Internet Protocol
DARPA Internet Program

Jon Postel, Editor

Information Sciences Institute · University of Southern California

IP

PREFACE. This document specifies the DoD Standard Internet Protocol. This document is based on six earlier editions of the ARPA Internet Protocol Specification, and the present text draws heavily from them. There have been many contributors to this work both in terms of concepts and in terms of text. This edition revises aspects of addressing, error handling, option codes, and the security, precedence, compartments, and handling restriction features of the internet protocol.

3.1. Internet Header Format[1]

A summary of the contents of the internet header follows:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Version|  IHL  |Type of Service|          Total Length         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Identification        |Flags|      Fragment Offset    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Time to Live |    Protocol   |         Header Checksum       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Source Address                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Destination Address                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Options                    |    Padding    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Example Internet Datagram Header
Figure 4.

Note that each tick mark represents one bit position.

Version: 4 bits

The Version field indicates the format of the internet header. This document describes version 4.

IHL: 4 bits

Internet Header Length is the length of the internet header in 32 bit words, and thus points to the beginning of the data. Note that the minimum value for a correct header is 5.

Type of Service: 8 bits

The Type of Service provides an indication of the abstract parameters of the quality of service desired. These parameters are to be used to guide the selection of the actual service parameters when transmitting a datagram through a particular network. Several networks offer service precedence, which somehow treats high precedence traffic as more important than other traffic (generally by accepting only traffic above a certain precedence at time of high load). The major choice is a three way tradeoff between low-delay, high-reliability, and high-throughput.

```
Bits 0-2:  Precedence.
Bit    3:  0 = Normal Delay,      1 = Low Delay.
Bits   4:  0 = Normal Throughput, 1 = High Throughput.
Bits   5:  0 = Normal Relibility, 1 = High Relibility.
Bit  6-7:  Reserved for Future Use.

   0     1     2     3     4     5     6     7
+-----+-----+-----+-----+-----+-----+-----+-----+
|                 |     |     |     |     |     |
|   PRECEDENCE    |  D  |  T  |  R  |  0  |  0  |
|                 |     |     |     |     |     |
+-----+-----+-----+-----+-----+-----+-----+-----+

  Precedence

    111 - Network Control
    110 - Internetwork Control
    101 - CRITIC/ECP
    100 - Flash Override
    011 - Flash
    010 - Immediate
    001 - Priority
    000 - Routine
```

The use of the Delay, Throughput, and Reliability indications may increase the cost (in some sense) of the service. In many networks better performance for one of these parameters is coupled with worse performance on another. Except for very unusual cases at most two of these three indications should be set.

The type of service is used to specify the treatment of the datagram during its transmission through the internet system. Example mappings of the internet type of service to the actual service provided on networks such as AUTODIN II, ARPANET, SATNET, and PRNET is given in "Service Mappings" [8].

The Network Control precedence designation is intended to be used within a network only. The actual use and control of that designation is up to each network. The Internetwork Control designation is intended for use by gateway control originators only. If the actual use of these precedence designations is of concern to a particular network, it is the responsibility of that network to control the access to, and use of, those precedence designations.

Total Length: 16 bits

Total Length is the length of the datagram, measured in octets, including internet header and data. This field allows the length of a datagram to be up to 65,535 octets. Such long datagrams are impractical for most hosts and networks. All hosts must be prepared to accept datagrams of up to 576 octets (whether they arrive whole or in fragments). It is recommended that hosts only send datagrams larger than 576 octets if they have assurance that the destination is prepared to accept the larger datagrams.

The number 576 is selected to allow a reasonable sized data block to be transmitted in addition to the required header information. For example, this size allows a data block of 512 octets plus 64 header octets to fit in a datagram. The maximal internet header is 60 octets, and a typical internet header is 20 octets, allowing a margin for headers of higher level protocols.

Identification: 16 bits

An identifying value assigned by the sender to aid in assembling the fragments of a datagram.

Flags: 3 bits

Various Control Flags.

```
Bit 0: reserved, must be zero
Bit 1: (DF) 0 = May Fragment,  1 = Don't Fragment.
Bit 2: (MF) 0 = Last Fragment, 1 = More Fragments.

    0   1   2
  +---+---+---+
  |   | D | M |
  | 0 | F | F |
  +---+---+---+
```

Fragment Offset: 13 bits

This field indicates where in the datagram this fragment belongs.

