Network Working Group
INTERNET-DRAFT

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# Pip Header Processing

Changes Since Last Version

This version has the following changes from the previous version, dated November 1992.

1. The management of the HD and RC fields has changed (though the semantics and evolvability of them has not). The HD and RC fields are still opaque (meaning that the semantics of the HD and RC cannot be determined without additional information), but Pip will operate globally under well-known sets of semantics, and each packet indicates which set the packet falls under. The need to remap the HD and RC fields hop-by-hop has been eliminated (though tagging is still a feature of Pip).

2. This version has made options faster to process and more general. It has introduced fields in the fixed part of the Transit Part to indicate which options are present, and the first option now indicates where each individual option is in the list of options. In addition, the Transit Options part can now be in the self-encapsulation header.

3. The router and host options have been combined into one options part.

4. The entire Host Part has been moved into the Initial Part.

5. All checksums have been removed.

6. The FTIFs have been limited to a single length (16 bits). No that this does not limit a single "number" in the FTIF chain to 16 bits or less. A "number" can be encoded as mulitple FTIFs.

Status of this Memo

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Abstract

Pip is an internet protocol intended as the replacement for IP version 4. Pip is a general purpose internet protocol, designed to handle all forseeable internet protocol requirements. This specification defines the Pip header processing for Routers and Hosts.

Acknowledgements

I want to individually acknowledge Rob Coltun, Steve Deering, Ramesh Govindan, Joel Halpern, John Ioannidis, Chris Petrilli, Bob Smart, and Zheng Wang. I want also to acknowledge the many people from the Pip working group who have participated in developing Pip. Finally, I want to acknowledge the SIP protocol (or, more accurately, the people behind the SIP protocol) for providing certain good ideas.

Conventions

All functions in this specification are mandatory.

## 1. Introduction

Pip is an internet protocol intended as the replacement for IP version 4. Pip is a general purpose internet protocol, designed to

handle all forseeable internet protocol requirements. This specification defines the Pip header processing for Routers and Hosts.

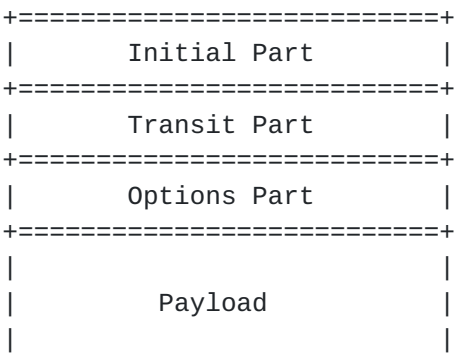
The design of Pip is fundamentally different from that of previous internetwork protocols. Pip is designed to be as general as possible, but without significantly compromising performance. Because of Pip's generality, it can handle forseeable routing and addressing requirements. It is hoped that it will be able to handle most if not all future routing and addressing requirements.

There are many detailed aspects of Pip that provide this generality that are not discussed here. It is useful, however, to mention one general aspect. That is, Pip strives to remove as much "functional semantics" from the base specification as possible. Pip defines a packet header and forwarding rules that can include many different functional semantics (that is, routing, addressing, and flow paradigms). Therefore, the reader may often find him or herself asking "But how do you do foo with Pip?" The answer to this sort of question belongs in companion documents to the basic Pip spec.

Pip can be thought of as a mechanism for triggering actions in hosts and routers, just as a machine language can be thought of as a mechanism for triggering actions in CPUs. The machine language has no functional semantics outside of the specific actions it triggers (move this register, write that memory location, etc.). But, the machine language is a very powerful tool upon which functional semantics are built. Likewise, Pip is a powerful tool upon which routing, addressing, and flow functions can be built.

