

NETWORKS AND NETWORKING

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ABSTRACT

The purpose of this paper is to provide an overview of computer networks and their associated communications systems. In developing that overview we will first define the idea of a "network", then describe communications systems including commentary on equipment and costs. Having dealt with the role of communications we will then turn to computer networks per se and review the contributions networks can make to computing. The discussion of computer networks will deal with shared hardware resources, shared software, types of systems, and network configurations. The general discussion of networks will be followed by a description of a developing network: the Kentucky Educational Computer Network (KECNET). The paper will conclude with a comment on some of the opportunities provided through the use of networks.

In the following pages we will attempt to explore some of the characteristics, problems, and opportunities provided through the establishment and use of computer networks. Because computer networks are dependent on communications networks, several attributes of communications systems--as those systems apply to computers--will first be described. The core of the paper centers on a discussion of computer networks and their characteristics followed by a discussion of various configurations networks might take. The more general discussion of networks will be made concrete by describing one operating network--the Kentucky Educational Computer Network (KECNET)--which is still in the process of growth. Finally, we will attempt to bring theory and practice together in a summary discussion of why we should use networks and what applications--especially in higher education--are possible.

INTRODUCTION

The title of this paper, "Networks and Networking", may not provide the reader with the topic as self-evidently as it might seem. The term "network", as used by those of us who use computers, may refer to communications networks, computer networks, or both. The topic of this paper is directed primarily toward computer networks, although it will become evident that we will have need to speak of communications networks as well.

What are computer networks? One commonly used definition of a computer network is the following: One or more computers accessed by users via some communications network. The computers may consist of main-site, or host computers, and/or remote computing systems. Generally it may be said that communications networks can exist without computers, but computer networks cannot exist without communications networks.

## COMMUNICATIONS NETWORKS

A communications network consists of a communications medium and computers or other devices used in the control of the communications process itself. The most pervasive communications system available to most of us for voice-grade exchange is the telephone system. The telephone system has, of course, been with us for a considerably longer period of time than have computers. While the telephone is the basis for the most common communications network, there are other such systems linked by land-lines, microwave or other radio transmissions, and, most recently, lasers. Because most communications systems predated the need for data transmission, there has been a tendency to provide means by which digital data can coexist with voice messages. In order to control the communications process it has been necessary to provide instruments capable of providing the proper level of service for data handling.

In a normal telephone conversation, two or more people speak to one another over lines connected by means of public exchanges. These lines are called "public" or "switched" lines and can be used for communicating data as well as voice communications. The alternative to public lines--although still provided by telephone companies--are "private" or "leased" lines which are connected permanently or semi-permanently in a data communications system. Regardless of the kind of line used, the signal carrying capacity of communications lines is usually described in terms of frequencies those lines will carry. The range of frequencies is called the bandwidth of the channel and the quantity of data that can be communicated over a channel is proportional to the

bandwidth. To transmit data over a telephone line, whether public or private, that data must be manipulated electronically so that it fits into some segment of the frequencies into which a channel may be divided. This manipulation is accomplished by a device called a modem. The speed of the line--the rate at which data are transmitted--are measured in "bits per second", sometimes called baud rates. In the period from about 1970 to about 1977 there was over a 400 percent increase in the normal baud rate at which data could be transmitted over conventional telephone lines (cf. Martin, 1970, p. 7, for the earlier rates).

## Communications Equipment

While we cannot delve very far into the establishment and control of communications networks in this paper, it would be well to explore a few of the devices needed in the transmission of data. Among those having importance for our purposes are modems, and their extensions, multiplexors and concentrators.

There is a relatively narrow range of frequencies which may travel without much distortion over telephone circuits. The human voice has a middle frequency of about 1500 hertz. If we translate binary data into a modulated frequency of about 1500 hertz, then data too can be transmitted without great distortion. A device called a modulator is used when sending data in order to achieve the necessary modulation of the data. At the other end, a demodulator is used to change the modulated carrier back to normal binary data a computer can use and understand. Normally these units--the modulator and demodulator--are combined into

a single unit with the abbreviated name of modem. Modems are made by independent vendors as well as by telephone companies. Ma Bell often calls modems "data sets." Although it is outside the scope of this paper, it should be noted that there are at least three different types of modulation. Moreover, data processing equipment may be directly wired to the telephone line or may be connected via an acoustic coupler when dial-up is the normal mode for accessing a target computer.

