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A Survey on Topological Design of Networks Using Various Graph Theoretical Algorithms in Grid Environment

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Abstract: Computers have become incredibly smaller, cheaper and numerous since the last decade. Interconnecting them, results in a computer network. Researchers say that two computers are interconnected if they can exchange information. Two computers are said to be autonomous, if one does not control the other. A computer network is an interconnected collection of autonomous computers. Connection of two or more distinct networks results in internetworking. Sometimes, a computer network is also called as a distributed network. Strictly speaking, a distributed system is a computer network with a high degree of cohesiveness. Networks satisfy a broad range of purposes and meet various requirements. Facilitating communications, sharing hardware, files, data, information and software are some of the common objectives of computer communication networks. This study presents the survey on principles on network design and topological design of the computer network.

Key words: Computer, network, data, software, hardware

INTRODUCTION

Applications of computer communication networks are growing in every field of human activity. Computer communication networks have applications in education, business, telemedicine, telesurgery, media, infotainments, multitime multiplayer computer gaming, etc. All these applications demand the design of efficient fault tolerant survivable computer communication network topology with minimum transmission delay, response time and maximum throughput (Kesherbaum, 1993; Chen *et al*., 2008). Further, in the design of adhoc networks, energy, memory, transmitting and computing power of a node are limited. The efficient utilization of these resources is influenced by the underlying network topology. Also, the optimization of the link constraints such as line of sight interference, length of link, signal loss, noise is achieved by designing efficient network topological algorithms (Ammari and Das, 2006).

The topological structure of interconnection network can be modeled by a simple graph whose vertices represent components of the network and whose edges represent physical communication links where directed edges represents one way communication links and undirected edges represent two way communication links. The incidence function specifies a way that the components of the network are interconnected by links. Such a graph is called the topological structure of the interconnection network or in short, network topology. Conversely, any graph can also be considered as a topological structure of some interconnection network. Topologically, graphs and interconnection networks are the same (Korman, 2010; Levitin, 2006). This fact has been universally accepted by computer scientists and engineers. Moreover, practically it has been demonstrated that graph theory is a very powerful mathematical tool for designing and analyzing topological structure of interconnection networks (Tanenbaum, 1987).

The network link can be a terrestrial link or a satellite link or a radio link or optical fiber link. Any link can be designed to function in three modes namely simplex, half duplex and full duplex mode (Avizienis, 1997; Ball, 1980).

LITERATURE REVIEW

The advent of very large scale integrated technology has enabled the construction of very complex and large interconnection networks. The next generation computers will achieve its gains by increasing the number of processing elements rather than using faster processor. Selecting and designing an appropriate and adequate topological structure of an interconnection network has become a critical issue on which many research efforts have been made over the past decade. One such is the topological design of fault tolerant survivable network. Researchers have mainly used the notion of connectivity

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as a key graph theoretical concept as a measure for survivability of a network topology (Bermond *et al*., 1983, 1989).

Bern and Plassmann (1989) have proposed a method for topological design of a k-connected communication network. In their method, nodes are numbered arbitrarily. The decimal number of each node is converted into a k bit Gray code. Thus, each node has a Gray code associated with it. Between any two nodes, if their gray codes differ only in one place then a link is established between them. Thus, every node gets connected to k nodes and has a degree of k. This method assumes that the number of nodes in the network is 2k.

Hao *et al*. (2004) have presented an algorithm for designing a k-connected network when all the nodes of the network are equi-spaced and lie on a circle. The algorithm is discussed for three different cases when k is even and n is either even or odd, k is odd and n is even and both k and n are odd.

MOTIVATION

From the earlier literature survey, one can observe that the major research effort in the topological design of computer communication networks is towards three major areas namely:

- Generation of fault tolerant k-connected survivable network
- Checking and computing the network connectivity
- Systematic numbering of nodes in computer communication network

One of the most well suited problems in the framework of the survivable network design problem is given a computer communication network with cost on its edges and a connectivity requirement k for each pair v, w of nodes, the goal is to find a minimum cost subset of edges that ensures that there exist k disjoint paths for each pair v, w of nodes. This problem is referred as the design of minimum cost fault-tolerant survivable network topologies (Bose *et al*., 1995).

Looking into the research work related to the design of k-connected fault tolerant survivable network topologies, a few methods for generating k-connected networks are proposed in the literature. Steiglitz has presented the most widely used heuristics algorithm, called the link deficit algorithm to design a low cost survivable network. Algorithms have also been presented for producing local improvements in given networks and for testing the redundancy of networks. Their heuristic begins by numbering the nodes at random. This randomization lets the heuristic to generate many topologies from the same input data. Further this method involves repeated searching of nodes when conflicts occur. This demands more computational effort (Cao *et al*., 1999).

