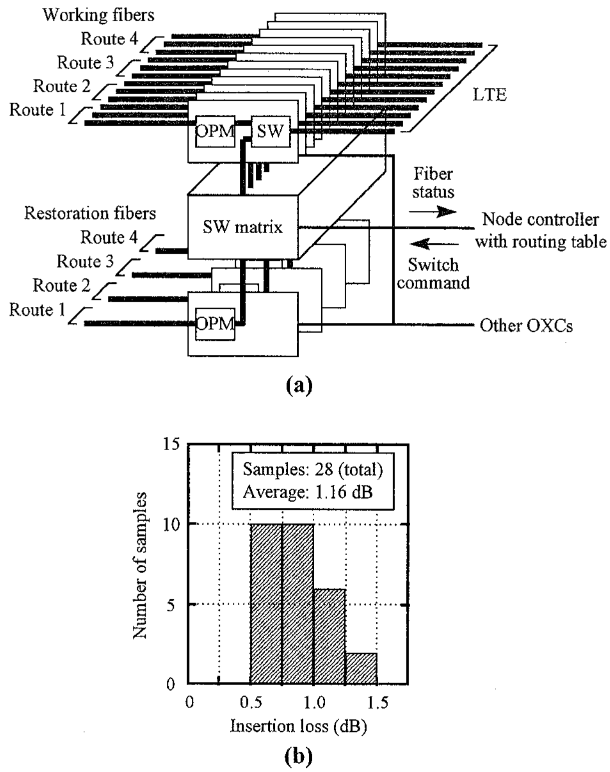
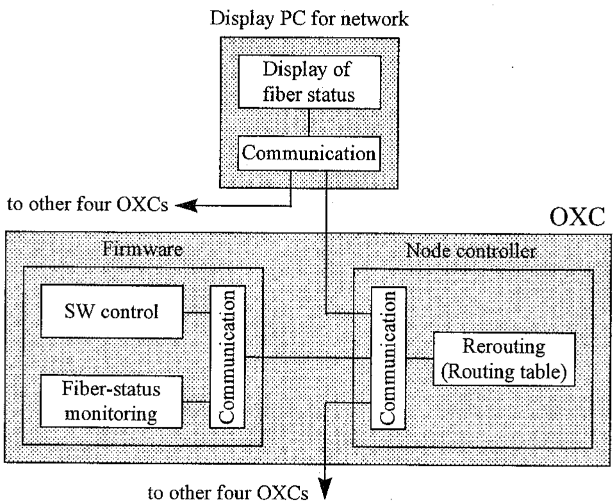


ThD3 **Fig. 2.** Optical cross-connect system; (a) Switch architecture, (b) diagram of the insertion loss for connection between LTE and working fibers.



ThD3 **Fig. 3.** Functional blocks of control software.

In summary, OXC systems are demonstrated using five bays. A low insertion loss of 1.16 dB for working fiber and a high-speed restoration of <150 msec were achieved.

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1. G.R. Hill *et al.*, IEEE J. Lightwave Technol. **11,** 667–679 (1993).
2. K. Sato, in *First Optoelectronics and Communications Conference,* 1996, paper 18A2.
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ThD4 **9:45am**

Attack detection in all-optical networks

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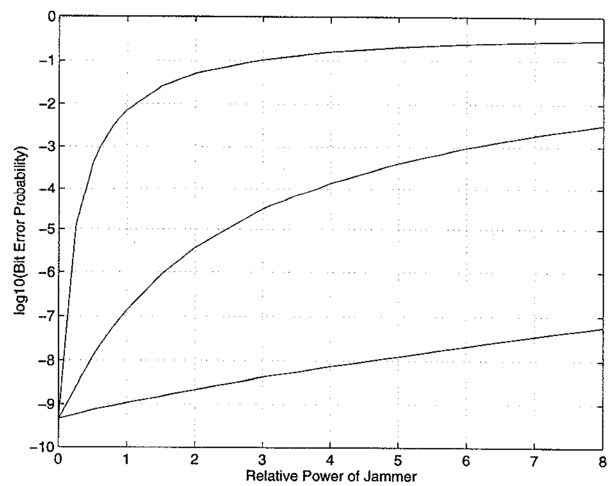
All-optical networks (AONs) may be attacked by nefarious users that misuse the network to disrupt the normal operations of nodes in the AON. Such attacks differ from failures and must therefore be treated differently. Figures 1 and 2 show example attacks. Figure 1 shows the bit error rate (BER) for OOK with an AWGN attacker who jams via cross talk at a switching node. Figure 2(a) shows the results of a 1530-nm 2.5-ms-long uniform pulse attack at an erbium-doped fiber amplifier (EDFA). Figure 2(b) shows the same attack for an EDFA for which internal out-of-band oscillation is used to clamp the gain.

