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The National Biomedical Communications Network has evolved both from a set of conceptual recommendations over the last twelve years and an accumulation of needs manifesting themselves in the requests of members of the medical community. With a short history of three years this Network and its developing structure have exhibited most of the stresses of technology interfacing with customer groups and of a structure attempting to build itself upon many existing fragmentary unconnected segments of a potentially viable resource-sharing capability. In addition to addressing these topics, the paper treats a design appropriate to any network devoted to information transfer in a special interest user community. It discusses fundamentals of network design, highlighting that network structure most appropriate to a national information network. Examples are given of cost analyses of information services and certain conjectures are offered concerning the roles of national networks. (Other papers from this conference are available as LI 003360 - 003387 and LI 003389 - 003390) (Author)

THE NATIONAL BIOMEDICAL COMMUNICATIONS NETWORK AS A DEVELOPING STRUCTURE

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I. INTRODUCTION

A. Historical Background

The development of a National Biomedical Communications Network can be considered the culmination of a long series of actions beginning some twelve years ago with the "Baker Report," named after Dr. William O. Baker of the Bell Telephone Laboratory. This report to the President on a study led by Dr. Baker was the first of a series of such reports having national information networks as their theme.

These studies continued into the decade of the 1960's and wound up recently with a set of recommendations in the two Presidential Task Forces concerned with National Telecommunications Policy and with th[illegible]k for Knowledge. The first of these is headed by Eugene Rostow and its report was transmitted to the President in November 1968; the second was headed by Donald Hornig. The Biomedical Communications Network is a relevant model of the national networks considered and recommended during these last ten years.

The theme of all these studies is that national networks or information systems are proving to be increasingly necessary for the proper application of science and technology and the orderly development of research and development applied to the social problems of today.

Indeed society, itself, has become mission-oriented. The medical community, both as customers for and suppliers of information and education services, occupies a privileged position. The medical community has traditionally espoused continuing medical education. At present, its active interest exceeds that of any other equivalent profession or community of interest. This education, aimed at preventing technical and professional obsolescence, can be considered as any process by which an individual having been brought abreast of current knowledge in his chosen medical specialty through traditional college, medical school and post-graduate curricula continues to keep his knowledge up to date as new developments occur in his specialty.

The medical community has also actively supported medical libraries. The Medical Library Assistance Act of 1965 is the only such legislation directed towards improvement of the libraries of a single discipline or profession. There are only two national libraries specifically charged with serving single professions -- the National Library of Medicine and the National Agricultural Library.

National political leaders and leading scientists have recognized the overriding importance to each individual citizen of health information. The timeliness, accuracy and intelligibility of health information permit measurement in terms of human lives. Everyone has a personal interest in reducing his own medical illiteracy both through information and education. As a result, it is not surprising that the first national scientific and technical.

information system directed by the President upon the advice of his Scientific Advisory Committee was the Toxicological Information System.

The aggregate of these somewhat unique characteristics of the medical community and of health information led to the demand in 1965 and 1966 for the establishment of a biomedical communications network. Members of Congress, of the Executive Branch and spokesmen for the medical community all separately endorsed the concept.

In the period since 1965 the Biomedical Communications Network has taken shape. It consists for planning purposes of four service-oriented components and one supporting component as follows:

The Library Services Component

The Specialized Educational Services Component

The Specialized Information Services Component

The Audio and Audiovisual Services Component

The Data Processing and Transmission Facilities Component

With its definable community of customers, its substantive importance to every individual, its supporting community of medical professionals dedicated to services and to self-improvement through continuing medical education the Biomedical Communications Network is a natural prototype for a national information network.

B. Rationale for National Network Development in the Medical Community

From the viewpoint of the responsible organization, a network development offers the opportunity/ for limited experimentation with accompanying organized and continual evaluation. It provides the structure for local or regional experimental developments while simultaneously allowing large or national-scale testing. Thus, it avoids the possibility of "failing" many times at the same experiment in different locations throughout the country. It also allows, for the same reasons, the rapid spreading of "success" in innovations from the single point of origin to all desirous customers. Scarce resources can as a result be spread further in meeting customer needs.

For example, there appears to be little need for four or five local institutions to expend developmental funds on setting up experimental models of ECG transmission via facsimile or for designing experimental dial-up access systems for computer-provided data bases. Coordination by a group with wider geographical or national interests would allow the national group to "sit down" with regional or local groups and determine the best allocation of a planned set of experimental developments among the interested regional or local representatives. In this way unnecessary redundancy will be reduced and local centers of excellence can develop.

The Biomedical Communications Network is viewed as a prototype or a model which as it evolves will adjust itself to individual consumer needs and to social and technological changes. The construction of a network implies the adding of links connecting various centers of activity and individual customers, the moving of links as customers or activities move, and the deletion of links as centers or resources are no longer needed. A network stands for orderly change and structure: it obviates the need for unrealistic deterministic planning. In the case of the BCN, it allows the interests of the DHEW to be pursued without demanding a long term commitment to a rigid predetermined structure.

There is an excellent radio advertisement by AT&T which illustrates quite effectively one of the major advantages of a network. The actors in the little drama discuss the fact that the telephone instrument is identical in France and in the United States, and yet the service is so much better here in the United States. The AT&T proponent concludes by stating that it "isn't the telephone that makes the difference; it's the network." It is indeed the network which provides the interconnections, the control, the structure, the reliability and the cost economy.

It is such an understanding of the advantages of networks which has caused the studies of the last decade concerned with information, education, libraries and communications to increasingly emphasize the need for national networks.

National networks as their name implies assume a different responsibility than do regional and local networks. It is their objective to provide equal opportunities and equal capabilities everywhere in the nation constrained only by local needs and local traditions. History has shown that this can be done best through encouraging individual initiative wherever it can be found and providing assistance to those regions and groups with the need and motivation but without the capabilities or resources. When done properly the whole can be made greater than the sum of its parts.

One of the strengths of a national Biomedical Communications Network lies in its symbiotic relationships with the individual institutions and programs which are springing up throughout the country to improve biomedical communications. No national network can be created out of whole cloth. It must be constituted from vigorous, lively and progressive systems, networks, programs and institutions. The State University of New York (SUNY) network, the Computer Center at the University of Missouri and the

Wisconsin "dial access" system epitomize these kinds of regional endeavors. Such regional projects should never be lost in the structure of any larger national networks. They should be highly visible entities surviving and viable because of the local freedom of initiative responsible for their very creation.

One might ask the question now as to the reason for a national Biomedical Communications Network at all. What are the advantages for the medical community of having such a network and why does one need a network to obtain these advantages?

One reason is that are required for point-to-point communications among members of a community. Specifically, this means that networks are demanded by the existence of individuals or individual institutions needing selective information, documents or educational resources which are available from geographically dispersed locations. In short, the medical community possesses special information or data collections or other communicable resources located at a single institution but useful to an audience which is geographically dispersed. Such information sources require a network in order to disperse the information.

From the local users' point of view, inadequacy of local data banks underlies a second reason for networks. A network can provide access to information collections in other areas to meet the needs of a specific area in a complementary fashion.

The third reason for networking is a combination of the first two: a variety of unique data collections or information sources spread throughout a geographical area through interlinking can provide complementary reinforcing services to a variety of users who are also geographically dispersed.

The fourth major reason for network development is that economy and improved use of technical competence can be achieved through the centralization of programming services, processing capabilities, and scientific resources which can still be made available to geographically dispersed users.

The fifth reason for network development is the simple need of interpersonal (including intergroup) direct communications, such as teleconferencing and educational activities. A sixth class of justifications for network development includes economic, privacy, or professional reasons for distributing responsibility or workload among a variety of organizations or geographic regions.

Most of these abstract justifications for network development have immediate and obvious application to biomedical information requirements; i.e., medical libraries are each in a way unique and a composite network has substantially greater holdings than does any one individual library as is shown for example by a recent study of New York Medical Libraries.

The problem of biomedical communications is assuming increased urgency because of both the "technology push" and the "need pull." The fact that technology now offers new hope for solutions to old problems has already been stated. There also seems to be some evidence that the need is becoming more urgent particularly in medical libraries.

These then are the reasons advanced for considering a network for biomedical communications. But is a network feasible? We believe the answer is yes. A network is a complicated development. It represents the application of technology to complex processes which are heavily dependent upon communication, control, and feedback where each of the many components within the process may have varying functions. Yet, a network is possible today.

II. COMPONENTS OF A NATIONAL BIOMEDICAL COMMUNICATIONS NETWORK

A network designed to assist in the transfer of biomedical information is more encompassing than communications for the medical community. It includes the dissemination of medical information to non-medical audiences. It also includes the transfer of information for the allied health professions which number more than one million in this country.

In this paper, however, the network under consideration is a network for the Medical Community. The transfer of information or communications within the medical community includes more than the dissemination of research results, journals and books or the formal and informal communications associated with conferences. It includes:

- communications about patients' health status. These might be patient records. They might be more dynamic in nature such as the outputs of body sensors. Patient monitoring involves real time communications. Patient records, on the other hand, are historical except when used as a part of a clinical diagnosis. Then they too become real time in nature.

- communications about patients' health services. These are generally administrative records used for health insurance or other health payment services. The advent of MEDICARE and MEDICAID have highlighted the need for these records. It has also highlighted the present lack of good record keeping capabilities and the direct translation of poor record keeping into excessive costs for the country as a whole.

- communications about doctors. Doctors are intermediaries between medicine and patients. The professional services they provide relate directly to their training and education.

The medical community has long maintained records about doctors listing their location, their specialties, their continuing education and their experiences. Recently a number of states have set up requirements for relicensure of physicians, based on completion of a minimum number of continuing education courses. Relicensure regulations necessitate more record keeping about doctors.

. communications about medical facilities. The medical community monitors or accredits its medical facilities. These are principally hospitals and medical schools. It keeps its own records and furnishes selected statistics in its own publications. It assesses the capabilities of its facilities itself. These records are of prime importance in determining means of increasing health manpower, of providing health care and of costing health services.

