Computer Networks and Management at the University of Minnesota

Final Report of the All-University Committee for Network and Communications Planning

June 13, 1988

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HISTORY AND GENERAL PRINCIPLES

The All-University Committee on Network and Communications Planning was appointed by Vice Provost V. Rama Murthy in February, 1987. The committee was asked to establish a network topology, recommend standard protocols, set priorities for applications to be supported for all network users, develop policies for wide-area networks, recommend operating and accounting policies, and establish a planning framework for allocating resources for network needs.

An initial report was issued on April 29, 1987. It made seventeen recommendations concerning network hardware and software. The committee recognized that the charging policy plays a major role in determining the direction that the University's network will evolve, and it promised to develop some recommendations in that area. The second report, issued November 30, 1987, made fifteen recommendations for overall management of computing at the University of Minnesota, electronic mail, security, and external networks and services. This document consolidates the first two reports and presents all of our findings and recommendations, including additional ones for charges and subsidies. A Glossary of the specialized terms and acronyms used in networking is presented in Appendix 1.

These recommendations result from deliberations almost weekly over a period of fifteen months. We examined the technical and economic aspects of networks, their role in academic and administrative functions of the University, and the questions of management of computing at the University of Minnesota. Several general principles emerged from our discussions. They shaped our recommendations, and we believe that they are even more important than our specific recommendations.

1. Networks are vital to the University's future. The computing environment will consist of many different components that are networked together. Students, faculty and staff will use networks for instruction, for learning, for research, and for administration. They will use them to keep in touch with each other and with colleagues at other institutions, to retrieve data, to place orders, to search databases, and to compute.

2. Universal connectivity is critical. Everyone on campus must be connected to the network. The more users and services that can be reached through a network, the more valuable it is. Today we find a few departments in which nearly everyone is connected, a number of departments with a few connections, and many departments with no connections at all. We must make special efforts to avoid splitting departments into the connection-rich and the connection-poor.

3. Flexibility is important. The technology for computing and networks is changing so rapidly that it is impossible to predict what will be needed and available. We must avoid large investments that lock us into a particular technology and impede our ability to remain current. We should proceed incrementally, conducting many small experiments and adopting the most successful strategies.

4. Competition is essential. Because of the need for flexibility, competition between providers is needed to keep them efficient, motivated, up to date, and responsive to the user community. Because of the rapid changes which are taking place, this need for competition outweighs the possible efficiencies to be gained from a single, monopolistic provider. As particular computer centers or servers outlive their usefulness, they must be eliminated, so their support can be re-directed to meet new user needs.

5. Users Know Best. By this we mean that users should not be forced to learn a variety of operating systems, editors, word processors, mailers, and databases. Users, rather than developing expertise on one computer, will often be occasional users of many computers. They should be able to work on any of these computers using the environment of their own workstation.

6. Accounting Should be Simple. The diversity of services employed by each user makes accounting difficult. It is important to develop an accounting system which does not require each faculty member or student to have dozens of user numbers and passwords.

WHY NETWORKS ARE NEEDED

The use of networks – local to international – is exploding on the academic scene, probably with even greater rapidity than did the personal computer.[1] Here are a few examples of current uses of networks:

Local

- Students in Project Sunrise are using networked computers to learn cooperative writing in a course taught by the Rhetoric department in St. Paul. Because all of the public laboratories in the Twin Cities are networked together, students can work on their assignments on either campus.
- Faculty working in their university or home offices can use LUMINA to search the union library catalog. They may, for example, select a reading list for a class, verify references for a manuscript, search for publications by site visitors, or explore new research areas.
- Electronic databases are burgeoning. Libraries are becoming repositories for these databases and are providing discounted prices for access to commercial databases across the country. Those able to pay a small search fee can search databases such as Minne(sota)Medline, Gen(etics)Bank, and legal and commercial databases.
- A number of department and college offices use dial-up or permanent connections to the Administrative Information Services computers to view or modify student records, order supplies from the storehouse, examine account information, and generate studies about students or budgets.
- Groups of faculty and staff are linked together by Local Area Networks to share printers and transfer files among themselves. When these Local Area Networks are connected together through the campus-wide network, they can do the same with a larger number of colleagues.
- Faculty, staff and students use the network to run computing jobs on large computers, obtaining graphics output which could not be sent over telephone lines in a reasonable length of time.

Regional

- Coordinate campus users easily access LUMINA, use computers elsewhere, and communicate with colleagues on other campuses using the present network facilities, all without incurring long distance charges.

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[1]*Campus Networking Strategies.* Publication of the EDUCOM Networking and Telecommunications Task Force, Digital Press, 1988.

- A regional network called MRNet allows collaborators at the University and the Mayo Clinic to communicate easily and share documents and files.

National and International

- A knowledgeable person at Minnesota can now access the on-line catalogs at several major university libraries. This service would be available to anyone connected to the campus-wide network.

- Databases need not be in our own library. Berkeley is developing databases of images in several areas: geography, literature, art history, paleontology, etc. Researchers will be able to retrieve these images (if the data transmission rate is high enough) and manipulate them at their own workstations for viewing, comparison, and analysis.

- BITNet and other nation-wide networks allow electronic mail and other documents to be sent to colleagues not only across campus, but across the continent or across the ocean. A Professor of Medieval Spanish at Berkeley collaborates with colleagues at Michigan, Brown, Texas, Wisconsin, and Madrid. He uses the network both for research and as editor of *Romance Philology*.

- More and more journals accept manuscripts in electronic form, both for review and for final publication. Titles, abstracts, and full text are circulated to reviewers via electronic networks.

- The National Science Foundation is installing a nation-wide backbone to connect regional high speed networks. Minnesota currently has a regional network (MRNet) which connects our campus to this backbone.

- Both the National Science Foundation and the National Institutes of Health are investigating electronic transfer of grant applications to speed up the review process. They are supplying universities and departments with software to format the required pages. The material is transmitted via BITNet to Washington and then to reviewers across the country. In 1987 the University received $86.8 million from these two agencies.

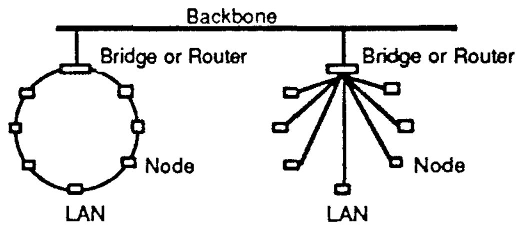
- Co-investigators in multi-center collaborative studies use electronic mail to transmit forms, manuals, reports, and manuscripts for peer review between meetings.

WHAT NETWORKS ARE

A network is a group of microcomputers or workstations connected together and to *servers*. A server can be a printer, a plotter, an optical character reader, a disk server, or a computer, shared by the users on the network. A user on campus can choose from two basic networking technologies:

A **"dial-up user"** dials a telephone number, logs into a computer, and thereby connects a workstation, personal computer, or terminal to a single host computer. One then sends or receives mail, transfers files, or runs a program. One then logs out, breaking all connection with the host computer, and thereafter uses the workstation in isolation. This is done at slow speeds (30-240 characters per second) with a modem, or at medium speed (960 characters per second) with a digital telephone line or some of the newest modems.

A "**networked user**" is continuously connected to the entire network. It is not necessary to dial a number, log in, or leave the native environment of the workstation in order to send or receive mail at any time, execute programs, print a document elsewhere, or access a file. The workstations or servers in a suite of offices or a building are connected through a *Local Area Network*. Each LAN can in turn be connected through a *router* to a *backbone* which spans the campus and allows users on different LANs to communicate with each other. The Campus Backbone, which is described below, provides access to other Local Area Networks, to other campuses, and to national and global networks. Typical speeds are 10,000 to 300,000 characters per second.



