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Introduction

   The software for the ARPA Network exists partly in the IMPs and
   partly in the respective HOSTs. BB&N has specified the software of
   the IMPs and it is the responsibility of the HOST groups to agree on
   HOST software.

   During the summer of 1968, representatives from the initial four
   sites met several times to discuss the HOST software and initial
   experiments on the network. There emerged from these meetings a
   working group of three, Steve Carr from Utah, Jeff Rulifson from SRI,
   and Steve Crocker of UCLA, who met during the fall and winter. The
   most recent meeting was in the last week of March in Utah. Also
   present was Bill Duvall of SRI who has recently started working with
   Jeff Rulifson.

   Somewhat independently, Gerard DeLoche of UCLA has been working on
   the HOST-IMP interface.

   I present here some of the tentative agreements reached and some of
   the open questions encountered. Very little of what is here is firm
   and reactions are expected.

I.   A Summary of the IMP Software

Messages

   Information is transmitted from HOST to HOST in bundles called
   messages. A message is any stream of not more than 8080 bits,
   together with its header. The header is 16 bits and contains the
   following information:

             Destination   5 bits
             Link   8 bits
             Trace   1 bit
             Spare   2 bits

   The destination is the numerical code for the HOST to which the
   message should be sent. The trace bit signals the IMPs to record
   status information about the message and send the information back to
   the NMC (Network Measurement Center, i.e., UCLA). The spare bits are
   unused.

Links

   The link field is a special device used by the IMPs to limit certain
   kinds of congestion. They function as follows. Between every pair of
   HOSTs there are 32 logical full-duplex connections over which messages
   may be passed in either direction. The IMPs place the restriction on
   these links that no HOST can send two successive messages over the
   same link before the IMP at the destination has sent back a special
   message called an RFNM (Request for Next Message). This arrangement
   limits the congestion one HOST can cause another if the sending HOST
   is attempting to send too much over one link. We note, however, that
   since the IMP at the destination does not have enough capacity to
   handle all 32 links simultaneously, the links serve their purpose only
   if the overload is coming from one or two links. It is necessary for
   the HOSTs to cooperate in this respect.

   The links have the following primitive characteristics. They are
   always functioning and there are always 32 of them.

   By "always functioning," we mean that the IMPs are always prepared to
   transmit another message over them. No notion of beginning or ending
   a conversation is contained in the IMP software. It is thus not
   possible to query an IMP about the state of a link (although it might
   be possible to query an IMP about the recent history of a link --
   quite a different matter!).

   The other primitive characteristic of the links is that there are
   always 32 of them, whether they are in use or not. This means that
   each IMP must maintain 18 tables, each with 32 entries, regardless of
   the actual traffic.

   The objections to the link structure notwithstanding, the links are
   easily programmed within the IMPs and are probably a better
   alternative to more complex arrangements just because of their
   simplicity.

IMP Transmission and Error Checking

   After receiving a message from a HOST, an IMP partitions the message
   into one or more packets. Packets are not more than 1010 bits long
   and are the unit of data transmission from IMP to IMP. A 24 bit
   cyclic checksum is computed by the transmission hardware and is
   appended to an outgoing packet. The checksum is recomputed by the
   receiving hardware and is checked against the transmitted checksum.
   Packets are reassembled into messages at the destination IMP.

Open Questions on the IMP Software

1. An 8 bit field is provided for link specification, but only 32 links are provided, why?

2. The HOST is supposed to be able to send messages to its IMP. How does it do this?

3. Can a HOST, as opposed to its IMP, control RFNMs?

4. Will the IMPs perform code conversion? How is it to be controlled?

II. Some Requirements Upon the Host-to-Host Software

Simple Use

As with any new facility, there will be a period of very light usage until the community of users experiments with the network and begins to depend upon it. One of our goals must be to stimulate the immediate and easy use by a wide class of users. With this goal, it seems natural to provide the ability to use any remote HOST as if it had been dialed up from a TTY (teletype) terminal. Additionally, we would like some ability to transmit a file in a somewhat different manner perhaps than simulating a teletype.