The fragment offset is measured in units of 8 octets (64 bits). The first fragment has offset zero.

Time to Live: 8 bits

This field indicates the maximum time the datagram is allowed to remain in the internet system. If this field contains the value zero, then the datagram must be destroyed. This field is modified in internet header processing. The time is measured in units of seconds, but since every module that processes a datagram must decrease the TTL by at least one even if it process the datagram in less than a second, the TTL must be thought of only as an upper bound on the time a datagram may exist. The intention is to cause undeliverable datagrams to be discarded, and to bound the maximum datagram lifetime.

Protocol: 8 bits

This field indicates the next level protocol used in the data portion of the internet datagram. The values for various protocols are specified in "Assigned Numbers" [9].

Header Checksum: 16 bits

A checksum on the header only. Since some header fields change (e.g., time to live), this is recomputed and verified at each point that the internet header is processed.

The checksum algorithm is:

> The checksum field is the 16 bit one's complement of the one's complement sum of all 16 bit words in the header. For purposes of computing the checksum, the value of the checksum field is zero.

This is a simple to compute checksum and experimental evidence indicates it is adequate, but it is provisional and may be replaced by a CRC procedure, depending on further experience.

Source Address: 32 bits

The source address. See section 3.2.

Destination Address: 32 bits

The destination address. See section 3.2.

Options: variable

The options may appear or not in datagrams. They must be implemented by all IP modules (host and gateways). What is optional is their transmission in any particular datagram, not their implementation.

In some environments the security option may be required in all datagrams.

The option field is variable in length. There may be zero or more options. There are two cases for the format of an option:

```
Case 1:  A single octet of option-type.

Case 2:  An option-type octet, an option-length octet, and the
         actual option-data octets.
```

The option-length octet counts the option-type octet and the option-length octet as well as the option-data octets.

The option-type octet is viewed as having 3 fields:

```
1 bit   copied flag,
2 bits  option class,
5 bits  option number.
```

The copied flag indicates that this option is copied into all fragments on fragmentation.

```
0 = not copied
1 = copied
```

The option classes are:

```
0 = control
1 = reserved for future use
2 = debugging and measurement
3 = reserved for future use
```

The following internet options are defined:

```
CLASS NUMBER LENGTH DESCRIPTION
----- ------ ------ -----------
  0     0      -    End of Option list.  This option occupies only
                    1 octet; it has no length octet.
  0     1      -    No Operation.  This option occupies only 1
                    octet; it has no length octet.
  0     2     11    Security.  Used to carry Security,
                    Compartmentation, User Group (TCC), and
                    Handling Restriction Codes compatible with DOD
                    requirements.
  0     3     var.  Loose Source Routing.  Used to route the
                    internet datagram based on information
                    supplied by the source.
  0     9     var.  Strict Source Routing.  Used to route the
                    internet datagram based on information
                    supplied by the source.
  0     7     var.  Record Route.  Used to trace the route an
                    internet datagram takes.
  0     8      4    Stream ID.  Used to carry the stream
                    identifier.
  2     4     var.  Internet Timestamp.
```

Specific Option Definitions

End of Option List

```
+--------+
|00000000|
+--------+
  Type=0
```

This option indicates the end of the option list. This might not coincide with the end of the internet header according to the internet header length. This is used at the end of all options, not the end of each option, and need only be used if the end of the options would not otherwise coincide with the end of the internet header.

May be copied, introduced, or deleted on fragmentation, or for any other reason.

No Operation

```
+--------+
|00000001|
+--------+
  Type=1
```

This option may be used between options, for example, to align the beginning of a subsequent option on a 32 bit boundary.

May be copied, introduced, or deleted on fragmentation, or for any other reason.

