Communications Research Centre

The CANUNET Project
A Progress Report

by

C.D. Shepard

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F O R E W O R D

This progress report on the CANUNET project was prepared for the University Research Committee of the Department of Communications. The Research Committee has given three contracts for the fiscal year 1972/73 totalling $70,000 in support of CANUNET. The present report was prepared by C.D. Shepard of the Communications Research Centre of the Department of Communications, who is the contract officer for all three of the above mentioned contracts. Dr. Shepard is also the Department of Communications Project Officer for CANUNET. He is carrying out his responsibilities in regard to CANUNET on behalf of D.F. Parkhill, Assistant Deputy Minister for Planning in the Department of Communications.

The CANUNET project depends on the cooperation and assistance of many people, most of whom are outside the Department of Communications. As the project moves in to its next phases, this will become increasingly true. It is intended that the present progress report, and subsequent reports, will be of value to this growing community in the planning activities necessary to the realization of CANUNET.

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THE CANUNET PROJECT: A PROGRESS REPORT

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1. STATEMENT OF THE PROBLEM

The availability of a wide variety of computing services at Canadian universities has been steadily increasing over the past decade and more. By 1971, NRC had put over $17,000,000 into establishing university computing centres. Without this funding, the steady growth of university computing centres would very likely not have occurred. Looking to the future, there may someday be a network linking these centres together across the country. The questions that follow from this possibility are when the network will come into being, and what developments must occur before the network can be realized.

At the design Integration Workshop held from 26 - 30 June 1972, in Montebello, Quebec, Norman Housley of the Council of Ontario Universities Office of Computer Coordination, (COU/OCC) formulated the goal of university computer networking activities in Canada as 'a *functionally cohesive* computer resource sharing network which will allow a heterogeneous collection of computers to be used as a single computing resource'. Factors to be considered in reaching this goal include:

1) each university in Canada is essentially an autonomous body, with its own interests, aspirations and existing computing resources;
2) the technology of computer networks is evolving rapidly. How can a network be installed, operated and kept up to date in such a heterogeneous institutional framework?
3) how can the growth of the network be made responsive to the needs of users in the universities, including provision of new services and possible cost reductions in the provision of existing services, while minimizing the responsiveness of network growth to pressures resulting from changes and uncertainties in network technology?

These factors are expanded on and discussed at some length in the following progress report. As a preliminary step, the experience of one large computer network project in the U.S. is discussed to see if any lessons can be drawn to apply to the Canadian context. Next, some analysis of the reasons for building a computer network among universities will be given. The remaining sections of this report describe the direction of evolution of network management functions, an evolutionary approach to the technical considerations necessary to realize a network, and some suggestions as to the immediate next steps to be taken.

1.1 THE EXPERIENCE OF ARPANET

One approach to building a network of university computers in Canada (for the sake of brevity, referred to hereafter as CANUNET) is to do what ARPA (Advanced Research Projects Agency - an agency of the Department of Defense in the U.S.) has done to create ARPANET. That is for an agency of the federal government to fund and manage the entire project. In the Canadian context, this is unacceptable for a number of reasons.

1. University computing centres in Canada are funded primarily through a budgeting process that operates through the individual university administrations to the provincial governments. The only role played by the federal government is to provide a percentage of the total funding required each year, according to cost sharing agreements that have been worked out between the federal and provincial governments. The federal government has no say in how the funds are actually spent, primarily because education is a provincial matter under the BNA Act. In the case of the ARPANET, all of the sites that joined the network originally were already receiving substantial amounts of money from ARPA in support of their computing activities.
2. In large measure, ARPANET is an experiment in computer network technology. The best indication of this fact is that very little effort has been put by ARPA into discovering and promoting applications for ARPANET. Canada may not be able to afford this luxury, and may therefore have to develop network applications in parallel with the growth of the network.
3. Sharing of computing resources among different universities implies that each university will become dependent for part of its computing requirements on facilities at other universities. The effort required to arrive at the level of mutual understanding necessary for this to take place is large. In addition, it is essentially the concern of existing regional authorities and associations in Canada. ARPA has not needed to emphasize this aspect of networking, largely because most of the computing centres in the network have been research computing facilities. In CANUNET, nearly all of the potential member sites have substantial responsibilities to user populations outside the context of research on computing.

1.2 REASONS FOR A NETWORK

Why should CANUNET eventually be built? There are many reasons, most of which are difficult to quantify. Ideally, all of the reasons given should fall in the category of providing improved computing services for lower total national cost, and the amount by which the costs would be reduced on a national basis would be given in each case. The following list of reasons is far from ideal in this respect, although efforts are being made, in part through a study at the University of Waterloo, to improve these estimates.

1) Access to data banks. In many cases, it would not be economical to maintain large data banks on line at more than one computer if a network were available to provide rapid access from across the country. This is especially true for data banks that are being updated frequently. For example, CANUNET could provide the communications network for university access to:

   (a) the national scientific and technological information services being developed by the National Science Library;

   (b) the legal data bases at Queen's, University of Montreal, and Laval;

   (c) the Financial Research Institute data base at McGill;

   (d) the PDP-10 at NRC, for the development of courses in the coursewriting language being developed by NRC;

   (e) a data base for social science research being developed at York University.

