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Review of Network Management Problems and Issues

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FOREWORD

This report is one of a series of publications produced by the Institute for Computer Sciences and Technology, National Bureau of Standards, under Grant AG-350 from the National Science Foundation.

This grant supports a broad program of research into the foundations of computer networking in support of scientific efforts.

A listing of completed and planned publications produced by the Institute under this grant follows:

1. Primary Issues in User Needs
   D. W. Fife
   Chapter 10 in Networks for Research and Education: Sharing of Computer and Information Resources Nationwide
   MIT Press, Cambridge, Mass.
   Expected Publication October, 1973

2. Some Technical Considerations for Improved Service to Computer Users
   T. N. Pyke, Jr.
   COMPCON, 1973
   Seventh Annual IEEE Computer Society International Conference

3. Computer Networking Technology - A State-of-the-Art Review
   R. P. Blanc and T. N. Pyke, Jr.
   COMPUTER Magazine
   Computer Society of the IEEE
   August, 1973

4. Review of Network Management Problems and Issues
   A. J. Neumann
   NBS Technical Note 795
   September 1973

5. Annotated Bibliography of the Literature on Resource Sharing Computer Networks
   R. P. Blanc, I. W. Cotton, T. N. Pyke Jr. and S. W. Watkins
   NBS Special Publication 384
   September 1973

6. Network Management Survey
   I. W. Cotton
   NBS Technical Note, September, 1973

7. User Procedures Standardization for Network Access
   A. J. Neumann
   NBS Technical Note, September, 1973

8. Review of Computer Networking Technology
   R. P. Blanc
   NBS Technical Note, September, 1973

9. Microeconomics and the Market for Computer Services
   I. W. Cotton
   Submitted to Computing Surveys

10. Cost Analyses for Computer Communications
    R. P. Blanc
    NBS Technical Note, Fall, 1973

11. Network User Information Support
    A. J. Neumann
    NBS Technical Note, Fall, 1973

12. Quality Service Assurance Experiments
    R. Stillman
    NBS Technical Note, Fall, 1973

13. A Guide to Networking Terminology
    A. J. Neumann
    NBS Technical Note, Fall, 1973

14. Research Considerations in Computer Networking
    D. W. Fife
    NBS Technical Note, Fall, 1973

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Review of Network Management Problems and Issues

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Computer networking is broadly considered including hardware, software, procedures and people. Networking encompasses many activities; such as, creation of network products, distribution processes, user activities, and supporting services like marketing, documentation, information services and maintenance. Network management covers both the establishment of networking operations and actual operation of the network facilities. It includes all management functions performed at such network nodes as computing centers, documentation facilities, and service distribution centers.

In order to survey the problems facing development of network management, user requirements and system requirements are outlined in a qualitative manner. Examples of political, economic and legal constraints are summarized, such as the economic impact of extended networks on regional and local computing activities. Critical issues for networking management, and other areas of significant management concern are outlined.

Organizational alternatives are conceived in terms of a four layer organization model. Conclusions deal with continuing problem areas, the need for a structural model for network management, critical experiments and tasks to be undertaken to further networking capabilities, and a suggestion to establish planning teams to initiate some of the initial steps required for further networking development.

Key Words: Academic computing; networks; network management; regional networks; research computing.

1. INTRODUCTION

There has been substantial growth in academic computing in recent years, stimulated partly by marketing successes of manufacturers and partly by Government financial support. Questions are now arising as to how the new technology of computer networking might best be utilized in support of higher education and research, and how academic computing could be channeled to become less dependent on Federal grant support, and what steps should be taken by all participants -- Government, universities, and users -- to use computer technology more effectively. There is a consensus of opinion that computer network technology is now available, and a strong desire is evident to apply this technology in a proper manner to provide possibly far reaching benefits to higher education and research.

Related to the problem of introduction of technology are the

problems of development of an organization, of the management of the available resources -- people, material, and financial -- and of development of new management concepts, procedures, and methods. Network management is concerned both with planning of network operations and the operation of networks. It is concerned with organization, direction and control of all activities which develop and distribute network resources and network services in the academic environment. This environment commonly is limited to a single campus at this time, but the growth of multi-campus institutions and of regional cooperation among institutions is tending toward a national orientation for networking activities. Nationally oriented networking is imminent through interconnection among regional networks, and between regional networks and special purpose computing centers.

This study is concerned with identification of existing or potential problem areas related to network management. This includes definition of network parameters which can be used to specify network properties, identification of network constraints, and isolation of major concepts of network management. These form the basis for network planning, organization, and control.

The study is addressed to those who will be involved in the planning and development of academic networking capabilities. They may be top-level university administrators, who are concerned with the raising of funds or the development of policies for academic networking efforts; they may be directors of local, or regional computing centers, who need to interface with networking development, and who need to develop operating procedures, policies and funding mechanisms, to interrelate network facilities with their needs and their installation capabilities. The report should also be useful to users, or user representatives, who would like to investigate the impact of networking on their special discipline, or who would like an overview of points to be considered in establishing network organizations. Finally, the study should

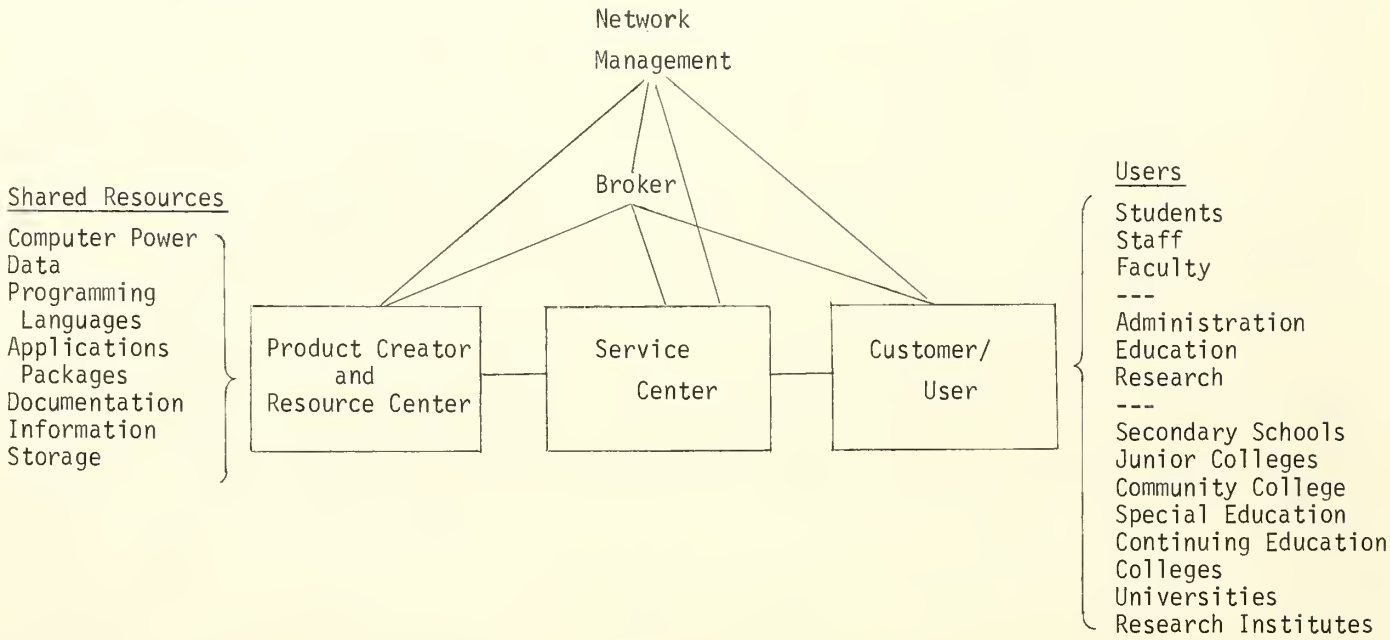
be of interest to technical managers, system planners, and designers of computing networks who have to interact with their managements and who may want an overview of the networking management environment.

1.1 Definitions and Scope

"Network" is given a rather broad meaning. A network is considered a combination of processing nodes, communications linkages, hardware and software, people and their organizational relationships, and various rules, policies, and regulations which permit smooth operation and interaction of the network components. This broad definition is used to permit an integrated approach to the overall system development during the formative and conceptual stage of network development. Some nodes may be centers which are primarily resource oriented, and which deliver specialized resources to the network; such as, one-of-a-kind data bases, or a unique processing capability. Other nodes may be usage oriented and provide service distribution or access capability, e.g.regional computing centers. Still other nodes may serve both functions with the mix determined by local requirements. Processing nodes will have both automated and human processing, each providing their own unique capabilities. Communication linkages may be simple information channels, where mail flows between regional centers, human communications channels established over dial-up voice lines, narrow band communications, or broad band computer-to-computer linkages. No preconceived notions exist at this time as to the composition of either the network nodes, or the linkages of a future science networking capability. Description and elucidation of management concepts for such networks will require comprehensive understanding of the functioning of the network.

Major network functions and possible participants are shown in Figure 1, in symbolic form. Eventually there will be many resource centers, a diversity of users, and as many service centers as required by the needs of the network community.

Major resources are provided to the network by the resource centers. The creator of the resource may or may not be affiliated with the resource center. There are resources such as proprietary data



NETWORK FUNCTIONS AND PARTICIPANTS

FIG. 1

banks, which may be owned by a separate organization, but are made available to the resource center and to the network under special licensing agreements. Individuals who have written special computer programs may want to retain ownership, and may want to permit network users access to their programs. Thus there may be a distinction between the resource creator, the resource owner, and the resource center. Similarly, depending on the nature of the network product and its distribution process, there may be other needs for division of labor as indicated by the emergence of wholesalers and retailers. An existing regional network, as part of a national network, may take on the task of acting as a major distributor, or wholesaler, and furnish services to various campus computing centers, who act as local distributors, or retailers of services. The local centers in turn may serve a customer; such as, a research project or university department, and through them it may serve individual users. Legal service agreements will have to be executed between the retailer and the customer. The user, or ultimate consumer is a member of the customer organization.

Major functions are concerned with network support, facilities and personnel at all the major network nodes. A special box in Figure 1 labeled "broker" indicates the need for a brokerage type of liaison function, which in a large network will provide a linkage between sources of service and user needs. This linkage function matches the temperaments and capabilities of usage oriented researchers, and distribution oriented providers of services. The location of the brokerage function in the resource to user chain depends on circumstances, type of service, type of customers and type of network organizations. This will be discussed in more detail later on.

Network management is defined as comprising all activities directly concerned with the making of major decisions regarding both network planning and network operational activities, at all levels, of all organizations engaged in planning, operations, support and maintenance of network resources, network distribution and network services.

1.2 Types of Potential Network Application

Several types of resource sharing may occur on a network. In load sharing, a given work load is distributed among several computers. This equalizes the load on participating computers, and permits accommodation of peak loads and perhaps the installation of smaller computers if work load estimates can be predicted with reasonable certainty.

Hardware sharing could provide computational machines; such as, extremely fast machines, or machines with very large storage capacities, for unique research applications beyond the capability of individual computing centers. Hardware sharing also refers to sharing of unique output hardware capabilities; such as, machines for preparation of hard copy, photo composition, or unique graphic production capabilities.

In data, or data base sharing, several users at different sites would access one data base, of unique characteristics. This may become economically feasible with very large data bases on the order of 10^{10} bits, where the cost of copying and transfer of the data base would be prohibitive.

Program or software sharing would permit users at different sites to use programs at a resource center, by providing their own data, transmitting the data to the resource node, and receiving the results from the resource node. This could include various software packages which may not be available locally because of hardware or language incompatibilities.

Various types of network applications place different burdens on network management, in terms of requirements for services, standardization, support, and documentation.

1.3 Modes of Network Operation

A future networking capability would provide a variety of modes of operation. Some users may require interactive service, where relatively small programs are entered from a console and the results appear at the console practically immediately. Other users may want to operate in the remote batch mode, entering data from a terminal, and receiving

results from a batch process some time later. Other users may transmit a deck of cards to a remote computer for batch processing, and receive the results via a similar process, or by the mails. Finally there may be use for capabilities where a chain of computers may be involved, and various processes are executed at various levels of a hierarchical computing system.

1.4 Prospective Users

In order to assess requirements for a broader networking capability, some estimates must be made regarding the usage requirements; i.e., the number and types of users, their potential distribution, actual user time required and various types of services to be used. Furthermore, one needs to know the characteristics of the individual customers and their particular needs.

The user community may include private institutions, state supported schools, municipal colleges, community and junior colleges, professional schools, and also some secondary and even primary schools. Some users may be associated with government agencies and non-profit research centers.

