DOD Internet Protocol

External Reference Specification

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PROPRIETARY NOTICE

DOD Internet Protocol ERS

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02	DoD Traceability and preTDRB	JRL3	02/01/85
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05	Updated after coding	JRL3	02/25/86
06	ICMP support added	JRL3	03/28/86

Table of Contents

1.0 INTRODUCTION

1.0 INTRODUCTION

1.1 PURPOSE

This document describes the external specifications of the Internet Protocol (IP) module. IP is the Department of Defense (DoD) standard for what is called a level three protocol in the OSI Reference model. IP is currently being used by various networks, including ARPANET. IP has also been included in the BSD 4.2 version of UNIX.

In the CDCNET environment IP will be implemented as a level 3B module. IP will use the standard 3A software to interface with the real world. This will allow the IP module to make use of all of the standard CDCNET network solutions. The general flavor of the IP interface is similar to the Xerox internet interface.

1.2 REFERENCES

The following manuals contain material that either defines the operation of the IP module and the modules it interfaces to, or provides additional insight into the use of the IP module.

```
1)  RFC-791       SRI   Internet Protocol
2)  RFC-792       SRI   Internet Control Message Protocol
3)  MIL-STD-1777  DoD   Internet Protocol Standard
4)  RFC-793       SRI   Transmission Control Protocol
5)  MIL-STD-1778  DoD   Transmission Control Protocol
6)  ARH6866       CDC   Transmission Control Protocol ERS
7)  ARH6879       CDC   Intranet 3A ERS
8)  ARH7118       CDC   DoD IP static Routing ERS
```

2.0 SERVICE OVERVIEW

2.0 SERVICE_OVERVIEW

2.1 SERVICES_PROVIDED

The services that the IP provides to the ULP can be divided
into five basic groups; general, fragmentation/reassembly, SAP
management, data transfer, and ICMP services. Each of these
services is described in one of the following sections.

2.1.1 GENERAL SERVICES

The Internet Protocol (IP) is designed to interconnect
packet-switched communication networks to form an catnet. The
IP transmits blocks of data, called IP datagrams, from sources
to destinations throughout the catnet. Sources and
destinations are hosts located on either the same network or
connected networks. Each IP datagram is an independent entity
unrelated to any other IP datagram. The IP module does not
create connections or logical circuits and has no mechanism to
promote data reliability, flow control, or sequencing.

The IP module provides services to transport layer
protocols and relies on the services of the lower layer
network protocol (3A intranet). The IP module also provides a
gateway function between networks.

An Upper Layer Protocol (ULP) passes data to the IP module
for delivery. The IP module packages the data as an IP
datagram and passes it to the local network protocol (3A
intranet) for transmission across the local network. If the
destination host is on a local network, IP sends the datagram
through the network directly to that host. If the destination
host is on a remote network, then IP sends the datagram to a
local gateway. The gateway, in turn, sends the datagram
through the next network to the destination host, or to
another gateway. The sequence of IP modules handling the
datagram in transit is called the gateway route. The gateway
route is based on the destination internet address. The IP
modules share common rules for interpreting internet addresses
to perform internet routing.

2.0 SERVICE OVERVIEW
2.1.1 GENERAL SERVICES

The IP module adds an IP header block to the front of all data that it receives from the ULP to create an IP datagram. This header block contains information including: the source address, the destination address, and the network parameters. The format of this header will not be described in this document due to the excellent description in [3]. Sections 9.1 thru 9.3 in [3] describe each of the fields and its use.

Occasionally, a gateway IP module or destination IP will encounter an error during datagram processing. Errors detected are reported via the Internet Control Message Protocol (ICMP) which is implemented in the IP module.

The interface to the IP module provides the ULP with the ability to specify certain properties of the transmission service according to its needs. The network parameters fall into two categories: service quality parameters and service options. The service options include; security labeling, source routing, route recording, stream identification timestamping, and the don't fragment flag. The service options are handled exclusively by the IP module and are implemented in full. The service quality parameters include; precedence, transmission mode, reliability, and speed. The service quality parameters are not handled by the IP module. The IP Routing module may use some of these parameters when choosing a route. The 3A Intranet layer Does not accept any of these parameters.   !

2.0 SERVICE OVERVIEW
2.1.2 FRAGMENTATION AND REASSEMBLY SERVICES

2.1.2 FRAGMENTATION AND REASSEMBLY SERVICES

   While traveling from source to destination, datagrams may
need to traverse a network those maximum packet size is
smaller than the size of the datagram.   To handle this
condition, the IP module provides the ability to fragment and
reassemble datagrams. A gateway at the smaller-packet network
fragments the original datagram into pieces, called datagram
fragments, that are small enough for transmission.   The IP
module in the destination host reassembles the datagram
fragments to reproduce the original datagram. This operation
is totally transparent to the layers above the IP layer.   :

2.0 SERVICE OVERVIEW
2.1.3 SAP MANAGEMENT SERVICES

2.1.3 SAP MANAGEMENT SERVICES

All services provided by the IP module are accessed through
a Service Access Point (SAP). A SAP is basically defined as a
set of routines which determines the two way interface between
the IP module and a user module. The IP SAP management
routines are accessed through global entry points, their
functions are described below.

    Open_sap   The open SAP routine does a number of
things. First, the protocol is checked; if
the protocol specified is not being used then
an entry is registered in the IP tables.
Second, the addresses of the upper level
protocol (ULP) indication routines are stored
into the registered entry. Finally, the
address of the IP send request routine and
the SAPid are returned.

    Close_sap   The close SAP routine releases a SAP
currently in use and allows the associated
protocol to be used in a subsequent open
request.

