

# Learning Computer Communication Network Through Software-based Experiments

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## A b s t r a c t

The traditional teaching of computer communication network, which is mostly based on lectures, has numerous shortcomings, such as grasping many abstract concepts underpinning networking technology but lacking the opportunities to experiment with many important details. This project designs and develops creative software-based experiments to facilitate the teaching and learning of this subject. We chose a problem-driven approach to design the experiments. The purpose of this project is to enhance students' self-discovery ability and problem-solving skill.

## Background

Practical knowledge and experience of computer network technologies is becoming an important asset for a computing professional. This is evident from the exponential growth of the Internet, excellent employment opportunities in the field and the great demand for networking technology courses in the part-time MSc programmes.

Based on the experience of many employers in the computer communication industry, most fresh graduates have sound theoretical background in computer networking, but are not well prepared for handling the technical details of real world applications. To overcome this problem, we have developed a new way of teaching computer communication networks, which puts more emphasis on practical applications as compared with the traditional lecture-based networking courses.

Most academic institutes have laboratory sessions to provide students with practical hands-on experience. However, this method has certain disadvantages, e.g., (1) some institutes do not have enough laboratory equipment for a large number of students; (2) the laboratory schedule may not be able to accommodate every student's time-table; (3) the laboratory facilities are difficult to maintain; and (4) the number of tutors are normally not enough to provide individual guidance. Therefore, there is a need to provide practical computer communication networking experience, which is free from the problems encountered by laboratory-based learning.

To solve these problems, we propose that the students learn computer communication network through software-based experiments on the World Wide Web (WWW). This method has a number of benefits, which supplements traditional lecture-based or laboratories-based learning. First, due to the rapid development of the Internet, we can now make our software accessible to a large number of students without worrying about time, space and resource restrictions of the laboratory facilities. Second, the use of hypertext encourages user interaction and self-discovery while using the educational software, hence alleviating the problem of insufficient tutoring. Third, through simulation of practical situations, software-based experiments can increase student's motivation and help them understand the lectures.

## Network Course

The basic element of a computer communication network is the communication protocol. There are several communication protocols used by different kinds of networks. The TCP/IP protocol stack has been chosen as the main course subject for its popularity. The protocol was developed by the Defence Advanced Research Projects Agency (DARPA) and has already become the de facto standard of the Internet. Therefore, knowledge of TCP/IP is essential for a computing professional.

The computer networking course in the Department of Computing consists of two parts: traditional lectures and software-based experiments. The lectures teach the students abstract concepts, which provide a theoretical foundation. On the other hand, the software-based experiments help students learn the operations of the network. We have designed five sets of experiments. They are (1) Ethernet utilization – Data link; (2) IP, Subnet Addressing and Routing – Network layer (Internet layer); (3) TCP and UDP – Transport layer; (4) Programming interface, Telnet, ftp – Application layer; and (5) The Domain Name System. Each experiment consists of synopsis, background and discussion sections. The background sections assist the students in discussion sections by providing just adequate background knowledge, tools and hints.

### Design Methodology

In this project, we chose the problem-driven (solving) approach to design the experiments. This method of education/instruction has gradually been developed in response to the increasingly obvious shortcomings of traditional education. Before going into the details of our methodology, it is worthwhile to re-examine the traditional method of teaching.

#### *Traditional Education*

The traditional way of lecturing aims at conveying maximum amounts of material to the students within a limited period of time. However, it is difficult to ensure that the students really understand the course materials.

In order to deliver a maximum amount of information within a limited time, student participation in the classroom and consequently, the student interaction with the subject matter is not sincerely encouraged. This leads to a rather passive way of education.

As a consequence, students receiving this kind of traditional education suffer from inadequate training as they graduate and search for employment. In general, the industry has made the following observations about most graduates:

- The graduates do not use more than 20% of what they are taught in school (Tarricone, 1990).
- Most of the learning takes place on the job at a high cost to the industry.
- The graduates are not able to think critically and see the big picture.
- Most graduates do not have enough knowledge of the latest technologies, which are most important for the industry.

#### *The Problem-Driven Approach*

Having observed the consequences of the above facets of traditional education, a problem-driven (solving) model of education is evolving to improve the situation. This model enhances educational effectiveness with a number of desirable features.

- Students should actively participate in their own learning and interact with the subject matter so that constructive understanding can take place.

