DOE/ER/70214--T1

MASTER

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

AD HOC COMPUTER NETWORKING GROUP

EXPERIMENTAL PROGRAM

AT03-76 ER 70214

Trans. rtd. dtd. 5/21/75
filed 34/214/2-2

March 19, 1975
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ERDA Ad Hoc Computer Networking Group Experimental Program

Contract Number AT(04-3)-34, PA 214

March 1975

The ERDA (formerly AEC) Ad Hoc Computer Networking Group (CNG) was established by representatives of ERDA and contractor facilities to investigate the potential advantages and costs of the newer forms of remote resource sharing and computer networking to ERDA's research missions and programs. The formation of the group and the purposes of its two panels are outlined. The areas of research and investigation that are within the scope of the ERDA CNG are described and some potential yields anticipated from the program are presented. Appendices to the document are memoranda that were prepared in reviewing the communications offerings available for networking.

1. INTRODUCTION

Among the major developments of the last decade in electronic data processing has been the emergence of economic and cost effective networks of computers. These networks have brought new capabilities to their users in industry, commerce, education, and research communities. The benefits of computer based service have been made available to facilities which have not been able to cost justify their own computers. Entirely new capabilities of control, communication, and experimentation have been afforded to both commercial and research organizations.

In a very real sense, computer networking has evolved naturally from the remote batch services provided within companies, by service bureaus and from the technologies applicable to time sharing. The progress in communications has resulted in lower costs and more pervasive facilities. Drastic reductions of hardware costs occurred due to large scale integrated circuits. Development experience in time sharing permitted evolution of sophisticated operating systems featuring multi-programming and multi-processing. As a result of the above the time was ripe for networks of computers to be viable and cost-effective.

Many corporations have erected dedicated networks of computers and communication links for the purposes of reservation systems, credit systems, production and inventory control systems, management and marketing information systems, etc. Many universities and educational institutions have banded together in regional or national networks to take mutual advantage of the resources developed by each and not available previously to the others.

The Mathematics and Computer Science Program of the Atomic Energy Commission has historically fostered research into the problem of systems architecture of various computer organizations which were vital to its research programs.

Both the use and the understanding of networking raised just such crucial issues. This research has been designed to foster new system architectures and the mathematical depth which would enhance the computational capabilities applicable to problems of interest to the Atomic Energy Commission and now the Energy Research and Development Administration.

Dr. Milton E. Rose suggested the importance of hands-on experience and experiment with these new networking technologies in 1973.⁽¹⁾ At his suggestion, Professor Gerald Estrin of UCLA's Computer Science Department, a principal investigator of systems architecture and networks, organized a group of senior personnel to form the Ad Hoc Computer Networking Group (CNG). The members of the CNG reflect senior management of major computational facilities currently engaged in or intending to initiate or extend their facilities' ability to provide cost effective computation both locally and remotely. Some members of the CNG were invited for the experience which they could bring to bear and for the significance of the studies to their future responsibilities.

The CNG has representatives from the following ERDA agencies and contractors:

ERDA/Germantown

Mathematical and Computer Sciences Program, Division of Physical
Research, Management Information and Telecommunications Systems
Division, Controlled Thermonuclear Research Program, Division of
Physical Research

Argonne National Laboratory

Brookhaven National Laboratory

Iowa State University, Ames Laboratory

Lawrence Berkeley Laboratory

Lawrence Livermore Laboratory

Los Alamos Scientific Laboratory

Mass. Inst. of Tech., Laboratory for Nuclear Science

New York University, Courant Institute of Mathematical Sciences

Stanford University, Stanford Linear Accelerator Center

UCLA, Computer Science Department

The intent of the CNG is to familiarize itself with the many aspects of networking to determine how it can satisfy agency computational requirements for research programs and missions in a more efficient manner and,

significantly, to ascertain how the richness of resources agency-wide can be made available more rapidly to a larger community and thus add new research dimensions for future efforts. The CNG membership serves through two panels.

The Objectives Panel membership formulates suitable objectives for experimentation. It will oversee experimentation to ascertain proper adherence to objectives. It will evaluate, as a group, the importance of the positives and negatives determined from the experiments, and will recommend potential implementation methodologies for ERDA network designers. The members of the Objectives Panel, due to their representative nature, will be able to interpret the results of the experiment program in terms of their own institutions' activities. The Objectives Panel members will therefore be a major resource to ERDA dealing with the broad spectrum of problems and solutions for computer networking and remote-resource sharing.

Some of the CNG represented facilities have designed their initial networking experimentation utilizing the ARPANET. Each of these facilities has assigned senior systems personnel to represent them on the CNG Implementation Panel. The members of the Implementation Panel have as their task the provision of all the modalities of hardware and software that are necessary to interconnect their computation facilities and computer users for experimentation. The Implementation Panel's immediate function has been to implement the functional specifications which they agreed to satisfying the protocols required for the ERDA/ARPANET community. Likewise, the Implementation Panel will be responsible for implementing interconnections for their experiments with other network carriers.

It is hoped that in the course of CNG's experimentation a number of salient results will be attained. For the ERDA, it is anticipated that a better grasp of how to use the computational facilities that have been developed

at various contractor sites will be achieved. For the directors of computer centers, it is anticipated that many managerial and technical advances and insights relating to center productivity and user computational satisfaction will be achieved. Possibly some significant savings in software production costs, a major cost area, will result from network instrumentalities.

There will continue to be great need for dedicated computers at various ERDA or contractor facilities to meet the needs of varied missions. In the case of high priority programs such as Controlled Thermonuclear Research need has been determined for a dedicated computer network. CNG investigations should contribute strongly to an appreciation of each method of providing computer power as the fields of computers, data management and communications evolve..

Section 2 of this document will give a brief history and status of computer networking and what is being accomplished in this important field. Section 3 will discuss the broad spectrum of investigations that the ERDA CNG may engage in and the kinds of advantages, costs and difficulties that may result from ERDA's increased usage of networking. Section 4 consists of a short progress-to-date report on both the Objectives and Implementation Panels. Section 5 will present the concepts behind the future programs and plans of the ERDA computer networking group.

2. COMPUTER NETWORKING AND RESOURCE SHARING

Evolution to Networking

The earliest computers were stand-alone computers totally dedicated to the users working with them at any particular time. With time and the insights gained from usage and experimentation, sequential batch computing was developed in which operating systems, STET, were developed to quickly, and as automatically as possible, carry out the functions of the many operators servicing the computer system. These batch operating systems permitted many jobs to be submitted to the computer and the computer carried them out in accordance with an expeditious schedule. The sequential batch computing systems made a very considerable step forward towards increased computing efficiency at the expense of user intimacy with a system. Users submitted jobs, adapted to sometimes onerous bureaucratic procedures, and waited patiently for results. With the further development of multiprogramming, batch processing was able to accomodate many batch jobs simultaneously. These techniques reduced the delay or turn-around that the user experienced at such facilities.

Developments in both hardware-and software-systems' architecture provided for the development and maturation of time-sharing services. In time-sharing systems the user thinks he has the full attention of the computer to himself while in reality the computer is simultaneously processing and intercommunicating for many users. The systems have been designed so that the response time of the computer to the user for short computations makes it appear that he, alone, is using the machine. In that sense, the complete dedication of the machine again appears as it did in the early days of computers. Many frequently disconcerting and onerous batch procedures involved with job submissions and waiting for results have been dispensed with. These have, of course, been replaced by another kind

of protocol necessary to gain access to a shared system. The evolution of time-shared systems has been especially important for the development of software whereby quick and frequent testing of programs being written is permitted and also in applications where resort to computers for quick problem solving is needed.

The development of networks of computers, long foreseen by various designers, became feasible with the great reductions in costs for communications and for hardware. ^(2,3) Among other things, the reductions in communication costs resulted from net technology and government fostering of competition by specialized common carriers. ^(4,5) Medium scale and large scale integrated circuit technology resulted in drastically lower costs for computer hardware and storage. Minicomputers and microcomputers, both vigorously advancing commercial technologies, have complemented low cost logic functions in the implementation of interfacing and controller systems for networks. Recent network designs have shown that minicomputers may supplant more expensive larger machines in the applications of networking for remote resource sharing, at savings in cost and increase in system flexibility. ^(6,7,8,9)

In a very real sense, networks of computers that provide for remote resource sharing are an outgrowth of time sharing and remote batch processing based on the technologies of multiprogramming and multiprocessing joined with the above mentioned decreases in communications and equipment costs. The actual implementation of these networks has required substantial investments in systems and application software; usually dwarfing in amount the investment in hardware. Despite the many significant advances in software design capability which have served as a basis for many current systems, capacity for lowered cost software production has not kept pace with the advances in other fields of technology. Using 1955 as a base line, by 1975 the performance to cost ratio for the data processing industry had increased by a factor of 10,000, yet in the same period programmer productivity increased by a factor of 5.6. ⁽¹⁰⁾

Network Examples

The varieties of networks in existence and in process of design are great. In communications switching networks we find computers used in either a message store-and-forward technology or circuit-switch technology between different users and between facilities which may or may not incorporate computers. In many instances digital technology is used to interconnect large numbers of user terminals to centralized data computation facilities and/or data bases. Many reservations systems, credit systems, stock quotation systems, and management systems are of this variety. The systems have proved themselves cost effective and economically required for the conduct of many businesses. Computer networking has become a necessary condition for doing business. In many of these centralized systems it was possible to formulate the system design and implement it under strong central control.

In educational and research communities yet another set of circumstances obtains. ^(11,12) In many institutions the current computing facility has developed through lengthy evolution. The establishment of networking generally requires the interconnection of many different machines of different levels of complexity frequently with widely divergent software. These design difficulties have been addressed by numerous groups who have and are fashioning regional or national networks. ⁽¹³⁾ The justification for such networks in the educational and research communities is a more widespread availability of computer power, the interaction of researchers at various institutions in an easy ad hoc fashion (not requiring many trips) and the availability of software that ordinarily would have to be duplicated either by purchase or redesign at high cost. ^(14,15)

The ARPANET

The Department of Defense Advanced Research Projects Agency sponsored the investigation and implementation of a network of computers to come to

grips with the broadest variety of problems that such networks might raise.⁽¹⁶⁾
This project consciously did not attempt to institute a design philosophy using centralized control, but employed instead the consensus of many users at many different kinds of installations in formulating the functional requirements for their interconnection and intercommunication. A limited description of the projects defined and carried out include: the physical and logical connection of many different kinds of computers and terminals;^(17,18) the availability of data and programs existing at many network computers to other computers or terminals; and the ability of users to experiment intimately with a wide variety of unfamiliar machines and software. The group rules for the ARPANET precluded the exclusion of computers or other network equipment due to differences to manufacture, control philosophy, or other characteristics. To achieve this capability, the ARPANET developed conventions and protocols for all of the sub-tasks involved in communications and computations and these conventions and protocols were implemented in many different ways at different sites.^(19,20)

The advantages conferred by the ARPANET were many. With the development of well defined conventions, it became easier for new sites to join the network. New entries frequently could use or avail themselves of the experience of other sites with similar equipment and programs. In some instances, trade-off studies by institutions showed that they could more readily and economically obtain their data processing by accessing other sites on the network than by continuing to maintain their own facilities. For example, at the University of Illinois it was determined that many of the computational problems required different configurations, frequently larger or smaller than their existing computer configurations. Being connected to the ARPANET, permitted them to select the best available configuration suitable to the variety of their computational jobs in each instance. They experienced a considerable

decrease in their computational costs as a result of relying entirely on
(21)
ARPANET.

