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                 RObust Header Compression (ROHC):
              A Link-Layer Assisted Profile for IP/UDP/RTP

Abstract

   This document defines a ROHC (Robust Header Compression) profile for
   compression of IP/UDP/RTP (Internet Protocol/User Datagram
   Protocol/Real-Time Transport Protocol) packets, utilizing
   functionality provided by the lower layers to increase compression
   efficiency by completely eliminating the header for most packets
   during optimal operation. The profile is built as an extension to
   the ROHC RTP profile. It defines additional mechanisms needed in
   ROHC, states requirements on the assisting layer to guarantee
   transparency, and specifies general logic for compression and
   decompression related to the usage of the header-free packet format.
   This document is a replacement for RFC 3242, which it obsoletes.

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1. Introduction

   Header compression is a technique used to compress and transparently
   decompress the header information of a packet on a per-hop basis,
   utilizing redundancy within individual packets and between
   consecutive packets within a packet stream. Over the years, several
   protocols [VJHC, IPHC] have been developed to compress the network
   and transport protocol headers [IPv4, IPv6, UDP, TCP], and these
   schemes have been successful in improving efficiency over many wired
   bottleneck links, such as modem connections over telephone networks.
   In addition to IP, UDP, and TCP compression, an additional
   compression scheme called Compressed RTP [CRTP] has been developed to

improve compression efficiency further for real-time traffic using
the Real-Time Transport Protocol [RTP].

The schemes mentioned above have all been designed by taking into
account normal assumptions about link characteristics, which
traditionally have been based on wired links only. However, with an
increasing number of wireless links in the Internet paths, these
assumptions are no longer generally valid. In wireless environments,
especially wide-coverage cellular environments, relatively high error
rates are tolerated in order to allow efficient usage of the radio
resources. For real-time traffic, which is more sensitive to delays
than to errors, such operating conditions will be norm over, for
example, 3rd generation cellular links, and header compression must
therefore tolerate packet loss. However, with the previously
mentioned schemes, especially for real-time traffic compressed by
CRTP, high error rates have been shown to significantly degrade
header compression performance [CRTPC]. This problem was the driving
force behind the creation of the RObust Header Compression (ROHC) WG
in the IETF.

The ROHC WG has developed a header compression framework on top of
which profiles can be defined for different protocol sets, or for
different compression strategies. Due to the limited packet-loss
robustness of CRTP and the demands of the cellular industry for an
efficient way of transporting voice over IP over wireless, the main
focus of ROHC has so far been on compression of IP/UDP/RTP headers,
which are generous in size, especially when compared to the payloads
often carried by packets with such headers.

ROHC RTP has become a very efficient, robust, and capable compression
scheme, able to compress the headers down to a total size of one
octet only. Also, transparency is guaranteed to an extremely great
extent, even when residual bit errors are present in compressed
headers delivered to the decompressor. The requirements for RTP
compression [RTP-REQ], defined by the WG before and during the
development process, have thus been fulfilled.

As mentioned above, the 3rd generation cellular systems, where IP
will be used end-to-end, been one of the driving forces behind
ROHC RTP, and the scheme has also been designed to suit new cellular
air interfaces, such as WCDMA, making it possible to run even speech
services with spectrum efficiency insignificantly lower than for
existing one-service circuit switched solutions [VTC2000]. However,
other air interfaces (such as those based on GSM and IS-95) will also
be used in all-IP networks, with further implications for the header
compression issue. These older air interfaces are less flexible,
with radio bearers optimized for specific payload sizes. This means
that not even a single octet of header can be added without using the

next higher fixed packet size supported by the link, something that
is obviously very costly. For the already deployed speech vocoders,
the spectrum efficiency over these links will thus be low compared to
existing circuit-switched solutions. To achieve high spectrum
efficiency overall with any application, more flexible air interfaces
must be deployed, and then the ROHC RTP scheme will perform
excellently, as shown for WCDMA [MOMUC01]. However, for deployment
reasons, it is important to also provide a suitable header
compression strategy for already existing vocoders and air
interfaces, such as for GERAN and for CDMA2000, with minimal effects
on spectral efficiency.

This document describes a link-layer-assisted ROHC RTP profile,
originally defined by [LLA], extending ROHC RTP (profile 0x0001)
[ROHC], and compliant with the ROHC 0-byte requirements [0B-REQ].
The purpose of this profile is to provide a header-free packet format
that, for a certain application behavior, can replace a majority of
the 1-octet header ROHC RTP packets during normal U/O-mode operation,
while still being fully transparent and complying with all the
requirements of ROHC RTP [RTP-REQ]. For other applications,
compression will be carried out as with normal ROHC RTP.