- In order to clearly understand certain topics and theories, students should be able to change the parameters of the situation and see the consequences through a ‘what if?’ type of inquiry.
- Quality rather than quantity should be the guiding principle in deciding how much material needs to be covered.
- It is more important to teach students how to think and be flexible towards change. It is simply impossible to cover all the information that is available and the information itself is also continuously changing.

Learning in a laboratory setting involves all the aforementioned desirable features. In a laboratory, students participate in the experiment, interact with the subject matter and change the parameters to see the consequences. Students are constantly alert of what is going on. They learn by doing, and their learning is associated with experiences which can be accumulated. However, as mentioned in the first section there are a number of limitations of conducting laboratory experiments for each course. Thus, in the course of computer communication networks, we employ the WWW interface to solve these problems and adopt the problem-driven approach to design the experiments.

## The Experiments

The laboratory is designed to complement the lecture course of Computer Communication Network. We have developed five modules of experiments based on the TCP/IP protocol stack.

### 1. Ethernet utilisation — Data link layer

Data link layer is the lowest layer in the TCP/IP protocol stack. Its main purpose is to send and receive data packets for its immediate upper network layer. We have designed four questions for this module. It provides the students with opportunities to solve problems at this layer using software tools provided.

### 2. IP, Subnet Addressing and Routing — Network Layer

The network layer handles the movement of packets around the network. It includes the determination of a host’s address, subnetting and the routing of data packets. The student will examine the real data packet and discover correct information.

### 3. TCP and UDP — Transport layer

Transport layer is the upper layer of network layer. It composes messages received from applications and deliver those messages using IP’s packet delivery services. We will provide a brief background information of its capability and introduce a software tool *tcpview* to the students.

### 4. Programming Interface, Telnet, ftp — Application layer

The application layer is the highest layer in the TCP/IP protocol stack. This layer provides application services to users and programs by using the functions of lower layers. The most popular applications implemented on TCP/IP network are the *rlogin* and *telnet*. We will examine the philosophy (client/server model) behind these applications through programming examples.

### 5. The Domain Name System

This experiment illustrates the mechanism that maps between high-level machine names and IP addresses used by Domain Name System. We ask students to use this system to find requested information and review the system implementation, with a software package *dig*.

There is a laboratory established for the computer communication network course. The laboratory has three connected workstations with X-window interface installed. The students perform the

experiments in their own schedule within the semester. We present the experiments through the Netscape WWW browser (Figure 1).

The problem driven approach adopted here involves three steps, which could be refined through a number of iterations. The first one involves identification of the lesson goals. The second concerns the design of a set of problems to achieve the lesson goals. The third concerns the selection of background knowledge and tools for the students to solve the problems. In each experiment, there are three sections: Synopsis, Background and Discussion.

### ***Lesson Goals***

The experiments for the course complement the lecturing of the subject. The concepts and the theories needed for the experiments are provided during normal teaching sessions. And the experiments let the student interact with the network protocols.

### ***Design of Problems***

The problems given in the Discussion section are designed before the background materials. This will help us decide what kind of tools and background material to put in the background section. We illustrate this in the experiment Ethernet utilization - Data link.

As shown in Figure 2, there are four problems in the Discussion section. The first one is to ask for the physical address of the workstations in the laboratory without the instructions of how to get them. The students may find the answer by performing the following:

- The students review the background materials and examine the examples.
- Search other related information about the Ethernet physical through WWW.
- Try some software tools to get the required answers, e.g., *netstat*.

