Effect of Hot Spot on the Performance of Multistage Interconnection Networks

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Abstract

Hot spot in multistage interconnection networks (MSIN) results in performance degradation of the network. This paper develops an analytical model for the performance evaluation of unbuffered MSINs under a single hot spot, followed by a performance comparison with buffered MSINs. A hybrid network is proposed for optimum performance.

1 Introduction

An interconnection network connects processors to memory modules in a shared-memory multiprocessor system. Because of modularity, simplicity, and fault-tolerant capabilities of crossbar and multiple-bus interconnections, such interconnections requiring $O(N^2)$ switches have been widely investigated. MSIN reduces the number of switches required to $O(N \log N)$. Buffers may be used at the switches to increase the throughput and avoid internal loss of data. However, in the case of a hot spot, the throughput of a buffered system is significantly reduced due to a phenomenon called *tree saturation* [1].

Most of the previous work have dealt with uniform memory reference pattern. The objective of this research is to develop an analytical model for the performance evaluation of unbuffered multistage interconnection networks in the presence of a hot spot, and compare the performance of unbuffered with buffered MSIN under a single hot spot.

2 Modeling assumptions

First we consider an *unbuffered* Omega network (figure 1) connecting N processors to N memory modules, where one of the modules is a hot memory module. *Average memory bandwidth* is used as the performance measure. The operation of the system is assumed to be *synchronous*, and *packet switching* is used to route data through the network. *Fair routing* arbitration logic is used by the individual switches. The requests generated by the processors are assumed to have *temporal* and *spatial* independence. The probability of a request being directed to the hot or any particular non-hot memory module will be denoted by q and $q' = (1-q)/(M-1)$ respectively, where $q > q'$. A recursive technique similar to that used in [2] has been used to develop the analytical model. Several important theorems and lemmas have been derived to develop the model.

Secondly, we modify the unbuffered network to a *buffered* network by including a single buffer at each of the switch inputs. A simulator has been built for this buffered network.

3 Results

Figure 2 shows the bandwidth obtained from the analytical model of an unbuffered MSIN for different hot spot probabilities and request rates. It is observed that the bandwidth does not increase linearly with increased processor request rate. Moreover, because of increased contention at the switches, the bandwidth decreases with increased degree of non-uniformity (q) in the requests. Simulation has been used to validate the analytical model, and has been found to be in close agreement (less than 0.25% error) with simulation results.

In order to compare the performance of unbuffered networks with buffered networks, we have carried out stochastic simulation of a single-buffered Omega net-

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work. Figure 3 shows a comparison of the memory bandwidth of buffered and unbuffered Omega network for uniform memory reference ($q = q'$)and four different hot spot probabilities. It is found that buffered MSIN performs better than the unbuffered network for uniform traffic pattern. For low hot spot probability and moderate to high processor request rates, the unbuffered network performs better than the buffered one. As hot spot probability increases, the unbuffered network outperforms the buffered network for moderate to high network traffic. This is due to the fact that low hot spot probability but high processor request rate or high hot spot probability in a buffered network result in tree saturation which obstructs the flow of both uniform and non-uniform traffic. On the contrary, an unbuffered network does not suffer from tree saturation, resulting in a better performance in case of hot spot traffic, or network congestion, in general.

4 Conclusion

An analytical model for performance evaluation of unbuffered Omega network has been developed. Stochastic simulation has been used for buffered Omega network. For uniform traffic, a buffered network performs better than an unbuffered network. For non uniform traffic pattern causing congestion (for example, tree saturation) in the network, an unbuffered network outperforms a buffered network. This leads us to suggest a ***hybrid network*** which will be capable of switching from buffered mode to unbuffered mode in the presence of network congestion.

References

[1] G.F. Pfister and V.A. Norton, "Hot spot contention and combining in multistage interconnection networks," *IEEE Transactions on Computers*, vol. C-34, pp. 943-948, October 1985.

[2] J.H. Patel, "Performance of processor-memory interconnections for multiprocessors," *IEEE Transactions on Computers*, vol. C-30, pp. 771-780, October 1981.

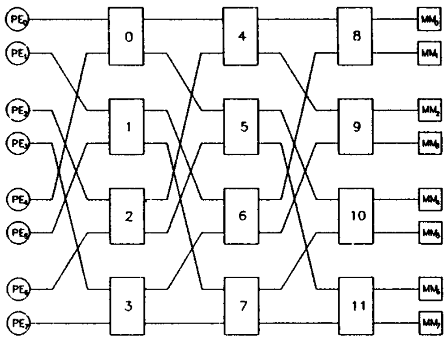

Figure 1: An 8 × 8 Omega network

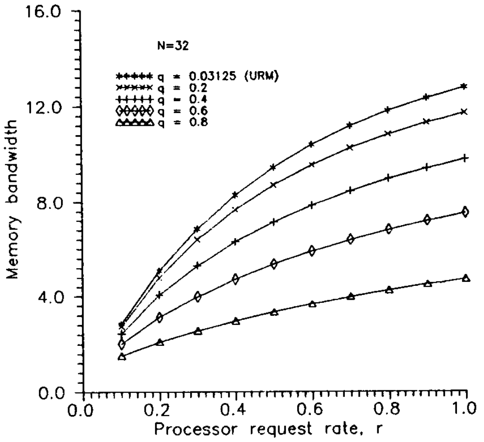

Figure 2: Bandwidth of an unbuffered Omega network

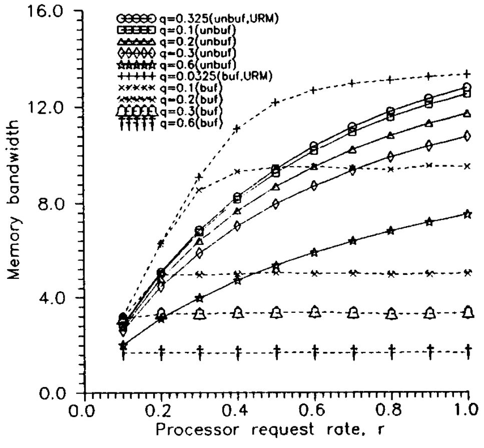

Figure 3: Performance comparison between buffered and unbuffered networks