2.0 SERVICE OVERVIEW
2.1.4 DATA TRANSFER SERVICES

   2.1.4 DATA TRANSFER SERVICES

      The data transfer service routines provide the ULP with the
ability to send and receive datagrams from other homogeneous
ULPs in the internet environment. The IP module does not
necessarily deliver datagrams in the same order that they are
sent, however, datagrams will be delivered to the destination
ULP in the same form as sent by the source ULP. Datagrams may
be discarded by the IP module when insufficient resources are
available for processing, and datagrams lost or discarded by
the network layer are not detected. The IP module is intended
to insulate the ULP from the characteristics of the network,
such as, the 3A address and the maximum 3A packet size.

   Send_data   The send routine is provided by the IP
                      module, and is called by the ULP to send a
                      datagram out on the network.

   Receive_data   The receive_data routine is provided by
                      the ULP module, and is called by the IP to
                      present a datagram received from the network.

2.0 SERVICE OVERVIEW
2.1.5 INTERNET CONTROL MESSAGE SERVICES

2.1.5 INTERNET CONTROL MESSAGE SERVICES

The IP module also provides all of the services of the
Internet Control Message Protocol (ICMP). These services are
provided through an interface composed of three subroutines.
The interface has been designed to provide complete service to
all IP users. Two seperate indication routines are available
to allow the user to specify the level of information that
will be provided. The function of each routine is described
below.

Send_icmp   This routine is provided by the IP module
                             and allows the ULP to send the following ICMP
                             datagrams. Any ULP can send these ICMP
                             datagrams but, it is suggested that this
                             routine be used with caution. When an echo,
                             timestamp, or information request is sent the
                             identifier field of the datagram is set to
                             the sending protocol number to allow the
                             response to be presented to the sender only.

                                  Network unreachable.
                                  Host unreachable.
                                  Protocol unreachable.
                                  Port unreachable.
                                  Fragmentation needed and DF bit set.
                                  Source route failed.
                                  Time-to-live exceeded in transit.
                                  Fragment reassembly time exceeded.
                                  Parameter problem.
                                  Source Quench.
                                  Network redirect.
                                  Host redirect.
                                  TOS/network redirect.
                                  TOS/host redirect.
                                  Echo request and reply.
                                  Timestamp request and reply.
                                  Information request and reply.

icmp_ind   This routine is provided by the ULP. The
                             IP module will call this routine to present
                             an indication of all ICMP datagrams that are
                             received for this host. If the ULP does not
                             require this information the address may be
                             specified as NIL on the open_sap request. If

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2.0 SERVICE OVERVIEW
2.1.5 INTERNET CONTROL MESSAGE SERVICES
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an echo, timestamp, or information reply is
received it will be delivered to the protocol
which is specified by the identifier field of
the datagram. IF an echo, timestamp, or
information request is received it will be
delivered to all protocols. The following
indications may be presented.

 Network unreachable.
 Host unreachable.
 Protocol unreachable.
 Port unreachable.
 Fragmentation needed and DF bit set.
 Source route failed.
 Time-to-live exceeded in transit.
 Fragment reassembly time exceeded.
 Parameter problem.
 Source Quench.
 Network redirect.
 Host redirect.
 TOS/network redirect.
 TOS/host redirect.
 Echo request and reply.
 Timestamp request and reply.
 Information request and reply.

error_ind   Most ULPs will only need indications for
ICMP datagrams that are directed to their
specific protocol. This routine is provided
by the ULP and is called by the IP module to
present indications of ICMP datagrams direct
to the ULP specific protocol. Not all ICMP
datagrams will generate an indication, the
following indications may be presented to the
ULP.

 Network unreachable.
 Host unreachable.
 Protocol unreachable.
 Port unreachable.
 Fragmentation needed and DF bit set.
 Source route failed.
 Time-to-live exceeded in transit.
 Fragment reassembly time exceeded.
 Parameter problem.
 Source Quench.

2.0 SERVICE OVERVIEW
2.2 FUNCTIONAL RELATIONSHIPS

2.2 FUNCTIONAL RELATIONSHIPS

Before the IP data transfer services can be used an IP SAP
must be opened.   Data may then be transferred as long as
needed. When all data transfers have been completed the SAP
should be closed.

All IP SAPs will be opened by a user that is "well known"
to all IP modules. This is because each SAP has a protocol
identifier (PID) linked to it, and a PID can only be used by a
single ULP. Unfortunately, there are only 254 PIDs available.
For this reason, most users that need to exchange datagrams
should work through the User Datagram Protocol (UDP) module
instead of the IP module.

