Robust Header Compression over Unidirectional Lightweight Encapsulation (ULE) and MPEG2 Transport Stream (TS) frames

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Abstract

This document describes a set of Extension Headers for the Unidirectional Lightweight Encapsulation (ULE), RFC4326 to carry packets compressed with RObust Header Compression (ROHC), RFC 3095 over ULE Stream.

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1. Introduction

Header compression promotes efficient use of available bandwidth. This is more apparent in the case of DVB-S where satellite link is used. This document introduces a method to compress headers of IP packet encapsulated within ULE [RFC4326] Stream using ROHC framework [RFC3095].

Important concepts of ROHC channel in MPEG2-TS system is introduced to differentiate between normal, uncompressed ULE Stream from ROHC compressed stream. Method to map outgoing packet to a ROHC channel is also presented. For completeness, a protocol to automate the negotiation and setup of parameters for ROHC channel is discussed.

This document doesn’t try to address compression of broadcast or multicast traffic for there is no reliable way to handle ROHC feedback from multiple ROHC decompressor. Implementation that wants to enable ROHC compression for broadcast or multicast traffic must ensure that all recipient gateways are capable of decompressing ROHC packet and that all contexts for broadcast and multicast traffic must operate in unidirectional mode.
2. Terminologies

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].

Compressor Gateway

Gateway that is capable of compressing header of IP packets using ROHC.

Decompressor Gateway

Machine that can perform ROHC decompression.

DVB


Gateway

Machine that can either host ROHC compressors and ROHC decompressors.

MAC

Medium Access Control [IEEE-802.3]. A link-layer protocol defined by the IEEE 802.3 standard (or by Ethernet v2 [DIX]).

MPEG-2

A set of standards specified by the Motion Picture Experts Group (MPEG) and standardized by the International Standards Organisation (ISO/IEC 13818-1) [ISO-MPEG2], and ITU-T (in H.222 [ITU-H222]).

PDU

Protocol Data Unit. Examples of a PDU include Ethernet frames, IPv4 or IPv6 datagrams, and other network packets.

ROHC
ROust Header Compression. A framework to compress header of IP packets as defined in [RFC3095].

ROHC channel

A logical unidirectional point-to-point channel carrying ROHC compressed packets for a pair compressor and decompressor.

ROHC profile

Specification of how to compress the headers of a certain kind of packet stream as defined by [RFC3095]

SN DU

SubNetwork Data Unit. An encapsulated PDU sent as an MPEG-2 Payload Unit.

TS

Transport stream (TS) is a format specified in MPEG-2 Part 1, Systems (ISO/IEC standard 13818-1). Its design goal is to allow multiplexing of digital video and audio and to synchronize the output. Transport stream offers features for error correction for transportation over unreliable media, and is used in broadcast applications such as DVB and ATSC.

ULE Stream

An MPEG-2 TS Logical Channel that carries only ULE encapsulated PDUs. ULE Stream may be identified by definition of a stream_type in SI/PSI [ISO-MPEG2].

MRRU

Maximum Reconstructed Reception Unit as defined in [RFC3095].

Context Identifier

[RFC3095] provides a definition for context identifiers.

ACK

Positive Acknowledgement.
NACK

Negative acknowledgement.

CID

Context Identifier.

B

Byte. Groups of bytes are represented in Internet byte order.

b

Bit.

Next-Header

A Type value indicating an Extension Header [RFC4326].

NPA

Network Point of Attachment [RFC4326]. In this document, refers to a destination address (resembling an IEEE MAC address) within the DVB-S/S2 transmission network that is used to identify individual Receivers or groups of Receivers.

ULE

Unidirectional Lightweight Encapsulation (ULE) [RFC4326]. A method that encapsulates PDUs into SNDUs that are sent in a series of TS Packets using a single TS Logical Channel. The encapsulation defines an extension format and an associated IANA Registry.