. communications about procedures and products. Exchange of information on the effects of various drug dosages or medical procedures used is essential to good medical practice. Regular and standardized record keeping is a prerequisite to this exchange which presently occurs too infrequently. The transfer of information about new industrial products or drugs is much better organized. It is done principally by industrial salesmen and drug detail men.

. communications in support of continuing medical education. In the Report of the President's Commission on Heart Disease, Cancer and Stroke of December 1964, it was stated that: "Most of the physicians practicing today received their education in the 1930's and 1940's. The fact that they are practicing two or three decades later would have been unimportant in earlier, quieter centuries. Today, it poses a critical obstacle to the delivery of up-to-date health care. Therefore, a systematic, nationwide program of continuing education for physicians is a categorical imperative of contemporary medicine. . . .The imaginative use of new communications media offers the best hope for necessary breakthroughs in continuing education."

. communications in support of undergraduate and graduate medical education. In the United States all members of the medical profession graduate from one of 99 four-year medical schools or five two-year medical schools with students enrolled. Presently, at any given time, there are approximately 35,000 students enrolled in these schools which graduate 8,000 per year. In medical schools, as in all universities, communications forms the basis for the transfer of knowledge and skills.

. communications to support the physician (dentist) in practice. The physician (dentist) in practice needs a continuous stream of information. He needs journal articles and books to inform him of research underway, of meetings, of events of interest, of available courses and educational material, of new developments, et cetera. He needs specialized information packaged to meet his individualized needs covering topics he has selected. Information Analysis Centers, Specialized Information Services or audiovisual repositories have been established for this purpose. In practice many other sources are more commonly used.

- communications to support the medical researcher. The research worker generally needs highly specialized information in areas relevant to his research or he needs the ability to browse as a means of intellectual stimulation. Both these needs are commonly met through library resources available to the medical community.

It has been found possible to satisfy these needs by designing a network separated into components distinguished by broad type of services provided, by information media or carrier characteristics and by supporting technology.

The Biomedical Communications Network is thus an interrelated complex of four service components and one network support component.

The Library Component or Document Handling Component, the most advanced of present biomedical communications forms, has as its primary functions the acquisition, indexing, cataloging, and classifying of reports of new medical scientific knowledge wherever recorded; the storage of this knowledge for use in both present and future time; bibliographic access to and retrieval of this knowledge; and the dissemination of books, reports, journals, containing knowledge as well as the bibliographic tools for accessing them. The Component will be a flexible netting of a large number of medical libraries and other repositories of scientific information. In its entirety, the Library Component will serve to provide access to medicine's scientific and professional knowledge. This Component is essential to and ultimately relates to all biomedical communications facilities.

The Specialized Information Services Component, like the Library Component, is an organizer and a disseminator of medical scientific knowledge; however, this Component operates only in relatively narrow, well defined fields and, in response to queries, provides specific information bearing on a subject.

Unlike the Library Component, the Specialized Information Services Component provides information rather than the bibliographic services and books normally associated with a library. This Component will be a sophisticated meeting of existing facilities, e.g., DHEW biomedical information analysis centers, other Federal information analysis centers, and new systems, e.g., a toxicology information system, now being developed. The Component will make use of computer processing, data communications, electronic displays, and a wide range of advanced information handling technology.

The Specialized Education Services Component provides the basic communication services and facilities required for the continuing education of medical professionals, for undergraduate and graduate medical education, and for the delivery of basic health information to the medically uninformed. With regard to the medical professionals, the Component is oriented to providing that information which is necessary to improve the overall quality of medical services provided. In addition to providing purely health oriented information and transmitting the results of on-going research, this Component will keep the health professionals informed about relevant, new technologies that are potentially exploitable for the advancement of medicine. A major portion of the Specialized Education Services Component will be directed toward the undergraduate and graduate programs of medical schools. With regard to the medically uninformed, the Component will make available the facilities for transmitting basic health science information services aimed at increasing health awareness of the public.

The Audio and Audiovisual Component is responsible for the acquisition, creation, maintenance and distribution of audio and audiovisual materials for the Biomedical Communications Network. These materials complement the information and other educational materials provided by other network components. The Audio and Audiovisual Component will create materials where necessary to satisfy user requirements; it will also arrange to acquire such materials from other agencies or to have another agency produce such materials for use in the Biomedical Communications Network. The Component may well provide a variety of other services such as serving as a national referral center for biomedical films, and providing a network of audio lecture materials.

The Data Processing and Data Transmission Component is a support component comprising all the data processing and communications facilities of the Biomedical Communications Network; in effect, it is the bond which holds all the other biomedical communications components together in a disciplined network. In the areas of Library Component and Specialized Information Services Component, this Component will provide the computer processing and communications facilities to receive requests, search and retrieve responses, and transmit the answer back to the requestor. In the case of Specialized Education Services, this Component will provide the communications facilities for transmitting alphanumeric educational materials of various kinds to locations wherever medical educational activities are conducted.

An example of a computer-based service recently initiated within the Library Component of the Biomedical Communications Network is the AIM-TWX Service providing rapid, responsive searching of the medical literature. The bibliographic information for the last five years on over one hundred journals in clinical medicine is stored in a large, time-sharing computer in Santa Monica, California, run by the System Development Corporation. The journals covered include those in the new Abridged Index Medicus. This computer can be called from either TWX terminals or Teletype terminals connected to the telephone network. After placing a call to the computer and signing in with his number, the terminal user will have instructions provided to him from the computer explaining how to search in a simple, conversational way the bibliographic information in the computer. He will be able to search the vocabulary to find appropriate search terms or enter directly subjects, subheadings, dates, authors' names, language, or other search terms. The computer will respond by informing him of the number of documents for each term. He will be able to combine terms using "or," "and," and "not" to pinpoint his interest. And, finally, he will be able to print out his bibliography at his terminal or have it mailed to him. This service is offered from 8:00 a.m. to 12:00 noon Pacific Time (or 11:00 a.m. to 3:00 p.m. Eastern Time) Monday-Friday and started in June 1970. The computer costs for this service are being paid by the Lister Hill Center; the costs of terminals and toll calls will have to be paid for by the users. Most users of the system would start with available terminals for which there would be no additional cost. Communication costs would run from $.20 to $.60 per minute for TWX and from local call costs to $.45 per minute for phone-system teletypes. An average search runs near 15 minutes and may cost up to $9.00 to the user.

III. FUNDAMENTALS OF NETWORK DESIGN INHERENT IN A NATIONAL BIOMEDICAL COMMUNICATIONS NETWORK [1]

A. Basic Network Elements

1. A Connection Set

Networks have inherent to them a set of connections between isolated points or separated locations. The separation distance is widely variable. "Intercom" networks connect staff members of the same organization located in the same building. Intelsat uses satellites for communications between the West Coast and the mainland of Asia. The NASA Communications Network now allows men on earth to talk to men on the moon.

2. Network Structure

Networks also have inherent to them the notion of structure. When a communications network is constructed someone has in mind an organization of channels, connections, terminals, telephone lines or routes by which a user in one location can talk to a user in another location. The element of chance is generally ruled out through network structure. When a highway network is designed, it is intended to interconnect a predetermined number of locations by a minimum set of road miles. It may be required that the roads be so constructed as to permit vehicle speeds of N miles/hour

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1. Ruth M. Davis, "Man-Computer Network"(unpublished documentation from a course presented at the University of Pittsburgh, April 1969).

3. Network Control

Networks also have inherent in them the concept of control. The existence of a structure to serve a process, say, in the case of communications, necessitates control over the location of users, the numbers of users, the equipment used in the network, the kinds of allowable communications, allowable traffic loads, and the like. Most of these types of control are accepted without question and, really, without thought. It is apparent that one cannot talk via phone to someone in Africa if there are no phone lines in that region of Africa; it is also obvious that both users need phones and that equipment is needed at intermediate locations to route the call and maintain a "hearable" signal. Control over traffic loads is tolerated rather than understood by the average customer. He realizes that if a large number of new phones were added to an existing telephone exchange busy signals would be common and many users would have to share lines. Therefore, he is easy to convince that additional phone service must wait for additional lines and exchanges.

The main element of network control is generally connoted as switching logic. In its most simple manifestation it allows one to pick up a telephone, get a dial tone, dial and cause a phone at another location to ring. It is the switching function that allows the network to exist in a continually varying set of states. These states are characterized by the combination of terminals interconnected via any given allowable combination of connections (or channels or routes). The change from one allowable network state to another is governed by switching logic.

In the field of transportation, switching logic allows the control of trains to be performed with safety and dispatch. Aircraft control is accomplished by a manual switching process commonly referred to as air traffic control. Here the logical switching device is the human controller who receives the necessary inputs and produces the necessary output with the assistance of a radar scope or modern variations of radar scopes.

Presently, the switching logic of electronic digital computers represents the peak of modern switching theory. These computers operating at high rates with pulse frequencies measured in megahertz have made it necessary to develop new types of switching circuits and to introduce more complex switching logic.

Other facets of network control involve availability of network access, monitoring of network status, network diagnosis, control of the network process (e.g., of the information disseminated through the network) and maintaining records of network status and usage.

4. Terminals

Finally, networks must consist of a set of terminals. These terminals may be any kind of physical devices whose interconnection is essential to network operation. There are often more than one type of terminal, particularly in networks of hierarchical structure. For example, a television network has local TV stations with their receivers and transmitters as terminal devices. The homeowners' TV set is also a terminal of a television network. In a railroad network one type of terminal is the local railroad yard. Another type of terminal device is the telegraph by means of which operators transmit messages on the location and content of railway cars. In a banking network terminal devices may include facsimile machines for check transmittals, input keyboards for transmitting fiscal information and telephones for checking bank account status.

It is apparent that terminal devices may serve the specific function or purpose of the network itself or they may serve the control function. The railroad yard as a terminal serves the specific function of the railroad network, i.e., the movement of freight or passengers via railroad car: the telegraph serves the control function of the network.

5. A Network as a Physical Entity

A network as described in the previous paragraphs is a physical entity intended to function as a unit. The physical elements which comprise a network have been cited as:

1. A set of connections
2. A structure

3. A control system

4. A set of terminals

A network can be depicted pictorially as in Figure 1.

