
Computer Networks in Higher Education: Socio-Economic- Political Factors

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This study presents the results of a nationwide survey of computer networks in higher education conducted during 1971-73. Five major and 18 minor networks were identified. The five major networks included: the ARPA Net, the California State College network, the University of Iowa/Iowa State University network, the Michigan Educational Research Information Triad, Inc., and the Triangle Universities Computation Center network in North Carolina. In-depth studies were conducted of the latter two nets. Based on the experiences of these operating networks, a number of factors are identified for consideration in developing networks. Finally, recommendations are advanced regarding the development of networks in higher education in the future.

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Recent studies of computer capabilities in U.S. colleges and universities [4] have revealed that few colleges with enrollments below 600 have computers, while only about half in the 800 to 1,200 group have on-campus computer capability. This was further supported by an NSF sponsored study [3] which found that only about half of the higher education institutions in the country have any computing at all. Clearly, due to costs and related factors, the availability of computers for support of educational programs in higher education has been largely restricted to the medium and large sized colleges and universities.

To alleviate this problem, some major institutions began a few years ago to share their computer power with each other and with educational institutions which had little or no computer facilities available to them [5]. Moreover, state governments began to initiate plans aimed at the forced sharing of computer facilities among the state educational institutions. Finally, at about the same time, the federal government initiated experimental projects directed toward the eventual sharing of computer resources among a number of large computer installations around the world (the Advanced Research Projects Agency—ARPANET).

The above efforts have become known as computer networking, and the initial problems which arose were essentially technical in nature. As Stefferud [10] has recently pointed out, however, technical problems now show promise of being solved, and the time has come to attack general management problems involved in networking. The focus in this paper has therefore been predominately on the socio-economic-political aspects of networking in higher education. The goals have been, first, to determine the state of the art through a nationwide examination of educational computer networks, secondly, to isolate and define factors which have resulted in promising ventures, and finally, to make recommendations regarding the future course that networking should follow in higher education to provide computer capabilities to all educational institutions.

In surveying the literature on the topic of networking, we were surprised to find such a meager amount of information—only a few general articles [2, 6]—although the more recent works of Peterson and Viet [8] and Weingarten [12] provide good descriptions of some nets.

Research Survey—Method and Results

Fifty-nine public and private universities in the 48 contiguous states were contacted about their shared use of computers. Contacts were made by telephone using a questionnaire developed for the study. Because of the costliness of this method, data were not obtained by telephone from Alaska and Hawaii. In-depth studies of North Carolina's Triangle Universities Computation Center Network and Michigan's MERIT Network were conducted by making personal visits to these centers. In

addition, two of the faculty associated with the development of the MERIT network spent several days on the University of South Florida campus (the base from which the study was conducted) discussing their networks with the research team. The data were gathered during the period 1971-73.

For purposes of analysis and discussion, we arbitrarily differentiated major from minor networks since a very large number of small networks were found to be in existence. Major networks were defined as the shared use of two or more computers of at least the sophistication of an IBM 360/50 located in diverse areas. A minor network was defined as one computer at least the size of an IBM 360/50 with one or more small stand-alone computers as terminal(s) at diverse locations.

Major Networks

The ARPA Network. The ARPA network (ARPANET) is probably the most sophisticated and the largest computer network which we have studied. ARPANET began in late 1969 with four installations. By 1973, 28 installations had been connected with 15 additional sites expected to be operating shortly. The network includes major U.S. universities as nodes, plus such institutions as the University of London and the University of Hawaii, which is connected via satellite. There are a total of 15 universities involved in the network. Administratively, the responsibility for intercomputer communications in the ARPA net has rested with ARPA and control over the local computer installation has remained with the installation. This was done deliberately in order to preserve local autonomy.

The California State University and Colleges Network. In 1969 the California State College computer network began with the participation of 19 state colleges. The system consisted of local computers on each campus, mainly CDC 3150's, which were connected to two larger computers at regional centers. In turn, the regional computers were connected together and to the IBM 360/91 located at UCLA. Presently, however, the two regional centers have been combined into one center at Los Angeles housing two CDC 3300 computers and a CDC 3170 computer as a front-end communications processor. There are also two CDC 3170 computers at Northridge, which provide 128 interactive terminals to the entire network.