Research usage will serve the very sophisticated user, with unique computational requirements. Another category is graduate and undergraduate students. Their needs may be characterized partially by course work requirements in a variety of courses, by terminal use at all hours, and by specific requirements towards the end of the term or of the academic year, where computing use rises traditionally, in support of term papers and thesis projects. Other beneficiaries or participants will be faculty and university staff, engaged in teaching or research. Another group to whom network services may be useful are the school administrators. It is not clear at this time whether all of the above can be or should be accommodated on one network, or whether there should be separate administrative, research and teaching networks. Another area of use would be computer aided instruction (CAI), which has been developed for all levels of teaching and instruction, from graduate level (1),[1] through undergraduate to high school and grade school. Special

[1] Figures in parentheses indicate the references at the end of this paper.

applications have been developed for "distributed populations" (2) and for training in a specialty; such as, nursing. Administrative applications in the educational sector may include handling of student records, class scheduling, billing, plant maintenance, and preparation of address lists and directories.

If conventional library functions are made part of a network, interlibrary loan and reference queries, as well as circulation data and catalog preparation, would be candidates for network services.

Another application of network technology would be mass utilization of minicomputers, which would provide on-line process or experiment control, and would at the same time be linked to the network to provide specific inputs or to utilize specific network services in support of local experimentation. Much work has yet to be done in classification of experimental functions, development of experiment control languages, and special hardware or software functions.

1.5 Extent of User Distribution

Several analyses address the possible extent of academic networking requirements.

A survey by Hamblen (3) of computer facilities in institutions of higher learning showed that as of June 1969 there were 1255 institutions with computer facilities and 1282 without. The Pierce report recommended that all universities and colleges should have some kind of computer facilities (4). In 1968 - 69 the 1282 institutions without computers enrolled about 1.2 million students. DeGrasse(7) also estimated that there might be 6000 terminals in higher education by 1975, and 12,000 terminals by 1980. One can easily envision at some future time interconnected networks of thousands of terminals and several hundred nodes entirely devoted to higher education.

1.6 Potential Resources and Services

Potential network resources will be made available to remote users from resource centers having the hardware, software, and people necessary to support service nodes in service

distribution. Hardware may include specialized machine capability; such as, high speed, multi-font, hard copy production capability, very high speed computing capability, or very large storage facilities. Software may include very large data bases, proprietary applications programs, or other unique research capability, while people will include functional specialists, system programmers, operations experts, and others, who would be available for advice to and consultation with users. Resource centers may be discipline oriented, having expertise in one or several of the academic disciplines, like chemistry or physics, or in subdivisions like theoretical chemistry, or nuclear physics, or they may be interdisciplinary and problem oriented such as a center for urban studies or for pollution research. Potential networking services have been described in the literature (5),(6),and there are a variety of candidate types for potential networking services (See Table 1). Before such services can become viable products for broader, even nation-wide distribution , management will have to make decisions on priorities of needs. Guidelines for implementation will have to be developed to fill these needs.

Potential Network Services

Computing Services

- research computing
- educational computing
    - computer aided instruction
    - computational training
- administrative computing

Information Services

- data services
- retrospective search
- current awareness
- selective dissemination
- document production and publishing

Communications Services

- teleconferencing

Control Services

TABLE 1

1.7 Networking Development

The problem of remote computing in higher education has been addressed by DeGrasse (7) who studied potential patterns of development of remote computing.

His findings, although reported in 1971, are still relevant and are summarized here. He asks three questions:

1. Is a national (educational teleprocessing) network evolving by itself?

2. Is a national (educational teleprocessing) network worthwhile?

3. What is the effect of computer hardware and software?

He answers "No" to the first question. "A national network will not evolve if we define a national network as connecting a majority of institutions of higher education on a single network or utilizing a common utility. We have a number of (approximately twenty-five) small disconnected regional networks with little incentive for them to connect together. The future will bring more small, local networks, but no single national network or utility without a great deal of federal government stimulation."

DeGrasse answers the second question in the affirmative, "provided it is economical and with the national education goal of effective utilization of teleprocessing technology by as many institutions as possible . The concept is worthwhile ... if it includes the relatively disadvantaged institutions as well as the leaders in educational computing."

Regarding the impact of hardware and software, he concludes that hardware effects will be small, since a good many of them (i.e., the majority of institutions of higher learning) have little if any hardware in the first place. The main challenge is "tailoring the applications programs to serve the great many different needs of educational practitioners in a useful, attractive, economical way, is our biggest challenge ... Nearly half of the institutions in the country have little or no computing at all which means we have a long way to go before we find the computer ... used extensively in an efficient

cost-effective manner for class support in a majority of disciplines".

There are three elements of higher educational computing: administration, instruction, and research. They are in different stages of evolution. Instructional computing comprises the newest group of users, and is growing fastest, and "has the greatest potential need for networks". (This does not necessarily imply a "national network"). "Because of the nature of research, research users will always find use for networks as long as government support is available." (One might argue that loss of such support, may reduce research use considerably). "Individual institutions' administrative users are a large, well defined group but administrative networks are unlikely without a major restructuring of both public and private higher education." In this connection, it is interesting to note that the TUCC network has started to provide administrative computing services for several institutions (8). This has been successfully carried out for some smaller institutions but with the three larger universities there is a greater reluctance to shift their administrative data processing to TUCC, although Duke University has already accomplished this for their student record processing. "One problem which must be overcome ... is the administrators' reluctance to give up a machine on which he can exercise direct priority pressure." Implementation by TUCC of centralized administrative services will require additional machine capacity at the central site, and approval of such an extension by the other partners of the consortium. This development, if successful, will be of interest, because it will demonstrate the utility of centralized administrative processing.

A national network should be envisioned as a developmental effort which will slowly and naturally evolve into a useful instrument. In its early stages the network may consist of a loose federation of regional computing centers, linked by no more than dial-up lines, and some jointly developed policies, procedures, and minimum facilities. At some later stage, computer - to - computer linkages and additional service nodes may be added, which will provide specialized capabilities for the regional networks. Individual institutions may join the network and have access

to the network on an independent basis, not related to existing regional centers. At a later time, as additional institutions and traffic requirements may justify, a special communications network may become the basis for a national educational and research network.

The overall system economics should make it possible for all institutions to participate in the network. Both the rich and large private or public schools, and the small, less endowed institutions would be able to derive fullest benefits of the networks. Both the "have" and "have-not" schools should be accommodated.

2. USER AND SYSTEM REQUIREMENTS

One of the fundamental requirements for development of any extended computer based networking capability is consideration of the needs and characteristics of the users, for whose benefit the system is being developed. The user requires ease of system access, ease of system operation, and a variety of services which aid him in efficient and productive operation. The user is cost conscious and would like to obtain a maximum of service at minimum cost. Finally, certain basic system performance requirements such as reliability, availability and product quality must be met both from the users' standpoint and from the system operators' and managers' viewpoint.

Network management organizations must be concerned with fulfillment of the user needs and of system requirements, because only if these needs are met will there be continuing use of the networking facilities. We will discuss both in somewhat more detail in the next sections.

2.1 Ease of Access

The sign-on or log-in procedure must be simple, easy to understand and logical. With many different services available on a network, there could arise a proliferation of possibly confusing or conflicting log-in procedures, which would inhibit easy systems access. In order to use network facilities, many administrative arrangements must be understood and learned. User documentation exists in a variety of formats, with different degrees of detail of contents. User assistance may often

not be available when needed. Improvement of uniformity, simplicity of operation and standardization in this area is required.

2.2 Ease of Use and Operation

Once a user has "logged on", operation should be possible without much effort on the users' part. Messages from the system to the user operator, should be unambiguous and should indicate what action is required on the user's part. Commands from the user to the system should also be simple, and system actions depending on these commands should be well documented and easy to find in the documentation.

2.3 One - Point Contact

In order to facilitate easy access, efficient operation, and support of the network user, it would be desirable to have a one point contact, where the user may make arrangements for services, obtain the latest information on types of services, availability and prices, obtain advice and consultation on how to solve operational problems in terms of access procedures, identification, and other details. Here he either would obtain all general purpose documentation required for network operation, or he would learn where and how to obtain special documentation published and distributed elsewhere. Such capability exists today only in a very rudimentary fashion.

Administrative procedures which are required before access to the network can be granted, must be well documented and simple; completion of the access authorization should not take undue time.

2.4 Terminology Problems

The emergence of the new network technology has brought computer technologists, communications engineers, software specialists, educators, and scientists face to face. The technical language used to describe and to specify networks and to measure systems and systems performance reflects this diversity and as a consequence the terminology used today is confusing to say the least. The same word may mean different things in various environments, and the same concept may be known by different names. A logical path is called a link, a connection is an extension of

a link, a synchronization string is called marking, an open connection, may also be considered a closed path, and so on.

2.5 On-Line User Assistance

There are several forms of user assistance, which must be provided. Certain information can be conveniently disseminated "on-line", upon user request, at sign-on or sign-off, or at other times. The format and language of such "system messages" must be unambiguous, clear and easily understandable. Many system messages on existing commercial timesharing systems leave much to be desired in this respect. Types of information which can be handled in this manner may be tutorials regarding systems operation or applications, new product announcements, system changes, documentation changes, or status reports.

While operating, the user should have a capability to know the system status; i.e., the operating conditions of all those parts of the network involved in his operations over which he has control or which affect him. He also should be able to know the service cost so far, or other measurements which are used for accounting purposes such as terminal time or machine time. If errors occur, error messages should be provided, if at all possible, with a guide towards solution of the problem.

Other assistance resources should be developed as part of the overall network development. This would mean human professional assistance in systems analysis, systems programming support, or general consultation in a specialty available at a network resource center.

2.6 Consultation

Human communications are often being neglected in the design of automated information systems. In a national networking capability as it is being considered here, there is great need for human intellectual support to all potential users. Highly individualized assistance may be required by a local user in debugging of programs, additional programming assistance on a contract basis, or special applications such as curriculum development or the interfacing of laboratory minicomputers. These

tasks may be best performed by local talent and may not be national network functions, although some guidelines or policies in this respect may be useful to local computer centers.

Since consultation by its nature is a human communications process, it is best done in direct person-to-person contact, but various "hot-line" arrangements have been successful where a large geographic area has to be covered.

Some of the major regional networks have established the position of "campus coordinator", which performs this function. Off campus they act as "circuit riders", and provide consultation and communications to an area beyond the immediate campus.

2.7 Orientation and Training

Certain orientation and training activities are required periodically for all echelons of all organizations participating in a national networking effort. These may range from short concise briefings on network objectives, network status, or current problem areas to top level managers, to detailed specific courses in operational aspects such as operation of certain terminals, or operational procedures for students, faculty, or administrators. Timing of such efforts is of importance and needs to be considered in the overall planning of introduction of services, or the development of new capabilities.

2.8 Documentation

Documentation in various forms is required for hardware, software and system procedures. It is required for system operations, maintenance, orientation and training, as well as for all management functions.

Documentation may have to be prepared in different formats and with different content for various types of users, such as the expert computer professional, or the casual non-computer oriented administrator or educator, or the junior college student.

Documentation will also vary in level of detail, from general network-wide policy and procedures statements, to details regarding

network access methods, log-in procedure, identification, passwords and emergency procedures.

All publications must meet minimum acceptable standards, as to clarity, content, readability and format. Uniform numbering procedures, and format standards will probably be beneficial on a network wide basis.

System-wide standards will also aid both the mobility of users, throughout the network, and of products.

Various types of documentation pertaining to the network are operations and maintenance manuals, policy and procedures manuals, directories, reference manuals and training documentation. Also there will be required some material for general orientation and public relations purposes.

Experience has shown that documentation problems have been ignored in many cases by management both in the planning process and as part of the operational aspects of networking. Documentation deadlines have been set unrealistically, documentation requirements have been ignored or minimized, and production and distribution problems have been solved on an ad-hoc, post facto basis, to the detriment of both system user and system manager.

2.9 Terminal Design

Terminal design must accommodate all user and system requirements to provide a useful and efficient system, and to provide basic capabilities to the network user. Especially for interactive users, many of the user and system requirements are only approximated by present day terminals, which in the case of teletypewriter types, were designed for different purposes, and in a different technological environment.

Development of requirements for low cost, state-of-the-art terminals is being pursued at this time (9). These efforts are being evaluated as to their impact on the educational process and as to the expected reduction of cost for a student terminal. Positive results of these efforts will enhance networking applications to the educational process.

2.10 User Feedback

Development of interactive processing has given the user a greater capability to influence an ongoing computational or information handling process. This capability of communication between the user and the system can also be used to elicit responses from the user which can provide valuable information to management, on system usage, system performance, and system utility. Such feedback can also be gained as part of the consultation process, where user replies can be translated into new policies and operational procedures.

