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40 Gbit/s NRZ Packet-Length Insensitive Header Extraction for Optical Label Switching Networks

Jorge Seoane, Efstratios Kehayas, Hercules Avramopoulos and Palle Jeppesen

***Abstract*—A simple method for 40 Gbit/s NRZ header extraction based on envelope detection for optical label switching networks is presented. The scheme is insensitive to packet length and spacing and can be single-chip integrated cost-effectively.**

I. Introduction

In recent years and as data traffic continues its increase, important concerns have been risen on the handling capability of all-electronic nodes in optical communication systems. As a result, considerable effort has been dedicated to all-optical label swapping (AOLS) networks [1, 2].

However, the migration scenario of optical systems has been recently redefined, and in the near future both all-optical and electrical signal processing are expected to co-exist [3, 4]. In this new inwards penetration path depicted in Figure 1, header extraction is currently at the forefront of all-optical processing subsystems, as it will allow the payload to remain in the optical domain, while header processing could be treated electrically. Due to its simplicity and excellent bandwidth utilisation, time-serial is commonly recognised as the most straightforward method of encoding the header. Therefore, this migration scenario would benefit from a simple and robust time-serial label and payload separation subsystem.

In this paper, we demonstrate a novel concept for header extraction suitable for NRZ modulated packets, based on packet-by-packet envelope detection using generic hybrid integrated optical gates.

II. Envelope detection

The header-payload separator relies on configuring a Mach-Zehnder interferometer with embedded semiconductor optical amplifiers (SOA-MZI) as a 1×2 optically-controlled space switch.

This functionality can be very briefly explained as follows. An interferometric structure creates amplitude fluctuations at its output relative to the phase difference between its arms due to a cross-phase modulation (XPM) process. In a SOA-MZI, this phase difference is determined by the SOAs. The phase of a SOA is affected by the carrier density, which in turn is related to the presence or absence of light at its input facet. By conveniently lighting the inputs of the SOA-MZI, and therefore choosing the phase difference in the interferometric structure, the input signal can be routed to any of the outputs.

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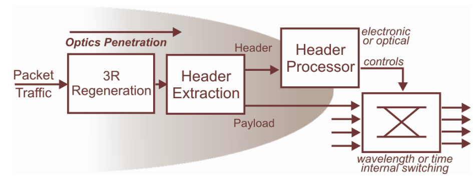

Fig. 1. Penetration path of all-optical signal processing.

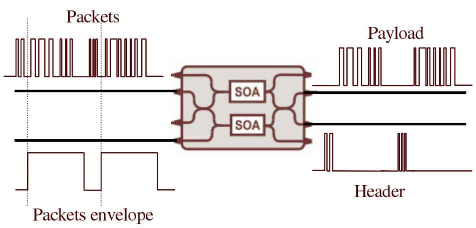

Fig. 2. Header/payload separation based on envelope detection.

In this paper, we propose to utilise the incoming optical packets and delayed versions of their respective recovered envelopes to achieve this spacial switching, and therefore effectively obtain separation by redirecting header and payload to different output ports of the SOA-MZI, as shown in Figure 2. Simple generation of the packet envelope is achieved by wavelength converting the original data signal using a second SOA-MZI. It should be noted, that since creating the enveloped requires *slow* recovery times in the SOAs, low speed devices can be used for this stage, which illustrates the potential of the subsystem to operate at bit rates beyond 40 Gbit/s.

III. Experimental set-up and results

The implemented set-up is presented schematically in Figure 3. The light from a continuous wave (CW) laser at 1550 nm is modulated in an external Mach-Zehnder modulator by a user-defined pattern at 40 Gbit/s, creating two repetitive packet types as shown in Figure 4 a). Each packet comprises a header and the payload. The header is a 10 bit sequence, where the first two bits are preamble bits to facilitate the generation of the packet envelope. The space between packets and their payload has a variable length to fully validate compliance with asynchronous networks. The guard band between header and payload corresponds to 4 bits or 100 ps.

