

On Noninterruptive Rearrangeable Networks

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Abstract—In this paper, we study a new class of nonblocking networks called noninterruptive rearrangeable (NIR) networks, which are rearrangeable under the additional condition that existing connections are not interrupted while their paths being possibly rerouted to accommodate a new request. We give a complete characterization of NIR Clos networks built of switching elements of various nonblocking properties. In particular, we propose a novel class of NIR Clos networks that leads to recursive constructions of various cost-efficient multistage NIR networks. Finally, we present examples of such constructions and compare them with the best previously known results.

Index Terms—Clos network, doubled path, noninterruptive rearrangeable (NIR), output (input)-divertability, Paull's matrix, rearrangeably nonblocking (RNB), strictly nonblocking (SNB), wide-sense nonblocking (WSNB).

I. INTRODUCTION

A request is a pair of input and output requesting a connection; once routed, a request turns into a connection, which is a path link-disjoint to all other connections. Traditionally, we classify nonblocking interconnection networks into three levels, that is: strictly nonblocking (SNB), wide-sense nonblocking (WSNB), and rearrangeably nonblocking (RNB) or rearrangeable. A network is SNB if a request can always be routed by a path link-disjoint to all existing connections, regardless of how they are routed. A network is WSNB if the above can be achieved under a routing algorithm. A network is RNB if link-disjoint paths exist for any set of requests (routed simultaneously). Another equivalent definition of the RNB network is: a request can always be routed under the condition that existing connections are allowed to be rearranged (rerouted). Currently, not much is known about WSNB networks. Generally speaking, an SNB network involves more hardware (cost), sometimes more than twice than an RNB network, and an RNB network may involve some delay before a given request is routed where an SNB network can always route a request immediately.

Besides the delay problem, an RNB network usually needs to disconnect and to reroute some existing connections before routing a request (see Fig. 1). In many applications, the main concern in using RNB networks is that the disconnected connections may be lost during the interruption period. In this paper, we study a new class of nonblocking networks called *noninterruptive rearrangeable (NIR)* networks, which are rearrange-

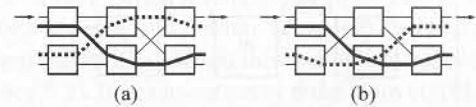


Fig. 1. Well-known RNB network, the Benes network of size 4×4 . (a) The indicated request cannot be routed directly. (b) The request can be routed after the dot-line connection is rearranged (disconnected-and-rerouted).

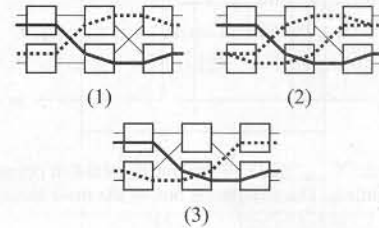


Fig. 2. Rearrangement with a doubled path.

able under the additional condition that no connection is taken down before its rerouted path has already been connected (thus, a *doubled path* is formed momentarily, although the new path can share some internal links with the original path). This implies that the rearrangement operation is done sequentially along with incoming requests, not the case that all requests are present simultaneously. Fig. 2 illustrates an example for such a process.

In 1994, Bowdon [2] first proposed a three-stage Clos NIR network. However, the network requires all its switching elements (switches) to have the NIR property when recursively constructing NIR Clos networks for more than three stages. In this paper, we give a complete characterization of three-stage NIR Clos networks based on switches of various nonblocking properties. In particular, we propose a novel network in this class without requirement on the middle switches to be NIR. We show that this network allows recursive construction of multistage NIR networks that are more cost-efficient than the ones based on Bowdon's network.

The remainder of this paper is organized as follows. In Section II, we introduce some background knowledge. In Sections III and IV, we introduce and characterize various classes of three-stage NIR Clos networks. In Section V, we discuss an additional nonblocking property of the introduced NIR Clos networks that is needed for further constructions of multistage NIR networks. In Section VI, we present examples of such constructions and compare them with the best previously known results.

II. TERMINOLOGY AND PRELIMINARY

The three-stage Clos network $C(n, m, r)$ is one of the most basic multistage interconnection networks. The first stage of $C(n, m, r)$ consists of $r n \times m$ switches, the second stage $m r \times r$ switches, the third stage $r m \times n$ switches, and the linking

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