In Figure 1, the T_{F_i} are the terminals serving the specific function of the network in question. The T_{C_j} are the terminals serving the control system of the network.

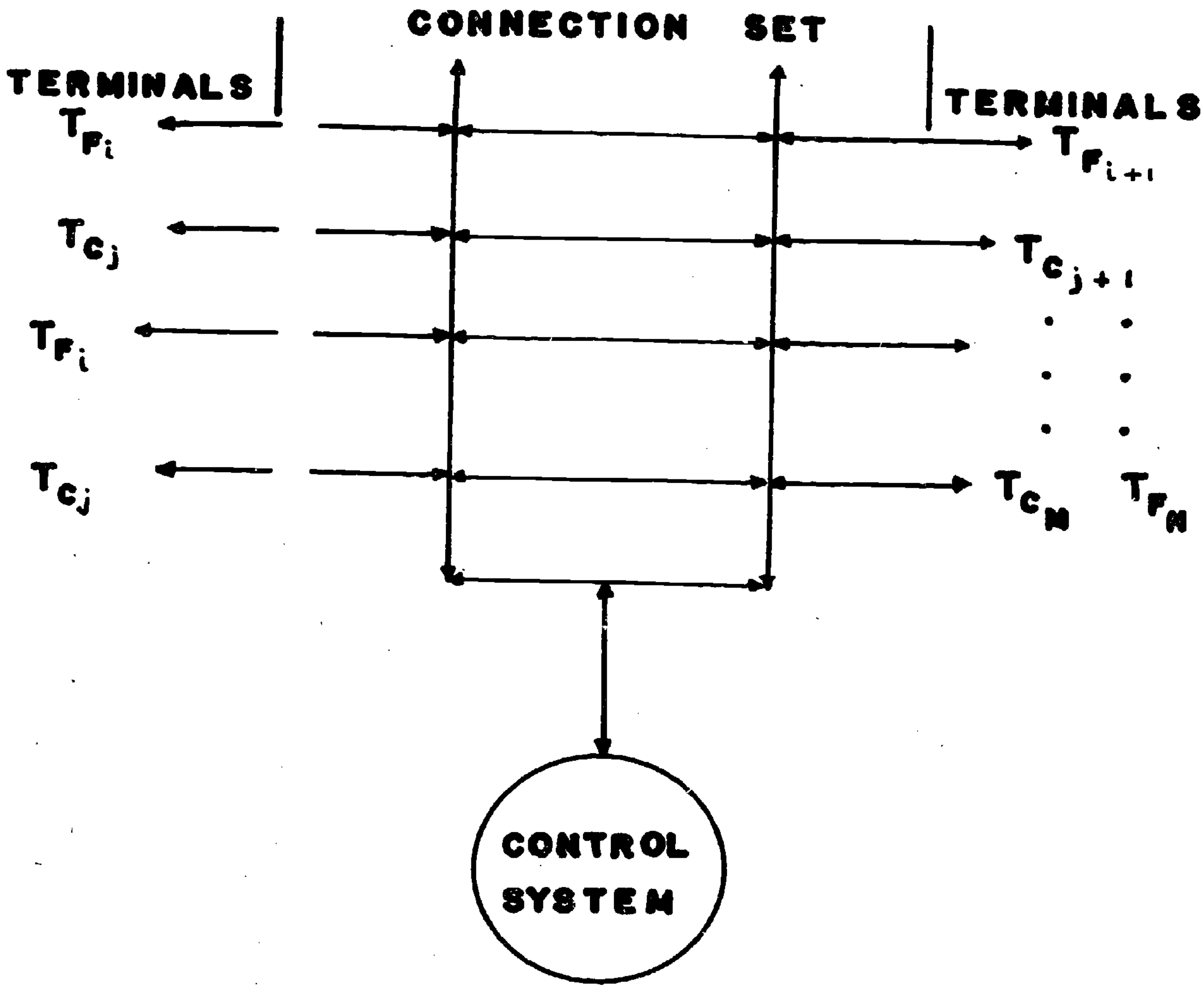
B. Performance Goals

Networks are usually designed with some performance goals in mind. The goal may be the transfer of a given volume of traffic in a given time period. It may be the servicing of a given number of customers in a given time period. Often, in computer-centered networks the goal is to keep the customer wait-time less than a prescribed maximum.

Whatever the performance goal is, it generally impacts upon all the basic network elements. It affects the number of interconnections and the type of interconnections through demands on speed of transfer and on numbers of parallel or duplicative interconnections between terminals.

It affects the network structure by requirements of redundancy of terminals and by demands on types and means of access to terminals. Performance goals markedly influence network control. The sophistication of the queuing required, the allocation of requests around the network and the control over transactions underway throughout the network is dependent upon the performance goals prescribed.

The privacy afforded to requests and to the content of network traffic can escalate rapidly the numbers of controls needed for network transactions.



NETWORK STRUCTURE

FIGURE I

Performance goals are most clearly visible to network customers in their impact upon network terminals. The type of terminal, e.g., keyboard or CRT, reflects the demands for speed and customer interaction in certain kinds of communications networks. High-speed printer terminals generally signify batch-processing computer networks designed against traffic volume goals.

As might be expected an explicit statement of goals is essential to network design. Cost of network implementation increases as understanding of network goals lessens. The typical "user need" study must be translated into performance goals before these needs can be reflected in network design. Indeed, questions asked of potential users should be so formulated as to result in explicit performance goals and to allow differentiation between the several possible types of performance goals.

C. Time

Throughout all discussions of networks and contained in each general network element is the important ingredient of time. The switching logic used for networks cannot be completely described by logical algebra. Combinatorial logic is most often used as the basis of switching logic but it does not take into account the sequential nature of switching. Generally, the same combinatorial logic operators can be used for switching logic but one must add another operator which can be called the delay operator. Then most network structures can be adequately defined. The algebra that evolves has been termed by some engineering groups as sequential logical algebra. The introduction of the delay operator and the delay line permits the essential transfer between spatial and temporal distribution of networks.

The dependency on time is often the determining factor in the set of interconnections of a network. It determines whether slow speed 4 kilohertz lines can be used or whether 9600 baud lines are demanded. The feasibility of interconnection of slow and high speed lines in turn determines the kinds of control logic and of terminals that must be introduced.

The timeliness (or time element) demanded in availability of network product at the terminals of the network can impose requirements on the interconnections, the control system and the types of terminal devices themselves. The monitoring of network performance deemed necessary dictates the complexity of control logic, the numbers and types of monitoring devices and consequently has a profound effect on network cost.

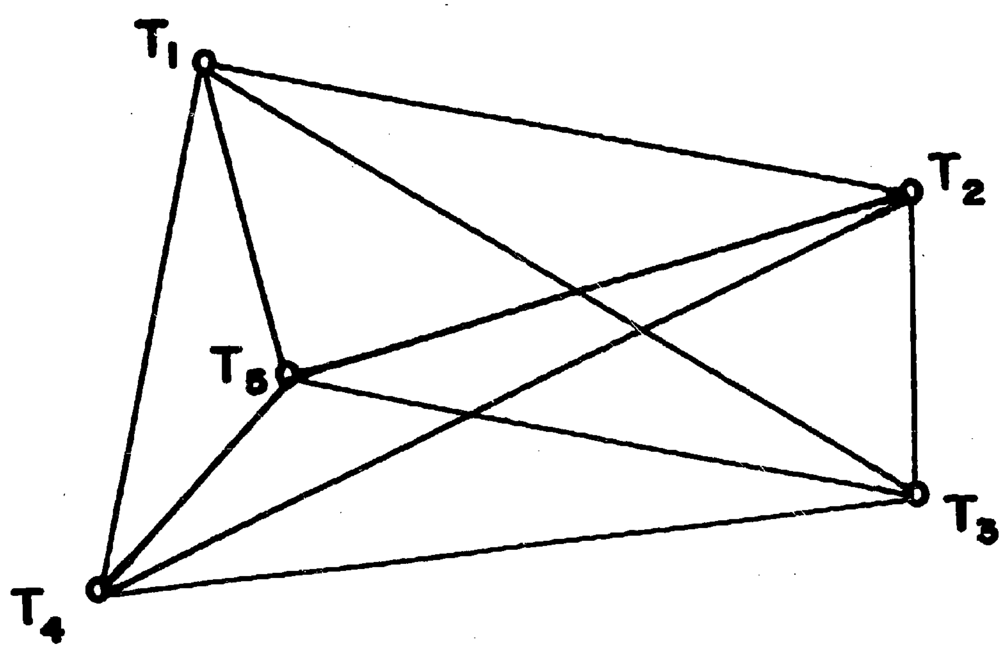
There is probably no more important pervading factor in network structure, cost and control than the critical element of time. It is probably safe to surmise that no structure which is static, i.e., in which the processes carried out are time-independent, can be called a network.

D. Examples of Network Structure

1. The Totally Decentralized Network, N_D

The simplest form of a network is one in which every terminal T_i is directly connected to all other terminals via bidirectional links or crosspoints. This is pictured in Figure 2.