The network was specifically designed so that each college with more than 5,000 full-time equivalent students would have a stand-alone computer which would primarily provide for instructional usage, but which would also serve administrative and research needs. The regional centers were designed primarily to handle administration processing, plus overload instructional work.

The California State Colleges have made a deliberate effort to combine instructional and administrative work

load. This was done because investigation showed that the administrative work load occurred at the beginning and end of semesters, at nights, and on weekends. These times were generally when the instructional work load was lightest. Thus it was reasoned that combining the two work loads would provide significant savings. They estimate that they can process a computer job approximately 20 to 50 percent cheaper than comparable institutions.

The Iowa State University and The University of Iowa Network. In 1971, the IBM 360/65 at the University of Iowa in Iowa City was connected to the IBM 360/65 at Iowa State University in Ames. Since one of the universities was on the quarter system and the other on the semester system, their peak computer loads occurred at different times of the year. Thus it was found that the network approach would enable sharing of loads during the peak period. A second advantage of the network approach permitted the splitting of specialized software and maintenance of software systems. The two computer centers have worked closely together at all levels in standardizing functions such as procedure names, and they have established charging schemes which are approximately the same.

Case Studies

Michigan Educational Research Information Triad, Inc., (MERIT), and the Triangle Universities Computation Center (TUCC). The Michigan Educational Research Information Triad, Inc. (MERIT), and the Triangle Universities Computation Center (TUCC) are both private corporations formed by several universities interested in developing greater computer capability than was possible on any of their individual campuses. However, MERIT and TUCC represented two distinct types of university computer networks. MERIT has as its primary goal the sharing of resources, while TUCC was designed to share computing load.

For the purposes of this paper, load sharing is used to indicate a system whereby computing load is transferred from one computer to another to provide the most economical service. Resource sharing, on the other hand, refers to the transfer of computing from one machine to another to obtain a service which is not available locally, or one which can be obtained faster on the other computer.

Michigan Educational Research Information Triad, Inc. (MERIT). In 1968, the University of Michigan, Michigan State University, and Wayne State University obtained a grant from the National Science Foundation (NSF) to establish the Michigan Computer Network Project among the three universities. To provide a legal instrument to receive monies from nonstate sources, the Michigan Educational Research Information Triad, Inc. (MERIT) was formed. The total support for this project was \$800,000 of which 50 percent was furnished

by NSF and 50 percent by the State of Michigan. The network, which became operational in 1972, ties together the IBM duplex 360/67 computer at the University of Michigan, the IBM duplex 360/67 computer at Wayne State University, and the CDC 6500 at Michigan State University. Three DEC PDP-11 computers are used to interface each computer to the other two computers. The three computing centers are cooperating in the development and use of the network, which operates without a formal structure and with only a few agreements.

One problem which has received a great deal of consideration within the three universities is that of one university charging another for computer time. This could become an acute problem if one computer became a "center of gravity" such that it began to do more computing for the other universities than it sent them to do. Thus a balance of payments problem could occur with perhaps significant amounts of money flowing to one university (this could be caused by a number of factors including cheaper rates and better turnaround at a given university). Unfortunately, the network has not been in existence long enough, nor has it received sufficient use as yet to permit adequate examination of this possible problem. Overall, however, the MERIT system provides great advantages in resource sharing, both in the variety of computers and also in the various data files which become available to users on the three campuses. In our interviews on the campuses, we found many computer users enthusiastic about the possibilities which having access to another brand of computer and its associated software would offer.

Triangle Universities Computation Center (TUCC). The TUCC computer network at the Research Triangle Park in North Carolina [13] began in 1965 when the University of North Carolina at Chapel Hill, North Carolina State University, and Duke University formed a private corporation (TUCC) to house a central IBM 360/75, tied to smaller IBM computers at each campus. The original concept of TUCC envisioned approximately equal computing demands by each of the three universities, and therefore each university was, and is still, charged an equal amount for the support of TUCC. An operating system leveling algorithm was developed, which gives a university faster turnaround if it uses smaller amounts of computing time.

