# THE EVALUATION OF LOCAL AREA NETWORK DESIGNS THROUGH SIMULATION

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*The widespread growth in the use of local area networks (LANs) is not surprising when considering that three-quarters of the traditional information distribution needs of an organization are within departments or shared among departments. Current LANs even demand access beyond department boundaries and are reaching into the factory and process control applications. Therefore, the managerial analysis of the capabilities of proposed LANs as well as the analysis of competing LAN designs is becoming more complex. As a result, many organizations are finding that it is advantageous to simulate a proposed LAN or internetwork of several LANs prior to implementation. This paper addresses how a special-purpose LAN simulation and modeling tool, LANNET II.5, can be used by data communications management to answer a variety of questions that frequently arise when considering decisions related to the implementation of LANs in an organization. Such a tool would also be appropriate for use by management information systems (MIS) students in a business data communications course, as it allows concentration on the nature of the activities of LAN users without the need for programming.*

The advent of the microprocessor in the early 1970s and the development of the first microcomputer systems in the late 1970s spurred the growth of distributed computing that characterized the first half of the 1980s. As the decade progressed, however, it rapidly became clear that an essential element was missing--connectivity. Microcomputer users began to realize that they needed to communicate with each other as well as with the centralized data processing facilities of the organization. The era of what might be called distributed connectivity had begun and continues to this day.

The local area network (LAN) has played a major role in distributed connectivity as it has allowed microcomputer users within a relatively small geographic area, such as a building or group of buildings, to communicate with one another. Many of the earliest LANs served a variety of office automation functions including electronic filing, scheduling, data base inquiry, word processing, and information dissemination (McGovern, 1988; Stallings, 1990; Stamper, 1990). The benefits of such an arrangement are widely known and include the sharing of expensive equipment such as printers, plotters, and storage devices, as well as the sharing of software, files, and data bases. Other benefits were an

Manuscript originally submitted May 8, 1991; Accepted August 7, 1991 for publication.

increase in the productivity and performance of work groups as a result of electronic messaging and the spawning of new applications that provide innovative solutions to everyday business problems (Allan, 1989; McGovern, 1988).

More recently, LANs have also been making their tracks in factory applications (Heisterberg, 1988; Stamper, 1989). These include computer aided design (CAD) in the automobile and aerospace industries and computer aided manufacturing (CAM) and its associated control of assembly line operations, robots, manufacturing processes, and machinery. Another important goal of LANs in the factory is the integration of a factory's data bases: material handling, labor reporting, quality control, tool and machine maintenance, work-in-progress inventory control, and material requirements.

Along with the increasing use of LANs in the office and factory, as well as the associated need for internetworking these LANs into an integrated corporate network, came a variety of puzzling questions:

- What LAN protocol is best for a particular environment? Should the protocol be a collision based Ethernet or a token based ring or bus?
- What is the maximum number of users that the LAN can support for the data entry function?
- How will internetworking two LANs via a bridge, router, or gateway affect traffic patterns on the individual LANs?
- What will be the effect on current LAN traffic if data base query capability is added to the existing application repertoire of E-mail and data entry?
- What will be the effect on LAN traffic if CAD/CAM applications are implemented that involve a significant number of high volume image transfers?
- Will the response times provided by the LAN be within the acceptable limits established by management and users prior to LAN implementation?
- What storage capacity will be required by the file server so that it may adequately serve the needs of all users?

All of the above questions share the common thread of being concerned with some aspect of the performance of a LAN. They all involve the analysis of the capabilities of proposed LANs in addition to the analysis of the performance of competing LAN designs. The nature of these questions also suggests that it may, in many cases, be appropriate for management to provide for simulation of LANs and their expected traffic patterns before investing tens-of-thousands of dollars into their acquisition and implementation.

This article discusses how a special-purpose LAN simulation tool, LANNET II.5, may be used by data communications management to address questions such as those just posed (LANNET, 1990). For a variety of reasons, LANNET II.5 is also an excellent package for teaching LAN modeling and analysis to students of management information systems (MIS). First, since no programming is required, the student can concentrate on the activities of the LAN users as well as the characteristics of the workstations in use by the users. Second, the package allows for easy animation of the LAN so that one can follow a visual trace of events on the LAN as they occur. Finally, the developer of LANNET II.5, CACI Products Company, offers worldwide university support for its product.

The next section of this article describes, in general terms, the nature of LAN simulation as it is accomplished through LANNET II.5. The final section takes the reader on a tour of an example LAN that illustrates how the data communications manager or MIS student might think through the simulation of a LAN. In addition, the final section analyzes some of the performance data that are generated as a result of simulation of the example LAN.

