7147

July '71

Host/Host Protocol for the ARPA Network

I. INTRODUCTION

This document specifies a protocol for use in communication between Host computers on the ARPA Network. In particular, it provides for connection of independent processes in different Hosts, control of the flow of data over established connections, and several ancillary functions.

The ARPA Network provides a capability for geographically separated computers, called *Hosts*, to communicate with each other. The Host computers typically differ from one another in type, speed, word length, operating system, etc. Each Host computer is connected into the network through a local small computer called an *Interface Message Processor (IMP)*. The complete network is formed by interconnecting these IMPs, all of which are virtually identical, through wideband communications lines supplied by the telephone company. Each IMP is programmed to store and forward messages to the neighboring IMPs in the network. During a typical operation, a Host passes a message to its local IMP; the first 32 bits of this message include the "network address" of a destination Host. The message is passed from IMP to IMP through the Network until it finally arrives at the destination IMP, which in turn passes it along to the destination Host.

Specifications for the physical and logical message transfer between a Host and its local IMP are contained in Bolt Beranek and Newman (BBN) Report No. 1822. These specifications are generally called the *first level protocol* or Host/IMP Protocol. This protocol is not by itself, however, sufficient to specify meaningful communication between processes running in two dissimilar Hosts. Rather, the processes must have some agreement as to the method of initiating communication, the interpretation of transmitted data, and so forth. Although it would be possible for such agreements to be reached by each pair of Hosts (or processes) interested in communication, a more general arrangement is desirable in order to minimize the amount of implementation necessary for Network-wide communication. Accordingly, the Host organizations formed a Network Working Group (NWG) to facilitate an exchange of ideas and to formulate additional specifications for Host-to-Host communications.

The NWG has adopted a "layered" approach to the specification of communications protocol. The inner layer is the Host/IMP protocol. The next layer specifies methods of establishing communications paths, managing buffer space at each end of a communications path, and providing a method of "interrupting" a communications path. This protocol, which will be used by all higher-level protocols, is known as the *second level protocol*. Examples of further layers of protocol currently developed or anticipated include:

1) An *Initial Connection Protocol* (ICP) which can be used by many, perhaps most, processes to gain access to specific processes (such as the "logger") at another Host.

2) A *Telecommunication Network* (TELNET) protocol which provides for the "mapping" of an arbitrary keyboard-printer terminal into a Network Virtual Terminal (NVT), to facilitate communication between a terminal user at one Host site and a terminal-serving process at some other site which "expects" to be connected to a (local) terminal logically different from the (remote) terminal actually in use. It is anticipated that the TELNET protocol will specify use of the ICP to establish the communication path between the terminal user and the terminal-service process.

3) A *Data Transfer* protocol to specify standard methods of formatting data for shipment through the network.

4) A *File Transfer* protocol to specify methods for reading, writing, and updating files stored at a remote Host. The File Transfer protocol will probably specify that the actual transmission of data should be performed in accordance with the Data Transfer protocol.

5) A *Graphics* protocol to specify the means for exchanging graphics display information.

The remainder of this document describes and specifies the Host/Host, or second level, protocol as formulated by the Network Working Group. Inquiries about the protocol should be addressed to:

Steve Crocker
Advanced Research Projects Agency
1400 Wilson Boulevard
Arlington, Virginia 22209

Telephone: (202) 694-5921 or 5922

II. COMMUNICATION CONCEPTS

The IMP sub-network imposes a number of physical restrictions on communications between Hosts; these restrictions are presented in BBN Report Number 1822. In particular, the concepts of leaders, messages, padding, links, and message types are of interest to the design of Host/Host protocol. The following discussion assumes that the reader is familiar with these concepts.

Although there is little uniformity among the Hosts in either hardware or operating systems, the notion of multiprogramming dominates most of the systems. These Hosts can each concurrently support several users, with each user running one or more processes. Many of these processes may want to use the network concurrently, and thus a fundamental requirement of the Host/Host protocol is to provide for process-to-process communication over the network. Since the first level protocol only takes cognizance of Hosts, and since the several processes in execution within a Host are usually independent, it is necessary for the second level protocol to provide a richer addressing structure.

