University of Minnesota
All-University Committee for Network
and Communications Planning

INITIAL REPORT
April 29, 1987

The Committee has come to agreement on a number of the issues in its charge. Since some of these issues require immediate action, we present these recommendations while we continue our discussion of other issues.

A communications network involves several conceptual layers, ranging from the physical (wire or fiber) to the user application which is using the transmitted data (see the Glossary). 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.

The recommendations in this report cover the lower layers of the network, some general management issues, and some solutions to immediate problems experienced by users of the existing supercomputer network. The committee is continuing to discuss the issues raised on page 4 and will make recommendations in future reports.

GENERAL ISSUES

1. There are several networks within the University which provide data communication. Each is appropriate for certain types of use, and we should continue to provide all of them. Users can be expected to migrate between them as conditions change. They are

a. Low speed asynchronous data transfer from point to point by telephone.

b. Medium speed host-to-host interconnection via LANmark.

c. High speed connection of hosts to hosts or LANS to other LANS via fiber.

d. A coaxial cable which was designed for two way video and which has not been analyzed by this committee.

2. Telecommunication Services should have responsibility for the fiber backbone, LANmark, and the dialup network, from the physical layer through the management of level three addresses. They must *immediately* hire staff with the necessary technical background.

3. There must be a very strong and active permanent advisory committee to help the University's telecommunication networks and services remain current and responsive to users' needs.

4. 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 have found that the University is not considered a leader in the computer communications field; indeed, it is often forgotten or ignored. The University must continually learn of new developments at all protocol levels. It is essential, therefore, that the central administration invest funds in staying current: in touch with national networking circles, TCP/IP users groups, etc.

5. 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 people who gave us 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. We expect to make further recommendations in this area.

CHARGING FOR SERVICES

6. Current policy is to recover telecommunications expenses by charging the users. We have already seen 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. Moreover, there are technical issues which may make it difficult to measure service to be charged. On the other hand, some charge may be necessary to ensure responsible use of the resource by departments. We expect to recommend that costs not be recovered entirely by charge-back. This would be a major change in university policy, and we will provide further advice in this area.

THE LANmark NETWORK

7. LANmark is part of the telephone system. It is a new product, particularly in terms of supporting the IEEE 802.3 (ethernet) protocol. 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.

8. We expect that it will be necessary to limit our support of the ethernet portion of LANmark to specific level-three protocols such as IP (Internet Protocol). By support we mean that Telecommunication Services guarantees that this protocol 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.

9. We recommend that for now (except for certain Supercomputer users as discussed below) users be charged the established rate for LANmark connections. We will make recommendations about all charges in a later report.

THE FIBEROPTIC BACKBONE

10. The fiber which was installed as part of the new telephone system is a valuable resource. We commend the University for showing this foresight. Additional hardware is required to use it as a backbone. Since this is an area where hardware changes are being made rapidly, we recommend *not* bringing the entire 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 the network become obsolete before it is fully used.

11. 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.

12. 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. In the former case Telecommunication Services should certify specific bridging

equipment as suitable for use on the backbone. Telecommunication Services should limit its support to certified equipment.

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). This means that 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.

14. 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. We recommend that Telecommunication Services have the responsibility to invest in experiments with FDDI and to implement it prudently. This is a model for how all new improvements will be evaluated and implemented. We point out again that these experiments will require money that should not be recovered from the users of the network.

SUPERCOMPUTER USERS

15. Access to the Supercomputers is provided by the Minnesota Supercomputer Institute (MSI) Network to some users and by LANmark to others. We recommend that equipment be purchased to provide access over the Fiberoptic Backbone. *All* of the networks are still experimental. The MSI network is in some cases unreliable; LANmark has not been tested at high traffic volumes; the Fiberoptic Backbone is proposed, but does not yet exist. Therefore, each of the present users of the MSI network should have the option of being connected to one of these three networks. The Minnesota Supercomputer Center (MSC) has agreed to provide gateways to all three networks.

16. 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 network that it would be provided without cost, and they have often purchased equipment to connect to the network on this basis. Because of this, 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. We anticipate that these connections can be

provided for under $100,000. After July 1, 1988, some partial cost recovery should be charged. The amount will become clearer when we have completed our analysis of charging.

17. 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. Our recommendation for rate subsidies will be provided later.

