Properties and Performance of Cube-Based Multiprocessor Architectures

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ABSTRACT

Parallel architectures provide the possibility of solving highly computational parallel applications in a variety of ways. Numerous interconnection topologies have been designed to achieve the desired performance. Nevertheless, the actual performance is far below the expectation of users when executing parallel applications on a particular multiprocessor network. This paper presents the performance study on a special class of parallel architectures known as cube based multiprocessor architectures. It describes the issues and challenges related to the design of cube-based architectures. The issues related to the design of highly parallel system such as scalability, complexity of the system and mapping of parallel application on to it are discussed. Furthermore, the problem of routing between nodes has been analyzed along with the topological properties of cube-based architectures. Simulation results are obtained by applying task scheduling algorithm on various multiprocessor networks. The comparative study implies the various aspects while designing an efficient multiprocessor interconnection network with optimal scheduling algorithm.

KEYWORDS

Cube Networks, Degree, Diameter, Interconnection Network Topology, Parallel System, Routing Algorithm

1. INTRODUCTION

Parallel computing have been widely studied in the field of computer science and has proven to be critical when researching high performance solutions. Modern computer systems employ multiple processors which may take part in execution in parallel to enhance the performance of an application. The benefits of parallel computing need to take into consideration the number of processors being deployed, the complexity of the system as well as the communication incurred between various processing units known as nodes. The topology of interconnection networks plays a key role in the performance of parallel computing systems. Significant progress has been made in the past decades in the design and development of efficient interconnection networks (Chhabra et al., 2009; Parhami, 2000; Kim et al., 1999; Cheng et al., 1994; Shi et al., 2005; Zhang, 2002). Hypercube architecture is a promising approach to improve the performance of multiprocessor parallel systems. Numerous variants of hypercube have been reported in the literature (Amway et al., 1991; Kumar et al., 1992; Efe, 1991; Loh et al., 2005; Khan et al., 2013). These variants include many attractive properties, including regularity, symmetry, small diameter, high connectivity and scalability. A number of approaches have been suggested and implemented to improve the overall performance of such systems (Efe, 1992; Ghose et al., 1995; Kumar, 2012). Nevertheless, no single topology claims to have all the desirable topological features. For example the Crossed Cube architecture denoted by CC is derived
from the hypercube to have a smaller diameter which is almost half of its parent architecture (Efe, 1992). However, the CC makes no significant improvement in the hardware cost compared to the hypercube. Similarly, a new architecture known as Folded Crossed Hypercube (FCH) (Khan et al., 2013) network is designed by augmenting the CC network. Some extra links called complementary links are introduced which help to reduce the diameter further. The improved diameter is obtained however at a greater value of degree. The Exchange Hypercube (EH) is another example which is also derived from hypercube and has lesser hardware cost by reducing number of links in the hypercube (Loh et al., 2005). This, however, results no improvement in the diameter and the connectivity in the EH is decreased. Similarly, there are other numerous interconnection networks which are designed by improving a particular topological parameter. Some examples are the Folded Hypercube (FH) (Amway et al., 1991), Dual Cube (DC) (Li et al., 2000), Folded Dual Cube (FDC) (Adhikari et al., 2008), Meta Cube (MC) (Li et al., 2002), Folded Met cube (FMC) (Adhikari et al., 2009), and the Folded Cross Cube (FCC) (Adhikari et al., 2010).

In contrast to the cube based architectures several research have been carried out in the design of linear type architectures which are considered less complex and easily extensible (Samad et al., 2010; Rafiq et al., 1995; Rajput et al., 2012). Some examples are Linearly Extensible Tree (LET) (Rafiq et al., 1995), Star Graph (Tripathy, 2004) and Torus Ring Network (Kwak et al., 2007), etc. Besides their lesser complexity they suffer from the drawbacks of high connectivity and symmetry. Another class of multiprocessor architecture is hybrid architecture which expects the desirable properties of cube based architecture as well as they are less complex and easily extensible. Thus, they embed the features of various types of architectures in themselves. One such example is Linearly Extensible Cube (LEC) architecture (Samad et al., 2010). It embedded the desirable properties of hypercube architecture and also has a rich connectivity and symmetry when extended in to higher level. Though the extensibility of LEC is linear still it has a lower bisection width when expanded to higher level of architecture and could not be considered as a good candidate with high fault rate (Khan et al., 2013).

The objective of this paper is to present an observation study of recently emerged class of topology known as cube based interconnection network along with their desirable topological properties. The performance of such multiprocessor architectures are evaluated by applying optimal scheduling algorithm. The present study suggests where to apply such network and how much cost-effective they are when applied in parallel systems.

The paper is organized in sections. In section 2 a detail review of cube based multiprocessor networks is given. It presents the variants of hypercube along with their desirable properties. The topological properties which are considered important from cost point of view are discussed in section 3. It also describes some observations based on mathematical calculations and a comparative study is made. In section 4 the given topologies are analyzed based on implementation of routing algorithm and finally concluded the paper in section 5.

2. CUBE BASED ARCHITECTURE

2.1. Hypercube (HC)

Hypercube also known as n-cube or simply binary n-cube is a loosely coupled parallel multiprocessor based on the binary n-cube network. An n-dimensional hypercube contains $2^n$ nodes and has $n$ edges per node. The Hypercube has been one of the most popular interconnection networks for parallel computer systems. In hypercube, the number of communication links for each node is a logarithmic function of the total number of nodes. The major drawback of the hypercube is the increase in the number of communication links for each node with the increase in the total number of nodes. A number of variants of hypercube are reported in the literatures which are designed to improve the specific topological property.
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