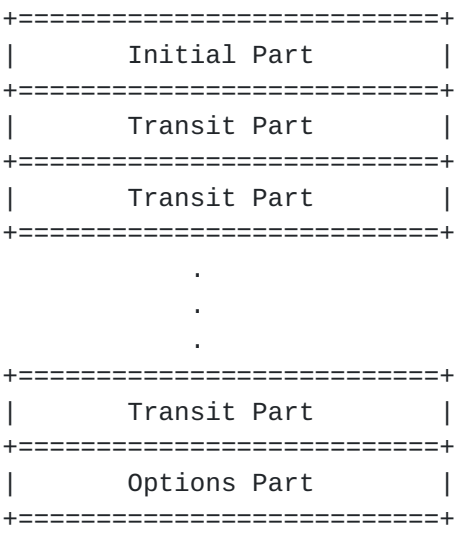
## 2. Pip Specification

The Pip header is partitioned into three parts, the Initial Part, the Transit Part, and the Options Part.




Each part falls on a 32-bit boundary (as indicated by the double lines shown), and the Transit Part falls on a 64 bit boundary.

The concept of tunneling in an integral part of Pip. Pip achieves tunneling by encapsulating the Transit Part of the Pip header in another Transit Part. Therefore, when tunneling, there is one Transit Part for each (nested) tunnel:




Because each Transit Part has only what is necessary for router forwarding and handling, this method of tunneling is reasonably efficient in terms of packet size.

## 2.1. Initial Part

The Initial Part is formatted as shown in Figure 1.

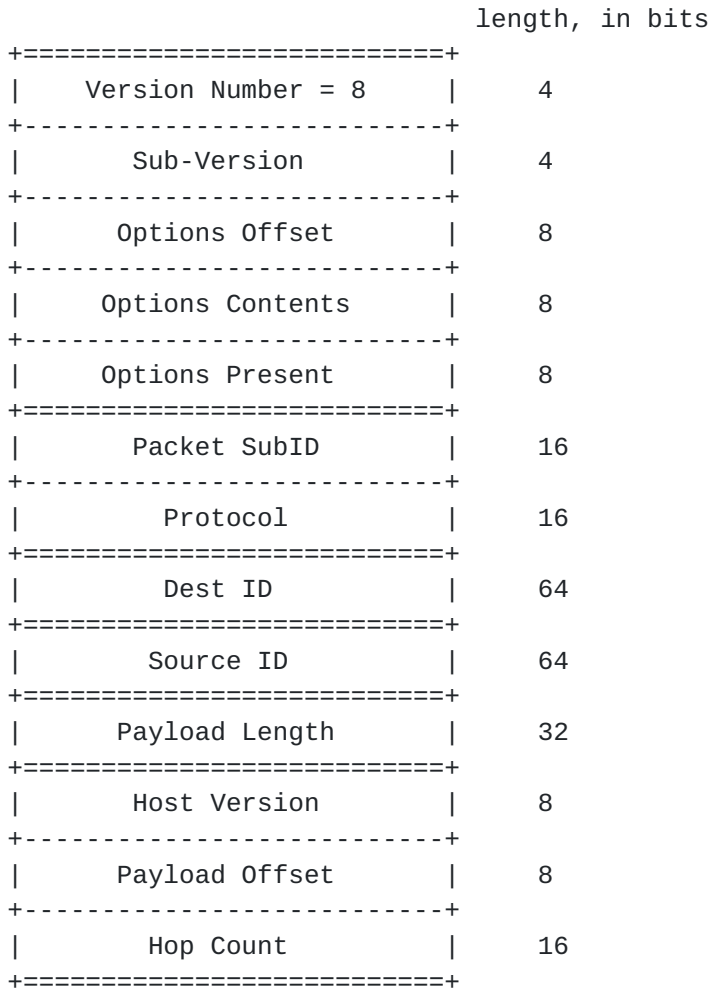



Figure 1: Initial Part

An explanation of each field follows.