2.11 Information Control

Users have certain requirements for keeping their files, data and programs restricted to their own use, or they may want to keep usage restricted to persons authorized or licensed by them. There is a need for restricting access to personal records, which may be part of medical, psychological, or social research files. There also is a need to protect unpublished research work from unauthorized access. Users may want to restrict access on a file basis, or on a partial file basis. Various data management systems provide such capabilities, but not all systems are flexible enough to accommodate all user requirements.

2.12 Reliability

Regarding performance requirements, there is a substantial distinction between an experimental timesharing system which is run by a university computer laboratory for internal student experimentation only, and a nation-wide service that serves hundreds or possibly thousands of users. In the former case irregular operation is a nuisance, and while it may inconvenience individuals at times, it can be tolerated, especially if an alternate source for services is not available. A nation-wide network must, however, run on a precise schedule and must be available when scheduled. Technical performance criteria such as mean time between failures and mean time to repair are available for hardware components, and overall systems criteria can be developed for availability and reliability, and must be specified.

System reliability is an important ingredient contributing to user confidence; only a trouble free performance record will insure continuity of use of the system. Another related factor is system stability, which not only insures that the system remains operational within specified operating conditions and operating times, but that the system characteristics remain unaltered. This refers to hardware configuration, software capabilities, and operating procedures. A class of students depending on the system for end-of-term results, must be assured of the continuing stable operation of the network. An educational computer aided instruction program must remain essentially the same, as seen by the user, format and content wise, at least during the school year, to permit consistent measurement of student progress. Researchers must be assured of stability of system languages, operating system programs and routines so that their research may progress, and may be completed within planned time periods.

2.13 Product Quality

Hardware quality control has become a specialized branch of engineering and has made great progress over the years. Software quality control, in contrast, is still in the research stage. Only recently has the problem been addressed in a comprehensive and determined way. In a national network formal mechanisms have to be established for classification of software malfunctions, reporting, evaluating and correcting of errors. Efforts are underway to improve software and program structures to permit location of incorrect program parts, and to localize faults. Related to this are system requirements for software documentation, and software design, to permit programs to operate on dissimilar machines, with minimum of adjustments. A central facility for software quality research and development and test may well prove to be beneficial, and may even become necessary in the network context.

2.14 Network Continuity

The network must be so organized that various pieces can be planned and added at various times based on growth requirements. Bell (10) calls this "dynamic rejuvenation". Older generation machines can be shifted to different system tasks, while new generation machines take

over the tasks of the older machines. Purchased last generation machines may be obtainable at less cost per operation than newer machines, at least for certain classes of problems. Thus, with increased demand for service both machines can remain in operation.

A network should be able to accommodate addition or removal of equipment or system features without subjecting the users to the major transients associated with system configuration changes. Furthermore, elimination of any user node must not affect the rest of the network, as far as operations at other nodes are concerned. Similarly organizational and financial provisions must be made to minimize a crippling loss of revenue, and to provide operational compensating mechanisms to continue service. Technically it is necessary to make provision for assumption of certain network functions by other nodes, to replace those functions performed by the node leaving the network.

2.15 Network Performance Criteria

Various echelons of network management would like to be apprised of the "state of well being" of the network at times when major decisions have to be made. No widely recognized general concepts of network status and performance have been developed yet to suit this need. Some commercial timesharing systems do measure system response time and system capacity respectively in terms of the time required between completion of a user request and the start of a system reply and total number of users, which can access the system stimultaneously, without degrading system response time to unsatisfactory levels. Further work is required to develop meaningful criteria for networks and to have these criteria generally applied by network managers.

2.16 Standards

Interoperation of various regional and campus wide networks requires standards for description of systems operation and performance, standards for system measurements, and standardized evaluation criteria to permit service evaluation and comparisons.

Standards will be required, in the not too distant future, for system command languages, user identification methods and codes, programming languages, file structures, library card catalog formats, and record forms required in network administration (6). Also required is a system-wide scheme of classification for all types of service, for service priorities, and related operational detail and data elements. Uniformity is necessary for accurate system-wide cost determination and billing, as well as for the measurement of network operational characteristics and for network planning.

3. MAJOR CONSTRAINTS ON NETWORKING INNOVATIONS

There are a variety of existing factors which significantly limit or constrain the future development of academic networks, particularly in regard to management approaches. These factors pertain to the "real world", or the environment in which networks are developing and in which networks will continue to exist. We analyze some of the major factors here to show the domain in which realistic management concepts have to be developed. The constraints are primarily of a legal, organizational, economic and political nature.

3.1 Legislative Restrictions

3.1.1 State Legislation

Some states have enacted protective legislation pertaining to state supported information networks. Thus, in Oregon special justification may be required to buy "outside services". In the Oregon State University network "no contract for the purchase of computing services from a commercial source will be consummated without approval ... of the executive department. The request for services must include a statement of examination as to what specific steps were taken to insure that State computing resources are, in fact, not available and that support requirements can only be satisfied by commercial services " (11).

In the State of California, a master plan has been put into effect which creates four data centers specializing in business and services, state colleges, law enforcement, and revenue. Funds for these

centers have been appropriated and are included in the state budget (12).

Both these legislative actions are typical examples of state legislation which directly affects networking. Dependence on state budgets creates rigidities in timing and fund allocations which do not permit system reaction and hardware adaptations to rapidly changing requirements.

3.1.2 Federal Legislation

Another set of laws which impact on computing and networking are those dealing with anti-trust matters. The Sherman Act of 1890 prohibits "contracts, combinations or conspiracies in restraint of trade," and makes it "unlawful to monopolize trade, attempt to monopolize trade or combine or conspire to monopolize trade." The Clayton Act of 1914 makes it unlawful for a seller to discriminate in price between different customers when the effect might be "to substantially lessen competition or tend to create a monopoly". The Clayton Act also prohibits tie in sales or contracts under which commodities are made available only upon the condition that other, different commodities are taken. As with other legislation in such a broad area, effectiveness of the legislation depends greatly on court decisions and the actions of the Justice Department, which is charged with bringing suit against potential offenders. As time goes on, courts have increasingly held, that continuing dominance of an important market is, in itself, grounds for anti-trust action. The term "restraint of trade" has been interpreted as "unreasonable" restraint of trade, but the term "unreasonable" has never been defined. Similarly, monopoly power has been defined as "the power or ability to fix or control prices in a market or ability to exclude competition from a market", but the term "market" has not been defined and there are no simple tests for monopoly power; such as, the percentage of the market held. Legal action against firms which were found guilty of anti-trust law violation usually has tended to strengthen competing firms. Impact of this legialation must be considered by networking organizations and will affect pricing policies, and marketing strategies, especially in areas where unique resources are distributed on a national scale.

Any firm in the United States which offers communications services for sale is considered a public utility and is subject to the regulatory power of the Federal Communications Commission (FCC) under the Communications Act of 1934. In addition, State and local authorities also exercise some regulatory power. There are some networks which provide computing services like the GE, TYMSHARE, or ARPA network. These networks are considered private networks and do not fall under the regulatory powers of the FCC. If they should begin to offer information services which could be considered communications services, they would fall under FCC regulations. In practice, this would mean that they have to apply to the FCC for construction permits, and if authorized, would have to file tariff schedules, describing their price structure and service conditions. Thus, establishment of a general network type communications service would require FCC authorization and be subject to the attendant time delays.

Introduction of teleconferencing capability, in connection with computer networks, may either be interpreted as a general communications capability, in which case it would be subject to government regulation, or it may be interpreted as a specialized service, in which case government regulations would not apply. We must await further developments on this vital issue.

The products and services of the network are partly intellectual products and questions regarding ownership and use rights have to be resolved. Proprietary programs, data, and textual material can under some conditions be protected by the owner under existing copyright, patent, trademark and trade secret legislation. Actual use of products requires agreements and contracts between users, service center resource suppliers and resource creators. Responsibility for content of material, and for application has to be defined in some cases, in terms of warranties or liabilities.

Certain legal bases, differing from state to state, exist for various types of organizations which may be set up as part of the overall network organization; such as, individual ownership, partnerships,

corporations, consortia and cooperative associations.

Legal bases for communications and common carrier tariffs vary between within state, and between interstate operations, and thorough understanding of these factors is required to design optimum communications networks. Legal problems arise also in connection with privacy, controlled access and security of information, data bases and programs.

The rights of authors, resource providers, service centers and users must be protected, as much as their responsibilities must be defined and their adherence to these must be monitored.

There is a need for product protection, so that as a minimum, the owner can prevent use of the product without remuneration. In some cases, the owner may want exclusive control of the use of certain products.

Legislation by municipalities, states, and federal authorities having an impact must be identified and considered.

3.2 Academic Environment

Various network components will exist in the academic environment and network planning must take into account some of the "facts of life" surrounding academic institutions.

Higher education is big business, the capital invested in the educational plants, the annual gross operating income and gifts and endowments are cumulatively in the billions of dollars. One of the most critical functions of governing boards is the continuous raising of money, to augment tuition fees and other income, and to provide for growth and increase of quality of instruction.

The top level manager is a president or chancellor, assisted by vice presidents or vice chancellors. All are selected by the board. Direct responsibility for various functional areas lies with various deans and directors, who direct faculties, finances, libraries, schools and institutes, centers, laboratories, student affairs, community affairs and fund raising. The faculty operates in the environment of tenure, academic freedom, and university tradition. The individual department

head or senior faculty member has an opportunity to establish and develop a research organization in an entrepreneurial fashion which often is quite independent of other departments even if there are possible common goals. This is quite noticeable in the computing environment. Despite the fact that there are central computing centers in many universities, there are also numerous local, small departmental installations, which are grant supported and sometimes are in competition with established computing centers.

Involvement of top level university officials in inter-university cooperative efforts will depend very much on individual personalities. It may be very difficult to achieve, in networking, considering long standing traditions, differing objectives and educational goals of institutions and attitudes of independence which are part of our educational system. There are, however, changes occuring now in academia which indicate a growing desire for cooperation among the highest levels in the academic environment. Inter-university programs are being set up at an increasing rate. Inter-institutional cooperation also exists at departmental levels which have pooled their resources so that courses at different institutions may be taken by students at all participating institutions.

The problem of inter-institutional cooperation can be solved by personal involvement of top level managers in development of common goals and objectives, by personal commitment to these goals and objectives, and by transmitting this commitment to their institutions through effective leadership.

3.3 Economic Constraints

The real crux of the economics of network development and evolution is that large sums of money will be required for additional system hardware, system software, and system management before an economically viable network can be in place and operating.

New computer installations, where required, involve capitalization in the millions of dollars. Participation of existing computing centers and of regional networks in national networking will require

considerable funds for additional functions to be performed by the centers and networks. These functions require additional documentation, maintenance, and other support necessary for network participation.

With consistent inflation, increasing pressures on universities to maintain existing facilities, and the need to accommodate growing enrollments in continuing education and special education courses, university administrations find it increasingly difficult to maintain their computer center budgets at an adequate level. Any additional networking costs must be borne out of existing budgets, which is most difficult to do. At the same time, some government channels for funds are being cut off, so that financing of networking activities presents a real problem and a prime constraint on future development.

In addition the establishment of extended networks may impact on operations of regional networks, just as the establishment of regional networks has had an effect on individual computing centers. Emergence of networking may impact on existing capabilities in several ways. A local computing center may be forced to compete with an emerging regional network for Federal funds, and may lose financial support or key personnel in the process. An existing regional network may be able to provide better services than the local center, and thus may divert customers and revenue from the local facility. Also services on a regional network may be obtainable at lower cost, or under more beneficial conditions, and may thus affect utilization and revenue of local services. These and other factors need to be considered in the developing of academic networking capabilities.

3.4 Government Interfaces

The historical independence of private institutions, and the

separation between state-supported and private schools is being bridged more and more, under the impact of decreasing enrollment in and decreasing financial support of private institutions. To provide needed services without unnecessary duplication has become the order of the day, and 27 states have set up planning boards for higher education. Under Federal educational grant programs, up to 2 billion dollars will no longer be distributed to individual institutions, but will go to state planning boards for allocation to the schools (13). This measure will stimulate creation of new boards where they do not exist and will strengthen existing boards. An additional federal requirement specifies that the state boards must represent private schools as well as public institutions in distribution of federal funds through state agencies. Private college administrators fear that state planning will rob them of their independence. On the other hand, receipt of federal funds through the medium of state planning agencies may solve some of their critical financial problems.

The previous discussion illustrates a tendency towards state planning under Federal sponsorship. Other problems arise as a result of establishment of regional organizations, which may cross municipal or state boundaries. Effects of state law and possible interstate variations in laws regarding networking organizations need to be determined. Details remain to be worked out on a regional and national basis.