The ARPANET uses packet switching for the transmission of its information between computers and other computers or terminals. This nodal form of information transfer has been explored only in the last decade, and has shown itself eminently applicable to a wide variety of network applications. The ARPANET uses the concept of the network virtual terminal in which all network transfers of information are similar internally and the translation from external to internal characteristics takes place at the terminal information message processor (TIP). The Network Virtual Terminal facilitates the interconnection of new types of terminals that have not previously been considered for the network.

A number of salient features characterize the ARPANET. Of interest to researchers who are widely dispersed are the facilities for rapid communication with each other via the network. A system known as MAIL permits users to send messages to each other and to exchange thoughts very quickly with respect to experiments, computation, program development, etc. A number of conferencing techniques have been developed on the ARPA network and permit many persons to engage in conversations requiring many minds to be brought to bear on the problem. Such conversations can take place in real time or may be distributed over extended periods with provisions for responses by temporarily absent participants.

The ARPANET continues to expand. Control and management of the network is being transferred from ARPA to the Defense Communications Agency. Permission has been granted to some ERDA facilities to use the ARPANET. Whether or not there will be restrictions on further non-DOD agency usage of the ARPANET is a policy matter being determined in the near future.

The Advanced Research Projects Agency has brought much of the research underlying the technical aspects of communications to a sufficient level of maturity that it is now being exploited in commercial development by others. Under the DCA it is anticipated that much experimentation in usage of the network will continue in many different scientific fields and in management type data processing.

Other Candidate Networks

ARPANET was discussed here at some length because experimentation in networking by the ERDA CNG will make use of it. There are many other candidate network forms for ERDA consideration. Packet switching, as is used in ARPANET is the communication technique of choice for a broad variety of ERDA type network processing. However, circuit switching media, such as used in the telephone system, also has a broad spectrum of applicability to various ERDA problems. There are many variations in packet switching, message switching, circuit switching, and hybrid switch systems that seem to have much to recommend them in different applications. The ERDA CNG is monitoring the various commercially available, or soon-to-be available, communication offerings by different vendors in order to be aware of the cost efficiency of each offering and its characteristic beneficial uses.

Until recent years, all communications to or from computers via terminals or other devices were provided by regulated common carriers such as American Telephone and Telegraph Company and Western Union. The FCC has moved to create a situation of competition between providers of bandwidth or of digital transmission. ^(5,6,22) Specialized common carriers have been authorized to provide services competing with those of the regular common carriers. The intent of the competition was to make communications less costly, more

efficient, and more responsive to the requirements of many new classes of users. As a result of the competition, published tariffs by the specialized common carriers and the response of the regular common carriers has been such that many features, sufficiently more attractive than the older pre-competitive communication offerings, have been achieved.

Not only have rates come down for single or multiple phone lines, but many significant features are also offered. ⁽²³⁾ Datran, one of the specialized common carriers is offering an entirely digital transmission system, similar in principle, to circuit switching and with charges applicable to small increments in time. Their claimed reliability is two orders of magnitude better than that of digitally encoded analog transmission systems which were standard heretofore.

Telenet Communications Corporation is offering a commercial version ⁽²⁴⁾ of Arpanet-like packet switched technology. The reliability called out in their offering is seven orders of magnitude better than digital transmission using standard phone lines. There are other offers of packet switched technology, circuit switched technology, and digital transmission technology. The varied menu of offerings makes it eminently feasible to design applications of computer networking and remote resource sharing to fit a wide variety of data transfer rates and quantity of data to be transferred, spanning a large number of applications. The appendices treat candidate networks.

Educational Computer Networking

EDUCOM, an organization founded in 1964, fosters the collaboration of colleges and universities in the use of computers and communications to support the aims of higher education. It has given special emphasis since ^(11,12) 1966 to the subject of computer networks.

The institutions participating in EDUCOM have accumulated considerable experience with remote resource sharing and computer networking either through

centralized computer facilities supporting many remote terminals or through the networking of computer facilities at different campuses within regional networks. Their experience with networking has been both gratifying and frequently painful as is the case in the introduction of any new technology affecting a varied user community. EDUCOM participants have achieved many new capabilities and have access to broad areas of software and computational configurations which individual installations need not duplicate.

The experience of EDUCOM participants has yielded considerable insight into the organizational, political, social, and economic problems associated with the introduction of computer networking between organizations that have facilities of varying power and different historical development. (12)

In many respects, the experiences of EDUCOM and similar organizations parallel some of the experience that ERDA may have in using or in bringing to bear the economic and research advantages of computer networking among its highly developed installations.

3. AREAS OF RESEARCH AND INVESTIGATION

Initial Investigations

The first activities in computer networking by members of the ERDA CNG will be probing efforts to become familiar with the ARPANET, its operation, and the characteristic problems associated with processor-to-processor interaction at each site. Many of the research centers have had a long, and in some cases pioneering, experience with the provision of centralized remote resource sharing. Indeed, the remote computational services currently provided by the sites is among the most comprehensive and sophisticated in the nation. However, they will initially be in a learning and interacting mode in the distributed network of ARPANET.

Computation center personnel and users will explore the many varieties and philosophies of software and hardware architecture comparing implementations at their own facilities with those at other facilities. The management personnel will be especially interested in the varieties of service offered by other facilities as compared with their own service offerings. The intimate interaction on technical and managerial aspects of remote resource sharing should prove beneficial for each facility and for the totality of computational power within the ERDA. The interaction of ERDA facilities with each other and with other facilities available to them on the network will give them an opportunity to make their own assessments of the status and directions in computer networking and remote resource sharing.

The reasons for ERDA CNG selection of ARPANET as the first major arena in which to experiment and gather experience are many. Firstly, the community of servers and users within the ARPANET, because of their participation in the development of a highly sophisticated network, represents a user community well versed in each other's problems and the art of technical

compromise. The ARPANET, being primarily a research network, gathered many statistics concerning communications and computer usage, and user-server interaction. Many new areas of future networking payoff were explored in depth by ARPANET users and designers. The ARPANET community, because it does include such a variety of types of facilities as well as many of the most highly research-oriented facilities, represents probably the most sophisticated and experienced community involved in remote resource-sharing exploration. A very significant aspect of ARPANET-associated users is the ongoing nature of their research in various scientific disciplines via the network. The availability of such a community is a major plus to the ERDA subnet of experimenting facilities.

As soon as all of the CNG experimenter sites are connected to the ARPANET by communication lines and ARPANET interface hardware, the first specific tasks of each site will be to check out, in the actual network, the software and hardware that each site developed for network use.

The participating computer scientists at each of the experimental sites will coordinate their efforts via ARPANET MAIL and teleconferencing capabilities. The significance of these techniques on initial attempts and also on future ERDA use of computer networking is very great because of the ability to quickly intercommunicate on the same network being used for computation. Both experimenting computer scientists and researchers, in the various fields that will be the subject of first trial uses, will be able to coordinate, clarify, and resolve their intentions, meanings, and misunderstandings readily and quickly without travel to each other's sites. Progress of the experiments should therefore be hastened and budgets be less strained.

The computer networking ability to implement teleconferencing and MAIL become very powerful tools in many aspects of research supporting

ERDA missions and goals. In many instances scientists travel to the computation center which will be utilized in their research in order to become familiar with the mode of operation and computation services, to prepare programs and debug them, and to execute production runs. After returning to the home laboratory, there may be need to request additional computational runs at the original computation center or to use the programs developed at another computation center. Quite frequently programs are found to contain modifications which other scientists have installed and which alter the computational intentions of the original program generator. In the absence of communication capabilities, this usually gives rise to much confusion and additional costs in terms of manpower.

Despite all of the recent advances in hardware cost reduction, there has not been an even remotely comparable decrease in the cost of software preparation. ⁽¹⁰⁾ This remains a major impediment in many research and development programs. It is expected that networking will be a major force impacting the cost of software. For example, many more ERDA sites would utilize code certification capabilities at Argonne National Laboratories if they could reach out via the network to acquire well debugged programs or to gain assistance of its code certification center in the testing of their own programs. Moreover, the power of a code certification center would be enormously increased if testing could be effected via the network at different centers with varied configurations directly by the center.

Through comparison of services needed for specific problem-solving at many different computational centers, users can gain a better appreciation of the effectiveness of different service offerings. Their communication with computer center managers could result in more effective planning of future service offerings. ⁽²⁵⁾ The overall impact on ERDA's use of funds for

computation can be a higher level of efficiency and a more accurate assessment of the impact of computational funding supporting various programs.

The intent of the CNG's experimentation is to determine good ways of utilizing computer networking and remote resource-sharing and to determine the areas where use is contraindicated. Though many of the technical problems of networking will of necessity be addressed, the CNG program is primarily designed to expose the kinds of problems which future network users may find, and to determine means of coping with and overcoming these problems. For example, we do not intend to focus on the general problem of computer networking and remote resource sharing or on the analysis of a particular network component. The approach that the CNG will take will emphasize the evaluation of network systems service as opposed to the strength of individual computer system architectures or communications configurations or software systems. (26,27) We should be concerned with error-prone characteristics of protocols with overhead, with failures to complete a remote computation and with cost. Extensions to our current concepts of performance evaluation will be required to cover the "value" of the network service to the research program or activity which it supports.

Effective evaluations of network performance would include consideration of many system characteristics among which are: hardware, software, special system features, response to benchmark tests, security assurance, procedures of communication, procedural support, data and program transferability, reliability and recovery procedures, resource management techniques, communication sub-system control procedures, the level of development of standards, etc.

In summary, we must realize that computer networking and remote resource sharing are in the infancy of their development. Though it is true that many

instances of these technologies have been successfully accomplished, these, by and large, have been resources shared via a network at one facility, or if more than one facility was used the computer systems were mainly homogeneous. The notable exception is the ARPANET. The maturation of these technologies will no doubt take a decade or longer, though positive advances will occur in many areas before maturation.

What benefits may accrue from the sharing of resources at many different sites? To give a partial listing,

1. More efficient use of computer power via loadsharing.
2. Users may access special programs or standard codes and application packages developed for general use or for their particular disciplines, which are not locally available.
3. Users and computer scientists may gain "hands-on" experience with a wide variety of computer configurations and software resources which would enhance their research and allow them to make more informed choices as to computational resources to be used.
4. Computers can be used in joint experimentation where the particular capabilities of each are supportive of the tasks of others in large experiments. Numerous instances on the ARPANET have been given where this has been done. For instance, one remote computer was used to prepare input files for another remote computer, the output from which was converted for graphic representation by another computer.⁽²¹⁾
5. User access to on-line conversational facilities not available locally.
6. User reference to varied bibliographic search repositories for research.