### 2.1.1. Version Numbers

The first octet is divided into two 4-bit fields, the Version and the Sub-Version. The Version field is set to be 8, and is meant to be version 8 of IP. (As of this writing, this is an experimental number assigned for development of Pip.) Thus, all encapsulation schemes defined for IP can work for Pip as well.

As long as the Version field is 8, the Initial Part and Options Part of the Pip Header is as specified in this standard. (In other words, the Sub-Version field refers only to the Transit Part.)

By doing this, we allow the Transit Part of the Pip Header to change completely without necessarily requiring a host to understand the new Transit Part. If a host receives a Pip header with a Version number of 8 and an unknown Sub-version number, the host does not try to parse the Transit Part at all, rather it processes only the Initial Part and the Options Part. (By using the Pip Header Protocol to format Pip Headers, a host can be made to formulate the right Transit Part, even though the host doesn't understand the semantics of the Transit Part. This allows radical migration of the Transit Part while potentially not requiring changes to hosts.)

If a host or a router receives a packet with an unknown Version number, the packet is silently discarded.

The Sub-Version field is set to the value 0 for the version of Pip defined in this specification. As long as the Sub-Version number is 0, the Transit Part is as specified in this standard. Any packet received by a router with a Version number of 8 and an unknown Sub-Version number is silently discarded.

### 2.1.2. Options Offset

The Options Offset indicates the position of the Options Part. The unit of measure of the Options Offset is 32-bit words, counting the first word of the Pip Header as word 0.

### 2.1.3. Options Contents

This field indicates how the Options Present field should be interpreted. Each bit of the Options field indicates if each of up to eight options is present in the Options Part. The Options Contents field indirectly indicates which option each bit of the Options Present field refers to. We say indirectly because the mapping referred to by the Options Contents field is stored locally. In other words, without additional information (the mapping), it is not possible to examine the Options Contents field and know what option each bit of the Options Present field refers to.

Any of 256 possible Options Contents values can be active at a given

time. (Note that the means by which the meaning of the Options Contents values are assigned and conveyed to routers and hosts is outside the scope of this specification.)

### 2.1.4. Options Present

This field indicates which of the Options indicated by the Options Contents field are actually present in the Options Part. Each bit of this field refers to a single option type. The mapping of each bit to its' option type is determined by the Options Contents field.

For instance, assume that the Options Contents field indicates that bit 0 of the Options Present field refers to the PDN Address option, that bit 1 of the Options Present field refers to the foo option, and that bit 2 of the Options Present field refers to the Fragmentation option. (As of this writing, there is only one option. Until there are more than eight options, there is no need to define more than one Options Contents values.)

In this case, a value of 101 in the Options Present field indicates that the PDN Address and Fragmentation options are present in the Options Part, and that the foo option is not present.

Note that an Options Present value of 0 indicates that there are no options present, regardless of the value of the Options Contents field. Note also that no more than 8 options, not including the default first option (the Options Descriptor), can be present in any Options Part.

The Options Contents/Options Present method of processing options allows for efficient processing of options. First, a router can ignore any options that may be present but that do not impact it (for instance, a router not attached to a PDN need not consider the PDN Address option). Second, the desired option can be very quickly retrieved, because the first option, the Options Descriptor option, contains the offset of each of the up to eight options indicated by the Options Present field.

### 2.1.5. Packet SubID

This field is used by Pip hosts to correctly associate received PCMP messages with local control blocks. This is necessary because the semantics of the Transit Part can change while a packet is in

transit. Therefore, a router sending a PCMP message cannot necessarily provide all of the information needed by the Pip host to correctly identify the context of the received message (that is, which "packet flow" it is identified with).

A PCMP message uses the Protocol, Source ID, Dest ID, and Packet SubID to define the PCMP messages context. It is not sufficient to use just Protocol, Source ID, and Dest ID, because two hosts running the same protocol between them may have multiple "flows", for instance, a data flow, a video flow, and an audio flow in the case of multi-media. Each flow may have a different Transit Part, and take different paths. Therefore, the Packet SubID field is needed to further differentiate.

