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IIASA Working Paper

WP-75-162

1975

PART III. IIASA DATA COMMUNICATION NETWORK

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December 1975 WP-75-162

2361
Laxenburg
Austria

International Institute for Applied Systems Analysis

CSN 003
September 1975

IIASA DATA COMMUNICATION NETWORK

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Summary: This paper presents IIASA Computer Science Project plans for the construction of a computer-computer network connecting centers in National Member Countries.

IIASA Data Communication Network

Brief Description of Plan

In March of this year a formal proposal to construct a data communication packet switching network linking IIASA to computer centers in National Member Organizations was circulated. This step had been preceded by long range preliminary contacts with various projects in this Institute and some computer centers in the NMO's. Circulation of this paper was also a demonstration of our belief that the communication between scientists involved in inhouse research and their counterparts in NMO's is essential to the success of this unique institution.

The initial plan is to connect the following centers: IIASA, The Computer and Automation Institute, Budapest, The Computing Research Center, Bratislava, The Institute of Control Science, Moscow, The Cybernetics Institute, Kiev, and the Technical University, Vienna. Some schemes for doing this are shown in Figure 1.

Bulgarian and Polish Academies of Sciences have also expressed their willingness to join the IIASA network and provide needed computer facilities and manpower. Exploratory contacts have been made with EIN and UN authorities on possible cooperation.

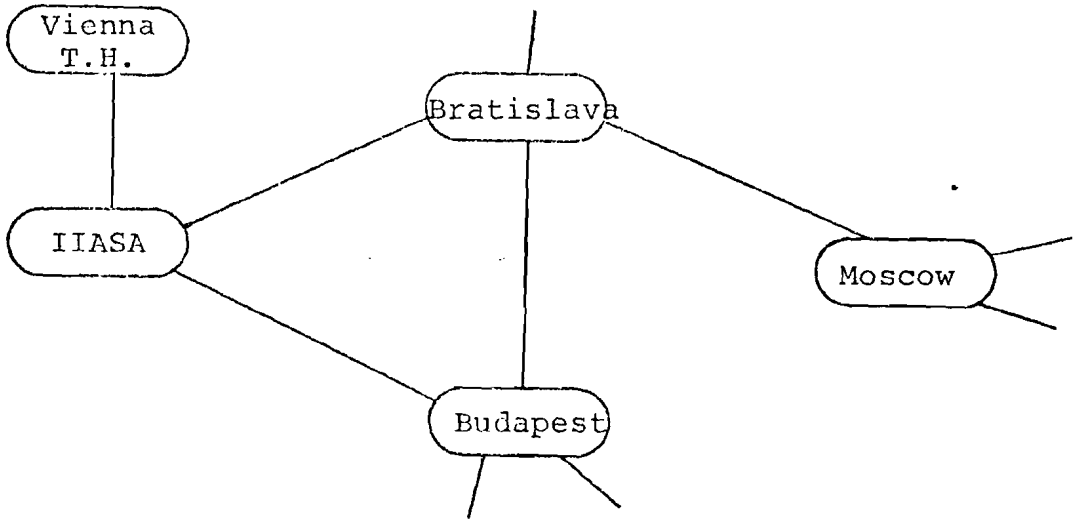
Purpose

In order to understand IIASA's interest in data communications, it is necessary to know something of how the Institute functions. This institute is characterized by a large variety of research fields and disciplines. We have here 11 projects, in which the scientists of 14 National Member Organizations are involved. The Institute relies inevitably on the support and intellectual supply from the national institutions. Scientists come to IIASA for

Figure 1

Some Possible Alternative Configurations for the IIASA Network

I.