3.5 Networking Trends

The recent history of computing networks shows a trend towards regional centralization of computing services. Individual centers at various campuses have exploited communications and computer technologies and have provided campus-wide, university-wide, or regional computing services from a central facility. This has been effected under Federal sponsorship, as well as with state support. Possible development of a national networking capability may build on this trend. Linking of some of the present regional centers may be one avenue of a natural evolution, in the desire to extend services on an equitable basis to a wider audience, throughout the country. Another possibility would be for

independent service providers to compete with existing networks and service providers. Several steps are possible here:

1. Further extension of existing regional and local centers, together with establishment of more regional nets to serve a national clientele.

2. Linking of existing regional centers, to serve a national clientele, without a central facility.

3. Independent development of new national centers for resources and service distribution, linked to regional networks.

4. Independent national resource centers, available only to existing local computing centers or to individuals.

Case 1 would represent an interim solution. It would extend capabilities of regional centers, beyond their present reach, possibly over the extent of the whole country, it would not, however, provide linkage to other network systems. This may be likened to a group of completely independent airline reservation systems covering the country.

Case 2 would be illustrated by linking existing regional centers such as the TUCC network in North Carolina, the MERIT network in Michigan and the California state network to provide additional capability for all three networks.

Case 3 is best illustrated by the emergence of the National Crime Information Center (which provides information to a central facility from various state networks). As of 1970, about 20 state networks had direct access to the central facility. It is planned that eventually all 50 states will have state-wide computerized law enforcement systems, which will be linked to the central facility.

Case 4 would occur if these resource centers develop their own communications linkages, which would be accessible to any local computing center or user node if desired.

In the long run it appears desirable to develop competitive capabilities, which will favor the user by helping in reduction of prices for comparable services, by improvement of service quality and service availability.

In the case where local centers also handle distant products, some motivation will have to be provided to the local center to handle "foreign" products. These may be:

1. Financial rewards, in terms of service charges, for handling of outside products.
2. Motivation to provide "public service" to the academic community.
3. User demand for augmentation of local service.
4. Personal or political reasons for providing service.

In the case of the monopoly situation, the user will have little choice and will have to adjust himself to whatever service may be offered if it is usable and if he is willing to pay the price.

We thus recognize that existing regional networks are powerful contributors to a growing national networking capability and that their existence must be taken as given. Similarly their experiences and know-how provide a good start-off point for extension of services to a wider market, and to new types of products.

4. CRITICAL ISSUES FOR NETWORKING MANAGEMENT

In the previous discussion we have outlined the initial considerations for broader, academic networking, and have sketched the scope and possible content of such capabilities. We now briefly review some of the viewpoints, which have been expressed in recent publications, concerning what generically are called "network management problems."

4.1 Management Problems as Mirrored in the Literature

Stefferud, for example, lists the following specific issues, which should be resolved in order to share computer resources (14): "User/supplier agreements for the exchange of services over the network; controls to protect and regulate competition among suppliers and users; policies for decisions to add computer capability to the network; establishment of responsibility for allocation of network resources, with or without congestion; and ways to buffer users from each other, so they can suballocate their resources within their own areas of responsibility."

Similarly, Norris raises the following questions (15): Who should manage the network? Who should make policies and what should these be? What should the membership policies be? What should be the relationships among members, regional or disciplinary subnets, and the national network? What kind of standards are needed regarding priorities, security, and technical compatibility? How do we ensure the effective and efficient operation of the network now and in the future?

Haas (16) divides administrative questions into three catagories: technical, policy and network relationships to institutional goals and resources. As a prime technical problem he cites the need of management and of administrators for technical assistance in comparison of service offerings. Specific service performance measures and criteria are required for such items as: stability, network capacity, network flexibility, network charges, service growth, network reliability, data reliability, ease of use, and security. He further identifies policy type problems; such as, the protection of interest of the participating institutions, assurance of economic and effective satisfaction of service needs, and need of having influence on the policy making mechanisms by the universities. Finally at the level of relationships of the network with the institutional goals and resources, he points out the importance of understanding and accommodating the relationship between the instructional goals of the participating institutions and the network.

Stefferud (14) draws several general conclusions: 1. Large scale pooling of computer resources into networks threatens to weaken the accountability relationships of many administrators and managers of our mission oriented activities -- unless we adjust our organizational structures to counter this effect. 2. Computer networks are creating large potential marketplaces, which need to be carefully managed, if they are to achieve their potential; it is not yet clear who will develop and manage this marketplace. 3. Networking may force a restructuring of traditional marketing methods. Service vendors will have to find new ways to package their services. 4. The impact of networks on management will be felt at all levels, as a conflict between mission oriented and resource oriented control.

All these issues reduce to three basic areas of management concern: planning, organization and control. An essential linkage between these broad areas, extending in the time and space domain, is provided by communications, throughout and between all organizations involved, which provide the "right information", to the "right people", at the "right time", in the "right amount".

The critical issues addressed next are concerned with development of plans, goals and objectives, implementation of marketing functions, organizational problems and the financing of networking operations.

4.2 Critical Issues

4.2.1 Planning and Policy Development

There is little experience in the educational field with a truly national network. To evolve toward national networking capabilities, of an operational as opposed to experimental form, will require a set of objectives to provide uniform direction for networking development. Lack of such objectives has so far prevented development of nationally-oriented operational concepts, and thus is one of the major problems to be researched.

Such objectives would be concerned with the types of services to be provided, the number and types of users to be included, and some of the ground rules pertaining to a flexible network, such as types of financial support expected, general type of organization, and envisioned goals for method of operation. Objectives would also be concerned with broad statements on measurement activities, and on methods of assessing how well the objectives have been achieved. The network objectives, and the network management objectives constitute a basis for further development of networking plans at all levels.

4.2.2 Weakness in Marketing of Products and Services

Development of viable networking operations depends on needs for the services, availability of suitable products and services, and distribution mechanisms for making the services available to the users at reasonable costs, with suitable quality, and under market conditions to sustain continued operation of service delivery.

In the past, there has been little need for the individual academic software developer to consider implications of a national market for his products. Even if he would recognize that need, he may as a creative scientist not want to engage in what easily could be a full-time job of tracking down potential users, demonstrating advantages of the package, and "selling" his product. Furthermore, the product itself in most cases is not in a condition to be "marketed" nation-wide. Even if good documentation were available, -- and no definitive rules exist today on what constitutes "good" program documentation, -- that would not be enough. In addition, there would be a need for users' manuals, sales tools, guidelines on pricing, and references to related literature, applications, and other documentation. All of this material must be prepared to appeal to a large particular segment of the market. Market analyses must be made to determine applicability of existing products or need for further development. In addition, consideration must be given to protection of the package, in terms of copyright, trademark or patent laws. Prices will have to be set and conditions for use have to be determined and made known to potential users, or intermediaries, who may want to distribute the material. All in all, the marketing of software and network products requires specialized skills, knowledge and time, which at present are neither available nor can they easily be obtained by developers of software. It appears that lack of marketing effort is one of the major factors standing between the creators of service oriented products and the users of such products.

Stefferud (14) and Hootman (17) mention this problem as part of their discussion of the "brokerage function". Hootman quotes the classical definition of brokerage: "one who for a commission or fee brings parties together and assists in negotiating contracts between them". It is not yet clear by whom and where the marketing and brokerage functions should be performed. If automated facilities are available, these functions should have access to the network, and new methods of marketing and of brokerage are undoubtedly in the offing. Some authors speak of the "electronic market place", and both marketing and brokerage organizations might become direct participants in network operations, which

would affect the network measurement schemes, accounting structures, and billing systems.

A networking capability does therefore present a new form of marketplace, where buyers and sellers can come together, make agreements on what and how much is needed, and what the compensation for the services will be.

4.2.3 Organizational Problems

As the complexity of networking operations extends beyond the individual campus or regional network, organizational interactions multiply. Assumption of responsibility for local computational activities by regional centers raises questions as to possible elimination of jobs, consolidation of functions, and reorganization. Computing activities are managed by a "director of computing activities", rather than by the manager of the local computing center. Questions arise on responsibility for support functions, documentation, consulting and maintenance. As regional centers begin extending their services into other jurisdictions, statutory and legal barriers to communications appear in terms of what can and cannot be done by a local manager. Finally, the human element, personal attitudes, needs, capabilities, as well as interpersonal relationships enter into organization structures. In the development of a national networking capability, as hierarchies of organizations begin to work with each other, redundancies will occur, as well as communication gaps.

Questions such as: who will develop networking goals and policies? who will direct the effort? who will do the work and what will happen at the local service delivery level? must be investigated, answered and documented in terms of a networking organization. We will consider some of the alternatives and make recommendations in the next sections of this study.

4.2.4 Financing

The contemplated NSF Networking for Science program envisions "permitting institutions from every sector of our society to participate

at minimum cost and without Federal subvention"(18). This requirement places heavy responsibilities on the planners and implementors of networking capabilities. Heavy capital investments may be required for the start-up of new resource centers. If operating expenses are to be paid out of current computing budgets, some adjustments have to be made to provide networking funds. Development of equitable user charges must involve development of some general notions related to inter-institutional accounting, charging, and billing schemes. Limited financial resources and the possibility of financial losses in competitive service will require clear objectives and emphasis on economic evaluation to ensure highest payoff commensurate with the objectives. Some of the suggested demonstration tasks will address the financial and economic side of the networking effort.

5. OTHER SIGNIFICANT MANAGEMENT CONCERNS

Other significant functions are concerned with operations management, resource management, and user and support management. Some of the areas of concern are network control, service agreements, information control, accounting, costing and pricing, network measurement, standardization, critical size of network nodes, and resource allocation.

5.1 Network Control

A multi-node network requires special provisions for monitoring of the technical facilities to guarantee reliable network operation. An example is the network control center, which has been implemented on the ARPANET (19). A small dedicated computer receives reports from every interface message processor on the net. Traffic summaries, status and trouble reports are generated from these reports. Line errors, storage counts in excess of capability, occurrences of reloading from the net, and checksum errors are logged. Detailed and summary logs of service center computer and line traffic are produced. The Network Control Center serves as a coordinating point for network monitoring, testing and diagnosing of troubles. Lines throughout the network can be switched from the center to permit isolation of line difficulties. Personnel from the center coordinate all debugging, maintenance, repair and modification

of equipment. The computer capability is presently oriented towards statistical measurement and troubleshooting. Baran (20) has proposed an on-line monitoring capability for a control center, which introduces human judgment control in connection with displays of both the availability of communications resources and the demand for service. In addition, some devices for suballocation of resources would be developed. The controller would observe the communications capacity "on line" i.e., the present allocation and the size of the individual demand. A resource display would indicate system status, resource availability, number of jobs in queue, and the communications status. Standardized measures for allocated resources and for demand for various functions, used throughout the network, could provide useful network management information for operations, planning and charging purposes. A true network control capability, serving the network as defined here, has yet to be conceptualized. Eventual implementation would provide a powerful tool for network management.

5.2 Service Agreements

Formal agreements will be required between the user or customer of network services and the service provider. If there is a wholesaler acting as service provider, agreements are in turn required between local distributor and wholesaler and between wholesaler and the service provider.

Such an agreement, as a minimum, should be concerned with the following service conditions:

- amount of service available
- service time periods
- service quality guaranteed
- type of service
- turnaround times
- cost per service unit and type of service
- available security and privacy categories
- user responsibilities
- billing and payment conditions and procedures

User responsibilities with regard to authorship, copyright, patents, trademarks, and proprietary software must be established, and agreed on by the appropriate parties. Similarly, legally binding system performance criteria, which are measurable by the user and service provider, would be made part of such agreements to provide quality service to the users.

5.3 Information Control

Policies are required on what types of information should be included in a network data base which in turn requires some taxonomy of products as seen from the producer, distributor and user standpoints.

One might want to stipulate that all information and data pertaining to research and educational objectives ought to be available to all authorized users on a permissive basis. Information excluded from this blanket authority must be identified, as for instance administrative data, student and health records, unpublished research and the like.

After users are authorized to enter the system, certain information will be restricted to certain individuals only. This type of information includes personal records, pertaining to named individuals in connection with psychological or medical research, health or personnel records, etc. In an expanded network a rather complex access control scheme needs to be developed, with several levels of access control, and various types of control. Security is becoming increasingly important in terms of protection of installation, software and contents of files stored in computer systems. Willis provides a good overview of the problem (21). The physical hardware must be located in a safe place; physical protection, access limitation, fire protection for machines and storage devices, and personal security are mandatory. Software is protected by access limitation based on personal identifiers or by organizational affiliation, personnel level, by file or subfile, by activity or by functional limitations such as "read only", "read and write", "update", or "execute only". Threat monitoring devices and methods are available. Protection of the operating system is especially important. Finally protection against malfunctioning is partially

achieved by good documentation and sound operational procedures.