Another factor which influenced the Host/Host protocol design is the expectation that typical process-to-process communication will be based, not on a solitary message, but rather upon a sequence of messages. One example is the sending of a large body of information, such as a data base, from one process to another. Another example is an interactive conversation between two processes with many exchanges.

These considerations led to the introduction of the notions of connections, a Network Control Program, a "control link", "control commands", connection byte size, message headers, and sockets.

A *connection* is an extension of a link. A connection couples two processes so that output from one process is input to the other. Connections are defined to be simplex (i.e., uni-directional), so two connections are necessary if a pair of processes are to converse in both directions.

Processes within a Host are envisioned as communicating with the rest of the network through a *Network Control Program* (NCP), resident in that Host, which implements the second level protocol. The primary function of the NCP is to establish connections, break connections, and control data flow over the connections. We will describe the NCP as though it were part of the operating system of a Host supporting multiprogramming, although the actual method of implementing the NCP may be different in some Hosts.

In order to accomplish its tasks, the NCP of one Host must communicate with the NCPs of other Hosts. To this end, a particular link between each pair of Hosts has been designated as the *control link*. Messages transmitted over the control link are called *control messages*,* and must always be interpreted by an NCP as a

*Note that in BBN Report Number 1822, messages of non-zero type are called control messages, and are used to control the flow of information between a Host and its IMP. In this document, the term "control message" is used for a message of type zero transmitted over the control link. The IMPs take no special notice of these messages.

sequence of one or more *control commands*. For example, one kind of control command is used to initiate a connection, while another kind carries notification that a connection has been terminated.

The concept of a message, as used above, is an artifact of the IMP sub-network; network message boundaries may have little intrinsic meaning to communicating processes.* Accordingly, it has been decided that the NCP (rather than each transmitting process) should be responsible for segmenting interprocess communication into network messages. Therefore, it is a principal of the second level protocol that no significance may be inferred from message boundaries by a receiving process. *The only exception to this principle is in control messages, each of which must contain an integral number of control commands.*

*To review the Host/IMP protocol briefly, a message is to consist of not more than 8096 bits of data (including 32 bits of leader and at least 1 bit of source padding) and is transmitted over a specific link. The link is specified by the source Host, and is defined by the source Host's address, the destination Host's address, an additional 8-bit number called the link number, and a transmission direction. Of these four quantities, only the destination address and the link number are <u>explicitly</u> specified by the source Host. The IMP will refuse additional messages over this link until the message has been delivered to the destination, at which point the source Host is notified by a message of type five (RFNM - Ready for Next Message) from its IMP. The message size limitation insures that the IMP sub-network need accept only as much data as it can reasonably store during store-and-forward operations. The right to refuse messages over links "in use" gives the sub-network some ability to prevent congestion problems which might otherwise arise. These considerations, although of great importance to the correct operation of the network, are of no particular interest to processes within Hosts.

Since message boundaries are selected by the transmitting NCP, the receiving NCP must be prepared to concatenate successive messages from the network into a single (or differently divided) transmission for delivery to the receiving process. The fact that Hosts have differing word sizes means that a message from the network might end in the middle of a word at the receiving end and thus, to concatenate the next message, extensive bit-shifting might be required. Because bit-shifting is typically very costly in terms of computer processing time, the protocol includes the notions of connection byte size and message headers.

As part of the process of establishing a connection, the processes involved must agree on a *connection byte size*. Each message sent over the connection must then contain an integral number of bytes of this size. Thus the pair of processes involved in a connection can choose a mutually convenient byte size, for example, the least common multiple of their Host word lengths. It is important to note that the ability to choose a byte size <u>must</u> be available to the processes involved in the connection; an NCP is prohibited from imposing an arbitrary byte size on any process running in its own Host. In particular, an outer layer of protocol may specify a byte size to be used by that protocol. If some NCP is unable to handle that byte size, then the outer layer of protocol will not be implementable on that Host.

The IMP sub-network requires that the first 32 bits of each message (called the leader) contain addressing information, including destination Host address and link number. The second level protocol extends the required information at the beginning of each message to a total of 72 bits; these 72 bits are called the *message header*. A length of 72 bits is chosen since most Hosts either can work conveniently with 8-bit units of data or have word lengths of 18 or 36 bits; 72 is the least common multiple of these lengths. Thus, the length chosen for the message header should reduce bit-shifting problems for many Hosts. In addition to the leader, the message header includes a field giving the byte size used in the message, a field giving the number of bytes in the message, and "filler" fields. The format of the message header is fully described in Section III.