FUTURE WORK OF THE COMMITTEE

The following areas still need work by the committee:

a. Control and management of the middle and upper layers of the protocols.
b. User services
c. Electronic mail
d. External networks
e. Experimentation
f. Charging policies
g. Coordinate Campuses
h. Evaluating need for access to the Fiberoptic Backbone
i. Provision for the purchase of new telecommunications equipment (rapid obsolescence)
j. Compatibility of user equipment and software
k. Enhancing Minnesota's reputation in computer networks

APPENDIX A

GLOSSARY

Asynchronous. Transmission technique in which the time interval between characters may be of unequal length; used for low-speed terminal links.

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. Communication device that passes packets between two similar LAN channels (e.g. Ethernet-to-Ethernet).

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.

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 B.

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.

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

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

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

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.

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

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

APPENDIX B

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 do 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):

18. 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.

19. **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.

20. **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.

21. **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.

22. **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.

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

24. **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.

<table>
<tr><td>7</td><td>Application</td><td colspan="2">FTP</td><td>TELNET</td><td colspan="3">Mail Programs</td><td colspan="2">TFTP</td><td colspan="3"></td><td>User Programs</td></tr>
<tr><td>6</td><td>Presentation</td><td colspan="2"></td><td></td><td colspan="3">SMTP</td><td colspan="2"></td><td colspan="3">name server</td><td>RPC</td></tr>
<tr><td>5</td><td>Session</td><td colspan="6" rowspan="2">TCP</td><td colspan="6" rowspan="2">UDP</td></tr>
<tr><td>4</td><td>Transport</td></tr>
<tr><td>3</td><td>Network</td><td colspan="12">IP</td></tr>
<tr><td>2</td><td>Link</td><td colspan="4">CSMA/CD</td><td>X.25 HDLC</td><td colspan="5">Token Ring</td><td colspan="2">MAC (FDDI)</td></tr>
<tr><td>1</td><td>Physical</td><td>Coaxial (Ethernet)</td><td colspan="3">Optical Fiber</td><td></td><td colspan="2">Optical Fiber</td><td colspan="2">Twisted Pair</td><td>Coaxial (Domain)</td><td colspan="2">PHY (FDDI)</td></tr>
</table>

Terms used in the chart:

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.

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REVISED

February 23, 1987

TO: Russell K. Hobbie, Associate Dean, Institute of Technology, CHAIR
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FROM: V. Rama Murthy VRM
Vice Provost and Associate Vice President for Academic Affairs

SUBJECT: All-University Committee for Network and Communications Planning

I would like to request that you serve on an all-University committee responsible for developing an integrated plan for computer communications network capable of adequately supporting the instructional, research, administrative and external service missions of the University. The existing infrastructure provides an appropriate starting point and the Committee's role is to recommend appropriate network services to link to coordinate campuses, state-wide, regional and national networks in the context of the various missions of the University. In addition, the Committee should make recommendations concerning policies and guidelines for the management of such services and appropriate organizational structure to implement the plan. The specific charges to the committee are as follows:

1. Establish a network topology that provides access through easy availability and application-appropriate transmission rates. Recommend services in the context of presently available facilities.

2. Recommend appropriate standard protocols and converters to insure connectivity between all devices and applications on the network. Review LANMARK capabilities and develop guidelines for LAN gateways.

3. Prioritize applications to be supported on behalf of all network users. Develop policy for wide-area networks to be procured on a University-wide basis.

4. Recommend policies to insure the integrity and operability of the network. Recommend a resource accounting mechanism that satisfies traffic management requirements and meets expense recovery objectives.

5. Establish a planning framework within which resources are allocated to meet current and future network services needs.

This planning effort must adhere to the guidelines and criteria for evaluation set for all programs in Provost Benjamin's "A Strategy for Focus." Specifically, it must demonstrably satisfy the criteria of quality, centrality, comparative advantage, demand, effectiveness and efficiency. At the same time, a networking architecture must incorporate the President's statement of direction for telecommunications which affirmed the University's intent to maximize the benefit from investments already made in communications technology, rather than to promote telecommunications research at the leading edge of technology.

I will greatly appreciate your help and cooperation in generating the plan for review by the Provost's Office and the central administration by April 15, 1987.

:plh

c: Kenneth H. Keller, President
Roger Benjamin, Provost and Vice President for Academic Affairs
C. Eugene Allen, Dean, College of Agriculture
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