In addition, this document also borrows some terminologies defined in section 2 of [RFC3759]. When there is any ambiguity between terminologies defined in other documents and this document, the terminologies in this document should be consulted to interpret the content of this document.
3. Topology

Compressor gateways and decompressor gateways are connected through unidirectional links. This document assumes that these unidirectional links carry IP packets within ULE over MPEG2-TS frames. A unidirectional link from a compressor gateway may have multiple decompressor gateways listening to it. The following figure depicts a generic topology of a compressor gateway, Comp1, with 2 decompressor gateways, Decomp 1 and Decomp 2.

![Diagram of generic topology]

Each decompressor gateway has a dedicated unidirectional link connected to compressor gateway. Each unidirectional link may contain multiple logical channels identified by the PID field of MPEG2-TS frame. Of these logical channels, some may be dedicated for traffic of ROHC compressed packets only. While the rest of the logical channels may be used to carry uncompressed packets.

For the purpose of this discussion, the group of logical channels used to carry streams of uncompressed packets are called uncompressed channels. An uncompressed channel is not reserved exclusively between a pair of gateways and may be shared by multiple receiver gateways.

A ROHC channel is a logical channel that is used to carry ROHC compressed packets from a compressor gateway to a decompressor gateway. ROHC channel is exclusive to a pair of compressor gateway and decompressor gateway.

A ROHC feedback channel is a logical channel that carries ROHC feedback packet from decompressor gateway to compressor gateway.
When co-located compressor and decompressor are associated, ROHC feedback can be piggybacked within ROHC compressed stream. When used in this manner, ROHC feedback channel of decompressor and ROHC channel of co-located compressor at the decompressor gateway share the same logical channel.

However, in the absence of co-located compressor at the decompressor gateway, ROHC feedback doesn’t necessitate a dedicated logical channel as it can be sent via uncompressed channel in the encapsulation format depicted in Figure 6. As such, ROHC feedback channel is not an exclusive channel and may be a part uncompressed channel or ROHC channel.

Figure 2 depicts a possible combination of logical channels for the topology shown in Figure 1. The following topology assumes that there is no co-located compressor at both decompressor gateways and ROHC feedbacks are sent back through uncompressed channel.
feedback is being forwarded from Decomp 1 to Comp 1. Decomp 2 is the corresponding decompressor of compressor Comp 1. ROHC feedback from Decomp 2 can be sent back to Comp 1 through ROHC channel established between Comp 2 and Decomp 1.

Figure 3: Topology of Gateways with Pairs of ROHC peers
4. Encapsulation Format

This section briefly describes the notation used in all diagrams. "=" in the following diagrams indicates the number of octets occupied by the indicated field is not presented in a precise manner. This situation appears when a field spans variable number of bytes.

4.1. Encapsulation Format of ULE SNDU within ROHC Channel

All ULE SNDUs sent within ROHC channel have their payload compressed using ROHC. ULE Type field of these packets are the same as their counterparts in uncompressed channel. For instance, IPv4 PDUs compressed with ROHC will still have ULE type of 0x800. Likewise, compressed IPv6 PDUs will have ULE type of 0x86dd. Figure 4 depicts the format of ULE SNDU with compressed IPv6 PDU.

```
  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----------------------------------------------+
| D | Length (15b) | Type = 0x86dd |
+-----------------------------------------------+
| +-----------------------------------------------|
| | Receiver Destination NPA Address* (6B) |
| +-----------------------------------------------|
| +-----------------------------------------------|
| = Compressed IPv6 PDU |
| +-----------------------------------------------|
| =CRC-32 |
| +-----------------------------------------------|
```

Figure 4: Packet Format of Compressed IPv6 PDU

The semantics of D-bit, Length, Type, Receiver Destination NPA Address and CRC-32 fields are defined in section 4 of [RFC4326] except for the PDU. If the decompressed PDU doesn’t yield the same PDU type as defined in Type field, the PDU is corrupted and should be discarded. For example, when the value of the Type field is 0x800, ROHC decompressor should discard the packet if it yields an IPv6 PDU after decompression.