One of the problems with telephone lines is that they are relatively expensive. One way of cutting costs, especially when using relatively low speed communication equipment, is to employ multiplexing. Through the use of multiplexing it is possible to send signals from more than one terminal over the same line at the same time. In a multiplexed system, two or more signals are combined and transmitted over a line with an appropriate bandwidth. The term "multiplexing" then, means the use of one facility to transmit in parallel several different channels of data over a single communications link.

One of two multiplexing methods are normally used: frequency-division multiplexing or time-division multiplexing. Frequency-division multiplexing requires a modem or data set that provides several groups of channels over one line, dividing the total bandwidth of the line into channels of some smaller frequency range. Such a device performs the normal functions of a modem while carrying out the multiplexing. By way of contrast, signals may be sent in a round-robin fashion so that only one signal occupies the channel or line at any one time. The time available is divided into small slots and each

is consumed by a chunk of one of the signals to be sent.

While multiplexing equipment is relatively inexpensive, and while multiplexing may be a convenient method of using one high speed line for a number of lower speed tasks, there are some occasions where multiplexing does not work well. Multiplexing is limited by the total bandwidth available thus providing a limit on the number of channels into which a given link may be subdivided. One way of getting around the limitations is to use a "hold-and-forward concentrator" which is nothing more than a small computer which receives messages from a variety of terminals, stores the data in some memory (buffers), then fires the signals up the line to another computer. The advantage of a concentrator is that many different kinds of entry devices may be attached to it, all running at differing baud rates, and the capacity is limited only by the capabilities of the concentrator itself. Unlike multiplexors, however, which are transparent to the end-user, concentrators may cause delays in turnaround and, being more complex, are more subject to failures of various kinds. Judgments as to which kind of approach to use should be governed largely by cost/benefit considerations in the overall design of the network.

### Cost Considerations

As Martin has noted (1970, p. 1), the "facts about the transmission links which most concern a systems analyst are the cost of the links and the rate at which data may be sent over them." It is becoming clear that the cost of communications is an increasingly important factor in the cost of

computing and as large computer networks expand, and as we become more dependent on networks, communications costs will expand at a significant rate. It has been estimated that by 1985 ninety out of every one hundred computing dollars will be spent for data communications rather than for the data processing itself (Ferreira and Nilles, 1976). As a result of the cost considerations and potential expenditures in the future, systems analysts and organizational managers will have to become more cognizant of the demands for allocating resources for telecommunications. A byproduct of the projections noted is that manufacturers are increasingly turning to the production of communications hardware and software (Totaro, 1976). In the end, however, the objective is not only to move the data, but to process it. Consequently, we should consider the computer network which is supported by the communications system just described.

### COMPUTER NETWORKS

Why should computers--and therefore end users--be organized into networks in the first place? With computer hardware becoming less expensive and at the same time more sophisticated, the answer to the foregoing question is likely to be somewhat different in the latter 1970's than it was earlier in the decade. To a large extent the remainder of the paper will be devoted to answering the question "why networks?". Before going further, however, it will be helpful to explore some of the outcomes and characteristics of networks, then turn to a description of the various configurations networks may take.

### Shared Hardware Resources

Certainly one of the early motivating factors behind the establishment of computer networks was the fact that through networks many users could use expensive computer systems, thus spreading the cost of such systems over a much larger user base. Very often the total number of users on a large network can support equipment on a scale no individual user or user institution could manage alone. "Why both networks and stand alone computers", one might ask, "when mini and micro computers are getting to be so inexpensive?" While it is true that some micro computers cost little more than expensive terminals, and while the capabilities of such computers are great, they remain inappropriate in situations where the same data base must be accessed by many different users, where files are large and must be accessed rapidly, and/or where user programs require very large amounts of memory to do the task needed. It may be helpful to look at each one of these points in turn.