Another major concern of the second level protocol is a method for reference to processes in other Hosts. Each Host has some internal scheme for naming processes, but these various schemes are typically different and may even be incompatible. Since it is not practical to impose a common internal process naming scheme, a standard intermediate name space is used, with a separate portion of the name space allocated to each Host. Each Host must have the ability to map internal process identifiers into its portion of this name space.

The elements of the name space are called *sockets*. A socket forms one end of a connection, and a connection is fully specified by a pair of sockets. A socket is identified by a Host number and a 32-bit socket number. The same 32-bit number in different Hosts represents different sockets.

A socket is either a *receive socket* or a *send socket*, and is so marked by its low-order bit (0 = receive; 1 = send). This property is called the socket's *gender*. The sockets at either end of a connection must be of opposite gender. Except for the gender, second level protocol places no constraints on the assignment of socket numbers within a Host.

III. NCP FUNCTIONS

The functions of the NCP are to establish connections, terminate connections, control flow, transmit interrupts, and respond to test inquiries. These functions are explained in this section, and control commands are introduced as needed. In Section IV the formats of all control commands are presented together.

Connection Establishment

The commands used to establish a connection are STR (sender-to-receiver) and RTS (receiver-to-sender).

8*	32	32	8
STR	send socket	receive socket	size

8	32	32	8
RTS	receive socket	send socket	link

The STR command is sent from a prospective sender to a prospective receiver, and the RTS from a prospective receiver to a prospective sender. The send socket field names a socket local to the prospective sender; the receive socket field names a socket local to the prospective receiver. In the STR command, the "size" field contains an unsigned binary number (in the range 1 to 255; zero is prohibited) specifying the byte size to be used for all messages

*The number shown above each control command field is the length of that field in bits.

over the connection. In the RTS command, the "link" field specifies a link number; all messages over the connection must be sent over the link specified by this number. These two commands are referred to as requests-for-connection (RFCs). An STR and an RTS match if the receive socket fields match and the send socket fields match. A connection is established when a matching pair of RFCs have been exchanged. *Hosts are prohibited from establishing more than one connection to any local socket.*

With respect to a particular connection, the Host containing the send socket is called the *sending Host* and the Host containing the receive socket is called the *receiving Host*. A Host may connect one of its receive sockets to one of its send sockets, thus becoming both the sending Host and the receiving Host for that connection. These terms apply only to data flow; control messages will, in general, be transmitted in both directions.

A Host sends an RFC either to request a connection, or to accept a foreign Host's request. Since RFC commands are used both for requesting and for accepting the establishment of a connection, it is possible for either of two cooperating processes to initiate connection establishment. As a consequence, a family of processes may be created with connection-initiating actions built-in, and the processes within this family may be started up (in different Hosts) in arbitrary order.

There is no prescribed lifetime for an RFC. A Host is permitted to queue incoming RFCs and withhold a response for an arbitrarily long time, or, alternatively, to reject requests immediately if it does not have a matching RFC outstanding. It may be reasonable, for example, for an NCP to queue an RFC that refers to some currently unused socket until a local process takes control of that socket number and tells the NCP to accept or reject the request. Of course, the Host which sent the RFC may be unwilling to wait for an arbitrarily long time, so it may abort the request. On the other hand, some NCP implementations may not include any space for queueing RFCs, and thus can be expected to reject RFCs unless the RFC sequence was initiated locally.

Connection Termination

The command used to terminate a connection is CLS (close).

8	32	32
CLS	my socket	your socket

The "my socket" field contains the socket local to the sender of the CLS command. The "your socket" field contains the socket local to the receiver of the CLS command. *Each side must send and receive a CLS command before connection termination is completed and the sockets are free to participate in other connections.*

It is not necessary for a connection to be established (i.e., for both RFCs to be exchanged) before connection termination begins. For example, if a Host wishes to refuse a request for connection, it sends back a CLS instead of a matching RFC. The refusing Host then waits for the initiating Host to acknowledge the refusal by returning a CLS. Similarly, if a Host wishes to abort its outstanding request for a connection, it sends a CLS command. The foreign Host is obliged to acknowledge the CLS with its own CLS. Note that even though the connection was never established, CLS commands must be <u>exchanged</u> before the sockets are free for other use.

