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RObust Header Compression (ROHC): A Compression Profile for IP

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Abstract

The original RObust Header Compression (ROHC) RFC (RFC 3095) defines a framework for header compression, along with compression protocols (profiles) for IP/UDP/RTP, IP/ESP (Encapsulating Security Payload), IP/UDP, and also a profile for uncompressed packet streams. However, no profile was defined for compression of IP only, which has been identified as a missing piece in RFC 3095. This document defines a ROHC compression profile for IP, similar to the IP/UDP profile defined by RFC 3095, but simplified to exclude UDP, and enhanced to compress IP header chains of arbitrary length.

Table of Contents

1. Introduction

The original RObust Header Compression (ROHC) RFC [RFC-3095] defines a framework for header compression, along with compression protocols (profiles) for IP/UDP/RTP, IP/ESP (Encapsulating Security Payload), IP/UDP, and also a profile for uncompressed packet streams. The profile for uncompressed data was defined to provide a means to encapsulate all traffic over a link within ROHC packets. Through this profile, the lower layers do not have to provide multiplexing for different packet types, but instead ROHC can handle any packet stream, even if compression profiles for all kinds of packet streams have not yet been defined or implemented over the link.

Although the profile without compression is simple and can tunnel arbitrary packets, it has of course a major weakness in that it does not compress the headers at all. When considering that normally all packets are expected to be IP [RFC-791, RFC-2460] packets, and that the IP header often represents a major part of the total header, a useful alternative to no compression would for most packets be compression of the IP header only. Unfortunately, such a profile was not defined in [RFC-3095], and this has thus been identified as an important missing piece in the ROHC toolbox.

This document addresses this missing compression support and defines a ROHC compression profile for IP [RFC-791, RFC-2460] only, similar to the IP/UDP profile defined by [RFC-3095], but simplified to exclude UDP. Due to the similarities with the IP/UDP profile, the IP compression profile is described based on the IP/UDP profile, mainly covering differences. The most important differences are a different way of terminating the static header chain, and the capability of compressing IP header chains of arbitrary length.

2. 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 [RFC-2119].

ROHC UDP

"ROHC UDP" in this document refers to the IP/UDP profile (Profile 0x0002) as defined in [RFC-3095].

3. ROHC IP Compression (Profile 0x0004)

In general, there are no major differences between the ROHC UDP profile and the IP profile (ROHC IP) defined in this document, since the removal of UDP has no impact on the compression mechanisms in principle. As for ROHC UDP, the compressor generates a 16-bit sequence number which increases by one for each packet compressed in the packet stream, simply called SN below. The most important difference between this profile and ROHC UDP is about static chain termination and the handling of multiple IP headers. Unless stated explicitly below, mechanisms and formats are the same as for ROHC UDP.

3.1. Static Chain Termination

One difference for IP-only compression, compared to IP/UDP compression, is related to the termination of the static chain in IR headers. For the UDP profile, the chain always ends with a UDP header part, which per definition provides the boundaries for the chain. The UDP header is also the last header in the uncompressed packet (except for a potential application header). For the IP-only profile, there is no single last header that per profile definition terminates the chain. Instead, the static chain is terminated if the "Next Header / Protocol" field of a static IP header part indicates anything but IP (IPinIP or IPv6). Alternatively, the compressor can choose to end the static chain at any IP header, and indicate this by setting the MSB of the IP version field to 1 (0xC for IPv4 or 0xE for IPv6). The decompressor must store this indication in the context for correct decompression of subsequent headers. Note that the IP version field in decompressed headers must be restored to its original value.

3.2. Handling Multiple Levels of IP Headers

The ROHC IR and IR-DYN packets defined in [RFC-3095] are used to communicate static and/or dynamic parts of a context. For each of the compression profiles defined in [RFC-3095], there is a single last header in the header chain that clearly marks the termination of the static chain. The length of the dynamic chain is then inferred from the static chain in the IR header itself, or from the static chain in the context for the IR-DYN header. The length of both static and dynamic chains may thus be of arbitrary length and may, in theory, initialize a context with an arbitrary number of IP levels.