In this network structure each of the five terminals requires four crosspoints or links to reach the other four terminals yielding a total of 20 links. Utilizing two-way crosspoints reduces



A TOTALLY DECENTRALIZED NETWORK

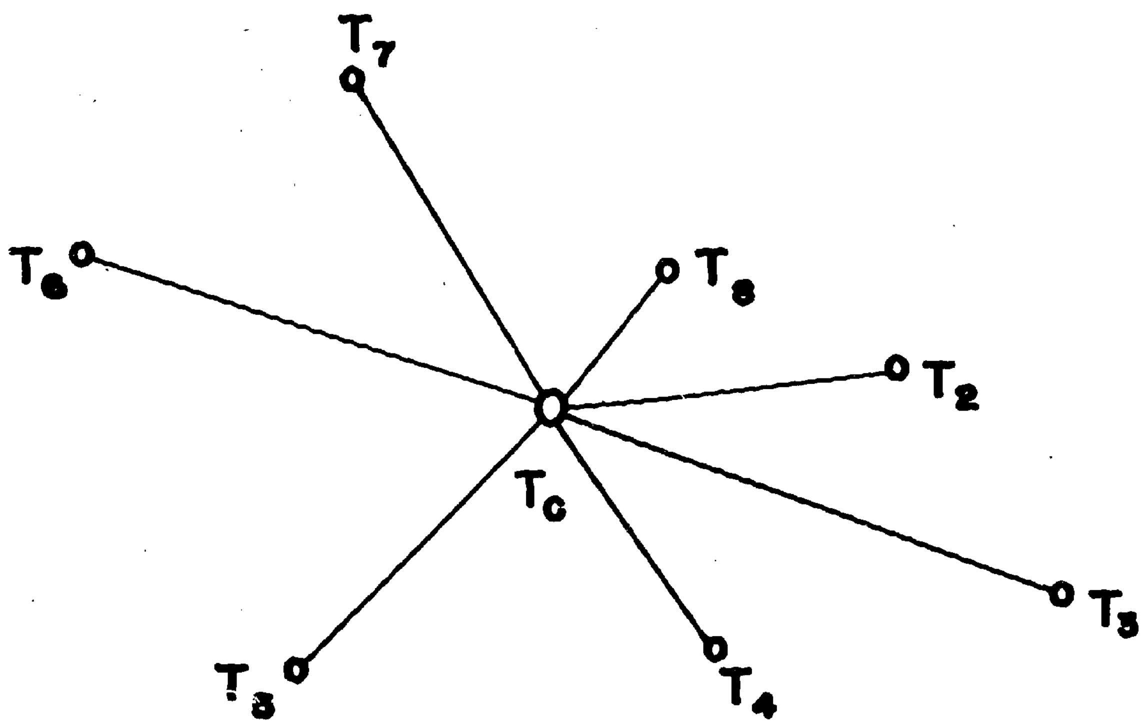
FIGURE 2

the number to 10 as in Figure 2. For N terminals, however, a total of $N(N-1)/2$ links is needed. As an example of the inappropriateness of this structure consider the 200-odd computers in the hospitals of the United States. Linking them together with bidirectional communications in the structure of Figure 2 would require $200(199)/2 = 199 \times 10^2$ or 19,900 links. This structure represents total decentralization and such a network will be denoted as N_D.

2. The Totally Centralized Network, N_C

Another very common network structure can be called the totally centralized structure. There are two distinct types of terminals, T_1 and T_i $(i=2,\ldots,N)$. To dramatize T_1 on the network graph of Figure 3, the label $T_1 \equiv T_C$ will be used. Again the crosspoints will be bidirectional. The number of two-way crosspoints or links in N_C is N-1, a reduction of $(N-1)/2$ from the totally decentralized networks. Here it takes two links for any T_i to reach any other $(i=2,\ldots,N)$ where each link is connected to any other at the node T_C. This network structure is that of the NASA tracking network where all stations or terminals report in to the central terminal. It is also typical of most timesharing systems, such as is exemplified by Project MAC at MIT.

The structure N_C is thus typical of what is frequently referred to as a Computer Network, which is a single computer center having a multiplicity of remote terminals. In this case T_C is the computer center and the T_i $(i \geqq 2)$ are the remote terminals. In the case of N_C being a computer network, one immediate implication is that the



A TOTALLY CENTRALIZED NETWORK: N_c

FIGURE 3

entire control and information bank functions for the network are performed at the central installation T_C.

Organizational networks that connect the main office of an organization to its many branch offices also often utilize the centralized network structure N_C. Local law enforcement is generally centralized with each patrol car reporting in to a central dispatcher and receiving its orders from the central dispatcher, as depicted in Figure 3. A final example of a totally centralized network is the automated airline reservation system. Terminals of the type T_j $(j \geq 2)$ are located at ticket agencies and airline desks in airports. They communicate directly and only with one central computer terminal T_C. Actually, most information networks now in existence are of the type N_C.

One could surmise with some validity that the totally centralized network N_C is the most easily controlled network structure.

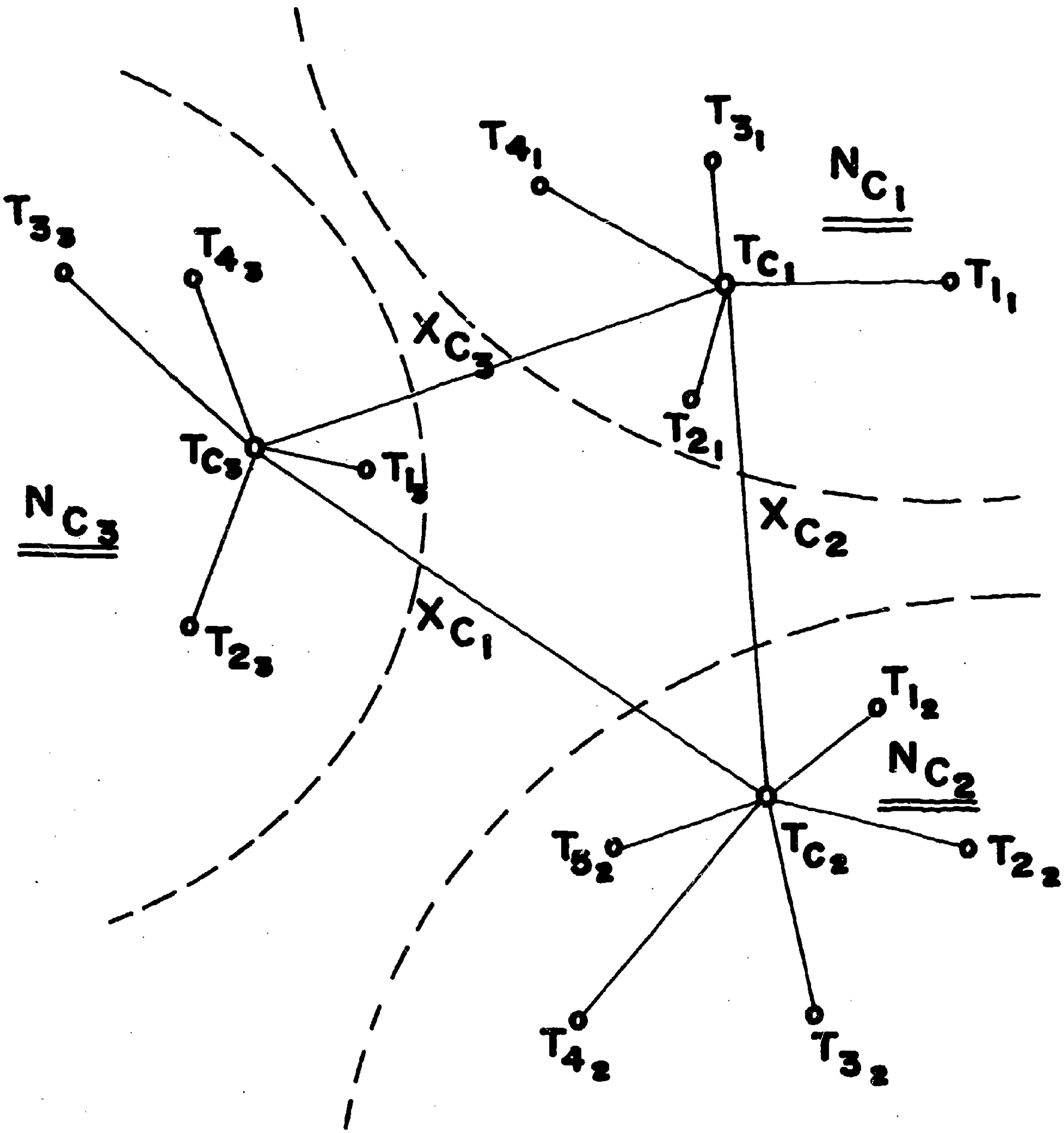
3. The Composite-Centralized Network, N_{CC}

A simple extension of the totally centralized network structure N_C is depicted in Figure 4. It is constructed by taking several centralized networks N_{C_1}, N_{C_2}, ...N_{C_k} and joining the terminals T_{C_1}, T_{C_2}, ...T_{C_k} by crosspoints X_{C_1}, X_{C_2}, ...X_{C_k}. This is the most simple extension in that for K networks N_{C_k}, $K(K-1)/2$ bidirectional links or crosspoints are used to connect the centralized networks N_{C_k}. No hierarchical or ranking order is imposed on the resultant network N_{CC}. Each centralized constituent network N_{C_k} retains its original status and no constituent network is given precedence over the others. Integration of the centralized networks is minimal and each can operate as a separate entity merely by severing the K(K-1)/2 crosspoints. In Figure 4 with K=3, these are X_{C_1}, X_{C_2} and X_{C_3}. Such a network will be termed the composite-centralized network N_{CC}.

The control system for a composite-centralized network N_{CC} normally controls only the operation of the crosspoints X_{C_k}. In addition, it often is a passive receiver of information from the control systems of the constituent networks N_{C_k}. Traffic in the network N_{CC} is usually the sum of the traffic of the N_{C_k} augmented by the traffic over the crosspoints X_{C_k}.

The composite-centralized network structure N_{CC} has been that most frequently advanced by those realistically attempting to set up national or community-wide networks such as National Scientific and Technical Information (STINFO) Networks. For example, it permits the NASA-sponsored STINFO Networks N_{C_1} to be linked to the Biomedical Communications Network N_{C_2} of the Department of Health, Education, and Welfare. Both of these, in turn, could be linked to the AEC-sponsored STINFO Network N_{C_3}, et cetera

No ranking is required. All constituent networks have equality of status. Control of the resultant national network N_{CC} can be equated to standardization and compatibility requirements imposed on the traffic passing over the crosspoints X_{C_1}, X_{C_2},...X_{C_k}. Accordingly, no new terminal representing a control terminal or central organization is added to the constituent networks when the composite-centralized national network N_{CC} is formed.



A COMPOSITE CENTRALIZED NETWORK

FIGURE 4

Probably, the most significant feature of such a network N_{CC} is that in forming it from a set of totally centralized networks N_{C_k} no new terminal is added and therefore no senior control system terminal exists.