At the present time, TUCC has an IBM 370/165 tied to medium to large IBM computers at each institution. The individual computer centers are controlled by the university concerned, and in turn the universities help to govern TUCC through representation on TUCC's Board of Directors. TUCC has a much more formal governing structure than does MERIT. TUCC also serves a number of other colleges and one high school through the North Carolina Educational Computing Service (NCECS). It is important to note here that TUCC serves the three universities and NCECS in a "wholesaler" capacity; i.e. TUCC supplies the computing power, while user services and general interface problems with users are handled

by the local university centers and NCECS. This local "corner grocery store" concept of user services appears to work very well.

An overview of TUCC indicates that it is a successful operation and that most users are happy with the services provided. The success of TUCC, however, has been greatly aided by a number of factors: (1) the universities are close together geographically (each is approximately 15 miles from TUCC); (2) the universities have had a history of close cooperation in many academic programs; (3) the legislature of North Carolina, in its support of the Research Triangle Park, has eased the establishment of TUCC. For example, by legislative act, the Research Triangle Park is a local phone call from any one of the three cities.

There is one major operational aspect worth considering, however, with such a load-sharing computing center. A great deal of day to day communication between local centers and TUCC is necessary. Thus, in order to adequately plan for and meet the day to day computing needs of three major institutions, frequent meetings have been found to be necessary at the upper management level and among systems programmers, scientific programmers, and individual faculty members on the three campuses. This has not been a severe problem, however, because of the geographical closeness of users to TUCC.

Summary of All Major Networks

In the five major networks discussed, all were designed primarily to increase the computing power available to the user. This seems to be a rather vital ingredient for successful networking. In addition, administrative and instructional/research computer applications were increasingly found to be operating successfully on the same machine. From the user viewpoint, combining such services could result in greater inconvenience. However, adequate scheduling of the types of use, plus adequate communication to users of these schedules, has resulted in good instructional/research and administrative services being provided on single machines on many campuses.

It therefore appears that maintaining separate computers on the same campus for administrative and instructional/research work may be due more to historical and political reasons than to economic considerations.

In the organizational structure of the major networks, it was found that Michigan and North Carolina both established private corporations to handle funding of the networks. In the case of TUCC, one of the chief reasons for this was to allow for flexibility in the choice of equipment and personnel which would probably not have been obtained had the organization been under state control.

Finally, legislative support has provided needed support for development of major networks.

Minor Networks

Minor networks were found in 18 states. These nets essentially represented universities providing services to smaller colleges and high schools in their states or immediate areas, where computer services had not previously existed (whereas major nets essentially increased the computing power of those educational institutions that already had some computing capability).

States Considering Some Type of Computer Network

Some additional states are now considering the possibility of developing major educational computer networks. These include the States of Mississippi, North Dakota, Georgia, and Illinois (7).

Discussion and Analysis

In reference to our original goals, which were to survey current practices and then to isolate and identify relevant socio-economic-political factors associated with promising network attempts, we offer for consideration the factors listed below which we feel should be considered and resolved prior to reaching a decision to develop a network as a solution to providing or expanding the computer capabilities in institutions of higher education.

Factors Which Should Be Considered Prior to Planning a Network

1. *Philosophy regarding use of the computer at the institutions involved.* Before the decision is made to develop or not to develop a network, some basic decision must be reached in each of the user institutions as to the role the computer will play. Obviously, if anticipated participants are elementary or secondary schools or community colleges, the purposes of these institutions will determine the extent to which the computer will be used. In the case of colleges and universities, however, it must be determined whether the philosophy of the institution is similar to Dartmouth's—i.e. that each undergraduate should have experience with a computer. Or will the computer be used mainly to support faculty research? Is the mission of the institution heavily oriented toward the natural sciences which traditionally are heavy users, or is the emphasis more toward the arts and humanities which in the past have been less heavy users? Is research to be encouraged through college or university support of computer costs for nonfunded research? In administrative computer usage, does the institution simply want to improve its financial and student record-keeping, or is there strong interest in experimentation in on-line management information systems, etc.? Finally, how

great a share of its resources is each institution willing to devote to computer activities? (This point must be kept in mind for the future if "seed money" of some sort provides for initial costs of networks. The network participants must be concerned with the continuing base of support.) Until all of the above basic decisions are made, institutions are unprepared to realistically determine whether or not a computer network is advantageous.