To completely eliminate the compressed header, all functionality
normally provided by the 1-octet header has to be provided by other
means, typically by utilizing functionality provided by the lower
layers and sacrificing efficiency for less-frequently occurring
larger compressed headers. The latter is not a contradiction, since
the argument for eliminating the last octet for most packets is not
overall efficiency in general. It is important to remember that the
purpose of this profile is to provide efficient matching of existing
applications to existing link technologies, not efficiency in
general. The additional complexity introduced by this profile,
although minimized by a tight integration with already-existing ROHC
functionality, implies that it should therefore only be used to
optimize performance of specific applications over specific links.

When implementing this profile over various link technologies, care
must be taken to guarantee that all the functionality needed is
provided by ROHC and the lower layers together. Therefore,
additional documents should specify how to incorporate this profile
on top of various link technologies.

The profile defined by this document was originally specified by RFC
3242 [LLA], but to address one technical flaw and clarify one
implementation issue, this document has been issued to replace RFC
3242, which becomes obsolete.

1.1. Differences from RFC 3242

   This section briefly summarizes the differences of this document from
   RFC 3242. Acronyms and terminology can be found in Section 2.

   The format of the CSP packet, as defined in [LLA], was identified as
   non-interoperable when carrying a RHP header with a 3-bit or 7-bit
   CRC. This problem occurs because the payload has been dropped by the
   compressor, and the decompressor is supposed to use the payload
   length to infer certain fields in the uncompressed header. These
   fields are the IPv4 total length, the IPv6 payload length, the UDP
   length, and the IPv4 header checksum field (all INFERRED fields in
   [ROHC]). To correct this flaw, the CSP packet must carry information
   about the payload length of the RHP packet. Therefore, the length of
   the RTP payload has been included in the CSP packet.

   This document also clarifies an unclear referencing in RFC 3242,
   where Section 4.1.3 of [LLA] states that upon CRC failure, the
   actions of [ROHC], Section 5.3.2.2.3 MUST be taken. That section
   specifies that detection of SN wraparound and local repair must be
   performed, but neither of these steps apply when the failing packet
   is a CCP. Therefore, upon CRC failure, actions to be taken are the
   ones specified in Section 5.3.2.2.3, but steps a-d only.

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 [RFC2119].

   CCP   Context Check Packet
   CRC   Cyclic Redundancy Check
   CSP   Context Synchronization Packet
   LLA   Link Layer Assisted ROHC RTP profile
   NHP   No Header Packet
   ROHC   RObust Header Compression
   RHP   ROHC Header Packet (a non-NHP packet; i.e., RRP, CSP, or CCP)
   RRP   ROHC RTP Packet as defined in [ROHC, profile 0x0001]

   Assisting layer

      "Assisting layer" refers to any entity implementing the interface
      to ROHC (Section 4.2). It may, for example, refer to a sub-layer
      used to adapt the ROHC implementation and the physical link layer.
      This layer is assumed to have knowledge of the physical layer
      synchronization.

   Compressing side

      "Compressing side" refers to the combination of the header
      compressor, operating with the LLA profile, and its associated
      assisting layer.

   Lower layers

      "Lower layers", in this document, refers to entities located below
      ROHC in the protocol stack, including the assisting layer.

   ROHC RTP

      "ROHC RTP" refers to the IP/UDP/RTP profile as defined in [ROHC].

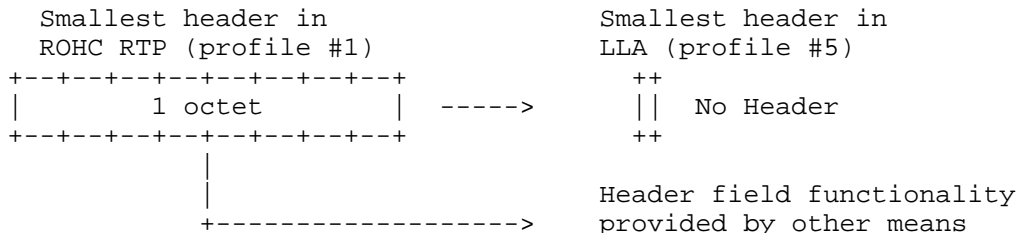3. Overview of the Link-Layer Assisted Profile

   The ROHC IP/UDP/RTP profile defined in [LLA] and updated by this
   document, profile 0x0005 (hex), is designed to be used over channels
   that have been optimized for specific payload sizes and that
   therefore cannot efficiently accommodate header information when
   transmitted together with payloads corresponding to these optimal
   sizes.

   The LLA profile extends, and thus also inherits all functionality
   from, the ROCH RTP profile by defining some additional functionality
   and an interface from the ROHC component towards an assisting lower
   layer.

```
                +---------------------------------------+
                |                                       |
      The LLA   |    ROHC RTP,                          |
      profile   |    Profile #1       +-----------------+
                |                     | LLA Additions   |
                +--------------------+-----------------+
```

   By imposing additional requirements on the lower layers compared to
   [ROHC], it is possible to infer the information needed to maintain
   robust and transparent header compression, even though the headers
   are completely eliminated during most of the operation time.