5.4 Accounting

In a regional or national network transfer of usage measurements, service charges, and other operational and financial data is a requirement for equalization of services and monies exchanged between centers. DeGrasse (7) has pointed out that major difficulties exist in the University environment in connection with uniformity of financial accounting procedures. Due to existing procedures, actual computing costs cannot be determined and different accounting systems at different schools do not represent the same things. This makes cost comparisons meaningless. The Pierce Panel (4) recommended that schools standardize cost accounting for computing. One possible way for doing this would be to have regional centers use standardized practices without forcing the individual universities to change their accounting methods. A nation-wide system in turn could evolve from standardization of regional center methods.

In addition to financial accounting, there is a need for usage accounting; i.e., collection and processing of data on both use of system facilities; such as, processors or processor components, communications lines, terminals as well as various products. If we consider the network as an electronic "marketplace" (17), records must be kept in considerable detail on "who" uses "what", "where", "for how long", at "what price". The following detail must be available for each network transaction:

user identification
user location
institution and subdivision
service used and measure of service
time of use and time interval
to whom service should be charged (charge number)
project number

These accounting data serve many purposes such as cost determination, cost allocation to accounts, billing and collection of service charges.

Additional questions to be answered are related to "how well" the system has performed. This requires a set of efficiency criteria and additional measurements to provide data for computation of operational effectiveness. For planning purposes, one wants to know what measurements must be taken in order to provide projections on future system use.

5.5 Evaluation Criteria and Methodology

Evaluation has two aspects which need to be integrated into network planning, network operations, and network management: an assessment of the effectiveness of the system in achieving its objectives and an ability to use measured results in improving operations through system modification.

A distinction is made between efficiency of operations and effectiveness. The latter is concerned with how well the goals are achieved while the former is more concerned with the internal system operations. A very efficient network can be completely ineffective in achieving its stated goals. A further distinction can be made between impact evaluation and strategy evaluation (22). In impact evaluation overall effectiveness of the network is assessed in meeting its objectives. Appropriate output variables have to be defined and measured and appropriate comparison groups are used to measure results. In strategy evaluation, stress is on evaluation of the method of achieving goals. Here appropriate input, output, process and environmental variables are defined and compared usually on the basis of analytic models. Some means of user feedback need to be built into the network system so that impact analysis can be carried out. Results will influence further system and product development and will enhance overall system effectiveness.

With an automated network it should easily be possible to provide for handling of messages for user feedback to the system. This could be in response to system queries or provision could be made to handle messages sent by the users as required by his particular situation. Some aspects of system operations can be monitored now, such as, loading of various hardware components, utilization of certain software packages, turnaround times, storage capacity utilization, and many other

technical factors. Certain subjective factors regarding utility of applications to the user could be made the basis for evaluation of network impact and could lead to improvement of quality and of delivery systems performance.

Determination of utility of services will require collection of data on at least the following items:

amount of service delay (time between request for service completion and completion of service transaction),

amount of time required for service completion,

user's interest profile and service requirement,

some measure of his satisfaction or dissatisfaction of service.

5.6 Standardization

Implementation of widely common accounting procedures supported by automated procedures, requires a high degree of standardization of not only data elements, which can be generated, transmitted, and used in automated systems, but of definitions of these data elements, and of associated procedures. Examples are identification of individual users, network centers, individual network subsystems, locations, types of service, types of priority, types of authorization, types of programs or jobs. Network management at all levels will be concerned with establishment of policies regarding standards, establishment of mechanisms to create these standards, and with implementation and followup of the use of appropriate procedures. Care must be exercised to avoid "standardization for standardization's sake".

5.7 Cost Determination

Costs which must be taken into account are identified by Davis (23): Costs of intellectual effort required by customer, producer, maintenance, support; equipment costs required for customer, production, maintenance and support; manpower costs, required by customer, producer, maintenance distribution, design, development, test and control.

Additional costs derive from other services; such as, common carrier costs. Also included in the overall cost picture are expenses which pertain directly to becoming attached to the network; such as, major equipment costs, initial local software costs, and other initial capital expenses. Another part of the cost picture are continuing recurring costs; such as are required for operation, liaison, maintenance, documentation and management.

In some regional and national networks the communications costs are borne by the customer. This penalizes remote users. A more equitable means of cost distribution would be to distribute the total network cost over all users. Three methods are in use: Allocation on an:

1. equal basis; i.e., each of participants pays 1/n of the total communication cost.
2. on a usage basis; i.e., users pay an amount proportional to their time of usage during a basic time.
3. on a straight time basis.

5.8 Pricing

Pricing for computing network services is another problem area. This subject has been addressed by Hootman (24) who states five principles of pricing of computer services. Prices may be set based on:

1. cost
2. competitive alternatives
3. "what the market will bear"
4. all of the above
5. none of the above ("seat of the pants plan")

He points out that the last point seems to be the winning factor, although competition is a runner-up. Basing of price on cost has been difficult because of the difficulty of determination of system over-head or utilization. Hootman also lists five pricing "principles" which are relevant here:

The first he calls principle of resource utilization. The service supplier has a limited capacity of resources and must price its services such that a "reasonable load" will generate "sufficient revenue".

The second principle is that of user control. The user certainly can be charged for resources under his direct control. It is not clear how to accurately measure the overhead, and how to charge the user for this overhead. The third principle is one of demurrage: a user may be charged for resources he is not using directly, because the resource may not be charged to another user; such as, a dedicated port. Fourthly, there is the principle of "understandability" which states that the user ought to be able to fully understand the pricing scheme so it may be used in planning and estimating. A final principle is that of "differentiation", where every vendor provides slight service differences as compared to the competitor's services, to build his market, compete and hold his customers. Hootman concludes that further progress must be made in cost analysis, logging capability, and details in overall system accounting and measurement.

There are two limits which bound prices charges for services. Minimum price charged for a particular service could be the cost incurred in providing this service, plus either a reasonable profit, or at least an overhead charge which would cover all additional costs not directly attributable to the particular service provision; such as, required system changes or capital expansion. Maximum price for the same service would be based on the utility of the service to the user. In a monopoly situation, the user will pay what the market will bear, if the service provided is useful. Today's prices are often based on the monopoly case and the user pays the price. Introduction of competition will reduce prices, as a natural consequence of the action of the market, in response to the law of supply and demand.

5.9 Charging Algorithms

Several methods have been used to charge users for services. In block scheduling the user obtains use of the service for a fixed time and pays on a flat fee basis.

In metered services, computer access and communications use are metered on a "connect" or "holding time" basis. CPU time, storage space, connect time, and other charges in addition to overhead charge

are made. Additional charges accruing to the customer may be terminal, modem and line rental if these charges are not included by the service provider.

There is a question how far one should go in development of sophistication of charging algorithms, which can be handled by a computer. Individual centers will undoubtedly work out their own methods.

5.10 Resource Allocation and Rationing

There will never be enough resources to satisfy all users at all times. Some rationing schemes will have to be devised. Thus priorities may be established to prefer scientific users over administrative users or faculty over graduate students. Debugging runs may have priority over production runs. All these schemes have the characteristic of inflexibility. Some scheme should be available to make exceptions. To solve this kind of problem, a method is required which evaluates the degree of desire of a user to get access to a specific resource. This is achieved by requiring some payment for the services. This payment may be in time, as in a waiting line for first-come first-served common terminal or in money, either real or inter-departmental funds transfer. Given a certain price, some rationing will take place. The higher the prices, the less a user with a limited budget will be able to spend per unit of service. If the price is too high, no services will be bought. If the price is too low, the rationing process will fail and the services will saturate. There is an advantage to using money over the waiting time scheme. In the money case, resources are exchanged between user and supplier. In the waiting-time case, the waiting time is lost to both user and supplier. In the money transfer case, no resources are expended or consumed, they are just transferred from user to supplier.

5.11 Royalties and Copyright

One might ask where the various network products might come from and what the incentives might be to create these products. One powerful stimulant is pride of authorship. Another incentive is a monetary reward. Several related precedents exist in the field of publishing. Thompson (25) has pointed out that the Federal West German Government has recently

amended its copyright law to provide a reward to an author, every time one of his books is withdrawn from a public library, and Thompson also mentioned the performance right, which as a sub-concept of the copyright law, provides for royalties to the author and composer of musical selections each time the selection is performed in public. In the case of a computer network "need to prohibit illicit copying is lessened, but the reward to the creator of software is not diminished". This notion might become a powerful stimulus for potential contributors to networks.

Authors would be charged a storage fee for their products and users would pay royalties, in addition to communications charges, machine usage charges, and charges for services, other system support and overhead.

The General Electric Company uses a royalty compensation scheme and provides two classes of royalty recipients: those whose material contributes significantly to the general value of the system and is advertised by GE and those whom GE permits to offer their services on the network, which, however, are not advertised. Such a scheme affects not only the billing system but the resource information announcements and the "advertising schemes used".

5.12 Critical Mass of Small Service Centers

Another difficulty, which has to be faced by those concerned with management of networks, is the need for a minimum size organization and physical plant capability. Some of the smaller centers are limited in financial capability, hardware, and also in capabilities of personnel. They do not possess the diversity of talents which are required to support systems software and to support many sophisticated users with a variety of applications and applications related problems. A secondary effect is the inability of such a center to attract and to hold competent staff. Senior, experienced systems personnel gravitate towards the larger centers and the larger machines where work tends to be more interesting and the professional challenges - and probably salaries - appear to be greater.

6. ORGANIZATIONAL ALTERNATIVES

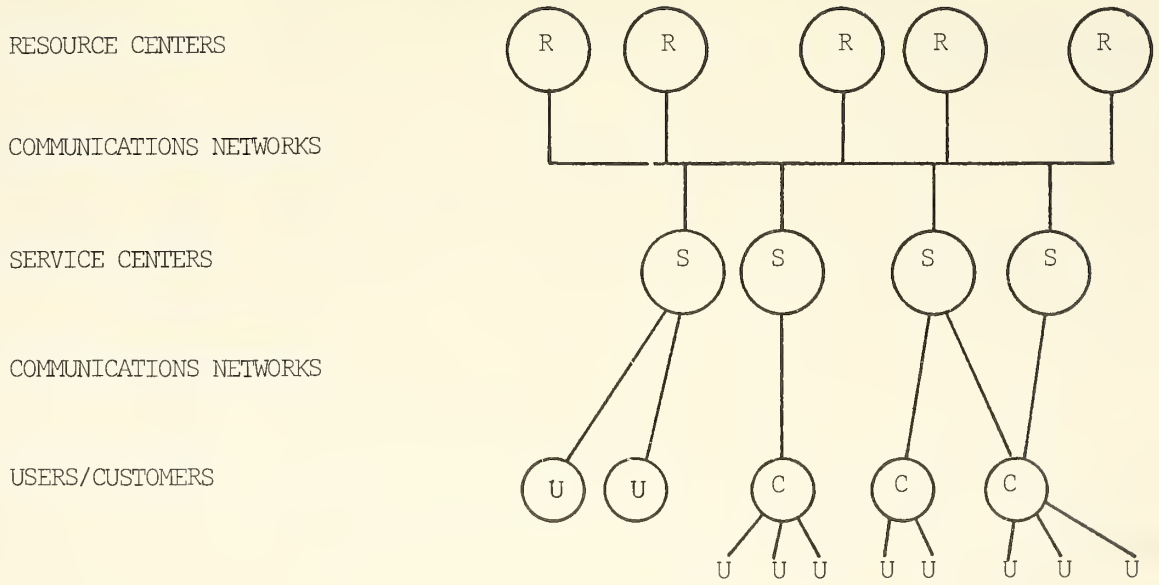
6.1 Network Organization

Network organization refers to the establishment of various working relationships between individuals, suborganizations, and organizations in support of achieving the networking objectives.

There are at least three major viewpoints which determine an organizational representation: (1) The organization structure, which symbolizes communications relationships, a power and authority structure, and a system of work flow and functional processes. (2) Another viewpoint focuses on the organizational tools, which are information processing devices in the broadest sense. This refers to the various communications media used by the network organization, as well as to electronic, mechanical or human information processors. (3) A third viewpoint considers the human elements and deals with the individuals, their attitudes, needs, capabilities and inter-personal relationships. All three viewpoints must be considered in determination of organization structures.

