# UNE PROPOSITION POUR UN RÉSEAU D'ORDINATEURS UNIVERSITAIRE CANADIEN (CANUNET)

préparée par le comité consultatif sur canunet
pour le ministère des communications





projet coordonné par l'université du québec · mars 72 

université du qué[bec]
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Ste-Foy, le 17 mai 1972

Monsieur D.F. Parkhill,
Sous-Ministre Adjoint (planification),
Ministère Fédéral des Communications,
100 rue Metcalfe,
Ottawa, Ontario



Cher monsieur Parkhill,

C'est avec plaisir que l'Université du Québec vous remet aujourd'hui le résultat des études qu'elle a acceptées de conduire il y a un an en vue de définir les conditions nécessaires à l'établissement d'un réseau interuniversitaire canadien permettant d'interrelier différents types d'ordinateurs.

Une telle contribution de l'Université du Québec s'inscrit dans sa volonté de faire servir son réseau informatique, tant au niveau de l'expertise qu'au niveau de l'équipement, à l'ensemble de la communauté. Il nous semble également nécessaire de pouvoir rendre disponibles à nos étudiants, professeurs, chercheurs et administrateurs, non pas seulement les informations cumulées au sein de notre propre réseau d'ordinateurs, mais aussi les informations cumulées par d'autres universités.

Nous tenons à souligner l'excellence de l'assistance apportée à M. Joseph B. Reid dans son travail, en particulier celle des universités de la Colombie Britannique, de Saskatchewan (Saskatoon) et de Waterloo ainsi que celle des spécialistes de votre ministère.

Vous réaffirmant notre volonté de participer à la réalisation de ce réseau interuniversitaire canadien, nous vous prions d'agréer, cher monsieur, l'expression de nos salutations les plus distinguées.

Le Vice-président par intérim
aux Communications

Louis Brunel

LOUIS BRUNEL

LB/cl

A PROPOSAL FOR A

# CANADIAN UNIVERSITY COMPUTER NETWORK

# ( CANUNET )

PREPARED BY THE CANUNET ADVISORY COMMITTEE

FOR

THE DEPARTMENT OF COMMUNICATIONS



*Project coordinated by*
*UNIVERSITE DU QUEBEC*
*March 1972*

PROPOSITION VISANT LA CREATION D'UN

# RESEAU UNIVERSITAIRE CANADIEN D'ORDINATEURS
# ( CANUNET )

PREPARE PAR LE COMITE CONSULTATIF DE CANUNET

A L'INTENTION DU

MINISTERE DES COMMUNICATIONS

*Projet coordonné par*
*l'UNIVERSITE DU QUEBEC*
*mars 1972*

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## 1. INTRODUCTION

During the 1960s, the use of telecommunication circuits for the transmission of data to computers grew rapidly. Bell-Northern Research estimates the present rate of growth of transmission of digital information in Canada to be 24% per year[1]. There is a similar rate of growth in the sale of terminal devices to communicate with computers from a distance. Most of these devices have no computing power in themselves, they simply allow a person or a machine to communicate with a computer. Typically, a terminal is a teletypewriter, a cathode ray screen with a keyboard, or a card reader and a line printer. The most extensive computer networks are probably those used for airline reservations. Financial networks, for branch banking and for credit checking, are growing rapidly. The usual pattern of these networks is a large computer at a central office joined by lines to satellite terminals in what may be called a star formation. The few examples of networks of computers communicating with computers are, almost all, confined to networks of computers of a single manufacturer. Examples of such networks are the System/360 computers of the Service Bureau Corporation, Cybernet of Control Data Corporation which includes Control Data 6600 and 3500 computers, the network of Univac 1108 computers of University Computing Corporation, Tymshare's Tymnet of XDS 940 and DEC-10 computers and the Fieldata network of the U.S. Army.

In 1968, D.W. Davies of the National Physical Laboratory proposed to link computers of a variety of types in Great Britain to a network of minicomputers which would deliver messages from any computer on the network to any other computer[2]. This network has been implemented within the NPL but funds have not been provided to extend it to other computer centers, probably because the British General Post Office is working on a more ambitious plan to provide a network of very high speed digital circuits throughout the country[3].

# 1. INTRODUCTION

Au cours des années soixante, l'utilisation des réseaux de télécommunication pour la transmission de données aux ordinateurs a augmenté rapidement. Les Recherches du Bell-Northern estime que le taux actuel d'augmentation de la transmission d'information numérique au Canada est de 24% par année[1]. La vente de stations terminales permettant de communiquer à distance avec les ordinateurs accuse un taux d'augmentation semblable. La plupart de ces dispositifs ne sont pas conçus pour le calcul; ils ne font que permettre à une personne ou à une machine de communiquer avec un ordinateur. Une station terminale peut être, par exemple, un télescripteur, un écran cathodique muni d'un clavier ou un lecteur de cartes et une imprimante par ligne. Les réseaux d'ordinateurs comportant le plus de ramifications sont probablement ceux utilisés par les compagnies aériennes pour la réservation des sièges. Les réseaux financiers servant aux opérations bancaires entre les succursales et aux vérifications de solvalibilité augmentent rapidement. La configuration habituelle de ces réseaux consiste en un gros ordinateur situé au bureau central relié par des circuits à des terminaux et constituant ce que l'on pourrait appeler une disposition en étoile. Les quelques exemples de réseaux d'ordinateurs en communication avec ordinateurs se résument, pour la plupart, à des réseaux d'ordinateurs d'un même fabricant. Citons, par exemple, le système d'ordinateurs 360 du Service Bureau Corporation, de la Cybernet de Control Data Corporation qui comprend des ordinateurs Control Data 6600 et 3500, le réseau d'ordinateurs Univac 1108 de la University Computing Corporation, le réseau d'ordinateurs XDS 940 et DEC-10 de Tymnet de Tymshare et le réseau Fieldata de l'armée américaine.

En 1968, D.W. Davies du National Physical Laboratory en Angleterre proposa de relier divers types d'ordinateurs à un réseau de mini-ordinateurs qui pourrait transmettre des messages d'un ordinateur du

In the United States the Advanced Research Projects Agency of the Department of Defense started to build a network of large computers in 1969 (see Appendices A and B)[4]. First tests of transmission over the network were made in the fall of that year. Appendix C shows the computers connected to ARPANET in March 1972.

In June 1969 the Committee of Presidents of Ontario Universities established an Office of Computer Coordination with the objective of rationalizing computer resources in the Province. In 1971, this Office reported that the objective could best be achieved by making the computing power of all the universities available to workers in each university through a computer network (see Appendix D). A technical proposal has been prepared[5], tenders have been called for the detailed design of the network[6], and a technical staff has been assembled.

In 1966, Michigan State University, the University of Michigan and Wayne State University entered into a program of mutual cooperation in information processing. This led to the establishment in July 1969 of the MERIT (Michigan Educational Research and Information Triad) Computer Network Project with funding from the National Science Foundation and the State of Michigan. This network is now coming into operation[7].

A network to share computing loads between four universities in the West of England is being developed[8].

The proposal to develop a Canadian University Computer Network (CANUNET), which is the subject of this report, arose from two separate events.

réseau à tout autre ordinateur[2]. Ce réseau a été mis sur pied dans le cadre du NPL (National Physical Laboratory) mais n'a pu obtenir les fonds nécessaires pour s'étendre à d'autres centres d'ordinateurs, probablement parce que le General Post Office britannique consacrait ses efforts à un projet beaucoup plus ambitieux, à savoir, établir un réseau de circuits numériques très rapides à travers le pays[3].

Aux Etats-Unis, l'Advanced Research Projects Agency du ministère de la défense a annoncé en 1969 l'établissement d'un réseau d'ordinateurs géants (voir Annexes A et B)[4]. Les premiers essais de transmission par le truchement du réseau ont été effectués au cours de l'automne 1969. On trouvera à l'Annexe C la liste des ordinateurs reliés à ARPANET en mars 1972.

En juin 1969, le Comité des Présidents des Universités de l'Ontario a mis sur pied l'Office of Computer Coordination dont le but était de rationaliser les ressources offertes par les ordinateurs de la province. En 1971, cet organisme déclarait que l'objectif pourrait être atteint au mieux en mettant à la disposition des chercheurs dans chacune des universités le potentiel offert par les ordinateurs de toutes les universités par le truchement d'un réseau d'ordinateurs (voir Annexe D). Une proposition technique fut préparée à cet effet[5], un appel d'offres portant sur la conception détaillée du réseau fut lancé[6], et une équipe de techniciens fut réunie.

En 1966, l'Université du Michigan, le Michigan State University et le Wayne State University ont amorcé un programme de collaboration mutuelle dans le domaine du traitement de l'information. Ce programme donna lieu à la création, en juillet 1969, du projet de réseau d'ordinateurs MERIT (Michigan Educational Research and Information Triad) qui reçut l'appui financier de la National Science Foundation et de l'état du Michigan. Ce réseau entre maintenant en opération[7].

In November 1970 the Interuniversity Communications Council (EDUCOM) circularized the universities of the United States and Canada regarding their possible interest in joining ARPANET. Dr. Leon Katz of the University of Saskatchewan and Chairman of the Science Council Committee on Computer Applications and Technology proposed in December 1970 to the Department of Communications that a Canadian university computer network should be established as soon as possible so that Canadian university computers could communicate over a Canadian network, rather than over north-south links to an American network.

The Université du Québec applied to the Department of Communications in March 1971 for a grant to initiate work to develop a university computer network. This report is the final product of the resulting research grant.

As a result of these initiatives from Saskatchewan and Québec (see Appendices E and F), the Department of Communications convened a CANUNET Advisory Committee in August 1971 (see Appendix G). A questionnaire was sent to the directors of the computing centers of all Canadian universities. The replies indicated widespread interest in the project, particularly among the smaller universities (see Appendices H and I). A second meeting of the Advisory Committee in November 1971 set up four study groups to report on the diverse aspects of the project (see Appendix J):

1) Network topology and communication costs;
2) Network design, apart from communication lines;
3) Utilization of the network;
4) Organizational structure.

The reports of these study groups are included in this report as Appendices K, L, M and N.

Dans l'ouest de l'Angleterre, on envisage présentement l'établissement d'un réseau qui permettra aux ordinateurs de quatre universités de se partager le fardeau du traitement de l'information[8].

Ce sont deux événements distincts qui ont donné naissance à la proposition, faisant l'objet du présent rapport, de mettre sur pied un réseau d'ordinateurs à l'intention des universités canadiennes (CANUNET).

En novembre 1970, EDUCOM (Interuniversity Communications Council) adressait une circulaire aux universités américaines et canadiennes pour s'informer de leur intention éventuelle de se joindre à ARPANET. Le Dr. Léon Katz de l'Université de la Saskatchewan, président du Comité du Conseil des sciences pour les applications de l'informatique et la technologie des ordinateurs, soumettait au ministère des Communications, en 1970, une proposition concernant la création immédiate d'un réseau d'ordinateurs reliant les diverses universités canadiennes pour permettre aux ordinateurs des universités canadiennes de communiquer entre eux par le truchement d'un réseau canadien plutôt que d'emprunter des chaînes de communication nord-sud aboutissant au réseau américain.

L'Université du Québec a sollicité l'aide financière du Ministère des Communications en mars 1971 pour mettre sur pied un réseau interuniversitaire d'ordinateurs. Les présentes constituent le résultat du subside accordé pour effectuer des recherches en ce sens.

Devant les démarches entreprises par la Saskatchewan et le Québec (voir Annexes E et F), le Ministère des Communications convoquait une réunion du comité consultatif Canunet au mois d'août 1971 (voir Annexe G). Un questionnaire fut adressé aux directeurs des centres de calcul de toutes les universités canadiennes. Les réponses témoignaient un vaste intérêt pour le projet, particulièrement parmi les universités de moindre envergure (voir Annexes H et I). Quatre groupes d'étude furent constitués au cours de la deuxième réunion du comité consultatif tenue en novembre 1971;

## 2. WHY A UNIVERSITY COMPUTER NETWORK?

The benefits to Canada of computer networks in general have been ably presented in Report No. 13 of the Science Council of Canada[9]. The particular value of a Canadian university computer network was outlined in a position paper from the universities attached to this report as Appendix F. The question is discussed in greater detail in the report of the study group on the utilization of the network Appendix K. These benefits may be summarized as:

1) Access to data banks. It is usually not economical to maintain a large data bank in direct access storage at more than one computer. A network will provide rapid access across the country to data banks on the network. In particular CANUNET can provide the communications network for the national scientific and technological information service being developed by the National Science Library.

2) Specialization of computer centers. 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 center to offer its users access to all the specialized systems of programs available in participating Canadian universities, while itself maintaining only a few. Some examples of large proprietary program packages are listed in Appendix O.

ces groupes d'étude devaient faire rapport sur les divers aspects du projet (voir Annexe J):

1) Topologie du réseau et frais de communication;

2) Conception du réseau, exception faite des circuits de communication;

3) Utilisation du réseau;

4) Structure de l'organisation.

On trouvera aux Annexes K,L,M et N les rapports de ces groupes d'étude.

## 2. POURQUOI UN RESEAU INTER-UNIVERSITAIRE D'ORDINATEURS?

De façon générale, les avantages pour le Canada d'un réseau d'ordinateurs ont été démontrés fort habilement dans le rapport no 13 présenté par le Conseil des Sciences du Canada[9]. L'intérêt particulier d'un réseau inter-universitaire canadien d'ordinateurs a été souligné dans une prise de position rédigée par les universités et que l'on trouvera sous ce pli, à l'Annexe F. La question est analysée plus à fond dans le rapport du groupe d'étude sur l'utilisation du réseau à l'Annexe K. Les avantages peuvent être résumés comme suit:

1) Accès aux banques de données. Il n'est normalement pas rentable de maintenir un stockage important de données dans la mémoire à accès direct de plus d'un ordinateur. Un réseau d'ordinateurs permettrait un accès rapide aux banques de données affiliées au réseau d'un bout à l'autre du pays. CANUNET pourrait entre autres servir de réseau de communication pour le service national d'information scientifique et technique en développement à la Bibliothèque scientifique nationale.

3) Access to the most suitable computer for a given problem. This is of most interest to the smaller universities that cannot support a large computer.

4) Opportunity to develop the new technology of packet switching.

5) Interconnexion of regional networks.

6) Creation of a national computing community.

7) Reduction of cost of data communications due to pooling of traffic.

If it should be thought surprising that interest in networks of computers is much higher among universities than in industry, it might be useful to recall the early history of computers. The first developments were at Harvard and the University of Pennsylvania, followed by Cambridge University, Princeton, University of Manchester, Massachusetts Institute of Technology and University of London. Other computers were produced by the National Bureau of Standards in the United States and the National Physical Laboratory in Britain. Private industry was represented by UNIVAC (formed by University of Pennsylvania personnel), and Ferranti in association with the University of Manchester, and later, by IBM. In Germany, Züse was an individual pioneer. The implication is that university people recognize significant concepts and are prepared to work on them long before they have reached the stage of profitability.

2) Spécialisation des centres de traitement de l'information. Les systèmes complexes de programmation exigent des équipes de techniciens et de programmeurs hautement spécialisés pour maintenir et utiliser efficacement ces programmes. Une autre raison militant en faveur de la spécialisation est que les droits d'auteur imposés pour l'utilisation d'un programme particulier constituent habituellement un taux fixe pour l'ordinateur sur lequel les opérations sont exécutées; il n'est aucunement tenu compte du temps d'utilisation du programme pour l'établissement de ce taux fixe. CANUNET permettra au centre d'informatique de chaque université,d'offrir à ses utilisateurs l'accès aux divers systèmes de programmes spécialisés existant dans les universités canadiennes participant à CANUNET,tout en ne maintenant lui-même qu'un nombre limité de programmes. On trouvera à l'Annexe O quelques exemples de gros packages de programmes particuliers.

3) Accès aux ordinateurs les mieux appropriés pour répondre à un problème donné. Cet aspect est particulièrement important pour les universités de moindre envergure qui ne peuvent assumer le coût d'un gros ordinateur.

4) Possibilité de pousser plus à fond les nouvelles techniques de commutation par paquet.

5) Interconnexion des réseaux régionaux.

6) Création d'une communauté nationale du traitement des données.

7) Réduction des coûts de communication de données par la mise en commun du trafic.

## 3. PROPOSED DESIGN CONCEPT

The following general criteria for CANUNET were proposed in the Position Paper of June 1971 (Appendix F):

"The only constraints which should be placed upon the development of a master plan at this time are the following:

a) the plan must be for a truly national network with a minimum of one campus in each province invited to participate in some aspect of its development;

b) the plan should accomodate regional diversity and technological alternatives within a framework of objectives, standards and conventions;

c) the network should be designed to accept various types of computers and to operate over a variety of lines, and

d) the computer network must be transparent to the using computers and terminals."

To these criteria the Advisory Committee have added the following:

e) the network should be designed to be compatible with future general computer networks in so far as the outlines of the latter can be discerned, and preferably, should be designed as a prototype element of such networks:

f) design decisions should be made in terms of the ultimate network, rather than in terms of the easiest or cheapest communication between a few computers;

Si l'on trouve plus étonnant que les milieux universitaires témoignent plus d'intérêt pour les réseaux d'ordinateurs que n'en témoigne le secteur industriel, il serait peut-être opportun de se rappeler les débuts de l'histoire des ordinateurs. Les premières tentatives ont été faites à Harvard et à l'université de Pennsylvanie, puis à Cambridge, à Princeton, à l'université de Manchester, au Massachusetts Institute of Technology et à l'université de Londres. D'autres ordinateurs ont été produits par le National Bureau of Standards aux Etats-Unis et par le National Physical Laboratory en Angleterre. L'entreprise privée était représentée par UNIVAC (constitué du personnel de l'université de Pennsylvanie) et par Ferranti, de concert avec l'université de Manchester puis, plus tard, par IBM. En Allemagne, Züse faisait oeuvre de pionnier individuel. C'est donc dire que le milieu universitaire sait déceler des concepts importants et est disposé à s'y consacrer bien avant que ceux-ci aient atteint un seuil de rentabilité.

## 3. CONCEPTION PROPOSEE

Les critères généraux suivants ont été proposés pour la réalisation de CANUNET dans la prise de position soumise en juin 1971 (Annexe F):

"A ce stage-ci, les seules contraintes dont il faudra tenir compte dans l'élaboration d'un plan directeur sont les suivantes:

a) Ce plan devra servir de cadre de référence à un réseau à caractère vraiment national englobant au moins un campus universitaire pour chacune des provinces qui seront invitées à participer d'une façon ou d'une autre à la réalisation de ce projet;

g) a message should be delivered and an acknowledgement received from the destination host in under a second because of the needs of conversational computing, e.g. computer aided learning;

h) certain features of the design need not be implemented during the stage of experimental operations. For example, slow lines may be used in certain parts of the network, and the objective of reliable availability 24 hours a day may be postponed by not providing alternate lines or by using dial-up lines initially.

As mentioned above in section 1, almost all existing networks consist of an array of lines joining terminals or auxiliary computers to a large computer system at the center of a star. The central computer system either performs services for the terminals, or it forwards messages from one terminal to another. This star design has been rejected for CANUNET because:

1) The line costs of a star network are higher (it might involve routing messages from Victoria to Vancouver via Ottawa).

2) If the central computer goes down the network is paralysed.

e) If a line goes down its terminal or terminals are cut off.

4) It would be politically difficult to select a center.

b) Ce plan devra tenir compte des disparités régionales et des alternatives technologiques dans un cadre d'objectifs, de normes et de conventions;

c) Le réseau devra être conçu de façon à pouvoir accepter divers types d'ordinateurs et à fonctionner au moyen d'une variété de lignes; et

d) Le réseau devra être transparent aux ordinateurs et aux terminaux qui en feront usage."

A ces critères, le comité consultatif a ajouté les suivants:

e) Le réseau devra être conçu de façon à être compatible à d'éventuels réseaux généraux d'ordinateurs,dans la mesure où les caractéristiques principales de ceux-ci peuvent être discernées, et devra être conçu, de préférence, comme un élément prototype de tels réseaux;

f) La conception du réseau devra être pensée en fonction d'un réseau ultime plutôt qu'en fonction des méthodes de communication les moins coûteuses et les plus faciles entre les ordinateurs;

g) Le temps d'envoi d'un message et de réception d'une réponse de l'ordinateur destinataire devra être inférieur à une seconde en raison des besoins du traitement en mode conversationnel comme, par exemple, l'apprentissage par ordinateur.

h) Certains aspects du réseau pourront être complétés une fois la période expérimentale terminée. On pourra, par exemple, utiliser des circuits plus lents dans certaines parties du réseau et le but d'un service fiable de 24 heures par jour pourra être remis à plus tard en ne prévoyant pas de lignes alternatives au départ ou en utilisant des lignes commutées par cadran.

The networks of computers of comparable power, such as Cybernet and ARPANET, suit the CANUNET requirement more exactly because they have no center. If a computer or a line goes down, the rest of the network continues functioning. ARPANET served as the model for the CANUNET design because it connects computers of different makes.

ARPANET may be described as an electronic post office, with a delivery time of less than 0.2 second. It is based on a "subnet" of identical minicomputers that handle the receiving, storing, forwarding and delivery of electronic letters or "packets". The minicomputers, or IMPs (Interface Message Processors) are joined by communication lines. To provide reliability, at least two physically separated paths are provided between any pair of IMPs. The computers that the network serves are connected to the IMPs, at least one to each IMP. These large computers are called host computers. Each electronic letter or packet, consists of a maximum of 1 008 bits (binary digits), with the address of the destination at the front end of the packet, and a check sum to verify the correctness of transmission at the back end. A packet may pass through as many as five intermediate IMPs on its way from the source IMP to the destination IMP.

The great advantage of the ARPANET store-and-forward design over specialized star network designs is economy. Each ARPANET line carries messages between many source-destination pairs intermixed, just as the post office carries letters from many sources for many destinations intermixed in the same mail bags. The specialized

Comme nous l'avons mentionné à la section 1, la plupart des réseaux existants sont constitués de lignes reliant des terminaux ou des ordinateurs auxiliaires à un gros système d'ordinateurs situé au centre d'une étoile. Le système central d'ordinateurs exécute des opérations pour les terminaux ou achemine les messages entre les terminaux. La configuration en étoile fut rejetée dans le cas de CANUNET parce que:

1) le coût des communications d'un réseau en étoile est plus élevé (il faudrait parfois acheminer des messages de Victoria à Vancouver en passant par Ottawa).

2) si l'ordinateur central tombe en panne, tout le réseau est paralysé.

3) si une ligne est bloquée,son ou ses terminaux ne sont plus alimentés.

4) Il serait difficile, pour des raisons politiques, de choisir un centre.

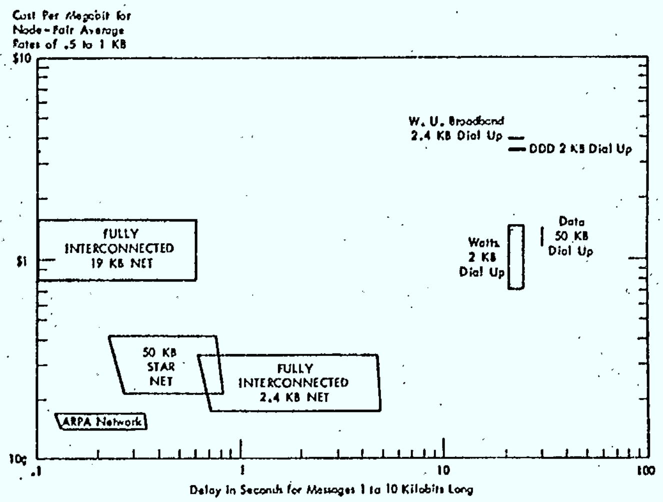
Les réseaux d'ordinateurs de puissance analogue tels que Cybernet et ARPANET, répondent mieux aux exigences de CANUNET parce qu'ils n'ont pas de centre. Si un ordinateur ou une ligne tombe en panne, le reste du réseau continue à fonctionner. ARPANET a servi de modèle pour l'élaboration de CANUNET parce qu'il regroupe des ordinateurs de différentes marques.

ARPANET peut être décrit comme un bureau de poste électronique dont le temps de livraison est inférieur à 0.2 seconde. Son ossature se compose d'un sous-réseau de mini-ordinateurs qui s'occupent de la réception, du stockage et de la livraison de lettres ou de "paquets" star networks resemble private couriers; they provide faster service, but they are more expensive. The transcontinental transmission time with ARPANET can be up to 0.2 second or longer when traffic is heavy, while it is about 0.02 second for a dedicated line. The cost of ARPANET can be shared among many users, whereas specialized star networks are usually underused and hence more expensive. The following graph copied from reference 4, shows the relationship between speed and cost, for a transcontinental network linking 20 computers using various designs.

électroniques. Les mini-ordinateurs ou IMP (Interface Message Processors) sont reliés par des lignes de communication. Pour plus de sûreté, il existe toujours au moins deux voies de communication entre chaque couple d'IMP. Les ordinateurs desservis par le réseau sont reliés aux IMP à raison d'au moins un ordinateur par IMP. Ces gros ordinateurs sont appelés ordinateurs-hôtes. Chaque lettre ou paquet électronique comprend, au maximum, 1 008 bits (chiffres binaires), l'adresse de la destination au début du paquet et une somme de contrôle à la fin pour vérifier l'exactitude des informations transmises. Il se peut qu'un paquet passe parfois par cinq IMP intermédiaires avant d'être acheminé du IMP source au IMP de destination.

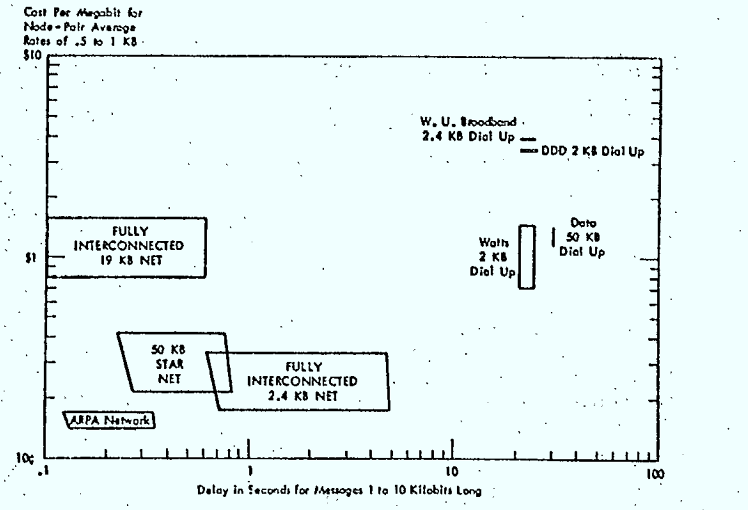
Le grand avantage du réseau ARPANET à commutation de message par rapport aux autres réseaux spécialisés à configuration en étoile est son économie. Chacune des lignes ARPANET véhicule des messages mêlés entre les nombreux couples d'ordinateurs de source et de destination de la même façon qu'un bureau de poste manipule les lettres en provenance et en direction des endroits les plus variés et dans des mêmes sacs de courrier. Les réseaux spécialisés en forme d'étoile ressemblent à des courriers particuliers; leurs services sont plus rapides mais plus chers. ARPANET peut mettre jusqu'à 0.2 seconde et même davantage lorsque la circulation est dense pour véhiculer un message d'un bout à l'autre du continent tandis que le temps de transmission au moyen d'une ligne particulière sera environ 0.02 seconde. Les frais de communication d'ARPANET peuvent être répartis entre ses nombreux usagers; par contre, la fréquence d'utilisation des réseaux spécialisés est normalement beaucoup moindre et entraîne évidemment un coût plus élevé. Le graphique ci-après, tiré de la référence no 4, illustre le rapport qui existe entre la vitesse et le coût du fonctionnement d'un réseau transcontinental comprenant 20 ordinateurs de conceptions diverses.

FIGURE 1




COST VS DELAY FOR POTENTIAL
20 NODE NETWORK DESIGNS

FIGURE 1




COUT VS DELAI POUR UN RESEAU
POTENTIEL DE 20 NOEUDS

## 4. ARPANET and CANUNET

The Study Group on Network Design (Appendix L) has proposed for CANUNET a design that differs from ARPANET in the following particulars:

1) The division of functions between the software of the host computers and the node computers (or IMPs) is more clearly defined. This simplifies the node computers and their software without significantly increasing the work of the host computers.

2) The interface between the host and the node is microprogrammed to provide maximal efficiency of transfer, using the appropriate byte width and addressing technique for the host side of the interface, while leaving the node computer side of the interface identical in every case.

3) Terminals may be attached to a node computer through a separate minicomputer called a pseudo-host. ARPANET combines these functions in a single minicomputer(TIP = Terminal Interface Processor), which must be larger and faster and have more complex software than the CANUNET minicomputers.

4) The development of CANUNET is running about four years behind that of ARPANET, hence CANUNET can profit from the advances in minicomputers and interfaces in those four years.

## 5. THE NETWORK OF ONTARIO UNIVERSITIES and CANUNET

The computer communications network proposed for Ontario Universities by the Office of Computer Coordination [5,6] differs from the CANUNET proposal in three points:

## 4. ARPANET ET CANUNET

Le groupe d'étude sur la conception du réseau (Annexe L) a proposé, pour CANUNET, une conception qui diffère d'ARPANET sous certains aspects particuliers, à savoir:

1) La répartition des tâches entre le software des ordinateurs-hôtes et des ordinateurs nodaux (ou IMP) est plus nette. Ceci simplifie le software et le travail des ordinateurs nodaux sans augmenter considérablement le travail des ordinateurs-hôtes.

2) L'interface entre l'hôte et le noeud se fait par micro-programme assurant ainsi un déplacement optimal des données; pour ce faire, on utilise une largeur de multiplet et un type d'adressage appropriés à l'hôte d'un côté de l'interface tandis que le côté de l'interface présenté à l'ordinateur nodal demeure identique en tous les cas.

3) Des terminaux peuvent être liés à un ordinateur nodal par le truchement d'un mini-ordinateur qu'on appelle un pseudo-hôte. ARPANET combine ces deux fonctions dans un mini-ordinateur unique (TIP = Terminal Interface Processor), lequel est forcément plus gros et plus rapide, avec un software plus complexe, que les mini-ordinateurs de CANUNET.

4) Il existe un écart d'environ quatre ans entre la création d'ARPANET et celle de CANUNET; CANUNET pourrait donc tirer profit des progrès réalisés dans le domaine des mini-ordinateurs et des interfaces au cours de ces quatre années.

## 5. LE RESEAU DES UNIVERSITES ONTARIENNES ET CANUNET

Le réseau de communication pour ordinateurs proposé pour les universités ontariennes par l'Office of Computer Coordination [5,6] diffère de la proposition de CANUNET sous trois aspects:

1) The Ontario network is designed with a view to its usability at its first implementation level, which is to enable a distributed population of user terminals (both batch and interactive) to access host computers of the network (see Appendix P.) The full development of networking functions including interprocess communication, data base transfer and conversion, and a unified language for network utilization will take place over a period of seven to nine years. CANUNET will start as a computer to computer network.

2) The Ontario network will allow terminals to be directly connected to the node computers, while CANUNET will leave them attached to host computers, or to minicomputers that appear to the nodes as hosts. The Ontario design will require more node software and larger and faster node computers.

3) The Ontario node computer is expected, in the initial implementation, to appear to its host as the standard communications controller supplied for that host by its maker. This approach has the advantage that a host can be attached to the network with minimal changes to the host software. The CANUNET approach is to seek the optimal division of functions and the optimal interface between the host and the node computer, in accordance with criterion f of section 3.

## 6. PROBLEMS OF USING A NETWORK

Network applications may be divided into

1) terminal-to-computer operations;

2) computer-to-computer operations.

1) Le réseau ontarien est conçu en vue de son utilité lors de sa réalisation au premier niveau qui est d'offrir à une population dispersée de terminaux (soit lourds, soit interactifs) l'accès aux ordinateurs-hôtes du réseau (voir Annexe P). Le développement complet des fonctions du réseau, y compris la communication entre processus, le transfert et la conversion de banques de données et un langage unifié pour l'utilisation du réseau sera étendu sur une période de sept à neuf ans. CANUNET débutera comme réseau ordinateur-à-ordinateur.

2) Le réseau ontarien permettra la liaison directe des terminaux aux ordinateurs nodaux tandis que CANUNET entend les laisser branchés aux ordinateurs-hôtes ou aux mini-ordinateurs qui, par rapport aux ordinateurs nodaux, constituent des ordinateurs-hôtes. La conception du réseau ontarien demande plus de software nodal et des ordinateurs nodaux plus grands et plus rapides.

3) On s'attend à ce que, dans la réalisation initiale, l'ordinateur nodal du réseau ontarien soit perçu par son hôte comme le contrôleur standard des communications fourni pour l'hôte en question par le fabricant. Cette méthode présente l'avantage suivant: un ordinateur-hôte peut être incorporé au réseau moyennant peu de modifications du software de l'hôte. Le principe de CANUNET est d'en arriver à une répartition et à une interface optimales des fonctions ainsi qu'à une interface optimale entre l'ordinateur-hôte et l'ordinateur nodal conformément au critère f de la section 3.

## 6. PROBLEMES D'UTILISATION D'UN RESEAU

Les applications d'un réseau peuvent se résumer en:

1) communications entre un terminal et un ordinateur et en

2) communications entre ordinateurs.

Terminal-to-computer operations are similar to those currently available with multiterminal computer systems that have low and high speed terminals for input and output. A network renders more computers accessible to the terminal user, at reduced transmission costs and more reliably if the network has redundant lines. The major problem to be resolved here is that of providing the user with adequate information about the services available. Here the network itself may be used, as it is with ARPANET. The study group on the utilization of the network has summarized the problem as follows: "A computer network must supply services which are tailored to the user who has minimal expert knowledge in order that sufficient traffic will be generated to justify the construction of a network" (see Appendix K). It should be noted that the network should provide terminal-to-computer operations for terminals connected to a host, which may already be the center of a network. Further, terminals may frequently want large print-outs on the local host of jobs run on a remote host, or the transfer of files from a remote host to the local host for further treatment. Thus, terminal-to-computer operations lead directly to demands for computer-to-computer operations.

Computer-to-computer operations may produce an order of magnitude increase of computing power since they will allow several computers to participate in a computation. The first problem to be solved here is the transfer of files from one computer to another; this problem is not trivial. Computer-to-computer operations will make specialization of computer hardware attractive. One computer may have very fast arithmetic; another, such as ILLIAC IV or STAR, may be particularly suited to array computations; another may have an enormously large cheap memory. Some computers may be dedicated to fast FORTRAN compilations, others to the interpretation of APL. The problems to be solved, compounded by the incompatibilities of different makes of computers, are as great as those of operating systems for single computers which were so preoccupying during the 60s.

Les communications entre un terminal et un ordinateur sont semblables à celles qui se font habituellement dans les systèmes d'ordinateurs à terminaux multiples et pourvus de terminaux lents et rapides pour les entrées et les sorties. Un réseau permet à l'utilisateur d'un terminal d'accéder à un plus grand nombre d'ordinateurs moyennant un coût moindre de transmission et de façon beaucoup plus sûre si le réseau comprend des lignes redondantes. Le principal problème auquel on doit faire face dans un tel cas est de fournir suffisamment d'informations à l'utilisateur sur les services qui lui sont offerts. Le réseau lui-même peut être utilisé à cette fin, comme c'est le cas pour ARPANET. Les membres du groupe d'étude sur l'utilisation du réseau ont résumé le problème comme suit: "Un réseau d'ordinateurs doit pouvoir dispenser des services qui répondent aux besoins de l'utilisateur affichant le moins de connaissances spécialisées de façon à ce que les échanges d'informations soient suffisamment nombreux pour justifier la mise sur pied d'un réseau" (voir Annexe K). Il serait peut-être opportun de signaler que le réseau doit mesurer les communications entre terminaux et ordinateurs dans le cas des terminaux reliés à un ordinateur-hôte se trouvant déjà au centre d'un réseau. De plus, il arrivera souvent que des terminaux demanderont à l'ordinateur-hôte local des imprimés de travaux exécutés par un autre ordinateur-hôte éloigné ou le transfert de fichiers d'un ordinateur-hôte éloigné à l'ordinateur-hôte local en vue d'un traitement plus poussé des données. Les communications d'un terminal à un ordinateur nous obligent donc à considérer également les communications entre deux ordinateurs.

Les communications entre ordinateurs peuvent augmenter d'un ordre de grandeur la puissance de calcul étant donné qu'elles permettent à plusieurs ordinateurs de participer à une même opération. Le premier problème auquel on doit faire face dans le cas présent est le transfert de fichiers d'un ordinateur à l'autre; ce problème n'est pas sans importance. Les communications entre ordinateurs rendent intéressante la spécialisation du matériel des ordinateurs. Un ordinateur pourra

## 7. NETWORK TOPOLOGY

It is not possible to propose a definite configuration of communications lines for CANUNET without knowing which universities will participate in the initial network, and the load of messages that will pass between them. The study group on communications therefore simulated the performance of various terrestrial and hybrid (terrestrial-satellite) networks for 10, 14 and 18 node topologies (see Appendix M); three speeds of lines were assumed for these networks, viz. 4.8 kbit/s, 9.6 kbit/s and 50 kbit/s. Estimates of the cost of lines and modems at the standard rates of the Trans-Canada Telephone System range from $14 217 per month for a 10-node network at 4.8 kbit/s to $242 850 per month for an 18-node network with alternate paths at 50 kbit/s. These figures exclude the cost of the lines from the local exchanges to the universities, which could cost up to $300 per month per node. Thus the maximum cost of lines for an 18-node fully redundant 50 kbit/s network is $250 000 per month, or $13 900 per node per month. This figure could probably come down appreciably when the new digital lines of Trans-Canada Telephone System come into operation. Cheaper lines may also be obtainable through the Government Telephone Agency.

A cost of $3 000 000 per year has been established by Telesat Canada as the minimum rental for an FR channel and a complement of earth station equipment. The total yearly cost for the hybrid network would include the cost for the terrestrial networks. As shown in Appendix M the yearly rental cost of ANIK would go down if shared with other customers. For example, if three organizations shared seven stations per network then, the yearly rental cost of ANIK would be $1.29 million. This therefore suggests that the use of satellites will only become attractive when more than one organization or network share in the effectuer des opérations arithmétiques de façon très rapide; un autre comme l'ILLIAC IV ou le STAR pourra convenir particulièrement aux calculs vectoriels; un autre encore pourra disposer d'une très grande mémoire de coût minime. Quelques ordinateurs pourront être consacrés aux compilations rapides du langage FORTRAN et à l'interprétation d'APL. Les problèmes à résoudre, compliqués par l'incompatibilité des différentes marques d'ordinateurs, sont aussi importants que ceux des systèmes d'exploitation à ordinateur unique pour lesquels on se faisait tant de soucis au cours des années soixante.

## 7. TOPOLOGIE DU RESEAU

Il n'est pas possible de proposer une configuration précise des lignes de communication pour CANUNET sans savoir quelles universités participeront au réseau initial et la quantité de messages qui seront véhiculés entre elles. Le groupe d'étude sur les communications a donc simulé le rendement de plusieurs réseaux terrestres et hybrides (terrestre-satellite) pour des topologies de 10, 14 et 18 noeuds (voir Annexe M); on a présumé trois vitesses de lignes pour ces réseaux, à savoir, 4.8 kbit/s, 9.6 kbit/s et 50 kbit/s; Le coût estimatif de ces lignes et de leurs modems au taux normal établi par le Réseau Téléphonique Transcanadien varie de $14 217 par mois pour un réseau à 10 noeuds dont le débit est 4.8 kbit/s à $242 850 par mois pour un réseau à 18 noeuds dont le débit est de 50 kbit/s et pourvu de routes alternatives. Ces chiffres ne comprennent pas les frais de communication entre le centre de communication locale et les universités, frais qui peuvent s'élever à $300 par mois, par noeud. Ainsi, le coût maximum d'un réseau de communication à 18 noeuds, complètement pourvu de lignes redondantes et dont rental of an ANIK channel. It should be noted, however, that the system outlined possesses considerable flexibility and operational advantages especially in configurations involving more than two earth stations.

The simulations showed that the performance of the network depends more on line speeds than on network configuration. The following table shows the range of total network capacity, and the range of costs per megabit transmitted for the terrestrial networks. The complete table is given in Appendix M.

le débit est de 50 kbit/s, serait de $250 000 par mois ou $13 900 par mois, par noeud. Ce montant diminuera probablement de façon appréciable lorsque le Réseau Téléphonique Transcanadien inaugurera ses nouveaux réseaux de données. Enfin, il serait possible d'obtenir des lignes à coût moindre grâce à l'Agence des Télécommunications gouvernementales.

Telesat Canada a établi un loyer minimum de $3 000 000 par an pour un canal FR et un jeu d'équipement pour les stations terrestres. Le coût total annuel du réseau hybride inclut le coût des réseaux terrestres. Comme on le voit à l'Annexe M, le loyer annuel d'ANIK baisserait s'il était partagé avec d'autres clients. Par exemple, si trois organismes partageaient sept stations par réseau, le loyer annuel d'ANIK serait alors de $1.29 million. Ceci suggère donc que l'utilisation des satellites deviendra attrayante seulement lorsque plus d'un organisme ou réseau partageront le loyer d'un canal ANIK. Cependant, on doit noter que le système ébauché possède une flexibilité appréciable et des avantages opérationnels, surtout dans le cas des configurations impliquant plus de deux stations terrestres.

Les simulations nous ont permis de constater que le rendement du réseau dépendait plus de la rapidité des circuits que de la configuration du réseau. On trouvera dans le tableau ci-dessous la gamme de la capacité totale du réseau et la gamme des coûts de transmission par mégabit pour plusieurs réseaux terrestres. On trouvera le tableau complet à l'Annexe M.

| Line Speed (kbit/s) | 100% Network capacity * (kbit/s) | Cost ** (¢/Mbit) |
|---|---|---|
| 4.8 | 1 to 45 | .23 to 8.78 |
| 9.6 | 47 to 108 | .12 to .26 |
| 50 | 302 to 591 | .11 to .20 |

* 100% capacity represents the total input data rate for which total average delay does not exceed 0.5 sec.

** Cost per megabit transmitted for a network operating at an average delay of 0.5 second, 24 hours a day, 7 days a week, but excluding local lines and node computers.

## 8. OPERATING COSTS

The operating costs of a network depend on its capacity and acceptable message delays but not on the traffic that it actually carries. For the terrestrial networks studied, the cost per month per node for lines (excluding local lines) varies from $1 260 to $2 810 for a 4.8 kbit/s network, from $1 820 to $3 710 for a 9.6 kbit/s network, and from $6 510 to $20 000 for a 50 kbit/s network. In the development plan of Section 11 we have assumed that line costs for an operational CANUNET will lie between $5 000 and $10 000 per node-month, depending on the speed of the lines and the rates that are negotiated. To this we have added $1 000 for the operation and maintenance of the node computer and $4 000 for staff concerned with network matters, giving a total cost of $10 000 to $15 000 per node-month.

| Vitesse de la ligne (kbit/s) | 100% de la capacité du réseau* (kbit/s) | Coût ** (¢/mégabit) |
|---|---|---|
| 4.8 | 1 à 45 | 0.23 à 8.78 |
| 9.6 | 47 à 108 | 0.12 à 0.26 |
| 50 | 302 à 591 | 0.11 à 0.20 |

* 100% de la capacité représente le taux total d'entrée de données pour lequel le délai total moyen n'excède pas 0.5 sec.

** Coût de transmission par mégabit pour un réseau fonctionnant à un délai moyen de 0.5 seconde, 24 heures par jour, 7 jours par semaine, mais ne comprenant pas le coût des circuits locaux et des ordinateurs nodaux.

## 8. FRAIS D'EXPLOITATION

Les frais d'exploitation d'un réseau sont fonction de sa capacité et de son temps de transmission supportable et non du trafic qu'il véhicule. Dans le cas des réseaux terrestres faisant l'objet de cette étude, le coût mensuel des lignes par noeud (exception faite des lignes locales) varie de $1 260 à $2 810 pour un réseau dont le débit est de 4.8 kbit/s, de $1 820 à $3 710 pour un réseau dont le débit est de 9.6 kbit/s et de $6 510 à $20 000 pour un réseau dont le débit est de 50 kbit/s. Nous prévoyons, dans le plan d'élaboration de la Section 11, que le coût des lignes pour un CANUNET fonctionnel se chiffrera entre $5 000 et $10 000 par mois et par noeud, selon la vitesse des lignes et le tarif que l'on négocie. Nous avons ajouté à ces montants $1 000 pour l'exploitation et l'entretien de l'ordinateur nodal et $4 000 pour le personnel concerné par les questions du réseau, d'où un montant total allant de $10 000 à $15 000 par mois, par noeud.

## 9. CHARGES FOR SERVICES

For the same reasons that the post office charges a flat rate for the delivery of a letter to anywhere in the country, it is proposed that the network should charge each host a fixed amount for each packet it transmits to the network, regardless of the destination. ARPANET will break even if it charges each host $1 700 per month plus 30¢ per million bits transmitted, when the load reaches 36% of capacity. (Appendix A). (The load in December 1971 was 9% of capacity). CANUNET might reasonably operate on the basis of a fixed charge per month, of the order of $2 000; plus a fixed charge per packet transmitted, of the order of 0.1¢.

The question of charges for services rendered by hosts computers over the network is a separate one which raises many complex issues of relations between the parties concerned. The matter is dealt with in detail in Appendix N, starting at page 15, and on page 31 of Appendix K.

9. DROITS D'UTILISATION

Pour les mêmes raisons que le service des postes impose un taux fixe pour la livraison d'une lettre n'import'où au pays, on propose que le réseau impose à chaque ordinateur-hôte un taux fixe pour chaque paquet qu'il transmettra par le truchement du réseau, peu importe la destination. ARPANET couvrira ses frais s'il impose aux ordinateurs-hôtes des droits de $1 700 par mois et $0.30 par million de bits transmis alors que la charge atteindra 36% de la capacité (Annexe A). (En décembre 1971, la charge atteignait 9%). CANUNET pourrait donc raisonnablement imposer à ses membres des droits fixes par mois de l'ordre de $2 000, plus un droit fixe par paquet transmis, de l'ordre de 0.1¢. Les droits pour services rendus par les ordinateurs-hôtes à d'autres abonnés du réseau constituent une autre question qui soulève bien des problèmes complexes concernant les relations entre les parties intéressées. On considère le sujet en détails à l'Annexe N commençant à la page 15, et à la page 31 de l'Annexe K.

10. STRUCTURE DE L'ORGANISATION

Le groupe d'étude sur la structure de l'organisation de CANUNET est d'avis que les premières difficultés à surmonter pour la réalisation des objectifs de CANUNET sont d'ordre économique et structurel (Annexe N). Même si le réseau peut sembler intéressant sur un plan national, il ne sera pas utilisé si, au niveau régional, l'utilisateur individuel n'est pas séduit par ses attraits économiques. Pour franchir cette barrière économique, il sera nécessaire d'obtenir du gouvernement fédéral une partie substantielle des frais d'exploitation pour une période de 3 à 5 ans.

## 10. INSTITUTIONAL FRAMEWORK

The study group on the institutional framework for CANUNET considers that the primary obstacles to be overcome in achieving the objectives of CANUNET are organizational in nature and have to do with economics (Appendix N). Even though the network may be attractive on a national basis, unless it appears economically attractive to the individual user, the network will not be used. To overcome this economic barrier it will be necessary to obtain from Federal sources a substantial part of the operating costs for a period of 3 to 5 years.

On the assumption that CANUNET should proceed as quickly as possible into a prototype development phase, a short-term organization is proposed. A project team should be established under the Department of Communications, with work groups to develop the necessary hardware and software and to establish communications protocol. The personnel for these work groups are to be provided by direct secondment of university personnel or by contract with universities to undertake defined projects.

In addition, it is proposed to encourage the Association of Universities and Colleges of Canada to become directly involved in CANUNET by providing AUCC with sufficient funds to undertake a study of the Rationalization of Computing Resources for Canadian Universities. This activity should go on regardless of the fate of CANUNET.

As CANUNET develops beyond the prototype stage, a project organization affiliated with AUCC should be established that would be ultimately responsible for the operation, education, application development and continued improvement of the CANUNET system. This organization should include an Advisory Council, a Management Board, and a full-time Secretariat. Task forces for such special applications as Social Sciences, Legal Systems, CAI, Physical Sciences and Library Systems should be set up.

En supposant que CANUNET puisse s'attaquer le plus rapidement possible à la mise sur pied d'un prototype, une organisation à court terme est proposée. Une équipe chargée du projet devra être mise sur pied par le ministère des communications qui devra également constituer des groupes de travail pour élaborer le matériel et le software nécessaires et établir un protocole des communications. Le personnel de ces groupes devrait être détaché des universités et les universités devraient entreprendre certains projets particuliers sous contrats.

Il est également proposé que l'on invite l'Association des universités et collèges du Canada à participer activement à CANUNET en fournissant à cette association des fonds qui lui permettront de mener une étude sur la rationalisation des ressources informatiques disponibles dans les universités canadiennes. Ce projet devrait être mené à bien peu importe le sort de CANUNET.

Lorsque CANUNET aura dépassé le stage de prototype, une organisation chargée du projet et affiliée à AUCC devra être mise sur pied pour assumer l'entière responsabilité du fonctionnement, de l'enseignement, de l'élaboration des applications éventuelles et du perfectionnement du système CANUNET. Cet organisme devrait comprendre un conseil consultatif, un conseil d'administration et un secrétariat à plein temps. Des groupes de travail devront être constitués pour s'occuper de divers programmes spécialisés: sciences sociales, systèmes juridiques, apprentissage par ordinateur, sciences physiques et systèmes de bibliothéconomie.

## 11. PLAN DE REALISATION

Le diagramme d'acheminement critique de la figure 2 indique la corrélation des activités nécessaires à la réalisation de CANUNET. Les nombres se rapportent à des événements ou à des points temporels. Chaque activité se présente comme une flèche et sa description dans les paragraphes suivants s'indique par le numéro de l'événement qui

## 11. DEVELOPMENT PLAN

The critical path diagram of Figure 2 shows the relationship of the activities required to develop CANUNET. The numbers refer to events or points in time. Each activity is shown as an arrow and its description in the following paragraphs is denoted by the number of the event that must preceded it and the number of the event that marks its completion. Following the description of each activity is given the estimated minimum and maximum elapsed time for completion, the minimum and maximum man-months involved, and the minimum and maximum cost based on the assumption of using university full time personnel for the development of hardware and software calculated at $2 000 per man-month. If commercial personnel are used the rate should be $4 000 per man-month. The schedule resulting from the optimistic estimates of elapsed times is shown by the Gantt chart of Figure 3, while the pessimistic estimates were used to construct the Gantt chart of Figure 4. No dates are indicated because the starting date is unknown. However, preliminary work on activities 0-1, 1-2 and 4-10 is under way.

Activity 0-1 Constitution: Obtain commitments from universities to join CANUNET. Convene an advisory council, adopt a constitution and appoint a management board.

12-18 months, 6-12 man-months, 15 - 30 k$.

Activity 1-2 Specifications: Establish specifications for the node computer, the interface between the node and the communication lines, and interfaces between the node and host computers (IBM System/360, IBM System/370, Control Data 6000 series, Sigma 7, DEC System 10, Burroughs 6700 are possible hosts). Call for tenders.

4-6 months, 12-18 man-months, 24 - 36 k$.

Activity 1-3 Host-host protocol: Define a first version of a protocol for communication between the various hosts.

6-12 months, 18-36 man-months, 36 - 72 k$.

doit la précéder et le numéro de l'événement qui signale son achèvement. Suivant la description de chaque activité, on donne la durée globale estimative, minimale et maximale, pour achèvement, les mois-hommes impliqués et le coût minimum et maximum basé sur l'hypothèse de l'utilisation du personnel universitaire à plein temps, lequel se chiffre à $2 000 par mois pour la réalisation du hardware et du software. Si l'on utilise un personnel commercial, le taux serait de $4 000 par mois. Le calendrier qui découle des estimations optimistes est démontré par le diagramme Gantt de la Figure 3 tandis que les estimations pessimistes ont été utilisées pour la construction du diagramme Gantt de la Figure 4. Aucune date n'est indiquée étant donné que la date de début est inconnue. Cependant, on travaille déjà sur les activités 0-1, 1-2 et 4-10.

Activité 0-1 Constitution: Obtenir des engagements d'adhésion à CANUNET de la part des universités. Convoquer un conseil consultatif. Adopter une constitution. Nommer un conseil d'administration.

12-18 mois, 6-12 mois-hommes, 15-30 k$

Activité 1-2 Spécifications: Etablir les spécifications de l'ordinateur nodal, de l'interface entre le noeud et les lignes de télécommunication et des interfaces entre le noeud et les ordinateurs-hôtes (le IBM Système/360, IBM Système/370, le Control Data série 6000, le Sigma 7, le DEC Système 10, le Burroughs 6700 sont autant d'hôtes possibles). Faire un appel d'offres.

4-6 mois, 12-18 mois-hommes, 24-36 k$

Activité 1-3 Protocole hôte-à-hôte: Elaborer un protocole provisoire des communications entre ordinateurs-hôtes.

6-12 mois, 18-36 mois-hommes 36-72 k$

Activité 1-4 Nommer un secrétariat: 1 directeur, 1 programmeur d'applications, 1 programmothécaire, 3 coordonnateurs techniques, 2 secrétaires.

s'élevant à 8 hommes, 15 k$/mois, en permanence

Activity 1-4 Appoint secretariat: 1 director, 1 applications programmer, 1 librarian, 3 technical coordinators, 2 secretaries.

Rising to 8 men, 15-20 k$/month, continuing.

Activity 1-10 Topology: Design initial network topology on the basis of known membership of CANUNET, estimated traffic, and rates negotiated with telecommunications carriers.

6 months, 6-12 man-months, 12 - 24 k$.

Activity 2-5 Await submissions: Allow manufacturers time to respond to call for tenders.

4 months

Activity 4-10 Documentation, coordination: Collect specifications, prices and instructions for use of data bases, systems of programs, and computers available through CANUNET. Establish a system of documentation for these resources. Distribute this documentation to member universities and update it periodically. Coordinate technical development of network. Develop standards. Organize accounting. A continuing secretariat function.

8 men 15-20 k$/month

Activity 5-6 Select node computer: Evaluate tenders and select suppliers of node computer and interfaces.

3-5 months, 9-15 man-months, 18 - 30 k$.

Activity 6-8 Node software: Program the node computer. Microprogram interfaces for IBM System/360 and Control Data 6000.

12-18 months, 96-144 man-months + computer time, 204 - 324 k$.

Activité 1-10 Topologie: Etablir la topologie initiale du réseau en fonction des participants connus de CANUNET, du trafic prévu et des tarifs conclus avec les services de télécommunication.

6 mois, 6-12 mois-hommes, 12-24 k$

Activité 2-5 Attendre des soumissions: Allouer aux manufacturiers le temps de répondre.

4 mois

Activité 4-10 Documentation, coordination: Recueillir des spécifications, des tarifs et des directives concernant l'utilisation des banques de données, des systèmes de programmes et des ordinateurs accessibles par le truchement de CANUNET. Elaborer un système de documentation concernant ces ressources. Distribuer cette documentation aux universités participantes et la mettre à jour de façon périodique. Coordonner le développement technique du réseau. Développer des normes. Organiser la comptabilité. Un service permanent de secrétariat.

8 hommes 15-20 k$/mois

Activité 5-6 Choix d'un ordinateur nodal: Faire l'évaluation des soumissions et choisir les fournisseurs de l'ordinateur nodal et des interfaces.

3-5 mois, 9-15 mois-hommes 18-30 k$

Activité 6-8 Software nodal: Programmer l'ordinateur nodal. Microprogrammer les interfaces pour l'IBM Système/360 et le Control Data 6000.

12-18 mois, 96-144 mois-hommes+temps d'ordinateur 204-324 k$

Activité 6-9 Obtention de 6 ordinateurs nodaux et des interfaces: Au cours de la période expérimentale, deux petits réseaux de trois noeuds chacun pourront être envisagés, un réseau étant créé dans l'est et l'autre dans l'ouest.

6-12 mois de délai 180-450 k$

Activity 6-9 Procure 6 node computers and interfaces: During the experimental period, two small networks, with three nodes in each, are envisaged, with one network in the east and one in the west.

6-12 months lead time 180 - 450 k$.

Activity 7-9 Host software: Modify host operating systems to interface with node computers (OS/360 and MTS for System/360, SCOPE and KRONOS for Control Data 6000). Write network control programs for System/360 and Control Data 6000 to implement first version of host-host protocol.

12-18 months, 144-216 man-months+computing time, 336 - 576 k$.

Activity 8-11 Additional interfaces: Microprogram interfaces for DEC-10, Sigma 7 and Burroughs 6700.

9-12 months, 18-24 man-months+ computing time, 36 - 48 k$.

Activity 9-10 Pilot operation: Operate an eastern and a western network with three computers in each, including both makes of host, over short lines.

6-8 months, 108-144 man-months, 432 - 816 k$.

Activity 9-11 Additional hosts: Repeat Activity 7-9 for DEC-10, Sigma 7 and Burroughs 6700 computers.

12-18 months, 108-162 man-months+computer time, 252 - 432 k$.

Activity 10-11 Implementation: Implement network of 18 nodes by installing an additional 12 node computers one at a time. Conduct educational campaign on use of network.

Installation of each node: 1-2 months, 2-4 man-months 34 - 83 k$.
Operation, each node-month: 2 men, 10 - 15 k$.

Activity 11-12 Operation:

Each node: 2 men 10 - 15 k$.
Secretariat: 8 men 15 k$.

Activité 7-9 Software-hôtes: Modifier les systèmes d'exploitation des ordinateurs-hôtes pour assurer la liaison avec les ordinateurs nodaux (OS/360 et MTS dans le cas du Système/360, SCOPE et KRONOS dans le cas du Control Data 6000). Elaborer le programme de surveillance du réseau pour le Système/360 et le Control Data 6000 en vue de l'application du protocole préliminaire hôte-à-hôte.

12-18 mois, 144-216 mois-hommes+temps d'ordinateur 336-576k$

Activité 8-11 Interfaces additionnels: Micro-programmer des interfaces pour le DEC-10, le Sigma 7 et le Burroughs 6700.

9-12 mois, 18-24 mois-hommes+temps d'ordinateur, 36-48 k$

Activité 9-10 Fonctionnement pilote: Faire fonctionner deux réseaux, un dans l'est et l'autre dans l'ouest, comprenant trois ordinateurs chacun, parmi lesquels on comptera des ordinateurs des deux marques.

6-8 mois, 108-144 mois-hommes 432-816 k$

Activité 9-11 Hôtes additionnels: Refaire l'activité 7-9 pour le DEC-10, le Sigma 7 et le Burroughs 6700.

12-18 mois, 108-162 mois-hommes+temps d'ordinateur, 252-432 k$

Activité 10-11 Réalisation: Constituer un réseau de 18 noeuds en installant 12 ordinateurs nodaux, un à la fois. Entreprendre une campagne d'information sur son utilisation.

Implantation de chaque noeud: 1-2 mois, 2-4 mois-hommes 34-83 k$.
Fonctionnement par noeud et par mois: 2 hommes, 10-15 k$.

Activité 11-12 Fonctionnement:

| | | |
|---|---|---|
| Chaque noeud: | 2 hommes, | 10-15 k$/mois |
| Secrétariat: | 8 hommes, | 15 k$/mois |

FIGURE 2 CRITICAL PATH DIAGRAM

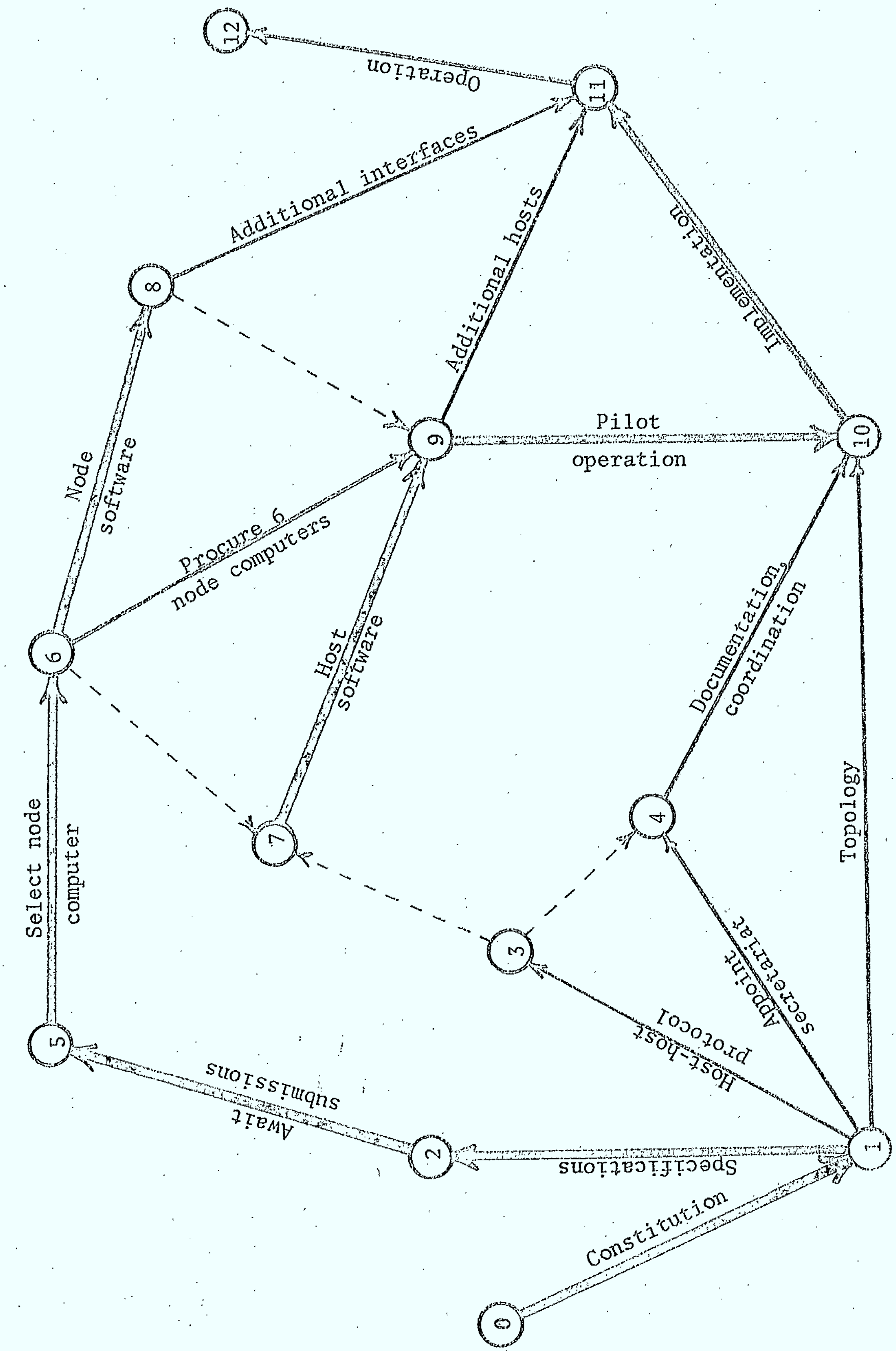
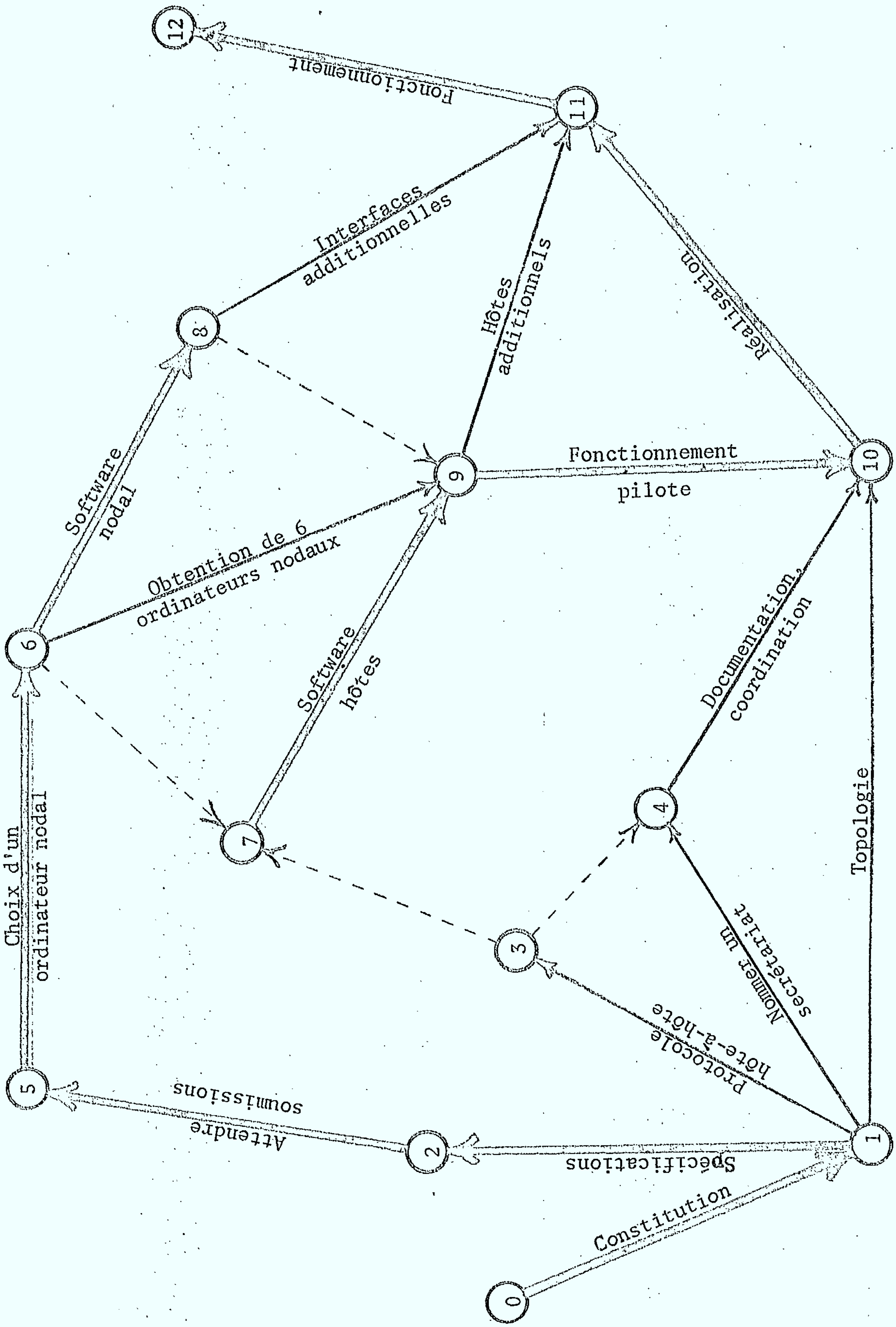


FIGURE 2 DIAGRAMME D'ACHEMINEMENT CRITIQUE



```
ACTIVITY                            TIME (months)

                                    0           12          24          36          48          60
0-1    Constitution                 :xxxxxxxxxxxx           :           :           :           :
1-2    Specifications               :           :xxxx       :           :           :           :
1-3    Host-host protocol           :           :xxxxxx     :           :           :           :
1-4    Appoint secretariat          :           :xxxxxxxxxxxxxxx        :           :           :
1-10   Topology                     :           :           :           xxxxxx      :           :
2-5    Await submissions            :           :    xxxx   :           :           :           :
4-10   Documentation, coordination  :           :           :   xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
5-6    Select node computer         :           :        xxx:           :           :           :
6-8    Node software                :           :           xxxxxxxxxxxx:           :           :
6-9    Procure 6 node computers     :           :           :     xxxxxx:           :           :
7-9    Host software                :           :           xxxxxxxxxxxx:           :           :
8-11   Additional interfaces        :           :           :           xxxxxxxxx   :           :
9-10   Pilot operation              :           :           :           xxxxxx      :           :
9-11   Additional hosts             :           :           :           xxxxxxxxxxxx:           :
10-11  Implementation               :           :           :           :     xxxxxxxxxxxx      :
11-12  Operation                    :           :           :           :           :     xxxxxxxx
```

FIGURE 3

GANTT CHART

OPTIMISTIC ESTIMATE

| ACTIVITE | | CALENDRIER (mois) 0 | 12 | 24 | 36 | 48 | 60 |
|---|---|---|---|---|---|---|---|
| 0-1 | Constitution | xxxxxxxxxxxx | | | | | |
| 1-2 | Spécifications | | xxxx | | | | |
| 1-3 | Protocole hôte-à-hôte | | xxxxxx | | | | |
| 1-4 | Nommer un secrétariat | | xxxxxxxxxxxx | xxx | | | |
| 1-10 | Topologie | | | | xxxxxx | | |
| 2-5 | Attendre des soumissions | | xxxx | | | | |
| 4-10 | Documentation, coordination | | | xxxxxxxx | xxxxxxxxxxxx | xxxxxxxxxxxx | xx |
| 5-6 | Choix d'un ordinateur nodal | | xxx | | | | |
| 6-8 | Software nodal | | | xxxxxxxxxxxx | | | |
| 6-9 | Obtention de 6 ordinateurs nodaux | | | xxxxxx | | | |
| 7-9 | Software hôtes | | | xxxxxxxxxxxx | | | |
| 8-11 | Interfaces additionnelles | | | | xxxxxxxxx | | |
| 9-10 | Fonctionnement pilote | | | | xxxxxx | | |
| 9-11 | Hôtes additionnels | | | | xxxxxxxxxxxx | | |
| 10-11 | Réalisation | | | | xxxxxx | xxxxxx | |
| 11-12 | Fonctionnement | | | | | xxxxxx | xx |

FIGURE 3

DIAGRAMME GANTT
HYPOTHESES OPTIMISTES

```
       ACTIVITY                                      TIME (months)

                                0           12          24          36          48          60          72          84
0-1    Constitution             :xxxxxxxxxxxxxxxxxx
1-2    Specifications                             xxxxxx
1-3    Host-host protocol                         xxxxxxxxxxxx
1-4    Appoint secretariat                        xxxxxxxxxxxxxxx
1-10   Topology                                                                       xxxxxx:
2-5    Await submissions                                        :xxxx
4-10   Documentation,coordination                                       xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
5-6    Select node computer                                         xxxxx
6-8    Node software                                                    xxxxxxxxxxxxxxxxxx
6-9    Procure 6 node computers                                         xxxxxxxxxxxxxxxxxx
7-9    Host software                                                    xxxxxxxxxxxxxxxxxx
8-11   Additional interfaces                                                              xxxxxxxxxxxx
9-10   Pilot operation                                                                    xxxxxxxx:
9-11   Additional hosts                                                                   xxxxxxxxxxxxxxxxxx
10-11  Implementation                                                                             xxxxxxxxxxxxxxxxxxxxxxxx:
11-12  Operation                                                                                                          xx
```

FIGURE 4

GANTT CHART
PESSIMISTIC ESTIMATE

| ACTIVITE | | CALENDRIER (mois) 0 – 12 – 24 – 36 – 48 – 60 – 72 – 84 |
|---|---|---|
| 0-1 | Constitution | xxxxxxxxxxxxxxxxxx |
| 1-2 | Spécifications | xxxxxx |
| 1-3 | Protocole hôte-à-hôte | xxxxxxxxxxxx |
| 1-4 | Nommer un secrétariat | xxxxxxxxxxxxxxx |
| 1-10 | Topologie | xxxxxx |
| 2-5 | Attendre des soumissions | xxxx |
| 4-10 | Documentation, coordination | xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx |
| 5-6 | Choix d'un ordinateur nodal | xxxxx |
| 6-8 | Software nodal | xxxxxxxxxxxxxxxxxx |
| 6-9 | Obtention de 6 ordinateurs nodaux | xxxxxxxxxxxxxxxxxx |
| 7-9 | Software hôtes | xxxxxxxxxxxxxxxxxx |
| 8-11 | Interfaces additionnelles | xxxxxxxxxxxx |
| 9-10 | Fonctionnement pilote | xxxxxxxx |
| 9-11 | Hôtes additionnels | xxxxxxxxxxxxxxxxxx |
| 10-11 | Réalisation | xxxxxxxxxxxxxxxxxxxxxxxx |
| 11-12 | Fonctionnement | xx |

FIGURE 4

DIAGRAMME GANTT
HYPOTHESES PESSIMISTES

FIGURE 5.1 COST OF IMPLEMENTATION, OPTIMISTIC ESTIMATE

Cost (k$)

| Activity | Month → | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-1 | Constitution | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 1 |
| | Monthly total | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 1 |
| | Cumulative total | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 12 | 14 | 15 |

| | Month → | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-2 | Specifications | 6 | 6 | 6 | 6 | | | | | | | | |
| 1-3 | Host-host protocol | 6 | 6 | 6 | 6 | 6 | 6 | | | | | | |
| 1-4 | Appoint secretariat | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 5-6 | Select node computer | | | | | | | | | 6 | 6 | 6 | |
| 6-8 | Node software | | | | | | | | | | | | 17 |
| 7-9 | Host software | | | | | | | | | | | | 28 |
| | Monthly total | 13 | 14 | 15 | 16 | 11 | 12 | 7 | 8 | 15 | 16 | 17 | 57 |
| | Cumulative total | 28 | 42 | 57 | 73 | 84 | 96 | 103 | 111 | 126 | 142 | 159 | 216 |

| | Month → | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-4 | Appoint secretariat | 13 | 14 | 15 | | | | | | | | | |
| 1-10 | Topology | | | | | | | | | | | | 2 |
| 4-10 | Documentation, coordination | | | | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| 6-8 | Node software | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | |
| 6-9 | Procure 6 node computers | | | | | | | | | | | 180 | |
| 7-9 | Host software | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | |
| 8-11 | Additional interfaces | | | | | | | | | | | | 4 |
| 9-10 | Pilot operation | | | | | | | | | | | | 72 |
| 9-11 | Additional hosts | | | | | | | | | | | | 21 |
| | Monthly total | 58 | 59 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 240 | 114 |
| | Cumulative total | 274 | 333 | 393 | 453 | 513 | 573 | 633 | 693 | 753 | 813 | 1053 | 1167 |

## Coût (k$)

| Activité | Mois → | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-1 | Constitution | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 1 |
| | Total mensuel | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 1 |
| | Total cumulatif | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 12 | 14 | 15 |

| | Mois → | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-2 | Spécifications | 6 | 6 | 6 | 6 | | | | | | | | |
| 1-3 | Protocole hôte-à-hôte | 6 | 6 | 6 | 6 | 6 | 6 | | | | | | |
| 1-4 | Nommer un secrétariat | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 5-6 | Choix d'un ordinateur nodal | | | | | | | | | 6 | 6 | 6 | |
| 6-8 | Software nodal | | | | | | | | | | | | 17 |
| 7-9 | Software hôte | | | | | | | | | | | | 28 |
| | Total mensuel | 13 | 14 | 15 | 16 | 11 | 12 | 7 | 8 | 15 | 16 | 17 | 57 |
| | Total cumulatif | 28 | 42 | 57 | 73 | 84 | 96 | 103 | 111 | 126 | 142 | 159 | 216 |

| | Mois → | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-4 | Nommer un secrétariat | 13 | 14 | 15 | | | | | | | | | |
| 1-10 | Topologie | | | | | | | | | | | | 2 |
| 4-10 | Documentation, coordination | | | | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| 6-8 | Software nodal | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | |
| 6-9 | Obtention de 6 ordinateurs nodaux | | | | | | | | | | | 180 | |
| 7-9 | Software hôte | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | |
| 8-11 | Interfaces additionnelles | | | | | | | | | | | | 4 |
| 9-10 | Fonctionnement pilote | | | | | | | | | | | | 72 |
| 9-11 | Hôtes additionnels | | | | | | | | | | | | 21 |
| | Total mensuel | 58 | 59 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 240 | 114 |
| | Total cumulatif | 274 | 333 | 393 | 453 | 513 | 573 | 633 | 693 | 753 | 813 | 1053 | 1167 |

FIGURE 5.1 COUT DE REALISATION, HYPOTHESES OPTIMISTES

Cost (k$)

| Activity | Month → | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-10 | Topology | 2 | 2 | 2 | 2 | 2 | | | | | | | |
| 4-10 | Documentation, coordination | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| 8-11 | Additional interfaces | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | | | | |
| 9-10 | Pilot operation | 72 | 72 | 72 | 72 | 72 | | | | | | | |
| 9-11 | Additional hosts | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | |
| 10-11 | Implementation | | | | | | 104 | 114 | 124 | 134 | 144 | 154 | 164 |
| | Monthly total | 114 | 114 | 114 | 114 | 114 | 144 | 154 | 164 | 170 | 180 | 190 | 179 |
| | Cumulative total | 1281 | 1395 | 1509 | 1623 | 1737 | 1881 | 2035 | 2199 | 2369 | 2549 | 2739 | 2918 |

| | Month → | 49 | 50 | 51 | 52 | 53 | 54 |
|---|---|---|---|---|---|---|---|
| 4-10 | Documentation, coordination | 15 | 15 | 15 | 15 | 15 | 15 |
| 10-11 | Implementation | 174 | 184 | 194 | 204 | 214 | |
| 11-12 | Operation | | | | | | 180 |
| | Monthly total | 189 | 199 | 209 | 219 | 229 | 195 |
| | Cumulative total | 3107 | 3306 | 3515 | 3734 | 3963 | 4158 |

FIGURE 5.2 COST OF IMPLEMENTATION, OPTIMISTIC ESTIMATE

FIGURE 5.2 COUT DE REALISATION, HYPOTHESES OPTIMISTES

Coût (k$)

| Activité | Mois → | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-10 | Topologie | 2 | 2 | 2 | 2 | 2 | | | | | | | |
| 4-10 | Documentation,coordination | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| 8-11 | Interfaces additionnelles | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | | | | |
| 9-10 | Fonctionnement pilote | 72 | 72 | 72 | 72 | 72 | | | | | | | |
| 9-11 | Hôtes additionnels | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | |
| 10-11 | Réalisation | | | | | | 104 | 114 | 124 | 134 | 144 | 154 | 164 |
| | Total mensuel | 114 | 114 | 114 | 114 | 114 | 144 | 154 | 164 | 170 | 180 | 190 | 179 |
| | Total cumulatif | 1281 | 1395 | 1509 | 1623 | 1737 | 1881 | 2035 | 2199 | 2369 | 2549 | 2739 | 2918 |

| | Mois → | 49 | 50 | 51 | 52 | 53 | 54 |
|---|---|---|---|---|---|---|---|
| 4-10 | Documentation, coordination | 15 | 15 | 15 | 15 | 15 | 15 |
| 10-11 | Réalisation | 174 | 184 | 194 | 204 | 214 | |
| 11-12 | Fonctionnement | | | | | | 180 |
| | Total mensuel | 189 | 199 | 209 | 219 | 229 | 195 |
| | Total cumulatif | 3107 | 3306 | 3515 | 3734 | 3963 | 4158 |

## FIGURE 6.1 COST OF IMPLEMENTATION, PESSIMISTIC ESTIMATE

Cost (k$)

| Activity | Month → | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-1 | Constitution | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| | Monthly total | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| | Cumulative total | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 11 | 13 | 15 |

| | Month → | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-1 | Constitution | 2 | 2 | 3 | 3 | 3 | 2 | | | | | | |
| 1-2 | Specifications | | | | | | | 6 | 6 | 6 | 6 | 6 | 6 |
| 1-3 | Host-host protocol | | | | | | | 6 | 6 | 6 | 6 | 6 | 6 |
| 1-4 | Appoint secretariat | | | | | | | 1 | 2 | 3 | 4 | 5 | 6 |
| | Monthly total | 2 | 2 | 3 | 3 | 3 | 2 | 13 | 14 | 15 | 16 | 17 | 18 |
| | Cumulative total | 17 | 19 | 22 | 25 | 28 | 30 | 43 | 57 | 72 | 88 | 105 | 123 |

| | Month → | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-3 | Host-host protocol | 6 | 6 | 6 | 6 | 6 | 6 | | | | | | |
| 1-4 | Appoint secretariat | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 5-6 | Select node computer | | | | | 6 | 6 | 6 | 6 | 6 | | | |
| 6-8 | Node software | | | | | | | | | | 18 | 18 | 18 |
| 7-9 | Host software | | | | | | | | | | 32 | 32 | 32 |
| | Monthly total | 13 | 14 | 15 | 16 | 23 | 24 | 19 | 20 | 21 | 66 | 67 | 68 |
| | Cumulative total | 136 | 150 | 165 | 181 | 204 | 228 | 247 | 267 | 288 | 354 | 421 | 489 |

| | Month → | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-4 | Appoint secretariat | 19 | 20 | | | | | | | | | | |
| 4-10 | Documentation, coordination | | | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| 6-8 | Node software | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| 7-9 | Host software | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |
| | Monthly total | 69 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 |
| | Cumulative total | 558 | 628 | 698 | 768 | 838 | 908 | 978 | 1048 | 1118 | 1188 | 1258 | 1328 |

FIGURE 6.1 COUT DE REALISATION, HYPOTHESES PESSIMISTES

Coût (k$)

| Activité | | Mois → 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-1 | Constitution | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| | Total mensuel | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| | Total cumulatif | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 11 | 13 | 15 |

| | | Mois → 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-1 | Constitution | 2 | 2 | 3 | 3 | 3 | 2 | | | | | | |
| 1-2 | Spécifications | | | | | | | 6 | 6 | 6 | 6 | 6 | 6 |
| 1-3 | Protocole hôte-à-hôte | | | | | | | 6 | 6 | 6 | 6 | 6 | 6 |
| 1-4 | Nommer un secrétariat | | | | | | | 1 | 2 | 3 | 4 | 5 | 6 |
| | Total mensuel | 2 | 2 | 3 | 3 | 3 | 2 | 13 | 14 | 15 | 16 | 17 | 18 |
| | Total cumulatif | 17 | 19 | 22 | 25 | 28 | 30 | 43 | 57 | 72 | 88 | 105 | 123 |

| | | Mois → 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-3 | Protocole hôte-à-hôte | 6 | 6 | 6 | 6 | 6 | 6 | | | | | | |
| 1-4 | Nommer un secrétariat | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 5-6 | Choix d'un ordinateur nodal | | | | | 6 | 6 | 6 | 6 | 6 | | | |
| 6-8 | Software nodal | | | | | | | | | | 18 | 18 | 18 |
| 7-9 | Software hôte | | | | | | | | | | 32 | 32 | 32 |
| | Total mensuel | 13 | 14 | 15 | 16 | 23 | 24 | 19 | 20 | 21 | 66 | 67 | 68 |
| | Total cumulatif | 136 | 150 | 165 | 181 | 204 | 228 | 247 | 267 | 288 | 354 | 421 | 489 |

| | | Mois → 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-4 | Nommer un secrétariat | 19 | 20 | | | | | | | | | | |
| 4-10 | Documentation, coordination | | | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| 6-8 | Software nodal | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| 7-9 | Software hôte | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |
| | Total mensuel | 69 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 |
| | Total cumulatif | 558 | 628 | 698 | 768 | 838 | 908 | 978 | 1048 | 1118 | 1188 | 1258 | 1328 |

Cost (k$)

| Activity | | Month → 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-10 | Topology | | | | | | 4 | 4 | 4 | 4 | 4 | 4 | |
| 4-10 | Documentation,coordination | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| 6-8 | Node software | 18 | 18 | 18 | | | | | | | | | |
| 6-9 | Procure 6 node computers | | | 450 | | | | | | | | | |
| 7-9 | Host software | 32 | 32 | 32 | | | | | | | | | |
| 8-11 | Additional interfaces | | | | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 9-10 | Pilot operation | | | | 102 | 102 | 102 | 102 | 102 | 102 | 102 | 102 | |
| 9-10 | Additional hosts | | | | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 |
| 10-11 | Implementation | | | | | | | | | | | | 184 |
| | Monthly total | 70 | 70 | 520 | 150 | 150 | 154 | 154 | 154 | 154 | 154 | 154 | 232 |
| | Cumulative total | 1398 | 1468 | 1988 | 2138 | 2288 | 2442 | 2596 | 2750 | 2904 | 3058 | 3212 | 3444 |

| | | Month → 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4-10 | Documentation, coordination | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| 8-11 | Additional interfaces | 4 | 4 | 4 | | | | | | | | | |
| 9-11 | Additional hosts | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | | | |
| 10-11 | Implementation | 109 | 199 | 124 | 214 | 139 | 229 | 154 | 244 | 169 | 259 | 184 | 274 |
| | Monthly total | 157 | 247 | 172 | 258 | 183 | 273 | 198 | 288 | 213 | 279 | 204 | 294 |
| | Cumulative total | 3601 | 3848 | 4020 | 4278 | 4461 | 4734 | 4932 | 5220 | 5433 | 5712 | 5916 | 6210 |

| | | Month → 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4-10 | Documentation, coordination | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| 10-11 | Implementation | 199 | 289 | 214 | 304 | 229 | 319 | 244 | 334 | 259 | 349 | 274 | |
| 11-12 | Operation | | | | | | | | | | | | 270 |
| | Monthly total | 219 | 309 | 234 | 324 | 249 | 339 | 264 | 354 | 279 | 369 | 294 | 290 |
| | Cumulative total | 6429 | 6738 | 6972 | 7296 | 7545 | 7884 | 8148 | 8502 | 8781 | 9150 | 9444 | 9739 |

FIGURE 6.2 COST OF IMPLEMENTATION, PESSIMISTIC ESTIMATE

FIGURE 6.2 COUT DE REALISATION, HYPOTHESES PESSIMISTES

Coût (k$)

| Activité | Mois → | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-10 | Topologie | | | | | | 4 | 4 | 4 | 4 | 4 | 4 | |
| 4-10 | Documentation, coordination | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| 6-8 | Software nodal | 18 | 18 | 18 | | | | | | | | | |
| 6-9 | Obtention de 6 ordinateurs nodaux | | | 450 | | | | | | | | | |
| 7-9 | Software hôte | 32 | 32 | 32 | | | | | | | | | |
| 8-11 | Interfaces additionnelles | | | | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 9-10 | Fonctionnement pilote | | | | 102 | 102 | 102 | 102 | 102 | 102 | 102 | 102 | |
| 9-10 | Hôtes additionnels | | | | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 |
| 10-11 | Réalisation | | | | | | | | | | | | 184 |
| | Total mensuel | 70 | 70 | 520 | 150 | 150 | 154 | 154 | 154 | 154 | 154 | 154 | 232 |
| | Total cumulatif | 1398 | 1468 | 1988 | 2138 | 2288 | 2442 | 2596 | 2750 | 2904 | 3058 | 3212 | 3444 |

| | Mois → | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4-10 | Documentation, coordination | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| 8-11 | Interfaces additionnelles | 4 | 4 | 4 | | | | | | | | | |
| 9-11 | Hôtes additionnels | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | | | |
| 10-11 | Réalisation | 109 | 199 | 124 | 214 | 139 | 229 | 154 | 244 | 169 | 259 | 184 | 274 |
| | Total mensuel | 157 | 247 | 172 | 258 | 183 | 273 | 198 | 288 | 213 | 279 | 204 | 294 |
| | Total cumulatif | 3601 | 3848 | 4020 | 4278 | 4461 | 4734 | 4932 | 5220 | 5433 | 5712 | 5916 | 6210 |

| | Mois → | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4-10 | Documentation, coordination | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| 10-11 | Réalisation | 199 | 289 | 214 | 304 | 229 | 319 | 244 | 334 | 259 | 349 | 274 | |
| 11-12 | Fonctionnement | | | | | | | | | | | | 270 |
| | Total mensuel | 219 | 309 | 234 | 324 | 249 | 339 | 264 | 354 | 279 | 369 | 294 | 290 |
| | Total cumulatif | 6429 | 6738 | 6972 | 7296 | 7545 | 7884 | 8148 | 8502 | 8781 | 9150 | 9444 | 9739 |

## 12. COST OF IMPLEMENTATION

The cost of implementation under the optimistic assumptions of section 11 is shown month by month in Figure 5, and under the pessimistic assumptions in Figure 6. The truth will probably lie between the two extremes. The cost of implementation is summarized under the headings of manpower, hardware, and communication lines in Figure 7.