   Basically, this profile replaces the smallest and most frequent ROHC
   U/O-mode headers with a no-header format, for which the header
   functionality must be provided by other means.

```
   Smallest header in                   Smallest header in
    ROHC RTP (profile #1)                LLA (profile #5)
   +--+--+--+--+--+--+--+--+              ++
   |        1 octet         | ----->      ||  No Header
   +--+--+--+--+--+--+--+--+              ++
                     |
                     |                    Header field functionality
              +------------------->       provided by other means
```

   The fields present in the ROHC RTP headers for U/O-mode PT0 are the
   packet type identifier, the sequence number, and the CRC. The
   subsequent sections elaborate more on how the functionality of these
   fields is replaced for NHP.

3.1. Providing Packet Type Identification

   All ROHC headers carry a packet type identifier, indicating to the
   decompressor how the header should be interpreted. This is a
   function that must be provided by some means in 0-byte header
   compression. It will be possible to distinguish ROHC RTP packets
   with compressed headers thanks to the packet type identifier, but a
   mechanism is needed to separate packets with a header from packets
   without a header. This function MUST therefore be provided by the
   assisting layer in one way or another.

3.2. Replacing the Sequence Number

   From the sending application, the RTP sequence number is increased by
   one for each packet sent. The purpose of the sequence number is to
   cope with packet reordering and packet loss. If reordering or loss
   has occurred before the transmission point, the compressing side, if
   needed, can easily avoid problems by not allowing the use of a
   header-free packet.

   However, at the transmission point, loss or reordering that may occur
   over the link can not be anticipated and covered for. Therefore, for
   NHP, the assisting layer MUST guarantee in-order delivery over the
   link (already assumed by [ROHC]), and at the receiving side, it MUST
   provide an indication for each packet loss over the link. This is
   basically the same principle as that which the VJ header compression
   [VJHC] relies on.

   Note that guaranteeing in-order delivery and packet loss indication
   over the link not only makes it possible to infer the sequence number
   information, but also supersedes the main function of the CRC, which
   normally takes care of errors due to link losses and bit errors in
   the compressed sequence number.

3.3. CRC Replacement

   All context-updating RRP packets carry a CRC calculated over the
   uncompressed header. The CRC is used by the decompressor to verify
   that the updated context is correct. This verification serves three
   purposes in U/O-mode:

      1) Detection of longer losses than can be covered by the sequence
         number LSBs.

      2) Protection against failures caused by residual bit errors in
         compressed headers.

      3) Protection against faulty implementations and other causes of
         error.

   Since this profile defines an NHP packet without this CRC, care must
   be taken to fulfill these purposes by other means when an NHP is used
   as a replacement for a context-updating packet. Detection of long
   losses (1) is already covered, since the assisting layer MUST provide
   an indication of all packet losses. Furthermore, the NHP packet has
   one important advantage over RHP packets in that residual bit errors
   (2) cannot damage a header that is not even sent.

   It is thus reasonable to assume that compression and decompression
   transparency can be assured with high confidence, even without a CRC
   in header-free packets. However, to provide additional protection
   against damage propagation due to undetected residual bit errors in
   context-updating packets (2) or other unexpected errors (3), periodic
   context verifications SHOULD be performed (see Section 4.6).

3.4. Applicability of This Profile

   The LLA profile can be used with any link technology capable of
   providing the required functionality described in previous sections.
   Thus, whether LLA or ROHC RTP should be implemented depends on the
   characteristics of the link itself. For most RTP packet streams, LLA
   will work exactly as ROHC RTP, and it will have a higher compression
   efficiency for packet streams with certain characteristics. LLA will
   never have a lower compression efficiency than ROHC RTP.

   Note as well that LLA, like all other ROHC profiles, is fully
   transparent to any packet stream reaching the compressor. LLA does
   not make any assumptions about the packet stream but will perform
   optimally for packet streams with certain characteristics, e.g.,
   synchronized streams exactly timed with the assisting link over which
   the LLA profile is implemented.

   The LLA profile is obviously not applicable if the UDP checksum (2
   bytes) is enabled, which is always the case for IPv6/UDP. For
   IPv4/UDP, the sender may choose to disable the UDP checksum.

4. Additions and Exceptions Compared to ROHC RTP

4.1. Additional Packet Types

   The LLA profile defines three new packet types to be used in addition
   to the RRP packet types defined by [ROHC]. The following sections
   describe these packet types and their purpose in detail.

4.1.1. No-Header Packet (NHP)

   A No-Header Packet (NHP) is a packet that consists only of the
   payload of the original packet. The NHP MAY be used when only the
   sequence information needs to be conveyed to the decompressor. In
   other words, the NHP can be used when all header fields are either
   unchanged or follow the currently established change pattern. In
   addition, there are some considerations for the use of the NHP (see
   sections 4.3, 4.5, and 4.6). An LLA compressor is not allowed to
   deliver NHP packets when operating in R-mode.