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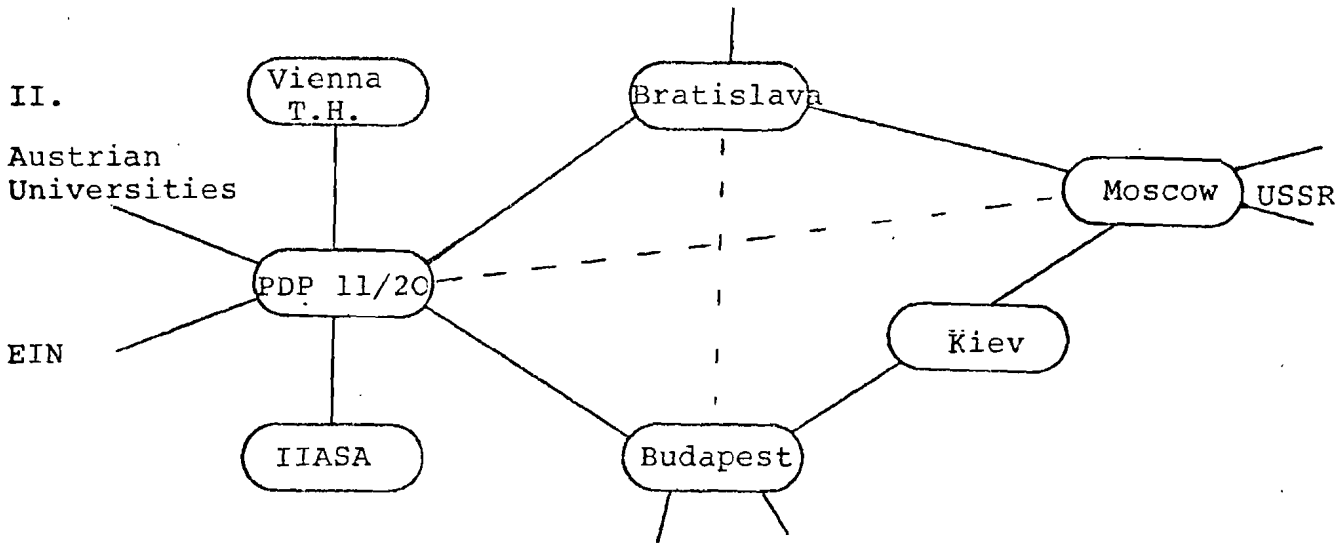

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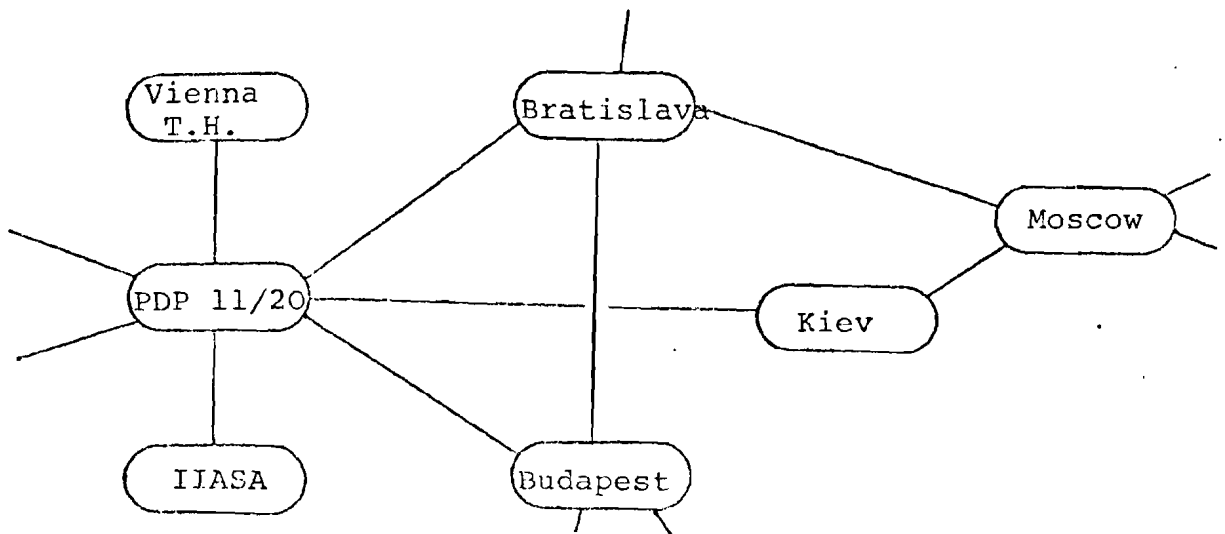


periods of a few weeks to several months. This continuing inflow and outflow leads to working relationships being established between IIASA and the national institutions providing these scientists. As a result IIASA is in a unique position to stimulate cooperative research, but joint projects require adequate communication facilities. Because of the computer intensive nature of most of our projects, all of which involve the applications of Systems Analysis to problems of global interest, we firmly believe that data communication forms an important part of such facilities. We also firmly believe that improved communication facilities will both stimulate international research and also provide a basis for collaborative research of a type which is practically impossible with the small number of people that can be brought together at this institute.