FIGURE 7 SUMMARY COST OF IMPLEMENTATION
OPTIMISTIC & PESSIMISTIC ESTIMATES

(k$)

| | Manpower | | Hardware | | Lines | | Total | |
|---|---|---|---|---|---|---|---|---|
| | OPT | PES | OPT | PES | OPT | PES | OPT | PES |
| Year 1 | 15 | 15 | | | | | 15 | 15 |
| Year 2 | 201 | 108 | | | | | 201 | 108 |
| Year 3 | 735 | 366 | 186 | | 30 | | 951 | 366 |
| Year 4 | 941 | 839 | 310 | | 500 | | 1751 | 839 |
| Year 5 | 502 | 986 | 248 | 580 | 490 | 550 | 1240 | 2116 |
| Year 6 | | 996 | | 570 | | 1200 | | 2766 |
| Year 7 | | 1048 | | 566 | | 1910 | | 3524 |
| Total | 2394 | 4358 | 744 | 1716 | 1020 | 3660 | 4158 | 9734 |

It should be noted that manpower accounts for 45% to 58% of the cost. A significant part of this manpower will probably be contributed by universities interested in the project.

## 12. COUT DE REALISATION

Le coût de réalisation sous les hypothèses optimistes de la section 11 est démontré, mois par mois, à la Figure 5 tandis que le coût sous les hypothèses pessimistes est démontré à la Figure 6. La vérité se retrouvera probablement entre les deux extrêmes. Le coût de réalisation est résumé à la Figure 7 sous les rubriques de main-d'oeuvre, matériel et lignes de communications.

FIGURE 7 COUT SOMMAIRE DE REALISATION
ESTIMES OPTIMISTES ET PESSIMISTES

(k$)

| | Main-d'oeuvre | | Matériel | | lignes de communications | | Total | |
|---|---|---|---|---|---|---|---|---|
| | OPT | PES | OPT | PES | OPT | PES | OPT | PES |
| Année 1 | 15 | 15 | | | | | 15 | 15 |
| Année 2 | 201 | 108 | | | | | 201 | 108 |
| Année 3 | 735 | 366 | 186 | | 30 | | 951 | 366 |
| Année 4 | 941 | 839 | 310 | | 500 | | 1751 | 839 |
| Année 5 | 502 | 986 | 248 | 580 | 490 | 550 | 1240 | 2116 |
| Année 6 | | 996 | | 570 | | 1200 | | 2766 |
| Année 7 | | 1048 | | 566 | | 1910 | | 3524 |
| Total | 2394 | 4358 | 744 | 1716 | 1020 | 3660 | 4158 | 9734 |

Il faut noter que la main-d'oeuvre représente 45% à 58% du coût. Une partie appréciable de cette main-d'oeuvre sera probablement fournie par les universités intéressées au projet.

## 13. WHY CANUNET NOW ?

The present proposal for CANUNET can be realized with today's technology using the lines of today. It may be argued, however, that we should wait for the new digital circuits that the telecommunications carriers are building and the digital circuit and message switching facilities that they are planning. The reason for pressing on now is that the major portion of the work to be accomplished before a computer network becomes fully effective lies in the area of the host-host protocol, the documentation of the facilities available on the network and the education of users. ARPANET became operational experimentally in the fall of 1969, but its load is only now starting to build up because of the work to be done in this area of user software, documentation and education. It is therefore important to start on this area now so that the major problems of using a computer-to-computer network will have been solved, or at least well defined through experience, when the digital circuits become available.

These problems of utilization cannot be effectively solved theoretically. It is only when a working network exists that a wide variety of users, many of whom are not theoretical informaticians, can be involved. It is only when a network is really in use that all the problems of using it will become clear and that a consensus will develop on how to solve those problems.

It may be that future developments in digital circuits and switching equipment may render the CANUNET proposed here obsolete. Certainly, CANUNET will evolve as better digital circuits become available, just as the post office started by using stage coaches, then moved to the railways, and finally to the airlines. In any case, what is achieved in the way of the documentation and standardization of software and the education of users will not be lost but will be transferable to any network that supersedes CANUNET.

## 13. POURQUOI MAINTENANT?

Le présent projet de réseau CANUNET peut être réalisé en utilisant les techniques que nous possédons à l'heure actuelle et les lignes qui sont présentement à notre disposition. On pourrait s'opposer à l'établissement de ce réseau en faisant valoir qu'il serait préférable d'attendre que les sociétés de télécommunications aient terminé leurs circuits numériques ainsi que les dispositifs de commutation de messages pour ces circuits qu'ils entendent mettre au point. Il faut mettre l'accent sur maintenant car la majeure partie du travail à effectuer avant qu'un réseau d'ordinateurs fonctionne de façon efficace se situe au niveau du protocole de communications entre ordinateur-hôtes, de la documentation du matériel disponible et de l'éducation des utilisateurs. ARPANET fonctionne depuis l'automne 1969 mais sa capacité ne commence qu'à être exploitée à cause de l'énorme travail à accomplir dans les domaines suivants: software des utilisateurs, documentation et éducation. Il importe donc de commencer le travail dans ces domaines afin que les principaux problèmes afférents à un réseau ordinateur-à-ordinateur puissent être résolus ou du moins bien définis par expérience lorsque les circuits numériques seront mis à notre disposition.

La théorie seule ne peut résoudre les problèmes d'utilisation de façon efficace. C'est seulement lorsqu'un réseau fonctionnel existe qu'une grande variété d'utilisateurs, dont beaucoup ne sont pas des informaticiens théoriques, peut être impliquée. Ce n'est que lorsqu'un réseau est vraiment exploité que les problèmes d'utilisation se concrétisent et que les utilisateurs s'entendent quant à la manière de résoudre ces problèmes.

Certains événements dans le domaine des circuits numériques et du matériel de commutation pourraient fort bien rendre le projet CANUNET désuet. Sans doute que CANUNET saura s'adapter à l'évolution dans

## 14. CANUNET AS A PILOT TRANS-CANADA COMPUTER COMMUNICATIONS NETWORK

Report No. 13 of the Science Council of Canada calls for the development of a Trans-Canada Computer Communications Network as Phase 1 of a national Major Program on Computer Applications and Technology [8]. CANUNET may be considered to be a pilot project for this national computer network. Tests of ARPANET and simulations of extensions of ARPANET have not indicated any inevitable limit to its size. Due to its being a network of identical node computers, without a center, and with each node able to adapt to changing loads and failures of its neighboring lines and nodes, it appears that the network can be extended indefinitely by adding nodes and lines. This is another way in which it is analogous to the postal system. Also, tests and simulations have shown that the message delivery time between any pair of nodes increases quite slowly as the load is increased from zero up to nearly the capacity of the network, at which point the delivery time increases sharply. It is a simple matter to increase the capacity of the network and reduce the message delivery time by adding lines and increasing their speed. All these considerations apply to CANUNET. It is most unlikely that CANUNET will be fully loaded with university traffic within five years, but there is no technical reason why other traffic should not be added. Other customers that come to mind are:

1) Industrial and government research laboratories;

2) Computer utilities;

3) The National Library and the National Science Library;

4) Economic data banks, such as that of Statistics Canada;

5) Legal data banks;

6) Hospitals and medical services;

7) Stock exchange quotation services.

ces domaines tout comme les services postaux ont su mettre à profit le cheval, la locomotive et l'avion. De toute façon, tout ce qui aura pu être effectué dans les secteurs de la documentation, de la normalisation du software et de l'éducation des utilisateurs ne sera pas perdu et pourra servir à tout système qui pourrait remplacer CANUNET.

## 14. CANUNET COMME PROJET PILOTE D'UN RESEAU TRANSCANADIEN DE TELEINFORMATIQUE

Le rapport no 13 du Conseil des sciences du Canada préconise l'élaboration d'un réseau transcanadien de téléinformatique comme première étape d'un programme national majeur sur les applications de l'informatique et de la technologie des ordinateurs[8]. On pourrait considérer CANUNET comme le précurseur d'un tel réseau national d'informatique. Les essais effectués sur le réseau ARPANET et les simulations des prolongements d'ARPANET n'ont pas indiqué une borne inéluctable à sa grandeur. Etant donné que ce réseau est composé d'ordinateurs nodaux identiques, sans un centre et que chaque noeud peut s'adapter aux charges variables et aux pannes de ses lignes et de ses noeuds affiliés, tout porte à croire que l'on peut prolonger le système indéfiniment par l'ajout de noeuds et de lignes. Sous cet aspect, le réseau s'apparente encore une fois au système des Postes. De plus, des essais et des simulations ont démontré que le temps de transmission d'un message entre deux noeuds quelconques augmente assez lentement lorsque la charge augmente entre zéro et la pleine capacité. Lorsque le réseau a presqu'atteint sa capacité, le temps de transmission monte en flèche. On peut facilement accroître la capacité du réseau et réduire le temps de transmission en ajoutant des lignes et en augmentant leur vitesse. Toutes ces considérations s'appliquent à CANUNET. On croit que les universités ne pourront utiliser CANUNET à plein régime avant cinq ans; mais aucune raison technique n'empêche le réseau de desservir d'autres utilisateurs comme:

Each class of customer could set up its own host-to-host protocol, its own organization and its own charging arrangements. Logically and organizationally it would be a separate network, although using the physical subnet of nodes and lines, in common with other groups of users, as an electronic post office. When carrying the load of these various groups of customers the network, or more strictly the subnet of nodes and lines, would be economically viable. At this stage, the operation of the subnet should be turned over to an organization of telecommunications carriers. CANUNET would become a logical network of university users of the subnet or electronic post office and the organization outlined in Appendix N would continue to deal with the continuing development of host-host protocol, documentation of resources of interest to universities, development of standards, and accounting arrangements between universities.

## 15. DECISIONS REGARDING IMPLEMENTATION OF CANUNET

In this section we list some of the key decisions that must be made regarding the CANUNET project.

1) Should CANUNET be established, or should industry be left to provide computer-to-computer networks when profit is assured?

   Networks will continue to arise and to grow on the basis of what is economical at the moment for the parties concerned. Eventually an electronic post office service will be provided when it can be shown to be unquestionably more effective than a multitude of separate networks. On the other hand, there is the planning approach of envisaging the ultimate system, however imperfectly, and then steering directly towards it. We favor the planning approach.

1) les laboratoires de recherche de l'industrie et du gouvernement;

2) les services publics d'ordinateurs;

3) la Bibliothèque nationale et la Bibliothèque scientifique nationale;

4) les banques de données économiques comme celle de la Statistique du Canada;

Chaque classe de clients pourrait établir son propre protocole hôte-à-hôte, sa propre organisation et sa propre comptabilité. Au point de vue de concept et d'organisation, ce serait un réseau distinct quoique cette classe, en commun avec d'autres classes d'utilisateurs, utiliserait le sous-réseau physique de lignes et noeuds comme un service de postes électroniques. Le réseau, ou plutôt le sous-réseau de noeuds et lignes, sera rentable lorsque chargé du trafic de ces groupes de clients. A ce stade, il faudrait confier l'exploitation du sous-réseau à une organisation des services publics de télécommunication. CANUNET deviendrait un réseau conceptuel de clients universitaires du sous-réseau, ou service de postes électroniques. L'organisation CANUNET ébauchée à l'Annexe N continuerait à s'occuper du développement permanent du protocole hôte-à-hôte, de la documentation des ressources susceptibles d'intéresser les universités, de l'élaboration de normes et de systèmes comptables interuniversitaires.

## 15. DECISIONS SUR L'ELABORATION DE CANUNET

La présente section énumère les principales décisions à prendre au sujet du projet CANUNET.

1) CANUNET devrait-il être établi, ou devrait-on laisser à l'industrie le soin de fournir les réseaux ordinateurs-à-ordinateurs

2) Should CANUNET import American hardware and software or should the development be done in Canada?

The cheapest and most rapid way to get a pilot CANUNET functioning is to buy ARPANET hardware and software. We favor the choice of Canadian development for the reasons set forth in Science Council Reports 4 and 13. In addition, learning from the experience of ARPANET and taking advantage of the advances in minicomputers and interface hardware in the last four years, we can produce a better network at a lower cost per node computer, if development costs are not included. If it is decided that CANUNET should be developed in Canada, the next question is:

3) Should the subnet hardware and software be developed at the universities or by industry?

This question has been dealt with at some length by the study group on institutional framework (Appendix N) and is mentioned in the report of the study group on network design (Appendix K). The former group suggest that the selection of a university group is viable only if a demonstration model of the network is to be undertaken with the objective of "tuning up" the software/hardware specifications of the "service" version of the network to be built by contract later. The prime recommendation of this report is that CANUNET should be regarded as a prototype and precursor of the future trans-Canada computer communications network. We therefore favor the approach of entrusting the development of the prototype subnet to the universities as being the one that will lead to the clearest and most original concepts. The development of the "service" version for the trans-Canada computer communications network can be left to the organization that will eventually operate it.

lorsque la rentabilité de ceux-ci sera assurée?

Des réseaux continueront de naître et de croître en fonction de ce qui est économiquement allêchant à un moment donné pour les parties en cause. Un jour un service de postes électroniques sera assuré lorsque l'on pourra prouver que ce système est plus efficace qu'une multitude de réseaux distincts. Par contre, il y a l'approche de la planification: on envisage le système ultime quoique imparfaitement et on se dirige droit au but. Quant à nous, nous optons pour la planification.

2) CANUNET devrait-il importer du hardware et du software des U.S.A. ou l'élaboration devrait-elle être effectuée au Canada?

L'achat du hardware et du software utilisés par le réseau ARPANET constituerait le moyen le plus rapide et le plus économique de mettre CANUNET sur pied. Nous préconisons une élaboration canadienne pour les raisons énoncées aux rapports nos 4 et 13 du Conseil des sciences. De plus, en tirant profit de l'expérience d'ARPANET et en se prévalant des progrès réalisés au cours des quatre dernières années dans le domaine des mini-ordinateurs et du matériel d'interfaces, nous pouvons mettre en place un réseau supérieur à un coût moindre par ordinateur nodal, abstraction faite des frais de développement. Le choix d'une élaboration canadienne donne lieu à la question suivante:

3) Le hardware et le software du sous-réseau devraient-ils être élaborés par les universités ou par l'industrie?

Cette question a fait l'objet d'un exposé assez détaillé par le groupe d'étude sur la structure institutionnelle (Annexe N), et le rapport du groupe d'étude sur la conception du réseau (Annexe K) en fait état. Ce dernier groupe propose que le choix d'un groupe

4) Should host-host protocol be developed by the universities or by software houses?

The answer of the network design study group is that host-host protocol design and network oriented host software development properly belong in the universities. The institutional framework study group appears to agree by implication.

5) How will CANUNET be financed?

The only evident sources of funds in the initial stages are governments. When the network is operational some revenue from the universities using it can be expected. It will become self-supporting only when it carries commercial and government traffic as well as academic traffic. In view of the necessary involvement of the telecommunications carriers their financial participation might be invited at an early stage.

6) Who will organize CANUNET?

In view of the key role of the Federal government in financing CANUNET, the Department of Communications should control the project initially through contracts with universities. The AUCC should be invited to set up a permanent organization to assume control at a later date.

universitaire n'est viable que si l'on entreprend un modèle de démonstration de réseau en vue de mettre au point les spécifications software/hardware d'un réseau "utilitaire" à être construit sous contrat par la suite. La préconisation principale qui se dégage de ce rapport est à l'effet qu'on doit considérer CANUNET comme le prototype et le précurseur du futur réseau transcanadien de téléinformatique. Nous croyons donc que l'approche de laisser aux universités le soin d'élaborer un prototype du sous-réseau conduira aux concepts les plus nets et les plus originaux. L'élaboration de la version utilitaire du réseau transcanadien de téléinformatique pourra être confiée à l'organisme qui l'exploitera finalement.

4) Le protocole de communications entre ordinateurs-hôtes devrait-il être élaboré par les universités ou par les maisons qui se spécialisent en software?

La réponse que donne le groupe d'étude sur la conception du réseau est à l'effet que la conception du protocol de communications entre ordinateurs-hôtes et l'élaboration du software afférents au réseau soient confiées aux universités. On peut déduire que le rapport du groupe d'étude sur la structuration donne une réponse analogue.

5) D'où proviendront les fonds pour CANUNET?

Il semble que seul les gouvernements pourront faire les apports de capitaux nécessaires lors des premières étapes de CANUNET. Lorsque le réseau fonctionnera, on peut s'attendre à ce que les universités utilisatrices contribuent leur quote-part. Le réseau ne deviendra rentable que lorsqu'il servira au commerce et au gouvernement tout aussi bien qu'aux universités. Etant donné que les sociétés de télécommunications seront nécessairement impliquées, on pourrait solliciter leur appui financier dès les débuts.

## 16. CONCLUSIONS

1) The universities of Canada can be linked by an effective computer network using existing technology and communication lines. The development of the network will enable Canadians to master a significant and rapidly growing technology.

2) The greatest value of the network will be in establishing a community of users across Canada and in providing that community with access to data banks, information services and computing power located anywhere on the network. The development of methods of using the network is the area that requires the most work, and the skills and methods thus developed will be transferable to any larger or more effective networks that may arise in the future.

3) The cost of developing a network with 18 nodes using mainly Canadian university personnel is estimated to be between 4.2 and 9.5 million dollars, and the time required to be between $4\frac{1}{2}$ and 7 years. Governments are the only likely sources of funds of this magnitude.

4) Although universities must be prepared to pay for membership in the network and for the services they receive from it, the traffic they generate is most unlikely to load the network fully during the first five years of operation. The network must therefore be largely supported by governments as a pilot project for future networks, and it should be made available to commercial and governmental computer centers as soon as it is functioning effectively.

6) Qui organisera CANUNET?

Vu que le gouvernement fédéral sera appelé à jouer un rôle de premier plan dans le financement de CANUNET, le Ministère des Communications devrait en être responsable au début, par l'entremise de contrats accordés aux universités. On devrait inviter l'AUCC à créer un organisme permanent pour en prendre le contrôle par la suite.

## 16. CONCLUSIONS

1) Les universités du Canada peuvent être reliées par un réseau téléinformatique efficace utilisant la technologie et les lignes actuelles de télécommunication. La réalisation du réseau permettra aux Canadiens de maîtriser une technologie significative et en évolution rapide.

2) Les plus grandes valeurs du réseau seront d'établir une communauté d'utilisateurs à travers le Canada et de fournir à cette communauté l'accès aux banques de données, aux services d'information et aux services de calcul localisés n'importe où sur le réseau. L'élaboration de méthodes d'utilisation du réseau est le domaine qui demande le plus de travail. La compétence et les méthodes ainsi développées pourront être transférées à des réseaux éventuels plus grands et plus efficaces.

3) On estime que le coût de réalisation d'un réseau de 18 noeuds par un personnel provenant surtout des universités canadiennes se situerait entre 4.2 et 9.5 millions de dollars et que le temps requis serait entre $4\frac{1}{2}$ et 7 ans. Les gouvernements sont les seules sources probables de fonds à ce niveau.

5) Responsibility for the technical development of the network should be undertaken by the Department of Communications which should form a project management team at one location, including persons seconded by or recruited from universities. The development should be done through contracts with Canadian industry and universities, as decided by the project management team.

6) An organization of participating universities, possibly affiliated to the Association of Universities and Colleges of Canada, should be set up to operate, develop standards for and facilitate the use of the network. The management of the subnet of nodes and lines should be turned over to a more broadly based network organization as soon as one evolves. The university organization should continue to deal with matters of interest to universities as users of the subnet.

4) Quoique les universités doivent être disposées à payer des droits d'adhésion au réseau et des taux pour les services reçus, le trafic universitaire est très peu susceptible de charger le réseau au complet durant les cinq premières années d'opération. Il faut donc que le réseau soit soutenu par les gouvernements comme un projet pilote pour les réseaux futures. Il devra être disponible pour les centres de calcul commerciaux et gouvernementaux dès qu'il fonctionnera efficacement.

5) Le Ministère des Communications doit assumer la responsabilité de la réalisation technique du réseau. Il doit établir, à un endroit unique, une équipe pour la direction du projet incluant des personnes soit libérées, soit embauchées directement des universités. La réalisation doit être accomplie par le truchement de contrats avec l'industrie et les universités canadiennes suivant les décisions de l'équipe de direction.

6) Une organisation des universités participantes, éventuellement affiliée à l'Association des Université et Collèges du Canada, doit être établie pour exploiter le réseau, pour élaborer des normes et pour faciliter l'utilisation du réseau. Aussitôt qu'une organisation d'utilisateurs du réseau évolue sur une base plus large, la gestion du sous-réseau de noeuds et de lignes doit lui être confiée. L'organisation universitaire doit continuer à traiter des questions d'intérêt pour les universités en temps qu'utilisateurs du réseau.

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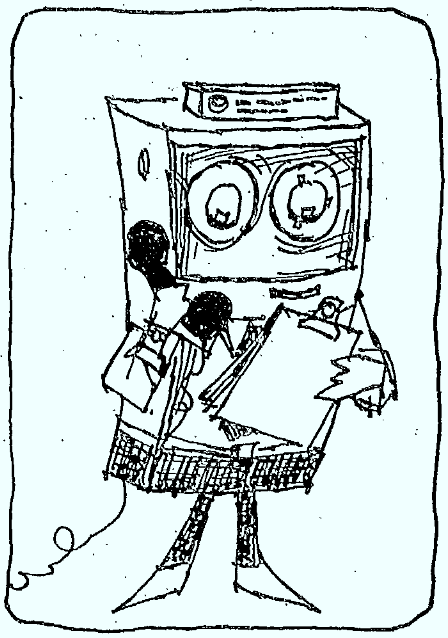
# ANNEXES

# APPENDICES

# ARPA Network Implications

**Lawrence Roberts**
**Advanced Research Projects Agency**



Computer-to-computer data communications today might be compared with people-to-people communication via telegraph before the day of the telephone. Sending a message by telegraph was so slow that the media could only be used for non-interactive transmission of essential information. As such, its use was limited. The telephone provided an ability for people to interact, thus permitting a whole new range of applications. Considering people somewhat mechanistically, we might view their use of the telephone as inter-human resource sharing. To solve a problem, a man will call those people who have bits of data which he needs and will call on specialists for opinions, thus making use of other human resources. This is achieved because the media is appropriately responsive for human requirements and permits interactive conversation, thus eliminating the need for transmitting excessive detail, much of which may be unnecessary. Also, with an interactive dialogue, information does not need to be formatted in a standard way since details can always be clarified if misunderstood. This increase in utility and the many new applications thereby permitted have resulted, as we know, in a vast increase in telephone traffic volume over telegraph traffic levels.

Communication between computers would most likely be effected in an analogous manner if a data communication system were made available which matched the needs of computers as well as the phone matches the needs of humans. Such a system would, of course, have to have different technical parameters (such as connection time, data rates, and reliability) than those required for voice communication; but if it permitted truly interactive conversations between a large ensemble of computers the effect should be much the same in permitting remote access to specialized hardware and software resources, joint problem solving and the dynamic retrieval of data from remote files. The analogy with the telephone is just one way of examining the potential impact of substantially improved data communication between computers and the resultant increase in applications and traffic that such a change might bring about.

## Intercomputer Differences

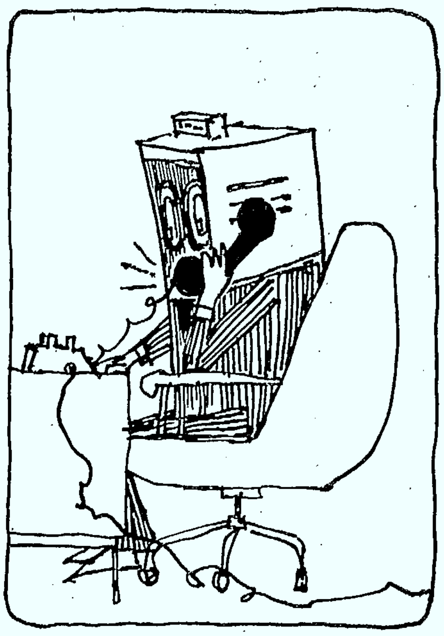
Intercomputer communication has many quite substantial differences from interpersonal voice communication. Whereas voice conversation is a rather continuous, constant data rate process, communication with computers, either from computer consoles or other computers, requires a burst transmission rate several orders of magnitude higher than the average rate, even during a single conversation. Since there has been very little experience so far with real intercomputer traffic where two programs are talking to each other, it is useful to examine the characteristics of computer console traffic which is both a component of, and is also likely to have the same general parameters as, computer-to-computer traffic. From statistics on teletypes, graphic consoles, and remote batch stations, it appears that the ratio of burst rate to average rate is approximately 100 to 1. This means that if a standard communications line is established for a computer conversation, the average utilization of that line will only be about 1 percent and therefore the cost will be 10 to 100 times higher than the raw cost of moving the bits. A second characteristic of computer-to-computer communications is that the connect time to establish a conversation must be short enough that the computers or the computer users are not held up unduly when the need to access a special resource is determined. For computers the "connect time" should be considerably less than a second as opposed to the 20 or 30 seconds commonly experienced for voice communications. Third, the maximum data rate required in man-machine interaction must be considered. It is known that for useful comprehension by a human, the peak data rate for graphical material is on the order of 20 kilobits per second, which suggests the required bandwidth for console-to-computer communications. This also suggests at least a minimum for computer-to-computer communications.

Finally, the error rate for intercomputer traffic must be far lower than required for voice communications or computer console traffic since there is usually very little, if any, redundancy inherent in the data. For many applications the error rate must be less than one in $10^{12}$ bits. At the same time, the reliability (up time) of the data communications system must be very high if the user is to depend on remote resources. The cost of a data service providing the characteristics outlined above must be compared with the cost of duplicating the computer resources involved. Very simply, if the monthly cost of adequate communications service exceeds or even approaches the cost of a reasonably well-endowed computer installation, it is not likely to be economical to use that communications service rather than duplicate that facility. Arbitrarily setting a threshold at 20 percent of a computer facility cost, it can be predicted that the communications system should not cost more than $10K per month per node.

## ARPANET, IMP and TIP

A few years ago no communications system in existence even came close to providing the type of service just described. Therefore, the Advanced Research Projects Agency (ARPA) undertook to develop such a capability so as to make resource sharing between computers possible. The communications system that resulted is utilized in the ARPANET and currently interconnects more than 20 computers at 15 locations around the country. By early 1972, expansion to 25 locations is expected (Figure 1). A delay-engineered message switching system, the ARPANET consists of Interface Message Processors (IMPs) at each node intercommunicating over 50 kilobit per second leased communication lines and connected to one or more Host computers at each site. The IMP accepts messages from the Host, breaks them into thousand bit packets, and sends each packet toward the destination over whichever communication line is currently optimal. Each IMP in turn checks the error detection code on the packet and, if it checks, routes the packet on to the next node and sends an acknowledgment to the previous node. At the destination, packets are assembled back into a message and delivered to the Host.

In practice, this organization proves to be extremely responsive, delivering short messages anywhere in the



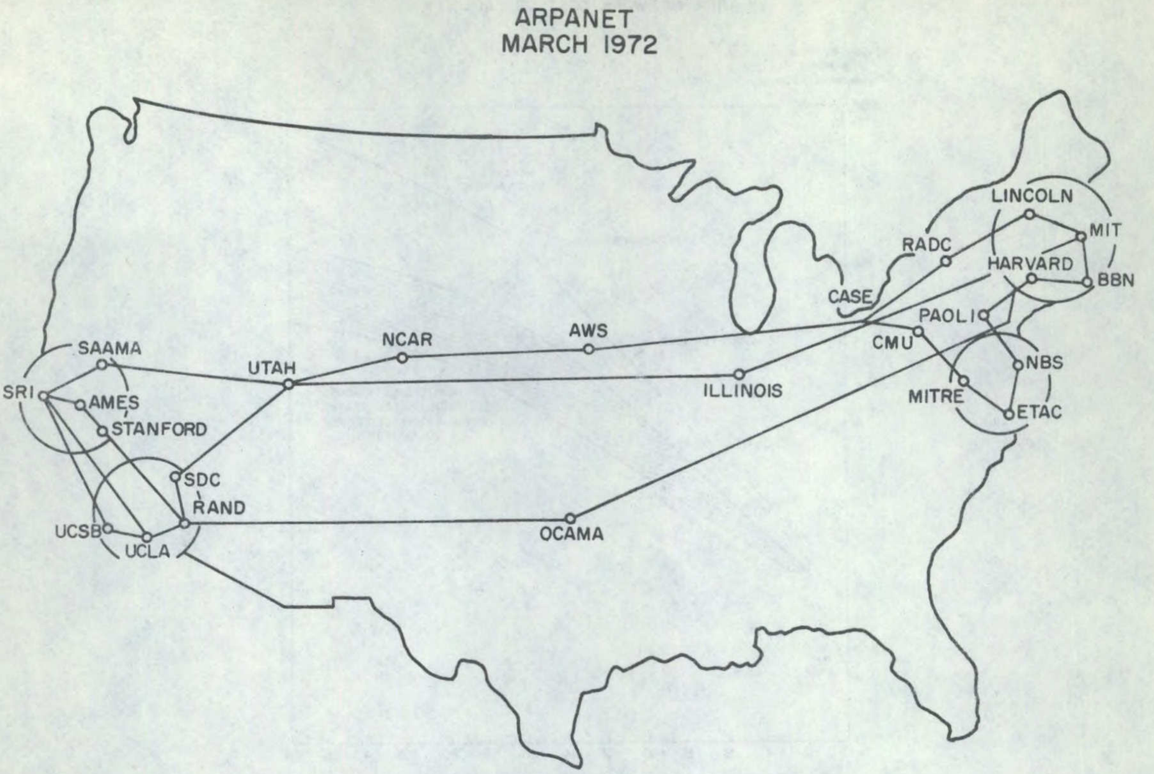



FIGURE I

country within .1 second and permitting throughput rates for long messages of up to 80 kilobits per second. By adjusting the number of communication lines which are leased, the network can be engineered to have almost any desired overall average capacity between 2 kilobits per node and 60 kilobits per node. Since each communication line is being used for traffic between many pairs of nodes simultaneously, it can be loaded quite efficiently even though the individual Host-to-Host conversations have such a high ratio of burst rate to average rate. The actual cost of the total network communications system including the cost of IMPs, maintenance, and communication lines ranges from $3K to $6K per month per node, depending on the overall traffic levels and the facilities required at each node. For new people entering the network, the February 1972 network of 23 nodes is currently estimated to cost $4.8K/node/month: $3.1K for an equal share of the communication lines cost and $1.7K for the lease of a minimal IMP.

Dr. Lawrence Roberts is Director for Information Processing Techniques, Advanced Research Projects Agency. At ARPA Dr. Roberts is principally concerned with new information processing techniques in the areas of computer graphics, languages, computer architecture, man-machine interaction, text manipulation, and information retrieval. In addition, he is the developer of the ARPA Computer Network, a new concept for interconnecting autonomous computer systems in order to share hardware, software, and data resources. Prior to joining ARPA, Dr. Roberts headed the computer software group at the MIT Lincoln Laboratory.

If a user wishes to provide direct console access to the network, a Terminal Interface Processor (TIP) would be used. The TIP, which will become available in August 1971, will act both as an IMP and as a simple host, permitting up to 64 consoles and peripheral devices to intercommunicate with any host in the network at rates up to 20 kilobits/sec. Thus the TIP expands the network concept to include nodes without an interactive host of their own, but who wish high bandwidth support for graphic consoles, printers, and large collections of lower speed devices. Use of a TIP increases the cost by $1.6K/mo.

Although an equal share of the communication line cost is currently allocated to each node, this policy will be changed, as soon as feasible, to one of charging only

ARPA NETWORK COST VS CAPACITY

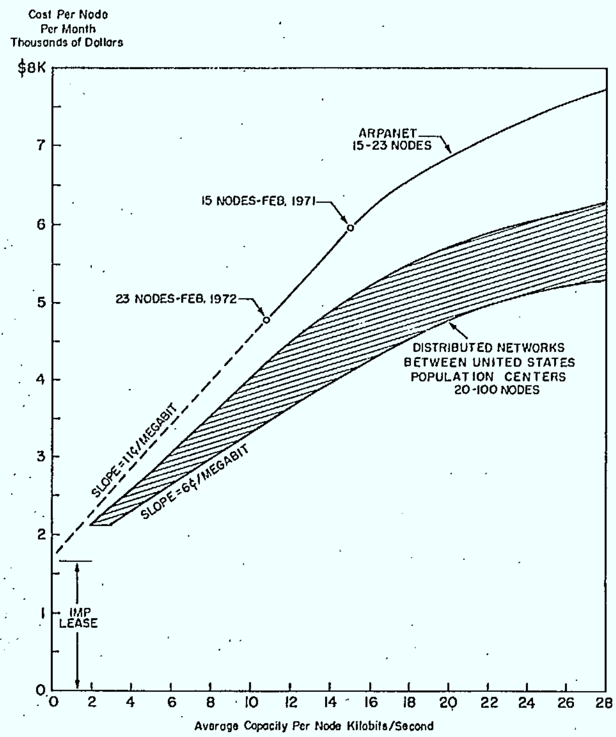



FIGURE 2

for the bits actually sent from each node. Referring to Figure 2, it can be seen that the cost of the network increases almost linearly with capacity, at least for bandwidths below 16 KB/node. Also, it turns out that the capacity and cost of these distributed networks are remarkably insensitive to the distribution and destination of traffic, the total traffic being the only important parameter. Thus, it is appropriate to charge for traffic initiated at a node, based on the cost of increasing the total capacity of the network by that amount. From Figure 2 it can be seen that this will be 11¢/megabit for the ARPANET. However, since the network cannot be expected to be always fully loaded to peak capacity, day and night, it is likely the actual rate will be 30¢/megabit based on an estimated 36 percent average loading. The total cost per node would then be $1.7K/month plus 30¢/megabit.

## A Look Ahead

Looking ahead, assuming the broad availability of a data communications service similar to the ARPANET system, it is clear that very significant changes in computer system organization will take place. Some of these changes will occur rapidly—within the first five years—and others will take a decade or more before people fully accept the concepts. Soon after a network with a dozen or more reliable computer services becomes available, many institutions will find it far more economic to obtain their computing services from a selected set of these remote systems, rather than run their own computer center. For example, take the case of an institution about ready to upgrade its facility. One choice would be to obtain a medium scale, general purpose batch system. This would be admittedly a compromise for their large numerical users and time-sharing users, but the best single system that they could afford. Alternatively, they could buy no new machine and obtain access to several of the systems on the network through a Terminal Interface Processor. This approach permits their large numerical users to use a large "number-cruncher," their statistical and payroll users to access a large scale general purpose system, and their interactive users to have teletype or graphic console access to a good time-sharing system.

Overall the cost of each service is less than it would have been on a dedicated G-P computer by factors between two and ten. Also, they can buy just the capacity they need and expand smoothly rather than having to pay for an oversize machine for a year or two. The peripherals cost the same in either case and the network cost is negligible compared to the direct computer cost savings. As added benefits, the computer services they use are probably better run and more reliable than they could hope to do themselves since the services must stay competitive; a wider range of software is available and can be accessed directly without translation or transfer; and as new hardware is introduced which is economically useful, they can transfer jobs to it on a selected and leisurely basis.

The direct use of distributed hardware services just described will probably account for most of the initial use of the network. This growth should proceed about uniformly over the next eight years—two computer replacement cycles. Some additional traffic will be introduced by the gradual transfer of current data traffic from other data communication networks to the computer network due to the economy or reliability, but the total quantity of this traffic is minor in comparison to the new traffic generated by the computer resource sharing activity.

## Data Base Sharing

A second major application of the computer network is data base sharing—direct retrieval from remote, one-of-a-kind data bases. Currently, when large data bases or files are needed at several computer centers, duplicates are maintained at each center. This difficult and costly practice can be avoided if the access speed through the network is fast enough so that neither human users nor computer processes are unduly delayed. The ARPANET response speed of one-tenth of a second for a question and three-tenths of a second for a one-page answer is quite acceptable for a human user and for a computer program it is no worse than a slow disc.

To start with, this response appears adequate; however, further experience may indicate a need for faster response in future networks. Data base sharing will not build up as rapidly as hardware service sharing, however, since it represents only an incremental saving for an installation and demands considerable faith in the network. Copying a $10^9$ bit data base monthly might cost $2,000—less than the minimum network cost and therefore not a prime motivation for joining the network. However, the cost of accessing the data base through the network would cost at most $300 even if all the data were required, providing a considerable cost saving and convenience as long as the network connection had other justification. Of course for very large data bases, such as the $10^{11}$ bit weather-climate data base being developed by the Air Weather Service for the ARPANET, the cost of either copying or storing a duplicate would immediately justify network connection.

In most cases very large data bases would not be developed at all without a network making possible nationwide access, since the cost would be prohibitive. Data base sharing, therefore, is not likely to grow rapidly until the network is reasonably well established, lagging the service-sharing growth by perhaps two years, but then growing exponentially as everyone requests access to all the information available.

Software sharing, the third major application, is the remote use of software subroutines and packages, programs not available on the users' primary computer due to incompatibility of hardware or languages. An example of this type of activity might be the use by M.I.T. scientists of the Stanford Heuristic Dendral System, a program for determining molecular structure given the mass spectrum. On a computer at M.I.T. the scientists would collect and preprocess the mass spectrum data. Then, much like using a subroutine, the Stanford computer would be called, the data sent and the molecular structure, when determined, sent back. If interaction were required, the M.I.T. scientist would be interrogated much as if he were at Stanford, thus building up the heuristic model based on nationwide inputs. The M.I.T. computer, upon receiving the response, would proceed locally with the calculations or displays desired.

Software sharing like this will be required if we are to maintain maximum progress as the volume of useful software continues to expand. Since the annual cost for software is already larger than that for hardware and, to some extent, should be cumulative rather than wearing out, the long range importance of software sharing is clearly greater. However, due to human inertia and a strong "not invented here" syndrome associated with software, it is clear that the cross-utilization of software will take years to develop. The buildup of software sharing activity will most likely begin very slowly, growing exponentially, but not become a major factor until the network becomes well established in four to eight years.

Besides hardware, software, and data base sharing, there are many other important network applications, all of which require a large viable network before they become important in their own right. These include teleconferencing, publishing, library services, and office paperwork filing and distribution. Ten to twenty years from now these applications may well dominate computer usage and network usage but they are not likely to be important factors for at least five years.

Overall, then, hardware service sharing is likely to be the major factor causing networks to come into existence since the effective cost of computing can be drastically lowered for only a moderate communications cost. Then, data base sharing will become the dominant force expanding the traffic in three to four years. Software sharing, although very important in the long run, will not become a major factor for four to eight years. The text-oriented services, libraries and office work, will then come into their own in ten to twenty years. The whole trend should decrease the importance of the general purpose computer as stand-alone systems, and substantially increase the importance of specialized systems—ones which can provide a specific service at the lowest cost.

*Communications*

# ARPA Network to Go Commercial

"Many of our users have cut their costs significantly; some would have to invest a million dollars in additional systems if they didn't use the network."

Dr. Larry Roberts, the tall, quiet-spoken, pipe-smoking developer of the ARPA Network, was talking about his favorite subject — the first, and so far only, large-scale attempt to interconnect many specialized computers of different makes and offer their capabilities to a multitude of remote users.

Dr. Roberts' comments are particularly significant right now because ARPA — the Defense department's Advanced Research Projects Agency — wants the network to become a commercial service. The tentative plan calls for selling the federal interest "in about two years," Dr. Roberts said. Bids will be invited from both specialized common carriers and communications-oriented computer service firms. Between now and then, he added, ARPA may continue running the show, or the Arpanet may be transferred to another government agency. That decision will be made "shortly."

Illiac IV, the giant parallel processor developed by Burroughs and the Univ. of Illinois, will remain federal property even after the Arpanet goes commercial, Dr. Roberts said. Illiac was recently shipped from the Burroughs plant in Paoli, Pa., to Ames Research Center, Moffett Field, Calif., where it will be interfaced with the Arpanet.

Implementation of the network began late in 1969 with a "research and test" phase that included connection of the first 15 users (nodes). The system went operational in the summer of 1971. Last March, there were 21 nodes, and by this month or next, there should be a total of 26. Dr. Roberts indicated several more users were on the way. Apparently, there is plenty of room for expansion because ARPA has simulated a 200-node network. An even larger number of users can be accommodated without much difficulty, Dr. Roberts added.

## A basic charge

Each user being added currently pays a basic charge of $13,500 per year. This covers the cost of the communications subnetwork required at each node and also allows the user to send 4,500 "kilopackets" of data per month. A packet is 1K bits. If he sends more than this minimum amount of data, he pays 30¢ per kilopacket. The fee schedule is set up so that each new user pays nothing toward the cost of developing the system previous to the time he comes aboard. But if he generates enough traffic to require an increase in network capacity — i.e., if he generates more than 4,500 kilopackets per month — he pays the related costs.

The current charges per node will remain the same regardless of how many users are added, at least while ARPA is in charge, said Dr. Roberts.

An Arpanet terminal costs about $100K. Typically, it consists of a "terminal interface processor" (TIP) that connects directly with up to 63 console-type terminals and with the user's existing computer. The terminals can be local or remote, and can range from slow-speed teletypewriters up to crt's and high-speed line printers. An "interface message processor" (IMP), the component within the TIP that interfaces with the "host" computer, can be acquired separately by those users who don't need direct access to the network through terminal consoles. The IMP's, designed and fabricated by Bolt, Beranek & Newman, use Honeywell computers — the 316 IMP has a 500 kilobit per second throughput. The nodes are knitted together by three transcontinental 50 Kb/second long lines leased from the phone company.

The network transmits a message between any two nodes within 0.1 second. Long messages move at a rate of 80 Kb/second. Transmission downtime has averaged 2.3% for each 50 Kb line; but, because duplicate transmission paths exist between every node pair, the actual downtime rate is under 0.5%. Undetected errors amount to $1:10^{12}$ bits transmitted. Currently, traffic amounts to about 370 kilopackets/day, of which one-half to two-thirds is actual job data; the rest is test data. The job data is increasing rapidly, says Dr. Roberts.

The computers connected to the Arpanet include a large number of PDP-10s and 11s, but IBM, Burroughs, Honeywell, Univac, and XDS are well represented. The IBM complement runs the gamut from an 1800 at Rand Corp., Santa Monica, to a 360/91 at UCLA. The oldest machine is Lincoln Lab's TX-2. (See "Networks: An Introduction," p. 36.)

Many of the applications are highly scientific. Rand, for example, is model-

APPENDIX B



ing weather systems, using the 360/91 at UCLA and a 50 at UC Santa Barbara. The Univ. of Utah is using the 91 at UCLA to study the digital reduction of photographs. "Several people, " says Dr. Roberts, are accessing multiple data bases stored inside time-shared PDP-10s at Bolt, Baranek & Newman in Cambridge, Mass., and at Rand.

A more mundane application involved a computer conversion job at Stanford Research Institute (SRI) several months ago — from an XDS 940 to a PDP-10. SRI rewrote its existing programs, then used the Arpanet to test them on a PDP-10 at the Univ. of Utah. This was done before SRI's new machine was delivered. Within a month after delivery, the physical changeover was completed and the PDP-10 was running on a regular basis. Dr. Roberts estimates that SRI, by using the Arpanet and the Utah computer, shortened its conversion job "almost a year."

Doug Engelbart, who was in charge of this program conversion job, has developed a text-manipulation language, NLS, which ARPA hopes to use as the basis for an interactive "teleconferencing" system. The basic idea is to store speeches, scientific papers, and similar material in a remotely accessible data base so that other researchers can look at it on-line and add their own comments. People-people dialogs are also part of the plan.

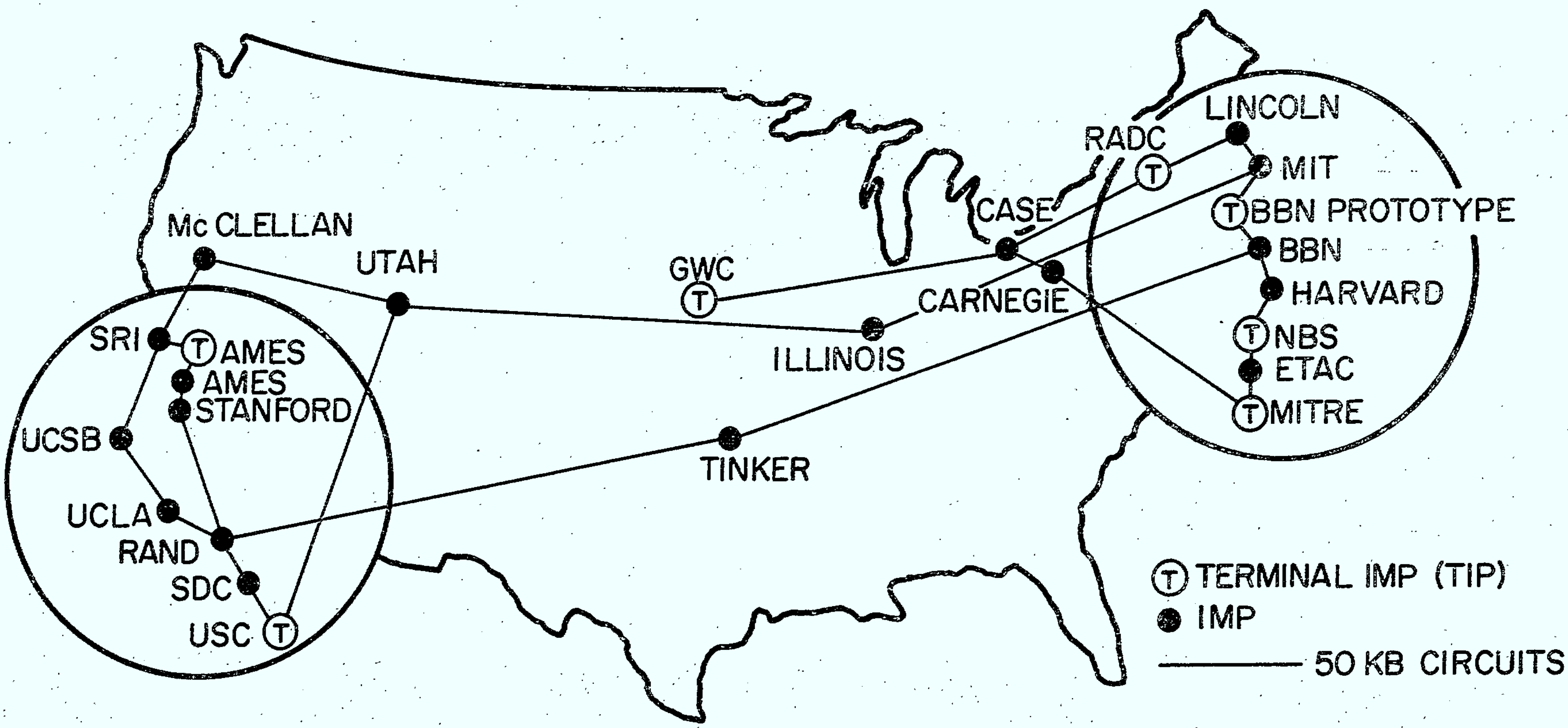
ARPA has several other R&D projects under way or planned. They range from use of multiple computers at dispersed sites to process different parts of a single complex problem like simulated deployment of military forces — to experiments involving new methods of transmitting data via satellite. The Univ. of Hawaii, which will be connected to the Arpanet shortly via satellite, is undertaking the latter project. The university already has developed a data transmission system, using terrestrial broadcast channels, which permits much greater utilization of the bandwidth during peak periods.

### Its commercial future

Regarding the Arpanet's future as a commercial data communications medium, Dr. Roberts believes "there are many possibilities. Visualize a network in which suppliers and their customers are each connected to the network via consoles and/or computers. Stock market information, simulation and modeling services needed by a company's engineering or marketing department, access to specialized statistical data bases, and additional computer support in the form of machine time and/or specialized software are just a few of the services that could be offered. Although these services are now available on-line in many areas, the user frequently needs a different terminal for each and has to learn a number of different communication protocols. Also, once he begins patronizing a given supplier, it's difficult to change.

"The network would eliminate these problems, since each user's terminal would be common to all applications, and a common communications protocol would be employed. Also, assuming more than one supplier of a particular service was accessible through the network, the user could shop around before contracting with any of them and could change suppliers easily later on if a competitor offered better prices or services."

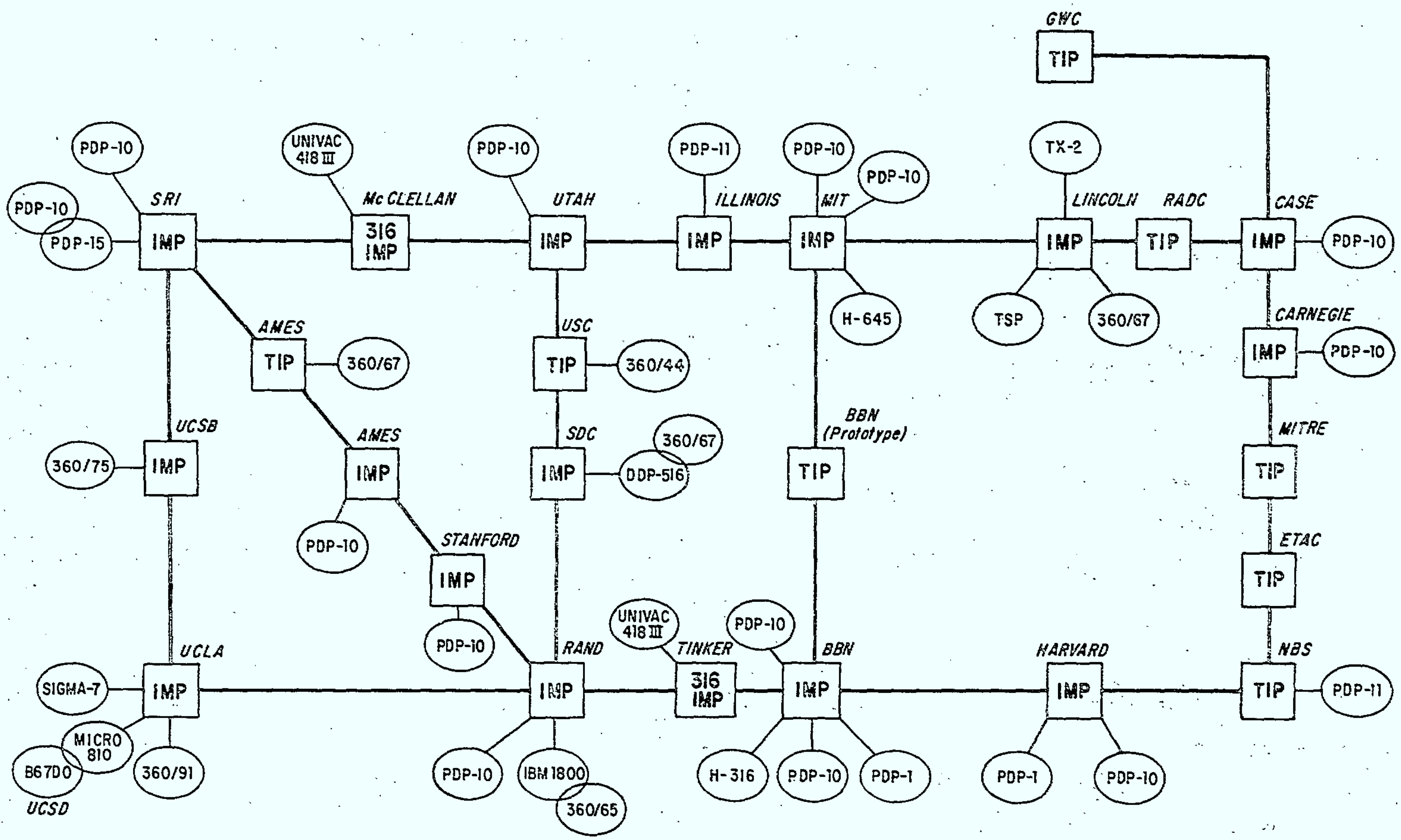
— Phil Hirsch




ARPA NETWORK, GEOGRAPHIC MAP, MARCH 1972

APPENDIX C

# APPENDIX C




ARPA NETWORK, LOGICAL MAP, MARCH 1972

COUNCIL OF ONTARIO UNIVERSITIES

monthly review

CONSEIL DES UNIVERSITÉS DE L'ONTARIO

formerly
Committee of Presidents
of Universities of Ontario/
Comité des Présidents
d'Université de l'Ontario

102 Bloor St. West
Toronto 181, Ontario

Volume 3, Number 3 November, 1971

## WHY A COMPUTER COMMUNICATIONS NETWORK FOR ONTARIO UNIVERSITIES

This statement attempts to review past and present plans for an Ontario Universities Computer Communications Network, including the benefits and impact to be expected from such a Network.

### THE PAST:

In June 1969, the Ontario Government endorsed the decision of the then Committee of Presidents to establish a full-time Computer Coordination Group (now the Office of Computer Coordination - OCC). This decision arose from recommendations contained in the final report of the Joint Ad-Hoc Subcommittee on Regional Computing Centres, formed in 1968 by CPUO and the Committee on University Affairs to study and advise on questions relating to the establishment of a regional computing centre in Ontario. The Joint Subcommittee's final recommendations, which departed from the original notion of setting up a regional computing centre, suggested the desirability of investigating alternative patterns to provide for the universities' computing needs.

### OBJECTIVES:

The objectives of the OCC are: first, to enable the universities to exploit economies of scale which can be derived from their aggregate purchasing power of computing services in such a way as to negate the effects of geography as far as possible; second, to ensure that the universities are kept informed about developments in computing technology; and third, to study and advise on future arrangements for cooperation among the universities in the provision of computer services, and on methods of financing such arrangements.

Most of the activities of the OCC involve cooperation and participation by individual members of the universities in its several Task Forces and Interest Groups. Currently, the major area of activity for the OCC centres on developing an Ontario universities' computer communications network.

Editor: John Butcher

NETWORK ACTIVITIES:

The Council of Ontario Universities gave the Office of Computer Coordination its support in the analysis and development of plans for a computer communications network, as outlined in the report of the Task Force on Data Communications.

The OCC is currently involved in the first phase, which consists of creating a threshold service through the establishment of a minimal working network by linking together a number of universities with data transmission lines, developing an inter-university tariff structure and performing a major network system design. The first two are ongoing activities which are continuously monitored.

The first step toward a major system design, a document entitled "Preliminary Design Specifications for a Computer Communications Network", was completed in July, 1971.

A brief design summary, based on the above report, was sent to agencies which supply products or services, with a view to seeking an evaluation of the design and estimated costs, taking into account existing products and services. The preliminary design specifications will be reviewed and modified in view of the responses by suppliers and independent expert appraisers.

It is expected that the final design specifications, financial plans, management plans and a detailed cost/benefit analysis will be submitted to the Council of Ontario Universities for approval in February 1972.

The proposed network is planned to be a distributed, store-and-forward system, based on Node Control Units (NCUs) located at each computer site. The NCUs will be developed around mini-computers and will use special hardware and software. The primary functions of an NCU will be to handle user terminals and to interface with both a high speed communcations network and large-scale computer systems.

This network will enable a geographically distributed population of user terminals to communicate with a diverse population of large-scale computer systems. Further, the network will be invisible to both the user terminals and the computer systems. With regard to reliability, the network is expected to provide a level of performance as good as, or better than, that attainable using direct point-to-point connections.

In planning a network, a number of other non-technical areas have to be investigated, including inter-university computer charging, long-range planning of computer facilities, standardization and pulication of software documentation, network performance monitoring and tuning, and user support and education. All of these areas are being actively pursued by appropriate task forces and interest groups.

The present and planned network, expressing in tangible form both the independence and the inter-dependence of the universities, should offer significant benefits.

BENEFIT AND IMPACT OF A COMPUTER NETWORK FOR THE ONTARIO UNIVERSITIES:

Dr. H. Brooks, Chairman of the Committee on Science and Public Policy of the National Academy of Science, in an introductory letter to a National Academy of Science report - *Computational Support for Theoretical Chemistry* - wrote the following, which could apply word-for-word:

> *In the field of scientific computing generally, we appear to be in a transition between large-scale general university computing centers, which attempt to serve virtually all the computing needs of a single campus, or nearby groups of campuses, to a system of regional computing centres specialized to the needs of particular groups of disciplines or types of computing. In the last few years the diversity in types of computing services that are needed has increased enormously to the point where a single campus computing center can no longer economically satisfy all its users at the same time. The improvements in data communications and input-output equipment have led to a situation in which economies of scale for a particular class of computing can be better*

*realized by combining the demands of a single class of users on many campuses, rather than those of a variety of users on a single campus. These economies apply not only to hardware, but also to software, programs, and consulting services to a special community of users.*

Dr. C. Smith, Director of Management Services, State of California, in a paper presented at the 1971 Spring Joint Computer Conference said:

> *...we (the State of California) expect the colleges to establish and agree upon the extent to which they truly need EDP (electronic data processing) resources, to determine the best way to use them, and to make certain that they are used in that way. Given the current state of economic reality, we can no longer afford the luxury of each department, or even each campus, acting independently. It has become imperative to adopt a sound and comprehensive approach in deciding what computers will do on campus and how it will be done.*

The need to rationalize computing expenditure while at the same time creating equal opportunities and greater computing power for all university computer users, prompted the proposal for the development of a Computer Communications Network.

The principal aim of the proposed Ontario Universities Computer Communications Network will be to make every local computer resource, including computer hardware, software and data, available to any user on the network. The projected design of the network aims to eliminate the size and distance limitations which currently affect the user communities. The greatest immediate benefits will be to users at the smaller or more remote universities who will, through the network, have available the combined resources of many computing centres as opposed to being limited to the capacity of any single computing facility.

Of wider significance is the fact that the design of the proposed Ontario network would be consistent with, and would be an important building block in, a future national network, such as that recently proposed by the Science Council of Canada.

The economic benefits of computer networks were stated in the Science Council's Report *No. 13*, August 1971, *A Trans-Canada Computer Communications Network:*

> a) *A network will offer a greater variety and a greater number of users, thus.....a host of new computing and information services will become possible.*
>
> b) *Economics of shared resources will become possible. First, copies of certain information files are currently kept permanently in many computers. When these computers can communicate via a network, it will be possible to do away with many of the copies and use remote access to shared copies with a saving in cost. Second, there is considerable surplus computer capacity ... (and a network) could allow a restricted form of load sharing (analogous to load sharing on electric power grids), thus permitting fuller use of our computer capacity.*
>
> c) *Economy of specialization will be encouraged. Specialized computer designs which do certain kinds of work with greatly improved efficiency are being developed. By permitting wider access to computers, the network will allow work to be directed to the most suitable machine, thereby encouraging the use of these specialized and more efficient designs.*
>
> d) *Economies of scale will be encouraged. Within certain limits, it appears that doubling the cost of a computer roughly quadruples its capacity (Grosch's Law). Again, access by computers to wider circles of users will permit this technical fact to be exploited more fully.*

In brief, the major impact of a network will be that the computer user will no longer be subject to the restrictions

APPENDIX D



imposed by the use of any one machine. He will have available to him a spectrum of machines and services, enabling him to make the fullest and most effecient use of his computer expenditure.

* * *

Council of Ontario Universities/
Conseil des Universités de l'Ontario
102 Bloor Street West
Toronto 181, Ontario

Minutes of the 1st Meeting held between the University of Saskatchewan, the University of Waterloo, The Department of Communications (Ottawa), the Computer Coordination Group (Ottawa), Université Laval and l'Université du Québec

2050 West St-Cyrille Boulevard
St-Foy, Quebec 10, P.Q.

Friday, March 19th, 1971, 10.15A.M.

Present:

Messrs. Pierre Ardouin, Comité de coordination d'informatique
Raymond A. Beaudoin, Université du Québec
C.F.A. Beaumont, University of Waterloo
M.P. Brown, Computer Coordination Group, Ottawa
Dr. D. Cowan, University of Waterloo
Dr. J. de Mercado, Communications, Ottawa
Dr. W.F. Forbes, University of Waterloo
Blaine Holmlund, University of Saskatchewan
Dr. D. Morgan, University of Waterloo
Glenn Peardon, University of Saskatchewan
Joseph B. Reid, Université du Québec
Louis P.A. Robichaud, Université Laval
Dr. C.D. Sheppard, Communications, Ottawa
Richard Shirley, Comterm, Montreal
Dr. Larry Symes, University of Saskatchewan

Mr. Beaudoin welcomed the visitors to l'Université du Québec and invited the representatives of the University of Saskatchewan to proceed.

Mr. Peardon and Mr. Holmlund said that the University of Saskatchewan, which now feels isolated, strongly support the concept of a Canadian university computer network. Later they would like to join the ARPA network. The University now has an IBM 360 Model 50 at its Saskatoon campus and a Model 40 at its Regina campus. The Model 40 can now send jobs to the Model 50 by remote job entry. Soon, using a software package designed by Dr. James Fields of Waterloo, they hope to be able to send jobs in either direction. Each computer will then be specialized. WATFIVE will be resident in only one computer. Data banks that will be accessible through the network are the catalog of the Provincial Library in Regina, and the Library of Congress catalog cards on magnetic tape in Saskatoon. The Saskatchewan Government Telephone System is giving support to the network. Two people are working full time on the software.

Dr. Cowan said that Waterloo is well supplied with computing power, with an IBM 360 Model 75, Model 50 and Model 44, and a PDP 11, but they hope to exchange information through a network. They will probably be a node in the network of Ontario universities. They are interested in the technical problems of communication, in linking incompatible computers and in simulation of networks to determine their usefulness. They have a mini-network within the university and for a time they supplied remote computing to Brock University, St. Catharines. Waterloo could devote their Model 50 to the network. They have a technical staff of two full-time, plus four or five co-op students, who can build interfaces. Two or three are now working on interfacing.

Mr. Brown summarized the work of the Computer Co-ordination Group of the Committee of Presidents of the Universities of Ontario which was set up in the fall of 1969. In October 1970 the proposal of the Group for the development of a computer-communications network received the unanimous approval of the 14 universities of the Committee. The Group has studied the ARPA network and the network being developed by the National Physical Laboratory in the United Kingdom. In December 1970 the preliminary analysis of the Group was completed and Mr. Shirley was retained as a technical consultant. A tentative proposal for support was made to the Department of Communications on March 8, 1971. The reception was favorable, but Mr. Brown believed more support from the Department could be expected if the network crossed provincial boundaries. L'Université Laval have said that they are interested in joining the Ontario network but l'Université de Montréal have not yet decided. The Group has already spent $70,000. and its budget from the Committee of Presidents is $140,000. for the year 1971-72. The total funding needed over a two-year period is $1,600,000.

Dr. Forbes, who is a member of the governing committee of the Computer Co-ordination Group, could not predict the reaction of the Committee of Presidents to a cross-border network.

Mr. de Mercado thought that the common carriers, who have 2,000 men working on setting up a Canadian computer network, would welcome a university computer network and might donate the necessary circuits for some months. The Department of Communications could help in this regard. The Department thinks we can do better than ARPA in Canada and is prepared to go to bat for the universities if they can agree among themselves. A proposal from universities across Canada would be politically very opportune and could hardly be rejected by Cabinet. The addition of the University of British Columbia to the group represented here would give critical mass.

Mr. Brown, although confident in the proposal of his group, thought that more than one technology should be explored in Canada so that we should not put all our eggs in one basket.

Mr. Robichaud said a start could be made with sub-networks that could be joined later if designed properly.

Mr. Ardouin said that la Conférence des Recteurs et des Principaux des Universités du Québec set up a Comité de Coordination d'Informatique des Universités du Québec two years ago. On 4 December 1970 le Comité requested a grant of $33,000. from le Ministère des Communications du Québec to support a study of the implications and means of pooling certain of the computing resources of the universities of Quebec. No money has yet been granted for this purpose.

Mr. Beaudoin mentioned that he is the Chairman of the Communications Committee of la Conférence des Recteurs, which is concerned with computing, audio-visual aids, and libraries. L'Université du Québec recently signed an agreement with le Ministère des Communications du Québec to set up a Secrétariat de Communications to study communication questions in Quebec. L'Université du Québec has its own network linking CDC 3150's at Montreal, Trois-Rivières and Chicoutimi and CDC 200 terminals at Varennes and Rimouski to a CDC 6400 at Quebec. If l'Université du Québec is limited to a purely provincial network it will not be able to serve l'Université Laurentienne and l'Université de Moncton. Although le Ministère des Communications may not support a Quebec network they cannot object to a national network.

Dr. de Mercado suggested a meeting in Ottawa on April 27 of representatives of the universites, the Department of Communications, the Department of Trade and Commerce, the National Research Council and the common carriers to develop a plan of action.

Dr. Forbes suggested that only one more university should be brought in at this stage, but that it should be made clear that this is not an exclusive group.

Dr. de Mercado mentioned the University of British Columbia, and Mr. Beaudoin said Dalhousie University would want to join.

Dr. Cowan asked what would be the reaction of the Department to regional networks.

Mr. Reid said that if regional networks are to be established, it is important to agree to standards for the messages to be exchanged between computers so that these regional networks can later be united.

Dr. Morgan agreed that the message format is the key problem. He was not clear what type of network was being discussed - distributed intelligence, star, distributed star, Davies hierarchical. The ARPA network is not capable of allowing a process in one computer to communicate with another process in another multiprogramming computer.

Dr. Forbes said somebody has to write a proposal. Should we link with the proposal of the Committee of Presidents of the Universities of Ontario, or should we create another network ?

Dr. Sheppard asked what the traffic will be on the network.

Mr. Robichaud said a unified, nation-wide network should be conceived first. Then regional networks might develop, but they could be unified later without problems if they followed the national concept.

Mr. Peardon said that a full-time director and staff would be needed to coordinate meetings of the technical people of the participating universities.

Dr. de Mercado stressed the need of a high level group in order to gain support.

Mr. Beaudoin proposed that the Department of Communications should set up a national advisory board to advise the government in distributing funds for the network.

Mr. Holmlund said the network could not be divorced from the Committee on Scientific and Technical Information of the National Research Council. We should ask the government to support two people in each region and the interface equipment; otherwise regional groups will develop. He recommended something more positive than an advisory committee. Compatibility is achieved by initiating something. A central group should be charged with standardization and deciding what interfacing is necessary.

Mr. Brown supported the positive approach, but asked that nothing be done that might hold back the development of the Ontario network.

After some discussion, the meeting agreed on the following points:

1) that a national advisory committee should be set up by the Department of Communications to prepare and to oversee the implementation of a master plan for a trans-Canada university computer network;

2) that a staff of two persons in each region should be provided to work full-time to oversee the development of the network;

3) that the network should:

   a) be a distributed, store-and-forward network;

   b) be transparent to the using computers and terminals;

   c) accept computers of various types;

   d) operate over a variety of lines;

4) that the master plan should take account of networks that exist or are under development, and should endeavor to incorporate them in the national network.

It was also agreed that a representative from each of the organizations present will meet Dr. de Mercado in Ottawa on March 26 to prepare an invitation to a meeting in Ottawa on April 27 to draft a proposal. The invitation will be issued by the Department of Communications to the organizations present, the University of British Columbia, Dalhousie University, the National Research Council, the Department of Industry and Commerce, the Trans-Canada Telephone Network, CN-CP Telecommunications, and Bell Northern Electric Research.

Quebec, March 25th, 1971
JBR/amc

APPENDIX F

2 June 1971

# A POSITION PAPER

# ON THE DEVELOPMENT OF A NATIONAL UNIVERSITY COMPUTING NETWORK

To be submitted to the Department of Communications, Ottawa

## Introduction

The challenge facing Canadians (particularly those concerned with the creation of a nation) in 1871 was to apply state-of-the-art technology to develop a trans-Canada transportation system -- a railway to carry the essential nutrients of a growing nation, people and materiel, to all parts of the country. How this challenge was met is now history. Nonetheless, it gives perspective to what is proposed in this document to note that what was a controversial concept in 1871 became an accepted reality by 1900, and formed the essential main component of a network of regional railway lines blanketing the nation.

One of the challenges facing Canadians in the 1970's is to establish the necessary foundation upon which a state-of-the-art, trans-Canada communications system might be developed to carry information, ideas, symbols of commerce, and national values -- an essential electronic nervous system for a nation to thrive in the 21st century. The importance of this development to the welfare of the nation and to each Canadian has been recognized by the Federal Government and the resources of the nation are being mobilized to meet the challenge. The Department of Communications established a Telecommission in 1969 and reports from studies commissioned are now being released. Related to this, the Science Council of Canada has suggested the development of a TRANS-CANADA COMPUTER NETWORK[1] -- a completely new store-and-forward message switched telecommunications system linking together computers in different physical locations. This system would make it possible for any computer in the network to be used through remote terminals.

This possible development is of particular interest to the universities in Canada who have developed a substantial computing resource both in terms of equipment and trained personnel. Recently, limited financial resources have forced the universities in each province to attempt to rationalize expenditures for computing by developing regional computing networks. The broader goal of evolving a TRANS-CANADA COMPUTER COMMUNICATIONS NETWORK, and also that of developing systems to meet the regional needs of the universities might both benefit from the development of an experimental CANADIAN UNIVERSITY COMPUTING NETWORK.

1. "Instant World- A report on telecommunications in Canada", Information Canada, 1971, page 168.

## Potential Benefits of a Pilot Canadian University Computing Network (CANUNET)

The advantages of developing the pilot national university computing network as a precursor to the possible development of a TRANS-CANADA COMPUTER COMMUNICATIONS NETWORK are many and only a few are listed below.

(1) The development and training of personnel. If Canada is to develop large scale national systems, a supply of highly trained personnel must be available. The universities participating in the development of the experimental network CANUNET can provide this training.

(2) Research and development experience. During the past several years, many theoretical studies of computer networks have been published. In addition, a number of computer communications networks are being developed in the United States and in Britain. However, the need in Canada is to gain practical experience on a broad scale in building and operating computer networks. A pilot network using today's technology and available telecommunication circuits can develop a broadly distributed base of Canadian experience which will be invaluable in the development of computer networks of the future.

(3) A greater variety of hardware, software, and data banks would be made available to a larger number of administrators, researchers, and scholars. For example, a computer network would enable someone in a small university to have available the computing power of the larger centers. Similarly, specialized data banks (such as the proposed NRC bank of scientific and technical information, the legal data banks at Queen's, Montreal and Laval, and the economic data bank at McGill) which cannot be maintained economically at more than one place could be made available to a larger community of scholars by a computer network.

(4) The proposed network would provide the opportunity to study the economics of computer networks. Much is yet to be learned concerning the economics of operating a large-scale network. Computers differ in their suitability for various tasks. If a number of different computers are available in a network, each one might become more specialized in its tasks and a higher degree of efficiency may result. In addition, there would appear to be a possibility of off-loading local peak loads at area centers particularly because of different time zones across the country. Further, complex systems of programs require teams with specialized technical and programming knowledge to maintain and operate them effectively. The transfer of a system of programs from one computer to another of different characteristics is often surprisingly difficult and expensive. Hence, in many cases, it is better to send the data to the programs than to try to operate the programs wherever the data may be.

(5) The opportunity to develop new applications. For example, the network would make it possible to study the feasibility of a Canadian Universities Library System. It would also facilitate inter-university research programs.

A Proposal for Developing the Network

The establishment of a CANADIAN UNIVERSITY COMPUTING NETWORK is a substantial undertaking requiring a great deal of planning and co-ordination. It is, therefore, proposed that the Department of Communications:

(1) Establish a national board consisting of two university members in each participating province, and other members as deemed appropriate by the Department of Communications. This body should be advisory to the Department and its functions should be policy formulation, co-ordination between activities in the different regions and evaluation. The national board may wish to create a small operating group consisting of full-time personnel plus appropriate representation from participating universities.

(2) Appoint a small group to be charged with the task of developing a master plan for the development of a university computing network. This group should visit Canadian universities to make an inventory of not only how these institutions might participate in the development of such a network, but also what needs exist at each institution that might be satisfied by the establishment of a university computing network. The master plan should describe the various phases of the overall project and indicate how each phase might be co-ordinated to realize the ultimate network. Insofar as possible, the master plan should give details of time, personnel, equipment, and costs required for the realization of the system.

The only constraints which should be placed upon the development of a master plan at this time are the following:

(a) the plan must be for a truly national network with a minimum of one campus in each province invited to participate in some aspect of its development;

(b) the plan should accomodate regional diversity and technological alternatives within a framework of objectives, standards and conventions;

(c) the network should be designed to accept various types of computers and to operate over a variety of lines, and

(d) the computer network must be transparent to the using computers and terminals.

(3) After receipt of an approved master plan, ask a number of Canadian universities, with the appropriate experience and representing various geographical regions of Canada, to construct a pilot computer network with the support of the Federal Government. The pilot network might initially comprise only a limited number of universities with additional universities being added as progress permits. Nonetheless, the network (CANUNET) should be considered as a co-operative venture of all the participating provinces and as many universities as possible should be encouraged to become involved in specific research projects that necessarily are a part of this proposed development.

Prepared by: Morris P. Brown, Council of Ontario Universities
Donald D. Cowan, University of Waterloo
Blaine A. Holmlund, University of Saskatchewan
J.M. Kennedy, The University of British Columbia
Joseph B. Reid, Université du Québec

APPENDIX G

# MINUTES

## of the

## FIRST CANUNET MEETING

Meeting held on Wednesday, August 11th, 1971.

Present: See attached list.

Meeting

On behalf of the Department, the Chairman, Mr. D.F. Parkhill thanked everyone for attending the meeting. A short review on the background of the DOC involvement in this project was then presented.

Mr. Parkhill pointed out that the main objective was to prepare a viable plan on which the Cabinet could take action. Hence, the plan would have to include the technical uncertainties, identify the development work, give a description of the cost and the possible sources of funding, in addition to the Federal Government, as well as recommend an organization to build, operate and maintain the network.

Mr. Parkhill suggested that a possibility could be a non-profit organization, capitalized by its membership, and which would manage the network.

The Chairman also noted that some money ($35,000) has been set aside by the University of Quebec to help defray the costs of contributions by the participating universities. He also pointed out that the focal point for this project would be John deMercado, Department of Communications, and Joseph B. Reid, University of Quebec.

The meeting was then opened to discussion.

General Expression of Opinions

Terry Shepard explained that the main objective of the ARPA network had been to foster a community of users. Presently the system consisted of 20 nodes but the ARPA people were now thinking of 200 nodes. Dr. Shepard stated that Larry Roberts, the "father of ARPA" has expressed his willingness to come to Canada and discuss CANUNET.

Morris Brown then gave a short resume of his work on the linking of six universities in the Province of Ontario. He noted that some preliminary design work has been done but no final plan has yet been developed. He also identified two problems that this study could face:-

1) A timing problem, if the Master Plan had to precede a pilot plan;

2) Problems in interfacing a national network with provincial computing networks.

Brown also mentioned, that he envisaged that the Ontario project would involve expenditures of $3,000,000 over 3 years. This would be the cost of developing and manufacturing the node control units, the system software, etc., as well as management and operating costs. He also estimated that it would cost $75,000 to add a node to the network.

Mr. Bonneau talked about the CESIGU (Comité d'élaboration d'un systéme d'informatique et de gestion des universités) project which is studying the possibility of developing a network of Quebec universities. It was started 3 years ago with the idea of establishing a common data bank for all universities. They have developed an information booklet and he promised to send a copy to the Department of Communications. Their network would:-

-- consist of a computing center to supply all coding
-- have a computer to supply all the required statistics and which would:

  - provide for the interchange of information between all universities;
  - allow the possibility of using any centre and its available programs;
  - permit IBM or CDC computers to work together on the same network.

He expressed the hope that by 1972 a final decision concerning the system will be reached so that an operational network could be in existence by next June or July.

This year's budget is $1,000,000 with a staff of 30 to 40 people. Ten million to fifteen million dollars will be required in the next five years, 40% to 50% will be from the actual university budgets and at the end of five years the man power should have grown to two hundred man months. Mr. Bonneau pointed out that the work has been divided among the different universities, for example Laval is considering the financial implication, Quebec the student files, etc. They hope that before Christmas they will have finished defining their objectives and agreed upon the network standards.

Mr. Bonneau also mentioned that they have not yet touched upon the library problem.

Mr. Parkhill pointed out that the National Network we are proposing might not be as technically sophisticated as the CESIGU one.

Dr. Jim Kennedy of UBC stated that no inter university computer committees exist in British Columbia. He also pointed out that since UBC is located so far away from the eastern universities, communication costs are very high. He is anxious to see the introduction of flat rate (i.e., distance independent) tariffs for communication/computer networks. He also mentioned that he had a team of experts on tele-processing software and hardware, who might be committed to this project.

Mrs. Elizabeth Payne of Dalhousie, said that it is becoming very clear that their computing centre would not be capable of supplying the full range of services required by its users. Hence, they would like to be able to access outside facilities. Current communications costs however are a major obstacle. Consequently she fully supported the plea for a distance independent tariff.

Mr. Parkhill said that it might be possible to arrange special tariffs for the universities.

Mr. MacRae discussed some of the National Library's efforts in the area of large scale networks and pointed out that the National Library and the National Science Library are integrating their systems. A budget of $500,000 for this fiscal year has been assigned to these projects.

Dr. Holmlund of Saskatchewan noted that a regional network is being investigated in his Province and that presently Regina and Saskatoon are linked up without charge by the Telephone Co. They have also developed a resource group to meet the operational needs of organizations like small hospitals. In addition they are also linked to the Queen's University legal data bank system.

## Conclusion

It was agreed, that in order to initiate the preparation of the first draft of the Master Plan, that universities should send written submissions of their problems, their ideas of what the network should do and what they could offer to the project in terms of equipment and expertise.

The universities will submit their comments to Mr. Reid by the 10th of September. He will then generate the first draft report in time for the next meeting.

The next meeting will be held on FRIDAY, OCTOBER 1st, 1971.

Meeting adjourned at 3:45 p.m.

René Guindon

R. Guindon,
Secretary.

APPENDIX G

| NAME | | ORGANIZATION |
|---|---|---|
| (1) | D.F. Parkhill | Department of Communications |
| (2) | E.R. Acheson | Government Telecommunications Agency (DOC) |
| (3) | Elizabeth Payne | Dalhousie University |
| (4) | C. Falardeau | Secretary of State Department |
| (5) | D.D. Cowan | University of Waterloo |
| (6) | B.A. Holmlund | University of Saskatchewan |
| (7) | M.P. Brown | Council of Ontario Universities |
| (8) | L.P. Bonneau | C.E.S.I.G.U. - Québec |
| (9) | R. Guindon | Department of Communications |
| (10) | B.A. Bowen | Carleton University |
| (11) | C. Lemyre | University of Ottawa |
| (12) | Louis P.A. Robichaud | Université Laval |
| (13) | Pierre Ardouin | Université Laval - Comité d'Informatique des Universités du Québec |
| (14) | L.F. MacRae | Associate National Librarian |
| (15) | C.D. Shepard | Computer/Communications Task Force / DOC |
| (16) | J.B. Reid | Université du Québec |
| (17) | E.A. Seaman | DOC / Communications Research Centre |
| (18) | W.C. Brown | National Research Council |
| (19) | J.W. Brahan | National Research Council |
| (20) | C.C. Gotlieb | University of Toronto / Council of Ontario Universities |
| (21) | J.M. Kennedy | University of British Columbia |
| (22) | Leon Katz | Science Council of Canada / U. of Sask. |
| (23) | Louis Brunel | Université du Québec |
| (24) | John deMercado | Department of Communications |
| (25) | John Madden | Computer/Communications Task Force - DOC |
| (26) | Judith Wright | Computer/Communications Task Force - DOC |
| (27) | Hans von Baeyer | Computer/Communications Task Force - DOC |
| (28) | Ron Walsh | Dept. Industry, Trade and Commerce. |

université du québec

SIÈGE SOCIAL: 2525, BOULEVARD LAURIER, STE-FOY, QUÉBEC (10e). TÉL.: (418) 651-7220

7 September 1971

Several Canadian universities have expressed an interest in working together to establish an experimental Canadian University Computer Network (CANUNET) and have approached the Department of Communications in this regard. Two meetings have been held to discuss this proposal, one at the Université du Québec, in Québec, on 19 March 1971, and one at the Department of Communications, in Ottawa, on 11 August 1971. A position paper, a copy of which is attached, was prepared by representatives of some of the interested universities.

The Department of Communications has awarded a contract to the Université du Québec to study the feasibility of, and to develop a plan for creating CANUNET. The University has been given the task of forming a study group composed of professionally qualified members to define by 31 March 1972 an inter-university computer network plan, its modalities, its costs and its revenue sources, and to recommend management structures and institutional arrangements.

The contemplated network will consist of high and medium power computers of various makes and it must be open ended and capable of accommodating all Canadian universities. It must be able to function over telecommunication lines of various speeds as expansion and traffic requirements dictate. It should be transparent to user terminals. It should use existing elements as much as possible.

.../2

The project will, so far as possible, comprise the following stages:

(1) Investigation of the present situation and search for documentation.

(2) Development of concepts and guidelines for the network.

(3) Definition of the message format and the telecommunication protocol, including the necessary network control.

(4) Evaluation of alternative institutional arrangements, i.e., management structure for operational network financial arrangements, rules for participation, etc.

(5) Definition of the modalities of the implementation.

(6) Preparation of estimates.

(7) Identification of sources of financing.

The coordinating committee that took place in Ottawa on 11 August proposed that sub-committees be established to work on five aspects of the project:

(1) Communication costs: what will they be and how can they be most equitably shared?

(2) Utilization of network: what are the problems for the user caused by different operating systems, languages, conventions, packages, etc., employed at the various computers of the network? How can these problems be minimized so that users can be persuaded to take advantage of the network.

(3) Coordination between regions: how can the various regional university networks now in the discussion stage be connected to form a Canadian university network.

(4) Network design: the hardware and software specifications of the network elements, and, in particular, the message format and telecommunication protocol.

.../3

(5) Institutional framework: management structure, financial arrangements, rules for participation, etc.

The purpose of this letter is to ask for:

(1) Your comments on this study;

(2) A preliminary statement of your university's possible interest in the development of CANUNET;

(3) The names, appropriate qualifications, and special interests, of individuals at your university who might participate in the work of one or other of the sub-committees listed in the previous paragraph.

(4) The computing resources - hardware, software and data banks - at your university that could be of use to other universities through CANUNET.

The work plans and funding of the sub-committees will be discussed at the next meeting of the coordinating committee on 1 October 1971. Hence, a prompt reply, even though very provisional, would be very much appreciated.