7. Users having access to various centralized and decentralized data bases located at many different installations.

8. User choice among various system configurations to meet cost or deadline criteria.

9. Resource mobility by transfer of programs from one system to another for use there or for more efficient computation.

10. Joint development of programs by colleagues at dispersed locations.

11. Availability of existing graphics systems locally and remotely.

12. Resource mobility for adaptation to changing roles of research and locale.

13. Joint experimentation involving scientific users at many remote locations.

14. Access by educational institutions to national laboratories for computation in support of manpower training for disciplines of high priority.

15. Possible interconnection between different networks to occasion even wider resource sharing. It is possible, for example, to interconnect ARPANET or another commercial network used by ERDA experimenters to the CTR network (if permission is granted).

16. Teleconferencing by remotely located scientists for general confabs and computer experimentation using digitized information transfer for fax, voice and textual materials.

From the partial listing above our experiments will determine the feasibility and problems associated with the accomplishment of these capabilities.

In our experiments we hope to augment existing ARPANET statistics gathering by eventually including monitor provisions for experimentation of

a) Process responsiveness for batch or on-line

b) Effective communication throughput, bidirectionally

- c) Effective processing throughput
- d) Amount of data transferred
- e) Error and recovery statistics of system and user
- f) System availability
- etc.

We also hope to gather statistics on user reactions and difficulties encountered. These will permit us to come to grips with the manifold problems involved in the user interface - documentation, guidance and on-line help routine standards for user facilitation.

4. PROGRESS TO DATE

The Objectives Panel of the ERDA Computer Networking Group represents a broad spectrum of computation and communications requirements and experience within the agency. The current membership of the Objectives Panel follows:

Betty Campbell
Massachusetts Institute of Technology
Laboratory for Nuclear Sciences

Irving Cohen (Vice Chairman of CNG)
Computer Science Department
UCLA

Gerald Estrin (Chairman of the CNG)
Computer Science Department
UCLA

Sidney Fernbach
Computation Division
Lawrence Radiation Laboratory
University of California

Max Goldstein
The Courant Institute of
Mathematical Sciences
New York University

Robert Harvey
Mathematics and Computing
Lawrence Berkeley Laboratory
University of California

Jack Worlton
Computer Science & Services Division
Los Alamos Scientific Laboratory
University of California

Clair Maple
Mathematics & Computer Division
Ames Laboratory
Iowa State University

Bennet Miller
Controlled Thermonuclear Research Pgm.
Molecular Sciences and Energy Research
Division of Physical Research
USERDA

Milton E. Rose
Mathematical & Computer Science Pgm.
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USERDA

Richard J. Royston
Applied Mathematics Division
Argonne National Laboratory

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Div. of Management Information and
Telecommunications Systems
USERDA

Robert Marr
Applied Mathematics Department
Brookhaven National Laboratory

Lyle Smith
Stanford Linear Accelerator Center
Stanford University

The Objectives Panel of the CNG has met three times. The first meeting in November 1973 at Albuquerque was devoted to getting acquainted with each other's motivations and desires with respect to networking and remote resource sharing and to expressing a broad range of views with respect to these subjects. Each member discussed the facilities at his site and the services, programs,

languages, configurations, and data bases he could offer to others; and his desires in these same categories at other sites with which his users might interact for purposes of experimentation. There were informative presentations on Sacnet and ARPANET. But the main business was the formulation of objectives for the experiments and the definition of the kinds of information which the panel members felt would be critical to the evaluation of networking and remote resource sharing. The second meeting, at N.Y.U. in April 1974, continued these discussions, as did the third, at Bethesda in October 1974.

During the second meeting, recognition was made of the probability of having to use communication facilities other than the ARPANET. Reports were made on other packet switching carriers, and Dr. L. Roberts, President of Telenet Communications Corporation, a commercial specialized common carrier offering packet switching, addressed the opening session of the meeting. The rapid changes in telecommunications offerings which occurred in the spring and summer of 1974, and their impact on planned experimentation and potential networking was addressed at the third meeting.

It is of interest to point out that centralized networking experience most sites had accumulated contributed to the deliberations. Local experiences have been informative with respect to planning for more geographically broad networking. In fact, some site representatives are interested in sampling and experimenting with resources not available at ERDA experimenter sites but at other locations on the ARPANET. Unfortunately, some facilities are off-bounds due to security requirements. But each member indicated the utility to him and his community of users of various aspects of remote resource sharing (RRS) and computer networking (CN).

With respect to the data to be gathered from the experiments, it was generally agreed that that data which reflected the ease of use and user

satisfaction would be highly important. Depending on the specific service at a site accessed by a user, his satisfaction may be tempered by many factors; his own level of sophistication and the relative development of the user interface for that service, among others. Much study has been given by others in the CN and RRS field to measuring the quality of computational use. This depends upon many subjective as well as objective factors. Methods for gathering and processing quality criteria have to be developed. It is difficult to quantify simplicity, understandability, consistency, user trauma or astonishment at system responses, but at this state of our experimental planning, we need to come to grips with these phenomena.

A very partial listing of the factors we should like to measure in the user experiments are:

- Relative costs of local versus remote computation

- Relative reliability and availability of services

- Minimization of user error opportunities

- System tenderness toward user errors (forgiveness)

all, as seen from the user's point of view. We should note that relative costs include user time and preparation as well as hard dollar charges for computation.

We should like to differentiate between problems associated with the network, the computer system, and the user interface. We should like to be discriminating in assessing user comments. One "good" experience might reflect a relatively poor former service which was dependent upon the dial-up network. A "poor" comment might reflect insufficient familiarization with the system service or overly high expectations. It is necessary, therefore, to monitor the experiments by computer scientists during their operation. The computer scientists will also analyze the trade-offs among experimental variables with respect to overall computational productivity.

Pending the beginning of organized experimentation on the ARPANET, much primitive experimentation has been going on. For example, information used in this report was transmitted to UCLA from L.N.S./MIT (via MULTICS) and from Argonne on the ARPANET. A terminal at UCLA accessed the Argonne 360/75 TSO system for another report transfer and some other experimentation over the dialed network. Pending the installation of the CTR network, personnel at the CTR Program Office are using the On-Line Mathematical System at UCLA/CCN via ARPANET. There are, surprisingly, many ERDA researchers who use ARPANET and other networks for remote resource sharing all around the country, and one objective will be to acquire knowledge of each user and his type of usage.

The Implementation Panel has held five formal meetings since May of 1973. Panel members had as their initial task familiarization with ARPANET protocols and methods of implementing them. For the ERDA experimental sites, agreements were made for protocol implementation and efforts toward implementation begun. Each site, however, did have differing approaches to methods of network interconnection, which reflected their system design requirements commitments to other programs, etc. So there will be a variety of technical interfaces to the ARPANET.

The membership of the CNG Implementation Panel includes:

Larry Amiot
Argonne National Laboratory
Harvey Baumel
Programming Development Office
Information Processing Center
Massachusetts Institute of Technology
Graham Campbell
Computing Center
Brookhaven National Laboratory

Irving Cohen
Computer Science Department
UCLA

Robert L. Fink
Lawrence Berkeley Laboratory
University of California

Ed Franceschini (Panel Chairman)
Courant Institute of Math. Sciences
New York University

UCLA is already connected to the ARPANET triply; via the PDP 11/45 at the ARPANET Networking Measurement Center (NMC), the UCLA Campus Computing Network (CCN), and the Computation Center for the Behavioral Sciences (CCBS). The NMC machine is for network measurements, with most computation being done remotely, so that the CCN host will be used as UCLA's prime machine in the experimentation.

Lawrence Berkeley Laboratory will front-end their 7600 to ARPANET via a 6000 series CDC machine. Argonne National Laboratory is using Varian 73 minicomputers as a front-end for their IBM computers (370/195 and 360/75). The front-end concept permits the concentration of networking software outside the main frame, where its operation would contribute inordinately to processing overhead.

Both N.Y.U. and Brookhaven National Laboratory were counting on the development of the ANTS network oriented (front-end) software system operating in a PDP 11 series machine to act as a front-end). However, the progress of the ELF II front-end system makes it the more likely choice for front-ending in a PDP 11. N.Y.U. has already contracted for the PDP 11 and Brookhaven will probably follow this implementation.

MIT's Laboratory for Nuclear Science (LNS) is currently conducting a study jointly with MIT's Information Processing Center for the best method of interfacing to the ARPANET. MIT is already multiply connected to the ARPANET. For the immediate future LNS will experiment on ARPANET via the MULTICS system.

Los Alamos Scientific Laboratory is planning to participate in the experimental program and will access the ARPANET via Kirtland Air Force Base's terminal message interface processor (TIP).

The ARPANET protocols, which are in process of production at ANL and LBL are designed to permit process-to-process communication. That is, the

programs in operation on separate computers can interact with each other. Provision is also made for terminal access to computers. The protocols being developed are called Telnet (for terminal access) and File Transfer Protocol (FTP) for file transfers between computers. Their work in conjunction with a network control program (NCP) which acts as an application program associated with the computer's operating system. In the instances of ELF 11 systems, the NCP and protocols will be available as part of the software.

The ARPANET Interface Message Processors, which transport messages to and from hosts in the network, and the 50 kilobaud telephone lines, necessary for data transmission, were installed at N.Y.U. and Argonne during February 1975. No order has yet been placed by Brookhaven, which would use the IMP at N.Y.U. via phone lines (50KB). UCLA and LBL have IMP's and communication lines available.

The NCP and protocols should be completed and debugged and run through their network shakedown by the end of fiscal 1975.

Now that ARPA may pass control of the ARPANET to another government agency, there may be redirection in the use of ARPANET. It may be restricted to DOD contractors and agencies or it may be thrown open to non-DOD agencies and contractors. Current users, including the ERDA initial experimental sites, will remain on the ARPANET. Because ARPANET policy is undefined, the CNG has explored the possibilities of using commercial packet switching with Telenet Communications Corporation. Possibility of inter-communication between Telenet and ARPANET have also been discussed, but this awaits policy decisions on the part of both network managements.

5. PLANS FOR THE FUTURE

The future program of experimentation by CNG members will proceed in phases. A short description of anticipated phases is given here.

1. Definition of Objectives

This activity of the Objectives Panel started with the first meeting and will continue throughout the program. As initial objectives are met new objectives may be perceived and delineated for further investigation. The results of experiments, both positive and negative, will be analyzed for their precise import to networking and remote resource sharing. In a sense, the Objectives Panel will be placing results of experimentation in proper perspective. Positive results will be weighed for their applicability to the spectrum of user needs and server capabilities. Negative results will be analyzed as problems to be overcome, if advisable, to meet Agency computation needs.

2. ARPANET Interconnection Preparation

This is the phase in which we now find ourselves. Network Control Programs, protocols, and hardware requirements are being implemented. Although the initial activities are to take place on the ARPANET, studies of other techniques of networking will continue. Contact with all commercial network ventures is to be kept active and advantage is to be taken of any opportunity to try a new system. Benchmark uses should be singled out so that comparative results may be obtained.