At the same time international computer networking is a developing problem of global interest and therefore appropriate for study at the Institute. In brief the goals of the proposed IIASA network are:

1) To provide data communication links between IIASA and cooperating National and International institutions;
2) To provide access for IIASA scientists to specialist Data-Base and computing facilities, particularly those at the home institutions;
3) To provide a practical base for research in computer inter-networking.

In a later section of this paper we shall draw your attention to some topics of basic research conducted by this project.

The General Framework

When considering the implementation of our network we have to take into account a number of constraints and limitations. We also have to bear in mind how these will change with time and how our plans may develop.

We give here some details concerning hardware, topology, type, etc. There are some very heavy constraints imposed on the development of the IIASA Network. Because of the nature of this project we cannot expect an entirely homogeneous network even at the level of switching nodes. There have been and partly remain some differences in understanding the goals and scope of the project between people from various computer centers and time has been needed to reach an understanding and achieve a common terminology.

At IIASA we have one in-house machine, a PDP 11/45 which we run in time-sharing mode using the Bell Labs UNIX operating system. There are currently 8 terminals attached. Because of the heavy demand on this machine as a general purpose computing resource it is planned not to include packet switching functions but rather to attach it to our network as a Host. At Budapest a TPA 70 mini-computer will be used as a node (packet switch) and similar arrangements are proposed for Bratislava using a NORD 20 and in Moscow using a PDP 11/20. In these three cases it is also proposed to attach some local general purpose computers as Hosts. These include an ICL system 4 and a Siemens 4004 in Moscow and large R series machines in Budapest.

One installation of special interest is the Cyber 74 of the Vienna Technical University, which has especially good communications

facilities built in. From IIASA we have been using this machine for some time, but now we want to include it directly in our network. One possible solution to this is to introduce another node, perhaps a PDP 11/20 between IIASA and Vienna, to which each site could attach its Hosts. Such an arrangement is particularly attractive since it would permit the connection of other centers in Austria and also (something of great importance to us) would facilitate connection to other networks in Western Europe, such as EIN.

Links

For the links we intend to use the telephone service. We are starting with dialled-up lines and are trying speeds of 600 and 1200 bits/sec but as soon as possible will upgrade these connections by changing to leased lines and speeds of 2400 bits/sec. For higher speeds conditioned lines will be required. The primary constraint in this particular is the question of cost, and a need to justify new expenditure by demonstrating feasibility. Furthermore, we do not expect very heavy usage of the computer network in the early stages. The initial goal is to provide the physical capability to establish the needed connection on demand for relatively short periods of time, and not to run this connection permanently.

For the same reason it has been agreed to operate the links with Bratislava and Moscow using asynchronous modems, but it is hoped that some of the links will be operated in synchronous mode and the line protocol has been designed with this in mind.

Protocols and Software

It is proposed to take a fairly conventional approach to the communication protocols, at least at the lowest levels. That is to say software will be written to form a series of levels. These

are: line protocol, packet protocol, and host-to-host protocol. However, we intend to rationalize this approach as much as possible and avoid duplication or provision of little used facilities. We feel strongly that there is a real need to reduce the communication software to a small volume and avoid excessive use of precious core store.

Language and Operating Systems

We are making a study of necessary operating system features and available systems programming languages. On the IIASA PDP 11 we use a language called "C" which is almost identical with BCPL. A language which is available to all centers is PL 11. We believe that by being careful about programming methodology we can make our software better, smaller and faster to implement. At IIASA we are constrained to work within the framework of UNIX but at the other centers, especially nodal centers we expect to have to build an operating system. We intend to make it as small as possible, consistent with provision of basic essentials. Some desirable features are:

1) Parallel processing;

2) Inter-process communication;

3) Process priority scheduling system;

4) Automatic restart.

We intend to build a modular system and wherever possible to aim for transportability, so that modules developed at one center, can be distributed and used at others. Systematic documentation will form an important part of this.