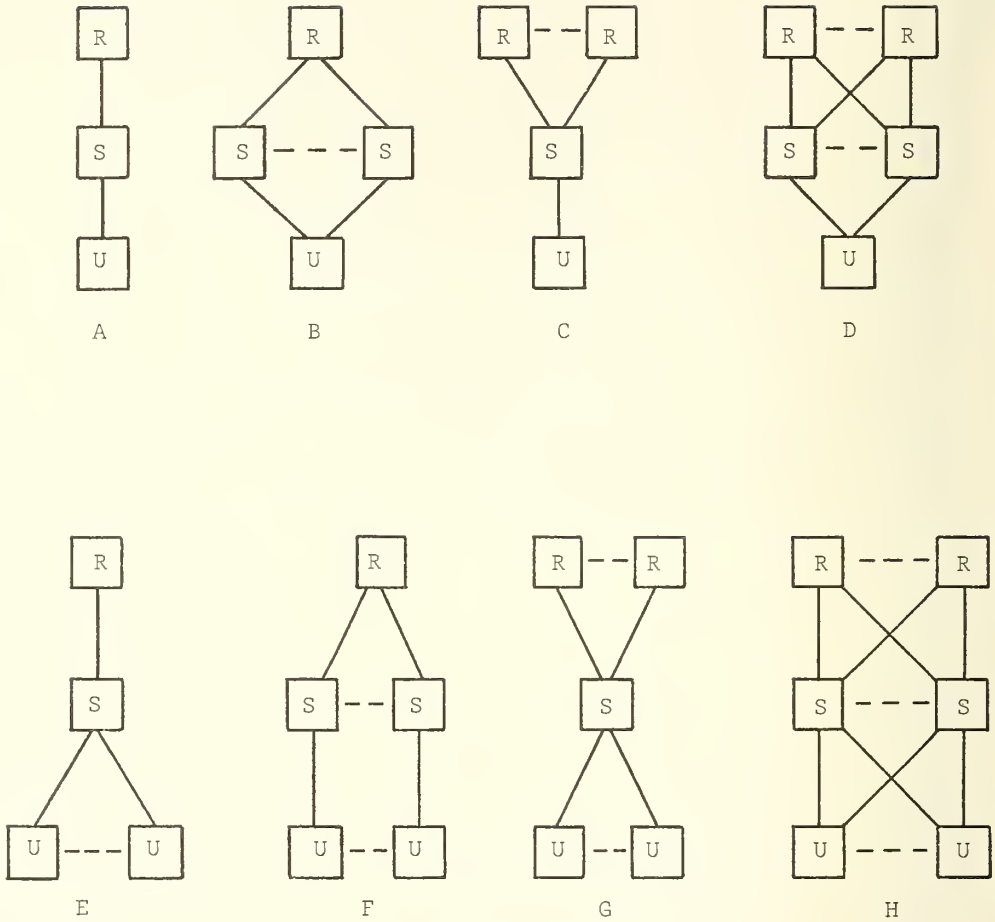
6.1.1 Structuring of Network Nodes

The organization of network management will depend to a great extent on the network itself or the grouping of networks to be managed. We wish to expand on Figure 1 and develop several typical network structures which illustrate problem areas which must be handled by network management. Figure 2 shows an overall scheme of various resource centers, service centers, and user nodes linked by communications networks. For the sake of argument, we consider the simplest combination, one user, one service center and one resource center, Figure 3A. This case is similar to the free standing computer center and no particular problems arise from the network configuration. If we allow existence of several service centers, Figure 3B, and if the services provided are roughly equal, the user will have a choice between several centers, while the one resource center will have to serve several service centers. User choice will introduce an element of competition into service provision.



MULTIPLE RESOURCE AND SERVICE NODES

FIG. 2



USER-RESOURCE RELATIONSHIPS

FIG. 3

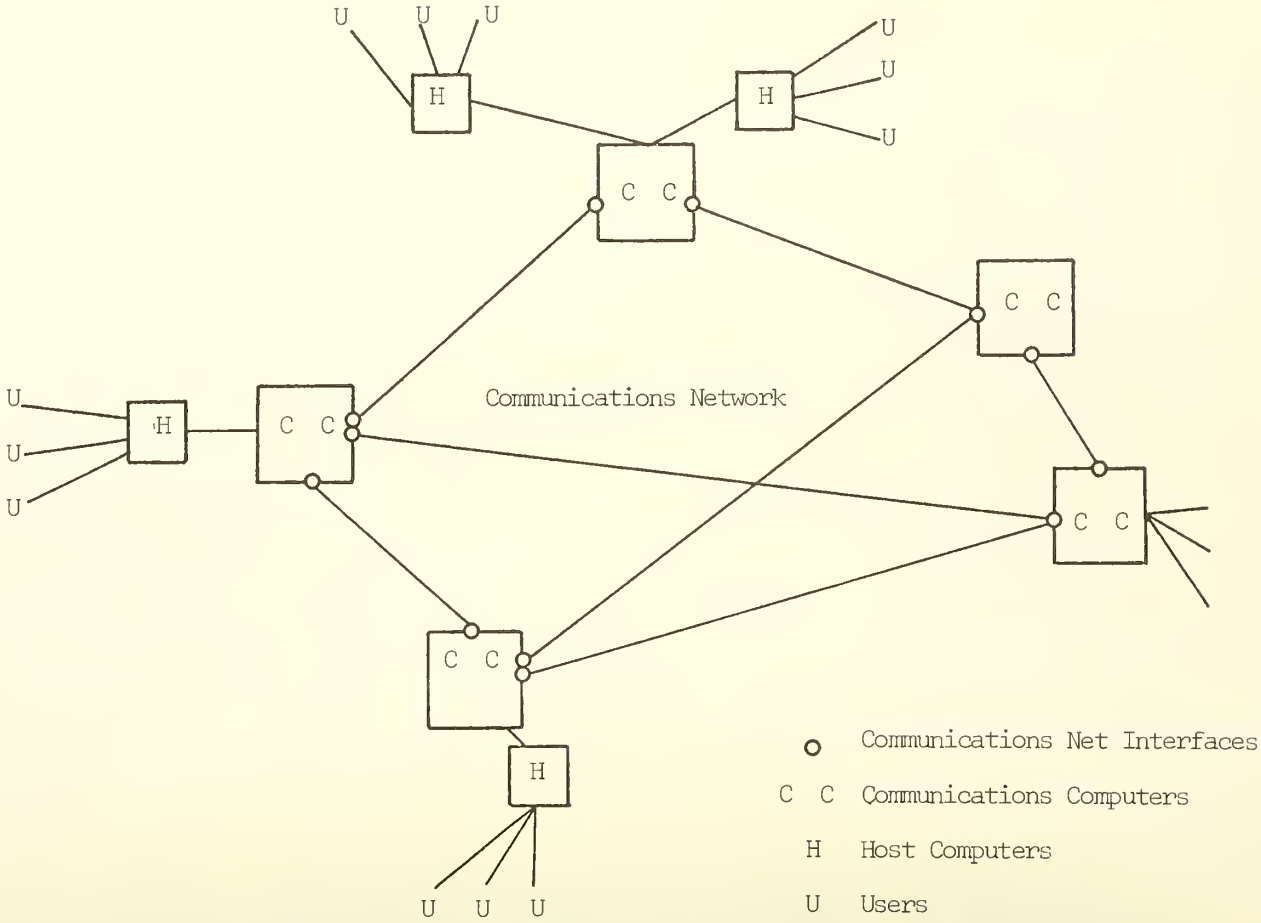
At the same time, needs of several service centers must be accommodated and decisions on resource allocation have to be made at the resource level. Similar considerations apply in Figure 3C for the relations of several resource centers with one service center.

If we now add many users to the same configurations, we multiply the possibilities for competition; i.e., user choices of service, and also needs for resource allocation decisions, where many servers accommodate one user. In the most general case, many users are served by many servers and many resource centers. The diagrams in Figure 3 illustrate the network complexities which will arise as equivalent services are developed, and as products and services are increasingly diversified and standardized. As the network increases in complexity, new demands are made on product description, specification, and measurement. New criteria will be developed by the user for choice of services based on price, availability and the other factors outlined above. Also new methods for allocation of resources will be developed by suppliers at the resource level and at the service center level. This increased complexity will put new demands on all aspects of network management which is concerned with resource center, service center and user operations, and support.

Finally another dimension of complexity will be added by the emergence of new types of communications networks. They may or may not be government regulated, they will, however, operate either in a monopoly or competitive monopoly situation. This will add additional requirements for communications management.

6.1.2 Ownership and Organization of Network

It is necessary to consider ownership relationships in connection with the network, as another aspect of the alternate organizational patterns which we have discussed before. Figure 4 shows a stylized network, containing, moving from the inside out: a communications network with network interfaces, a series of communications computers, C C, a set of host computers, and a group of user installations U.



NETWORK OWNERSHIP RELATIONSHIPS
FIG. 4.

In the simplest case we might consider a large organization, which has its own private communications system and which owns all interfaces, communications computers, network facilities, host computers and user installations. Some industrial organizations, or special purpose networks approach this situation, although many of the communications networks are leased lines obtained from a common carrier.

In the ARPANET situation, the communications network consists of leased lines assigned to the ARPA organization. ARPA also owns the communications computers, called interface message processors (IMP). The IMPS physically are at or near the HOST location, but the HOST is owned by the HOST sponsoring organization. Similarly user terminals are owned or leased by the user organization which may or may not be the same as the HOST organization.

Ownership may be even further diversified, in a case where the communications network, the communications computers, the host computers and the terminal facilities all have different owners. Using a model of concentric rings to denote ownership borders, we can in this case have radial diversification of ownership, between one and four owners. Similarly for any one type of facility, like the communications network, the communications processors, the host computers, and the terminal installation, there may be different owners for similar types of equipment or facilities. Communications network ownership may diversify as time goes on and competition among common carrier system may become a reality. Several applications for certification as common carrier are on file with the Federal Communications Commission at this time, and it is likely that there will be a variety of data carriers with competing and possibly differing rate structures in the not too distant future. Similarly the installation, maintenance and development of network interfaces may become a commercial venture, or may become of interest to an organization especially created for that purpose possibly on a cooperative basis. Thus, a group of network interface companies may spring up whose sole purpose would be to provide communications interface services, independent of applications and independent of the communications network itself. Finally, in the user area, there might be demand for special

purpose terminal facilities, as they have already been developed for the airline industry, retail sales, securities information handling, and other applications. These might be leased to users by their owners who would provide attendant services, maintenance, and training.

From the user's viewpoint, a proliferation of owners may increase total operational cost and his proportional cost, since there would undoubtedly be a hierarchy of overhead charges, which eventually must be reflected in user charges. On the other hand, there would be increased competition, which may help to improve service quality and the variety of services offered.

From a total management standpoint, proliferation of ownership will increase organizational complexity, which, in turn, will lead to increased complexity of management communications, of transfer of funds, to increase in operating expenses, and increased difficulties of control and coordination.

From the users standpoint, if a multiplicity of owners will be involved in service delivery, an important point in system design will be to provide single point user contact and to simplify inter-organizational procedures so that they do not present an undue burden for the user of services.

In the further development of networks and of network management concepts, it is important that development be guided in a direction which will provide the proper balance between central ownership of network facilities, and too great a diversification, which might lead to overcomplexity and inefficiencies of the overall service delivery.

So far, we have been concerned with ownership of facilities. Another important facet of network operations are the products and resources which permit provision of services. Here there again is a great variety of types of ownership. Data, programs, applications packages may remain the property of the creator, in which case royalties or fees will have to be paid to him. He may want to sell various products, in which case the new owner will have property rights, and will be able to exploit

his products commercially. Again charging methods, pricing mechanisms, and measurement techniques will have to be worked out and the network "marketplace" will have its impact on network services evolution. Again management planning must be conscious of the conflict between user needs for minimum cost, maximum quality and reliability and between needs for centralization to eliminate redundancy, wasted effort, and reduction of operating costs and capital investment.

Relationships based on major missions and ownership of network nodes are two viewpoints which characterize the network structure. Management of this network requires a structuring based on several levels, which will be discussed in the next section.

6.1.3 Major Levels of Networking Management (Vertical Structuring)

In order to establish guidelines which are useful in formation of networking management organizations, several major functional levels are defined. The distinguishing characteristics are basic funding and independence of control of the organizational level. The four main functional levels are: policy development, executive direction, operations management, and service delivery.

The policy level group includes representation from all institutions involved in the networking arrangement. This will include resource providers, service centers, distributors and user representatives from the executive level.

While at the policy level there must be broad representation of all interested parties, executive direction requires one central directive force, here called the director of networking, supported by a staff immediately reporting to the director.

