Experimental Demonstration of Optical TTL Based Selective-3R in OLS Network Testbed with Label Rewriting

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Abstract: We demonstrate optical-TTL-based selective-3R regeneration in an OLS testbed with OLS routers, which intelligently apply 3R only when necessary. The experiment achieves error-free operation with all-optical burst-mode clock recovery.

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1. Introduction

Optical-label-switching (OLS) is an attractive technology that enables seamless integration of data and optical networking. Optical 3R regeneration in OLS routers re-amplifies, re-shapes, and re-times the OLS packets to extend the reach of the optical signal without repeated high-speed O/E/O conversions. On the other hand, optical 3R regeneration is not always necessary for all the packets at every OLS router hop in every linecard, and it is far more complicated than 1R or 2R counterparts [1]. This paper demonstrates optical time-to-live(TTL)-based selective-3R in OLS routers to apply 3R regeneration only when necessary. The OLS router includes one linecard with optical 3R regenerator in the loopback path to be shared by all other linecards. The switch controller in the OLS router examines the optical TTL values, and selectively sends the packets requiring 3R regeneration to the 3R port in the loop-back path, whereas other packets will skip the 3R regeneration. The proof-of-principle experiment demonstrates the proposed selective-3R scheme in a 10 Gb/s 3-node OLS network testbed.

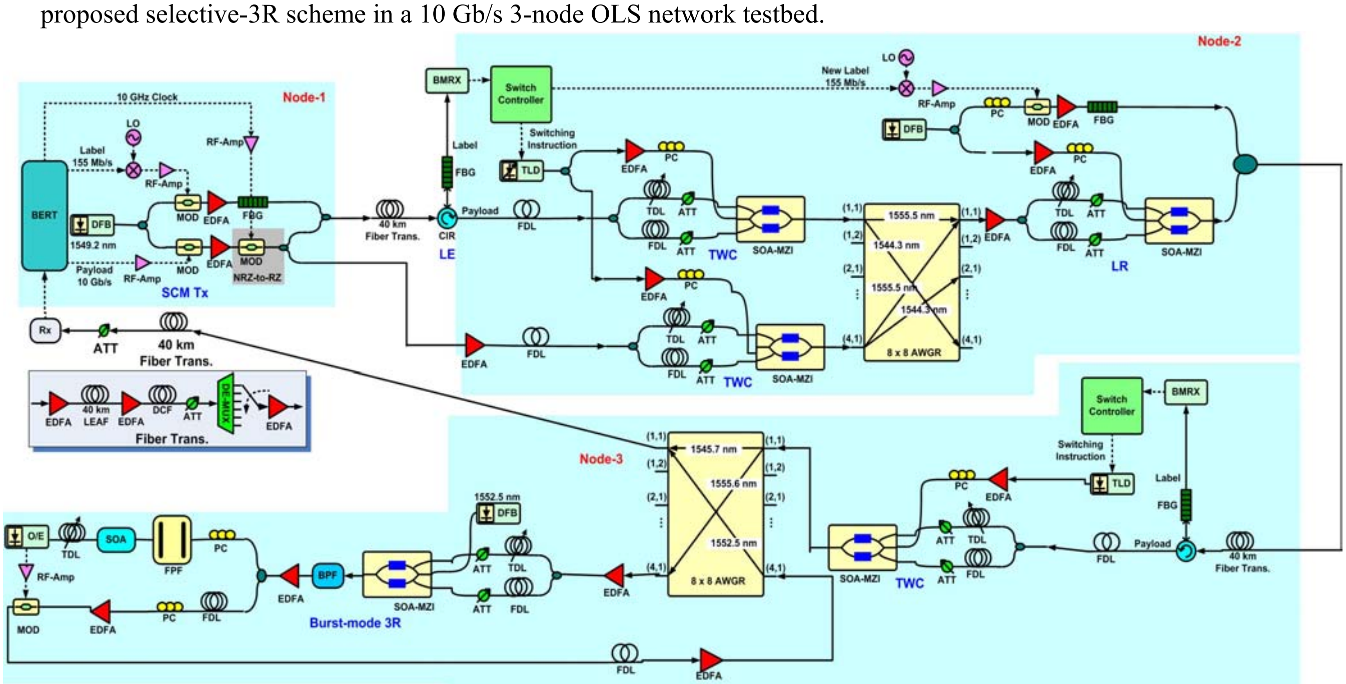

Fig. 1 Experimental setup, BERT: bit-error-rate tester, LO: local oscillator, RF-Amp: RF amplifier, DFB: DFB laser diode, MOD: $LiNbO_3$ modulator, EDFA: Erbium-doped fiber amplifier, FBG: fiber Bragg grating, Fiber Trans.: fiber transmission span, CIR: optical circulator, BMRX: label burst-mode receiver, FDL: fixed delay line, TDL: tunable delay line, PC: polarization controller, ATT: variable attenuator, BPF: band-pass filter, O/E: optical-to-electrical converter, LEAF: large-effective-area fiber, DCF: dispersion compensation fiber, DE-MUX: wavelength de-multiplexer