3. ARPANET Interconnection and Shakedown

The ERDA contractor sites involved in experimentation on this network will require a trial period in which those software systems necessary to networking which have been debugged locally must be tested in actual network operation. Preliminary decisions to use restricted higher level protocols

are to be reviewed for facility in experimentation. This phase may be replicated for other network utilizations as they become feasible and necessary. For the ARPANET a continuation of such activities may be indicated to implement other protocols such as the Remote Job Entry, Data Reconfiguration, and Graphic protocols. A particular goal of this phase is for UCLA, NYU, ANL and LBL to be interacting through the network in the first quarter of fiscal 1976.

4. Experiment Design

The Objectives Panel is charged with monitoring the design, performance and evaluation of network use. Periods of probing network usage will involve cooperating computer scientists at the various sites. Mutual review of plans and procedures can be a force to assure that critical problems are addressed and that provision is made for the acquisition and analysis of relevant data.

5. Experimentation with Candidate Users

The variety of user requirements can only be partially explored by the CNG. Candidate users will be selected from the many disciplinary communities participating in agency research. Experimentalists will have to cope with a broad range of attitudes and competences in computer usage, as well as with unanticipated "expectations" of research users. To complement CNG's experiments, continuing study of developments in other areas of research and industrial endeavor will be made for their import to ERDA computation e.g. NERCOMP. (13)

Examples of candidate uses which have already been identified are:

- a. Work on quality mathematical software between ANL, experts in the United Kindom, and other researchers in the U.S.;
- b. Work in high energy physics at MIT, Stanford, UCLA and CIT;
- c. Work on access to ANL's Code Certification Center;
- d. Potential interaction of academic researchers in CTR and other areas of plasma physics pending their interconnection to the CTR network;

- e. Cooperative development of methods and tools for designing reliable software and systems.

6. Evaluation

The experimental sites and the Objectives Panel have complementary roles in evaluation. Each site should be able to derive from the networks tests some information which is valid for the extension of its own remote resource sharing and the policies necessarily attendant to them. The Objectives Panel, as an entity, should recognize the overall impact of the results of the evaluation to the agency. Many panel members, though not experimenters, should draw conclusions for their own operations, with respect to management and technical policies to be followed for both analytical and A.D.P. networking and resource sharing. The policies should reflect the technical, management, organizational, and human interface methodologies necessary to the benefits of networking -- for funders of research involving computational resources, for managers of resource sharing services, and for managers responsible for providing the necessary networked resources for the successful accomplishment of their research missions.

7. On-Going Investigation

It is anticipated that many experimental results will indicate new areas of experimentation. The tableaux of experiments are not, therefore, readily predictable at this time. However, with time, some of the experimentation will give rise to new remote resource sharing services offered by the experimenting sites and that some experiments will be designed to optimize their utility to users. Some experiments will lead to new production capabilities and feedback from usage of such production capabilities, though not formally a part of our experimental program, will be valuable to our deliberations. Also, the real probability of experimenting on other networks should give rise to investigations which compare networking

techniques. It should be emphasized that the networking experiments are complementary to on-going remote resource sharing planned by each of the sites individually, and that feedback from these efforts, especially in the areas of user interface will be highly valuable. We may be able to attempt inter-network experiments using commercial networks, ARPANET, the ERDA CTR NET, etc.

8. Overview

Many of the evaluations, conclusions and recommendations emanating from this program will be of use to planners for agency networks to provide remote resource sharing either for specific programs or for use by many programs on common networking facilities. Though most of the planned investigations will deal with analytic computing, much yield is also anticipated which will be of value to agency ADP applications. Indeed, the feasibility of common usage of varieties of facilities for both analytic and ADP applications may be furthered. It is planned that a systematic overview of the experimentation will be published, to be used as a significant guide to agency planners and implementers. Contributions to this guide will be issued as experimentation and evaluation proceeds, and it is expected that during the tenure of the experimental program much interaction will take place with parallel research and plans for remote resource sharing by other groups within the agency.

6. REFERENCES

1. Rose, M. E., Private Communication to G. Estrin
2. Roberts, L. G., "Data by the Packet," Spectrum, February 1974.
3. Doll, D. R., "Computer Networking - The Giant Step in Data Communications," Data Communication Systems, September 1973.
4. Mathison, S. L. and P. M. Walker, "Regulatory and Economic Issues in Computer Communications," Proc. IEEE, November 1972.
5. Cohen, I., AECONOTE UCLA-1 (A CNG Memo), Included as Appendix #1 of This Document
6. Ashenhurst, R. L. and R. H. Vanderohr, "A Hierarchical Network," Datamation, February 1975, pp. 40-44.
7. Farber, D. J., "A Ring Network," Datamation, February 1975, pp. 44-46.
8. Wulf, W. and R. Levin, "A Local Network," Datamation, February 1975, pp. 47-50.
9. Fraser, A. G., "A Virtual Channel Network," Datamation, February 1975, pp. 51-56.
10. Share Secretary's Distribution #249, October 15, 1974 (Revision to be published in book form). Available from Share, Inc.
11. Brown, G. W., J. G. Miller and T. A. Keenan, "Edunet, Report of the Summer Study on Information Networks Conducted by the Inter-University Communications Council," John Wiley and Sons, Inc., 1967.
12. Greenberger, M., J. Aronofsky, J. L. McKenney, and W. F. Massy, Networks for Research and Education: Sharing Computer and Information Resources Nationwide, MIT Press, 1974.
13. Kurtz, T. E., "The NERComP Network," in Greenberger, et al. (Ref. 12 above), pp. 282-287.
14. Licklider, J. C. R., "Potential of Networking for Research and Education," in Greenberger (Ref. 12 above), pp. 44-50.
15. Shull, H., "Resource Sharing in Theoretical Chemistry," in Greenberger (Ref. 12 above), pp. 263-272.
16. Roberts, L. G. and B. D. Wessler, "Computer Network Development to Achieve Resource Sharing," SJCC, May 1970.
17. Heart, F. E. et al, "The Interface Message Processor for the ARPA Computer Network," SJCC, May 1970.

18. Ornstein, S. M. et al, "The Terminal IMP for the ARPA Computer Network," SJCC, May 1972.
19. Carr, C. S., S. D. Crocker, and V. G. Cerf, "Host-Host Communication Protocol in the ARPA Network," SJCC, May 1970.
20. Crocker, S. D., et al, "Function Oriented Protocols for the ARPA Computer Network," SJCC, May 1972.
21. Sher, M. S., "A Case Study in Networking," Datamation, March 1974, pp. 56-59.
22. Cohen, I., AECONOTE UCLA-2 (A CNG Memo), Included as Appendix #2 of This Document.
23. Cohen, I., AECONOTE UCLA-5 (A CNG Memo), Included as Appendix #3 of This Document.
24. Cohen, I., AECONOTE UCLA-4 (A CNG Memo), Included as Appendix #4 of This Document.
25. Morris, M. F., "Performance Evaluation: An Emerging Discipline of the Computer Sciences," Proceedings of the Jerusalem Conference on Information Technology, 1974.
26. Abrams, M. D., "A New Approach to Performance Evaluation of Computer Networks," 1974 Symposium - Computer Networks: Trends and Applications, pp. 15-20.
27. Abrams, M. D., "Measuring Service Delivered in Interactive Computing," Proceedings of the Jerusalem Conference on Information Technology, 1974, pp. 749-754.

APPENDIX #1

EXPERIMENTAL PROGRAM

A.T.T. Hi-Lo Density Tariff and Dataphone Digital Service
and Their Competition

1. INTRODUCTION

A.T.T. long line service has traditionally determined the tariffs for its analog or data channels on the basis of nationwide cost averaging. This was designed to equalize the cost for providing comparable grades of service in different parts of the country and to rural or suburban as well as to urban areas.

The FCC, in its decision to encourage competition in communications, had in mind the generation of new services especially for digital transmission, and to have the competition itself regulate the going prices. A host of specialized common carriers came into being. Microwave Communications, Inc., Southern Pacific, Western Telecommunications, Inc., etc., proposed to offer competitive voice (and other analog) and data communications [1,2,3]. Datran proposed to build a pure switched digital network [4]. The value added carriers such as Packet Communications, Inc., Telenet, Graphnet, Inc. etc., proposed to lease bandwidth from other carriers to provide packet switched communications for digital users [5, 6].

The new competition to A.T.T. and other regulated common carriers became intense, as the new or specialized common carriers invariably quoted more attractive rates. They also proposed to service the more lucrative markets, exclusively, while providing interconnection to the less lucrative markets via interconnection to the regulated common carriers [7, 8, 9, 10].

"Cream-skimming" was the charge brought by A.T.T. against those specialized common carriers that were primarily purveyors of bandwidth, and long fights and litigation ensued. A.T.T. refused to interconnect to MCI (the test case) but this seems to have been resolved in MCI's favor [11].

The Bell system responded with two major thrusts. It revised its digital tariffs to be more competitive via the new Dataphone Digital Service [12]. This brought objections to the FCC from Datran because their profit margins were impacted adversely; but Datran published even more competitive rates. MCI, for example, did not contest this because its business mix of digital to analog service currently is 20% to 80%. Bell's second thrust was to discard national cost averaging and base its tariffs more on actual costs of service supplied [1,7]. This new offering was called the HI-LO Density tariff. Because of adverse responses from MCI, etc., the FCC retarded the implementation of the tariff which finally de facto went into effect in June 1974 [9,11].

The HI-LO tariff reflects actual costing more directly. The costs of supplying service to non-dense non-urban communities are higher than those of urban, dense communities. Hence the charges or tariffs for service reflect the costs of implementation and maintenance of service. Even in some urban areas there may be locales of low density demand and the tariffs reflect this. Hi density and low density areas must be determined by reference to the phone company [9,13].

The HI-LO tariff applies only to the series 2000 and 3000 services, essentially transmission over voice grade or conditioned voice grade channels. The wideband services such as series 8000 are not affected by HI-LO.

In the Dataphone Digital Service tariff, there is no provision for joint user service and the composite data service vendor. A composite data service vendor is a customer who uses the telephone company provided communication service in the provision of a composite data service to his patrons and who does not engage in the provision of telecommunication service other than composite data service. A composite data service is one that adds value to the basic telecommunication service such as by data speed

changing, automatic alternate routing, etc. Thus the value added carriers such as Telenet, PCI, Graphnet, etc. would comply, whereas pure telecommunication service vendors such as MCI, etc. may not.

Users who do not need a full voice grade channel may share it as joint users. In earlier situations the principal subscriber could not do this because he would be a "purveyor of bandwidth" and hence subject to regulation.

2. HI-LO TARIFF

Two distinct rate classifications are applicable to links longer than 25 miles. There is a rate for high density routes and a rate for low density routes. Rates for less than 25 miles remain at \$3.00/mile, and are termed short-haul.