### 2.1.6. Protocol

Indicates the protocol header found in the payload. The values for this field are the same as those used for IPv4.

### 2.1.7. Dest ID

The Dest ID field indicates the Pip ID of the final recipient of the Pip packet. This field is examined by both hosts and routers.

When a Pip System processes the Routing Directive (RD), it may determine that it needs to examine the Dest ID for further processing. This may happen both when a host or router receives a Pip packet destined for itself, or when a router receives a packet that should be forwarded based on Dest ID (as indicated by the RD).

When a Pip system determines at forwarding time that a packet is destined for itself, it checks the Dest ID to verify if that packet is destined for it. If the complete Dest ID matches one of its own Pip IDs, then the packet is for it, and is passed to the layer indicated by the Protocol field (in the Host Part). (The Pip system may of course wish to check a security option before passing a packet to an upper layer.)

If the complete Dest ID field does not match one of its own IDs, then an ID/RD Mismatch PCMP message is sent to the source of the packet, as indicated by the Source ID and potentially source information in the RD. The purpose of this message is to flush the ID to RD binding in the source Pip host.

#### 2.1.8. Source ID

This is the Pip ID of the source of the packet. It is passed to upper layers for the purposes of identifying the context for the packet.

#### 2.1.9. Payload Length

The Payload Length gives the length of the Pip packet payload in units of 8 bits. The Payload Length does not include the length of the Pip header.

#### 2.1.10. Host Version

The Host Version field indicates what "version" of Pip software the sending host has implemented. This is to allow a host to inform a router which ancillary protocols/messages the host is able to accept. It is envisioned that over time, new host functions will be developed. Different hosts will install these new functions at different times. This field allows routers to know what functions the host can and cannot handle.

#### 2.1.11. Payload Offset

The Payload Offset indicates the position of the Payload Part. The unit of measure of the Payload Offset is 32-bit words, counting the first word of the Pip Header as word 0.

If a Pip system encapsulates a Transit Part in another Transit Part, then the Payload Offset is increased by the length of the new Transit Part.

#### 2.1.12. Hop Count

The Hop Count is decremented by every router that forwards the Pip packet. If a system receives a Pip header with a Hop Count equal to 0, and is not the recipient of the packet, then the packet is discarded and a PCMP Destination Unreachable is routed to the system indicated by the Routing Directive. (In other words, a host can legally receive a Transit Part with a Hop Count of 0, and indeed a host doesn't look at the Hop Count field upon reception.)

## 2.2. Transit Part

The Transit Part is formatted as shown in Figure 2.