## The Nature of LAN Simulation

Figure 1 shows how a local area network

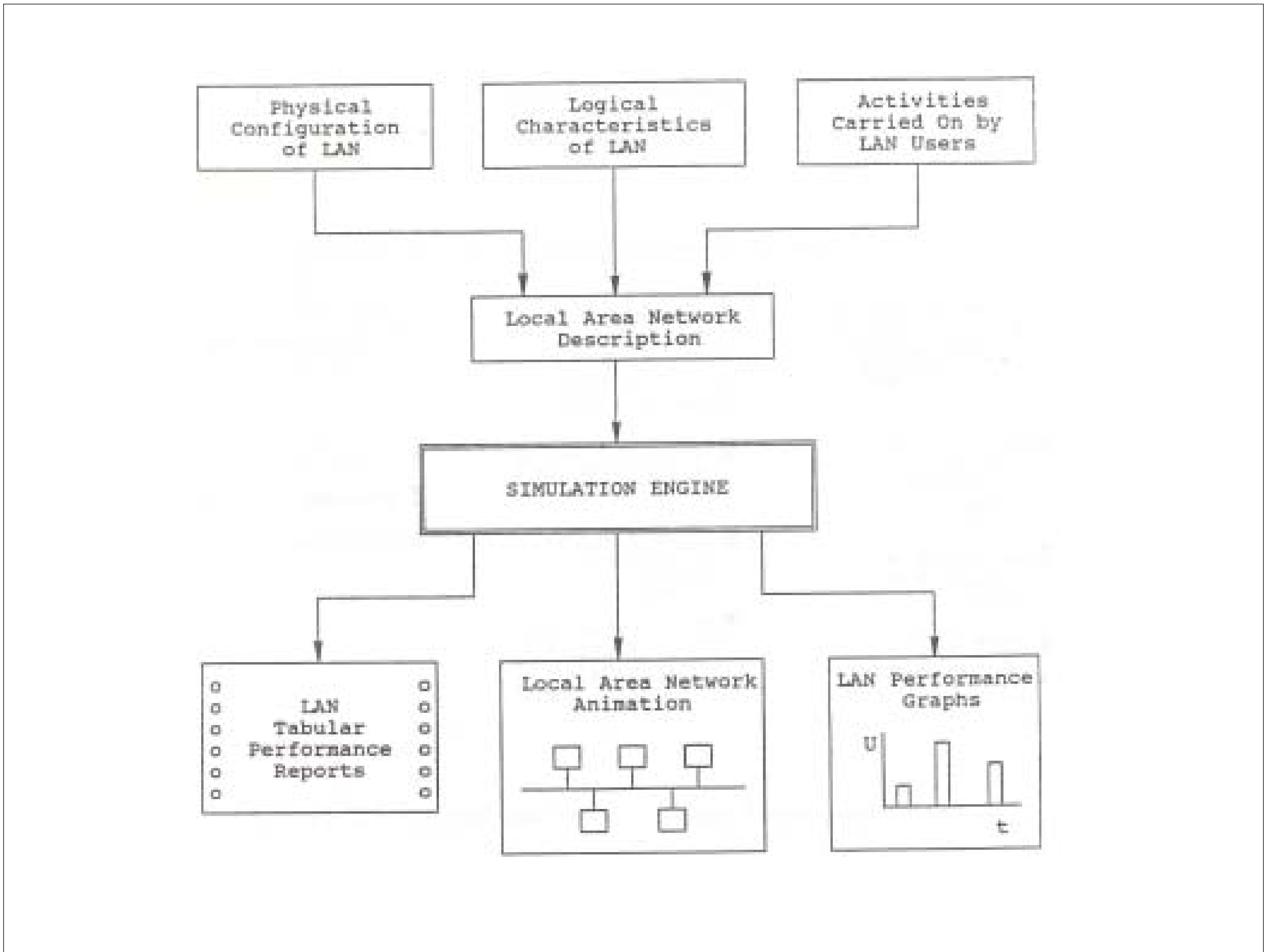


**Figure 1: Local Area Network Simulation**

can be simulated by the use of a package such as LANNET II.5. Via mouse and keyboard input on a hierarchy of color forms, the designer interactively enters information concerning the LAN to be simulated. The information falls into three general classes--the physical configuration of the LAN, the logical characteristics of the LAN, and the activities that are carried on by the LAN users. These general classes of LAN information will be clarified when discussing Figures 2 through 4.

After all necessary information has been supplied regarding the LAN design, the result is a local area network description file that serves as input to a special program that might be referred to as the simulation engine. The simulation engine then runs the simulation of the specified LAN description file and produces the data required to analyze the performance of the LAN. As indicated at the bottom of Figure 1, LAN performance can be studied by viewing any combination of tabular reports, screen animation of the LAN, and graphical reports. The tabular reports include statistics on utilization, delays, and queue sizes, statistics on activities completed by stations, and information concerning messages that have been delivered and received by the LAN. Graphical reports provide utilization and status of devices making up the LAN as a function of time.