JBR/rc

Joseph B. Reid
Directeur à l'exploitation informatique
Université du Québec

THE UNIVERSITY OF BRITISH COLUMBIA

VANCOUVER 8, CANADA

COMPUTING CENTRE

September 8, 1971.

M. Joseph Reid
Directeur à l'exploitation informatique
Université du Québec
2050 Quest, Boul. St-Cyrille,
Ste-Foy
Québec (10e).

Dear Joe:

I have returned from vacation so close to the September 10 deadline for submissions on CANUNET that there isn't time to prepare a polished document. In fact, I don't know that I have a great deal to add to what you already know of my feelings and the "British Columbia Position" as set out in our correspondence earlier this year and in the minutes of the meeting on August 11. Anyhow, here are a few random thoughts.

Perhaps I am too much influenced by reading Volume 2 of Berton's book on the CPR over the weekend and the Science Council's release on Leon Katz's report yesterday. But I think if we are going to call this a national pilot network we should emphasize the national benefits, and be less pre-occupied with what it will do for this or that university, or this or that scholar in some corner of the country.

There seems to have been a failure to grasp this point on the part of some of the university participants, and this has carried over into the thinking of the Department of Communications in what I regard as an unfortunate way. In this respect, the "Position Paper" scores a good deal better than Doug Parkhill's memorandum of July 12, 1971 to Mr. Pelletier: the latter lists the benefits to the participating universities first, and fails to give enough weight to the potential benefits to Canada.

As a result, we seem to be sliding into a position of approaching DOC as if it was the National Research Council with its mandate to foster university research. This leads to DOC's position, as outlined by Mr. Parkhill, that the federal government cannot make grants to provide educational facilities, but could deal with some consortium if the universities and/or provinces would set one up.

I think we have somehow got the whole thing turned upside down.

Cont'd .... /

M. Joseph Reid, Universite du Quebec. September 8, 1971.

Let's stop trying to fit DOC into the role of benefactor for a number of present or projected regional networks, or into the role of equalizer of regional disparities in available university facilities and concentrate on (1) what advantages a pilot network offers to Canada that would justify its support by DOC; and (2) why the universities are the right group to undertake it. I think most of the points are already lying around in our other documents -- if your first draft comes out along these lines I'll be happy to try to add further points for the next one.

So much for philosophy. I have already indicated that U.B.C. is prepared to contribute some talent and some CPU time to a national system over the next two or three years if it looks as if we are going to get anywhere. I am convinced that within a few years, my duty to the University requires that I get us hooked into some network that will keep U.B.C. computer users at the forefront of modern techniques. I also foresee a need for participation in a library network of some kind.

At present, we have completed our expansion plans to look after the university's needs for the early seventies: our Duplex 360/67 has been running well for nearly a year, and the MTS time-sharing software is in good shape. Thus the group of three or four professionals (with technical assistants) who have been working on new projects -- including the attachment of remote devices and remote computers to our system through a pair of minicomputers attached to the multiplexor channels -- are available for some new major effort. Their main contribution could probably be in the area of design of the actual network and its software protocols.

Good luck in pulling all this stuff together. I'll be seeing you on October 1 -- or will you be in Toronto for the Computer Conference?

Sincerely yours,

Jim Kennedy

JMK:ls

J. M. Kennedy
Director.

## COMMENTS ON THE CANUNET PROJECT

A Preliminary Response from The Alberta Universities Commission Steering Committee on Computer Development

In mid-1970, on the initiative of the Alberta Universities Commission, a Steering Committee representing all post-secondary educational institutions in the Province was set up to study cooperative planned development of computing facilities. The Committee is most interested in the proposed CANUNET project, because availability of computing power outside the Province would directly influence development of computing within the Province, and because post-secondary institutions within the Province could potentially communicate through the network.

Preliminary contact with the University of Alberta, University of Calgary, and University of Lethbridge indicate a high degree of interest in the project, a willingness to participate in its planning, and a willingness to channel input to the Department of Communications through the Universities Commission Committee. It is hoped that this mechanism to provide representation from the Province of Alberta can be officially ratified at an early date.

The position paper of 2 June 1971, prepared by Brown, et al, is a statement consistent with the aims and interest of the Universities Committee at this time.

We are enthusiastic about the CANUNET concept and delighted that the Committee has been financially enabled to undertake the present feasibility study.

A statement from each of the three Alberta Universities together with a list of nominees for the proposed working committees follows.

## The University of Lethbridge

The network will no doubt be of benefit to the large universities in many ways. For the small, emerging institutions its implementation may well prove to be crucial. As the uses of computing in education diversify and the computing facility becomes a substantial and essential part of a university's educational resources, the small university will be quite unable to furnish the capital equipment from its budget alone and will consequently be left far behind in the current advances in the computing art, unless it can share a large-scale system within the university community. Experience here indicates that the size of the computer needed is a function more of the computer application than of the size of the institution. The difference then between the requirements of small and large institutions lies mainly in the amount of use required of any class of computing facility. At Lethbridge, the diversity of desired computing facilities is similar to those experienced at large institutions, although the usage of each class of facility will be relatively smaller.

At the University of Lethbridge, the present technology gap between the small and large institutions is felt keenly. Specialized research in the physical sciences here requires access to computers up to a CDC 7600 class. Computer Aided Instruction experiments of interest to Education faculty await access to a specialized CAI computer facility. Access to the economics data bank at McGill and the law bank at Queens will likely be valuable in the near future. An advanced management information system and library information exchange system would contribute to University operations.

Experience at the University of Lethbridge using the DDD telephone facility and private computer utilities indicates that this route cannot fulfill the requirements. The error rate in transmission is excessive while the services offered by utilities suffer from lack of diversity. There is evidence of "cream skimming" in the choice of services provided. Alternatives to the DDD service, such as private line rental, were economically unacceptable and are clearly wasteful of resources. A rationally organized network appears to be the effective way to close the technology gap.

In considering the degree of participation by the telephone companies, the experience of some western universities may provide useful input.

## The University of Alberta

*Available Equipment*

The Department of Computing Services operates an IBM 360/67 computer using the MTS (Michigan Terminal System) to provide comprehensive time-sharing service to the University and environment. This system could be made available to other institutions if a link were provided through CANUNET.

*Interest in CANUNET*

The following list indicates some uses of the network than can be projected at the present time.

- access to other computing facilities during peak loading periods
- use of other computing facilities for specialized hardware and software applications.
- access to the NRC computer for CAI use
- access to Statistics Canada data bases
- access to National Science Library and National Library CAN/SDI bibliographic data bases
- access to the economics data base at McGill University
- access to the law data base at Queens University
- direct data link to the TRIUMF project at University of British Columbia
- access to administrative data bases at other Universities

*Resources for Network Design*

The Department of Computing Services has an active systems development group whose expertise could be made available at various stages of the project. In addition the Department of Computing Science has a comprehensive research program and a number of faculty members have expressed willingness to participate in the work of the CANUNET committees. The research program within the Department of Computing Science includes information retrieval studies with emphasis upon on-line access to large data banks, optimum methods of access, and data compression techniques. Fundamental studies are also being made of operating systems design.

A list of nominees for the proposed working committees of the CANUNET design project is attached.

# Preliminary Position Paper

on

# Canadian University Computer Network (CANUNET)

by

The University of Calgary

October 27, 1971

# CONTENTS

## I Comment On Study

The interest of The University of Calgary in participating in the CANUNET project is in its potential for resource sharing.

We can envisage three distinct resource types in the following order of priority:

1. Data Bases
2. Software Packages and Operating Systems
3. Hardware Features and Availability

In the context of regional computer networks, hardware availability is the most important factor. In national and international networks data bases and to a lesser degree software availability are the over-riding concerns.

Since CANUNET is national in scope we believe that greater emphasis should be given to data-base and software-package access and less importance be placed on raw computer power which is in most cases adequately available at the regional level. In short more emphasis should be placed on the resource and less on the tool to exploit it. This does not mean that hardware networks at the national level are unimportant.

It would be an extremely significant achievement if CANUNET could make Statistics Canada data-bases as available in Vancouver as they are in Ottawa or if bibliographic data-bases residing in the National Library could be accessed with equal facility in all parts of the country. Funding of CANUNET will have wider support if the emphasis is on the sharing of information rather than computer power.

With respect to significant applications of the network we see the following of special significance in the order cited:

1. Give impetus to use of computers as information processors.

2. Give direction to developments in communication technology.

3. Open new areas of teaching and research.

4. Specialization of use - centres of excellence concept.

5. Standardization, data element dictionaries.

## II Statement Of Interest

Computer Networks have been around for a decade as concepts. The time is right for getting an experimental project up and running so that those of us in the profession can get some hands-on experience in their associated promises and problems.

We do not see networks and the panacea for all our ills. Most honest university computer service heads will confess that their problems locally are indeed sufficient for the day. At the same time, we want to insure that the Department of Computer Services at The University of Calgary participates in any developments in computer technology particularly when there developments relate to universities and are national in scope.

To this end we are prepared to consider contributing such resources (men, money and machines) as the benefits, in time, may justify.

III <u>Sub-Committee Representatives</u>

With respect to The University of Calgary representation on the various sub-committees we make the following suggestions:

1. Computer Costs Sub-Committee - Nowakowsky, E.F., CA; Manager, Department of Administrative Systems.
2. Utilization of Network Sub-Committee - Baecker, H.D., BA MA (Camb) F.B.C.S., Associate Professor and Administrative Officer, Department of Mathematics, Statistics and Computing Science.
3. Coordination between Regional Sub-Committee - Sheehan, B.S., BE (N.S.T.C.), SM (M.I.T.), PhD (Conn.), PEng; Director, Office of Institutional Research.
4. Network Design Sub-Committee - Marx, C.B., B Comm (Alta) MBA (Alta) CDP.
5. Institutional Framework Sub-Committee - Norrie, D.H., BE (Cant.), BSc (Otago), PhD (Adel.); Director of Information Services Division.

Additional resource personnel who have expressed interest in participation include:

1. Hallworth, H.T., BA DipT MA (Lond.), PhD (Birm.), V-BPsS; Professor Department of Educational Psychology, and Academic Co-ordinator, Faculty of Education Computer Applications.
2. Wittig, R.J., Bsc (Calg.); Systems Programmer, Department of Computer Services. Experienced in interfacing computers of various types.
3. Harrison, D.G., BSc (Lond.), ACGI, MICE, PEng; Programmer-Analyst, Department of Computer Services. Experienced in ICES and GENESYS, large application packages in Engineering.

## IV Computer Resources at The University of Calgary

(a) Power:

Our most significant power resource in terms of an actual regional and potential national contribution to a computer network is our CDC 6400 computer which is configurated as follows:

CDC 6400, 65K, 10-peripheral processors, 64 ports for interactive terminals, 16 ports for batch terminals, 4-604 7-track tapes, 1-609 9-track tape, 1-6603 disk, 6-854 disks to be replaced by 2-844 disks in June 1972. On-line storage is currently limited to application programs and small user files. Operates under KRONOS 2.0.

The design of this machine, 10-peripheral processors linked to a central processor, makes it a computer network within itself.

We also have a 360/50 which is dedicated to administrative type use:

IBM/360 Model 50, 512K, 3 channels, 6-2401-V 1600/800 bpi tapes, 10-2314 disk drives, unit record equipment. On-line storage is limited to application programs. Uses OS with MVT option.

A study is under-way to ascertain the feasibility and desirability of adding teleprocessing facilities to this system.

In addition The University of Calgary presently has 2 TSS8's and several other mini-computers some of which now communicate with the CDC 6400.

(b) Software:

Below is a list of the software which could potentially be made available provided interfacing problems could be resolved.

COMPASS (CDC Assembler)
FORTRAN*
BASIC*
TEXT-EDITOR*
ALGOL
COBOL
APT
SIMSCRIPT
SIMULA
PERT
MIMIC
SPSS (Statistical Package for the Social Sciences)
SSP (Scientific Subroutine Package)
ECAP
SCEPTRE**
BMD (UCLA Statistics Packages)**
Dartmouth Basic Programs **
MACRAN**
CalComp Plotting
SORT/MERGE
File Manipulation, Storage and Retrieval Utilities
ICES
GENESYS
TEXT-PAC
KWIC/KWOC
DATAMAN
SIS II
* available on TTY network
** soon to be installed or contemplated for installation

In addition to this list we will be looking at some interactive statistics programs and if we can obtain CDC APL and convert our 360/APL libraries these would also be available.

(c) Data-Bases:

Data-Bases potentially available at The University of Calgary include:

1. Bibliographic Data-Bases (Engineering Index, ERIC, SPINO).
2. Scientific Data-Bases (Cosmic Ray).
3. University Management Data-Bases (Space, Student Information, Data-Base Dictionaries, etc.).

V Computer Resources Elsewhere of Interest to The University of Calgary

Resources which The University of Calgary would like to access through the network are as follows:

1. Access to NRC computer for CAI use.
2. Access to National Science Library and National Library CAN/SDI bibliographic data-bases (eg. Inspec, ISI, Chem. Titles, Chem. Condensates, Medlars, Geo-ref., PIP, BA Previews, Marc)
3. Access to Statistics Canada data-bases.
4. Access to University Administrative data-bases of other Universities.
5. Access to Scientific data-bases of other Universities.

We hope that the views expressed in the Position Papers submitted by the various institutions can be synthesized into a statement of objectives which we can fully endorse.

UNIVERSITY OF SASKATCHEWAN

DEPARTMENT OF
COMPUTATIONAL SCIENCE

SASKATOON, CANADA

September 20, 1971

Mr. Joseph B. Reid
Directeur à l'exploitation informatique
Universite du Québec
2525 Boulevard Laurier
Ste-Foy, Québec

Dear Joe,

The following is in response to your letter of September 7, 1971.

*GENERAL COMMENTS ON THE STUDY*

The University of Saskatchewan supports the project to study the feasibility of, and to develop a plan for the creation of CANUNET. Although the need for such a national network would appear to be minimal at the present time, it is reasonable to suggest that planned or not, such a network will evolve within the next two decades. It is, therefore, important that steps be taken at an early date to ensure that this evolution take place in as orderly a manner as possible.

There is little doubt that a Canadian University Computing Network can be designed and constructed with presently available technology. Indeed, there is probably less uncertainty about the eventual success of the technological aspects of this project than others. A more difficult problem to resolve is how such a network could be operated and managed. The full support and co-operation of the provinces will be required to make the venture a success. Being very realistic, this co-operation will be forthcoming only if there is significant advantage in the national network approach to providing computing power. This, in turn, suggests what is perhaps the most challenging planning problem -- how to pace the design and implementation of the network to correspond with the generation of need. Unless the latter develops, the former (design and implementation) becomes an expensive academic exercise.

The University of Saskatchewan has, during the past two years, attempted to develop a modest network between its two campuses. Many of the arguments now used to support the CANUNET proposal were used in promoting the provincial University computing network. The network has been made operatable, yet very little effective use is being made of the link between the two computing centers. There are many reasons for this situation but the basic reason appears to be that there simply has not been a persuasive enough need. A link is now being established between the University centers and the Provincial Government computing center in Regina. Prospects for realizing effective utilization of this link appear to be better because specific needs associated with each institution have been identified and are to be satisfied by the link.

Based on the Saskatchewan experience, a meaningful demonstration project which will make use of the national computing network should be clearly identified at the outset. It is also clear that work will continue toward the development of a provincial network. It is, therefore, essential that work proceed immediately to establish the critical network parameters and to provide guidelines so that provincial networks will be designed in such a manner that they can be easily integrated into a national system at some future date.

In our view, the plan to be formulated should, therefore, attempt to specify the following:

a) A meaningful national computing application that has the potential for involving a large number of universities. The library system might be an example. Alternatively, universities which are currently restricted by insufficient computing power could be asked to test out the network as a means of overcoming this deficiency.

b) The specifications or basic parameters that should be adopted by all regional networks so that they can be merged into a larger network as the need to do so develops.

c) A series of projects whereby currently developing regional networks could be influenced by federal financial support to adopt the prescribed guidelines suggested in b).

The sub-committees suggested by the co-ordinating committee in Ottawa on August 11, 1971 appear to cover the important areas of concern. It is assumed that these sub-committees are intended to assist in the preparation of a master plan by gathering information for the Univérsite du Québec.

*POSSIBLE PARTICIPATION BY THE UNIVERSITY OF SASKATCHEWAN*

The personnel that we would suggest for the various sub-committees are as follows:

1. Utilization of Network and Co-ordination between Regions -- Mr. Glenn Peardon, Director, University Systems Study Group.
2. Network Design -- Professor D. Cole and Dr. L. Symes.
3. Institutional Framework -- Professor B.A. Holmlund.

Mr. Peardon is responsible for activities at this University which are roughly analagous to those suggested on a broader scale for the sub-committee on Utilization of Network and Co-ordination between Regions.

Professor Cole has been actively engaged in developing local computer networks and gives courses in network design. Dr. Symes is similarly involved.

The computing resources that are available at this University which may be of interest to other universities are those associated with Library System software. For the past four years a system of programs have been developed based on the Library of Congress MARC tapes. Acquisition and cataloguing systems have been developed and are being used by both campuses and are about to be used by the Provincial Library. A Selective Dissemination of Information system has also been developed and is currently being used by the National Library. Circulation systems are currently under design. Interest in these systems has been expressed by two other western universities. The University feels that it could make a significant contribution towards the development of library systems.

APPENDIX H-5



A large scale biological experiment of international interest is being carried out under the name of the MATADOR project. A large amount of data associated with the natural grasslands environment are being collected. Computer models based upon the data are being designed.

In terms of hardware, we view ourselves as a potential "user" of the network as opposed to a supplier of power. If a network were available now, we would probably defer the acquisition of additional computing power for at least one year. A review of equipment bids is currently underway for an up-grade on both campuses by July, 1972.

Yours sincerely,

Blaine

Blaine A. Holmlund
Professor and Head
DEPARTMENT OF COMPUTATIONAL SCIENCE

s.

**The University of Manitoba**

Computer Centre
Winnipeg 19, Manitoba, Canada

September 24, 1971.

Professor J.B. Reid,
Directeur a l'exploitation informatique,
Universite du Quebec,
Siege Social: 2525, Boulevard Laurier,
Ste-Foy, Quebec.

Dear Professor Reid:

On behalf of the University of Manitoba I am replying to your request for information on the setting up of CANUNET. While I have received some feedback from persons in the University, I have not had enough time to formally analyze and prepare these. Thus, this report is, as you suggest, provisional.

Personally, I feel that the concept of a national network is a good one. The actual implementation from both a management and technical point of view is indeed a very interesting project with many complex problems to be solved. However, as stated in the position paper sent to us, the benefits to be received from successful implementation of CANUNET will be of great advantage to computer users.

The University is interested in this project as any sharing of resources can do nothing but help to establish more effective teaching and research programs at a more reasonable cost than if attempted on its own.

I am suggesting three names for possible sub-committee participation. Two of these are people from my staff who I know have the necessary technical and systems background to make a valuable contribution. These persons are Bill Reid and Doug Reimer. Bill could serve on committees 1 or 4, as numbered in your letter and Doug on committee 2: I personally would be interested in committees 2 and 5. Attached find brief resumes.

The following list of resources has been drawn up rather hurriedly but I think it reflects the services and facilities we are offering our users. These could be of interest to other Universities. I have included a short description of some of the data bases that might be of interest.

.../2

HARDWARE (that could be of use to users on a network)

- IBM /360-65, 1 million byte memory, 2311 and 2314 disk storage, 2301 drum storage, tapes, card readers, printers, etc.
- Calcomp Plotter, off-line

SOFTWARE

- Operating System is MVT - HASP, with the standard software available on most IBM machines plus many programs accumulated over the years. We also have some purchased packages such as DYNAMO, 15X, SYMAP, GRID. Again because of time I have not been able to get a complete list.
- Terminal Systems - MUM - an editing and remote job entry facility
  - ITF - BASIC and PL1
  - cafeteria style student terminal (The capabilities can be used remotely.)
- TSO and APL planned for this Fall.

DATA BASES

1. Settlement Studies

   i) Newstart Data
   - Human Resources data from Northern Manitoba
   - also planning to get similar data from Saskatchewan, Alberta, Prince Edward Island, Nova Scotia and New Brunswick

   ii) Census Data 1961 for all of Canada

   iii) Settlement Studies Surveys
   - wide range of socio-economic data from resource frontier communities

   iv) Indian Affairs Data for 1966 - 1969
   - yearly census of treaty Indians of Canada

   v) Welfare Data on North West Territories

2. Health Sciences

   i) Respiratory Survey of Persons in Manitoba (60,000 on file)

   ii) Cardio-Respiratory Lab Data
   - daily hospital reports on pulmonary disease

   iii) Coronary Heart & Diabetic Data for Indians in Northern Manitoba

2. Health Sciences (con't)

   iv) Soil Testing Data, Manitoba

3. Agriculture

   i) Interlake Fact

   - data on population, farm and urban data for Interlake District in Manitoba

   ii) Acreage and Crop Yield Data, Nation Wide

   iii) Department of Transport Weather Data (1900 - present)

   iv) Soil Testing Data, Manitoba

4. Athletics

   i) Physical Fitness Survey of Canadian High School Students in Centennial Fitness Program

5. Earth Sciences

   i) Description of World's Known Mineral Deposits

   ii) Seismographic Records of Trend in Alberta, Saskatchewan and Manitoba

6. Architecture

   i) Set of Slides for Building, Structures and Art

Yours truly,

Paul Dirksen

P.H. Dirksen,
Director,
Computer Services.

PHD:mkt
Attach.

COUNCIL OF ONTARIO UNIVERSITIES
CONSEIL DES UNIVERSITÉS DE L'ONTARIO

102 BLOOR STREET WEST
TORONTO 181, ONTARIO
(416) 920-6865

Office of Computer Coordination

September 24 1971.

Mr J.B. Reid,
Directeur a l'exploitation Informatique,
Université du Québec,
2525 Boulevard Laurier,
Ste-Foy, Québec.

Dear Joe,

Thankyou for your letter of September 7 concerning participation in CANUNET.

I have discussed this with the Sub-Committee on Computer Services, which is made up of the Directors of Computing Centres in the Ontario universities. At their September 14 meeting, the Directors agreed that the Office of Computer Coordination should perform the liaison role with CANUNET. I understand the Chairman, Mr G.T.Lake, will be contacting you soon in this regard.

I believe you are generally aware of the viewpoint held by the C ouncil of Ontario Universities concerning CANUNET. This can be summarised as follows:

- Support in principle.
- A need to act quickly.
- Concern that CANUNET incorporate more than one kind of network design.

The following names of qualified individuals are offered as participants in the work of the Sub-Committees.

-over-

c.c. Mr G.T.Lake.
Director, Computing Centre,
Univ. of Western Ontario,
LONDON, Ont.

| SUB-COMMITTEE. | PARTICIPANT. | QUALIFICATIONS. |
|---|---|---|
| 1. Communications Costs. | J.Massouras, Mgr., Operations, Computing Centre, Un. of Ottawa. | -responsibilities include the operation of a data communications network linking Queen's, Ottawa, York, Saskatchewan and British Columbia.<br>-participation in cost studies for Task Force on Data Communications. |
| 2. Utilization of Network. | D.S.Macey, Associate Director, Planning, Computing Centre, York University. | -responsibilities include the planning of future facilities to meet the needs of users. |
| 3. Co-ordination between regions. | M.P.Brown, Director, Office of Computer Coordination, Council of Ont. Universities. | -planning and implementation of Ontario network. |
| 4. Network Design. | N.Housley, Network Systems Engineer, Office of Computer Coordination, Council of Ont. Universities. | -technical design of Ontario network. |
| 5. Institutional Framework. | M.P.Brown. | |

It is not possible, at this time, to give a comprehensive answer to your fourth question concerning resources in the area of hardware, software and data banks.

A joint program of data gathering has been initiated by the Ontario Universities and it is likely that a useful summary will be made available to you when it is compiled.

I look forward to working with you on CANUNET.

Yours truly,

Maurice

M. P. Brown,
Director.

mal.

The University of Western Ontario, London 72, Canada

Computing Centre

September 17, 1971

Mr. Joseph B. Reid,
Directeur à l'exploitation informatique,
Université du Québec,
2525 Boulevard Laurier
Ste. Foy, Quebec

Dear Mr. Reid:

Your letter of September 7, 1971 concerning CANUNET was discussed at the September 14 meeting of the Committee on Computer Services of the Council of Ontario Universities (COU). As chairman of the Committee I have been asked to reply on behalf of the 14 provincially assisted universities in Ontario.

We are extremely interested in participating in any computer communications activity involving universities in Canada. The universities in Ontario have been actively exploring the possibilities of a network to serve our own needs for over a year now. We actively support the proposal for an Ontario universities network currently being developed by the Office of Computer Coordination of COU and plan to work closely with them in this area. It is our understanding that Mr. Maurice Brown, Director of the Office of Computer Coordination, will be cooperating with CANUNET to the fullest extent possible and we feel that any role the universities in Ontario might play in CANUNET should be coordinated through the Office of Computer Coordination. To this end Mr. Brown has been requested to reply on our behalf to the detailed questions raised in your letter.

Further, we endorse the concept of a "National Spine" coordinated by the Federal Government to link regional networks across Canada, as outlined in the recent report by the Science Council on this subject. We believe that development along this line will permit a rapid but orderly growth of computer communications in Canada and at the same time permit a variety of techniques to be explored to meet the variations of needs apparent in the various geographical regions and functional groupings.

......2

Mr. Reid

Thank you for your invitation to participate in the development of CANUNET.

Yours truly,

G. T. Lake

GTL/ft

G. T. Lake, Chairman,
Committee on Computer Services
Council of Ontario Universities

c.c. Dr. J. B. Macdonald, Executive Director, Council of Ontario Universities

Dr. W. F. Forbes, Chairman, Board for the Office of Computer Coordination

Mr. M. Brown, Director, Office of Computer Coordination COU

SUBMISSION ON THE DEVELOPMENT OF A NATIONAL UNIVERSITIES COMPUTING NETWORK (CANUNET)

This paper is a submission to Mr. J.B. Reid, University of Quebec on a master plan for the CANUNET Computer Network. These are preliminary views of a number of people at the University of Waterloo on:

1) Motivation for constructing a Canadian Universities Computer Network.
2) Present level of computer research being conducted at the University of Waterloo.
3) The resources of the University of Waterloo which might be available either for use in the network or in order to support research projects associated with the network or in some consulting capacity.
4) The areas that need to be studied before a network is started or experiments that should be conducted on a prototype computer network.

These four points are discussed in more detail in the next few paragraphs.

WHY A COMPUTER NETWORK?

A computer network is usually considered to be a collection of independent computer systems which are interconnected so as to permit resource sharing between any pair of systems.

Thus it is possible, most importantly, for terminal users at a remote location to use a computer as though they were in physical proximity (terminal to computer connection). It is also possible for one computer to access data, programs or hardware devices resident in another computer (computer to computer connection). We feel that the first kind of connection will be prevalent for the first few years of network operation. The utlimate goal of any computer network is to make resources local to one computer available to users of any computer in the network without a degradation in performance. It is not clear if we can achieve this goal and still maintain reasonable cost/price performance; however, before this stage is reached, a computer network can provide many useful facilities.

BENEFITS TO THE UNIVERSITY OF WATERLOO

The Canadian Universities Computer Network (CANUNET) would have several benefits. In particular, the University of Waterloo is interested for the following reasons:

(i) The CANUNET project will provide a focus for some of our research projects. In particular, we feel that we can contribute extensively in the software and hardware areas of computer networks. We also can provide some contribution in economic and policy development aspects of the network as two faculty members have spent considerable time in this area during the past year.

(ii) Development of a computer network will provide a basis for the training of large numbers of personnel in computing and communications, something which will definitely be of benefit to the universities and to the country at large.

(iii) A computer network will probably provide closer liaison between universities and the computing and communications industries. Such association cannot help but be of benefit to the country as a whole and the universities in particular.

(iv) In the long term, when a network is operational, hopefully,

  (a) a large variety of hardware devices, software and data banks will be available to various classes of computer users.

  (b) rationalization of computing resources will occur owing to time differences and availability of different resources around the country.

(v) CANUNET will be an experimental prototype which will allow testing of many of the ideas associated with future public networks.

As well as these direct benefits to the University of Waterloo, computer networks with their instantaneous transmission of data could provide Canada with a strong force for national unity.

RESEARCH PROJECTS AT THE UNIVERSITY OF WATERLOO RELATED TO COMPUTER COMMUNICATIONS NETWORKS:

The Computer Science and Electrical Engineering Departments at the University of Waterloo are both quite active in research projects, associated with computer communications networks. Recently, the groups in these two departments with interest in this area have established a joint computer communications research laboratory. A specific goal of this laboratory is the construction of a prototype local area computer network (PLAN) which will allow us to investigate the many problems inherent in connection of computers via telecommunications lines. The members of the Computer Science Department are specifically interested in the overall design of such a network and the hardware and software at each node. The research personnel in Electrical Engineering are primarily interested in developing communications media which will provide for efficient transmission between computers. As well as the laboratory, a number of other research projects are being conducted. There is a study currently underway on the utilization of networks, i.e. how do we actually use a network once the hardware is operational. Some work is also being performed on operating systems for distributed networks. Hopefully, operating systems can be designed which will be able to communicate as though the operating system in each computer were part of an entire network operating system. Significant work is also going on in measurement of computer system and computer networks. Some research both on actual measurement of machines and in construction of models of these measurements has been conducted over the last two years. As well, a preliminary software package has been prepared which will allow elementary simulation of some network configurations.

RESOURCES AVAILABLE AT THE UNIVERSITY OF WATERLOO FOR NETWORK USAGE

The following few paragraphs describe in a general way, the resources which are being directed to network research at the University of Waterloo.

Faculty:

At present, we have five faculty members in Computer Science and three or four in Electrical Engineering who can devote up to an average of fifty per cent of their research time towards network research. As well, there exist a number of people in our Computing Centre who are knowledgeable in the area of computers and communications and who could be called upon from time to time to participate in discussions and to offer advice based on experiencc. A short curriculum vitae for each of the people in Computer Science is in Appendix A. Time constraints have prevented us from determining the interests of the members in thc Electrical Engineering Department and Computing Centre.

Support Staff:

There are also two or three technical staff members who work in such areas as logic design and programming. These would probably be available on a part-time basis.

Equipment:

The University of Waterloo's IBM 360/75 Computer is available for computational work associated with network research. The IBM 360/50 of the Faculty of Mathematics is available for more fundamental research and development in computer systems and may be used for research on a stand-alone basis. It may also be available for connection to a computer network and has 1.5 megabyte of core and a shared 2314 disc file. Presently, the Faculty of Mathematics also owns a programmable communications controller which may simplify connection of these machines to a network. There are also a number of mini-computers which will be devoted to computer network research. It is intended to use some PDP-11's to build a prototype local area network. There are also, of course, a number of other pieces of equipment to support research in networks and these will be in the laboratory which was mentioned earlier.

AREAS FOR STUDY

There are a large number of areas which should be examined before, during and after the construction of a Canadian Universities Computer Network. Areas for study are not necessarily presented in any order of priority.

Communications: Costs, (distance independent, dependent on message length) method of communications (i.e. common carriers, satellite, land lines and exotic media).

Utilization: What capabilities can a network realize economically; how can we use facilities provided by the network; how can a user effectively use facilities remote from his own installation (interesting problem here).

User Support: Even when a user can get his terminal connected to a system running on a remote computer, there are many barriers due to physical isolation. How does the user find out how to begin? What about incomprehensible messages and responses? At the very least, the network should provide voice as well as data links, and some very practical research needs to be done.

Network Management:

- planning and managing the research and development prior to network construction;
- planning and managing network construction;
- managing the network when it is operational;
- accounting, i.e. charging for network services;
- orderly plan for expansion of the network to more universities.

Network Standards:

- message protocols
- systems compatibility

NETWORK DESIGN:

- what type of network design should we use (ARPA, Davies, Farber, Fraser or other).

SOURCES OF SUPPORT:

- funding;
- provision of communications facilities;
- identification of network projects already initiated;
- preparation of estimates.

POLITICAL SUPPORT: ( under guidance of Department of Communications)

- identification of parties interested in network (Science Council, Ministry of State for Science and Technology, Provincial Government Departments and agencies).
- meetings to discuss plans.

PRESENT NETWORKS:

- obtain background on other network projects;
- obtain inside information on successes and failures.

YORK UNIVERSITY

4700 KEELE STREET, DOWNSVIEW 463, ONTARIO

Steacie Science Library,
Room 030A.
September 27th, 1971.

Mr. Joseph B. Reid,
Directeur a l'exploitation Informatique,
Universite du Quebec,
2525 Boulevard Laurier,
Ste-Foy, Quebec.

Dear Mr. Reid:

Thank you for your correspondence of September 7th, 1971, re York University participation in CANUNET.

York University is an advocate of the 'network' concept of computing and in this regard have cooperated wholeheartedly with the work of the Sub-Committee on Computer Services of Ontario Universities and with Mr. M. P. Brown of the Office of Computer Coordination of the Council of Ontario Universities. As you are aware, the universities in Ontario have agreed that liaison with CANUNET would be performed by the Office of Computer Coordination and we offer you our full support under this arrangement.

With reference to Mr. M. P. Brown's correspondence with you on September 24th, 1971, concerning participation on the Sub-Committees, I would like to endorse his offer of my services on the Sub-Committee for 'utilization of the network'. I have participated on Task Forces in computer charging, cooperative software libraries, cooperative user training programs, data communications, systems performance measurement and also in the development of a proposal to establish an Ontario university computer 'network'. My particular interest has been the realm of the 'user' and to this end I have maintained communication with those planning user functions in the ARPA and MERIT networks in the U.S.A. and would envision this providing us with a basis for assessing like problems in CANUNET.

continued.................

Mr. Joseph B. Reid,
Universite du Quebec.


September 27th, 1971.

Computing resources as described in your letter are unfortunately incomplete and unavailable at this time but will be forthcoming in a joint program initiated by the universities in Ontario.

I wish you every success with CANUNET and look forward with great interest to participating in its evolution.

Yours truly,

DAVID S. MACEY,
Manager of Planning,
Computer Services.

DSM/lb

UNIVERSITY OF TORONTO *Toronto 181, Canada*

DEPARTMENT OF COMPUTER SCIENCE

September 17th, 1971.

Mr. Joseph B. Reid
Directeur à l'exploitation informatique
Université du Québec
2525, Boulevard Laurier
Ste-Foy, Qué.

Dear Mr. Reid:

I have discussed your letter of September 7th, inviting comments from the University of Toronto on the CANUNET project, with Dr. John C. Wilson, the Director of the University of Toronto Computer Centre. We are of course extremely interested in participating in any computer network which might evolve for use by Canadian universities.

Dr. Wilson points out that we are actively supporting the proposal for an Ontario network presently being generated by the Office of Computer Coordination of the Council of Ontario Universities. It is our understanding that Mr. Brown, the Director of the Office of Computer Coordination, will be cooperating with the CANUNET group to the fullest extent possible, and that he is preparing a detailed reply to the questions in your letter. Dr. Wilson and I feel that in the interest of simplicity any role the University of Toronto undertakes in CANUNET should be through the Office of Computer Coordination (OCC). We plan to have members of the University of Toronto Computer Centre work closely with OCC, and would expect that any answers given by OCC to your questions will represent our views as well.

Yours sincerely,

C. C. Gotlieb
Professor

CCG:mc

cc: Dr. J. C. Wilson
Mr. Maurice P. Brown

APPENDIX H-12

# CARLETON UNIVERSITY

OTTAWA 1, CANADA

COMPUTER CENTRE

September 22, 1971.

Mr. Joseph B. Reid,
Directeur à l'exploitation
informatique,
Université du Québec,
P.Q.

Dear Mr. Reid:

Thank you for your letter dated September 7, 1971, asking for our comments on our interests in the development of CANUNET.

We are very interested in such a network, or for that matter, any inter-university computer network. We are currently active in this field and are doing systems work with special communication processors, towards making such a network possible.

This work is being done in co-operation with the Office of Computer Co-ordination. This office is a permanently staffed group reporting to the Council of Ontario Universities. The Director of this group, Mr. Maurice Brown, knows of our work and we are working through his office towards such networks.

I believe it would be best if we would co-ordinate any further network activity between ourselves and you, through the offices of Mr. Maurice Brown. We do not wish to duplicate any work or cause any possible confusion by being represented on too many different committees all working towards the same end.

Thank you for your interest in asking for our comments.

Yours sincerely,

W. Dietiker,
Director,
Computing & Data Processing.

cc. Mr. Maurice Brown,
Mr. George Lake.

McGILL UNIVERSITY
805 SHERBROOKE ST. WEST
MONTREAL 110, QUEBEC, CANADA

COMPUTING CENTRE
(514) 392-5974

September 28, 1971.

Universite du Quebec
Siege Social
2525, Boulevard Laurier
Ste-Foy, Quebec (10e)

Attention: Joseph B. Reid
Directeur a l'exploitation informatique

Dear Mr. Reid,

Thank you for your letter of 7 September 1971 regarding CANUNET.

Sometime ago McGill was invited to participate in a computer network under development in the U.S. I declined since we can efficiently and economically service most of our potential computer users, and could not justify the high initial cost and overhead associated with developing and maintaining such a network. We, in common with most other Canadian universities, already have the facility of accessing specialised software and data banks at other institutions. About six other universities are currently accessing the financial and economic programs and data at McGill through typewriter-like devices using the Bell dial network.

We are pleased to make our computer facilities available to all users, since it can be clearly demonstrated that this enables us to offer a wider variety of services and at a more economical cost than would be possible if our resources were restricted to the McGill community.

I would be willing to participate with the sub-commitees concerned with the management and/or user aspects of the network, and could provide a member of my staff for the sub-commitee on network design if so desired.

Yours truly,

W.D. Thorpe
Director
Computing Centre

WDT/sam

Bishop's University
Lennoxville, Que.

FACULTY OF SCIENCE - Department of Computer Science

September 16, 1971

Mr. Joseph B. Reid
Directeur à l'exploitation
informatique
Université du Québec
2525 Boulevard Laurier
Ste-Foy, Québec

Dear Mr. Reid:

Thank you for your letter describing the plans for CANUNET. Certainly, we are interested as potential users of the system. However, we will be unable to assist in the study, since we have no professional computer scientist here. Our computing resources are also unlikely to be of use to the network - an IBM 1130 - neither do we yet have any data banks of interest to others.

I would be pleased to receive any reports which emanate from the study.

Yours sincerely,

J.L. Redding
Chairman
Computer Centre
Committee

JLR/mel

APICS Computer Sub-Committee

Mrs. E. Payne
Director, Computer Centre
Killam Library
Dalhousie University
Halifax, Nova Scotia

October 18, 1971

Mr. Joe Reid
Directeur à l'exploitation informatique
Université du Québec
Siège Social: 2525
Boulevard Laurier
Ste.-Foy, Québec

Dear Mr. Reid

I am writing to you as secretary of APICS (Atlantic Provinces Inter-University Committee on the Sciences) Computer Sub-Committee.

The Computer Sub-Committee (see attached membership list) has asked that you be informed of their interest in CANUNET and that they support in principle the position paper submitted by yourself to the Department of Communications.

Yours sincerely

(Mrs.) Elizabeth Payne
Secretary

jd

## APICS COMPUTER SUB-COMMITTEE MEMBERSHIP

| Institution | Member |
|---|---|
| Acadia University | Dr. D.A. Bonyun |
| Dalhousie Medical School | Dr. P. Rautaharju |
| Dalhousie University | Mrs. E. Payne |
| Memorial University of Newfoundland | Professor A.N. Betz |
| Mount Allison University | Mr. K. Hayward |
| Mount St. Vincent University | Mrs. Maureen Lyle |
| Nova Scotia Agricultural College | Professor S. Smith |
| Nova Scotia Technical College | Dr. J.H. Ahrens |
| St. Francis Xavier University | Dr. R. MacKinnon |
| St. Francis Xavier University, Computer Centre | Dr. A. MacEachern |
| St. Mary's University | Mr. M. Tingley |
| Universite de Moncton | M. R. Cyr |
| University of New Brunswick | Professor W.D. Wasson |
| | Dr. D.M. Fellows |
| University of Prince Edward Island | Dr. C. Dawson |
| University of Prince Edward Island, Computer Centre | Professor J. Mainwaring |
| University of the West Indies, Mona, Kingston, Jamaica | Professor R.C. Reid |
| Bedford Institute, Atlantic Oceanographic Laboratory | Dr. C.D. Maunsell |
| | Dr. M. Darwood |
| Bedford Institute, Marine Ecology Laboratory | Dr. L.M. Dickie |
| C.D.A. Station, Charlottetown | Dr. Carl Willis |
| C.D.A. Station, Kentville | |
| Defence Research Establishment Atlantic | Dr. A. Mohammed |
| Fisheries Research Board, St. Andrews, N.B. | Dr. A. Sreedharan |
| National Research Council, Halifax | Dr. A.G. McInnes |
| N.S. Research Foundation, Dartmouth, N.S. | Professor T. Nickerson |
| Provincial Government of Nova Scotia, Halifax | Mr. H. Fairclough |
| AIRI (Atlantic Industrial Research Institute) | Dr. T. Gray |
| **Special Members** | |
| Nova Scotia Institute of Technology | Mr. Bernard Green |
| | Mr. George Williams |
| Newfoundland Technical College | Mr. Gus Collins |
| New Brunswick Institute of Technology | |
| Nova Scotia Eastern Institute of Technology | Mr. J. Adams |
| Holland College of Prince Edward Island | |

THE UNIVERSITY OF NEW BRUNSWICK
FREDERICTON, N.B.
CANADA

COMPUTING CENTRE
SIR EDMUND HEAD HALL

TELEPHONE: (506) 475-9471

September 21, 1971

Professor Joseph B. Reid
Directeur à l'exploitation
informatique
Université du Québec
2525, Boulevard Laurier
STE-FOY, QUEBEC

Dear Professor Reid:

Your letter of September 7, 1971 requested comments on the proposed CANUNET. In general, I am in agreement with the June 2/71 position paper presented to the Department of Communications. I believe that CANUNET would provide invaluable experience and training for the design and operation of a full-fledged Trans-Canada Computer Communications Network.

The University of New Brunswick is now offering, via a communications network, computational services to four other centres in the Atlantic region involving six post-secondary educational institutions. We have also been involved with the development of a Land-Titles data-bank in co-operation with the Provincial Department of Natural Resources. Therefore, we are aware of some of the technical and management difficulties involved.

Tentatively, I suggest the following persons for possible participation in the work of the proposed sub-committees:

| | | |
|---|---|---|
| Utilization of Network<br>Network Design | } -- | John DeDourek<br>Barton Claus |
| Communication Costs<br>Co-ordination between Regions | } -- | Hans Larsen<br>W. Dana Wasson (myself) |

Professor DeDourek, a Computer Science graduate of Case Western Reserve University, has worked with Cases' system for a number of years. Professor Claus is Systems Director of our Computing Centre, while Professor Larsen is an economist with broad interests in computers and data-banks.

Sincerely yours,

W. Dana Wasson

W. Dana Wasson, Director,
Computing Centre

WDW/sc

SERVICE D'INFORMATIQUE

UNIVERSITÉ DE MONCTON

MONCTON, NOUVEAU-BRUNSWICK, CANADA

le 15 septembre, 1971

M. Joseph B. Reid
Directeur à l'exploitation
informatique
Université du Québec
2525, boulevard Laurier
Ste-Foy, Québec

Cher M. Reid,

C'est avec un très grand intérêt que j'ai lu votre lettre du 7 septembre. La téléinformatique m'interesse pour plusieurs raisons. La principale est une raison d'économie.

A cause de notre position économique désavantageuse nous, à l'Université de Moncton, avons constaté que la seule façon viable pour nous de faire de l'informatique c'est par télécommunication.

Depuis plus d'un an nous sommes raccrochés - par un unité IBM 2780 (2400 BPS) - à un réseau de communication provincial centré sur un ordinateur IBM S/360 MOD.50. L'objectif principal de ce réseau est de donner un service d'ordinateurs au secteur sous-gradué de l'engeignement universitaire.

Nous sommes donc en mesure de juger des bienfaits de la téléinformatique, mais nous constatons aussi les lacunes d'un réseau aussi restreint que le nôtre.

Quant à contribuer à CANUNET nous sommes prêts à le faire dans les limites de nos ressources. Ces ressources sont:

(a) Equipement -
- un ordinateur IBM 1620 MOD I, 40K, deux disques
- un unité de télécommunication IBM 2780

(b) Personnel -
- Directeur
- Secrétaire
- Opératrice

.../2

Il est à peu près certain que d'ici peu ces ressources s'accroîtront. Ainsi nous serons plus en mesure d'apporter une contribution réèlle à CANUNET.

Bien à vous,

J. Robert Cyr
Directeur du Centre de Calcul

JRC:gd

MOUNT ALLISON UNIVERSITY
SACKVILLE, NEW BRUNSWICK
CANADA

September 29, 1971

Prof. Joseph B. Reid
Directeur a L'exploitation Informatique
Universite du Quebec
2525 Boulevard Laurier
Ste-Foy, Quebec

Dear Prof. Reid:

In reply to your letter of 7 September 1971, the items below correspond to the numbered queries on page 3:

1. No comment, except that we are in favour of the idea of the study.

2. We are interested in the development of CANUNET.

3. Mr. K.G. Hayward, Systems Analyst, Computer Centre, Mount Allison University; B.Sc. (Honours Mathematics); Univ. of Windsor; 3 years experience as systems programmer on a 16K IBM 1130; the latter year involved in the installation, utilization and modification of a Remote Job Entry (HASP) system to a 360/50. Interests lie in the area of computer network design, as related to the small computer terminal.

4. Our present configuration includes the capability of communicating with other computers.

Thank you for your attention.

Yours very truly,

G. W. Hannah
Ass't Director
Computer Centre

GWH/dw

COMPUTING CENTRE

Acadia University

WOLFVILLE, NOVA SCOTIA

October 1, 1971

Mr. Joseph B. Reid
Directeur à l'exploitation informatique
Université du Québec
Boulevard Laurier
Ste-Foy, Québec

Dear Mr. Reid:

Thank you for your letter of September 7. I am sorry to be so long in replying but your letter got lost, I'm afraid, in a pile of other papers.

Acadia University is particularly interested in your work. Because we are (a) small and (b) remote, we have particular problems in the area of computing. We have had experience using the communications facilities of the telephone network in working to Montreal, Ottawa, Quebec City, and Halifax.

There is one side of the picture which I personally feel should not go unconsidered. This is the possibility of using a computer communications network at least part of the time for voice communications between members of various universities. It is my contention that it is at least as important for human beings to be able to talk to one another across this vast land as it is for computers. I believe the causes of Canadian identity and unity would be served if it were possible for people in one part of the country to talk to people in distant parts of the country for about the same cost as to talk to the next town. A place to begin this is between universities -- the money spent on travel to Learned Societies might be better spent allowing telephone calls throughout the year. If a computer network is indeed established with something approximating equalized cost for unequal distance, then I believe that provision should be made for voice as well.

. . . page 2

The only people at Acadia who could make any contribution to your project are Professor S. Deleu and myself, both in the Department of Computer Science. Professor Deleu's specialty is hardware.

Please accept once more my apologies for being so tardy. I wish you every success.

Yours truly,

David A. Bonyun
Director

DAB:lls

DALHOUSIE UNIVERSITY
HALIFAX, N. S.

COMPUTER CENTRE

September 9, 1971

Mr. Joseph B. Reid
Directeur a l'exploitation informatique
Boulevard Laurier
Ste-Foy, Quebec (10e)

Dear Mr. Reid:

Following is the submission from Dalhousie to be used for writing the draft for CANUNET.

It is suggested that the best arguments that can be made for developing such a network are: (1) to ascertain if current communications technology is adequate; (2) to determine if such a network could become of practical value in terms of cost and performance; (3) to promote the development of a set of standards for hardware and software systems; (4) to help in determining guidelines which will bring about the maturation and ordered growth of the Canadian computer industry.

Dalhousie is interested in participating in such a network for the above general reasons. However, specific to Dalhousie are a number of benefits which could be realized by the network. They are the increased availability of the following services:

(a) machine systems
(b) personnel specialized in areas of computer use and techniques
(c) research
(d) data banks
(e) software systems

These benefits will not be limited to Dalhousie because some other Canadian universities find it difficult to supply a full range of services to users.

The contribution which Dalhousie can make is basically twofold. Firstly, Dalhousie currently has in operation a province-wide computer network. By November 1971, all but one of the universities in Nova Scotia will be accessing computer facilities at Dalhousie via telephone links. In addition, on-line services are being provided to federal and provincially subsidized research institutes in the area. A computer education program is provided to local high schools and some private businesses acquire computer services from Dalhousie. This network has been established on a completely voluntary basis with no special funding. Cooperation resulted when it was determined that better service at less cost per computing unit would become available. The network consists of C.D.C. and I.B.M. computers together with C.D.C., TWX, and Olivetti terminals.

Secondly, the network channels into one centre the expertise of a large research activity in the area. Halifax is probably second only to Ottawa in the extent of research activity located in one area of the country. In particular, marine research, chemical research, and electrocardiac research applications which are highly developed in this area depend on computer facilities available at Dalhousie.

Dalhousie cooperated with the University of Quebec in submitting the position paper to the Department of Communications. It agrees that the paper may stand as an outline for technical considerations of the network for presentation to the Cabinet. Dalhousie would like to point out however, that it is of the opinion that no university should be excluded from participation should it wish to do so.

Sincerely yours,

Elizabeth Payne

(Mrs.) Elizabeth Payne
Director

/an

ST. FRANCIS XAVIER UNIVERSITY
ANTIGONISH, NOVA SCOTIA

COMPUTATION CENTRE

24 September, 1971

Professor Joseph B. Reid
Directeur à l'Exploration Informatique
Université du Québec
2525 Boulevard Laurier
Ste-Foy, P. Québec.

Dear Professor Reid:

I would like to respond to your letter of 7 September, 1971, and comment on the issues you raise.

As a small university with limited computer facilities, our general reaction to CANUNET as presented in your letter is very favorable. We believe that CANUNET could be an exciting solution to the problem of providing adequate computer facilities to a small university, expecially, those in the Atlantic Provinces, where our universities have limited financial resources.

For the past year, we have used our IBM-1130 as a Data Link to the IBM-360/50 at the University of New Brunswick. Except for the cost, we have been pleased with this arrangement. CANUNET could be a logical extension of our current situation. We are very interested in the development of CANUNET, and would very much like to be an early participant in any plans to implement or experiment with such a network.

Unfortunately, we do not have any computing resources to offer. However, with all the large computing facilities available, perhaps there will be a need for a few plain users in various parts of the country. It is conceivable that the inclusion of some smaller universities, like St. F. X. U., and most Atlantic Provinces universities in your plans, might prove worthwhile when the inevitable approaches to Government must be made for funds.

../2

**ST. FRANCIS XAVIER UNIVERSITY**
**ANTIGONISH, NOVA SCOTIA**

COMPUTATION CENTRE



LETTER: Professor J. B. Reid:

We would be willing to cooperate with your Committee in any way we can. I am not sure what we can offer. However, I will indicate the background of Dr. Alexander MacEachern and myself, and say that we would be willing to participate, in any capacity that would be helpful.

Alexander MacEachern: Doctorate, Computer Science - (Iowa State University); Special Interest: SOFTWARE.

Ronald MacKinnon: Doctorate, Mathematics - (Oklahoma State University); Director; St. Francis Xavier University Computer Centre since 1966.

Chairman; Atlantic Provinces Inter-Universities Committee on the Sciences, Sub-Committee on Computers - (APICS) 1970 - 1972.

I might mention that all the Universities in the Atlantic Provinces are represented on the APICS Sub-Committee on Computers. It would appear that this body could serve as the contact agency between your Committee and the Universities here. We are having our regular Fall Meeting on October 8th, and CANUNET is one of the items on our Agenda. Since your coordinating Committee meets on October 1st, would it be possible to send us a summary of your deliberations or conclusions, by October 8th, so that we can have a meaningful discussion of CANUNET at our forthcoming APICS Meeting?

As Chairman of the APICS Computer Sub-Committee, I can assure you of our continued cooperation in bringing CANUNET to fruition.

Yours sincerely,

Ronald J. MacKinnon

Ronald J. MacKinnon
Director, Computer Centre
and
Chairman, APICS Computer Sub-Committee.

RJM:dr

## Suggested benefits of CANUNET

### THE UNIVERSITY OF BRITISH COLUMBIA

"A need for participation in a library network."

### UNIVERSITY OF SASKATCHEWAN

"A meaningful national computing application that has the potential for involving a large number of universities. The library system might be an example... universities which are currently restricted by insufficient computing power could... test out the network as a means of overcoming this deficiency."

### UNIVERSITY OF WATERLOO

"A focus for some of our research projects.
training of large numbers of personnel in computing and communications.
Closer liaison between universities and the computing and communications industry.
A large variety of hardware devices, software and data banks will be available.
Rationalization of computing resources.
Testing of many of the ideas associated with future public networks.
A strong force for national unity."

### THE UNIVERSITY OF NEW BRUNSWICK

"would provide invaluable experience and training for the design and operation of a full-fledged Trans-Canada Computer Communications Network."

### UNIVERSITE DE MONCTON

"la seule façon viable pour nous de faire de l'informatique c'est par télécommunication."

### ACADIA UNIVERSITY

"particularly interested... because we are (a) small and (b) remote."
"The possibility of using a computer communications network... part of the time for voice communications... should not go unconsidered... The causes of Canadian indentity and unity would be served if it were possible for people... to talk to people in distant parts... for about the same cost as to talk to the next town."

ST. FRANCIS XAVIER UNIVERSITY

"could be an exciting solution to the problem of providing adequate computer facilities to a small university."

DALHOUSIE UNIVERSITY

"to ascertain if current communications technology is adequate.
"to determine if such a network could become of practical value in terms of cost and performance.
"to promote the development... of standards for hardware and software.
"to help in... the maturation and ordered growth of the Canadian computer industry.
"increased availability of:

- machine systems
- personnel specialized in areas of computer use and techniques
- research
- data banks
- software systems."

Compiled from letters received up to 19 October 1971

JBR/rc

# MINUTES
## of the
## SECOND CANUNET MEETING

Meeting held on Monday, November 1st, 1971.

Present: See attached list.

Meeting:

The Chairman stated that the purpose of the meeting was to try and divide and assign the workload for the Canunet study. He also restated the position of the Department of Communications toward this project which is that CANUNET:

a) would provide for more effective use of computer resources in Canadian Universities;

b) would provide an excellent vehicle for gaining experience and expertise for larger undertakings like the Trans-Canada Computer Network.

The following documents were distributed:

1. Agenda
2. Documents for "Canunet Advisory Committee Meeting". (yellow booklet)
3. Minutes of the First Canunet Meeting.
4. A Forward Look on ARPA by L. Roberts.
5. Letter by Mrs. E. Payne of Dalhousie.
6. Updated Report of a Network Working Group for ARPA.
7. Comments on the Canunet Project from University of Alberta.

Professor Joe Reid, from the "Université du Québec", then gave a resumé of his activities since the last Canunet Meeting. These are summarized by the documents contained in the yellow booklet.

Mr. Brown from the Council of Ontario Universities gave a description of his current activities. He stated that in the Ontario study, they, so far, have solicited various written quotations from approximately twenty sources with a closing date of 20 October, 1971. As a result of these proposals, they are presently reviewing the design criteria and the possible uses of the network. By mid-December they are confident of producing a design plan. By then, a firm idea of the cost and architecture of the network should have emerged. These findings will be submitted to the Council in February 1972.

Mr. Brown also said that the time estimate of 3 years is likely to be compressed to only two. Also, the initial cost estimate of $3 million for the project seems at the moment to be high. The initial plan will be for a 6 node pilot network at a cost of $6,000 per node per month. Mr. Brown promised to distribute what information he could on the project as it became available.

Dr. Kirstein then gave a resumé on the U.K.'s activities in this area. He stated that several organizations are involved with different projects. They are also trying to propose an ARPA-like network among various Common Market countries in Europe.

He discussed briefly the GPO plans for a national circuit switched digital network to be operational in 1978.

Dr. Kirstein also has presented a proposal to link certain U.K. universities into the ARPA Network, and this is now being considered.

It was then proposed that the study program for CANUNET be broken down and assigned to the following four study groups.

1. Communication Studies
2. Utilization of Network
3. Network Design
4. Institutional Framework.

It was agreed that each of these groups would have a chairman and co-chairman and they would be expected to prepare their reports by the end of January 1972.

The suggested membership of these groups at the time of the meeting was:

<u>Communication Studies</u>

DOC - Chairman: J. deMercado
Univ. of Quebec - Vice-Chairman: J. Fortier
Univ. of Toronto - E. Newhall

<u>Utilization of Network</u>

Univ. of Waterloo - Chairman: D. Cowan
Univ. of Toronto
D.O.C.
Univ. of Alberta
Univ. of Calgary
Univ. of British Columbia
National Library
Queens University
York University

Network Design

Univ. of British Columbia - Chairman: J. Kennedy
Univ. of Saskatchewan - Vice-Chairman: D. Cole
Univ. of Calgary
Univ. of Alberta
NRC
Univ. of Quebec
Dalhousie University
D.O.C.
Council of Ontario universities

Institutional Framework

Univ. of Saskatchewan - Chairman: B. Holmlund
Univ. of Quebec - Vice-Chairman: L. Brunel
Queens University
Council of Ontario Universities
Univ. of Calgary
D.O.C.
Univ. of Manitoba
St. Francis Xavier University

It was agreed that draft reports would be circulated for approval by the different committees and be finalized for general approval by the end of January.

It was agreed that the University of Quebec would make up to $10,000 available to each of these study groups to cover the cost of travel for group participants and any other expenses agreed to by the University and the Department.

The next meeting is tentatively scheduled for Monday, 28 February, 1972.

R. Guindon,
Secretary.

APPENDIX J

| | NAME | ORGANIZATION |
|---|---|---|
| (1) | D.F. Parkhill | Department of Communications, 100 Metcalfe OTTAWA, Ontario |
| (2) | N.D. Brewer | Department of Communications, 100 Metcalfe OTTAWA, Ontario |
| (3) | J.M. Kennedy | Computing Center, Univ. of British Columbia, VANCOUVER, 8, B.C. |
| (4) | D.D. Cowan | Department of Computer Science, Univ. of Waterloo, WATERLOO, Ontario |
| (5) | Joseph B. Reid | University of Quebec |
| (6) | J.O. Fortier | University of Quebec |
| (7) | Paul Dirksen | University of Manitoba |
| (8) | C.C. Gotlieb | Department of Computer Science, Univ. of Toronto, TORONTO, Ontario |
| (9) | Louis P.A. Robichaud | Centre de Traitement de l'Information, Université de Laval |
| (10) | W.D. Thorpe | McGill University, P.O. Box 6070, MONTREAL 101, P.Q. |
| (11) | C.D. Shepard | Department of Communications, Computer/ Communications Task Force, 100 Metcalfe OTTAWA, Ontario |
| (12) | E.A. Seaman | Department of Communications, Communications Research Centre |
| (13) | M.A. Maclean | Department of Communications, Communications Research Centre |
| (14) | L.F. MacRae | National Library |
| (15) | Alex Curran | Bell/Northern Research, P.O. Box 3511, OTTAWA, Ontario |
| (16) | Peter Kirstein | Institute of Computer Science, 44 Gordon Sq., LONDON |
| (17) | Blaine Holmlund | Univ. of Saskatchewan, SASKATOON, Sask. |
| (18) | Dr. J. deMercado | Department of Communications |

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| | | |
|---|---|---|
| (19) | René Guindon | Department of Communications |
| (20) | Eleanor Douey | Quic/Law Project, Queen's University, KINGSTON |
| (21) | Elizabeth Payne | Dalhousie University, HALIFAX, N.S. |
| (22) | Ron MacKinnon | St. Francis Xavier University, ANTIGONISH, N.S. |
| (23) | Tom Croil | Department of Communications, Computer/ Communications Task Force, 100 Metcalfe OTTAWA, Ontario |
| (24) | Dale Bent | Alberta Universities Commission |
| (25) | M.P. Brown | Council of Ontario Universities, TORONTO, Ontario |
| (26) | W.C. Brown | National Research Council |
| (27) | C. Lemyre | University of Ottawa, Electr. Eng. Dept. |
| (28) | R.L. Walsh | Department of Industry, Trade & Commerce |
| (29) | Paula Skippon (Miss) | Secretary of State Dept., 130 Slater St. |
| (30) | Joao Da Silva | Department of Communications |

APPENDIX K

# UTILIZATION OF COMPUTER NETWORKS

A PRELIMINARY STUDY OF

THE METHODS OF USING COMPUTER NETWORKS

AND OF

APPLICATIONS WHICH MIGHT BE AVAILABLE OVER

A COMPUTER NETWORK

A Report Prepared for

THE CANUNET COMMITTEE

by

D.D. Cowan
N.D. Brewer
C.C. Gotlieb
L.F. MacRae

March, 1972.

APPENDIX K

Table of Contents

Page No.



CANUNET UTILIZATION: A PRELIMINARY SURVEY OF SPECIALIZED COMPUTER APPLICATIONS

UTILIZATION OF COMPUTER NETWORKS

Summary

The following report is one facet of the study to determine the feasibility of constructing a Canadian Universities Computer Network (CANUNET). There are two parts to this report; the first part examines the problems inherent in implementing various applications on a computer network, and the second part surveys the specialized computer applications presently under active development in Canadian universities.

The first part of the report called "Mechanisms for Utilization of Computer Networks" presents an overview of the services which would be required in a computer network to support various applications. Problems inherent in these various services are discussed in some detail. In particular, network utilization is examined when the transactions are between users at terminals and computers and when the transactions are primarily between two or more computers. This paper also looks at the problems of documentation on a computer network, i.e. how do we notify the user of the available applications and how do we provide him with enough information to use these applications?

Many of the problems of terminal to computer transactions have been examined and at least partially solved in multiterminal time-sharing and multiprogramming computer systems. Applications which are primarily oriented toward this type of transaction should have a reasonable chance of success on a computer network. Applications in which the main requirement is for large scale computer-to-computer transactions are

not likely to be successful at this time on a computer network, since most of the problems are not really well understood. Research in various aspects of computer-to-computer transactions should be undertaken as one aspect of the CANUNET project. Topics such as high volume data transmission between computers and centralization of bulk storage capability need a more thorough investigation before any definitive statements can be made. Of course, no applications on a computer network can be generally successful unless adequate documentation and training are available. Research on methods of distribution, standards of documentation and user education is very important.

The second part of the report is "A Preliminary Survey of Specialized Computer Applications" in Canadian universities, and was prepared for the network utilization committee by Mr. T.A. Croil. This section of the report is a result of a survey conducted by Mr. Croil in April 1971 for the Computer Communications Task Force of the Department of Communications. This part identifies the major application areas, the universities most actively involved in their development and the time when these applications will likely be operational. It also identifies which applications are likely to be of value when offered over a computer network. Since the time available was rather limited, this survey can only be considered as a preliminary document. There are at least two further phases of this investigation which are suggested. First, the potential supply of applications should be more clearly defined, in particular, it should be determined if an application should be offered over a network, whether the authors of the application wish to make it available over a network and finally an estimate of raising an application to a "network standard" of documentation and service should be obtained. Second, some attempt should be made to forecast the potential demand for the various applications over the proposed network. From this information we can supply a forecast of utilization and identify data traffic patterns.

These are the results of a study of network utilization conducted over the past few months. It is hoped that this document has identified many of the problems and in some way has indicated the next steps to be undertaken.

## MECHANISMS FOR UTILIZATION OF COMPUTER NETWORKS

### Introduction

In this paper a computer network is defined to be a set of autonomous independent computer systems interconnected so as to permit interactive resource sharing between any pair of systems. This definition is identical to the one proposed by Roberts and Wessler [11]. The paper examines the potential uses of computer networks and discusses the feasibility of these uses.

Computer networks offer a real potential for resource sharing. Examples of resource sharing and the reasons for it are presented in [11]. In summary though one can say that resource sharing in a computer network implies that all users of the network and computers in the network should be able to make use of all the resources in the network (software, data and other computers) as if they were local. If this resource sharing can be achieved then it might be possible to avoid the high cost of duplication of hardware and software at every user installation.

Before we make many claims for the potential of computer networks, the feasibility and problems of resource sharing or network use should be examined very carefully. Such a study is important since the possible uses of a network will determine

(i) if a network should be built

and (ii) to a large extent its design, operation and management, if a network is built.

There are three aspects to utilization of computer networks which must be investigated. It must be determined

(i) what primitive operations or basic services will be provided by the network;

(ii) how these primitive operations or basic services can be made adequately available to the user;

and (iii) how one can combine these primitive services to provide services of real use to real people.

The idea of primitive operations on a computer network should be considered to be distinct from its applications. A detailed examination of the number of applications of a network is obviously beyond the scope of this paper; however, it is hoped that primitive operations described here would be the basis for the construction of any application.

The reader of this paper should be aware that a general purpose computer network or data network[1] is being examined and not just one for a specialized application such as on-line banking. Although there are many problems inherent in any computer network, specializing its function will probably reduce many of the problems to manageable proportions.

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1 The words "computer network" and "data network" will be used interchangeably in this paper. It is assumed that this term implies a communication system to which computers and terminals can be attached and over which data may be transmitted between these terminals and computers.

Computer Network Services

There are a large number of applications for which computer networks have been or are being conceived. The number of applications is so large that no single paper can do justice to more than one or two of them. Most applications, however, require certain basic services from a network and it is intended that this paper should discuss these basic services. The basic services can be considered as primitives which can be used in constructing any application. After formulating and classifying the basic services which might be offered on a network, these services will be discussed in some detail. The object of the discussion is to discern the problems which must be solved in order to make the basic service feasible.

Services on a computer network can be divided into two broad categories:

(i) terminal-to-computer and computer to terminal transactions and (ii) computer-to-computer or interprocessor transactions. Category (i) implies a man-machine transaction while (ii) is machine to machine in nature.

There are a number of different primitive operations inherent in man-machine interaction and these can be presented under different headings. We shall consider the following:

I Transactions related to programming and data

II Parametric transactions

III Data Bank Transactions

IV Transactions in which Files are shared among Users.

The computer to computer transactions can be subdivided in a similar manner:

I Transmission of Files

II Load-Sharing between Computers

and III Functional Specialization

(a) Store-and-Forward Message Switching Systems

(b) Bulk and Organized File Systems (Wholesale and Retail File Systems)

(c) Other Specialized Computers.

There are probably other ways to characterize the services which can be offered by a computer network but it is hoped that this method will cover the services in a comprehensive manner.

## Terminal-to-Computer Transactions

Terminal-to-computer transactions as presented in this paper are similar to the type of operation which is carried out on most multiterminal computer systems. In such a computer system a number of low and high-speed terminals are connected to a central computer and these terminals are used for input, output and to request the use of resources of the computer system. A computer network allowing terminal to computer transactions is an extension of this concept since now the user of the network can query any one of several different computer facilities connected to the network. We will not distinguish among the different ways of connecting terminals to the network and between a terminal local to the computer it is using and remote from it. A network of such computer systems has certain advantages.

(i) transmission costs can be reduced if there is enough data traffic to justify construction of special purpose facilities. This situation will arise if enough services are available for the non-expert user.

(ii) it will be more reliable than a single computer system as alternate data transmission paths and alternate equivalent services could be available.

and (iii) more resources would be available to network users, thus reinforcing (i).

I Transactions Related to Programs and Data

This section looks at the general characteristics of transactions related to programs and data, and attempts to classify them into three categories by speed of the terminal needed to conduct the transaction.

Program and data transactions can be divided into three categories by speed of operation of the terminal required and the corresponding transmission line, i.e. low speed (usually teletypes, 2741's, TWX Terminals, Point of Sale devices), low-speed input, high-speed output (usually character graphics terminals) and high-speed (usually card-reader printer stations, tape stations or graphic displays).

Such terminals use lines ranging in speed from 45 bits per second up to about 100 kilobits per second and even higher using special broadband channels.

Let us look at the characteristics of the three kinds of terminals and determine the ways in which they will fit into a computer network.

Low-Speed Terminals

On a low-speed terminal a user usually conducts a character-by-character or line-by-line conversation with a computer. There are two types of conversations which might be considered typical. Data base interrogation and modification should be considered as a prominent user of either general or special purpose terminals. For example, such activities as computer-assisted learning and data bank enquiry may be typical in a few years [4]. Both data bank access and point of sale transactions will be discussed in more detail in a later section. These applications tend to be characterized by inputs and outputs which might consist typically of one to twenty characters or control signals. In a programming environment, such activities as file editting and interactive construction and execution of programs are more typical. This type of activity has inputs and outputs which are usually from one to several lines in magnitude, although one or two character responses also occur frequently.

The input to the computer system from a single terminal normally cannot be massive in extent because it is being constrained by human speeds. This is the usual constraint on any primary input to the computer since humans are involved in its original construction. The problem here is of course to automate input by producing a large amount from very little. Any output received from low-speed terminals must be rather limited (normally from one character to one or two pages in length) since printing large amounts of data on a low speed printer is just not economical as well as trying to the patience of any user.

Low speed terminals can be connected to a computer system by two different mechanisms:

(i) directly through a dial up or leased line. The choice of these two depends on the total connect time during a given period, distance, reliability and other criteria.

or (ii) directly to a data network interface through a line and then over a data network to the computer being used. The data network interface is not specified here. For example, it could use a host or IMP as in the ARPA network [11] or some multiplexor.

There are a number of criteria to be considered when a choice is to be made between (i) and (ii). We must make a decision based on such information as urgency of transmitting the data, distance, transmission speed required, reliability and available line grades. For example, if the data traffic at any point in time through low-speed terminals to the computer systems being used is not heavy, then it is probably best to use the technique under (i) for connection. If the data traffic is heavier than there is a point at which it is better to place multiple users of computer systems on a data network and multiplex their transmissions together to utilize high-speed lines [11]. This will tend to decrease the cost/bit of transmission. In other words, if a large amount of data is being sent from a number of different users to a number of computer systems then these systems could be connected together by high speed communication lines (a data network) so that all users can share in the substantially lower costs of transmission.

The technology that should be used for the data network is not specified here. At least two different methods of data switching - virtual lines and packet switching - are serious candidates for consideration [see Appendix I].

When a terminal is used for a conversation with a computer the user must either

(i) learn all the conventions, such as the command language (e.g. JCL for the IBM 360 or the command language for the CDC 6600) for the computer he is about to use and also a network command language which will allow him to control his call;

(ii) learn a simple set of conventions (such as a small subset of the command language) because a specific set of services is required (e.g. APL) or the computer being called only offers a very limited set of services (e.g. a PDP-11 offering BASIC) and also a simple network command language which will allow him to control his call;

or (iii) learn a network command language which will allow him to exploit all the services offered by any computer in the network or any computer likely to be connected to the network.

The situations covered in (i) and (ii) in the previous paragraph are the ones that exist at the present time and will likely exist well into the future. This will make use of a computer in a network more complex than at present and will probably mean that most of the services offered initially will be of the type mentioned in (ii).

The development of a reasonable all purpose network command language (i.e. one which is not the union of all command languages) as mentioned under (iii) may be impossible. The computers connected to a data network may well be so different in scope and operation that their requirements may not be encompassed in an all purpose network language. In fact the extensive differences among computers is one of the prime reasons that a network might be built.

Of course, this discussion has been very general in that it did not make any assumptions about the number of users who were conducting short conversations and the number writing programs. It may well be that the primary use of a network will be the provision of specialized services such as data bank inquiry, computer-assisted learning, etc., which will generate large amounts of data traffic and will require minimal knowledge on the part of the user. One suspects that a large proportion of general purpose computing will be performed on a single computer (either local or remote) by a large user group (such as a university users group) and that some specialized services will be available on a computer network.

Low-Speed Input and High-Speed Output Terminals

The comments made about low-speed terminals also apply to this type as well. However, since this type of terminal needs its output displayed very quickly it must have a high-speed data link from computer to terminal or the terminal must incorporate some processing capability. Since there is a mismatch in input speed and output speed a mechanism which can provide both speeds of communication (at different costs) is very important. More effective use (i.e. in terms of communication speeds) can probably be made of such a terminal if it is connected to a computer network, since it could have the capability of providing both speeds of transmission for input and output.

High-Speed Terminals

The comments made about low-speed terminals apply to these terminals as well. However, high-speed terminals do provide a mechanism for moving bulk input and output quickly from user to computer and back. They are also more economical to use since high-speed lines usually less per bit transmitted than low-speed lines. As well, low-speed terminals are more dependent on human reaction time and this tends to increase their transmission costs still further since connect time will be longer.

If there is enough high-speed traffic among users of a group of computer systems then we can economically justify the construction of a data network. Unfortunately, we do not know what constitutes an economic traffic load and such a question deserves serious study.

Terminal transactions are probably sufficient reason for construction of a computer network if

(i) data traffic is high enough;

(ii) enough specialized services are available which require minimal knowledge of the characteristics of the computer being used.

Under (ii) it should be noted that if very few specialized services are available, then data traffic will be too low and that if the specialized service requires too much knowledge on the part of the user then it will not be used. In other words, a computer network must supply a variety of services which are tailored to the user who has minimal expert knowledge in order that sufficient traffic will be generated to justify the construction of a network.

In a network with many different computers and different types of terminals it will be necessary to standardize on a permissible character set (including control characters).

II Parametric Transactions [9,10]

In this paper, parametric transactions are defined to be terminal to computer transactions which are usually characterized by short messages of a few characters. In most cases these few characters are input parameters (hence parametric transactions) to a set of programs and usually restrict the user's capability to manipulate data and programs. The terminal used can be of any type as long as it allows short messages. There are many types of terminals specially designed for short transactions and these are often called point-of-sale (POS) terminals. These terminals often accept such items as credit cards and have a simple keyboard to input the required parameters. Both the messages from the terminal to the computer and from the computer to the terminal are short. Such messages are usually sent to a central computer which uses the message content to query or modify various pieces of data stored in a file.

There are many commercial examples of parametric transaction systems such as on-line banking systems, retail sales reporting systems, etc., and there are probably many applications in universities such as on-line book circulation systems which generate parametric transactions. One might also consider data bank query and update as examples of parametric transactions but since there is usually more freedom to manipulate the data in data bank it shall be discussed under a separate heading. Parametric transactions including data bank access will probably constitute a large proportion of the data traffic on any computer network [4].

The messages in a parametric transaction system are short and will incur a certain overhead in being transmitted. For example, in a store-and-forward system such as a message or packet switching system the information required to send the message (i.e. the address) may well exceed the size of the message. This means the cost of sending a message in such a network could easily double the cost of the message alone. Any computer network designed to handle this type of transaction should use technology which will keep the cost of sending a message to an acceptable level. In a network designed for parametric transactions it might be appropriate to batch messages to a given destination in order to minimize address overhead or to transmit the messages over some form of time division multiplexed transmission line [see virtual lines in Appendix I].

In a network which is denoted to parametric transactions serious consideration should be given to a design which minimizes the cost of sending a message. This requirement may conflict with the methods of designing networks for other types of traffic.

## III <u>Data Bank Transactions</u>

Data banks are large collections of data containing comprehensive and authorative information about some subject e.g. the statutes of Canada, the social characteristics of a certain group of people in Ontario, etc. This section examines the feasibility of using data banks which are connected to a computer network.

There are four basic operations which would normally be performed on a data bank, i.e. creation, validation, reading and updating. Creation of a data bank is a large scale process involving massive input of data usually under the control of authorities in the field. The data bank is usually created and input on a computer local to the creators even though it may be available on a data network.

Modification or updating of a data bank is usually done in one of two ways:

(i) the new data before being placed in the data bank is carefully screened and validated by a group of "experts";

or (ii) the new data is sent to the data bank by almost any user, (such as in a retail sales situation) but it is usually completely validated by computer programs before being entered.

Both types of transactions are similar to parametric transactions which have already been discussed.

Reading of data banks usually occurs because most users require information about some subset of the data, e.g. how many Canadian companies exceeded $50 million in sales last year and what are their names? Such questions require that the data in the data banks be processed so that the necessary information can be extracted. This processing can occur in one of three ways:

(i) all the information in the data bank can be transmitted in its entirety to the computer closest to the user. The processing of the data bank information can then take place in this local computer;

(ii) a program can be written for the data bank computer[2] which partially reduces the information in the data bank to a smaller file which can then be transmitted to the local computer for further processing;

(iii) a program can be written for the data bank computer [3,5] which produces the final output required by the user. This final output is then produced as a "print file" which is sent to the computer closest to the user and printed on his console.

All the methods described here will run into problems of file transmission. Since this is such an important topic in computer-to-computer transactions it is presented as a separate section. The conclusions drawn in that section indicate that transmitting files between two computers and then processing them is a very difficult problem and that the amount of data transmitted and the amount of processing on the local computer should be minimized. The method described under (iii) in the previous paragraph minimizes these two problems and may make data bank access manageable.

Of course the problem of shared files becomes important in data bank services and these are examined in the next section.

## IV <u>Transactions In Which Files Are Shared Among Users</u>

Shared files are files accessible to a number of users. The users may wish to read, write, execute or even delete the files.

If the files are shared by users using a computer local to the entire group then the problems they face are:

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[2] This term will be used for the computer which directly controls the storage containing the data bank.

(i) protection, so that only authorized users may access the file;

(ii) communications to ensure that -

(a) the correct file is being read at any given time, and

(b) some ability to indicate what changes have been made to the file since it has been updated.

Under (ii)(a), it is important to decide whether the user can access afile while it is being changed and also what happens if a file is in use before it is being changed, e.g. a number of jobs may be using the FORTRAN compiler and yet it is also being changed. How can you ensure that both the user and changer operate with the correct copies?

Under (ii)(b), it is important to communicate the changes that have been made to a file either explicitly or implicitly. In the case of an airline or theatre seat reservation system and perhaps a library borrowing system. The changes are usually implicit in that the seat or book count is changed with each transaction. If a group is developing a numerical analysis package and making modifications as they work, then some more formal means are needed to communicate changes and the reasons they are needed.

When the file becomes remote from some of the users but is still accessible by terminals directly without intervention of a network, then (ii)(b) becomes even more important. Most systems which would make reservations for airline seats or books perform the communication in an implicit manner.

When the file becomes accessible through a local computer attached to a computer network then all the problems of remote data banks and file transmission raise their heads. If we make a copy of the file for use in the local computer, then of course there are multiple copies in the system which could have alterations made to them independent of each other. In certain types of applications this would be possible, i.e. multiple copies could exist providing a master copy was updated every few hours.

It would appear that if multiple copies are not maintained and yet instantaneous transmission of file modifications is important then the best approach is to operate on the file via the remote computer and transmit small files to indicate status information, individual records, summary reports or communication of changes.

This is only a short discussion to indicate the complexities of sharing files particularly when the users are widely separated. There are solutions to some of these problems but they are not necessarily applicable to all situations. A careful study should be made of this problem and the many possible solutions should be examined as they are a function of both data transmission speeds and application.

Computer-to-Computer Transactions

Computer to computer transactions are not usually under the direct control of an operation initiated at a terminal. Rather they are a consequence of the execution of some program which was perhaps initiated from a terminal but is now almost completely under computer control.

Since computers, operating systems and file systems are so completely different it is extremely difficult to do computer-to-computer transactions in a general computer network. The computers involved must be aware in some sense of all possible combinations of character sets, command languages, word lengths and many other important things. Terminal-to-computer transactions differ significantly in that the human element is involved and can adapt to differing computer configurations.

For the reasons in the previous paragraph, it may well be some time before any extensive applications involving general computer-to-computer communication will be realized. Some degree of uniformity of standards will likely have to be reached before any significant degree of success is achieved.

The rest of this section is devoted to discussing the feasibility and problems of the computer-to-computer services which might be available.

I <u>Transmission of Files</u>

There is a number of reasons for wanting to transmit files; file transmission, however, may not always be practical. The types of file transmission are:

(i) transmission of card files and print files from and to remote job entry stations;

(ii) transmission of operating systems and documentation from one centre to another, e.g. transmission of IMP software from BBN in the ARPA network or MULTICS between MIT and Bell Laboratories;

(iii) transmission of files for processing, e.g. files created from larger files such as a data bank.

The type of transaction under (i) has already been discussed under terminal transactions. Types (ii) and (iii) appear to be the same type of transaction in that large files are being sent from one computer to another.

The speed of file transmission is important in any computer network. As long as file requirements can be anticipated before a program is placed in execution or a program can wait a significant length of time after requesting access to a file then transmission can proceed at a reasonable rate such as 40 kilobits per second or even slower. If a file is to be accessed and transmitted at the time it is required (a situation which may occur when a program is operating under time constraints) then the transmission rate for the network will have to be increased to a range comparable with the rate of high-speed peripheral devices. General purpose files, such as programs in higher-level languages or data files would have to be "translated" as they are sent from computer-to-computer particularly if either the computers are different, the operating systems are different or the specifications of the file system differ. What happens if the character sets differ, e.g. smaller character set on one machine than the other or different character configurations, i.e. the letter A is not the same on both machines. These questions are going to require significant study before they can be resolved. File mechanisms may also differ because either the hardware or the software specifications will be different enough that files cannot be adequately mapped. For example, how does one map data from an IBM data cell onto a CDC disk, or from the IBM data management system onto the DEC PDP-10 file system?

In summary, the file transmission problem appears to be one of transmission speed and lack of uniformity among computer systems. It is certainly a problem which needs significant study before the difficulties can be resolved, although no doubt solutions will ultimately be found. Partial solutions have already been found in such areas as ASCII character sets, and ANSI FORTRAN and COBOL.

## II Load-Sharing Between Computers

Load-sharing consists of submitting a job consisting of one or more programs at a computer and having this program sent by communications media to a second computer for execution. This sounds like a good idea since it would be possible to ship programs on the east coast of Canada to the west coast during peak load times in the east and vice-versa. Computing power would then be used in a more uniform way over a 24 hour period. Also programs could be directed to the most suitable computer.

This form of load-sharing was used between the various branches of the Bell Telephone Laboratories in the early 1960's when three IBM 7090's were connected together.

There are a number of problems associated with load-sharing. Let us look at three separate cases.

(i) Programs input on Computer X and executed on Computer Y where X and Y are the same type of computer with the same operating system using the same options.[4] The programs only access a single input card file and create a single output print file. This is a fairly straightforward case in that the programs should run successfully on either machine since the machines are identical.

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[4] See next page.

(ii) Different computers and the programs only access a single input file and a single output print file. If we assume that language compilers exist on both computers and that they both obey the same standard (not a safe assumption, e.g. compare IBM and CDC FORTRAN) then we appear to have only two problems, the incompatibility of command languages[3] and the options[4] available in each operating system. Since the two computers have different command languages and different operating system options some form of translation must take place before the job is executed. Provision of a universal command language so that two computers are almost compatible would be a partial solution to this problem. For the execution of simple jobs using languages such as FORTRAN, this is probably not too difficult, although at present it has not been done.

(iii) Situations (i) or (ii) where the programs have access to a number of files. This type of program makes load-sharing very difficult since (a) Many of the files would not be available on Machine Y and would have to be sent with the program (This could be a very expensive operation). (b) There would be duplication of file names causing clashes which must then be resolved. (c) The command language and options are now very complex and for two different machines and operating systems and it is not clear whether the command language and options for Machine X could be transformed into those for Machine Y.

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[3] Command languages for computers are singificantly different, e.g. CDC uses the concept of input and output streams while IBM does not.

[4] These options would include space and time available for the program and the defaults such as memory initialized to zero and error responses.

There are several technical problems to be solved in order to have a general load sharing capability and it is not clear that these problems can be solved in all generality.

It appears we can be reasonably sure that we can handle programs that do not make extensive use of files. Perhaps most student jobs and some debugging runs fit into this category. Can we economically justify load-sharing this type of program, or should the communications costs and the cost for rental of a remote computer be invested in a local facility? It would be very interesting to look at the percentage of jobs in a given computer installation which fall into categories (i), (ii) and (iii).

There is another form of load-sharing called brokerage which has all the properties mentioned previously. In this case the programmer has control of where his program is executed.

The programmer creates a program on one machine and then asks several different computers to bid on the execution of the program. The bidding is based on resources, i.e. the bidding computer must have all the facilities required for the job CPU, memory, compilers, files, etc. The bid is accepted only if the user wants his program run on that machine. The user might decline a bid, for instance, for security reasons, i.e. a commercial firm might not want to run a proprietary program on a competitor's machine. The user may also have knowledge of the bidding installation, e.g. some computer may be I/O bound or some file he needs to use is available and will not need to be transmitted.

It seems that this application is comparable to the load-sharing situation except the user can determine whether it is even worth asking for a machine to bid. It may be recognized that the files needed for the job are only available on one machine (such as the host machine) and bidding is unnecessary. In a computer network where files are stored in some central place (a situation true for load-sharing as well) it may be possible to run programs on any computer that will accept them.

III <u>Functional Specialization</u>

Computers are quite often constructed with a specific function in mind. For example, computers are often used as line switches in a telephone network and therefore are produced with characteristics quite different from a general purpose digital computer. It has been suggested that with the advent of computer networks, many of the computers in the network will be highly specialized in function and that jobs will be sent to them for execution. This is proposed for the ARPA network. It is expected for instance that programs requiring a high degree of parallel processing will be sent to ILLIAC IV in the network. This section examines the uses of functional specialization in a computer network and looks at some of the problems which may be inherent in these uses.

