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INTERFACE MESSAGE PROCESSORS FOR THE ARPA COMPUTER NETWORK

QUARTERLY TECHNICAL REPORT NO. 7
1 July 1970 to 30 September 1970

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1. INTRODUCTION

This Quarterly Technical Report No. 7 describes several aspects of our technical progress on the ARPA Computer Network during the third quarter of 1970.

• During this period, we installed IMPs No. 10 and No. 11 at Lincoln Laboratories and Stanford University, commenced experimental testing with 230.4 kilobit/sec circuits in the test cell at BBN, and completed retrofits of new control panels and auto restart circuitry.

• We developed a new version of the operational IMP program (IMPSYS 24) for release in November 1970. The organization of the IMP program has been substantially changed from the previous operational program to allow a large number of modifications to be efficiently incorporated. This activity is described in Section 2.

• A primary development effort during this quarter has been directed toward the preliminary design of the terminal IMP. Initial logic design has been completed for a multi-line controller that will handle up to 64 asynchronous or synchronous terminal devices, and all standard codes and speeds. In addition, we have produced preliminary coding of the inner loop of the terminal IMP program. This effort is described in Section 3.

• The Network Control Center has now been in operation for over three months. This effort has progressed particularly smoothly. A mini-Host was constructed in the prototype IMP for use by Network Control Center personnel in obtaining hourly summaries of network performance. A sample of this summary information is presented in Section 4.

• We have continued to participate in discussions of Host protocol. Several modifications have been made to the IMP program to conform with the Host protocol. In addition, we formulated an alternate Host protocol scheme. This activity is described in Section 5.

2. IMP PROGRAM DEVELOPMENT

During this quarter, the operational IMP program was extensively revised. Revision was necessary to the efficient incorporation of many new system features and to modifications in the new version of the IMP Program (IMPSYS 24), scheduled for release in November.

New system features include a single line test message that each IMP transmits to its neighbors at half-second intervals. All routing, HELLO, and I HEARD YOU information is combined and transmitted in this single message. Previously, these three line test messages were transmitted separately. The quality of a given line is now measured by the number of line test messages which fail to get through on that line in a time interval of approximately one minute.

A remote crosspatching feature was incorporated to allow a selected interface or modem to be looped under control of the operational IMP program. This capability enables the Network Control Center to locate accurately the source of most field problems. IMP personnel can now isolate a faulty communication line, a faulty modem, and most hardware interface problems

directly from the Network Control Center. However, the on-site assistance of Honeywell or telephone company personnel is still required for subsequent diagnosis and repair.

The long-term timeout period was reduced from 15 minutes to one minute. This reduction involved careful attention to timing in each of the major system routines to insure that the sequence of time-out mechanisms involving one or more IMPs would be executed in the proper order.

Approximately a hundred minor revisions have been made to the IMP program. For example: 1) partially reassembled messages are now discarded when their source goes dead; 2) the Host can no longer use all the IMP's buffers by causing error messages to be generated but not accepting them; 3) an IMP may be induced to reload from a specific line instead of a random line; 4) the IMP number is not changed when an IMP is reloaded with its memory protect switch in the off position; 5) the Host routines may be put in a hardware test mode by the control center to facilitate Host debugging; 6) all phone lines are initialized to be down rather than up.

3. TERMINAL IMP

We have begun to work on the design of a terminal IMP that will serve the dual function of an IMP and a terminal device handler. It will provide a capability for direct connection of terminals into the net. Specifically, the terminals need not be connected to a Host computer; but, rather, they may access any remote Host computer via the terminal IMP and the network.

A brief description of our initial design for the terminal IMP and its device handling capabilities, as presently envisioned, is given below. Built into the terminal IMP will be a multi-line controller capable of handling up to 64 terminal devices. The controller provides all of the logic for assembly and disassembly of characters and for transferring characters into and out of the IMP's memory. Both synchronous and asynchronous lines can be handled, the practical distinction being whether or not the controller must provide the clocking signal. All input characters must be of "asynchronous format" in that both start and stop bits are required by the terminal IMP. Output characters will also be provided in "asynchronous format" to each terminal on either synchronous or asynchronous connections. Character sizes of from five to eight bits can be

handled. The program will be able to set both the character size and speed for each device, thus enabling the program to determine the type of terminal connection and permitting a number of options, such as a dial-up capability, to be provided.

A terminal device may be operated on input or output at speeds up to and including 19.2 kilobits/sec. However, no more than 10 devices may have speeds exceeding 2400 bits/second; the remaining devices must all be operated at speeds of 2400 bits/second or less. The overall bandwidth of the terminal IMP for combined input and output is limited by the program's capability to process characters. Present estimates are that the terminal handling bandwidth will be about 100 kilobits/second.

The interface to the terminals will conform to the RS232 standard. A terminal device may be directly connected to the multi-line controller or a device may be remotely connected via a modem. Several standard modem types will be available on cards that can be housed in the terminal IMP enclosure.

We have begun preliminary work on the program design for the terminal IMP. Our initial estimates, based on the Honeywell H-316, indicate that the inner loops of both the input and output sections require about 50 cycles to process a

character. The central task on output is to handle the transfer of packed characters from a single buffer one at a time out a multiplexed DMC channel. The central task on input is to pack input characters and to monitor the input for mode changes. The programs must also provide echoing, do character conversion if needed, and must process user-specified information such as the message destination.

4. NETWORK CONTROL CENTER

During the last quarter, the Network Control Center (NCC) maintained the ARPA Network, scheduled time as appropriate for network maintenance and testing, and coordinated activities among Honeywell, the telephone company, and the sites.