Data packets are tapped and applied to a wavelength conversion stage in a SOA-MZI to create the packet envelope. Since the unsaturated recovery time of the SOAs is under 80 ps, the memory effect of a Fabry-Perot filter was

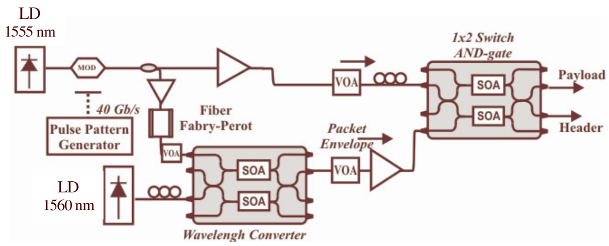

Fig. 3. Experimental set-up for header/payload separation in SOA-MZI based on envelope detection. MOD: optical modulator; VOA: variable optical attenuator; SOA: semiconductor optical amplifier.

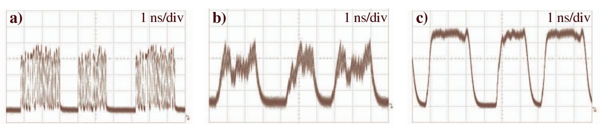

Fig. 4. Envelope generation process. a) Pattern; b) Fabry-Perot filter output; c) Packet envelope after wavelength conversion.

used to flatten the modulated data signal and prevent the SOAs from following the data pattern. Screen shots after the filter and the generated packet envelope, recorded using a 50 Gbit/s sampling scope after optoelectronic conversion, can be seen in Figure 4.

The primary tap of the original data signal is injected into the second SOA-MZI, which performs the header and payload separation following the principle explained in the previous section. Specifically, the data packets are synchronized with their respective packet envelopes, so that only the payload part coincides with the packet envelope signal (Figure 2). Since the packet envelope determines the switching state of the SOA-MZI space switch, whenever the data packet and its envelope coincide at the input ports of the SOA-MZI, the signal is transferred to the upper output port of the SOA-MZI (payload port). Otherwise, the signal propagates unaffected within the switch and exits at the lower output port of the SOA-MZI (header port). A delay line ensures that the rise time of the packet envelope coincides with the guard band between header and payload, so that error-free operation is guaranteed.

At both outputs, there is a 1.3 nm filter centered at 1550 nm that filters out the packet envelope at 1560 nm before entering the receiver.

Figure 5 a) shows typical oscilloscope traces of the generated packets. As can be seen, payload bit length and packet-to-packet guard band times are random, as would be the case for a asynchronous multi-purpose network. Figure 5 b) and c) illustrate the recovered payload and header respectively. The inset figure shows the large contrast ratio achieved after header/payload separation.

BER performance of the system is presented in Figure 5 d). Measurements for the header and payload were done sequentially using a 40 Gbit/s programmable receiver. Nevertheless, neither the settings of any SOA-MZIs, nor polarisation of the system were modified while measurements were taken, which demonstrates simultaneous optimum performance of both output ports.

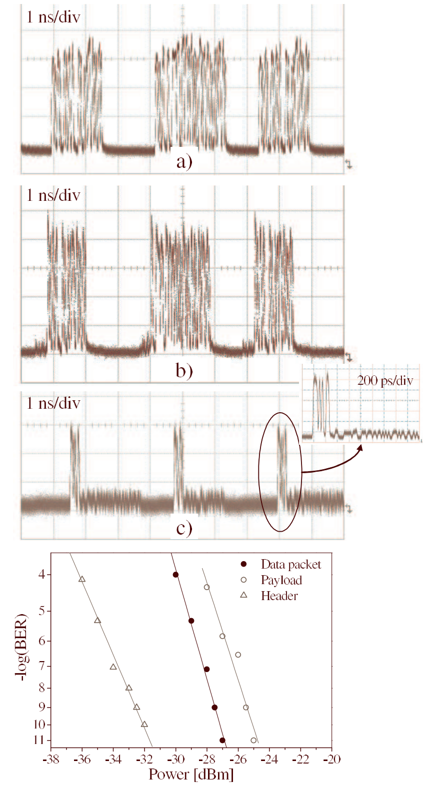

Fig. 5. a) Generated packets; b) Extracted payload; c) Extracted label. Inset illustrates the high extinction ratio obtained using this method; d) BER measurements

IV. Conclusion

A novel concept for header/payload separation applicable to NRZ modulated packets has been demonstrated at 40 Gbit/s. Compared to the back-to-back case, a 2 dB penalty has been measured for the payload whilst yielding 6 dB improvement for the header. Moreover, this header /payload extraction method guarantees subsystem legacy when migration from NRZ to other modulation formats, such as RZ, is considered.

Acknowledgment

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