Dial-up access will always be needed for those working off campus. This dial-up connection may be to a particular computer or may be through appropriate equipment to the backbone.

In this report we refer to *the Network* (note the capitalization). The Network is the collection of networks and backbones which are managed centrally and which give users in the University community access to servers on various campuses. The server might be a computer that runs an application program, transfers a file to or from the user, provides an electronic mail service, or provides access to a database. Through the Network the user has access to such things as the library on-line catalog, bibliographic databases, administrative databases, a supercomputer, and electronic mail delivery to students, faculty and staff.

By *campus backbone* we mean the optical fiber plant and LANmark (a feature of our telephone system) on the Twin Cities Campus. The optical fibers, which were installed as part of the new telephone system, are a valuable resource. We commend the University for showing this foresight. Additional hardware is required to use them as part of the Campus Backbone. Long-distance telephone connections at various speeds connect the campus backbone to the coordinate campuses.

A communications network involves several conceptual *layers*, ranging from the physical (wire or fiber) to the user application which is using the transmitted data. There are many communications protocols which cover at least some of the layers. Examples are System Network Architecture from IBM, DECnet, Appletalk, Ethernet, etc. Most protocols are not compatible with one another. Important policy decisions must be made for all layers. Appendix 2 shows the layers in the ISO (International Standards Organization) model called OSI (Open Systems Interconnect). The ISO/OSI model is a standard which everyone will support, but it has not yet been completely defined. In the meantime many scientific users are using a standard called TCP/IP (Transmission Control Protocol/Internet Protocol). An increasing number of vendors are providing support for TCP/IP.

THE ORGANIZATION OF COMPUTING AND NETWORKING

Major changes are taking place in computing. Because workstations can provide computing power once available only on expensive mainframe computers, many computing tasks are moving from computer centers to individual workstations. More and more faculty and students are using computers. The computer centers are providing new services: communications, electronic mail, maintenance of databases, and storage of applications. Traditional computer centers currently provide some network services. In fact, central computing seems to be growing as more of us become users. We expect that centers will change much more rapidly than they have in the past, and that those which are not responsive to the user will disappear.

We cannot make recommendations for network management without considering the management of all central computing services at the University of Minnesota. We feel that it is appropriate for us to make these recommendations because we are a broadly representative committee which has given them a great deal of thought. However, we expect that they will require further discussion before they are implemented. Some of this discussion has already taken place, in other committees and in central administration.

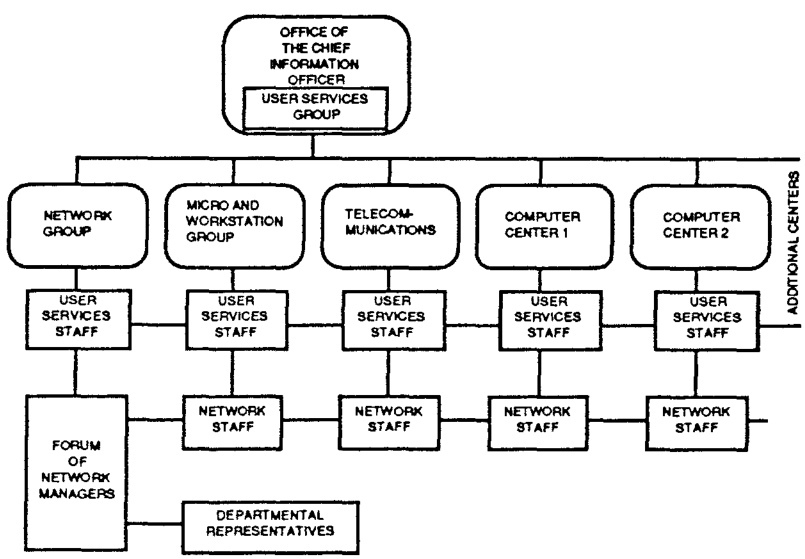
The Office of the Chief Information Officer

Recommendation 1. There should be a Chief Information Officer at the level of an Associate Vice President and Vice Provost for Academic Affairs. The directors of all computer centers (including Administrative Information Services and the Minnesota Supercomputer Center) should report to the Chief Information Officer. The director of Telecommunications should also report to the Chief Information Officer.

The Chief Information Officer should be responsible for planning and coordination of all central computing and The Network. The Office of the Chief Information Officer will also have responsibility for fostering a commitment to User Services in all of the computing centers. (This is described in the next section.)

Network and computing issues will require nearly the full-time attention of the Chief Information Officer. The Chief Information Officer must have both technical and political skills. The Office of the Chief Information Officer will need a small technical staff to coordinate the competing interests of the various computing centers.

This organization is shown in the chart below. Many of the details of this chart will be explained in the sections that follow.



User Services

Recommendation 2. Establish a User Services Group in the Office of the Chief Information Officer. The User Services Group and the User Services staffs in each center must receive sufficient resources to provide good service to the users.

With a complex network of servers available to the entire University community, User Services will become increasingly important. Most users will not be experts on a particular computer. Rather, they will employ a variety of servers, often for short periods of time. This will make it much more difficult to gain and to retain expertise. Users will need assistance with a wide variety of questions. Some will have to be answered by user services staff associated with a particular computer center. Others will be more general. Some will be complex, and the user will need assistance in determining where to get the answer.

The staff of the User Services Group (USG) will coordinate the user services activities of the various centers and will work closely with them to provide user education. In addition, the USG staff must be able to answer general questions, refer the user to the appropriate specialized user services staff when necessary, and help the user obtain an answer when the problem is complex and involves several units. The USG will, when necessary, serve as a sophisticated advocate for the user. The User Services Group should not charge customers. Their role is to help members of the University community use major resources more effectively.

The Network Group

Recommendation 3. Establish a Network Group, with a Director who reports to the Chief Information Officer.

The Network Group will consist of the Director of Networks and a small staff. It will be responsible for establishing a Network Plan and for continually updating the Network Plan to keep the University current with advances in networking. The Director of Networks will be charged with ensuring that The Network has the capacity and current technology to provide what the users need. This will require keeping abreast of emerging technology and making sure that it is installed at the University of Minnesota in a timely fashion. Each Computer Center will have to contribute to the network planning activities.

The Network Group will coordinate the network activities of the various centers and make sure that links to coordinate campuses and external networks are provided. The Network Group will be responsible for ensuring cooperation between centers and users regarding the use of networks. It will have a User Services Staff which is more specialized than that of the User Services Group. This staff will help users plan Local Area Networks and their connection to the Network. The Network Group will have responsibility for overall coordination of Electronic Mail. The characteristics of the Electronic Mail service are described later, in Recommendations 16-18.

Recommendation 4. The Network Group should establish the Forum of Node Managers to facilitate communication among managers at the departmental and center level.

Every computer center and some departments will have a group of some size that manages and operates its own machines and Local Area Networks. Some individual in each of these groups will have responsibility for networks connected to their machines and for networking aspects of applications that use or serve the networks. These individuals should serve on the Forum of Node Managers. The Forum of Node Managers is a technical group. It should consist of technical representatives from the Network Group, the Computer Centers, and any department or Local Area Network that requests membership. It will be chaired by someone from the Network Group and will meet frequently to discuss networking issues.

Recommendation 5. The Director of Networking should establish a Network Advisory Committee.