Figure 1: Interface for the experiments in computer networking

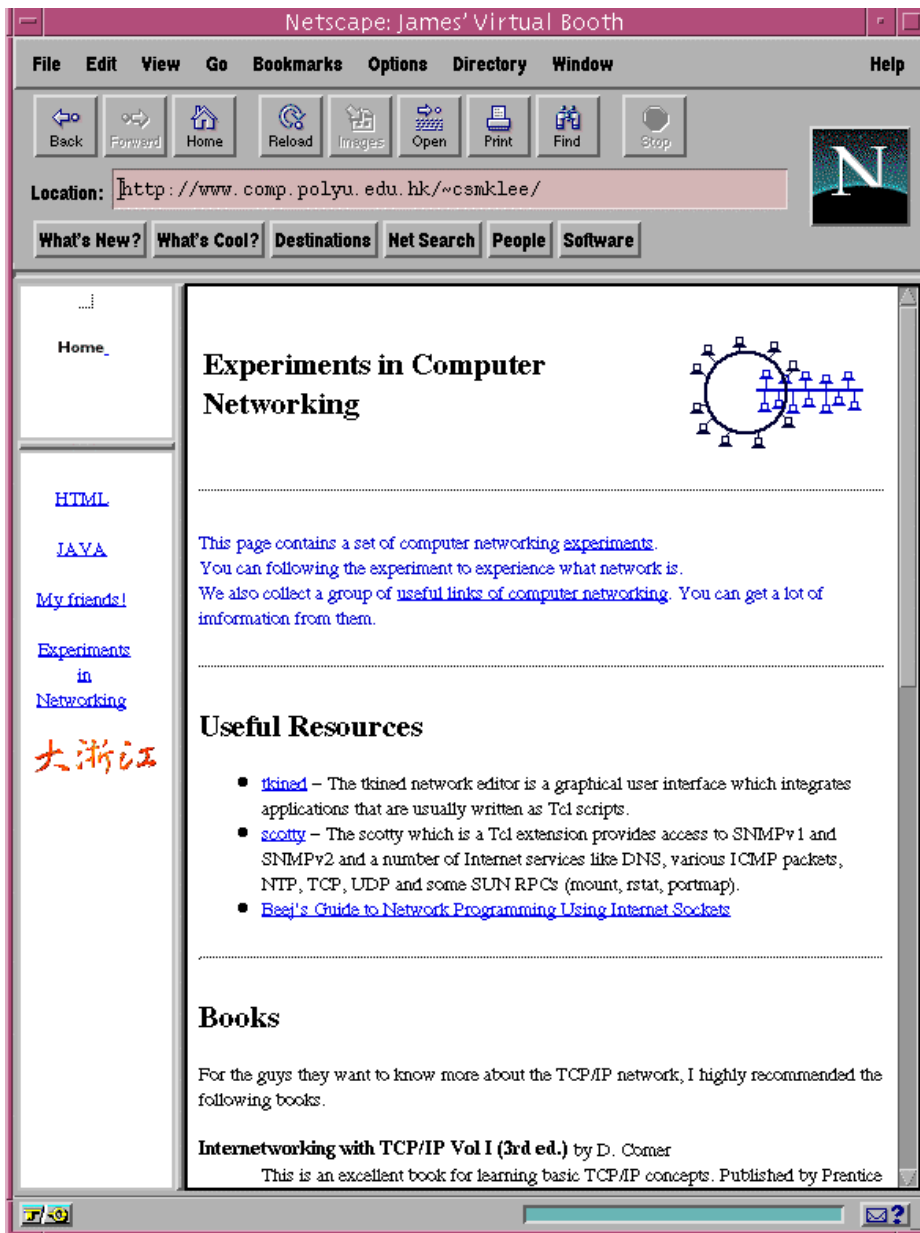


Figure 2: Design of problems for 'Ethernet Utilization - Data Link'