After a connection is established, CLS commands sent by the receiver and sender have slightly different effects. CLS commands sent by the sender indicate that no more messages will be sent over the connection. *This command must not be sent if there is a message in transit over the connection.* A CLS command sent by the receiver acts as a demand on the sender to terminate transmission. However, since there is a delay in getting the CLS command to the sender, the receiver must expect more input.

A Host should "quickly" acknowledge an incoming CLS so the foreign Host can purge its tables. However, *there is no prescribed time period in which a CLS must be acknowledged.*

Because the CLS command is used both to initiate closing, aborting and refusing a connection, and to acknowledge closing, aborting and refusing a connection, race conditions can occur. However, they do not lead to ambiguous or erroneous results, as illustrated in the following examples.

Example 1: Suppose that Host A sends Host B a request for connection, and then A sends a CLS to Host B because it is tired of waiting for a reply. However, just when A sends its CLS to B, B sends a CLS to A to refuse the connection. A will "believe" B is acknowledging the abort, and B will "believe" A is acknowledging its refusal, but the outcome will be correct.

Example 2: Suppose that Host A sends Host B an RFC followed by a CLS as in example 1. In this case, however, B sends a matching RFC to A just when A sends its CLS. Host A may "believe" that the RFC is an attempt (on the part of B) to establish a new connection or may understand the race condition; in either case it can discard the RFC since its socket is not yet free. Host B will "believe" that the CLS is breaking an established connection, but the outcome is correct since a matching CLS is the required response, and both A and B will then terminate the connection.

Flow Control

After a connection is established, the sending Host sends messages over the agreed-upon link to the receiving Host. The receiving NCP accepts messages from its IMP and queues them for its various processes. Since it may happen that the messages arrive faster than they can be processed, some mechanism is required which permits the receiving Host to quench the flow from the sending Host.

The flow control mechanism requires the receiving Host to allocate buffer space for each connection and to notify the sending Host of how much space is available. The sending Host keeps track of how much room is available and never sends more data than it believes the receiving Host can accept.

To implement this mechanism, the sending Host keeps two counters associated with each connection, a *message counter* and a *bit counter*. Each counter is initialized to zero when the connection is established and is increased by allocate (ALL) control commands sent from the receiving Host as described below. When sending a message, the NCP of the sending Host subtracts one from the message counter and the *text length* (defined below) from the bit counter. The sender is prohibited from sending if either counter would be decremented below zero. The sending Host may also return all or part of the message or bit space allocation with a return (RET) command; it may do this either spontaneously or upon receiving a give-back (GVB) command from the receiving Host (see below).

The *text length* of a message is defined as the product of the connection byte size and the byte count for the message; both of these quantities appear in the message header. Messages with a zero byte count, hence a zero text length,are specifically permitted. Messages with zero text length do not use bit space allocation, but do use message space allocation. The flow control mechanisms do not pertain to the control link, since connections are never explicitly established over this link.

The control command used to increase the sender's bit counter and message counter is ALL (allocate).

8	8	16	32
ALL	link	msg space	bit space

This command is sent only from the receiving Host to the sending Host, and is legal only when a connection using the link number appearing in the "link" field is established. The "msg space" field and the "bit space" field are defined to be unsigned binary integers specifying the amounts by which the sender's message counter and bit counter (respectively) are to be incremented. The receiver is prohibited from incrementing the sender's message counter above (2^{16}-1), or the sender's bit counter above (2^{32}-1). In general, this rule will require the receiver to maintain counters which are incremented and decremented according to the same rules as the sender's counters.

The receiving Host may request that the sending Host return all or part of its current allocation. The control command for this request is GVB (give-back).

8	8	8	8
GVB	link	f_m	f_b

This command is sent only from the receiving Host to the sending Host, and is legal only when a connection using the link number in the "link" field is established. The fields f_m and f_b are defined as the fraction (in 128ths) of the current message space allocation and bit space allocation (respectively) to be returned. If either of the fractions is equal to or greater than one, all of the corresponding allocation must be returned. Fractions are used since, with messages in transit, the sender and receiver may not agree on the actual allocation at every point in time.