At   this   level, opening a SAP can be likened to picking up
the phone to make a call. Once the phone has been picked up,
a number of separate calls may be made and information may be
transferred on each call. When finished with all calls the
phone is hung up, this is similar to closing the SAP.
Although this analogy is not quite perfect it does show the
basic principles of the IP module. The following picture
shows the modules that interface with the IP module.

```
              +----------+   +----------+   +----------+
              :          :   :          :   :          :
              :   EGP    :   :   TCP    :   :   UDP    :
              :          :   :          :   :          :
              +----------+   +----------+   +----------+
                   :              :              :
 +----------+      :              :              :
 :          :      :              :              :
 :  Static  :  +-------------------------------------+
 :  Routing :--:                                     :
 :          :  :                IP                   :
 +----------+  +-------------------------------------+
                              :
                              :
              +-------------------------------------+
              :                                     :
              :          3A   Intranet              :
              :                                     :
              +-------------------------------------+
```
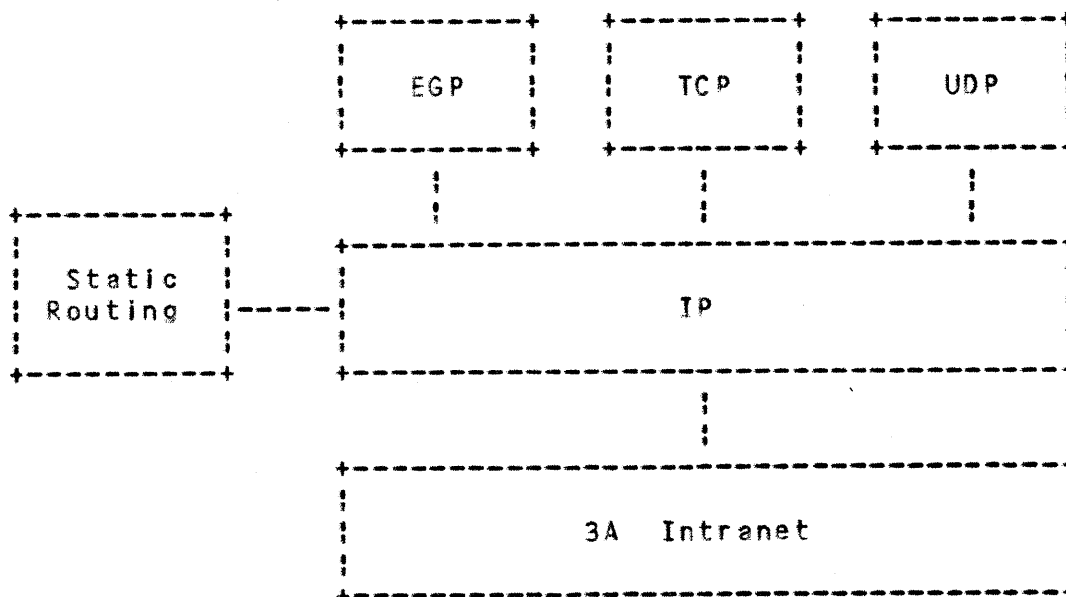
2.0 SERVICE OVERVIEW
2.3 EXTERNAL SERVICES UTILIZED

2.3 EXTERNAL SERVICES UTILIZED

The following external interfaces are utilized by the IP module.

2.3.1 NETWORK LAYER

The network layer used by the IP module will be the 3A Intranet layer. The 3A module will provide transparent data transfer between the host within a single network. The only input required from the IP module should be the IP datagram, the network identification, and the local network address of the destination host. It is assumed that data will have a non-zero probability of arriving at the destination. If the network interface fails, then the 3A module is expected to notify the IP module.

The 3A module will provide a send routine which the IP module will call specifying the network identification, the local network address of the destination, and the data buffer. The data buffer will not be examined or changed by the 3A module.

The IP module will provide a receive routine which the 3A module will call to present data that it has received on an IP network. The 3A module will specify the network number, the local network address of the source, and the data buffer. The 3A module will not examine or modify the data buffer. The receive routine and the send routine are totally independent of each other and are asynchronous.

The IP will also provide a routine which the 3A module will call to inform the IP module that the status of a network connection has changed. This routine will receive the network number, the networks status, the maximum datagram size, and other unused information.

DOD Internet Protoco.

2.0 SERVICE OVERVIEW
2.3.2 IP STATIC ROUTING MODULE   2-10

2.3.2 IP STATIC ROUTING MODULE

     The IP Static Routing (IPSR) module is responsible for
determining the next destination for all datagrams received by
the IP module. The IPSR keeps track of the status of each
network that IP can route datagrams to. The IPSR module will
provide a routine which the IP module can call to obtain the
destination of a datagram. The routine will accept the source
address, the destination address, the network parameters, and
the routing options from an IP datagram and return the next
destination of the datagram and the maximum size of datagrams
on that network.

3.0 SERVICE DESCRIPTIONS

3.0 SERVICE_DESCRIPTIONS

3.1 SAP_MANAGEMENT_SERVICES

3.1.1 DESCRIPTION

This section describes the routines that provide the SAP
management services. A SAP is defined by a sapid and a set of
routine addresses. The routines that provide SAP management
are global addresses; all other services pass the addresses of
their routines as parameters to and from the open_sap routine.

3.1.2 EXTERNAL INTERFACES

3.1.2.1 ip_open_sap_request

The open SAP routine is used to register a Service Access
Point with the IP module. The IP module allows a total of 254
SAPs to be open at one time. Each SAP is identified by its
SAPid value which is linked to the protocol value. The format
of the CYBIL interface is as follows:

```
PROCEDURE ip_open_sap (
    protocol     : 0..255;
    data_ind     : ip_data_ind;
    error_ind    : ip_error_ind;
    icmp_ind     : ip_icmp_ind;
    VAR send_req : ip_send_req;
    VAR icmp_req : ip_icmp_req;
    VAR sapid    : INTEGER;
    VAR status   : ip_status_type);
```

protocol   In   This value specifies the user
                             protocol to the IP module. The IP
                             module will only allow one SAP for
                             each protocol number. The ULP must
                             specify an appropriate value between
                             1 and 254 inclusive.

data_ind   In   This is a pointer to a user
                             supplied routine, which the IP
                             module will call to present data
                             messages to the ULP.