   This is by no means an exhaustive list of potential data bases which might be economically accessed over a network.

2) Specialization of computer centres. Complex systems of programs require teams with specialized technical and programming knowledge to maintain and operate them effectively. Another reason for specialization is that the royalty charged for the use of a proprietary program is usually a flat rate for the computer on which it is run and does not take account of the hours of use of the program. CANUNET will allow each university computer centre to offer its users access to all the specialized systems of programs available in participating Canadian universities, while itself maintaining only a few.

   The possible benefits of specialization are clearly exemplified by the following rough analysis of the savings that might be realized by installing a computer somewhere in Canada to handle all university requirements for APL. L.P. Robichaud, Director of the Computing Centre at Laval University, has estimated the present expenditures for APL services in Canada to be as follows:

	Annual Expenditure
Laval	$ 500,000
Toronto	600,000
Waterloo	500,000
Lakehead	200,000
York	250,000
U. of Alberta	200,000
U. of British Columbia	100,000
Miscellaneous	300,000
	$ 2,650,000

It was anticipated that if this expenditure was replaced by an expenditure on one computer (an IBM 370/165, for example), the centre costs would be as follows:

$ 60,000	per month for equipment
40,000	per month for operating costs, including staff and overhead
$100,000	per month or $1.2 million per year.

Communications costs would be on the order of $150,000 a year for a leased voice grade multidrop line across Canada, giving a total cost of $1,350,000 per year, and a potential saving of $1,300,000 per year.

3) Use of a variety of local and remote resources, each adapted to the solution of a particular part of a given problem. Experience in the ARPANET has indicated that it is economically advantageous in some cases to prepare programs and data using a local editing system, send the programs and data to a large computer (such as the 360/91 at UCLA or, eventually, the ILLIAC IV at NASA Ames) for processing, and retrieve the output for local post-editing and display.

4) Increased interaction among Canadian universities, with possible fruitful exchanges of experience and a reduction in duplication of research efforts.

5) Centralization and coordination in the provision of data communications facilities will result in lower costs due to economies of scale. This reason makes sense only if a substantial growth in data communications among Canadian universities is anticipated. The indications are that this growth is in fact occurring. For example, the universities of Lethbridge, Trent and Moncton presently satisfy the bulk of their computing needs remotely. The COU/OCC is spending about $30,000 this year for data communications, up substantially from last year. The Quic/Law project at Queen's is spending several thousand dollars per year to operate a small network of terminals across the country. This list could be extended; it would be more useful to have comprehensive estimates.

Another indication of the present demand for on-line computing services (which has grown from virtually zero in the past five to seven years) is provided by the following two tables, which were compiled from estimates made at the Design Integration Workshop in Montebello:

TABLE 1

Numbers of Individual Terminals

(TTY, 2741, 2260, etc.)

	Terminals	Ports
Western Provinces	370	286
Ontario	500	350
Quebec and Maritimes	163	?
Approximate Total National	1,100	750

TABLE 2

Numbers of Remote Reader Printer Terminals

	Terminals	Ports
Western Provinces	16	38
Ontario	35	?
Quebec and Maritimes	41	?
Approximate Total National	100	?

NOTE: More detailed breakdowns suggest that keyboard terminals, RPT, alphanumeric displays, and interactive graphics each could generate peak loads of about 250K Bps.

It is hoped that the study presently in progress at the University of Waterloo will further quantify and expand upon these five reasons for building CANUNET.

2. EVOLUTION OF NETWORK MANAGEMENT FUNCTIONS

From an administrative point of view, a national network linking universities is a most awkward project. No organization with the responsibility to engage in projects such as this network presently exists in Canada. It is therefore necessary for the creation of CANUNET to create such an organization, either from scratch, or by making use of existing organization on an ad hoc basis. To create such an organization where none existed before requires that an existing organization make funds available on a continuing basis before it has become clear that the network is in fact going ahead. Thus an ad hoc approach has been taken for CANUNET, with the hope that a permanent project organization will evolve.

2.1 GENERAL NETWORK MANAGEMENT AND COORDINATION

To date, the planning for CANUNET has been handled by DOC and the University of Quebec, with the help of an ad hoc committee structure. The CANUNET Advisory Committee, composed primarily of representatives from universities across Canada, has met three times in the past year. The first meeting was on 11 August 1971. At its second meeting on 1 November 1971, four subcommittees were established:

Network Design
Communications Studies
Institutional Framework
Utilization.

These subcommittees prepared their first reports in time for the third meeting of the Advisory Committee, held 29 March 1972. The end result of this activity was the preparation of a report by Mr. J.B. Reid of the University of Quebec, entitled *A proposal for a Canadian university computer network.*

Included in that report are cost estimates for the building and initial operation of an integrated message switching network linking eighteen universities together across Canada. The optimistic estimate of cost finally arrived at is $4.2 million, spread over five years. The pessimistic estimate is $9.7 million, spread over seven years. Bearing in mind that the total amount of money spent for computing services by the eighteen largest universities in Canada is presently in excess of $35 million per year, even the pessimistic estimates are only four per cent of the present annual costs for university computing in Canada.