The Director of Networking must have a Network Advisory Committee which is user oriented while having technical expertise. The Committee will provide advice to the Director of Networks and make sure that faculty and student needs are known to those planning the future of the Network. The Committee should have faculty, student and staff representation. It should be appointed by the Director, with at least 40 per cent of its members being users. It should meet at least once a year jointly with the Computing and Information Systems Committee, which is a Standing Committee of the University Senate.

Microcomputer and Work Station Support

Recommendation 6. Establish The Microcomputer and Workstation Group as a separate entity.

The Microcomputer and Workstation Group will have responsibility for running public microcomputer and workstation laboratories. It will negotiate university-wide purchase agreements and sales through the Book Store for selected machines. It will also have to provide certain software packages (including communications software). Some of these it may have to develop. The User Services Staff of the Microcomputer and Workstation Group will be responsible for providing users with information on personal workstations at all levels, ranging from simple microcomputers to elaborate single-user workstations. The Director will report to the Chief Information Officer.

The Microcomputer and Workstation Group will have a difficult and conflicting set of responsibilities. The Group should inform itself about new workstations as they evolve. At the same time, it should provide long-term user assistance for machines (and their software) which have been sanctioned by the university in the past, even if these machines are no longer available in a university purchase program. A policy for how long this support should be provided will have to be developed.

Telecommunications

Recommendation 7. Telecommunications should report to the Chief Information Officer on the same basis as the Director of Networks and the various Computer Centers.

The Telecommunications Department has a dual role. It has responsibility for managing the traditional voice network. On our recommendation, it has also been given responsibility for the transmission media in the Network, including the charge to keep abreast of evolving technologies. The staff of the Telecommunications Department will work with the User Services Group and the Network Group.

THE NETWORK

Recommendation 8. The University should encourage networked connections rather than dial-up connections and should play an active role in helping departments design, install and manage local area network connections.

Recall that a user may either have dial-up access to a particular computer or to the Network (a dial-up connection) , or may be connected to the Network through a Local Area Network (a networked connection). A subcommittee chaired by Professor Marcel Richter has considered the cost of providing access to the campus Network under different circumstances. The subcommittee studied a wide variety of configurations and local area network sizes. Dial-up access costs Telecommunications either $12 or $25 per month to provide, depending on whether existing equipment is fully loaded. (We estimate that it is very unlikely to become fully loaded.) *It would cost Telecommunications about $25 per month ($300 per year) per node to provide a local area network of ten or more nodes, complete with wiring plant, connection to the campus backbone, maintenance, network management, and replacement of obsolete equipment. These costs do not include the user's machine nor any board needed to connect the machine to the network.* While the network connection currently costs about twice as much as a dial-up connection, the quality of service is superior.

Some comparisons of file transfer times were done for this committee. A fairly large file (374,000 characters) took about one minute to transfer to a networked user and 18 minutes to transfer to a dial-up user. Whether the latter is acceptable depends on how often the user does it.

Local Area Networks

Networked connections mean that there will be Local Area Networks in offices, in departments, and in buildings. Some LANs will be simple, connecting one or two personal computers to a printer. Most will be more complicated, including routers that connect them to the Campus Backbone.

The Network Group, User Services Group, Microcomputer and Workstation Group, and Telecommunications Services should work together to confer with prospective users, to examine user requirements in relation to other users, and to explain choices. This is essential because local area network technology cannot grow properly in isolation. Since it is undesirable to connect an individual directly to a backbone, both because of cost and because of traffic load, it will be necessary to work with users who are close to one another to establish local area networks.

Each Local Area Network requires management. There are two kinds of management problems: those relating to the Network, such as net addresses and fault diagnosis, and those relating to servers or machines on the LAN. Local Area Networks vary greatly in their sophistication and their need for management. For a sophisticated local network, management may be expensive. In terms of machine or server management, a sophisticated workstation may require as much software and file management as was needed in a computer center a few years ago. Both kinds of management are a departmental responsibility.

Recommendation 9. Each unit establishing a Local Area Network should have the option of installing and managing the LAN itself or contracting with Telecommunication Services or someone else to do it.

Within a building, departments should have the option of providing their own Local Area Networks or contracting with Telecommunication Services or some other provider. Telecommunication Services should have the responsibility for making sure that any installation meets code requirements and should certify specific bridging equipment as suitable for use on the backbone. Telecommunication Services should limit its support to certified equipment. The cost estimate for a networked connection which was given above includes network management, but not management of network servers.

The Campus Backbone

The Campus Backbone consists of optical fibers and LANmark. The optical fibers, which were installed as part of the new telephone system, are a valuable resource. We commend the University for showing this foresight. Additional hardware is required to use them as part of the Campus Backbone. Since this is an area where hardware changes are being made rapidly, we recommend *not* bringing the entire fiber network into service at once. Rather, some nodes should be brought into operation now, and others should be connected as users need them. This may avoid having all the fiber network terminations become obsolete before the fibers are fully used.

LANmark is part of the telephone system. It allows simultaneous transmission by many users, using either the IBM 3270 protocol or the IEEE 802.3 (ethernet) protocol. It is a relatively new product, particularly in terms of the IEEE 802.3 protocol support. We should get as much experience as possible with LANmark, using it immediately as a major mode of access to the supercomputers. This will solve some immediate problems relatively inexpensively and allow us to learn more about traffic management at medium speeds. (Since this paragraph was written in Part 1 of our report, LANmark has proved to be very useful.)

Recommendation 10. Telecommunication Services should have responsibility for the fiber backbone, LANmark, and the dial-up network, from the physical layer through the management of OSI level-three addresses.

Our first report recommended that they immediately hire staff with the necessary technical background. We are pleased that this has, to some extent, been done.

Recommendation 11. We expect that it will be necessary to limit our support of LANmark to specific OSI level-three protocols such as IP (Internet Protocol).

By support we mean that Telecommunication Services guarantees that IP will work with LANmark. Other level-three protocols may be compatible with the network; they can be certified for use on the network if they are shown not to interfere with other users, but reliability will not necessarily be guaranteed.

Recommendation 12. The fiber connects many buildings, but not all. As need for connection to the Fiberoptic Backbone arises in other buildings on campus, Telecommunications Services should provide fiber to these buildings without charge.

Telecommunication Services should provide connections to the backbone at standard points of access within buildings. Within a building, departments should have the option of providing their own local area networks or contracting with Telecommunication Services to provide them (Recommendation 9). Telecommunication Services should certify specific bridging equipment as suitable for use on the backbone.

Telecommunication Services should limit its support to certified equipment. The budget at the end of this report provides for terminating the fiber in two or three locations per year.

Recommendation 13. The communications protocol TCP/IP (Transmission Control Protocol/Internet Protocol) should initially be the standard protocol for the Fiberoptic Backbone, with the expectation that later, when it becomes available, we will migrate to ISO/OSI (the International Standards Organization's Open Systems Interconnect).

Telecommunication Services will guarantee service for those protocols that are compatible with TCP/IP, and that others will be certified for use at the user's risk if they do not degrade service. The technology of fiber communications is changing rapidly. This means that the hardware and software used with the fiber will change every few years. For example, equipment currently available will support data transmission at about 10 Mbps. This should increase by about a factor of ten when the new FDDI (Fiber Distributed Data Interface) protocol becomes available.

Recommendation 14. It is essential that the central administration invest funds in staying current and in touch with national networking circles, TCP/IP users groups, etc.