The same concept applies for compressed bridge frame PDUs. However, the Ethernet header is left untouched. Only the headers after the Ethernet frame header are compressed. Decompressed payload should result in payload of the type indicated in the EtherType field. If
not, the frame should be discarded. Figure 5 depicts the format of compressed SNDU bridged frame. Any padding bytes carried within content of original bridged MAC frame to fulfill the minimum Ethernet frame size should be stripped off before compression and should not be present within ROHC compressed payload as the total length field of IP header is not present in compressed header and may confuse ROHC decompressor. Decompressor gateway should insert necessary padding bytes to decompressed Ethernet frame to fulfill the minimum Ethernet frame size.

Figure 5: ROHC Compressed Packet Encapsulated within SNDU Bridged Frame

The rationale of reusing existing ULE type to carry ROHC compressed packets is twofold:

1. Decompressor gateway can recognize the content of SNDU easily and handle the SNDU in the same way as its uncompressed counterpart after the PDU is decompressed.

2. The framework will be more extensible. If in the future, when new ULE types are introduced to carry SNDU that can be compressed by ROHC, these new ULE types can be used again to cover for its ROHC compressed counterparts.
There can be no ambiguity as to whether a SNDU is carrying ROHC compressed PDU or uncompressed SNDU because ROHC compressed PDU can only exist in ROHC channel.

4.2. ROHC Feedback

ROHC feedback is not compressed per se and is only used by decompressor to send feedback to compressor when it is operating in bidirectional mode. Format of ROHC feedback is depicted in Figure 6.

| D | Length (15b) | Type = ULE ROHC-Feedback |
|--------------------------------|
| Receiver Destination NPA Address* (6B) |
| ROHC feedback |
| CRC-32 |

Figure 6: Format of ROHC feedback encapsulated within ULE SNDU

It should be noted that ROHC feedback may be embedded within a ROHC compressed packet and doesn’t necessarily have to be sent in the format presented in Figure 6.

ROHC feedback may be sent through uncompressed channel from decompressor gateway. However, there may be multiple gateways listening to uncompressed channel. To uniquely identify the recipient gateway, Receiver Destination NPA Address field must store the Address of the compressor gateway when ROHC feedback is sent through uncompressed channel.

If, however, there is a dedicated ROHC channel from decompressor gateway to compressor gateway, Receiver Destination NPA Address need not be used. This is situation may occur when there is a co-located compressor at the decompressor gateway with a corresponding decompressor at the compressor gateway like the example shown in Figure 3. Therefore, if a decompressor gateway needs to send ROHC feedback, it should do so through ROHC channel if one is available.
5. Topological Learning

Since there may be more than one gateway listening to a transmission, a gateway may need to setup multiple ROHC channels each for a listening gateways. Before a gateway can compress a packet, it needs to decide the right recipient gateway. If not, the gateway won’t be able to determine which ROHC compressor to use, thereby the right ROHC channel to use. Thus, a gateway that needs to send ROHC compressed packet need to learn the topology of its network.

The following subsection will present a simple technique for a gateway to learn about topology of its network. Implementation of this document may choose to use any other technique to inform the gateway about the topology of the network.

5.1. Automatic Learning

Since a gateway needs to listen incoming traffic of other peer gateways through individual frontend of DVB receiver card for each peer gateway. Thus each frontend must be mapped to a corresponding ROHC channel exclusively.

When an incoming packet arrives at a frontend, the source address for the packet will need to be identified. The source address may be source IP address of IPv4 and IPv6 PDU or source MAC address of a bridged frame SNDU. Collectively, these source addresses are mapped to the ROHC channel that corresponds to this frontend.

When compressor gateway needs to send a packet, it needs to identify the destination address of the packet. The destination may be destination IP address of IPv4 and IPv6 PDU or destination MAC address of a bridged frame SNDU. The compressor gateway then needs to look for a ROHC channel that has a matching address with this destination address. If a match is found, the ROHC channel and its corresponding ROHC compressor will be used to compress and send the packet. If no match is found, compressor gateway must send the packet uncompressed through the uncompressed channel.
6. Establishing ROHC Channel

This document presents an approach to setup ROHC channel(s) over DVB links through a negotiation protocol. Implementation of the protocol mentioned in this document is not strictly required, implementers may choose to have static configuration to setup the parameters of ROHC compression and decompression.

