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Optical-Label and Code Empowered Systems for Next Generation Photonic Networks

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Abstract: *This paper discusses optical-label and optical-code based networking technologies for next generation photonic WAN, MAN, and LANs. Optical-Label switching is expected to play a key role in photonic WANs and MANs, and Optical-CDMA offers flexible network reconfiguration in photonic LANs. All-optical code translation capability helps cascaded operation of secure optical networks.*

Introduction

Optical-label switching (OLS) [1] and optical-code-division-multiple-access (O-CDMA) [8,9] technologies both emerged as viable future networking technologies. Optical-Label switching (OLS) facilitates introduction of optical packet switching by providing a shim layer between IP and WDM, and allows seamless upgrades from optical circuit switching and burst switching networks towards agile OLS networks supporting optical packet/burst/circuit traffic. OLS routers deployed in the future WANs and MANs can facilitate this transition. The O-CDMA technology also provides flexible networking in LANs. It offers flexible assignment and access of bandwidth using optical-codes, and the data plane can support IP and other format traffic. This paper discusses successful systems integration of OLS routers, O-CDMA nodes, and network demonstrations incorporating OLS and O-CDMA technologies.

Optical Label and Optical Code Empowered Networks

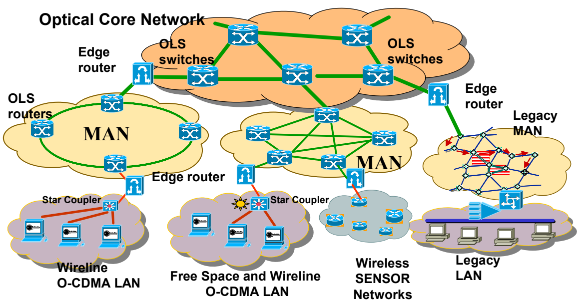


Fig. 1 A hierarchical schematic of future optical networks based on OLS and O-CDMA technologies interoperating with legacy networking technologies.

The key underlying networking concept behind Optical-Label Switching [1] is an efficient and transparent packet forwarding method using an optical-label switching mechanism which can co-exist with legacy WDM technologies on the same fiber. Figure 1 shows OLS networking in the WAN and MANs working together with O-CDMA LANs. New signaling information is added in the form of an optical signaling label which is carried in-band within each wavelength in the multi-wavelength transport environment. The optical-label containing routing and control information such as the source, the destination, the priority, and the length of the packet, will propagate through the network along with the data payload. Each optical-label switching router will sense this optical-label, look-up the forwarding table, and take necessary steps to forward the packet. If the packet is to be routed to a wavelength/path where there is already another packet being routed, the optical label switching router (OLSR) will seek routing by an alternate wavelength, by buffering, or by an alternate path. This wavelength, time, and space domain contention resolution is a key to implementing optical-router without heavily relying on time-buffers as conventional electronic routers do [2].

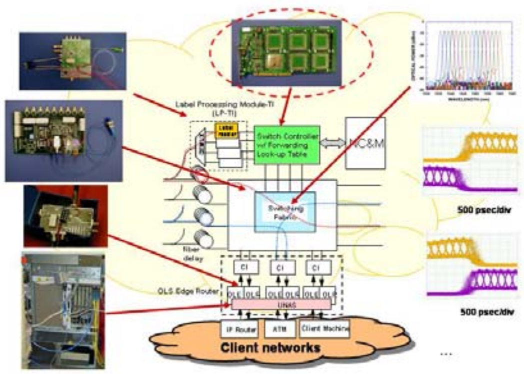
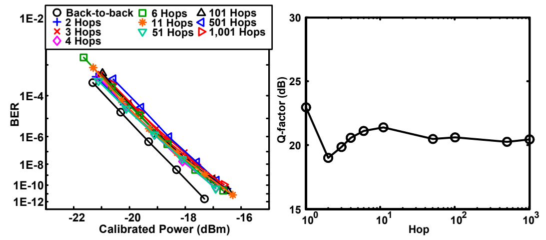


Fig. 2. An integrated optical-label switching router system.

