted over 25km SMF successfully. 1.5dB crosstalk between P2P and multicast signal is observed, which can be eliminated by a low pass electrical filter at the PolSK receiver. The downstream signal is re-modulated by 2.5Gb/s OOK signal with large extinction ratio. The power penalty for the downstream multicast signal is 0.2dB at 10^{-9}, while the power penalty is less than 0.1dB for the upstream signal after transmission over 25km SMF.

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