Upon receiving a GVB command, the sending Host must return at least* the requested portions of the message and bit space allocations. A sending Host may also spontaneously return portions of the message and bit space allocations. The control command for performing this function is RET (return).

8	8	16	32
RET	link	msg space	bit space

This command is sent only from the sending Host to the receiving Host, and is legal only when a connection using the link number in the "link" field is established. The "msg space" field and the "bit space" field are defined as unsigned binary integers specifying the amounts by which the sender's message counter and bit counter (respectively) have been decremented due to the RET activity (i.e., the amounts of message and bit space allocation being returned). NCPs are obliged to answer a GVB with a RET "quickly"; however, there is no prescribed time period in which the answering RET must be sent.

*In particular, fractional returns must be rounded up, not truncated.

Some Hosts will allocate only as much space as they can guarantee for each link. These Hosts will tend to use the GVB command only to reclaim space which is being filled very slowly or not at all. Other Hosts will allocate more space than they have, so that they may use their space more efficiently. Such a Host will then need to use the GVB command when the input over a particular link comes faster than it is being processed.

Interrupts

The second level protocol has included a mechanism by which the transmission over a connection may be "interrupted." The meaning of the "interrupt" is not defined at this level, but is made available for use by outer layers of protocol. The interrupt command sent from the receiving Host to the sending Host is INR (interrupt-by-receiver).

8	8
INR	link

The interrupt command sent from the sending Host to the receiving Host is INS (interrupt-by-sender).

8	8
INS	link

The INR and INS commands are legal only when a connection using the link number in the "link" field is established.

Test Inquiry

At any time (regardless of RST/RRP status - - see below) a Host may send a test inquiry to any other Host. The control command to be used is ECO (echo).

8	8
ECO	data

The "data" field may contain any bit configuration chosen by the Host sending the ECO. Upon receiving an ECO command an NCP must respond by returning the data to the sender in an ERP (echo-reply) command.

8	8
ERP	data

There is no prescribed time period, after the receipt of an ECO, in which the ERP must be returned.

Reinitialization

Occasionally, due to lost control messages, system "crashes", NCP errors, or other factors, communication between two NCPs will be disrupted. One possible effect of any such disruption might be that neither of the involved NCPs could be sure that its stored information regarding connections with the other Host matched the information stored by the NCP of the other Host. In this situation, an NCP may wish to reinitialize its tables and request that the other Host do likewise; for this purpose the protocol provides the pair of control commands RST (reset) and RRP (reset-reply).

8

$\boxed{\text{RST}}$

8

$\boxed{\text{RRP}}$

The RST command is to be interpreted by the Host receiving it as a signal to purge its NCP tables of any entries which arose from communication with the Host which sent the RST. The Host sending the RST should likewise purge its NCP tables of any entries which arose from communication with the Host to which the RST was sent. The Host receiving the RST should acknowledge receipt by returning an RRP. *Once the first Host has sent an RST to the second Host, the first Host is not obliged to communicate with the second Host (except for responding to ECO or RST) until the second Host returns an RRP.* In fact, to avoid synchronization errors, the first Host should not communicate with the second until the RST is answered. Of course, if the IMP subnetwork returns a "Destination Dead" (type 7) message in response to the control message containing the RST, an RRP should not be expected. If both NCPs decide to send RSTs at approximately the same time, then each Host will receive an RST and each must answer with an RRP, even though its own RST has not yet been answered.

Some Hosts may choose to "broadcast" RSTs to the entire network when they "come up." One method of accomplishing this would be to send an RST command to each of the 256 possible Host addresses; the IMP subnetwork would return a "Destination Dead" (type 7) message for each non-existent Host, as well as for each Host actually "dead." *However, no Host is ever obliged to transmit an RST command.*

IV. DECLARATIVE SPECIFICATIONS

Message Format

All Host-to-Host messages (i.e., messages of type zero) shall have a header 72 bits long consisting of the following fields (see Figure 1):

Bits 1-32	Leader - The contents of this field must be constructed according to the specifications contained in BBN Report Number 1822.
Bits 33-40	Field M_1 - Must be zero.
Bits 41-48	Field S - Connection byte size. This size must be identical to the byte size in the STR used in establishing the connection. If this message is being transmitted over the control link the connection byte size must be 8.
Bits 49-64	Field C - Byte Count. This field specifies the number of bytes in the text portion of the message. A zero value in the C field is explicitly permitted.
Bits 65-72	Field M_2 - Must be zero.

