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A New Nonblocking Optical Switching System for All-optical Communication Networks

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Abstract

Future communication networks will demand a huge bandwidth that cannot be handled by electronic communication networks. However, optics as a carrier of information can handle this huge bandwidth. The major obstacle in this regard is a suitable switching system that can efficiently route optical signals. An all-optical switch network, in which data remains in the optical domain throughout its journey from source to destination, is central to such switching systems. The present trend to merely embed the optical signal into the existing electronic switch network cannot achieve the goal of having a huge-capacity switching system because of the different physical properties of optics. There are two major problems, namely crosstalk and path-dependent signal loss, that need to be addressed while designing a switch network with guided-wave technology. Because of the stringent bit error-rate requirement of optical transmission facilities, elimination of crosstalk has become an important issue for making optical networks work properly. It is also difficult to handle path-dependent signal loss and delay in the optical domain with such a high bit rate – especially if the variation is large. Another practical problem is the cost, since the optical components are very expensive. That is why an all-optical switch network needs to be customized according to different cost-performance requirements for different switching systems.

The switching technique in optical switching systems needs special attention. Although centralized control routing is easy to implement in optical switching systems, it is not suitable for a large system because of its $O(N)$ routing complexity. On the other hand, it is difficult to implement a self-routing algorithm in all-optical switching systems because optical buffers are not available. By now, a single switch network does not have all the good properties desired for all-optical switching systems.

In this dissertation, an all-optical switching system is proposed in which a new optical switch network is used in conjunction with a new switching technique. The switch network has almost all of the good features that were discussed above. It is strictly nonblocking, and theoretically has no path-dependent loss and delay. In addition, it provides constant first-order crosstalk and, therefore scales well.

The switch network is constructed by using building blocks recursively. The building blocks are independent: they have their own architecture and routing strategies. Any $M \times N$ network can be developed by using building blocks of size $m \times n$, where $\log_2(N/n)$ and $\log_2(M/m)$ are integers. Thus, by choosing appropriate building blocks, it can be customized according to the cost-performance requirement of a system. Also proposed are small wide-sense nonblocking switch networks as building blocks with novel routing algorithms. These wide-sense nonblocking switch networks can establish any new connection without interrupting an existing connection, like strictly nonblocking networks. The proposed wide-sense nonblocking switch networks require the fewest know switching elements.

Furthermore, a new routing technique called *Distributed Control Routing* has been introduced. The *Header* is converted into the electronic domain only once, when it is at the input of the switching system, after which it is routed through a separate control network using a self-routing algorithm and appears at the output. *Data* is transmitted in circuit switching fashion. An appropriate amount of delay is inserted between *data* and *header* to let the switches change their states accordingly. If t_C is the time required to convert an optical header into electronic signal, t_S is the time required to set up the state of a switching element and t_E is the time for an electronic signal to cross one stage, then the total delay of the data is $\Delta T = t_C + t_S + O(t_E \log_2 N)$, unlike in self-routing, in which $\Delta T = O((2t_C + t_S)\log_2 N$. In self-routing the switch-setup-delays are additive; here they are not. This ensures that data remains in the optical domain from input to output and that delay is similar to the best achievable delay of electronic signal routing. This switching system can easily be implemented using present technological knowledge.

Keywords: Optical switch networks, Nonblocking networks, Optical crosstalk, Signal loss, Recursive networks, Distributed control routing.