3.0 SERVICE DESCRIPTIONS
3.1.2.1 ip_open_sap request
----

error_ind	In	This is a pointer to a user supplied routine which the IP module will call to present ICMP indications that are specific to the protocol of the ULP. If the ULP doesn't need these indications then the pointer should be set to NIL.
icmp_ind	In	This is a pointer to a user supplied routine which the IP module will call to present all ICMP datagram indications. If the ULP doesn't need these indications then the pointer should be set to NIL.
send_req	Out	This is a pointer to the IP modules routine to send data.
icmp_req	Out	This is a pointer to a routine provided by the IP module to allow the ULP to generate ICMP datagrams. It is suggested that this request be used very carefully.
sapid	Out	This is a 32 bit value that identifies the particular IP SAP in all later requests. This parameter is used by the IP module as a password value.
status	Out	This is the status of the request. The following values may be returned: ip_insufficient_resources ip_protocol_illegal ip_protocol_inuse ip_successful

3.1.2.2 ip_close_sap_request

     The close SAP routine is used to terminate the use of an IP
SAP. This frees up the SAP for use by another ULP.

```
        PROCEDURE ip_close_sap (
            protocol   : 0..255;
            sapid      : INTEGER;
            VAR status : ip_status_type);
```

3.0 SERVICE DESCRIPTIONS
3.1.2.2 ip_close_sap request
----

protocol   In   This value specifies the user
                        protocol to the IP module.

sapid   In   This is the SAPid returned on the
                        original open request.

status   Out   This is the status of the
                        request.   The following values may
                        be returned:
                            ip_protocol_illegal
                            ip_sap_not_open
                            ip_successful

3.0 SERVICE DESCRIPTIONS
3.2 DATA TRANSFER SERVICES

3.2 DATA_TRANSFER_SERVICES

3.2.1 DESCRIPTION

    The data transfer services are provided by two routines.
The addresses of these routines are accessed through the
open_sap routine. The send routine is provided by the IP
module, and is called by the ULP module to send datagrams out
onto the network. The indication routine is provided by the
ULP module, and is used by the IP module to present datagrams
received from the network. Note that a send_data request does
not elicit any response, nor does a data_ind indicate that a
send_data request is required. The parameters on the routines
indicate how the data is to be packaged and where to send it,
the data buffer is not examined or changed by the IP module.

3.2.2 EXTERNAL INTERFACES

3.2.2.1 ip_send_request

    The send data routine is used to send data out on the
network thru a previously opened SAP. The address of this
routine is returned to the ULP when the open request is made.

```
        ip_send_req = ^PROCEDURE (
            header       : ip_header_rec;
            source       : ip_address;
            destination  : ip_address;
            options      : ^ip_option_rec;
            sapid        : INTEGER;
            VAR data     : buf_ptr;
            VAR status   : ip_status_type);
```

        header   In   This is a record which contains
                                 the IP header for the datagram. The
                                 ULP module does not fill in the
                                 entire header only the user
                                 specified fields as noted in the
                                 data type section.

        source   In   This is the address of the
                                 sender. This address may be
                                 partially or completely unspecified.
                                 This address is specified when a ULP

3.0 SERVICE DESCRIPTIONS
3.2.2.1 ip_send request

---

needs to indicate which network
solution the IP should use if it is
multihomed.

destination   In   This is the address of the remote
                          IP that the data is being sent to.

options   In   This is a pointer to a record
                          which contains the IP options to be
                          sent with the datagram.

sapid   In   This is the SAPid returned by the
                          original open request.

data   In   This is a pointer to the system
                          buffer containing the data portion
                          of the datagram.

status   Out   This is the status of the
                          request. The following values may
                          be returned: ip_insuff_resource
                            ip_option_error
                            ip_protocol_illegal
                            ip_route_failed
                            ip_sap_not_open
                            ip_successful

3.2.2.2 ip_data_indication

The data indication routine is provided by the ULP, and is
used by the IP module to present data messages to the ULP.
The format of the Cybil interface is as follows:

```
ip_data_ind = ^PROCEDURE (
    header      : ip_header_rec;
    source      : ip_address;
    destination : ip_address;
    options     : ^ip_option_rec;
    sapid       : INTEGER;
    VAR data    : buf_ptr);
```

header   In   This is a record which contains
                          the IP header from the datagram.

source   In   This is the address of the remote
                          IP module that sent this datagram.

3.0 SERVICE DESCRIPTIONS
3.2.2.2 ip_data indication

---

destination	In	This is the address that the datagram was sent to. This address indicates which network solution the datagram was received on.
options	In	This is a pointer to a record which contains the IP options received with the datagram.
sapid	In	This is the SAPid returned by the original open request.
data	In	This is a pointer to the system buffer containing the data portion of the datagram.

3.0 SERVICE DESCRIPTIONS
3.3 INTERNET CONTROL MESSAGE SERVICES

3.3 INTERNET CONTROL MESSAGE SERVICES

3.3.1 DESCRIPTION

This section describes the routines which provide the
interface to the ICMP functions supported by the IP module.
All ULPs have the capability to send ICMP datagrams out on the
network. This ability should be used with care. ULPs also
have the option of receiving indications of all ICMP datagrams
received from the network. The ULP selects this option by
providing the address of an indication routine when it opens a
SAP. Finally, the ULP can choose to receive indications about
ICMP datagrams received from the network for its specific
protocol. This option is also selected by providing the
address of the ULPs indication routine when the SAP is opened.
It is assumed that most ULPs will use this last indication
service.

3.3.2 EXTERNAL INTERFACES

3.3.2.1 icmp_send_request

This routine is provided by the IP module to allow the ULP
to send ICMP datagrams out to the network. This service must
be used carefully to avoid flooding the network with useless
ICMP datagrams. The format of the CYBIL interface is as
follows.

```
ip_icmp_req = ^PROCEDURE (
    source      : ip_address;
    destination : ip_address;
    icmp_header : icmp_header_rec;
    protocol    : 0..255;
    sapid       : INTEGER;
    VAR data    : buf_ptr;
    VAR status  : ip_status_type);
```

source   In   This is the IP address of the
                            sender within this DI.

destination   In   This is the IP address of the
                            system which sent the datagram that
                            is being rejected.