   The assisting layer MAY send the NHP for RTP SN = X only if an NHP
   was delivered by the LLA compressor AND the assisting layer can
   guarantee that the decompressor will infer the proper sequencing for
   this NHP. This guarantee is based on the confidence that the
   decompressor

      a) has the means to infer proper sequencing for the packet
         corresponding to SN = X-1, AND

      b) has either received a loss indication or the packet itself for
         the packet corresponding to SN = X-1.

   Updating properties: NHP packets update context (RTP Sequence
   Number).

4.1.2. Context Synchronization Packet (CSP)

   The case where the packet stream overruns the channel bandwidth may
   lead to discarded data, which may result in decompressor context
   invalidation. It might therefore be beneficial to send a packet with
   only the header information and to discard the payload. This would
   be helpful to maintain synchronization of the decompressor context
   while efficiently using the available bandwidth.

This case can be handled with the Context Synchronization Packet
(CSP), which has the following format:

```
   0   1   2   3   4   5   6   7
 +---+---+---+---+---+---+---+---+
 | 1   1   1   1   1   0   1   0 | Packet type identifier
 +===+===+===+===+===+===+===+===+
 /        RTP Payload Length     / 2 octets
 +---+---+---+---+---+---+---+---+
 :  ROHC header without padding  :
 :     see [ROHC, Section 5.7]   :
 +---+---+---+---+---+---+---+---+
```

   RTP Payload Length: This field is the length of the payload carried
                       inside the RTP header, stored in network byte
                       order. That is, this field will be set by the
                       compressor to (UDP length - size of the UDP
                       header - size of the RTP header including CSRC
                       identifiers).

   Updating properties: CSP maintains the updating properties of the
   ROHC header it carries.

   The CSP is defined by one of the unused packet type identifiers from
   ROHC RTP, carried in the one-octet base header. As for any ROHC
   packet, except the NHP, the packet may begin with ROHC padding and/or
   feedback. It may also carry context identification after the packet
   type identifier. It is possible to have two CID fields present, one
   after the packet type ID and one within the encapsulated ROHC header.
   If a decompressor receives a CSP with two non-equal CID values
   included, the packet MUST be discarded. ROHC segmentation may also
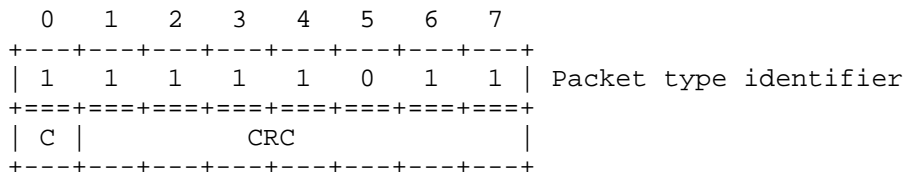   be applied to the CSP.

   In the CSP packet, the payload has been dropped by the compressor.
   However, the decompressor is supposed to use the payload length to
   infer certain fields in the uncompressed header (the IPv4 total
   length, the IPv6 payload length, the UDP length, and the IPv4 header
   checksum field). When dropping the payload, the CSP packet needs to
   contain information about the payload length carried in the RHP
   packet. Therefore, the length of the RTP payload is carried in the
   CSP packet. When the decompressor receives a CSP packet, it can use
   the RTP payload length field to calculate the value of fields
   classified as INFERRED in [ROHC] when attempting to verify a 3- or
   7-bit CRC carried in the RHP header enclosed in the CSP.

   Note that when the decompressor has received and processed a CSP, the
   packet (including any possible data following the CSP encapsulated
   compressed header) MUST be discarded.

4.1.3. Context Check Packet (CCP)

   A Context Check Packet (CCP), which does not carry any payload but
   only an optional CRC value in addition to the packet type identifier,
   is defined.

   The purpose of the CCP is to provide a useful packet that MAY be sent
   by a synchronized physical link layer in the case where data must be
   sent at fixed intervals, even if no compressed packet is available.
   Whether the CCP is sent over the link and delivered to the
   decompressor is decided by the assisting layer. The CCP has the
   following format:

```
     0   1   2   3   4   5   6   7
   +---+---+---+---+---+---+---+---+
   | 1   1   1   1   1   0   1   1 | Packet type identifier
   +===+===+===+===+===+===+===+===+
   | C |           CRC             |
   +---+---+---+---+---+---+---+---+
```

      C: C = 0 indicates that the CRC field is not used.
         C = 1 indicates that a valid CRC is present.

   Updating properties: CCP packets do not update context.