2. *Size.* A second consideration of prime importance relates to the size and anticipated growth of the institutions concerned. Obviously a small institution with little growth potential and no current computer capability might look more favorably at participating in the role of user tied to a computer at a host institution than a large or a small institution with rapid growth potential would. Again it must be kept in mind that networking must show some distinct advantages either in cost reduction (now or future) or increased services to warrant its use.

3. *Functions.* Once the philosophy and goals of the institution are defined in relation to computer usage, the specific functions can and must be defined. Specifically, the need for batch processing must be identified as well as the need for time-sharing. The types of user problems to be handled must be identified as to teaching, administrative work, research, etc., along with the particular mix of these applications at the institution. A vital problem to resolve also is the extent to which computer assisted instruction or computer managed instruction is to be implemented. From these data will emerge specifications for core storage requirement, disk, cpu speed, and type or types of local computation power needed. All of these needs must be identified in relation to current and projected usage before networking should be considered.

4. *Distance.* An obvious consideration in whether or not to develop a network is one which relates to distance involved. Although it is possible to tie computers together over long distances (as a number of the states are doing as indicated in the preceding section), several factors must be considered. Foremost is the cost of the lines. The greater the need for speed due to the amount of data or type of problem, the greater will be the cost for each mile that separates host and user. In addition, network hosts and users have found that heavy personal communications between them is essential, as indicated in the discussion of the TUCC network. Thus, telephone communications between center staffs, travel costs for frequent meetings and for delivery of tapes, and the like, must be considered. In some cases, "circuit riders" have been found to be essential. These are persons whose main responsibility is to go from user to user helping them resolve their network-related problems.

5. *User history and expectations.* This is an important variable in determining whether or not to construct a network. What is the history of computing within the institutions concerned? Is there strong local pride in

maintaining a computer locally? What is the history of cooperation between host(s) and users: Have they cooperated on issues in the past, or is there traditional rivalry and jealousy which could extend into the computer sharing area? To put it bluntly, will the host(s) and users look with anticipation upon involvement with a network, or will it be seen as a threat to their local autonomy? Obviously, since users are more oriented to services than to cost reduction, *the more the network provides an upgrade in services rather than a downgrade and the more impetus for a network arises from host(s) and users rather than being forced from above, the greater the possibility of success for the network.* Some light was provided on this topic by our survey in which we found in talking to hosts that normally there was a great deal of satisfaction with shared computers. Leiran (5), however, in his survey of U.S. universities offering the doctorate, found that only about one third of the respondents felt a shared computer would serve the purpose better than a dedicated computer facility. Further, of those now sharing a computer (about 25 percent of the respondents), about half felt a shared computer to be more advantageous than a stand-alone—but in further analysis it was found that the *hosts* accounted for the satisfaction with shared computers to a far greater extent than the users. It must be kept in mind that ultimately, users make or break a network. Their satisfaction with services must be given serious and continuing consideration.

6. *Preliminary costs.* Based on the above, preliminary cost estimates should be made to determine the general feasibility of dedicated computers versus networks. Schwab [9] pointed out that computer (cpu) power increases roughly with the third power of computing costs. To put it another way, *doubling computer costs would generate eight times the computer (cpu) power.* In addition, increasing costs by a relatively small amount through addition of core can quite often result in the capability of handling totally new research problems, using standard “canned” statistical programs which could not be used before, using interactive terminals, etc. Thus the addition of a small stand-alone computer and connecting it to a large computer elsewhere can at times obviously be advantageous both in terms of service and in costs. However, transmission costs, terminal costs, and additional equipment added to the main computer to handle the auxiliary load must be considered.

Assuming that all of the above items have been considered and the tentative decision has been reached to develop a network, providing final costs justify its initiation, the factors below should then be considered.