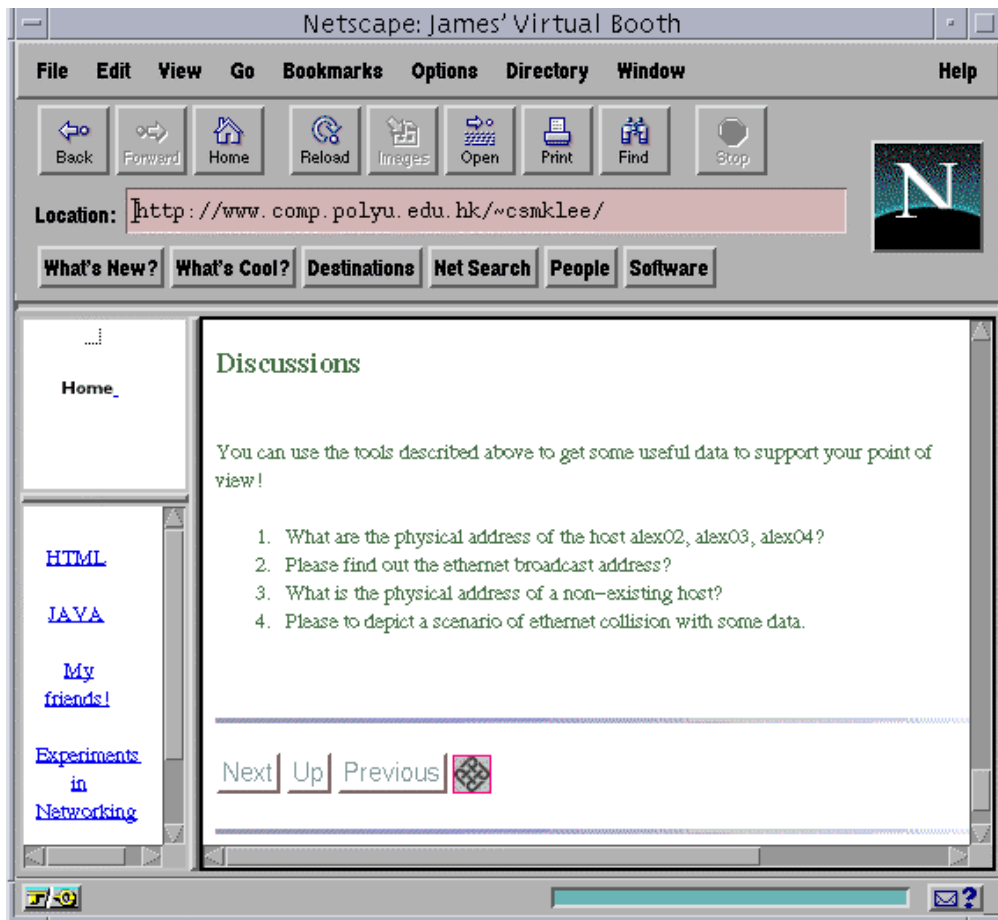
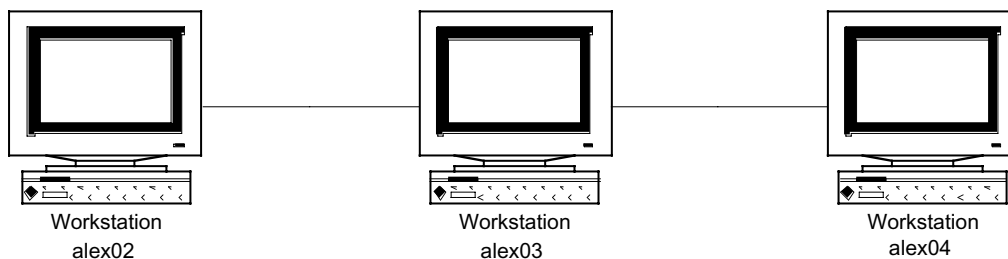


Figure 3: The laboratory network



The second question is to ask for the Ethernet broadcast address. In this question, the student must first know what a broadcast address is and its function, which have been covered in the lectures. They may find the answer by performing the following:

- The students review the background materials and examine the examples.
- Search other related information about the broadcast address through WWW.

- Try some software tools to get the required answers, e.g., *netstat*, *ifconfig*.

The third question is to ask for a physical address of a non-existing machine. Since the physical address of a machine can be found by the *arp* command, they may find the answer by performing the following:

- The students review the background materials and examine the examples.
- Search other related information about the broadcast address through WWW.
- Try some software tools to get the required answers, e.g., *netstat*, *ifconfig*.

The last question asks them to create a real situation of packet collision. Here the students may have to use a variety of software tools to achieve that and use a network monitoring tool to obtain the collision data.