Figure 2 gives a breakdown of the parameters related to the physical characteristics of a LAN that must be entered by the designer. The first parameter is the type of LAN based upon the protocol used. These include the major LAN types that have been standardized by the Institute of

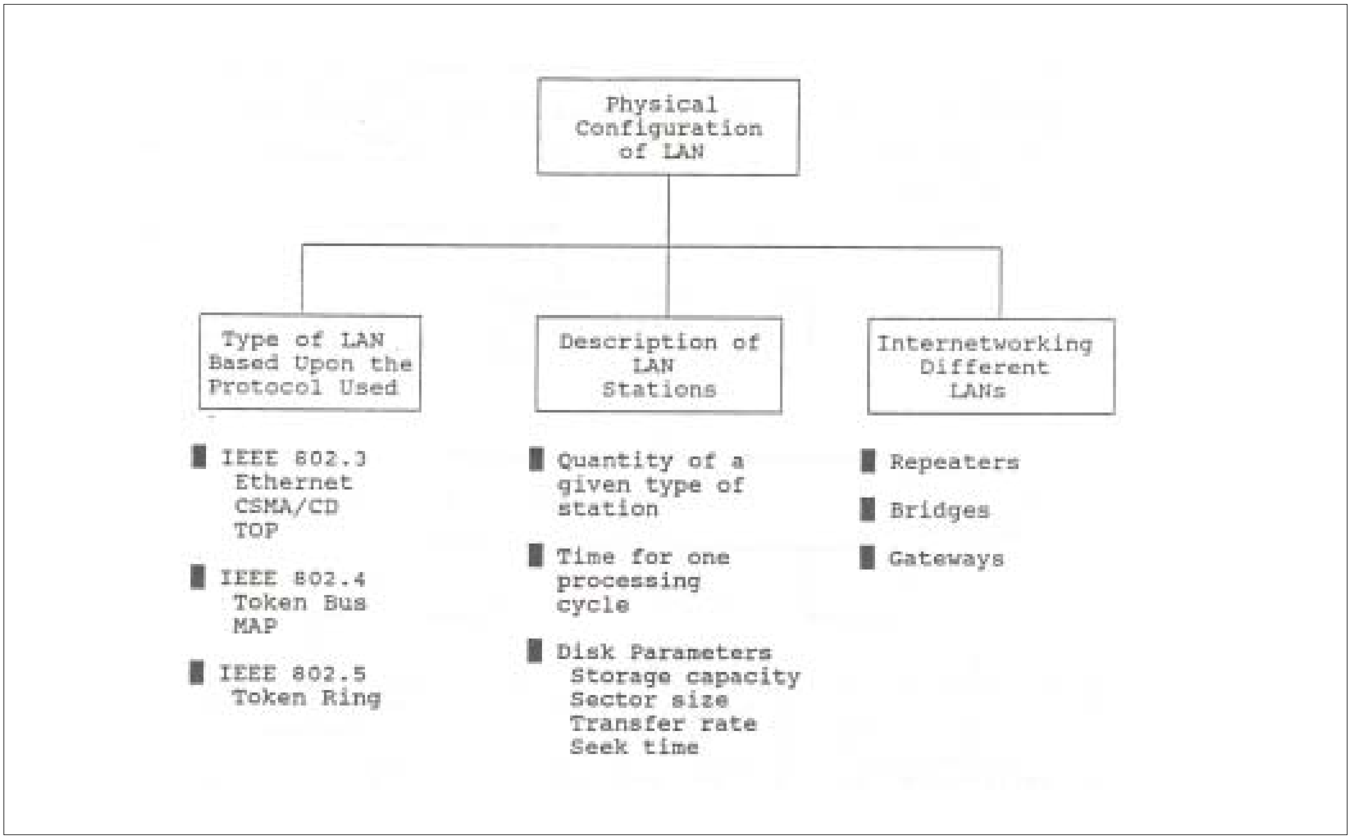


**Figure 2: Parameters Related to the Physical Configuration of a LAN**

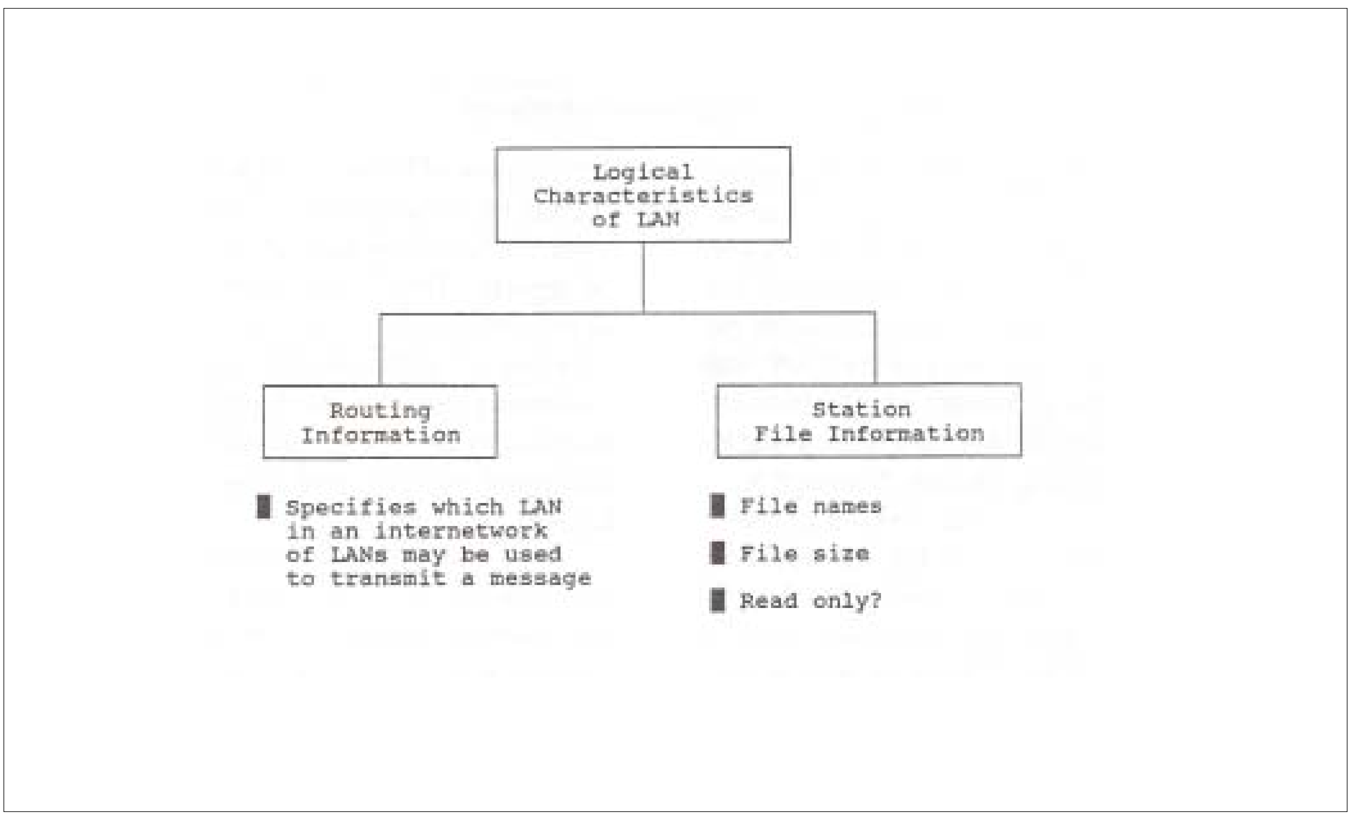


**Figure 3: Parameters Related to the Logical Characteristics of a LAN**

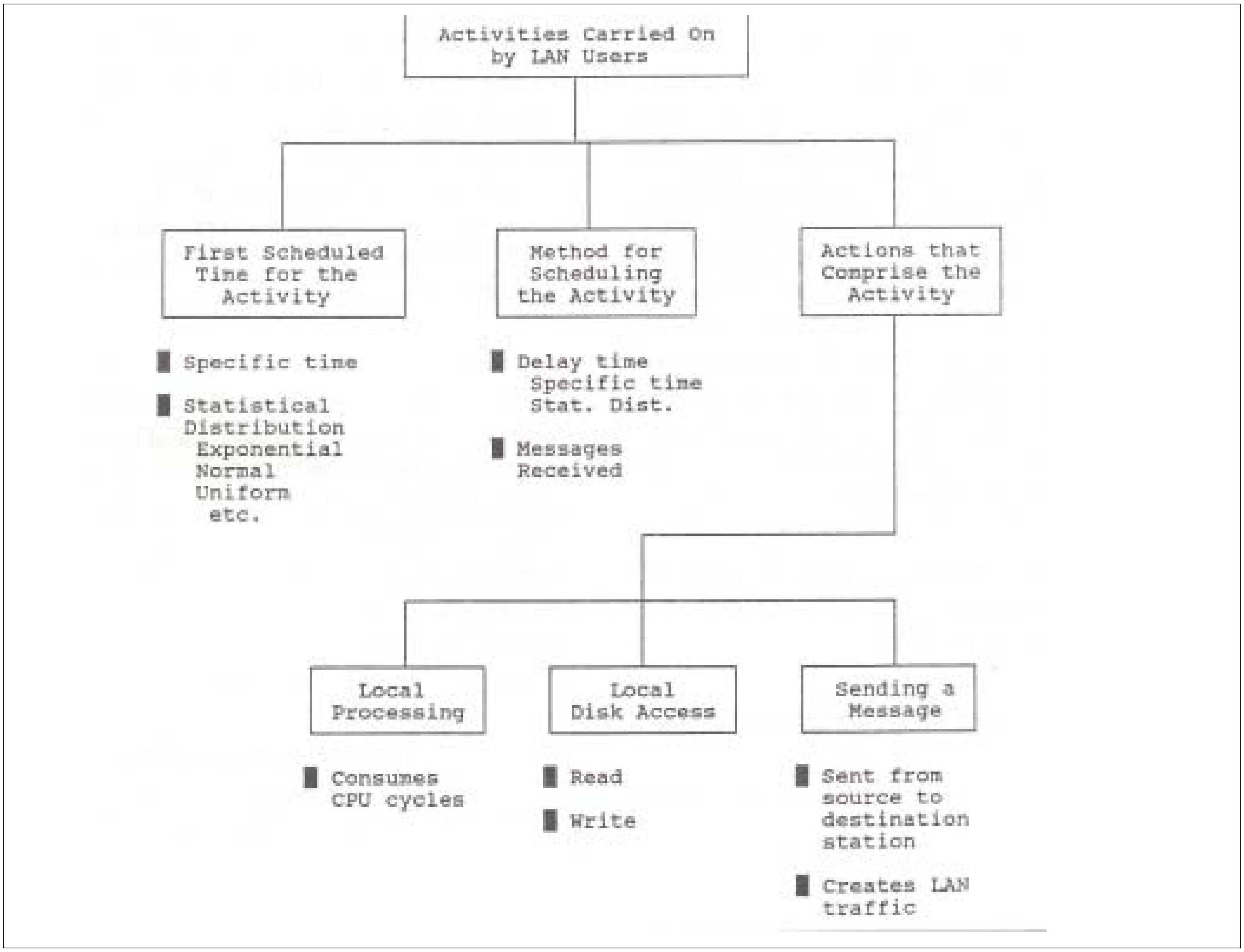


**Figure 4: Parameters Related to LAN User Activities**

Electrical and Electronics Engineers (IEEE) and its 802 Committee. The second group of parameters describes the stations that are connected to the LAN. These include the number of servers, the number of workstations, and processing time and disk parameters for each. The third group of parameters allows the designer to simulate the interconnection of any number of LANs of any type via repeaters, bridges, and gateways.

Figure 3 indicates the parameters that are related to the logical characteristics of the LAN to be simulated. These include routing information and station file information. Routing information specifies which LAN in an internetwork of LANs may be used to transmit a specific kind of message. For example, proper routing can allow one to avoid sending high volume image files over a LAN designed primarily for low volume data transaction traffic. Station file information specifies file names, size, and whether or not files are read only.