¹ Personal communication, Leland Williams, TUCC, Triangle Park, N.C., 1974; and Robert Brown, Computing Center, University of Iowa, Iowa City, Iowa, 1974.

Factors Which Should Be Considered in Developing a Network

1. *Resource sharing vs. load sharing.* *Resource sharing* refers to the MERIT type network in which the basic motivation is to provide a greater degree or breadth of service to users. Resource sharing permits a greater diversity of service plus access to unique and specialized data bases; however, it is not aimed at cost reduction, although this may be an ultimate side benefit. *Load sharing*, on the other hand, is exemplified by the TUCC network in which the basic motivation is to handle a volume of work at the least cost. Load sharing nets, to be maximally successful, must be sensitive to portability. Thus, commonality of operating systems, configurations, and software all enhance load sharing capability. When there is a heavy load of administrative computing, load sharing nets seem to work best where short distances are involved; on the other hand, resource sharing does not seem to be nearly so affected by distance (this appears to be related both to the type of workload-instructional/research versus administrative and to the amount of personal communication required). Obviously this is not a complete either/or type situation, but potential network developers must recognize this dilemma and decide just where the line should be drawn between maximizing services and minimizing costs.

2. *Major vs. minor network.* The size and growth patterns of the institutions concerned must again be examined to determine the need for a major or a minor network. Minor nets, with one large computer tied to several small computers, seem best suited for situations where one large college or university serves the needs of its own campus and of a number of small community colleges or high schools. Also, generally speaking, situations in which the total student population does not exceed 25,000 have been found to be handled adequately through minor nets. Major nets seem better suited for situations in which the student population served exceeds 25,000 (or where anticipated growth of net participants will exceed this figure within several years). However, in situations in which CAI or CMI are a significant part of an overall computing load, major nets may well make use of minicomputers for this purpose, with dial up capability through the minis to the main hardware for other purposes.¹

3. *Technical problems.* An overview of these problems has been provided by Turczyn and Jeng [11] and by Brewster [1].

Planning a computer network is extremely complex. Brewster [1] pointed out that since terminals can be connected in thousands of different ways, in the calculation of costs, a number of tariffs, etc., come into play, he concluded that: “Many companies find it worthwhile to hire a communications engineer to plan and monitor their data networks” [1, p. 23].

Technical problems in operating a network also

should not be minimized; our own study indicates some hair-raising problems can occur and have occurred in dealing with various companies on communications matters.

4. *Protection.* The protection of user data from being accessed by nonauthorized users in regular day-to-day usage within a network must be considered. In addition, the overall value of data and services must be considered in reference to measures needed to protect the data and provide reasonable services in case of equipment failure or destruction of equipment. To put it another way, how badly would users of the network be hurt if certain data and functions were assigned to a given center and this center (for one reason or another) was unable to perform? Obviously, the more critical the item or service to users, the more dependence should be put on providing multiple or backup computers to handle such data or to provide such services.

5. *Final costs.* Final costs should then be determined, based on the outcome of the above analyses.

6. *Governance.* Alternative governing structures include the following: (a) an incorporated network with a governing body composed of the participants as in the case of TUCC; (b) a network where the host maintains local controls and sells services to users; (c) a network governed by a nonincorporated body composed of hosts and users; and (d) a network where states or Boards of Regents assume overall direction for computer networks involving state universities.

Our case study of the TUCC network provides strong support for the case for incorporation, since it permits much greater flexibility in the acquisition of equipment and establishment of salaries and positions. Considering the rigid restrictions imposed by many states on their agencies, these advantages might well assume rather large proportions.

Recommendations

The remainder of this paper presents the recommendations of the authors in regard to the future role we feel that networking should play in meeting the computer needs in higher education. These have been based on our own experiences as well as on information gained from the survey of the literature and from the national survey and case studies.

In addition to the above, in arriving at recommendations we made several assumptions, as follows:

1. The importance of higher education to the American people is so well established that despite population fluctuations, the percent of the 18 year old and over population attending colleges and universities will continue to rise, so that the present sizes of colleges and universities will continue to rise, so that the present sizes of colleges and universities will be maintained.