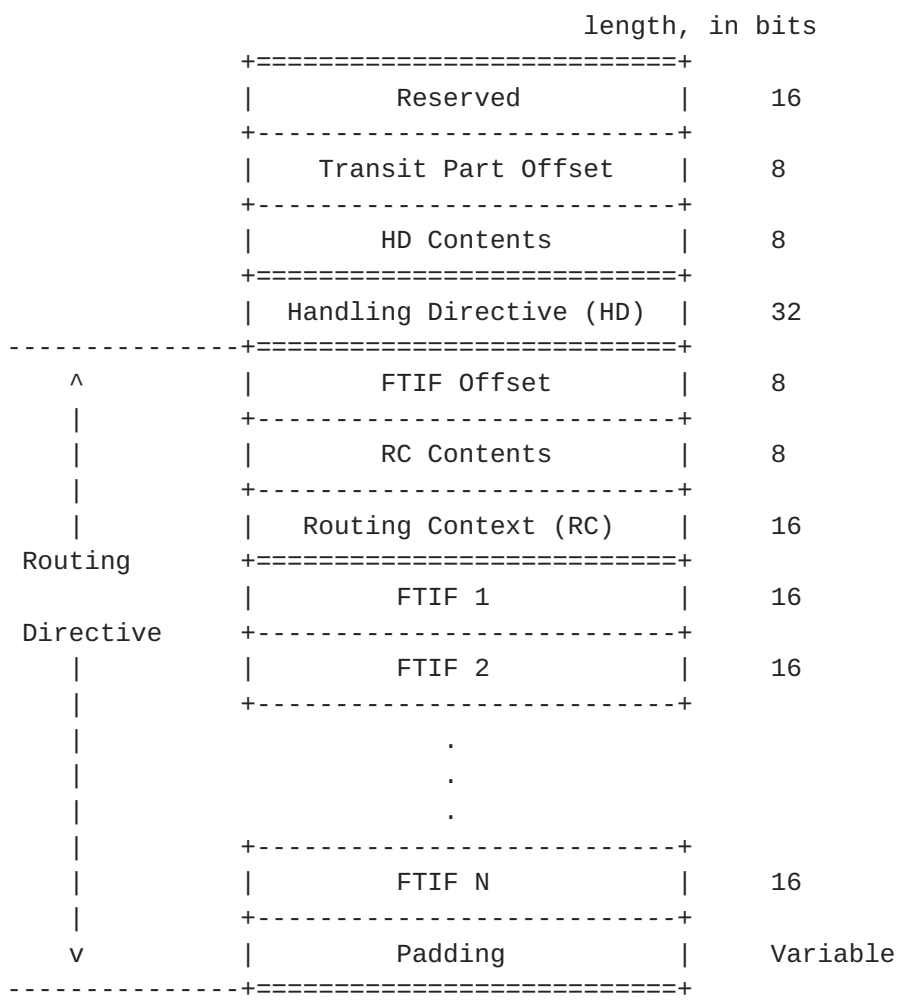



Figure 2: Transit Part

An explanation of each field follows.

### 2.2.1. Transit Part Offset

This field gives the position of the first word of the next Transit Part. The unit of measure of the Transit Part Offset is 32-bit

words, counting the first word of the current Transit Part as word 0. If there is no next Transit Part, then this field is written as all 0's.

### 2.2.2. HD Contents

He HD Contents field indicates how the Handling Directive (HD) field should be interpreted. The HD field is divided into multiple fields, each representing a different handling function. Each individual field in the HD is called an HD Unit (HDU). The Options Contents field indirectly indicates which HDUs are in the HD field, and where they are. We say indirectly because the mapping referred to by the HD Contents field is stored locally. In other words, without additional information (the mapping), it is not possible to examine the HD Contents field and know what the HDU locations are.

Any of 256 possible HD Contents values can be active at a given time. (Note that the means by which the meaning of the HD Contents values are assigned and conveyed to routers and hosts is outside the scope of this specification.)

### 2.2.3. Handling Directive (HD)

The HD is a general purpose field used for the purpose of triggering special packet handling by a Pip system. The HD field does not influence a Pip router's next hop choice for a Pip packet, nor does it influence a Pip host's determination as to whether the Pip packet is destined for it. Examples of special packet handling would be "low priority queueing", or "high priority discard", etc. (Note that the Transit Options also influence "handling", in the sense that handling is essentially defined here to mean "anything that is not routing. The HD field, though, is intended for the most common types of handling--handling that is expected to be in a significant percentage of packets.)

Both hosts and routers use the HD field. (Hosts may make use of the HD field for packet handling for both incoming and outgoing packets.)

There is a complete distinction between the syntax and the semantics of the HD field. (This can be contrasted with, for instance, IP, which couples the semantics and syntax of the TOS bits. That is, the IP specification itself determines, to a first degree, how the TOS bits are interpreted.) Each Pip system can modify the semantic

meaning of the HD, for instance, by increasing or decreasing the queueing priority of a packet. This is called packet tagging.