Two of the three points just noted deal with capabilities regarding files and file structures. Although the cost of computers is falling rather rapidly, the cost of large scale peripheral devices--devices which can be used to permanently store large quantities of data--are not decreasing in cost in any substantial fashion. Moreover, even should large-scale peripheral devices fall in cost, the lower price for hardware does not necessarily justify using such devices to keep multiple copies of the same data base. If, in a given application, several small computers can legitimately be used to replace one large computer, then the decision should be made on the basis of the comparative costs of

the two approaches when all elements of the two are considered as complete systems.

Notwithstanding the comment concerning the cost of large-scale peripheral devices, we should note that devices such as large disk drives--which are very costly items--are likely to be replaced in the relatively near future by electronic memory systems (such as the bubble memory), thus eradicating the arguments just presented. Similarly the question of the amount of main memory needed for user programs will become less problematic as the cost of memory is reduced and as micro computers are designed to address ever larger chunks of memory. None of the solutions or substitutions for networks are helpful, however, when one is dealing with a large database which must be used by various users located in different places.

### Shared Software Resources

While the differences in hardware capabilities among large, mini, and micro computers is becoming blurred, the personnel costs necessary for the programming and operation of computer systems of any size is becoming a larger proportion of the total cost of running such systems. Various commentaries on the direction of the development of computer facilities have suggested that over the next several years, as computers come more and more to be programmed in languages more nearly resembling natural languages, the role of the programmer will change. Notwithstanding that fact, or alleged fact, however, we will continue to see significant contributions of personnel time to the provision of programs which will allow the end user to use computers in a

reasonably straightforward manner. As a result of such personnel considerations, therefore, cost considerations will shift from concerns about hardware to concerns about the cost of the people to run the hardware. This same issue is closely related to the problem of shared data noted in the foregoing section. Each of these concerns provides arguments in favor of the continued use of networks. Networks can also make resources available to users which were not previously present. One interesting example of an added resource, discussed in some detail below, is computer conferencing. The very idea of computerized conferencing would not be feasible without the notion of networks of some form or fashion.

### Types of Systems

Computer networks may be structured to support remote batch, or timesharing, or some combination of the two. Alternative names for batch systems are "remote job entry (RJE)" and/or "remote batch terminal (RBT)" systems; the most current buzz-word is "RBT". Timesharing systems are often called "interactive" systems. RBT systems are those which operate essentially with card input (or its equivalents in the form of floppy disks, on-line job entry, etc.). Jobs are placed in a job stream, given a priority for the order of execution, and a job in its proper turn is executed and returned to the user. Once the job is submitted it is out of the hands of the user and dependent on the characteristics of the operating system under which the job is being run. In contrast to a batch approach to networking is the use of timesharing or interactive systems where the user sits at a

typewriter-styled terminal and the computer and the user interact with one another in real time. In such systems the user always has control over what is happening to his/her job and may make immediate responses to any problem which arises. Often hybrid systems are developed such as IBM's conversational job entry system (CJS) or DEC's approach to FORTRAN and COBOL on their large systems. In both approaches coding for programs is entered interactively through a text-editor, but the program, when finished, is actually submitted as a batch job. Both approaches to networking have positive and negative features, but what will be said in subsequent sections of this paper apply equally to both types of systems.

### Network Configurations

There are a variety of ways in which networks might be configured and many (perhaps most) networks are in a constant state of change and growth. If the computer network consists of only a main-site or host computer which does all data processing from one or more remotes, it is a centralized network. If there are remote computers processing jobs for end-users, as well as a main-site computer (which is itself optional), then we may have the beginnings of a distributed network. A distributed network can be either centralized or hierarchical in form, but a network which does not involve distributed processing can only be centralized since all data processing is done on a main-site computer. It is possible for a single communications system to provide communications services for two or more concurrently operating centralized computer networks. Although the comments which follow constitute an

oversimplification of networks, we will review four characteristic configurations: point-to-point; multipoint; centralized; and hierarchical.