However, the general compressed header formats defined in [RFC-3095, section 5.7.] specifies that at most two levels of IP headers (the 'Inner' and the 'Outer' level of IP headers) may be included in a compressed header. Specifically, the format defined for Extension 3 [RFC-3095, section 5.7.5.] can only carry one single 'Outer' IP header. In addition, while list compression may be used to compress other types of headers, it cannot be used to compress additional IP headers, as IP headers may not be part of an extension header chain in compressed headers [RFC-3095, section 5.8.].

For the compression profiles defined in [RFC-3095], the consequence is that at most two levels of IP headers can be compressed. In other words, the presence of additional IP headers at best partially disables header compression, as the compressor will only be allowed to send IR and IR-DYN packets in such cases.

For the compression of IP headers only, the additional IP headers would however not have to cause header compression to be disabled because there is no single packet type that ends the compressed chain. The excess IP headers could simply be left uncompressed by implicitly terminating the static and dynamic chains after at most two levels of IP headers.

The IP-only profile defined in this document goes one step further and supports compression of an arbitrary number of IP levels. This is achieved by adding a dynamic chain to the general format of compressed headers, to include the header part of each IP level in excess of the first two.

As explained above, the static chain within IR packets can be of arbitrary length, and the chain is terminated by the presence of a non-IP header (not IPinIP nor IPv6). Alternatively, the chain may be explicitly terminated with a special code value in the IP version field, as described in section 3.1. The dynamic chain is structured analogously.

For compressed headers, the information related to the initial two IP headers is carried as for the IP/UDP profile, and a chain of dynamic header information is added to the end of the compressed header for each and every additional IP header. Thus, this additional data structure is exactly the same as the one used in IR and IR-DYN packets. The length of the chain is inferred from the chain of static parameters in the context. While a dynamic chain carries dynamically changing parameters using an uncompressed representation, this ensures that flows with arbitrary levels of IP headers will not impair compression efficiency.

3.3. Constant IP-ID

Most IPv4 stacks assign an IP-ID according to the value of a counter, increasing by one for each outgoing packet. ROHC UDP compresses the IP-ID field using offset IP-ID encoding based on the UDP SN [RFC-3095]. For stacks generating IP-ID values using a pseudo-random number generator, the field is not compressed and is sent as-is in its entirety as additional octets after the compressed header.

Cases have also been found where an IPv4 stack uses a constant value for the IP Identifier. When the IP-ID field is constant, it cannot be compressed using offset IP-ID encoding and the field must be sent in its entirety. This overhead can be avoided with the addition of a flag within the dynamic part of the chain used to initialize the IPv4 header, as follow:

Dynamic part:

```
+---+---+---+---+---+---+---+---+
|        Type of Service        |
+---+---+---+---+---+---+---+---+
|         Time to Live          |
+---+---+---+---+---+---+---+---+
/        Identification         /   2 octets
+---+---+---+---+---+---+---+---+
| DF|RND|NBO|SID|       0       |
+---+---+---+---+---+---+---+---+
/ Generic extension header list /  variable length
+---+---+---+---+---+---+---+---+
```

SID: Static IP Identifier.

For IR and IR-DYN packets, the logic is the same as for ROHC UDP with the addition that field(SID) must be kept in the context.

For compressed headers other than IR and IR-DYN:

If value(RND) = 0 and context(SID) = 0, hdr(IP-ID) is compressed using Offset IP-ID encoding (see [RFC-3095 section 4.5.5]) using p = 0 and default-slope(IP-ID offset) = 0.

If value(RND) = 0 and context(SID) = 1, hdr(IP-ID) is constant and compressed away; hdr(IP-ID) is the value of context(IP-ID).

If value(RND) = 1, IP-ID is the uncompressed hdr(IP-ID). IP-ID is then passed as additional octets at the end of the compressed header, after any extensions.

Note: Only IR and IR-DYN packets can update context(SID).

Note: All other fields are the same as for ROHC UDP [RFC-3095].

3.4. Additional Mode Transition Logic

The profiles defined in [RFC-3095] operate using different modes of compression. A mode transition can be requested once a packet has reached the decompressor by sending feedback indicating the desired mode. As per the specifications found in [RFC-3095], the compressor is compelled to honor such requests.

For the IP profile defined in this document, the Mode parameter for the value mode = 0 (packet types UOR-2, IR and IR-DYN) is redefined to allow the compressor to decline a mode transition requested by the decompressor:

Mode: Compression mode. 0 = (C)ancel Mode Transition

Upon receiving the Mode parameter set to ’0’, the decompressor MUST stay in its current mode of operation and SHOULD refrain from sending further mode transition requests for the declined mode for a certain amount of time.

