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2.3.2.1 A Proposed New Internet Header Format

As a result of the recent TCP and internet working group meetings at the end of January, the notion of an internet layer of protocol has become somewhat clearer. The basic internet service is datagram oriented, but also accommodates the fragmentation of datagrams at gateways, reassembly taking place at the destination gateway associated with the destination host. Of course, fragmentation and reassembly of datagrams within a network or by private agreement between the gateways of a network is also allowed since this is transparent to the internet protocols and the higher-level protocols. This transparent type of fragmentation/reassembly is termed "network-dependent" fragmentation and is not dealt with further here.

At the meetings, the point was also raised that addressing my be confined to the internet header at least for the current host/host protocols such as TCP and the two undefined but planned protocols: datagram protocol (DGP) and real-time protocol (RTP). This strategy will better support multi-protocol synchronization when this is required for multi-media teleconferencing.

In the format proposal which follows, an attempt has been made to reduce the impact on header length of the new features of the internet protocol. It is proposed that some flexibility be given up in favor of reducing header sizes or processing requirements. Figure 1 illustrates the proposed new internet header format.

The proposed new internet format only allows two versions ("VER" field) of the internet header to co-exist. This seems sufficient to deal with any reasonable transition period during which one header is being phased out. Once the internet system is in operation on a regular basis, changes to the header format should be rare since such changes would affect all host and gateway software.

The 7 bit "protocol" field is designed to accommodate up to 128 protocols. This is in lieu of the "format" field found in the January 1978 TCP-3 draft specification, figure 4.3-1 [1]. This field supports the demultiplexing of incoming internet packets to the proper protocol specific processing modules.

The next eight bit field is for internet service control. The first bit ("OPT" for options) is set if options are present in the internet header. The second bit ("DF" for "don't fragment") is set if internet fragmentation of this packet is NOT permitted. This can be used to prohibit fragmentation in cases where the receiving host does not have sufficient resources to reassembly internet fragments. The TOS (type of service) field allows, as before, up to 16 different types of service to be selected. The definition of various types of service remains to be worked out.

The next 16 bit field contains the total internet packet length, measured in octets, including the internet header. The internet packet ID field, which comes next, can be used both to identify packet fragments for reassembly and to identify to which packets any internet error messages apply.

The next 12 bit field is used for fragmentation and reassembly. The high order bit, "MF," is set if the packet is not the last fragment (i.e. there are More Fragments). The next eleven bits identify the fragment number, relative to the beginning of the original unfragmented packet. Fragments are numbered in units of 8 octets. The fragmentation strategy is designed so than an unfragmented packet has an all zero fragmentation field (MF = 0, fragment number = 0). If an internet packet is fragmented, its text field must be broken on 8 octet boundaries.

At the internet meeting and the TCP meeting, it was proposed that only 8 bits be used for fragment identification with another bit to indicate the "last fragment." The fragments would be numbered in units of 64 octets. This would support packet lengths up to (2**8)*(2**6) = 2**14 = 16,384 octets. This strategy can lead to serious inefficiencies in the transport of fragments, since the unit of fragmentation is so large (512 bits). For example, an ARPANET packet can hold at most one 512 bit portion of a fragment. Since the internet header is at least 192 bits long, fragments carried as type 3 ARPANET packets could have an efficiency of 512/(192+512) = 0.71 [and that is not counting the TCP header of 128 bits which would cause efficiency to drop to 512/(192+128+512) = 0.63!].

To reduce the potential inefficiency of fragmentation, the new proposed format allows 2**11 = 2048 fragments of 8 octets each for a total of 16,384 octets. But fragmentation under this new scheme has an efficiency of 768/(192+768) = 0.80 for internet packets carried in ARPANET type 3 packets, and 688/(128+192+688) = 0.69 for TCP packets. Of course, efficiencies higher than this are possible for systems whose minimum packet size is larger than 1008 bits.

The data offset field is four bits long and indicates where, in 32 bit units, the data in an internet packet starts, relative to the beginning of the internet header. The offset permits internet header lengths (including options and padding) as long as 16*32 = 512 bits, if need be.

Addressing

The option-type octet can be viewed as having 3 fields: checksum exclusion flag (1 bit), option class (2 bits), specific options (5 bits). The option classes are:

0 = control

1 = internet error

2 = experimental debugging and measurement

3 = reserved for future use

At present only the following internet options are defined:

TYPE	LENGTH	DESCRIPTION
0	-	End of option list. This option occupies only 1 octet; it has no length octet.
1	-	Padding. This option occupies only 1 octet; it has no length octet.
304	var.	Internet timestamp field used to accumulate timestamping information during internet transit. The length field is variable and may change as the internet packet traverses the networks and gateways of the internet system.
305	var.	Satellite timestamp field. Used as above for special satellite network testing.

Note: The type field is given in octal in the list above.

Fragmentation

When fragmentation occurs, options are generally not copied, but remain with the first fragment. For concreteness, an example of a fragmented packet is shown in figure 2. The original packet had a text length of 120 octets. Note how the "OPT," "MF," "Fragment Number," "Data Offset," "Packet Length,"and "Options/Padding" fields change when a single internet packet is fragmented. Also note that the uniqueness of the fragments can be based on the Protocol field, the packet ID field, and the source/destination address fields.

The fields which may be affected by fragmentation include:

(1) option flag field

(2) options field

(3) fragment number and last fragment flag

(4) data offset field

(5) packet length field

One issue is whether to include an optional internet checksum which would be recomputed if the internet header is changed owing to additions or changes to internet options or due to fragmentation. Having such a non-end-to-end checksum for the raw internet system might reduce errors occurring during fragment reassembly, and would also protect the address fields.