   The CCP is defined by one of the unused packet type identifiers from
   ROHC RTP, carried in the first octet of the base header. The first
   bit of the second octet, the C bit, indicates whether the CRC field
   is used. If C=1, the CRC field MUST be set to the 7-bit CRC
   calculated over the original uncompressed header defined in [ROHC,
   Section 5.9.2]. As for any ROHC packet, except NHP, the packet MAY
   begin with ROHC padding and/or carry context identification.

   The use of the CRC field to perform decompressor context verification
   is optional and is therefore a compressor implementation issue.
   However, a CCP MUST always be made available to the assisting layer.

   If the assisting layer receives CCPs with the C bit set (C=1) from
   the compressor, it MUST use the last CCP received if a CCP is to be
   sent, i.e., the CCP corresponding to the last non-CCP packet sent
   (NHP, RRP or CSP). An assisting layer MAY use the CCP for other
   purposes, such as signaling a packet loss before the link.

   The decompressor is REQUIRED to handle a CCP received with the C bit
   set (C=1), indicating a valid CRC field, and to perform context
   verification. The received CRC MUST then be applied to the last
   decompressed packet, unless a packet loss indication was previously
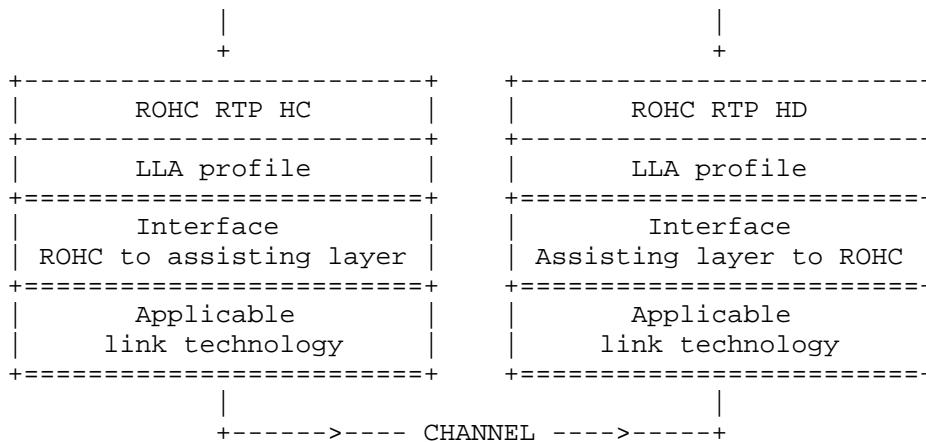   received. Upon CRC failure, actions MUST be taken as specified in

[ROHC, Section 5.3.2.2.3, steps a-d only]. A CCP received with C=0
MUST be ignored by the decompressor. The decompressor is not allowed
to make any further interpretation of the CCP.

When using the 7-bit CRC in the CCP packet to verify the context, the
decompressor needs to have access to the entire uncompressed header
of the latest packet decompressed. Some implementations of [ROHC]
might not save the values of INFERRED fields. An implementation of
ROHC LLA MUST save these fields in the decompressor context to be
able to successfully verify CCP packets.

The use of CCP by an assisting layer is optional and depends on the
characteristics of the actual link. Whether it is used MUST
therefore be specified in link-layer implementation specifications
for this profile.

4.2. Interfaces Towards the Assisting Layer

This profile relies on the lower layers to provide the necessary
functionality to allow NHP packets to be sent. This interaction
between LLA and the assisting layer is defined as interfaces between
the LLA compressor/decompressor and the LLA applicable link
technology.

```
                    |                            |
                    +                            +
      +-------------------------+  +-------------------------+
      |      ROHC RTP HC        |  |      ROHC RTP HD        |
      +-------------------------+  +-------------------------+
      |      LLA profile        |  |      LLA profile        |
      +=========================+  +=========================+
      |       Interface         |  |       Interface         |
      | ROHC to assisting layer |  | Assisting layer to ROHC |
      +=========================+  +=========================+
      |       Applicable        |  |       Applicable        |
      |     link technology     |  |     link technology     |
      +=========================+  +=========================+
                    |                            |
            +------>---- CHANNEL ---->-----+
```

The figure above shows the various levels, as defined in [ROHC] and
this document, constituting a complete implementation of the LLA
profile. The figure also underlines the need for additional
documents to specify how to implement these interfaces for a link
technology for which this profile is relevant.

This section defines the information to be exchanged between the LLA
compressor and the assisting layer for this profile to operate

   properly. While it does define semantics, it does not specify how
   these interfaces are to be implemented.

4.2.1. Interface, Compressor to Assisting Layer

   This section defines the interface semantics between the compressor
   and the assisting layer, providing rules for packet delivery from the
   compressor.

   The interface defines the following parameters: RRP, RRP segmentation
   flag, CSP, CSP segmentation flag, NHP, and RTP Sequence Number. All
   parameters, except the NHP, MUST always be delivered to the assisting
   layer. This leads to two possible delivery scenarios:

      a. RRP, CSP, CCP, NHP, and RTP Sequence Number are delivered,
         along with the corresponding segmentation flags, set
         accordingly.

