10 Gbps / 2.5Gbps GPON Coexistence by Downstream Bit-Stacking

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Abstract

Gigabit PON /10Gbps PON coexistence with two ONU generations on a single 1490 nm downstream wavelength is enabled by bitstacking and affiliated framing measures forming a novel electrical multiplexing technique.

Introduction

Architecting the next-PON generation receives significant attention at this time, including the question how several PON generations can best coexist on a joint fiber plant. Wavelength overlays are considered the solution to operate two PON generations on the same fiber plant [1]. This allows for a graceful transition period and two line bit rates to be present on a PON plant. However, setting up and observing a suitable wavelength plan which accounts for the required distributed optical filtering, makes a single downstream wavelength plan highly attractive.

Electrical multiplexing in PON downstream

An electrical multiplexing scheme is proposed, which can conduct two line bitrates on a single wavelength by electronic measures only, ensuring the continued operation of both ONU generations. To avoid disturbance of the legacy ONUs, the high-speed parts of the combined data streams are allocated at the borders of the eye-pattern. The signal is linearly composed of a stack of both line rate components, resulting in the characteristic eye diagram of Figure 1.

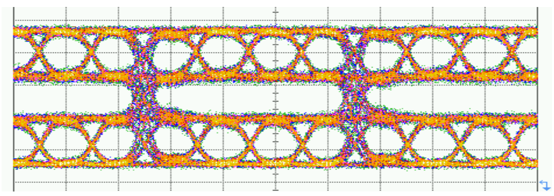

Figure 1: Bit-stacked eye pattern with legacy-speed component in the center and peripherial advanced-speed component (H: 100ps/div)

Legacy receivers will evaluate only the central amplitude region of the bit-stacked signal. They will mostly ignore the higher speed signal components at the amplitude slicer due to the amplitude offset. A limiting amplifier will compress the outer bits. A linear receiver (AGC based) will ignore the outer bits during amplitude decision. Especially the clock recovery will not detect false (fast) transitions from the higher speed signal due to the amplitude separation, even after bandwidth limiting the combined signal by the legacy optical frontend.

To avoid in continuous downstream undesired re-lock delays, a permanent lock of the legacy ONUs clock recoveries (CDRs) is indispensable. Ensuring a prompt CDR lock-in, under all circumstances and independent from any special CDR make, is an important factor here.

Signal characteristics and Modes of Operation

The bit-stacked signal is a derivative of a multi-level coded signal and can be synthesized accordingly. The combined signal occupies the electrical bandwidth of the higher bitrate signal, in this GPON case at 9.95 Gbps. It fits the passband of 10 Gbps components, as f.i. transimpedance amplifiers.

As compared to the full swing of a pure binary signal, the bit-stacked signal incorporates, for the general case in Figure 1, a reduction in the optical modulation amplitudes of either component stream. To mitigate the induced receiver sensitivity reduction, and to balance transmit power requirements for 2.5 and 10 Gbps, a forward error correction on the 10 Gbps signal is envisioned. As a basic prerequisite, the legacy receiver stays as is today.

For legacy receivers, an unimpaired sensitivity can be achieved by dynamically switching between pure binary signaling and bit-stacked transmission. Thus, legacy ONUs are presented pure binary 2.5Gbps signal again. Stacked signals are delivered to the advanced ONUs. This gives rise to the Modes of Operation depicted in Figure 2.

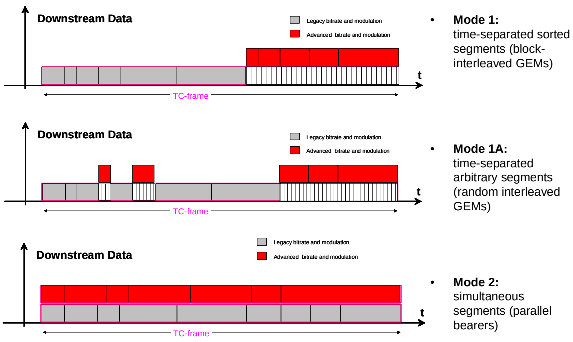

Figure 2: Electrical Linerate Multiplexing Options

Red colour denotes advanced rate signalling while grey sections mark legacy linerate transmission.

The alternating Modes 1 and 1A switch between binary and stacked transmission mode and trade a reduced capacity for improved receiver sensitivities. During stacked transmission periods, only clocking is provided to the legacy receivers. The corresponding

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eye-pattern is shown in Figure 3 at an interval border. The central eye (i.e. 2.5 dedicated for Gbps ONUs) in the left-hand interval has a small residual opening. It suffices to serve the clock recoveries, but does during these intervals not support error-free transmission.