Deep Use

One of the inherent problems in the network is the fact that all responses from a remote HOST will require on the order of a half-second or so, no matter how simple. For teletype use, we could shift to a half-duplex local-echo arrangement, but this would destroy some of the usefulness of the network. The 940 Systems, for example, have a very specialized echo.

When we consider using graphics stations or other sophisticated terminals under the control of a remote HOST, the problem becomes more severe. We must look for some method which allows us to use our most sophisticated equipment as much as possible as if we were connected directly to the remote computer.

Error Checking

The point is made by Jeff Rulifson at SRI that error checking at major software interfaces is always a good thing. He points to some experience at SRI where it has saved much dispute and wasted effort. On these grounds, we would like to see some HOST to HOST checking. Besides checking the software interface, it would also check the HOST-IMP transmission hardware. (BB&N claims the HOST-IMP hardware will be as reliable as the internal registers of the HOST. We believe

them, but we still want the error checking.)

III.   The Host Software

Establishment of a Connection

   The simplest connection we can imagine is where the local HOST acts as
   if it is a TTY and has dialed up the remote HOST. After some
   consideration of the problems of initiating and terminating such a
   connection , it has been decided to reserve link 0 for communication
   between HOST operating systems. The remaining 31 links are thus to be
   used as dial-up lines.

   Each HOST operating system must provide to its user level programs a
   primitive to establish a connection with a remote HOST and a primitive
   to break the connection. When these primitives are invoked, the
   operating system must select a free link and send a message over link
   0 to the remote HOST requesting a connection on the selected link.
   The operating system in the remote HOST must agree and send back an
   accepting message over link 0. In the event both HOSTs select the same
   link to initiate a connection and both send request messages at
   essentially the same time, a simple priority scheme will be invoked in
   which the HOST of lower priority gives way and selects another free
   link. One usable priority scheme is simply the ranking of HOSTS
   by their identification numbers. Note that both HOSTs are aware that
   simultaneous requests have been made, but they take complementary
   actions: The higher priority HOST disregards the request while the
   lower priority HOST sends both an acceptance and another request.

   The connection so established is a TTY-like connection in the
   pre-log-in state. This means the remote HOST operating system will
   initially treat the link as if a TTY had just called up. The remote
   HOST will generate the same echos, expect the same log-in sequence and
   look for the same interrupt characters.

High Volume Transmission

   Teletypes acting as terminals have two special drawbacks when we
   consider the transmission of a large file. The first is that some
   characters are special interrupt characters. The second is that
   special buffering techniques are often employed, and these are
   appropriate only for low-speed character at time transmission.

   We therefore define another class of connection to be used for the
   transmission of files or other large volumes of data. To initiate
   this class of link, user level programs at both ends of an established
   TTY-like link must request the establishment of a file-like connection
   parallel to the TTY-like link. Again the priority scheme comes into

play, for the higher priority HOST sends a message over link 0 while
the lower priority HOST waits for it. The user level programs are, of
course, not concerned with this. Selection of the free link is done
by the higher priority HOST.

File-like links are distinguished by the fact that no searching for
interrupt characters takes place and buffering techniques appropriate
for the higher data rates takes place.

A Summary of Primitives

Each HOST operating systems must provide at least the following
primitives to its users. This list knows not to be necessary but not
sufficient.

a) Initiate TTY-like connection with HOST x.

b) Terminate connection.

c) Send/Receive character(s) over TTY-like connection.

d) Initiate file-like connection parallel to TTY-like connection.

e) Terminate file-like connection.

f) Send/Receive over file-like connection.

Error Checking

We propose that each message carry a message number, bit count, and a
checksum in its body, that is transparent to the IMP. For a checksum
we suggest a 16-bit end-around-carry sum computed on 1152 bits and
then circularly shifted right one bit. The right circular shift every
1152 bits is designed to catch errors in message reassembly by the IMPs.