6.1. ROHC Channel Parameters Negotiation Protocol (RCPNP)

This protocol works through ULE Streams only. It is possible to modify this protocol to work on Generic Stream Encapsulation [GSE] in the future. While it is possible to extend this protocol to work over asymmetrical link as in the case of Link-Layer Tunneling Mechanism [RFC3077], this draft doesn’t try to address this issue. The ULE SNDUs defined in this section should be sent via uncompressed channel.

The structure of a ULE SNDU packet for RCPNP message is as such:

```
| 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 |
+-----------------------------------------------+
| D | Length (15b) | Type = ULE ROHC-Neg |
+-----------------------------------------------+
| +-----------------------------------------------+
| Receiver Destination NPA Address* (6B) |
+-----------------------------------------------+
| +-----------------------------------------------+
| Version | OpCod | |
+-----------------------------------------------+
| Source Address * (6B) |
+-----------------------------------------------+
| +-----------------------------------------------+
| Identifier * (2B) | Ref ID * (2B) |
+-----------------------------------------------+
| +-----------------------------------------------+
| Body * |
+-----------------------------------------------+
| +-----------------------------------------------+
| CRC-32 |
+-----------------------------------------------+
```

Figure 7: Minimal format of RCPNP message
Type

New ULE type needs to be assigned for ROHC negotiation protocol.

Receiver Destination NPA Address

Destination address field should exist for all types of message except for Compressor Solicitation and Compressor Advertisement messages.

Version

Version of ROHC Channel Parameters Negotiation Protocol (RCPNP). Currently, only version 0 is supported.

OpCod

OpCod field is an abbreviation for Operation Code. The value of Operation Code field determines the message type.

Source Address

Source address field should exist for all messages except for Compressor Solicitation message and is used to indicate the address of the sender.

Identifier

An identifier that is used to identify related exchange of messages. This field only exists for Compressor Shutdown, Decompressor Shutdown, Heartbeat, Request and Reply messages.

Ref ID

Reference identifier. This field identifies the value of Identifier of the message that the current message is replying to. This field only exists for Reply, Acknowledgement and Negative Acknowledgement message. The value contained in this field is the value of Identifier it is referring to.

Body

Body of message. This content of this field is dependent on Operation Code. This field may not be present for certain type of messages.

All fields marked with ‘*’ are optional and may not be present for certain type of messages. Unless specified otherwise, these fields
will be present in all RCPNP messages. The following subsections will explain the type of messages for this protocol. As mentioned, the type of message is determined by Operation Code field.

6.1.1. Compressor Advertisement

Operation Code

The value is 0.

Body

This field is not present in this message.

This message is used by the compressor site to advertise the availability of ROHC Compressor. Out of concern for bandwidth and energy consumption, compressor site should limit the broadcast of this message to a few times when it first joins the network. This message should also be broadcasted when a Compressor Solicitation message is received. The decompressor site will use the value specified in the Source Address field when addressing compressor site.

6.1.2. Compressor Solicitation

Operation Code

The value is 1.

Body

This field is not present in this message.

This message is broadcasted by decompressor to solicit for compressor. Decompressor site should rate-limit the frequency of solicitation to avoid flooding DVB link.
6.1.3. Request

Figure 8: Format of Request message

The fields shown in the figure above collectively form the Body field of a Request message. This message is sent by decompressor site to compressor site when it wants to establish a ROHC channel. The meaning of each fields in the message are described below:

Operation Code

Not shown in the diagram, but this field carries the value of 2.

MRRU

Maximum Reconstructed Reception Unit tolerated by decompressor. Value of 0 indicates the negotiated channel doesn’t allow for segmentation of ROHC compressed packet.

Maximum CID

Maximum Context Identifier tolerated by decompressor. For example, if the field carries the value of 0, the ROHC channel can only support 1 context.

Number of profiles

Number of profiles supported by decompressor. Must be at least one.
Profile IDs

ROHC Profile IDs supported by decompressor. Each profile ID occupies 2 octets.

6.1.4. Reply

The fields shown in the figure above collectively form the Body field of a Reply message. This message is sent by compressor site to decompressor site in response to a Request message sent by decompressor site.