Following the header, the message shall consist of a text field of C bytes, where each byte is S bits in length. Following the text there will be field M_3 followed by padding. The M_3 field is zero

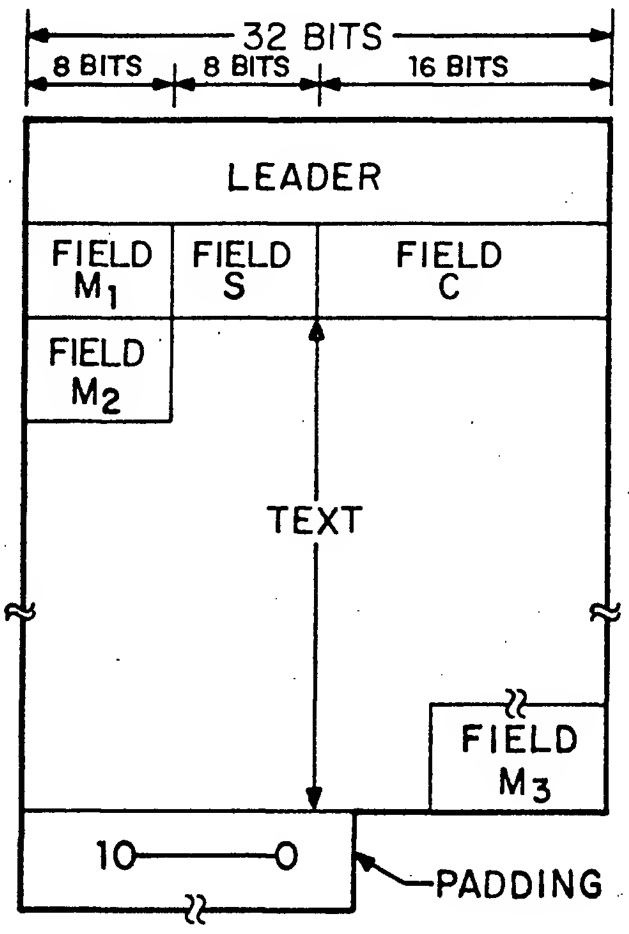


FIG.1 MESSAGE FORMAT

or more bits long and must be all zero; this field may be used to fill out a message to a word boundary.

The message header must, among other things, enable the NCP at the receiving Host to identify correctly the connection over which the message was sent. Given a set of messages from Host A to Host B, the only field in the header under the control of the NCP at Host B is the link number (assigned via the RTS control command). Therefore, each NCP must insure that, at a given point in time, for each connection for which it is the receiver, a unique link is assigned. Recall that the link is specified by the sender's address and the link number; thus a unique link number must be assigned to each connection to a given Host.

Link Assignment

Links are assigned as follows:

Link number	Assignment
0	Control link
2-71	Available for connections
1, 72-190	Reserved - not for current use
191	To be used only for measurement work under the direction of the Network Measurement Center at UCLA
192-255	Available for private experimental use.

Control Messages

Messages sent over the control link have the same format as other Host-to-Host messages. The connection byte size (Field S in the message header) must be 8. Control messages may not contain more than 120 bytes of text; thus the value of the byte count (Field C in the message header) must be less than or equal to 120.

Control messages must contain an integral number of control commands. A single control command may not be split into parts which are transmitted in different control messages.

Control Commands

Each control command begins with an 8-bit *opcode*. These opcodes have values of Ø, 1, ... to permit table lookup upon receipt. Private experimental protocols should be tested using opcodes of 255, 254, ... Most of the control commands are more fully explained in Section III.

NOP - No operation

$$\overset{8}{\boxed{\text{NOP}}}$$

The NOP command may be sent at any time and should be discarded by the receiver. It may be useful for formatting control messages.

RST - Reset

8
RST

The RST command is used by one Host to inform another that all information regarding previously existing connections, including partially terminated connections, between the two Hosts should be purged from the NCP tables of the Host receiving the RST. Except for responding to ECOs and RSTs, the Host which sent the RST is not obliged to communicate further with the other Host until an RRP is received in response.