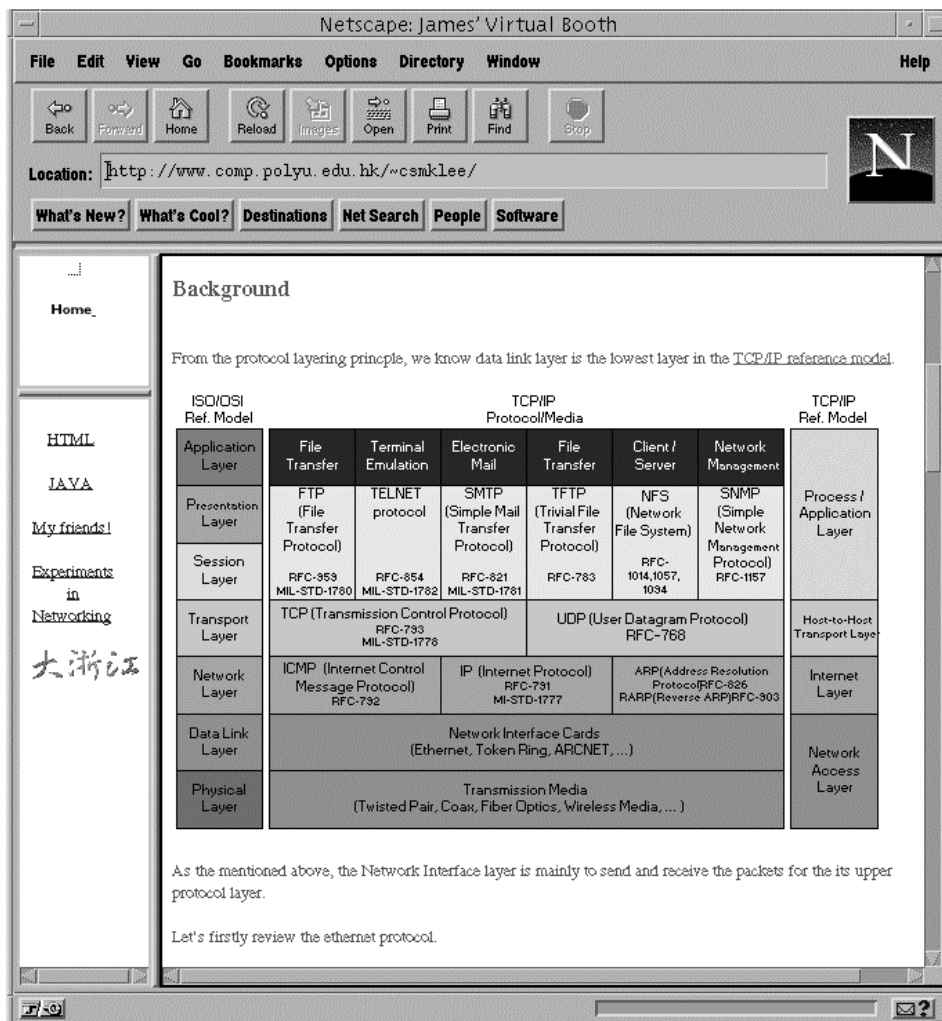
- The students are required to understand the CSMA/CD concept from the lecture notes or text book.
- The students may need to generate data to the network using tools like ftp.
- The students will be able to collect the traffic statistic to show the collision software tools such as netstat.

Driven by the problem in hand, the students will learn how to choose and use the proper software tools to collect useful information. This experience will enhance students' ability to solve practical problems in the real network, and reinforce the concepts learnt in lectures. After the set of problem is designed, we proceed to provide necessary material in the Background section.

### ***Background for the Experiments***

The Background section provides a brief concept related to the experiments and introduces common software tools with adequate examples. The material provided in the Background section is minimal. The students may get the detail of related topics through the WWW. An example is shown in Figure 4.

Figure 4: The background section of experiment 'Ethernet utilization – data link'



