DISCUSSION PAPER

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Network Communications for a National Computational Facility
A Report to the NSF SubCommittee on Computational Facilities for Theoretical Research

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DISCLAIMER

1. INTRODUCTION

This report considers in detail the use of an existing public network to provide access to a National Computational Facility from terminals at numerous sites throughout the country and to permit computer to computer communications. At the present time two public networks are available, GTE's Telenet and Tymnet operated by TYMSHARE. Telenet offers significant advantages over Tymnet and the facilities it offers are the basis of the discussion in this paper.

Telenet is value-added network which offers significant advantages over the use to leased lines between designated nodes in a communications system developed and maintained by a user. These advantages result from the sharing of network resources among a number of users, over 300 separate coporate entities in the case of Telenet.

· *complete-end-to-end switched service*

Telenet undertakes to arrange for connecting use equipment, wherever located, to its network. In many areas throughout the US a terminal of any kind can be connected to Telenet through a local phone call. Connections from other sites can be arranged in several ways, including as a dedicated access facility at a fixed charge for unlimited access to Telenet. It is not necessary to reconfigure or reoptimize the network as it expands.

· *distance independent pricing*

One of the most significant features of Telenet is the way its services are priced. Charges are based on the number of packets (128 characters) of data sent without regard to the distance which these packets travel. Users also pay an hourly port charge for dial-in ports or a monthly charge for a dedicated port plus a variable fee based on the total number of packets transmitted each month. Substantial volume discounts are applied to these charges for a customer (e.g. for a

national computer center together with all its users) which has a monthly billing in excess of $5,000 per month.

·*communications among dissimilar computers and terminals*

Telenet provides the ability for the code, speed, and format translation necessary to enable any terminal or computer to access an otherwise incompatible host computer. Telenet uses the internationally accepted X.24 standard protocol which has now been adopted by every major computer manufacturer. It is therefore unnecessary for the user to pay for the cost of developing and maintaining his own software to accomplish this.

·*reliability, availability, and accuracy*

Telenet provides redundant links to every switching processor in the network. Sophisticated software provides for dynamic selection of alternate routes. A duplicate copy of each packet whose receipt is not acknowledged is transmitted. An error detection and correction scheme ensures an error transmission rate of less than one part in 10^{12}.

Further discussion of the computational center for theoretical physics is based on the use of Telenet. For this purpose the National Computational Center for Theoretical Physics would subscribe to Telenet as a single, corporate customer. All charges for the use of Telenet by the Center and by its authorized users of Telenet. Therefore these charges would be subject to the substantial volume discounts available to any Telenet customer.

2. NETWORK COMMUNCIATIONS, FOR A NATIONAL COMPUTATIONAL FACILITY

2.1 Requirements

Some goals in establishing a National Computational Facility for theory would be (1) to provide uniform access by all university-based scientists, to a supercomputer, (2) to facilitate exchange of programs and encourage the development of software libraries, (3) to provide access to data bases, and (4) to reduce wasteful duplication of effort and encourage collaboratiion on significant computationally demanding problems. A key element to the success of such a center, or any venture involving shared computer resources and data bases, is the establishment of good communications at a cost effective level. The cost effectiveness must be determined by analyzing the savings from the development of shared software, the more efficient use of hardware, and the reduction of "hidden" costs for the management of computer resources by research faculty (including graduate students and postdoctoral research associates.)

The operational requirements for a communications system to accomplish these goals are the following:

(1) accessibility by public telephone using <u>any</u> terminal with an acoustic coupler at speeds form 110 bps to at least 1200 bps; provision for nodes consisting of a large number of terminals and fast line printers;

(2) support for computer to computer communications using the internationally accepted X.25 protocal;

(3) reliable and accurate transmission of data;

(4) controlled access by authorized users with an accurate accounting by user and by site of connect time and traffic charges;

(5) international links to major computing centers throughout the world and accessibility by authorized users on a world-wide scale.

These requirements can be met by using the facilities and services provided by Telenet to its customers.

2.2 Available Facilities and Services

2.2.1 Network Coverage

As a packet switching network Telenet consists of (1) switching and network access centers called "Telenet central offices" (TCO), (2) transmission facilities leased from other common carriers, (3) a network control center and (4) network access equipment located on customers' premises. A user can access the network by leasing an access port or by dialing into the nearest TCO. Currently there are 91 switching centers which provide access through a local call to 182 U.S. cities with a population of 50,000 or more. Telenet provides WATS lines for users in other locations. Currently there are over 300 subscribers to Telenet including a number of universities, government agencies, and private corporations. These subscribers provide a variety of services to users throughout the world.