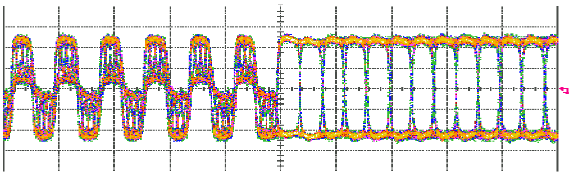

Figure 3:Alternating Mode 1 Eye Pattern (H: 1ns/div)

Simultaneous *Mode 2* refers to permanent data transmissions taking place on both bearers, as in Figure 1. A high 12.5 Gbps aggregate capacity can be reached.

PHY-layer System Experiments

Performance of bit-stacked waveform signaling has been analysed in laboratory experiments for the legacy and the advanced bitrate bearers.

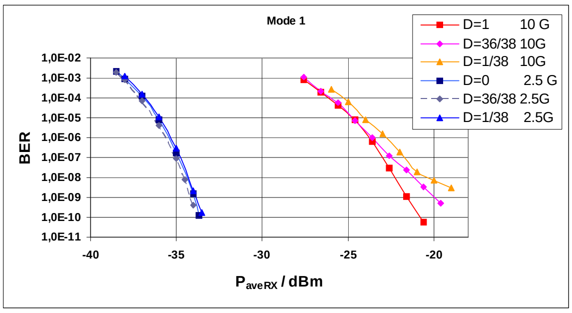

Figure 4: Mode 1 Bit Error Curves for both linerates under varying 2.5 and 10Gbps dwelling ratio

The negligible influence on legacy ONU receiver sensitivity is proven under Mode 1 operation for a 1/38 and a 36/38 ratio of the 10Gbps-stacked transmission interval. This confirms also the clock recovery's permanent lock condition.

The advanced receiver is composed of commercial 10Gbps components. It employs a linear receiver design (Figure 5), conserving the peripheral bit waveform. It exhibits a slight dwelling ratio dependence which originates from the clock recovery.

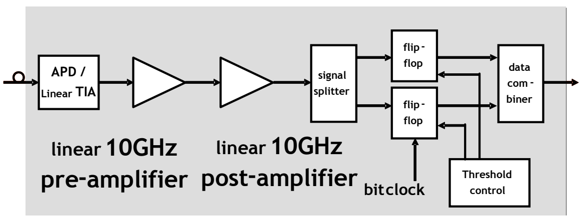

Figure 5: Block diagram for 10Gbps receiver

Using a RS(223,255) forward error correction at a 1E-4 raw BER yields a receiver sensitivity of -25dBm. The advanced ONU's sensitivity is well comparable then to the one of the legacy ONUs. Since both signals originate from a shared transmitter and undergo the same PON plant attenuation, a balance is desirable here.

The achieved -25 dBm receiver performance allows to address the G.984 GPON Class B+ attenuation budget with a transmit power of +5 dBm, including a fiber dispersion penalty. An externally modulated transmitter with an electro-absorption modulator (EAM) or even a direct modulated high power laser can be employed as the OLT optical emitter.

Collateral GTC and GEM layer measures

The described PHY layer techniques to multiplex two downstreams onto a single wavelength pose on the two constituents so far only the requirement of a bit edge alignment. Additional measures for the format-switching Modes 1 and 1A are necessary to mask the gaps of absent valid data. In the following, specifically the GPON protocol [2] is considered.

- BIP8 GTC frame check will detect the bit errors occurring during the 10Gbps time periods
- GEM delineation (HEC) will notice bit errors and also depends on readable PLI indicators

To contain error alarm propagation and to prevent undesired legacy ONU shut-downs, the BER threshold can be remotely set to a level that is not exceeded by BIP8 under the significant BER overload situation.

Alignment of the PHY layer switchovers and GTC/GEM layers and sending GEM headers strictly in 2.5Gbps and binary format, enables continued and error-free GEM parsing. Bitstacked 10 Gbps intervals receive an underlying legacy GEM frame addressed to a dummy ONU. *Mode 2* operation intrinsically supports independent GTC and GEM frames.

Upstream upgrades

Upstream is not legacy bound, as a multi-rate OLT receiver can serve two ONU generations in time-division-multiple-access on a single shared wavelength. Upstream sharing requires, however, coupled GTC layers and synchronised (US-) bandwidth maps.

Conclusions

Novel electrical multiplexing for simultaneous operation of two PON generations on a shared downstream wavelength has been described. Bit-stacking and collateral measures offer several operation modes which can serve Class B+ PONs and legacy ONUs avoiding wavelength-domain multiplexing.

References

1 IEEE 802.3av, 10Gbps EPON draft specification

2 ITU-T G.984.x, Gigabit-capable passive optical networks (GPON)