#### Point-to-Point

A point-to-point network is, without doubt, the simplest kind of network for it consists of a computer, a telephone line, and one terminal at the other end of the telephone line. The terminal can be either an MFT or interactive. This simplest of systems is depicted in Figure 1. Many networks begin as point-to-point systems and gradually develop into more complex entities.

#### Multi-point Networks

Multipoint networks constitute a straightforward extension of point-to-point systems in that instead of a single remote station, there are multiple remote stations. Those remote stations may be either MFT's or interactive or a combination of both. The remote stations may be connected via independent communications lines to the computer or may be multiplexed over a single line. Such a system is illustrated in Figure 2. In either a point-to-point system or a multipoint system, the characteristics of the remote work stations are a function of the work to be accomplished at the remote site.

#### Centralized Networks

As noted above, a centralized network is one in which primary computing is accomplished at a sin-

Hierarchical Networks

A hierarchical network represents a fully distributed network in which computers feed into computers which in turn feed into computers. The computers used for remote devices may have independent processing capabilities and draw upon the resources at higher or lower levels as information or other resources are required. Such a network is pictured in Figure 4. A hierarchical network is not the only kind of distributed network but it is a completely distributed network.



Figure 1: Point-to-Point Network

single site with all remote stations feeding into that site. Often such a system is thought of as a star network with each remote site entering the central system via a single communications line as noted in Figure 3. Both a multipoint and a star network are centralized systems in that they are controlled by a single, centralized computer. Typically, however, a multipoint network may not have distributed processing capabilities while a star network may have other computers out at the end of its communications lines. In fact, the computer which supports a multipoint network might, itself, be linked into a star network.

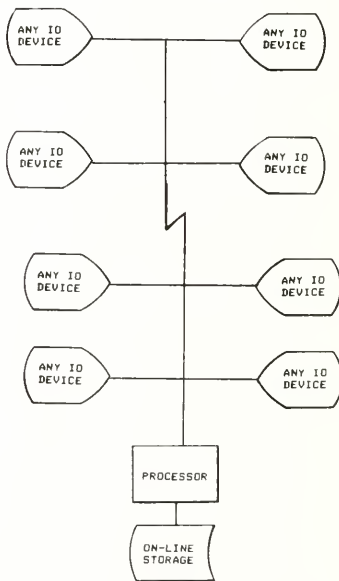


Figure 2: Multipoint Network

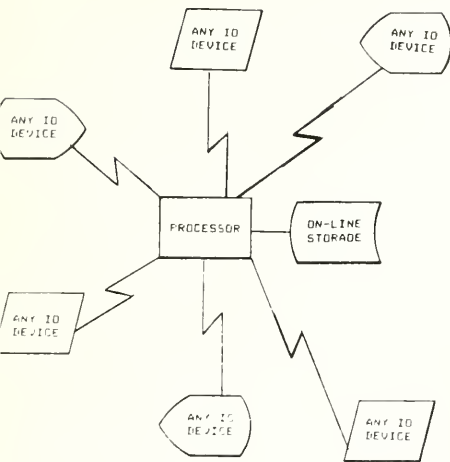


Figure 3: Centralized or Star Network

distributed systems without conscious design on the part of systems analysts. As often as not, a typical batch terminal in a network, rather than being a "dumb" terminal such as IBM's 3/80, will be a mini or micro processor based device providing local file storage and processing capabilities as well as the capacity to read cards and print paper.

The decision to acquire a terminal with intelligence may, in fact, be the decision of the end user rather than the decision of network analysts. If there is the possibility of dialing into the system with some low-speed teletype-like device, an end user may decide to acquire a microcomputer for home use, but program it to communicate with the larger system via the telephone. Thus, the decision to turn a centralized star network into a distributed processing network may be even further removed from decisions made by analysts at the central site. As an example of the way in which a network might develop we will turn next to a brief examination of the Kentucky Educational Computer Network (KECNET).