More specifically, with reference to the parameters C_TRANS, C_MODE, D_TRANS, and D_MODE defined in [RFC-3095, section 5.6.1.], the following modifications apply when the compressor cancels a mode transition:

Parameters for the compressor side:

- C_MODE:

  This value must not be changed when sending mode information within packets if the mode parameter is set to ’0’ (as a response to a mode transition request from the decompressor).

- C_TRANS:

  C_TRANS is (P)ending when receiving a mode transition request from the decompressor. C_TRANS is set to (D)one when the compressor receives an ACK for a UOR-2, IR-DYN, or IR packet sent with the mode parameter set to the mode in use at the time the mode transition request was initiated.

Parameters for the decompressor side:

- D_MODE:

  D_MODE MUST remain unchanged when receiving a UOR-2, an IR-DYN, or an IR packet sent with the mode parameter set to '0'.

- D_TRANS:

  D_TRANS is (P)ending when a UOR-2, IR-DYN, or IR packet sent with the mode parameter set to '0' is received. It is set to (D)one when a packet of type 1 or 0 corresponding to the unchanged mode is received.

The resulting mode transition procedure is described below:

```
           Compressor                     Decompressor
          ----------------------------------------------
 C_MODE = X      |                                |  D_MODE = X
                 |       Mode Request(Y) +-<-<-<-|  D_TRANS = I
                 |       +-<-<-<-<-<-<-<-<-+      |
 C_TRANS = P     |-<-<-<-+                        |
 C_MODE = X      |                                |
                 |->->->-+ IR/IR-DYN/UOR-2(SN,C) |
                 |       +->->->->->->->->-+      |
                 |->-..                  +->->->-|  D_TRANS = P
                 |->-..                           |  D_MODE = X
                 |           ACK(SN,X)   +-<-<-<-|
                 |       +-<-<-<-<-<-<-<-<-+      |
 C_TRANS = D     |-<-<-<-+                        |
                 |                                |
                 |->->->-+   X-0, X-1*            |
                 |       +->->->->->->->->-+      |
                 |                       +->->->-|  D_TRANS = D
                 |                                |
```

where X: mode in use before the mode transition was initiated
Y: mode requested by the decompressor
C: (C)ancel mode transition

3.5. Initialization

The static context for ROHC IP compression can be initialized in either of two ways:

1) By using an IR packet as in ROHC UDP, where the profile is 0x0004, and the static chain ends with the static part of an IP header, where the Next Header/Protocol field has any value but IPinIP (4) or IPv6 (41) [PROTOCOL], or where the IP version field indicates termination (see section 3.1). At the compressor, SN is initialized to a random value when the first IR packet is sent.

2) By reusing an existing context. This is done with an IR-DYN packet, identifying profile 0x0004, where the dynamic chain corresponds to the prefix of the existing static chain, ending with an IP header where the Next Header/Protocol field has any value but IPinIP (4) or IPv6 (41) [PROTOCOL], or where the IP version field indicates termination (see section 3.1). At the compressor, SN is initialized to a random value when the first IR-DYN packet is sent.

For ROHC IP, the dynamic part of an IR or IR-DYN packet is similar to the one for ROHC UDP, with a two-octet field containing the SN present at the end of the dynamic chain in IR and IR-DYN packets. It should be noted that the static and dynamic chains have an arbitrary length, and the SN is added only once, at the end of the dynamic chain in IR and IR-DYN packets.

3.6. Packet Types

Except for one new feedback option (see section 3.7), the only packet format that differs from ROHC UDP is the general format for compressed packets, which has no UDP checksum in the end. Instead, it ends with a list of dynamic header portions, one for each IP header above the initial two (if any, as indicated by the presence of corresponding header portions in the static chain).