Closer Interaction

The above described primitives suggest how a user can make simple use
of a remote facility. They shed no light on how much more intricate
use of the network is to be carried out. Specifically, we are
concerned with the fact that as some sites a great deal of work has
gone into making the computer highly responsive to a sophisticated
console. Culler's consoles at UCSB and Englebart's at SRI are at
least two examples. It is clear that delays of a half-second or so
for trivial echo-like responses degrade the interaction to the point
of making the sophistication of the console irrelevant.

We believe that most console interaction can be divided into two

parts, an essentially local, immediate and trivial part and a remote,
more lengthy and significant part. As a simple example, consider a
user at a console consisting of a keyboard and refreshing display
screen. The program the user is talking typing into accumulates a
string of characters until a carriage return is encountered and then
it processes the string. While characters are being typed, it
displays the characters on the screen. When a rubout character is
typed, it deletes the previous non-rubout character. If the user
types H E L L O <- <- P <CR> where <- is rubout and <CR> is
carriage-return, he has made nine keystrokes. If each of these
keystrokes causes a message to be sent which in return invokes
instructions to our display station we will quickly become bored.

A better solution would be to have the front-end of the remote program
-- that is the part scanning for <- and <CR> -- be resident in our
computer. In that case, only one five character message would be
sent, i.e., H E L P <CR>, and the screen would be managed locally.

We propose to implement this solution by creating a language for
console control. This language, current named DEL, would be used by
subsystem designers to specify what components are needed in a
terminal and how the terminal is to respond to inputs from its
keyboard, Lincoln Wand, etc. Then, as a part of the initial protocol,
the remote HOST would send to the local HOST, the source language text
of the program which controls the console. This program would have
been by the subsystem designer in DEL, but will be compiled locally.

The specifications of DEL are under discussion. The following
diagrams show the sequence of actions.