Figure 4 diagrams the parameters that are related to LAN user activities. Some examples include requesting the use of a spreadsheet package from the file server, working with the spreadsheet software at the user's workstation, and requesting that the working spreadsheet be saved on the disk at the file server.

The first parameter related to LAN user activities is the first scheduled time for the activity. This might be designated as a specific time or perhaps randomly selected by the use of a common statistical distribution. The second parameter is the method for additional scheduling of the activity. This might be given as a delay time between schedulings or it could be based upon the receipt of a specific message. As an example, if a workstation user sends the message DIR to the server, the server would, upon receipt of the message, send the directory listing to that user station. The third parameter is simply a list of the actions that comprise the activity. As shown at the bottom of Figure 4, actions may be of three types. Local processing actions are any actions that consume CPU cycles such as calculations. Local disk access actions include disk read and disk write. The third type of action is that of sending a message to another workstation. The message sent may vary in size from as small as a few bits representing the status of a particular process control device in a factory setting to as large as a several kilobyte text or image document. Message actions are essential for the simulation as they are responsible for the creation of traffic on the LAN.

## An Illustrative Local Area Network

Imagine that upper-level management of a nationwide firm has recently given approval for establishing a local area network at its corporate headquarters. The LAN is to be implemented in phases, and the first year of operation should accomplish two goals. The first goal is to connect the entire data entry staff of 30 clerks to the network and offload some of their tasks, including order entry, from the mainframe to a data entry department server on the LAN. The second goal is to connect the 20 managers at the corporate headquarters so that a management server might be able to handle their database queries.

The Network Analysis and Design team is considering a variety of alternatives for accomplishing these goals, and plans to simulate each alternative before making the final decision on the best design approach. One of the alternatives will be analyzed in this section of the article in order to provide a feeling for the processes required in producing a LAN simulation.

### Physical Configuration

Figure 5 presents a diagram of the proposed LAN. The backbone is an IEEE 802.3 CSMA/CD 1BASE5 LAN. CSMA/CD, short for