RRP - Reset reply

8
RRP

The RRP command must be sent in reply to an RST command.

RTS - Request connection, receiver to sender

8	32	32	8
RTS	receive socket	send socket	link

The RTS command is used to establish a connection and is sent from the Host containing the receive socket to the Host containing the send socket. The link number for message transmission over the connection is assigned with this command; the "link" field must be between 2 and 71, inclusive.

STR - Request connection, sender to receiver

8	32	32	8
STR	send socket	receive socket	size

The STR command is used to establish a connection and is sent from the Host containing the send socket to the Host containing the receive socket. The connection byte size is assigned with this command; the size must be between 1 and 255, inclusive.

CLS - Close

8	32	32
CLS	my socket	your socket

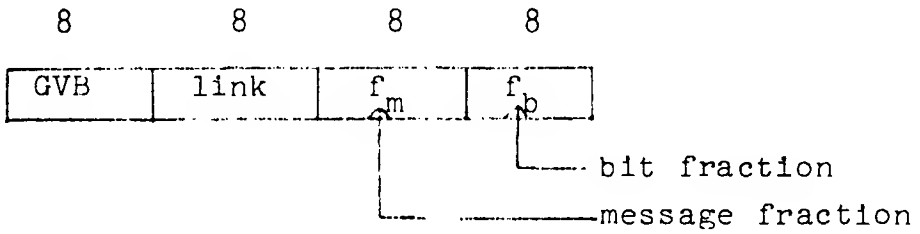
The CLS command is used to terminate a connection. A connection need not be completely established before a CLS is sent.

ALL - Allocate

8	8	16	32
ALL	link	msg space	bit space

The ALL command is sent from a receiving Host to a sending Host to increase the sending Host's space counters. This command may be sent only while the connection is established. The receiving Host is prohibited from incrementing the sending Host's message counter above $(2^{16}-1)$ or bit counter above $(2^{32}-1)$.

GVB - Give back



The GVB command is sent from a receiving Host to a sending Host to request that the sending Host return all or part of its message space and/or bit space allocations. The "fractions" specify what portion (in 128ths) of each allocation must be returned. This command may be sent only while the connection is established.

RET - Return

8	8	16	32
RET	link	msg space	bit space

The RET command is sent from the sending Host to the receiving Host to return all or a part of its message space and/or bit space allocations, either voluntarily or in response to a GVB command. This command may be sent only while the connection is established.

INR - Interrupt by receiver

8	8
INR	link

The INR command is sent from the receiving Host to the sending Host when the receiving process wants to interrupt the sending process. This command may be sent only while the connection is established.

INS - Interrupt by sender

8	8
INS	link

The INS command is sent from the sending Host to the receiving Host when the sending process wants to interrupt the receiving process. This command may be sent only while the connection is established.

ECO - Echo request

8	8
ECO	data

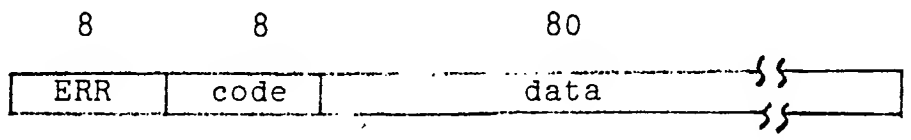
The ECO command is used only for test purposes. A Host may send an ECO command at <u>any</u> time, and should expect to receive an ERP command in reply. The data field may be any bit configuration convenient to the Host sending the ECO command.

ERP - Echo reply

8	8
ERP	data

The ERP command must be sent in reply to an ECO command. The data field must be identical to the data field in the incoming ECO command.

<u>ERR - Error detected</u>



The ERR command *may* be sent whenever a second level protocol error is detected in the input from another Host. In the case that the error condition has a predefined error code, the "code" field specifies the specific error, and the data field gives parameters. For other errors the code field is zero and the data field is idiosyncratic to the sender. Implementers of Network Control Programs are expected to publish timely information on their ERR commands.