THE KENTUCKY EDUCATIONAL COMPUTER NETWORK

KECNET was established in 1974 to provide academic computer services for the eight public institutions of higher education in the Commonwealth of Kentucky. Although the original design called for both batch and interactive processing capabilities, interactive services were not actually established until late 1975. The batch system is based on an IBM 3/0/105 and the interactive system is based on a

At several points in this paper we have spoken of centralized and distributed processing as if the two concepts in networks were at opposite ends of some continuum, although such is not the case. Nor can distributed processing be thought of simply as decentralized computing. One definition, suggested by Data 100 as reported by Lusa (1976) states that distributed computing places "a substantial part of the pre- and post-processing of data, and access to data at the places where the data originates and is used . . . while maintaining central control of the network." In today's computing world, networks which start as relatively simple star systems often become



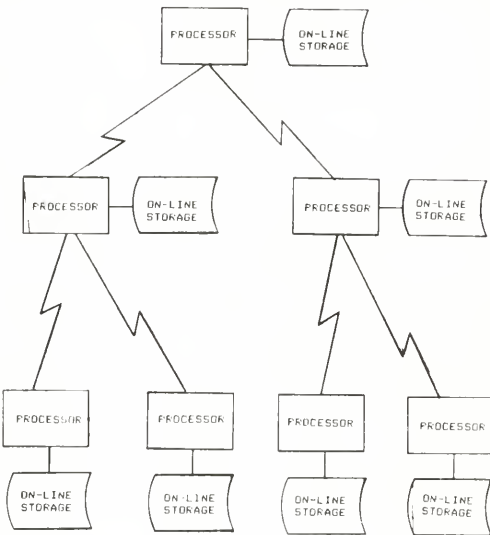


Figure 4: Hierarchical or Tree Network

DECSYSTEM 10. The original batch system developed as a centralized star network and had its origins in the use Western and others had already had of the state's system at the Bureau of Computer Services in Frankfort, the state capital.

The establishment of the full network was conceived of as taking place in stages or phases, with the first phase connecting the eight institutions into the computers at Louisville and Lexington over a common communications system. The original idea behind the first phase is illustrated in Figure 5. The second stage was to expand the original communications system to that depicted in Figure 6. The

network currently approximates Figure 6, although variations in design have taken place. In particular, the node labeled BCS (Bureau of Computer Services, Frankfort) is not now linked into the system at all, and may never be. That decision has been a political rather than a technical one.

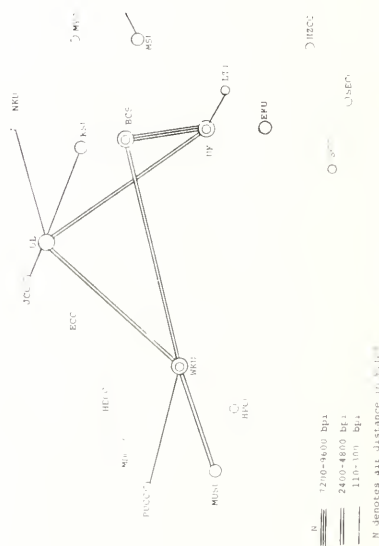


Figure 5: Kentucky Educational Computer Network, Phase 1

To illustrate the way in which the system has developed we might look more closely at the link between Western Kentucky University (WKU) and the system. Western constitutes a communications sub-

We are now shifting slightly the configuration as just described. A direct link (at 9600 baud) is being established between Western and Lexington, a move made necessary by two events: Western's decision to upgrade its RBT to a higher speed intelligent terminal (to a Harris 1600 from an IBM 3780) and to allow the use of the vacated channel by Paducah Community College.

For interactive or on-line computing, a modem in Louisville diverts the user to either the DEC-System 10 or the IBM 370/105, depending upon whether a user has sent a "1" or a "2". At the present time the two computers are not in direct communication with one another, although that is planned for the future. In addition, all of the institutions also have local computers for administrative computing and it is projected that sometime in the future these may also be hooked into the KECNET system thus providing computing nodes other than those at Louisville and Lexington. Already Northern Kentucky University's IBM 370/115 can access the system as a high speed terminal. Clearly what was once a centralized star network is turning into a large distributed network.