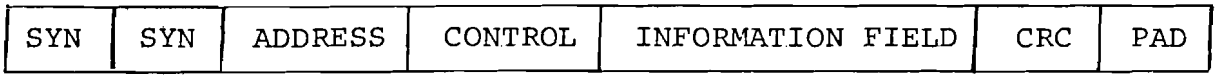
Data Link Protocol

We have made a survey of existing and developing protocols in this area and are dismayed to see how many separate developments

there are. It seems that every new entry to the networking field develops its own line protocol. At IIASA we have decided to forgo this pleasure and to adopt the emerging European standard HDLC. Having said that, we have to admit that it is not quite what we need and we have had to tinker with it a little. Firstly, it is intended for synchronous communication and some of our lines will be operated asynchronously. This, however, is no problem and we intend simply to construct a frame for synchronous transmission and allow the interface to segment this and add the start and stop bits. In this way we avoid a distinction between these modes of operation and also avoid having to alter our software for synchronous communication at a later date.

For us, a more serious problem arises, because HDLC employs a bit stuffing technique, which would be very inefficient to do by software. In the absence of hardware we have therefore been forced to rethink this and have decided to adopt the HDLC frame structure but to employ the older "synchronization character, data-link-escape" technique. Our frames will therefore have the structure shown in Figure 2.

Figure 2



1 byte 1 byte 1 byte 1 byte 0 or more bytes 2 bytes 1 byte

When it exists, the information field shall be terminated by ETB. To achieve transparency and avoid premature termination due to the accidental occurrence of ETB in the data, all occurrences of SYN, DLE and ETB in the data shall be immediately preceded by DLE.

From here on we adapt HDLC without change. However, it is clear that we only need a subset and we have decided on the following choice of features:

HDLC Subset

We shall use only Normal Response Mode in half-duplex.

Supervisory and Unnumbered Commands will be limited to the following set:

RR, RNR, SNRM, DISC,

and Supervisory and Unnumbered Responses to

RR, RNR, UA, CMDR.

We shall not use the extended modes.

In agreement with ISO standard DIS 3309 we shall use the address field to identify the secondary, but we shall divide that field into two subfields as shown in Figure 3.

Figure 3

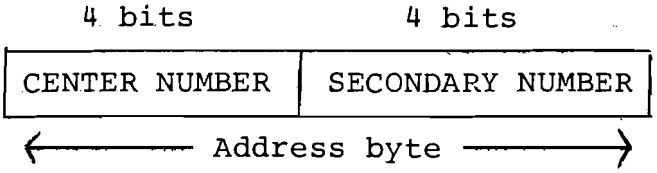


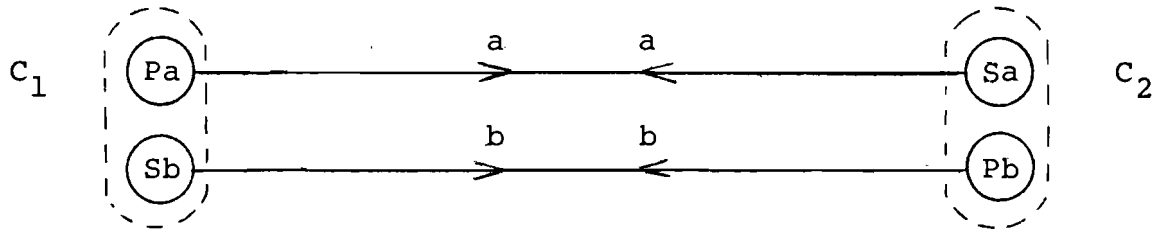
Table of Center Numbers

Center	Number
IIASA	1
Bratislava	2
Budapest	3
Kiev	4
Moscow	5
Vienna	6

If FILL characters are transmitted between frames to maintain an active channel state, that character shall be SYN.

To overcome the unsatisfactory asymmetry between primary and secondary stations we propose the following solution. On each link there shall be two logical channels with a primary at each end. See Figure 4.

Figure 4



Primary Pa and Secondary Sa shall communicate with one another using the center number for C_2, while Primary Pb and Secondary Sb shall communicate using the center number for C_1. The secondary numbers for such a pair shall be the same. The Send and Receive Sequence numbers shall be distinct for each channel in accordance with the standard. In order to avoid confusion between the traffic on the two logical channels, the Primary and Secondary at a given center shall cooperate according to the following rule, which applies to the state where both channels have been initialized in normal mode.