<u>Store-and-Forward Message Switching Systems</u>

For computer-to-computer communication to be a reality there should be a computer system in the network which will store and forward messages sent between computers. A program which is currently active in a computer may wish to send a message to another program in another computer. It is possible that the receiving computer may not be able to receive the message, since possibly -

(i) the receiving computer is inoperative;

(ii) the receiving computer is unable to accept more messages for any of its programs because its message capacity has already been reached;

or (iii) the program receiving the message is available in the receiving computer system, but it is not currently scheduled for execution.

This message handling capability for a computer network is the same capability that is either implicitly or explicitly inherent in operating systems. For an excellent example of this store-and-forward message system in an operating system the reader is referred to [1]. In all computer networks presently suggested there is no mechanism for storing messages for a period exceeding a few milliseconds. The packet switched systems only hold a packet (part of a message) long enough to assemble the entire message at the destination or to ensure that a packet has been forwarded correctly.

There are a number of problems associated with store-and-forward message systems in a data network. Some of the problems are:

(i) Are all computer-to-computer messages sent to their destination and then only redirected to the store-and-forward system if the destination computer cannot accept them?

(ii) Are they all sent to the store-and-forward system for transmission?

or (iii) Are they sent to both at the same time?

These questions are obviously dependent upon the amount of message traffic and the average amount of data traffic generated by the message and to some extent determines whether the store-and-forward system is an integral part of the network or just another subscriber. A store-and-forward system could be centralized or it could be distributed so that each subscriber to the network has this capability at the site of his network interface.

We might also examine signalling conventions and methods of organization. The following problems arise:

(i) How are computers notified that there are messages waiting? Do we poll a special signal, or ask the store-and-forward system if it has any messages?

(ii) How do we organize the store-and-forward system since the requests for messages will be random?

As well as these problems we will have all the problems of transmitting small files around the network. In particular -

(i) character codes would have to be modified between the sending and receiving computers;

and (ii) standard messages files would have to be designed.

This store-and-forward capability appears to be a key prerequisite to a network which will permit computer-to-computer transactions.

<u>Bulk and Organized File Systems (Wholesale and Retail File Systems)[3,5]</u>

Since access to on-line storage requires a heavy concentration on input/output it might make sense to group most on-line storage at several points in the computer network and provide it with a file accessing computer. Such a computer might have sophisticated channels for table lookup and elaborate code conversion hardware in order to communicate with all the computers in the network. The front end computer will accept requests for a record(s) from the user file and will then send the record or part of it to the requesting computer. The commands may be even more powerful and even allowing updating, etc.

This is a bulk or wholesale file system, that means that the storage space is for sale and that the user is responsible for organizing any files that are placed in storage. Such files will then by definition be compatible with the user's computer and file requirements.

Three problems immediately arise as a consequence of this concept of a bulk or wholesale file system.

(i) Considering the costs of data transmission at a satisfactory speed[5] is it more economical to concentrate on-line storage in one location with a special purpose computer or to allow each computer in the computer network to have its own storage? That is, are there economies of scale in bulk storage and functional specialization?

(ii) Will a bulk or wholesale file system be able to present the appearance of peripherals native to the computer making the request at a reasonable cost? For example, will the bulk or wholesale file system look like an IBM 2314 disk to an IBM 360 and a DEC disk to a PDP-11?

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5 Data will likely have to be transmitted at a rate comparable to the rate presently supplied by most peripheral devices since we will likely be transmitting a record at a time.

(iii) Since a wholesale file system will involve computer-to-computer transactions, it will be necessary to have a store-and-forward message capability in the network. This was described in the previous section.

These questions all bear some investigation as such a concept might be cost-effective. If a bulk or wholesale file system cannot be realized for a complete computer network, it might well be realized for local networks where there are a number of computers in close proximity and communications costs are reasonable. In particular, the economies of scale of centralized mass data storage should be thoroughly investigated.

An organized or retail file system not only offers on-line storage, but it is also organized into files for the deposit of information. The technical feasibility of constructing a retail file system has already been demonstrated by at least one group. [8] By standardizing or constraining various aspects of the file system such as the type of file structure allowed and the languages and methods of data access it is possible to build a retail file system. A retail file system would probably offer services similar to the ones provided by a generalized data base system such as GIS[2]. Such a service may well be a viable network offering. Of course, it would have to be determined if the costs of providing such a service on a network would make it economically attractive.

## Other Specialized Computers

Since a specialized computer such as ILLIAC IV can appear in a network, will it be possible to have computer programs which will run on independent computers and yet communicate with each other?[6] For example, a program may be initiated in one computer, call a program in another computer such as an array processor and then send the results to a third computer which drives displays. Such a situation could happen with numerical weather predictions or nuclear reaction calculations. Such computations would require the design of interfaces for the passing of messages between programs. At least certain aspects of this problem would require the design of a "network operating system" to control communications (see section on Store-and-Forward Message Switching Systems). Of course, if the files for such programs are not available at the site of the program then we have the difficulties inherent in file transmission. If large applications require this type of communication problems to be solved then they certainly can be handled for special cases. However, a more general solution to this problem may prove to be intractable.

We might also consider specialized computers in several other ways. It has been suggested that computers could be specialized to run programs in one or two languages, i.e. we might have a FORTRAN computer, an ALGOL computer, an APL computer, etc. The problems in this type of specialization have all the problems which were discussed in the previous paragraphs.

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[6] Some experiments on this problem are being conducted on the ARPA network.

Another form of functional specialization would be the use of one computer for compilation, another for execution, etc. This form of specialization has all the problems of the previous discussion.

Accounting and scheduling for all of these specialized processors will pose some interesting questions. Is accounting for all computers in the network centralized or does each computer do its own accounting? Perhaps we might even use a billing scheme such as the one used by the telephone company. In that case the "local" telephone company bills on behalf of all companies which handled the telephone call. If programs are executed on different computers how is the scheduling handled? Jobs could easily spend an indefinite period of time in the computer network waiting to be scheduled on a processor.

In summary, the problems in this type of specialization indicate difficulties in the areas of message transmission, accounting, and scheduling.

## Use of Computer Network Facilities

One of the most difficult problems in the use of a computer, whether it is local or remote, is to adequately notify the user of the services available and provide adequate documentation and training for the use of any of the services. It is hard to define adequate, but the user should be able to -

(i) find out by some reasonable scheme if a "service" is available to solve his problem;

and (ii) to obtain documentation by some reasonable scheme which allows the user to utilize the "service" with no reference to the source of the "service" except for very unusual circumstances.

## I Availability of Computer Network Services

Some form of mechanism for storage and retrieval of a catalogue and documentation might be established as part of the network mechanism. This information could be handled in several different ways. It seems appropriate for the catalogue to be stored on-line in the network and to have several different mechanisms for searching it, i.e. by subject, key word, etc. The organization and maintenance of this catalogue will be a job comparable to handling a catalogue in a small (?) library. Certainly any new entries will have to be very carefully placed in the index.

Any such scheme as the one proposed in the previous paragraph should be compared against other catalogue schemes for cost of storage and retrieval. Alternatives could be:

(i) a paper catalogue at each user installation which is periodically updated by mail or transmissions through the network. (We should ask what happens to remote terminal users; do they also receive a catalogue?)

(ii) a tape cassette which is periodically changed by mail or transmission over the network. The cassette could be used to drive an intelligent terminal and a TV set. Again, the remote user would suffer and some combination of services is probably in order.

Finally who pays for these services? Does the user pay a fixed charge per enquiry or is this service provided by the supplier in a manner similar to the yellow pages in the telephone directory?

## II <u>Documentation of Computer Network Services</u>

Documentation becomes a problem at least an order of magnitude larger than the catalogue problem. Individual pieces of documentation must meet a very high standard in order for any user to make any use whatsoever of services offered by a remote installation. When a user encounters faulty documentation in his own installation, a telephone call or a half hour meeting usually sets him on the right track. Of course, important details will be left out, but several attempts at this process will usually iron out most the difficulties. A remote user will not have any of these benefits and will only be able to receive help either through the network or by several telephone calls to the source of the service. This type of help will tend to be expensive[7] and not very satisfactory.

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[7] Some data sets do provide a voice as well as a data channel to speak to the centre being used. However, this is only useful for speaking to the operations people; it is doubtful if the person needed to explain a program will be available when needed.

No doubt many questions will arise about the "service" after its originator has moved to a new position. The only satisfactory answer to this problem is to provide adequate documentation and to develop user-oriented software. Neither of these problems have been fully solved although there is no doubt that there are excellent examples of solutions in existence.

How is documentation for a computer network distributed? Is there a central repository such as ARPA's NIC (Network Information Center) for all documents or does each user centre maintain a "skinny" set of documentation to start a user? How is documentation distribution controlled in a computer network? Do we use the postal system or the network itself? Perhaps a combination of these two media will be required and distribution will be a function of the urgency with which the documentation is required.

## III Network Languages

Since computer networks might offer a wide variety of services and applications there must be a network control language which allows the user to specify which services are required. In computer-to-terminal transactions the network command language should be relatively straightforward since it will only be necessary to set up a call to the appropriate computer and then use the facilities of the called computer such as its command language and compilers. Since computer networks offering computer-to-computer transactions can be considered as distributed computers, there will be a complex network control language which specifies how the various components of the network will be used.[8] This language will be incorporated

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[8] This will be analogous to command languages for individual computers.

into the programming systems of the various computers in order to have dynamic interjob communication.

In computer to terminal transactions it is probably appropriate to devise a simple network language for controlling a call and then reverting to the facilities of the called computer. Such an approach is certainly simpler than devising a universal network and command language and it also has the advantage that it will not destroy the distinguishing characteristics of the various computers in the network - one of the reasons for building a network.

Computer-to-computer transactions are complex and one needs to study this problem before making any definitive statements about the type of network language required. One suspects that various special purpose network languageswill develop as computer-to-computer services become available.

Conclusions

Resource sharing is an important concept in the computing field since

(i) it may help to decrease the cost of certain types of resources by decreasing the necessity of duplication of hardware, software and data;

(ii) it may possibly increase the cost-effectiveness of existing resources through increased utilization;

and (iii) it may broaden the base of computer resources available to the computer user.

Any research that is directed toward this goal should be considered worthwhile. Computer networks, i.e. computers and terminals connected together by a communications system hold some promise of at least partially achieving the goal of sharing computer resources among members of a widely scattered group of users.

This paper has considered a general purpose computer network and examined the type of services it might offer. These services were not interpreted as applications but rather as the components some of which would be used to provide the services required in any application. No assumptions were made about the transmission technology for the network, but at least two candidates (packet switching and virtual lines)[9] should be seriously considered.

The services have been separated into two types of primitive operations which are the constituents of all network applications. These two types of services are:

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[9] See Appendix A.

(i) terminal-to-computer and computer-to-terminal operations;

and (ii) computer-to-computer operations.

Terminal-to-computer operations are similar to the type currently available in most multiterminal computer systems, i.e. a central computer with a number of low and high-speed terminals used for input and output. A network is useful in this environment for a number of reasons. Specifically -

(i) a network may help to reduce transmission costs if there is enough data traffic. This situation may only arise if enough services are available to the non-expert user;

(ii) a network may be more reliable than a single computer system because of possible alternate data transmission paths and possible equivalent alternate services;

and (iii) more resources may be available to the users of the network.

The development of a network for terminal-to-computer transaction will face problems of transmission economics, differing character sets, and network languages, but these problems have been faced in existing single computer networks and at least partially resolved. Probably the most difficult problem to be faced will be providing the user with adequate information about services available from the network and it is a problem worthy of serious study.

Computer-to-computer transactions, if they can be accomplished, probably present an order of magnitude increase in the power of computer networks since they will allow several computers to participate in a computation. In order to achieve this type of operation, it will be necessary to be able to -

(i) transmit files of all sizes;

and (ii) store and forward messages between programs and processors.

At present, it is not known how to perform either of these operations since there are so many inherent incompatibilities in computer systems. For example, such things as hardware (word lengths, character sets, peripherals), software (operating systems, file systems), and languages and their processors (command and programming languages) all suffer this fate. Some method of achieving uniformity must be attempted so that an interface between incompatibilities might be realized. It would be disastrous, however, to make everything uniform since we would be destroying the distinguishing characteristics of the computers and hence one of the chief reasons for a computer network.

There are many questions to be resolved before specialized computer-to-computer services are likely to be a reality. Some of these questions are:

(i) Is high-speed transmission of files likely to be required?

(ii) Can files be transmitted successfully between different file systems?

(iii) Are there enough programs with minimal file requirements or specialized requirements to make load sharing feasible?[10]

(iv) How do we incorporate a store-and-forward message system in a computer network and is it a necessity?

(v) Can bulk fast access peripheral devices be housed in a location remote from the accessing computer such as in a wholesale file system?

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10 The computer network under development in the Southwest of Britain is supposedly based on the supposition that such a computing load exists.

(vi) Are various forms of functional specialization such as special purpose processors (e.g. a FORTRAN computer) economically feasible?

From the contents of the paper and the list of conclusions, it is evident that computer-to-computer operations require careful study and research before being implemented. In fact, it is not clear that some of the computer-to-computer operations being suggested in the literature will ever be feasible.

In summary, it should be stated that a computer network which is oriented toward terminal-to-computer transactions may have a reasonable chance of success. Computer-to-computer transactions will require careful study before implementation. Finally a computer network will only be truly successful if enough services are provided for the non-expert user to ensure an economic level of data traffic.

APPENDIX K



## APPENDIX A

### METHODS OF COMMUNICATION BETWEEN COMPUTERS

(i) LEASED OR SWITCHED LINES [6,7]

This technique uses telephone circuits of various speeds to connect computers together. Switched lines are dialled as required and usually operate at multiples of speeds required for voice communication. For low-speed terminals the speed of such lines is too high for the speed of the terminals. For high-speed data transmission the time required to establish a circuit (the connect-time) is too long relative to amount of data being transmitted. The problem of long connect-times can be solved by leasing a line of suitable capacity. In most situations the line will only be used for short periods and therefore the cost of transmission will be inordinately high. The remaining techniques described in this Appendix illustrate some of the known mechanisms for utilizing transmission lines more effectively.

(ii) LOCAL LOOP USING ECOMMERCIALLY AVAILABLE LINES [11]

A local loop transmission system consists of a communications link capable of transmitting at a rate of about 1 to 2 megabits. The link is formed into a loop which has a driving computer in the loop. Frames of 200 to 300 bits are transmitted synchronously around the loop. Each frame has an address and space for a message. A number of stations are attached to the communications link and these are used to receive and transmit messages. The host computer (attached to a station) sends a message to the station, the station then waits for an empty frame and places the link until it reaches a receiver with the correct address that is willing to receive the message. If a message frame passes the driving computer twice, it is assumed that the receiving station was not able to accept the message. The message is

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[11] There are various local loops operating on an experimental basis.

then removed from the system and the frame is now clear to accept another message. This type of transmission system appears to be most useful in a system where the communication is only a few miles in length. T1 lines of the Bell System are available commercially and probably could be used in a local loop.

(iii) VIRTUAL LINES

In order to achieve better utilization of high speed communication lines, it is common practice to multiplex a number of low-speed signals onto the high-speed line. Two techniques called frequency division multiplexing (FDM) and time division multiplexing (TDM)[9, 10] are often used. When the signals are digital in nature and the medium is designed to transmit digital signals directly, TDM is the usual technique. TDM methods consist of placing several low-speed signals onto a high-speed synchronous transmission line by mixing them with each other in a predetermined sequence. Since the line is synchronous, the digital signals can be received and sent to their destination in the same sequence that they were transmitted. No address will be needed on any of the transmitted bits and an entire message will be transmitted without the overhead of an address.

If the switches connecting lines of different capacities are programmable then it would be possible to establish a dynamic communications system. When a host computer wishes to send a message to another host computer, it negotiates with the network for a line of a certain capacity. This information directing the network to make the connection would be sent to the various programmed network switches. When the connection was complete the message would be multiplexed (TDM) onto the lines and transmitted. The switches in this system must have storage to store the programs and provide synchronizing delays. The concept of using a programmed switch to select the lines and transmit is called the virtual line concept.

(iv) STORE-AND-FORWARD MESSAGE SWITCHING

In a store-and-forward message switching system, an entire message between two computers is usually sent to a central computer which reads the destination address and then stores the message. The message is then transmitted to the receiving computer. A store and forward system is able to take entire messages and hold them for prolonged periods of time from a millisecond to several hours or even days, i.e. it has a significant amount of storage. It is necessary in such a system to have a communications link between the storing computer and this link is usually used for the duration of the message.

(v) PACKET SWITCHING SYSTEMS

A packet switching system is the type of system which is being used in the ARPA Network. In this case, a message is broken into small uniform pieces called packets and transmitted to the receiving computers. The packets are transmitted between the computers as fast as they are formed and are not stored for any length of time. There is no long term storage capability available in a packet switching system. Breaking up a message into pieces allows better use of communication lines; however, it increases overhead since each packet will require an address, which must be interpreted at each switch. Packet switching is a form of TDM since the line is shared among a number of different packets rather than bits or characters.

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APPENDIX K



## CANUNET UTILIZATION: A PRELIMINARY SURVEY OF SPECIALIZED COMPUTER APPLICATIONS

### Introduction

The feasibility of a Canadian University Network (CANUNET) will depend to a degree on the planned usage of the network by the participating universities. Therefore as part of the CANUNET Utilization study it was decided to examine not only the methods available for providing and using network services, but also the computer applications which may generate traffic on the network. Apart from computer time usage of specialized network hardware, which is difficult to predict, the major data traffic is expected to come from the use of specialized applications and data banks which are located at other universities on the network. Therefore, as the first step to developing a forecast of network utilization, it seemed appropriate to identify these specialized computer applications and to assess the benefits of a network which would make them immediately available to other universities.

This report identifies the major application areas, the universities which are most actively involved in their development, and the time when the applications will likely be operational. The information for this report comes mainly from a survey of university computing conducted in April and May, 1971, by the Canadian Computer Communications Task Force. This survey, while not exhaustive in the application area, is the only known report on specialized computer applications at Canadian universities. As a more thorough analysis has not been possible in the time available, the Task Force survey material has been restructured and expanded here to form the basis for more exhaustive utilization analyses in subsequent phases of the CANUNET feasibility study.

Specialized University Computer Applications

The major specialized applications have been dealt with under six main headings - Library, Legal, Education, Medical, Hospital and Environment. The applications, their status and the university staff members responsible are summarized under each of these headings in Exhibit I. This section describes more fully the nature of these applications and the role a university computer network might play in making their benefits available on a wider scale.

1. Library Systems

While nearly every university in Canada has some form of automated library system, the approach to automation has varied. The following examples indicate some of the different types of library systems either under development or operating in Canadian universities:

a. University of Toronto

The basic concept has been to build a common catalogue data base which can be used for many applications. There are about 700,000 titles now in machine readable form which is equivalent to about 1.8 million volumes. The project was started in 1964 and is expected to take another five years to complete with the existing staff of 40 people. Investment to date has been about $2.5 million with a current annual budget of approximately $1.0 million.

The University of Toronto has recently announced that they have developed an on-line circulation control system but no details were available at the time this document was written.

b. University of Guelph

This university is well advanced in its application of computers to libraries. An off-line batch system including catalogue processing, serials, government documents, acquisitions and circulation is 90% complete. Of these applications the Guelph Government Documents Systems is perhaps the best known and has been installed in a number of other U.S. and Canadian universities. The National Library Task Force on government documents has recommended that the National Library operate a specialized national system for government documents and the Guelph system and three other U.S. systems are being considered. There is also a plan to develop a common government documents data base for U.W.O. and Guelph, and other Ontario universities are expected to participate once the initial system is functioning satisfactorily.

Both the large catalogue data bases at the University of Guelph and the University of Toronto are combinations of material obtained from the Library of Congress MARC (Machine Readable Catalogue) project and the BNB (British National Bibliographie) project and of machine readable catalogue material produced in the respective universities. The fact that these data bases are being built from a number of separate data bases indicates that work in standardization and compatibility has been at least partially successful. In particular, about two-thirds of the data base at the University of Toronto has been derived from the previously-mentioned sources.

c. Université Laval

A system in operation at Laval for the past two years provides on-line access to a file of 25,000 technical publications giving information on the state of a collection and its location on the campus. The system could be expanded to include books, maps, records and other periodicals without major modification and its services could be extended to other universities via a computer communications network.

d. University of British Columbia

The primary emphasis here has been on developing a circulation system which will keep track of books on loan. When a book is borrowed, the student's I.D. and the book card are put in one of 23 badge readers, the identifying information punched on paper tape, and then processed off-line by a computer. The university plans to go on-line with this system eventually so that students and staff can enquire about the status of books which are out on loan.

e. Simon Fraser University

Simon Fraser University has experimented with an on-line circulation control system in the past. They discovered that the cost of such an on-line system was excessive and they have since returned to an off-line circulation system.

This is only a survey of some of the more interesting library applications encountered in visits to various Canadian universities. Detailed information on various library projects can be found in a report on Canadian universities' library automation which was produced by the Canadian Association of College and University Librarians for AUCC.

In total, the investment in library systems at universities is estimated to be $10-15 million with an additional annual expenditure of $5-10 million. The justification for these expenditures is primarily to improve the access to and the control over library holdings with little or no emphasis on cost reduction. A computer network could substantially improve access to holdings on a national basis by making all library catalogue files available on-line from any location. A network could also allow for immediate access to specialized national data bases, for example, on government documents, from any university location. However, in both these cases the network would only provide more immediate access to information than is currently possible by conventional means. As the need for this improved service is questionable in some cases, the network cost/benefit for library applications will have to be carefully analyzed.

On the other hand, the advent of networks could have a fundamental impact on how libraries function. Most university libraries are established to provide the best possible service to students and faculty from their own holdings. A network may make it possible to combine and rationalize those university holdings which are relatively static into regional libraries which can provide books to users on, say a 24 hour service basis. If 80% of the holdings are used 20% of the time (as is often true for many other types of inventory), and these holdings are duplicated in a number of other libraries, then it might be possible for one central library containing one set of these holdings to provide an acceptable level of service to all the surrounding universities. This would only be possible if each university subscribing to the service could provide its students and faculty with the ability to browse or search through the file of central library holdings and place a request for a book. A network could provide the communications and computational ability required to control and operate such a service; delivery and pick-up of books could be handled by car in much the same way as the inter-library loan service. The appealing aspect of this concept is that it could result in substantial reductions in library costs in terms of reduced holdings, administrative staff and storage facilities.

In terms of the wider implications of networks in the public sector, libraries present one of the more promising university areas. Many public systems will contain data of a personal nature which will require that proper security and privacy safeguards are built into the system. Library systems, on the other hand, are unlikely to require such stringent safeguards and should, therefore, be more easily designed and implemented. In addition, network systems developed for university libraries may be of direct benefit to other public institutions. For example, school, public and government libraries may be able to install components of an operating university system for their own use, or actually becomes subscribers to the same network.

2. Legal Systems

There are three major legal systems under development at Queen's, Montreal and Laval.

a. Queen's QUIC/LAW Project

This project, which was started in 1969, is now providing terminal services to Queen's, UBC, NRC and the Library of Parliament and will be expanding to the University of Saskatchewan, Federal Justice Department, and the University of Ottawa. Other universities interested in the service are Windsor, Western, Toronto, York, Carleton, Dalhousie and U.N.B. QUIC/LAW provides legal researchers with terminal access to the text of Federal Supreme Court Decisions 1923-70 and has been extended to provide NRC with access to 6,000 Pollution Documents. Both Federal Statutes and 4,000 additional Pollution Documents are in the process of being converted to this information retrieval system. In total, Queen's has about 15 million words of text in machine readable form including the following files on the information retrieval system:

Federal Supreme Court Decisions 1923-1970
Ontario Court Reports 1962-1970
Federal Statutes (consolidated)
Federal Regulations (consolidated)
Canadian Criminal Cases (part only)
B.C. Statutes (in process)
Treaties of the Commonwealth (in process)

Queen's is also receiving, in machine readable form, the Statutes of Ontario and the Exchequer Court Reports from other sources

Finances permitting, Queen's expect to have the QUIC/LAW system operating on a cost recovery basis by April, 1972. This will be dependent on the experience with a planned six month trial project using 20 terminals in Ottawa government and law offices.

b. University of Montreal DATUM Project

DATUM is an automated document retrieval system which is sufficiently general to be applicable to any kind of textual material. The project, which was started in 1968, has been in operation with limited data since May, 1970. The first data file developed for the system was the text of judicial decisions applicable to the Province of Quebec, including Supreme Court of Canada reports and four collections of decisions of Courts in the Province. These texts are in French, in English, or in both languages and together amount to about 200 million characters.

c. Université Laval, Quebec Statutes Project

Preliminary work started in August, 1967, to develop a data bank of Quebec Statutes. The bank, currently containing about 20 million characters of text, is to be used for information retrieval, index creation and automatic editing. The information retrieval system was to undergo volume testing in September, 1971 with full operation scheduled for January, 1972.

The usefulness of a university network in the development of legal applications is not yet clear. Certainly, if the network could provide lower communication costs and still meet the requirements for immediate access and high speed output, it would make the service attractive over a larger geographic area. However, if the data base remains relatively static, there may be economic and operational advantages in installing duplicate systems for use in other geographic regions. Further work is required to establish the trade-offs between these two approaches before any meaningful forecast of network utilization can be made.

3. Education Systems

The major university effort in the field of education is in the development of Computer Aided Learning and systems for university administration.

a. Computer-Aided Learning (CAL) Systems

The universities which seem to be most interested in CAL are Alberta, Simon Fraser, Western and Toronto. Alberta has an operating CAL system on a dedicated computer, covering a range of different subjects at all educational levels. However, the main emphasis has been on training doctors in cardiology and patient monitoring. Simon Fraser has specialized in Chemistry and is now offering about 50 courses in this subject to augment lecture material. Western has developed about 60 hours of CAL lessons in English, Psychology, Computer Science, Education and Mathematics and has experimented with a Computer Science course for credit combining CAL lessons with cable TV. Toronto, through the Ontario Institute for Studies in Education, has been experimenting with CAL for some time. Current projects under way are production of a remedial Mathematics course for entrants to manpower retraining programs, preparation of second language instruction and high school Physics. The remedial Mathematics course is under test at two or three community colleges, the high school Physics program is operated at two high schools in North York, and the second language instruction course is still in the design stage.

Although this is a survey of CAL in the universities, note should be made of the efforts of NRC in this field. Their co-operation with the universities and extensive work in developing a common CAL author language are particular things to be mentioned.

Most of the universities felt that if a computer network could reduce transmission costs and improve reliability of service, then the universities could make their CAL services available to users in a wider geographic area. However, it is not clear at this stage what ultimate form a university network should take to serve CAL users, for it will be dependent, among other things, on the market served by the CAL systems (which might include universities, community colleges and schools) and progress with the development and adoption of a common CAL author language. If a common author language is adopted, then courses can be computer independent and the need to have access to courses on other university computers through a network is reduced. In addition, if the market for CAL services expands into the secondary schools, then the development of specialized CAL time-sharing systems is foreseen which may serve all CAL users within a given region. If either or both of these developments occur, the value of a university computer network for Computer Aided Learning will be uncertain.

b. Administrative Systems

Many of the universities have their administrative systems in varying degrees of computerization, including applications such as financial accounting, course scheduling, student record keeping and space inventories. While many applications are being developed for use at only one university, there are several projects which envisage shared use by a number of universities and, therefore, are of particular interest to this study. Two important examples are the CESIGU project in Quebec and the Laval CACTUS project.

CESIGU (Comité d'élaboration du Système d'Informatique de Gestion Universitaire) is a joint project by the universities in Quebec to develop an administrative group of programs for such functions as financial accounting, space inventory and student and staff information systems. When parts of the project are operating, co-operating universities will start to use the system, either on their own computers or via a network. It is anticipated that the project will be completely operational by 1975.

CACTUS (Computer Automated Creation of University Timetables) is a program which will construct a fully optimized timetable given inputs such as student course requests, lecture rooms available, professor availability and preferences, and the courses offered. The system is fully operational and documented and is expected to be used to create timetables for other universities and community colleges in Quebec this year. While CACTUS may be used on a shared basis by various universities, there does not appear to be any real need for the on-line real-time capabilities of a network to make good use of the system, especially as it will probably be used only once or twice a year by any participating university.

In summary, the anticipated use of CANUNET by educational systems is uncertain. If the CESIGU concept of developing and using common administrative programs extends to using common computing facilities as well, and the concept is adopted across Canada, then there may be significant use of a university network but probably only on a regional basis. The use of a network by the CACTUS and CAL systems is even less certain, and more information is required on the expected development of these systems before any forecast of network usage can be made.

4. Medical Systems

There are four universities where real-time medical computer systems are well advanced - Alberta, Manitoba, Toronto and Dalhousie. All systems perform a range of real-time, on-line and batch services for research.

a. University of Manitoba

The medical computer centre at Winnipeg General Hospital is currently running 35 application programs made up as follows:

Real-Time 15% (e.g., lung mechanics, video angiograms)
On-Line 45% (e.g., statistical packages)
Off-Line 40% - about 100 miscellaneous jobs/day

The centre has two CDC 1700's with a connection to the universities 360/65 where they send half the batch work. The project was started in 1967 and about $1 million has been invested in development and production to date. The system is operational and about 60% documented. The centre estimated that its staff could install an identical system elsewhere in one to two months but would require at least six months to train new staff.

b. <u>University of Toronto</u>

The primary applications here are real-time data acquisition and control for biomedical research. The centre has a SIGMA 5 dedicated to these applications, which is currently providing services to seven laboratories with seven more in the process of being added. Full operational status should be reached by mid-1972.

c. <u>Dalhousie University</u>

Dalhousie also has a SIGMA 5 dedicated to medical research projects with special emphasis on EEG and ECG analyses. Four terminals in the intensive care unit at Victoria Hospital are connected to the SIGMA 5 for testing purposes. It is estimated that it will take two years to fully evaluate this system at which time the services could be provided to more hospitals in the province. However, there are present concerns about the reliability and cost of communications to these hospitals.

d. <u>University of Alberta</u>

In addition to the Computer-Aided Learning systems for training doctors in cardiology and patient monitoring, this university has developed files on all cardiac surgery, appendix and neuroradiology cases for research purposes. The Faculty of Medicine has their own Hewlett-Packard HP 2116B but make use of the main data centre as well.

In general, the justification for these medical systems is that the research they are used for could not be done otherwise. While medical projects remain in the research environment, the availability of a university network would not appear to offer any particular advantage. However, when projects, such as the ECG analysis systems at Manitoba and Dalhousie become fully operational, a network could make the services from a central ECG computer available to a number of university and general hospitals in a region.

5. Hospital Systems

Considerable effort is being expended at some universities to develop computer based hospital systems. These systems vary in their application but all relate to the general administration of hospitals and the analysis of hospital problems.

a. Université de Sherbrooke

The Centre Hospitalier Universitaire (CHU) is developing a centralized administrative system for all 14 hospitals in Quebec Administrative Region #5 which contains nine counties and 600,000 people. The objective is to develop and test a pilot system which can then be implemented in all hospitals in Quebec province. The data bank associated with the system will contain critical medical records on-line, historical records, results of lab tests and administrative data. Currently the centre is processing the payroll for ten hospitals, performing some real-time lab tests and analysis of medical records. The project was started in 1966 and the first major modules were due for completion by the end of 1971. The schedule calls for the pilot project to be completely operational by the end of 1972.

b. <u>University of Saskatchewan</u>

The Hospital Systems Study Group, based at the University of Saskatchewan in Saskatoon, has been assigned the major responsibility for the development of computerized programs for the hospitals in Saskatchewan. The following systems are operative at the University Hospital, Saskatoon: Payroll, Inventory, Medical Records, Operating Room Management, Medical Information, Retrieval, ECG Interpretation, Plant Ledger, Capital Budget, and Automated Laboratory Reporting. In addition, three projects are under development: satellite pharmacy drug distribution (multi-phasic screening program) and on-line ECG interpretations for other remote hospitals. Another major project is the development of a financial system to be used jointly by eight hospitals. Phase I (Payroll/Personnel) has been operative since January 1, 1971 while Phase II (Accounts Payable, Patient Accounting, General Ledger, Plant Ledger and Management Reports) is expected to be operational by mid-1972.

c. <u>McMaster University</u>

The staff in the Health Science faculty have developed a number of specialized computer systems. The CCISS (Conversational

Computer Information and Statistical System) allows users who have no knowledge of computers to enter data in a prescribed method and to select and analyze the data in a diversity of ways. The system is being converted to allow requests from terminals with remote or local outputs. There are about 50 to 100 projects on the system including a study of medical care utilization. The Pathology Department has developed a procedure for the creation of flexible medical records based on the NASA Medata System for astronauts. In addition, there is work progressing on the development of Ambulatory Patient Records, Regional Medical Records and the matching of donors and recipients of transplant surgery.

d. <u>University of Western Ontario</u>

The Department of Pathology has a system for creating hospital records which was developed and tested in operation at St. Joseph's Hospital. The objective of the system is to shorten the work of the physician and possibly shorten the time patients stay in hospital. The method is based on recording on a data file, prior to admission, information on a patient derived from history and physical examination questionnaires. A gross description of the surgical specimen and the diagnosis are added to the file by the physician after surgery. The system is not suitable for general use at this stage.

The effectiveness of the hospital systems described here does not generally depend on immediate access to programs or data bases which may exist in distant locations. These systems would not, therefore, be substantially enhanced by the availability of a national computer network. However, there could be some use made of a network on a local or regional basis where economies of scale may be realized through shared use of a specialized hospital computer system. In this regard the availability of a university network could allow university hospitals in a given region to develop and use common systems which may ultimately be adopted for use by other hospitals.

6. Environmental Systems

This section deals with specialized computer applications relating to land and its use, natural resources, such as minerals and forests, and the environment in general.

a. Survey, Mapping and Land Titles

One of the most significant computer systems under development in Canada is a project to computerize the land titles for Prince Edward Island and New Brunswick. The University of New Brunswick, in conjunction with the New Brunswick Department of National Resources, has played a major role in the design and implementation of the system and is currently processing all the data at their computer centre.

The system has been operational for Prince Edward Island since September, 1970, and should be partially operational for New Brunswick by the end of 1972 and fully completed by 1976. In this first phase, all data pertaining to a parcel of land, such as location, ownership, dimensions, etc., will be available via a terminal for title searching. In Phase II, it is planned to include assessment data, and in Phase III, community planning (health, water, sewage) data. Documentation for the system is reasonably complete and it has been estimated that it would take three to four months to install the system in another location.

b. Geodetic Surveys

A satellite positioning method has been developed for carrying out geodetic surveys in the remote Canadian Arctic and along the Eastern Continental Shelf. The work has been a joint project of the University of New Brunswick, Bedford Institute and Shell Oil. Data obtained from satellite fixes is sent to a computer for validation and then complex correction calculations. Communications could play a role in transmitting data to and from the computation centres where rapid response is required.

c. Soil Data

Data banks are being developed for analysis, classification and model building of soil types for specific use (e.g., sewage, highways, buildings, farming, etc.). British Columbia, Guelph and Laval were identified as centres where work is progressing on this project. Each centre is constructing its own data bank but they are all in early stages of development.

d. Geological Data

Western and Alberta have been involved in the development of SAFFRASS - Self Adapting Format Flexible Retrieval and Storage

Systems which will allow access to any of 100 machine-readable Canadian geological data files from a computer. The system is fully documented and installed at six locations with nine more users expected by early 1972. Because of its generality SAFFRASS can be applied to other information retrieval applications and is currently being installed for use in libraries.

e. <u>Forest-Fire Warning Systems</u>

The University of New Brunswick operates a system for computing the Fire Weather Index (FWI) for 177 forest stations in N.B., N.S., and P.E.I. These stations report Temperature, Relative Humidity, Wind and Rainfall to the Fire Weather Forecaster in Halifax who relays this data via TWX to U.N.B. for computation. The FWI is computed twice daily for each station and sent back to Halifax. The system is operational and could be installed elsewhere or its services offered to larger geographic areas through a network or communications facility.

f. <u>Urban and Regional Planning</u>

Sherbrooke is building a data bank for regional development which will contain information such as number and type of buildings, industry, small business, etc., for a given set of geographic co-ordinates. The project is still in its early stages and it is not expected to reach full operational status for at least three years. Another similar project is the Geography Data Bank being developed at Western which will contain land use data for four counties. This data bank is part of the Lake Erie Project being sponsored by the Department of Regional and Economic Expansion.

In summary, there are a number of environmental applications in various stages of development at Canadian universities. These tend to be based on the need to access large data files either to retrieve specific information or to analyse quantities of data. In some cases, either computational complexity or the requirement for rapid response suggests that a computer network may be of benefit. However, the use which may be made of such a network and whether either a university or a national network is appropriate are areas which must be investigated further.

7. Financial Systems

The most highly developed financial computer services in Canada are provided from the Financial Research Institute in Montreal. The Institute provides services for financial analysis, economic analysis, and portfolio management to banks, brokerage houses, trust companies, insurance companies, mutual funds, government institutions, industrial firms and seven universities. The service is provided via terminals from the McGill University Computing Centre, the cost of communications tending to establish the area in which the service can be obtained at a reasonable price. A university network could enlarge the service area enabling researchers and students at universities across Canada to benefit from this financial data.

8. Social Science Data Banks

In conducting this survey information on data banks and needs of the social sciences did not seem to be readily available. This may be owing to the fact that most of the data in universities appears to be in small private collections of individual research workers, rather than being accumulated in a large data bank. There are two reports on social science data which should be mentioned here, namely,

"Information for Urban Affairs in Canada", by M. Barcelo, H. Campbell and D. Young, Canadian Council on Urban and Regional Research, 1971.

and "Inventory of Social Science Quantitative Data Sources in Canada", by H. Campbell, Social Science Research Council of Canada, 1971.

It should be determined if presently compiled social science data are interesting to a wider community than the individual research worker and whether some of this data might be accessible over a network. Also, it should be determined how more general information from such agencies as Statistics Canada, might be made available to social scientists and if a university computer network might be a possible vehicle for its dissemination.

In summary, this section has identified some of the specialized computer applications at Canadian universities whose benefits could be made available to a wider user community through the facilities of a national university network. In most cases these applications have only been identified in very general terms, and a far more detailed investigation is required before any quantitative forecast of network utilization can be developed. The next section describes a suggested plan for achieving this objective.

Forward Plan

Two further phases of investigation are suggested, the first to more clearly define the potential "supply" of appropriate specialized applications and the second to forecast the potential "demand" for their use over the proposed network.

The next phase of this study should be devoted to a more precise analysis of the existing and planned specialized applications which are likely to be used over a network. Some applications are transferrable to other university computers, others do not require the response-time available from a network and still others may not be suitable in their fully developed state to be offered from a network operated by the universities. The purpose of this phase should be to reduce the list of special applications to those whose usefulness would be clearly enhanced by the availability of a network, and to determine which of these applications the universities would be prepared to make available on a service basis and at what cost.

A final phase is required to assess the potential market for these special applications at all universities which may be participants in CANUNET. This will involve interviewing potential users, informing them of the services that may be available, and estimating their usage and its associated revenue potential over a selected time period. From this information it should be possible to construct a reasonably accurate forecast of network utilization which will identify the major user and supplier universities and the likely patterns of data traffic between them.

<u>Conclusion</u>

A number of specialized computer systems have been identified and assessed in terms of their general applicability to a university computer network. Some applications appear to have potential for generating traffic on the network but no firm conclusions can be drawn at this stage. Two further phases of investigation are suggested to complete the study: the first to pin point more exactly the applications which could generate network traffic and the second to determine what the potential market is for these applications. At the completion of these two additional phases it should be possible to develop a reasonably accurate forecast of network utilization.

## SOME MAJOR SPECIALIZED COMPUTER APPLICATIONS UNDER DEVELOPMENT AT CANADIAN UNIVERSITIES

| Application Name | University | Approximate Date Fully Operational | Anticipated Use of Network(1) | Contact |
|---|---|---|---|---|
| 1. Library | | | | |
| Geneeral | U of T | 1976 | ? | K. Frost |
| Gov't Documents | Guelph | now | possible | L. Porter |
| Circulation | UBC | now | ? | Mr. Dennis |
| Periodicals | Laval | now | yes | C. Bowdon |
| 2. Legal | | | | |
| QUIC/LAW | Queen's | now | possible | H. Lawford |
| DATUM | Montreal | now | yes | J. Boucher |
| Quebec Statutes | Laval | 1972 | yes | P.H. Fortin |
| 3. Education | | | | |
| CAL * | Simon Fraser | now | possible | Dr. S. Lower |
| CAL | Alberta | now | " | Dr. S. Hunka |
| CAL | Western | now | " | Mr. P. Suttie |
| CAL | Toronto (OISE) | now | " | Dr. L. McLean |
| SIGU * | Quebec Universities | 1975 | likely | |
| CACTUS * | Laval | now | unlikely | L. Robichaud |
| 4. Medical | | | | |
| Research Unit | U of T | mid 1972 | unlikely | A. Heyworth |
| " | Dalhousie | 1973 | possible | Dr. P. Rautsharju |
| " | Alberta | ? | ? | Dr. D. Fenna |
| " | Manitoba | now | possible | Dr. Saunders |
| 5. Hospital | | | | |
| Admin/Lab. | Sherbrooke | end 1972 | possible | Dr. M. Lavallee |
| Admin/Lab. | Saskatchewan | now | " | Mr. C. Shanks |
| Laboratory | UBC | July 1971 | " | Dr. R. Pearce |
| CCISS * | McMaster | April 1972 | " | Dr. G. Anderson |
| Records | Western | ? | ? | Dr. J. Frei |

| Application Name | University | Approximate Date Fully Operational | Anticipated Use of Network | Contact |
|---|---|---|---|---|
| 6. Environment | | | | |
| Fire Weather Index | UNB | now | yes | A.J. Kayll |
| SAFFRASS * | Western | now | no | Prof. Sutterlin |
| Lake Erie Project | Western | ? | ? | Dr. Filbrich |
| Regional Development | Sherbrooke | ? | no | P. Lacasse |
| Geological Bank | Alberta | ? | no | G. Dickey |
| Survey, Mapping & Land Titles | UNB | now | yes | B. Claus |
| Geodetic Surveys | UNB | 1973 | yes | E. Krakiwsky |
| Soil Sample Data | UBC | ? | possible | Dr. Lavkilutch |
| 7. Miscellaneous | | | | |
| Medical Statistical Analysis | Waterloo | 1978 | ? | Dr. W. Cherry |
| Industrial Simulation | McMaster | now | ? | Dr. A. Johnson |
| Bilingual Terminology | Montreal | 1972 | likely | R. Dubuc |
| Demography | Montreal | ? | ? | J. Legare |

Notes

* CCISS Conversational Computer Information and Statistical System
CAL Computer Aided Learning
SIGU Système d'Informatique de Gestion Universitaire
CACTUS Computer Automated Creation of Timetables in University Scheduling
SAFFRASS Self Adapting Format Flexible Retrieval and Storage System

1. The scale used to assess the anticipated use of a network is as follows:
   - Yes
   - Likely
   - Possible
   - Unlikely
   - No

# A Network Design for CANUNET

by

D.A.Twyver, J.F.Hogg, W.Dettwiler
University of British Columbia

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## F O R E W O R D

This report is submitted on behalf of the Network Design Committee of CANUNET. It is based on the draft "A subnet Design for CANUNET" dated December 10, 1971, but includes substantial changes and extensions arising from written comments and from a meeting held in Toronto in February, 1972.

We regret that a draft report from the Network Utilization Committee was not available to us; some of the proposals made here may have to be reconciled with the Network Utilization report at a later stage. Also, a very complete paper by Norman Housley of the Council of Ontario Universities was received too late to have much influence on this report. Mr. Housley's document, which covers many aspects of the plans for CANUNET, should be regarded as a separate report to the Advisory Committee.

J. M. Kennedy
University of B.C.

March 17, 1972.

APPENDIX L

The University of British Columbia

Computing Centre

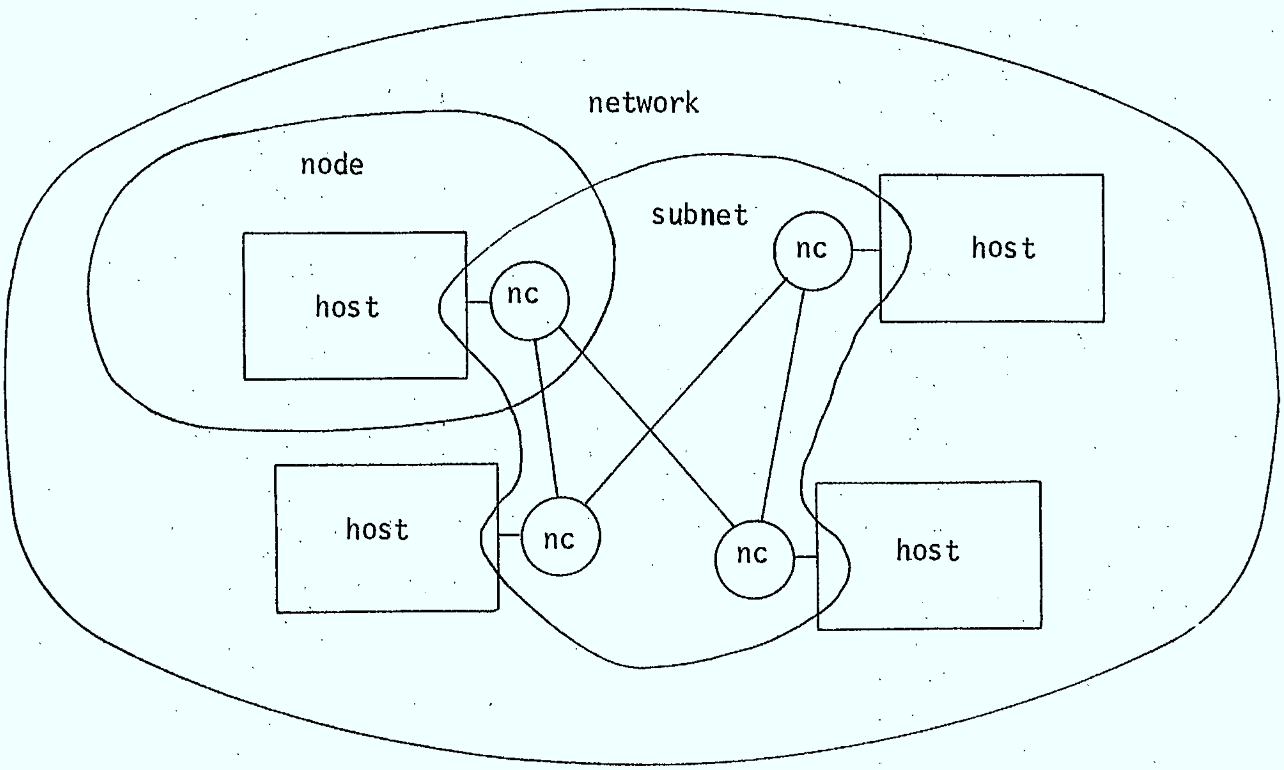
# A Network Design for CANUNET

D.A. Twyver, J.F. Hogg, W. Dettwiler 17 March 1972

## Introduction

The Canadian University Computer Network (CANUNET) is intended as a communications facility linking computers of various manufacture on Canadian campuses. CANUNET must also facilitate network access by campuses without a large computer and must provide for communication with computers on other networks. This paper describes a design concept for such a network, drawing heavily on features of the ARPA[1], MERIT[2], and NPL[3] computer network designs. It does not concern itself with the detailed topology of the network or the justifications for, and administration of, CANUNET, as these are subjects of separate studies. It does, however, propose features and criteria which affect these subjects.

For the purposes of this paper, several terms require definition. The term host computer will refer to a resource-bearing digital computer equipped with an operating system which can provide service to multiple, simultaneous users. A node computer is a small, dedicated computer attached to a host and to two or more communications lines leading to other node computers. A node is the combination of host and node computer. A computer network is the collection of all nodes and communications lines. A subnet is the collection of communications lines and node computers (including their interfaces to the hosts). The subnet communications protocol is the set of procedures which the node computers use in transmitting information through the subnet, and assuring its delivery. A host-host protocol is a higher level convention which defines the means by which a host computer can be utilized via the network (e.g. how to initiate a remote-batch-entry job).



## Design Objectives and Constraints

Orientation - Two of the justifications[4] for constructing CANUNET appear to be the sharing of the computing resources of Canadian universities, and the need for research into the economies and efficiencies of computer networks and of various network utilization protocols. These objectives may not be compatible. Trial-and-error protocol research may jeopardize network stability, while resource sharing will become a fact only if the network is usable and dependable. The subnet design should then (1) be modular enough to allow experimentation during implementation, (2) be stabilized when utilization demands, (3) be as topology-independent as possible to allow continuing topological permutation, and (4) be as independent as possible of the host-host protocol to allow multiple protocols and protocol experimentation without impairing network stability.

Scope - The network design must accommodate all resource-bearing computers presently installed on Canadian campuses and must be sufficiently extensible to accommodate their immediate successors. Provision must be made for network access by campuses without "hosts". The CANUNET implementation effort should include the design and construction of a terminal multiplexor or "data concentrator" for use at such installations. However, the network must not be limited to being simply a telephone exchange for terminals. Rather, it must allow all presently conceived network transactions, including remote conversational computing, remote batch job submission, remote database access, inter-process communication, and inter-host file operations. CANUNET must also allow for communication with computers on other networks. This requires an early start on consultations and co-operation with other existing and planned networks to establish mutually acceptable protocols.

Reliability - Every possible means must be employed to assure that messages consigned to the network are delivered without error. The ARPANET undetected error expectation of one bit per year in the entire, loaded network seems a reasonable goal. Note that delivery of messages may be blocked by partial network failures, but this is a reflection of network availability, not reliability (see below).

Availability - It is the authors' strong opinion that CANUNET must be designed for maximum availability if it is to serve as a useful research vehicle and productive tool. It must be capable of overall uninterrupted operation, although economics may dictate a reduced schedule during the development stage. Sufficient hardware reliability and redundancy must be incorporated to provide a virtual certainty that messages will be delivered even in the event of a partial network failure. One of the few circumstances which will block delivery of a message is failure of the destination node. Meeting the maximum availability objective requires that the subnet hardware and software be extremely reliable and independent of host hardware and software.

Performance - A computer network provides communication between processes in independent host computers or between a human user and a computer process. While computers may be content to converse with each other at a rate of one transaction per minute, a human will require response times of about one second to keep him from frustration. Therefore the CANUNET subnet must follow ARPANET's example of providing transcontinental response times of well under one second, to allow for delays in the host operating systems. A patient network implementation group may tolerate worse performance during the initial stages.

Usability - The user must find the network at least as easy to use as local peripherals. This is primarily the concern of the host-host protocol and the network interface software in each host. Such software should allow the use of network facilities in a manner consistent with the way in which local programs, files, and devices are used. However, the network need not, and should not, be limited to those activities conceived for local programs and equipment by the - perhaps short-sighted - designers of any particular operating system.

Impact - The network design must minimize detrimental impact to host operations during the implementation phase. Effective utilization of the network will require minor additions to host operating systems. It has been demonstrated by ARPANET, MERIT and individual Canadian universities that the attachment of network facilities and non-standard terminal equipment to an operating system can be performed in a fashion "transparent" to most of the system, while not restricting the use of these facilities by the operating system. As well, the host/subnet hardware interface will probably not be supplied by the host computer manufacturer. The attachment of non-standard hardware and the modification of complex operating systems inevitably causes some disruption. It is expected however, that the network hardware and software can be sufficiently well designed, constructed, and tested, to produce minimal impact when installed.

Cost - Several avenues of implementation are open to CANUNET, ranging from an in-house university effort to complete industrial contracting. Since the time and cost frameworks for these extremes vary considerably, this paper will attempt to present minimum and maximum figures.

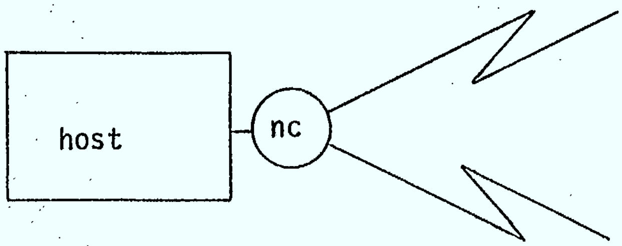
## Subnet Design Selection

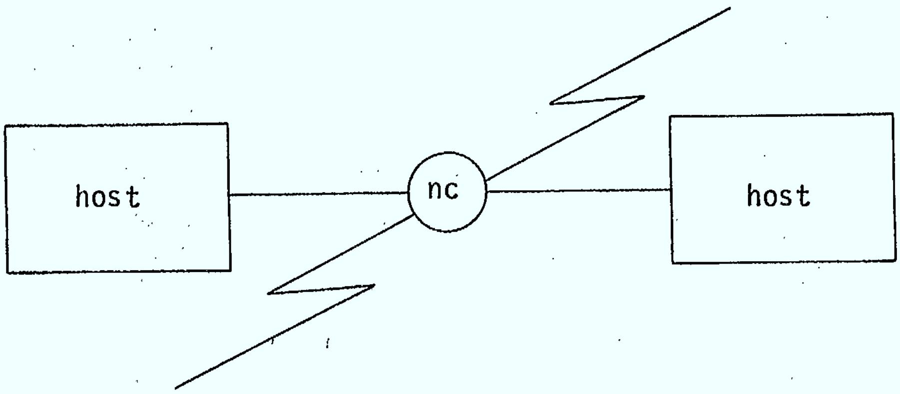
The above design objectives, Canada's geography, ARPANET's experience, and the Science Council's report 13[5] combine to suggest that a distributed, store-and-forward, message-switched subnet is most appropriate for CANUNET. This implies that leased communications lines connect the nodes and that a message may have to pass through several intermediate nodes before reaching its destination.

An overconnected topology with at least two separate paths between any two nodes is necessary to ensure maximum availability. Full duplex communications lines operating at speeds in the order of 50 kilobaud will be required to meet the performance objectives in a loaded network.

## Node Configurations

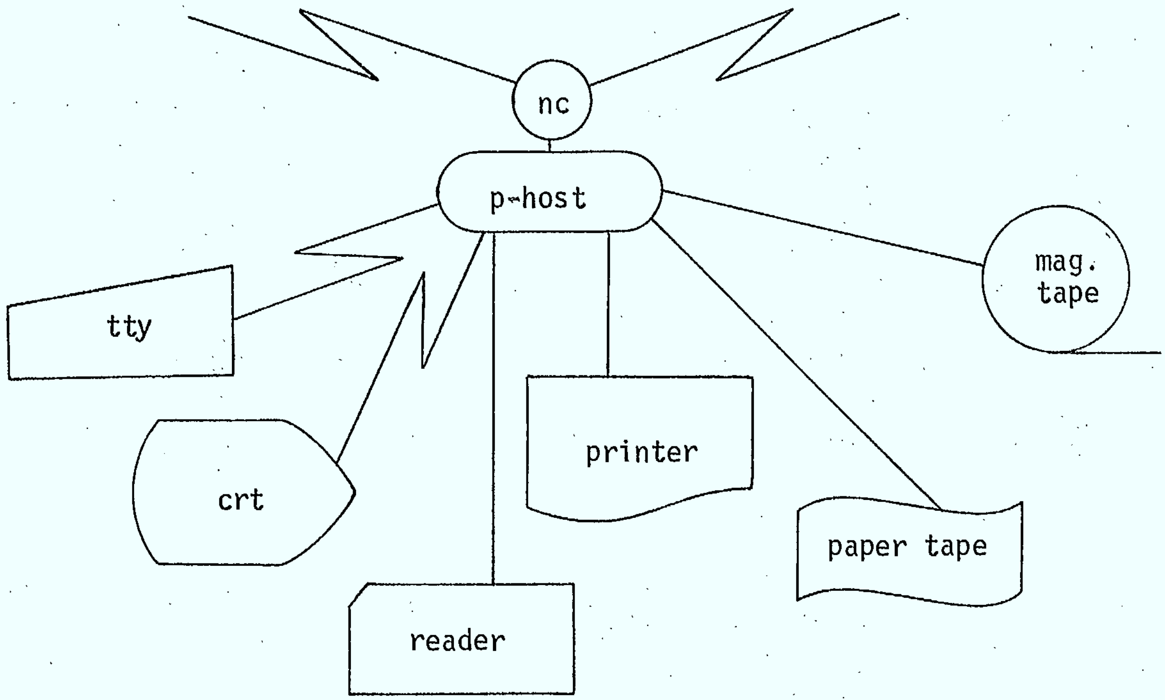
The normal node configuration will consist of a node computer interfaced to a host, and at least two communications lines interfaced to the node computer.



Minor variations would allow two or more hosts to be connected to a node computer, or multiple node computers to be connected to a host or hosts. These configurations would satisfy the needs of installations with multiple systems and installations where high traffic and/or extreme availability were required.

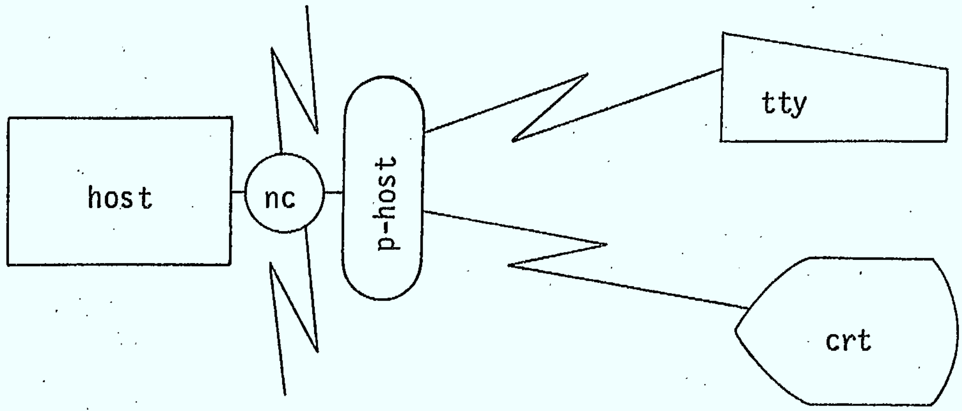
An installation without a large computer would have access to the network via a satellite node. This special node configuration includes a pseudo-host instead of a large host computer. The pseudo-host is a small computer which: supports peripheral devices such as teletypes, graphics terminals, card readers, line printers, plotters, paper tape equipment, and magnetic tape equipment; and multiplexes these devices into the node computer.



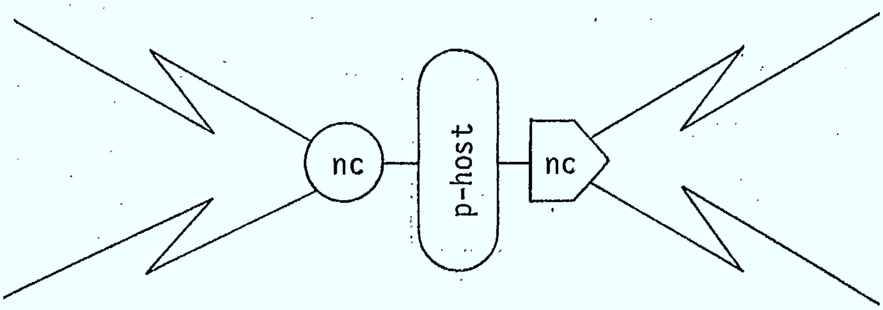
APPENDIX L



The subnet design does not allow for the attachment of peripheral devices directly to the node computer since it is the authors' opinion that the complexity so introduced would impair network availability. A legitimate node configuration, however, could include a host, a node computer, and a pseudo-host that supports peripheral devices. The devices attached to the pseudo-host would have access to the local host (as well as to the entire network) via the node computer.




A special <u>inter-network</u> <u>node</u> configuration is required for interfacing to other computer networks. Again, a pseudo-host would be used, but in this case it would be connected to the node computers of both networks. The inter-network node would be responsible for transmitting messages between networks and for resolving differences in host-host protocol.



## Subnet Hardware

The physical subnet will consist of communications lines and node computers. The communications lines must be full-duplex, leased point-to-point. Their performance characteristics may vary in different stages of implementation and in different parts of the network, the line speeds being typically fifty kilobaud.

The node computer hardware will be comprised of three components: (1) the processor and memory, (2) the host interfaces(s), and (3) the controllers for the communications lines.

The processor and memory should have certain characteristics. They must be sufficiently fast to handle an aggregate data rate of over 100 kilobytes per second. At least 32K 8-bit bytes of memory, with parity control, must be available. The processor must have a comprehensive logical and fixed point instruction set, including convenient character and bit manipulation capability. The processor and input/output hardware must be convenient and efficient to program. A power-fail detection and restart mechanism must be present. Reserve power is required if the memory is of the volatile semi-conductor type. Read-only memory is desirable for bootstrap software. A micro-programming capability may prove useful. Such computers presently on the market have a single-unit price of approximately $18,000 and are subject to substantial quantity discounts.

The node computer should be connected to its host via a micro-program controlled interface. The host side of the interface would vary minimally among host types, with the interface micro-program compensating for most of the hosts' differences. Since the hardware for all host interfaces would be virtually identical, advantage could be taken of the economies of quantity. Constructing an interface for a new host type would be a staightforward matter of developing a different micro-program for the interface's control memory. This type of interface would be equally well suited to the connection between a satellite pseudo-host and its node computer. Great flexibility would be possible in the byte width and addressing techniques for the host side of the interface. The node computer side would be identical for all host types so that the software in all node computers can be as similar as possible. To have such host interfaces designed and constructed will cost between $2,000 and $10,000 per unit.

The node computer will have two or more 8-bit, binary synchronous communications controllers. These could be a variation of the micro-programmed host interface. The communications controller would be capable of detecting and processing several transmission control characters. It must store and fetch data from memory on a "cycle steal" basis, interrupting the processor only at the end of a complete transmission. It must also perform the required checksum calculation and be capable of operating in a full duplex manner at speeds in excess of 50 kilobaud. The design and construction of such communications controllers will cost between $2,000 and $5,000 per unit.

Node Computer Software

As far as is possible, every node computer should have identical software. Such items as the node number and initial routing tables may differ from node to node. The basic components of the node computer software will be the supervisor (2K bytes), the host interface service routine (4K), the communications controller service routine (2K), the message router-dispatcher (4K), and the background statistics sampling routine (2K). There will also be a bootstrap procedure and various tables (2K), and queues and buffers (16K). Since the software in all node computers will be identical, a node computer will be able to initialize (or re-initialize) itself from a neighbor. Developing the node computer software will require a two to five man-year effort if performed in the universities, or a $100,000 to $200,000 contract to industry.

Subnet Communication Protocols

The procedures by which the node computers communicate with each other and with their hosts should be characterized by several features: (1) The overall performance of the subnet must be such that a message can be delivered and acknowledged in under one half-second, between any two hosts in the network. (2) The integrity of the delivered message must be assured as much as possible. This will require sophisticated error detection and correction techniques. (3) The availability of the network must be maximized by dynamic routing algorithms which compensate for partial network failure and saturation. (4) A statistics gathering mechanism must be able to provide information to the network implementors and administrators, in order to assist network development and allow traffic accounting.

Further considerations for subnet protocols appear in Appendix A.

## Host-Host Protocol

A network host-host protocol provides a basis for agreement between processes in different host computers, regarding how to establish a connection, how to interpret data and control messages, and how to terminate a connection. A sufficiently flexible, general and "subsettable" protocol[6] can substantially diminish the need for recognizing and dealing with the individual idiosyncracies of particular hosts on the network.

The natural approach to host-host protocol implementation is an hierarchical one in which the higher level protocols use the lower ones.

Level one would be the host-subnet conventions and is properly part of the subnet protocol.

Level two is used by the host's "network control program" to communicate with network control programs in other hosts.

Level three protocols are user-process oriented. This level recognizes that a bit stream may be interpreted in a number of different ways, depending on how it is to be used. Suggested useful protocols are: (1) Initial Connection Protocol for invoking remote processes by name and getting access to them (by "logging in" or whatever). (2) Data Transfer Protocol for specifying whether data is binary, EBCDIC, ASCII, etc. (3) File Transfer Protocol for moving files between hosts. (4) File Access Protocol for accessing remote files, as opposed to sending whole files. This would involve defining a Network Ideal File. (5) Terminal Protocol for allowing a user with one kind of terminal to access a process which expects another (this would involve specifying a Network Ideal Terminal). (6) Graphics Protocol for sending generalized image descriptions (perhaps tied to the definition of a Network Ideal Graphics Terminal). (7) Remote Job Entry Protocol for accessing batch service at remote hosts. (8) Disconnection Protocol for terminating connections and sending standard formatted accounting information. Among other things, this would allow a host to limit local use of remote facilities.

A more detailed description of an hierarchy of host-host protocols appears in Appendix E.

Host Software

The additions required to host operating systems will be in two areas. A subnet support routine will be needed for each different host operating system. It will take the form of a "device support routine" in MTS, an "access method" in OS, an "I/O driver" in SCOPE and KRONOS, etc. This routine will allow programs to access the subnet in a manner similar to other host peripherals. It will be responsible for interfacing the user or his program with the system's "network control program". The network control program in each operating system would multiplex the network traffic into the node computer and perform the functions required by the host-host protocol. Additional host software may be necessary if it is desired to provide "transparent" interfaces to existing terminal-oriented subsystems. Each university would presumably be responsible for the development of this network-oriented software in its host and could expect to allocate one to two man-years to the task. However, co-operation among installations with like operating systems could substantially reduce the total investment.

Pseudo-host Hardware and Software

A pseudo-host for use in a satellite node must be capable of supporting various peripherals and be easily interfaced to the node computer. This interfacing would be simplest if the pseudo-host were the same model as the node computer. Another advantage to this choice would be the ready availability of appropriate supervisor software. The satellite pseudo-host software must perform the subnet support routine and network control program functions. It must also provide full support for its attached peripherals, including any necessary code translation. The

CANUNET implementation should provide for a standard satellite pseudo-host, while at the same time allowing the attachment of independently developed pseudo-hosts. This would allow a particular university to tailor one to its specific needs, for example, a real-time control application. The costs of developing the pseudo-host would be similar to those for the node computer.

The inter-network pseudo-host must be capable of being interfaced to the node computers of both networks. It must perform subnet support for both and simulate the host-host protocols of both networks while communicating messages between. This area needs perhaps the most research of any in the CANUNET design.

Network Implementation

The network implementation may be divided into several areas with different approaches used for each.

The node computer hardware procurement and maintenance could be contracted to Canadian industry. Cost of a typical node computer configuration should be between $25,000 and $50,000. Lead time for the delivery of the first production model would be about one year, with perhaps a production rate of one per month thereafter. It would be desirable to have a prototype node computer available as early as possible for the development of software and protocols.

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The node computer software and detailed subnet design could also be contracted to industry, or alternatively, it could be performed by a small group of experienced professionals drawn from participating universities. Either approach would result in a development time of about one year and a cost in the order of $250,000.

The pseudo-host hardware and software development could follow the same pattern, perhaps utilizing the same contractors after the node computer effort was complete. Development time and cost would be about the same as for the node computers.

CANUNET would require a small, technically competent group to specify, tender, and monitor the above work. This group must have the confidence of all participants and have scle authority in technical matters.

Host-host protocol design and network-oriented host software development properly belongs in the universities. An early start, and extensive co-operation, will be required in order to keep pace with the subnet implementation and to encourage earliest utilization of the network. This effort would greatlv benefit from a centralized advisory and information centre. Such a centre would require a staff of several people with access to appropriate computing resources.

The area of inter-network communication requires substantial effort. A liason group should be commissioned very early to consult with other network organizations and to influence the CANUNET design accordingly.

## Summary

The described network design takes advantage of the experiences of previous network implementations but offers new features in the micro-programmed host interface and the satellite pseudo-host. The micro-programmed interface will be economic while providing tremendous flexibility. Using pseudo-hosts at satellite nodes, instead of a combination node and peripheral support computer, will increase subnet availability at little added cost, while allowing local tailoring of the pseudo-host. The independence of the subnet from host hardware and software will also contribute to availability. Subnet performance objectives may be met with a range and combination of line speeds, depending on subnet topology and load. A multi-pronged implementation effort is possible, involving universities, industry, and government. The design describes a viable, economic subnet with flexibility for future expansion and modification.

## Acknowledgments and References

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## CANUNET SUBNET PROTOCOLS

The subnet protocols must cover three areas: (1) communication of messages between the network control program in a host or pseudo-host and its node computer; (2) management, transmission, and routing of messages within the subnet; and (3) background control and measurement transactions.

1. The host-node computer protocol, or level one protocol, for a particular host will be influenced by the appearance of the host side of the hardware interface to its node computer. The network control program, or the hardware interface, must map the host's input/output bit stream into subnet bytes.

Messages which enter and leave the subnet must contain such control information as the destination or source host number and process identification. The network control program, and the subnet, must be able to uniquely specify each logical path between communicating processes and prevent data overrun or loss of process synchronization on that path.

2. The actual subnet communications protocol, or the level zero protocol, is concerned with getting the message from the node computer of the source host to that of the destination host. For this purpose, the message is converted into one or more "packets" of a size appropriate to the line speed and error control techniques being used. Each packet contains sufficient control information to allow it to be independently and accurately routed

to its destination.

The routing mechanism in the node computer software should not be required to know the topology of the network. Rather, it should use feedback from neighboring nodes to maintain its routing tables and thus be able to accommodate subnet failures and congestion, and topological changes.

As each packet is transmitted from one node computer to the next on the route to its destination, the receiving node computer must acknowledge reception of the packet and accept responsibility for it. This acknowledgment, and the "feedback" mentioned above, take the form of special control packets which are not themselves acknowledged. Another special packet is used to reload one node computer from another

3. Node computers themselves may act as "fake hosts" and originate or receive certain kinds of messages.

Each node computer will perform a statistics gathering function and send statistics messages to a particular host. A debugging feature may also be enabled and will cause the node computer to transmit program and packet trace messages to some host.

A node computer can receive messages for diagnostic purposes, or to accept commands which set internal parameters and switches.

## HOST-HOST PROTOCOL FOR CANUNET

The design constraints on CANUNET host-host protocol are quite stringent. Two factors in particular affect the range of possibilities:

1. The history of other networks shows that experience is necessary to evaluate the effects of protocols (or the lack thereof) on network usage. We have none, so we must draw on the experience of others.

2. One of the important design goals of CANUNET is to allow for network interconnection, both to networks already in existence and to networks yet to be built. This implies:
   a. There must be a certain amount of parallelism in protocol (relative to connected networks) to allow for reasonable ease of mapping between protocols.
   b. Close co-operation is necessary with other network design groups to ensure that a pseudo-host which interconnects two networks can deduce enough information from the messages in transit to be aware of which sub-protocol is in use and behave accordingly. Within a network, it is enough that a process "knows" which protocol is expected by another process. Across networks, the protocol should be identifiable by looking at the message. The less desirable alternative is to require a process to recognize that it is communicating with a process in another network, and to

inform the network interconnection pseudo-host each time a new protocol is invoked.

c. Ideally, the inevitable inter-network protocol differences should be confined to extensions that are "discardable" across network bounds. This would include options that need not be invoked (and could not be invoked in the special case of inter-network communication), and extra information that can be stripped off by the inter-network pseudo-host without altering the basic nature of the information interchange.

Currently, the best model for protocols would seem to be the ARPA network. The reasons for this are the amount of experience and the likelihood of future connection. The extensions to the current ARPA protocols suggested below are the File Access Protocol and the Disconnection Protocol.

If history is any guide, the one sure thing about the model (and therefore its derivatives) is that it will change. What follows is descriptive, and does not attempt to get down to the bit level. The intent is to outline the functions which would be performed by the various protocols.

The general scheme is fairly straightforward in principle. Each level of protocol uses some message space for its control information which is stripped off before the message is handed up to the next level and added on after information is handed down from the next level.

Level one protocol consists of the host-subnet conventions. These will vary at the host end depending on the host type. Basically, this amounts to a description of how the node computer appears as an input-ouput device to the host system.

Level two protocol is the basic host-host protocol. It is implemented by the network control program or its equivalent and is invoked implicitly by input-output requests on network addresses by other programs in the host computer. The functions that must be supported at this level include:

a. connect and disconnect (establish and terminate links) to remote processes,

b. control message flow (buffer space management, error checking and "sense" requests),

c. deal with pseudo-interrupts to and from the remote process.

Level three protocols are closer to the user process level. These provide data handling conventions and mapping conventions oriented to the most frequently encountered uses of the network. Suggested level three protocols and their functions follow:

1. Initial Connection Protocol would establish a logical connection between remote processes. This would include conventions for:

   a. identifying a process by name ,

   b. identifying the prospective user of the process ,

   c. dealing with access controls to the system in which the desired process resides (passwords etc.).

2. Data Transfer Protocol for specifying data formats (byte size, whether data is bit stream or character stream, escape conventions, etc.) and signal conventions (end-of-file, for instance).

3. File Transfer Protocol for moving files between systems. This would define how to gain access to a file (establishing its name and dealing with system access controls) and transferring data (using the Data Transfer Protocol). A means of acquiring a standardized set of information about a file would be useful; in particular, the size of the file and its maximum record length would be useful in creating the receiving file.

4. Terminal Protocol for dealing with the many types of

terminal in use. Specifications would be for codes (ASCII,EBCDIC, etc.), line description (standard terminator character), escape conventions (for idiosyncracies of terminal types known to the driving process), attention handling, echo specification (preferably none - character echoing on the network is inefficient), and sensing (the facility should be available to find out what kind of terminal is on the other end of a connection).

5. Remote Job Entry Protocol for access to batch service. Conventions would be required for submitting a job (probably as a series of card images), receiving a receipt number for the job, querying the status of a job (asking where in the queue a job with a given receipt number is, etc.), changing the status of the job (modifying its priority, where that is allowed, for instance), and retrieving the job's output.

6. Graphics Protocol for interfacing with graphics terminals. This would involve conventions for image decriptions: vector and character information, cursor and light pen positional feedback. Subconventions would be required to deal with the differences between plotters, raster displays, true vector displays, and storage scopes.

7. File Access Protocol for performing individual input-output operations on files across the network rather than transferring the whole file. This would include conventions for file access (parallel to the conventions used by the

File Transfer Protocol) and for read, write, and signal operations (such as end-of-file and record-not-in-file signals). It should be possible to describe a network ideal file to reduce the number of mappings to and from different record and key formats. For instance, it would be quite straightforward to define a format which would include, as subsets, OS/360 Fortran-produced direct access data sets, TSS/360 line data sets, and MTS line files.

8. Disconnection Protocol for itemizing charges for the process being disconnected. Installations will want to charge for outside usage of their systems and control the degree to which their users make use of other systems. The disconnection information might consist of two parts: an optional section containing an itemized breakdown of charges (for such things as CPU time, memory usage, input-output operations, etc.), and a section containing a standard format dollar cost. It might also be useful to provide a means to enter the dollar cost into the statistics collection facility of the subnet. This would give a measure of the value of the business conducted over the network.

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DEPARTMENT OF COMMUNICATIONS

CANADA

MINISTÈRE DES COMMUNICATIONS

# Topological Analysis of CANUNET

BY

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April 1972

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# Table of Contents

Summary

This report presents the topological analysis of various possible networks for CANUNET. Several Network Topologies based on the use of terrestrial facilities are analyzed in Part I. In Part II possible network topologies for CANUNET based on the use of the ANIK satellite with terrestrial facilities are analyzed.

Part III gives various cost comparison figures for the networks of Parts I and II.

The computer programs used to simulate these various topologies were developed within the Department, are completely conversational, and are located on its Sigma-7 computer at Shirley's Bay in Ottawa.

# PART I

## TERRESTRIAL NETWORKS FOR CANUNET

Introduction

This is the final report of the Communication Studies Group of the CANUNET project. The work as outlined in this report was performed within the Department of Communications by members of the Terrestrial Planning Branch Staff.

In this part of the report various topologies for 10 node, 14 node and 18 node message switched store and forward network configurations of a Canadian Universities Computer have been simulated. Specifically, for each of these topologies, various levels of message traffic were simulated and used to determine average message delay for message lengths of 640 bits, and average of message plus acknolwedgements lengths of 400 bits. These message delays were plotted against the levels of simulated traffic for each of these topologies having 4.8,9.6 and 50 kilobit lines.

Chapter I contains a brief discussion of some of the considerations made with respect to Network Configurations, Node Selection, Traffic Distribution, Routing Procedures and a summary of the Queuing theory results that have been applied to CANUNET. It also contains diagrams of the terrestrial network topologies, with tables of the various speed lines, as well as graphs of the average delay versus simulated traffic for each of these options.

TCTS preliminary quotations of communication costs are in Chapter II. Chapter III contains TCTS quotations of the communication costs for several possible realizations of a 28 node CANUNET.

The computer program developed in the Department of Communications for simulating CANUNET can handle up to 30 nodes and hence would allow for simulation of all possible future extensions of CANUNET. It should also be apparent from the topologies shown in Chapter I, and especially for the 18 node one that it is being suggested that the Network Control units allow more than one university computer in a given region (say within 40 to 50 miles) to join the network. This is a slight departure from the ARPA idea, however it appears to offer attractive possibilities for enlarging the network. It should be stressed that this assumption could be removed and that the simulation programs in the Department could readily simulate situations in which there was only one computer per network control unit. We have done the more general case in which there is more than one host computer per network control unit.

In Chapter IV, the full "output" of the simulation program is given for a 10 node topology of Chapter 1. The simulation program did in fact produce such outputs for each of the simulations of the 14 and 18 node cases, however for the sake of brevity it was decided to include only the 10 node case.

Included in the output shown in Chapter IV, is a matrix $|\lambda|$ , where

$|\lambda| \equiv$ matrix of the average number of messages that travel every second between nodes $j$ along the indicated arcs (channels).

Of course what $|\lambda|$ really indicates from a design point of view is the size of the buffers required in each of the Network Control Units to handle the traffic.

It should also be emphasized that a message length of 640 bits was assumed. This is by no means a restriction as this is a variable in the simulation program.

The purpose of this report is to promote further dialogue on the CANUNET Communication Network Design. It is hoped, then, that discussions will carry on both in written and in verbal form so that we can arrive at a mutually acceptable network.

# CHAPTER I

## NETWORK MODEL CONSIDERATIONS

### Network Configuration

There is no single best topology for a network like CANUNET. Consequently, in considering possible topologies for CANUNET, we have considered those that are flexible and adaptable to new demands without incurring too high a cost. In addition, the topologies considered are predicated on the use of existing common carrier facilities and offer satisfactory levels of reliability.

Standard message lengths have also been assumed. Since ARPA has adopted a packet length of approximately 1000 bits, we have done the same. This guarantees a certain ease of interconnectibility or interworking between ARPA and CANUNET, should this be desirable in the future.

### Node Selection

The node selection was based on those Universities that have to date expressed an interest in the CANUNET project. This is not necessarily the way in which the participating Universities will be selected but for the purpose of this study, it was the assumption made. As the need arises, modifications to this selection procedures can easily be accommodated by our model.

In the case for a selection of nodes in a Province there are two possible choices that dictate basic network configuration as far as the numbers of networks control units is concerned. These are:

a) assign one network control unit per host computer

b) assign one network control unit to several host computers. This has the advantage that new hosts could be added to the network, at least up to a point without changing the topology.

## Traffic Simulation

There are no known results that allow precise estimates of traffic levels to be given apriori, there is however, an empirical formula due to Frank & Chou[2)] that allows the simulation of various levels of traffic. We have used a variation of this formula to generate various levels of traffic (in bits per second) out of each node so that the performance of the various topologies could be examined with this traffic, etc.

The formula used was quite a simple one, that is the simulated traffic from node i to node j was

$$K \frac{P_i P_j d_{ij}^{\alpha}}{\sum_k P_k d_{ik}^{\alpha}}$$

where

- $P_i$ and $P_j$ are the populations, in students at the universities at nodes i and j respectively
- $d_{ij}$ is the distance in miles between nodes i and j (for $i \neq j$)
- $\alpha$ is a non negative constant. ($\alpha = 0$ was used in the model; that is the traffic was independent of distances between nodes)
- K is a numerical constant which determines the traffic level; that is, by varying K various levels of traffic between nodes i and j are generated.

## Routing Procedures

Route selection is one of the most important design features of a computer network given its effect on the average time delay encountered by a message flowing in the network.
Ideally in order to minimize this average time delay, the route selection should be adaptive i.e. a function of the traffic level. The ARPA network not only provides a minimum of two physically separated paths to route each message but also is capable of adaptive routing. Therefore, the routing procedure used in the ARPA network is in a sense optimal because the routes are chosen according to the traffic level and availability of the lines.

In our studies of the CANUNET network we chose to have a fixed routing procedure which is based on the shortest path a message has to travel from origin to destination. We are aware of the fact that the best fixed routing procedure is such that a path should contain the fewest number of intermediate nodes from origin to destination.

Queuing Theory (Summary)

The queuing theory model that we have used to study CANUNET performance is the M/M/1 queue model.

For a M/M/1 system, the average time that a message would spend using and waiting for the single $i^{th}$ channel would be.

$$T_i = \frac{\rho_i/\lambda_i}{1-\rho_i} \qquad (1)$$

where

$\lambda_i$ = average number of messages per second is the $i^{th}$ channel

$C_i$ = capacity of the $i^{th}$ channel in bits/sec.

$\rho_i$ = utilization factor of the $i^{th}$ channel $= \frac{\lambda_i}{\mu C_i}$

$\frac{1}{\mu}$ = mean of the exponentially distributed message lengths

Making these substitutions in (1) becomes

$$T_i = \frac{1}{\mu C_i - \lambda_i} \qquad (2)$$

Then, the message delay in the $i^{th}$ channel averaged over the entire network using M/M/1 theory is

$$T = \sum_i \frac{\lambda_i}{\gamma} (T_i) \qquad (3)$$

where $\gamma$ is the total input data rate ie. the traffic in mess./sec. In order to take into account the fact that nodal delays are not negligible, a constant $10^{-3}$ is added to (3), and the total message delay T averaged over all the channels in the network becomes from (3)

$$T = \sum_i \frac{\lambda i}{\gamma} (T_i + 10^{-3}) \qquad (4)$$

The time spent waiting for a channel is dependent upon the total traffic(including acknowledgements) whereas the time spent in transmission over a channel is proportional to the message length of the real message traffic flow, thus equation (3) is not correct. However, a new equation is easily derived from the POLLACZEK-KHINCHIN formula which gives:

$$T_i = \frac{\rho_i}{\lambda_i} + \frac{(\rho_i)^2 \ (1 + C_b^2)}{2\lambda_i \cdot (1-\rho_i)} \qquad \ldots.$$

where $C_b = 1$ for the M/M/1 queue.

Equation (4) can be rewritten as

$$T_i = \frac{\rho_i}{\lambda_i} + \frac{(\rho_i)^2}{\lambda i\ (1-\rho_i)} \qquad (5)$$

where

$$\rho_i = \frac{\lambda_i}{\mu C_i}$$

The first term on the right side of (5) is the average service time per message, and the second term is the average waiting time per message. Since this service time depends on $\frac{1}{\mu'}$, and the waiting time depends on $\frac{1}{\mu}$, equation (5) can be rewritten as

$$T_i = \frac{1}{\mu' C_i} + \frac{(\lambda_i/\mu C_i)}{\mu C_i - \lambda_i} + PL_i \qquad (6)$$

where the term $PL_i$ has been added to take into account the propagation time.

Thus the total average delay time T for a message in the network is found by substituting (6) into (3), and is

$$T = \sum_i \left(\frac{\lambda i}{\gamma}\right)\left(\frac{1}{\mu' C_i} + \frac{(\lambda_i/\mu C_i)}{\mu C_i - \lambda_i} + PL_i + 10^{-3}\right) + 10^{-3}$$

....(7)

The last term in equation (7) accounts for the delay introduced by the final destination network control unit in delivering the message to its host. This figure of $10^{-3}$ was used in the cas of ARPA where each host is located only a short distance away from its IMP (or network control unit). In the case of CANUNET simulations, the same formula was used, although it should be appreciated that if a host was located far from its network control unit, this delay of $10^{-3}$ sec. could be different.

In developing the model for CANUNET, we have as in the ARPA case, taken the fact that acknowledgement messages increase message traffic rates, and for the CANUNET simulations, we have assumed

$$\text{Average packet length} \equiv \frac{1}{\mu'} = 640 \text{ bits}$$

$$\text{Average packet length with acknowledgements} = \frac{1}{\mu} = 400 \text{ bits}$$

---

*) These lengths are variable in the simulation program and the simulations could have been done for the ARPA lengths which are 560 bits, and 350 bits respectively.

NOTE: The total average delay as computed by equation (7) takes only in account the traffic of short messages (packets).

Program Description

The input/output for the simulation program is:

INPUT:

| | | |
|---|---|---|
| N | → | Number of Nodes |
| [P] | → | Vector of the population at each node |
| [D] | → | Matrix of distances between any two nodes |
| [C] | → | Branch capacity matrix |
| $1/\mu$ | – | Overall average message length |
| $1/\mu'$ | – | Average packet length |

OUTPUT:

| | | |
|---|---|---|
| [T] | – | Traffic matrix in bits/sec. |
| T.I.D.R. | – | Total input data rate in bits/sec. |
| T.I.D.R.' | – | Total " " " in mess/sec. |
| [S] | – | Shortest distance matrix |
| [ρ] | – | Network Utilization Matrix |
| [R] | – | Routing Matrix |
| [λ] | – | Matrix of the average number of messages |
| [A] | – | Average Delay Matrix |
| T.A.D. | – | Total Average Delay |

## Network Topologies and Performance Graphs

### Summary

Following is a summary of results for the 10, 14 and 18 node options for CANUNET. It includes for each network its topology, and graphs of "Total Average Delay" versus "Total Input Data Rate".