If decompressor doesn’t receive within any Reply message within a specific interval, it should resend the same Request message for a few more times. If these few attempts fail to result in any Reply message, decompressor should wait for a longer period before starting a new round of negotiation.

If compressor site doesn’t receive an ACK nor a NACK message within a reasonable interval for the Reply message, it should resend the Reply message for a few times before discarding any information of negotiated ROHC channel parameters.

The meaning of each fields in the message are described below:

Operation Code
Not shown in the diagram, but this field carries the value of 3.

**MRRU**

Maximum Reconstructed Reception Unit tolerated by compressor. Decompressor site should send a NACK if it receives higher MRRU than what it requested.

**Maximum CID**

Maximum CID tolerated by compressor. This value of this field should be less than or equal to the negotiated value in Request message, otherwise decompressor site should send a NACK. If the maximum CID is less than 16, CIDs will be encoded using small CID format for the ROHC channel. Otherwise, large CID format is implied.

**PID**

Packet Identifier of MPEG2-TS frames that will carry ROHC compressed packet.

**Res**

Reserved field. Unused and should be ignored.

**Number of profile IDs**

ROHC framework reserves the most significant octet of profile ID to denote the version number of a ROHC profile. Due to this constraint, there can only be 256 active profiles per channel. Therefore, this field occupies 1 octet instead of 2. Decompressor site should send a NACK if it receives more profile IDs than it can support. If the value of this field is 0, the message is corrupted and should be discarded.

**Profile IDs**

Profile Identifiers of the ROHC profiles that will be used for the negotiated ROHC channel. Decompressor site should send a NACK if it receives any profile ID that it doesn’t support.

### 6.1.5. Acknowledgement

Decompressor site should send an acknowledgement if the parameters negotiated in Reply message is agreeable. An acknowledgement must also be sent to decompressor site when compressor site receives Decompressor Shutdown message. Likewise, this message will also be
sent to acknowledge a Compressor Shutdown message.

Operation Code

The value of this field is 4.

Body

This field is not present in this message.

6.1.6. Negative Acknowledgement

Operation Code

This field carries the value of 5.

Body

This field is not present in this message.

Negative Acknowledgement may be sent for various types of messages depending on the Ref ID field. Negative Acknowledgment is sent for the following messages for the following reasons:

Request

Compressor site receives a Request message with no parameter that it can support or when it doesn’t have the resource to establish a new ROHC channel.

Reply

The decompressor site receives a valid Reply message with unsupported ROHC channel parameters or it is unable to allocate resource for the creation of ROHC decompressor. Compressor site should discard any information regarding negotiated ROHC channel parameters upon receiving this message.

Decompressor Shutdown

Compressor site doesn’t have any compressor for the channel. This can happen for a number of reasons. For example, decompressor site may resend a Compressor Shutdown if the Acknowledgement message was not lost. By the time the resent Compressor Shutdown is received, the compressor on the compressor site may have been destroyed. Decompressor site can free the resources allocated for decompressor when it receives this message.
Compressor Shutdown

Decompressor site doesn’t have any decompressor for the channel. This can happen for a number of reasons. Compressor site can free the resources allocated for compressor when it receives this message.

Heartbeat

Decompressor and compressor doesn’t exists. This may be due to abnormal shutdown of compressor and decompressor. If a Negative Acknowledgement is received in return, the sender should treat it as a sign for the absence of compressor/decompressor at its counterpart site. Resources should be freed immediately upon receiving a Negative Acknowledgement.

6.1.7. Compressor Shutdown

Operation Code

The value is 6.

Body

This field is not present in this message.

This message is sent by the compressor site to notify the decompressor site that it is about to stop compressing IP packets. Upon receiving this message, decompressor should release all resources that are being held for decompression.

Compressor must wait for an acknowledgement or a negative acknowledgement from decompressor site before freeing its resource. If it doesn’t receive one of these messages within a reasonable interval, it should keep sending a shutdown message for a number of times before freeing its resource.

6.1.8. Decompressor Shutdown

Operation Code

The value is 7.

Body
This field is not present in this message.