3.0 SERVICE DESCRIPTIONS
3.3.2.1 icmp_send request
----

icmp_header   In   This is the header portion of the
                             ICMP datagram that the ULP is
                             requesting the IP module to
                             transmit.

protocol   In   This is the protocol number of
                             the ULP requesting that an ICMP
                             datagram be transmitted.

sapid   In   This is the SAPid allocated by
                             the IP module when the SAP was
                             opened.

data   In   This is a pointer to the system
                             message buffer with contains any
                             data that needs to go as part of the
                             ICMP datagram.

status   Out   This is the status of the
                             request. The following values may
                             be returned.
                                 ip_destination_illegal
                                 ip_invalid_icmp_type
                                 ip_invalid_icmp_code
                                 ip_sap_not_open
                                 ip_source_illegal
                                 ip_successful

3.3.2.2 ip_icmp_indication

    This routine is provided by the ULP and is called by the IP
module when an ICMP datagram is received from the network.
The ULP can refuse to accept these indications by specifing a
NIL address on the open_sap request. The format of the Cybil
interface is as follows:

```
        ip_icmp_ind = ^PROCEDURE (
            source      : ip_address;
            destination : ip_address;
            icmp_header : icmp_header_rec;
            sapid       : INTEGER;
            VAR data    : buf_ptr);
```

source   In   This is the IP address of the
                             host which sent this ICMP datagram
                             out on the network.

3.0 SERVICE DESCRIPTIONS
3.3.2.2 ip_icmp Indication

---

destination   In   This is the IP address of an
                           entity within this DI that the
                           datagram pertains to.

icmp_header   In   This is the header portion of the
                           ICMP datagram that was received from
                           the network.

sapid   In   This is the SAPid allocated by
                           the IP module when the SAP was
                           opened.

data   In   This is a pointer to the system
                           message buffer with contains any
                           data that came with the ICMP
                           datagram.

3.3.2.3 ip_error_indication

The error indication routine is provided by the ULP and is
used by the IP module to present indications to the ULP which
are protocol specific. The ULP can refuse to accept these
indications by specifing a NIL address on the open_sap
request. The format of the Cybil interface is as follows:

```
ip_error_ind = ^PROCEDURE (
    header       : ip_header_rec;
    source       : ip_address;
    destination  : ip_address;
    options      : ^ip_option_rec;
    sapid        : INTEGER;
    data         : buf_ptr;
    error        : ip_status_type;
    bad_param    : INTEGER);
```

header   In   This is a record which contains
                           the IP header from the datagram.

source   In   This is the address of the remote
                           IP module that sent this datagram.

destination   In   This is the address that the
                           datagram was sent to. This address
                           indicates which network solution the
                           datagram was received on.

3.0 SERVICE DESCRIPTIONS
3.3.2.3 ip_error indication
----

options	In	This is a pointer to a record which contains the IP options received with the datagram.
sapid	In	This is the SAPid returned by the original open request.
data	In	This is a pointer to the system buffer containing the data portion of the datagram.
error	I	This is the type of error that occurred. The following errors are defined:

        ip_net_unreachable
        ip_host_unreachable
        ip_protocol_unreachable
        ip_port_unreachable
        ip_fragmentation_needed
        ip_route_failed
        ip_timeout
        ip_assembly_timeout
        ip_option_error
        ip_congestion

bad_param	IN	This is the identifier of the bad parameter in the case of an option error. The identifier may have the following values.

    0 = Version or IHL
    1 = Type of service
    2 = Total length
    3 = Identification
    4 = Flags or fragment offset
    5 = Time-to-live
    6 = Protocol
    7 = Checksum
    8 = Source address
    9 = Destination address
  10 = Security option
  11 = Streamid option
  12 = Routing option
  13 = Timing option

3.0 SERVICE DESCRIPTIONS
3.4 ERROR RECOVERY

3.4 ERROR_RECOVERY

Although it can be assumed that the IP module will not be running in a hostile user environment, it is assumed that users will make mistakes. Therefore, the interfaces of the IP module are designed to catch errors as soon as possible. Most errors can be caught by simply checking parameters passed into the IP module. In terms of the IP module this is really error prevention rather than error recovery. The following list itemizes the steps that will be taken to catch errors.

1.   Each SAP has a 32 bit SAPID to identify it. The sapid will be generated from a counter which will be updated each time a SAPID is used. This will prevent a user from trying to access a closed SAP and perhaps send data through a SAP reopened by another user.

2.   All parameters will be tested for legality. The addresses passed in the open_sap request are the only exceptions to this rule. It is probably not possible to validate the addresses completely. The compiler will make sure that a parameter is the correct type, so other than checking for NIL pointers no checks will be made. Therefore, the IP module could possibly fail if those addresses are messed up.

3.   There should be no error due to protocol that can make the IP module fail. If the 3A module passes bad information the error should be caught by parameter checks.

4.0 PERFORMANCE

4.0 PERFORMANCE

4.1 OPERATING CHARACTERISTICS

A large number of other modules are dependent on the IP module. It is therefore necessary that the IP module be as efficient as possible. For every datagram that the IP module processes, a call is made to the IP routing module, therefore, part of the IP modules efficiency will depend upon the IP routing module. In general the following goals have been set.

      Assume: 1)   Transmission rate of 10meg bits/second.
                 2)   Average packet size of 500 bytes.
                 3)   Average 2 microseconds/68000 instruction.

      Compute: 1)   Average 2500 packets/second.
                 2)   Average 400 microseconds/packet.
                 3)   Approximately 200 instructions/packet.