Our charge states the University's intent to "maximize the benefit from investments already made in telecommunications technology, rather than to promote telecommunications research at the leading edge of technology." While we agree with this philosophy for the production network, we must continually learn of new developments at all protocol levels. Unfortunately, the University is not considered a leader in the computer communications field; indeed, it is often forgotten or ignored when national plans are being made.

DEMAND

There are currently about 1,800 dial-up data connections and an unknown number of networked users (probably about 750[1]) in the Twin Cities. There are 800 users connected to the AIS computers. There are also an unknown number obtaining access through modems. We estimate that eventually there will be a total of 15,000 nodes connected to the Twin Cities portion of the Network. We obtained this number by assuming that every faculty or P & A staff member (about 5,000 on the Twin Cities campus) and every Civil Service staff member who works at a desk and has a telephone (again, about 5,000) would have a node. We also estimated that there would be one graduate student with a node for every faculty member.[2] The buildup of demand which we project is presented in Appendix 3.

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[1]There are 300 active networked users in Computer Science and about 100 using the supercomputers.

[2]The estimate ignored connections in dormitories. We believe that the least expensive way to provide dormitory access is through local area networks connecting 40-50 dormitory rooms together. These could also provide print servers for dormitory residents. We assume that the cost would be recovered in the room charge.

Recommendation 15. We recommend that the Twin Cities Campus plan for networking on the assumption that all 15,000 potential nodes will have networked connections in five years and that the demand will increase linearly: 3,000 new nodes per year.

The annual cost is estimated to be $300 for a networked connection. In addition, the user faces a significant additional cost for the equipment (work station, printer, or file server) placed on the node.[1] At these rates the current cost of network access is about $450,000 per year. This will rise to $4.5 million in five years if all of the potential nodes have access. We recommend below (Recommendation 24) that this be charged to the user's department (to encourage efficiency), and that a subsidy be provided to the department (to encourage universal connectivity) for those users who are paid from 0100 funds.

ELECTRONIC MAIL AND DOCUMENT DELIVERY

Electronic Mail and Document Delivery (EMDD) is an important new technology which provides the potential for communication with colleagues around the world. Users should have access from any point on the Network, whether it is a terminal, workstation or a larger machine. Access should be by dial-up or through Local Area Networks that are connected to the campus backbone. A sender should be able to send a message to anyone from any node on The Network. It should be possible to store and send non-text files including formatting information and graphics. It should be possible to send documents for automatic printing at selected sites. For example, a professor of economics should be able to print a report at the Institute for Mathematical Analysis. Administrators should be able to distribute documents to Deans and Departments electronically. A user who connects to a Local Area Network which is in turn connected to The Network backbone should automatically receive an indication that new mail is waiting. If mail arrives while a user is connected, there should also be an automatic signal.

Mail technology is changing rapidly, and what is the best way to provide mail service is very fluid. We expect it to remain that way for several years. While the software that allows direct transmission and reception of mail exists now only on sophisticated workstations, we expect that it will become available on personal computers in a year or so. Because the situation is so fluid, in terms of both costs and convenience, we feel that it is premature to recommend a single electronic mail technology.

Appendix 4 shows our estimate of demand for EMDD. We only consider messages which use the Network to go from one LAN to another. If we assume that each user of the Network sends four messages per day, then we currently have 10,200 messages per day, rising to 60,000 when everyone is networked. If instead we assume that the number of messages each user sends is proportional to the number of other users on the system, then we project 24 messages per day per person when everyone is networked, or a total of 360,000 per day. We believe that even this high estimate is conservative, because mail systems will be providing more and more services: document distribution, calendars, storehouse orders, and other administrative transactions which are now done with paper forms.

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[1]The workstation costs between $1,500 and $30,000. With proper amortization and maintenance, the associated annual cost is between $750 and $14,000. An average workstation might have a purchase price of $4,000, corresponding to an annual cost of $1,900 per year, including maintenance and amortization. Thus 10,000 nodes would have a total cost of $19 million per year. Our estimate of these additional costs is conservative. For example, applying the experience at MIT ($1,500 per student per year for computing) suggests that in I.T. alone, the total computing investment should be over $10 million per year.

Recommendation 16. The University should develop an electronic mail service which can handle at least 360,000 messages per day by 1993. The service should not rely on a single mail technology. The Networking Group, Microcomputer and Workstation Group, and the various computer centers should work together to develop a transparent mail service, independent of how the user accesses the network and to provide better and less expensive mail service.

Even though we wish to encourage competition between different mail servers while the situation is so fluid, the system must be easy to use. For example, it should appear to the user that there is a single address registry, even though the implementation requires that several copies of the registry be maintained. If there are several copies, they should be brought into conformity at frequent intervals.

Recommendation 17. In addition to the staff of the various centers that support electronic mail, at least two additional staff should be hired by the Networking Group and charged with planning and coordinating the electronic mail service.

Currently there are a number of different mail systems, with little coordination between them. We feel that establishment of coordination is very important, and that it is needed right away.

Recommendation 18. Users should be charged for electronic mail service. Some users should receive a subsidy, as indicated in Recommendation 25.

Future costs are also difficult to estimate. Electronic mail transmission using store-and-forward techniques on our present central machines costs about 30 cents per message. The breakdown of this cost is also shown in Appendix 4. A person who sends and receives a total of four messages per day for 45 weeks is currently charged $225 per year. If there were 15 messages per day, the charge would be $675. A dedicated mail-only machine should cost one-tenth as much: see Appendix 4. Those with sophisticated workstations bypass the central machines and send mail directly to each other. They perceive electronic mail transmission to be free, even though they are using some central resources for transmission, address registry, etc.

EXTERNAL NETWORKS AND SERVICES

The University requires access to national networks. Part of the charge to the Network Group should be the management of the connections of the University's EMDD System to these external networks.

Recommendation 19. The University should continue to be involved in two regional networks: MRNet (the Minnesota Regional Network) and CICNet (the Committee on Institutional Cooperation Network).

MRNet is a regional network within the state of Minnesota connecting educational, research, and commercial entities. CICNet will be a faster network, fully managed, connecting the Big Ten institutions and the University of Chicago. This will be a seven state regional network within the upper-Midwest. No multistate network currently covers this area.

Recommendation 20. The University should have access at least to the following national networks, preferably through the regional networks:

Internet	**- a national research network (includes NSFNet, ARPANet, MILNet, and other networks)**
BITNet	**- a national educational network managed by EDUCOM**
CSNet	**- Computer Science Network**
USENet	**- UUCP News Network**
SPAN	**- Space Physics Analysis Network**
HEPNet	**- High Energy Physics Network**
RLG	**- Research Libraries Group**
OCLC	**- On Line Computer Library Center**

If the regional networks do not provide this access, the University should acquire and manage the necessary connections.

University-provided connections will be necessary in some cases and should be considered part of the "cultural exchange" necessary to obtain other connections from other institutions on the regional networks.

Recommendation 21. Access to off-campus networks should take place through centrally-managed gateways which will provide the appropriate protocol conversions. (Protocol conversions will be needed, for example, if the off-campus network does not operate with the TCP/IP protocol suite.)

There are available a number of external value-added networks, to which some faculty members and students will need access. The computer account described in Recommendation 23 could be charged for this access.

SECURITY AND AUTHENTICATION

Recommendation 22. There must be security of access to programs and data on the Network. Staff of the Network Group and computer centers must be assigned the responsibility to develop or acquire methods to provide security.

Security is very important. There will be sensitive administrative and academic data as well as confidential research data such as clinical information on the network. Data must be protected against accidental or intentional destruction.