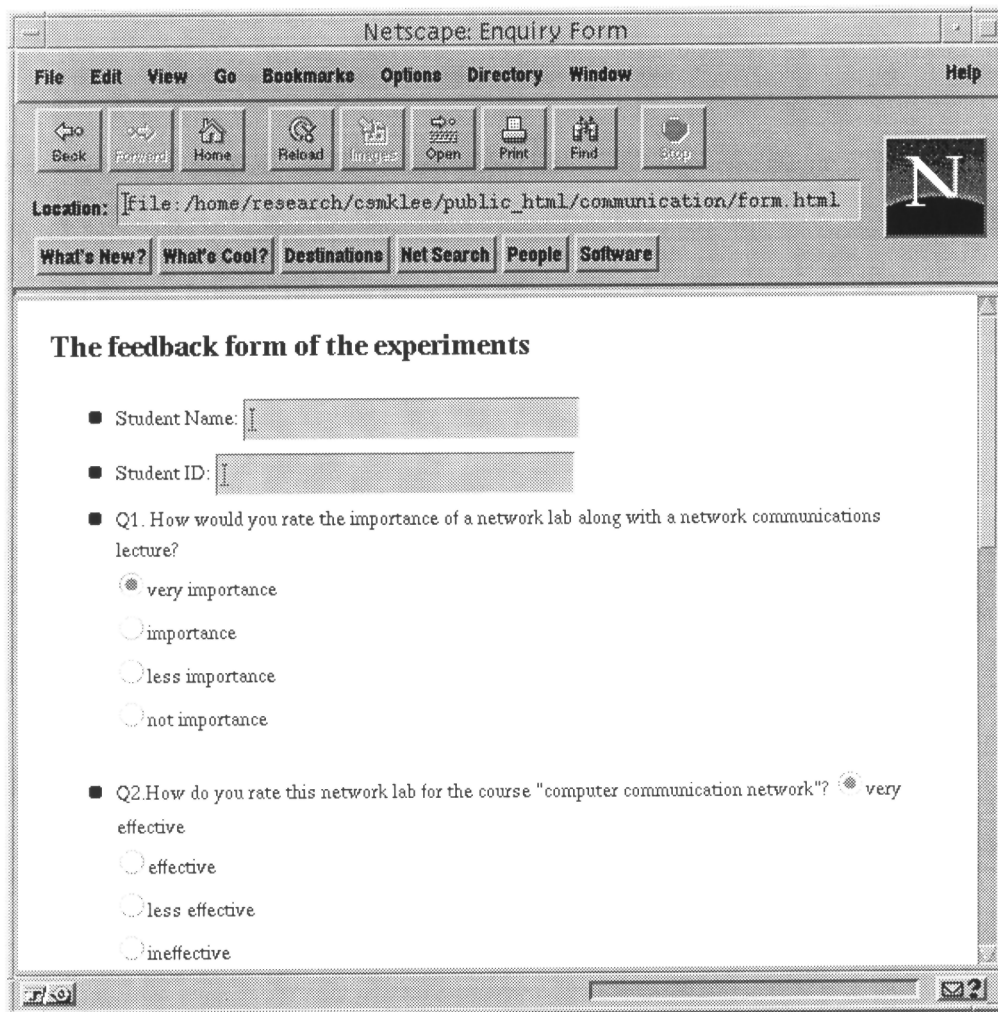
## User Interface

We adopt the hypermedia on the WWW as our presentation interface. The hypermedia is based on Hypertext, which is a non-linear method for organising and displaying information

*in the form of text, graphics, animation, sound and video. This property gives us a number of variations to present the laboratory materials in different formats.*



Figure 5: The questionnaire of the experiments



The screenshot shows a Netscape browser window titled "Netscape: Enquiry Form". The address bar contains the file path: "File: /home/research/csmklee/public\_html/communication/form.html". The browser interface includes a menu bar (File, Edit, View, Go, Bookmarks, Options, Directory, Window, Help) and a toolbar with icons for Back, Forward, Home, Reload, Images, Open, Print, Find, and Stop. Below the toolbar are navigation buttons: "What's New?", "What's Cool?", "Destinations", "Net Search", "People", and "Software". The main content area displays the title "The feedback form of the experiments" and the following questions:

- Student Name:
- Student ID:
- Q1. How would you rate the importance of a network lab along with a network communications lecture?
  - very importance
  - importance
  - less importance
  - not importance
- Q2. How do you rate this network lab for the course "computer communication network"?  very effective
  - effective
  - less effective
  - ineffective

## Data Evaluation

We are planning to offer the set of experiments to the BScIT(Hons) year 2 and year 3 students in 1997/98. We will assess the effectiveness of the experiments through an on-line survey. A sample of the survey is given in Figure 5. They will be asked the following questions:

- 1 How would you rate the importance of a network laboratory in addition to lectures on a scale of 1 (not important) to 4 (important)?
- 2 How do you rate the quality of the network laboratory for the course Computer Communication Network on a scale of 1 (ineffective) to 4 (effective)?
- 3 How does the laboratory help you understand the networking technology?
- 4 What should be improved in this set of experiments?
- 5 What other laboratories do you recommend?

## Conclusion and Future Works

We will continuously refine the contents of the experiments including the development of interactive application, which can be embedded on the Web pages. One application that we have

started to design is a network simulator. This simulator allows students to experiment with networking equipment such as network hosts, routers, bridges and switches. We will also let the student learn more commercial network products, e.g., Windows NT and Novell Netware. They will also gain experience in connecting two or more separate LANs as well as connecting them to the Internet.