4. Hierarchical Networks, N_H

The totally decentralized network, N_D, is, of course, very inefficient in its use of crosspoints (or links or channels). As was noted in the discussion of these networks N(N-1)/2 bidirectional links are needed. Even if all N terminals were in use simultaneously only 1/N of the channels would be busy, or $\left[N(N-1)/2\right]/N=N-1/2$ unidirectional links. The only way to reduce the number of links (crosspoints) and maintain the same amount of connectibility is to add switching to the network. The addition of switching is equivalent to adding terminals to the network whose function is to interconnect the original set of network terminals. The original set of terminals is designated customer or user terminals T_{U_j}. The new switching terminal set is designated T_{S_q}. The addition of T_{S_q} causes a decrease in the number of needed crosspoints X_i to effect the same amount of network connectibility.

One method of introducing switching is to go to the totally centralized network N_C of Figure 3. Here one central switching terminal T_S ($\equiv T_C$) is added. Each customer terminal is connected to it and through it to all other customer terminals. This reduces the number of links in the network from N(N-1)/2 to N-1. In this manner switching control is exercised by T_S and a two rank network results. Hierarchical ordering has been imposed.

An alternative method of introducing switching is to take the total set of original terminals and arrange them in clusters, N_{C_P}. A switching terminal T_{S_q} is added for each cluster of terminals T_{U_k}, q=1,2,...,P where P equals the number of clusters. Then each of the P switching terminals T_{S_m}, m=1,2,...,P, is connected to all the other switching terminals T_{S_m}. This yields the network structure of Figure 4 which has been called the composite-centralized network N_{CC}. If there are P clusters of terminals in the network then the number of crosspoints in the network is now $P(P-1)/2 + \sum j-1$ (where j is summed over N_{C_j} from 1 to P) where N as before was the number of customer or user terminals, T_U.

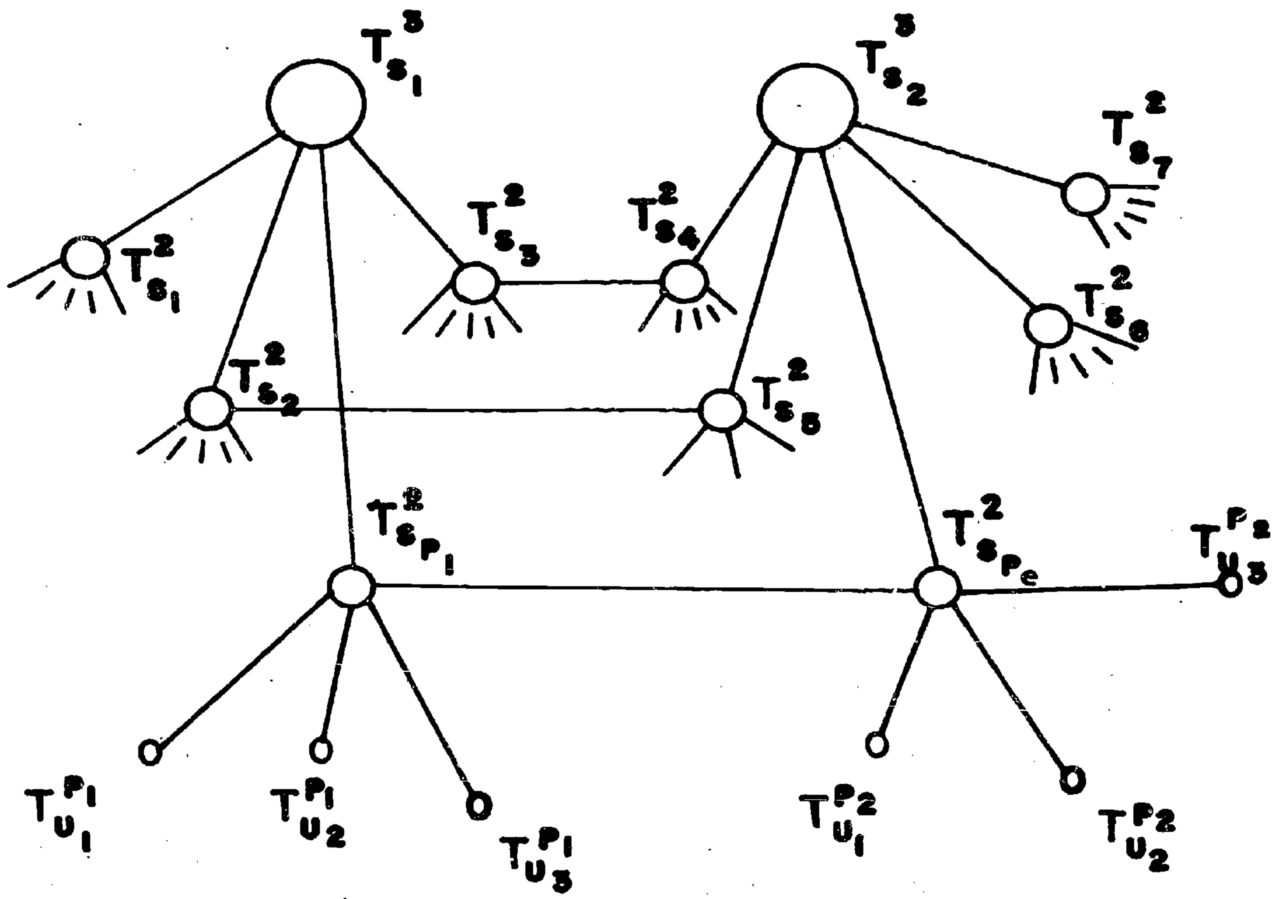
Although the number of links has been increased from that of the totally centralized network the use factor of the P(P-1)/2 lines is greater than that of the N customer lines. If the N customer lines are made the short crosspoints and the P links between the local switching terminals are made the longer lines then economies of cost are introduced. In the United States, there are 18,500 local switching terminals (corresponding to the T_S) serving approximately 1×10^8 or 100,000,000 customers (corresponding to the T_U).

By adding additional ranks of switching terminals, the hierarchical ordering is increased. Figure 5 shows a hierarchical network of order 3, i.e., with three rank orders of terminals. The customer or user terminals are always designated as rank order 1.

Hierarchical networks have a structure that has considerable utility. It is the only practical way in which alternate routing between terminals can be handled. This can be considered as redundancy in the interconnection set which increases the reliability of the network as a whole. It can also be considered as a means of attaining economy of scale through obtaining higher use factors for individual crosspoints or links of the connection set. The complexity of the control system of the network of course increases with hierarchical structure and demands for alternate routing or maximizing use factors of lines.

Hierarchical network structures allow more network states. Concomitantly, there are more equivalent network states in the sense of interconnection of a combination of terminals. That is, there are many ways in which connections can be made between any given set of terminals. In a completely centralized network, N_C, there was only one possible means of interconnection between combinations of terminals. This was also true of the composite-centralized network, N_{CC}, when no control function was assigned to the central terminals, T_C. The same statement can be made concerning the completely decentralized network structure, N_D.

In this discussion hierarchical network structures have been built up on the basis of introducing versatility along with alternate usage of the connection set of a network. They could just as easily have been introduced on the basis of organizational ranking. Terminals whose activity is of lower priority are assigned a lower rank in the network. Then their access to the connection set or the links of the network is less than those of terminals of higher rank or with activities of higher priority. Control of access to the network connection set by terminals of rank N is always exercised by terminals of rank r+1.



A HIERARCHICAL NETWORK OF RANK 3

FIGURE 5

In organizational networks, information networks, management networks and others, priority of activity is more often the cause for the use of hierarchical network structure than is versatility of the interconnection set. In cases of structure governed by priority of terminal activity one normally finds access to the connection set governed by activity priority where such priority is exercised by funding limitations on the use of connecting links. In many existing automated networks, remote terminals can only gain access to computer terminals during certain periods of a day. Or, they can only use so many hours of connection time to a computer terminal per month.

As mentioned earlier, however, organizational considerations usually dictate that national networks such as the Biomedical Communications Network utilize the structure of the composite-centralized networks.

IV. THE STRUCTURE AND COMPOSITION OF THE MEDICAL COMMUNITY RELEVANT TO NETWORK DESIGN

The planning and implementation of a biomedical communications network to serve the medical community assumes a special interest audience and a content-dominant communications policy. The network begins to take form when its geographical coverage, its media, and its content are describable.

The medical community typifies the special interest audience -- a social phenomenon which is attracting considerable attention in this decade. Its homogeneity of scientific interests, its desire to be a self-regulated community, its tradition of performing its own research, and its intent to educate its own members is matched against the wide geographical dispersion of its members and their customer audience -- the American patient. The communications needs of such a special interest audience are not yet clearly understood or voiced. There is a growing recognition that to maintain itself as an entity the medical community must be a highly communicative community. Further, the medical world generally assumes an obligation to generate and assess the content of its internal communications, and to prescribe the amount and timing of its interactive communications.

There are presumably a number of ways to characterize an audience as "special." All of these result in bounding its interests to something less than those of the general public. Considered in this light the medical community as a professional group is a special interest audience.

In addition, there are more implications to the phrase than this, and these implications deserve explicit attention. This is especially true when we are attempting to determine the communications necessary to meet the needs of a special interest audience.

Let us consider the elusive matter of content. Its limitation of range and domain are what makes the medical community a special interest audience in the first place. More important is:

- Who determines the range of interest? Do assigned groups in the medical community itself or the suppliers of information do it? The action of passive rejection of unwanted information has always been used effectively by special interest audiences as a protective device. It is not conducive, however, to any planning process and operates well only when time is of little importance in achieving objectives. One must assume in planning that it is possible to assign responsibilities for selecting, assessing and producing the content of the communications which *de facto* defines the special interests of the medical community. In most cases, these responsibilities will be assumed by groups within the medical community. In some cases, such as patient health care and health status records, groups external to the medical community which administer health service plans will play an important role. In a few cases external groups will probably continue to take the sole responsibility. A case in point is drug information generated and supplied by drug companies.