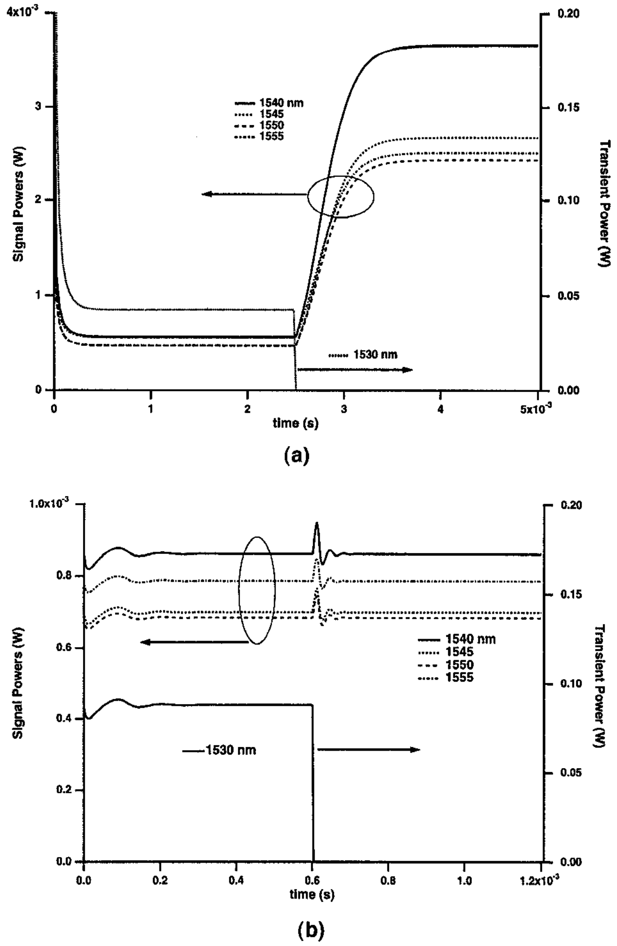
Most conventional diagnostics would fail to detect the above attacks. Wideband power integration[3] is eliminated because total output power is not reduced. Wavelength-specific power detection might work for the unclamped EDFA but might not work for a gain-clamped EDFA unless the integration time is under 10^{-4}s. An out-of-band supervisory signal (e.g. pilot tone or OTDR signal)[5,2,4] may not be affected by crosstalk jamming and might remain detectable after an EDFA attack. An in-band sub-carrier-multiplexed pilot tone (10–100 kHz)[1] might detect EDFA attacks (with transients ≈10 kHz) but not sporadic cross talk jamming attacks. An optical spectrum analyzer would detect the EDFA attacks but not sporadic (order of bits) jamming through cross talk. BERTs would detect degradations after they have caused several errors. For instance, detecting with certainty that the BER is 10^{-8} versus 10^{-9} takes 1s at 1 Gbps.