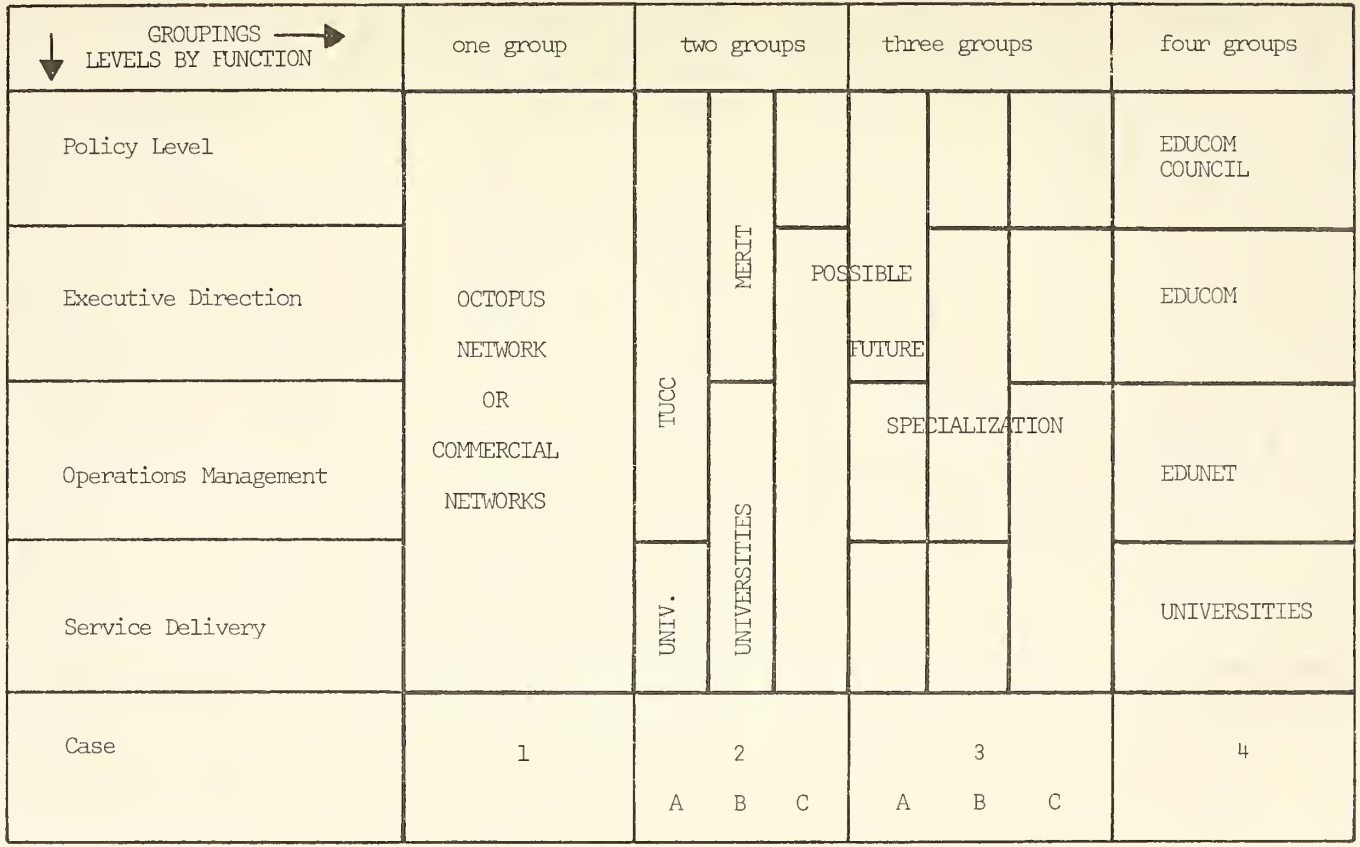
Management of network operations requires considerable size and diversity of organization, depending on the number of nodes, and the functions performed. Part of network operations management can be envisioned as being organizationally close or physically close to the director's office. Another part will be located both physically and

organizationally at a resource node, service node, or at a location determined by geographic, political, or other needs. For the various functions the balance between centralized and decentralized organization must be determined on the basis of not only functional and economic requirements, but also on grounds of personal preference, political expediency and many other intangible factors. Finally the service delivery group will center around the regional or campus network node. Each academic institution has its own policies, education and research objectives, political, and cultural environment, traditions and constraints. A viable networking capability must have demonstrated its utility to the university, and should interfere not at all, or only minimally, with the internal workings of the institution it serves. At the same time, it must provide services to the university, which the university alone could not provide for technical, personnel, or financial reasons.

These four major levels of organization may be grouped in different ways which lead to alternate organizational management arrangements. Figure 5 illustrates these relationships, by analogy with some existing networks.

In the simplest case there is close coupling between the four levels and top level policies can directly influence the service delivery (case 1) by use of authority and financial control. This organization is typical of a commercial timesharing service; such as, TYMSHARE, CYBERNET, or the GENERAL ELECTRIC Timesharing system. This is also typical for service organizations owned, or part of one major organization; such as, the OCTOPUS system (26). Since university prerogatives and individuality must be carefully protected, this case appears unsuitable for application here, where the network management organizations must by definition be independent of the organization of the individual institutions it serves.

The next case shows a two-layer type organization. Depending on the interests and capabilities of the service delivery organization, which is part of the university if a computing center exists, and which may become part of the university if a service center is to be



Network Management Level Groupings and Illustrative Cases

FIG. 5

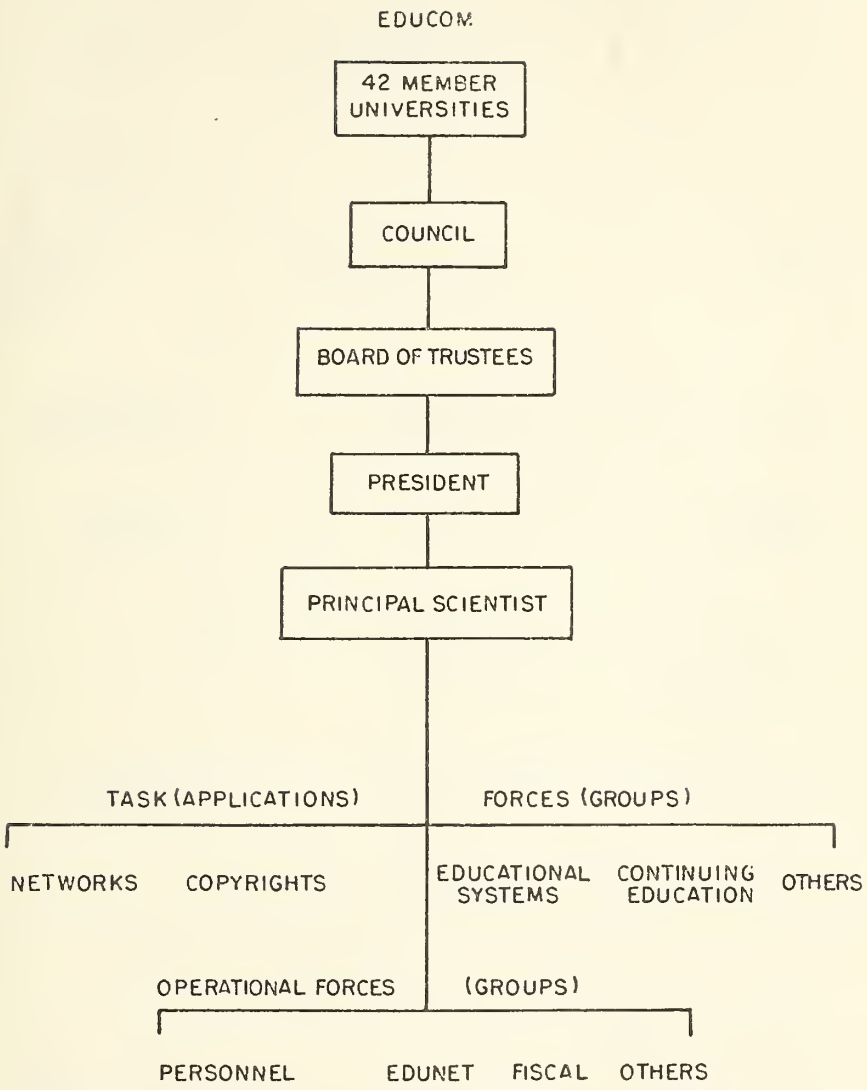
established, the institution may also carry the bulk of operations management, (case 2B), or include top level direction (case 2C). In the latter case, only the policy level group remains outside of the institutional organization. Similarities may be established between cases 2A and the TUCC System, and case 2B and the MERIT system. In the case of TUCC centralized operations management is part of the headquarters operation. In the case of MERIT, each university carries the burden of operational control and management, although network management is still responsible for communications facilities.

As the organization becomes more highly structured, various organization groupings can be established as shown in case 3. Here case 3C symbolizes decentralized operations, where the bulk of operations management is carried by the individual institutions, but centralized top level direction and policy development, are carried out by separate organizations.

Finally in case 4, there are four organizational groupings, each concerned with one of the primary functions. An example of this type of organization might be the EDUCOM proposed organization resulting from the 1966 summer study (6) (See Figures 6 and 7). Four distinct groups are proposed here, with the Council and the Board at the policy level, the EDUCOM organizations at the direction level, the EDUNET organization at the operations level, and the individual institutions at the service delivery level.

The previous discussion assumes that there is or will be a computer center service organization as part of each institution.

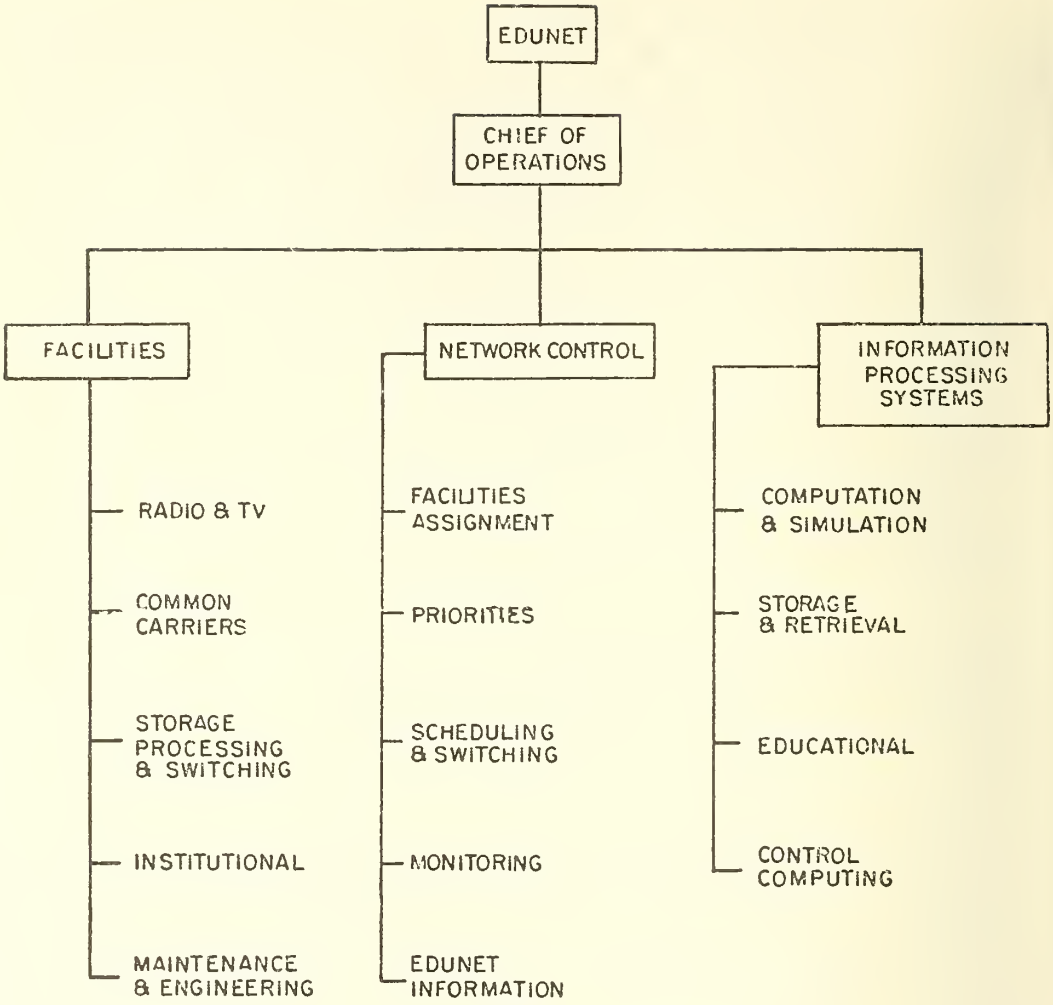
Since each organizational interface implies separate funding mechanisms and also adds communications barriers, and other impediments to operational and management control, the ideal organization would be such that policy level, direction, operations, and service delivery are all within the same organization. Network management will, however, have to deal with the University management organizations and also with existing computing center organizations. The next best solution would be case 2A, where there is one organization which provides policy level,



Source: EDUCOM

EDUCOM Organization Proposal: Boulder Study 1966

FIG. 6



Source: EDUCOM

EDUNET Organization Proposal: Boulder Study 1966

FIG. 7

direction and operations management, which then serves the universities. Another possibility would be to decentralize operations management (case 2B), but let policy and top direction remain within one organization. From the standpoint of ease of communications, across organizational barriers and of lack of administrative impediments, case 4 appears to be the most complex.