Security

This option provides a way for hosts to send security, compartmentation, handling restrictions, and TCC (closed user group) parameters. The format for this option is as follows:

```
+--------+--------+--- // ---+--- // ---+--- // ---+--- // ---+--- // ---+
|10000010|00001011|SSS  SSS|CCC  CCC|HHH  HHH|  TCC   |
+--------+--------+--- // ---+--- // ---+--- // ---+--- // ---+--- // ---+
 Type=130 Length=11
```

Security (S field): 16 bits

Specifies one of 16 levels of security (eight of which are reserved for future use).

```
00000000 00000000 - Unclassified
11110001 00110101 - Confidential
01111000 10011010 - EFTO
10111100 01001101 - MMMM
01011110 00100110 - PROG
10101111 00010011 - Restricted
11010111 10001000 - Secret
01101011 11000101 - Top Secret
00110101 11100010 - (Reserved for future use)
10011010 11110001 - (Reserved for future use)
01001101 01111000 - (Reserved for future use)
00100100 10111101 - (Reserved for future use)
00010011 01011110 - (Reserved for future use)
10001001 10101111 - (Reserved for future use)
11000100 11010110 - (Reserved for future use)
11100010 01101011 - (Reserved for future use)
```

Compartments (C field): 16 bits

An all zero value is used when the information transmitted is not compartmented. Other values for the compartments field may be obtained from the Defense Intelligence Agency.

Handling Restrictions (H field): 16 bits

The values for the control and release markings are alphanumeric digraphs and are defined in the Defense Intelligence Agency Manual DIAM 65-19, "Standard Security Markings".

Transmission Control Code (TCC field): 24 bits

Provides a means to segregate traffic and define controlled communities of interest among subscribers. The TCC values are trigraphs, and are available from HQ DCA Code 530.

Must be copied on fragmentation. This option appears at most once in a datagram.

Loose Source and Record Route

```
+--------+--------+--------+---------//--------+
|10000011| length | pointer|     route data    |
+--------+--------+--------+---------//--------+
 Type=131
```

The loose source and record route (LSRR) option provides a means for the source of an internet datagram to supply routing information to be used by the gateways in forwarding the datagram to the destination, and to record the route information.

The option begins with the option type code. The second octet is the option length which includes the option type code and the length octet, the pointer octet, and length-3 octets of route data. The third octet is the pointer into the route data indicating the octet which begins the next source address to be processed. The pointer is relative to this option, and the smallest legal value for the pointer is 4.

A route data is composed of a series of internet addresses. Each internet address is 32 bits or 4 octets. If the pointer is greater than the length, the source route is empty (and the recorded route full) and the routing is to be based on the destination address field.

If the address in destination address field has been reached and the pointer is not greater than the length, the next address in the source route replaces the address in the destination address field, and the recorded route address replaces the source address just used, and pointer is increased by four.

The recorded route address is the internet module's own internet address as known in the environment into which this datagram is being forwarded.

This procedure of replacing the source route with the recorded route (though it is in the reverse of the order it must be in to be used as a source route) means the option (and the IP header as a whole) remains a constant length as the datagram progresses through the internet.

This option is a loose source route because the gateway or host IP is allowed to use any route of any number of other intermediate gateways to reach the next address in the route.

Must be copied on fragmentation. Appears at most once in a datagram.

Strict Source and Record Route

```
+--------+--------+--------+---------//--------+
|10001001| length | pointer|     route data    |
+--------+--------+--------+---------//--------+
 Type=137
```

The strict source and record route (SSRR) option provides a means for the source of an internet datagram to supply routing information to be used by the gateways in forwarding the datagram to the destination, and to record the route information.

The option begins with the option type code. The second octet is the option length which includes the option type code and the length octet, the pointer octet, and length-3 octets of route data. The third octet is the pointer into the route data indicating the octet which begins the next source address to be processed. The pointer is relative to this option, and the smallest legal value for the pointer is 4.

A route data is composed of a series of internet addresses. Each internet address is 32 bits or 4 octets. If the pointer is greater than the length, the source route is empty (and the recorded route full) and the routing is to be based on the destination address field.

If the address in destination address field has been reached and the pointer is not greater than the length, the next address in the source route replaces the address in the destination address field, and the recorded route address replaces the source address just used, and pointer is increased by four.

The recorded route address is the internet module's own internet address as known in the environment into which this datagram is being forwarded.

This procedure of replacing the source route with the recorded route (though it is in the reverse of the order it must be in to be used as a source route) means the option (and the IP header as a whole) remains a constant length as the datagram progresses through the internet.

This option is a strict source route because the gateway or host IP must send the datagram directly to the next address in the source route through only the directly connected network indicated in the next address to reach the next gateway or host specified in the route.

Must be copied on fragmentation. Appears at most once in a datagram.