It would be possible for someone in Bowling Green to obtain a small microcomputer system for personal use, be able to program it to automatically access either of the two large systems on KECNET by making a local call to the University, thence being linked into the state's system. Although such a situation has not developed at the time of writing of this paper it is technologically feasible without enormous cost to the end user.

While a considerable amount of time and effort has entered the planning of KECNET changes have been made in the original design.

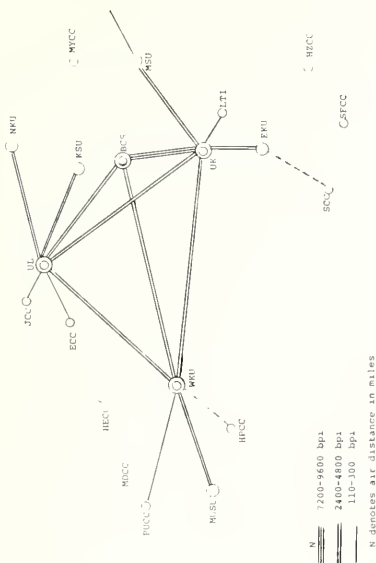


Figure b: Kentucky Educational Computer Network, Phase 11

center in the system using a time-division multiplexor to divide a 9600 baud line into four 2400 baud channels. There are two RBT centers on western's campus each of which, until recently, have used one of the 2400 baud channels which go to Louisville and are then switched over to Lexington (the location of the IBM 370/105). Murray State University (MUSU), located further to the west is linked to the multiplexor at WKU via a 2400 baud line into a third channel. The fourth channel is further time-division multiplexed into eight 300 baud channels for interactive computing at Western.

Some of the changes were made necessary as a function of political decisions influencing the funding of the system, some changes were made on the basis of the availability of hardware (communications) at unusually good prices, and some were made as a result of user institutions requiring better or different kinds of services.

Once a large network comes into operation it is not always possible to restrict the range of its development. Furthermore, decisions which might be good for private industry may not be equally good for public agencies. The cost per mile of leased telephone lines for state government in Kentucky, for example, is less than one third the cost of equivalent services to private enterprise. Because of these cost differentials in phone service different decisions concerning specific approaches might be made depending on whether one was designing a public or a private system. In any event, once we have a network in operation, what can we do with it?

### NETWORK OPPORTUNITIES

There are a number of advantages (and some disadvantages) in using networks. We will note three opportunities provided by such systems: Economy of scale; decentralization of organization; and shared applications. Each of these will be considered in turn.

#### Economy of Scale

As has already been noted, one of the earliest reasons for networks was the ability to spread the costs of large scale computing

equipment across relatively large numbers of users. By so spreading the costs it was possible to provide each user with access to larger, more powerful, central processors and peripherals, yet to hold individual costs to something resembling that on smaller systems. Although the cost of small systems is steadily declining, the same argument can still be made in the latter half of the 1970s.

Economies of scale are obtained not only in hardware, however, for if multiple users need access to the same database, then it is necessary to maintain only a single copy of the data rather than copies for each potential user. When the number of copies can be reduced we reduce the cost of expensive disk storage, maintenance of the database, and other attributes inherent in having multiple users of a single database with multiple copies.

The key consideration as computing hardware becomes less expensive and communications costs become more important is whether the cost of communications is exceeding the cost of providing local computing on the same scale as a network without incurring the cost of communications. At least in the 1970s these cost differentials have not become so great as to require the end of networks. Consequently, while the argument in favor of networks based on an economy of scale are still important and true, there may come a time when the economy of scale argument no longer has merit.

#### Decentralization of Organizations

If, indeed, economies of scale can be achieved through networking, then as large-scale organizations tend toward decentralization such

economies become ever more important. An apparent contemporary fact of life in large-scale organizations today is a tendency toward at least geographical decentralization and possibly administrative decentralization. Yet many large organizations continue to require access to common data, program libraries, and the like. As a result, within a large organization a computer network can provide those centralized services necessary, and at the same time help maintain coherence and standardization within a largely decentralized system. Each individual component of the organization may be doing local computing, as well as remote computing on a network. Particularly in higher education this argument has merit. At least in Kentucky not one of the eight state institutions of higher education would have, or could individually afford, computers of the size and performance of those in KECNET.