TOPOLOGICAL DESIGN

The topological design of a network assigns the links and link capacities for connecting the network nodes. This is a critical phase of network synthesis, partly because the routing, flow control and other behavioral design algorithms rest largely on the given network topology. The topological design has also several performance and economic implications. The node locations, link connections and link speeds directly determine the transit time through the network. For reliability or security considerations some networks may be required to provide more than one distinct path for each node pair, thereby resulting in a minimum degree of connectivity between the nodes. The topological design algorithms select links and discrete link capacities within several constraints such as connectivity, message transmission delay, cost and network traffic. Perhaps the most difficult aspect of topological design is to permit possible future expansion of the network. Such expansion may require increased link capabilities or additional links or nodes (Swamy and Shmoys, 2008).

The goal of the topological design of a computer communication network is to achieve a specified performance at a minimal cost. A reasonable approach is to generate a potential network topology (starting network) and see if it satisfies the connectivity and delay constraints. If not, the starting network topology is subjected to a small modification (perturbation) yielding a slightly different network which is now checked to see if it is better. If a better network is found, it is used as a base for more perturbations. If the network resulting from perturbation is not better, the original network is perturbed in some other way. This process is repeated till the computer budget is used up (Huang *et al*., 2007).

The topological design of computer communication network can be modeled by a graph. This fact has been universally accepted and used by computer scientists and engineers. Moreover, practically it has been demonstrated that graph theory is a very powerful mathematical tool for design and analysis of computer network. When the network requirements are expressed in terms of graph theoretical parameters, the problem of analysis and design of networks becomes finding a graph G satisfying some specified requirements (Peel *et al*., 2005).

BASIC PRINCIPLES OF NETWORK DESIGN

The basic principles of network design are discussed by Coulouris *et al.* (2000). These principles can be stated as follows:

Fault tolerance: The network must continue to work in case of vertex or edge failures. Different notions of fault tolerance exist, the simplest one corresponding to connectivity of the network graph that is the minimum number of nodes which must be deleted in order to destroy all paths between a pair of nodes. The maximum connectivity is desirable since it corresponds to not only the maximum fault tolerance of the network but also the maximum number of internally node disjoint paths between any two distinct nodes.

Small and fixed degree: The degree of a network graph corresponds to the number of connections to each component. This number is bounded by the number of the interfaces available for I/O devices attached to each component in the network. An excess of any physical connection will result in replacement of the components in the network to increase the number of the interfaces. The larger the degree, the more wiring. More wiring not only costs much money but also is disadvantageous to implementation of VLSI layout. Thus, a small or fixed maximum degree is desirable.

Transmission delay that is small diameter or average distance: Transmission delay or signal degradation for sending a message from one vertex to another is approximately proportional to the number of times that a message has to be stored and forwarded by intermediate nodes. Thus, a small average distance or diameter is desired to obtain a highly efficient interconnection network. In particular, diameter should be bounded by a given value for a real-time processing system.

Symmetry: It is desired that all components behave in the same manner and that they communicate in similar ways. This implies at least some regularity and some symmetric properties on the graph. A highly symmetric network is desirable since it is advantageous for the construction and simulation of some algorithms.

Embeddability of other topologies: This important issue deals with the ability of a given architecture to match various algorithms that solve different types of problems. The network built would enable one to use various algorithms originally designed for another topological structure. In other words, when a graph is used as an interconnection network, it should contain certain subgraph structures since existence of these structures has special importance for executing certain algorithms.

Extendability: It should be possible to build a network of any given size or at least to build arbitrarily large versions of the network. Furthermore, it would be easy to construct large networks from small ones. When a small network is extended, some desirable properties should be retained and some useful parameters should be calculated easily.

Routing algorithm: The routing is an important function of communication networks. It specifies a fixed route which carries the message from one node to another. Thus, the choice of an easy routing algorithm is important. A routing algorithm strongly depends on the chosen topological structure. Thus, a network should be designed such that a routing algorithm can be easily obtained (Huang *et al.*, 2007).

The methods and heuristics developed in this thesis focus on the issues of fault tolerance, transmission delay, embeddability, extendability, symmetry of the network topology and small and fixed degree of a computer communication network.

CONCLUSION

Keeping in view the earlier extensive literature, the primary objectives of this thesis are summarized as follows:

- Designing graph theory based methods for generation of minimum cost k-connected fault tolerant survivable network topology
- Given a k-connected network topology and l-connected network topology, an algorithm to merge these topologies into a single topology of maximum connectivity among k and l, without disturbing the position of nodes and links in the given topologies
- Desiging a non-iteration algorithm to compute the connectivity number k of a given computer communication network
- Systematic numbering of nodes in a computer communication network based on principles of network design and graph theoretical concepts

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