2. The importance of computer knowledge to all college graduates will be accepted by college and university

faculties much more rapidly in the future, and within five years the bulk of all undergraduates will be receiving some form of training involving the computer.

3. The use of the computer in research will continue to pervade the areas of social sciences and education to the extent that within five years demand from these areas will be equivalent to the current demand from the natural sciences and engineering.

4. The expansion of undergraduate and graduate training in computer science will be significant in the near future due to national, state, and local demands, and, within five years, training through the bachelors level will be offered at most colleges and universities, and through the doctoral level at most major universities offering the Ph.D.

5. The use of computers to solve administrative problems will continue to increase in all administrative areas, and expanded computer services will be demanded.

Based on these assumptions, we offer the following recommendations:

1. *Colleges and universities should provide leadership in developing regional load-sharing networks* to provide greater computer capabilities to each other, to community colleges, and to secondary and elementary schools.

2. *Regional (load-sharing) networks should have compatible hardware/software at each participating institution.* This in essence dictates common vendor(s) for all participating campuses having major computer equipment. It does not preclude having different hardware for administrative applications, research applications, and CAI/CMI, but it does indicate a standardization of operating systems, meeting minimal configuration needs, using common programming languages, etc., for each major purpose throughout the net. Compatibility (and thus portability) is one of the greatest stumbling blocks to the development of successful load-sharing networks in the various states, not because of the inadequate computer capabilities of given vendors, and not because of the inability of participating colleges and universities to reach agreements, but primarily because of the pressures from vendors and the inability of central governmental offices concerned to cope with these pressures and to resolve the problems in ways other than through standard "low-bid" procedure methods.

3. *High calibre user services* should be provided for all network participants. If a number of institutions are participating, a full-time consultant or "circuit rider" may be needed to visit the participating institutions. These services should be provided on a local or "corner grocery store" type basis.

4. *Regional (load-sharing) networks, with user services as above, should be limited to a geographic radius of approximately 50 to 75 miles.* This is especially recommended where volume is heavy and when administrative computing applications are involved, since beyond these distances, transmission charges, personal calls, and visits involved with overall administrative matters as well as

day-to-day procedural problems become too costly, time-consuming, and generally annoying.

5. *Regional (load-sharing) networks should be multi-purpose, covering instructional, research, and administrative applications.*

6. *Resource sharing networks should be strongly considered to handle those instructional or research needs of campuses which are sufficiently different from normal needs so as to constitute a small segment (10 to 15 percent) of the total load.*

A prime mission of networking should be to provide computer support to those instructional and research areas whose needs are the least well met by the computer configuration on the campus. Obviously the local configuration must be chosen to fit the major needs of the campus. This in turn will always leave a small, but quite often very important, group of users (or potential users) unsatisfied. It is this small group of physicists, astronomers, or educators whose needs may best be served by transmitting their work to a computer of a diverse sort at a different location; and thus it is important to go "shopping" for the best service available. Since these jobs will represent only a small percent of the total load, and since they will mainly be instructional or research in nature, distance among network members is not a significant factor. The most important ingredient in this type of network is, of course, diversity of hardware, software, and available data bases.

7. *Networks should disregard all artificial barriers.* Whether educational institutions are funded from public or from private funds should have no bearing on participation in networks. Similarly, an artificial barrier such as county, state, or national lines should not be a barrier to computer sharing.

8. *Resource sharing and load sharing networks should provide expanded services.* Generally speaking, networks should *not* be used to downgrade overall computer services available to users, since growth patterns of computer needs (as indicated in our assumptions) indicate a continued increase in computer usage in higher education (and also since users respond to service charges rather than to cost effectiveness).

9. *Network hosts should maintain local control over networks, should charge users for services, and should provide some type of coordinating committee* as advisory on policies and procedures and to hear user problems as needed.

10. *The advisability of incorporation should be strongly considered in each case,* since incorporation accommodates problems arising from artificial boundaries such as public versus private funding of network participants.

11. *Finally, careful evaluations should be made of all such experiments,* both in regard to effectiveness and to costs.

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