In summary, we have observed the scalability and modularity of the parametric WIXC architecture. A WSXC can be upgraded to a partially blocking WIXC to a rearrangeably nonblocking WIXC in a modular manner.

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TuJ4 **3:00pm**

Crosstalk performance of a wavelength selective cross-connect mesh topology

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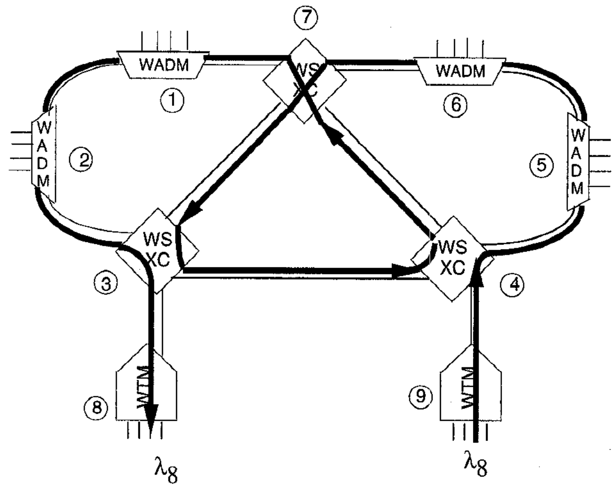
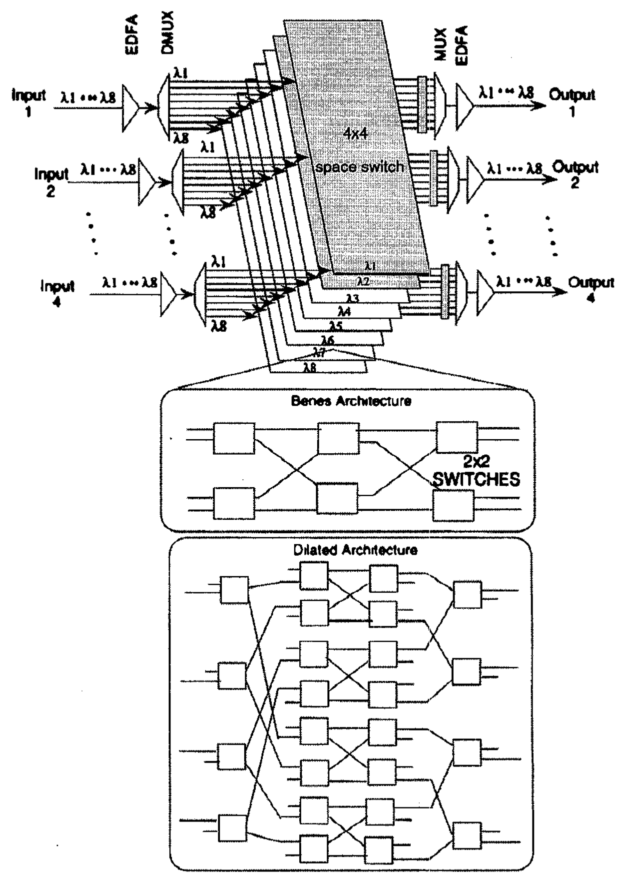
The analytical performance evaluation of national scale multiwavelength networks is difficult due to the large number of components and complexity. As part of the Multiwavelength Optical Networking (MONET) program,[1] a wavelength-domain simulation tool has been developed[2] for the study and design of the optical transport layer. The simulator evaluates the signal, amplified spontaneous emission (ASE) noise,[3] and linear crosstalk powers at every point in the network.

Linear optical crosstalk, generated at the optical switches and MUX/DMUXs, can lead to significant network performance degradation and impose severe requirements on the components.[4,5] In this paper, wavelength-domain simulation is used to study the accumulation of common-channel cross talk (or intraband cross talk) in a mesh of wavelength selective cross-connects (WSXCs) and wavelength add/drop multiplexers (WADMs). Common-channel cross talk is generated when signals of the same nominal wavelength interfere at the receiver. Multipath-homodyne cross talk is the common-channel cross talk that is generated from either the MUX/DMUX pairs or the switching fabrics when signals from the same source interfere at the receiver. Adjacent-channel cross talk is rather small and is thus neglected.

The block diagram of the network topology under study is shown in Fig. 1. It consists of three eight-wavelength 4 × 4 WSXCs and four WADMs[3] forming two interconnected bi-directional WADM rings. Each 4 × 4 WSXC shown in Fig. 2 consists of four pre-amplifiers, eight MUX/DMUXs, eight layers of a 4 × 4 switching fabric, 32 servo-controlled attenuators and four booster amplifiers. All network elements are connected with duplex fiber links of 17-dB span loss, corresponding roughly to 57 km, assuming a fiber loss of 0.3 dB/km. Wavelength terminal multiplexers (WTMs) are used for adding/dropping the eight wavelengths, which are equally spaced by 200 GHz in the range of 1549.31–1560.60 nm.[1] For simplicity the routing scenario was chosen so that all wavelengths are present on all links. The steady-state erbium-doped fiber (EDF) model of Ref. 6, adequate for low-gain amplifiers ($G \simeq 20$ dB), is used. The pump power and EDF length are adjusted so that they provide an average gain of 17 dB, with maximum gain variation among the channels 0.5 dB and with a noise figure of 4.2 dB at 1550 nm.



TuJ4 **Fig. 1.** Block diagram of the network connecting three WSXCs, four WADMs and two WTMs. Duplex fiber links of 17-dB loss connect the network elements. The worst optical path is denoted by a bold line.



