Adaptive Routing Strategy for Large Scale Rearrangeable Symmetric Networks

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ABSTRACT

This paper proposes an adaptive unicast routing algorithm for large scale symmetric networks comprising 2 × 2 switch elements such as Beneš’s networks. This algorithm trades off the probability of blocking against algorithm execution time. Deterministic algorithms exploit the rearrangeability property of Beneš’s networks to ensure a zero blocking probability for unicast connections, at the expense of extensive computation. The authors’ algorithm makes its routing decisions depending on the status of each switching element at every stage of the network, hence the name adaptive routing. This method provides a low complexity solution, but with much better blocking performance than random routing algorithms. This paper presents simulation results for various input loads, demonstrating the tradeoffs involved.

Keywords: Connecting Graph, High Performance Computing, Interconnection Networks, Permutation, Rearrangeable Networks, Symmetric Networks

INTRODUCTION

High performance computing today requires a high performance communication system. This is typically an optical system in today’s state of the art, although optical switches suffer from imperfections such as the crosstalk effect (Ho, 1999), which worsens with increasing port capacity. The increasing bandwidth of state of the art computers means that, over time, increasing the throughput of interconnection networks by increasing port capacity will become problematic. Hence, the use of Multistage Interconnection Networks (MINs) (Wu & Feng, 1980) with a large number of port numbers, each of comparatively low transmission capacity will be design alternatives for high throughput optical switches. MINs allow large switching networks to be constructed efficiently from smaller subnetworks. Such networks include the baseline (Wu & Feng, 1980), omega (Lawrie, 1975), data manipulator (Feng, 1974), flip (Batcher, 1976), and SW-Banyan(S = F = 2) (Goke & Lipovski, 1973) networks. A major issue with such networks is their blocking properties -
they cannot establish connecting paths for all input-output requests simultaneously. A solution to the blocking problem is to concatenate one such network with its reverse, for example: baseline+baseline−1 or omega+omega−1. This combination will give a symmetric structure among the link patterns in the network from center stage. The Beneš network is one such symmetric network commonly constructed with baseline+baseline−1. The Beneš network is one MIN that has \( N = 2n \) inputs and outputs and comprises \( (2\log N - 1) \) stages of \( 2 \times 2 \) switch elements. This network is a permutation network (Beneš, 1965) because it can realize all \( N! \) possible patterns of input-output requests.

Benes (1965) and Beizer (1968), showed that the Beneš network is a rearrangeable network (Hwang, Lin & Lioubimov, 2006; Yeh & Feng, 1968) from the family of Clos (Clos, 1953) type network. Figure 1 shows a \( 16 \times 16 \) Beneš Network.

### A. Related Work

The use of Beneš networks has been advocated in high performance computing (Beetem, Denneau, & Weingarten, 1985) areas such as in shared memory multiprocessor systems (Leighton, 1992), telecommunication networks, TDMA systems (Keshav, 1997). It has been used as a permutation network in the middle of the switch fabric for routing packets from input queues to output (Prabhakar & McKeown, 1999; Newman, 1988). Waksman (1968) proposed a recursive algorithm for setting the switching element state in the Beneš network for uniprocessor system. Nassimi and Sahni (1981) and Nassimi and Sahni (1980) proposed a parallel self-routing method for a particular class of permutations. Nassimi and Sahni (1982) proposed a way to implement Waksman’s (Waksman, 1968) approach in a parallel processing (Leighton, 1992) mode. The algorithm proposed by Opferman and Tsao-Wu (Opferman & Tsao-Wu, 1971), called the looping algorithm, works from the outer stage towards the center stage. It works by dividing the entire network into smaller networks and recursively setting paths in the smaller networks, thereby setting the complete path. Later Andeson (1977) provided an extended version of the looping algorithm for base \( 2^t \) networks. Lee (1985) and Lee (1985), proposed a non-recursive algorithm, wherein the network is divided into two parts: \( \text{NS1} \) and \( \text{NS2} \). This algorithm works on a single stage of the network from left to right. Kim, Yoon, and Maeng (1997) showed that the Inside-out rout-
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