Optical-label switching accommodates data packets of any length, flows of an arbitrary number of packets, a burst of a long datagram, and even a circuit-connection. Fig. 2 illustrates the schematic of the integrated OLSR [5]. The OLSR consists of the optical router controller, the optical label extractor, the optical label rewriter, the optical label detector, a switch fabric, and client interfaces. The optical router controller, implemented by a field programmable gate array (FPGA) incorporates the wavelength-time-space domain contention resolution algorithm. The switching fabric consists of rapidly tunable wavelength converters and arrayed wavelength grating routers (AWGR) [4] and fixed wavelength converters. With the GMPLS extension, the OLS system is designed to interoperate with MPLS, MPLambdaS and IP [2]. Successfully integrated OLSRs achieved 1,001-hop cascaded operation thanks to all-optical 3R burst mode regeneration incorporated in the OLSR. Fig 3 shows the experimental data. Recent experiments also showed a successful field trial across 477 km San Francisco bay dark fiber NTON-Sprint networks, and a demonstration of IP-client-to-IP-client multimedia demo with multicast packet switching across an all optical label switching network using the OLS edge routers.



(a) (b)

Fig. 3. Cascaded OLSR performance measurement up to 1,001 hop operation showing (a) BER v.s. calibrated optical packet power, and (b) Q-factor evolution for calibrated power of -12 dBm.

For O-CDMA, we employed Spectral Phase Encoded Time Spreading (SPECTS) method for coherent O-CDMA. The eventual goal is to achieve flexible optical code based networking using integrated O-CDMA chips like one shown in Fig. 4.

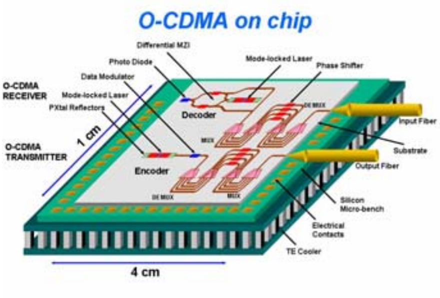


Fig. 4. A schematic of an integrated SPECTS O-CDMA transceiver on a chip. [10]

Using an InP based integrated SPECTS O-CDMA encoders and decoders, we achieved all-optical code translations. Figure 5 shows the cross-correlation traces of O-CDMA code decoding and translation achieved all-optically. [11]

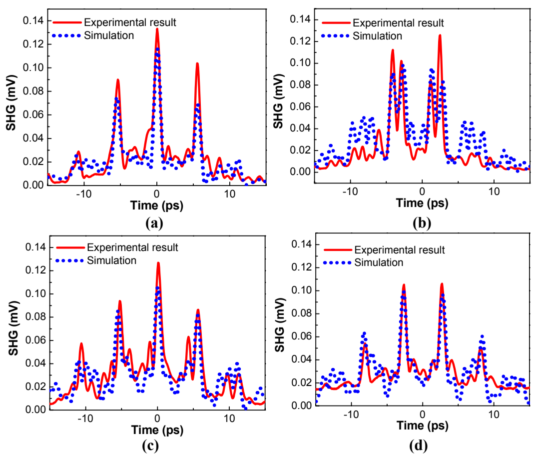


Figure 5 Cross-correlation traces of (a) the cascaded encoder-decoder output with only phase error compensation applied to the phase modulators, (b) the encoder output under W5 encoding, (c) the decoder output for correctly decoded signal, and (d) the decoder output for incorrectly decoded signal. (Solid lines are experimental results and dotted lines are simulated results. W5 code is [11110000].) [11]

Using a bulk optics testbed, we have demonstrated 320 Gb/s O-CDMA LAN in support of 32 users at 10 Gb/s data rates [12]. Fig. 6 shows the BER performance of the testbed (a) with Forward-Error-Correction (FEC) and (b) without FEC.

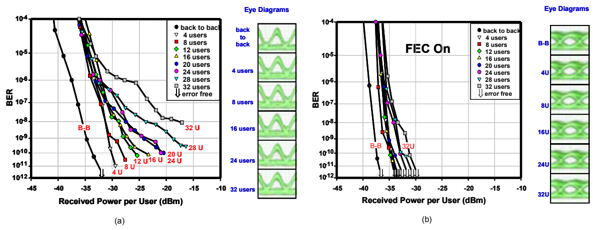


Fig. 6. The BER performance of the 32 user 10 Gb/s testbed (a) without FEC and (b) with FEC. [12]

Conclusion

OLS and O-CDMA technologies can offer powerful means to realize flexible and unified next generation networks spanning WAN, MAN, and LANs with agility to support packet/burst/circuit traffic on a unified platform with full interoperapability with legacy networks.

Acknowledgments

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