4.0 PERFORMANCE
4.2 OPERATIONAL MEASUREMENTS

4.2 OPERATIONAL_MEASUREMENTS

The IP module accumulates a number of statistics which indicate the load that it has been working under. This information may be accessed through the standard CDNA Statistics Command Processor. The content and basic format of the information provided is shown below.

IP Statistics

Total Number of OPEN Requests = ########
Total Number of CLOSE Requests = ########
Number of SAPs Currently Open =   ###

Protocol	Sent	Received	Packet errors
###	Packets= #######	Packets= #######	Resource= #######
	Bytes= #########	Bytes= #########	Content= #######
###	Packets= #######	Packets= #######	Resource= #######
	Bytes= #########	Bytes= #########	Content= #######
###	Packets= #######	Packets= #######	Resource= #######
	Bytes= #########	Bytes= #########	Content= #######
Total	Packets= #######	Packets= #######	Resource= #######
	Bytes= #########	Bytes= #########	Content= #######

5.0 FINITE STATE MACHINE

5.0 FINITE_STATE_MACHINE

The IP module will use a very simple FSM. The FSM is composed of three states, 12 input conditions, and 9 output actions. Each IP datagram will basically have it's own FSM. Each FSM instantiation will be identified by the source address, the destination address, the protocol, and the datagram identifier. The following sections describe the FSM.

5.1 FSM_DIAGRAM

```
              *----------------------*
              :                      :
   *----------:                      :
   *          :      SAP Closed      :
   :          :        (S0)          :
   :   *-->:                      :   <-------*
   :   :      :                      :          :
   :   :      *----------------------*          :
   :   :                                        :
   :   :                                        :
   V   :                                        :
*----------------------*        *----------------------*
:                      :        :                      :
:                      :<-------------------:          :
:         Idle         :        :      Reassembly      :
:         (S1)         :        :         (S2)         :
:                      :------------------->:          :
:                      :        :                      :
*----------------------*        *----------------------*
```
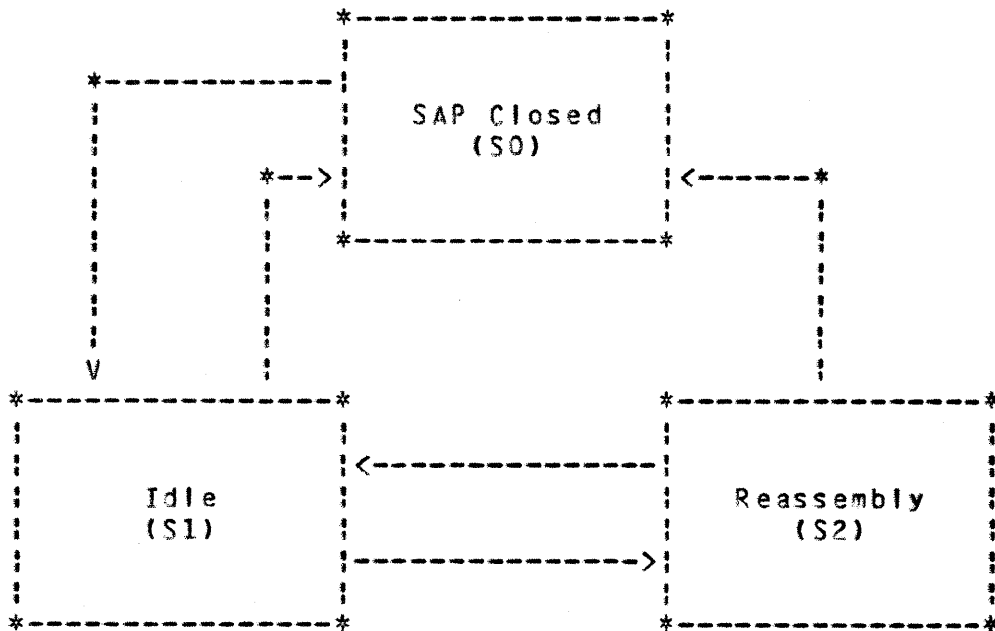
5.0 FINITE STATE MACHINE
5.2 FSM INPUT CONDITIONS

5.2 FSM INPUT CONDITIONS

The following list contains the input conditions to the
FSM. Each of the input conditions will, in combination with
the current state, determine th next state and may produce an
output action. Note that not all input conditions cause a
change in the state, nor do all input conditions produce an
output action.

(C1) A valid open request is received from the ULP.

(C2) A valid close request is received from the ULP.

(C3) A valid send request is received from the ULP.

(C4) A complete datagram is received from 3A.

(C5) A fragment of a datagram is received from 3A for a local
     destination.

(C6) A fragment of a datagram is received from 3A for a
     remote destination.

(C7) The assembly of a fragmented datagram is completed.

(C8) The timeout interval expires for a fragmented datagram
     under construction.

(C9) A datagram is received from 3A with a checksum error.

(C10) A datagram is received from 3A with an error other than
      a bad checksum.

(C11) A redirect error datagram is received from 3A.

(C12) A general error datagram is received from 3A.

5.0 FINITE STATE MACHINE
5.3 FSM OUTPUT ACTIONS

5.3 FSM_OUTPUT_ACTIONS

The following list contains the output actions that the FSM
produces.   These   output   actions are produced when the input
condition and the current state have the correct values.

(A1) Open the SAP.

(A2) Close the SAP.

(A3) Return the proper error status.

(A4) Determine the datagrams destination and send it to the
     ULP or 3A.

(A5) Discard the datagram.

(A6) Discard the datagram and send an error datagram to its
     source.

(A7) Begin or continue fragment collection.

(A8) Call the routing module to update the status of the
     route used.

(A9) Present the error datagram to the ULP.

