Performance and Scaling of a Recirculating Optical Buffer.

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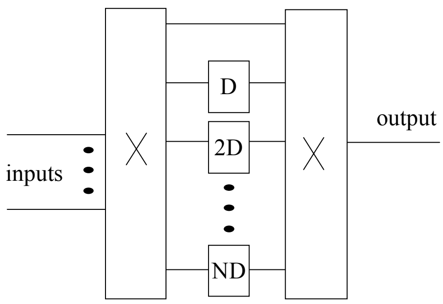
Abstract: *An important component of future optical routers or layer two switches is the optical buffering used to overcome output port contention within the switch fabric. In this paper we present the simulated behaviour of an optical output buffer to be realised using an NxN optical switch and recirculating integer delay optical delay lines. This investigation highlights the scaling behaviours of such an architecture to maintain efficient use of the buffer under Poisson traffic loading.*

1. Introduction.

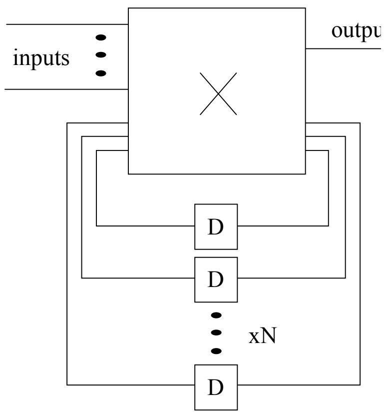
Photonic routing has been proposed as an approach to realising an all-optical packet network [(1,2)]. In order to handle the packet contention that will occur in an asynchronous and mesh connected network optical buffering will be required. Two simple forms of this output buffer are the switchable delay single pass buffer shown in figure 1, where the buffer fabric requires the use of *N* switch ports and delay lines and a total of *ND(N-1)/2* metres of fibre with two switch passes. Figure 2 illustrates the recirculating delay line buffer where multiple packet delays are generated by multiple passes through a smaller delay fabric of switched delay lines requiring only *ND* metres of fibre, but incurring a high loss from traversing the switch a maximum of *N+1* times for equal delay.



Dilated buffer

- high buffer cost
ND(N+1)/2 m fibre
-minimum passes through switch (low loss)
2 traversals

Figure 1



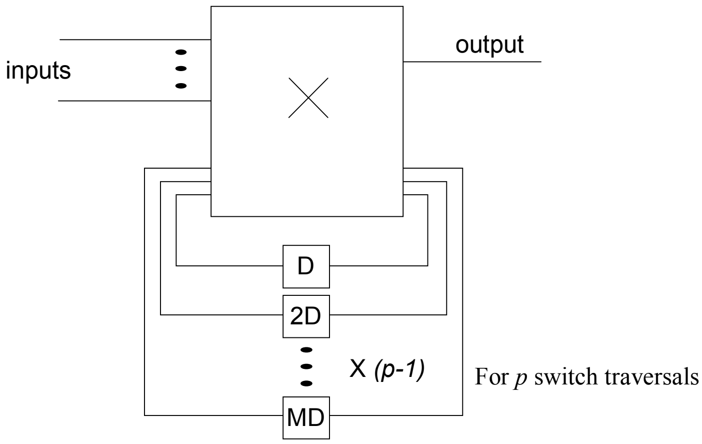
Loop buffer

-minimum buffers
ND m fibre
-multiple passes through switch (high l
N+1 traversals

Figure 2

This investigation concentrates on a hybrid of these two approaches, a recirculating integer array delay line optical buffer, using the optimum aspects of each, i.e. the delay line array of the switched delay single pass, with the greater buffer depth per switch port of the recirculating delay buffer as shown in figure 3. This approach still has the compromise of switch loss due to multiple passes, but to a lesser extent than the recirculating delay buffer.

This takes advantage of the network requirement to normalise optical packet powers at the switch output, but losses should be controlled to be within the dynamic range of the network equipment.



Recirculating Integer Array Delay Line Optical Buffer

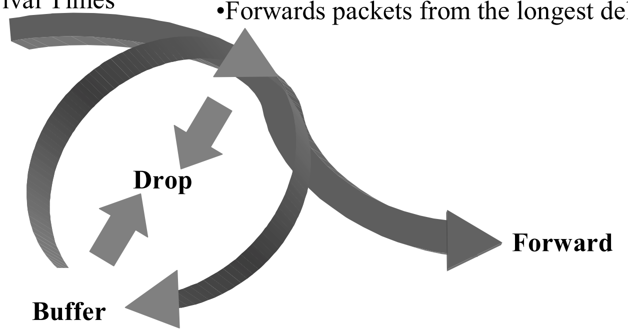
•Minimum buffer: D, •Maximum buffer: $\sum_{k=1}^{M} kD$

•Effective buffer: Traffic dependent

Figure 3

In order to assess the potential of this recirculating integer array delay line optical buffer, and the limits to performance of this architecture a behavioral model has been written that allows exploration of the basic physical parameters that are under design control, i.e. switch fabric size, number and value of the delay lines and the policy of packet priority within the fabric.