2. Experimental Setup and Results

Fig. 1 shows the experimental setup. At OLS Node-1, the subcarrier-multiplexed transmitter (SCM Tx) in a two-arm configuration modulates 155 Mb/s labels and 10 Gb/s return-to-zero (RZ) payloads separately before combining them into OLS packets [2]. The OLS packets propagate to Node-2 through 40 km fiber transmission. Meanwhile, 50% power of the RZ payload is tapped at Node-2 without label insertion or fiber transmission for emulating the local packet-addition. Fig. 2(a) shows the logical schematic and packet sequences of the experiment. The packets from Node-1 are referred to as P1 and P2, while the packets added locally at Node-2 are referred to as P1′ and P2′. Variable-length packets with 8192 and 5120 bits have been used for packets P1 and P1′, as well as P2 and P2′, respectively. Node-2 taps the optical labels for P1 and P2 [3] at the label extractor (LE), and sends the demodulated label contents to the switch controller for routing decisions. P2 is dropped locally, and P1′ is sent to a destination other than Node-3. P1 and P2′ are forwarded to Node-3 after the label rewriting module (LR) re-attaching labels on them [2]. Upon instructions from the switch controller, the tunable wavelength converters (TWC's) and the AWGR perform switching for P1, P2, P1', and P2'. The output of the tunable laser (TLD) is split and fed into two TWC's to realize synchronized local addition of P1' and P2'. The TTL value of P1 decrements by one (1) in the new label and reaches the threshold for selective-3R at the next hop (Node-3). Packets P2' do not need selective-3R at Node-3 because they are locally added at Node-2. As P1 and P2' reach Node-3 after another 40 km fiber transmission, its switch controller determines that P1 needs to go through selective-3R by examining the TTL value in its label. P2' gets pass through without selective-3R. The OLS router at Node-3 achieves selective-3R by sending P1 to the 3R port. The 3R regenerator inside that port has 2R regeneration with a Semiconductor Optical Amplifier based Mach-Zehnder interferometer (SOA-MZI)[4], and retiming with synchronous modulation [5]. The all-optical clock recovery is burst-mode with a Fabry-Perot filter (FPF) and a semiconductor optical amplifier (SOA)[5, 6]. The free spectrum range of the FPF is 10 GHz, while the finesse is 100. The 20-80% rise time of the clock envelope is approximately 1 ns. As shown in Fig. 2(a), the payload data stream is delayed 1.3 ns in the 3R regenerator to ensure being retimed with reasonably good clock. After 3R, P1 is combined with P2' at the output of Node-3 and propagates through 40 km fiber before reaching the optical receiver (Rx). The payload BER evaluation utilizes 2^{23}-1 PRBS. Fig. 2(b) shows the BER curves and the eye-diagrams. All BER curves are free of error floors and reach below 10^{-11} at an average receiver power –8 dBm, indicating error-free operations. The burst-mode 3R regeneration achieves 1.7 dB negative penalty for P1 at 10^{-9} BER relative to that at Node-3 input. The eye-diagram also shows that signal after 3R has smaller timing jitter and clearer space- and mark-levels.

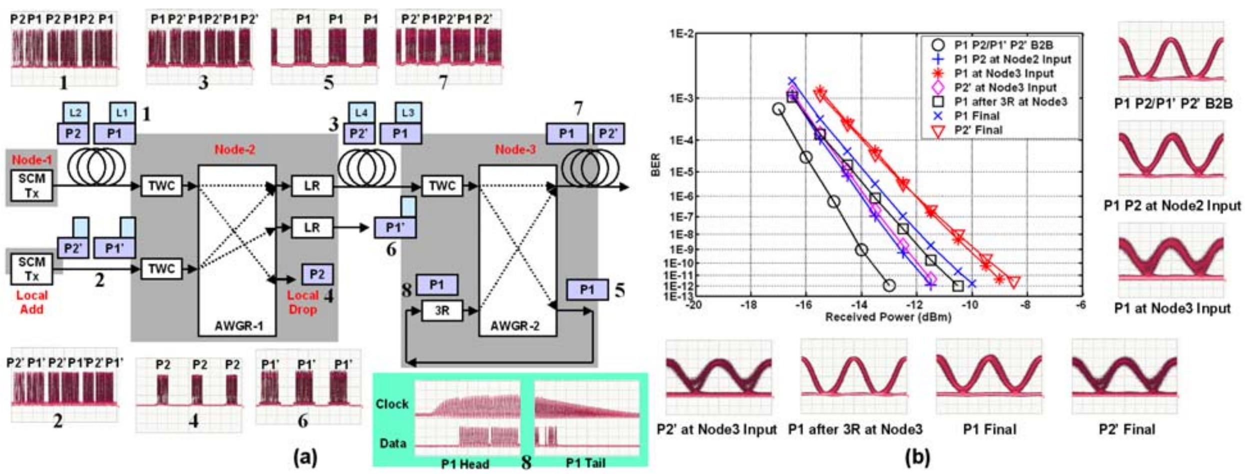

Fig. 2 Experimental results, (a) Logical topology and packet sequences, and (b) BER curves and eye-diagrams

3. Summary

This paper demonstrated optical TTL based selective 3R regeneration in an OLS network testbed with label rewriting. The experiment achieved error-free operation of the selective, packetized 3R regeneration employing all-optical burst-mode clock recovery in an OLS network testbed with fiber transmissions. The burst-mode 3R regeneration obtained 1.7 dB negative power penalty at 10^{-9} BER.

4. References

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