A WDM-PON System Providing Quadruple Play Service with Converged Optical and Wireless Access

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Abstract *We demonstrate a WDM-PON structure providing quadruple play service integrating optical and wireless access based on hybrid modulation formats. Downstream signals are re-modulated for upstream transmission enabling source-free ONUs.*

Introduction

Passive optical network (PON) providing triple play service with video, voice and data delivery has become an attractive solution to the increasing bandwidth driven by the emerging multimedia applications [1]. Due to the recent advances in wireless communication and strong desire of flexible wireless-data access, convergence of optical and wireless technologies for quadruple play (voice, data, video and mobility) is promising to provide broadband and ubiquitous access in an integrated platform with cost-effective configuration [2].

In this paper, we propose and demonstrate a novel wavelength-division multiplexing (WDM)-PON system to deliver downstream video, voice, data and radio-over-fiber (RoF) based wireless access signals simultaneously. For the first time to the best of our knowledge, we realize the quadruple play service (QPS) with a single wavelength by sub-carrier modulations at different bias conditions of the modulators, combined with amplitude modulations. Upstream data are re-modulated on the downstream optical signals, which eliminate light sources in the optical network units (ONUs). For wireless access, RoF technology minimizes the cost of the distributed ONUs and shift the system complexity and expensive devices to the optical line terminal (OLT) [3]. Transmitting the four kinds of service in dedicated physical channels can provide guaranteed individual bandwidth, and avoid complicated scheduling algorithm among different services.

Principle and architecture

Figure 1 shows the proposed WDM-PON architecture providing QPS including RoF based wireless access, voice, data and broadcast video service with source-free ONUs. In the OLT, for each WDM channel, the output of a continuous wave (CW) laser is split into two paths. One part is launched into a Mach-Zehnder modulator (MZM) which is biased at its null point. The MZM is driven by an electrical sub-carrier multiplexed (SCM) signal, which is produced by mixing an alternating current (AC)-coupled bipolar data with a radio frequency (RF) carrier, to generate an optical carrier suppressed-differential phase-shift keying (OCS-DPSK) signal. The other part of the CW carrier is modulated by a dual-drive MZM (DDMZM). As each arm of the DDMZM is a phase modulator, an optical double-sideband (DSB) sub-carrier DPSK signal is obtained by driving one arm of the DDMZM using a mixed signal of bipolar data with an RF clock signal. The two sidebands without the central tone in spectrum can be also considered as an OCS-DPSK signal. In the other arm of the DDMZM, the optical phase of the light carrier is modulated by an electrical baseband signal. After interference with the central carrier of the DSB sub-carrier DPSK signal, the phase shift transfers to amplitude variation, resulting in an amplitude-shift keying (ASK) baseband signal. Therefore if RF clock signals of different frequencies are applied to the MZM and DDMZM, respectively, one can obtain an optical signal carrying three different streams of data, including two in OCS-DPSK format and one in ASK format. The MZM and DDMZM can be integrated into one chip to form a dual-parallel MZM, in order to further shrink the transmitter size. The optical signals from different channel are coupled into one fiber through an arrayed waveguide grating (AWG). An interleaver with a proper channel spacing is used to separate the OCS-DPSK components with lower repetition rate from the input signals for each WDM channel. Broadcast video data are subsequently superimposed through ASK modulation to generate OCS-DPSK/ASK signal format. Note that the extinction ratio (ER) of the ASK modulation should be low enough to maintain the phase information of the OCS-DPSK signal. The OCS-DPSK/ASK signal is combined again with the OCS-DPSK signals at higher RF frequency and the baseband signals, thus optical signals in hybrid modulation formats are obtained to carry four independent services, which are then pre-amplified and delivered downstream.

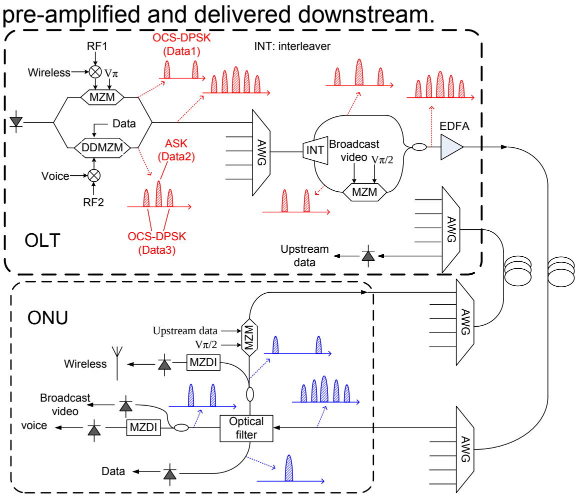

Figure 1: The proposed WDM-PON providing QPS.