The applicable charges for inter exchange channels are:

	<u>\$/Mi./Mo.</u>	<u>CHANNEL TERMINAL</u>	<u>STATION TERMINAL</u>	<u>INSTALLATION CHARGE</u>
Hi-Density	\$.85	\$35.00/mo.	\$25.00/mo.	\$50.00
Lo-Density	2.50	15.00/mo.	25.00/mo.	50.00
Short-Haul	3.00	3.00/mo.	*	50.00

*Short-haul users pay \$15.00 for the first station terminal for non-foreign exchange service, \$10.00 for foreign exchange service and \$3.00 for additional stations.

Note that channel and station terminals are differentiated. Channel terminal refers to a channel termination and station terminal refers to an actual user instrument. Thus in going from a locale greater than 25 miles from Los Angeles to a local greater than 25 miles from New York, both locales requiring low density interchange rates, we would have, for variable monthly charges:

LOCALE A to LAX: - \$2.50/mi. + 2 x \$15.00/ch. terms + \$25.00/sta. term.

+LAX to NYC: - \$.85/mi. + 2 x \$35.00/ch. terms

+NYC to LOCALE B:- \$2.50/mi. + 2 x \$15.00/ch. terms + \$25.00/sta. term.

Note that LAX (Los Angeles) and NYC (New York) do not have customer station terminals so that these charges do not apply.

3. DATAPHONE DIGITAL SERVICE

In March of 1974 A.T.T. filed the Dataphone Digital Service tariff (FCC 267) [12]. The D.D.S. service will initially be point-to-point, full period at the customer's chosen data speed. Hub cities or digital cities are defined as the major nodal cities to which traffic is served. Within the hub cities access to the D.D.S. service will be via Digital Access Lines (DAL). A Type 1 DAL will service those customers within about 5 miles of the hub rate center and will bear a fixed monthly charge. A Type 2 DAL will service customers outside the DAL 1 area and will bear a fixed monthly charge plus a mileage charge per month. Note that it is important to know where, within a city, the hub rate center is located.

A Data Service Unit (DSU) or Channel Service Unit (CSU) is the customer interface. The CSU is included in the DAL prices. The CSU converts the bipolar format of the DDS system into a conventional binary format. A customer can arrange for an interface between his equipment and the CSU or can obtain a DSU from A.T.T. for an additional \$15.00 per month (\$20.00 at 56 Kbps). The DSU delivers the conventional EIA standard interface to the customer's equipment.

Provision is made for joint use of channels at no premium. Resale of capacity is authorized for composite data service vendors. Joint use can be on an alternate basis or via multiplexing.

The actual circuits used by DDS are the conventional tariff channels such as Type 3000, 5000, and 8000. Off-net extensions to other locales will begin in early 1975 to service customers outside the DAL 2 service areas.

DATAPHONE DIGITAL SERVICE CHARGES

Channels Between Digital Cities Monthly

For Transm. Speed of:	Fixed Charge	Rate Per Airline Mile
2.4 Kbps	\$20.00	\$.40
4.8 Kbps	40.00	.60
9.6 Kbps	60.00	.90
56 Kbps	125.00	4.00

Digital Access Lines in Digital City Serving Areas

Type 1

For Transm. Speed of:	Monthly Charge	Non-Recurring Charge
2.4 Kbps	65.00	100.00
4.8 Kbps	85.00	100.00
9.6 Kbps	110.00	100.00
56 Kbps	200.00	150.00

Type 2

For Transm. Speed of:	Monthly Fixed Charge	Rate Per Airline Mile	Non Recurring Charge
2.4 Kbps	90.00	.60	100.00
4.8 Kbps	110.00	.90	100.00
9.6 Kbps	130.00	1.30	100.00
56 Kbps	250.00	6.00	150.00

Multi-Station Arrangement: A monthly charge of \$15.00 per station (USOC 00Z)
Data Service Unit

For Transm. Speed of:	Monthly Charge	Non-Recurring Charge
2.4 Kbps	15.00	25.00
4.8 Kbps	15.00	25.00
9.6 Kbps	15.00	25.00
56 Kbps	20.00	25.00

Maintenance of Service Charge. Each visit - \$25.00

PROPOSED IMPLEMENTATION SCHEDULE

1974	Boston Philadelphia Baltimore St. Louis Kansas City, Mo. Denver Atlanta Houston	New York Chicago Pittsburgh Detroit Hartford Los Angeles Milwaukee Miami	Washington, D.C. Newark Cleveland New Haven Dallas San Francisco Portland Minneapolis
1975	Trenton Charlotte Orlando Omaha Oklahoma City Des Moines Salt Lake City Sacramento New Orleans Poughkeepsie Santa Barbara	Indianapolis Memphis Springfield, Mass. Columbus Akron Syracuse Cincinnati Providence Birmingham Harrisburg Nashville	Seattle Wilmington Phoenix Albany Dayton Tulsa Riverside, Calif. Louisville San Diego Toledo Buffalo
1976	Worcester Wilkesbarre Rochester Reno Greensboro Knoxville Allentown Albuquerque Lansing Grand Rapids Flint E. Moline	Greenville Richmond Stockton Shreveport Spokane Wichita Waynesboro El Paso Lincoln Reading Baton Rouge Little Rock	Tampa Norfolk Youngstown Colorado Sprgs. Fresno Ft. Wayne South Bend Las Vegas Chattanooga Peoria Madison Roanoke

References and Notes

1. "Alternatives to the Phone Systems", Computer Decisions, pp. 28-33, September 1973.
2. "Users Cash in on Cost, Service Benefits of Special Carriers", The Data Communications User, p. 31, November 1973.
3. Gaines, E.C., "Specialized Common Carriers - Competition and Alternative", Telecommunications, September 1973.
4. Worley, Allen R., "The Datran System", Proceedings of the IEEE, Vol. 60, No. 11, pp. 1357-1368, November 1972.
5. "VANS - Value Added Network Services", Staff Report, Telecommunications, November 1973.
6. Weiner, H., Lettieri, L., "Packet Switching: The Uncommon Carrier", Computer Decisions, pp. 34-37, December 1973.
7. "Guide for the Perplexed", Data Channels, A Datamation Newsletter, Vol. 1, #3, pp. 4-5, April 1974.
8. "Ma Bell: Big Cuts in the Big Cities", Datamation, April 1973.
9. "Major Carriers Delay Hi-Lo Till June", The Data Communications User, p. 13, 14, June 1974.
10. "Specialized Common Carriers React to A.T.&T. Hi-Lo Tariff, Communications News, p. 1, August 1974.
11. "Connections, Disconnections, and Reconnections", Modern Data, pp. 44-46, June 1974.
12. D.D.S. Tariff and Proposed Implementation Schedule, A.T.T., March 19, 1974.
13. Conversations with A.T.T. Long Lines Sales Office, Los Angeles and Tariffs Overview, K. Born, C. Williams.
14. Conversations with A.T.T. salesmen at National Computer Conference, 1974.

APPENDIX #2Value Added Carriers Overview

The FCC's announced desire to invigorate the field of telecommunications by fostering competition has given rise to the formation of new specialized common carriers that will compete with ATT and other established communications companies [1, 2]. Here, the focus is on those new entities known as value-added carriers or VAC's. VAC's are primarily communications service companies which utilize the circuits available from the established or specialized common carriers (which are really communications transmission organizations) and add value by their added services [3, 3A, 4]. The VAC's considered here provide for packet switching, a form of store and forward message switching, which permits interconnection of different types of computers and terminal devices in a common network. The organizations which have to date been approved by the FCC are Packet Communications, Inc., Telenet Communications Corporation, M.C.I. Data Transfer Corporation, and Graphnet Systems, Inc. [5, 21]. Graphnet provides mainly packet switched facsimile or graphics communications. In what follows the discussion will deal primarily with computer and terminal oriented systems such as that of P.C.I. and Telenet.

P.C.I. and Telenet grew out of the technologies developed under sponsorship of the Department of Defense Advanced Research Projects Agency Information Processing Techniques Office. IPTO funded and guided the development of the ARPANET which by the beginning of this year had about 50 host computers of various varieties and many different types of terminals interconnected [5, 7, 8]. The main thrust of Arpanet was to explore the possibilities of remote sharing of resources by facilities of diverse types. A network philosophy was forged and the Arpanet grew. The basic assumption was that trying to conceptualize requirements for interacting computers, terminals, etc. was not as effective as letting these devices interconnect and attempt to experimentally determine the barriers to effective resource sharing.

Out of this experiment there were developed Interface Message Processors (IMP's) [4] for routing information through the communications sub-net; that portion of the network which deals entirely with data transmission, Terminal Interface Message Processors (TIP's)[10] were developed to permit many terminals to access and interact with network hosts without a host of their own to communicate through. In order for these diverse facilities to understand each other a set of protocols or interaction disciplines were forged. These provided for IMP-IMP, IMP-HOST, HOST-HOST and finally process to process (within different hosts) procedures and controls [11,15,22]. Terminals interact with hosts via a Telnet protocol; file transfers are possible via the File Transfer Protocol (FTP);and remote job entry batch processing is possible via the Net RJE protocol. Each host type's system programmers agreed on the logic of these protocols and then implemented them with their own tools and languages. Some are still in process of modification [22].

The method of data transfer chosen was packet switching [4,17]. This is a form of message switching in which the messages are divided into packets of constant size and these packets are transmitted through the network to their destination. At the destination the packets are reconstituted into messages and delivered to the host or terminal intended. Packets were limited to about 1000 bits and up to 8 packets would constitute a message, with a leader for necessary transfer control. Typically, a host sends a message to an IMP. The IMP divides the message into packets and transmits each packet to the destination via the best route available at the moment. Adaptive routing is used and each IMP which accepts messages is at least dually connected to the network for reliability. The connection of IMPs constitutes a distributed net, as opposed to the more common star or loop configurations. The packets

usually traverse a number of intermediate IMPs before reaching the destination IMP which is connected to the intended destination host. For purposes of error control, each packet is error checked and if found faulty a retransmission is requested. Upon reconstitution of the message at the destination IMP the message receipt is acknowledged to the source IMP. Where the source or destination is a terminal without a host a TIP acts as the source or destination IMP. TIPs also engage in the routing of packets, error control, and other activities performed by the IMP's.

Store and forward techniques using IMPs were chosen so that the best use could be made of interconnecting communication links. Point to point circuit switching, as in the telephone public switched network was deemed too prodigal of bandwidth. In many dedicated circuit switched networks it is common to find less than 10% utilization of the links due to intermittent use or the limitations of terminal transfer rates (there are also effective techniques for increasing utilization and reducing the cost per bit for communications in circuit switching). Adaptive routing was chosen so that information transfer would not be interrupted by breakage or degradation of links in the network and to also balance the use of network links (e.g., relatively idle link paths can be used to ease congestion on highly used paths) [6, 7, 9].

The ARPANET was and is a research effort in which widely varying requirements and participant perception were encouraged to mix into the amalgam of tools and techniques represented in the current implementation. New sites joining the net bring new problems but on the whole the breadth and depth of perception of the instrumentalities needed by the early participants has provided a good basis for the fundamental objective - how to effect remote resource sharing. Many rich ideas have been proposed which have not as yet been implemented. The work on ARPANET has constantly

been guided by modeling and measurement activities at the Network measurement and operation centers.