From an abstract modeling perspective, the HD is handled as follows:

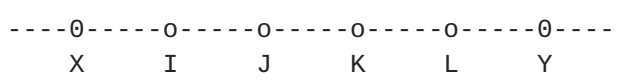
1. Extract the semantic meaning(s) (the handling instructions associated with the HDUs) from the HD field. Transmitting Pip hosts determine the semantic meaning by some other means, such as the upper layer protocol. If the receiving system decapsulates multiple Pip headers, then the HD semantics are extracted from the lowest Pip header for which it is not the target (see example on tunneling below).

2. Handle the Pip packet according to those instructions. In some cases, it is possible that the Pip system does not understand the semantics of one or more HDUs of the HD field. For each HDU whose semantics are not understood, however, the pip system at least knows whether to 1) pass the HDU on untouched, 2) set it to all 0s, 3) set it to all 1s, 4) discard the packet silently, or 5) discard the packet with a PCMP HDU Not Understood packet.

3. Modify the semantic meaning if necessary. Note also that if the Pip packet is replicated for multicast, each packet has its HD semantics modified individually.

### 2.2.4. Tunneling

Consider two Pip systems, X and Y, separated by one or more intermediate Pip systems. X wishes to tunnel a Transit Part to Y. Y is therefore the target system of the tunnel. A Transit Part He arrives at X. In order to forward the Transit Part to Y, X encapsulates He in another Transit Part, Hy. Y is the target system for Transit Part Hy. X sets the HD of He to what it would have been if Y was directly connected to X (that is, there were no intermediate Pip systems between X and Y). Further, it is intended that Y will derive its HD semantics from the HD of Transit Part He, not Transit Part Hy.



Now consider the operation of Pip system L (the previous hop system to Y). When L forwards the packet to Y, it may either decapsulate the packet (in the knowledge that Y is the target for Hy), or not decapsulate the packet. Either way, L derives its HD semantics from the HD of Transit Part He.

If L does not decapsulate the Transit Part, then it is as though I, J, K, and L are a "subnetwork" (albeit a Pip subnetwork), and Y is stripping the "subnetwork" header (Hy) off before processing the true Transit Part (He). If L does decapsulate the Transit Part, then, from Y's perspective, it is essentially as though Y were directly connected to X.

### 2.2.5. Routing Directive (RD)

The RD consists of the Routing Context (RC), the RC Contents, the FTIF Offset, and a series of zero or more FTIFs (Forwarding Table Index Fields). This series of FTIFs is called the FTIF Chain. The sole purpose of the RD is to determine how to forward the Pip packet--the RD does not influence handling in any way.

Figure 3 illustrates the decision process for forwarding the Pip packet.

Figure 3 is interpreted as follows. The FIB is the Forwarding Information Block. The FIB contains all the information needed to forward a packet, and may contain multiple next hop (for multicast). This information includes 1) the outgoing interface, 2) how to encapsulate the packet, including lower-layer address(es) (the lower-layer address(es) along with the outgoing interface determine the next hop Pip system), 3) whether and how to tunnel, 4) how to modify the semantics of the HD and RC, and how to modify the FTIF Offset. The goal of the forwarding algorithm is to reach the appropriate FIB.

The directed lines in Figure 3 start at the RC and, through various possible paths, reach a FIB. These lines represent the various information that can influence the forwarding decision (that is, the FIB chosen). For instance, there is no way to reach a FIB without first examining the information in the RC. However, it is possible to identify a FIB by considering only the information in the RC (as indicated by the directed line leading directly right from the RC). Based on the information in the RC, it is also possible to determine