If there is information to be sent then it shall be sent on the channel last used, unless the line has been quiescent for a certain time (a constant yet to be fixed). When the line has been quiescent for this time a station wishing to restart activity will do so by transmitting from its primary, which may or may not be the same logical channel as before. The clash which can occur

in this quiescent situation will be resolved by having a different timeout for each primary.

Cross links are easily detected in this arrangement, but for the purpose of local testing cross linking could be allowed by forcing the channel numbers to be equal.

Initialization, Disconnection and Recovery from a CMDR will be symmetrical but each channel can in principle be initialized and disconnected separately, so that at times and in some cases there will only be one available channel (or none) and in such situations one station will function solely as the primary and the other as the secondary. This will allow symmetrical testing and progressive activation of a communication link.

In deciding on the above implementation of HDLC we considered adopting the SESA-LOGICA solution for the European Information Network. But abandoned it because it is not in accord with HDLC in that it does not use either the address or control fields and because it does not represent any real advantage. The argument that using 8 logical channels makes better use of a half duplex protocol is just false since each cycle is reduced to 2 frames, rather than the cycle of 8 available with the 3 bit HDLC sequence numbers. In either case, at most 8 frames can be transmitted before an acknowledgement is received. Whether one should have several logical channels or not is entirely irrelevant at the line protocol level and is an example of the needless complication in communication protocols referred to earlier.

Packet Switching

The description of the line protocol above is rather extended because this is the area we have spent most time studying so far, but we are also beginning to think about the packet structure and protocol and Host-Host protocols. All that can be positively stated at this stage is that we shall probably use the "D" format packet header as proposed by Pouzin and packets of 0-255 data bytes. Uniformity in computer networking standards is something which we feel to be important and this is one reason for preferring the D format, but another is that it is one of the few that provide adequate address space for inter-network communication. As has already been stated, our network cannot be entirely homogeneous, and it is quite probable that we shall have to connect to a number of existing networks. Indeed we plan to do this in the case of some existing networks in Western Europe.

Host-Host and Higher Level Protocols

Our present timetable includes the development of a Host-Host protocol, but unlike the lower levels we are at last faced with contact with the end users. Since we plan to participate in inter-networking, it is clear that we cannot develop such a protocol in isolation. We may then consider ourselves obliged to adopt an international standard if one then exists, or whatever is being widely used on the networks that we wish to connect to. It might be feasible to adopt a subset or to ensure a sufficient intersection, but it is clearly highly desirable to support standardization in this area, while at the same time keeping

enough room for experiment bearing in mind our goal of reducing the volume of software needed to support communication.

As to higher level protocols, we expect to participate in the studies that are currently being made and hope to contribute new ideas especially where they assist in standardization and the widening of useful resources available over a network.

Development Timetable

A program of work has been drawn up for the period to the end of August 1976. It includes the development and implementation of communication protocols to the level of Host-Host communication between at least two centers. We have tried to distribute the development between the centers to avoid duplication as much as possible and to exploit the different areas of expertise available at each center. Inevitably though, some duplication cannot be avoided and is even desirable, in order that each center should understand the complete system. In particular, it would be wrong to maintain a complete dependence on IIASA, since staff members come and go and the same is true for IIASA projects. Further, it is very desirable that centers should establish working projects with one another, and in order to realize one of our principal goals, it is necessary for National centers to continue the growth of the network by connections to research institutes in their own countries. At the same time, IIASA will continue to take the initiative and we have recently proposed the formation of a Network Management Committee to unit and guide the growth of the network.

The timetable calls for the implementation and testing of the line protocol to be completed between IIASA and one or two centers by the end of January 1976. To this end the Czechoslovak center is proposing to bring its NORD 20 to IIASA from mid-November. This will materially assist the human communication and the solution of the development problems which inevitably occur at this stage of a network project. The experience which is gained at IIASA of its own limitations and local problems will make the connection to other centers a much smoother process.

Relation to Other Networks

As has been mentioned above we are very interested in the possibilities of connecting to other Research Networks. For some time we have been exploring the available opportunities and are considering connections to EIN, RPC in Italy and CYCLADES. That is not to say that we shall connect to all three with direct links, but are looking for ways of connecting to centers on these networks, especially those which are doing work of relevance to IIASA projects.