         This corresponds to the case when the compressor allows sending
         of an NHP packet, with or without segmentation applied to the
         corresponding RRP/CSP packets.

         Recall that delivery of an NHP packet occurs when the ROHC RTP
         compressor would have used a ROHC UO-0.

      b. RRP, CSP, CCP, and RTP Sequence Number are delivered, along
         with the corresponding segmentation flags, set accordingly.

         This corresponds to the case when the compressor does not allow
         sending of an NHP packet. Segmentation might be applied to the
         corresponding RRP and CSP packets.

   Segmentation may be applied independently to an RRP or a CSP packet
   if its size exceeds the largest value provided in the PREFERRED
   PACKET_SIZES list and if the LARGE_PACKET_ALLOWED parameter is set to
   false. The segmentation flags are explicitly stated in the interface
   definition to emphasize that the RRP and the CSP may be delivered by
   the compressor as segmented packets.

   The RTP SN MUST be delivered for each packet by the compressor to
   allow the assisting layer to maintain the necessary sequencing
   information.

4.2.2. Interface, Assisting Layer to Decompressor

   Here the interface semantics between the assisting layer and the
   decompressor are defined, providing simple rules for the delivery of
   received packets to the decompressor. The decompressor needs a way

to distinguish NHP packets from RHP packets. Also, when receiving
packets without a header, the decompressor needs a way to infer the
sequencing information to keep synchronization between the received
payload and the sequence information of the decompressed headers. To
achieve this, the decompressor MUST receive the following from the
assisting layer:

    - an indication for each packet loss over the link between the
      compressing and decompressing sides for CID=0.

    - the received packet together with an indication of whether the
      packet received is an NHP.

Note that the context is updated from a packet loss indication.

4.3. Optimistic Approach Agreement

ROHC defines an optimistic approach for updates to reduce the header
overhead. This approach is fully exploited in the Optimistic and
Unidirectional modes of operation. Due to the presence of a CRC in
all compressed headers, the optimistic approach is defined as a
compressor issue only because the decompressor will always be able to
detect an invalid context through the CRC verification.

However, no CRC is present in the NHP packet defined by the LLA
profile. Therefore, the loss of an RHP packet updating the context
may not always be detected. To avoid this problem, the compressing
and decompressing sides must agree on the principles for the
optimistic approach, and the agreed principles MUST be enforced not
only by the compressor but also by the transmitting assisting layer.
If, for example, three consecutive updates are sent to convey a
header field change, the decompressor must know this and invalidate
the context if three or more consecutive physical packets are lost.
Note that the mechanism used to enforce the optimistic approach must
be reinitialized if a new field change needs to be conveyed while the
compressing side is already sending packets to convey non-linear
context updates.

An LLA decompressor MUST use the optimistic approach knowledge to
detect possible context loss events. If context loss is suspected,
it MUST invalidate the context and not forward any packets before the
context has been synchronized.

It is REQUIRED that all documents describing how the LLA profile is
implemented over a certain link technology define how the optimistic
approach is agreed to between the compressing side and the
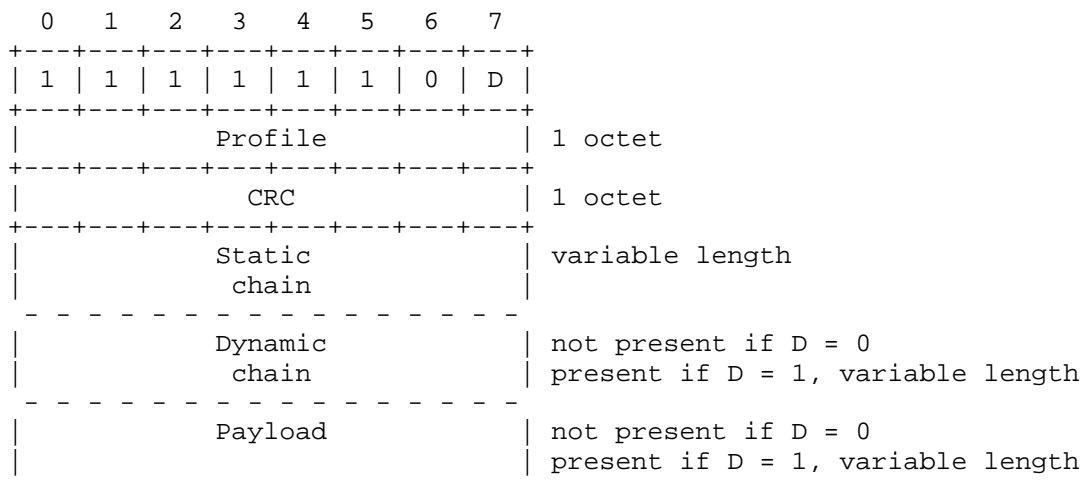decompressing side. It could be handled with a fixed principle, with

   negotiation at startup, or by other means, but the method must be
   unambiguously defined.