- Who determines who receives what information? This responsibility has many facets to it. Denial of information is one of the most effective means of control. One can assume this practice as not being employed by the medical community. Instead, one assumes the communications policy of the medical community to be characterized by:

1. Permissive availability to the entire community of all educational, research, product and procedure-oriented information.
2. A capability for individuals to be selective about the information they receive through the use of communications networks that allow selectivity and rejection. This capability does not presently exist.
3. Availability after proper authorization of patient health status records and patient health service records.
4. Community-wide accessibility (after authorization) to patient records so that appropriate records "follow" patients as they move about the country.
5. Community-wide accessibility to directories, indices or guides listing available information, means of acquisition and its credibility as assessed by recognized groups.
6. Sufficient standardization of language and format so that information may be exchanged without the need for manual interpretation and changes at each step in the dissemination process.
7. Selection of appropriate types of equipment and media with recommendations for their use by members of the medical community so that information can be effectively transmitted.
8. Continual assessment and evaluation of content to permit purging, replacement and description of material for dissemination purposes.

A <u>content-dominant</u> communications policy such as that just delineated is the first goal against which one plans communications for the medical community. The communication network or system which is implemented may differ from that desired because of the imposition of:

intellectual constraints
technological constraints
funding constraints, or
managerial constraints.

For example, we run into difficulties intellectually when we try to select the content of educational materials for the first two years of medical school. We run into both technological and intellectual problems when we try to formalize clinical decision making. Neither the logic of problem solving nor the data needed is currently adequate.

The technology that allows for self-paced learning either in medical schools or as part of continuing medical education does not exist today. Funding is not the fundamental problem. Electronic memories, film memories, selective retrieval strategies and control logic are key technical problems barring self-paced learning from being a reality.

Costs augmented by technical problems force us to pay $15 an hour for use of interactive terminals connected to computers. Their widespread use to aid the communication of information is dependent upon at least a 500 percent reduction in their cost.

Communications costs currently preclude us from extending nationwide medical telelecture systems such as that of the University of Wisconsin. Known as the "Dial-Access System" it enables medical professionals to dial the University of Wisconsin, request a three to five minute telelecture by number and then listen to it on the telephone.

Managerial constraints are felt more subtly. They generally affect the permissible means by which one can proceed to achieve goals. Their universality suggests that we need not deal with them specifically for the medical community.

One important input to this network is the structure and composition of the medical community. The "medical community" as used here is assumed to be comprised of individuals who have obtained the degree of M. D. or D. O. (medicine, osteopathy). In the United States this community encompasses a significant segment of society. It is identified by its professional organizations and institutions, as well as by the disciplines in which its individual members specialize. It is made up of some 317,000 such individuals, as of 1968.[2] At the end of 1968, approximately 68 percent of the medical doctors were members of the American Medical Association.

The medical community provides medical education at 99 four-year medical schools and five two-year schools. Presently there are some 35,000 students enrolled in these schools. The spokesman society for the medical schools of the country is the Association of American Medical Colleges.

There are 7,172 hospitals listed by the American Hospital Association. The majority of practicing physicians are affiliated with some hospital so that hospitals can serve as distribution points to the physician for materials and education. The Council of Teaching Hospitals represents 334 hospitals directly affiliated with medical schools. These latter hospitals serve the clinical practice needs of medical students and should be excellent points for the collection of patient and clinical data and recorded experience.

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2. This and all other factual material in the remainder of this section is from Ruth M. Davis, Communications for the Medical Community--a Prototype of a Special Interest Audience, American Institute of Aeronautics and Astronautics Paper no. 69-1072 (New York, 1969).

Some 6,000 health-related libraries serve the medical community. They are capped by the National Library of Medicine, the only national library authorized by public law. The Medical Library Association is the group that represents medical librarians.

The medical community has presently organized its practicing members into 35 different specialty groups and 19 Specialty Boards. Presumably the numbers of physicians associated with each gives an indication of the size audience to be expected for communications in each of these specialized areas of interest.

Once knowledge exists of the structure and composition of the medical community different approaches to network design may be followed. Several were attempted by the Lister Hill National Center for Biomedical Communications.

The first approach was a comprehensive examination of the types and frequency of services to be provided by the BCN. The lack of detailed policy for or experience with such a network make this approach relatively unproductive. The second approach was to gather statistics on the location of individual and institutional members of the biomedical community and to attempt to construct network models as tools for comparing various methods of network interconnection. Suggested networks were then developed as a basis for estimating the cost of the various interconnection schemes. The third approach was to investigate all potentially attractive communication links which could be applied to meeting the communications requirements of the models developed in the second approach.

The problem of interconnecting a wide variety of users and information resources even for a special interest audience is not unlike that of developing a multiple access communication scheme such as the national telephone system. The problem of distributing information to users in a metropolitan area is quite different from the distribution of information between and among the metropolitan areas. For the BCN and especially the educational TV segment, local distribution means that have been considered are: 1) common carrier broad-band coaxial lines, 2) utilization of broadcast techniques through either dedicated or the shared use of educational television facilities, 3) privately owned coaxial cables similar to community antenna distribution systems, 4) point-to-point dedicated microwave links, and 5) possibly, direct reception from a dedicated, relatively high powered satellite. The choice among these will depend upon the number of users in the metropolitan area, the number of hours of use per day, the topological configuration of the users as well as the intervening terrain, the number of years it is expected the network will exist, and the expected network growth. Cost is the principal criterion in considering and choosing among the options.

A somewhat different set of link options has to be considered for connecting the major metropolitan areas and the isolated users. One link option is supplied by the common carriers, utilizing coaxial cables, microwave links and/or, potentially, communication satellites. The existing rate structure does not differentiate between the different links and therefore all combinations of these, when provided through a common carrier, can be considered as a single link category. The second alternative is to utilize a dedicated network equivalent to those which the common carriers operate. Although it is doubtful whether such a network should truly be competitive with common carrier service, owing to the increased efficiency with which a common carrier can operate by serving a broad and diversified set of customers, the rate structure for a common carrier's services may nevertheless favor a dedicated transmission system.

A number of sources have been examined in an effort to determine the location of potential users of the BCN. Census statistics, organized by states, gave limited insight into the geographical distribution of the biomedical community. Locations of hospitals and medical schools help to further suggest the detailed structure of the geographical distribution. All of the sources indicate that the medical community is concentrated in about the same manner as the general population, with a tendency to be even more concentrated in central metropolitan areas.

The distribution of medical personnel and facilities is geographically uneven. In general, the distribution tends to follow the distribution of population in the United States and one finds the heaviest concentration of medical practitioners and facilities in the heavily populated areas. For example, the 10 most populated states, California, New York, Pennsylvania, Illinois, Texas, Ohio, Michigan, New Jersey, Florida, and Massachusetts, which account for about 55 percent of the total U. S. population, have among them 62 percent of the physicians, 61 percent of the dentists, 59.5 percent of the nurses, 46.5 percent of the hospitals and 58 percent of the hospital beds in the nation. When considering regional distribution, the Middle Atlantic region has by far the largest number of physicians, dentists, nurses, hospital beds, and health-related professional schools. This results from grouping three heavily populated states (New York, New Jersey, and Pennsylvania) into one division. The Middle Atlantic region is followed by the East-North Central and Pacific regions. The South Atlantic ranks next in size, while the East-South Central and the Mountain regions are lowest, both in terms of facilities and personnel. Another pattern which is discerned in this analysis is that large metropolitan areas serve as the sites for most medical, dental and other professional schools, research institutes, large hospitals, and medical societies of various specialties. These metropolitan areas are largely in the Northeast, Midwest, and in California. The distribution of physicians, dentists, hospitals, and hospital beds is such that in twenty-eight metropolitan areas, each of which will have a projected population of one million or more in 1980, will be more than 50 percent of the biomedical personnel in the United States. Although their share of the total number of hospitals and hospital beds is far less, they do have more than 40 percent of the hospitals with 300 or more beds. Since the large medical centers, research institutes, and educational schools are concentrated around great metropolitan areas, perhaps most of the educational programs should originate from and be distributed over these areas.

A variety of types of communications are envisioned in the BCN. Many of the objectives of the BCN will be accomplished with conventional non-electronic communication means such as physical transportation of printed material, film, and videotape. The network will also require the real-time communications such as telephone, teletype, facsimile, and television. Television will be the pacing requirement because of its wide bandwidth requirements. Television standards similar to those used in present commercial television in the United States have been assumed in the planning.

V. COST ANALYSES OF BIOMEDICAL COMMUNICATIONS AND INFORMATION NETWORK SERVICES

The desirability of a service or product is normally highly dependent upon its cost. Choices between alternative services or products, all of them desirable or needed, are usually made on the basis of what can be afforded. Asking someone to choose between services or products without indicating costs is unrealistic. Making such a choice without knowing costs should be avoided except in those instances where it is agreed that "cost is no object." However, cost analyses for information networks are almost non-existent in the literature.

There are many ways of presenting costs. Similarly, there are many premises underlying statements concerning cost-effectiveness or cost-benefits of services or products. Some of the more important of these are:

- Cost should be stated in terms of funds, time, or manpower.
- Cost-benefits may be realized by shifting manpower requirements from a scarce skill to a more available skill. For example, health manpower is an extremely scarce skill. If services now demanding the time of health professionals can be satisfactorily provided utilizing other less scarce professional skills and technologies then cost-benefits accrue. It is a fruitless endeavor to attempt to increase available health manpower through the initiation of services heavily reliant upon the health manpower one is attempting to conserve.
- Cost-benefits may be realized through:

  1. Providing equivalent services or products at lower cost (dollars, manpower, or time).

  2. Providing better services or products at a less than proportional increase in cost.

3. Providing services or products presently not available against a known objective expressed as savings in dollars, time, or manpower.

. The continuing costs of maintaining network services are significant and should be explicitly calculated. Services and products differ in concept in this respect. A "product" does not carry with it the implication of continuing maintenance.

. Savings in time for health professionals is a recognizable cost-benefit.

. Recognized or expected improvements in quality of health services are not readily translated into cost benefits. The results of changes in quality of health services demand measurements on the patient population which are generally statistical in nature and thus long-term. No predictive techniques in this regard appear applicable because of the lack of usable patient or medical records.