The EDUCOM structure (Figures 6 and 7) represents the vertically most diversified structure among the various combinations of the four basic functions.

6.1.4 Horizontal Structuring

In contrast to the discussion in the previous section which considers "vertical levels," we may separate network management organizations also into horizontal elements which may be performing the same functions, may however be independently owned, financed and managed. In a national networking environment, we will undoubtedly soon encounter not only a variety of resources and service providers, but a host of organizations set up to support these services with information, documentation, maintenance and other functions. From an overall management standpoint, in a nation-wide networking context, there need to be horizontal information channels, coordination, transfer of funds, exchange of data and information, and interplay of work processes. We may envision many communications networks and other organizations covering all of the functions outlined above. From a management standpoint, increasing horizontal diversification puts constraints on management control, and increases requirements for coordination, which in turn requires establishment of communications channels to help in achieving of common objectives.

The preceding analysis illustrates the complexities of interrelating both vertical and horizontal building blocks, which are required by viable networking management operations.

Relationships between the various building blocks are expressed in terms of control or in terms of information flow. Control implies also various types of information flow, which supports direction,

measurement, and decisions. In addition, other information channels are required for motivation, and other supportive needs. We now will discuss these in somewhat more detail.

6.2 Management Control

One can define different degrees of control, in terms of strength or weakness of control. One form might be the issuance of a written directive from a manager to a geographically distant organization. Without any followup, further amplification or human communication this would be a very weak, and possibly ineffective type of "open loop" control. Contrasted to this might be issuance of a verbal order, followed by written directive, with a request for confirmation of compliance, personal staff followup, and some judgment on the effectiveness of the action performed. This has all the elements of a "closed loop" control process, and could be termed "close" or "tight" control. Between these two extremes there is a whole spectrum of possibilities. Establishment of periodic reporting, exception reporting schemes, and incorporation of automatic measurement schemes into hardware and software, all contribute to management control.

Another effective medium of control is coordination through special coordinating groups, advisory panels, or committees. Here control can be effected without the formalized authority structure implied in a fixed organization chart, yet channels are established to exert pressure, use persuasion, and get things done, often in an informal, yet effective way. Coordination will be a powerful tool in the establishment and further development of the network organization, and in the consolidation of network services.

Part of the design of the management structure will have to deal with the design of the management communications subsystem and the required management information flow, which must be considered as part of the overall management planning effort.

6.3 Information Handling

Both planning and control activities depend on communications and information processes. As part of networking development, and the

development of a management structure, informational activities must be considered. They may range from a variety of one-shot or periodic publications, to on-line computer processes, and human verbal communications. There will be requirements for newsletters, formal documentation of actions taken at meetings, of plans and objectives, policy and procedure statements, and a host of other documentary matter. Appropriate distribution, and dissemination is also required. On-line services could aid by providing a rapidly updatable, and fast communications medium. Development of on-line capabilities must be preceded by considerable system analysis to determine types of communications required, frequencies and transmission rates, and other related system criteria.

Establishment of a central, all embracing, all governing tightly controlled management organization covering all aspects of academic and research networking would probably be difficult to set up, and even more difficult to operate. The evolving organization structure more likely will be a loose federation of independent, sovereign entities, the universities, with some superstructure, which will fulfill minimum management requirements. Network management, most likely will evolve as such a kind of superstructure, added to and augmenting existing networks and existing university functions.

7. CONCLUSIONS

A survey of the literature pertaining to network management, discussions with knowledgeable people in the academic networking field, and application of judgment and experience to a variety of impressions lead to a set of conclusions which in a way highlight and summarize the present state of the art in academic networking management.

7.1 Principal Research Needs

Many problem areas need to be addressed further, before expanded or national networking can be planned and implemented. Analysis of needs, financing schemes, marketing mechanisms, and organization are among these, and are now highlighted as principal research areas to expand networking for science.

7.1.1 Requirements Analysis

Progress in networking will be a function of real needs and bona-fide requirements, and of documentation of advantages accruing to universities and research institutions as a result of their participation in networking efforts. Further research, analysis, and planning is required to quantify requirements and benefits to potential user groups under various networking arrangements.

Requirements analysis is an interdisciplinary effort and is best performed in a cooperative effort involving potential users, participating regional networks, and specialists in pertinent subject areas.

Requirements research would be concerned with identification of needs at the user level, and would be heavily centered at the universities and the research institutions who might be likely network customers. A simple two-dimensional model would show classes of users versus classes of services. Inherent in this effort would be a development of classification schemes. Other dimensions to be added would include quantifiable data such as cost, location, size and type of user populations. Other data would include time factors such as turn-around time, and functional communications and hardware requirements.

Some background data are available from the Digest of Educational Statistics of the US Office of Education, U.S. Census data, and other sources. More specific data would have to be collected through surveys, questionnaires and opinion polls. Since such programs are costly, a strong planning effort should precede the actual survey tasks. Initial emphasis should be on development of pertinent methodology, dealing with the needs of specific, initially small, user classes and services. After some testing, the methodology could perhaps be extended and applied to wider network services. Uniform classification schemes, and measurement methods would permit correlation and extrapolation of both survey and operational data which initially may have been collected on a decentralized or regional basis, to serve expanded networking plans.

7.1.2 Financing

Financing for capitalization of new facilities and for support of current operations, is a particular challenge when there is a requirement to achieve self supporting capability. In the present environment, university cost data are difficult to analyze, partly because they are highly proprietary. Coordinated accounting schemes, which permit maintenance of individualized methods, but some commonality and orderly interchange of information between universities, need to be developed in connection with pricing schemes, billing procedures, and inter-network performance measurement.

7.1.3 Documentation

Documentation is required at all levels of the networking effort by servers, processors, distributors and users. Requirements need to be researched on types of documentation, user characteristics addressed, updating requirements, and economical distribution mechanisms. Applicable standards need to be followed in identification, classification and indexing, formatting, and citation of the variety of networking documents, instructions, and other hard copy products. Trade-offs have to be determined as to what types of communications should be sent electronically and what types should be moved physically in hard copy, or possibly microfiche copy.

7.1.4 Marketing

Present networking efforts suffer to some extent from a lack of marketing capability. Extension of them toward a nationally oriented capability would be even more hampered by this lack. A key need here is information on "what is available where" to potential users of networking capabilities. This would involve description of products and services in some standardized format, and measures which permit the user to select among a variety of pertinent services. Marketing capability requires substantial, perhaps full-time attention to definition of desired services and consequent development of useful packages.

7.1.5 Model Development

There is a need for development of a unifying structural model for description, measurement, and evaluation of networking management concepts. Such a model in its simplest form would be a classification scheme including management functions and networking relationships, i.e., a purely descriptive device. This could be extended later into quantifiable units, which would lead to a measurement and evaluation capability.

The various networking functions, and interrelationships among networks, and outside agencies, form complex systems and subsystems of facilities, people, processes and machines. Evaluations and comparisons between various network operations and management structures require a common reference base or conceptual model. This report includes a first step towards such a model, having outlined major system and management functions. Further refinement would lead to identification of data, information flows and product flows. A next step would be development of detailed parameters, system measures and units, in which overall service performance could be evaluated. Development of such a conceptual model is thus a basic requirement in research on networking concepts.

7.2 Experimentation

There is need for coordinated performance of some critical experiments and tasks, whose successful completion will provide answers to some of the open problems.

Some typical tasks are outlined here:

7.2.1 Establishment of a Catalog of Existing Network Services

A catalog of existing services and resources may be established. It would list name of service or resource, description, language, and other technical characteristics, field of application, development status, availability conditions, means of access, personnel contact with address and phone number, and other detail useful to potential users, or distributors. Stress would be on utility and scope of needed information, with secondary effort on mechanization or methodology of automation. This also could develop into a self-supporting service function.

It would help interdisciplinary efforts; e.g., use of data bases that may be useful in other areas, or where analysis programs may be used in fields other than for which they were designed. Such a catalog would help materially in initial marketing efforts, and would aid seller, buyer, distributor and users.

7.2.2 Perform Selective Market Analyses

A few selective market analyses may be performed, in well specified limited discipline or problem oriented areas. Typical factors considered for a particular product, would be size of market, characteristics and location, usage habits, competitive factors, pricing schemes, share of market expected and best method for distribution. Stress will be on methodology of analysis, to make the analyses useful in other applications. Another facet would be a determination of needed services, and how the resource providing organization might develop additional resources. This would involve analysis of the developing organization, marketing capability, financing, and administration with respect to development of new resources. The work would be done in a real environment, within defined time and financial limits.

7.2.3 Support Requirements Experiment

One or more existing network services may be analyzed in terms of network support requirements. Supporting services, including documentation, on-line services, consultation, maintenance, general information services, should be analyzed as to costs, functions, documents produced, and user needs and user impact. Cost, personnel and time factors should be developed.

7.2.4 Establish a Working Group on Network Objectives

An Ad Hoc group could be established, which within a stated time span, will develop a set of network objectives, within the constraints set forth by the National Science Foundation (18). The group may consist of regional networks, discipline-oriented centers, and users. It would determine scope, priorities, economic feasibility, and other operating and development criteria. It would be directed by a chairman and a

secretariat, funded partially by Government sources, and partly by the participating institutions. Time and travel expenses of participants would be contributed by participating institutions.

7.2.5 Establish a Working Group on Product Packaging

The group would determine user requirements for packaging of potential network products. It will consist of "users", "creators of products", and administrators who have marketed programs, both in the commercial and academic environment. Objective is to define what would be a minimum product package, what contents would be, and what would be required to develop, maintain, and distribute such product information. Estimates of service cost factors should also be developed.

7.2.6 Develop a Methodology for Network Impact Analysis

A methodology for impact analysis should be developed to determine the network effect on user task performance, which will be integrated into network operations. Significant output variables will be selected and defined. Appropriate measurements will be performed and results will be returned to the network, so that system improvements can be made. Positive results would be a powerful stimulant to network development, especially in the non-profit applications, where price may not necessarily be directly related to user acceptance of products.

7.2.7 Establishment of a Networking Newsletter

A monthly newsletter could be established to provide information on "who has developed what , where", "who needs what, where", latest operating practices, packaging methods, pricing schemes, and other items of use to networkers. It could also provide updating information for the Network Catalog described below. A newsletter might initially be supported by a grant, but could work however towards becoming self supporting or even a revenue generator in support of other management activities.

7.3 Planning Teams

Development of expanded networking for science may require establishment of several nucleus network planning projects with the capability to develop their own financial, material and personnel resources. These groups may have an evolving mission. They would be concerned initially with information exchange between regional centers, university centers and service nodes. As time goes on they may undertake active coordination among projects where required, or they could assume direction of research tasks or projects on behalf of expanded or interconnected networking, where such tasks cannot be adequately coordinated among existing organizations. Eventually these planning teams may merge into nationally-oriented organizations to encourage operation on a basis of "supra-regional" cooperation.

The planning projects will initially be concerned with development of supra-regional networking objectives, service policies, and experimental operations. They also would participate in solution of problems which involve interinstitutional considerations. Teams will necessarily interact with user and server nodes, as well as with public or private communications carriers. They would develop, coordinate and publish network operating procedures, rates of various services, and could provide staff support to agencies and institutions participating in networking.

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16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

Computer networking is broadly considered including hardware, software, procedures and people. Networking encompasses many activities; such as, creation of network products, distribution processes, user activities, and supporting services like marketing, documentation, information services and maintenance. Network management covers both the establishment of networking operations and actual operation of the network facilities. It includes all management functions performed at such network nodes as computing centers, documentation facilities, and service distribution centers. In order to survey the problems facing development of network management, user requirements and system requirements are outlined in a qualitative manner. Examples of political, economic and legal constraints are summarized, such as the economic impact of extended networks on regional and local computing activities. Critical issues for networking management, and other areas of significant management concern are outlined. Organizational alternatives are conceived in terms of a four layer organization model. Conclusions deal with continuing problem areas, the need for a structural model for network management, critical experiments and tasks to be undertaken to further networking capabilities, and a suggestion to establish planning teams to initiate some of the initial steps required for further networking development.

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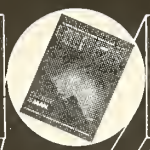

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