4.4. Fast Context Initialization, IR Redefinition

   As initial IR packets might overrun the channel bandwidth and
   significantly delay decompressor context establishment, it might be
   beneficial to initially discard the payload. This allows state
   transitions and higher compression efficiency to be achieved with
   minimal delay.

   To serve this purpose, the D-bit from the basic structure of the ROHC
   RTP IR packet [ROHC, Section 5.7.7.1] is redefined for the LLA
   profile. For D=0 (no dynamic chain), the meaning of the D-bit is
   extended to indicate that the payload has been discarded when
   assembling the IR packet. All other fields keep their meanings as
   defined for ROHC RTP.

   The resulting structure, using small CIDs and CID=0, becomes:

```
     0   1   2   3   4   5   6   7
   +---+---+---+---+---+---+---+---+
   | 1 | 1 | 1 | 1 | 1 | 1 | 0 | D |
   +---+---+---+---+---+---+---+---+
   |            Profile            | 1 octet
   +---+---+---+---+---+---+---+---+
   |              CRC              | 1 octet
   +---+---+---+---+---+---+---+---+
   |            Static            | variable length
   |             chain            |
    - - - - - - - - - - - - - - - -
   |            Dynamic           | not present if D = 0
   |             chain            | present if D = 1, variable length
    - - - - - - - - - - - - - - - -
   |            Payload           | not present if D = 0
   |                              | present if D = 1, variable length
    - - - - - - - - - - - - - - - -
```

       D: D = 0 indicates that the dynamic chain is not present
            and that the payload has been discarded.

   After an IR packet with D=0 has been processed by the decompressor,
   the packet MUST be discarded.

4.5. Feedback Option, CV-REQUEST

   The CV-REQUEST option MAY be used by the decompressor to request an
   RRP or CSP for context verification. This option should be used if
   only NHPs have been received for a long time and the context
   therefore has not been verified recently.

   +---+---+---+---+---+---+---+---+
   | Opt Type = 8 | Opt Len = 0 |
   +---+---+---+---+---+---+---+---+

   If the compressor receives a feedback packet with this option, the
   next packet compressed SHOULD NOT be delivered to the assisting layer
   as an NHP.

4.6. Periodic Context Verification

   As described in Section 3.3, transparency is expected to be
   guaranteed by the functionality provided by the lower layers. This
   ROHC profile would therefore be at least as reliable as the older
   header compression schemes [VJHC, IPHC, CRTP], which do not make use
   of a header compression CRC. However, since ROHC RTP normally is
   extremely safe to use from a transparency point of view, it would be
   desirable to be able to achieve this with LLA also.

   To provide an additional guarantee for transparency and also catch
   unexpected errors, such as errors due to faulty implementations, it
   is RECOMMENDED that context updating packets be sent periodically,
   even when the compressor logic allows NHP packets to be used.

4.7. Use of Context Identifier

   Since an NHP cannot carry a context identifier (CID), there is a
   restriction on how this profile may be used, related to context
   identification. Independent of which CID size has been negotiated,
   NHP packets can only be used for CID=0. If the decompressor receives
   an NHP packet, it can only belong to CID=0.

   Note that if multiple packet streams are handled by a compressor
   operating using LLA, the assisting layer must, in case of physical
   packet loss, be able to tell for which CID the loss occurred, or at
   least it MUST be able to tell if packets with CID=0 (packet stream
   with NHPs) have been lost.

5. Implementation Issues

   This document specifies mechanisms for the protocol and leaves
   details on the use of these mechanisms to the implementers. The
   present section aims to provide guidelines, ideas, and suggestions
   for implementation of LLA.

5.1. Implementation Parameters and Signals

   As described in [ROHC, Section 6.3], implementations use parameters
   to set up configuration information and to stipulate how a ROHC
   implementation is to operate. The following parameters are
   additions, useful to LLA, to the parameter set defined for ROHC RTP
   implementations. Note that if the PREFERRED_PACKET_SIZES parameters
   defined here are used, they obsolete all PACKET_SIZE and PAYLOAD_SIZE
   parameters of ROHC RTP.

5.1.1. Implementation Parameters at the Compressor

   ALWAYS_PAD -- value: boolean

      This parameter may be set by an external entity to specify to the
      compressor that every RHP packet MUST be padded with ROHC padding
      of one octet, minimum.