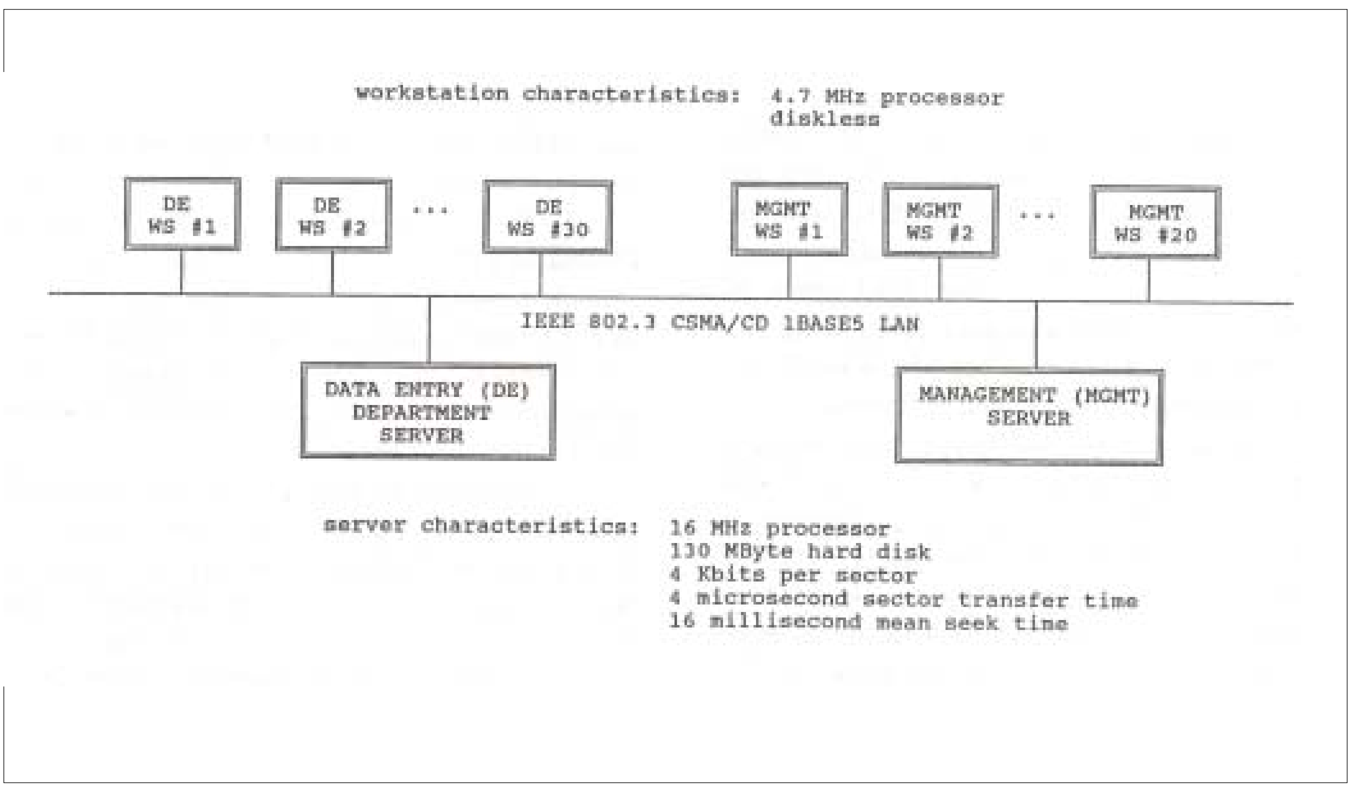


**Figure 5: An Example Local Area Network**

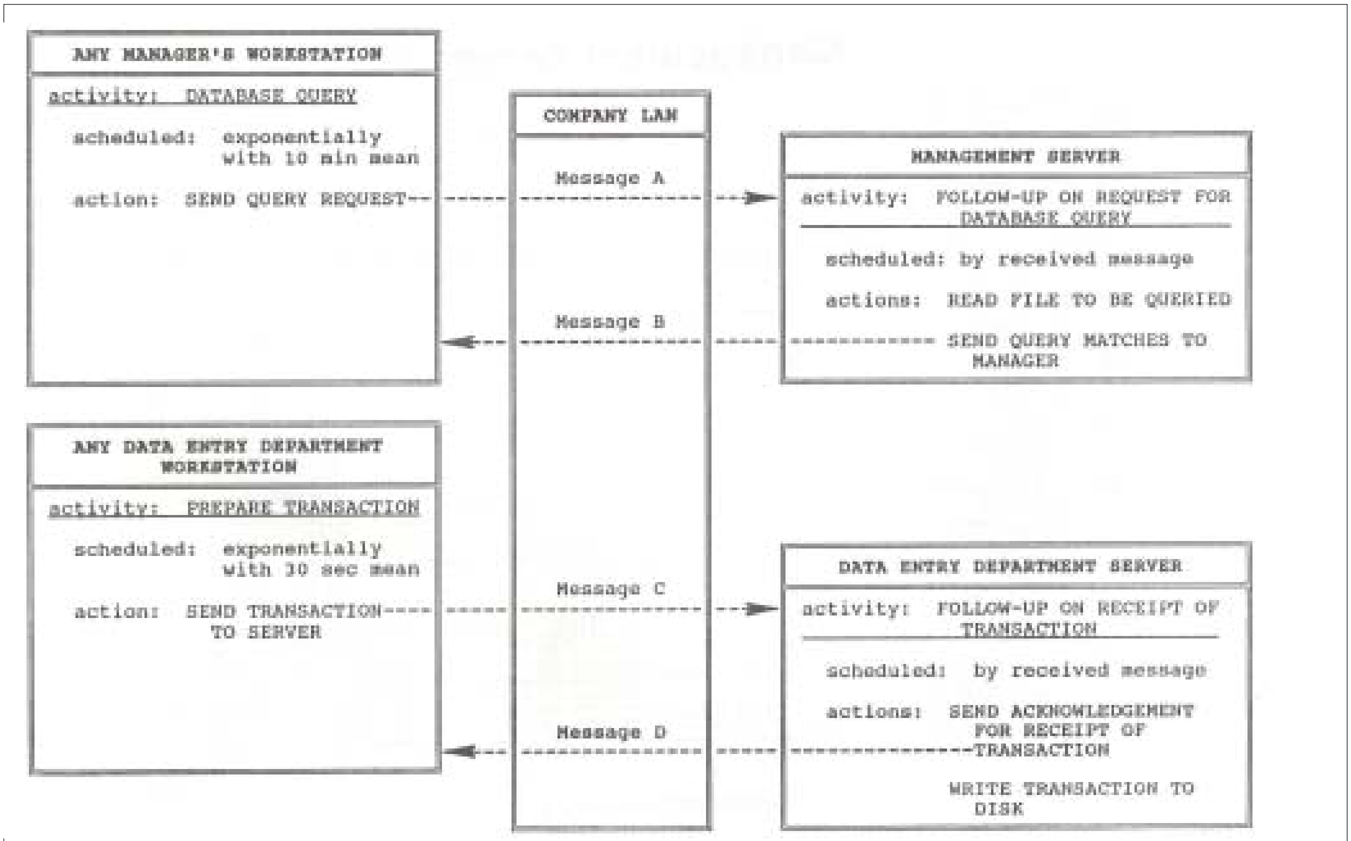


**Figure 6: User Activities for the Example Local Area Network**

Carrier Sense Multiple Access with Collision Detect, is a contention based protocol in which any node can sense the presence of a signal on the cable, and if no signal is present, may access the cable. In the event that two or more nodes attempt to access the cable simultaneously, a collision is detected and each station waits a random amount of time before again attempting to access the cable. The term 1BASE5 means that the LAN can transfer at a rate of 1 megabit per second, is baseband, and allows a maximum distance of 500 meters.

The 30 data entry (DE) workstations (WS) are shown attached to the LAN along with a data entry department server. In addition, the 20 management (MGMT) workstations are shown along with a management server. In order to help promote corporate network security, all workstations will be diskless. In order to keep hardware costs down, the workstations will use 4.7 MHz (megahertz) processors. The servers will be 80386-based microcomputers with 16 MHz processors and will include 130 MByte hard disk drives with 4 Kbits per second transfer rate, 4 microsecond sector transfer time, and 16 millisecond mean seek time. These characteristics, necessary for the simulation, provide the physical configuration of the proposed LAN and can readily be obtained from vendor specifications.

### Logical Characteristics

No routing information needs to be specified as the proposed LAN is not an internetwork of several LANs. Station file information, however, does need to be specified. The data entry department server will maintain a daily transaction file that contains the orders keyed in by the clerks during a given workday. The simulation will provide statistics regarding the size of this file in bytes as the simulation proceeds. Such information will be useful for determining more precisely the required capacity of the hard disk on the data entry department server. The management server is expected to contain a 200,000 byte read-only file that will be queried by management via SQL