### Applications

#### Shared Resources

Noted numerous times above is the fact that with networks come shared data, software, and hardware. Within the context of a computer system there is another very major resource constituted by the skills of the people associated with the system. When working within the context of a network it is no longer necessary for every local unit to provide staff with all possible skills, since each remote location has the possibility of making use of the skills of those at other remote sites or at the central site if one exists. AS a consequence of the possibility of making full use of all the resources available in the system,

including personnel resources, it should then become possible for remote sites to devote relatively more time and attention to user problems rather than to the problems of maintaining hardware and keeping it up and going.

#### Computerized Conferencing and other Opportunities

Once a network has been established certain opportunities are provided which were not previously available. One such opportunity is computerized conferencing. Computerized conferencing is a process by which "groups may communicate about complex problems through members' terminals instead of telephones" (McKendree, 1978) or in person. Because of the computer's capacity for maintaining ongoing proceedings, the conference may extend for days or weeks or longer. There are several advantages which might accrue from such conferencing:

1. Participants are freed from constraints of time.
2. Information related to the discussion is automatically processed and stored.
3. Text, statistics, and/or cases are printed in easily used and standardized formats and are available as needed.
4. Periodic voting on proposals raised in the discussion may be accomplished with speed.
5. Conferees may be coupled to various modeling, simulation, or other com-

putational and planning resources, such as Delphi Method studies.

Computerized conferencing would not be possible without networks. Through the use of conferencing it is possible to reduce travel time and costs yet provide the basis for more thoughtful discussions among individuals. While networks are costly they still provide services difficult to duplicate at remote sites.

#### REFERENCES

- Bump, Robert E. Starting up with Datran. DATAMATION 21 (April 1975), 50.
- Dick, George M. The Lowly Modem. DATAMATION 23 (March 1975), 69-73.
- The Communications Channel: It's Broken--Now What? DATAMATION 23 (October 1977), 113-126.
- Digital. INTRODUCTION TO MINICOMPUTER NETWORKS (Maynard, Mass.: Digital Equipment Corporation, 1974).
- Ferreira, Joseph and Nilles, Jack M. Five-year Planning for data Communications. DATAMATION 22 (October 1976), 51-57.
- Gray, James P., and Blair, Clark R. IBM's systems network architecture. DATAMATION 21 (April 1975), 51-56.
- Hohri, William. MCI's microware service. DATAMATION 21 (April 1975), 48-49.
- Hirsch, Phil. Problems and predictions for communications processing. DATAMATION 22 (June 1976), 117-120.
- Kelly, Neil, et al. Data Communications, Part 2. INFOSYSTEMS 24 (March 1977), 35-42.
- Kelly, Neil, et al. Information Networks: a management update. INFOSYSTEMS 24 (July 1977), 41-44, 101.
- Lusa, John M. et al. Distributed Processing: alive and well. INFOSYSTEMS 23 (November 1976), 35-41.
- Lusa, John M. Data Communications, Part 1. INFOSYSTEMS 24 (February 1977), 39-46.
- Martin, James. TELEPROCESSING NETWORK ORGANIZATION. (Englewood Cliffs, N.J.: Prentice-Hall, 1970).
- McKendree, John D. Computerized Conferencing. DATA MANAGEMENT 16 (January 1978), 105-110.
- Sanders, Ray W., and Cerf, Vinton G. Computability or chaos in communications. DATAMATION 22 (March 1976), 50-55.
- Tenkhoff, P. A. and Collard, J. C. The Common carriers' uncommon offerings. DATAMATION 21 (April 1975), 45-47.
- Totaro, J. Burt. Communications processor survey. DATAMATION 22 (May 1976), 151-170.
- Turoff, Murray, and Hiltz, Starr Roxanne. Meeting through your computer. SPECTRUM 14 (May 1977), 58-64.
- Woods, Larry D. Distributed processing in manufacturing. DATAMATION 23 (October 1977), 60-63.