. Ideally costs should be stated in terms of:

1. Intellectual effort required
   - of the customer
   - of the producers
   - of the maintenance group
   - of the supporting technical groups
2. Equipment required
   - for the customer
   - for the production
   - for the maintenance
   - for the distribution or provision
   - for the technical support group

3. Manpower required

- by the customer
- in the production
- in the maintenance
- in the distribution
- in the design, development, test, evaluation, and control

4. Tariffs or costs for externally provided services such as common carrier costs

Practically, data is spotty covering only a few of the above costs.

Some considerable effort has been devoted to the collection, analysis, and interpretation of cost data for selected biomedical communications services and products. It will be a continuing effort which will become more satisfying as cost record-keeping is improved within the medical community.

The remainder of this section addresses certain cost aspects of three biomedical communications network services, namely: [3]

1. An audio-access system for medical information (Medical Information Telephone Service)
2. A medical ETV service, and
3. An on-line bibliographic access system to medical literature.

Two illustrative groups of services have been graphed in Figures 6 and 7. Figure 6 shows a cumulative cost of ETV services at one hour per month, of medical information services, and of bibliographic access services. Figure 7 shows the Medical Information Telephone Service, the Bibliographic

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3. Ruth M. Davis, "Cost-Benefit Analyses of Biomedical Information and Communications Services" (Paper delivered at the Thirty-seventh National Meeting of the Operations Research Society of America, Washington, D. C., April 20-22, 1970).

Access Service, and the Medical ETV Service at one hour per week usage. Cost data are shown on a double scale along the vertical axis. The total annual cost is shown on the left side; the annual cost per American Medical Association member (assuming 219,000 members) is shown on the right side as a measure of cost per physician.

The percent of demand on the horizontal axis of the curve in Figures 6 and 7 necessarily has different meanings for different services. In general, an attempt to estimate the total reasonable demand was made and demand levels were then expressed as a percent of this total. For the Medical ETV Service, the measure was simply the percent of the physician population reached.

By the end of 1969, there were 183 ETV stations operating in the United States. Of these, 135 can be considered distinct for purposes of networking. The remaining are either in statewide networks or in cities with multiple stations.

One hundred and six of these 135 stations reach about 97 percent of all the physicians residing in Standard Metropolitan Statistical Areas (SMSA's). Since about 85 percent of all physicians reside in SMSA's, the 106 station networks can reach about 82 percent of the total physician population of the U.S. In addition, the population distribution of physicians is quite skewed: about 30 percent of the physician population is in the five largest SMSA's. A 45 percent decrease (excluding the cities with the smallest physician population) in the number of stations included in the network will cause only about a 10 percent decrease in the size of the potential physician audience.

The cost for networking TV, using AT&T facilities and services, has three separate components: 1) an inter-exchange channel charge based on the

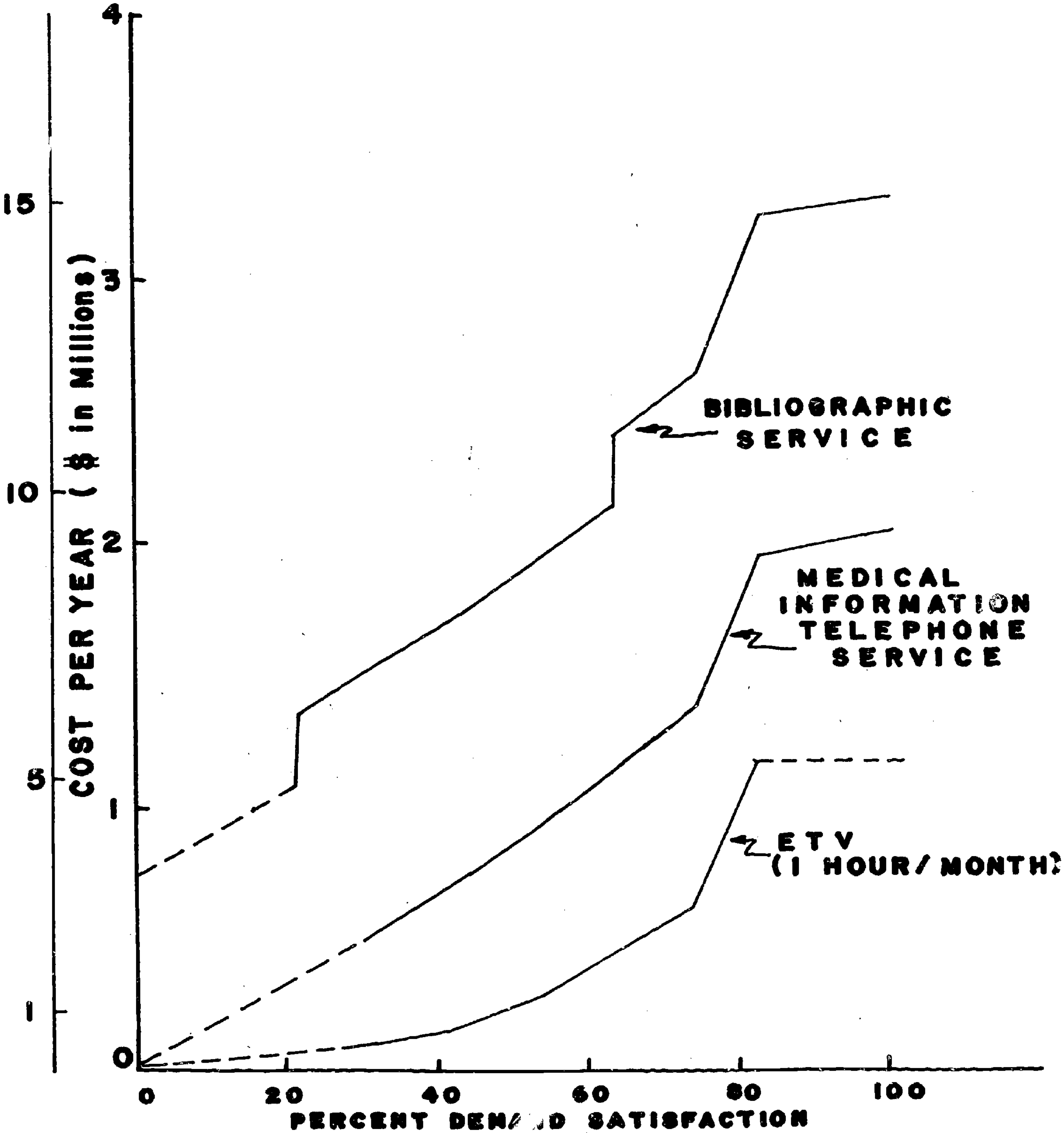
4
3
2
1
0
15
10
5
1
COST PER YEAR ($ in Millions)
BIBLIOGRAPHIC SERVICE
MEDICAL INFORMATION TELEPHONE SERVICE
ETV (1 HOUR/MONTH)
0
20
40
60
80
100
PERCENT DEMAND SATISFACTION

FIGURE 6

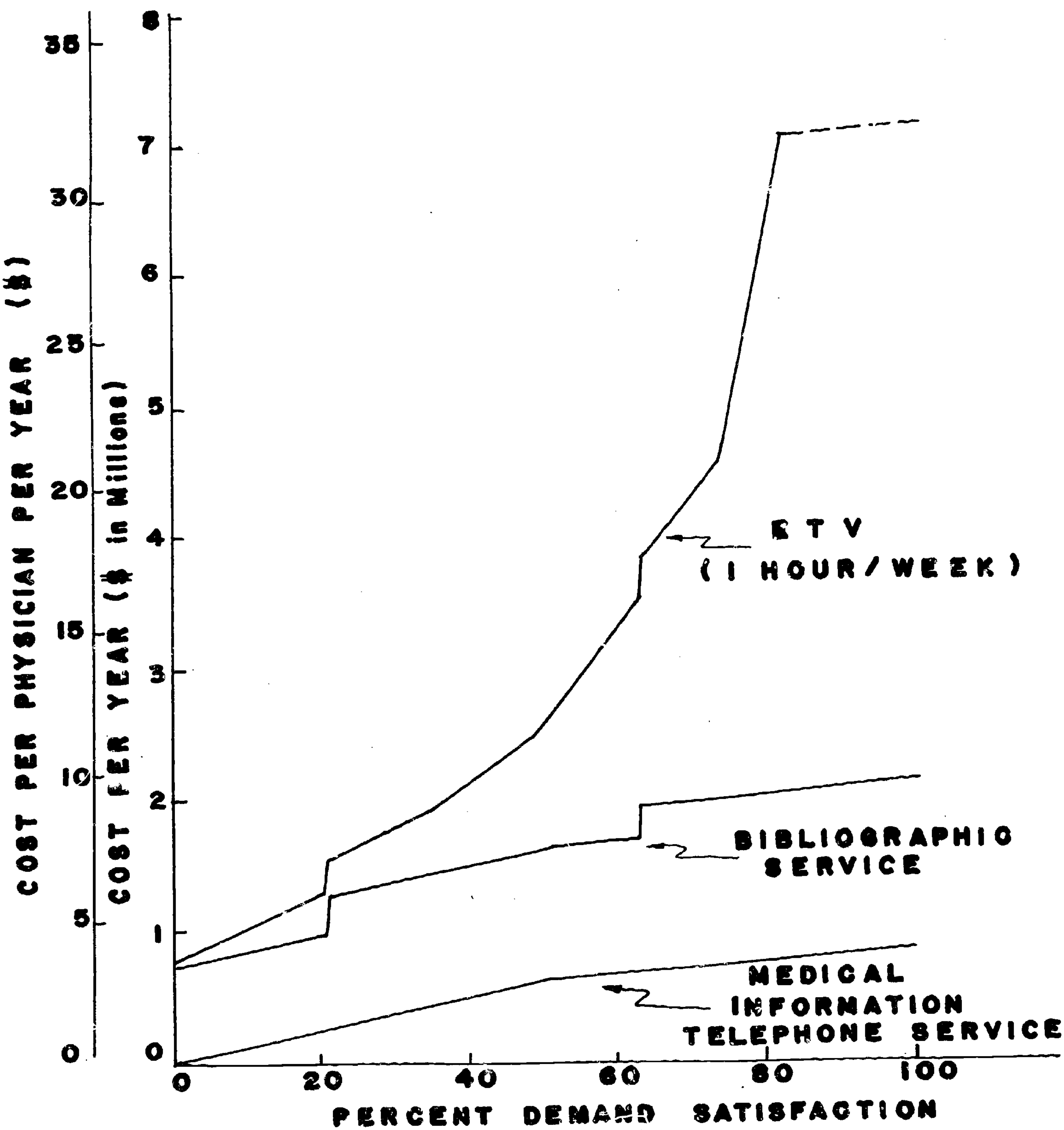
COST PER PHYSICIAN PER YEAR ($)
35
30
25
20
15
10
5
0
COST PER YEAR ($ in Millions)
8
7
6
5
4
3
2
1
0
ETV
(1 HOUR/WEEK)
BIBLIOGRAPHIC
SERVICE
MEDICAL
INFORMATION
TELEPHONE SERVICE
0
20
40
60
80
100
PERCENT DEMAND SATISFACTION

FIGURE 7

airline distance between cities and the amount of broadcasting time, 2) a station connection charge, a fixed charge plus a rate based on the amount of broadcasting time for connecting the local station to the AT&T network, and 3) a local channel charge based on mileage between the ETV station and the AT&T facility. It should be noted that the costs do not include TV sets for individual customers.

