High-Performance and Robust Burst Reception in Coherent PON

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Abstract: One of key issues in Coherent PON is the realization of upstream coherent burst-mode reception. We review challenges, key enabling technologies and recent progress of high-performance and robust burst reception in coherent PON.

1. Introduction

To support the ever-growing bandwidth demand from emerging services, such as B5G/6G mobile Internet, cloud networking, and high-definition (HD) video streaming services, the optical access network industry is ushering in a new wave of innovations [1]. The interest in the application of coherent optics to the next generation access network is unprecedented. As shown in Fig. 1(a), after generations of PONs that are based on intensity modulation and direct detection (IM/DD), new technology will be needed for 100G and 200G PON since IM/DD PON will reach its sensitivity limit above 50 Gb/s speeds per wavelength [1]. Thanks to the superior receiver sensitivity, high-order modulation formats, advanced digital signal processing and flexible deployment capability, coherent optics is considered a promising candidate for realizing single-wavelength passive optical networks (PONs) at 100G and beyond. However, before commercialization, there are still some major challenges to be solved. One of the key issues here is the realization of efficient and robust upstream coherent burst-mode detection as shown in Fig. 1(b) [2].

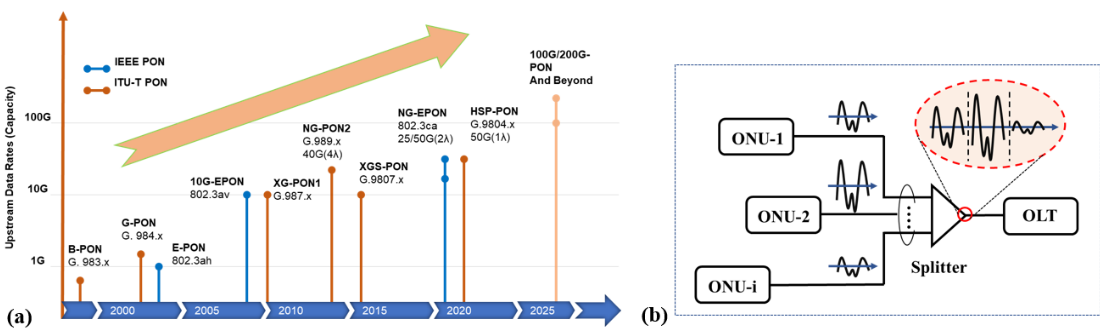

Fig. 1 (a) The evolution of the PON from B-PON to 1G/λ 10G/λ, 25G/λ, 50G/λ and future 100G/λ and beyond; (b) The schematic of upstream network.

In this invited talk, we will review challenges, key enabling technologies and recent progress of high-performance and robust burst reception in coherent PON. Comprehensive studies on the key functions required, solutions for burst-mode amplification burst frame design and burst-mode digital signal processing for upstream burst-mode detection in CPON are presented.

2. Challenges for coherent burst-mode reception

Burst-mode linear amplification and burst-mode signal processing are two main issues to be resolved. Burst-mode amplification can enlarge the dynamic range by dealing with different signal power levels. As shown in Fig. 2 (a), after sampling by the ADC with a constant scale, the high-power signal is clipped and the low-power signal suffers from the quantization noise. Therefore, burst-mode amplification is required. It can be done by the electrical amplifiers (EAs) or in the optical domain by optical amplifiers (OAs). Burst-mode signal processing is another issue [1]. Different from the conventional DSP algorithm, burst-mode DSP has a high demand for response speed to detect and perform signal processing. In this condition, several studies have been reported to solve this issue by using specially designed preambles and fast DSP [2]. Fig. 2 (b) shows the main steps of the burst-mode DSP, consisting of frame synchronization, burst clock recovery, preamble-based state of polarization (SOP) correction, and data-aided carrier recovery. Note that the burst-mode DSP should be quick enough to track the diverse channel distortion in frames.

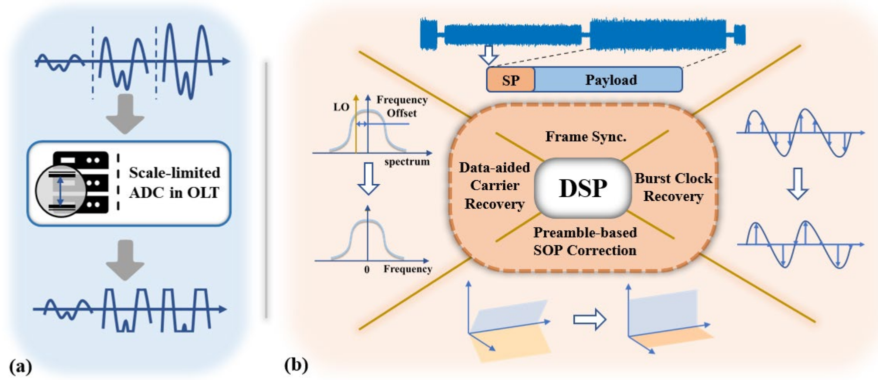

Fig. 2 Main challenges for coherent burst-mode reception: (a) burst-mod amplification; (b) burst-mode signal processing