The ongoing annual cost of operating the network after installation is estimated to be between $2.2 million and $3.3 million, including provision for network management, network support at each site and communications lines. The variability in this estimate is entirely due to a variable estimate of between $5,000 and $10,000 per month per node for the cost of communications lines. This estimate is in turn based on the assumption that the bulk of the lines in the network will be 50,000 Bps. If they turned out to be only 9600 Bps, the cost per node per month would drop to somewhere between $2,000 and $4,000, giving an ongoing annual cost of operating an 18 node network of between $1.5 million and $1.9 million. It is clear that the operating cost is extremely sensitive to communications costs. It should be pointed out that no attempt has been made to reduce these cost estimates through negotiations with the common carriers on volume discounts. A good deal of work remains to be done in refining these cost estimates before a proposal for funds can be made.

Some of the factors that have not been adequately considered in the present estimates are the actual levels of data traffic expected, the pattern of growth of this traffic, the present computing facilities actually available at a particular site, the extent to which these facilities would have to be modified to handle the projected traffic requirements, the feasibility of in-house development activities at the universities as a means of realizing the network initially, and the possibility of immediate cost reductions through the use of the network (for example, by establishing a computer dedicated to providing an APL service).

2.2 MARKETING AND DEVELOPMENT OF NETWORK SERVICES

One of the major difficulties in estimating the pattern of growth of data traffic between Canadian universities is the fact that many of the specialized applications which could be expected to give rise to a substantial amount of traffic are still in the early stages of development. Thus, although it is clear that document retrieval systems will eventually require data links between universities, either to handle requests for specific documents, or to speed the distribution of current awareness listings, or to facilitate exchange of bibliographic citations between libraries, or to conduct on-line searches of document collections in any of a large number of different disciplines, it is by no means clear when these developments will take place. In fact, it can be argued that the existence of a nationwide university data communications network is a prerequisite to these developments, because they cannot individually justify such a network on economic grounds, while collectively, they would account for a substantial portion of the use of such a network.

The following analysis is offered as an indication of the potential size of the market for data traffic among universities in just one discipline, the law. Initially, of course, only a tiny fraction of this demand would manifest itself.

There are approximately 7,000 professors and students of law in Canada. According to Prof. Hugh Lawford of Queen's University, each of them spends 10 per cent of each day looking up material. Suppose a legal information retrieval system such as Quic/Law reduced this to one per cent. The total time at Quic-Law terminals might then be:

$$8 \text{ hours/day} \times 0.01 \times 7{,}000 = 560 \text{ hours/day.}$$

Since there are 3600 seconds in an hour, and assuming that the terminals operate steadily at a peak rate of 2400 Bps, this works out to:

$$560 \times 2{,}400 \times 3{,}600 \text{ bits/day.}$$

If this service is provided over a 10 hour period in each working day, then the average peak load requirement will be:

$$\frac{560 \times 2{,}400 \times 3{,}600}{10 \times 3{,}600} = 560 \times 240 = 144{,}400 \text{ Bps.}$$

Clearly a number of factors are not adequately considered in the above analysis:

- actual peak bit rate requirement at peak times of the day,
- geographic distribution of demand,
- actual requirement for bit rate during the one per cent of each user's day that is spent at the terminal. Presumably no user will be capable of driving the terminal at its full capacity of 2,400 Bps for the whole time he is at the terminals.

Nonetheless, peak bit rate requirements on the order of 100,000 Bps for some sections of a national network would appear to be required to meet the potential demand for legal information retrieval services at Canadian universities. At this stage, it is impossible to estimate the fraction of the potential demand that will be realized in the years ahead.

Clearly, the demand for CANUNET will increase substantially when services such as a legal information retrieval system are in use. Thus, there is a need to consider the development and marketing of such services as part of a larger development in which CANUNET plays a key role. The mechanism by which this would be done remains unclear.

2.3 FINANCIAL MANAGEMENT OF THE NETWORK

There are two problems associated with financing CANUNET at this stage:

a) finding a sufficient amount of money to build and begin operation of the network;

b) ensuring that a mechanism is found to permit each university on the network to purchase computing services wherever those services are offered on the network.

The first of these problems will eventually solve itself in a sense, in that either funds will be found from various sources in sufficient amounts to build and operate the network, or the network will not be built and all the problems associated with establishing a network will disappear. Almost inseparable from this first problem is the question of who the responsible fiscal agent should be to disburse that portion of the funding for CANUNET that comes from the federal government. The reason for this inseparability is that the federal government is the only source of funds likely to provide enough funding to permit a university computer network to go ahead, and, in addition, the leverage provided by this funding can be used to ensure that regional networking activities are coordinated to create a national network. In order to make use of this leverage, a coordinating body must be established at the national level. This coordinating body must then take fiscal responsibility for funds from the federal government for CANUNET. This is potentially an awkward situation if DOC is to act as the coordinating body for some interim period, because DOC has no control over the actions of the provincial governments and the universities once the funds have been committed. These are several possible solutions to this difficulty:

1. DOC could let a single contract to a prime contractor in Canadian industry to design, build and install CANUNET;
2. DOC and the regional networks could come to an agreement on the technical specifications of each of the component parts of the network, and then DOC could let contracts for the development of each component directly, while simultaneously making funds available as necessary to regions and/or individual universities to allow them to acquire those components that they do not develop themselves;
3. funds could be made available through DOC, or through some other federal agency, such as NRC, or through existing cost sharing agreements to existing regional network planners with the proviso that they agree on standardization of those aspects of a network that must be standard to facilitate inter-network communication;
4. funds could be made available without restriction, either through a negotiated development grant from NRC or through increased provincial contributions resulting in increased federal contributions through existing cost sharing agreements.

None of these solutions make any mention of who has the responsibility for coordinating each university's participation in CANUNET, for managing the rational growth of CANUNET, or for preparing and distributing documentation relating to the use of CANUNET. Nor do they make mention of how funds from provincial governments and universities should be handled, nor of the relative proportion of funds from each source.

Some discussion of the merits of the four possible solutions is necessary. The first two solutions would appear to offer the best chance of ensuring that compatible networks develop in all parts of Canada, while the second solution avoids the excessive control of network development by DOC implicit in the first solution. The third solution provides the regional networks with a slightly greater degree of autonomy, although not as much as the fourth solution. Both the third and fourth solutions recognize provincial autonomy to the point where it becomes possible for incompatible networks to evolve.

The second of the problems associated with financing CANUNET is finding a mechanism which will permit each university to purchase computing services through the network. The reason that this is a problem is that each university that has its own computer centre requires a stable source of funds to support that centre. If the funds available for computing at a given university are not allocated by the university administration to that university's computing centre, then, as a practical matter, the computing centre may not receive sufficient money to enable it to fulfill its commitments to its staff and to pay the rent on its equipment. For computing centres providing a high standard of service at reasonable cost, this will not be a problem, because their revenues will increase by virtue of the services they sell over the network. In fact, it can be argued that no computing centre should suffer if a network were installed, because the network would allow demand for computing services to be satisfied wherever excess capacity was available. However, the natural and justifiable inclination of any university having a demand for more routine computing than it can presently supply is to install additional computing facilities on campus to meet that demand.

What are the possible mechanisms for transfer of funds among universities for computing services?

1. System of credits.
2. External direct financing of off campus computing.
3. Each university explicitly commit some fraction of its computing budget to be spent for off campus computing.

The first of these mechanisms is an artificial payment mechanism which works by transferring credits in return for services purchased over the network. These credits can only be used to purchase computing services at other universities belonging to the same system of credits. The system will work well so long as the flows of credits in and out of each university, are approximately equal. This can be ensured by putting a ceiling on the number of credits any one university is allowed to accumulate, or the number of credits any one university is allowed to owe. As a first step in developing a payments mechanism, it makes some sense, because it does not involve the transfer of any real money between universities.

The second mechanism can also be used as a first step. Either the federal or a provincial government could provide such funds to stimulate the use of off campus computing services. This is being done in New Brunswick, where, for example, Mount Allison University makes substantial use of the computing facilities at UNB, and this use is paid for by the Higher Education Commission of the province. As an ongoing method of transferring funds, this is less desirable than either of the other two methods, because it requires continuing external funding.

If a network is to exist on a permanent basis, the third mechanism is probably the only one that will work in the end. It is also the most difficult mechanism to establish, because it requires that each university in effect reduce its budget for on-campus computing (although with the possibility of actually increasing it through off-campus revenues). This is the mechanism used by the Triangle Universities Computing Centre (TUCC) in the southern U.S. Each of the three universities involved, Duke, North Carolina, and South Carolina, get together with the director of TUCC once a year and pledge a fixed amount of money to support TUCC for the coming year. This amount is related to anticipated usage of TUCC facilities, but is not altered for that year if the actual usage turns out to be different. Such a mechanism could be introduced on a small scale to the tune of about 10 per cent of total university computing in Canada, if all money made available through NRC research grants for computing services were freely allowed to be used to purchase computing services off campus.

2.4 DOCUMENTATION

A critical aspect of building and using a computer network is ensuring that everyone associated with the activity has easy access to all the information he requires. This implies that the network planners must set up a number of information collection and dissemination services. A partial list of such catalogues includes:

1. a catalogue of services available from different sites on the network, broken down into subcatalogues of
   a) prices for services,
   b) technical descriptions of services,
   c) people to contact for assistance in using the services.
2. A catalogue of activities related to the network itself, broken down into
   a) technical descriptions of all aspects of the network,
   b) management information for the network,
   c) activities which may impact the network in the future.

Estimates of the size of these catalogues, and hence of the cost of preparing them, have not yet been made. As a rough indication, EDUCOM has been working on the EIN Software Catalogue since 1968 with annual support of $150,000. It could be a part of the catalogue suggested in 1. above. As of June 1972, it contained material on 162 programs. This works out to a cost of about $3800 per program documented.