The impact of ARPANET technology on the development of computer communications systems and their design has been profound. Accompanied by significant developments in other network technologies such as circuit switching, satellite communications, etc. the design of networks of processors has evolved much more rapidly than had been anticipated. This, despite the existing greater data-handling capacities of earlier networks such as those for time-sharing and remote computer services.

Among the significant benefits that have been claimed are [20, 21]:

1. The ability to price data transmission as a function of volume independent of geographical location.
2. Reliability of communications 4 to 5 orders of magnitude better than pure circuit switching technologies.
3. The ability to have communications between different computers and a wide variety of peripherals and terminals without significant hardware or software modification.
4. The ability to support a wide range of communication speeds, formats, and codes.
5. The ability to interconnect new models of equipment and software as they appear with minimal investment.
6. Rapid interconnection of terminals and acceptable turn around times for interactive messages.

The implications of the above are many. New applications and industry sectors now may require less entry capital to start up because of a more rationalized and less expensive approach to their communication needs. Users of computers and communications are less tied to the offerings of their suppliers and can

elect to optimize their systems from a broader, more competitive array of vendors. Already developed facilities for computations or information storage need not be duplicated and organizations with broad computing and data management needs can make more facilitative and economic design decisions in enhancing or modifying their information processing systems.

During the five year history of ARPANET development there have been many increments in the service that it afforded. Development and refinement of protocols gave qualitative increments. Though these have stabilized bugs still appear, and it is not completely evident that the particular philosophies implemented will continue to be preferred for other packet switching applications [16, 17, 18, 22]. With respect to the availability and reliability of the network there has been incremental improvements. For the six months from June through November 1972, IMP downtime for either hardware or software failure averaged less than 1.1% out of more than 128,000 hours of operation, with an MTBF of 409 hours. Line outages during the same period average 1.5% [8]. Overall availability for the was 97.43%, 97.6% and 98.64% for calendar years 1972 and 1973 and the first four months of 1974 respectively [19]. This contrasts with advertized claims of better than 99.5% by the forthcoming commercial V.A.C.s [20, 21].

From the information available to date the protocols required for interconnection to the V.A.C.'s will differ from ARPANET protocols. V.A.C. protocols will probably deal primarily with communications subsystem activities such as Host or Terminal to communication subnet interaction, whereas ARPA protocols encompass process to process interaction. ARPA protocols are no doubt more complex than VAC protocols. Thus where process to process communication is desired, communication computers would have to use manufacturer supplied or specially developed additional levels of protocol.

Innovations of similar scope are also taking place in other communication technologies which will be discussed in later documents. Though packet switching and emergence of VACs will have very broad applications, there are many application areas which are not significantly aided by them. There are broad areas which will be economically supported by new offerings of other specialized common carriers and of the regular common carriers (viz. A.T.T.'s newly announced Dataphone Digital Service).

References

1. "Alternatives to the Phone Systems", Staff Report, Computer Decisions, pp. 28-33, September 1973.
2. Gaines, E.C., "Specialized Common Carriers - Competition and Alternative", Telecommunications, September 1973.
3. VANS - Value Added Network Services", Staff Report, Telecommunications, November 1973.
- 3A. "Packet Switching Starts to Move", Electronics, pp. 44-46, December 6, 1973.
4. Weiner, H., Lettieri, I.L., "Packet Switching: The Uncommon Carrier", Computer Decisions, pp. 34-37, December 1973.
5. Roberts, L.G., "Data by the Packet", Spectrum, February 1974.
6. Roberts, L.G., Wessler, B.D., "Computer Network Development to Achieve Resource Sharing, Proceedings, S.J.C.C., pp. 543-549, May 1970.
7. Frank, H., Kahn, R.E., Kleinrock, L., "Computer Communications Network Design - Experience with Theory and Practice", Proceedings, S.J.C.C., pp. 255-270, May 1972.
8. Wolf, E.W., "An Advanced Computer Communication Network", AIAA Proceedings, Computer Network Systems Conference, Paper 73, Huntsville, Ala., April 1973.
9. Heart, F.E., Kahn, R.E., Ornstein, S.M., Crowther, W.R., Walden, D.C., "The Interface Message Processor for the Arpa Computer Network", Proceedings, S.J.C.C., pp. 551-567, May 1970.
10. Ornstein, S.M., Heart, F.E., Crowther, W.R., Rising, H.K., Russel, S.B., Michel, A., "The Terminal IMP for the Arpa Computer Network", Proceedings, S.J.C.C., pp. 243-257, May 1972.
11. Carr, C.S., Crocker, S.D., Cerf, V.G., "Host-Host Communication Protocol in the Arpa Network", Proceedings, S.J.C.C., pp. 589-597, May 1970.
12. Crocker, S.D., Heafner, J.F., Metcalfe, R.M., Postel, J.B., "Function Oriented Protocols for the Arpa Computer Network", Proceedings, S.J.C.C., pp. 271-280, May 1972.
13. "Specifications for the Interconnection of a Host and an IMP", Bolt, Beranek and Newman, Inc., Report No. 1822, March 1974 (Latest revision).
14. "Host/Host Protocol for the Arpa Network", McKenzie, A., Arpa Network Information Center (NIC) #8246, January 1972.
15. Postel, J., "Official Initial Connection Protocol", NIC #7101, June 1971.
16. Walden, D.C., "A System for Interprocess Communication in a Resource Sharing Computer Network", Communications, ACM, Vol. 15, No. 4, April 1972.
17. Metcalfe, R.M., "Packet Communication", MIT, MAC TR-114, December 1973.

18. Cerf, V.G., Kahn, R.E., "A Protocol for Packet Network Intercommunication", IEEE Transactions on Communications, Vol. CM-22, No. 5, May 1974.
19. Schelonka, E.P. Letter to AFETR/ENLD Re: Arpanet 1975 funding
20. PCI Application to FCC for approval, January 23, 1973.
21. Telenet Corp. Application to FCC for approval, October 9, 1973.
22. ARPA Network, Current Network Protocols, NIC 7104, Revised May 8, 1974.

APPENDIX #3

1. History and Position of the Company

Datran was founded in 1968 to provide digital communications for the data processing industry. It is one of the new specialized common carriers that have been permitted by the FCC. Datran differs from most of the specialized common carriers (SCC's) in that it is constructing an entirely new digital network based on microwave radio trunks for the data communications it will offer[2]. Many of the other SCC's are utilizing previously available microwave radio or cable trunks or slowly adding new facilities to them or purchasing bandwidth from the regular regulated common carriers.

Datran, a subsidiary of WYLY Corporation, started with a very ambitious program to serve 35 major cities at an estimated cost of \$400 million. The tempering of the 1969-1971 money crunch revised its plans considerably and it began construction of its network in April 1973[1]. It cost \$15 million to erect approximately 1,200 miles of their transmission facilities between Houston and St. Louis. This portion of their network, which eventually will be nationwide, contains one half million miles of customer channel capacity (4.8KBPS). As of March 6, 1974 Datran had made arrangements for \$58 million in equity financing, including foreign groups, and was essentially debt-free. However, to complete its network additional capitalization will be needed and its facility for arranging this capitalization should be monitored by those choosing to use Datran. The network should be coast-to-coast in 1975, although not fully articulated with all spurs or cities.

Datran is proposing to provide an all digital network. That is to say, all transmission will be digital in nature, not digital modulation of a basically analog network. In analog networks all noise encountered along the transmission path is retained and additive. In an all digital network

(2)

each signal is reconstructed at each repeater. Thus the error characteristics for pure digital transmission is superior. Datran's method of switching and transmission is via a synchronous time division multiplex system. Its channel derivation and multiplexing are also purely digital.

Datran's network is a circuit switched network. That is, if A transmits to B, then a connection or circuit must first be made between A and B at the desired channel capacity. This is as opposed to the mail type networks of packet switching. The channels to be provided are for 2.4; 4.8; 9.6; 56.0; 1,344; 2,688 Kbps, with provision being made for asynchronous service at 75-1800 baud. Metered service is provided and the minimum calling increment is six seconds.

Datran will assume end-to-end responsibility for a communication system and assist in its design to maximize resource utilization and efficiency.

Many aspects of Datran's offering are of interest to the AEC community in the sense that there are many uses to which a computer compatible circuit switched network can be put effectively, in addition to the broad usages for a packet switched network.

Datran, as other specialized circuit switching common carriers, has been charged with cream-skimming by the regular common carriers [3]. That is, Datran is constructing the backbone of its network along the main corridors of business communication usage. It therefore can address itself to the mature data communications markets, whereas the regulated common carriers must service the entire country both urban and rural. The response of A.T.T. has been to reverse its former procedure of averaging costs for all users to one of the different rates for high density and low density traffic areas (the A.T.T. hi lo tariff now in effect) [4]. This has caused the specialized common carriers to reduce their rates to compete with the regular common carriers. How this will affect their profit on sales or return on investment may pose problems in finding capital. The choice of

Datran or any specialized common carrier should therefore be made mindful of its financial strength.

Datran projects a strong corporate image. It has covered the proprietary aspects of its network by a recently issued patent. Datran claims innovation in areas of radio, timing and multiplexing equipment [5].

Though original plans called for a wholly Datran erected system, Datran has entered into an agreement with Southern Pacific Communications Company for a joint building program and the sale and lease-back of certain Datran assets. Also, Datran may co-locate its digital microwave equipment on certain facilities leased from SPCC between St. Louis and Boston [6]. This provides a faster extension to the East Coast for service. An earlier agreement provided for SPCC to provide interconnect services for Datran from Texas to the West Coast. Both companies will retain separate management and operational control of their respective networks.

(41)

2. Services Offered

Datran will tailor a service to a user's specific requirements and maintains a consultation group for such purposes. It will take end to end responsibility for service even if it has no Datran "local loops" for inter-connecting with the system but must arrange for them with the local common carrier. End to end responsibility connotes full responsibility for smooth fault free operation of data channels. Currently, subscribers to Datran have available either dedicated channel service or switched channel service. The subscriber must be connected to the Datran system via a dedicated line and can have two-point leased channels or be switched to any other connected subscriber. There are not as yet provisions for dialing out of Datran to others for occasional usage though this may be a future feature. The most succinct characterization of Datran is that it is a digital data transmission utility.

There are a wide variety of service options, including many different speeds, synchronous or asynchronous transmission, and exclusive use channels, etc. Each subscriber receives a Datran communications console (DCC) containing all user push-button controls.

Medium Speed Private Channel Service (MSPCS)

2.4 KRPS

4.8 "

9.6 "

Asynchronous service is available at 75-1800 baud and MSPCS is available with both split channel and multidrop options.

A switched channel service will be available in early 1975, in which dial-up is permitted for metered usage. The minimum increment is six seconds of channel time, though billing is computed to the nearest second of usage.

High Speed Private Channel Service (HSPCS)

56.0 Kbps

168.0 "

1.344 Mbps

2.688 "

For HSPCS, metered service will be offered for users with predictable peak loads.