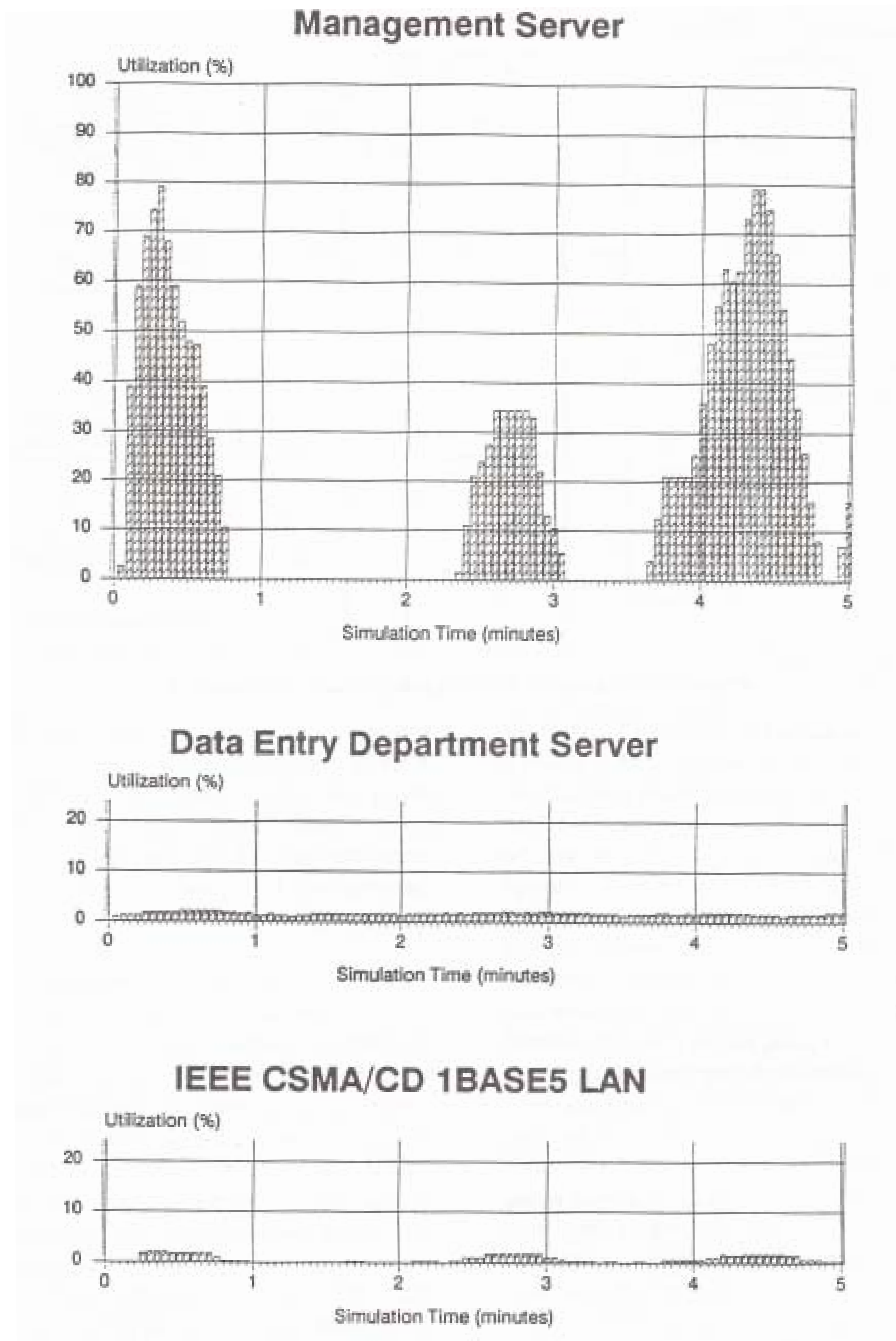


**Figure 7: Utilization Graphs for the Example Local Area Network**

(Structured Query Language) throughout the course of a workday.

### LAN User Activities

Figure 6 shows in diagrammatic form the user activities for the proposed local area network. It is anticipated that each of the manager workstations will initiate a database query every 10 minutes, exponentially distributed. The parameters related to the query are sent as Message A over the LAN to the management server. Message A is modeled as constant in length at 120 bytes; however, any other distribution can be modeled just as easily. When the query request of Message A reaches the management server, a server activity that consists of two actions is triggered. The first action causes the server to read the file to be queried from its hard disk. The second action causes any query matches to be echoed as Message B back to the requesting manager's workstation. The length of the Message B query matches is assumed to be normally distributed with a mean of 20,000 bytes and a standard deviation of 6000 bytes.

It is expected that each of the data entry workstation clerks will complete entry of a transaction every 30 seconds, exponentially distributed. The transaction is sent to the data entry department server as Message C, whose length is normally distributed with a mean of 240 bytes and a standard deviation of 70 bytes. When the transaction of Message C reaches the data entry department server, a two-action server follow-up activity is triggered. The first action causes the server to echo a 10-byte acknowledgement to the station that originated the transaction, while the second action simply causes the server to write the transaction to the daily transaction file on its hard disk.

### Simulation Results

Based upon the physical configuration of the LAN, the logical characteristics, and user activities presented in the previous three subsections, the modeler describes the LAN through a hierarchy of interactive, menu-driven screens using both keyboard and mouse input. The result is a LAN description file that serves as input to the simulation engine. A variety of statistics regarding the performance of the LAN is produced by running the simulation, and some of the major results will now be discussed.

Device utilization, or the percentage of time that a device is not idle, is probably one of the most important measures of performance of a LAN. Figure 7 shows the utilization statistics for the management server, the data entry department server, and the LAN responsible for carrying all message traffic. It should be noted from the horizontal axis that the LAN was simulated for five minutes and that each small tick mark represents three seconds of simulated time. Utilization, which has a range from 0% to 100% is plotted along the vertical axis using the same scale on all three graphs. The height of a bar therefore represents the average utilization over the three second interval that it represents.

Each of the three "humps" in the management server utilization graph primarily represents time the server is busy waiting for the query file to be read from the server's hard disk. From the high utilizations, it is clear that such queries are demanding upon the resources of the management server. A study of the data entry department server, however, shows that the transactions that arrive every 30 seconds on the average from each of the 30 data entry workstations produce very little drain on the performance of the server. This is evidenced by the fact that the utilization of the data entry server never exceeds more than about 2%. It should also be observed that the utilization of the data entry department server is relatively constant over time, whereas the management server's utilization varies significantly with random arrivals of queries approximately every 10 minutes from each of the 20 manager workstations. The three humps in the management server graph, in fact, represent only nine query requests from managers.

The graph at the bottom of Figure 7 indicates the utilization of the LAN itself. The three humps in this graph, each showing a utilization of less that 2%, represent primarily the query matches the are sent to the manager workstations over the LAN. The transactions from the data entry workstations and the return acknowledgements produce an imperceptible drain on the capacity of the LAN. Statistics from the simulation indeed show that there were no collisions during the five minutes of simulated time. It appears that the 1 megabit per second LAN that is proposed will be more than sufficient for the projected needs for the first year of LAN implementation.

The real bottleneck is more likely to be the management server under the proposed method of handling queries. Simulation statistics reveal that the average query time is 6.7 seconds. The Network Analysis and Design team will want to compare this average query response time to the response time requirements that were obtained during initial interviews with management. If the requirements are not satisfied, the team may need to consider changes in the network and then run additional simulations to determine the effect of such changes.

## Summary

The rapid deployment of LANs nationwide, as well as the requirement to interconnect them to form a useful corporate tool, have resulted in the need for data communications management to simulate a variety of alternatives prior to acquisition of LAN hardware and software. This paper has discussed how a special-purpose LAN performance and simulation modeling software package can be utilized to address this decision-making need. By means of an illustrative example, it was shown how the LAN designer can specify the physical configuration, the logical characteristics, and the activities carried on by LAN users. In addition, the student of MIS can gain some hands-on experience in simulation modeling in a context that allows concentration on the solution to the local networking needs of an organization rather than on the intricacies involved in programming such simulations.

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