A standard procedure was developed for site personnel to report trouble or repairs directly to the control center. In most instances, requests for use of the IMP to perform maintenance or testing have been easily coordinated through the control center. At any given time, the NCC has fairly complete knowledge of the current and expected state of the network, and as such is usually able to deal straightforwardly with most problems that arise.

Status information on the lines and IMPs in the net is printed on the IMP teletype at BBN as received from each IMP in the net. The NCC has been using this information as a standard reference for monitoring network status.

The Network Control Center has also implemented a program to provide hourly summaries of network performance. This program has led to a simplification in the procedures for monitoring the net, has improved upon the capabilities for detecting

status changes, and has provided a more convenient means of recording information. We plan to improve the capabilities of this program during the next quarter.

A sample of the summary output is illustrated below:

```
DAY 24

**********IMP STATUS**********

TIME      IMP SITES
          Ø1 Ø2 Ø3 Ø4 Ø5 Ø6 Ø7 Ø8 Ø9 1Ø 11 12
12ØØ       1  1  1  1  1  1  1  1  *  *  1  *

**********LINE STATES**********

TIME      NETWORK LINES
          Ø1 Ø2 Ø3 Ø4 Ø5 Ø6 Ø7 Ø8 Ø9 1Ø 11 12 13 14 15

12ØØ      1  1  1  1  1  1  1  1  1  1  1  1  1  1  1

**********LINE ERRORS**********

LINE      TOTALS *(+/-)*

Ø1        ØØØØ/ØØØØ
Ø2        ØØØØ/ØØØØ
Ø3        ØØØ1/ØØØØ
Ø4        ØØØØ/ØØØØ
Ø5        ØØØØ/ØØØØ
Ø6        ØØØØ/ØØØØ
Ø7        ØØØØ/ØØØØ
Ø8        ØØØ7/ØØØØ
Ø9        ØØØØ/ØØØ6
1Ø        ØØ33/ØØØØ
11        ØØØ6/ØØØØ
12        ØØØØ/ØØØØ
13        ØØØØ/ØØØØ
14        ØØØØ/ØØØØ
15        ØØØØ/ØØØØ
```

A mini-Host system was implemented in the prototype IMP in which this program and several other useful programs are run. The prototype IMP is currently connected to BBN's regular IMP. The operational IMP program at BBN has been temporarily patched so that all messages to BBN's teletype are copied and passed to the prototype. which in turn examines each received message and processes only the trouble reports.

Every hour on the hour, a summary report is printed showing: 1) the status of each IMP in the net at the beginning of the hour and each subsequent change in status; 2) similar status information for all lines in the net; and 3) a cumulative sum of line errors for each line during the hour.

In the current version of the program, an IMP is said to be up only if a status report has been received from the IMP within the last 20 minutes. A line is said to be up if the IMPs at both ends of the line report it to be up.

5. HOST PROTOCOL

Two new control message types, *cease sent* and *retract cease*, were added to the IMP/Host Protocol to conform with the Host-to-Host Protocol. The *cease sent* is presented to the Host whenever a cease on link RFNM is constructed. The *retract cease* message negates the effect of a cease message if it can.

To assist the Hosts in their debugging efforts, we have modified the IMP program to discard any Host messages sent on a blocked link. A *blocked link* error message is returned to the Host. Previously, the message was not discarded, and the Host line was hung for 15 minutes in this situation. One consequence of this change is that messages sent on blocked links from the real Host will be discarded to unblock the Host interface; messages sent on blocked links from a Fake Host will hang the Fake Host until the link is unblocked.

In Network Working Group 67 a change to the IMP program was proposed that would have resulted in the leader of a message being sent as a separate message before the text in all communication between the Host and its IMP. We believe that this change could have simplified the Host message handling procedures. Although this proposed change met with general approval, it

would have introduced a negative transient in some Host efforts to achieve timely use of the net. We are therefore no longer considering this change at this time.

A Host protocol document entitled "Interprocess Communication in a Resource Sharing Network" was generated by David Walden in an effort to provide some fresh insights into this area. The scheme described in this document is philosophically different from the Protocol currently under implementation for the ARPA Network.

In this protocol scheme, connections are non-permanent entities that are established each time a message is communicated between processes. Each message carries a complete set of identification information, including the receive and send socket pair. A rendezvous scheme, that permits dynamic reconnection to occur, is an intrinsic part of the basic communication procedure. Although this scheme is not suitable for incorporation with the current protocol implementation for the ARPA Network, it is a document worthy of study for possible application to future protocol efforts.

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13 ABSTRACT

The basic function of the IMP computer network is to allow large existing time-shared (Host) computers with different system configurations to communicate with each other. Each IMP (Interface Message Processor) computer accepts messages for its Host from other Host computers and transmits messages from its Host to other Hosts. Since there will not always be a direct link between two Hosts that wish to communicate, individual IMPs will, from time to time, perform the function of transferring a message between Hosts that are not directly connected. This then leads to the two basic IMP configurations -- interfacing between Host computers and acting as a message switcher in the IMP network. The message switching is performed as a store and forward operation. Each IMP adapts its message routine to the condition of those portions of the IMP network to which it is connected. IMPs regularly measure network performance and report in special messages to the network measurement center. Provision of a tracing capability permits the net operation to be studied comprehensively. An automatic trouble reporting capability detects a variety of network difficulties and reports them to an interested Host. An IMP can throw away packets that it has received but not yet acknowledged, transmitting packets to other IMPs at its own discretion. Self-contained network operation is designed to protect and deliver messages from the source Host to the destination IMP.

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