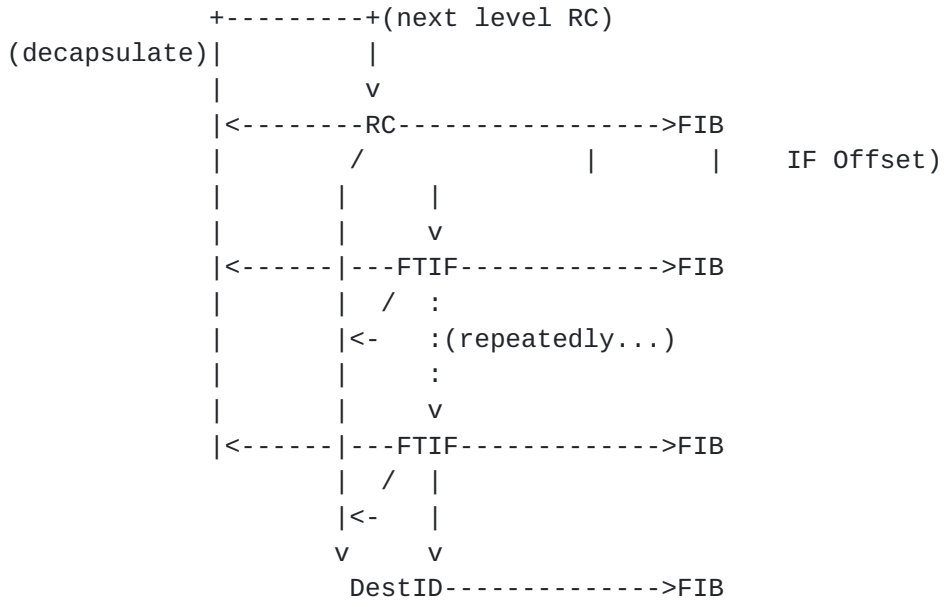



Figure 3: Forwarding Process

that the Transit Part must be decapsulated, and 1) the RC of the next Transit Part be processed (the line leading directly left), 2) the FTIF indicated by the FTIF Offset is processed (the line leading down and right), or 3) the Dest ID is processed (the line leading down and lest).

Likewise, when considering the value of an FTIF (in addition to all information already considered), the resulting action may be that 1) a FIB is identified, 2) the Transit Part is decapsulated, 3) the subsequent FTIF is processed, or 4) the Dest ID is processed.

The RC is handled similarly to the HD. The RC Contents field indicates how the RC should be interpreted. While the RC is constructed similarly to the HD in the sense that it consists of multiple fields, the RC can be interpreted as a flat field in-so-far as forwarding a Pip packet is concerned, whereas the HD cannot.

Thus, in a mechanical sense, the RC Contents can be viewed as an index into a table that returns a pointer to another table (an rcTable), which is indexed by the RC itself. (Or, the combined RC Contents/RC can be viewed as a single large index into a single table, etc.)

The FTIF Offset field indicates which FTIF is active. The active FTIF is the one that is used to index the forwarding table indicated by the RC Contents/RC. An FTIF Offset value of 0 means that the first FTIF is active, an FTIF Offset value of 1 means that the second FTIF is active, and so on. If there are no FTIFs, then the FTIF Offset has no meaning, and can be any value. In this case, the RC field itself will indicate how to forward the packet.

The FTIF Chain is padded out to a 32-bit boundary. Note that there can be more than 16 bits of padding (for instance, if it is desirable to pad out to a 64-bit boundary). The padding is ignored upon receipt, and can be transmitted as any value (that is, it does not have to be any specific pattern of 0's or 1's).

Note that a single "number" in the FTIF chain may in fact be more than 16 bits in length. In this case, the number can be encoded as multiple FTIFs with no loss of generality. It is only required that in all cases a multiple FTIF number be distinguishable from a single FTIF number.

### 2.2.6. Router RD Forwarding Algorithm

This section describes the forwarding algorithm for a Pip router.

1. Using the value of the RC field as an index, retrieve one of the following instructions (steps 2 - 5) from the rcTable determined by the RC Contents.

2. If the instruction is decapsulate, then decapsulate the Transit Part and re-execute step 1 using the next Transit Part.