      The assisting layer MUST provide a packet type identification. If
      no field is available for this purpose from the protocol at the
      link layer, then a leading sequence may be used to distinguish RHP
      packets from NHP packets. Although the use of a leading sequence
      is obviously not efficient, since it sacrifices efficiency for RHP
      packets, the efficiency loss should be insignificant because the
      leading sequence applies only to packets with headers in order to
      favor the use of packets without headers. If a leading sequence
      is desired for RHP identification, the lower layer MAY use ROHC
      padding for the leading sequence by setting the ALWAYS_PAD
      parameter. Note that in such cases, possible collisions of the
      padding with the NHP payload must be avoided.

      By default, this parameter is set to FALSE.

   PREFERRED_PACKET_SIZES -- list of:
        SIZE -- value: integer (octets)
        RESTRICTED_TYPE -- values: [NHP_ONLY, RHP_ONLY, NO_RESTRICTION]

      This parameter set governs which packet sizes are preferred by the
      assisting layer. If this parameter set is used, all RHP packets
      MUST be padded to fit the smallest possible preferred size. If
      the size of the unpadded packet (or, in the case of ALWAYS_PAD

being set, the packet with minimal one-octet padding) is larger
than the maximal preferred packet size, the compressor has two
options. Either it may deliver this larger packet with an
arbitrary size, or it may split the packet into several segments
using ROHC segmentation and pad each segment to one of the
preferred sizes. Which method to use depends on the value of the
LARGE_PACKETS_ALLOWED parameter below.

NHP packets can be delivered to the lower layer only if the
payload size is part of the preferred packet size set.
Furthermore, if RESTRICTED_TYPE is set to one of NHP_ONLY or
RHP_ONLY for any of the preferred packet sizes, that size is
allowed only for packets of the specified type.

By default, no preferred packet sizes are specified. When sizes
are specified, the default value for RESTRICTED_TYPE is
NO_RESTRICTION.

LARGE_PACKETS_ALLOWED -- value: boolean

This parameter may be set by an external entity to specify how to
handle packets that do not fit any of the preferred packet sizes
specified. If it is set to TRUE, the compressor MUST deliver the
larger packet as-is and MUST NOT use segmentation. If it is set
to FALSE, the ROHC segmentation scheme MUST be used to split the
packet into two or more segments, and each segment MUST further be
padded to fit one of the preferred packet sizes.

By default, this parameter is set to TRUE, which means that
segmentation is disabled.

VERIFICATION_PERIOD -- value: integer

This parameter may be set by an external entity to specify to the
compressor the minimum frequency with which a packet validating
the context must be sent. This tells the compressor that a packet
containing a CRC field MUST be sent at least once every N packets,
where N=VERIFICATION_PERIOD (see Section 4.6).

By default, this parameter is set to 0, which indicates that
periodical verifications are disabled.

5.1.2. Implementation Parameters at the Decompressor

   NHP_PACKET -- value: boolean

      This parameter informs the decompressor that the packet being
      delivered is an NHP packet. The decompressor MUST accept this
      packet type indicator from the lower layer. An assisting layer
      MUST set this indicator to true for every NHP packet delivered,
      and to false for any other packet.

   PHYSICAL_PACKET_LOSS -- signal

      This signal indicates to the decompressor that a packet has been
      lost on the link between the compressing and the decompressing
      sides, due to a physical link error. The signal is given once for
      each packet that was lost, and a decompressor must increase the
      sequence number accordingly when this signal is received.

   PRE_LINK_PACKET_LOSS -- signal

      This signal tells the decompressor to increase the sequence number
      due to a gap in the sequencing not related to a physical link
      error. A receiving assisting layer may, for example, use this
      signal to indicate to the decompressor that a packet was lost
      before the compressor, or that a packet was discarded by the
      transmitting assisting layer.

5.2. Implementation over Various Link Technologies

   This document provides the semantics and requirements of the
   interface needed from the ROHC compressor and decompressor towards
   the assisting layer to perform link-layer-assisted header
   compression.

   However, this document does not provide any link-layer-specific
   operational information, except for some implementation suggestions.
   Further details about how this profile is to be implemented over
   various link technologies must be described in other documents, where
   specific characteristics of each link layer can be taken into account
   to provide optimal usage of this profile.

   These specifications MAY use a packet-type bit pattern unused by this
   profile to implement signaling on the lower layer. The pattern
   available to lower layer implementations is [11111001].

6. IANA Considerations

   ROHC profile identifier 0x0005 has been reserved by the IANA for the
   IP/UDP/RTP profile defined in this document.

7. Security Considerations

   The security considerations of ROHC RTP [ROHC, Section 7] apply also
   to this document, with one addition: in the case of a denial-of-
   service attack scenario where an intruder injects bogus CCP packets
   using random CRC values onto the link, the CRC check will fail for
   incorrect reasons at the decompressor side. This would obviously
   greatly reduce the advantages of ROHC and any extra efficiency
   provided by this profile due to unnecessary context invalidation,
   feedback messages, and refresh packets. However, the same remarks
   related to the presence of such an intruder apply.

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