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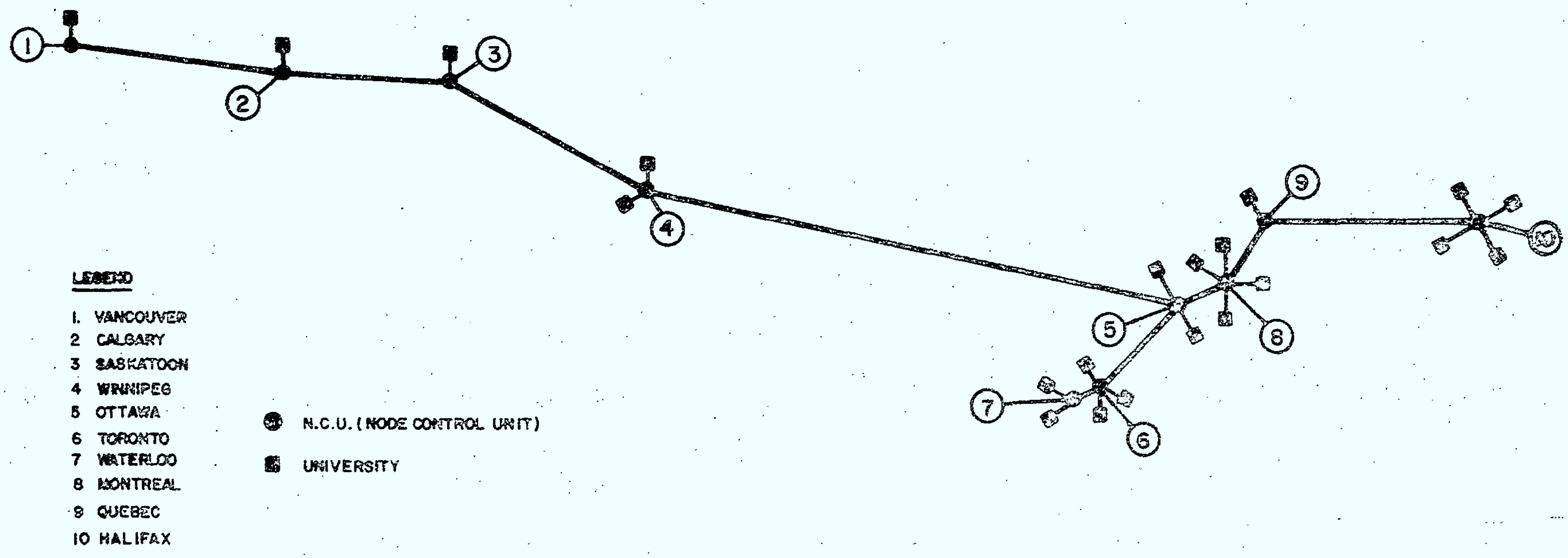
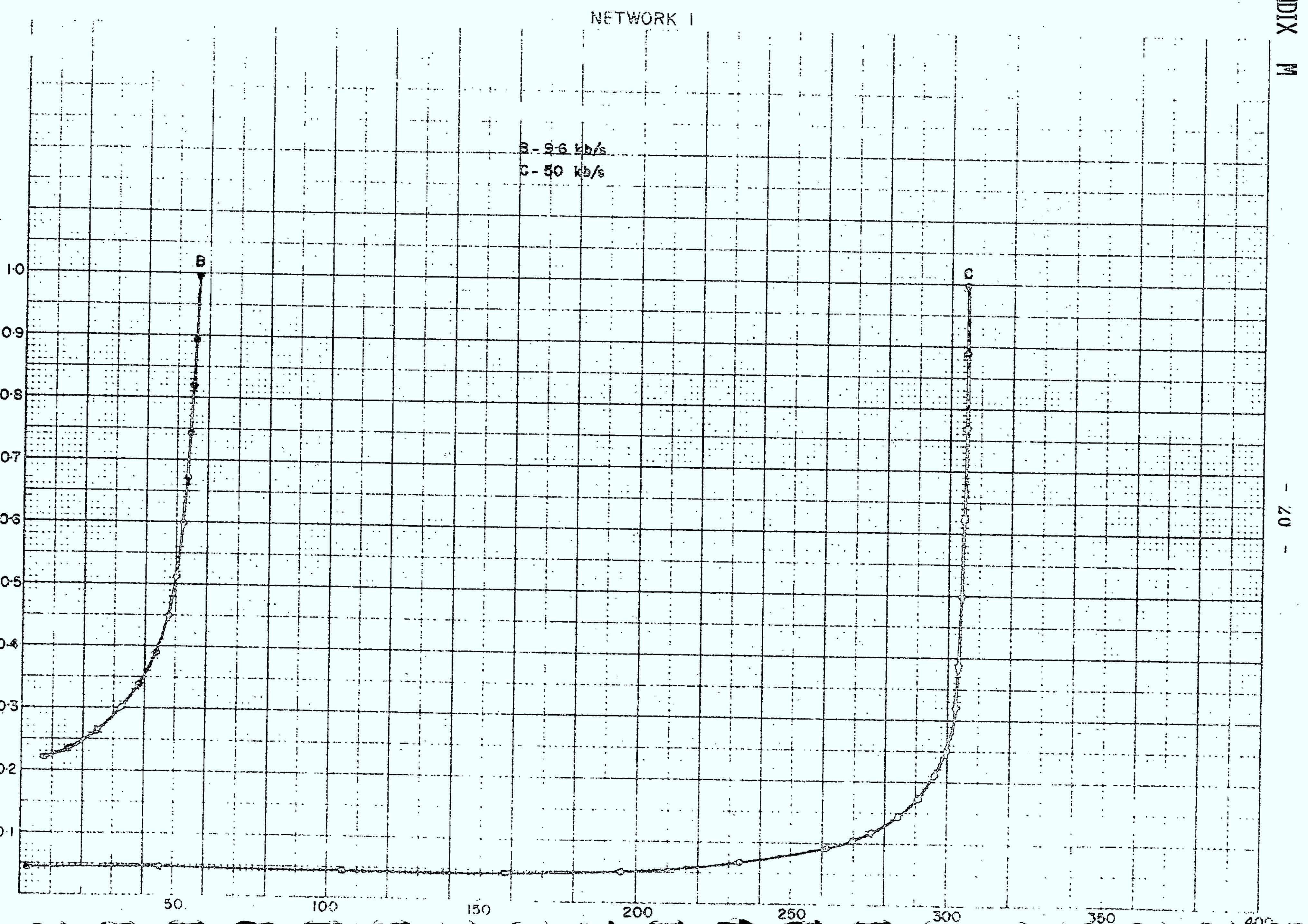
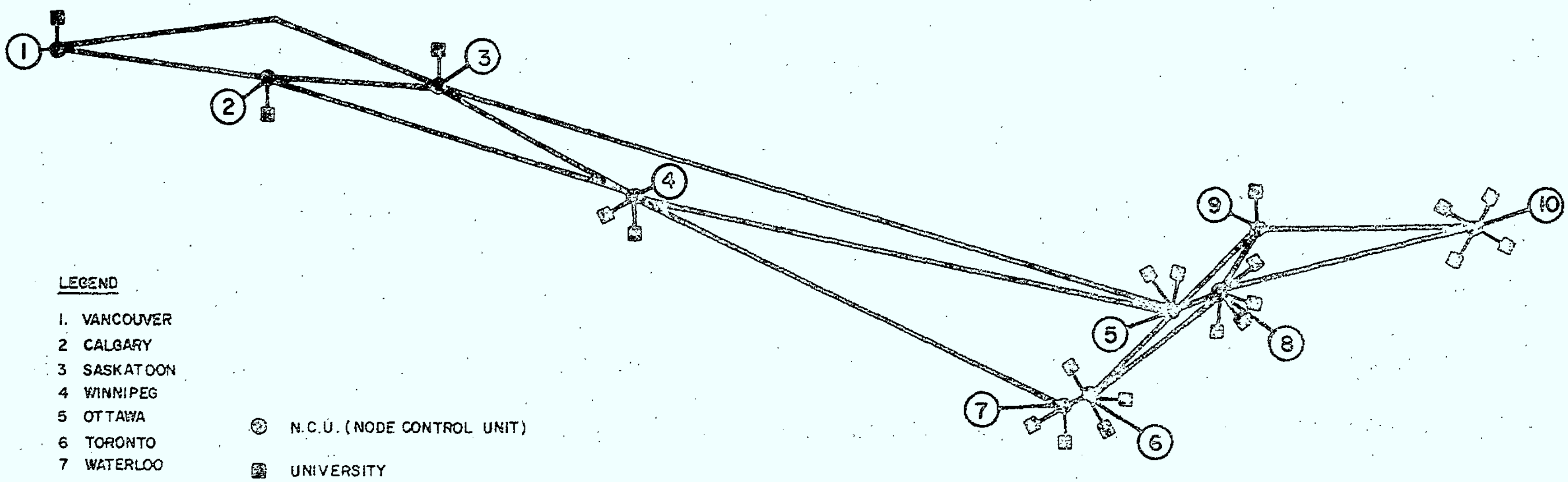
## NETWORK I




NETWORK 1
B - 9.6 kb/s
C - 50 kb/s
B
C
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
50
100
150
200
250
300
350
400

[redacted]

## NETWORK 2



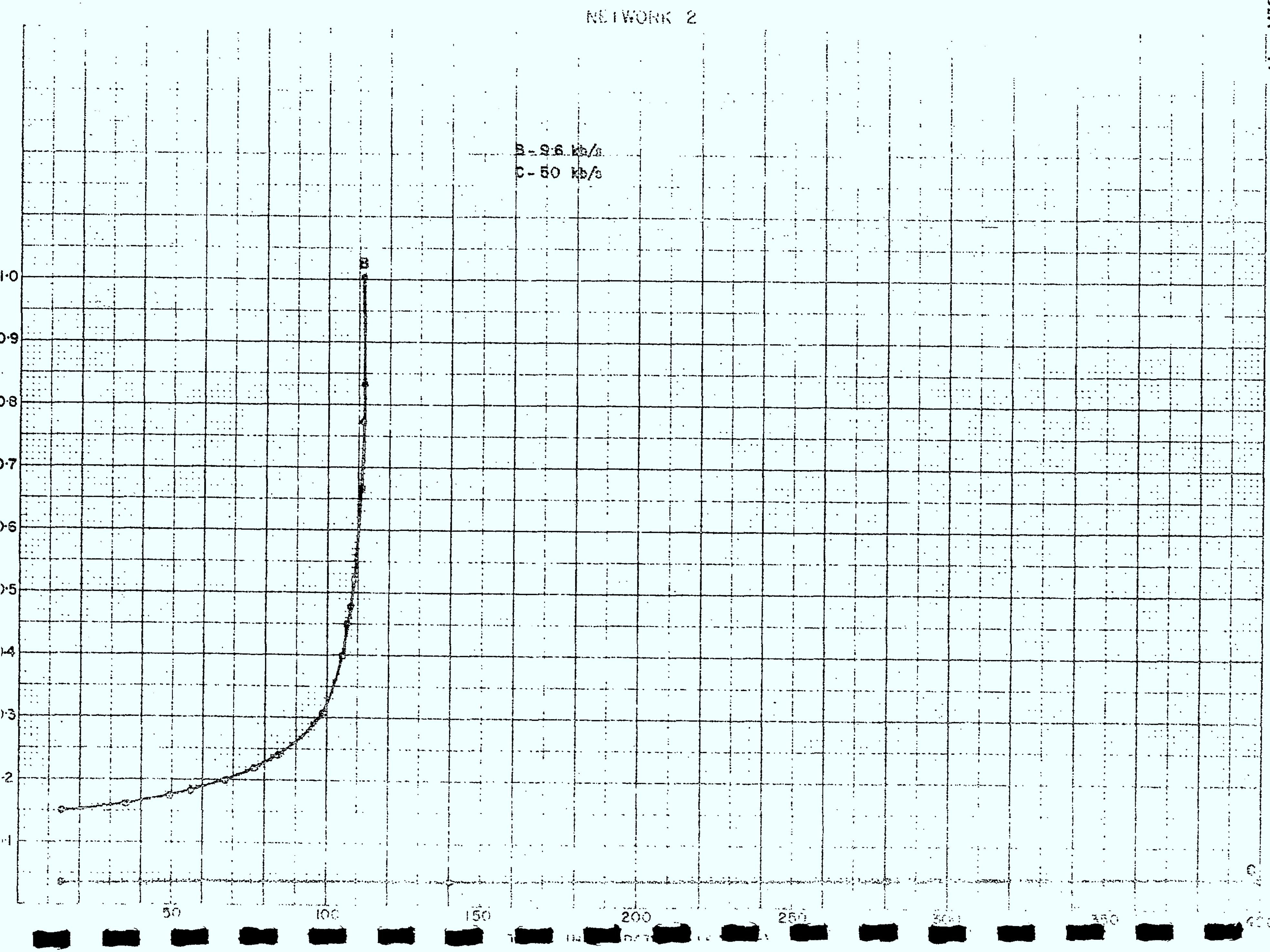

LEGEND

1. VANCOUVER
2. CALGARY
3. SASKATOON
4. WINNIPEG
5. OTTAWA
6. TORONTO
7. WATERLOO
8. MONTREAL
9. QUEBEC
10. HALIFAX

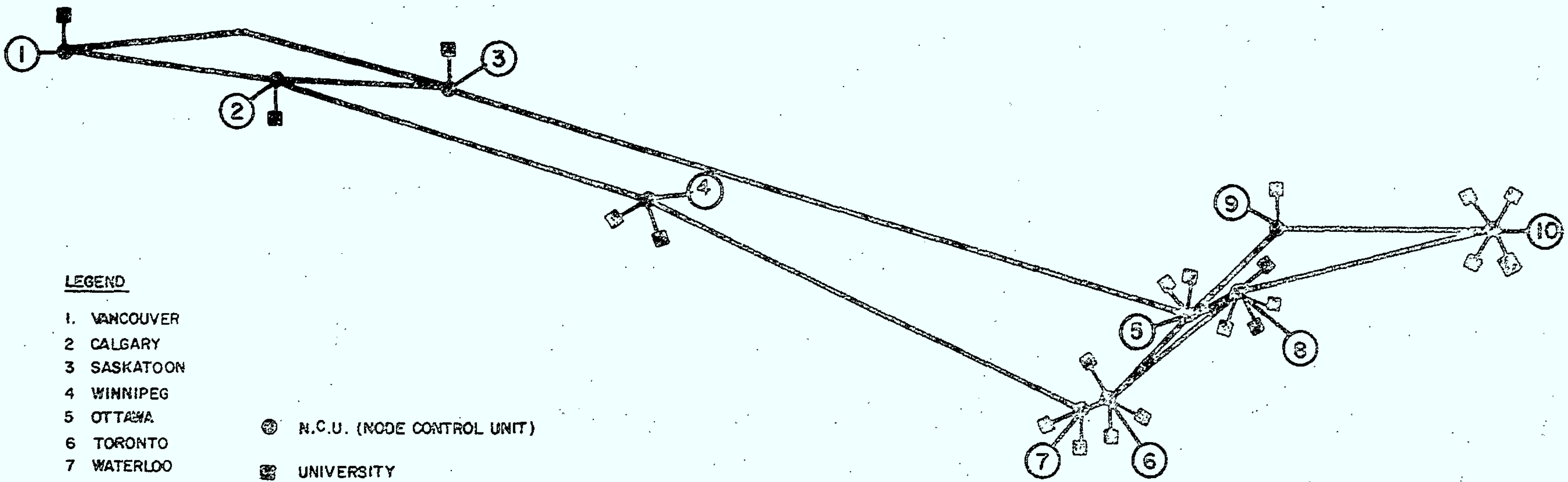
⊗ N.C.U. (NODE CONTROL UNIT)

▩ UNIVERSITY

APPENDIX M


NETWORK 2
B - 9·6 kb/s
C - 50 kb/s
B
C
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
·2
·1
50
100
150
200
250
350

## NETWORK 3



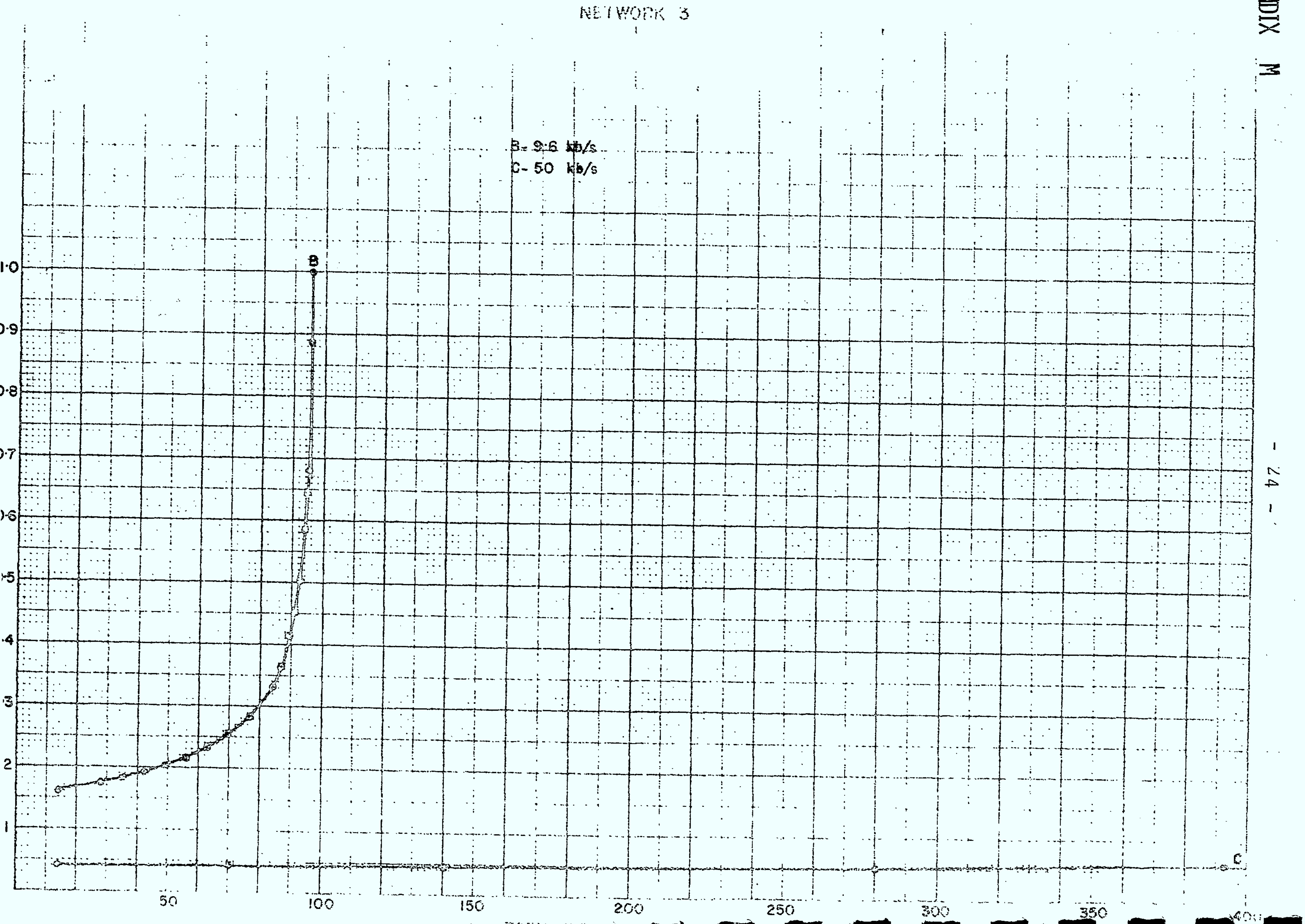

LEGEND

1. VANCOUVER
2. CALGARY
3. SASKATOON
4. WINNIPEG
5. OTTAWA
6. TORONTO
7. WATERLOO
8. MONTREAL
9. QUEBEC
10. HALIFAX

N.C.U. (NODE CONTROL UNIT)

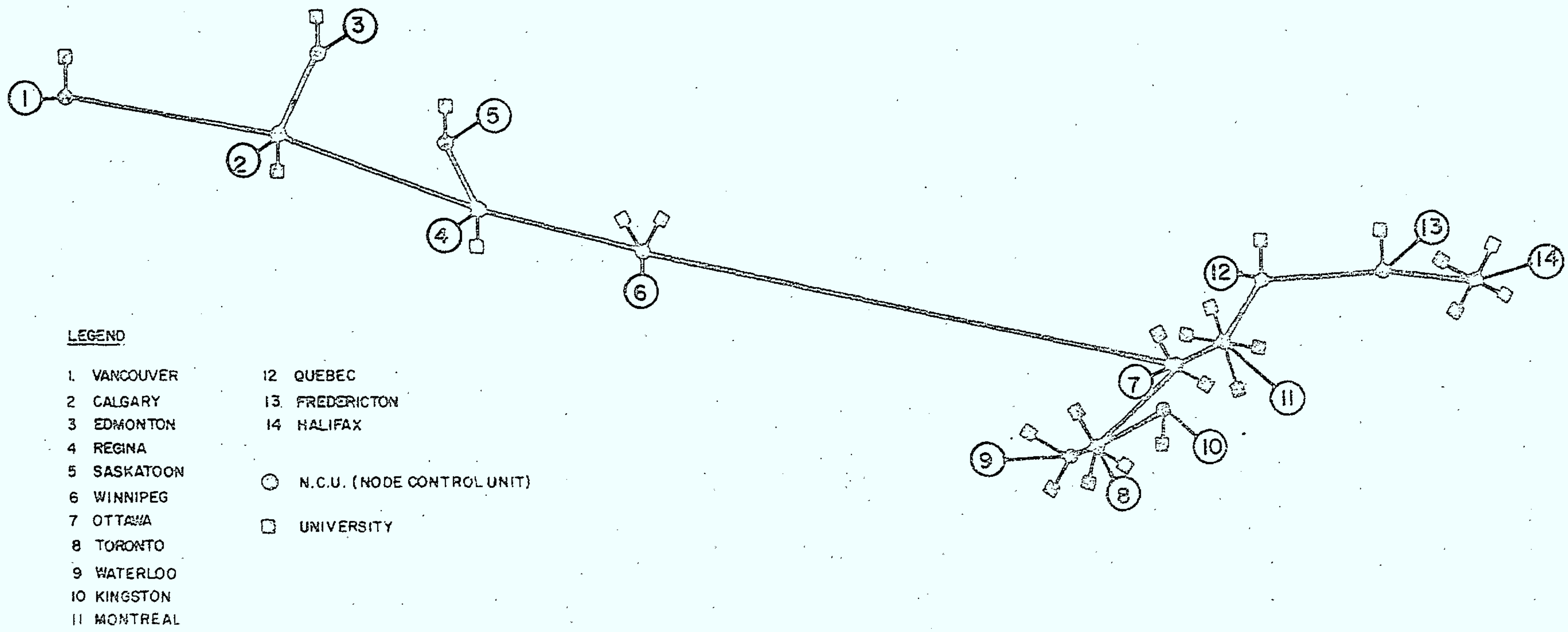
UNIVERSITY

APPENDIX M



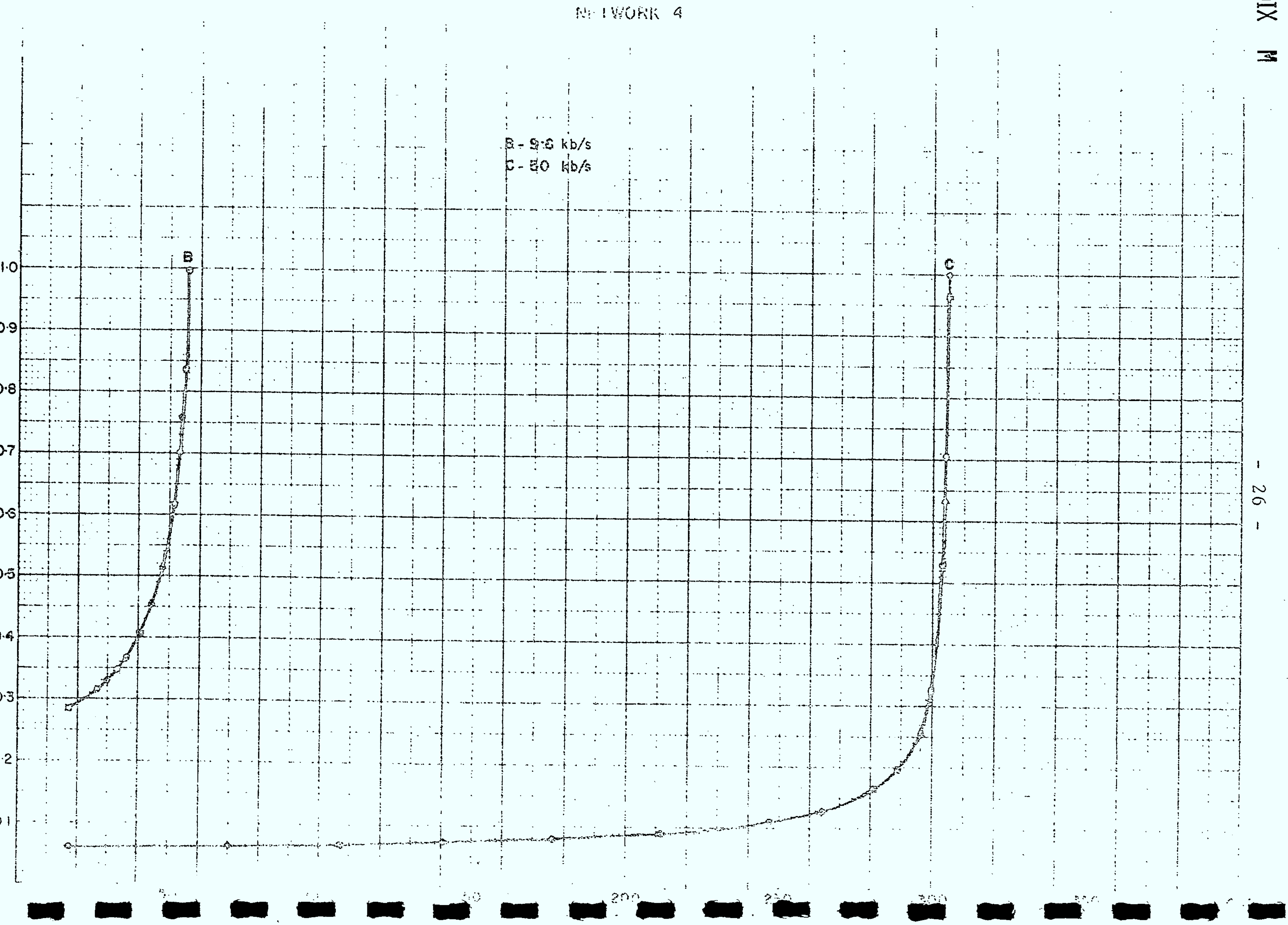

[redacted]

# NETWORK 4

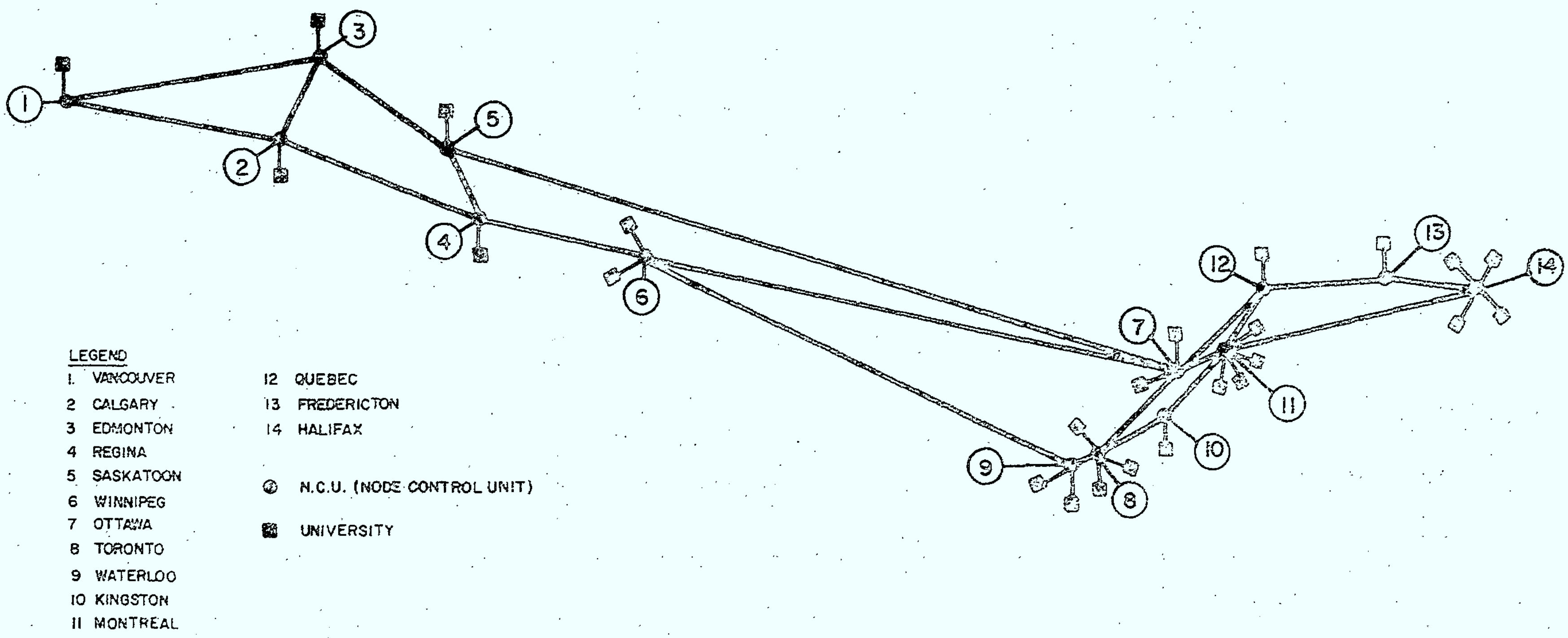





APPENDIX M

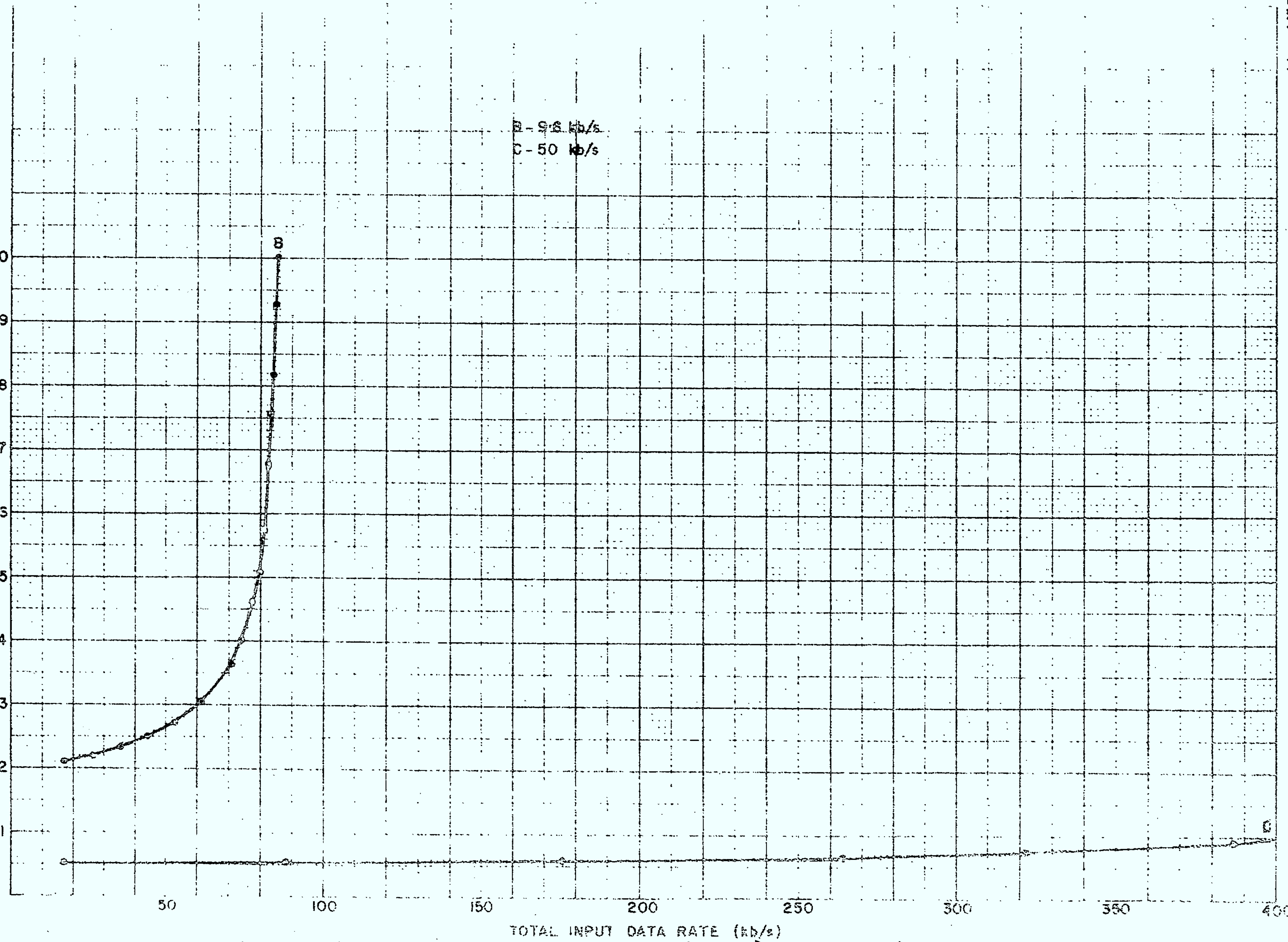

NETWORK 4
B - 9.6 kb/s
C - 50 kb/s
B
C

## NETWORK 5



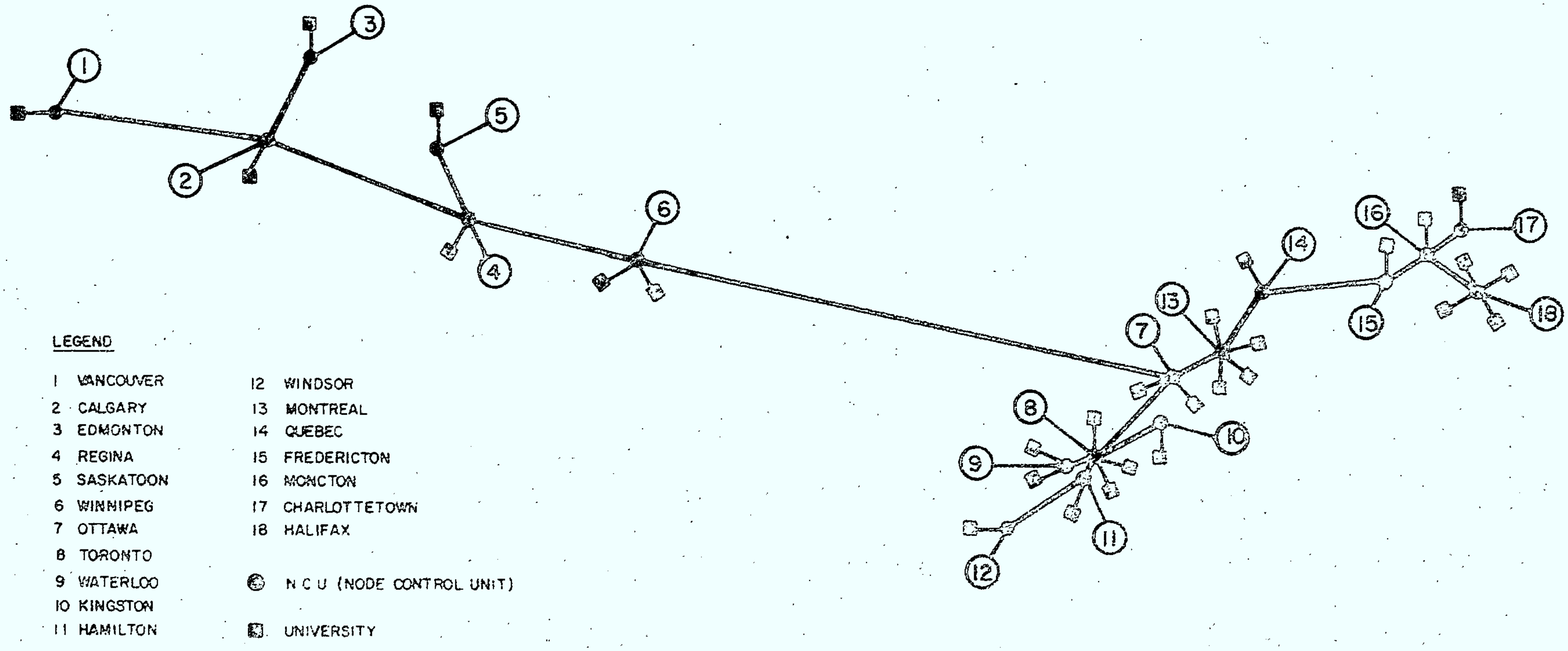

APPENDIX M

NETWORK 5

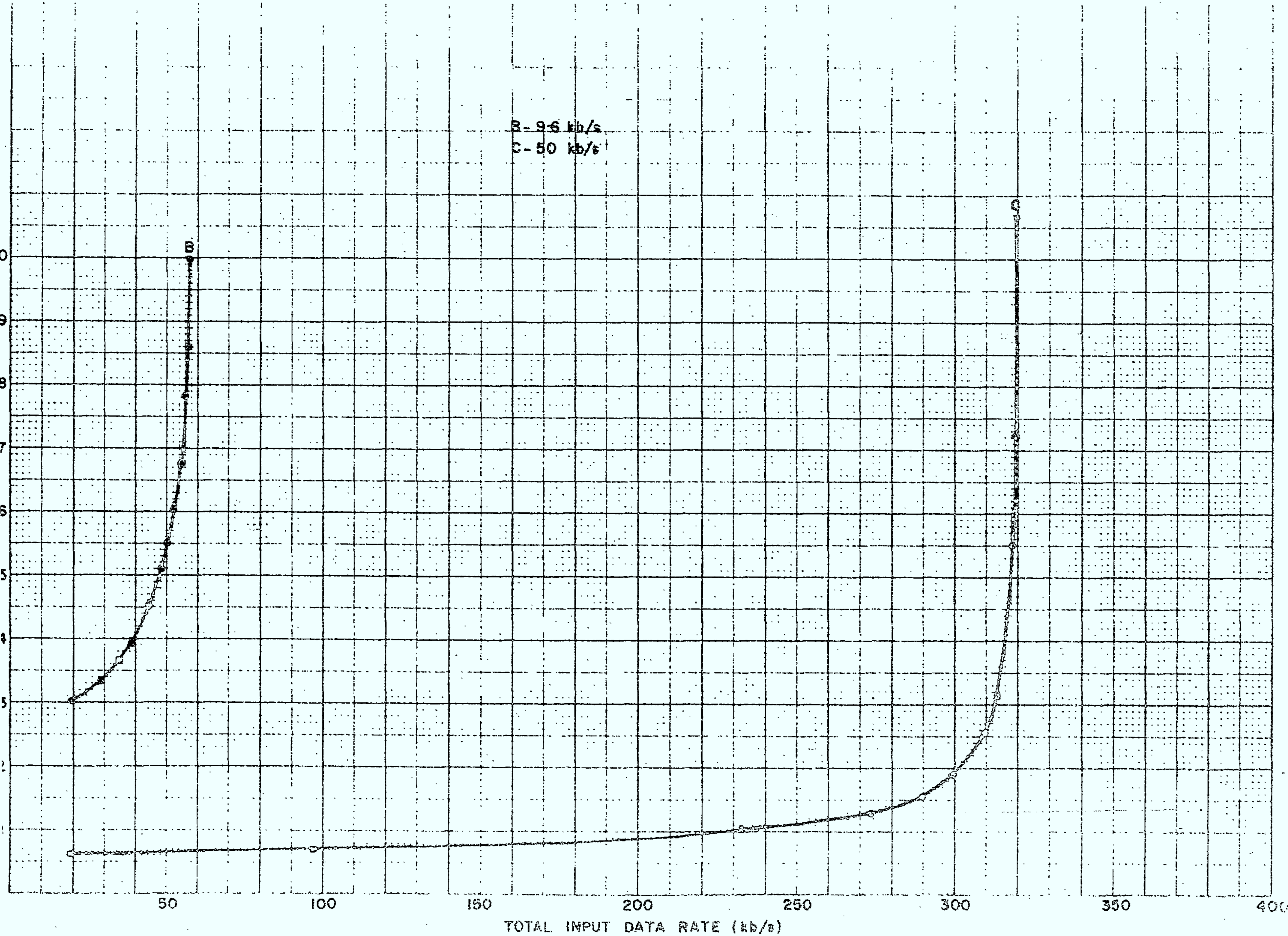

B - 9.6 kb/s
C - 50 kb/s
B
C
0
9
8
7
6
5
4
3
2
1
50
100
150
200
250
300
350
400
TOTAL INPUT DATA RATE (kb/s)

APPENDIX M

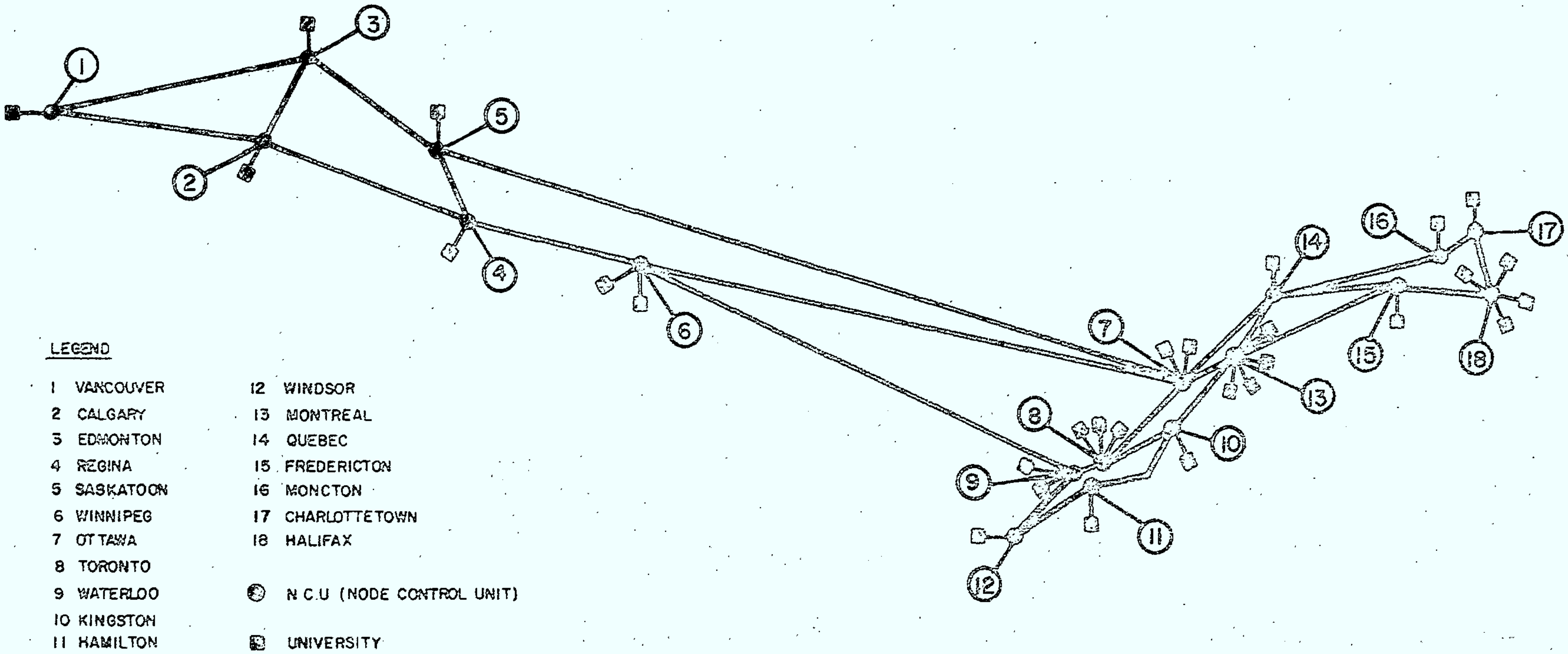
NETWORK 6



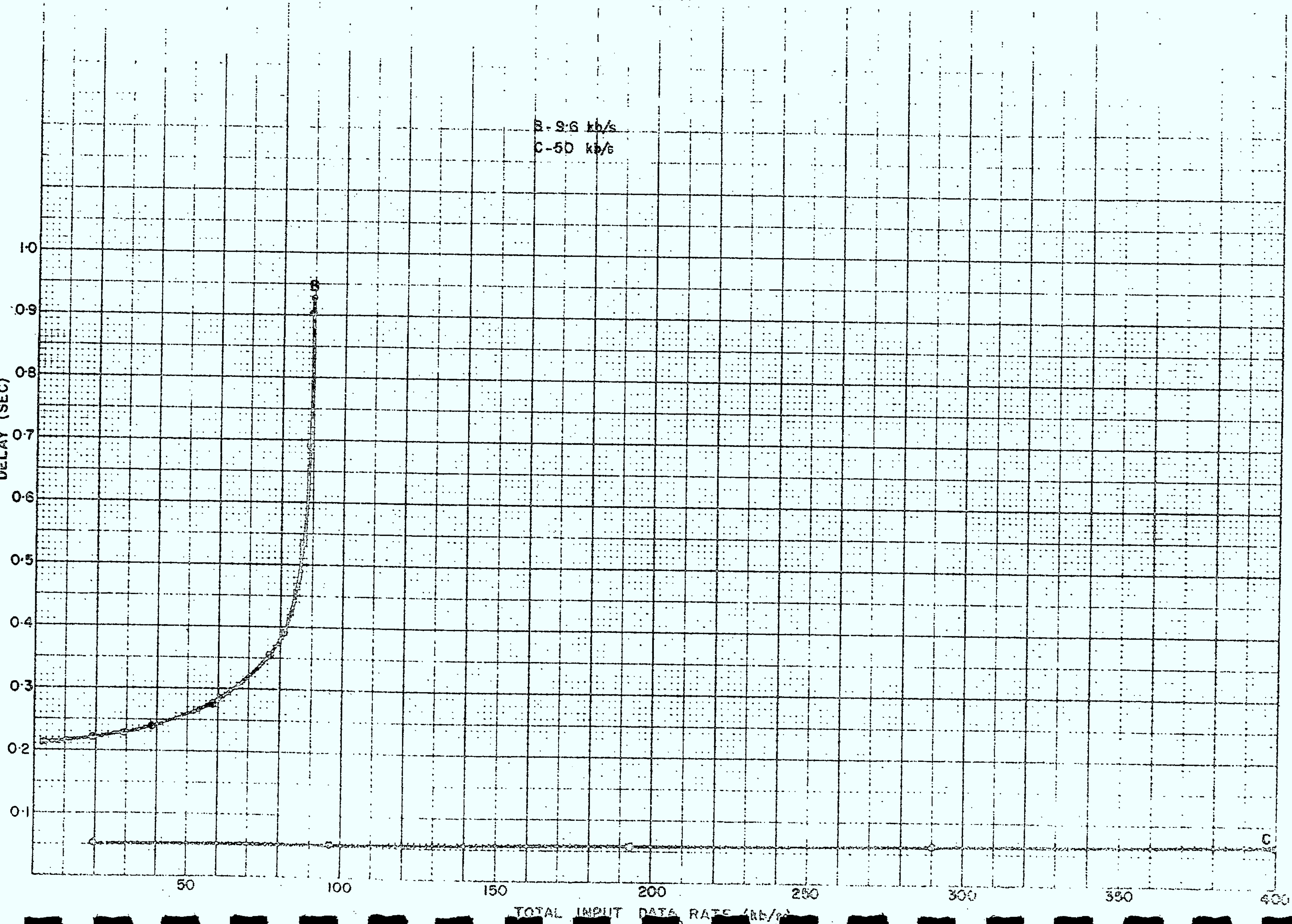
NETWORK 6


B - 9.6 kb/s
C - 50 kb/s
B
C
50
100
150
200
250
300
350
400
TOTAL INPUT DATA RATE (kb/s)

NETWORK 7


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
LEGEND
1 VANCOUVER
2 CALGARY
3 EDMONTON
4 REGINA
5 SASKATOON
6 WINNIPEG
7 OTTAWA
8 TORONTO
9 WATERLOO
10 KINGSTON
11 HAMILTON
12 WINDSOR
13 MONTREAL
14 QUEBEC
15 FREDERICTON
16 MONCTON
17 CHARLOTTETOWN
18 HALIFAX
N.C.U (NODE CONTROL UNIT)
UNIVERSITY

NETWORK 7


B - 9·6 kb/s
C - 50 kb/s
B
C
DELAY (SEC)
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
50
100
150
200
250
300
350
400
TOTAL INPUT DATA RATE

# CHAPTER II

## Communication Costs for Network Options

As a result of discussions with Trans-Canada Telephone System, an order of magnitude price guide for the seven CANUNET configurations was obtained and is given in Table I.*) These costs are provided for preliminary estimation purposes only, and the costs given could change when additional details become available on the overall system requirements.

It should be noted as per the letter from TCTS, that the prices quoted are only for the inter-node circuits and do not include circuits connecting the individual universities to the nodes. The prices quoted include inter-exchange circuits, conditioning and modems, but not "local loops".

*) See page 36

Trans-Canada Telephone System

1 Nicholas St., Ottawa 6, Ont.
P.O. Box 8462,
Telephone 613 239-2580
TWX 610 562-1941

Murray Robinson
District Account Manager

7 January 1972

Dr. John deMercado,
Director,
Communications Technology Analyses and
Terrestrial Systems Planning Branch,
Department of Communications,
Berger Building,
100 Metcalfe Street,
OTTAWA, Ontario.
K1A OC8

Dear Dr. deMercado:

We have priced your seven CANUNET configurations --- the attached maps give price detail.

It is important to remember that the prices quoted are only for the inter-node circuits and do not include circuits connecting the individual universities to the nodes.

The prices quoted include inter-exchange circuits, conditioning, and modems, but not "local loops".

We hope that this information is of use to you in your development of CANUNET.

Yours truly,

Computer Communications
Account Manager -
(Federal Government)

Attachments

TABLE I (Monthly Costs)

| Network | Speed of lines / No. of nodes | 4.8 kbs/sec | 9.6 kbs/sec | 50 kbs/sec | Option 1 | Option 2 |
|---|---|---|---|---|---|---|
| 1 | 10 | $14,217 * | $19,617 * | $85,500 * | $21,728 ** | |
| 2 | 10 | 28,130 | 37,130 | 200,000 | | $90,245 *** |
| 3 | 10 | 21,795 | 28,395 | 159,425 | | |
| 4 | 14 | 18,494 | 26,294 | 104,700 | | |
| 5 | 14 | 32,811 | 44,811 | 214,850 | | |
| 6 | 18 | 22,756 | 32,756 | 117,175 | | |
| 7 | 18 | 39,347 | 54,947 | 242,850 | | |

* - these prices were given for network "1" where instead of having the arc (4,5), we have the arc (4,7)

** - this price corresponds to network "1" where all arcs are 9.6 kbs/sec. lines except arc (5,8) which was 50 kbs/sec.

*** - this price corresponds to network "2" where all arcs are 9.6 kbs/sec. lines except arc (4,5) (4,8) (5,8) (6,8) which was 50 kbs/sec.

# CHAPTER III

APPENDIX M



**Trans-Canada Telephone System**

1 Nicholas St., Ottawa 8 Ont.
P.O. Box 8462.
Telephone 613 239-2586
TWX 610 562-1941

Murray Robinson
District Account Manager

24 December 1971.

RECEIVED
DEC 31 1971
CTP

Dr. John deMercado,
Director,
Communications Technology Analyses and
Terrestrial Systems Planning Branch,
Department of Communications,
Berger Building,
100 Metcalfe Street,
OTTAWA, Ontario.
K1A 0C8

Dear Dr. deMercado:

In response to your request, we have completed an order of magnitude price guide for the proposed "Canadian University Computer Network".

This guide is furnished for use only by the Federal Department of Communications and those universities involved in the CANUNET studies, and is for budgetary estimation purposes only, as the rates mentioned could significantly change when additional details become available on the overall system requirements.

The Trans-Canada Telephone System is prepared to work with those involved in the design of CANUNET to develop a workable, efficient, and totally cost effective overall telecommunications system for CANUNET.

Yours truly,

Murray Robinson

Attachment to letter of Dec 24/71 to Dr. John deMercado

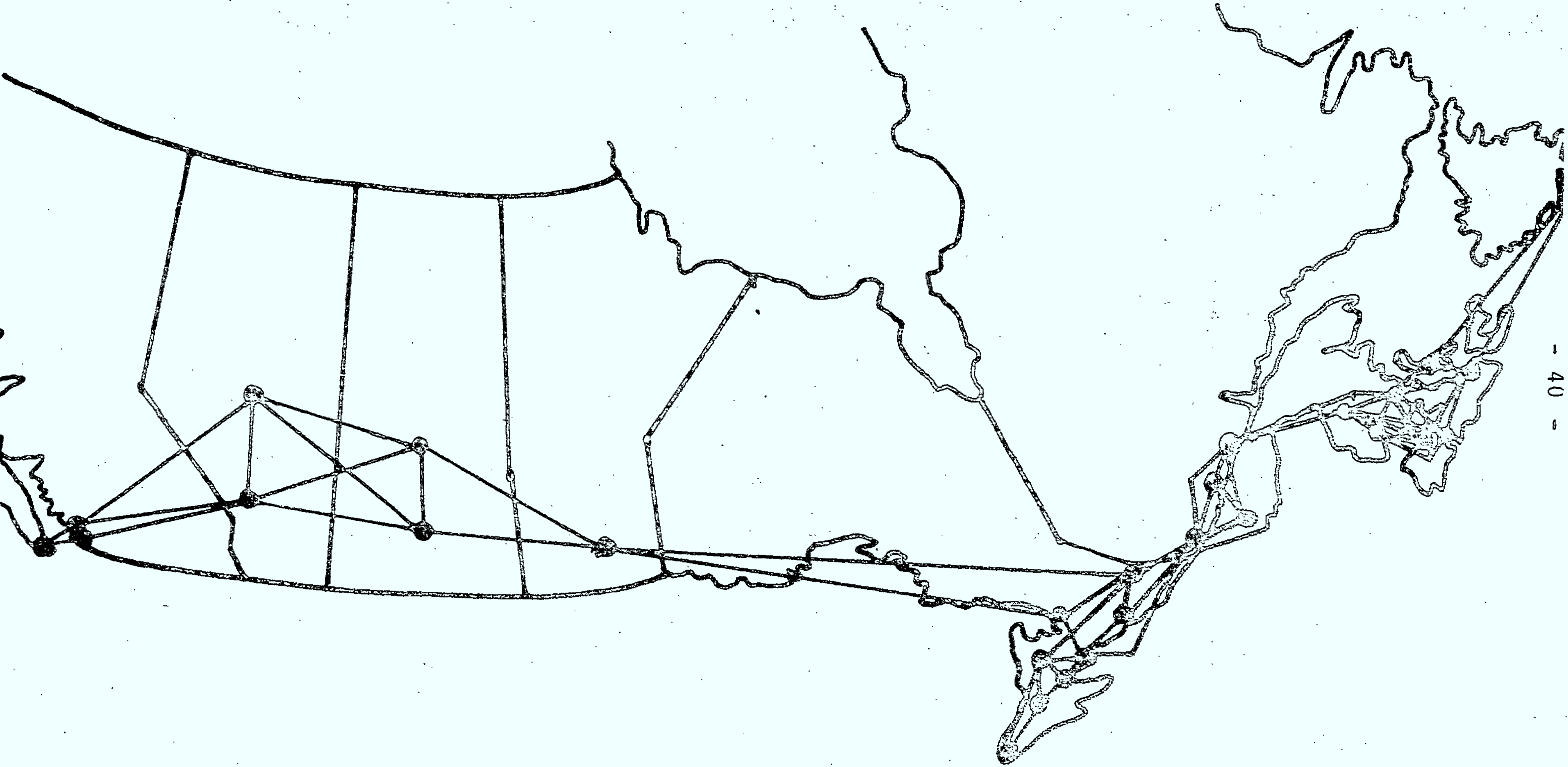
The following is a price approximation for the "many to many" circuit arrangement for CANUNET. It is based on having circuits between all those universities which have a community of interest (Fig. 1)

MONTHLY RATES

| SPEED | PRIVATE LINE | SWITCHED | |
|---|---|---|---|
| 2,400 bps | $57,500. | $13,500. | (one hour per day) |
| 4,800 bps | $59,500. | $25,000. | " " " " |
| 9,600 bps | $76,000. | $33,000. | " " " " |
| 50,000 bps | $372,000. | $307,800. | " " " " |
| | | $64,800. | (10 minutes per day) |

(The above includes line facilities, usage, modems and access lines, where required).

FIGURE I



Attachment to letter of Dec 24/71 to Dr. John deMercado

While there are many details that must be resolved in the design of CANUNET (volume of traffic, frequency and timing of traffic, etc.) we have considered some of the alternatives to the design shown in Figure I.

One possible alternative network design involves the use of three concentrators or store and forward message "switchers" (see Figure II). Exclusive of the cost of these switchers, the network facilities charges would be approximately as follows:

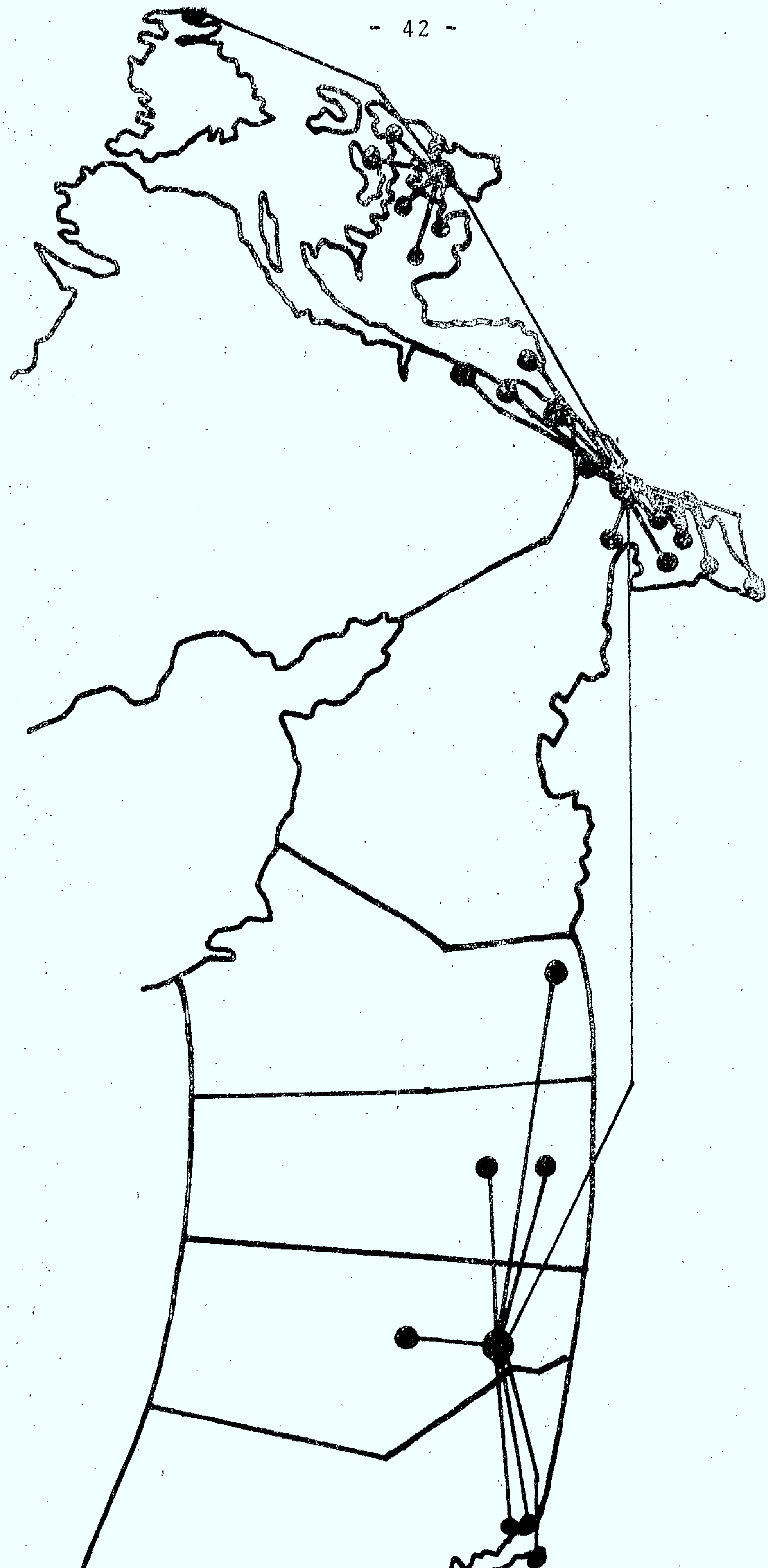
| | | |
|---|---|---|
| Private Line (2400 and 9600 bps) | | $34,500./mo. |
| Switched (2400 bps) | 1 hour/day | $11,000./mo. |
| | 5 hours/day | $24,500./mo. |
| | 8 hours/day | $35,000./mo. |

As before, the above prices include all lines, modems, and usage, where applicable.

# APPENDIX M



FIGURE II



Attachment to letter of Dec 24/71 to Dr. John deMercado

There are several advantages to this type of system operation, both in cost and operations.

There would be a substantial cost saving on the line facilities (approx. $23,000. per month) which would be only partly off-set by the cost of the three switchers. There might be further savings realized through the reduced "port" requirements at each participating university. Those universities which have an on-line capability would only require the addition of one input-output port, while those universities which will add on-line capability for CANUNET, would only require single line controllers rather than multi-line controllers. Furthermore, the use of common "switchers" would eliminate the need for standardization of transmission code, as the switcher could be arranged to provide a code (and speed) translation feature.

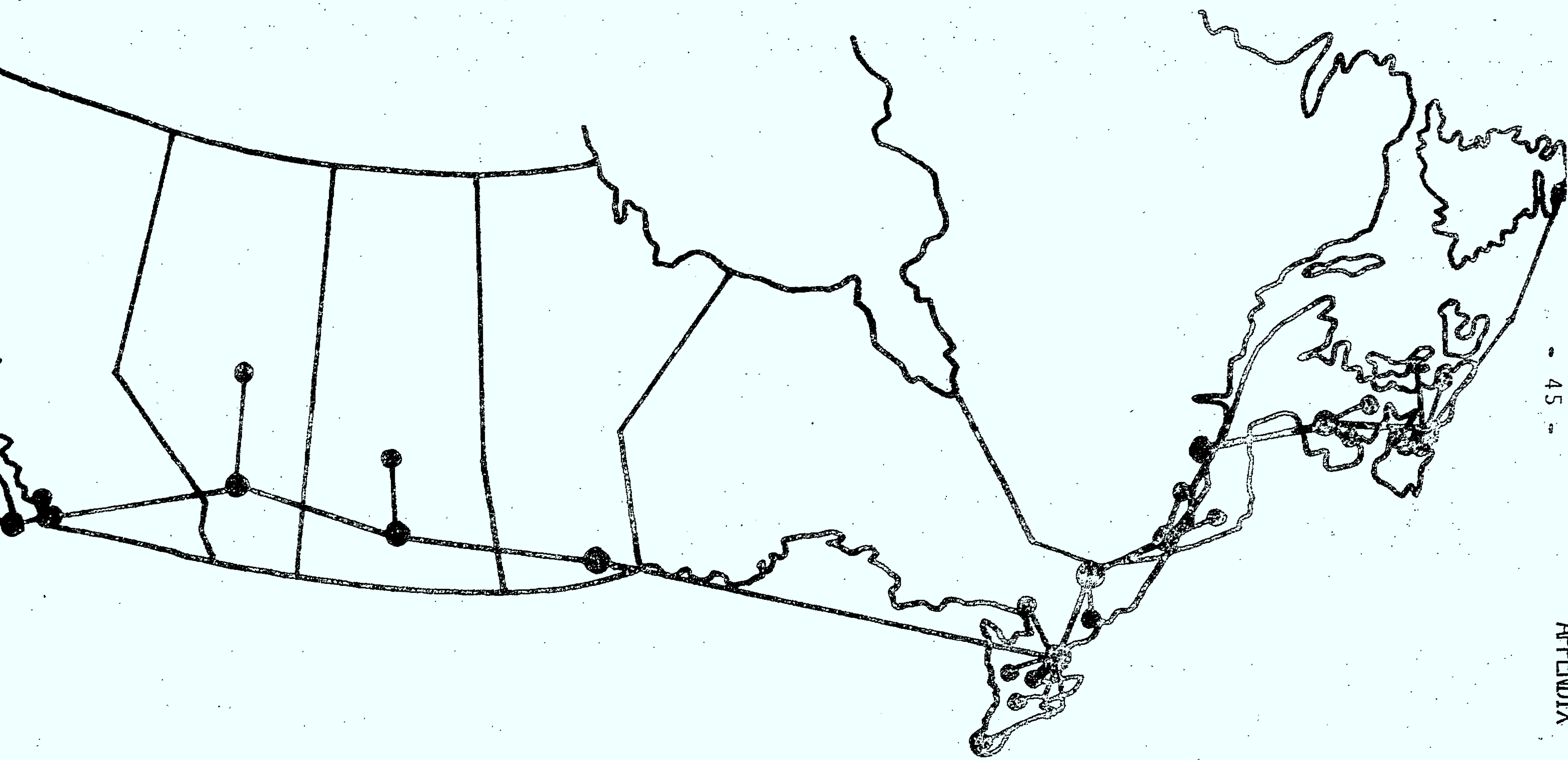
By placing the "switchers" as shown in Figure II, the three main communities of interest (Atlantic, Central, and Western) are kept intact. The majority of information transfer should be within these communities of interest, that is, within the switcher area, thereby reducing the volume of inter-switcher information flow, and reducing throughput time.

Attachment to letter of
Dec 24/71 to Dr. John
deMercado

There are several other types of network design which could be considered - a four switcher design, a daisy chain effect (see Figure III), or a single continuous circuit joining all locations (Figure IV).

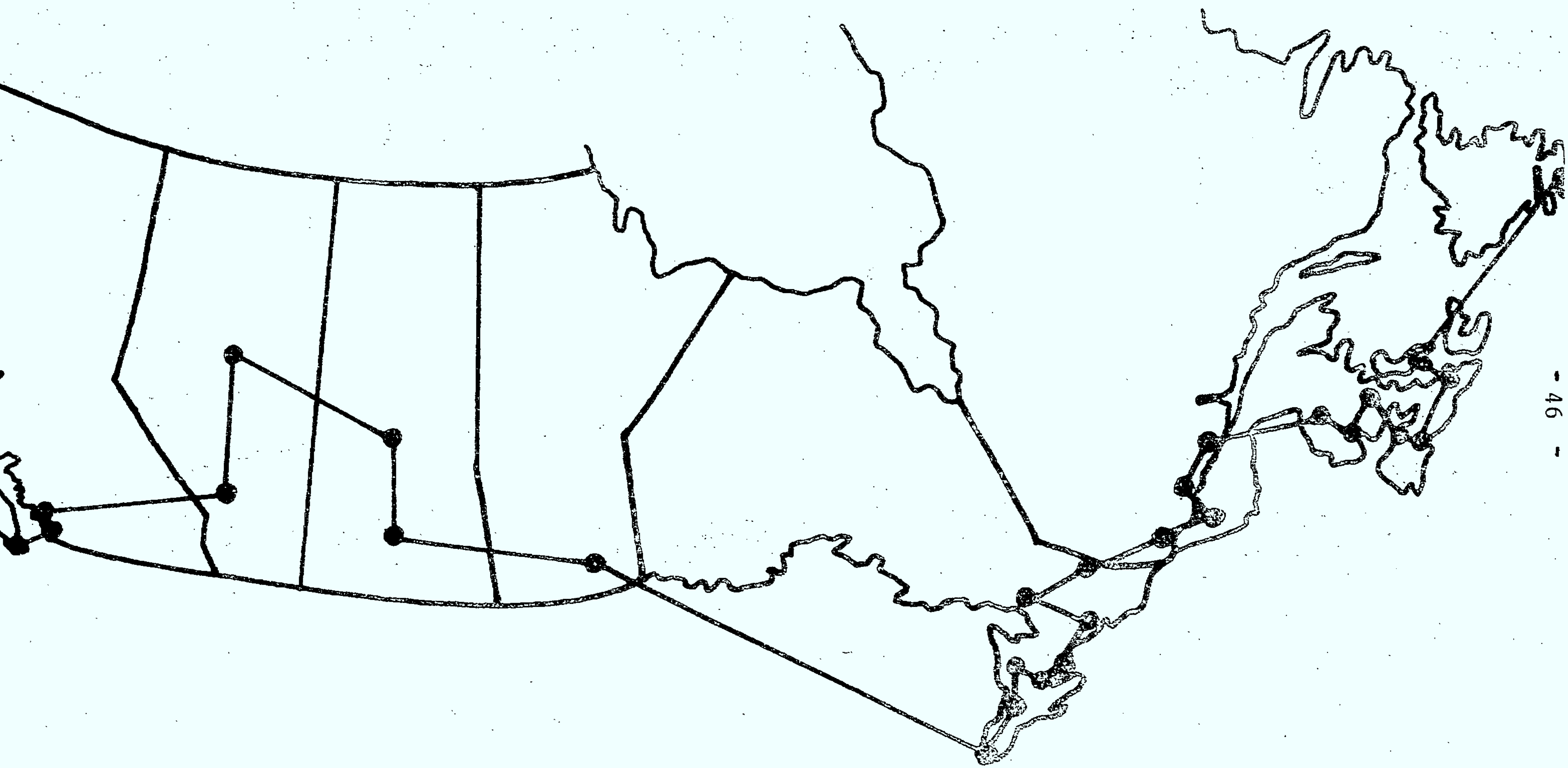
The final choice of the most efficient circuit design to serve CANUNET will have to be the result of extensive consultation between TCTS and the universities, to determine the exact values of various criteria such as traffic volumes, distribution, the frequency of "calls", and the operational requirements and capabilities of the associated existing computer hardware and software.

FIGURE III



APPENDIX M

FIGURE IV



Attachment to letter of Dec 24/71 to Dr. John deMercado

Over the last several years, as on-line computer systems have become more and more complex, problems of overall co-ordination and control of all facets of system operation have become more and more difficult. In response to this problem, TCTS has developed a service package called "S.M.S." - Systems Management Service. It consists of a total package of management services which can be tailored to a customers specific requirements, thus eliminating the need for the customer to play referee to a number of system suppliers.

The Trans-Canada Telephone System has extensive experience in the area of network management, as we manage one of the world's largest telecommunication networks - the common user Long Distance Network.

In order to ensure efficient network utilization and smooth flow of traffic, the network is continually monitored and adjusted to meet changes in traffic patterns.

To administer this network we co-ordinate the aquisition of extensive traffic statistics. Some of the statistical information is used in day-to-day network management; other data serve as the base for future projected loads. The projections are usually viewed in terms of switching machine components and circuits which must be ordered

Attachment to letter of Dec 24/71 to Dr. John deMercado

approximately two years before they will be required. These critical projections require the unique skills of our traffic analysts.

Day-to-day network management is co-ordinated at several Network Control Centres where the traffic flow is constantly controlled and the switching machine performance is monitored. Based upon these statistics, action is taken to control the flow and routing of traffic, ensuring minimum delay and maximum customer satisfaction.

These same principles can be applied to CANUNET, to achieve maximum efficiencies and economies.

In addition to managing switched networks we also manage a computer controlled network called Message Switching Data Service (M.S.D.S.). It uses computer technology to control and route messages. M.S.D.S., which has been in operation for several years, was conceived, designed, programmed and is maintained, entirely by TCTS staff.

We have recently announced a new family of computer communications services. These services, known as SCCS - Software Controlled Communication Services - will be based on

Attachment to letter of Dec 24/71 to Dr. John deMercado

minicomputers acting as either front-ends for larger "host" computers, remote concentrators, message switchers or combinations of these. Using programmable devices as part of total communications packages will enable us to provide the flexibility required in today's computer communications systems.

The first phase of SCCS will be the front-end capability. Development of a prototype system development is unique in that it is a Canadian undertaking entirely. The planning and software development have been done by TCTS personnel in conjunction with Bell-Northern Research. The hardware has been supplied by a Canadian Minicomputer manufacturer.

It is the first time that a total computer communications capability such as this has been made available in Canada, and we feel that our development in this area would be particularly applicable to CANUNET.

TCTS has recently announced plans for the development of a digital transmission network, to be fully operative coast-to-coast by 1976. This network could be of great benefit to CANUNET as the quality of these circuits will be far greater than anything available today.

Attachment to letter of Dec 24/71 to Dr. John deMercado

In summary, CANUNET is to be a complex system involving communications between a large number of dissimilar computers in widly dispersed locations.

We feel that the Trans-Canada Telephone System is uniquely qualified to act as supplier of telecommunications services for CANUNET. We have a complete range of services to meet all the design and operational requirements of major data systems, including such items as a total facilities package from local loops to inter-exchange facilities; a wide range of services covering the entire speed range required by customers, both on a private line and a switched basis; and lastly, we have recently developed two services which are un-paralleled anywhere - S.C.C.S. and the digital network.

The Trans-Canada Telephone System is prepared to work with the Department of Communications and/or the universities to develop a workable, efficient, and totally cost effective overall Telecommunications System for CANUNET.

Attachment to letter of Dec 24/71 to Dr. John deMercado

**NOTE:** The foregoing should not be construed to be an official TCTS quotation, firm or otherwise. It is an order-of-magnitude guide for budgetary purposes and is supplied to the Federal Department of Communications for this purpose only.

It is anticipated that network usage will be confined to information transfer between the universities involved in this co-operative programme.

# CHAPTER IV

Detailed Simulation of a 10 Node Terrestrial Network

The following is a description of the simulation for Network 2 with 50 kb/s lines.

Average packet length = 640 bits

Average of (packet & acknowledgement) = 400 bits.

It contains;

[C] = Branch Capacity Matrix (bits/sec)

[T] = Traffic Matrix (bits/sec)

[λ] = Matrix of the Average number of Messages/sec

[ρ] = Network Utilization Matrix

[A.D] = Average Delay Matrix in sec/message

## BRANCH CAPACITY MATRIX

[C] =

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| (1) | 0. | 50000. | 50000. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| (2) | 50000. | 0. | 50000. | 50000. | 0. | 0. | 0. | 0. | 0. | 0. |
| (3) | 50000. | 50000. | 0. | 50000. | 50000. | 0. | 0. | 0. | 0. | 0. |
| (4) | 0. | 50000. | 50000. | 0. | 50000. | 0. | 50000. | 0. | 0. | 0. |
| (5) | 0. | 0. | 50000. | 50000. | 0. | 50000. | 0. | 50000. | 50000. | 0. |
| (6) | 0. | 0. | 0. | 0. | 50000. | 0. | 50000. | 50000. | 0. | 0. |
| (7) | 0. | 0. | 0. | 50000. | 0. | 50000. | 0. | 0. | 0. | 0. |
| (8) | 0. | 0. | 0. | 0. | 50000. | 50000. | 0. | 0. | 50000. | 50000. |
| (9) | 0. | 0. | 0. | 0. | 50000. | 0. | 0. | 50000. | 0. | 50000. |
| (10) | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 50000. | 50000. | 0. |

C(i,j) = Capacity of branch (i,j)

## TRAFFIC MATRIX IN BITS/SEC.

[T] =

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| (1) | 0. | 966. | 1135. | 1820. | 1739. | 3126. | 1583. | 4625. | 1258. | 954. |
| (2) | 966. | 0. | 461. | 740. | 707. | 1271. | 644. | 1881. | 511. | 388. |
| (3) | 1135. | 461. | 0. | 870. | 831. | 1494. | 757. | 2210. | 601. | 456. |
| (4) | 1820. | 740. | 870. | 0. | 1333. | 2397. | 1214. | 3546. | 964. | 731. |
| (5) | 1739. | 707. | 831. | 1333. | 0. | 2289. | 1160. | 3387. | 921. | 698. |
| (6) | 3126. | 1271. | 1494. | 2397. | 2289. | 0. | 2085. | 6090. | 1656. | 1256. |
| (7) | 1583. | 644. | 757. | 1214. | 1160. | 2085. | 0. | 3084. | 839. | 636. |
| (8) | 4625. | 1881. | 2210. | 3546. | 3387. | 6090. | 3084. | 0. | 2450. | 1858. |
| (9) | 1258. | 511. | 601. | 964. | 921. | 1656. | 839. | 2450. | 0. | 505. |
| (10) | 954. | 388. | 456. | 731. | 698. | 1256. | 636. | 1858. | 505. | 0. |

The entries in this matrix are the amount of traffic in bits per second flowing along the arcs of the network.

# APPENDIX M

## MATRIX OF THE AVERAGE # OF MESSAGES/SEC.

[λ] =

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| (1) | .000 | 1.509 | 25.375 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| (2) | 1.509 | .000 | .721 | 9.598 | .000 | .000 | .000 | .000 | .000 | .000 |
| (3) | 25.375 | .721 | .000 | 15.078 | 19.802 | .000 | .000 | .000 | .000 | .000 |
| (4) | .000 | 9.598 | 15.078 | .000 | 15.722 | .000 | 19.509 | .000 | .000 | .000 |
| (5) | .000 | .000 | 19.802 | 15.722 | .000 | 9.287 | .000 | 29.495 | 10.547 | .000 |
| (6) | .000 | .000 | .000 | .000 | 9.287 | .000 | 25.143 | 17.291 | .000 | .000 |
| (7) | .000 | .000 | .000 | 19.509 | .000 | 25.143 | .000 | .000 | .000 | .000 |
| (8) | .000 | .000 | .000 | .000 | 29.495 | 17.291 | .000 | .000 | 3.828 | 10.901 |
| (9) | .000 | .000 | .000 | .000 | 10.547 | .000 | .000 | 3.828 | .000 | .789 |
| (10) | .000 | .000 | .000 | .000 | .000 | .000 | .000 | 10.901 | .789 | .000 |

The values of this matrix represent the average number of messages flowing on branch (i,j). Note that when an entry is zero, the corresponding term in the branch capacity matrix is also zero. i.e. no direct path exists between these two nodes.

## NETWORK UTILIZATION MATRIX

[ρ] =

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| (1) | .000 | .012 | .203 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| (2) | .012 | .000 | .006 | .077 | .000 | .000 | .000 | .000 | .000 | .000 |
| (3) | .203 | .006 | .000 | .121 | .158 | .000 | .000 | .000 | .000 | .000 |
| (4) | .000 | .077 | .121 | .000 | .126 | .000 | .156 | .000 | .000 | .000 |
| (5) | .000 | .000 | .158 | .126 | .000 | .074 | .000 | .236 | .084 | .000 |
| (6) | .000 | .000 | .000 | .000 | .074 | .000 | .201 | .138 | .000 | .000 |
| (7) | .000 | .000 | .000 | .156 | .000 | .201 | .000 | .000 | .000 | .000 |
| (8) | .000 | .000 | .000 | .000 | .236 | .138 | .000 | .000 | .031 | .087 |
| (9) | .000 | .000 | .000 | .000 | .084 | .000 | .000 | .031 | .000 | .006 |
| (10) | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .087 | .006 | .000 |

The entry (i,j) is a reflection of the use of that branch. The utilization factor was defined as:

$$\rho(i,j) = \frac{\text{Average number of bits flowing on branch } (i,j)}{\text{Capacity of branch } (i,j) \text{ in bits}}$$

$$\rho(i,j) = \frac{\lambda(i,j)}{\mu' . C(i,j)}$$

An entry $\rho(i,j)$ greater than one implies that the flow exceeded the capacity of the arc (i,j)

AVERAGE DELAY MATRIX IN SEC/MESSAGES

[A.D] =

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| (1) | .000 | .018 | .022 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| (2) | .018 | .000 | .017 | .022 | .000 | .000 | .000 | .000 | .000 | .000 |
| (3) | .022 | .017 | .000 | .019 | .030 | .000 | .000 | .000 | .000 | .000 |
| (4) | .000 | .022 | .019 | .000 | .025 | .000 | .024 | .000 | .000 | .000 |
| (5) | .000 | .000 | .030 | .025 | .000 | .017 | .000 | .017 | .017 | .000 |
| (6) | .000 | .000 | .000 | .000 | .017 | .000 | .017 | .018 | .000 | .000 |
| (7) | .000 | .000 | .000 | .024 | .000 | .017 | .000 | .000 | .000 | .000 |
| (8) | .000 | .000 | .000 | .000 | .017 | .018 | .000 | .000 | .016 | .020 |
| (9) | .000 | .000 | .000 | .000 | .017 | .000 | .000 | .016 | .000 | .018 |
| (10) | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .020 | .018 | .000 |

The entries of this matrix represent the average delay encountered by a message flowing on branch (i,j).

Total Average Delay = .0413 SEC/MES.

# PART II

# HYBRID NETWORKS FOR CANUNET

## Introduction

In this part, results are presented of the simulations that were made of various 10, 14 and 18 node network topologies using (hybrid) satellite - terrestrial communication facilities for CANUNET. Performance graphs are given of total input data rate versus average message delays for average message lengths of 640 bits for each of these topologies having the communication line speeds as noted.

Chapter V contains a discussion of the hybrid network configurations, as well as the figures of the actual networks topologies that were analyzed and the corresponding performance graphs.

Chapter VI contains the complete simulation of a 15 node hybrid network. Such simulations were conducted for all of the hybrid networks, but have not been, in the interest of brevity, reproduced here.

Chapter VII contains a detailed, but preliminary report from Telesat Corporation on the application of the ANIK satellite's facilities to CANUNET. It should be noted, as per their letter, that Telesat is prepared to undertake more detailed engineering studies in support of using the ANIK satellite to realize CANUNET.

# CHAPTER V

Network Model Considerations

The topologies considered here in Part II are derived from the joint use of the ANIK satellite and Common Carrier terrestrial communication facilities. This report contains an analysis of several possible 10, 14 and 18 node hybrid (satellite-terrestrial) networks for CANUNET.

The exact queuing model for the hybrid system should have been M/M/n *) for the satellite system and M/M/1 for the Node Control Unit in the terrestrial network. This is because in the satellite system, each ground station transmits at a particular assigned frequency which can be received by all other ground stations; thus the satellite simultaneously serves several frequencies depending on the number of carriers or stations.(see for example in Fig. 5 of the Telesat report in Chapter VII).

In order to be able to simulate the hybrid network, the simulation program used was based on the M/M/1 queue model for both the satellite as well as the terrestrial facility. Therefore, the results obtained were not valid for all representations of the system, but were rather a representation of the worst case situation. If M/M/n theory were used, it could be expected that the average message delay in the network would be less than that given in this report.