Telenet is currently interconnected to the Datapac network operated by the Trans Canada Telephone System, which provides access to over 55 Canadian cities. DASNET, a packet network operated in Hawaii by the Hawaiian Telephone Network, is also connected to Telenet. Through other carriers Telenet provides communications services between the U.S. and 22 other countries and overseas points in North America, Europe, the Pacific and the Far East. Packet switching networks based on X.25 protocol exist or are being developed in many European countries as well as Japan and Australia. Euronet is a packet switching network for all the Common Market Countries.

2.2.2 Operation of the Telenet Network

Telenet connects terminals to hosts through Telenet central offices or TCO's. Each TCO is connected to at least three cities to provide enhanced reliability, accessiblity, and serviec. The TCO recognizes any terminal type and properly encodes and decodes data to and from that terminal in the appropriate format, i.e. the TCO sets up the line width, supplies the

appropriate carriage return, etc.

The TCO encodes data from a terminal in blocks not exceeding 128 characters into "packets" of variable length but not exceeding 8192 bits. Each packet consists of a start indicata, a header, the text of the message, a termination indicator, and a 16 to 24 bit "cyclic redundance check" for error detection. The TCO's route each message through to its destination using the address and control information in each packet. If any node is unable to send a packet over the next scheduled leg of its journey due to congestion or failure of a line, it will select a new route and send it on its way. The last node in the network to receive the packet strips off the address and control information, assembles the packets in proper sequence and format and sends them to the destination terminal or computer.

The average network delay of a packet is 200 milliseconds. The TCO nearest the sender sets up a bookkeeping system and checks on receipt of the packets. If receipt of a packet is not acknowledged by the next TCO within 100 milliseconds, the local TCO sends a copy of the packet. The TCO nearest the destination must send an "acknowledgement of receipt" after every seven packets. If not received by the initiating TCO, it then sends a copy of the previous seven packets. More than one copy of a packet may reach the TCO nearest the intended destination, but only one copy is sent on to the host in the proper sequence. The cyclic redundancy check (CRC) provides for an error rate of less than 10^{-12} when the CRC is satisfied. This is equivalent to once in 32 years on a given leg of the network.

The switching processor at each TCO is a Prime minicomputer supervised by two network control centers (NCC) with dual responsibilities to moniter the functioning of the switching processors. Each TCO continually issues "handshakes" to the two NCC, which take corrective action in the event of failure of a TCO. If a TCO "dies" another computer assumes its role. The NCC also keep records of connect time, the number of packets exchanged between

two devices, etc. Thus Telenet is able to supply a user with the accounting information necessary for allocating service charges within his organization.

2.2.3 Electronic Mail

The electronic mail system operated by Telenet provides a very cost effective alternative to other means of communications between a central facility and individuals or groups of users, as well as among users. The system provides for the entry, editing, accessing, and storing of letters, memos, or "bulletin boards" to be distributed by individual or group name. The system can easily be used by secretaries with minimal training. The cost is base primarily on a connect charge of $13.25 per hour before 18:00 local time and $3.00 per hour later.

2.3 Proposed Structure of the Communications System

The communications system proposed for the system recognizes the need for distinct types of service: (1) access by individual users equipped with a variety of terminals, (2) nodes located in large research groups with several terminals and a fast line printer, and (3) computer to computer communications for the transmittal of data or results to the host supercomputer. These needs can be met by using the full range of facilities and services offered by Telenet.

I shall assume that the major component of a National Computational Facility is a supercomputer with an integrated terrabit mass storage system housed in a center together with the staff responsible for the operation of the NCF: consultants, programmers, documentarians, librarians, technicians, and office staff. This center will be connected to the network in the supercomputer on its "front end" using an X.25 software interface through a 56Kb dedicated access faculity (DAF) to the nearest TCO (Telenet central offica). A DAF includes a dedicated port at the nearest TCO, modems or digital interface units, and the transmission line between the TCO and customer site.

A second component of the NCF will be a number of nodes (perhaps 10) located in major laboratories through the country. Each such node will be assumed to have a computer which provides some local processing and acts as a concentrator for a large number of terminals and drives a fast line printer. This computer will also be connected to the network through a DAF, operating at the less costly speed of 9600 baud. This computer will also use an X.25 software interface to the network.

A third component will be a large number (perhaps 100) DAF operating at 1200 baud and providing unlimited access at a fixed monthly charge to users (groups or individuals) requiring more than 100 hours of connect time

each month. Each DAF will support any terminal with an acoustic coupler. A leased TP (Telenet processor) could support from three to fourteen terminals.