5.0 FINITE STATE MACHINE
5.4 FSM TRANSITION DEFINITIONS

5.4 FSM_TRANSITION_DEFINITIONS

This section shows what the next state and output action is
for each pair of current state and input condition
combinations. This table determines the total behavior of the
FSM.

Input State

		S0	S1	S2
	C1	S1,A1	S1,A3	S1,A3
	C2	S0,A3	S0,A2	S0,A2
	C3	S0,A3	S1,A4	S2,A4
	C4	S0,A6	S1,A4	S2,A4
	C5	S0,A6	S2,A7	S2,A7
	C6	S0,A6	S1,A4	S2,A4
Input	C7	S0,A5	S1,A5	S1,A4
Condition	C8	S0,A6	S1,A6	S1,A6
	C9	S0,A5	S1,A5	S2,A5
	C10	S0,A6	S1,A6	S2,A6
	C11	S0,A8	S1,A8	S2,A8
	C12	S0,A5	S1,A9	S2,A9

6.0 LOG MESSAGES

6.0 LOG_MESSAGES

The IP module issues log messages whenever it detects a
function call error from either the ULP of the lower layer
software. A log message will also be issued whenever a status
command is processed, and whenever a configuration command is
processed. The following is a list of each of the log
messages generated.

6.1 PARAMETER_ERROR

Message Id: ???

Descriptive Message: "IP Parameter Error"

Fields: "Caller: "   String(1..20)
          "Function: "   String(1..20)
          "Parameter: "   String(1..20)

Example: 84/10/31 11:29.35   123456789ABC
          IP Parameter Error
          Caller: Protocol_002
          Function: Send_data
          Parameter: Precedence

6.2 INTERNAL_ERROR_CONDITION

Message Id: ???

Descriptive Message: "IP Internal Error"

Fields: "Description: "   String(1..60)

Example: 84/10/31 11:29.35   123456789ABC
          IP Internal Error
          Description: Data structure corrupted.

7.0 INSTALLATION OPTIONS

7.0 INSTALLATION_OPTIONS

The IP module does not require any installation options.
All parameters are either closely dependent on the code or
must be set dynamically when the module is started or
reconfigured.

8.0 NEW DATA TYPES

8.0 NEW_DATA_TYPES

Each user of the IP module is associated with an IP
protocol type. There are a number of protocol types that are
well know to IP modules through out the DoD network. The
following protocol types are defined by the IP module and are
stated to be well known to this IP module.

    ip_protocol_ip ...... Internal IP protocol.
    ip_protocol_icmp .... Internal ICMP protocol.
    ip_protocol_ggp ..... Gateway to Gateway Protocol.
    ip_protocol_tcp ..... Transmission Control Protocol.
    ip_protocol_udp ..... User Datagram Protocol.
    ip_protocol_cdcgw ... CDC gateway module.

All functions provided by the IP module return a status
code. The following status codes are returned by one or more
of the IP functions or the IP error indication routine.

    TYPE
      ip_status_type = (
        ip_assembly_timeout,   { Timeout in reassembly.
        ip_congestion,   { No delivery, congestion.
        ip_destination_illegal,   { Illegal dest. address.
        ip_fragmentation_needed,   { Can't send without frag.
        ip_host_unreachable,   { Invalid host id.
       •ip_insufficient_resources,{ Memory/buffer congestion. ┊
        ip_invalid_icmp_type,   { ICMP type incorrect.   ┊
        ip_invalid_icmp_code,   { ICMP code incorrect.   ┊
        ip_net_unreachable,   { Invalid network id.
       •ip_option_error,   { Error in option.
        ip_port_unreachable,   { Invalid port.
       •ip_protocol_illegal,   { Illegal protocol number.
        ip_protocol_inuse,   { Requested protocol in use.
        ip_protocol_unreachable,   { Invalid protocol.
       •ip_route_failed,   { Errors in strict route.
       •ip_sap_not_open,   { The SAP is not open.
        ip_source_illegal,   { Illegal source address.
       •ip_successful,   { Operation completed.
        ip_timeout);   { Timeout during travel.

8.0 NEW DATA TYPES

    The address record used by the IP interface is shown below.
The "fields_inuse" field is used to indicate which of the
following fields are specified. The only time that a field
can be unspecified is when the address is the source address
of a send_data request.

    TYPE
        ip_address = RECORD
            fields_inuse : (ip_none, ip_net, ip_host, ip_both),
            network   : 0..0FFFFFF(16),
            host   : 0..0FFFFFF(16),
        RECEND,

        ip_double_word : -80000000(16)..7FFFFFFF(16);

    The following record is used to describe the header used by
the IP datagrams. This record is used by the ULP to pass the
parameters that IP would have to put into the header any way.
The only part of the header that IP processes in the source
address and the destination address. The following CYBIL code
defines the record and indicates which field the ULP must fill
before calling IP.