TARIFFS

In computing actual transmission costs a number of factors must be taken into consideration. Inter-city air line mileage may have to be calculated between the location of actual District Offices (D.O.s). Also, local loop costs may vary with the subscribers distance from the D.O. In the following tariffs it is assumed that the subscriber's data set is roughly within six miles of the D.O. or local office and the charges include the D.C.C. and local loop cost. Inter-office mileage is based on an airline mileage reference chart.

SWITCHED SERVICE

Rate	Variable Charge (Dollars/Mile/Minute)	Fixed Monthly Charge (D.C.C. & Local Loop)	Installation Charge For Subscriber Station
2400 BPS	\$.00015	\$130.00 (per end)	\$150.00 (per end)
4800 BPS	\$.0002	\$140.00 "	\$200.00 "
9600 BPS	\$.0003	\$150.00 "	\$200.00 "

For service between 8 PM and 7 AM there is a 20% reduction on the variable charge. In any case Datran provides for a maximum charge to limit the users' expense. In no case will Datran charge a higher rate than that for a full time available common carrier channel handling the same data rate.

Switched service is being considered for higher data rates in the high speed category.

HIGH SPEED LEASED CHANNEL SERVICE

Data Rate	Variable Charge (Dollars/Channelmile/Month)	Fixed Monthly Charge Data Station, Etc.
56 KBPS	\$4.50	\$85.00
168 KBPS	\$12.50	\$85.00
1.344 MBPS	\$75.00	\$85.00

The reason no charges are quoted for installation are that for many high speed applications direct Datran installed microwave local loops may be required. Also, these loops may be multi-hop microwave circuits. Installation charges are bid for each specific application.

3. The Datran Network

(6)

The Datran network is based on circuit switched digital transmission, using time division multiplexing techniques. The backbone or main trunk of the network passes through cities adjudged to be mature data communications markets. The main trunk is composed of very broadband microwave repeaters which transmit all TDM arranged data to selected cities having district offices from which interconnect is made to sources or destinations.

The components of the Datran system are:

1. The DDC, or user's console - a special interface unit which connects directly to the user's terminal or host computer
2. Multiplexers - which absorbs the user sending or receiving data rate into a higher bit rate stream. Up to three levels of multiplexers may be used to arrive at the bit rate stream required for the main trunk. Users using HSPCS may connect into a higher level multiplexer so that depending on the user data rate he may enter a third, second, or first level multiplexer.
3. Trunk Radio Modulator - this device accepts data streams from high level multiplexers or the local switch (D.O.) for transmission to other D.O.'s.
4. District Office - this is a local office TDM switch which routes all incoming data streams to eventual destination nodes; the originating DDC or destination DCC may be within the D.O.'s own distribution system or in another D.O.'s local distribution system. See below.
5. Local Distribution Facility - this is the network of multiplexers and lines which interfaces each of the DCC's with the local D.O.
6. Regional Office - this is the upper level of the two-level hierarchy switching system, the lower level of which is the D.O. It is analogous to what A.T.T. calls a tandem office as opposed to the local

7

office or D.O. The R.O. controls the routing (allocation of origin to destination channels in the main trunk) and is a trunk management version of the district office (D.O.).

7. Data Collection Office - the network facility which collects statistics and raw billing required information for each call during set-up and disconnect. This data is collected for off-line processing for statistical analysis and billing for customers and for Datran.

The functions of the R.O. and of the D.C.O. are somewhat analogous to the functions of the network control center in a packet switched system. The primary functions of the District Office are to:

- a) monitor status of all circuits and equipments in its local distribution net
- b) identify desired destination DCC and other characteristics of a call from an originating DCC
- c) maintain originating subscriber awareness of call status
- d) interconnect local subscribers to local subscribers or non-local subscribers
- e) get routing information from the R.O. during set-up
- f) derive statistics and information for each set-up and transmit it to the D.C.O.

The primary functions of the Regional Office are to:

- a) act as a local D.O. for its local distribution net
- b) provide routing information to a requesting D.O.
- c) maintain a complete network directory
- d) provide dynamic channel allocation for even loading
- e) maintain status of all active calls in each D.O. under its control and trunk assignments made or open
- f) provide backup on trunk and connection status as backup for D.O.'s

h) connect trunk to trunk as required by traffic

i) generate statistics for D.C.O. on calls using trunk facilities

The TDM switching techniques used in the D.O. and R.O. are of the non-blocking type. Their design and associated trunking circuits are meant to assure connection within 0.5 seconds of completion of dialing sequence. The R.O. manages the efficient loading of the trunks. The design philosophy of the entire TDM system is to provide timely and cost-effective interconnections for all known or projected user data transmission rates.

Because the network will be nationwide (and larger?) the timing or bit streams at different geographical locations assumes major importance. The system uses a synchronous technique in which all system portion timing is related directly or indirectly to each other or to some common reference. Thus there is a master-slave timing scheme, with designated slaves becoming master should the master go down. The timing scheme, which uses phase locked clocks, is designed to insure that the relative phase difference between any two signals are bounded and a scheme of elastic store at various nodal points is designed to absorb short term variations.

All equipment for channelizing or multiplexing is digital. The TDM system uses 8 phase coherent PSK and achieves 8000 circuits (4.8 KBPS) per radio trunk channel. Multiplexing is bit interlocked for transparent transmission of customer data. If overhead is to be lowered by bit stripping of non-essential bits (start, stop, parity, etc.) this must be done by customer equipment.

Local distribution nets may use regular common carrier local loops pending Datran's installation of full Datran supplied facilities. However, it has been determined that local users tend to form clusters or along a corridor or "backbone." Thus Datran may use backbone city radio net design where feasible rather than cable. Going to local radio is of course a function of spectrum management and interference.

Just now the lowest level (C) multiplexer has 4.8 KBPS in-ports and either 56.0 or 168.0 KBPS out-ports. 2,400 BPS is handled on the in-ports now but should this application increase, a fourth level of multiplexing may have to be added. The intermediate (B) level multiplexer has 56 KBPS in-ports and either 1.344 or 2.688 MBPS out-ports. The high level (A) multiplexer has 1.344 or 2.688 MBPS in-ports and a 21.504 MBPS out-port. Various level multiplexers may be strapped together to handle special situations in which a level is deleted.

The trunk radio modulator has three front ports, two handling 21.504 MBPS and one @ 307.2 KBPS (for supervision, signalling, etc.). The microwave radio backbone uses space diversity techniques. The bit stream arriving at the trunk radio modulator is processed through redundant modulators and transmitters. The output of the redundant transmissions are provided for, as well as redundant receptions. At the reception end there are redundant receivers and demodulators, which are compared to overcome fading, noise, etc. If the comparison scheme indicates that one receiver system is doing better than the other, that receiver system is switched to.

As Datran's system is a digital base band system, receiver systems can be switched within one pulse without a hit occurring. Datran refers to this reliability system as Hitless Diversity Switching and claims it is superior to the hot-standby switchover techniques of other specialized common carriers using hot standby transmitters.

Datran recently made an arrangement with Southern Pacific to connect from Chicago to New York via SPCC's lines. In the future they may overbuild, i.e. add their own radios on the same towers.

References and Notes

1. Most of the information was gathered from company brochures and documents supplemented by conversations with
 Glenn Pennisten, President (at U.C.L.A.)
 Ned Farinholt, Datran Headquarters, Vienna, Va.
 William Stone, Datran, Encino, Calif.
2. An early description of the network is presented in Worley, Allen, "The Datran System", P.I.E.E.E. 60, 11, November 1972. Much of the information herein was based on technical updating by N. Farinholt. Datran will, in the near future, release an updated technical description of the system.
3. "Ma Bell: Big Cuts in the Big Cities", Datamation, April 1973.
4. "Major Carriers Delay Hi-Lo Till June", The Data Communications User, p. 13, June 1974.
5. "New Patent Projects Datran Data Net", Communications News, p. 13, Sept. 1974.
6. "Datran and SPC Agree to Share Some Facilities", Communications News, p. 11, Sept. 1974.

APPENDIX #4

1. INTRODUCTION

Telenet Communications Corporation was formed to offer commercial packet switching to a broad range of data processing customers. Its president is Dr. Larry Roberts, who previously headed the ARPA Information Processing Techniques Office. IPTO, under Roberts, funded, directed and contributed to the research which developed the ARPANET. Telenet is a subsidiary of Bolt, Beranek and Newman, Inc. and derives considerable strength from the association. B. B. & N was an ARPANET subcontractor and in this capacity developed the IMPs and TIPs for the network as well as operating the Network Operations Center [1, 2].

The number of personnel at Telenet numbered seven in February 1974. This group was augmented by six persons under contract at B. B. & N, working on the design of Telenet's network and central offices. Thus there is a technical carry over from ARPANET experience to Telenet [3]. In addition the preliminary design of the satellite IMP is conducted at B. B. & N.

Telenet's packet switched communications offering is in principle similar to that of ARPANET in most of its modalities. Certain of the ARPANET features will be remodified to yield the tautness and service capability of a commercial vendor and major families of computers, as represented in the commercial and industrial world. Great attention is being given to design and maintenance for reliability and to the satisfaction of customer demands for service. Interfaces with the most popular computer systems will reflect matching to their existing methods of inter-computer and computer to terminal protocols and disciplines. This is so that minimal modifications have to be

made by a customer in tying into the Telenet network. However, customers may opt to modify their operating systems by their or Telenet's efforts to achieve increased throughput or other objectives [4].

Telenet's system supports the Arpanet concept of the Network Virtual Terminal and the same types of protocols for computer-computer and computer-terminal operation. However, modifications, simplifications and enhancements were indicated so that greater reliability and throughput would be achieved. Telenet's network will be a distributed one with a minimum of double redundancy connections in the net at the IMP level.

Telenet's market study has led to conclusions somewhat different from that of P.C.I. Telenet feels that there is a market which they can attack for computer to computer broadband communications. Thus, they are scheduling a relatively early introduction of satellite communication usage (probably within a few years). To support satellite communications technology, they are also in pre-design of the satellite IMP, or SIMP.

Telenet's approach to marketing is interesting. They are concentrating on providing interfaces for the most popular computer families (which will also yield them their highest revenues), but they are also interested in acting as a supplementary resource for load-leveling for other dedicated networks. Thus, they are interested in supplying the additional communications transfer capability, which dedicated network designs would find too costly or premature. An example in point is the possibility of providing peak traffic alternatives to the CTR dedicated network. Because of the Arpanet philosophy of communications transparency to varied makes of computers and terminals, they can provide additional access to dedicated nets, such as those of the growing computer utilities (GE's Mark III, Tymnet, Infonet, etc.). There have been some indications of interest in this latter type of business

but as of this writing, no agreements are known.

Telenet was later than others in applying to the FCC for its approval to offer packet switched communication services. However, it was recently approved and public announcement has been made of progress in financing the company [5, 6]. Infusion of funds is now under way and the leader of the investment group is the investment banking firm of Lehman Brothers. Though this was known earlier, it has only recently been announced.