We are currently engaged in a joint feasibility study with Austria to consider Austrian participation in international networking. One possible outcome of this study, could be that Austria would decide to join EIN. In that case of course we should link to the Austrian node.

One goal that we have had for some time is to obtain a connection to the World Health Organization and the International Computing Center in Geneva. Unfortunately there are no plans at the moment for a computer network in Switzerland, so our only

route would appear to be via EIN and CYCLADES. Such a connection would lead to some interesting problems in Gateway development.

Exploitation

The uses that we shall make of our networking capability remain to be more fully explored but IIASA is in a unique position to function as a real user of international networks, in the sense that our research projects have a genuine need to get at sources of data and remote computing resources. This arises just because our work is of an international character and our staff have links with home institutions and need to be able to access their home computers and data-bases which they know well. In the short periods that some scientists spend here, it is unrealistic to expect them to learn a whole new operating system, languages and system peculiarities. In any event their files and data are at home and not at IIASA.

It follows that IIASA has an important contribution to make to international computer networking especially in the scientific research area. It is able to provide existing and developing networks with grist for their mill, where previously they have only been used as tools for research upon themselves. It is probably time for the individual networks projects, at least throughout Europe, to unite their efforts with potential users to establish international networking as a tool for data-communication in scientific research.

Research Areas

While we view our task primarily to be that of the provision of a needed facility, it is clear that many interesting questions

will arise in the course of our work and the network can function as a vehicle for some experiments in Data-communication. The areas which are of especial interest to us include:

- Accounting and network performance;
- Access to heterogeneous information systems;
- The problems of small systems and compatibility of existing operating systems with data communication demands;
- The provision of network services;
- The special problems of inter-networking.

Concerning fundamental research, a study is under way on adaptive job allocation in large computer networks. The methods are aimed at combining in one process job allocation, routing and flow control, and are based on the concept of so called "pay functions" for the performance of a job, which depend on response time.

A technique is being developed which will allow very quick calculation of network (packet switching, or channel switching) performance. The method is based on a step by step modeification of a computed network model from a very simple one to the desired one, and is constructed as an iterative process, which converges to the solution, representing the network performance.

One member of our group is making a detailed study of IIASA requirements in Information Systems and looking at ways of reconciling these with access to existing data-bases.

Inter-networking brings many new problems. Gateways between networks are a topic of intensive discussion, especially where different packet conventions, lengths, etc. and protocols are

in use. At IIASA we would support moves towards an international standard Host-Host protocol, accepting that in many cases a protocol translation will have to be performed and a one-one translation is much preferred to one-many translations. In our case at least we shall have to give a lot of thought to the questions of privacy and right of access and mechanisms will probably be included in Gateways to determine the right of passage.

Network services will need a lot of attention. More than most we shall have to consider methods of uniform job control and file access. We propose too, the provision of a Network Information Service, whose job it is to provide information about the Network, its resources and capabilities, the methods of use and the rules of procedure. Distributed processing is an area of special interest. One can imagine an assembly line technique in which messages are processed by one host and then dispatched to another for further processing and so on until a result is finally returned or delivered to its destination. In this way one could exploit the specialist capabilities of different systems to achieve some grand plan. Generally one thinks of such services as being provided by Hosts on the network and not by the network itself, but Gateways and protocol conventers are special cases of sequential network servers. It is important to see data-communication as a means of inter-process communication and all that this implies.

Conclusion

We recognize that we have an ambitious project but are constantly being suprised by the interest being shown and new

requests to participate. It is clear that at IIASA we are in a good position to unify networking developments and this fits well with the spirit of our charter.

It should be mentioned that during the past year a number of successful experiments have been made including communication tests with Moscow conducted by V. Dashko and with Budapest by P. Darvas. These experiments have paved the way to our present plans and shown the feasibility, at least in principal of the project.

During the latter part of this year we have been joined by W. Orchard-Hays from the USA and Y. Masunaga from Japan. Orchard-Hays has written a series of working papers on "User - Oriented Networks" and we expect these to have a strong influence on the provisions of our Network. Masunaga's experience in the computer network for the Tohoku District of Japan will be particularly valuable.

To all of these people and many others the authors are indebted for a lot of advice and ideas.

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