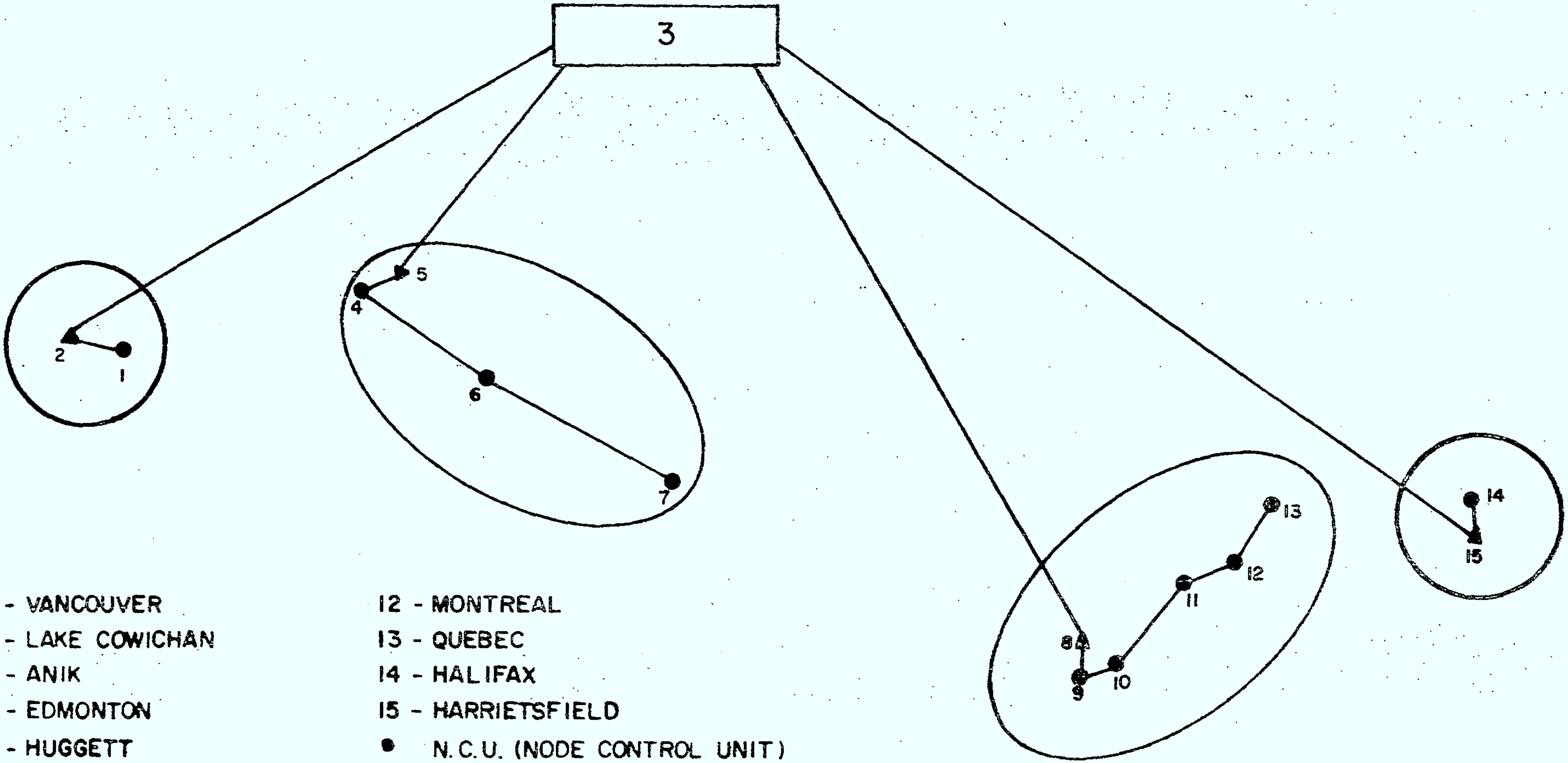
*) where n in this case is the number of carriers in the satellite (i.e. the number of servers).

Network Topologies and Performance Graphs

Following is a summary of results of the 10, 14 and 18 node hybrid option for CANUNET. It includes for each network its topology and graphs of "Total Average Delay" versus "Total Input Data Rate".

NOD 10 SAT 4

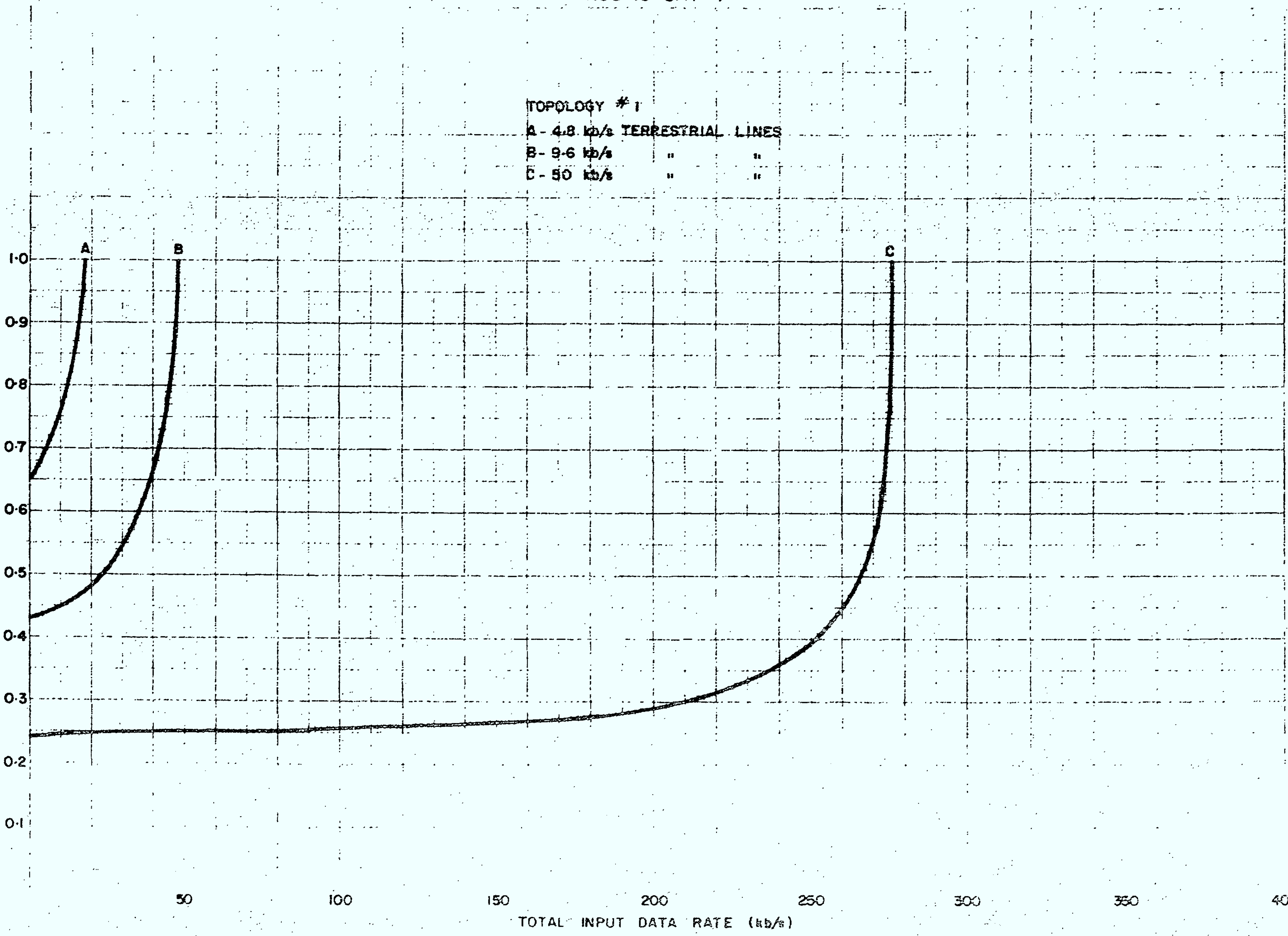
TOPOLOGY #1




1 - VANCOUVER
2 - LAKE COWICHAN
3 - ANIK
4 - EDMONTON
5 - HUGGETT
6 - SASKATOON
7 - WINNIPEG
8 - ALLAN PARK
9 - WATERLOO
10 - TORONTO
11 - OTTAWA
12 - MONTREAL
13 - QUEBEC
14 - HALIFAX
15 - HARRIETSFIELD

● N.C.U. (NODE CONTROL UNIT)
▲ GROUND STATION

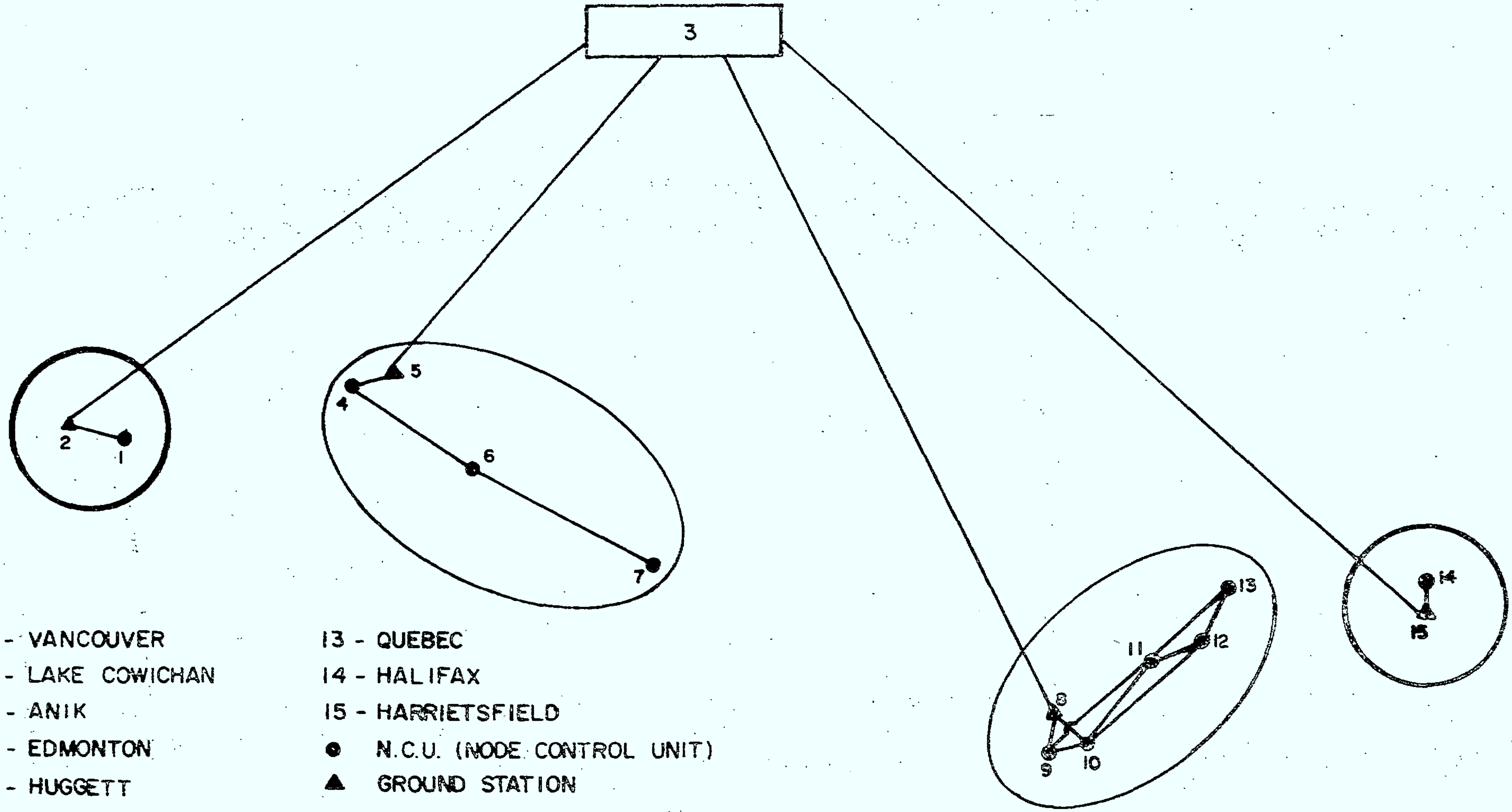
NOD 10 SAT 4





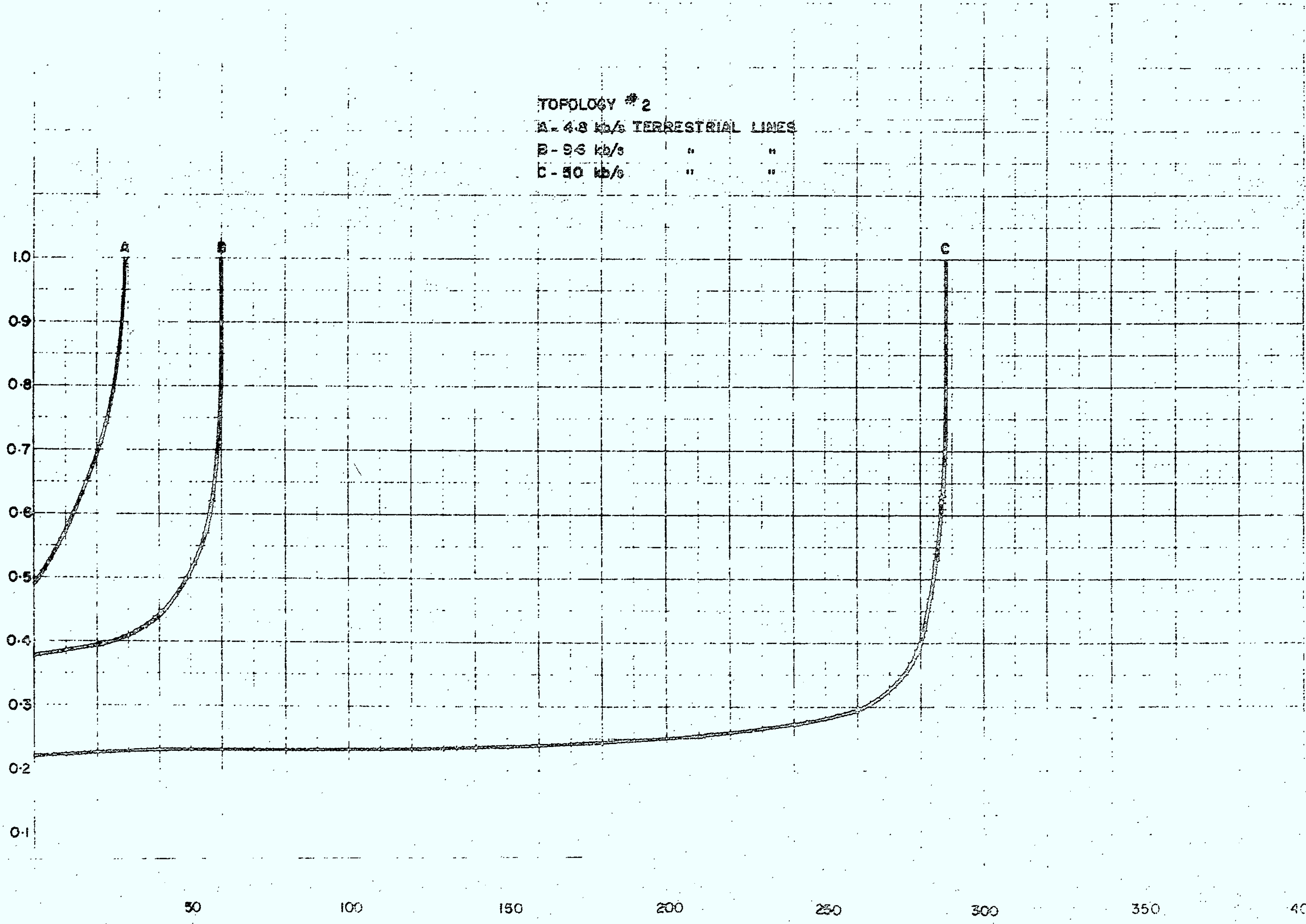

APPENDIX M

NOD 10 SAT 4
TOPOLOGY # 2




1 - VANCOUVER
2 - LAKE COWICHAN
3 - ANIK
4 - EDMONTON
5 - HUGGETT
6 - SASKATOON
7 - WINNIPEG
8 - ALLAN PARK
9 - WATERLOO
10 - TORONTO
11 - OTTAWA
12 - MONTREAL
13 - QUEBEC
14 - HALIFAX
15 - HARRIETSFIELD
● N.C.U. (NODE CONTROL UNIT)
▲ GROUND STATION

NOD 10 SAT 4

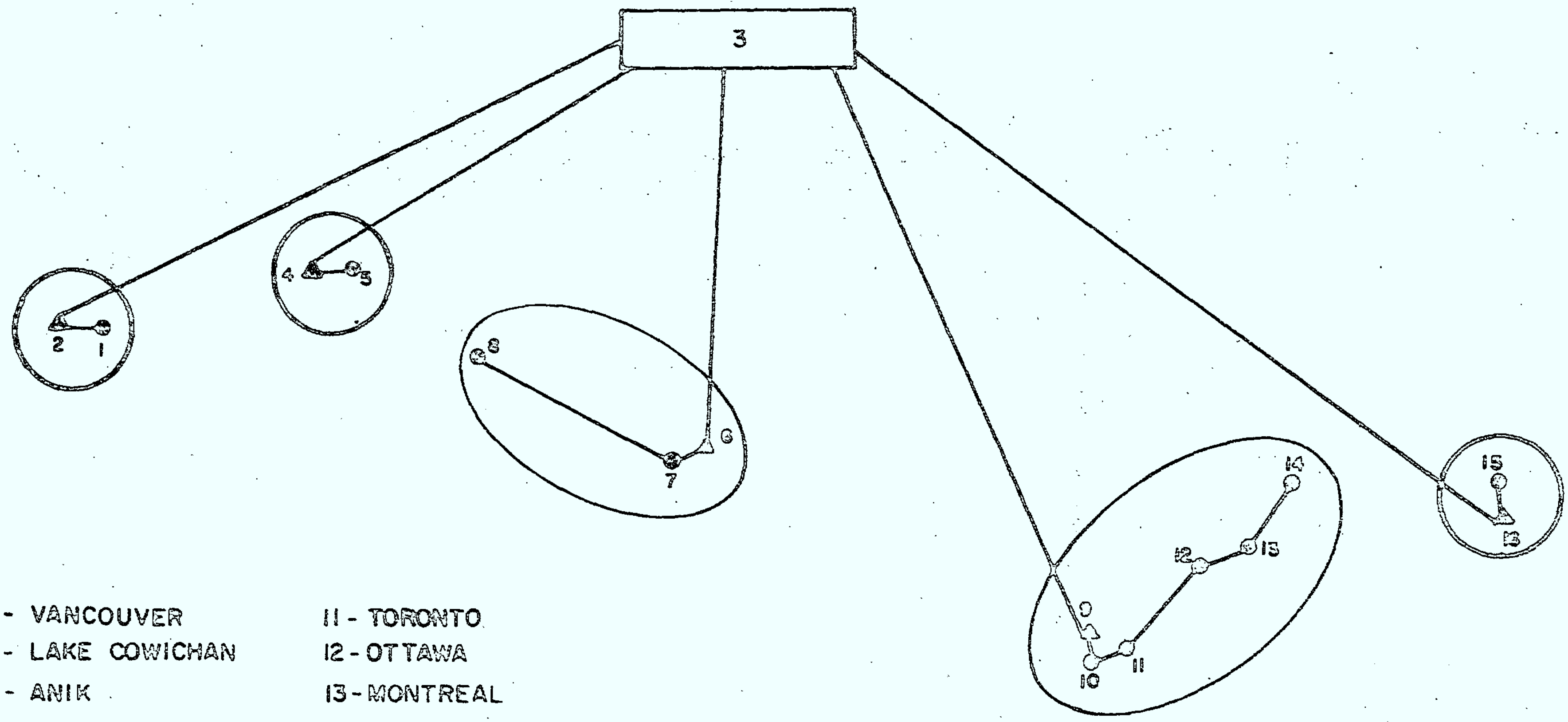





APPENDIX M

NCD 10 SAT 5 (ALLAN PARK)

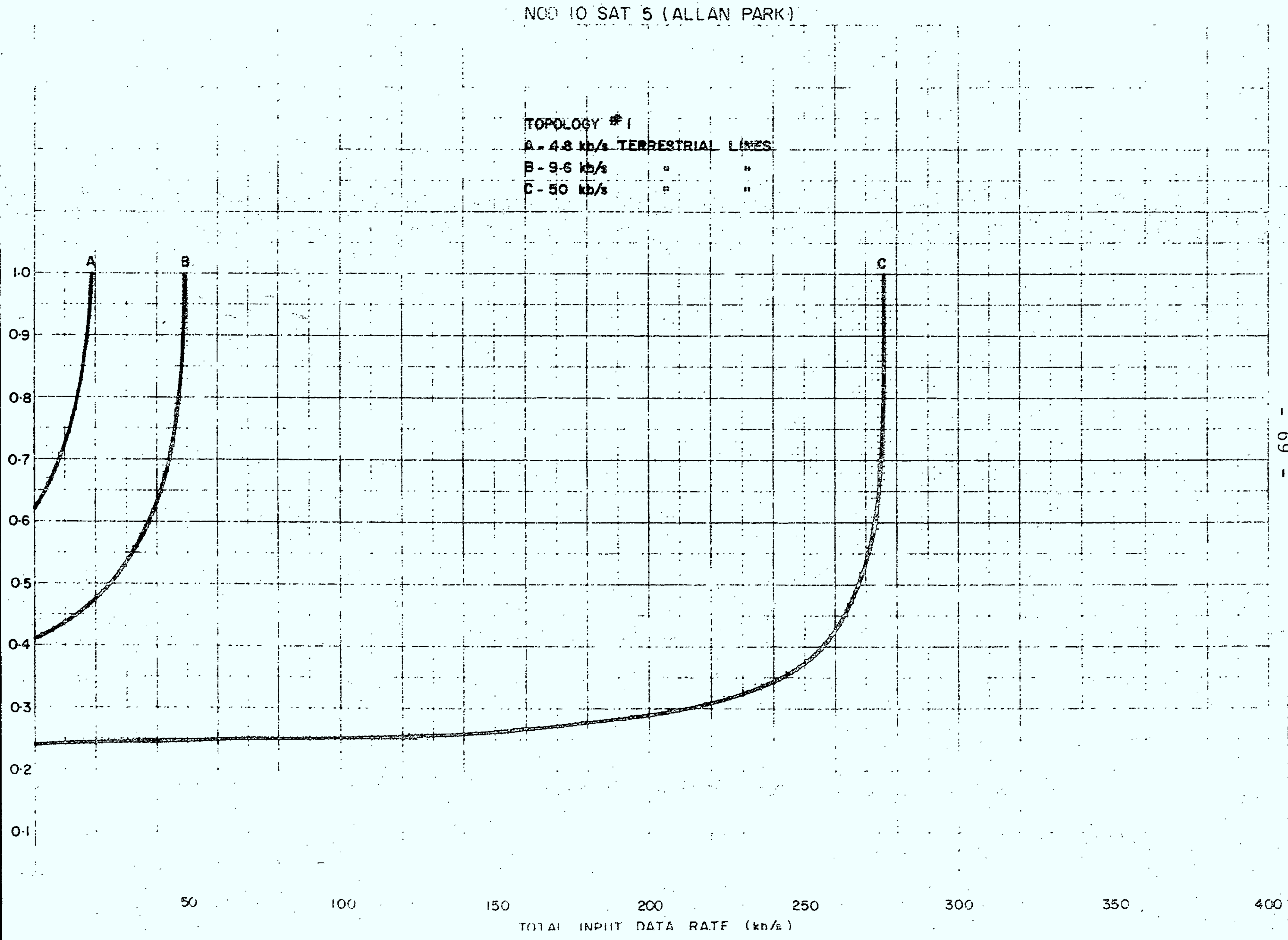
TOPOLOGY #1




1 - VANCOUVER
2 - LAKE COWICHAN
3 - ANIK
4 - HUGGETT
5 - EDMONTON
6 - GRAND BEACH
7 - WINNIPEG
8 - SASKATOON
9 - ALLAN PARK
10 - WATERLOO
11 - TORONTO
12 - OTTAWA
13 - MONTREAL
14 - QUEBEC
15 - HALIFAX
16 - HARRIETSFIELD

⊙ N.C.U. (NODE CONTROL UNIT)

△ GROUND STATION

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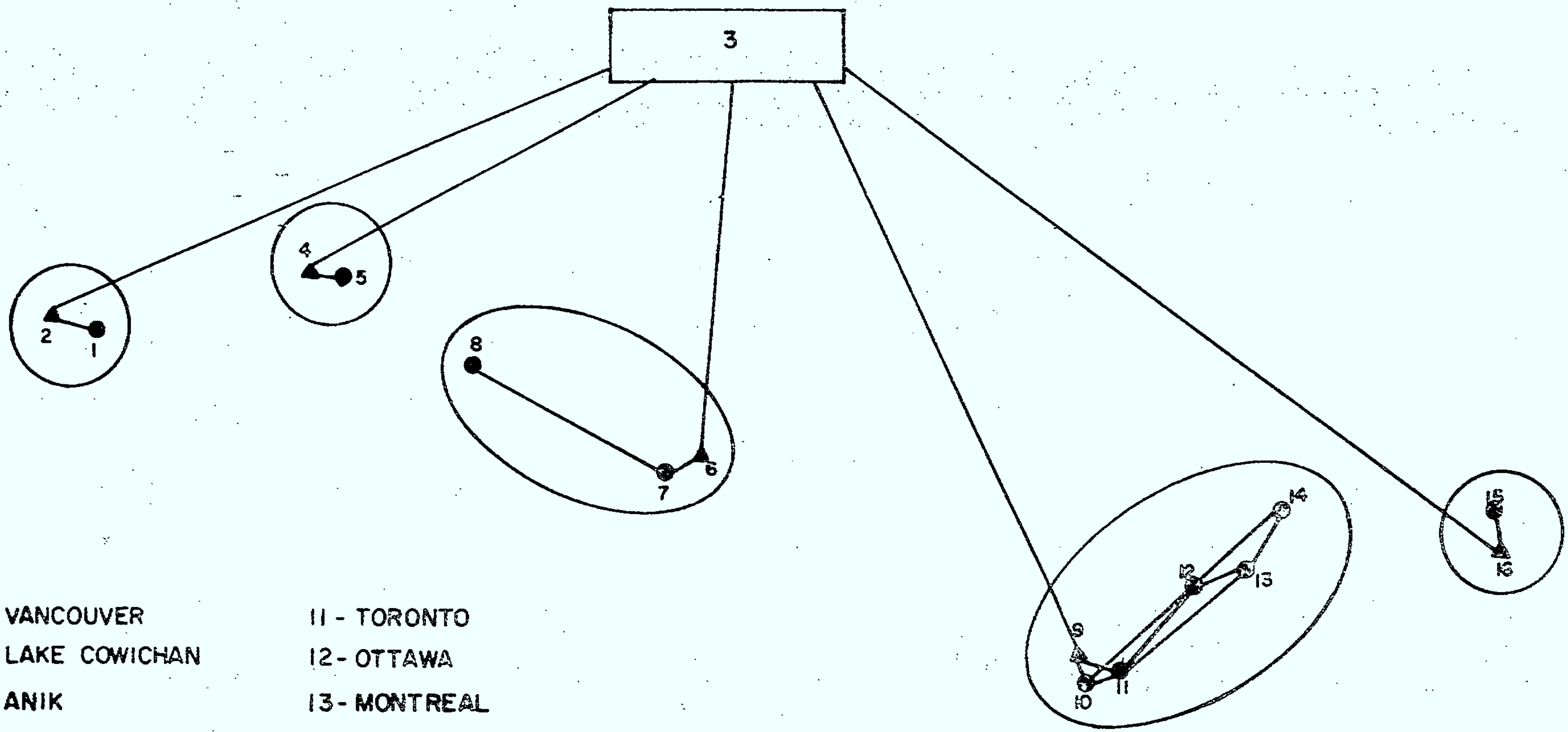
APPENDIX M

## NOD 10 SAT 5 (ALLAN PARK)
## TOPOLOGY # 2

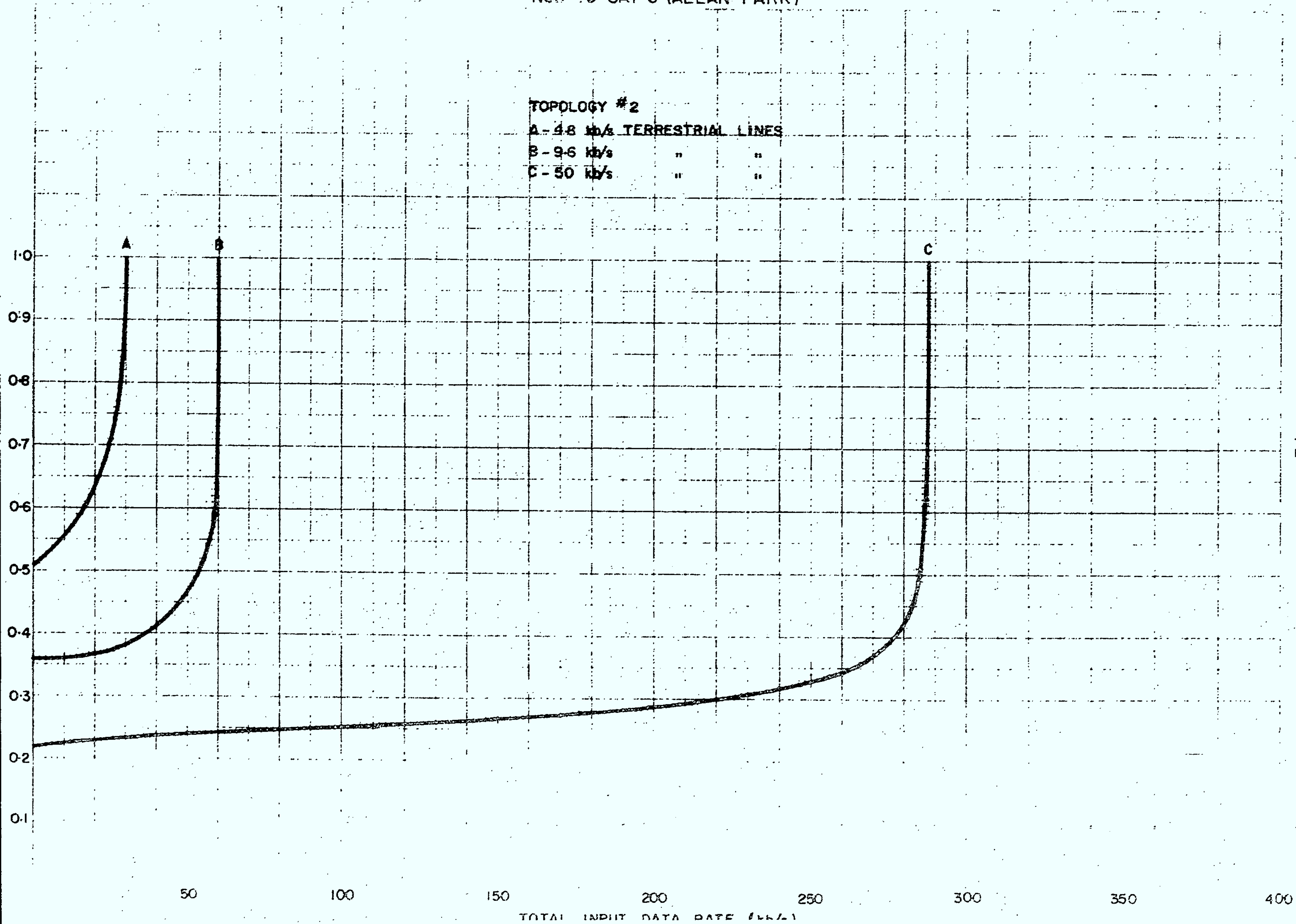



1 - VANCOUVER
2 - LAKE COWICHAN
3 - ANIK
4 - HUGGETT
5 - EDMONTON
6 - GRAND BEACH
7 - WINNIPEG
8 - SASKATOON
9 - ALLAN PARK
10 - WATERLOO
11 - TORONTO
12 - OTTAWA
13 - MONTREAL
14 - QUEBEC
15 - HALIFAX
16 - HARRIETSFIELD

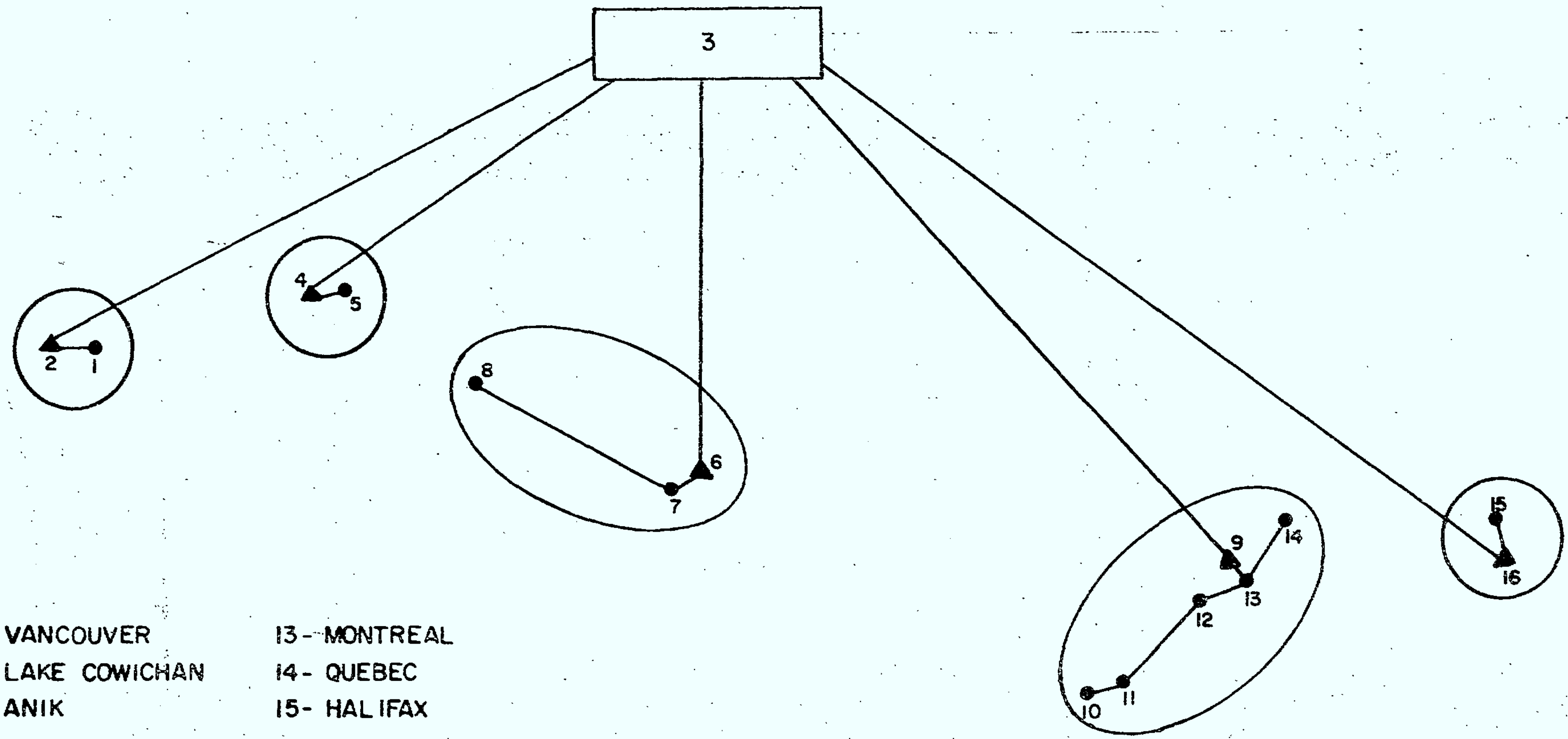
⊗ N.C.U. (NODE CONTROL UNIT)

▲ GROUND STATION

NOD 10 SAT 5 (ALLAN PARK)



NOD 10 SAT 5 (RIVIERE ROUGE)

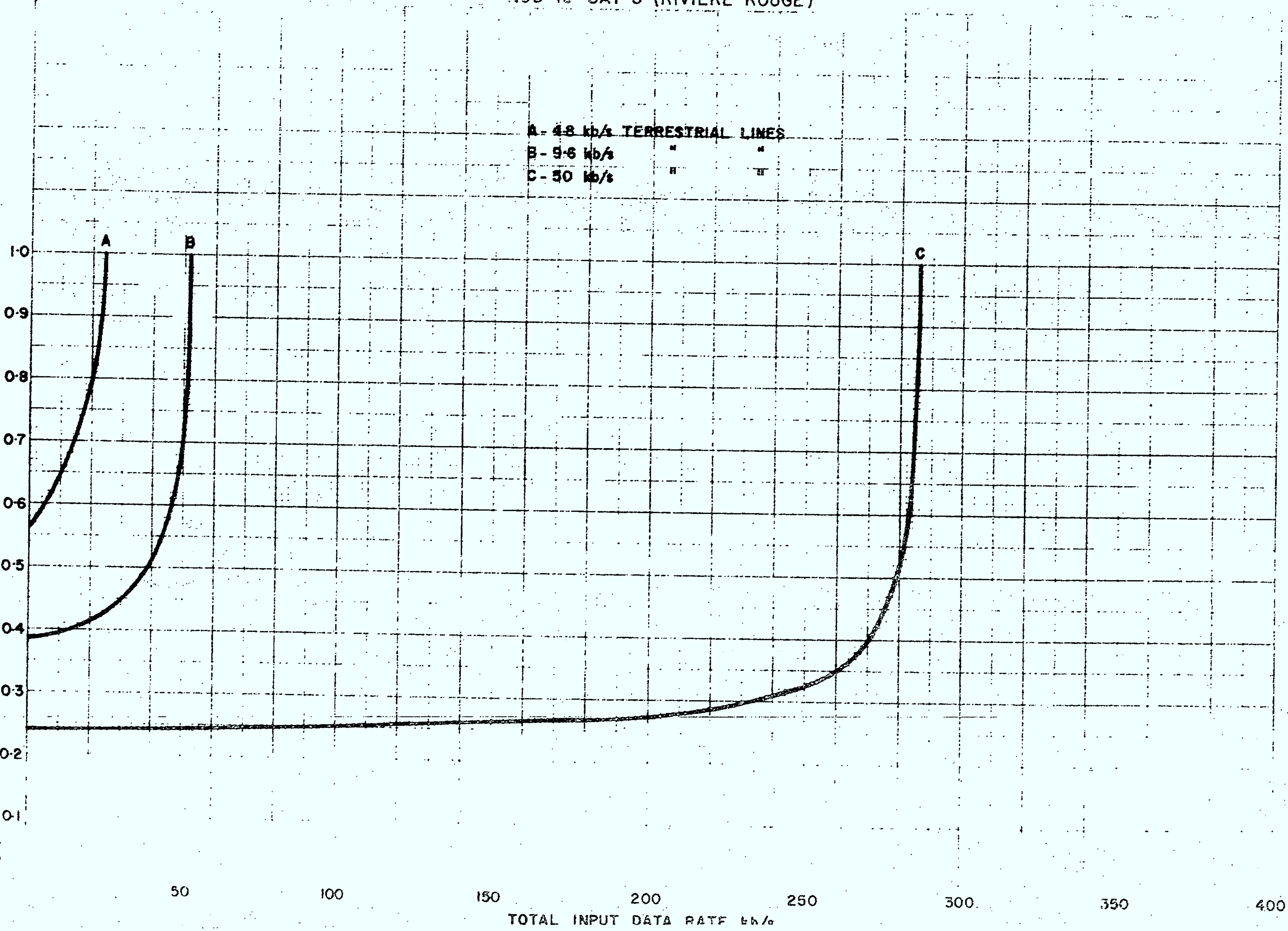



1 - VANCOUVER
2 - LAKE COWICHAN
3 - ANIK
4 - HUGGETT
5 - EDMONTON
6 - GRAND BEACH
7 - WINNIPEG
8 - SASKATOON
9 - RIVIERE ROUGE
10 - WATERLOO
11 - TORONTO
12 - OTTAWA
13 - MONTREAL
14 - QUEBEC
15 - HALIFAX
16 - HARRIETSFIELD

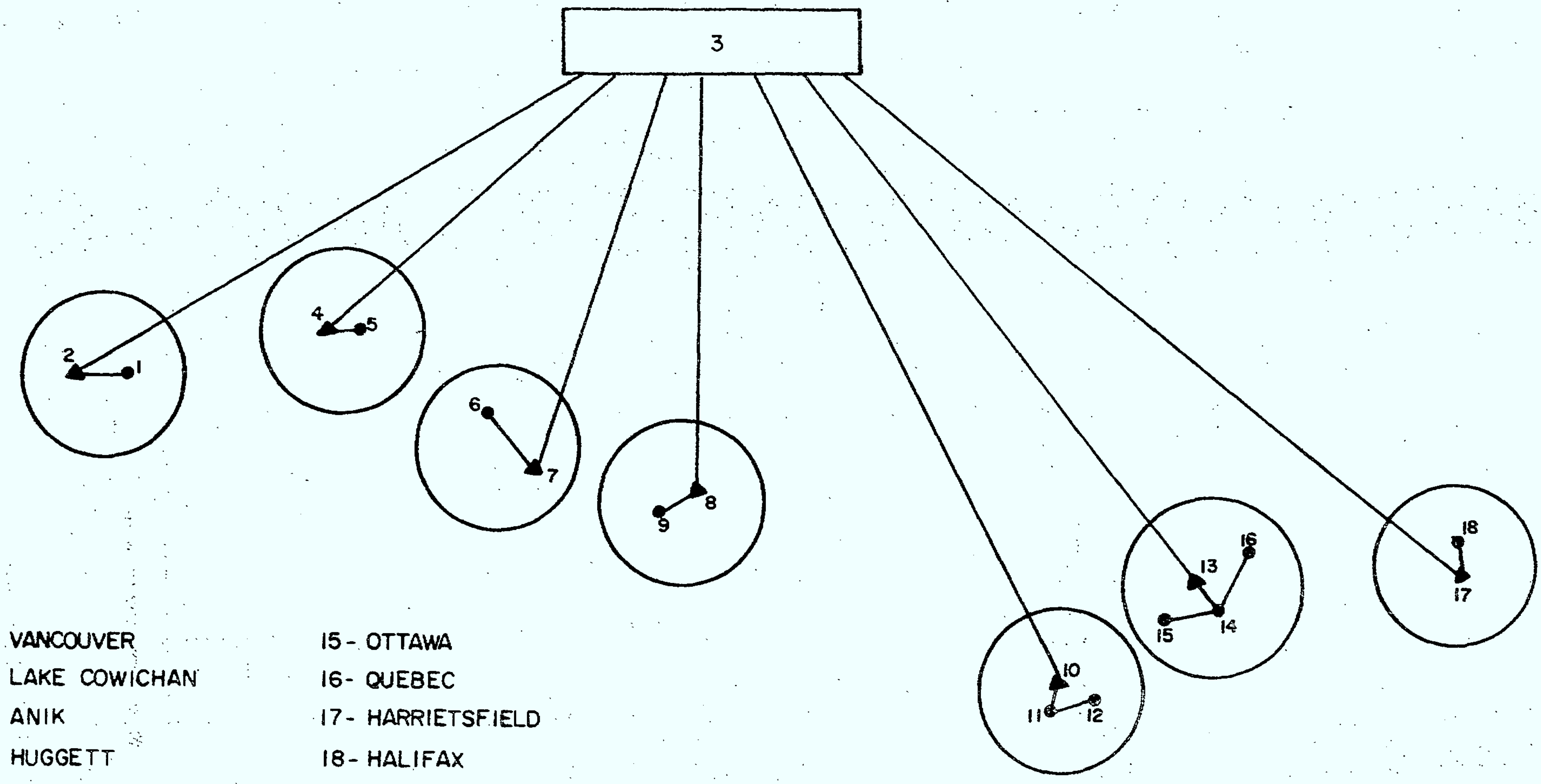
● N.C.U. (NODE CONTROL UNIT)

▲ GROUND STATION

NOD 10 SAT 5 (RIVIERE ROUGE)



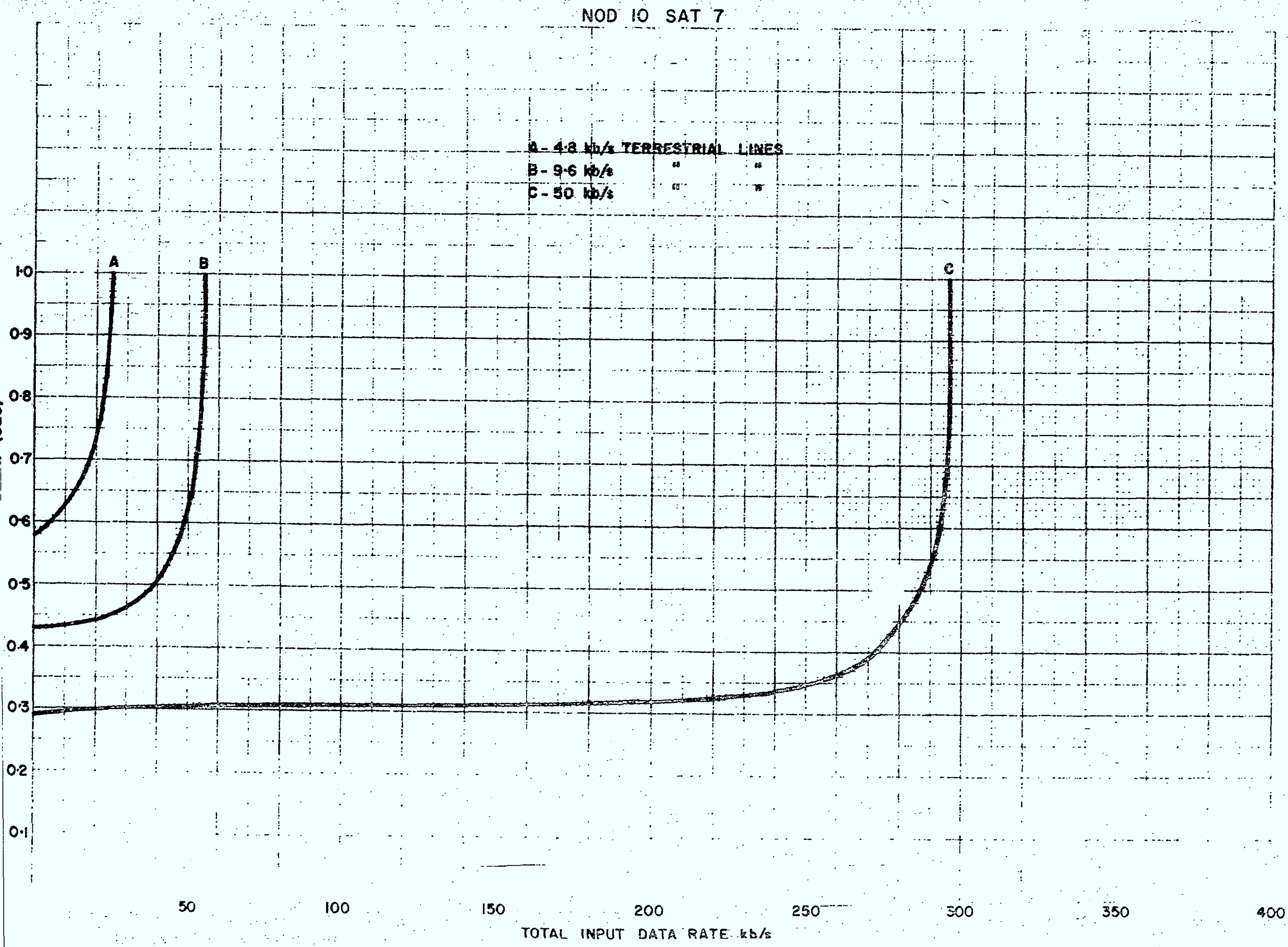
NOD 1.0 SAT 7



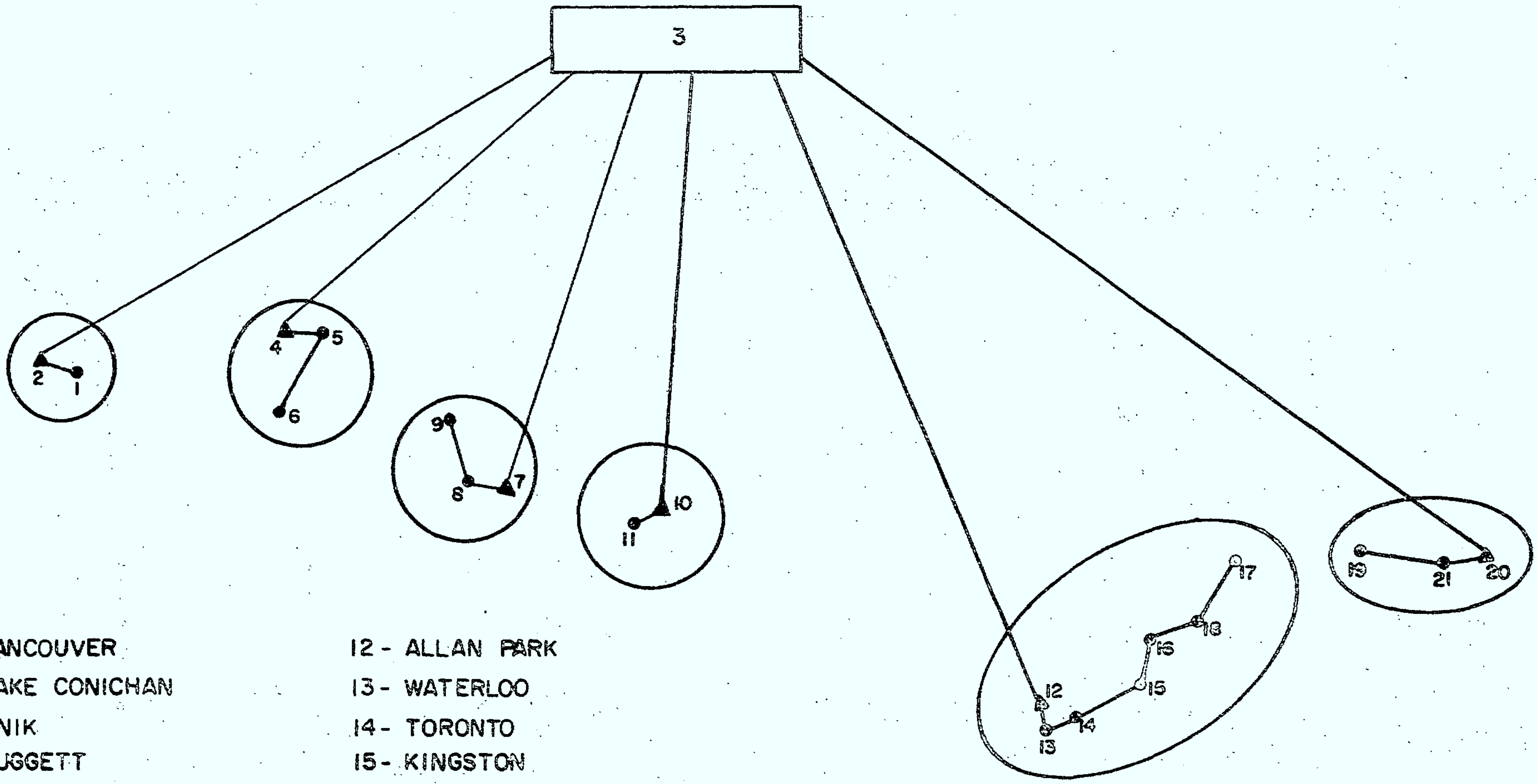

1 - VANCOUVER
2 - LAKE COWICHAN
3 - ANIK
4 - HUGGETT
5 - COMONTON
6 - SASKATOON
7 - QU'APPELLE
8 - GRAND BEACH
9 - WINNIPEG
10 - ALLAN PARK
11 - WATERLOO
12 - TORONTO
13 - RIVIERE ROUGE
14 - MONTREAL
15 - OTTAWA
16 - QUEBEC
17 - HARRIETSFIELD
18 - HALIFAX

● N. C. U. (NODE CONTROL UNIT)

▲ GROUND SYSTEM


NOD 10 SAT 7
A - 4·8 kb/s TERRESTRIAL LINES
B - 9·6 kb/s " "
C - 50 kb/s " "
A
B
C
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
50
100
150
200
250
300
350
400
TOTAL INPUT DATA RATE kb/s

NOD 14 SAT 6

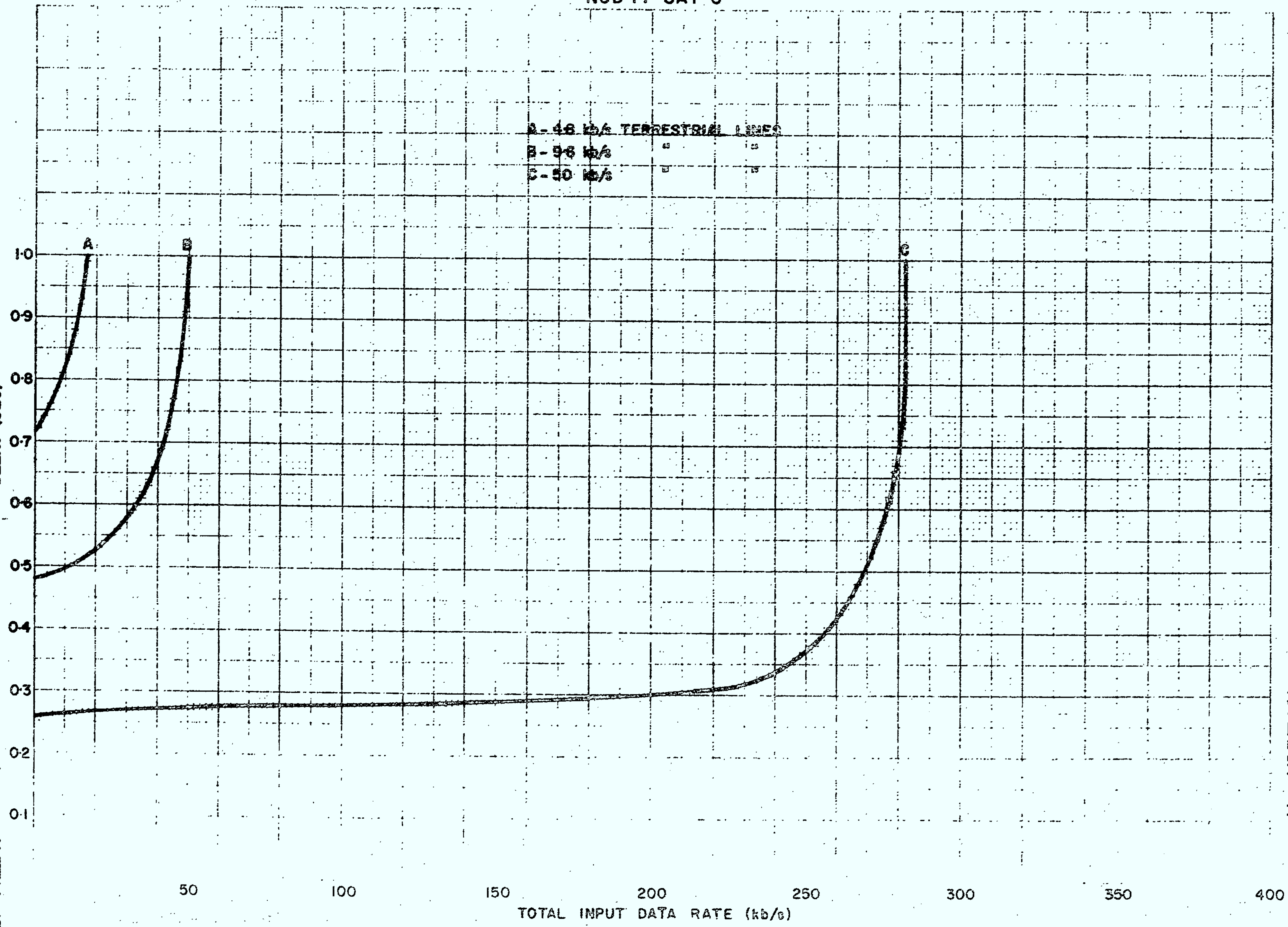



1 - VANCOUVER
2 - LAKE CONICHAN
3 - ANIK
4 - HUGGETT
5 - EDMONTON
6 - CALGARY
7 - QU'APPELLE
8 - REGINA
9 - SASKATOON
10 - GRAND BEACH
11 - WINNIPEG
12 - ALLAN PARK
13 - WATERLOO
14 - TORONTO
15 - KINGSTON
16 - OTTAWA
17 - QUEBEC
18 - MONTREAL
19 - FREDERICTON
20 - HARRIETSFIELD
21 - HALIFAX

⊙ N. C. U. (NODE CONTROL UNIT)

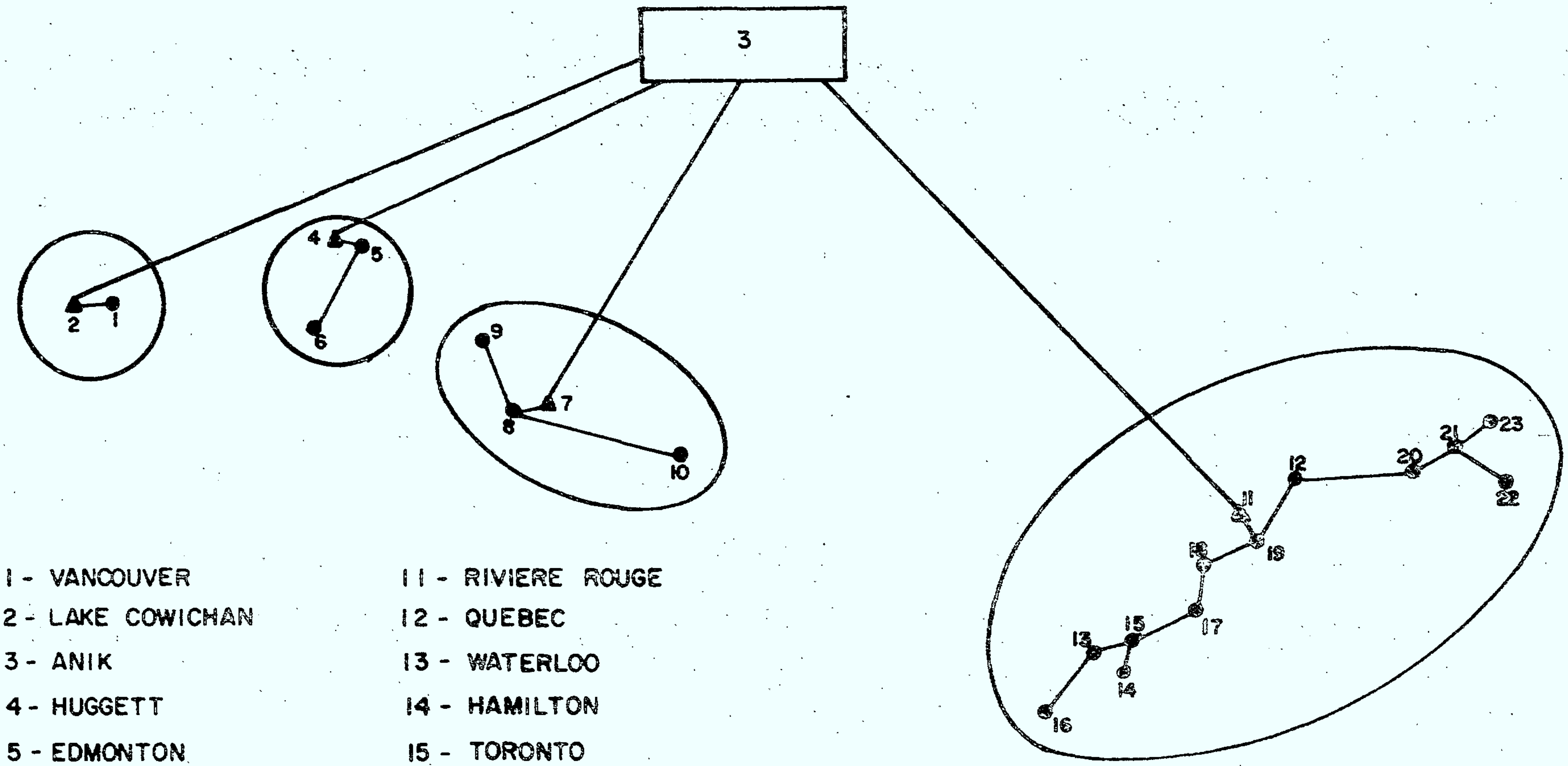
△ GROUND STATION

NOD 14 SAT 6



A - 4·8 kb/s TERRESTRIAL LINES
B - 9·6 kb/s " "
C - 50 kb/s " "
A
B
C
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
50
100
150
200
250
300
350
400
TOTAL INPUT DATA RATE (kb/s)

## NOD 18 SAT 4

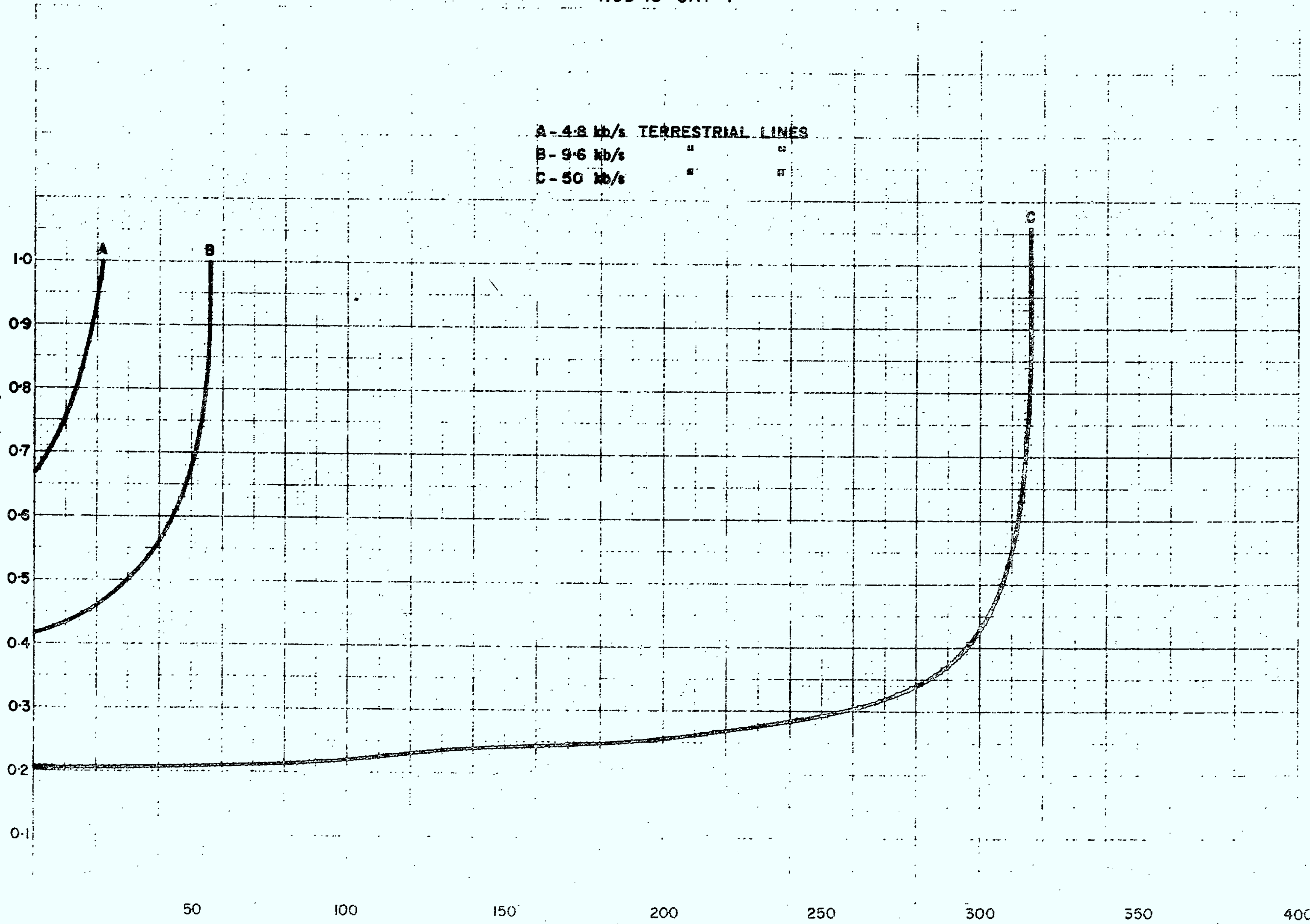



1 - VANCOUVER
2 - LAKE COWICHAN
3 - ANIK
4 - HUGGETT
5 - EDMONTON
6 - CALGARY
7 - QU'APPELLE
8 - REGINA
9 - SASKATOON
10 - WINNIPEG
11 - RIVIERE ROUGE
12 - QUEBEC
13 - WATERLOO
14 - HAMILTON
15 - TORONTO
16 - WINDSOR
17 - KINGSTON
18 - OTTAWA
19 - MONTREAL
20 - FREDERICTON
22 - HALIFAX
23 - CHARLOTTETOWN

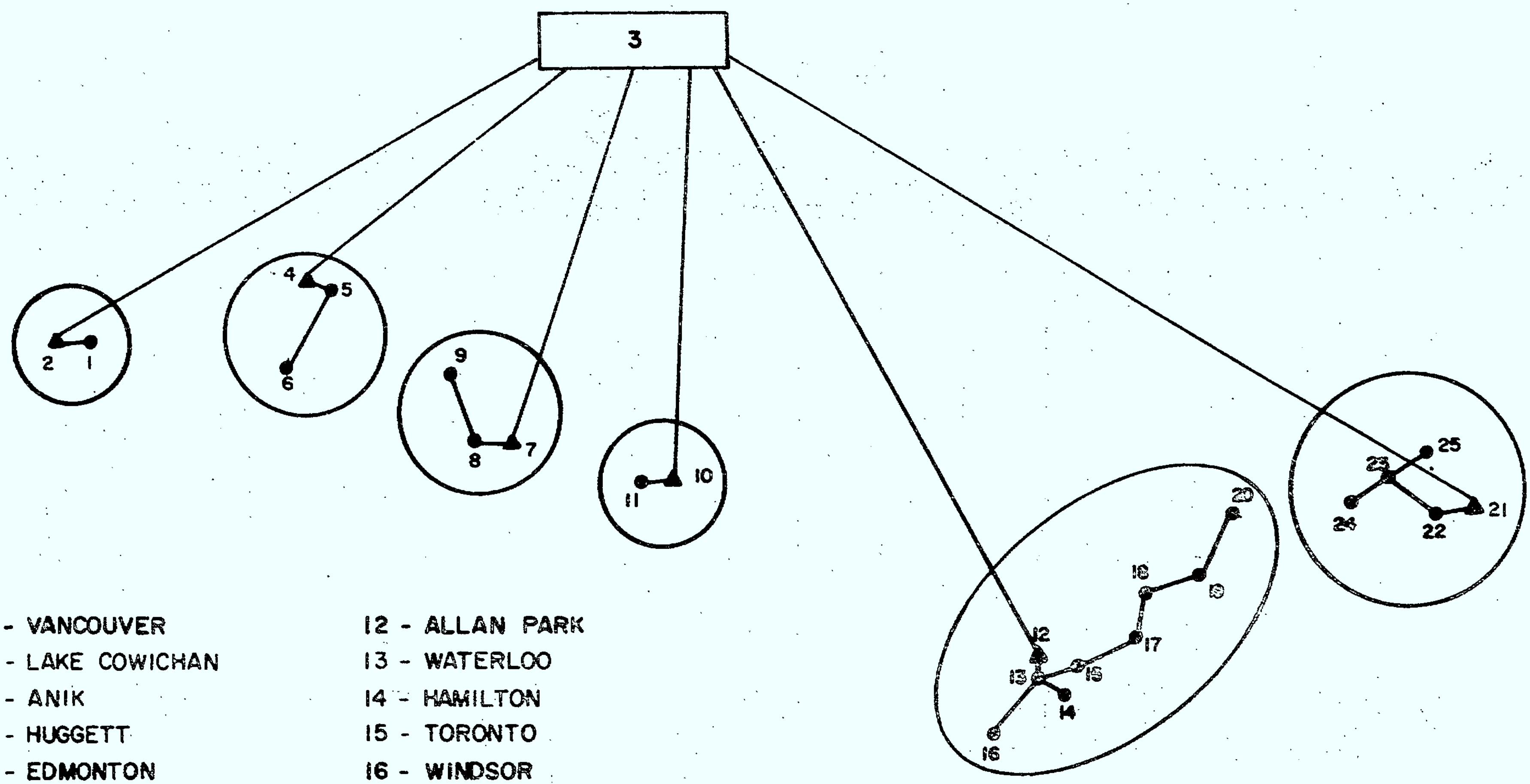
● N.C.U. (NODE CONTROL UNIT)

▲ GROUND STATION

NOD 18 SAT 4


A - 4·8 kb/s TERRESTRIAL LINES
B - 9·6 kb/s " "
C - 50 kb/s " "
A
B
C
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
50
100
150
200
250
300
350
400

## NOD 18 SAT 6

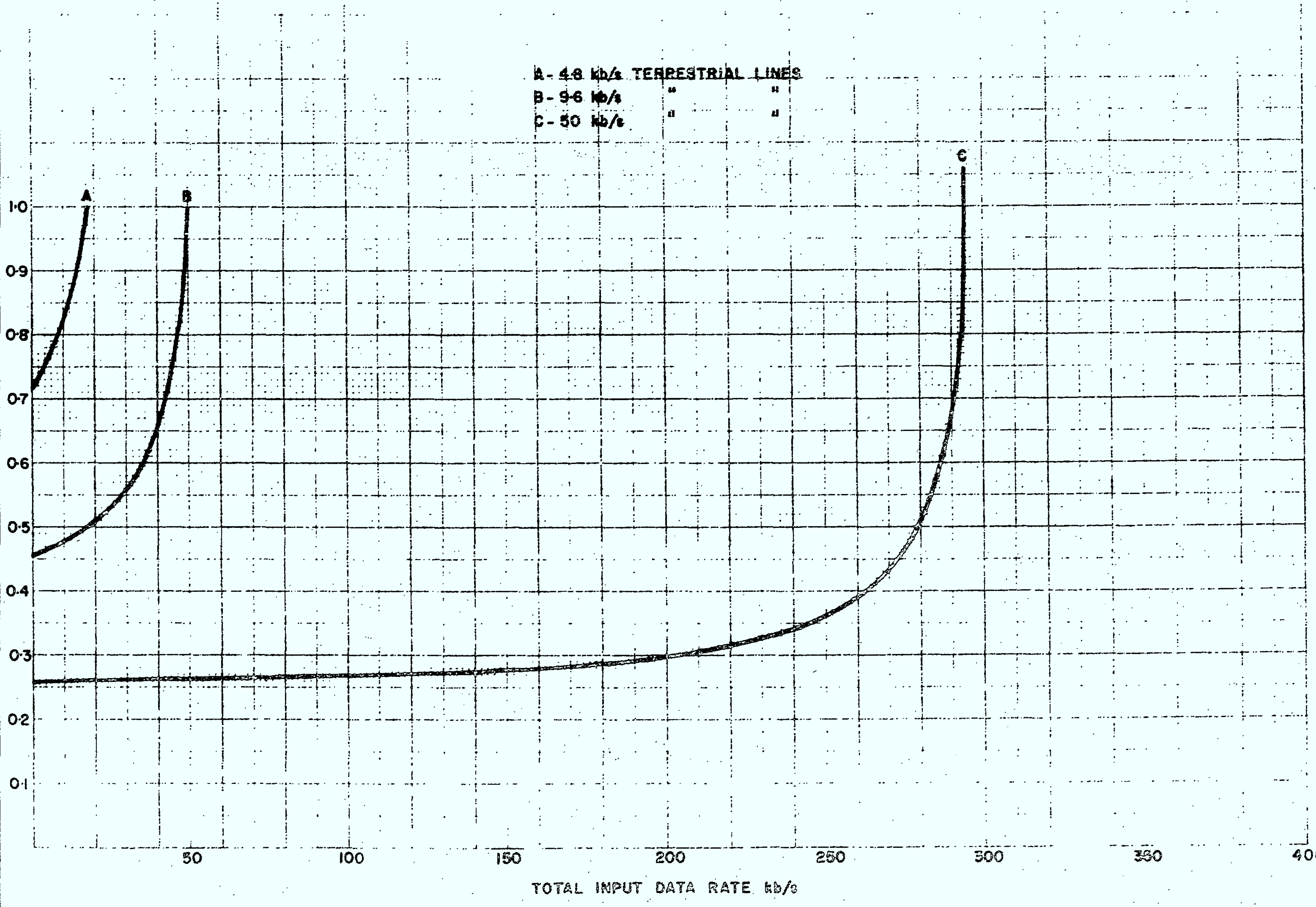



1 - VANCOUVER
2 - LAKE COWICHAN
3 - ANIK
4 - HUGGETT
5 - EDMONTON
6 - CALGARY
7 - QU'APPELLE
8 - REGINA
9 - SASKATOON
10 - GRAND BEACH
11 - WINNIPEG
12 - ALLAN PARK
13 - WATERLOO
14 - HAMILTON
15 - TORONTO
16 - WINDSOR
17 - KINGSTON
18 - OTTAWA
19 - MONTREAL
20 - QUEBEC
21 - HARRIETSFIELD
23 - HALIFAX
23 - MONCTON
24 - FREDERICTON
25 - CHARLOTTETOWN

● N.C.U. (NODE CONTROL UNIT)

▲ GROUND STATION

NOD 18 SAT 6






APPENDIX M

# CHAPTER VI

Detailed Simulation of a 10 Node Hybrid Network

The following is a description of the simulation for Network NOD 10 SAT 4 using topology #2*)and 50.0 kb/s lines.

Average packet length = 640 bits

Average of (packet and acknowledgement) = 400 bits.

It contains;

[C] = Branch Capacity Matrix (bits/sec)

[T] = Traffic Matrix (bits/sec)

[λ] = Matrix of the Average # of Messages/sec

[ρ] = Network Utilization Matrix

[A.D] = Average Delay Matrix in sec/message

[R] = Shortest Path Routing Matrix

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*) see page 66

## BRANCH CAPACITY MATRIX

$[C] =$

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | 0. | 50000. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| (2) | 50000. | 0. | 50000. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| (3) | 0. | 50000. | 0. | 0. | 50000. | 0. | 0. | 50000. | 0. | 0. | 0. | 0. | 0. | 0. | 50000. |
| (4) | 0. | 0. | 0. | 0. | 50000. | 50000. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| (5) | 0. | 0. | 50000. | 50000. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| (6) | 0. | 0. | 0. | 50000. | 0. | 0. | 50000. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| (7) | 0. | 0. | 0. | 0. | 0. | 50000. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| (8) | 0. | 0. | 50000. | 0. | 0. | 0. | 0. | 0. | 50000. | 50000. | 0. | 0. | 0. | 0. | 0. |
| (9) 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 50000. | 0. | 50000. | 50000. | 0. | 0. | 0. | 0. |
| (10) | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 50000. | 50000. | 0. | 50000. | 50000. | 0. | 0. | 0. |
| (11) | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 50000. | 50000. | 0. | 50000. | 50000. | 0. | 0. |
| (12) | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 50000. | 50000. | 0. | 50000. | 0. | 0. |
| (13) | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 50000. | 50000. | 0. | 0. | 0. |
| (14) | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 50000. |
| (15) | 0. | 0. | 50000. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 50000. | 0. |

C(i,j) = Capacity of branch (i,j)

## TRAFFIC MATRIX IN BITS/SEC.

[T] =

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | 0 | 0. | 0. | 2056. | 0. | 1062. | 1713. | 0. | 1485. | 2947. | 1645. | 4363. | 1188. | 902. | 0. |
| (2) | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| (3) | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| (4) | 2056. | 0. | 0. | 0. | 0. | 976. | 1573. | 0. | 1364. | 2706. | 1510. | 4007. | 1091. | 829. | 0. |
| (5) | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| (6) | 1062. | 0. | 0. | 976. | 0. | 0. | 813. | 0. | 705. | 1398. | 780. | 2070. | 564. | 428. | 0. |
| (7) | 1713. | 0. | 0. | 1573. | 0. | 813. | 0. | 0. | 1136. | 2255. | 1259. | 3339. | 909. | 691. | 0. |
| (8) | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| (9) | 1485. | 0. | 0. | 1364. | 0. | 705. | 1136. | 0. | 0. | 1955. | 1091. | 2894. | 788. | 598. | 0. |
| (10) | 2947. | 0. | 0. | 2706. | 0. | 1398. | 2255. | 0. | 1955. | 0. | 2165. | 5743. | 1564. | 1188. | 0. |
| (11) | 1645. | 0. | 0. | 1510. | 0. | 780. | 1259. | 0. | 1091. | 2165. | 0. | 3206. | 873. | 663. | 0. |
| (12) | 4363. | 0. | 0. | 4007. | 0. | 2070. | 3339. | 0. | 2894. | 5743. | 3206. | 0. | 2315. | 1759. | 0. |
| (13) | 1188. | 0. | 0. | 1091. | 0. | 564. | 909. | 0. | 788. | 1564. | 873. | 2315. | 0. | 479. | 0. |
| (14) | 902. | 0. | 0. | 829. | 0. | 428. | 691. | 0. | 598. | 1188. | 663. | 1759. | 479. | 0. | 0. |
| (15) | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |

The entries in this matrix are the amount of traffic in bits per second flowing along the arcs of the network.

MATRIX OF THE AVERAGE # OF MESSAGES/SEC.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | 0. | 27. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| (2) | 27. | 0. | 27. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| (3) | 0. | 27. | 0. | 0. | 49. | 0. | 0. | 64. | 0. | 0. | 0. | 0. | 0. | 0. | 11. |
| (4) | 0. | 0. | 0. | 0. | 49. | 32. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| (5) | 0. | 0. | 49. | 49. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| (6) | 0. | 0. | 0. | 32. | 0. | 0. | 21. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| [λ] = (7) | 0. | 0. | 0. | 0. | 0. | 21. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| (8) | 0. | 0. | 64. | 0. | 0. | 0. | 0. | 0. | 8. | 56. | 0. | 0. | 0. | 0. | 0. |
| (9) | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 8. | 0. | 3. | 7. | 0. | 0. | 0. | 0. |
| (10) | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 56. | 3. | 0. | 21. | 33. | 0. | 0. | 0. |
| (11) | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 7. | 21. | 0. | 9. | 11. | 0. | 0. |
| (12) | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 33. | 9. | 0. | 3. | 0. | 0. |
| (13) | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 11. | 3. | 0. | 0. | 0. |
| (14) | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 11. |
| (15) | 0. | 0. | 11. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 11. | 0. |

The values of this matrix represent the average number of messages flowing on branch (i,j). Note that when an entry is zero, the corresponding term in the branch capacity matrix is also zero. i.e. no direct path exists between these two nodes.

## NETWORK UTILIZATION MATRIX

$[\rho] =$

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | .000 | .217 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| (2) | .217 | .000 | .217 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| (3) | .000 | .217 | .000 | .000 | .398 | .000 | .000 | .518 | .000 | .000 | .000 | .000 | .000 | .000 | .094 |
| (4) | .000 | .000 | .000 | .000 | .398 | .261 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| (5) | .000 | .000 | .398 | .398 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| (6) | .000 | .000 | .000 | .261 | .000 | .000 | .171 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| (7) | .000 | .000 | .000 | .000 | .000 | .171 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| (8) | .000 | .000 | .518 | .000 | .000 | .000 | .000 | .000 | .066 | .452 | .000 | .000 | .000 | .000 | .000 |
| (9) | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .066 | .000 | .024 | .060 | .000 | .000 | .000 | .000 |
| (10) | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .452 | .024 | .000 | .173 | .266 | .000 | .000 | .000 |
| (11) | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .060 | .173 | .000 | .076 | .093 | .000 | .000 |
| (12) | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .266 | .076 | .000 | .029 | .000 | .000 |
| (13) | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .093 | .029 | .000 | .000 | .000 |
| (14) | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .094 |
| (15) | .000 | .000 | .094 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .094 | .000 |

The entry (i,j) is a reflection of the use of that branch. The utilization factor was defined as:

$$\rho(i,j) = \frac{\text{Average number of bits flowing on branch } (i,j)}{\text{Capacity of branch } (i,j) \text{ in bits}}$$

$$\rho(i,j) = \frac{\lambda(i,j)}{\mu' . C(i,j)}$$

An entry $\rho(i,j)$ greater than one implies that the flow exceeded the capacity of the arc. (i,j)

## AVERAGE DELAY MATRIX IN SEC/MESSAGE

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | .000 | .017 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| (2) | .017 | .000 | .146 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| (3) | .000 | .146 | .000 | .000 | .149 | .000 | .000 | .152 | .000 | .000 | .000 | .000 | .000 | .000 | .145 |
| (4) | .000 | .000 | .000 | .000 | .019 | .020 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| A.D] = (5) | .000 | .000 | .149 | .019 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| (6) | .000 | .000 | .000 | .020 | .000 | .000 | .020 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| (7) | .000 | .000 | .000 | .000 | .000 | .020 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| (8) | .000 | .000 | .152 | .000 | .000 | .000 | .000 | .000 | .015 | .021 | .000 | .000 | .000 | .000 | .000 |
| (9) | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .015 | .000 | .015 | .017 | .000 | .000 | .000 | .000 |
| (10) | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .021 | .015 | .000 | .018 | .020 | .000 | .000 | .000 |
| (11) | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .017 | .018 | .000 | .015 | .017 | .000 | .000 |
| (12) | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .020 | .015 | .000 | .016 | .000 | . |
| (13) | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .017 | .016 | .000 | .000 | .000 |
| (14) | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .015 |
| (15) | .000 | .000 | .145 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .015 | .000 |

The entries of this matrix represent the average delay encountered by a message flowing on branch (i,j).

Total Average Delay = .2444 sec/mess.

APPENDIX M

SHORTEST PATH ROUTING MATRIX

[R] =

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | 1 | 2 | 2 | 5 | 3 | 5 | 6 | 3 | 8 | 8 | 10 | 10 | 11 | 15 | 3 |
| (2) | 1 | 2 | 3 | 5 | 3 | 5 | 6 | 3 | 8 | 8 | 10 | 10 | 11 | 15 | 3 |
| (3) | 2 | 2 | 3 | 5 | 5 | 5 | 6 | 8 | 8 | 8 | 10 | 10 | 11 | 15 | 15 |
| (4) | 5 | 5 | 5 | 4 | 5 | 6 | 6 | 5 | 8 | 8 | 10 | 10 | 11 | 15 | 5 |
| (5) | 3 | 3 | 3 | 4 | 5 | 4 | 6 | 3 | 8 | 8 | 10 | 10 | 11 | 15 | 3 |
| (6) | 5 | 5 | 5 | 4 | 4 | 6 | 7 | 5 | 8 | 8 | 10 | 10 | 11 | 15 | 5 |
| (7) | 6 | 6 | 6 | 6 | 6 | 6 | 7 | 6 | 8 | 8 | 10 | 10 | 11 | 15 | 6 |
| (8) | 3 | 3 | 3 | 5 | 3 | 5 | 6 | 8 | 9 | 10 | 10 | 10 | 11 | 15 | 3 |
| (9) | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 9 | 10 | 11 | 11 | 11 | 15 | 8 |
| (10) | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 9 | 10 | 11 | 12 | 11 | 15 | 8 |
| (11) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 9 | 10 | 11 | 12 | 13 | 15 | 10 |
| (12) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 11 | 10 | 11 | 12 | 13 | 15 | 10 |
| (13) | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 12 | 13 | 15 | 11 |
| (14) | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 14 | 15 |
| (15) | 3 | 3 | 3 | 5 | 3 | 5 | 6 | 3 | 8 | 8 | 10 | 10 | 11 | 14 | 15 |

This matrix should be read in the following way:

$r(i,j) = j \Longrightarrow$ The path connecting node i and j does not contain any intermediate nodes.

$r(i,j) = k \neq j \Longrightarrow$ node k is an intermediate node on the path between nodes i and j.

# CHAPTER VII

TeleSat

Telesat Canada
333 River Road
Ottawa, Ontario
Postal code K1L 8B9

(613) 746-5920

File No. 24-2-1-1

February 23, 1972

Dr. J. deMercado,
Director,
Terrestrial Systems Planning,
Department of Communications,
Berger Building,
100 Metcalfe Street,
Ottawa, Ontario
K1A OC8

Dear Dr. deMercado:

As a result of discussions with members of your staff, we are pleased to submit for your information, preliminary engineering cost estimates and technical information for providing data transmission services for the proposed "Canadian University Computer Network".

It should be emphasized that this information is very preliminary in nature and is intended only for the use by CANUNET participants to establish whether or not further detailed study would be of value. As such, the cost information could change when detailed system requirements are defined and commercial arrangements are known.

You will note that Telesat Canada has provided information in the Attachment on utilization of a whole R.F. channel by a number of networks, one of which could conceivably be CANUNET. The minimum cost per network is achieved when the satellite R.F. channel is fully utilized. The practicability of achieving the per network minimum cost depends on the number of networks that may be established and the consequent extent of the R.F. channel cost sharing that can be achieved.

. . .

With regard to R.F. channel cost sharing, it is possible that another network similar to CANUNET could be implemented to serve Federal Government integrated data transmission requirements more economically. In addition, other networks for use by various professional communities such as law, medicine, etc., could probably be developed to exploit the most cost effective configuration.

The estimated charges are based on service at the earth stations outlined; we understand backhaul interconnection costs to the various universities from our earth stations will be developed within your Department.

Telesat Canada is prepared to undertake a more detailed engineering analysis in support of CANUNET and Federal Government data transmission requirements in order to arrive at the most effective overall system configuration.

Mr. P.M. Norman will be pleased to continue liaison with your staff on technical matters and Mr. B.F. Murphy of our Planning and Marketing group will be contacting you as well to discuss any further information you require in connection with the estimated annual charges for the various network configurations.

Yours sincerely,

R.M. Lester

R.M. Lester,
Director,
Communication Systems.

Attach.

ATTACHMENT TO LETTER TO

Dr. J. de Mercado

# SATELLITE COMMUNICATIONS SYSTEM
# FOR DATA TRANSMISSION (CANUNET)

Telesat Canada
Ottawa
February 23, 1972

## TABLE OF CONTENTS

## I INTRODUCTION

This study illustrates the application of the Telesat satellite telecommunication system for use in the provision of communication services to CANUNET. Particular emphasis is placed on those features which offer unique capabilities in the provision of the service. Several possible network configurations have been examined and are illustrated. With the budgetary costs and system concept provided, it is possible for other networks to be assembled to enable the designers of CANUNET to select the most appropriate system.

The information provided here is preliminary in nature and is intended to form a basis for further discussion. The system design concepts and estimated facility annual charges can only be firm after further studies with CANUNET personnel to better relate the satellite system design to the network needs. Furthermore, commercial rates may introduce other factors not taken into account in an engineering study.