2.5 THE FUNCTIONS OF REGIONAL NETWORK MANAGEMENT

The most important function of regional network management is the care and feeding of individual university computer centres in the region. Each computing centre has its own set of problems, ranging from organizational to technical, in connecting to a network. Even if certain aspects of the network design are standardized at the national level, there will of necessity be aspects which are not standard and can conveniently be handled at the regional level. These include:

1. arrangements for payments for use of off-campus computing resources within a province;
2. adaptation of standard network components to local hardware configurations;
3. analysis of the needs of individual university communities, and marketing of services available over the network to these communities.

3. AN EVOLUTIONARY APPROACH TO NETWORK DESIGN

A computer network has many parts. Some parts of CANUNET are already installed and operating. In particular, computing facilities at most Canadian universities already exist, and often have some capability for data communications. An ad hoc version of CANUNET could be put together in a few months by making use of existing facilities and systems programmers at the universities. The cost of an ad hoc version of CANUNET would be several man-months of time and a small amount of hardware at each participating university, the cost of coordinating the project until a full fledged integrated CANUNET was installed, plus an ongoing cost for communications lines, maintenance, and equipment rental. The capacity of such a network would be small, its response time would be erratic, its demands on the resources of central computing facilities could be large, and messages would have to be exchanged using bilateral protocols rather than uniform protocols. There are undoubtedly additional drawbacks to the ad hoc approach.

Initially it might not be necessary to involve the central computing facility at all sites--a terminal, or several terminals attached to a simple multiplexor would permit access to a few specialized services. The criterion for whether or not a site attached its central computer initially might very well be the willingness and ability of that site to modify the software of its computer on an experimental basis.

The virtues of an ad hoc CANUNET as an interim measure include

1. universities across Canada would begin to think more about demands they might have for off-campus computing, and traffic resulting from the satisfaction of those demands would begin to build up;
2. university computing centres would gain experience in the operation of a network, and hence would be better prepared for an integrated network;
3. it would form the nucleus of a project organization for CANUNET.

Exact figures for the cost of establishing and running an ad hoc network are difficult to arrive at because they are dependent on the particular sites that participate, and also dependent on the reasons for those sites participating. The key to the development of an ad hoc network is the establishment of a project team of two or three individuals, with a project fund which they would allocate on the basis of proposals received from universities across

Canada. This project team would have to visit individual universities, initially to assess their requests for funds, and subsequently in the course of the project, to coordinate the activities of the various universities involved. The team could be made up of people seconded from universities, and might operate under the auspices of the AUCC. On this basis, the support required for the project team itself would be $75,000 to $100,000 per year. In addition, a project fund on the order of $300,000 would be required in the first year, increasing to about $500,000 in the second year, to $750,000 in the third year, and so on until the integrated network proposed for CANUNET came into operation in three or four years. Note that this project team could form the nucleus of the secretariat proposed in the report prepared by J.B. Reid for DOC in March, 1972, and that the project fund proposed above would result in higher overall expenditures in the beginning than proposed in that report, but that the annual operating costs would be the same in the end. Detailed plans for the allocation of this project fund have not yet been drawn up.

Ideally, the ad hoc version of CANUNET would last only until traffic on the network had built up to the point where an integrated network could be economically justified. Thus the integrated network would come on stream at about the time when its annual cost (including the depreciated capital cost of installing it) was about equal to the amount being spent for a network on an ad hoc basis.

The discussion above centred on an ad hoc version of CANUNET as a means of evolving to a full fledged CANUNET. At the Design Integration Workshop in Montebello, P.Q., a parallel path of evolution was worked out. It is based on a modular and flexible approach to connecting university computers to a network. This approach centres around the concept of a Network Access Facility (NAF).

3.1 THE NETWORK ACCESS FACILITY: A MODULAR APPROACH

Agreement was reached at the Design Integration Workshop that there are logically three functions that must be supported by a NAF:

1. host support function;
2. switching function;
3. terminal support function.

These functions are independent, and so should be realized by three distinct modules:

1. host interface module (HIM);
2. subnet interface module (SIM);
3. terminal interface module (TIM).

It is also agreed that specifications for the interfaces between these interface modules could and should be worked out in detail to allow different physical realizations of the modules. This is a task of high priority for the success of both CANUNET and METANET (the proposed Ontario Universities Network).

The reasons that a modular approach to the design of the NAF was chosen include:

1. to allow flexibility in local connections and configurations;
2. to encourage experimentation with and evolution of support functions;
3. to allow architectural diversity while maintaining functional compatibility.

NAF modules may be realized as:

1. separate tasks in a minicomputer;
2. separate, interconnected minicomputers;
3. micro-programmed controllers;
4. a combination of the above.

A brief description of the tasks to be performed within each of the three types of modules is of interest.

The subnet interface module performs the communications switching task. The technique used for switching, whether it be circuit switching, packet switching, loop switching, or some combination, is known only to this module and is transparent to the other modules. One reason for this is that some experimentation with switching techniques is expected. In a distributed network the SIM also provides reliability and throughput for messages passing through it between other sites on the network. Finally, the SIM exchanges data with local computers and terminals through the local HIM and TIM, respectively. The SIM can be produced relatively inexpensively to enable easy connection to the network. The estimated cost of a SIM is on the order of $15,000. This estimate is consistent with an estimated cost of a small high-speed modular interface message processor (HSMIMP) for the ARPANET of $30,000, since only 30 per cent of the HSMIMP will be devoted to the switching function.