Finally, I shall assume a large number of users who require less than 100 hours of connect time each month and use dial-in ports through a local telephone call. These users will be able to use any terminal with an acoustic coupling which operates at 110, 300, or 1200 band. If a user is not at a telephone which is local to a TCO, there are several alternatives to long distance charges. A phone connected to a "foreign exchange" can often be arranged at a modest additional monthly charge. As an alternative Telenet will provide a In-WATS line to any location to provide service at $15.00. Finally a DAF which provides unlimited access to any location can be leased at $360 monthly for a 1200 band line. Since this charge is independent of site and in lieu of any long distance or connect charges, the DAF is usually the most cost effective arrangement for any user who incurs connect charges in excess of 100 hours per month (at $3.90 per hour).

Communications among the computers associated with the National Computer Facility, including the host, are easily established using X.25 software interfaces. This means that computers in large user groups can communicate with the central supercomputer and with each other. Moreover, the host supercomputer can solicit data from the management computer for any large data base on Telenet and store it for ready use by one of its users or forward it to another node.

3. COST ESTIMATES

Any cost estimate for the communications system of the National Computational Facility must be based on some scenario for the usage of the central supercomputer or other computers in the system. Monthly charges are independent of the distance between two correspondents. Instead charges divide by categories: (1) DAF monthly charges for unlimited access, (2) connect charges to the network for dial-in, and (3) traffic charges based on $0.50 per kilopacket with each kilopacket restricted to 128 characters or 1024 bits.

Any calculation of charges must take account, however, of the special low rate available from 18:00 to 7:00 local time and all day Saturday and Sunday as well as some holidays. This rate is $0.75 per hour of connect time including a traffic allowance of 2 free kilopackets per hour. Indeed, communication costs could be reduced considerably by making these hours sufficiently attractive to users to give a uniform load distribution on the system. A minimum monthly charge of $7,500 is imposed for this service.

The following discussion of costs is based on a pattern of rather heavy usage by a large community of users. Ten nodes established at Laboratories with perhaps 20-30 active users in all disciplines will serve 200-300 research scientists. One hundred DAF (dedicated access facilities) at 1200 band should be expected to serve another 200-300 people actively engaged in computing. I estimate costs for dial-in service by assuming 50% of the users at any time to be connected by telephone. The pattern of usage employed to estimate costs allows for 16,380 user-hours/month by dial-in. This allows 50 hours/month to each of 327 dial-in users. Thus the scenario provides for 700-900 active users in a given month.

With these assumptions the communications are estimated in the following tables, Table I and Table II.

TABLE I

Schedule of Monthly Costs

I. Dedicated access facilities

1	56 Kb - supercomputer center	$ 2,100
10	9.6 Kb - nodes	11,000
100	1.2 Kb - user centers	36,000

Total DAF charges. . . . . .$ 49,100**

II. Dial-in connect charges

A. Weekday (Time in Eastern Standard)

13:00-15:00 / 100 users × 50% = 100 user-hours
15:00-21:00 / 30 users × 50% = 90 user-hours
10:00-13:00 / 40 users × 50% = 120 user-hours

User-hours per day, prime time = 310 user-hours

1. User-hours per month.....7,130
   Connect charge @ $3.90 . . . . . .$ 27,807*

B. Weeknights (Local)

(East) 18:00-7:00 / 20 users = 260 user-hours
(West) 7:00-10:00 / 10 users = 30 user-hours

Off-peak usage each "night" = 290 user-hours

Off-peak usage on weeknights
per month user-hours.....6,670

C. Weekends

Assume 25% of a full weekday
(310 + 290) = 150
Weekend usage per month.....2,580

Total off-peak usage user-hours.....9,250

Off-peak connect and traffic cost
@ $0.75 $6,938

Minimum charge for off-peak usage . . . . . .$ 7,500

III. Traffic charges

Assume 2 (kilopackets/hr) @ $0.50 each
User hours in prime time per month

DAF users	7,130
Dial-in users	7,130

Total user-hours per month.....14,260

Traffic charge per month . . . . . .$ 14,260*

TABLE II

Summary of Costs

A.	Half-discountable items (**) $49,100			
	1. Discountable portion		$24,550	
	2. Fully discountable items (*)		$42,067	
	Total Discountable Costs		$66,617	
B.	1. Discounted costs (monthly)			$40,808
	2. Costs not discountable (monthly)			$24,550
	3. Off-peak usage (minimum)			$ 7,500
	Total Monthly Communication Cost			$72,858
	Annual Cost of Communications		$874,296	