At the ONU side, the received optical signal is filtered and separated to three components at different RF frequencies. The ASK signal in baseband is directly detected by a photodetector (PD). The OCS-DPSK/ASK sidebands adjacent to the central baseband signal are split into two equal parts. One is directly received by a PD for the ASK demodulation, while the other part is demodulated by a DPSK receiver consisting of a Mach-Zehnder delay interferometer (MZDI) and a low-speed PD. The OCS-DPSK signal at higher frequency is converted to OCS-ASK signal by an MZDI and an electrical RF signal with doubled repetition rate can be obtained after direct detection by a high-speed PD. Since the OCS-DPSK signal has a constant intensity envelope, part of the power is tapped as an optical carrier for upstream ASK data re-modulation, which eliminates the need of light sources in the ONU.

Experiment

To verify the principle of the proposed WDM-PON providing QPS, we perform an experiment to show the simultaneous transmission of data, voice, broadcast video, and RoF signal on one WDM channel.

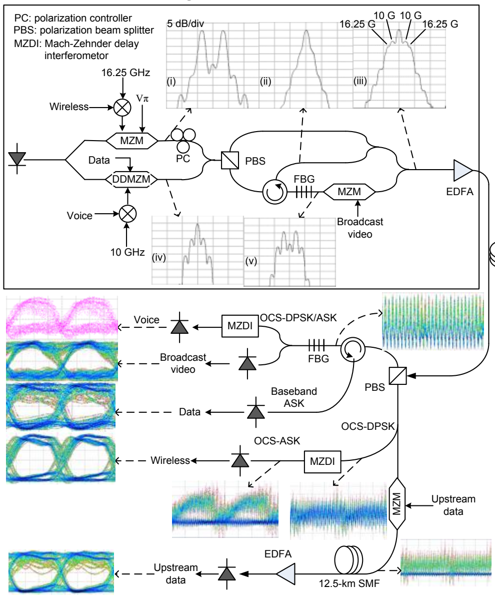

Figure 2: Experimental Setup.

Figure 2 depicts the experimental setup. The five types of traffic, i.e., downstream data, voice, broadcast video, RoF data and upstream data, are non-return-to-zero (NRZ) data streams from the divide-by-8 data ports of a pulse pattern generator (ANRITSU MP1763c). Five of the eight ports are used and each of them is programmed with a pseudo-random bit sequence (PRBS) length of 2^7-1. We emulate the filter function of the interleaver by a fiber Bragg grating (FBG) with a 3-dB bandwidth of 0.114 nm and a circulator. Polarization multiplexing is employed to further improve the performance. The MZM (inset (i) in Fig. 2) generates a 32.5-GHz OCS-DPSK signal and the DDMZM produces a 20-GHz OCS-DPSK signal with an ASK baseband component (inset (iv) in Fig. 2). The polarizations of the two outputs are controlled to achieve better separation after the polarization beam splitter (PBS) and filtering. Then the baseband signal is reflected by the FBG (inset (ii) in Fig. 2), while the remaining 20-GHz OCS-DPSK voice data (inset (v) in Fig. 2) is re-modulated by the broadcast video data to obtain an OCS-DSPK/ASK format, where the ER is ~3 dB. Limited by the spectrum resolution of 0.07 nm, the tones at 10 GHz and 16.25 GHz cannot be distinguished clearly after all the optical signals are combined (inset (iii) in Fig. 2).

After 12.5-km transmission, the optical signals are separated again by an FBG and a PBS in the ONU. The OCS-DPSK/ASK component is subsequently split into two parts, which are received by a 1.25-G DPSK receiver and a 2.5-G PD, respectively. The downstream data carried by the baseband ASK signal is directly demodulated by a 2.5-G PD. To measure the bit-error-rate (BER) performance of the OCS-ASK signal for wireless access, a 2.5-G PD instead of a high-speed one is used to filter the 32.5-GHz intensity oscillation. The re-modulated upstream ASK signal is demodulated after 12.5-km transmission.

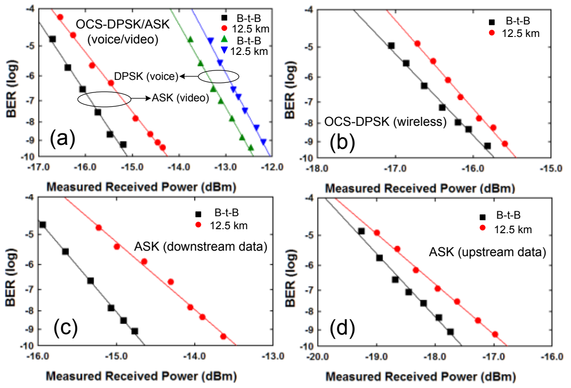

Figure 3: BER curves for (a) the voice/video, (b) RoF, (c) downstream data and (d) upstream transmission.

Figure 3 shows the BER curves of the five types of traffic. The downstream traffic suffers ~1.1-dB penalty, while less than 1-dB penalty is observed for other data. If balanced receivers were available, a 3-dB sensitivity improvement could be expected for the DPSK signals.

Conclusions

We have experimentally demonstrated a WDM-PON providing QPS with converged optical and wireless access employing sub-carrier modulations at different frequencies combined with amplitude modulations. Re-modulation based upstream transmission is also demonstrated to enable source-free ONUs.

Acknowledgement

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References

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