The terminal interface module performs the following tasks:

1. it multiplexes terminals, including all common terminal types, into the network through the SIM and into the local host, either directly through the HIM or indirectly through the SIM to the TIM;
2. it provides conversions between different types of terminals.

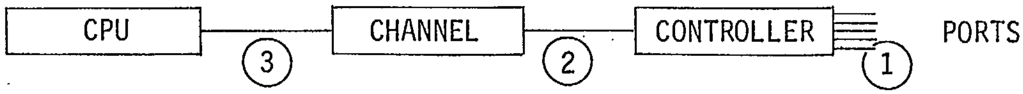
The TIM must be engineered for convenient use, and it must be easy to adapt for handling special types of terminals such as plotters and graphics displays.

The host interface module performs the following tasks:

1. it multiplexes host communications in and out of the network through the SIM;
2. it provides versatile attachment to host hardware and software and allows the method of attachment to change as the requirements for network services change at each site.

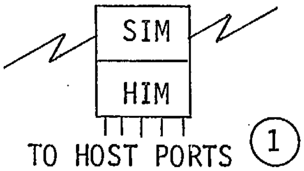
3.2 DIFFERENT NAF CONFIGURATIONS FOR DIFFERENT SITES

A simplified version of the I/O structure of most potential hosts is given by the following diagram:



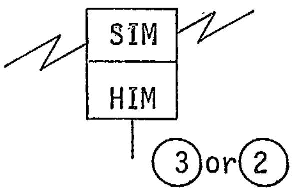
The potential points of attachment are indicated by the numbers in circles. The following six configurations of the three types of interface modules are intended as examples of the use of these modules.

3.2.1 Multiplex/Demultiplex (MUDEM)



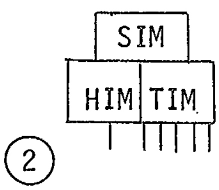
This configuration allows immediate interconnection of hosts which have telecommunications facilities. It may be the optimal method of interfacing to some hosts. It can be produced inexpensively, possibly for as little as $15,000.

3.2.2 Proposed CANUNET NAF



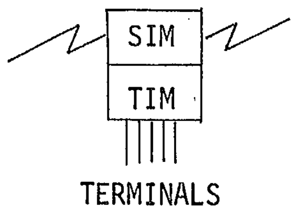
The proposed CANUNET NAF configuration provides connection close to the heart of the host system in order to optimize the interaction between the host and the network, possibly at the expense of requiring host software changes. It facilitates experimentation with interprocess communication and networking protocols.

3.2.3 Proposed METANET NAF



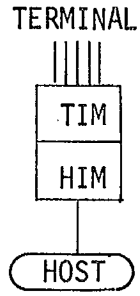
The purpose of the METANET NAF is to allow terminal access to the local host and to the network. The usual design of the HIM in this case is expected to be an emulation of host's standard transmission controller. This approach has the virtue of requiring few, if any, modifications of host software.

3.2.4 Satellite NAF



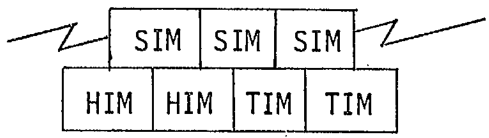
This configuration allows access to CANUNET by sites that either do not have hosts, or that prefer not to attach their hosts to the network.

3.2.5 Data Concentration



The data concentrator configuration is essentially a fringe benefit for those who do not want to belong to CANUNET, and for those who intend to belong eventually and want to get started. It provides terminal support for a local host compatible with network connections.

3.2.6 COMPLEX NAF



In this ultimate configuration, of which the drawing above is only a sample, many considerations come into play. Among them are:

- redundancy for reliability
- support for specialized terminals
- increased bandwidth
- support of very complex host configurations, including local networks.

3.3 BANDWIDTH AND RESPONSE TIME REQUIREMENTS

The attached graph* showing acceptable limits of response time and bandwidth performance for various types of traffic was put together by Joe Reid

* Appendix A.

of the University of Quebec during the Design Integration Workshop. The performance requirements of shared mass storage, reflecting typical disc seek times and transfer rates, and of highly interactive dynamic graphics, are considered to be too stringent to be feasible for CANUNET. All the other types of traffic can be supported in the CANUNET design. For a few applications, such as computer aided learning, the acceptable system response time to a line may in fact be less than a second, implying that the network delay must be on the order of a tenth of a second. A more detailed analysis of the present response times tolerated in all applications would appear to be required. For example, in using a reader printer terminal for WATFOR, it may be necessary to have response times as fast as or faster than line-at-a-time teletype response times, while if a reader printer terminal is being used to enter jobs into the regular batch stream, response time on the order of minutes will undoubtedly suffice.