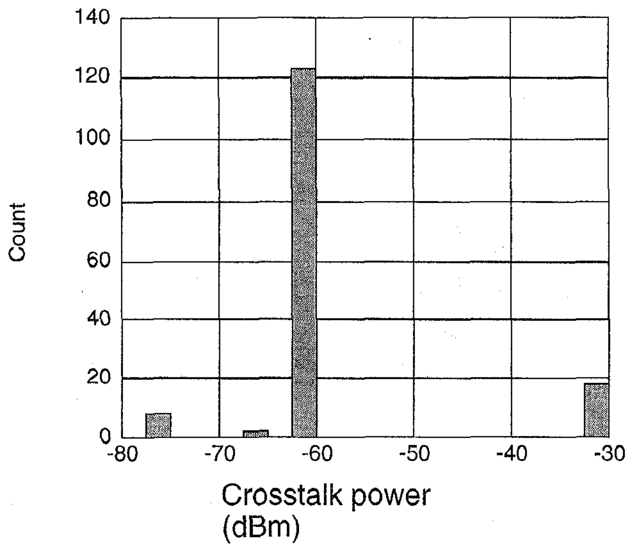
TuJ4 **Fig. 2.** Detail model of WSXC. Inset: two alternative 4 × 4 optical switch fabrics are examined: a rearrangeably nonblocking Benes switch and a dilated switch.

The MUX/DMUXs are modelled as cascades of multilayer interference (MI) filters.[3]

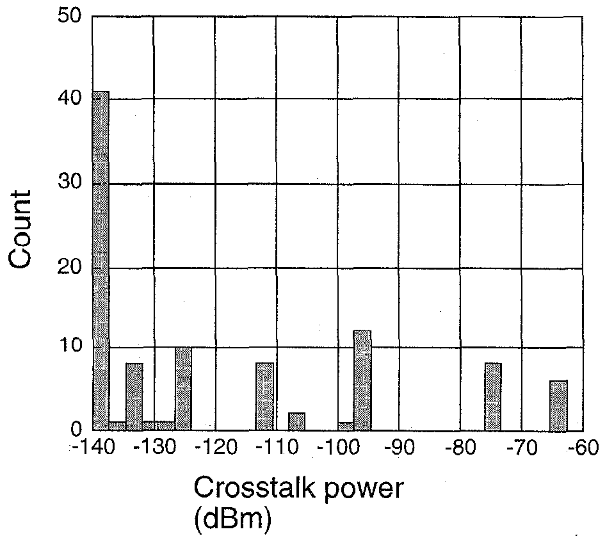
Two different switching fabrics (shown in Fig. 2) are used: a 4 × 4 rearrangeably nonblocking Benes switch and a 4 × 4 dilated architecture. The individual 2 × 2 *optical switches* have a crosstalk value of −30 dB and an insertion loss of 1 dB, which corresponds to excellent performance $LiNbO_3$ or polymer technology switches.

In our study we considered the cross talk for all components and all paths, but we report here only the worst optical path, which passes through all network elements (see Fig. 1). Transmission along this path uses wavelength λ_8. At this wavelength the erbium-doped fiber amplifiers present gain of 16.7 dB. Although this path is improbable, in a real situation, it does provide the most severe crosstalk penalties possible.

Figure 3 shows histograms of the power levels of the dominant cross talk terms at wavelength λ_8 for the Benes switch architecture [Fig. 3(a)] and the dilated switch architecture [Fig. 3(b)]. Due to the steep transfer functions of the MUX/DMUXs, the power of the strongest multipath-homodyne cross talk terms generated at the MUX/DMUXs is less significant than the second-order common channel cross talk terms generated by the optical switches. In the Benes structure of Fig. 3(a), 18 first-order common channel cross talk terms are generated. In the dilated architecture of Fig. 3(b), no first-order cross talk terms arise. The unused optical switches of the architecture are set to generate at most one second-order cross talk term per 4 × 4 switch. Only five second-order cross talk terms are generated for the above network. For the 4 × 4 Benes switch, it is shown that the above level of common-channel cross talk leads to an error floor that corresponds to a bit error rate (BER) higher than 10^{-9},[4,5] whereas for the dilated architecture, cross talk impairments are < a tenth of a dB and thus correspond to a BER $<10^{-9}$.



(a)



(b)

TuJ4 Fig. 3. Histograms of cross talk terms after 20 iterations for MONET wavelength eight passing through the worst path. (a) with 4 × 4 Benes optical switch fabric; (b) with 4 × 4 dilated switch fabric.

In the above example, 2558 modules are modelled and the execution time for the system is 1 hr on a SunSparc 20 workstation. Wavelength-domain simulation is thus a valuable tool for the study of realistic and complex architectures with thousands of components. It can provide guidelines for the optimal design of network elements and especially large cross-connects using dilated switch fabrics.

In conclusion, crosstalk-induced penalty depends on the cross talk level of the individual 2 × 2 switches as well as on the size and architecture of the switching fabric. With existing optical switch technologies, it is necessary to use dilated switch architectures to avoid error floors and achieve adequate network performance.

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TuJ5 **3:15pm**

Demonstration of an add-drop network node with time slot access for high-speed WDMA dual bus/ring packet networks

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High-speed wavelength division multi-access (WDMA) ring and bus networks are very promising architectures to support multi-access of high-capacity data. Most WDMA networks[1–3] are configured with fixed transmitter and tunable receiver (FTTR) and employ decentralized light sources. However, they require complicated control signaling and suffer from a wavelength matching problem. In this paper, we propose and demonstrate a practical WDMA ring/bus packet network node using tunable transmitter and fixed receiver (TTFR) configuration. Centralized light sources are used and time slot access is controlled by our proposed signaling scheme.

Figure 1(a) shows the architecture of our proposed network node. Multiple wavelengths with empty slots (unmodulated time slots with cw