## II INITIAL TELESAT SATELLITE SYSTEM

The initial satellite system is planned for commercial operation by Telesat in January 1973. At that time, some 36 earth stations will be in operation providing high quality voice, data, facsimile and television transmission across Canada. Figure 1 shows the initial locations of these earth stations. Of primary interest to CANUNET will be those earth stations located in Southern Canada.

The space segment will normally consist of two in-orbit satellites. One satellite will be in operation while the second will provide back-up protection in case of failure of the first. Each satellite has 12 RF channels, 10 of which are available for full time commercial operation and 2 for standby operation. The use of two satellites in orbit and RF channel protection within each satellite provides the high degree of system reliability which is necessary for the proper operation of important communications services.

The RF channels each have the capability for carrying up to 60 Mb/s or 960 one-way voice channels depending on the modulation scheme and type of earth station used. The capability of the system for voice and television applications as well as a more detailed system description is contained in the attached paper "Communications Capability of the Canadian Domestic Satellite System".*

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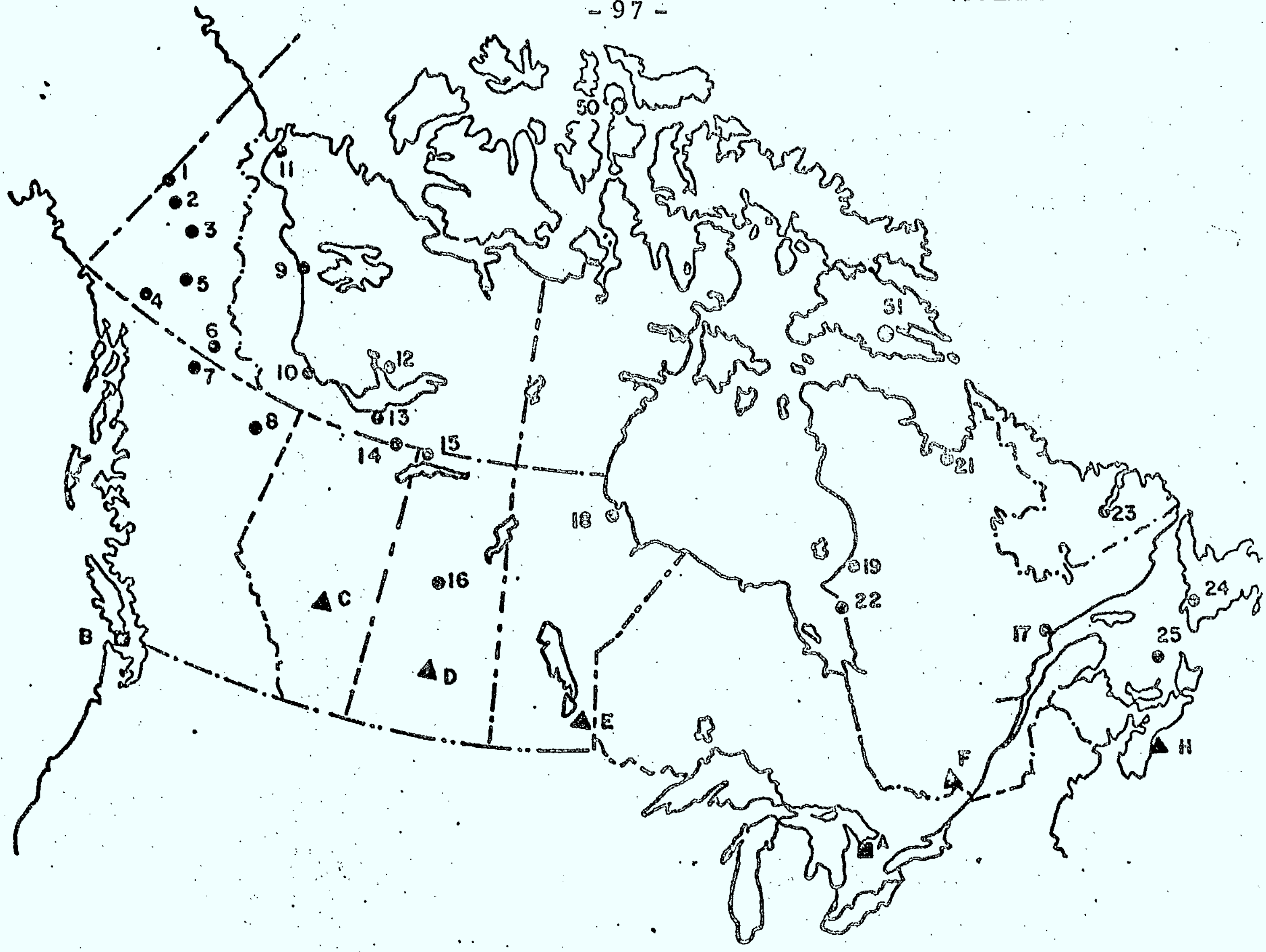
*J. Almond and R.M. Lester: "Communications Capability of the Canadian Domestic Satellite System." ICC Conference Paper, June 1971.




HEAVY ROUTE ■

A. Allan Park
B. Lake Cowichan

NETWORK TELEVISION ▲

C. Huggett
D. Qu'Appelle
E. Grand Beach
F. Riviere Rouge
G. Bay Bulls
H. Harrietsfield

NORTHERN TELECOMMUNICATIONS

50. Resolute
51. Frobisher Bay

REMOTE TELEVISION

1. Clinton Creek
2. Dawson
3. Elsa
4. Whitehorse
5. Faro
6. Watson Lake
7. Cassiar
8. Fort Nelson
9. Norman Wells
10. Fort Simpson
11. Inuvik
12. Yellowknife
13. Pine Point
14. Fort Smith
15. Uranium City
16. La Ronge
17. Sept Iles
18. Churchill
19. Great Whale
21. Fort Chimo
22. Fort George
23. Goose Bay
24. Port-au-Port
25. Magdalen Islands

Figure 1 INITIAL TELESAT EARTH STATION LOCATIONS

## III PROPOSED SYSTEM FOR CANUNET

### SYSTEM CONFIGURATION

Suitable communication system designs have been examined to provide bit rates of 9.6 and 50 kb/s interconnecting the Nodes shown in some of the Networks that have been proposed for CANUNET*. These Nodes are given in Table I. All schemes would require a combination of terrestrial and satellite facilities in order to provide the overall service. The characteristics of the proposed system to provide the satellite facilities are described in the ensuing paragraphs.

The system concept planned by Telesat would use a separate radio frequency carrier for each data stream transmitted through the satellite RF channel. This is the scheme illustrated in Figure 2. Each satellite RF channel can accommodate up to 70 carriers, each carrying data at up to 50 kb/s or approximately double the number of carriers at 9.6 kb/s. At a 50 kb/s bit rate the PSK modulator would operate at a nominal 64 kb/s and through the use of forward acting error correcting coders could provide a typical error rate of 1 in $10^7$ for 99.9% of the time or better. Other trade-offs in bit rate, error rate and satellite utilization are possible. If desired, it would also be possible to combine bit streams at 9.6 kb/s or lower rates into single streams transmitted over the satellite at higher rates. Thus, any data rate could be selected by CANUNET to be compatible with that carried on the terrestrial network between the earth stations and Nodes so that no buffering would be required.

In the specific configuration that is proposed for CANUNET each earth station would be assigned one channel having a bit rate of 9.6 or 50 kb/s and having a unique transmit frequency. Furthermore, each earth station would be equipped with receivers tuned to the transmit frequencies of all the other

---

*J. de Mercado, R. Guindon, J. Da Silva, M. Kadoch: Topological Analysis and Design of CANUNET. January 1972.

## TABLE I

## CANUNET NODES

| 10 Node Network | 14 Node Network | | 18 Node Network | |
|---|---|---|---|---|
| Vancouver | Vancouver | Montreal | Vancouver | Hamilton |
| Calgary | Calgary | Quebec | Calgary | Windsor |
| Saskatoon | Edmonton | Fredericton | Edmonton | Montreal |
| Winnipeg | Regina | Halifax | Regina | Quebec |
| Ottawa | Saskatoon | | Saskatoon | Fredericton |
| Toronto | Winnipeg | | Winnipeg | Moncton |
| Waterloo | Ottawa | | Ottawa | Charlottetown |
| Montreal | Toronto | | Toronto | Halifax |
| Quebec | Waterloo | | Waterloo | |
| Halifax | Kingston | | Kingston | |

Figure 2

## SATELLITE UTILIZATION SCHEME FOR CANUNET

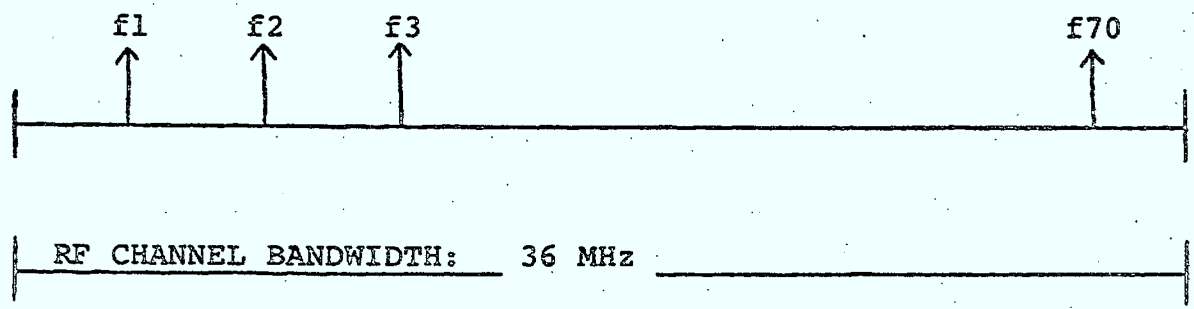
### PSK - FDMA MODULATION

**EXAMPLE**

NETWORK OF 2 TO 8 EARTH STATIONS

EARTH STATION G/T = 28 dB

APPROX. 70 CHANNELS AT 50 kb/s EACH THROUGH 1 RF CHANNEL (OR 140 AT 9.6 kb/s)




**FEATURES**

- 70 FREQUENCIES (i.e. CHANNELS) AVAILABLE TO EACH STATION (OR 140 AT 9.6 kb/s)
- EACH STATION CAN TRANSMIT ANY NUMBER OF CHANNELS
- A FREQUENCY TRANSMITTED BY ONE STATION CAN BE RECEIVED BY ONE OR ANY NUMBER OF OTHER STATIONS SIMULTANEOUSLY AS REQUIRED. THIS PROVIDES A FLEXIBLE ADAPTIVE ROUTING CAPABILITY.
- THIS SCHEME CAN BE ADAPTED TO PROVIDE FOR THE ASSIGNMENT OF CHANNELS BETWEEN DIFFERENT LOCATIONS ON DEMAND; i.e. DEMAND ASSIGNMENT BY COMPUTER CONTROL.
- ERROR RATE 1 in $10^7$ FOR 99.9% OF THE TIME OR BETTER.

earth stations in the network. Transmissions from any earth station will thus be received by all other earth stations in the network but will only be accepted for onward transmission upon recognition of an address appropriate to its destination. The addresses are assumed to be inserted at the originating universities and assembled into the data streams for transmission over the satellite system. This would result in an adaptive route selection capability since a message transmitted by any one earth station can be received by any number of earth stations simultaneously. Thus, individual direct links between any earth stations in Canada so equipped can be established on demand using the same specific channel in the satellite without passage through intervening Nodes. It is understood that such an arrangement with one channel transmitted per station would quite adequately meet CANUNET requirements.

The network configuration that has been described with earth stations equipped to receive data from more than one location could result in several bit streams being received simultaneously. It is assumed that CANUNET would arrange for the necessary recognition of addresses and any funnelling of data for transmission on the terrestrial network to the nearest Node.

Other arrangements than that described would, of course, be possible. For example, earth stations could transmit more than one radio frequency carrier at 9.6, 50 kb/s, or other bit rates. Furthermore, certain high usage links between Nodes could have dedicated, pre-assigned lines which would not be received by other stations. These features, to provide for growth after the initial system is in service, may easily be added on an incremental basis.

EARTH STATION LOCATIONS

The total cost of the communication system to provide service to CANUNET will be a combination of both the cost of satellite and terrestrial facilities. Telesat has attempted to select earth station locations which would provide the most cost effective solution to CANUNET. However, the total cost is a complex function of the overall network configuration and it is expected that the specific number of earth station accesses to the satellite will need to be considered carefully by the designers of CANUNET.

CANUNET is considering the interconnection of universities homing on either ten, fourteen or eighteen Nodes as illustrated in Table I.

Consideration of these requirements in relation to the presently planned Telesat earth stations listed in Table II reveals that about 50% of the locations are less than 100 miles from a Telesat earth station, 70% less than 150 miles and that 100% are within approximately 220 miles. These distances are based on the most probable routing of the terrestrial facilities required to link the city to the Telesat earth station and could be somewhat less if more direct links are available. However, they do not include route mileage required to link the individual universities to their respective Node Control Units.

The location of the presently planned earth stations in relation to the Nodes suggests that these stations could effectively be used to provide the long distance communication facilities for CANUNET. A preliminary examination of sites for new earth stations indicates that it would be more economic to use the existing ones. However, Telesat would be pleased to assist in considering such new earth stations should it become desirable.

Using the existing earth stations in Southern Canada which are shown in Table II, seven regional CANUNET networks could be established and interconnected via satellite as shown in Figure 3. The inclusion of St. John's, Nfld., although not shown as a Node could also easily be accomplished using the existing Bay Bulls station. Figure 4 illustrates other possible regional networks using different numbers of earth stations. These are based on minimizing the terrestrial mileage in each case.

TABLE II

Location of Earth Stations in Southern Canada

| Name | Closest Major Centres of Population | Approximate Distance |
|---|---|---|
| Bay Bulls | St. John's, Nfld. | 17 miles |
| Harrietsfield | Halifax, Nfld. | 10 |
| Riviere Rouge | Montreal, P.Q. | 55 |
| Allan Park | Toronto, Ont. | 80 |
| | Waterloo, Ont. | 60 |
| Grand Beach | Winnipeg, Man. | 55 |
| Qu'Appelle | Regina, Sask. | 27 |
| | Saskatoon, Sask. | 140 |
| Huggett | Edmonton, Alta. | 26 |
| | Calgary, Alta. | 150 |
| Lake Cowichan | Victoria, B.C. | 40 |
| | Vancouver, B.C. | 55 |

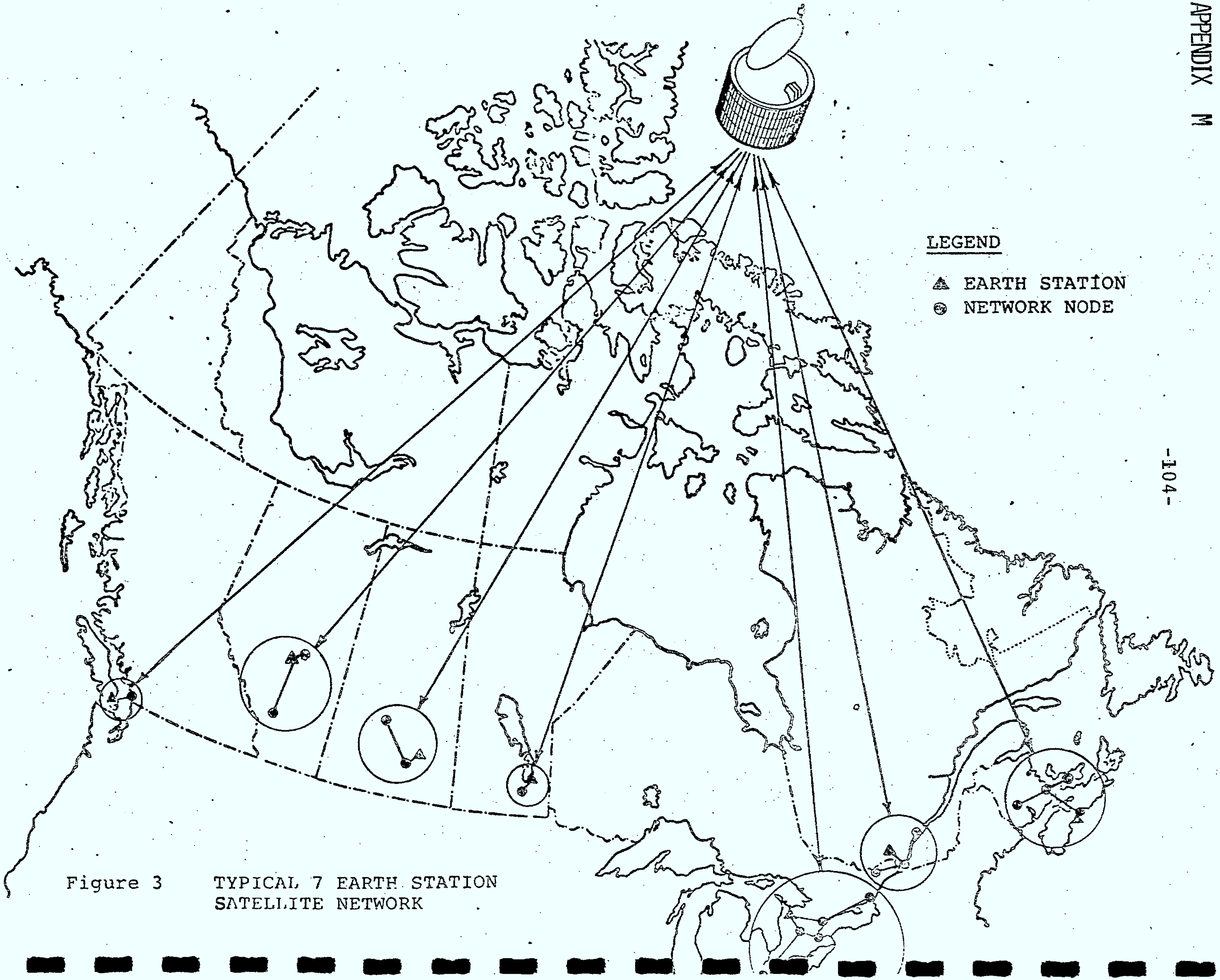



Figure 3 TYPICAL 7 EARTH STATION SATELLITE NETWORK

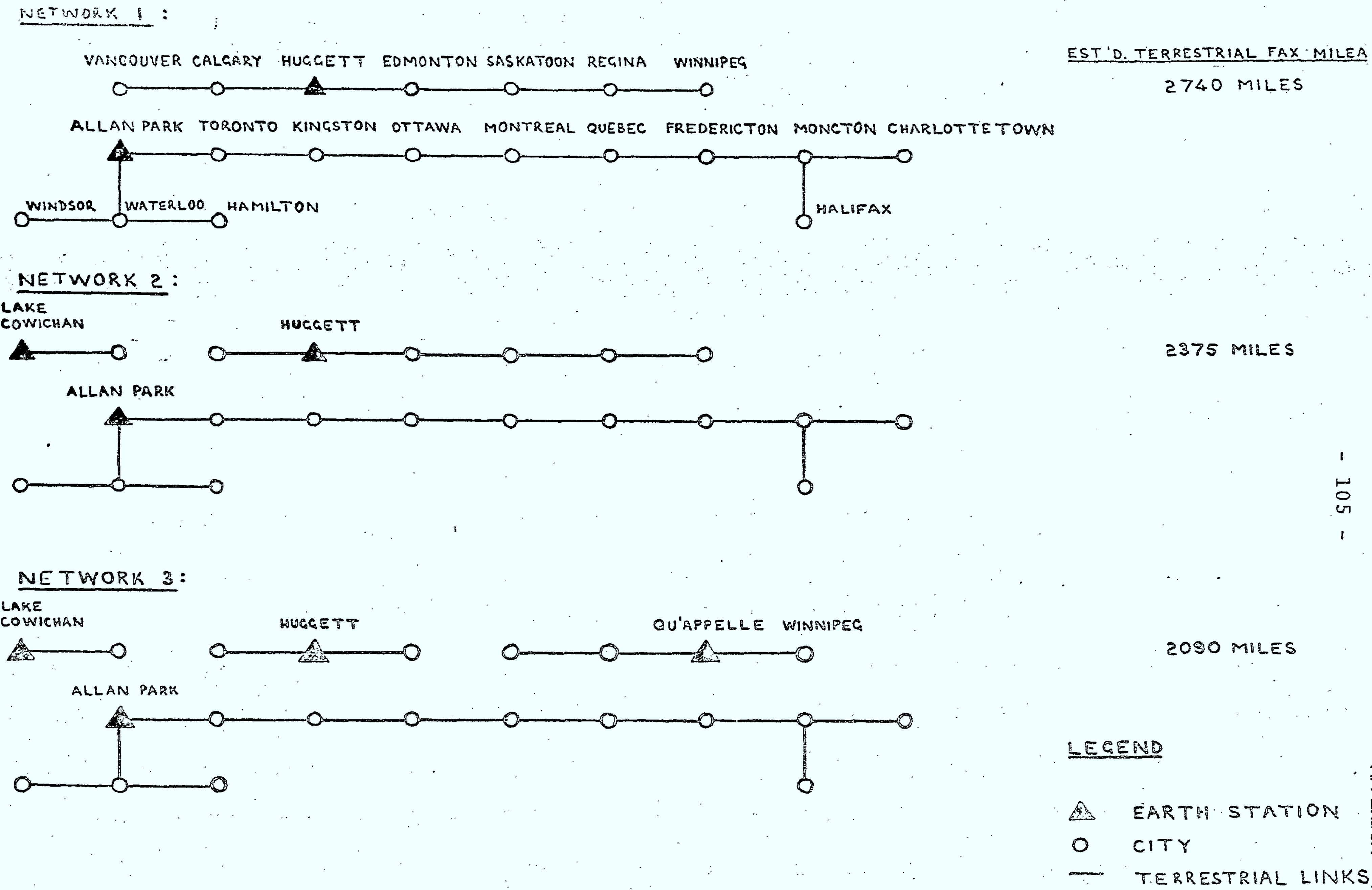



FIGURE 4 TYPICAL NETWORK CONFIGURATIONS

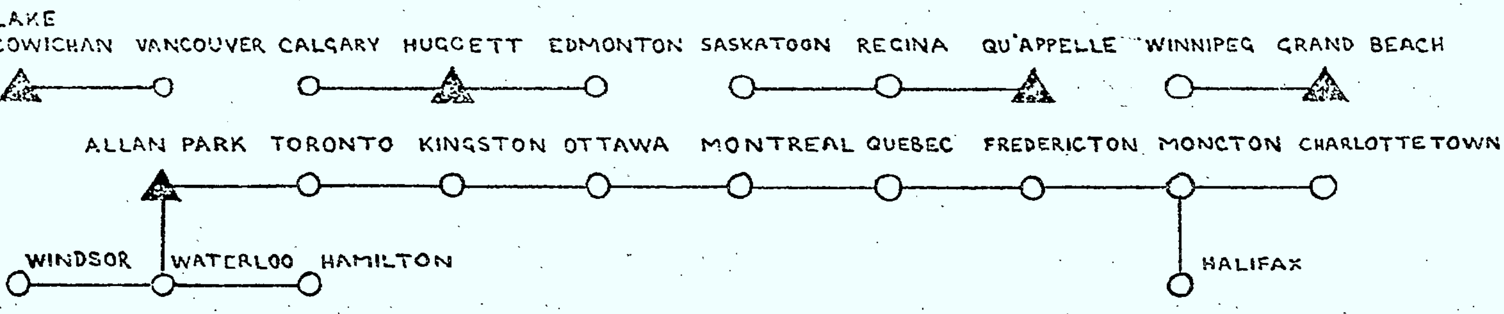
APPENDIX "I"



SH.1 CONTINUED ON SH. 2

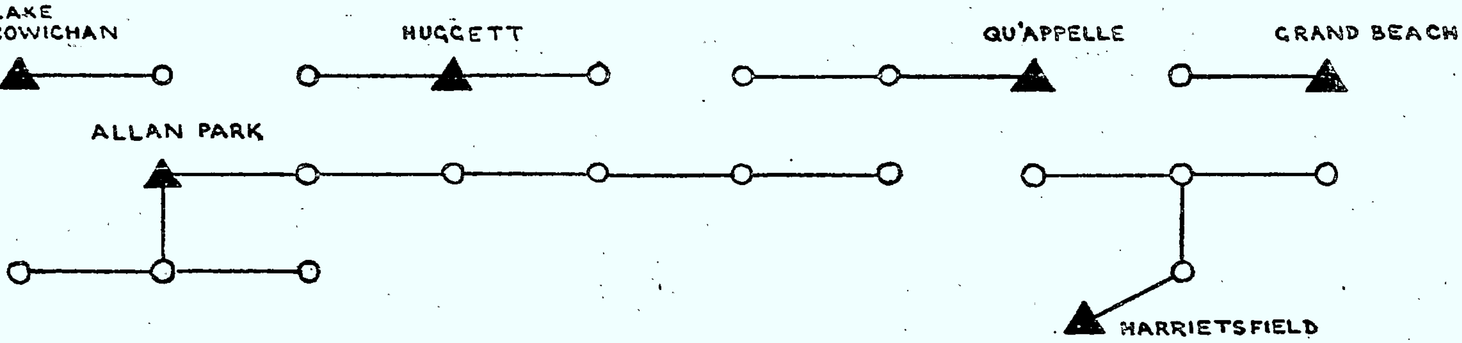
EST'D TERRESTRIAL FAX MILEAGE

NETWORK 4 :



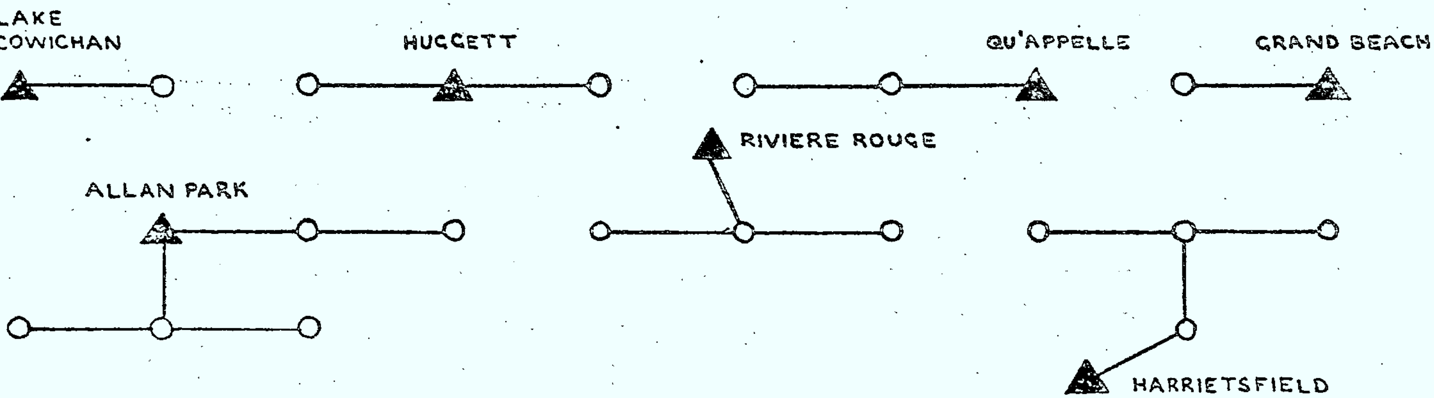

1815 MILES

NETWORK 5 :




1575 MILES

NETWORK 6 :




1470 MILES

FIGURE 4 TYPICAL NETWORK CONFIGURATIONS

NETWORK FLEXIBILITY

The system outlined possesses considerable flexibility and operational advantages especially in configurations involving more than 2 (two) earth stations. In the first place the system possesses a multi-point interconnection capability and any regional network is directly connected via a single satellite link to any other regional network. This is illustrated for a simple 3 earth station network in figure 5. The channel reliability and/or quality is thus independent of the distance between the interconnected networks in contrast to the situation using terrestrial facilities where the possibility of impairment or failure is proportional to the length of the channel involved.

Secondly, the grouping of Nodes into regional networks possessing a community of interest would tend to reduce the load on the long distance satellite links thus reducing queuing problems which might arise on a single trunk terrestrial scheme.

Thirdly, the network can be set up with only the interconnection capability initially required. Additional interconnection capability is very easily added by the provision of the necessary transmitters or receivers at the stations concerned.

SYSTEM RELIABILITY AND SERVICE AVAILABILITY

The reliability of the system for data traffic may be measured in terms of the error rate. A typical error rate of 1 in $10^7$ for 99.9% of the time has been assumed. Other trade-offs in error rate, bit rates and satellite RF channel utilization are possible.

The service availability objective would be to provide a two-way continuity of service of 99.98% of the time or better.

TIME DELAY

A significant design criteria in the CANUNET network is the time delay for a message to reach its destination. For a network using satellite facilities it is expected that the

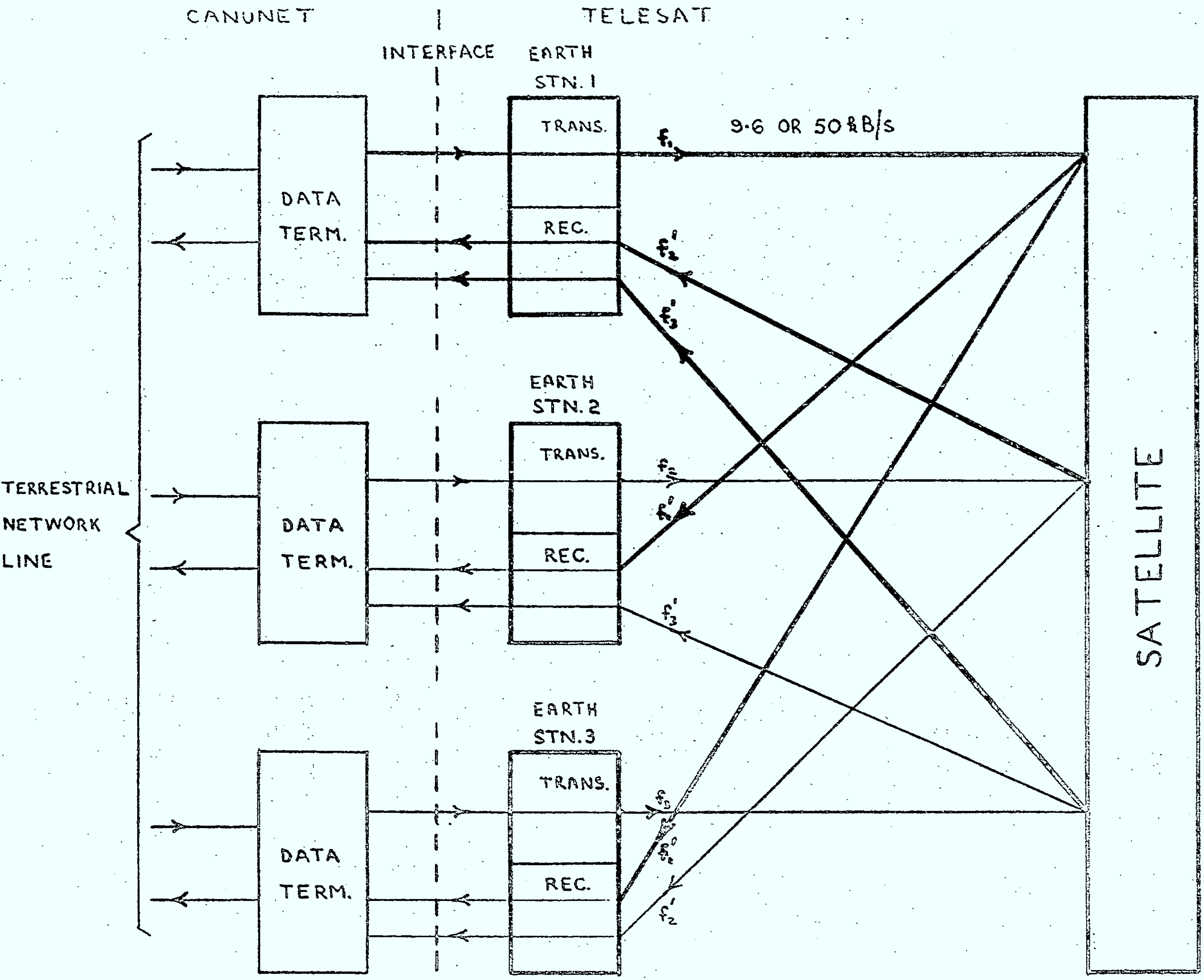



FIGURE 5 TYPICAL SYSTEM LAYOUT - 3 STATION CONFIGURATION

significant contributor to this will be propagation delay. However, delay which results from queuing at Nodes is not expected to be as significant as on the terrestrial network since an earth station transmitting to another can effectively leap frog the intervening Nodes.

The actual propagation delay via satellite will vary somewhat with the position of the satellite and the location of the earth stations. For design purposes it is suggested that a propagation delay of between 250 and 270 milliseconds be used for a one way link from a transmitting to receiving earth station. More precise values could be provided if desired.

COSTS

The costs associated with the rental of satellite facilities are discussed in the letter of transmittal with this Attachment. To further assist CANUNET in the planning of their network, separate estimates of annual charges have been made for a satellite system using from 2 - 8 earth stations. These are budgetary estimates only and would have to be refined to reflect further discussion concerning the system configuration. These estimates may be used for example, to assist in decisions on the economics of adding or removing earth stations, since the overall system cost to CANUNET would involve a combination of the terrestrial and satellite facility costs.

TABLE III

50 or 9.6 kb/s

TOTAL ANNUAL CHARGE $ MILLION / ANNUAL CHARGE PER NETWORK $ MILLION

| NO. OF STATIONS PER NETWORK | NUMBER OF NETWORKS: 1 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 | 25 | 30 | 35 | 70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 3 / 3 | 3 / 1.5 | 3 / 1.0 | 3 / 0.75 | 3 / 0.6 | 3 / 0.5 | 3 / 0.38 | 3.08 / 0.31 | 3.55 / 0.24 | 4.03 / 0.20 | 4.50 / 0.18 | 4.98 / 0.17 | 5.45 / 0.16 | 8.78 / 0.13 |
| 3 | 3 / 3 | 3 / 1.5 | 3 / 1.0 | 3 / 0.75 | 3 / 0.6 | 3.10 / 0.52 | 3.41 / 0.43 | 3.73 / 0.37 | 4.52 / 0.30 | 5.31 / 0.27 | 6.10 / 0.27 | 6.89 / 0.23 | 7.68 / 0.22 | |
| 4 | 3 / 3 | 3 / 1.5 | 3 / 1.0 | 3.09 / 0.77 | 3.32 / 0.66 | 3.56 / 0.59 | 4.02 / 0.50 | 4.48 / 0.45 | 5.64 / 0.38 | 6.79 / 0.34 | 7.95 / 0.35 | 9.10 / 0.30 | 10.26 / 0.29 | |
| 5 | 3 / 3 | 3 / 1.5 | 3.14 / 1.05 | 3.45 / 0.86 | 3.77 / 0.75 | 4.08 / 0.68 | 4.71 / 0.59 | 5.34 / 0.53 | 6.92 / 0.46 | 8.49 / 0.43 | 10.01 / 0.40 | | | |
| 6 | 3 / 3 | 3.03 / 1.5 | 3.44 / 1.15 | 3.85 / 0.96 | 4.27 / 0.85 | 4.68 / 0.78 | 5.50 / 0.69 | 6.32 / 0.63 | 8.38 / 0.56 | 10.43 / 0.52 | | | | |
| 7 | 3 / 3 | 3.26 / 1.63 | 3.78 / 1.29 | 4.29 / 1.07 | 4.81 / 0.96 | 5.32 / 0.89 | 6.35 / 0.79 | 7.38 / 0.74 | 9.96 / 0.66 | 12.53 / 0.63 | | | | |
| 8 | 3 / 3 | 3.52 / 1.76 | 4.15 / 1.38 | 4.78 / 1.20 | 5.41 / 1.08 | 6.04 / 1.01 | 7.30 / 0.91 | 8.56 / 0.86 | 11.71 / 0.78 | 14.86 / 0.74 | | | | |

50 and 9.6 kb/s ← → 9.6 kb/s

NOTES:

1. Assumes the use of existing Telesat earth stations. Costs for the addition of new earth stations could be provided if required.

2. Each earth station in a network is equipped to transmit one channel at the data rate specified

3. Each earth station in a network is equipped to receive the channels from all other earth stations in the same network simultaneously.

4. \$3 M per year has been established as the minimum rental for an RF channel and a complement of earth station equipment.

Terrestrial Costs for Hybrid Network

Table IV *) contains the yearly cost for the terrestrial networks which must be added to the $3,000,000 per year established by Telesat. This would be the total cost for the satellite/terrestrial network.

As shown in Table III **) this yearly rental cost of ANIK would go down if shared with other customers. For example, if 3 organizations share 7 stations per network then, the yearly rental cost of ANIK would be $1.29 million. This therefore suggest that the use of satellite will only become attractive when more than one or two organizations or networks share in the rental of an ANIK channel.

*) see page 113

**) see Telesat submission (page 110)

## TABLE IV

(Yearly Terrestrial Costs)

| Network \ Speed of lines | 4.8 kb/sec. | 9.6 kb/sec. | 50 kb/sec. |
|---|---|---|---|
| NOD 10 SAT 4 Topology #1 | $ 133,650 | $ 193,650 | $ 558,600 |
| NOD 10 SAT 4 Topology #2 | $ 206,200 | $ 290,200 | $ 905,700 |
| NOD 10 SAT 5 Topology #1 | $ 122,800 | $ 182,800 | $ 484,200 |
| NOD 10 SAT 5 Topology #2 | $ 195,400 | $ 279,400 | $ 831,300 |
| NOD 10 SAT 5 RIVIERE ROUGE) | $ 122,500 | $ 182,500 | $ 482,700 |
| NOD 10 SAT 7 | $ 102,400 | $ 162,400 | $ 344,100 |
| NOD 14 SAT 6 | $ 152,300 | $ 236,300 | $ 546,300 |
| NOD 18 SAT 4 | $ 222,300 | $ 330,300 | $ 848,700 |
| NOD 18 SAT 6 | $ 198,800 | $ 306,800 | $ 711,300 |

## PART III

## NETWORK COST COMPARISONS

## Cost Considerations

The emphasis of the Communication Studies Committee was directed towards the analysis of possible topological configurations for CANUNET. Some of these costs for terrestrial as well as for the hybrid networks given in this report are presented.

The terrestrial network costs in dollars per Megabits for 100% and 80% utilization are given in Tables 1, 2 and 3 *) for the various speed options and topologies. For example, in a 50 kb/sec. 10 node single topology network, the cost of transmission for 1 megabit was found to be 13.9 cents for 80% utilization.

In all the cases (terrestrial as well as hybrid) the actual total communication cost for the network would have to include, other than the above communication line costs, the cost of the Node Control Unit plus maintenance.

In the case of ARPANET **), a cost of 11¢/megabit was found based on a total capacity of 225 kb/sec. for the network. However, since it was felt the ARPA network was not expected to be always fully loaded to peak capacity, day and night, the actual cost was closer to 30¢/megabit based on a 36% average loading. This cost was for the communication lines only; it did not include the cost of the IMP nor maintenance..

In case of CANUNET, for 80% utilization, the communication line cost can go as high as 24.5¢/megabits for network 7 (Fig.1)***) Looking ahead, users of the network could be charged as a function of traffic initiated at a node based on the total usage of the network.

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(*) See pages 117-118-119

(**) "A Forward Look"; by Larry Roberts, June 1971.

(***) See page 121.

If a satellite is used to generate a hybrid realization then, the total cost of CANUNET will be the summation of the cost of satellite and terrestrial facilities. Table 4*) represents the total annual renting charge as supplied by Telesat for a full RF channel.

This channel could accommodate up to 70 carriers for the 50 kb/sec. lines and 140 carriers for the 9.6 kb/sec. lines. Table 4 should therefore be read by keeping in mind that the:

(Number of stations per network) x (Number of networks) $\leq$ 70 for the 50 kb/sec. lines,

and $\leq$ 140 for the 9.6 kb/sec. lines.

This table also indicates that a cost of $3,000,000 per year has been established as the minimum rental for an RF channel and a complement of earth station equipment. To this cost must now be added the yearly terrestrial costs. For example, using the topology given in Fig.2**) for the 18 node 6 earth station network the yearly terrestrial cost would be $711,300. Again this is an approximate cost and could change when the exact topology is known.

It should be noted that a more detailed engineering analysis would be required to arrive at the most effective overall system configuration.

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*) see page 120

**) see page 122

Terrestrial Networks (See Part I )

TABLE 4

| Speed of line / NETWORK | 4.8 kb/sec. | | |
|---|---|---|---|
| | Total Input Data Rate (kb/sec.) | Cost ($/Mbits) | |
| | | 100% Utilization | 80% Utilization |
| 1 | 11 | .506 | .632 |
| 2 | 45 | .241 | .301 |
| 3 | 36 | .233 | .290 |
| 4 | 3.5 | 2.038 | 2.55 |
| 5 | 23 | 0.555 | .694 |
| 6 | 1 | 8.779 | 10.97 |
| 7 | 25 | .607 | .759 |
| | | | |
| | | | |

Terrestrial Networks (See Part I)

TABLE 2

| Speed of line / NETWORK | 9.6 kb/sec. | | |
|---|---|---|---|
| | Total Input Data Rate (kb./sec.) | Cost ($/Mbits) | |
| | | 100% Utilization | 80% Utilization |
| 1 | 49 | .156 | .195 |
| 2 | 108 | .132 | .165 |
| 3 | 92 | .119 | .149 |
| 4 | 47 | .215 | .269 |
| 5 | 79 | .218 | .272 |
| 6 | 48 | .263 | .329 |
| 7 | 86 | .246 | .308 |
| | | | |
| | | | |

Terrestrial Networks (See Part I )

TABLE 3

| Speed of line / NETWORK | 50 kb/sec. | | |
| --- | --- | --- | --- |
| | Total Input Data Rate (kb/sec.) | Cost ($/Mbits) | |
| | | 100% Utilization | 80% Utilization |
| 1 | 304 | .111 | .139 |
| 2 | 591 | .130 | .163 |
| 3 | 508 | .121 | .151 |
| 4 | 302 | .133 | .166 |
| 5 | 455 | .182 | .225 |
| 6 | 317 | .142 | .178 |
| 7 | 477 | .196 | .245 |
| | | | |
| | | | |

TABLE 4

50 or 9.6 kb/s

(Key: TOTAL ANNUAL CHARGE $ MILLION / ANNUAL CHARGE PER NETWORK $ MILLION)

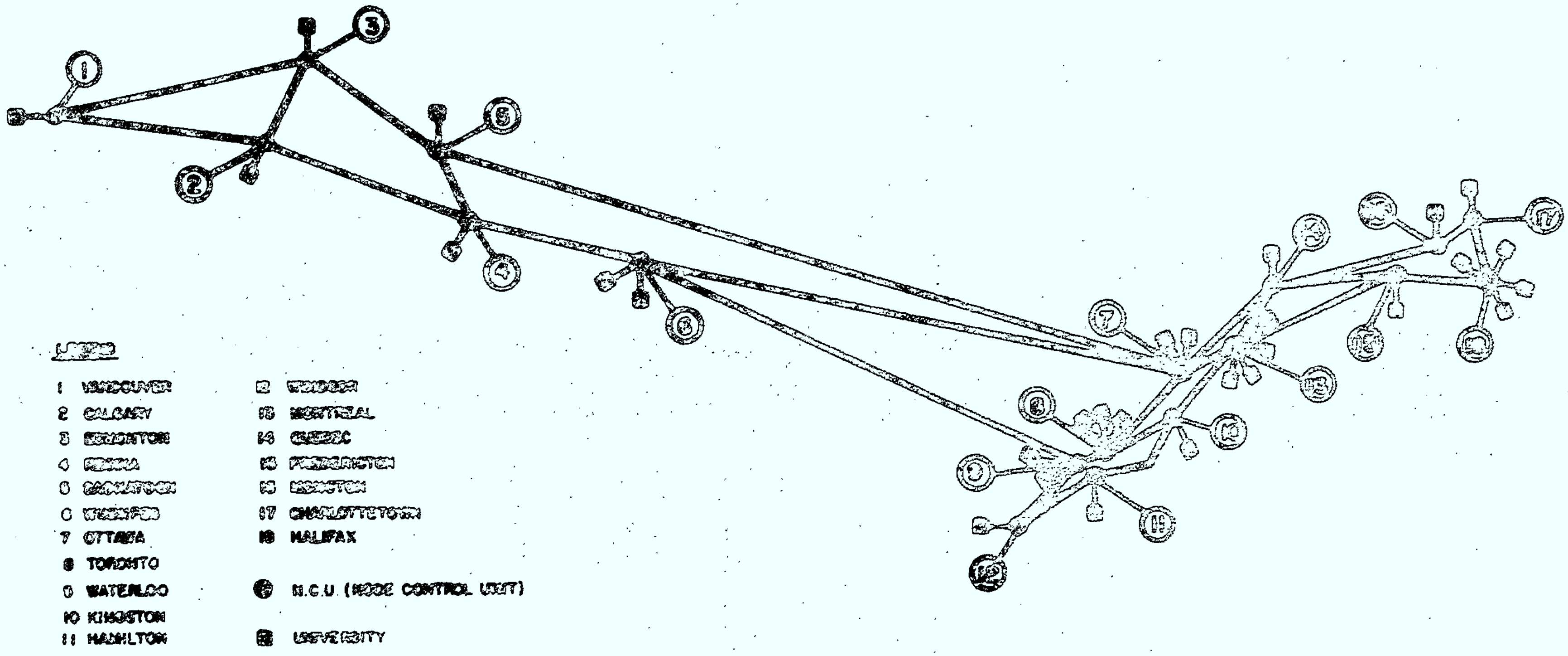
| NO. OF STATIONS PER NETWORK | NUMBER OF NETWORKS | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 | 25 | 30 | 35 | 70 |
| 2 | 3 / 3 | 3 / 1.5 | 3 / 1.0 | 3 / 0.75 | 3 / 0.6 | 3 / 0.5 | 3 / 0.38 | 3.08 / 0.31 | 3.55 / 0.24 | 4.03 / 0.20 | 4.50 / 0.18 | 4.98 / 0.17 | 5.45 / 0.16 | 8.78 / 0.13 |
| 3 | 3 / 3 | 3 / 1.5 | 3 / 1.0 | 3 / 0.75 | 3 / 0.6 | 3.10 / 0.52 | 3.41 / 0.43 | 3.73 / 0.37 | 4.52 / 0.30 | 5.31 / 0.27 | 6.10 / 0.27 | 6.89 / 0.23 | 7.68 / 0.22 | |
| 4 | 3 / 3 | 3 / 1.5 | 3 / 1.0 | 3.09 / 0.77 | 3.32 / 0.66 | 3.56 / 0.59 | 4.02 / 0.50 | 4.48 / 0.45 | 5.64 / 0.38 | 6.79 / 0.34 | 7.95 / 0.35 | 9.10 / 0.30 | 10.26 / 0.29 | |
| 5 | 3 / 3 | 3 / 1.5 | 3.14 / 1.05 | 3.45 / 0.86 | 3.77 / 0.75 | 4.08 / 0.68 | 4.71 / 0.59 | 5.34 / 0.53 | 6.92 / 0.46 | 8.49 / 0.43 | 10.01 / 0.40 | | | |
| 6 | 3 / 3 | 3.03 / 1.5 | 3.44 / 1.15 | 3.85 / 0.96 | 4.27 / 0.85 | 4.68 / 0.78 | 5.50 / 0.69 | 6.32 / 0.63 | 8.38 / 0.56 | 10.43 / 0.52 | | | | |
| 7 | 3 / 3 | 3.26 / 1.63 | 3.78 / 1.29 | 4.29 / 1.07 | 4.81 / 0.96 | 5.32 / 0.89 | 6.35 / 0.79 | 7.38 / 0.74 | 9.96 / 0.66 | 12.53 / 0.63 | | | | |
| 8 | 3 / 3 | 3.52 / 1.76 | 4.15 / 1.38 | 4.78 / 1.20 | 5.41 / 1.08 | 6.04 / 1.01 | 7.30 / 0.91 | 8.56 / 0.86 | 11.71 / 0.78 | 14.86 / 0.74 | | | | |

50 and 9.6 kb/s ← | → 9.6 kb/s

APPENDIX M

Fig. 1

## NETWORK 7



APPENDIX M

NOD 18 SAT 6

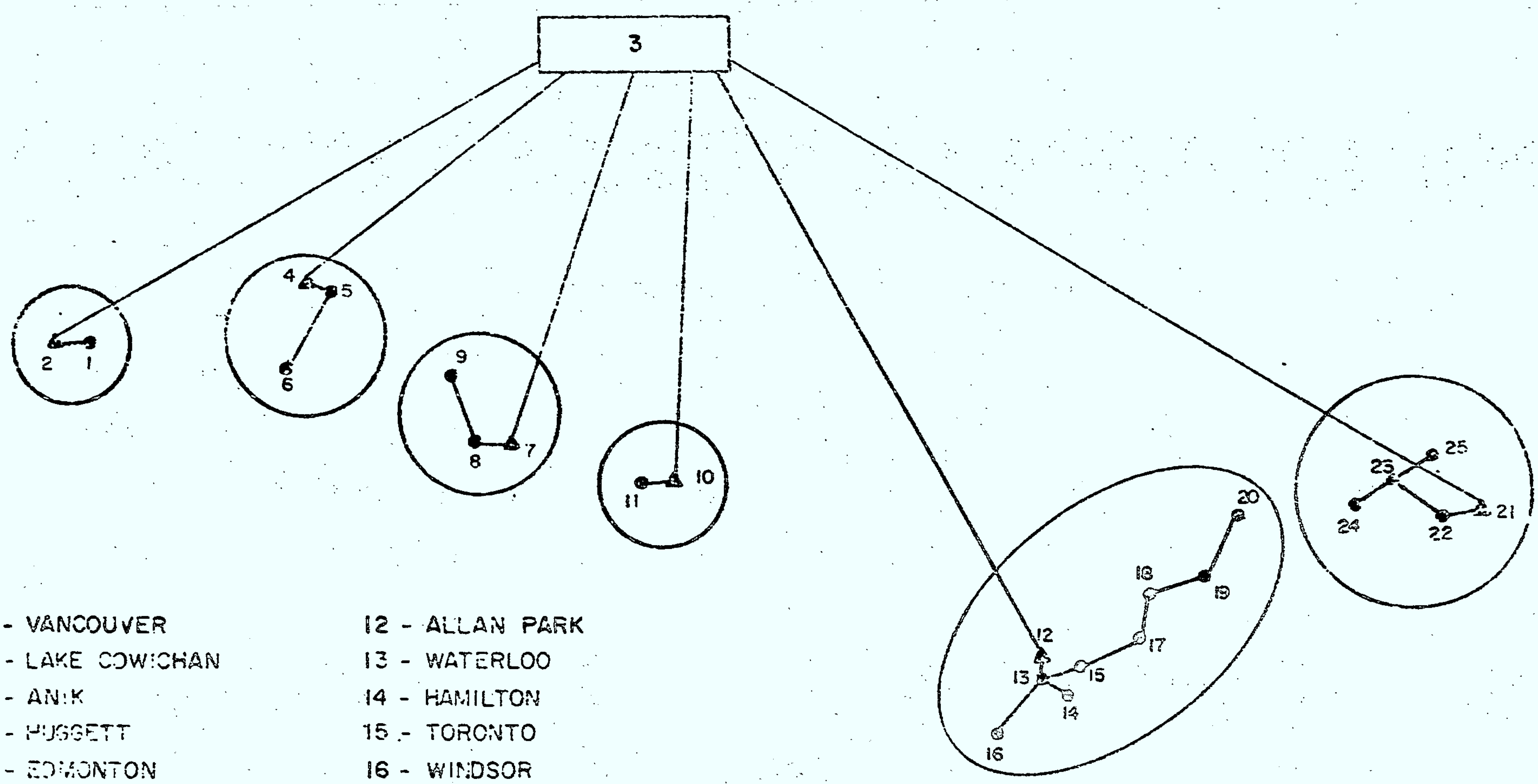



Fig. 2

1 - VANCOUVER
2 - LAKE COWICHAN
3 - ANIK
4 - HUGGETT
5 - EDMONTON
6 - CALGARY
7 - QU'APPELLE
8 - REGINA
9 - SASKATOON
10 - GRAND BEACH
11 - WINNIPEG

12 - ALLAN PARK
13 - WATERLOO
14 - HAMILTON
15 - TORONTO
16 - WINDSOR
17 - KINGSTON
18 - OTTAWA
19 - MONTREAL
20 - QUEBEC
21 - HARRIETSFIELD
22 - HALIFAX

23 - MONCTON
24 - FREDERICTON
25 - CHARLOTTETOWN

● N.C.U. (NODE CONTROL UNIT)

▲ GROUND STATION

Conclusions

The results obtained in this study are based on the analysis of computer-communication network performance using methods from queueing and network flow theory.

Various possible single and multi-connected topologies were analysed in order to get a relationship between the total amount of traffic in the network with the total average delay for different line capacities. These results were given in the form of tables and graphs showing the limitations of certain design criteria.

A significant result is shown in the graphs, namely that a series of curves can be obtained, which show the differences in network performance for the cases when some lines were 9.6 kbs/sec., and other 50 kbs/sec. This permits us to optimize trade-offs between total network capacity and cost.

The authors hope that the analysis results presented in this report will allow the Advisory Committee to speedily settle on the best topology for CANUNET.

## Conclusions

The results obtained in this study are based on the analysis of computer-communication network performance using methods from queueing and network flow theory.

The model used for the hybrid network simulation considered an earth station of the Satellite system as an IMP or an NCU (node control unit). If this function is not required at those stations then the total average message delay for the considered network would be less. The simulation results were given in terms of performance graphs where the minimum delays were found to be between 210 ms and 290 ms *). As was stated in the report those results were the worst case situation.

The authors hope that the analysis results presented in this report will allow the Advisory Committee to speedily settle on the best Topology for CANUNET.

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*) A minimum of 210 ms was found for NOD 18 SAT 4 using 50 kb/s terrestrial lines, and a minimum of 290 ms was found for NOD 10 SAT 7 using 50 kb/s terrestrial lines.

APPENDIX A

Introduction

There exists other network configurations which have not yet been considered for CANUNET. Among those, the loop or ring system is a possible alternative. This appendix briefly describes this type of network.

Loop Transmission Networks

Recently, several papers appeared in the literature [30,31,32,33,34] proposing data communication networks where the users were connected in a ring or loop topology. The loop-transmission system consists of a closed communication loop composed of a System Controller, terminals where traffic enters and leaves the loop, and gateways which provide a connection between two loops.(see fig.A.1) A user at some terminal inputs the message he wants to send, the terminals breaks the message into fixed size packets, supplies it with a header which contains source and destination addresses, and according to a scheduling algorithm feeds the packets into the line. The traffic flows in one direction around the loop from terminal to terminal. At each terminal, the address of a packet is examined to determine whether the packet's destination is at that particular terminal.

In order to explain the mechanism of multiplexing packets on and off the line, it is helpful to draw an analogy between a loop and a conveyor belt.(see fig. A.2) Time slots, into which packets may be placed, circulate around the loop. At the beginning of each time slot is a marker which indicates whether the time slot is empty or full, therefore a terminal can use an empty slot to feed its own packet on the line. If the slot is full a packet trying to enter the loop waits until an empty slot arrives at the particular terminal. In other words, the traffic already in transmission has priority over the traffic seeking entrance into the loop.

The functions of the System Controller are twofold;

a) synchronization of the ring.
b) prevention of traffic buildup. (a packet passing the System Controller twice, is destroyed)

The gateways provide a connection between two loops. The behaviour of these gateways is in some sense, the same as the terminal's with the difference that the packets are now passing from one loop to another.

As mentioned earlier, a packet has to wait in a terminal or gateway buffer if the loop is busy, and this waiting time is, of course, one of the most important figure of merit of any computer network.

Calculations of the average message delay were made by Hayes and Sherman [34] for a 10, 50 and 100 terminal loops and the results obtained show that the average message delay is quite small for a wide range of line loadings.

Loops of the type previously described are particularly suited to environments where terminals are clustered, but they could be used for provincial or national networks. (see fig.A.3) However, the major obvious drawback is the fact that the series nature of the loop can cause the failure of the entire loop if one of the terminals fails. A detailed study should be conducted to determine the cost of a loop vis-a-vis the cost of a distributed network like the one initially proposed for CANUNET.

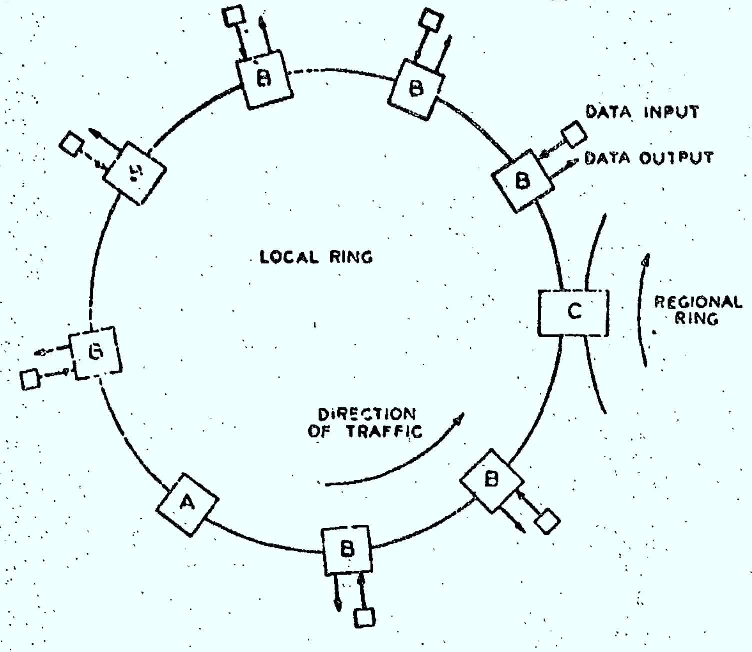


fig. A.1 - A- System Controller,
B- Terminal,
C- Gateway

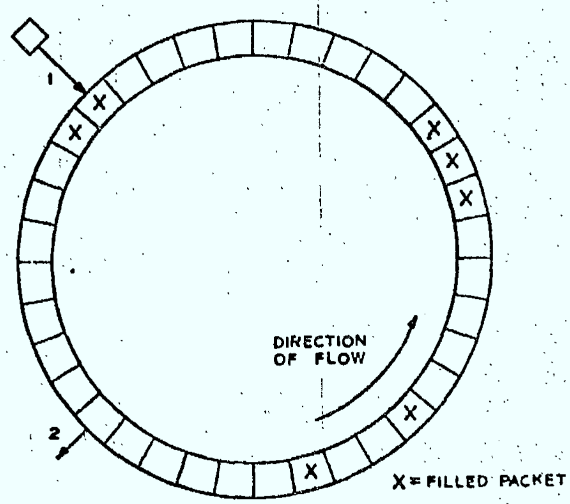


fig. A.2 - Packets enter at 1 and leave at 2.

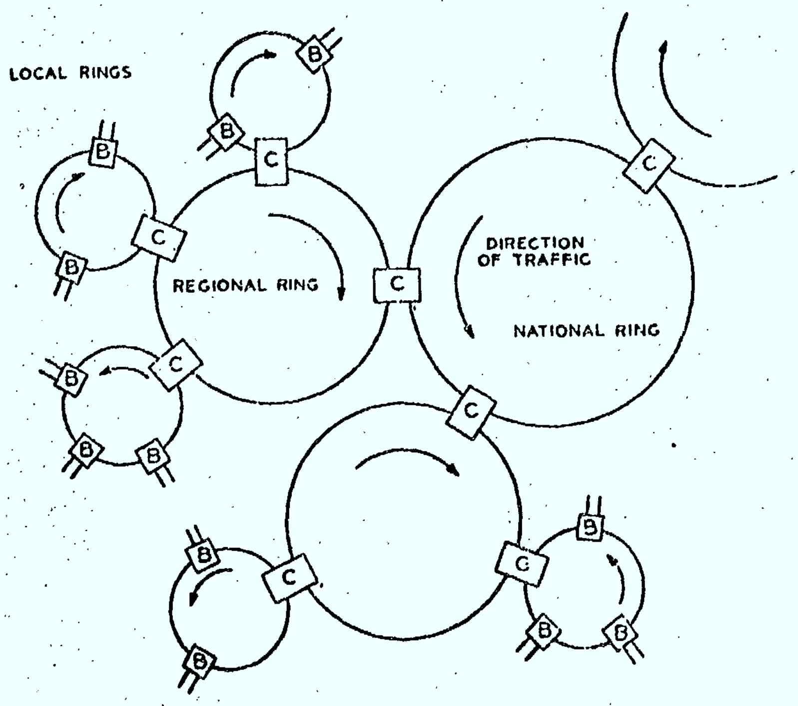


fig. A.3 - General Loop Network

APPENDIX B

## Introduction

So far, the design of CANUNET has been based upon the concept of message switched network. It was felt that more serious consideration should be given to the line switched network. This appendix explores this possibility.

Discussion of Message Switching versus Circuit Switching

Historically, two basic approaches have been utilized to switch data communications traffic. These two popular techniques are the space division switching or line switching and the message switching. Recently, with the need for faster and faster response times in computer networks, the second approach (message switching) appeared to be more attractive because the time delays encountered by a message flowing in the network were almost negligible compared to the time delays on a line switching network. This was due to the fact that the telephone network was originally designed to carry voice traffic.

More recently, several studies (35,36,37,38,39,40,41) were conducted in order to determine how a special line switched network separate from the telephone network, would behave when used only for data communications.

What follows is a resumé of the paper "Comparison of Switched Data Networks on the Basis of Waiting Times", by E. Post & F. Closs. The article evaluates the network response time when line and message switching are used. For a message switched, the response time is defined as the elapsed time between the moment a message enters the network and the moment the message arrives at destination; for a line switched network it is defined as the time between the moment a transmission service is requested and the moment the message arrives at destination. In a message switched environment, users have access to the network at any time but the messages sent are queued up at each node control unit. In a line switched network the request for service is queued up until a path from origin to destination is established, the message or messages are then sent without incurring any queuing delay. It should be noted that the processing time to set up a connection in a line switched network could be quite large if the switching exchange is of the electro-mechanical type. With the new electronic switching exchanges already in existence, one can neglect the processing time to set up a connection.

Waiting Time Evaluation

Figure B.1 represents two simplified network models.

In the line switched model, the terminals store the messages until one of the R channels of capacity $C_o$ becomes free. The request for service is served at the switching exchange possibly on a first -come first-served basis. Once a message is sent no queuing delays are encountered; the only delay being the transmission time necessary to send a given message.

Therefore the total delay is given by:

$$T_{dls} = T_t + T_{qls} \qquad \text{..........(1)}$$

where;

$T_{dls}$ = total delay (line switched case)

$T_t$ = transmission time or time it takes to send a message over a channel with capacity $C_o$.

$T_{qls}$ = total request for service queueing time.

In the message-switched model the terminals send the messages through the local loop of capacity $C_o$ to the node control unit where the message is stored. Once the message enters service (messages are served in order of arrival), it is sent to the next node control unit over a high speed line of capacity $C = RC_o$ and then delivered to the destination terminal over a channel of capacity $C_o$. Therefore, the total delay is given by:

$$T_{dms} = T_t + T_{qms} + \frac{T_t}{R} + T_t \text{ .........(2)}$$

where:

$T_{dms}$ = total delay (message-switched case)

$T_t$ = transmission time or time it takes to send a message over a channel with capacity $C_o$.

$T_{qms}$ = total queueing time.

It is now possible to compare equations (1) and (2), on the basis of the queueing time by disregarding the transmission time.

The queueing time $T_{qms}$ for the message switched case is easily found by assuming that the arrivals of messages form a Poisson process and that the message lengths are exponentially distributed. Furthermore, messages are served on a first-in first-out basis by a single server. This is the well-known M/M/1 queue model and therefore the average queueing time is found to be;

$$T_{qms} = \frac{\rho . T_s}{1 - \rho}$$

where;

$T_s$ = average service time on a channel whose capacity is $C = RC_o$.

$\rho$ = utilization factor

therefore, if $\frac{1}{\mu}$ is defined as the average message length;

$$T_s = \frac{1}{\mu} \cdot \frac{1}{C} = \frac{1}{\mu RC_o}$$

$$\rho = \frac{\lambda}{\mu C} = \frac{\lambda}{\mu RC_o}$$

where $\lambda$ represents the average number of messages.

Finally;

$$T_{qms} = \frac{\lambda/\mu C}{\mu C - \lambda} \quad \text{..................(3)}$$

With the same assumptions, the queueing time for the line switched case when R servers are present is given by; (*)

$$T_{qls} = \frac{1}{R} \frac{P(>o)}{(1-\rho)} \cdot T'_s \quad \text{..................(4)}$$

---

* Equation (4) can be found on page 116 of "Elements of Queueing Theory", by T.L. Saaty.

where P(>o): the probability that a request for service has to wait in the queue is the well-known ERLANG's C formula given by;

$$P(>o) = \frac{(R\rho)^R}{R!\ (1-\rho) \sum_{n=o}^{R-1} \frac{(R\rho)^n}{n!} + (R\rho)^R} \quad \ldots\ldots(5)$$

The service time $T_s'$ in equation (4) is R times larger than the service time found for the message switched case , that is;

$$T_s' = \frac{1}{\mu C_o} .$$

Dividing equation (4) by equation (5), the relation between the two queueing times is found to be;

$$\frac{T_{qms}}{T_{qis}} = \frac{\rho}{P(>o)} \quad \ldots\ldots\ldots\ldots\ldots(6)$$

From equation (6), several curves can be drawn by varying R, the number of subchannels of capacity $C_o$.

For R = 1, the numerator and denominator of the right hand side of equation (6) become identical. Therefore the queueing times for the message switched and line switched case are the same, as a function of ρ.

For $R = 2$, the following relation is obtained;

$$\frac{T_{qms}}{T_{qls}} = \frac{1 + \rho}{2\rho} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

From equation (7), it can clearly be seen that the average queueing time in the message switched case for small line loadings can be several times larger than the average queuing time for the line switched case.

As the line loading approaches full utilization the queueing times for the two cases become identical.

It can easily be shown that for higher values of R, the value of equation (6) becomes larger and larger for the same line loading.

The preceeding results were derived for a fully connected network i.e a network where a direct path exists between any two switching exchanges but these results can be extended to any network topology. Figure B.2 represents a typical relation between the two queueing times. It can be seen that depending on the line utilization, the queueing time for the message switched case can be smaller or larger than the queueing time for the line switched case.

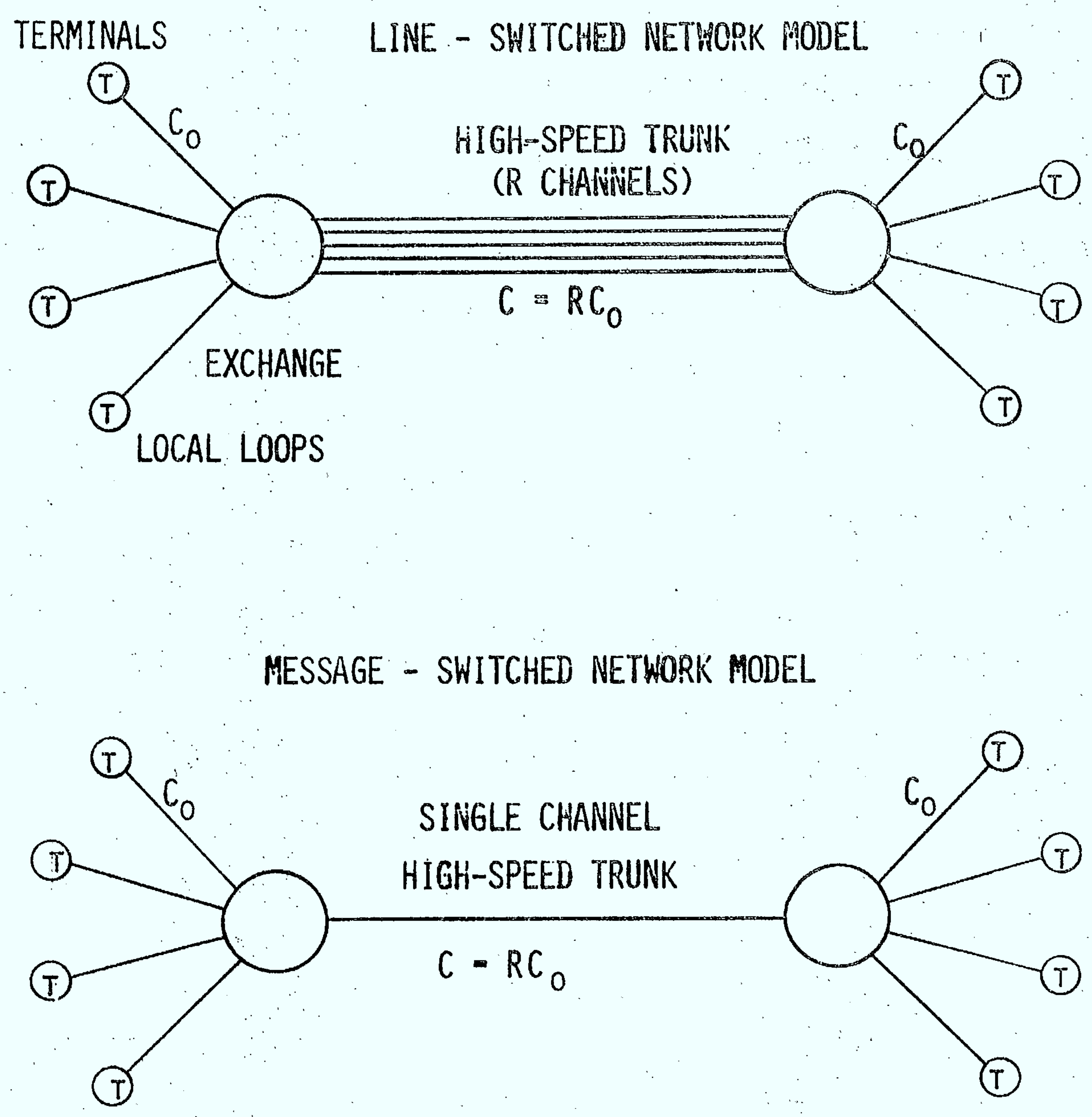


Fig. B.1 Simplified equivalent network models for message-switched operation.

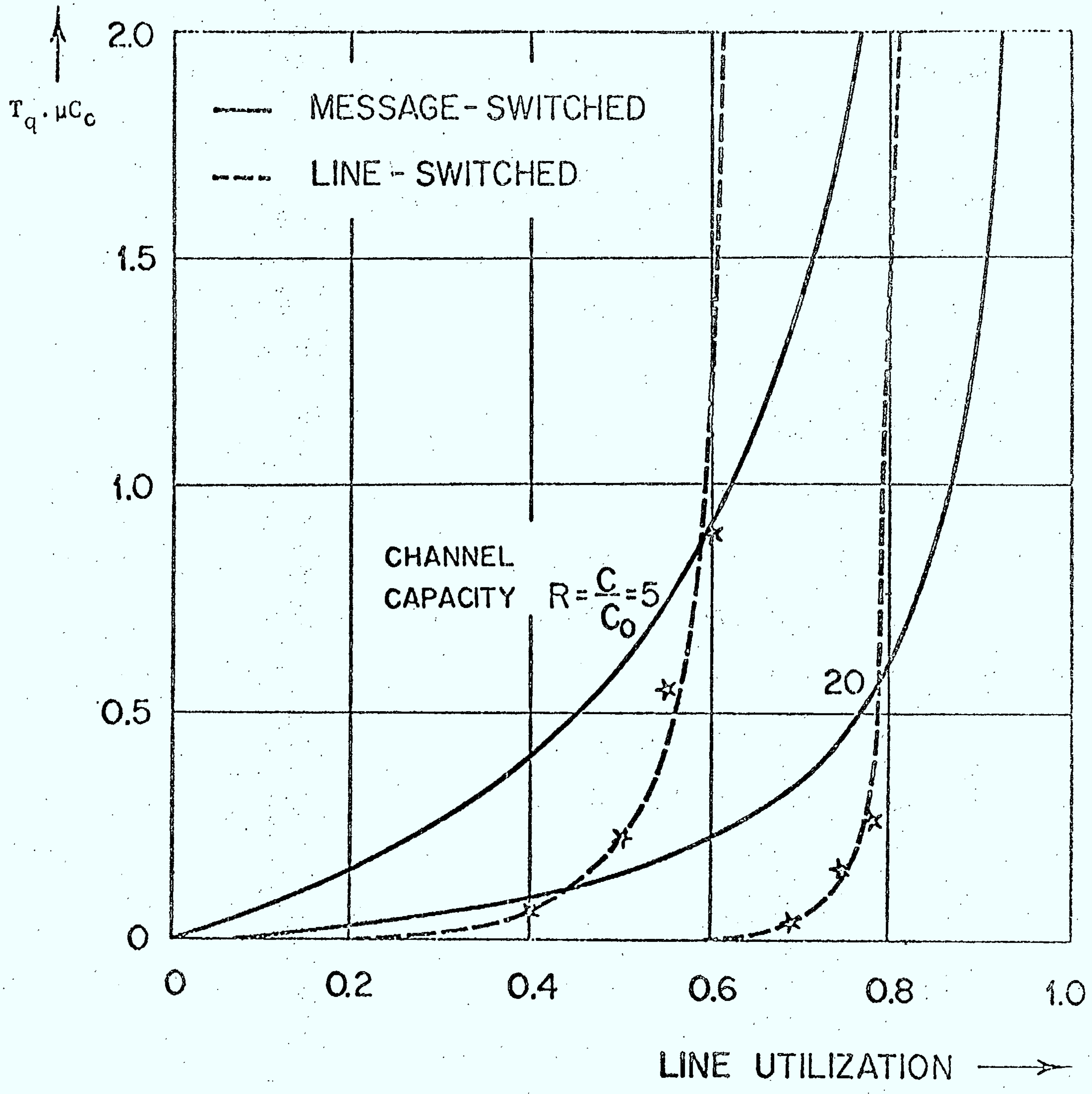


Fig. B.2 Average queuing times for line-switched and message-switched operation in a three-link network model.

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# REPORT ON INSTITUTIONAL FRAMEWORK

Revised as per meeting on March 29, 1972.

APPENDIX N

March 30, 1972

Mr. J.B. Reid
Director of Computer Operations
University of Quebec
2050 Ouest Boul. St. Cyrille
Ste-Foy, Quebec

Dear Joe,

Enclosed is the report from the Committee on Institutional Framework for CANUNET. The proposals presented should be considered as a "first pass" at approaching a very complex problem area. As reports from other Committees are received and studied, and as the total CANUNET project comes into clearer focus, the organizational structure should again be reviewed.

Because of pressures of time, the Committee met on the evening of March 28th prior to submitting the report to the General Advisory meeting on March 29th. Some minor changes were suggested and these changes, together with the modifications suggested at the Advisory meeting, are included.

I would like to express my appreciation to the following members of the Committee for their helpful advice and suggestions in preparing this report.

D.H. Bent
M.P. Brown
M.L. Brunel
P.H. Dirksen
E. Douey
R. MacKinnon
D.H. Norrie
C.D. Shepard

Yours sincerely,

Blaine A. Holmlund, Chairman
Committee on Institutional Framework

s.
Encl.

## I. INTRODUCTION

At the last meeting of the CANUNET Advisory Committee, four study groups or sub-committees were formed to undertake the following studies relating to CANUNET:

1. Communication System;
2. Utilization of the Network;
3. Network Design;
4. Institutional Framework.

The following is a report from the study group on Institutional Framework. It is based upon very preliminary reports from the other CANUNET study groups. The final reports of these study groups may well provide information concerning the scope and timing of various activities of the project which would alter the general recommendations concerning an Institutional Framework for CANUNET suggested herein.

## II. CHARACTERISTICS OF THE CANUNET PROJECT

A review of position papers submitted by various universities suggests that the main objectives for developing a Canadian University Computing Network are the following:

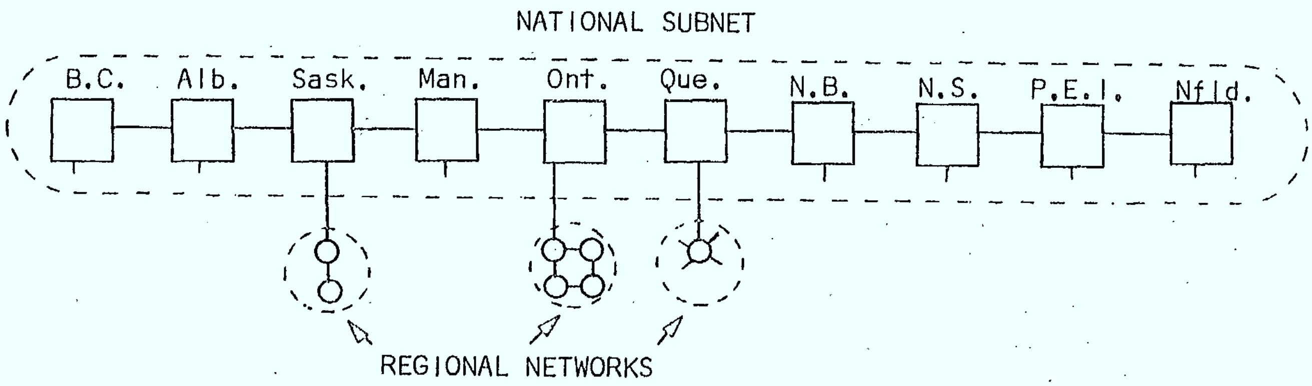
1. To serve as a necessary experiment to obtain an experience base in the design, development and operation of a large scale computing network. This experiment should provide information to evaluate the managerial and technical problems involved in realizing the full potential of a Canadian University Computing Network. In addition, experience gained in this experiment should be useful in establishing design specifications

and policies for emerging regional and trans-Canada computing networks.

2. To make available to Canadian universities and other institutions a new or enriched information resource consisting of data bases, specialized computer programs, et cetera.

3. To provide a means whereby universities are able to obtain access to adequate computing power which, because of regional disparity or size of university, would otherwise not be available.

At the time of writing, the exact form of the network proposed to achieve these objectives has not been finalized. The final reports from the study groups on Utilization of the Network, Communications Systems, and Network Design will bring this into focus. However, for the purpose of this discussion, the network proposed is assumed to be a collection of store and forward node computers and communication lines providing a national link across Canada. Diagrammatically, it is assumed to be some variant of the following.




The organizational structure required to carry out this project successfully is heavily dependent upon the intended scope of the project, the timing of each phase, and emphasis that is to be placed upon achieving each of the above stated objectives. For example, objective 1 could, at least in part, be achieved by a geographically restricted 'model' network. Indeed this would appear to be a rational way to begin a technical development project of this magnitude. Further, in attempting to match organizational structures to the stated objectives for CANUNET, one is constantly reminded that a national network of the type proposed may not be the most economical or 'best' way of achieving objectives 2 and 3. It will, therefore, not be possible to make definative recommendations on an Institutional Framework for CANUNET in this report. Nonetheless, general observations will be made which may be helpful in drafting the planning report for the CANUNET project as a whole. To do so it would appear desirable to suggest that the total project may be classified into three major classes of activities:

1. Development of the 'national spine' or 'national subnet'.
2. Developing applications and providing a higher quality of computing service to as large a segment of the university community as possible.
3. Research on computing networks.

Each of these three components may require different organizational ingredients to be successful.

## III. DEVELOPMENT OF THE NATIONAL SUBNET

This is the design, implementation and testing of the connecting link or delivery vehicle between regional networks or computers and/or between host computers and user terminals. In essence, it is the task of establishing an economical and reliable communications facility consisting of a collection of communications lines and node computers as proposed by the Communications and Network Design study groups. The final reports from these groups are not available but from previous communications it is assumed that the components of this network are not all off-the-shelf items (that direct purchase of the ARPA IMP computers is not contemplated), and that considerable technical development work is required. On the other hand, it is assumed that this necessary development is within the state-of-the-art and therefore this activity is not of a research nature. The primary development task is then to produce the necessary software and hardware for the nodes in the subnet. Presumably, the number of types of nodes in the subnet will be kept to a minimum and that standard software/hardware is to be developed for each type. The initial organizational task then is to develop and test the software/hardware for each type of node and to establish standard communications protocol. This is obviously a task for a small group(s) of highly technically qualified personnel working in close geographic proximity. Clearly, all universities cannot participate to an equal extent in this phase of the project.

Once the prototype nodes have been tested and the standard communications protocol established, the number of nodes in the network will be increased. Special software will have to be developed for each type of host computer and the network as a whole tested. From a project control and management point of view, a focus of responsibility, accountability and coordination must be maintained. The question becomes -- What organization(s) should perform the development of hardware and software for this 'subnet' or delivery vehicle?

The following possibilities have been suggested:

(a) That a single development contract be awarded to one university, and the work performed by computing center personnel and/or faculty members.

(b) The development be segmented into a few well-defined components and the development be contracted to a consortium of universities (or inter-university organizations) in different regions of the country.

(c) A competitive tender be let to commercial interests which could be, for example:
1. a common carrier (e.g., CN/CP or TCTS);
2. a computer manufacturer or communications specialist (e.g., Bolt Beranek & Newman);
3. a consortium of hardware and software companies (e.g., Digital Equipment of Canada and I.P. Sharp).

(d) The development be performed by an agency of the Federal government (e.g., Communications Research Center).

(e) A project organization be established (as a separate entity or within an organization such as the Association of Universities and Colleges of Canada or perhaps affiliated with the Department of Communications) to develop the subnet. Participation in the project could be on the basis of the secondment of university personnel and the hiring under contract of individuals from commercial suppliers (the MERIT organization is an example). A project organization of this type could also sub-contract certain components of the project to various universities, commercial, or government agencies.

In evaluating any alternative (or mix of them), it is useful to list a number of criteria for deciding on the relative merit of the different approaches. The following table, while not necessarily complete, offers a set of criteria which might be used in this evaluation process.

| | CRITERIA | ALTERNATIVE* a | b | c | d | e |
|---|---|---|---|---|---|---|
| 1. | Is this a cost effective approach to realizing the overall stated objectives of the project? | | | | | |
| 2. | Does it exploit university talent? | | | ? | ? | |
| 3. | Does it contribute to the development of high technology industry in Canada? | ? | ? | | ? | |
| 4. | Is there a high probability that time and cost constraints will be met? | ? | ? | | ? | |
| 5. | Is there a high probability that operating and reliability specifications will be met? | | | | | |
| 6. | Is the organization readily accountable for poor performance? | ? | ? | | | ? |
| 7. | Can this approach accommodate the need for cross-country, long-term maintenance and operation? | ? | ? | | ? | |
| 8. | Will the development group be responsive to directives from CANUNET management? | ? | ? | | ? | |
| 9. | Would this approach be responsive to regional requirements? | ? | ? | | ? | ? |
| 10. | Would such an organization be acceptable to a Federal funding agency and to the university community? | ? | ? | ? | ? | ? |

*One person's opinion. Not necessarily the view of other members of the study group.

The classification of alternatives is, of necessity, quite general and to apply the criteria listed above to these general classifications becomes a highly subjective evaluation and perhaps only exposes one's biases with respect to universities, free enterprise, and government. Nonetheless, the list of criteria does provide a good basis for evaluating any specific proposal that one might think of within the general class of alternatives. Some additional observations about the various alternatives suggested might be made.

(a) Single development contract to one university.

In accepting this approach, one is faced with the problem of selecting the most appropriate university to undertake the task. Undoubtedly, there are a number of universities that feel they are contenders in such a competition. Also, one has to keep in mind that universities are not particularly noted for their ability to manage a development type project of this complexity and produce reliable working systems within fixed time and cost constraints. This is not their normal line of business. Also, the development phase of this project must ultimately transform into an operational and maintenance phase. It is questionable if a single university should or would want to assume this latter responsibility. This, in turn, suggests another criteria for selecting alternatives. Would the organization that is ultimately going to have to make the system operational in a service environment accept the responsibility for operating a complex hardware/sofware system developed in this fashion?

It would seem reasonable to conclude that this alternative is viable only if a demonstration model of the network is to be undertaken with the objective of "tuning up" the software/hardware specifications to be submitted in tendering for the "service" version of the network. This approach could also be taken as a preliminary stage to the establishment of a national project organization which would then be made responsible for transforming the 'demonstration model' into a 'service version' suitable for the trans-Canada subnet.

(b) Consortium of universities.

The possibility of forming a consortium of universities to undertake this development task suffers all of the weaknesses of alternative (a), further dilutes accountability and responsibility for the overall project, and increases the problem of coordination. Organizationally, a single university (or person at one university) would have to assume ultimate responsibility for the project. Therefore, this alternative is really a variation of (a) or (e).

(c) Commerical contract.

The possibility of contracting the development of the network to a commercial interest is worthy of consideration. Selecting a Canadian organization or consortium of Canadian companies would help to promote this type of industry in Canada and would be a "tidy" arrangement if the specifications can be written tightly enough. Further, as the system expands, additional units could be purchased and installed readily. Also, long-term maintenance contracts could be made with the successful tender. The question arises as to whether or not the system specifications can indeed be sufficiently defined at this stage. It may, for example, be necessary and desirable to develop and test a series of prototypes before contracting with a commercial supplier. If a commercial tender is let, the question still remains as to what organization represents the universities, contracts for the work, accepts the completed system, ensures that specifications are met, and continues to operate and maintain it.