The phone access audio message center service analyzed is from a library of recorded messages providing brief summaries of new developments and current practice in various areas of medicine. The messages would be four to six minutes in length and be available by telephone on 24 hour 7 day week basis. Free access to the message library would be available to physicians by means of In-ward Wide Area Telephone Service (In-WATS).

The contemplated service would provide some 300 to 1000 separate information packets or messages from which the user can select. Costs include distribution of descriptive catalogues of the available service and other means of bringing the service to the attention of potential customers.

The analysis of the data from the Wisconsin Dial Access System has shown that utilization or demand experience can be explained reasonably well in terms of three basic variables: promotion policy (number of promotions or reminders per year), the size of the reachable population, and library size measured in numbers of messages. Given that the proposed center is to serve the nation as a whole, population must essentially be taken as given. This leaves two major policy or design variables which can be varied to affect utilization, promotion policy and library size.

The Medical On-Line Bibliographic Access Service provides a MEDLARS data base on-line to users having a TWX terminal or a teletype connected to the telephone system. It would allow search of the most current two and one-half years of MEDLARS information on (1) use of the NLM data base for the Abridged Index Medicus with slight augmentation to cover the bibliographic information and the most used medical literature, (2) use of part of a large, time-shared, computer system rather than all of a smaller one, and (3) connection of this system to the TWX network thus providing potential access through terminals already existing in some 500 institutions in the medical community at no cost to the government. Medical libraries now use the TWX network; NLM receives over 1,200 requests for interlibrary loans per month over this network. These come from several hundred different libraries across the nation. A review of the directory of the TWX network indicates that there are 120 hospitals on the network, 150 pharmaceutical firms, 125 schools including many medical schools, and a sprinkling of clinics and physicians.

The National Library of Medicine has contracted with the System Development Corporation (SDC) to provide such an experimental service in bibliographic access. It is possible for either teletypes on the telephone network with standard 103A2 data sets or Model 33 or 35 Teletypes in the TWX network to access the computer system in Santa Monica. Five special lines have been installed by the General Telephone Company to connect the IBM 360/67 to the TWX network. SDC provides the computer time and an additional disk storage unit to allow the provision of bibliographic access to about 150,000 citations out of the MEDLARS data base. This available storage space is adequate to provide access to a consensus list of medical journals over the five-year period covered by MEDLARS.

Service started in June 1970. This service is provided each week day from 11:00 a.m. to 3:00 p.m. EST/EDT. The cost of calling the system would be borne by the user, and TWX charges from \$.20 to \$.60 per minute depending on whether the station is calling from across the continent or from 50 miles away. In addition, SDC provides on-site training at a designated set of locations to selected users (physicians, hospitals, and libraries) of the system, and will run a spot survey on organizations that will use the system without training. The SDC system can be used without training, and instructions are provided from the terminal giving a minimum amount of information about how to call in to the system. In addition, the language interface, the way the user phrases his request, is variable and can be modified to be more effective during the service period as a result of the experience gained in the use of the system.

The costs covered are hardware and interconnection costs. The cost of content development is not included. It is singled out for separate treatment. In addition, there are several hardware and interconnection costs not covered. The most important are the cost of placing a call in the bibliographic access service and the cost of a TV set in the Medical Education TV Service. Costs of placing a call vary with the location of the customer and the length of time the teletype terminal is connected. These have not been included in the service in order to leave an incentive to rapid effective use of the computer system. The costs of TV sets can be added to the cost estimates provided here as a fixed increment.

The available data for bibliographic access was much less suitable for demand estimation. The New York data for three cities, not including the "home" of the SUNY Biomedical Communication Network, showed an annual request rate of 2.3 requests per physician; the state as a whole showed .65/physician. On the basis of this experience, it seems that one might expect as a conservative maximum about 1.0 requests per year per physician. Percent demand satisfaction is then percent of a request per physician.

The SUNY service time is about 1.2 minutes. A service goal of 90% of searches being processed in five minutes or less was adopted because it seems reasonable and corresponds to the maximum use of the SUNY system. Given this service criterion the maximum search demand rates can be computed. These can be translated to numbers of processors required to derive cost and to requests per physician to reflect demand satisfaction. For example, consider a line at 48%. The graph shows that this demand level could be met for $2.5 million/year, or about $11.50/physician. Of this $11.50 about $3.00 would provide dial-access service to a minimum library of 300 messages promoted only twice a year. An additional $4.40 would provide searches to half the physicians (actually one search for up to 63% of the physicians could be accommodated). And, finally, $4.10 would provide for networking enough ETV stations and for the broadcast time to beam special programs to 48% of the physicians in the country one hour a week.

VI. CONCLUDING COMMENTS

There are many reasons for the existence and growth of networks. The basic one--to communicate information--is as old as one desires to consider it, and it is expressed in a variety of forms from interlibrary loan services to the founding of the Royal Society (or "Invisible Colleges") and the Autodin networks of today. A second major reason is the increasing interdependence of the computer and communication technologies themselves.

Computers and mechanized data banks have most recently again highlighted networks as a means of communication. The circumstances which appear to call for the establishment of physical networks (as opposed to logical networks) are as cited earlier:

1. The existence of special data banks or special collections of information located at a single institution but useful to an audience geographically dispersed.

2. The inadequacy of local general data banks or general collections of information to meet local needs where remote resources can be used in a complementary fashion to fulfill the needs of the clientele.

3. The centralization of programming services, processing capabilities, reproduction facilities or scientific resources with a geographically dispersed need.

4. The need for interpersonal (including intergroup) direct communication. This includes teleconferencing and educational activities such as continuing medical educational TV.

5. A justification on economic, security or social grounds for distribution of responsibility for load sharing among organizations or geographical regions.

6. The need for intergovernmental interaction as by Federal, State and local authorities on law enforcement and/or the processing of Social Security and Medicare information.

In planning networks there is an hypothesis--in many cases proven--that communication services are the most effective means for joining customers to information where effectiveness is measured against established criteria.

The core of any information network involving automated data banks or communicable information (e.g., educational material, video or audio information) is a system of communication channels which serve network participants and provide for information exchange. The participating centers in the network interconnect with the communications system through buffer or "translator: equipment frequently referred to as a network interface. Each interface is connected (generally electronically) to the communications system of the network at a node. The communications system is simply a means for information exhange, and the interfaces are required to accommodate the many terminal devices, with their multiplicity of frequencies, electronic languages, etc., to the standardized mode of operation of the communications system.

The types of network communication system node variations which may be envisaged encompass:

1. Terminal-to-terminal communication. This includes single-transmitter to multi-receivers, multi-transmitters to multi-receivers, multi-transmitters to single-receiver and one-to-one transmit receive situations.

2. Terminal-to-computer communication with and without interaction.

3. Computer-to-computer communication with the total spectrum of allowable control mechanisms.

Network transmission itself may be by voice, through record or message exchange or by facsimile and video transmission. These communication types are classified into low-grade teletype, voice-grade data and record transmission, TELEX, TELPAK, narrow-band or slow-scan TV and facsimile transmission and wide band or standard video and TV transmission.

The communication media envisaged can be grouped in several ways such as:

Ground links or satellite

Common carrier, private or dedicated

Cable or free space

There is no question that there is a strong interdependence between the planning for a network communications system and other aspects of network design. A much abbreviated set of questions that impact on communication system planning is as follows:

1. What is the scope of the network?

a. Geographical coverage

b. Services to be provided by and to whom

c. Location and facilities of participants

d. Existing capabilities available

e. Required rate of development

f. The subject scope of the information exchange

g. Data bank media, e.g., document, data, information, etc.

2. What are the relevant software and data characteristics?

a. Privacy requirements

b. Accessibility and/or availability of program services

c. System management programs

d. Compatibility - convertibility

3. What are the network management and control requirements?

a. Standardization

b. Membership

c. Information and program manipulation

d. Feedback

e. Documentation

f. Costs of services

g. Priorities and scheduling

4. What are the pertinent legal regulations and practices?

a. FCC regulations

b. Carrier rate structures

c. Common carrier use

d. Responsibilities for information content

e. Privacy versus broadcast methods

f. Federal agency jurisdiction, e.g., DOT, DTM, HUD, FCC, HEW, DOD, etc.

g. Copyright regulations

h. Anti-trust regulations

5. What are the technological constraints?

6. What are the budgetary constraints and financially allowable rate of development?

A number of the questions listed in #2, 3 and 5 above could readily be considered as technological problems. A recently published report by Mary E. Stevens gives an excellent survey of the relevant literature.[4] However, there is no question that the problems of network design and operation are intellectual and managerial, as well as technological in nature. Most are still pending and awaiting attention and resolution. Experience with networks already existing or in advanced planning stages, whose development proceeded without benefit of such answers, will help solve the unanswered questions. The National Biomedical Communications Network is one of these.

4. Mary E. Stevens, Standardization, Compatibility and/or Convertibility Requirements in Network Planning (Unpublished report prepared for the Lister Hill National Center for Biomedical Communications).

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