National groups are actively doing research in the areas of security and authentication. A good solution to these problems is not yet available. In the meantime, routers should be used to keep traffic on as small a part of the network as possible. Sensitive information will have to be encrypted.

It is desirable that Network software incorporate audit trails. Audit trails would allow computer center or network staff to reconstruct who accessed a machine or transferred files. This is most important on central systems, which currently have the poorest implementation of audit trails. Older central systems, such as the Cybers, were much better in this regard.

It is desirable that the University develop or acquire encrypting versions of file transfer protocols and that as a matter of policy, the university require rapid and inexpensive encryption capabilities in new hardware[1] which it supports through special purchase programs, as soon as that is feasible.

We should require that backbone traffic be non-broadcast[2], secure from tampering, and enforce strict geographic addressing[3]. Public laboratories and locations which require extensive security should have separate backbone taps.

User education is vital. A document should be developed which can be distributed to faculty, staff and students. It should describe user responsibilities when handling secure data and how to keep data secure. It should state that intercepting and modifying data are not only unethical, but are criminal acts. It should quote the United States Code, as well as Minnesota Statutes 609.89 on Computer Theft.

USER ACCOUNTS

True connectivity will not exist as long as faculty, staff and students must establish separate billing accounts at each computer center. Some universities now provide students with an account number, usable on all machines, which is their student ID number. The University of Minnesota - Morris provides an account to each student. This account is permanent until the student leaves school, which avoids the problem of disk purges at the end of each quarter.

Connectivity would be enhanced even more if each user automatically had an account at all computer centers and used the same name to log onto all the computers on campus. However, we realize that this may be technically difficult, and we do not make a specific recommendation.

Unless major amounts of money are involved, it is both impossible and unnecessary to separate instructional, research, and administrative computer use by a single individual. The nuisance of using separate accounts for each is too great to bother with.

Recommendation 23. Each faculty member, each staff member whose job requires computer access, each graduate student, and each undergraduate should be able to establish a *single billing account* which is charged for all of the user's electronic mail, database searches, computing, and public laboratory charges. The following services would be charged to this account:

1. Purchase of access to the public microcomputer laboratories.

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[1]The hardware may be a workstation, or it may be a router between a LAN and the Network.

[2]On an Ethernet without routers, every packet is sent to all stations. This broadcasting is undesirable for security. Routers alleviate this problem.

[3]This means "level-3 routing." Each station has a unique geographic address, which helps in auditing the Network.

2. **Computer center charges. The center(s) can be used for electronic mail, database searches, instructional or research computing, and off-campus network connections.**

3. **Departmental charges for departmentally-provided computing services.**

This recommendation says nothing about how one pays for this use. It only addresses the question of the billing account.

CHARGES AND SUBSIDIES

Current policy is to recover telecommunications expenses by charging the users. The University has discovered that adherence to this policy has limited the use of the digital telephone. Experience at other institutions also shows that the growth necessary to remain competitive is throttled if one tries to recover the entire cost of a new technology by charge-back. In particular the cost of the communications infrastructure described above should not be recovered by charge-back. Also, there are technical issues which may make it difficult to measure service to be charged. Some charge may be necessary to ensure responsible use of the resource by departments; a subsidy encourages university-wide connectivity. (This is a partial subsidy, since the department has the responsibility to provide the computer that is connected to the Network.)

Network Access

Recommendation 24. Upon application, a Network Subsidy of up to $300 per year (at today's costs) should be provided to the user's department by the University for every faculty member and academic and professional and civil service staff member who needs network access. This should be paid from the same source (state funds, grant, etc.) as the person's salary.

This would be enough money to provide either a dial-up or a networked connection that is fully supported. We recommend that the funds be made available upon application, so that they are provided only when the user has a machine to place on the Network. The user should show that the LAN has been properly installed and is compatible with the backbone to which it is connected. With 6,350 faculty and staff network connections on all campuses which should be paid for from 0100 funds[1], the cost would be ($300)(6350) = $1.9 million. We recognize that the linkage to the source of the person's salary may not be the best way to handle it in all cases. The details will have to be worked out. Perhaps the network connection should be paid for from the same source as a faculty or staff member's telephone.

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[1]There are about 5,925 faculty and academic professionals, 5,693 civil service staff who might use the Network throughout the University of Minnesota system. Based on full-time equivalents in the printed budget, about 74% of the faculty and 63% of the civil service staff are paid from 0100 funds. The total number of faculty and staff, system wide, who should receive a subsidy is therefore 6350. We recognize that we have ignored the question of persons who are paid partially from 0100 funds.

Faculty and Staff Computing

Providing a network connection implies that the faculty or staff member will need some central services, whether they are mail, computing, or file service.

Recommendation 25. The University should provide a Computing Subsidy of up to $300 per year to the billing account described in Recommendation 23. It should be provided for every faculty member and academic and professional and civil service staff member who needs computing resources. It should be paid from the same source (state funds, grant, etc.) as the person's salary.

There are several advantages to providing basic computing for all staff members.

1. It is difficult to distinguish between administrative, instructional, and research computing.

2. The efficiency of all faculty and staff will be enhanced by the ability to use electronic mail, access administrative data, and process documents electronically.

3. The utility of the mail system will be enhanced if everyone else can be accessed through it.

4. Special computerized library services will be available only if the library can recover its costs. This system allows the library to charge for some services.

As in Recommendation 24, with 6,350 faculty and staff nodes system-wide which should have an 0100 subsidy, the maximum 0100 cost would be about ($300)(6,350) = $1.9 million. A faculty member who used up the $300 allotment would either use departmental funds or apply for a grant, such as a Keller grant[1], to cover additional costs. If a staff member exhausts the allotment, the department would pay for additional charges (assuming that the use was primarily administrative).

Student Computing Charge

Recommendation 26. All students should be charged a mandatory special computing access fee of $75 per quarter ($225 per year, or $6 per credit hour). This would provide them with access to the public laboratories and an initial allotment of up to $100 per quarter in the account mentioned in Recommendation 23.

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[1]The Keller grant program was set up to provide faculty and graduate students with access to central computing resources, primarily for research. Each faculty member or graduate student pays $50 per year and receives up to $1,000 of computing. While the original intent was that each faculty member would pay for all computing from a single grant, accounting incompatibilities dictated that users had to have a separate grant for each computing center (ACSS, HSCS, SPCS, or Coordinate Campus). Last year on ACSS there were about 1,600 accounts, split equally between faculty and graduate students. The average amount expended in each account was $400. Of these 1,600 accounts, 85 (5%) exceeded their $1,000 allotment and applied for a supplementary grant which averaged $1000. The $300 per faculty member that we propose would meet a large part of this need. We have not considered the issue of how supplemental grants should be provided.

We came to this conclusion reluctantly. This charge amounts to an effective tuition increase of about 16% and has no matching state subsidy. We recommend it only because the faculty have been requesting adequate resources for student computing for several years, and they are not yet in sight. In the meantime, the use of computers has expanded rapidly in nearly every discipline. We see no other way to provide the educational computing environment which our students deserve. A mandatory fee has been charged at the University of Michigan for several years. It is currently $130 per semester except in engineering and management, where it is $180 per semester. Significant fees are also charged at Illinois, Maryland, and Pittsburgh, and in some colleges at Iowa State, Iowa, and Penn State.

