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Performance Modeling of x-Folded TM Architecture in the Presence of Transpose Traffic

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Abstract

With the advance of Massively Parallel Computers usage, the interconnect technology overcomes the limitations of communication as a new concept. One of the most significant challenges in this concept is suitable architecture for these networks' applications. Recently, x-Folded TM architecture was introduced as a desirable design in interconnection networks. The attractive features for x-Folded TM are less number of links and nodes compared with other architectures. This paper proposes a new mathematical model of x-Folded TM architecture to predict the average network delay under the transpose traffic pattern. Besides the mathematical model derivation for x-Folded TM architecture, we discuss the simulation experiment in x-Folded TM using the same assumptions for the purpose of validation. The mathematical results indicate that the average network delay for x-Folded TM architecture is reduced when compared with other topologies under transpose traffic pattern. The implementation of x-Folded TM architecture relies on simulations to evaluate the performance impact of the architecture as well. Consequently, all results yield the superiority of the x-Folded TM performance compared to the other networks.

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Keywords: Interconnection Network, Mathematical Model, Architecture, TM, x-Folded TM, Transpose Traffic, Delay.

1. Introduction

Over the years, several research efforts have aimed to propose new architecture as essential components to solve application problems in Massively Parallel Computers (MPCs). Many studies have been conducted on these critical topics. Based on the related studies [1, 2, 3, 4, 5], improved network performance depends on the characteristics of network architecture, communication properties and

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applied routing within the architecture. Since the data transmission time among nodes is essential for system performance, the architecture is important for the networks with a higher number of nodes. Nowadays, the interconnection network is proposed as an important architectural choice for parallel system by many researchers. Motivated by the previous study, which introduced a new architecture called x-Folded TM [6] in interconnection networks by removing several links, the key focus of this paper is to analyze a x-Folded TM architecture in the presence of transpose traffic pattern.

In [6], the results were revealed that the performance advantages of x-Folded TM architecture over other interconnection networks are more noticeable in the presence of different traffic patterns, for example, uniform and non-uniform traffic patterns. Simulation used as an approach to evaluate the performance of an x-Folded TM architecture for a specific configuration. To the best knowledge of the authors, another approach is utilization of a mathematical model which is the most cost-effective tool for performance evaluation. Consequently, performance modelling of the x-Folded TM architecture has been described in comparison with different topologies in interconnection networks.

This paper proposes a mathematical model for computing the average delay in x-Folded TM architecture in the presence of transpose traffic which is non-uniform pattern. The rest of the paper is organized as follows: Section 2 describes the preliminaries of this study including the proposed architecture and applied routing algorithm. Section 3 presents the mathematical model of x-Folded TM architecture, while Section 4 validates the model using simulation and evaluates the network performance. Finally, Section 5 concludes this study.

2. Preliminaries

This section briefly describes the proposed architecture with its applied routing algorithm.

2.1. Proposed Architecture

Low communication delay and improved performance for MPCs needs interconnect architectures with low diameter and average distance. Different architectures have been proposed in interconnection networks. The popular architectures for interconnection networks are k-ary n-cubes (n is network dimension and k is number of nodes in each network dimension) such as torus and mesh with low delay and high bandwidth. Moreover, TM [7] was introduced for different k and $n = 2$ recently while it is a combination of torus and mesh architectures. The torus network is a low diameter and easy scalability regular architecture, however, mesh presents architecture with high diameter and low complexity compared with torus and the existing interconnection network architectures [8, 9, 10]. Very recently, the idea of folding [11] is used to create a new architecture with its applicability and enhanced performance. The new architecture is called x-Folded TM which is derived from a TM architecture by folding based on the imaginary x-axis and removing the specified links. Fig. 1 shows TM and x-Folded TM architectures.

x-Folded TM is defined where a node $a = (x, y)$ is a valid node if $0 \leq x \leq (k-1)$ and $0 \leq y \leq (k-1)$. Along x-axis, the nodes connecting to node a are: $(x+1, y)$ if $x < (k-1)$ and $(x-1, y)$ if $x > 0$. Along the y-axis, nodes $(x, y+1)$ if $y < (k-1)$ and $(x, y-1)$ if $y > 0$ are connected to node a. Then, the node $a = (x, y)$ is removed from the x-Folded TM if $(x+y) \bmod n = 0$ or 1 or ... or $k-3$, where $x > y$ and $(k-3) \leq x \leq (k-1)$ and $1 \leq y \leq (k-2)$. In addition, there is no link between two nodes (x, y) and $(x+1, y)$ if $x = i$ and $y = i+1$, when k is even and $i = (\frac{k}{2}) - 1$.

The main properties to design a network architecture are the number of nodes and links which are introduced in Table 1. Obviously, the number of nodes and links for x-Folded TM architectures have been computed less than the compared architecture. The achievement presents that these properties for x-Folded TM are desirable particularly by increasing k. However the superiority of the x-Folded TM has been proven in [6] previously.