The general format for a compressed header is thus as follows:

```
     0   1   2   3   4   5   6   7
    --- --- --- --- --- --- --- ---
   :         Add-CID octet         :                    |
   +---+---+---+---+---+---+---+---+                    |
   |   first octet of base header  |                    |
   +---+---+---+---+---+---+---+---+                    |
   :                               :                    |
   /   0, 1, or 2 octets of CID    /                    |
   :                               :                    |
   +---+---+---+---+---+---+---+---+                    |
   /   remainder of base header    /                    |
   +---+---+---+---+---+---+---+---+                    |
   :                               :                    |
   /           Extension           /                    |
   :                               :                    |
    --- --- --- --- --- --- --- ---                     |
   :                               :                    |
   +   IP-ID of outer IPv4 header  +
   :                               :     (see section 5.7 of [RFC-3095])
    --- --- --- --- --- --- --- ---
   /    AH data for outer list     /                    |
    --- --- --- --- --- --- --- ---                     |
   :                               :                    |
   +         GRE checksum          +                    |
   :                               :                    |
    --- --- --- --- --- --- --- ---                     |
   :                               :                    |
   +   IP-ID of inner IPv4 header  +                    |
   :                               :                    |
    --- --- --- --- --- --- --- ---                     |
   /    AH data for inner list     /                    |
    --- --- --- --- --- --- --- ---                     |
   :                               :                    |
   +         GRE checksum          +                    |
   :                               :                    |
    --- --- --- --- --- --- --- ---
   :            List of            :
   /        Dynamic chains         /    variable, given by static chain
   :   for additional IP headers   :           (includes no SN)
    --- --- --- --- --- --- --- ---
```

Note that the list of dynamic chains for the additional IP headers in compressed packets do not have a sequence number at the end of the chain, as SN is present within compressed base headers.

3.7. The CONTEXT_MEMORY Feedback Option

The CONTEXT_MEMORY option informs the compressor that the decompressor does not have sufficient memory resources to handle the context of the packet stream, as the stream is currently compressed.

```
  0   1   2   3   4   5   6   7
+---+---+---+---+---+---+---+---+
|  Opt Type = 9 |  Opt Len = 0  |
+---+---+---+---+---+---+---+---+
```

When receiving a CONTEXT_MEMORY option, the compressor SHOULD take actions to compress the packet stream in a way that requires less decompressor memory resources, or stop compressing the packet stream.

4. Security Considerations

The security considerations of [RFC-3095] apply equally to this document, without exceptions or additions.

5. IANA Considerations

ROHC profile identifier 0x0004 has been reserved by the IANA for the profile defined in this document.

6. Acknowledgements

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7. Normative References

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[RFC-2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[RFC-2460] Deering, S. and R. Hinden, "Internet Protocol, Version 6 (IPv6) Specification", RFC 2460, December 1998.

[RFC-3095] Bormann, C., Burmeister, C., Degermark, M., Fukushima, H., Hannu, H., Jonsson, L-E., Hakenberg, R., Koren, T., Le, K., Liu, Z., Martensson, A., Miyazaki, A., Svanbro, K., Wiebke, T., Yoshimura, T. and H. Zheng, "Robust Header Compression (ROHC)", RFC 3095, July 2001.

[PROTOCOL] "Assigned Internet Protocol Numbers", IANA registry at: http://www.iana.org/assignments/protocol-numbers

Appendix A. Detailed Procedures for Canceling Mode Transitions

The profiles defined in [RFC-3095] operate using different modes of compression: Unidirectional (U-Mode), Bi-directional Optimistic (O-Mode), and Bi-directional Reliable (R-Mode). Compression always starts in the U-Mode, and mode transitions can only be initiated by the decompressor [RFC-3095, section 5.6.]. A mode transition can be requested once a packet has reached the decompressor by sending feedback indicating the desired mode.

With reference to the parameters C_TRANS, C_MODE, D_TRANS, and D_MODE defined in [RFC-3095, section 5.6.1.], the following sub-sections describe the resulting procedures when a compressor declines a mode transition request from the decompressor as described in section 3.4.

A.1. Transition from Optimistic to Reliable Mode

When the decompressor initiates a mode transition from Optimistic to Reliable mode, the cancellation of the transition procedure is as follows:

```
             Compressor                     Decompressor
             ----------------------------------------------
                   |                               |
                   |        ACK(R)/NACK(R) +-<-<-<-|  D_TRANS = I
                   |       +-<-<-<-<-<-<-<-+       |
   C_TRANS = P     |-<-<-<-+                       |
   C_MODE = O      |                               |
                   |->->->-+ IR/IR-DYN/UOR-2(SN,C) |
                   |       +->->->->->->->-+       |
                   |->-..                  +->->->-|  D_TRANS = P
                   |->-..                          |  D_MODE = O
                   |           ACK(SN,O)   +-<-<-<-|
                   |       +-<-<-<-<-<-<-<-+       |
   C_TRANS = D     |-<-<-<-+                       |
                   |                               |
                   |->->->-+  UO-0, UO-1*          |
                   |       +->->->->->->->-+       |
                   |                       +->->->-|  D_TRANS = D
```

