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Transmission and Processing of IPv6 Extension Headers
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Abstract

Various IPv6 extension headers have been standardised since the IPv6 standard was first published. This document updates [RFC 2460](#) to clarify how intermediate nodes should deal with such extension headers and with any that are defined in future. It also specifies how extension headers should be registered by IANA, with a corresponding minor update to [RFC 2780](#).

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[1.](#) Introduction and Problem Statement

In IPv6, an extension header is any header that follows the initial 40 bytes of the packet and precedes the upper layer header (which might be a transport header, an ICMPv6 header, or a notional "No Next Header").

An initial set of IPv6 extension headers was defined by [\[RFC2460\]](#), which also described how they should be handled by intermediate nodes, with the exception of the hop-by-hop options header:

"...extension headers are not examined or processed by any node along a packet's delivery path, until the packet reaches the node (or each of the set of nodes, in the case of multicast) identified in the Destination Address field of the IPv6 header."

This provision meant that forwarding nodes should be completely transparent to extension headers. There was no provision for forwarding nodes to modify them, remove them, insert them, or use them to affect forwarding behaviour. Thus, new extension headers could be introduced progressively, used only by hosts that have been updated to create and interpret them [\[RFC6564\]](#). The extension header mechanism is an important part of the IPv6 architecture, and several new extension headers have been standardised since [RFC 2460](#).

Today, packets are often forwarded not only by straightforward IP routers, but also by a variety of intermediate nodes, often referred to as middleboxes, such as firewalls, load balancers, or packet

classifiers. However, experience has showed that as a result, the network is not transparent to IPv6 extension headers. Contrary to [Section 4 of RFC 2460](#), middleboxes sometimes examine and process the entire IPv6 packet before making a decision to either forward or discard the packet. This means that they need to traverse the chain of extension headers, if present, until they find the transport header (or an encrypted payload). Unfortunately, because not all IPv6 extension headers follow a uniform TLV format, this process is clumsy and requires knowledge of each extension header's format. A separate problem is that the header chain may even be fragmented [[I-D.ietf-6man-oversized-header-chain](#)].

The process is potentially slow as well as clumsy, possibly precluding its use in nodes attempting to process packets at line speed. The present document does not intend to solve this problem, which is caused by the fundamental architecture of IPv6 extension headers. This document focuses on clarifying how the header chain should be traversed in the current IPv6 architecture.

If they encounter an unrecognised extension header type, some firewalls treat the packet as suspect and drop it. Unfortunately, it is an established fact that several widely used firewalls do not recognise some or all of the extension headers standardised since [RFC 2460](#). It has also been observed that certain firewalls do not even handle all the extension headers standardised in [RFC 2460](#), including the fragment header [[I-D.taylor-v6ops-fragdrop](#)], causing fundamental problems of end-to-end connectivity. This applies in particular to firewalls that attempt to inspect packets at very high speed, since they cannot take the time to reassemble fragmented packets, especially when under a denial of service attack.

Other types of middlebox, such as load balancers or packet classifiers, might also fail in the presence of extension headers that they do not recognise.

A contributory factor to this problem is that, because extension headers are numbered out of the existing IP Protocol Number space, there is no collected list of them. For this reason, it is hard for an implementor to quickly identify the full set of standard extension headers. An implementor who consults only [RFC 2460](#) will miss all extension headers defined subsequently.

This combination of circumstances creates a "Catch-22" situation [[Heller](#)] for the deployment of any newly standardised extension header except for local use. It cannot be widely deployed, because existing middleboxes will drop it on many paths through the Internet. However, most middleboxes will not be updated to allow the new header to pass until it has been proved safe and useful on the open

Internet, which is impossible until the middleboxes have been updated.

The uniform TLV format now defined for extension headers [[RFC6564](#)] will improve the situation, but only for future extensions. Some tricky and potentially malicious cases will be avoided by forbidding very long chains of extension headers that need to be fragmented [[I-D.ietf-6man-oversized-header-chain](#)]. This will alleviate concerns that stateless firewalls cannot locate a complete header chain as required by the present document.

However, these changes are insufficient to correct the underlying problem. The present document clarifies that the above requirement from [RFC 2460](#) applies to all types of node that forward IPv6 packets and to all extension headers standardised now and in the future. It also requests IANA to create a subsidiary registry that clearly identifies extension header types, and updates [RFC 2780](#) accordingly. Fundamental changes to the IPv6 extension header architecture are out of scope for this document.

Also, Hop-by-Hop options are not handled by many high speed routers, or are processed only on a slow path. This document also updates the requirements for processing the Hop-by-Hop options header to make them more realistic.

[1.1.](#) Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [[RFC2119](#)].

In the remainder of this document, the term "forwarding node" refers to any router, firewall, load balancer, prefix translator, or any other device or middlebox that forwards IPv6 packets with or without examining the packet in any way.

[2.](#) Requirement to Transmit Extension Headers

[2.1.](#) All Extension Headers

Any forwarding node along an IPv6 packet's path, which forwards the packet for any reason, SHOULD do so regardless of any extension headers that are present, as required by [RFC 2460](#). Exceptionally, if this node is designed to examine extension headers for any reason, such as firewalling, it MUST recognise and deal appropriately with all standardised IPv6 extension header types and SHOULD recognise experimental IPv6 extension header types. The list of standardised and experimental extension header types is maintained by IANA (see

[Section 4](#)) and implementors are advised to check this list regularly for updates.