(d) Federal Government agency

The development of the network could be undertaken by an agency of the Federal Government. This possibility raises some political questions concerning the involvement of the Federal Government in what might be considered to be provincial responsibilities. The universities could collectively ask an agency of the Federal Government to undertake this task on their behalf. Presumably the Federal agency would then have to seek permission from the Provinces to do so.

Assuming, however, that agreement was forthcoming from the provincial government, this approach could also result in the Federal Government not only developing but maintaining and operating the national subnet. The universities and/or Provinces could then be free to develop regional networks which would tap into this national subnet. This approach has the advantage (or disadvantage) that the universities would presumably share the use of the national subnet with Federal agencies thereby making more effective use of the transmission capacity available. Certainly, the initial traffic volume between regions resulting from university traffic would appear to be very light. Hence, it would appear rational to adopt this shared approach. However, because of the political difficulties involved, requesting an agency of the Federal Government to undertake the development task may further delay any progress in the development of CANUNET. Nonetheless, the possibility of having an agency of the Federal Government operate and maintain the developed network is one that should be considered. The Government Telecommunications Agency would appear to be an existing organization capable of providing this service for CANUNET.

(e) The project organization

This approach could meet most of the criteria suggested. In theory at least, this type of organization has the flexibility to orchestrate the involvement of a number of universities, commercial companies or government agencies. It provides a structure wherein interested people could be recruited on the full-time basis to work on the project and it also provides for centralization of ultimate responsibility and accountability for the total project. Furthermore, such an organization spawned to undertake the development of the subnet could be transformed relatively easily to one which will be necessary to operate, maintain and improve the system on an on-going basis.

The question as to whether or not this project organization should be established as a separate entity or as an organizational appendage to an existing organization depends to some extent on the staging and magnitude of the project envisioned. If sufficient justification is presented so that a 10 node network is developed to evaluate a truly national subnet in a reasonably short period of time, a rather substantial and well defined project organization should be established as soon as possible. On the other hand, if a demonstration system consisting of two to four nodes is contemplated for the first year or so to test out design concepts prior to launching the national subnet, a more informal organizational approach might be more effective.

The latter seems to be the more reasonable approach. Hence, for the balance of this discussion on the organizational framework for the development phase of the project, this phasing of the project is assumed.

To ensure that the CANUNET project retains its emphasis on being a national subnet, the ultimate responsibility and control for the development should remain in the hands of a national organization or agency. It would also seem desirable to have the project organization affiliated with an organization which already represents all universities. The Association of Universities and Colleges of Canada (AUCC) is such an organization. It would, therefore, appear appropriate to encourage this organization to take a more active interest in the problems associated with the rationalization and provision of adequate computing services for universities and in particular to play an active role in the development of CANUNET. There would appear to be the potential, at least, of developing through the AUCC, a national version or equivalent of the office of Computer Coordination now established in the Council of Ontario Universities. Many of the functions that the Office of Computer Coordination now performs provincially and is planning to perform (vis-à-vis the development of the Ontario Regional Network and other coordinating activities) a CANUNET organization within the AUCC could do on a national level. This type of CANUNET organization could not only promote national coordination but could serve a useful role in encouraging and assisting universities to develop regional computing networks.

Unfortunately, the stimulus for investigating the feasibility of CANUNET did not originate within nor was it promoted via the AUCC. Furthermore, the AUCC is not a technical development organization (but then neither is the Council of Ontario Universities) and hence there is some reluctance and reservation on the part of some members of the Committee on Institutional Framework to transfer the responsibility for the development of CANUNET too quickly to an organization within the AUCC. Although the senior executive officers of the AUCC have expressed their moral support of the concept of CANUNET and are interested in the possibility of the AUCC playing a greater role in this development, it has not been possible for them to study this matter sufficiently to respond formally to the Committee with positive suggestions as to what that role might be. Unless the AUCC is prepared to take a very agressive leadership role in promoting CANUNET, the momentum that CANUNET has developed to date may be dissipated in a premature marriage.

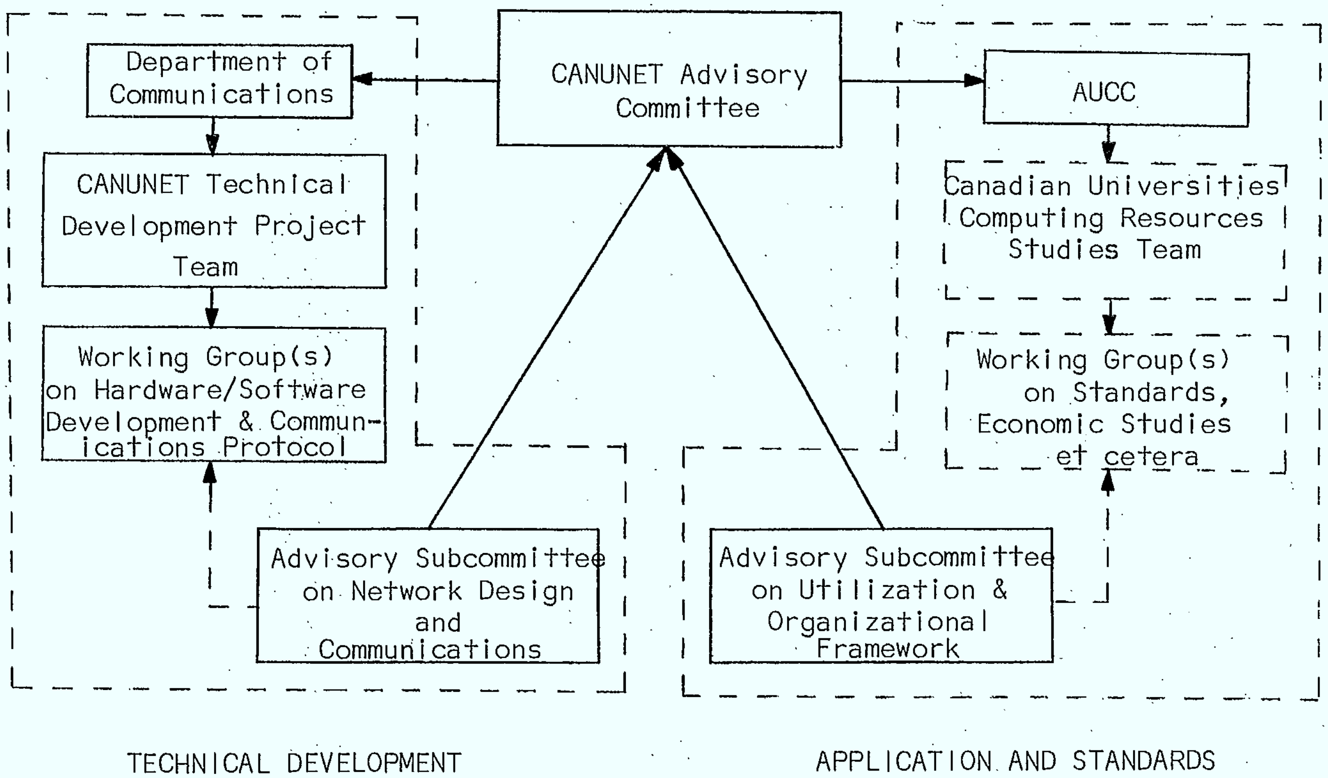
On the other hand, a good working relationship has been established with the Department of Communications (D.O.C.) and those universities interested in CANUNET. The contribution made by the D.O.C., in coordinating and stimulating the initial launching effort for CANUNET, has been greatly appreciated. Organizationally, the Department is in a good position to orchestrate the involvement (by contract) of universities, private companies, and other government agencies in this project. Further, members of the Department have the technical knowledge necessary to provide dynamic leadership for the development phase of this project.

A short term alternative then is to form an ad hoc project team under a Director based within the Department of Communications to continue the technical development and planning of CANUNET during the next year. This would provide a focus of responsibility at a national level. Participation in the CANUNET development project could be on the basis of secondment of university personnel and/or by contracting certain components of the project to various universities, commercial, or government agencies. During this year, the possibility of eventually transferring this ad hoc project organization under the umbrella of the AUCC should be further studied. Indeed, during this year the AUCC might be encouraged to undertake a study of the rationalization of computing resources in universities in much the same way as that organization is examining the rationalization of research in universities. Such a study could focus, in particular, on ways of achieving objectives 2 and 3 with or without CANUNET. By so doing, the AUCC would be in a better position to assess its future role in this project.

Adopting this ad hoc approach for the next year provides the maximum flexibility in the choice of future organizational options without impeding the development of CANUNET.

Proposed Organizational Structure for the Prototype Development Phase of CANUNET

The organizational structure proposed for this interim period is outlined below.




In essence the proposed structure centralizes responsibility and control in two national organizations; one concerned primarily with the technical development (i.e., D.O.C.) and the other primarily concerned with application, uses and standards. It is proposed that a technical development project team be



REVISED: March 29, 1972

established as soon as possible. It is further suggested that working group(s) be formed by direct secondment of personnel from universities or commercial organizations and/or by contracting directly with appropriate universities to develop the necessary hardware/software prototypes and to develop the communications protocol. It is also proposed that the present study groups on Communications and Network Design be combined into a single sub-committee to simplify coordination and to provide more effective advisory support for the technical development groups.

It is further proposed that a University Computer Resources Study Group be formed within the AUCC. The primary concern of this group in the initial stages of development of CANUNET will be to study the economics of computing, ways of making better use of existing computer resources, developing standards, et cetera. It is recommended that the AUCC make application for special funding from the appropriate organizations to establish a permanent staff to direct these studies. Again, it is expected that working groups will be formed by secondment of university personnel or by contracting with universities. It is proposed that the present study groups on Utilization and Organizational Framework be combined as a single advisory sub-committee reporting to the CANUNET Committee and to act as a resource group to the AUCC if the proposed study group within AUCC develops. The present CANUNET Advisory Committee would remain as the primary Advisory Committee for both the Technical Development and Applications and Standards sections.

The primary reasoning behind the proposal is that as CANUNET develops, ultimately the Technical Development section can merge with the Applications and Standards section and form a project organization within AUCC. If CANUNET fails to develop, the organization established within AUCC will continue to play a useful role as outlined in the following section.

## IV. DEVELOPMENT OF APPLICATIONS AND PROVISION OF SERVICE

It is very easy to accept the suggestion that computer networks offer a real potential for resource sharing and that all users will benefit by being able to make use of all resources in the network (software, data, and other computers) as if they were local. However, it must be recognized that until the non-sophisticated user can use the network as easily as he now can use local facilities; until there is a simple administrative mechanism whereby, for example, the University of Saskatchewan can use the computing facilities at the University of British Columbia without unduly upsetting budget officers, or the Administrative Vice-Presidents of both institutions (or indeed, running the risk of initiating a debate at the Premier level on the inequities of equalization payments between provinces!), the network will not realize even a fraction of its potential. The evidence for this judgement is that the technical potential already exists for small or less wealthy universities to have access to the larger computing facilities of other universities. The technical facilities now exist to make data bases, such as the DATUM and QUIC/LAW legal information systems, available to other universities. The technical potentials of non-sophisticated terminal to computer/computer to terminal network have not been fully exploited to provide these and other services (if they are indeed worthwhile and in demand).

It should also, however, be pointed out that there is no agency at the national level, to promote the better utilization of existing computing resources by seeking out and distributing information on newly developed systems. Nor is there a national agency charged with the responsibility of developing standards in design and documentation of these systems so that they may be easily used by other institutions. Consequently, it is difficult to determine whether it is an intrinsic quality of computer programs which causes them to "travel poorly" or they travel poorly because there is no program travel agency to make it easy for them to do so.

There are, of course, economic barriers which have inhibited the exploitation of existing technology to achieve objectives 2 and 3. These economic barriers are not only communications costs but are related to the pragmatics of optimizing locally available financial resources. Once the budget for computing facilities has been set by a university, it is to the institution's advantage to run jobs that take X hours on its own machine, suffering long turn-around times rather than to find extra 'real' dollars to run the job on another machine in X/10 hours at a lower per unit cost at another university. It is also generally more advantageous from an individual university's point of view to spend any money available for 'outside' computing on expanding its own facilities because by so doing it can usually:

(1) decrease the per unit cost of all of its computing, or

(2) provide an additional service to a large percentage of its users.

To place this in perspective, vis-à-vis CANUNET, one of the network proposals suggest 50 Kbs/sec lines connecting some 14 nodes. The cost would be $7,485 to $15,340 per node per month. This does not include the cost of the node computer nor the cost of computing. A university operating a batch-oriented IBM 360/50 could increase its capacity by four times and also provide some interactive capability for its users with an extra $15,000 per month. At a monthly cost per node of from $1,320 to $2,340 for 4.8 Kbs/sec service, the network may become more cost attractive but the need for this level of service is still in competition at the local level with such things as adding a second remote job terminal, extra plotting facilities, et cetera. At what cost will the network be the facility of choice for a particular computing task? The point to be made is that although the network may appear economically attractive on a global or national basis, unless it appears economically attractive to the individual user, the network will not be used.

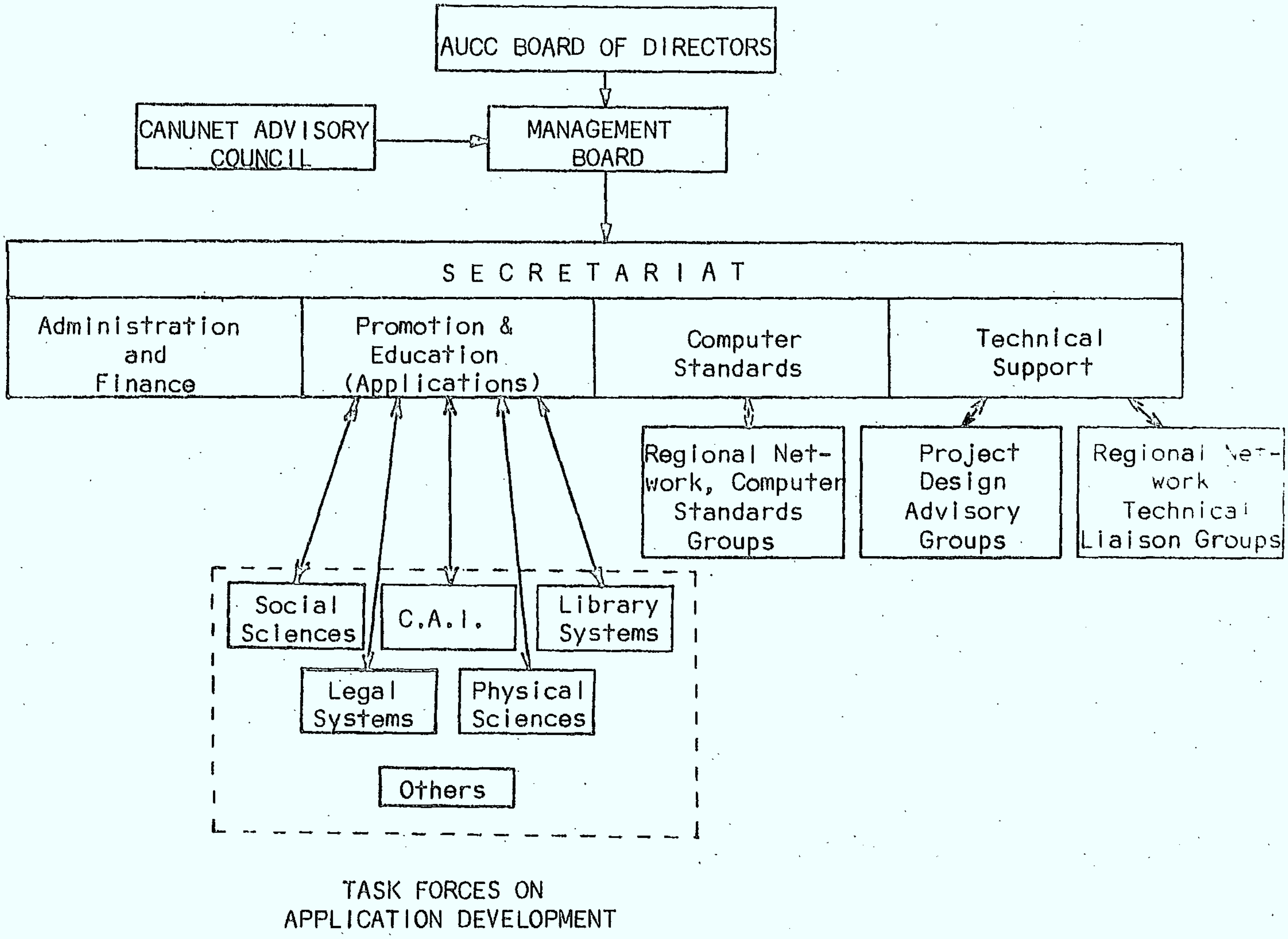
It is, therefore, perhaps fair to suggest that the primary obstacles to be overcome in achieving objectives 2 and 3 stated for CANUNET are not technical in nature but are organizational and have to do with economics, attitudes, and the barrier to meaningful communication and cooperation that exists when distances between groups are large. In planning CANUNET it is imperative that this be recognized.

To ensure that the network realizes its maximum potential, two conditions must be met. Firstly, to overcome economic barriers it will be necessary to obtain from Federal sources a substantial part of the operating costs for a period of 3 - 5 years. Funds must also be made available to encourage the development of 'national' applications. During this period, confidence and experience will be gained and the benefits of the network should become evident to member institutions. There will be a better understanding of the economics of networks upon which to propose cost sharing arrangements between users and suppliers of computing power in the network. At the end of that period it should be possible to establish workable financial arrangements for continuing the operation of the network by member institutions. There seems little possibility of CANUNET becoming fully operational without this assurance of long-term support.

Secondly, to ensure that the network will realize its maximum potential, the necessary financial resources must be provided to establish a national organization to promote its use and to manage and improve its operation on a continuing basis. This organization must have a commitment to provide top-level services and dynamically stimulate the development of new applications for the network. The functions to be performed by such an organization can be classified as the following.

1. Administrative: To provide the necessary staff to manage and administrate the operation of the network. It is possible that eventually the subnet may be operated by the Government Telecommunications Agency as suggested earlier, a Crown Corporation, or by a commercial organization. However, it is unlikely that the operator of the national subnet will own the computers tied into the network. Thus, administrative support will be necessary to handle transactions between suppliers and buyers of computing power.
2. Promotion and Education: To promote the use of the network by making it easy to use and by making universities aware of the services available at other universities via the network.
3. Development of Standards: If programs, data files, and computing facilities are to be collectively used by the university community, agreed-to standards must be established.
4. Technical Support and Maintenance: To continually improve and add modifications to the system as dictated by experience and to ensure trouble-free service.
5. Coordination with Regional University Networks and other Networks: One of the primary functions of the national organization will be to act as a coordinating agency for regional university computing networks. Although there is a tendency to refer to CANUNET as a single network, it will undoubtedly be more accurately described as a network of networks.

The above functions suggest a merging of the ad hoc structure outlined on page 13. As time goes on, the technical development aspects of the project will diminish but the activities associated with promotion, education, the development of standards, and administration of CANUNET will continue indefinitely. At some appropriate time, therefore, one could envisage the following organizational structure.



## Reporting Status of the Proposed Organization

The AUCC has spawned a number of organizations which now are, for the most part, autonomous entities but which remain affiliated with the parent organization. Examples of these are the Canadian Council on Animal Care (CCAC), the Service for Admissions to Universities and Colleges (SACO), and the Canadian Universities Service Overseas (CUSO). It is suggested that the CANUNET organization consider joining that family of organizations providing service to Canadian universities. The management board of CANUNET would then report directly to the AUCC Board of Directors.

### Advisory Council

There are many organizations such as the Science Council, the National Library, individual universities and colleges, departments and agencies of government and private organizations that will be able to provide advice and counsel, and perhaps resources which would be most valuable in ensuring the success of CANUNET. An Advisory Council is suggested to serve as a mechanism whereby a large number of organizations might have an influence or a voice in the formation of future policy with regard to CANUNET. It is proposed that in the first instance, this Council be made up of representatives appointed by universities and colleges currently members of the AUCC who have expressed an interest in joining CANUNET and that these members, by majority vote, may add other members to the Council on a term basis. This Advisory Council would be responsible for the following:

i) These members from universities and colleges in the following regions are to elect one member each to the Management Board:

British Columbia
The Prairie Provinces (Manitoba, Saskatchewan, Alberta)
Ontario
Quebec
Atlantic Provinces ( New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland).

ii) Meet at least twice a year or more at the call of the Chairman elected by the membership.

iii) Receives an annual report from the Management Board on the current status of CANUNET.

iv) Advises the Management Board on policy concerning CANUNET.

Management Board

The Management Board sets major policy, appoints the Director, arranges for necessary funding, adjusts long-term planning, and oversees the month-to-month progress of CANUNET. The following membership is tentatively proposed. The composition of the Management Board should be reviewed as the project develops.

5 - representatives from universities and colleges (elected as described earlier)

1 - representative of the AUCC who shall serve as secretary of the Board

2 - representatives from the Department of Communications (or primary funding agency)

1 - representative from the National Research Council

1 - representative from the Science Council

2 - representatives at-large elected by the above members because of their special interest in, or the contributions they can make to the welfare of CANUNET.

Elected membership on the Board should be on a term basis (2 or 3 years), once renewable.

Secretariat

The secretariat is the administration unit to implement the general policies developed by the Management Board. This group consists of a Director and such full-time staff as appropriate to carry out the functions listed on page 18 of this report.

Task Forces

It is proposed that a series of task forces be developed to promote and coordinate potential application areas, and to serve as advisory groups to the Secretariat on specific problems and projects. The task force/ Secretariat relationship can be considered as one which provides for direct communication with people who are particularly interested in a specific application or problem area.

For example, considerable work is now going on in the development of legal data bases in various parts of the country. It would seem desirable to have a formally constituted task force operating under the auspices of CANUNET consisting of resource personnel from various universities interested in the application of computer systems in the field of law. This task force would be coordinated by the full-time staff of the Secretariat and charged with the responsibilities of recommending standards, educational programs, and development plans. Hopefully, this arrangement would expedite the translation of these recommendations into action to create a new information resource for colleges of law in Canada.

The task force concept, operating through a permanent coordinating body (the Secretariat) might be the most appropriate organizational structure to ensure that the enormous job of education and promotion is carried out well and to ensure that full advantage is taken by as many universities as possible of the developing resources made available via CANUNET.

The number and type of task forces shown on page 19 are intended as examples and are not a definative list.

Financing

As stated earlier, it is essential to the success of CANUNET that firm fiscal commitment be made by the Federal Government for a substantial part of the operating costs for a five-year period. Unless this is done, the economic barriers, outlined in the previous sections of this report, will impede the use and development of the network to such an extent that the concept of a national subnet must be seriously questioned. At the end of the five-year period, commitments for the following five years would have to be arranged or alternatively, it may be decided to terminate the program. The economic and other benefits of the network will by then be apparent. It should then be possible to establish workable financial arrangements among member institutions for continuing the operation of the network.

## V. RESEARCH ON COMPUTER NETWORKS

Thus far, discussion in this report has concentrated on the development and service aspects of the CANUNET project. These activities have been within the state-of-the-art and have been carried out in some form elsewhere. There is a good deal of research to be done on computer networks. Examples might be host-to-host communications protocol, operating systems structures and design, job routing algorithms, et cetera. Although it is recognized that such work is essential and must be encouraged, it is important in the early stages of development of CANUNET not to confuse the desire to undertake this form of research with the need to develop a reliable service oriented subnet. Thus provision has been made in the CANUNET organizational structure to undertake research of this kind.

Projecting into the future, research on computer networks carried out by other organizations which require the use of CANUNET should be funded separately. Organizationally, such research projects should be arranged as now between the interested university and the appropriate funding agency. Permission to use the network would, of course, have to be arranged through the Management Board of CANUNET. The development of CANUNET should not restrict the funds available to universities that wish to do research or development on computing networks independent of CANUNET. However, CANUNET should be kept informed of any funding provided for projects relating to computer networks so that coordination may be achieved. It is not envisioned that CANUNET organization should in any way be in control of the allocation of all research funds relating to university computer networks. CANUNET may well sponsor research projects of its own. On the other hand, the CANUNET organization may wish to undertake research projects at a future date. It would then compete for research funds as any other organization.

## SUMMARY

The organizational structure required for the successful development of CANUNET is dependent upon the scope and timing of the various phases of the project. In anticipation that there will be a recommendation to proceed as quickly as possible into a prototype development phase, a short-term organization is proposed. This organization proposes that a project team be established under a Director within the Department of Communications with small work

groups being established to develop the necessary software/hardware and establish communications protocol. Personnel for these work groups are to be provided by direct secondment of university and other personnel or by contract with appropriate universities to undertake defined projects. In many respects, this is simply a proposal to continue with the present arrangement but with a clearer understanding concerning the focus of responsibility.

In addition, it is proposed to encourage the Association of Universities and Colleges of Canada to become more directly involved in the CANUNET project by providing that organization with sufficient funds to undertake a study of the Rationalization of Computing Resources for Canadian Universities; to study the economics of computing and establish appropriate standards. It is argued that this activity should go on regardless of the fate of CANUNET.

As the CANUNET project develops beyond the prototype development stage, it is proposed that a project organization affiliated with the AUCC be established which would ultimately be transformed into an organization responsible for the operation, education, application development and continued improvement of the CANUNET system.

Just what responsibilities this proposed CANUNET organization might have with regard to the ownership and operation of the physical subnet itself remains unclear at this time. The CANUNET organization may simply contract for the operation and maintenance of the subnet with a government agency such as the Government Telecommunications Agency or a commercial organization. On the other hand, experience might suggest that the CANUNET organization should retain responsibility for the node computers and simply contract for the telecommunications services. Arrangements for this latter service might be made with a telecommunication company. The choice among these various alternatives available will become clearer as the CANUNET system as a whole (physical network and organization) evolves.

Examples of large systems of programs

We here list a few examples of systems of programs of such complexity that they require a specialized staff to maintain them and advise on their use:

ASKA (Automatic System for Kinematic Analysis) has been developed during the past 11 years by the Institut für Statik und Dynamik der Luft-und-Raumfahrtkonstruktionen, Universität Stuttgart. The source program of ASKA consists of 100 000 FORTRAN cards and the price is 500 000 DM or C$ 160 000. In North America, ASKA has been purchased by North-American Rockwell and Pratt and Whitney (information of November 1970).

Certified Program Generator. Certified Computer Products. Price $85 000.

Computer System Simulator II. IBM. Rent $2 625 per month.

FLOWPACK for the analysis of steady state chemical processes. Developed by Imperial Chemical Industries. Price $50 000.

GEMINI information retrieval and data management system developed by Maurice Houle et Associés Inc. of Montreal. Price $120 000.

Generalized Information System. IBM. Rent $1 575 per month.

LINK-V, a mechanical engineering system sold by Com-Code Corporation of Washington. Price $32 000.

NASTRAN, similar to ASKA, developed by Computer Sciences Corporation for NASA over the past eight years. It is available on Control Data's Cybernet and from McDonnell Douglas in St. Louis, Mo.

OPHELIE II is a very powerful mathematical programming system for solving optimization problems by mixed methods. It was developed by Sociêté d'Informatique Appliquée of Paris and contains 500 000 FORTRAN statements in 18 subsystems. Price $7 500 plus a monthly royalty of $2 200.

SCERT (Simulated Computer Evaluation and Review Technique) developed by COMRESS Inc. of Washington, DC, is able to simulate accurately the performance of most currently available computers when running a wide variety of programs. Rent $1 000 per month.

SISMO seismic survey analysis program. Service in Informatics and Analysis Limited, London. Price $100 000.

APPENDIX P

# A BRIEF TO THE CANUNET NETWORK DESIGN STUDY GROUP

Office of Computer Coordination,
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102 Bloor St.West, Toronto, Ont.

February 29, 1972

APPENDIX P

# CONTENTS

## SUMMARY

This submission indicates the facets of CANUNET which have relevance to a national data transmission system. It suggests a set of requirements for that system and how these may be integrated with a user orientation. In doing so, it draws on the experience of other networking activities. Namely, those of the National Physical Laboratories (NPL, UK) and the Advanced Research Projects Agencies (ARPA, USA).

Attention is drawn to those areas requiring effort, if a usable facility is to be produced within time and cost goals. A possible implementation time scale is suggested which shows a total development period in the 7-9 year range. Research/service activities necessary to facilitate network development are listed together with an indication of relative priorities. Finally a set of conclusions and recommendations are derived.

# A SUBMISSION TO THE CANUNET NETWORK DESIGN COMMITTEE

## 1.0 PURPOSE

The purposes of this document are:

a) to demonstrate how the CANUNET project may become a pilot vehicle for the Trans Canada Computer Network as proposed in Report No. 13 of the Science Council of Canada.

b) to propose how the CANUNET project may be segmented into manageable components.

c) to point to important new areas in computer networking where Canadian universities can make a contribution.

## 1.1 Introduction

The CANUNET design activity should be a pilot solution to the development of a facility to correct the deficiencies of data transmission services that exist today. It should also point a direction for future common user (that is a facility with an obligation to serve the public) communication systems.

Report 13 of the Science Council[1] indicates:

"There is a great need, therefore, for a computer communications network able to selectively connect any user to any service, quickly, reliably and cheaply."

The present switched telephone network has been servicing the needs of data transmission to date. It is in this role that the telephone companies have been subject to an increasing barrage of user complaints. This has ocurred due to:

- high cost, both compared to the U.S. rates and to the independent equipment suppliers;
- reliability/error rate, high occurrence of errors and/or line outages;
- basic performance, in terms of response time, data rates and flexibility;
- reticence on the part of the carriers to be adaptable to requirements.

No doubt, advantages accrue by use of the switched network, these are however obtained at significant detriment to data users.

It is imperative that the CANUNET activity develop a facility oriented to <u>users</u> and their requirements. Certainly, the more advanced uses of computers and communications, e.g.

- inter-process communications and control
- data base structures, compatibility and conversion
- operating system structures for networks

- development of a unified language for network utilization

require consideration early in the design activity if we are to develop a cohesive network.

Network structures that exist today may be inappropriate to the Canadian geography, population distribution and the Trans-Canada communications systems. The design statement for CANUNET should address these areas. The CANUNET position paper[2] indicated a set of constraints for the network development, some of which are

- " the plan should accomodate regional diversity and technological alternatives within a framework of objectives, standards and conventions;

- the network should be designed to accept various types of computers and to operate with a variety of lines, and

- the computer network must be transparent to the using computers and terminals."

If the CANUNET activity is to point to future communication systems it should not be too biased to the computer aspects of a network.

Computer - computer communications are only one aspect of the requirement for a data transmission system. Leverage should be obtained from present and future developments, but it is also necessary to give attention to those areas that have been neglected or not implemented.

## 2.0 THE NATIONAL SPINE

### 2.1 Introduction

The requirements of the system are to provide a level of data transmission service presently unavailable. The service must address those unique and common user requirements. Although the CANUNET activity is oriented to universities, computers, communications, and users, insufficient attention has been paid to segmentation that will allow development of viable subsystems for common user communications.

There are two basic areas that require attention:

- develop those functions that will give an effective user interface;
- develop an efficient, reliable bit transmission system.

These points lead to a structure similar to that suggested by Science Council Report No. 13, Davies[3] and Baran.[4] That is, a high level data transmission system combined with a method for user access.

The national spine is that part of the network which serves as the bit transmission system. It is the carrier for inter-regional and user communications. As such, it is given data in a standardized form and has no responsibility for interpretation of message content. The spine should be optimized for the transfer of data blocks with sufficient redundancy to give error rates not exceeding one bit in $10^{12}$.

If one examines the present switching network it is found that a significant proportion of the cost is attributable to the local line-based equipment. Local line equipment is that equipment used to provide facilities to a subscriber on an individual basis. This equipment is not very dependent on the switching methods employed in the network. In addition, the network makes no attempt to accommodate special requirements and the interface to it is relatively well defined and standardized. Thus, any incompatibility is removed prior to entering the network.

Similarly, in a new data network, costs will be dominated by the local equipment facilities and responsibility. In considering alternative systems, judgement will be based on their ability to cater to special requirements of data communications, the wide variety of terminals and multiaccess computers (or other services) that are used.

Since a capability for circuit switching, which can be used for long files, is presently available (Multicom) the national spine should be optimized to handling the short response, bursty, transaction oriented traffic. This would seem to indicate a packet switching system. Since loops are still subject to an intense research study, the distributed store and forward system is preferred for the spine. Sufficient experience has been obtained (ARPA, NPL) with these to indicate the suitability and feasibility.

The national spine should, therefore, be a packet switching system, a la Davies and Baran. The major components of this type of network are:

- switch
- communications facilities (including interfaces to the communications facility).

The switch has the following characteristics:

- reliability

  i. consistent with that of available minicomputers.
  ii. bit transmission as for the ARPA network.
  iii. adaptive routing with overconnection.
  iv. a node by-pass arrangement to facilitate communication when a node failure has occured. This is mainly applicable to a "skinny" national spine.

- response time in the range 20-25 m.secs. for a 1000 bit packet. The major components of this time are:

  i. queue delays
  ii. packet acquisition
  iii. packet processing

- bandwidth in 500kb range.
- cost per node approximately $50,000.

The switch has functions such as:

- store/forward

- spur access. That is access from other networks and/or users.

- alternate routing.

The <u>communications facility</u> that connects nodes will consist of:

- point-to-point, dedicated full duplex links; (the type of facility, analog or digital is not really a consideration, since access always will be through some type of adapter. The major impact of digital versus analog is one of error rate. In the digital case it may result in a different trade-off in the switching node.)

- not less than 50 kb per second transmission rate. This minimum data rate is required in order to establish an acceptable response time in a time domain system with a high degree of multiplexing. Prices quoted recently from the telephone company, for a six node network in Ontario, show only a 10% differential between 19.2 and 50kbps facilities.

- error characteristics of one bit in $10^5$. If it is much worse than this, different error detection and recovery procedures are necessary.

The spine should have an overconnected topology in order to reduce downtime, consequence of node failure and to provide a vehicle for adaptive routing development.

The degree of overconnection must be balanced against cost (single path links may exist). Extensive localized overconnection will probably occur. Total end-to-end response time should be in the range 100 to 500 msecs. for a 1000 bit packet.

Procedures must be developed that allow cost and charging information to be produced. Previous studies seem to indicate costs to be in the range of 15¢-30¢ per megabit. It is relevant to note here plans and some constraints of the United Kingdom Post Office[5] with respect to data networks. This network will use extensive multiplexing in the local and high level areas and is expected to provide circuit and packet switching modes. Their economic studies again indicate a cost apportionment which is biased to the local area. Typical cost distributions are indicated below.

| | |
|---|---|
| Interface equipment | 6-20% |
| Local area network | 50-60% |
| Switching | 20-25% |
| Main network | 5- 7% |

This would seem to indicate those areas which should be subject to most study and effort.

## 2.2 Standards

Those mechanisms which organize and control communication between nodes on the spine are collectively named the Inter-Nodal Protocol (INP). It has the responsibility for the efficient, transparent and reliable movement of traffic inserted into the spine. It is mandatory that this protocol be identical at each node.

The rules governing access to the spine, collectively named the Spur Access Protocol, are as critical as the INP. It requires more effort since it is more directed to the user and hence must be somewhat protectionist of spinal integrity. This protocol will be very similar to the INP. At this level however there are two significant differences.

- Spur access has no responsibility for store/forward or routing of traffic on the spine.

- it should contain protection mechanisms against misuse. These are necessary since it is desirable to allow any organization to access the spine. We do not want the debacle with foreign attachments which has occured with the telephone company.

In developing spur access standards the following areas seem applicable:

- logical standards
- electrical standards
- physical standards

Logical standards should involve:

- initialisation procedures for connection
- possible modes of connection e.g. full duplex, half duplex, etc.
- master/slave relationships
- types of commands, status functions, etc.
- sequence procedures
- packet blocking characteristics, eg.
  1. maximum, minimum sizes
  2. control, address, status field definitions.
  3. pattern sensitivity restrictions
  4. error checking process

- error procedures
- definition of terms

Electrical standards should involve:

- definition of signals
- timing requirements
- signaling methods, eg. current or voltage modes.
- signal amplitudes and tolerances
- threshold levels and margins
- power-frequency constraints
- open circuit, power off states.
- cabling recommendations

The physical standards involve:

- layout, type and placement of connections
- assignment of signals to connectors
- safety regulations
- space requirements

## 2.3 Responsibilities for Network Development

There is a significant difference in effort required between producing a facility for common use and showing that some ideas can be implemented. Universities, in the present form are probably unsuited to the development of a practical, operational, useful network. Only by judicious use of the resources contained at universities, industry, federal and provincial research organizations will this be possible.

Nowhere, is this more true than in the development of the user orientated facilities and standards. NPL has placed considerable emphasis on the economics, requirements and solutions at the local distribution level. Universities, by virtue of their diverse requirements and population can however serve as pilot community for the development of an effective data transmission network.

In development of the ARPA network, it was decided to contract with industry for the design and implementation of the communications portion. Connection of the network to hosts and users was a site responsibility. The communications system was delivered on time and within specified cost. That portion developed by the sites was deficient in these areas. This was not a serendipitous happening.

Surely this points to the mandatory nature of the "right organizational approach." Planning responsibility for CANUNET should lie with the Department of Communications. It should exercise the same requirements and restraints on CANUNET development as it would on any other design and procurement activity. Clearly, the universities must be intimately involved, but this must not be done in a manner which prejudices time and economic constraints.

# 3.0 HOST/TERMINAL NETWORK

## 3.1 General

A host/terminal network can provide the pilot vehicle for development of a Trans-Canada Computer Communications Network. The hosts can be thought of as service complexes and the terminals the means of subscriber access. Due to the variety of resources (people, computers, terminals, etc.) in universities, the design of a university network will be required to provide solutions for problems on a common user network. Implicit in the design of a host/terminal network are requirements for reliable transparent communications and a mechanism for obtaining access. Figure 1 shows one typical configuration for a host/terminal network.

Report 13 has suggested the requirement to link regional networks together. It is desirable that the regional networks that exist or are being planned be technologically complementary and make the best use of the limited resources of skills and finances. A prime candidate for the design of the linking system would be the present CANUNET activity. This activity has made significant progress in establishing inter-provincial co-operation which should be fully exploited in the interests of a national spine.

## 3.2 Objectives

The objectives of the Host/terminal design should be:

- to enable a distributed population of user terminals (batch and interactive) to access a diverse population of large scale and/or specialised computer systems.

- to ensure that response time and bandwidth approach that expected from 'state of the art' terminals (when they are connected in a circuit switched manner).
- to have reliability approach that normally expected in operations between computers and peripheral equipment.
- to allow eventual interprocessor communications, data-base transfers and conversion.
- to make the network "invisible" to the user terminals and large scale computers.
- to remove the requirement for every user to know the command languages of all hosts.
- to point directions for the development of a common user communications system for data utilization.
- to motivate the establishment of specialized machines, services and "communities of interest."

## 3.3. The NCU Concept

Access to the resources available with a network is necessary. In recent network developments access has been through a combination of hosts and small computers. Hosts, IMPS for ARPA and nodal, interface computers for NPL. In the development of common user communications it is inappropriate to tie the communications sub-system too closely to any one component. NPL's direction has been in the common user area, their work does not display the host bias of ARPA. In meeting the requirements for access to the network, a subsystem called a node control unit (NCU) can be used. This subsystem has the responsibility for interfacing to the various classes of users. For example:

- key driven terminals
- batch terminals
- control/measurement devices
- host computers

The control/measurement devices above are typical data collection equipment like that used in library automation systems, analog conversion facilities etc. The NCU subsystem can be placed at appropriate geographical points to serve demand. Although it is necessary to have a high degree of commonality in the NCU sub-systems, there is no requirement for them to be identical.

The size and capability of the NCU is a function of traffic load and the special requirements of its user area. It is expected that the NCU will have one or more processors. It's peripheral complement will be highly dependent on the number of users, the set of features provided and the requirements for network integrity. This variation in capability will necessitate a high degree of software and hardware modularity if the subsystem is to be adaptable.

### 3.4 Transparency

Clearly, it is desirable that a network should be transparent to the user. That is, it should not perturb his input in transmission and response time should be similar to the case in which he is directly connected. This however, is only a relatively minor point in easing use of a network. The terminal may not be

- o compatible to the network
- o compatible to the service he wishes to use

In the first case, this is somewhat akin to the present state when using the telephone system. A modem is required in order to make the terminal satisfy the requirements. The solution is similar in any new network. The design goals may have produced a standard of hardware/software package that would guarantee compatibility. Other requirements would result in "special assembly" being necessary. The second point requires functional conversion to a form normally supported. In the terminal host network this may be done quite conveniently in the NCU. Many other requirements are necessary for other aspects of use of a service. These include the manner in which access to the service is obtained, the form of data being used, and whether multiple services over a distributed area are required.

### 3.5 Functional Translation

As pointed out in the previous paragraph, incompatibilities may exist between the using terminal, the network and the services available on the network. Although in the distant future a 'standard' terminal may be available, we are presently far from that stage. Thus, in order to obviate the need for multiple terminals per user, translation is necessary. A constraint on the translation process is that it should not introduce significant delay (particularly for human key driven terminals). The move to programmable terminals for batch use eases the development to a standard protocol scheme.

The intent of functional translation is to make terminals completely interchangeable. The two major classes of terminal are:

- character oriented
- message oriented

It would seem acceptable to consider translation only within classes, not across class boundaries. Code translation is only one aspect of the translation process. Listed below are some additional translation factors; these are not inclusive of all factors:

Interactive(character)

- characters per line
- character set
- bits per character
- full duplex, half duplex, etc.
- speed
- echo responsibility and flexibility
- lockable keyboard
- control functions, paper tape reader, tabs, etc.
- error recovery
- carriage return variables

Batch (message)

- compression techniques
- communications protocol
- data buffering, blocking and formatting scheme
- a subset of the interactive ones

Significant effort is necessary to address the functional translation area and possible modes of implementation.

## 3.6 Switching

There are three aspects of switching in a Host/terminal network:

- o store/forward (ie. internodal)
- o network to users
- o network to host services

As indicated previously, the services and users go through ancillary equipment prior to inserting network traffic. Host computers that are close to the NCU can be connected via a normal peripheral channel. This channel will have the normal peripheral error procedures. Those hosts that are remote and all user driven devices can be connected via the terminal input. Conventional communication error procedures will be used at this input. A set of well defined control procedures will allow communication between the areas indicated above.

Considerable study should be carried out to demonstrate the feasibility of solutions to problems in this area. These problem areas are mainly:

- o protocol for aspects of communication and use; how hosts, users are connected to the network.

- o balance: where should tasks be carried out, size of the NCU and its commonality.

- o standards for access and connection.

### 3.7 Site Dependancy

Since we have a heterogeneous set of users and hosts, there will be a degree of site dependancy. The manner in which hosts are connected is unlikely to be similar, either hardware or software. As indicated in previous paragraphs, the requirements of transparency and terminal translation are non-trivial. As progress is made in networking, certain hosts may be given specialized network organizational tasks, e.g. converting a data-base or manipulating the Network Access Language.

## 4.0 PLANNING CONSIDERATIONS

### 4.1 Terminal Population

The CANUNET Topological Analysis[6] report utilized student population at a university as a mechanism for deriving traffic levels. This is a satisfactory procedure to indicate long term expectations. In a pilot scheme it is appropriate to examine the terminal population and usage levels.

Examination of the terminal population has a further data fall out. It will establish the classes of terminal and their proportions. Since part of the network development task is functional translation of terminals, this is a valuable input to possible implementation methods.

### 4.2 Implementation Levels

In activities that encompass a long period of time it is useful to examine future expectations. This does not mean that those expectations will not change, but that they be used as indications or possible constraints. For example, in a 5 year plan it is quite common to update the plan each consecutive year. Thus, the plan always reflects the expectations of the following five years.

In considering the network design, certain intuitions regarding the future of networking (or netting) as an activity appear. CANUNET is a relatively balanced network, i.e. there is not one focus (there are a number of focii) for the sharing of computer based resources. The motivation for examination of future requirements is to determine the constraints that they may place on today's design.

The currently predominant mode of communication between users and computers is by use of common carrier facilities. Thus it would seem appropriate to develop, as a first level, an upgraded 'switched network-like' facility.

A network development plan might therefore take the form:

Level 1: A transparent communications facility, i.e. transparent to the user and to the operating system. That is, the operating system will not have to do anything that it does not already do for local terminal support. This facility should have a bandwidth and response time (these are not entirely related) to allow the appearance of a switched network facility.

The above requirements infer:

- terminal support facilities, but not necessarily cross terminal support
- levels of protocol for communication between:

  nodes
  users
  hosts

- somewhat inefficient use of the communications facility. Due to the variety of echoing philosophies in hosts it will be necessary to sometimes package single characters as the packet data. Thus, the proportion of useful bits to total bits will be low.

- short response time
- network support functions for allocation of node ports and traffic accounting, etc.
- minimization of operating system additions, i.e. make it able to support two teleprocessing devices, leave error recovery procedures in, but they should never be invoked by the NCU
- performance measurement and tuning
- routing algorithm development

Level 2: Terminal translation, selection of four terminal types for functional translation. One pair of the interactive type, e.g. TTY37 and IBM 2741. The other of the remote batch type, e.g. User 200 to 360-20 (multileaving procedure).

Level 3: More general translation facilities.

Level 4: Development of netting functions:

- Interprocess communication
- Data base transfer and conversion
- Unified language for network utilization

Development Period:

After the development process is started, the following time scales are likely to apply (assuming reasonable manpower levels):

| | | |
|---|---|---|
| Level 1 | ............... | 24-30 months |
| " 2 | ............... | 12-18 " |
| " 3 | ............... | 12 " |
| " 4 | ............... | 48-60 " |

It is expected that overlap will occur in development - even so, the total time expected is in the 7-9 year range.

## 5.0 THE ONTARIO PLAN

The present plan for Ontario is consistent with objectives listed earlier for Host/terminal network. It is intended to be a user oriented network utilizing many techniques that have been proven. Figure 2 indicates the general form of the network. The NCU's form a distributed communication system utilizing in-core store and forward techniques. The NCU's will be redundantly (or over) connected to increase reliability and responsiveness with load (Figure 3). It is expected that adaptive routing techniques will be used to ensure maximum use of communications facilities and sensitivity to load and node failures. Although in early implementations there is likely to be only one computer as a part of the NCU, the design will give extensive consideration to growth toward multi-computer NCU's. The applicability of multi-computer NCU's are a function of load, technology and network integrity.

The NCU will assume responsibility for network functions and terminal handling. In early implementations the hosts will function in a similar manner as they would if there were no network. Figure 4 shows the interrelationship. It is planned that one of the NCU's functions would be emulation of the normal teleprocessing device of the host, thus giving transparent service to users. There would be two teleprocessing devices on a host:

1. The one which is normally supported
2. The NCU which gives terminal and network support.

The design inherently has the ability to support users who do not have a host. They would obtain access to hosts via the network. In this mode of operation the NCU would behave as a remote concentrator. Access to a local host can also be obtained through the NCU. Figure 5 indicates the types of traffic flow that are expected in the NCU.

- Type A - local terminal/host support
- Type B - remote terminal/host support
- Type C - remote terminal/local host support
- Type D - store/forward traffic

A Network Access Language will be developed to ease the problem of user access to network services. This Language will have many features to ease the development of networking. It will have a number of different implementations dependant on the development of the network. Although many features will not be implemented during the initial few years, it is important that the concept be introduced during the early development period.

## 6.0 LOGICAL COMMUNICATION

### 6.1 Higher Level Protocol:

The expectations for CANUNET involve a network of heterogeneous facilities and, as such, provisions must be made very early for the implementation of a comprehensive higher level protocol. In the design of such a higher level protocol, it is necessary to consider that, due to the lack of adequate research efforts, interprocess communication should not be pursued too vigorously in the initial plan. The protocol must facilitate growth into an effective netting environment, and for this reason, the two basic goals of the design of the protocol should be:

- the production of a global design which provides a solid base for expansion.
- keeping in mind that an immediate implementation must be easily extractible.

Inter-process communication falls into the expansion category. In view of this, the focal point of host-to-host communication should be the transfer of small to medium scale data-bases. This data base transfer falls into two broad categories:

- programme sharing - where data is transmitted to a remote location, processed and results returned
- data sharing - where programmes are transmitted to a remote location to operate on a large data-base. An example of this use would be the 1961 Canada Census data base at the University of Alberta.

It is unfortunate that exploratory projects seldom, if ever, operate under ideal conditions. A major pitfall in protocol design is to design one which functions under ideal conditions. The problem which must be resolved is that of the threshold of acceptability and tolerance and the means to be used in order not to fall below that threshold. The threshold of acceptability and tolerance of the protocol is subjective and determined by the user, but in the main, there will be three broad classes of user where this threshold will be relatively non-random. For this reason, it may be necessary in the initial phase to quantize the higher level protocol so that the following categories of user are handled differently:

- novice
- intermediate, infrequent user
- expert

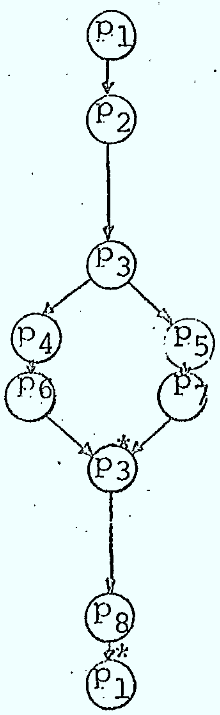
The higher level protocol must be flexible enough to provide a base for a dynamic environment. As such, it must be designed to be a structure which is not encumbered by the functions it performs. A possible approach to a design is outlined in the following paragraphs.

The design of any language or protocol should utilise 'primitives' which define the micro-capability of the protocol or language. These primitives have no intrinsic meaning until they are assigned a function, except that they may be used to illustrate the macro-capabilities of the protocol or language. Thus, the protocol should be based on functional primitives which can be chained together, each chain being executed in an incremental fashion. These chains can be constructed in such a way that they bear a striking similarity to one of three mathematical objects:

i. a finite state automaton
ii. a tree
iii. a directed graph

Then a suitable theory can be developed showing the behaviour of the primitives, in a way which is independent of the functions they perform. Also, by utilizing such an approach, the protocol is independent of the location of execution of the primitives.

The concept of incremental execution is quite important in that the chains can be shipped from location to location, with each site at which the chain requires processing removing one or more primitives from the chain and forwarding the rest along with the results of those removed, to another site. The following example illustrates the technique:




(1) Entire chain is shipped to the node which will process primitive $p_2$.

(2) The primitive $p_2$ is processed at step (2) and the remainder of the chain from $p_3$ onward is sent to another site.

(3) At step (3), $p_3$ is processed and sends two chains to separate sites.

(4)
(5) Steps (4) and (5) involve the processing of these two chains.

(6) At step (6) the results are returned to $p_3$ (indicated by a * (superscript) and the process again continues serially.

(7)

(8) At step (8) the results of executing the entire chain are returned to the site which originated the chain.

## 6.2 Network Access Language:

### 6.2.1 Purpose of the Language

The key to providing a good network service lies in providing a transparent service. That is to say, the user need not know that he is using one or more of many computers, some of which have differing control languages, differing representations of data, and differing resources.

In view of this, it seems apparent that if a Network Access Language (NAL) is not designed with adequate consideration for user sensitivity, the network may never be properly utilized. The purpose of a Network Access Language should be to provide a facility for using the network logically as if it were a computer (a meta-computer). It must be a concise, easy to use language which provides a convenient protocol for the allocation of resources to users and for the invocation of processes (programmes).

Since such resource allocation and process control is asynchronous by nature, the NAL must provide for the processing of asynchronous events and for the modification of program flow. This approach will make the language most useful for controlling events dynamically and for recovery from error caused by a host computer's inability to provide some service or resource.

6.2.2 Implications for Network Users.

One feature of the language must be the ability to bypass exceptional and undesirable conditions by using both conditional and unconditional transfer commands. In many cases, it will be possible for a user to provide an alternate assignment for a resource which he has failed to acquire. Whereas such alternate assignment is not too difficult to handle automatically in a single operating system, it is far more difficult to handle automatically in a network environment since the scope of the environment is so much larger.

An important point of consideration should be how users will be able to handle multiple processes, or how they will be able to chain processes together, between different sites.

The language must be defined to function across four broad categories

- Resource Management - allowing the user to manage external resources.
- Process Control - allowing the user to manage the processes that he has initiatied.
- Synchronization and Program Control - allowing the user to synchronize events within his NAL program, loop control, program block control (eg. BEGIN, END as in ALGOL), etc.
- Program definition, text editing, and listing of programs and data.

6.2.3 Implementations considerations.

It is obvious that a Network Access Language cannot be implemented without becoming deeply involved in the architecture and philosophy of the network. As such, we must speculate on the levels of implementation since they depend on the method of implementation of the network.

From the outset, the NAL must be designed to control both interactive and batch type environments. However, it can (in fact it should) be restricted in the pilot implementation to letting a user communicate with only one host computer at a time. In the latter part of the pilot implementation it should be extended to communication with more than one host of the same manufacturer and like operating systems. Other than this, a comprehensive language should be implemented since this will enable users to get a "feel" for proper network utilization.

As the network proceeds in its development, the major problem which will have to be resolved in extending the language to concurrent processing on more than one host, is resource allocation deadlock. The problems incurred by contention of processes for non-shared resources in a simple multi-programming environment are formidable and are usually solved by enqueueing the resources. This, unfortunately, would not be a suitable solution in a network environment since a process in one host may depend on many previous and concurrent processes. This dependance on concurrent processes prohibits enqueueing since that would "freeze" resources on other host computers. Similarly, dependance on previous processes prohibits cancellation of one process when two processes are deadlocked for one resource, since it may not be possible to determine whether or not the results of those previous processes are reversible.

## 7.0 NETWORK APPLICATIONS

### 7.1 Immediate Applications

As soon as the network becomes operational, there will be a number of immediate applications, which contribute to the improvement in the delivery and use of computing services.

a) The repertoire of hardware services available to the user through his computing centre will be increased dramatically. For example, physical scientists could have available the facility to perform large-scale numerical computations on CDC equipment. Further, users with a need for the processing of large files on IBM systems could have this service via the network.

b) Specialized applications will develop at different universities and become available to a wide community of users in the universities.

### 7.2 Medium Range Applications

During the medium term (3-6 years), the major development, in network utilization will relate to the growth and use of data bases.

a) Analytical data bases, such as the Social Science data base at the Institute for Behavioral Research at York University, will become available to network users. The cost of developing and maintaining such analytical data bases makes it important to have the widest possible base of users, as would be provided via the network.

b) Reference data base systems, in which text manipulation and retrieval plays an important part, constitute a very significant future load for the network. Again economic viability requires a large user base to support the creation and maintenance of reference data bases.

An important application in this field is an automated library system, with great potential for shared processing and shared library resources leading to long-run library rationalization.

## 7.3 Long Range Applications

In the long term (7-10 years) it is expected that certain applications will arise which relate to the impact of a new technology on the universities and society at large.

a) The network will be used to channel experimental data, collected on-line, to processing centres which will respond to the source experiments in real-time.

b) The installation of specialized machines will be permitted and encouraged, because of the network.

Such machines might perform functions such as archival storage, or data base management, or may have special hardware to execute high level languages without translation.

c) The existence of the network will have enormous ramifications for the development of technology-assisted education. The economics of programmed instruction suggest that large student bases must be available before the techniques become comparable in cost to current modes. The network, potentially, will provide the necessary connections to the large student populations and provide the basis for the development of major programs in which CAI, simulations, and reference systems support the teaching process.

## 8.0 RESEARCH ACTIVITIES

Even though certain network activities fall in the domain of research, the initial design must establish a sound basis for all such activities. This basis is necessary since it is clear that the initial implementation will colour the scope of all research into netting on this particular network. In the absence of this approach it is possible, indeed probable, that a re-implementation may be necessary, in future, to accommodate conditions previously not considered.

The two goals previously mentioned in the section on higher level protocol are most applicable to research considerations.

- produce a global design which will take into account as many aspects of netting as possible.
- produce a design from which an immediate implementation is easily extractible.

It is certainly unclear, at this time, which parties will be responsible for these research activities. However, it is clear that a maximum amount of flexibility in the initial implementation will make the research task easier. For example, in dealing with data bases on the network, efficient utilization of the communication facilities and a comprehensive network data management scheme (including a sophisticated cataloging structure) are necessary. Without such considerations, anyone wishing to do research in data bases would have to superimpose his own scheme on the network, which may lead to cumbersome and inefficient utilization, even though such superimposition is inherently possible when necessary.

The following list of topics, which is most definitely not exhaustive, points to areas of interest in the research domain.

- Inter-process communications protocol
- Operating System structure for networks
- Distributed multi-processing - both in the operating system and user program sense.
- load leveling - this can be taken in two senses:
    1) hosts which have free time should share with hosts which are overloaded.
    2) the network should be able to determine the optimum system for a user task.
- data base reconfiguration and data base transfer - the reconfiguration will be necessary to allow for transfer of data between heterogeneous systems.
- distributed data bases - that is, segmented data bases with segments at different locations.
- software error control and procedures
- performance evaluation and measurement
- studies in topological independance
- network loading control
- privacy and security in network utilization

The above research areas are presented in more concise form in Table 1. Included in this table are those service aspects of importance plus a possible task priority enumeration.

## 9.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the foregoing sections, a set of conclusions can be derived:

1) CANUNET has the opportunity to be a pilot programme for the development of a national spine. The interconnnection of regional networks can be best brought about by the early implementation of a national spine and the establishment of standards at the national level.

2) The development of a national spine is complementary to the development of inter-process communications and the implementation of user oriented host/terminal networks.

3) Emphasis on the requirements of the user community is necessary.

4) The development of standards will increase the leverage obtained from network activities.

5) The goals of network development should be both research and service oriented.

6) Universities should be involved but extreme care is necessary if an operational network is to be provided.

It is therefore recommended:

a) That a statement of developmental priorities be made and matched to the resources in the universities.

b) That the Department of Communications establish a group to be responsible for the development of CANUNET. This task should be the only one that the group is to carry out. The group need not be from within the Department. It could be as a result of bringing together the talent from within the universities, or utilizing Task Force on Data Communications personnel.

c) That the Department of Communications establish a group to be responsible for the development and use of network standards.

d) That the CANUNET programme include a funded activity concerned with network research such as Host-to-Host protocol, Operating Systems structures for networking and distributed database management.

e) That the CANUNET programme include support for regional networks that are compatible with national standards.

| Activity | Type | Priority |
|---|---|---|
| National Spine | Service | 1 |
| Host/Terminal Network | " | 2 |
| Applications | " | 3 |
| Inter-process communications | Research | 4 |
| Operating System Structures | " | 5 |
| for Network | " | 5 |
| Data base reconfiguration | " | 6 |
| Performance evaluation | " | 7 |
| Topological Independance | " | 8 |
| Software error control | " | 9 |
| Network loading | " | 10 |
| Distributed Data Base | " | 11 |
| Privacy and Security | " | 12 |
| Load levelling | " | 13 |
| Distributed Multi-programming | " | 14 |

TABLE 1. Activity/Priority Table

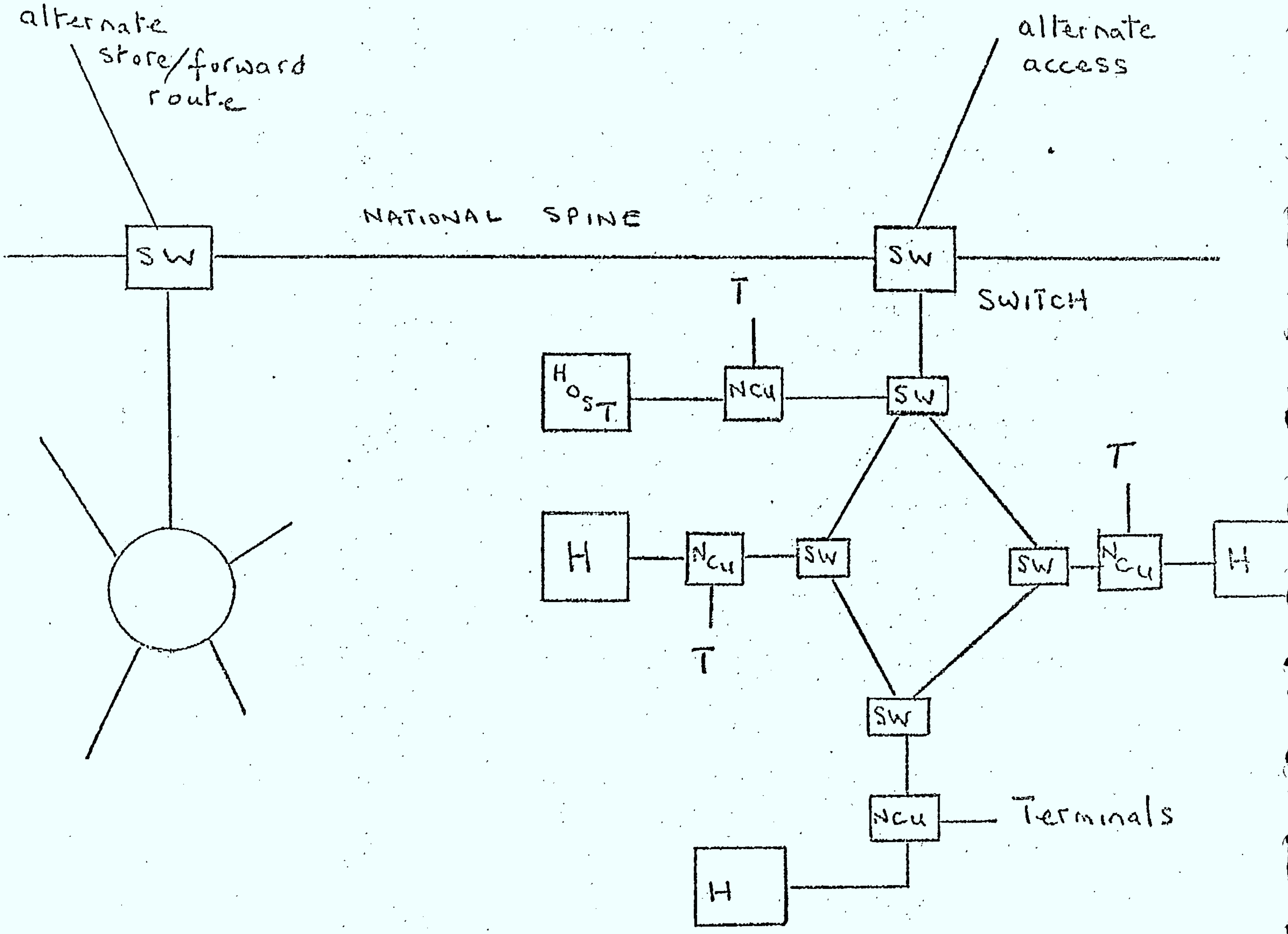
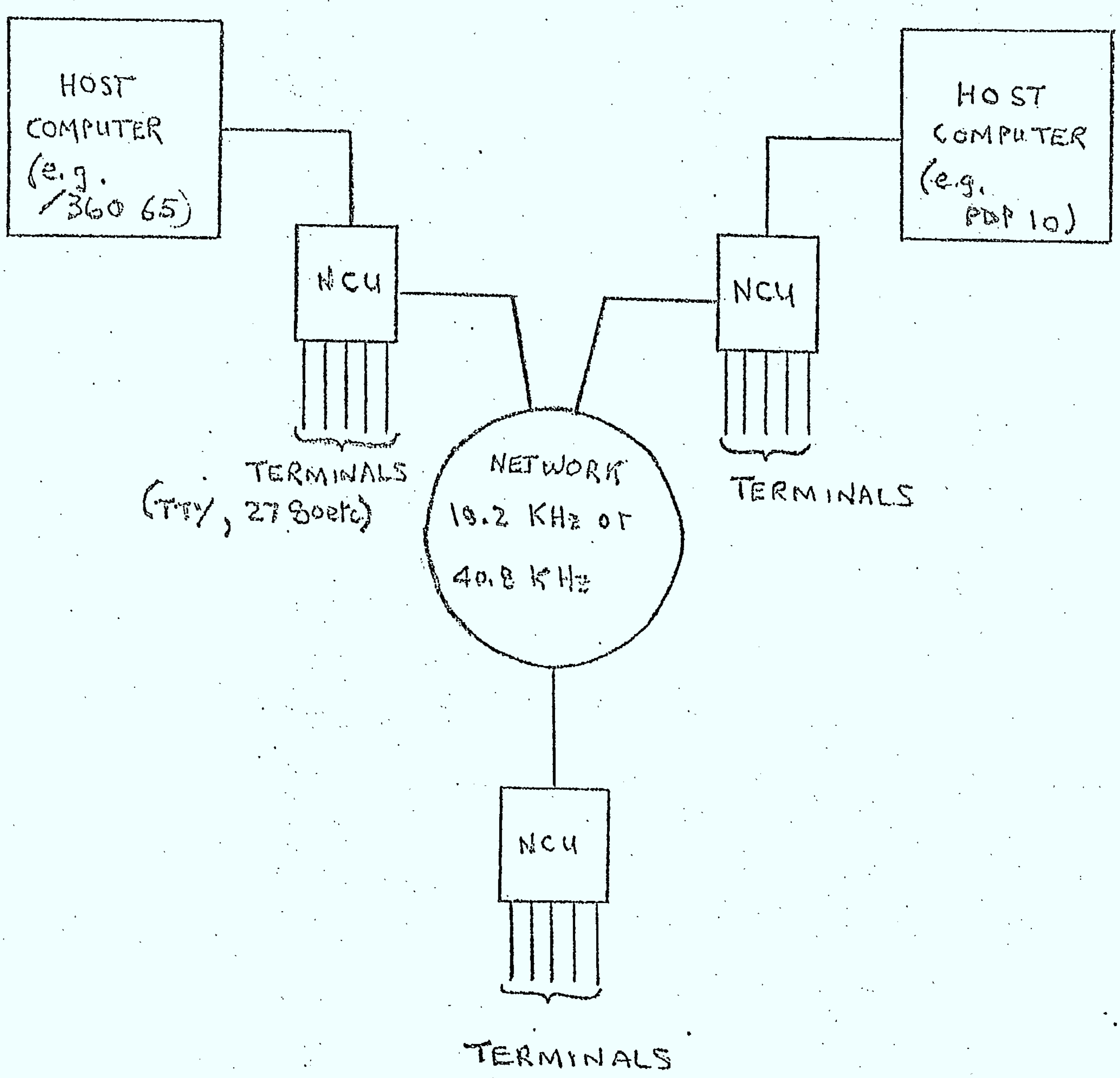
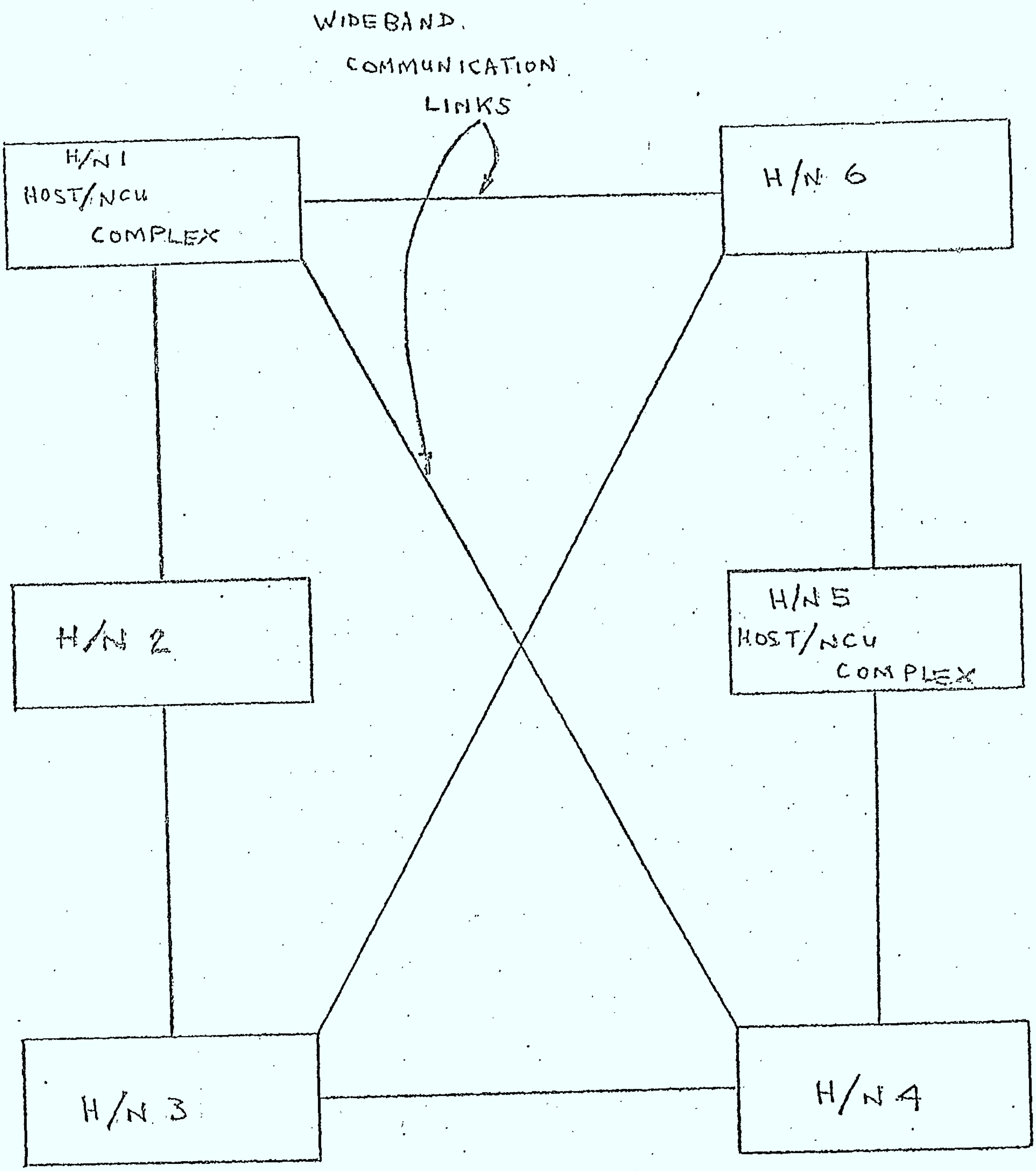



Figure 1 One Typical Host/Terminal Network



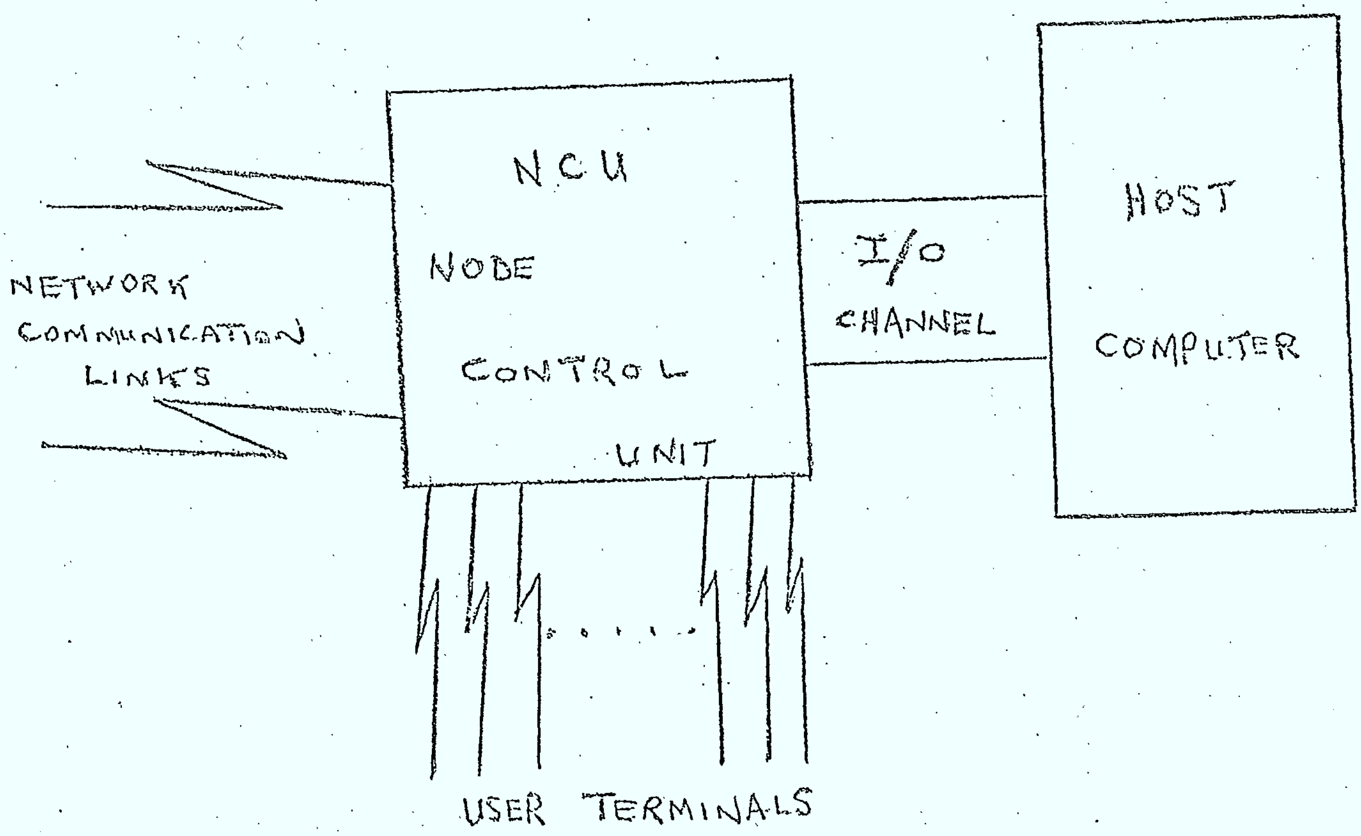

Diagrammatic Representation
of
Proposed Network

Figure 2



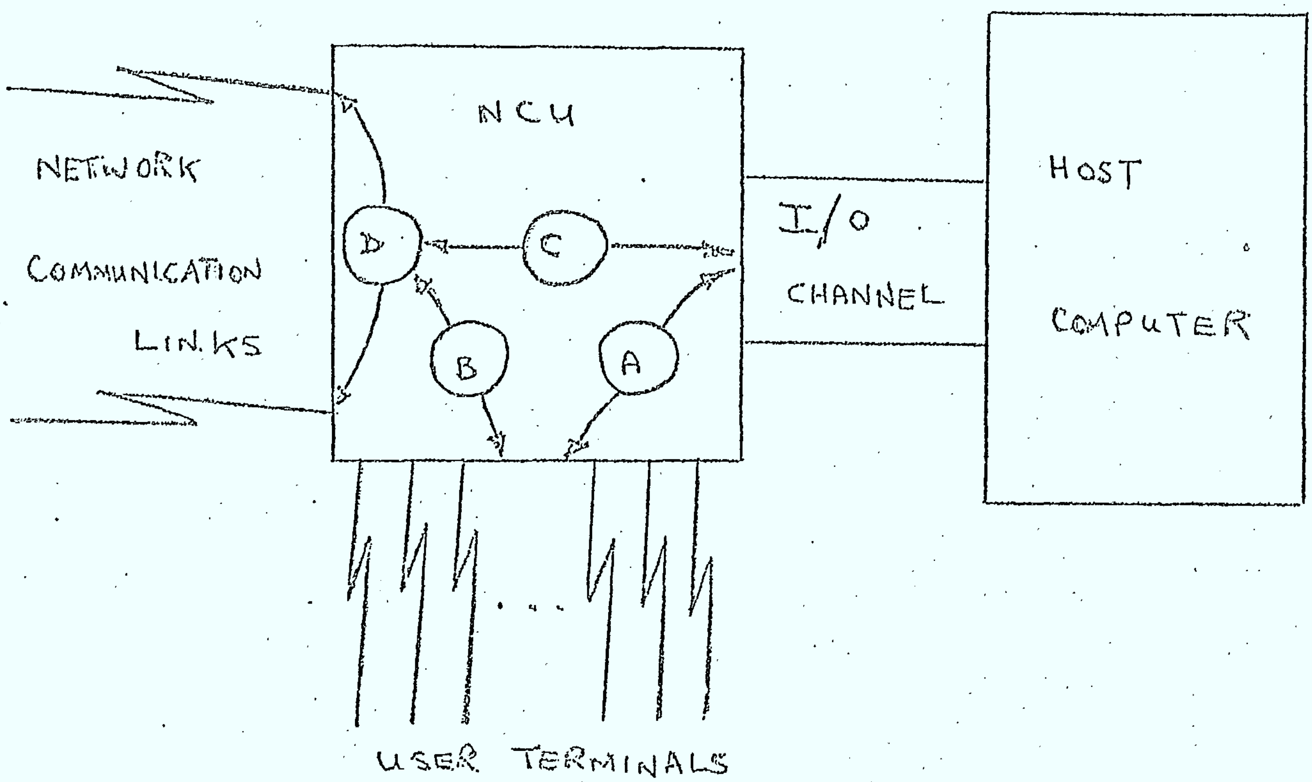

Six Node Network with Overconnection

Figure 3




Interrelationship of Network, NCU and Hosts

Figure 4




A: terminal ⟷ host

B: terminal ⟷ network

C: network ⟷ host

D: network ⟷ network

NCU Information Streams

Figure 5

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# MINUTES

## of the

## THIRD CANUNET MEETING

Meeting held on Wednesday, March 29, 1972.

Present: See attached list.

Meeting:

The Chairman opened the meeting by extending the full support of the Department of Communications for the program to be discussed and/or approved at this meeting and expressing his thanks for the contributions which so many different universities and individuals had made to the effort.

A brief description of results from the four study groups formed at the last CANUNET Advisory Meeting was then presented.

### Institutional Framework for CANUNET

The Chairman of this Committee, Mr. B. Holmlund, gave a resumé of his report.

His study focussed on three major objectives:

1) To develop a degree of expertise in the area of computer networks.

2) A network to produce an enriched information source.

3) A means for universities to gain reasonable access to computer time.

He felt that the total project should be categorized into three major classes of activities:

1) Development of a "national spine"

2) Developing applications and providing a higher quality of computing services.

3) Research on computing networks.

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Mr. Holmlund then suggested an Organizational Structure for the prototype development phase of CANUNET. He also presented a possible organizational structure that could be envisaged at some appropriate future times. It suggests that the management board of CANUNET report directly to an AUCC Board of Directors. A detailed description of this proposal can be found in his report.

The president of AUCC, Mr. Bonneau stated that the proposal was studied within AUCC and that such a function could be undertaken by them. However, in their decision, they have assumed that:

- This "national spine" is desired by the Canadian people and could evolve as a major network in Canada.

- With time, the intermediate phase proposal would evolve to the point where AUCC would be the main organization responsible for CANUNET.

- Personnel would be provided to AUCC for the undertaking since the organization has no budget for this type of activity.

Mr. Parkhill pointed out that our concern should be towards CANUNET only, and not with a "national spine" for Canada.

He also said that the funding mechanism for this project would be presented later by Mr. J. Reid.

Mr. Gotlieb from the University of Toronto, said that some justification has to be made at this time for a Canadian University Computer Network. Some mechanism is needed whereby the problems for such a network get smaller instead of larger as time goes on. He felt that some form of charging mechanism should be built into the institutional framework.

Mr. W.C. Brown from NRC pointed out that if CANUNET is to apply to NRC for some money then, for political reasons NRC should be part of the proposed chart.

Mr. Parkhill agreed.

It was moved and seconded that the presented report, with the addition of NRC to the organizational chart, be accepted. Motion carried.

Mr. Parkhill suggested that all written comments on this report be submitted to Messrs. Holmlund and Reid with a copy to Mr. Shepard.

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## Utilization of CANUNET

The Chairman of this Committee, Mr. D.D. Cowan pointed out that his report is one facet of the study to determine the feasibility of constructing a Canadian Universities Computer Network. He concerned himself with two aspects of utilization:

1. Overview of services required for applications.

2. Preliminary Survey of applications in Canadian Universities (prepared by Tom Croil).

A detailed description of these two aspects of utilization can be found in Mr. Cowan's submitted report "Utilization of Computer Networks".

It was suggested that the next phase of that report should also include the government's activities in this area, and a detailed forecast of traffic statistics.

Mr. Parkhill pointed out that the Department will be funding the University of Waterloo for a comprehensive forecast and analysis of applications and contributions for the participating universities. The report should be available by the summer.

After some general discussion, it was moved, and seconded that the report be adopted. Motion carried.

## Communication Studies

Mr. Guindon, Chairman of this Committee gave a resumé of the results of the study of traffic and message delay in a store and forward network for CANUNET and on the cost of those networks. The study focussed on:

A- Terrestrial Network for 10, 14 and 18 node topologies.

B- Hybrid Network (Satellite-Terrestrial) for 10, 14 and 18 node topologies for various earth station locations.

Details of the results of the study can be found in the two reports submitted by the Communication Studies Committee.

It was moved and seconded that the report be accepted (tentative). Motion carried.

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## Network Design

J. Kennedy, the Chairman of this Committee, presented the results of his study. He explained the design objectives and constraints of a network such as CANUNET and his opinion as to how the design criteria should be met. A detailed description of the proposals can be found in the March 1972 report "A Network Design for CANUNET".

It was moved and seconded that the report be approved (tentative). Motion carried.

## A Proposal for a Canadian University Computer Network (CANUNET).

Joe Reid stated that the intent of his proposal was to produce an introduction to the subject by giving a complete picture of CANUNET.

After some discussion, it was suggested that page 6 criteria e) and g) read:

e) the network should be designed to be compatible with future general computer networks, in so far as the outlines of the latter can be discerned, and preferably, should be designed as a prototype element of such networks.

g) a message should be delivered and an acknowledgement returned by the destination host in under half a second because of the needs of conversational computing, eg. computer aided instruction.

Mr. M.P. Brown from COU, pointed out that page 10 section 5 does not reflect the Council of Ontario Universities' position.

Mr. Parkhill suggested that it would be appropriate to ask Mr. Brown to write this section. Mr. Brown agreed to undertake this task.

A general discussion followed concerning the operating costs and charges for services in the network.

It was pointed out that this section (page 14) is a very important element in planning for CANUNET. It seemed that the costs suggested were not well substantiated and at this stage, should be expressed in the form of a possible range of charges, ie. maximum- minimum. It was also suggested that the cost of implementation (page 20) seemed very low, possibly by a factor of 3.

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Mr. Parkhill suggested that some people from the Department could help in rewriting this section. Dr. Shepard promised to arrange for such assistance.

It was then suggested that the circulated "Draft Resolutions" be changed to "Study Recommendations" which were to replace page 28-29 of the proposal.

Some changes in the wording were suggested and the political implications of items 5 and 6 were discussed.

Conclusion

After a lengthy discussion of "A Proposal for CANUNET", Mr. Parkhill suggested that Mr. Reid revise his document and circulate it to the Committee for consideration.

Mr. Parkhill also pointed out that by the end of the summer a formal report on operating and implementation costs plus the funds required for such a network should be presented to the Department for further action.

René Guindon
Secretary.

Attachment

APPENDIX Q

March 29, 1972

Third Meeting of the CANUNET Advisory Committee

| | |
|---|---|
| D.F. Parkhill | DOC |
| J. de Mercado | DOC |
| J.B. Reid | Université du Québec |
| David A. Twyver | U. of British Columbia |
| Elizabeth Payne | Dalhousie U. |
| Arnold Betz | Memorial U. |
| René Guindon | DOC |
| Louis Brunel | U. du Québec |
| J.O. Fortier | U. du Québec |
| J. Robert Cyr | U. de Moncton |
| J. Da Silva | DOC |
| L.P. Bonneau | A.U.C.C. |
| Michel Kadoch | DOC |
| John Madden | DOC |
| Walter Dietiker | Carleton U. |
| G.T. Lake | U. of Western Ontario |
| David S. Macey | York U. |
| L.F. MacRae | National Library |
| A.B. Donaldson | DOC |
| Alex Curran | Bell-Northern Research |
| C. Lemyre | U. of Ottawa |
| C.D. Shepard | DOC |
| N.D. Brewer | DOC |
| J.M. Kennedy | U. of British Columbia |
| C.C. Gotlieb | U. of Toronto |
| D.D. Cowan | U. Waterloo |
| Paul Dirksen | U. of Manitoba |
| J. Edmondson | Telesat |
| M.P. Brown | Council of Ont. Universities |
| D.H. Norrie | U. of Calgary |
| W.A. Young | A.U.C.C. |

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| | |
|---|---|
| B.A. Bowen | Carleton U. |
| W.D. Wasson | U. of New Brunswick, Fredericton |
| B.A. Holmlund | U. of Saskatchewan |
| Ron MacKinnon | St. Francis Xavier U. |
| T.A. Croil | T.A. Croil Associates Ltd. |
| W.C. Brown | National Research Council |
| F.W. Herrmann | Min. of State for Science & Technology |
| G.E. Lockwood | DOC |
| E. Dowey | Queen's U. |
| A. Zinger | U. du Québec, Montréal |
| P. Skippon | Secretary of State Dept. |

## LIST OF SUBJECTS

# APPENDIX R


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| | | |
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