    TYPE
        ip_header_rec = RECORD
            version   : 0..15,   { ***
            ihl   : 0..15,   { ***
            precedence   : 0..7,   { ULP
            delay   : BOOLEAN,   { ULP
            throughput   : BOOLEAN,   { ULP
            reliability   : BOOLEAN,   { ULP   !
            unused_flag_1 : BOOLEAN,   { **ZERO**   !
            unused_flag_2 : BOOLEAN,   { **ZERO**   !
            total_length   : 0..0FFFF(16),   { ***
            identification : 0..0FFFF(16),   { ULP   !
            unused_flag_3 : BOOLEAN,   { **ZERO**   !
            dont_frag   : BOOLEAN,   { ULP
            more_frags   : BOOLEAN,   { ***
            frag_offset   : 0..01FFF(16),   { ***
            time_to_live   : 0..255,   { ULP
            protocol   : 0..255,   { ULP
            checksum   : 0..0FFFF(16),   { ***
            source   : ip_double_word,   { ***
            destination   : ip_double_word,   { ***
        RECEND;

8.0 NEW DATA TYPES

There are a number of options that may be included in the
IP datagram. These options will specified by the user of the
IP module. The following constants and types define the
format of the options that are passed to and from the IP
module. For more information about the use of options see the
DoD specification MIL-STD-1777.

```
CONST
    ip_end           = 0,
    ip_no            = 1,
    ip_security      = 2,
    ip_loose_route   = 3,
    ip_timestamp     = 4,
    ip_record_route  = 7,
    ip_streamid      = 16,
    ip_strict_route  = 17,
    ip_max_option    = 31,

    ip_control_class = 0,
    ip_debug_class   = 2,
    ip_max_class     = 3,

    ip_loose  = 0,
    ip_record = 1,
    ip_strict = 2,

    ip_time_only    = 0,
    ip_record_addrs = 1,
    ip_stamp_addrs  = 2,


TYPE
    ip_option_rec = RECORD
        security : ip_security_rec,
        stream   : ip_streamid_rec,
        routing  : ip_routing_rec,
        timing   : ip_timing_rec,
    RECEND;

    ip_security_rec = RECORD
        inuse : BOOLEAN,
        s     : 0..0FFFF(16),
        c     : 0..0FFFF(16),
        h     : 0..0FFFF(16),
        tcc   : 0..0FFFFFF(16),
    RECEND,
```

8.0 NEW DATA TYPES

```
        ip_streamid_rec = RECORD
            inuse : BOOLEAN,
            id    : 0..0FFFF(16),
        RECEND,

        ip_routing_rec = RECORD
            inuse : BOOLEAN,
            rtype : 0..255,     { ip_loose..ip_strict
            index : 0..255,     { 0..8
            count : 0..255,     { 0..9
            list  : ARRAY[0..8] OF ip_double_word,
        RECEND,

        ip_timestamp = RECORD
            inuse    : BOOLEAN,
            ttype    : 0..255,     { ip_time_only..ip_stamp_addrs
            index    : 0..255,     { 0..8
            count    : 0..255,     { 0..9
            overflow : 0..255,     { 0..15
            CASE 0..1 OF
                =0= sm_array : ARRAY[0..8] OF ip_double_word,
                =1= lg_array : ARRAY[0..3] OF ip_full_stamp,
            CASEND,
        RECEND,

        ip_full_stamp = RECORD
            addrs : ip_double_word,
            time  : ip_double_wrod,
        RECEND;
```

The ICMP protocol uses IP datagrams to carry information.
The header of the ICMP datagram is defined by the following
record. The currently defined values for the TYPE and CODE
fields are also defined below.

```
    CONST
        icmp_echo_reply       = 0,
        icmp_dest_unreachable = 3,
        icmp_source_quench    = 4,
        icmp_redirect         = 5,
        icmp_echo_request     = 8,
        icmp_time_exceeded    = 11,
        icmp_parameter_error  = 12,
        icmp_time_request     = 13,
        icmp_time_reply       = 14,
        icmp_info_request     = 15,
        icmp_info_reply       = 16,
```

8.0 NEW DATA TYPES

```
        icmp_maximum_type      = 255,

        icmp_network_unreachable  = 0,
        icmp_host_unreachable     = 1,
        icmp_protocol_unreachable = 2,
        icmp_port_unreachable     = 3,
        icmp_fragmentation_needed = 4,
        icmp_source_route_failed  = 5,

        icmp_timeout           = 0,
        icmp_assembly_timeout  = 1;


    TYPE
        icmp_header_rec = PACKED RECORD
            error_type : 0..255,
            error_code : 0..255,
            checksum   : 0..0FFFF(16),
            CASE 0..2 OF
                =0=
                    gateway : ip_double_word,
                =1=
                    ptr    : 0..255,
                    unused : 0..0FFFFFF(16),
                =2=
                    identifier : 0..0FFFF(16),
                    sequence   : 0..0FFFF(16),
            CASEND,
        RECEND;
```

9.0 GLOSSARY

9.0 GLOSSARY

The following term definitions are provided to aid the reader in understanding this document.

CDNA: Control Data Distributed Network Architecture.

Datagram: This is a block of ULP data preceeded by an IP header and is the unit of data passed down by the IP module.

DoD: Department of Defense.

EGP: External Gateway Protocol. This protocol is used in the DoD network environment to pass simple routing information between individual catenets (see RFC-827, RFC-890, and RFC-904).

FTP: File Transfer Protocol. This is the protocol used in DoD systems to transfer files from host to host (see RFC-959).

IP: DoD Internet Protocol. This is the level three protocol used by the DoD. It provides the serves of an OSI internet layer.

OSI: Open System Interconnect. This is a model developed by the International Standards Organization (OSI) which defines a method of layering modules within networking software.

Protocol: Each user of the IP module is identified by a specific protocol identifier. This identifier is referred to throughout this document as the protocol.

SAP: Service Access Point. A SAP is defined in this manual as the point of access to the services that a module provides. In the case of the IP module this point of access is defined by a set of routine address provided by both sides of the service line.

9.0 GLOSSARY

TCP: DoD transmission control protocol. This
                        is the transport protocol used by the DoD.
                        TCP provides an error free orderly end to end
                        data transmission (see MIL-STD-1778).

UDP: DoD user datagram protocol. This is a
                        protocol which provides an single datagram
                        transfer service with no promises (see
                        RFC-768).

ULP: User Level Protocol. Used at various
                        times to indicate the user of the module
                        being discussed.