The details of how this user's fee would be allotted are shown in Appendix 5. In summary, $112 per year would provide public microcomputer laboratory access, and we would guarantee that each student had a credit of up to $100 per quarter ($300 per year) placed in the billing account mentioned in Recommendation 23. We anticipate that although each student would have a credit of up to $300 per year, the average cost would be only $113. Many details of this program still need to be worked out. One problem with our proposal is that a student could register for a single one-credit laboratory course each quarter, pay 3x$6 = $18, and have access to all of the facilities including $100 of central computing resources each quarter. A student doing course-related or research computing who spends more than $100 per quarter would apply for an additional grant. A preliminary estimate, shown in Appendix 5, suggests that this might cost $300,000 per year now, rising to $700,000 per year in five years.

Implementation of this will require a large number of public laboratories. This will take space (roughly 44 laboratories of 2,000 square feet each on the Twin Cities Campus). The proposal cannot be implemented unless these laboratories are there when the fee is charged. Otherwise we cannot justify the charge.

Some will argue that this charge penalizes the students who already have a personal computer. However, those students will be using the Microcomputer and Workstation Group's resources, as well as those of the User Services Group. They will also have access to a variety of laser printers, plotters, sophisticated workstations, file servers and software libraries in the public laboratories. They will be using the Network, either from the public labs or by dial-in connection from home. They would also pay $75 each quarter and receive the grant of up to $100 for central and departmental computing, including database searches.

COORDINATE CAMPUSES

The Coordinate Campuses are developing their own networks, generally using the protocols that we have described. They need faster connections to the Twin Cities, to each other, and to the off-campus networks. They need access to electronic mail, databases, and computing services. Our recommendations should make it possible for Coordinate Campuses to function as Campus-Area Networks on the Network.

Recommendation 27. The coordinate campuses should be connected to the Network, at data rates commensurate with their size and the service which is available from the Twin Cities to their locations.

Without making an extensive study, we understand that a T1 line (1.5 Mbps) to Duluth could be provided for about $75,000 per year, and that 14.4 kbps dedicated lines to all the other coordinate campuses would cost about $50,000 per year.

MISCELLANEOUS

Dormitories

We have not included dormitory rooms in the network estimates above. Many institutions are providing network access to their dormitory residents. At the same time, we must remember that many of our students live off campus and will have to access the Network through the modem pool.

Recommendation 28. Every dormitory room should have a networked connection. The cost of these connections should be included in the dormitory rent.

There are 4,500 dormitory rooms. We estimate the cost of providing the connection through a local area network on each floor to be somewhat less than the costs for departmental networked connections: perhaps $150 - $200 per year.

Future Developments

Recommendation 29. We recommend that Telecommunication Services have the responsibility to invest in experiments with FDDI and to implement it prudently.

Continuous experimentation on a small scale is necessary in order to implement new technologies in our production networks. The University is indebted, for example, to the experiments of the Supercomputer Institute staff who installed and maintained the first fiber network. We must ensure that such experiments will take place in the future, and that their results will be integrated promptly into the production environment. This should be a model for how all new improvements will be evaluated and implemented. These experiments will require money that should not be recovered from the users of the network.

Supercomputer Users

The recommendations in this section were made in the first part of our report. They are already being implemented and are given here for completeness. Access to the Supercomputers is provided by the Minnesota Supercomputer Institute (MSI) Network to some users and by LANmark to others. The staff of MSC and MSI and their users pioneered the use of fiber and high speed networks at the University of Minnesota. They have often endured poor service while learning things which are now proving very useful to the University computing community. Moreover, commitments have been made to users of the MSI network that it would be provided without cost, and they have often purchased equipment to connect to the MSI network on that basis.

Recommendation 30. We recommend that equipment be purchased to provide access to the supercomputers over the Fiberoptic Backbone.

This recommendation has been implemented.

Recommendation 31. We recommend that service to the present nodes on the supercomputer network be provided free of charge through June 30, 1988. We recommend that on request, the University provide to these users, at no cost to them, plug-compatible connections to either LANmark or the new Fiberoptic Backbone as it becomes available.

This recommendation has been implemented.

Recommendation 32. Others who want access to supercomputers can select LANmark or the new Fiberoptic Backbone when it is available. They (and other users of LANmark) will be charged a standard rate.

LIBRARIES

The library has recently made available LUMINA (Libraries of the University of Minnesota Integrated Network Access). An early recommendation of our committee to provide more dial-in ports and access through the Network has been implemented. The features of LUMINA will be enhanced in the next few years: better searching, circulation, and serials control. The possibility of using LUMINA to access course offerings is being explored. The Biomedical Library abd HCSS provide one local database, Minne-MEDLINE. The library provides access to external bibliographic databases and is exploring access to other commercial databases. The user account described earlier in this report would be one way to pay the charges incurred in searching databases.

COST ESTIMATES

We show here our estimate of total *additional* recurring costs for implementing our recommendations. They range from $3.25 million next year to $6.8 million in 1992. We have not made adjustments for inflation. *Student computing fee expenses and income have not been included.* Within each category, projects are arranged by recommendation number.

No. Recommendation	1987-88	1988-89	1989-90	1990-91	1991-92
Projects that have already been completed					
30. Replace MSC fiber with standard backbone	50,000				
33. Library: additional hardware	25,000				
19. MRNet hardware	10,000				
Projects of the Highest Priority					
1. Office of Chief Information Officer		295,000	315,000	335,000	355,000
2. User services Group (Referral group: 4 people)		123,000	135,000	147,000	159,000
3. Network Group ($150,000 salaries, fringe and supplies)		226,000	246,000	266,000	286,000
Managers of network upper layers	55,000	110,000	110,000	110,000	110,000
(19) Two electronic mail staff (2 @ 30,000 plus fringes and supplies)		76,900	76,900	76,900	76,900
6. Microcomputer and Workstation Group (in addition to permanent funding for the present staff) (6 additional @ 30,000, fringes and supplies)		443,000	463,000	483,000	503,000
9. Telecommunications management of fiber backbone (2 people)	85,000	85,000	85,000	85,000	85,000
11. Adding fiber terminations	150,000	200,000	200,000	200,000	200,000
20. MRNet membership (contrib. to management)	10,000	15,000	15,000	15,000	15,000
28. Faster connection to coordinate campuses		125,000	150,000	175,000	200,000
Subtotal		1,698,900	1,795,900	1,892,900	1,989,900
Projects of High Priority					
23. Development of security (2 @ 30,000 plus fringes and supplies)		76,900	76,900	76,900	76,900
20. CICNet membership		160,000	160,000	160,000	200,000
22. Provision of gateways to off-campus networks		100,000	100,000	100,000	100,000
25. Provision of Networked connections for 0100 users ($300/yr)		475,000	950,000	1,425,000	1,900,000
26. Computing and mail allowance for 0100 users		475,000	950,000	1,425,000	1,900,000
27. Supplementary grants for students		300,000	400,000	520,000	700,000
Subtotal		1,586,900	2,636,900	3,706,900	4,876,900
Total	**385,000**	**3,285,800**	**4,432,800**	**5,599,800**	**6,866,800**

APPENDIX 1

GLOSSARY

ACSS	Academic Computing Services and Systems
AIS	Administrative Information Services.
Asynchronous	Transmission technique in which the time interval between characters may be of unequal length; used for low-speed terminal links.
Backbone	A campus- or system-wide network that connects together a number of local area networks and servers. The Twin-cities backbone consists of LANmark and the fiber optic plant. The system-wide backbone consists of telephone lines connecting the various campus backbones.
Bandwidth	A measure of the information carrying capacity of a communications channel; the higher (wider) the bandwidth, the greater the information carried. Bandwidth is usually measured in Hertz (cycles per second). KHz (1,000 Hz). MHz (1,000,000 Hz), or GHz (1,000,000,000 Hz). Roughly, 1 Hz = 1 bps (bit per second).
bps	Bits per second. 1 Mbps = 1 million bits per second.
Bps	Byte (8 bits) per second.
Bridge	A communication device that passes packets between two similar LAN channels (e.g. Ethernet-to-Ethernet). It operates at ISO level 2.
EMDD	Electronic Mail and Document Delivery.
Ethernet	A level 1 and 2 protocol developed by Xerox and widely supported by many manufacturers. It is a packet technology that operates at up to 10 Mbps over coaxial cable and allows terminals, concentrators, workstations, and hosts to communicate with each other.
FDDI	Fiber Distributed Data Interface. This is a level 1 and 2 protocol which is under development. If successful, it will be ten times faster than current protocols.
Gateway	A protocol translating device used to relay data transmission on one network to other networks or to points separate from the network.
HSCS	Health Sciences Computing Services.
Host	Any computer system that provides user-level services. This could be a single user microcomputer or a large mainframe.
IEEE	Institute of Electrical and Electronic Engineers.