3. Solutions of Burst-mode amplification

Table 1 typical burst-mode amplification methods

Methods	Key devices	Advantages	Disadvantages
EA gain control[3], [4]	Burst-mode TIA	No additional amplifiers	Burst integrated EAs are still not available
OA gain control[5], [6]	EDFA or SOA	Better linearity and consistency	Decreasing OSNR
LO power control[7], [8]	LO laser	Easy integration; No out-of-band noise	Require Baseline wandering compensation

Burst-mode amplification is essential in an upstream network to deal with different signal power levels and enlarge the dynamic range. Several methods have been reported, including EA gain control, OA gain control, and LO power control, more details of which are shown in table 1. Linear burst-mode receivers based on variable gain transimpedance amplifiers (TIAs) have been demonstrated to resolve this issue [3], [4]. The signals from the PD are amplified at a proper gain suitable for the ADC scale. As considerable challenges, e.g., integration and linearity of burst EA, are still associated with the EA gain control method, optical burst-mode amplification is a more effective method for its better linearity and consistency. The amplification process undergoes in the optical domain by leveling burst signals before these signals are sent to coherent receivers. However, as an additional amplifier will lead to more noise, this method is still imperfect due to the decreased OSNR. Benefiting from the unique structure of a coherent receiver, optical burst-mode amplification can also be realized by a power-controlled LO. By changing the photocurrents of the LO laser, the power of the received signal can be adjusted to a suitable level. However, it still suffers from the baseline wandering effects that requires special design to compensate.

4. Burst-frame design and Burst-mode signal processing

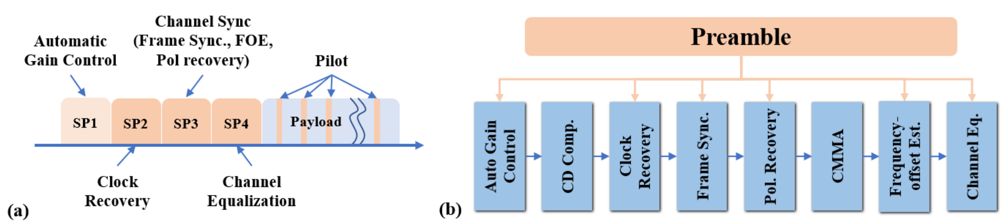

Fig. 3 A typical structure of (a) burst-frame design and (b) burst-mode signal processing

Upstream burst-mode digital signal processing (DSP) plays an important role in coherent PON. An efficient preamble is often designed to realize fast convergence for the coherent PON. A typical structure of a frame is shown in Fig. 3 (a), where 4 synchronization patterns (SPs) and a payload with periodically inserted pilot symbols construct a whole frame. The four SPs are designed for automatic gain control, clock recovery, channel synchronization, and channel equalization, respectively. and the inserted pilot can also undertake some part of channel equalization. In Fig. 3 (b), the whole burst signal processing is listed, and the preamble-aided parts are marked. In burst-mode DSP, the very first step is the auto gain control to adjust the signal level of different bursts which naturally have widely varying power levels. After the normalization and non-data-aided chromatic dispersion compensation [9], clock recovery is needed to eliminate the impact of the sampling clock error. The timing error can be initialized by using the preamble. The common clock recovery algorithms include Gardner [10], Godard [11], and square-timing-recovery algorithms [12]. After clock recovery with phase initialization, frame synchronization is realized by a sliding window with cross-correlation [13] or auto-correlation process [14]. Then using the preamble, the SOP is estimated by calculating the inverse Jones matrix [15] or using the maximal-ratio combining method [16]. The preamble-aided carrier recovery usually includes frequency offset estimation (FOE) [17] and carrier phase estimation (CPE) [18]. Finally, channel equalization can be realized by using a cascaded multi modulus algorithm (CMMA) or frequency domain MIMO channel estimation [19].

5. Discussions and Conclusions

Above we review and discuss challenges, key enabling technologies and recent progress of high-performance and robust burst reception in coherent TDM-PON. Studies on the burst-mode amplification, high-efficient burst-frame design and burst-mode signal processing are presented. These studies open new lines of research on point-to-multipoint coherent optics in access network. It is worth noting that coherent optics provide many benefits to access networks in addition to sensitivity improvement. Most recently, flexible multiplexing beyond TDM [20], i.e., TFDM-PON and rate adaptive access in coherent PON [21],[22] have been widely studied. Burst mode coherent detection faces new challenges in these new PON systems with wider dynamic range and more dimensional bandwidth allocations, and it is worth further study.

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