Telenet's schedule of network completion and service availability is as follows: Their control offices, which house IMP's and other equipment are designed to be centralized in various cities [4,7]. The Central Offices or C.O.'s should be designed by September 1974. From then till the first of 1975 seven C.O.'s will be installed in Boston, Chicago, Dallas, Los Angeles, New York, San Francisco and Washington and this period will also be used to debug the C.O.'s, Telenet anticipates that it will be dealing with several major companies during the first six months of 1975 and its efforts will be monopolized in shaking down all aspects of network operations and customer support. It has expressed keen interest in working with others, now and in near future to develop custom packet switching for applications of significant interest to themselves.

Telenet, or other packet switching carriers are of interest to the AEC ad hoc working group on computer networking because their appearance and service offering coincide with the working group's period of experimentation in remote resource sharing. Telenet may enhance the networking capabilities of the ARPANET which is the group's proposed vehicle for interconnection. As such, the objectives and implementation panels should closely follow Telenet's development. Indeed, the value added carriers are an eminent alternate to others who cannot afford the creation of a dedicated communication network.

2. TELENET SYSTEM DESIGN

2.1 The Network [3, 4, 8, 9, 10]

The Telenet packet switched communication systems will be composed initially of 50 Kbps terrestrial lines, spanning seven cities by early 1975 and extending to cities by the end of 1975. These lines will be leased from common or specialty common carriers. The lines terminate in what Telenet refers to as a Central Office or C.O. The C.O. collocates the communication switching, interface equipments, maintenance, technical and sales staffs. The C.O. contains IMPS and TIPS as well as line switching gear for flexible interconnection. The IMPS are generally similar to ARPANET IMPS. The TIPS seem to be generically different. No conclusive design information is available on the TIPS but they probably incorporate what in ARPANET are considered to be the functions of front ends or mini hosts as well as the functions of the ARPA TIP which interfaces terminal devices to the network in the absence of a host. In this sense a Telenet TIP is a terminal interface message processor for both hosts and terminals.

Within the C.O. IMPs and TIPS are at least doubly redundant, with each IMP having separate redundant network connectivity. IMPs and TIPS have complete connectivity for path assurance. Telenet suggests that only a leased line interconnects with the C.O. The extent of services resident in the TIPS is not fully clear, but it seems that with ARPANET hindsight they will tend to be simpler devices and provide a lesser number but more uniform set of services.

The IMP's within the C.O. packetize messages from host, convert character streams from customer terminal to network standard code, provide for dynamic routing and transfer packets via other C.O.'s to destination C.O.'s, detect

errors and retransmit packets as necessary, reconstitute messages from packets from other C.O.'s and transmit message confirmations as in ARPANET. The Telenet IMP also collects traffic statistics for network control and monitoring and for billing data. With regard to the latter, Telenet proposes to bill hosts for messages transmitted and for messages received from terminals. (The host will have to rebill the terminal users).

The network is to be expanded to include satellite communication channels. Satellite IMPs or SIMPs will be located at ground stations for handling the high speed transfer. The channels will operate at 1.544 MBPS in a multiaccess broadcast mode. There will be at least four C.O.'s connected to the satellite stations via 100 KBPS terrestrial line initially [See Fig. 1).

Telenet's intention to go early to satellite communications is reinforced by its market studies that there will be a reasonable market for high bandwidth data stream transmission. As part of its redesign software and protocols, Telenet is claiming 40 KBPs throughput on 50 KBPS lines. As traffic builds up, terrestrial lines will be expanded in bandwidth to 230 KPBS.

The number of IMP's and TIPs within a C.O. will grow with traffic requirements. Both units and software modifications (for efficiency and to introduce new services) will be added without service interruption. The design of the C.O. also includes power back-up for continuous service assurance.

Telenet claims that it will maintain an error rate of 10^{-12} which is 5 orders of magnitude better than that of the circuit switched specialized common carriers such as Datran and 7 orders of magnitude better than current long line facilities. (This will be upgraded in the new Bell Systems Dataphone Digital Service). This, of course, refers to Telenet's portion of the transmission network. Should terminals not have sufficient error control gear or should

dial up lines provide degraded performance, the overall reliability target will not be met.

2.2 Interconnection to the Network

2.2.1 Computers

Computers will be interconnected to C.O.'s by one or preferably two leased lines operating at 9.6, 19.2, 50 or possibly 230.4 Kbps. Format, signalling and error control protocols for host to IMP communications will be contained within the Network Control Program resident in the host.

Two types of NCP will be offered by Telenet. Type 1 will support standard data protocols supplied by manufacturers, no modifications to operating systems being required. Type 2 protocols will embody hopefully minimum modifications to manufacturer supplied operating systems to assure higher throughput. Type 2 will be custom engineered and charged for by Telenet. Thus for IBM hosts 270X and 370X controllers will be able to be expeditiously connected. Telenet proposes to provide NCP's, as well as IMP resident software for the less popular hosts. This all depends on the growth of customer usage and will be controlled by Telenet. If there is sufficient concentration of terminals or hosts at a user location, Telenet will lease a local TIP for interconnection to a remote C.O. [10].

2.2.2 Terminals

Telenet will support the Network Virtual Terminal concept developed on ARPANET. That is, all terminals interconnected will have their characteristics interpreted into those of a standard terminal for interface purposes with hosts.

The standard NVT will possess a complete character set and control procedure. All terminal transmissions to a C.O. are converted to NVT format for the transmission to hosts and transmissions from hosts, converted to NVT

format at the C.O. connected to the host, are then converted to actual terminal format and characters by the TIP connected to the terminal. The variety of terminals connectable will be broad. However, the caution must be stated that certain terminals may not possess the requisite error control to fully sustain the high reliability which the network can achieve.

Terminals, in the Arpanet philosophy, have both logical and physical interconnections. A terminal will initiate a request for a connection to a specific host via the TIP at the C.O. The TIP then sets the parameters for sending all subsequent data to that host. Parenthetically, where host access is controlled and security measures must be taken, reference will be made to the Network Control Center for interpretation of terminal requests. The local C.O. TIP instructs the host, remote or connected to the same C.O., which terminal it is to reply to. Interconnection time is expected to be substantially less than 1 second.

Terminals connect to the network via leased lines, dial-up, or by connection to a leased multi-drop line. Leased dedicated lines are indicated for multi-drop use, heavy loads, or where the nature of the interaction between terminal and host cannot sustain the delays of dial-up. The variety of terminal interconnects to the C.O. include:

- a) Leased lines to a manufacturer's or manufacturer's compatible communications controller, which controls terminals downstream.
- b) Leased lines to batch or conversational terminals via single lines or multi-drops.
- c) Many channels to a multiplexor which transmits to a remote multiplexor for retransmission to many terminals downstream (for applications very remote from C.O.'s).
- d) Connections to C.O. port via terminal dial-up line.

See Figure 2.

Now that Bell's Dataphone Digital Service has been announced, batch terminal dial-up will be supported. As stated above, a collocation of many terminals may justify the location of a TIP locally.

2.3 Telenet Network Characteristics

2.3.1 Network Control Centers

There will be two NCC's, one in the East and one in the West. Each can assume the duties of the other if an outage occurs. The functions of the NCC are

- a) Monitor all lines, C.O.'s, host and terminal sites.
- b) Detect and diagnose equipment failures and initiate maintenance procedures.
- c) Reload programs into remote C.O. equipts should they fail.
- d) Collect statistics on traffic between users and at network points
- e) Collect billing statistics from each C.O. for later processing.
- f) Provide statistics to customers on traffic between customer hosts and terminals (d,e, and f will be proprietary).
- g) Maintain an on-line file of all software and hardware resources connected to the network that are available to subscribers.
- h) Maintain control of access procedures.

2.3.2 Privacy and Security Aspects

Security of transmissions can be assured by either Telenet or customer supplied end to end encryption. Block encryption is recommended. It is one of the superiorities of the distributed packet switching network that packets from source to destination may travel arbitrary paths and that only disconnected portions of messages can be intercepted.

Access to resources may be controlled by the N.C.C. Passwords and terminal I.D. checks may be used by hosts. Telenet also proposes to institute

a limited addressing capability based on a password translation service, using an irreversible transform algorithm to be specified by each host. Given passwords, in translation, may confer access to more than one host.

2.3.4 Telenet Service Offering and Tariffs

The basic service offerings are classified as a) Computer to Computer (C/C), b) Terminal/Computer (T/C). These services offerings are especially valuable where dedicated networks are economically unfeasible.

The priority systems have not been fully defined, nor are the charges based upon them, if any. Priority in passing through the network is accorded short character streams from terminals. Short streams of less than or equal to 100 characters will traverse the network within 0.3 seconds; longer character streams up to one thousand characters will traverse the network within 0.8 seconds.

Charges are based on a number of factors. Volume of packets transmitted is the primary charge, regardless of distance between source and destination. Flat monthly charges are made for host or terminal interconnection to C.O.'s via leased lines. Dial-up charges are flat and per terminal connect hour. The monthly charges for leased lines include the lines and necessary modems at host or C.O. site.

In their initial application to the F.C.C., Telenet indicated discounts for higher volume packet charges. This is not posted in their January 28, 1974 tariff but may be revived. There is a discount for night and weekend messages. The potential service offerings have not been fully revealed. For instance, there may also be provision for packets entering the network which are held over for delivery due to an outage of a terminal or host.

Special service charges are provided for Telenet customization to customer needs. This includes charges for NCP's, special customer on-premise interface equipments and for encryption.

There are contract minima specified. Hosts connecting to the network must contract for 1 year. Notice periods are also specified. A summary of Telenet's tariff rates, posted January 28, 1974 follows:

A. Packet Charge: \$1.25/kilopacket

A kilopacket is 1,000 packets. Each packet contains up to 1,024 bits, or 128 characters. For batch traffic, packets are normally full. For transaction-oriented applications, each transaction typically requires two packets: one for inquiry and one for response. A 40% discount applies nights and weekends. Packet charges are independent of distance.

B. Port Charge for Leased Access Lines:

Up to 9.6 Kbps: \$50/month

50 Kbps: \$100/month

Installation charge: Equal to one month's charges for the local line and port.

Applies to both Host computers and terminals. In addition, Telenet will charge the customer for the cost of dedicated lines and modems leased from the local telephone company between the customer's premises and the nearest Telenet Central Office.

C. Dial-In Port Charge:

0-1800 bps \$1.00/hour

2400 bps \$2.00/hour

4800 bps \$3.50/hour

Dial-in port charges are proportionately reduced for calls less than an hour in duration.

Access to the network is only available at Telenet Central Offices via leased-line or dial-in ports. Where a customer has multiple Host computers or terminals at one site, Telenet will provide on-site equipment on a special service basis to connect all of the customer's devices into the nearest

Telenet Central Office via two leased lines.

LEGEND

Teletypewriter
Cathode Ray Tube Display Terminal
Batch	Remote Job Entry or Other Batch Terminal
Controller	Customer-owned CRT Control Unit
Host	Customer Computer
MUX	Telenet Multiplexer
TIP	Telenet Terminal Interface Processor

ILLUSTRATIVE TELENET LOCAL DISTRIBUTION ARRANGMENTS

PROPOSED TELENET 18-CITY NETWORK

Figure 1
Taken from Reference #4