References

1. Vinton Cerf and Jon Postel, "Specification of Internet Transmission Control Program. TCP - Version 3," January 1978, Internet Notebook Section 2.4.2.

```
 1     7         1 1  4     4               16
+-+-----------+-+-+----+------+--------------------------------+
[V!           !O!D!////!      !                                ]
[E! PROTOCOL  !P!F!////! TOS  !     Packet Length (octets)     ]
[R!           !T! !////!      !                                ]
+-+-----------+-+-+----+------+-+------------------------+-----+
[     INTERNET                  !M!    FRAGMENT          ! DATA ]
[    PACKET ID                  !F!     NUMBER           !OFFSET]
+-------------+-----------------+-+----------------------+------+
[DESTIN. NET  !              DESTINATION HOST                  ]
+-------------+------------------------------------------------+
[                 DESTINATION PORT                             ]
+-------------+------------------------------------------------+
[ SOURCE NET  !                SOURCE HOST                     ]
+-------------+------------------------------------------------+
[                           SOURCE PORT                        ]
+--------------------------------------------+-----------------+
[         OPTIONS . . .                      !    PADDING      ]
+--------------------------------------------+-----------------+
[                    TEXT . . .                                ]
----------------------------------------------------------------
```

Internet Header Format

Figure 1

```
 1      7      1 1  4      4              16
+-+-------------+-+-+-----+-------+----------------------------+
[0! PROTOCOL    !1!0!////! TOS    !    Packet Length (octets)  ]
[ ! (2 = TCP)   ! ! !////!        !           (152)            ]
+-+-------------+-+-+-----+-------+-+--------------------+-----+
[       INTERNET                   !0!    FRAGMENT       !OFFSET]
[      PACKET ID      (1075)       ! !    NUMBER   ( 0 )  ! ( 7 )]
+-------------+--------------------+-+--------------------+-----+
[DEST. NET (10)!        DESTINATION HOST (IMP = 22, HOST = 1) ]
+-------------+------------------------------------------------+
[                    DESTINATION PORT   ( LOGGER = 1 )          ]
+-------------+------------------------------------------------+
[SOURCE NET (6)!       SOURCE HOST (Packet Radio ID = 4104)    ]
+-------------+------------------------------------------------+
[                         SOURCE PORT   ( 232 )                 ]
+-------------+------------------------------------------------+
[  ( 304 )    !(length = 6 ) !  ( High Order Timestamp )       ]
+-------------+-------------+-------------+-------------+------+
[  ( Low Order Timestamp )   !  ( end = 0 )  !  ( pad = 1 )    ]
+-------------+-------------+-----------------------------------+
[         ( Text = 120 octets) . . .                            ]
+-------------+-------------+-----------------------------------+
```

Unfragmented Internet Packet

Figure 2 (a)

```
 1      7          1 1  4     4              16
+-+-------------+-+-+----+-----+------------------------------+
[0! PROTOCOL    !1!0!////! TOS !    Packet Length (octets)    ]
[ ! (2 = TCP)   ! ! !////!     !           (120)              ]
+-+-------------+-+-+----+-----+-+---------------------+-------+
[       INTERNET                !1!    FRAGMENT          !OFFSET]
[     PACKET ID    (1075)       ! !    NUMBER  ( 0 )     ! ( 7 )]
+-------------------------------+-+---------------------+-------+
[DEST. NET (10)!    DESTINATION HOST (IMP = 22, HOST = 1) ]
+--------------+-------------------------------------------+
[                DESTINATION PORT  ( LOGGER = 1 )           ]
+--------------+-------------------------------------------+
[SOURCE NET (6)!    SOURCE HOST (Packet Radio ID = 4104)   ]
+--------------+-------------------------------------------+
[                     SOURCE PORT  ( 232 )                  ]
+--------------+-------------+-----------------------------+
[   ( 304 )    !(length = 6 ) !  ( High Order Timestamp )   ]
+--------------+-------------+-----------------------------+
[  ( Low Order Timestamp )    !  ( end = 0 )  !  ( pad = 1 )  ]
+--------------+-------------+---------------+-------------+
[            ( Text = 88 octets) . . .                      ]
+--------------+-------------+-----------------------------+
```

First Fragment of Internet Packet

Figure 2 (b)

```
 1     7      1 1  4     4                16
+-+-------------+-+-+-----+------+-----------------------------+
[0! PROTOCOL    !0!0!////! TOS   !    Packet Length (octets)   ]
[ ! (2 = TCP)   ! ! !////!       !        (56)                 ]
+-+-------------+-+-+-----+------+-+-----------------+-------+
[     INTERNET                   !0!    FRAGMENT     !OFFSET]
[    PACKET ID    (1075)         ! !     NUMBER  (11) ! ( 5 )]
+--------------+-----------------+-+-----------------+-------+
[DEST. NET (10)!        DESTINATION HOST (IMP = 22, HOST = 1) ]
+--------------+-----------------------------------------------+
[                  DESTINATION PORT  ( LOGGER = 1 )           ]
+--------------+-----------------------------------------------+
[SOURCE NET (6)!        SOURCE HOST (Packet Radio ID = 4104)  ]
+--------------+-----------------------------------------------+
[                       SOURCE PORT  ( 232 )                  ]
+-----------------------------+-------------+-----------------+
[        ( Text = 32 octets) . . .                            ]
+--------------+--------------+-------------------------------+
```

Last Fragment of Internet Packet

Figure 2 (c)