The response time requirements for echoplexing are worthy of independent study. Some interactive systems work on the basis of not always printing the same character that is keyed in by the user of the terminal. This requires a full duplex connection to the terminal, and is referred to as echoplexing. As many as 20 per cent of the computers in CANUNET may use this mode of operation, which is very desirable for rapid interaction. Because echoplexing results in a lot of single character messages in the network, it may be advantageous to design the modules of the network to handle single character messages as special cases. This would reduce overheads and improve the response time for echoplexing.

3.4 REQUIREMENTS OF A TERMINAL ORIENTED NETWORK

Experience in various networks indicates that local printing, card reading, and other peripheral functions are desirable but not essential in conjunction with access to a remote computer through a terminal. Users are willing to put up with many inconveniences of this nature if the remote system they are using meets their other requirements, including response time, scope of services, reliability and availability. Thus these would appear to be the main requirements for a terminal oriented network.

4. WHAT NEXT FOR CANUNET

The following four sections give a very rough idea of the road ahead for CANUNET. Clearly, all of this activity is dependent on funding. Thus the prime activity in the immediate future for the limited resources of the DOC CANUNET project office will be the preparation of a project plan containing detailed justification and cost breakdowns for CANUNET. The material in the present progress report is an incomplete version of that project plan.

4.1 A NATIONAL STANDARDS MAKING ACTIVITY FOR CANUNET

A group to work out standards for functional specifications allowing different physical implementations of the various parts of a resource sharing computer network should be set up in DOC. Because of the uncertainty of present state-of-the-art knowledge concerning such specifications, it is suggested that this group should reside at CRC. It is anticipated that as time advances, the state of knowledge will improve, and responsibility for participation in such standards making activity in the future will largely be transferred elsewhere.

In the context of CANUNET, this group is of particular importance, and there is some urgency concerning its creation. Regional university networks, and regional initiatives to set standards for functional specifications, are steadily gaining momentum. Working groups must be set up at the national level to ensure that these regional initiatives do not result in networks in different regions being incompatible. These working groups are much more likely to be successful if they include knowledgable participants who do not belong to any particular region. It is difficult to see where such participants will come from if DOC does not take the initiative to establish some in-house competence in this area.

4.2 AN EVOLVING ROLE FOR THE ASSOCIATION OF UNIVERSITIES AND COLLEGES OF CANADA (AUCC)

The AUCC is dependent by its nature on its member universities for its financial support. It is therefore in a vulnerable position financially and in general has difficulty finding even small amounts of money with which to initiate new activities. Nonetheless, it is the only national association of universities in Canada, and, as such, is a prime candidate for the eventual home of any CANUNET project organization that evolves. It is capable of accepting financial contributions from all sources, including the universities themselves, for the support of the network when it becomes a reality and the subsidies that initially supported it begin to taper off. Preliminary steps that might be taken by the AUCC in the near future include the organization of national conferences of general interest for university people involved in computing, the convening of meetings of senior university officials to discuss the implications of a computer network for individual universities, and the preparation, cataloguing and distribution of useful reference material on computer networking in Canadian universities. Unfortunately, all of these steps require that additional funds be made available to the AUCC, with the possible exception that a national conference might be self-supporting.

4.3 SOME PROJECTS CURRENTLY IN PROGRESS

The following abbreviated list gives a good idea of the extent of the network related research development activity presently underway at Canadian universities. The total funding for the network related aspects of these projects is in excess of $350,000. It is anticipated that more extensive descriptions of these and other projects, including progress reports on their status, will be collected, and collated for distribution. DOC might do this, although there is a project at NRC into which this task fits naturally, and, as mentioned above, the AUCC is also a logical candidate.

1. Skinny network (WATERLOO; BNR)
2. Loop (WATERLOO, TORONTO)

3. Local networks: switching experiments,
   PDP-11 to CC70 bisync link,
   CC70 - DATANET 355 (WATERLOO)
4. CRC local loop (CRC, NEWHALL)
5. Star-Ring project (TORONTO)
6. APL postbox for job entry on other machines (LAVAL)
7. Regina-Saskatoon link (SASKATCHEWAN)
8. CDC 6400 to 3 CDC 3150s network (QUEBEC)
9. Microprogrammed intercomputer adapter (UBC)
10. Interface to multiple terminal types (UBC, MULTIPLE ACCESS LTD under contract to COU/OCC)
11. Network Control Language (COU/OCC)
12. Distributed protocols (COU/OCC)
13. CN-CP switching study (COU/OCC)
14. Languages for naive users (QUEEN's)
15. Virtual port terminal handler (SASKATCHEWAN)
16. CANUNET design study (QUEBEC)
17. Traffic study (WATERLOO)
18. Performance measurement (WATERLOO)
19. Interprocess use simulation (WATERLOO)
20. Remote terminal development (QUEBEC).

The results of these projects are expected to result in improvements in the design of networks.