A. Before Link Establishment

```
     /              +----------+              +----------+      \
     |              |          |              |          |      |
     |              | terminal |              | terminal |      |
     |              |          |              |          |      |
     |              +-----+----+              +-----+----+      |
     |                    |                         |           |
     |                    |                         |           |
     |              +-----+----+              +-----+----+      |
UCLA {              |          | Request connection |     |      } SRI
     |              |          | -> over link 25    |     |      |
     |              +-+-+      +-+               +-+ +-+-+       |
     |              | OS|---+-=|I|----------|I|=-+---| OS|       |
     |              +-+-+      +-+               +-+ +---+       |
     |              |          |                    |     |      |
     |              |          |                    |     |      |
     |              +----------+              +----------+      |
     |                 HOST: UCLA                HOST: SRI      |
      \                                                        /
```
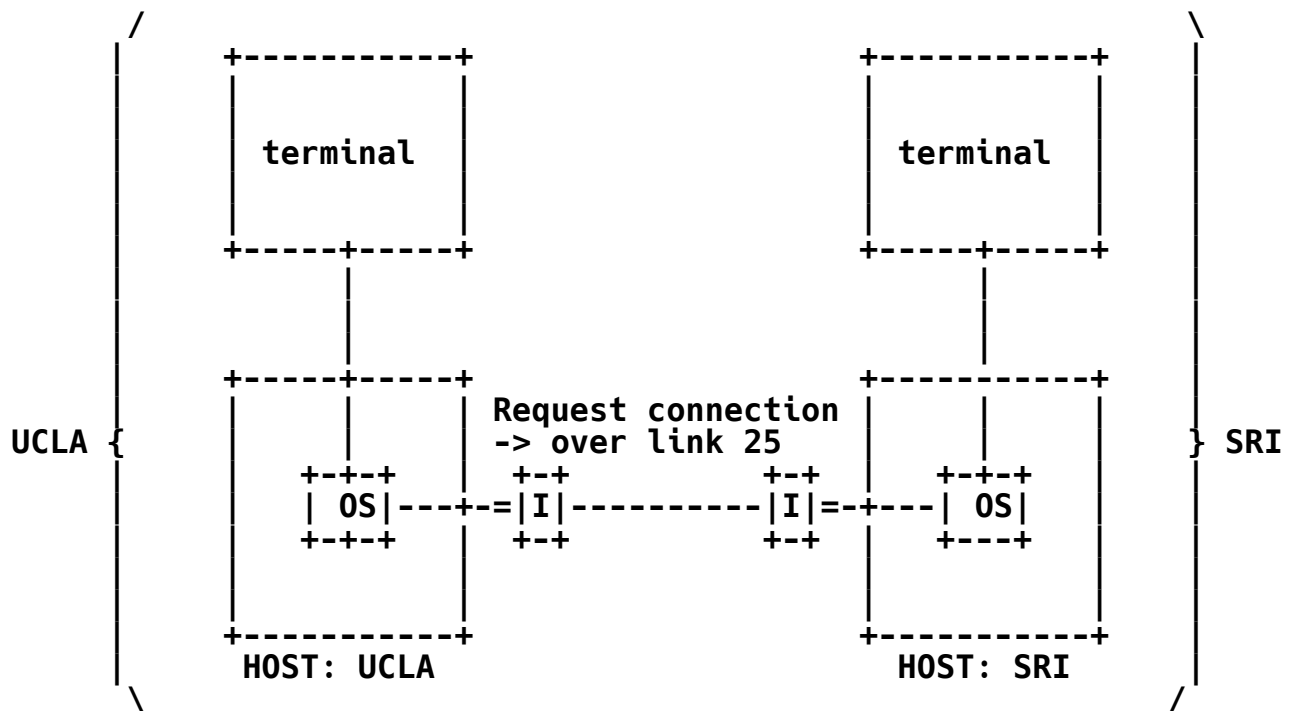
b. After Link Establishment and Log-in

```
      /                                                          \
      |     +----------+                      +----------+       |
      |     |          |                      |          |       |
      |     | terminal |                      | terminal |       |
      |     |          |                      |          |       |