ISO International Standards Organization, sponsor of OSI. See Appendix 2.

LANmark A feature of our present telephone system which provides IBM and ethernet-compatible communication at speeds of about 1 Mbps.

Local area network (LAN). A communications facility that covers limited topology and interconnects communication devices such as terminals and hosts computers.

LUMINA Libraries of the University of Minnesota Integrated Network Access

MSC Minnesota Supercomputer Center

MSI Minnesota Supercomputer Institute

Network A set of nodes connected via voice, data, or video communications to facilitate the exchange of information.

The Network The collection of networks and backbones which are managed centrally and which give users in the University community access to servers on various campuses.

Node A computer, terminal, or some type of communication control unit.

OSI Open Systems Interconnect. A standard now being developed. See Appendix 2.

Packet A collection of data and control bits in a specified format, sent through a network as a whole unit.

Protocol A set of procedures implemented in hardware and software to facilitate communications and assure end-to-end data integrity of links, circuits, messages, sessions, and application processes.

Router A "black box" that provides the ability to pass packets between like or unlike media. Routers can be passive or active, the distinction being determined by buffering ability. A like-media passive router is sometimes called a *bridge*. Active routers are sometimes, mistakenly, called gateways. Routers operate at OSI level 3.

Servers Computers that accept messages from a node or central workstation and perform a specific function, (e.g., file servers, print servers, etc).

SPCS St. Paul Computing Services.

TCP/IP (Transmission Control Protocol/Internet Protocol). A packet protocol originally defined for ARPANET and common on Ethernets and other LANs.

APPENDIX 2

INTERNATIONAL STANDARDS ORGANIZATION OPEN SYSTEMS INTERCONNECT

In 1977 the International Organization for Standardization (ISO) appointed a sub-committee to develop an architecture that would simplify the task of communications between applications on different computers. The result was the Open Systems Interconnect (OSI) model. The model consists of 7 layers, where each layer performs a subset of the overall task of communication. Each layer provides services to the next higher layer and relies on the layer below it to perform more primitive functions. In theory, the layers should be defined such that changes in one layer do not require changes in the other layers. In particular, this allows protocol migration as equipment and services are redefined.

It should be noted that this is only a model. Many protocols currently defined adhere to this model, but that does not imply that the different protocols can communicate or that gateways are easily implemented.

The seven layers of the OSI model are (from lowest to highest):

1. **Physical Layer.** This layer covers the physical interface that allows raw bit streams to traverse between stations. All electrical and mechanical aspects of the transmission are dealt with at this layer. Some of the details that must be covered include how to represent bits as signals, whether full or half duplex communications will occur, and what types of connectors will be used.

2. **Data Link Layer.** This layer attempts to make the raw bit stream reliable. It supplies the mechanisms to activate, maintain, and deactivate the physical link. The most prevalent data link protocol is HDLC (Higher Level Data Link Control). Another is "Carrier Sense Multiple Access/Collision Detect," used by Ethernet. It has low overhead but slows down at high data rates. The Token Ring has somewhat greater overhead but supports higher data rates.

3. **Network Layer.** This layer provides the mechanisms to establish, maintain, and terminate connections across the communications facility. It includes the routing mechanisms which are necessary if the network has multiple hops. The Interface Protocol of TCP/IP is an example.

4. **Transport Layer.** This layer provides for reliable end-to-end connectivity. It ensures that the data units are delivered sequentially and error-free with no losses and no duplications. The complexity of this layer is determined, in part, by how reliable the underlying layers are.

5. **Session Layer.** This layer establishes and manages reliable connections between pairs of processes on different hosts. Based on current implementations, this level blends into the transport layer and may be unnecessary.

6. **Presentation Layer.** This layer deals with the syntax of data exchanged between applications. It resolves differences in format and data representation.

7. **Application Layer.** This is the layer in which all applications programs that require network interaction reside. Examples of programs in this class include file transfer (FTP, TFTP) and user level electronic mail programs.

The drawing shows the seven layers.

7	Application	FTP	TELNET	Mail Programs	TFTP		User Programs	
6	Presentation			SMTP		name server	RPC	
5	Session	TCP			UDP			
4	Transport							
3	Network	IP						
2	Link	CSMA/CD		X.25 HDLC	Token Ring			MAC (FDDI)
1	Physical	Coaxial (Ethernet)	Optical Fiber		Optical Fiber	Twisted Pair	Coaxial (Domain)	PHY (FDDI)

Terms used in the drawing:

Carrier-sense multiple access (CSMA) A contention-resolving technique used on some local area networks, in which stations avoid transmitting when they sense that another station is transmitting (by detecting the carrier signal thus generated). Often combined with collision detection, in which case the acronym becomes CSMA/CD, for higher performance, in which the transmitting station detects when its own transmission has been interfered with by another station, stops transmitting, and resumes transmitting only after some randomly determined "back-off" period.

FTP File transfer protocol.
HDLC Higher Level Data Link Control.
IP Internet protocol.
MAC Media Access Control.
PHY Physical layer.
RPC Remote Procedure Call.
SMTP Simple mail transfer protocol.
TCP Transmission Control Protocol.
Telnet A virtual terminal service protocol.
TFTP Trivial file transfer protocol.
UDP User Datagram Protocol
X.25 Consultative Committee for International Telegraph and Telephone (CCITT) standard for packet switching networks.

APPENDIX 3

ESTIMATE OF DEMAND FOR NETWORK CONNECTIONS IN THE TWIN CITIES

These are head counts. In the Twin Cities there are 5,080 faculty and 4,910 civil service staff. There are 8,400 graduate students. We estimate that an average of one graduate student per faculty member will require a network connection.

These numbers lead to the estimates for network demand. Five models are presented:

Model 1. The Present Situation
Model 2. Our estimate in two years, 1989-90.
Model 3. Our estimate in five years, 1992-93.
Model 4. Our estimate if all potential nodes are connected to the Network, using 20% dial-up connections.
Model 5. Our estimate if everyone has a Network connection.