3. If the instruction is forward, then retrieve the associated Forwarding Information Block (FIB), and go to step 12.

4. If the instruction is to examine the Dest ID, then retrieve the FIB associated with the Dest ID, and go to step 12.

5. If the instruction is to examine the FTIF Chain, then retrieve the forwardingTable indicated by the rcTable entry, and continue on to step 6.

6. Using the value of the currently active FTIF (this is the FTIF indicated by the FTIF Offset if this is the first FTIF examined) as an index, retrieve one or more of the following instructions

(steps 7 - 10) from the forwardingTable identified in step 5 or step 10.

7. If the instruction is decapsulate, then decapsulate the Pip header and re-execute step 1 using the new header (this is the same as step 2).

8. If the instruction is forward, then (possibly additionally) retrieve the associated FIB, and go to step 12 (this is the same as step 3).

9. If the instruction is to examine the Dest ID, then retrieve the FIB associated with the Dest ID and go to step 12 (this is the same as step 4).

10. If the instruction is to examine the next FTIF, then, according to the information in the current forwardingTable entry, modify the current FTIF and choose a new forwardingTable.

11. Make the next FTIF the current FTIF and go to step 6.

12. The FIB contains a set of potential recipients for the Pip packet, including next hop Pip systems (both directly connected and at the end of Pip tunnels) and the upper layer of the local system. Taking into consideration 1) the incoming interface, 2) the previous hop Pip system if known (as determined by the lower-layer source address and incoming interface), and 3) potentially other local information (such as congestion on out-going queues), prune the set of potential recipients. (This may result in no pruning having taken place or in every potential next hop having been pruned.)

13. For each remaining next hop, format a Pip header by modifying a) the RC, b) the current FTIF, c) the FTIF Offset (to point to 1) the FTIF pointed to in the received RD, 2) the current FTIF, 3) the Nth FTIF counting from the 0th FTIF, or 4) the Nth FTIF counting forwards or backwards from the current FTIF) and d) any Pip header encapsulations, according to the information in the FIB, and transmit the packet to the recipient (either a next hop or upper layer).

## 2.3. Options Part

The Option Part is formatted as shown in Figure 4.

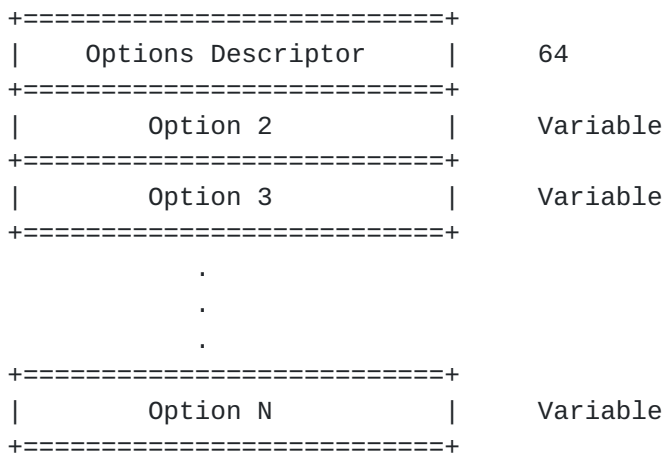



Figure 4: Options Part

Every Option is at least one 32-bit word in length, and ends on a 32-bit word boundary. Because the type of each option is known from the Options Contents field, there is no need to indicate the option type in the options field themselves. Thus, there is no common format among the options--each option has its own format. The individual options are defined in another specification.

### 2.3.1. Options Descriptor

The Options Descriptor option gives the offset of each option in the Options Part. The Options Descriptor consists of eight eight-bit Option Position fields, each of which gives the position of up to eight options (there can be no more than 8 Options Part). Each of the Option Position fields correspond to one of the bits in the Options Present field. The unit of measure of each Option Position is 32-bit words, counting the first word of the Options Part as word 0. The high order Option Position field corresponds to the high order bit in the Options Present field.