An Optical Crosspoint Buffered Switching Architecture
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Abstract - We propose an optical crosspoint buffered switching fabric to simplify the implementation of optical packet switches. With the proposed switching fabric architecture, the control complexity of the optical buffers can be significantly reduced.

Introduction
Optical buffer is one of the critical components of optical packet switching. Current optical buffers are mainly based on fiber delay lines (FDLs) which delay the packets rather than store them [1]. Several optical switches with optical buffers for output contention resolution have been proposed [1-3]. These switches focus on using optical buffers to reduce the packet loss rate. Very little attention was paid to the complexity of buffer control. In fact, these switches all assume a central scheduler to arrange the required delays for the packets in an output port contention [4]. This will significantly limit the switch size and the applications if the optical fiber transmission rate is high.

To have proper buffer scheduling, the central scheduler has to maintain a table containing the usage information of each switch output port and its associated buffers. The buffer scheduling procedure includes two kinds of search in the buffer usage table of the packet contending output port: (i) determining the required delays for the packets, (ii) searching for the suitable FDLs in the optical buffer to provide the required delays. The searching process has to be repeated until all packets have been assigned suitable FDLs. Hence, the complexity of buffer control will grow rapidly with the switch size and optical fiber transmission rate.

Crosspoint buffered switching (CBS) architecture has been proposed for building electronic packet switches to reduce buffer control complexity [5]. Apart from simple buffer scheduling, the CBS architecture also has the advantage of providing good performance with low hardware complexity. Recently, a high performance 4 Tbps electronic CBS switch has been demonstrated [6]. In this paper, we propose an optical implementation of the CBS switching fabric to simplify the architecture of optical packet switches and to reduce the optical buffer control complexity accordingly.

Optical crosspoint buffered switching fabric
Figure 1 shows the basic optical CBS switching fabric architecture for slotted optical packet switches. An input packet first passes a 1 × N switch to the corresponding column of switching cells of the output port. A switching cell is composed of a 2 × 2 optical switch with an output connected to a FDL of one packet transmission time delay. The FDL’s output is combined to the other output of the 2 × 2 switch with an optical coupler and is further connected to the downstream switching cell as shown in Fig. 1. Each switching cell has a ‘cross’ state and a ‘bar’ state. A switching cell will send its input packet to the downstream cell and the packet from the upstream cell to its FDL if it is in the ‘bar’ state. Otherwise, the arrangement of the two packets is reversed. The switching cell sets itself to the proper state at the beginning of a time slot. In the basic design, the switching cell sets itself to ‘cross’ state only if its FDL is empty and no input packet from the 1 × N switch. The 1 × N switch will automatically block a new packet if the corresponding switching cell has nonempty FDL. It seems that we can improve the system performance if the switching cell can take the status information of upstream cells into its state setting consideration. The performance improvement, however, is found to be insignificant unless the global information corresponding column of switching cells of the output port.
of the whole column of switching cells is available. Figure 2(a) shows the case of three packets arriving at the column of switching cells of a 4 × 4 CBS switching fabric. The switching cells A, B, C, D are therefore in states of ‘bar’, ‘cross’, ‘bar’ and ‘bar’, respectively. Hence, the packet 2 is blocked because of the nonempty FDL of switching cell C. Figure 2(b) shows the status of the switching cells at the end of the time slot. Packet 3 will be sent to the output of the switching fabric. Packets 1 and 4 will be in FDLs of switching cells C and D, respectively.

The blocking probability of this optical CBS switching fabric basic design is high because only the local information of a switching cell is used. Much more packets should be able to enter the switching fabric if the global information of the whole switching cell column is used in the state setting. Another approach is to add extra switching cell columns as shown in Fig. 3. The packets which are blocked by their original switching cells are sent to the extra switching cell column. If the packets are accepted, they will be reinserted into their original switching cell column through the 1 × N switch as shown at the top of the Fig. 3. The extra switching cell improves the blocking performance but also increases the hardware complexity and the packet delay variance. Additional optical amplifier may be required to guarantee the optical signal quality. The advantage however is that it keeps the switching cell and control signaling simple.

Performance evaluation

We model the packet arrival as Bernoulli random process. The system loading is defined as the average number of packet arrival per time slot to a switch input. The desired switch output of an input packet is assigned at random [2]. Figure 4 shows the packet loss probability of the basic and improved version of our proposed CBS switching fabric with different system loadings and switch sizes. The performance of the proposed optical CBS design has been investigated. From simulations, significant performance improvement has been observed. Further performance improvement of the proposed optical CBS design is possible with extra hardware.

Conclusions

We have proposed an optical implementation of crosspoint buffered switching (CBS) fabric to simplify the buffering control in optical packet switches. To improve the blocking performance, an improved version of the proposed optical CBS design has been investigated. From simulations, significant performance improvement has been observed. Further performance improvement of the proposed optical CBS design is possible with extra hardware.

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References