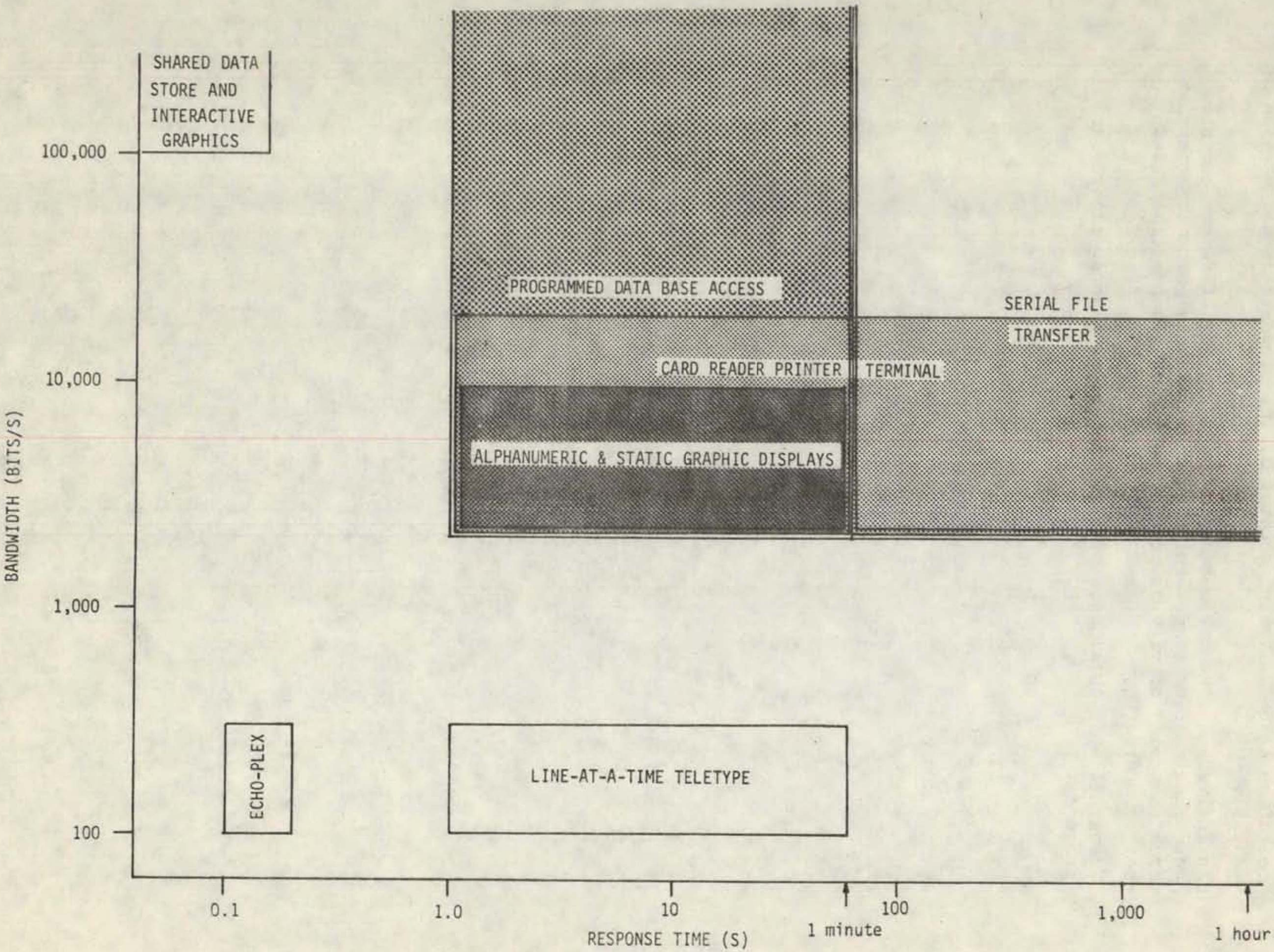
With careful planning, improvements in the design of one part of the network will not require redesign of other parts. This has been discussed in previous sections of the present report.

4.4 SOME PROJECTS FOR THE FUTURE

Projects that should be started as soon as possible include the following:

1. preparation of detailed specifications for the interfaces between the three types of modules (HIM, SIM and TIM) proposed for the Network Access Facility;
2. an analysis of response times for various applications presently being run at universities across Canada;
3. preparation of a model to permit quantitative analysis analysis of the tradeoffs between accessing a system (e.g., QUIC/LAW) over a network versus duplicating the system locally;

4. verification and reworking (possibly with the help of an independent consultant) of the estimates prepared for the cost of building and operating CANUNET, taking account of the proposed ad hoc version of CANUNET;
5. An analysis of the parameters in the design of different computer networks in order to determine which parameters are most important from the point of view of preventing serious incompatibilities between networks;
6. preparation of catalogues of network related papers, reports and projects.



Potential network services.

APPENDIX B

Participants in the Design Integration Workshop, Montebello, Quebec, 26-30 June 1972

C.D. Shepard, Department of Communications

J.B. Reid, University of Quebec

W.M. Gentleman, University of Waterloo

D.A. Twyver, University of British Columbia

N. Housley, Council of Ontario Universities.

In addition, the following people participated in the closing session of the Workshop, 30 June 1972:

D.F. Parkhill, Department of Communications

M.P. Brown, Council of Ontario Universities.

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