Record Route

```
+--------+--------+--------+---------//--------+
|00000111| length | pointer|     route data    |
+--------+--------+--------+---------//--------+
  Type=7
```

The record route option provides a means to record the route of an internet datagram.

The option begins with the option type code. The second octet is the option length which includes the option type code and the length octet, the pointer octet, and length-3 octets of route data. The third octet is the pointer into the route data indicating the octet which begins the next area to store a route address. The pointer is relative to this option, and the smallest legal value for the pointer is 4.

A recorded route is composed of a series of internet addresses. Each internet address is 32 bits or 4 octets. If the pointer is greater than the length, the recorded route data area is full. The originating host must compose this option with a large enough route data area to hold all the address expected. The size of the option does not change due to adding addresses. The intitial contents of the route data area must be zero.

When an internet module routes a datagram it checks to see if the record route option is present. If it is, it inserts its own internet address as known in the environment into which this datagram is being forwarded into the recorded route begining at the octet indicated by the pointer, and increments the pointer by four.

If the route data area is already full (the pointer exceeds the length) the datagram is forwarded without inserting the address into the recorded route. If there is some room but not enough room for a full address to be inserted, the original datagram is considered to be in error and is discarded. In either case an ICMP parameter problem message may be sent to the source host [3].

Not copied on fragmentation, goes in first fragment only. Appears at most once in a datagram.

Stream Identifier

```
+--------+--------+--------+--------+
|10001000|00000010|    Stream ID    |
+--------+--------+--------+--------+
 Type=136 Length=4
```

This option provides a way for the 16-bit SATNET stream identifier to be carried through networks that do not support the stream concept.

Must be copied on fragmentation. Appears at most once in a datagram.

Internet Timestamp

```
+--------+--------+--------+--------+
|01000100| length | pointer|oflw|flg|
+--------+--------+--------+--------+
|         internet address          |
+--------+--------+--------+--------+
|            timestamp              |
+--------+--------+--------+--------+
|                 .                 |
                  .
                  .
Type = 68
```

The Option Length is the number of octets in the option counting the type, length, pointer, and overflow/flag octets (maximum length 40).

The Pointer is the number of octets from the beginning of this option to the end of timestamps plus one (i.e., it points to the octet beginning the space for next timestamp). The smallest legal value is 5. The timestamp area is full when the pointer is greater than the length.

The Overflow (oflw) [4 bits] is the number of IP modules that cannot register timestamps due to lack of space.

The Flag (flg) [4 bits] values are

```
0 -- time stamps only, stored in consecutive 32-bit words,

1 -- each timestamp is preceded with internet address of the
     registering entity,

3 -- the internet address fields are prespecified.  An IP
     module only registers its timestamp if it matches its own
     address with the next specified internet address.
```

The Timestamp is a right-justified, 32-bit timestamp in milliseconds since midnight UT. If the time is not available in milliseconds or cannot be provided with respect to midnight UT then any time may be inserted as a timestamp provided the high order bit of the timestamp field is set to one to indicate the use of a non-standard value.

The originating host must compose this option with a large enough timestamp data area to hold all the timestamp information expected. The size of the option does not change due to adding timestamps. The intitial contents of the timestamp data area must be zero or internet address/zero pairs.

If the timestamp data area is already full (the pointer exceeds the length) the datagram is forwarded without inserting the timestamp, but the overflow count is incremented by one.

If there is some room but not enough room for a full timestamp to be inserted, or the overflow count itself overflows, the original datagram is considered to be in error and is discarded. In either case an ICMP parameter problem message may be sent to the source host [3].

The timestamp option is not copied upon fragmentation. It is carried in the first fragment. Appears at most once in a datagram.

Padding: variable

The internet header padding is used to ensure that the internet header ends on a 32 bit boundary. The padding is zero.

References

[3] Postel, J., "Internet Control Message Protocol - DARPA Internet Program Protocol Specification," RFC 792, USC/Information Sciences Institute, September 1981.

[8] Postel, J., "Service Mappings," RFC 795, USC/Information Sciences Institute, September 1981.

[9] Postel, J., "Assigned Numbers," RFC 790, USC/Information Sciences Institute, September 1981.

1 **Excerpt.** This poster reproduces section 3.1 of RFC 791 in full, with the preface of the document and the entries of its reference list that the section cites. The complete specification is at https://www.rfc-editor.org/rfc/rfc791.

doi:10.17487/RFC0791