[RFC 2460](#) requires destination hosts to discard packets containing unrecognised extension headers. However, intermediate forwarding nodes SHOULD NOT do this by default, since that might cause them to inadvertently discard traffic using a recently standardised extension header, not yet recognised by the intermediate node. The only exceptions to this rule are discussed below.

As mentioned above, forwarding nodes that discard packets containing extension headers are known to cause connectivity failures and deployment problems. Therefore, it is important that forwarding nodes that inspect IPv6 extension headers can parse all standard headers and are able to behave according to the above requirements. If a forwarding node discards a packet containing a standard IPv6 extension header, it MUST be the result of a configurable policy, and not just the result of a failure to recognise such a header. This means that the discard policy for each standardised type of extension header MUST be individually configurable. The default configuration SHOULD allow all standardised extension headers.

Experimental IPv6 extension headers, including types 253 and 254 defined by [\[RFC3692\]](#) and [\[RFC4727\]](#), SHOULD be treated in the same way as standardised extension headers, but they MAY be dropped by default.

Forwarding nodes MUST be configurable to allow packets containing unrecognised extension headers, but such packets MAY be dropped by default.

The IPv6 Routing Header Types 0 and 1 have been deprecated [\[RFC5095\]](#). However, this does not mean that the IPv6 Routing Header can be unconditionally dropped by forwarding nodes. Packets containing standardised and undeprecated Routing Headers SHOULD be forwarded by default. At the time of writing, these include Type 2 [\[RFC6275\]](#), Type 3 [\[RFC6554\]](#), and the experimental Routing Header Types 253 and 254 [\[RFC4727\]](#). Others may be defined in future.

[2.2.](#) Hop-by-Hop Options

The IPv6 Hop-by-Hop Options header SHOULD be processed by intermediate forwarding nodes as described in [\[RFC2460\]](#). However, it is to be expected that high performance routers will either ignore it, or assign packets containing it to a slow processing path. Designers planning to use a Hop-by-Hop option need to be aware of this likely behaviour.

As a reminder, in [RFC 2460](#), it is stated that the Hop-by-Hop Options header, if present, must be first.

3. Security Considerations

Forwarding nodes that operate as firewalls MUST conform to the requirements in the previous section in order to respect the IPv6 extension header architecture. In particular, packets containing standard extension headers are only to be discarded as a result of a configurable policy.

When new extension headers are standardised in the future, those implementing and configuring forwarding nodes, including firewalls, will need to take account of them. A newly defined header will exercise new code paths in a host that does recognise it, so caution may be required. It is therefore to be expected that the deployment process will be slow and will depend on satisfactory operational experience. Until it is complete, the new extension will fail in some parts of the Internet. This aspect needs to be considered when deciding to standardise a new extension. Specific security considerations for each new extension should be documented in the document that defines it.

4. IANA Considerations

IANA is requested to clearly mark in the Assigned Internet Protocol Numbers registry those values which are also IPv6 Extension Header types defined by an IETF action, for example by adding an extra column to indicate this. This will also apply to any IPv6 Extension Header types defined in the future.

Additionally, IANA is requested to replace the existing empty IPv6 Next Header Types registry by an IPv6 Extension Header Types registry. It will contain only those protocol numbers which are also marked as IPv6 Extension Header types in the Assigned Internet Protocol Numbers registry. Experimental values will be marked as such. The initial list will be as follows:

- o 0, Hop-by-Hop Options, [[RFC2460](#)]
- o 43, Routing, [[RFC2460](#)], [[RFC5095](#)]
- o 44, Fragment, [[RFC2460](#)]
- o 50, Encapsulating Security Payload, [[RFC4303](#)]
- o 51, Authentication, [[RFC4302](#)]

- o 60, Destination Options, [[RFC2460](#)]
- o 135, MIPv6, [[RFC6275](#)]
- o 139, experimental use, HIP, [[RFC5201](#)]
- o 140, shim6, [[RFC5533](#)]
- o 253, experimental use, [[RFC3692](#)], [[RFC4727](#)]
- o 254, experimental use, [[RFC3692](#)], [[RFC4727](#)]

This list excludes type 59, No Next Header, [[RFC2460](#)], which is not an extension header as such.

The references to the IPv6 Next Header field in [[RFC2780](#)] are to be interpreted as also applying to the IPv6 Extension Header field.

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6. Change log [RFC Editor: Please remove]

[draft-ietf-6man-ext-transmit-03](#): added details for experimental values, various clarifications and minor corrections, 2013-08-22.

[draft-ietf-6man-ext-transmit-02](#): explicit mention of header types 253 and 254, editorial fixes, 2013-08-06.

[draft-ietf-6man-ext-transmit-01](#): tuned use of normative language, clarified that only standardised extensions are covered (hence excluding HIP), 2013-05-29.

[draft-ietf-6man-ext-transmit-00](#): first WG version, more clarifications, 2013-03-26.

[draft-carpenter-6man-ext-transmit-02](#): clarifications following WG comments, recalibrated firewall requirements, 2013-02-22.

[draft-carpenter-6man-ext-transmit-01](#): feedback at IETF85: clarify scope and impact on firewalls, discuss line-speed processing and lack of uniform TLV format, added references, restructured IANA considerations, 2012-11-13.

[draft-carpenter-6man-ext-transmit-00](#): original version, 2012-08-14.

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