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An Analytical Study on Interconnection Network

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Abstract: *Interconnected networks are extremely important aspects of data communication. It is used to transport data between processing units of networks and memory units. It uses a series of interconnected devices to transfer the data using parallel processing. Parallel processing occurs when one process or operation is completed using multiple processors (i.e., multiple computers) independently of each other. This is done to reduce the time required for the operation, as well as to reduce the strain of the operation on one computer. The main parts of an interconnected network are called nodes: memory, processor, and switches, which turn the connections between the memory unit and processor on and off. There are many benefits to using an interconnected network, including an increased speed of data processing. One of the most frequently used examples of an interconnected network is a system of connected computers. Interconnected networks can use one of a number of topologies. The two major types of interconnected networks are static networks and dynamic networks. There are two main types of static networks (completely connected and limited connection), and many different types of dynamic networks, including bus, crossbar, and multistage. Static networks have constantly fixed connections between memory units and processors, whereas dynamic networks have switches that turn off these connections. Completely connected networks are most useful when speed is important, and the cost of data processing is not. Limited connection networks do not have a constant connection between nodes, so messages between the nodes must be efficiently routed.*

Keywords: Interconnected networks

I. INTRODUCTION

An interconnection network has a specific role and purpose. It is also referred to as a multi-stage interconnection network (MIN), which illustrates the way in which an interconnected network is structured and how it functions.

Interconnection networks are used to transfer data from a processing unit to a memory unit, and vice versa, in a very specific way through multiple stages. The three main parts of an interconnected network are called nodes: the memory unit, the processor, and switches which turn the connections between the other two nodes on and off.

The purpose of an interconnected network is to create the optimal conditions for data to travel from a point of origin to a destination (memory to processor, and processor to memory).

An interconnection network in a parallel machine transfers information from any source node to any desired destination node. This task should be completed with as small latency as possible. It should allow a large number of such transfers to take place concurrently. Moreover, it should be inexpensive as compared to the cost of the rest of the machine.

The network is composed of links and switches, which helps to send the information from the source node to the destination node. A network is specified by its topology, routing algorithm, switching strategy, and flow control mechanism.

II. EVALUATING DESIGN TRADE-OFFS IN NETWORK TOPOLOGY

If the main concern is the routing distance, then the dimension has to be maximized and a hypercube made. In store-and-forward routing, assuming that the degree of the switch and the number of links were not a significant cost factor, and the numbers of links or the switch degree are the main costs, the dimension has to be minimized and a mesh built.

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In worst case traffic pattern for each network, it is preferred to have high dimensional networks where all the paths are short. In patterns where each node is communicating with only one or two nearby neighbors, it is preferred to have low dimensional networks, since only a few of the dimensions are actually used.

2.1 Routing

The routing algorithm of a network determines which of the possible paths from source to destination is used as routes and how the route followed by each particular packet is determined. Dimension order routing limits the set of legal paths so that there is exactly one route from each source to each destination. The one obtained by first traveling the correct distance in the high-order dimension, then the next dimension and so on.

2.2 Routing Mechanisms

Arithmetic, source-based port select, and table look-up are three mechanisms that high-speed switches use to determine the output channel from information in the packet header. All of these mechanisms are simpler than the kind of general routing computations implemented in traditional LAN and WAN routers. In parallel computer networks, the switch needs to make the routing decision for all its inputs in every cycle, so the mechanism needs to be simple and fast.

2.3 Deterministic Routing

A routing algorithm is deterministic if the route taken by a message is determined exclusively by its source and destination, and not by other traffic in the network. If a routing algorithm only selects shortest paths toward the destination, it is minimal, otherwise it is non-minimal.

Interconnection networks are composed of following three basic components −

- **Links** − A link is a cable of one or more optical fibers or electrical wires with a connector at each end attached to a switch or network interface port. Through this, an analog signal is transmitted from one end, received at the other to obtain the original digital information stream.
- **Switches** − A switch is composed of a set of input and output ports, an internal “cross-bar” connecting all input to all output, internal buffering, and control logic to effect the input-output connection at each point in time. Generally, the number of input ports is equal to the number of output ports.
- **Network Interfaces** − The network interface behaves quite differently than switch nodes and may be connected via special links. The network interface formats the packets and constructs the routing and control information. It may have input and output buffering, compared to a switch. It may perform end-to-end error checking and flow control. Hence, its cost is influenced by its processing complexity, storage capacity, and number of ports.

2.4 Types of Interconnection Networks

Interconnection networks are composed of switching elements. Topology is the pattern to connect the individual switches to other elements, like processors, memories and other switches. A network allows exchange of data between processors in the parallel system.

There are two main kinds of interconnection networks: Direct and Indirect

- **Direct Connection Networks** −In a direct network, the nodes sit inside the network. It means that a node is both a endpoint and a switch in the other words the direct networks have point-to-point connections between neighboring nodes. These networks are static, which means that the point-to-point connections are fixed. Some examples of direct networks are rings, meshes and cubes.
- **Indirect Connection Networks** −In an indirect network, endpoints are connected indirectly via switches. In the other words indirect networks have no fixed neighbors. The communication topology can be changed dynamically based on the application demands. Indirect networks can be subdivided into three parts: bus networks, multistage networks and crossbar switches.

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Some other types of interconnection networks-

- **Bus Networks** − A bus network is composed of a number of bit lines onto which a number of resources are attached. When busses use the same physical lines for data and addresses, the data and the address lines are time multiplexed. When there are multiple bus-masters attached to the bus, an arbiter is required.
- **Multistage Networks** − A multistage network consists of multiple stages of switches. It is composed of 'axb' switches which are connected using a particular interstage connection pattern (ISC). Small 2x2 switch elements are a common choice for many multistage networks. The number of stages determine the delay of the network. By choosing different interstage connection patterns, various types of multistage network can be created.

2.5 Benefits of Interconnection Network

An interconnected network has several prominent benefits. Examples of the direct benefits provided by interconnected networks include:

1. Low processing time
2. Low processing power
3. Frequent access to large amounts of data
4. Flexible data transferring capabilities

Possible applications of interconnected networks include:

1. Phone networks
2. High-speed data processing
3. University computer labs
4. Campus networks (universities, businesses, libraries)
5. The Internet (interconnected networks)

III. MULTISTAGE INTERCONNECTION NETWORKS

Multistage interconnection networks (MINs) connect input devices to output devices through a number of switch stages, where each switch is a crossbar network. The number of stages and the connection patterns between stages determine the routing capability of the networks.

MINs were initially proposed for telephone networks and later for array processors. In these cases, a central controller establishes the path from input to output. In cases where the number of inputs equals the number of outputs, each input synchronously transmits a message to one output, and each output receives a message from exactly one input. Such unicast communication patterns can be represented as a permutation of the input addresses. For this application, MINs have been popular as alignment networks for storing and accessing arrays in parallel from memory banks. Array storage is typically skewed to permit conflict-free access, and the network is used to unscramble the arrays during access. These networks can also be configured with the number of inputs greater than the number of outputs (concentrators) and vice versa (expanders). On the other hand, in asynchronous multiprocessors, centralized control and permutation routing are infeasible. In this case, a routing algorithm is required to establish the path across the stages of a MIN.

Depending on the interconnection scheme employed between two adjacent stages and the number of stages, various MINs have been proposed. MINs are good for constructing parallel computers with hundreds of processors and have been used in some commercial machines.

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