Present Numbers for comparison

Total number of Graduate Students:	8,400 (for comparison)
Total phones for comparison):	18,000 (for comparison)
No. of dial-up data phones now:	1,800
No. of dial-up data phones for saturation:	6,800

Input data for the Models

Cost of dial-up connection per yr:	$120
Cost of LAN per yr:	$300
Total Number of TC Faculty:	5,000
Total Civil Service "desk" Staff:	5,000
Graduate Student Nodes:	5,000 (estimate)
Total Nodes:	15,000

Model 1. The Present Situation

Service	Fraction of potential nodes	Total Number	Annual Cost	
None	0.83	12,450	$0	
Dial-up	0.12	1,800	$216,000	
LAN	0.05	750	$225,000	
			$441,000	Cost/Node: $170/yr

Model 2. 1989-90

Service	Fraction of potential nodes	Total Number	Annual Cost	
None	0.60	9,000	$0	
Dial-up	0.20	3,000	$360,000	
LAN	0.20	3,000	$ 900,000	
			$1,260,000	Cost/Node: $210/yr

Model 3. 1992-93

Service	Fraction of potential nodes	Total Number	Annual Cost	
None	0.30	4,500	$0	
Dial-up	0.20	3,000	$360,000	
LAN	0.50	7,500	$2,250,000	
			$2,610,000	Cost/Node: $250/yr

Model 4. Everyone has one

Service	Fraction of potential nodes	Total Number	Annual Cost	
None	0.00	0	$0	
Dial-up	0.20	3,000	$360,000	
LAN	0.80	12,000	$3,600,000	
			$3,960,000	Cost/Node: $260/yr

Model 5. Everyone is networked

Service	Fraction of potential nodes	Total Number	Annual Cost	
None	0.00	0	$0	
Dial-up	0.00	0	$0	
LAN	1.00	15,000	$4,500,000	
			$4,500,000	
	Add: Lost DOB Revenue		$177,000	
			$4,677,000	Cost/Node: $310/yr

APPENDIX 4

PROJECTION OF ELECTRONIC MAIL DEMAND AND COST

In estimating Electronic Mail demand, we have distinguished between messages which will remain within a Local Area Network (such as within an office) and those which will be sent on the Network. The former can be handled easily by electronic mail packages on the individual personal computers. The latter will require some sort of central service, either for address table lookup or for storing and forwarding the messages. The Table below shows the number of electronic mail messages using the Network which we estimate are sent today and which will be sent when all potential nodes are connected to the Network. (ACSS cannot provide statistics on mail usage. The Computer Science department has about 300 active users who send or receive an average of 8 messages per working day. About one third of these have an off-campus origin or destination. AIS reports that 800 users send about 15,000 messages each day.) We have assumed that university-wide, the average number of mail messages using the Network is about four per user per day.

The lower limit in our estimate assumes that there will always to be 4 messages per day per node, regardless of the total number of nodes. The upper limit assumes that the number of messages sent and received increases as the number of potential recipients increases. There are large uncertainties in these estimates because we are trying to predict how people will behave. We may be underestimating, as we would have underestimated the use of personal computers five years ago. Or we may be overestimating because people will be reluctant to use a new technology.

	1988	1990	1993	Everyone Networked
Nodes	2,550	6,000	10,500	15,000
Lower estimate:				
Messages per user	4	4	4	4
Messages per day	10,200	24,000	23,000	60,000
Upper estimate:				
Messages per user	4	9	16	24
Messages per day	10,200	54,000	168,000	360,000

Cost Estimate

The Table below compares the *present charges* for providing electronic mail using the present central facilities with the *estimated cost* of providing mail on a dedicated mail machine. The dedicated machine is clearly less expensive as the demand increases. The cost estimated using a dedicated machine may also be an overestimate. As electronic mail facilities on personal computers become more sophisticated and more personal computers are more or less permanently attached to the Network, much of this load will probably shift to the personal computer.

The charge for using the present central mail facilities was estimated as follows. A series of simple measurements showed a charge of about $0.385 per message to use the ACSS Vax for electronic mail. The charges were $0.30 to login and send and receive a message, $0.027 to store the message for fifteen days, and $0.058 for connect charges. Measurements at the University of Minnesota - Duluth showed similar charges: $0.25 per message on the Vax and $0.20 per message on the Encore. The projections shown here assume a cost per message of $0.25. We believe that the increase in number of messages per day that we assumed is very modest and that our charges, large as they are, are probably an underestimate. We also show the cost of providing a mail subsidy for faculty and staff who are paid from 0100 funds at these charging rates. These costs are clearly too high.

The cost of a dedicated server was obtained by estimating the annual cost for hardware amortization and maintenance of a fully-configured Encore computer to be $500,000, and the cost of a mail staff to be $500,000. The sum of these is used as the maximum cost, and it is ramped up over a two-year period. We do not necessarily recommend the use of a dedicated server. Technology might leave it behind, and we need to see how effectively the various centers will compete to provide service.

Year	1988	1990	1993	Everyone networked
Faculty, CS, Grad				
Number of nodes	2,550	6,000	10,500	15,000
Average number of messages sent or received per day per node	4	9	16	24
Messages per day	10,200	54,000	168,000	360,000
Other students (UG)	36,000	36,000	36,000	36,000
Average messages/day	0.001	0.01	0.1	0.5
UG messages/day	36	360	3,600	18,000
Total messages per day	10,236	54,360	171,600	378,000
Total mail charges ($0.25 per message sent or received, 5 days per week, 45 weeks per year)	$576,00	$3,058,000	$9,653,000	$21,263,000
Cost of 0100 Subsidy (80% of the faculty and staff users)	$306,000	$1,620,000	$5,040,000	$10,800,000
Dedicated mail server (ramped up to full size)	$500,000	$1,000,000	$1,000,000	$1,000,000

APPENDIX 5

THE STUDENT COMPUTING FEE

If each student were charged an average of $75 per quarter ($225 per year) for computing, we could provide access to public microcomputing laboratories which contained a good mix of state-of-the art workstations, and an *average* allowance of $113 per year for central and departmental computing. We speculate that we could guarantee to provide each student up to $100 per quarter ($300 per year) for central and departmental computing and still stay within this average amount. The public laboratories would provide them with on-campus access to the Network.

1. Public laboratory microcomputer access

Student computing hr/credit/wk	0.2	hr/credit/wk (10% of homework time)	
Average registration	12	credits	
Public lab hours per student	2.4	hr/week	
Hr/wk from each ws	60	hr/wk/ws (assume lab open 100 hr/wk; 60% avg load)	
Number of ws/student	0.04	ws/student (one per 25 students)	
Ws/lab	40		
Labs/student	0.001		

1a. Supervision cost

Supervisor wage/hr	$8	
Hours open/week	100	
Weeks open per year	40	
Supervision annual cost/student		**$32**

1b. Micro maintenance and replacement

Workstation type	Cost	Fraction	
Mac/IBM PC	$3,000	0.6	
Mac II	$6,000	0.3	
Sun	$15,000	0.1	
Average workstation cost		$5,100 (with software)	
Pct annual interest		0.05	
Years lifetime		4	
Loan repayment		$1,400	
Maintenance (10%)		$510	
Networking cost ($100/ws/yr)		$100	
Total annual ws cost		$2,010	
Cost per student			**$80**

2. For the account (average) **$113**

We speculate that we could provide each student up to $100 per quarter ($300 per year) for central and departmental computing charges, and that the average cost would be only about 1/3 of this, $113.

TOTAL **$225**

Cost of supplemental grants.

We assume that the heavy users (at least for the next few years) already have Keller grants. Currently 700 graduate students pay about $35,000 and receive about $280,000 in Keller grants. Another 50 students receive about $50,000 in supplemental grants. The current computing costs are therefore $365,000. Under our scheme, these 700 students would contribute $78,400. The remaining cost is therefore $286,600, which we round to $300,000. We have increased this about 30% per year to account for increased demand. Thus, it goes from $300,000 in 1988-89 to $700,000 in 1993.