Chapter XIV
Empirical Prediction of Computer-Network Evolution

Sami J. Habib
Kuwait University, Kuwait

ABSTRACT

This article presents a computer-aided integration tool, iCAD, that can predict a network evolution. We have used the term a network evolution to mean predicting changes within the physical network topology as time evolves. iCAD is connected to four device libraries, each of which contains a distinct set of network-technology devices, such as Ethernet hubs, ATM switches, IP routers, and gateways. As a network technology changes, each device library is updated. Then, we have plotted the cost and performance changes between the old and recent network technologies, enabling us to predict future changes to a first order. This article presents empirical results from 1999 until 2005 recording the network evolution progress, where the lower and upper bounds of network evolution came out to be 10% to 25% and 57% to 74% respectively in terms of network-design cost reduction.

INTRODUCTION

The maintenance process of a network topology so that it can carry out all its communication tasks effectively and efficiently requires a steady tuning and upgrading. Therefore, how often and how to carry on such a process are questions yet to be answered. In other words, we want to identify a metric for predicting the network evolution and develop a design tool to carry on the prediction. Here we have defined a network-evolution metric analogous to Moore's Law (Moore, 1965), which states that the number of transistors in an integrated circuit doubles every 18 months. We have stated that the cost of network-topology design when considering three types of network technologies is reduced at a lower rate of 10-25% and an upper rate of 57-74% in every 24 months.

The network-topology problem with technology considerations entails the allocation and integration of network devices (such as ATM switch, Ethernet hub, IP router, and gateway) that enable all clients to communicate and access file servers while minimizing the network-integration cost. Literally millions of possible network topologies can be considered for a given network. It is impossible for a human network designer to examine all possibilities for typical large installations. We have applied computer-aided design (CAD) techniques to design and redesign hierarchical computer networks to determine the network topology and network devices. The problem is known to be NP-complete (requiring an exponential number of steps to find an optimal solution) according to Gerla and Kleinrock (1977). The continual changes in the price, performance, and availability of network devices make the network-design process more difficult. The choices of network devices, which are made at a particular time, may not be appropriate a few months later.

The CAD tool, iCAD, is based on evolutionary approach. The tool creates an initial population of network topologies by selecting all network devices randomly. The software analyzes and evaluates each topology in the current population, selects the most fit topologies, modifies some, and discards the rest. New topologies are created by mutating existing topologies or by crossing over genetic material between two topologies. Then the optimization process continues. After several generations specified by the user, the tool terminates. The iCAD is connected to four device libraries, each of which contains a distinct set of network-technology devices, such as Ethernet hubs, ATM switches, IP routers, and gateways. Each device library contains information about device types and their attributes, such as cost, capacity, number of ports, and type of wire. As the network technology matures, the device library is updated. Thus, we have extended the usage of iCAD in Habib, Parker & Lee (2002) so that it can synthesize networks based on the current price and on the predicted future price. Because of this extension on iCAD, we are able to collect many empirical data regarding the network-design evolutions. In addition, we have insured that the synthesized network, once designed, has been optimized for technologies available at the design time. We have examined the topological differences between the current network technologies and the future technologies. These differences would give guidance as to where the network should be upgraded in the future. Finally, we have upgraded existing design constraints by maintaining as much as possible of its original devices so that the upgrading costs are minimized. Maintaining as much as possible of the original devices is known as the legacy problem.

We have been observing and collecting the changes with the network technology, especially with respect to cost and capacity, for the past six years. Habib and Parker (2002) have recorded an initial study on the network evolution by comparing the outcomes from two sets of device libraries in years of 1999 and 2001. In this article, we have expanded our study by running iCAD with four different sets of libraries that go back to 1999, 2001, 2003, and 2005. We have plotted the cost and performance changes between networks designed with the old and recent network technologies. This enables us to predict future changes to a first order. The network-design cost has evolved at a decreasing rate from 10-25% to 57-74% for the past six years as our empirical data has shown. Over time, with more data points, the predictions will become more accurate.

The rest of the article is organized in four sections. The related work has been examined in following section. In “An Overview of the iCAD Tool,” we describe the network design tool that is going to carry out all network evolution studies. The experimental results are presented in the section of the same name, and the section after that contains the conclusion.