We show (Fig. 3) a new method for attack detection at nodes. Our method works for arbitrary modulations and rates and therefore is

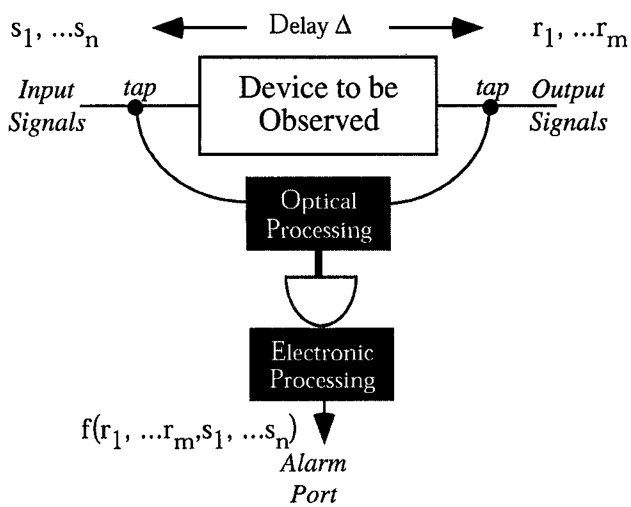


ThD4 **Fig. 1.** BER for 16 dB pre-attack SNR vs. power of AWGN attacker using cross talk. The top curve corresponds to −10 dB cross talk, the middle one to −20 dB and the bottom one to −30 dB.

suitable for transparent networks. The input $\{s_1, \ldots, s_n\}$ and the output $\{r_1, \ldots, r_m\}$ of a node are compared using the function f to determine whether the node operates properly. The attack detector must know the node's action, such as switching or amplification. For OOK, we evaluate the per-bit false positive and false negative probabilities for a particular detector. These probabilities yield rates of alarms. From the alarms we can diagnose degradations even before errors occur. Consider a cascade of 10 nodes and a distributed attack, which is the same at each node. The pre-attack end-to-end SNR is 16 dB and an attack increases end-to-end BER from 10^{-9} to 10^{-8} at 1 Gbps. For crosstalk jamming attack over 10 switches, consider a tone jammer that decreases the ON value and increases the OFF value by 0.1% of the ON level. Detecting the BER degradation takes 10 μs. For unclamped EDFAs, legitimate channels coming on can reduce gain, e.g. from 25 dB to 23 dB. Hence, the attack detectors would need to track the gain. For a gain competition attack over 10 gain-clamped EDFAs, the distributed attack reduces each EDFAs gain by about 1%. Note that the gain varies by <0.2% when legitimate channels turn on and off. Detecting the BER degradation takes under 1 μs.



ThD4 Fig. 2. (a) EDFA with 16 wavelengths evenly spaced between 1540 and 1555 nm, each with input power 10^{-5} W. There is a step attack at 1530 nm at 10^{-4} W. Output powers for four legitimate wavelengths and the attack wavelength are shown. (b) Gain-clamped EDFA with 16 wavelengths evenly spaced from 1540–1555 nm, each with input power 10^{-5} W. There is a step attack at 1530 nm at 10^{-4} W. Output powers for four legitimate wavelengths and the attack wavelength are shown.



ThD4 Fig. 3. Proposed attack detection scheme.

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2. M.N. Huber, O. Jahreis, in *Optical Fiber Communication Conference*, Vol. 8 of 1995 OSA Technical Digest Series (Optical Society of America, Washington, D.C., 1995), pp. 167–168.
3. I. Katzela, G. Ellinas, T.E. Stern, in *Digest of the LEOS Summer Topical Meetings*, August 1995, pp. 41–42.
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ThE

8:30–9:45am
Room A4

Advanced Submarine Network

Shoa Kai Liu, *MCI, Presider*

ThE1 (Invited) **8:30am**

The SEA-ME-WE 3 undersea cable system

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At the beginning of 1997, the contracts for the provision of the Sea-Me-We 3 Cable System have been signed; the total budget of the project is 1,300 M$. Owned by more than 90 Telecommunication companies, long of 38,000 km with 39 landing points in 33 countries, Sea-Me-We 3 is the most important submarine cable project ever launched. It will link Europe, Far East Asia, and Australia. Commercial service will begin in December 1998 and be completed in March 1999. The system will be initially equiped, in the cable stations, at half its maximum capacity.