The compressor must not send packet types 1 or 0 when C_TRANS is P, i.e., not until it has received an ACK for a UOR-2, IR-DYN, or IR packet sent with the mode transition parameter set to C. When the decompressor receives a UOR-2, IR-DYN, or IR packet sent with the mode transition parameter set to C, it must keep the value D_MODE as O and set D_TRANS to P. When the decompressor receives packet types 0 or 1, after having ACKed a UOR-2, IR-DYN, or IR packet, it sets D_TRANS to D.

A.2. Transition from Unidirectional to Reliable Mode

The cancellation of a transition from Unidirectional to Reliable mode follows the same procedure as defined in section 4.2 above.

A.3. Transition from Reliable to Optimistic Mode

When the decompressor initiates a mode transition from Reliable to Optimistic mode, the cancellation of the transition procedure is described as follows:

```
             Compressor                     Decompressor
           ----------------------------------------------
                  |                               |
                  |        ACK(O)/NACK(O) +-<-<-<-|  D_TRANS = I
                  |       +-<-<-<-<-<-<-<-<-+     |
   C_TRANS = P    |-<-<-<-+                       |
   C_MODE = R     |                               |
                  |->->->-+ IR/IR-DYN/UOR-2(SN,C) |
                  |       +->->->->->->->->-+     |
                  |->-..                  +->->->-|  D_MODE = R
                  |->-..                          |
                  |           ACK(SN,R)   +-<-<-<-|
                  |       +-<-<-<-<-<-<-<-<-+     |
   C_TRANS = D    |-<-<-<-+                       |
                  |                               |
                  |->->->-+   R-0, R-1*           |
                  |       +->->->->->->->->-+     |
                  |                       +->->->-|  D_TRANS = D
                  |                               |
```

The compressor must not send packet types 1 or 0 when C_TRANS is P, i.e., not until it has received an ACK for a UOR-2, IR-DYN, or IR packet sent with the mode transition parameter set to C. When the decompressor receives a UOR-2, IR-DYN, or IR packet sent with the mode transition parameter set to C, it must keep the value D_MODE as R. When the decompressor receives packet types 0 or 1, after having ACKed a UOR-2, IR-DYN, or IR packet, it sets D_TRANS to D.

A.4. Transition Back to Unidirectional Mode

When the decompressor initiates a mode transition from Reliable or Optimistic mode back to Unidirectional mode, the cancellation of the transition procedure is as follows:

```
           Compressor                     Decompressor
          ----------------------------------------------
             |                               |
             |        ACK(U)/NACK(U) +-<-<-<-| D_TRANS = I
             |       +-<-<-<-<-<-<-<-<-+       |
C_TRANS = P  |-<-<-<-+                       |
C_MODE = O/R |                               |
             |->->->-+ IR/IR-DYN/UOR-2(SN,C) |
             |       +->->->->->->->->-+       |
             |->-..                  +->->->-|
             |->-..                          |
             |          ACK(SN,O/R)  +-<-<-<-|
             |       +-<-<-<-<-<-<-<-<-+       |
C_TRANS = D  |-<-<-<-+                       |
             |          R-0, R-1* or         |
             |->->->-+  UO-0, UO-1*          |
             |       +->->->->->->->->-+       |
             |                       +->->->-| D_TRANS = D
                                               D_MODE = O/R
```

When the decompressor receives a UOR-2, IR-DYN, or IR packet sent with the mode transition parameter set to C, it must keep the value D_MODE to the bi-directional mode already in use (either O- or R-mode). After ACKing the first UOR-2(C), IR-DYN(C), or IR(C), the decompressor MUST continue to send feedback with the Mode parameter set to the bi-directional mode in use (either O- or R-mode) until it receives packet types 0 or 1. When the decompressor receives packet types 0 or 1, after having ACKed a UOR-2, IR-DYN, or IR packet, it sets D_TRANS to D.

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