      |     +-----+----+                      +-----+----+       |
      |           |                                 |            |
      |           |                                 |            |
      |     +-----+----+ "Please send front"+----------+        |
      |     |          |  end control"      |          |        |
UCLA {|     |          |      ->            |          |        } SRI ___
      |     |    +-+-+  |       +-+    +-+   |  +--+---+ |        |    /___|
      |     |    | OS|--+-=|I|----------|I|=-+--|OS|NLS| +----+---|   |   /
      |     |    +-+-+  |       +-+    +-+   |  +------+ |        |   |__/ |
      |     |          |     DEL prog.      |          |        |   |____|
      |     |          |        <-          |          |        |
      |     +----------+                    +----------+        |
      |      HOST: UCLA                      HOST:SRI           |
      \                                                         /
```
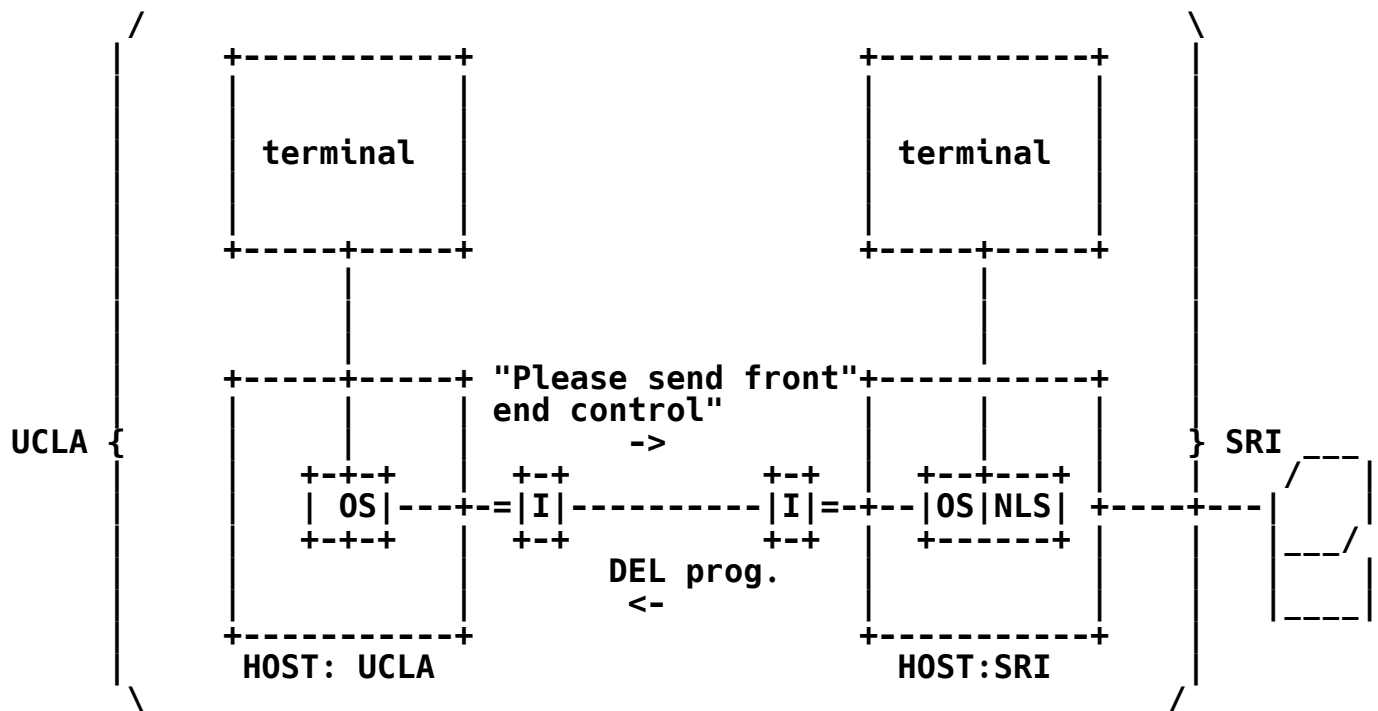
c. After Receipt and Compilation of the DEL program

```
       /              +-----------+              +-----------+      \
       |              |           |              |           |      |
       |              |           |              |           |      |
       |              | terminal  |              | terminal  |      |
       |              |           |              |           |      |
       |              +-----+-----+              +-----+-----+      |
       |                    |Trivial                   |           |
       |                    |Responses                 |           |
       |              +-----+------+             +-----------+      |