The following codes are defined. Additional codes may be defined later.

a. Undefined (Error code = 0)
   The "data" field is idiosyncratic to the sender.

b. Illegal opcode (Error code = 1)
   An illegal opcode was detected in a control message. The "data" field contains the ten bytes of the control message beginning with the byte containing the illegal opcode. If the remainder of the control message contains less than ten bytes, fill will be necessary; the value of the fill is undefined.

c. Short parameter space (Error code = 2)

The end of a control message was encountered before all the required parameters of the control command being decoded were found. The "data" field contains the command in error; the value of any fill necessary is undefined.

d. Bad parameters (Error code = 3)

Erroneous parameters were found in a control command. For example, two receive or two send sockets in an STR, RTS, or CLS; a link number outside the range 2 to 71 (inclusive); an ALL containing a space allocation too large. The "data" field contains the command in error; the value of any fill necessary is undefined.

e. Request on a non-existent socket (Error code = 4)

A request other than STR or RTS was made for a socket (or link) for which no RFC has been transmitted in either direction. This code is meant to indicate to the NCP receiving it that functions are being performed out of order. The "data" field contains the command in error; the value of any fill necessary is undefined.

f. Socket (link) not connected (Error code = 5)

There are two cases:

1. A control command other than STR or RTS refers to a socket (or link) which is not part of an established connection. This code would be used when one RFC had been transmitted, but the matching RFC had not. It is meant to indicate the failure of the NCP receiving

Control Command Summary

8
NOP

8	32	32	8
RTS	receive socket	send socket	link

8	32	32	8
STR	send socket	receive socket	size

8	32	32
CLS	my socket	your socket

8	8	16	32
ALL	link	msg space	bit space

8	8	8	8
GVB	link	f_m	f_b

8	8	16	32
RET	link	msg space	bit space

8	8
INR	link

8	8
INS	link

8	8
ECO	data

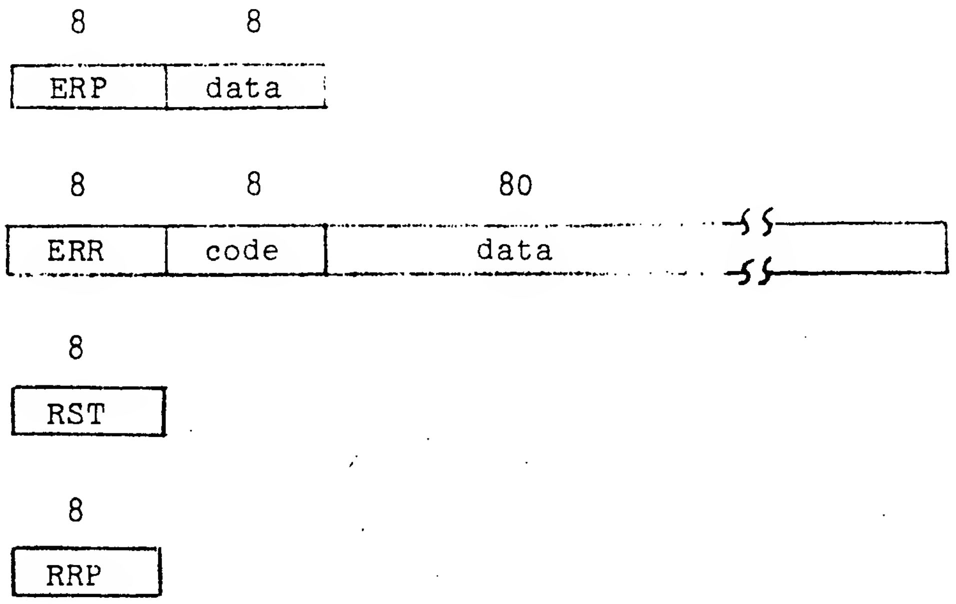
it to wait for a response to an RFC. The "data" field contains the command in error; the value of any fill necessary is undefined.

2. A message was received over a link which is not currently being used for any connection. The contents of the "data" field are undefined.

Opcode Assignment

Opcodes are defined to be eight-bit unsigned binary numbers. The values assigned to opcodes are:

NOP	=	0
RTS	=	1
STR	=	2
CLS	=	3
ALL	=	4
GVB	=	5
RET	=	6
INR	=	7
INS	=	8
ECO	=	9
ERP	=	10
ERR	=	11
RST	=	12
RRP	=	13


8
8
ERP
data
8
8
80
ERR
code
data
8
RST
8
RRP