The outline of this code is illustrated in figure 4, where the main functional blocks of packet generation, priority allocation and testing, buffer delay allocation and packet forwarding or drop can be seen.



Simulation Functionality
Figure 4

2. Optical Buffer Architecture.

The recirculating integer array delay line buffer may be used in a number of configurations to provide resolution of packet contention, depending upon the number of output ports available. For example, in the case where switch ports are not limited a single stage shared buffer architecture may be used. This investigation concentrated on the output port buffer, where the contention is resolved between *n* input ports for a single output port. This buffer would then be used with a bufferless input switch stage.

3. Efficient Buffer Utilisation.

Using this recirculating delay line buffer architecture one can see two mechanisms by which packets may be dropped, delay line exhaustion and exceeding a recirculation limit. The former is limited by the number of ports on the switch dedicated to buffer delay lines, and the latter will be limited by either the accumulated optical degradation (S/N) of the packet through the buffer or by exceeding the maximum delay allowed on any packet.

We investigate the relative effects of these two loss mechanisms, to ensure that the overall packet loss through the structure was optimised. The results of these simulations are presented in figures 5 and 6. It can be seen that within the integer granularity of the variables a simple trend emerges, i.e. that the buffer operated most efficiently when the number of incremental integer delay line equals the number of allowed circulations through the fabric, i.e. *p-1* where *p* is the number of switch traversals.

This result is in line with expectations, from the behaviour of delay line buffers with multiple fixed length delays, but the fact that the correspondence is held with integer incremental delay lines is not obvious.

The use of integer incremental delay lines is shown to improve the loss performance by an order of magnitude for very modest (four) delay line ports and a traffic loading of 70%.

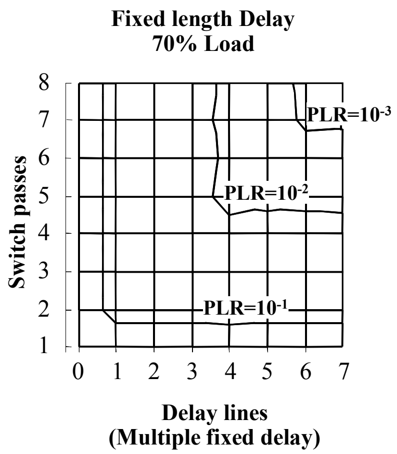


Figure 5

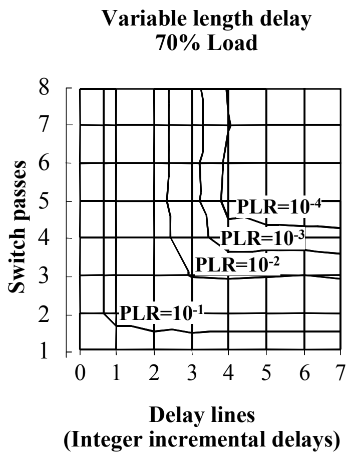


Figure 6

4. Buffer Scaling and Loading Limit.

As the buffer fabric is increased in size its ability to handle higher loading has been investigated to identify the optimum fabric size. Figure 7 illustrates the locus of the 10^{-3} packet loss ratio points as the load on the fabric is increased from 50% to 80%. It can be seen that we are approaching the load limit at this point as the 5% load increase increments are beginning to separate. This is confirmed by the simulation loaded to 85%, it did not achieve the required PLR. A simulation set with 1% load increments identified the limit of 82% for 10^{-3} PLR.

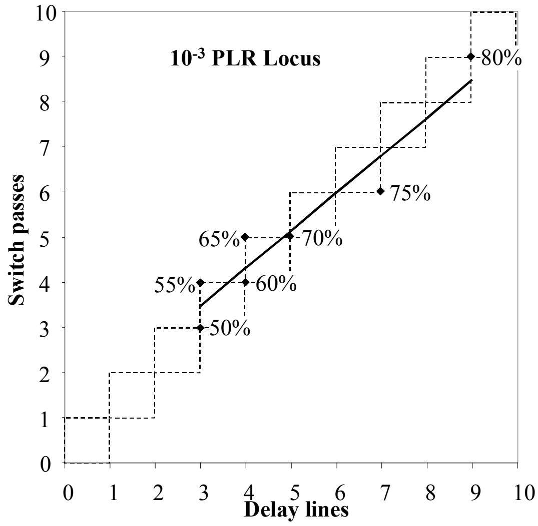


Figure 7

5. Summary.

This investigation into the simulated behaviour of an incremental integer delay line optical buffer has revealed a scaling rule which allows the packet loss ratio to be minimised, i.e. that the number of allowed recirculations through the fabric must be equal to the number of delay lines used in the fabric. In a network context this result can be used to predict the optical parameters, such as loss and signal to noise ratio degradation, which the optical switch should have to be effective. The buffer loading simulations indicate that a buffer fabric using an optical switch size of 16x16 (using 2^n scaling factor) is an optimum size for further investigation of effective buffer depth at lower PLR's.

Acknowledgments.

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