 UCLA {              |            | Major Responses  |    |    |   } SRI ___
       |             +--+--+      +-+          +-+  +--+---+   |      /___|
       |             |DEL  |---+-=|I|----------|I|=-+--|OS|NLS| +---+---|    |
       |             |front|      +-+          +-+     +------+   |    |___/|
       |             | end |                                     |    |____|
       |             |prog.|                                     |
       |             +-----+                                     |
       |             | OS  |                                     |
       |             +-----+                                     |
       |              |           |              |           |   |
       |              +-----------+              +-----------+   |
       |                 HOST: UCLA                 HOST: SRI    |
       \                                                        /
```
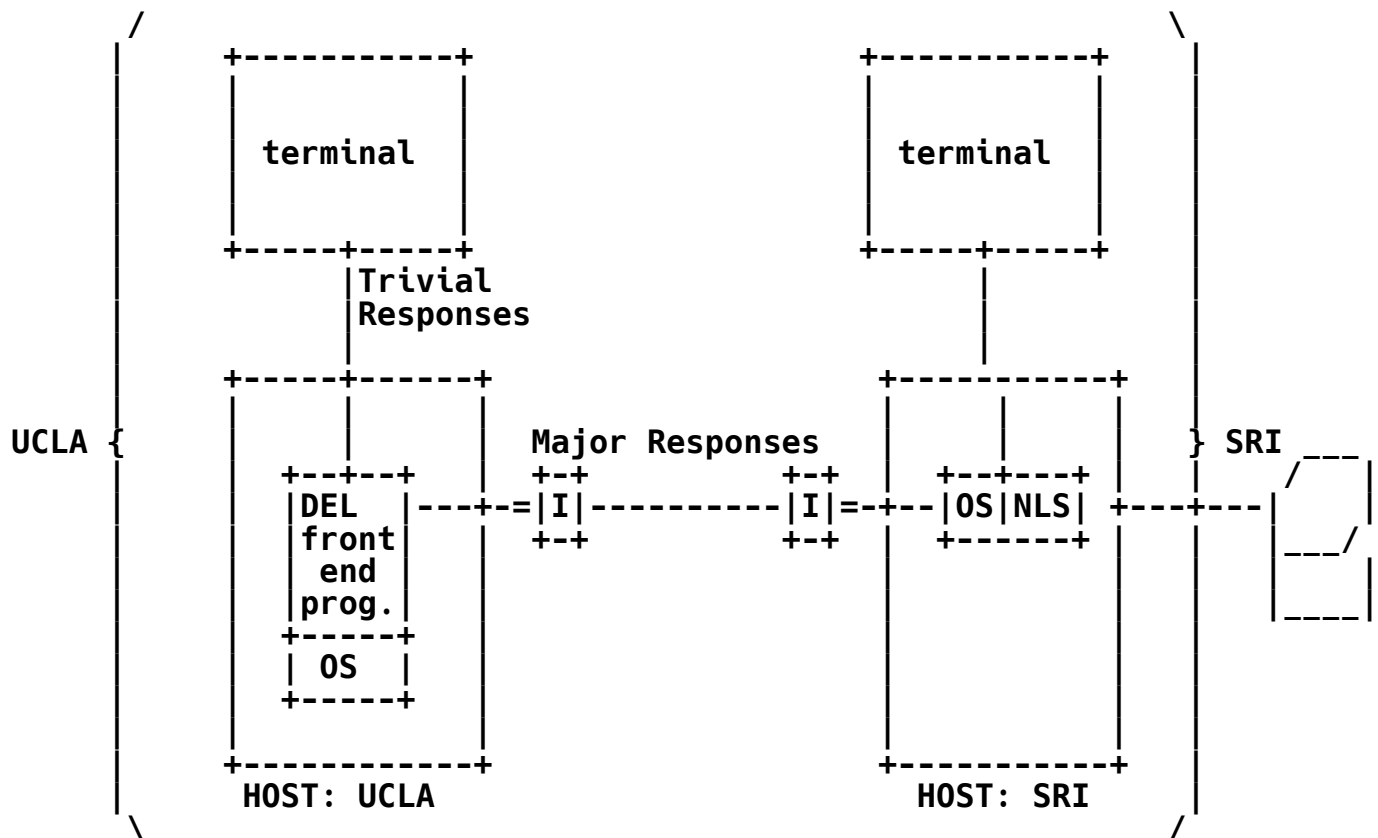
Open Questions

   1. If the IMPs do code conversion, the checksum will not be correct.

   2. The procedure for requesting the DEL front end is not yet
   specified.

IV. Initial Experiments

Experiment One

   SRI is currently modifying their on-line retrieval system which will
   be the major software component on the Network Documentation Center so
   that it can be operated with model 35 teletypes. The control of the
   teletypes will be written in DEL. All sites will write DEL compilers
   and use NLS through the DEL program.

Experiment Two

   SRI will write a DEL front end for full NLS, graphics included. UCLA
   and UTAH will use NLS with graphics.

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