This message is sent by the decompressor site to notify the compressor that it is about to stop decompressing IP packets. Upon receiving this message, compressor should release all resources that are being held and stop sending compressed IP packets.

Decompressor must wait for an acknowledgement or a negative acknowledgement from compressor site before freeing its resource. If it doesn’t receive one of these messages within a reasonable interval, it should keep sending a shutdown message for a number of times before freeing its resource.

6.1.9. Heartbeat

Operation Code

The value is 8.

Body

This field is not present in this message.

This message can be sent by either decompressor site or compressor site to probe for the presence of its counterpart. This message should only be sent periodically when the ROHC channel is experiencing inactivity. The recipient site should send an Acknowledgement to notify its counterpart about the presence of its compressor/decompressor.

If no Acknowledgement is received, the sender site should resend the Heartbeat for a few more times before freeing resources allocated for its compressor/decompressor.

6.2. Interaction of RCPNP

Diagrams within this section uses the the following notation:

Arrowed line with --- tail is used to indicate traffic within uncompressed channel. Whereas, arrowed line with === tail is used to indicate traffic within ROHC channel.

Figure 10 depicts a possible interaction between compressor site and decompressor site in establishing a new ROHC channel.
Figure 10: Packets flow of RCPNP negotiating a new ROHC channel and terminating a ROHC channel

RefID is the Ref ID field and ID is the Identifier in RCPNP messages. The Reply message uses A in Ref ID field to indicate that it corresponds to Request message with ID A. Likewise, Acknowledgement uses Ref ID field to identify the message it acknowledges. Termination of ROHC channel can be initiated either by compressor site or decompressor site.
Figure 11 shows a case where the decompressor suddenly terminates without sending Decompressor Shutdown message. The decompressor site tries to re-establish ROHC channel after abrupt termination of decompressor. Compressor site suspects that decompressor was terminated abruptly when it receives a Solicitation message and Request message when its compressor is still active. Upon receiving these unexpected messages, the compressor site probes for decompressor at decompressor site and receives a NACK from the decompressor site. Compressor site can then terminate existing ROHC channel and compressor. New round of negotiation to establish a new ROHC channel can be conducted henceforth.
7. Bidirectional ROHC Channels

While establishing bidirectional ROHC channels allows for the use of ROHC bidirectional optimistic mode and bidirectional reliable mode, RCPNP doesn’t concern itself with the establishment of bidirectional ROHC channels. Therefore, it is up to implementers of this protocol to support bidirectional ROHC channels. The implementation should be as straightforward as mapping correct pair of ROHC channels.

Bidirectional ROHC channels must be formed whenever possible by associating co-located compressor and decompressor. If co-located compressor and decompressor are not associated, decompressor won’t be able to parse any ROHC compressed packet that piggyback ROHC feedback properly since it doesn’t know the size of CID within the piggybacked ROHC feedback.
8. IANA Consideration

This document requires IANA involvement for the assignment of two new Next-Header Type values from the IANA ULE Next-Header Registry.

The following assignments have been made in this document, and registered by IANA:

XXX NOTE: IANA please replace TBD and TBD-1 when assigned XXX

+--------+-------------------+-------------+
<table>
<thead>
<tr>
<th>Type</th>
<th>Name</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBD:</td>
<td>ULE-ROHC-Feedback</td>
<td>Figure 6</td>
</tr>
<tr>
<td>TBD-1:</td>
<td>ULE-ROHC-Neg</td>
<td>Section 6.1</td>
</tr>
</tbody>
</table>
+--------+-------------------+-------------+

The ULE-ROHC-Feedback Extension is a Mandatory next-type Extension Header, specified in Figure 6 of this document. The value of this next-header is defined by an IANA assigned H-Type value of TBD.

The ULE-ROHC-Neg Extension is a Mandatory next-type Extension Header specified in Section 6.1 of this document. The value of this next-header is defined by an IANA assigned H-Type value of TBD-1.
9. Acknowledgements

We would like to extend our gratitude to Dr. Gorry Fairhurst for his guidance.

We also want to thank Rod Walsh (Nokia) for his valuable input and feedback.
10. Security Considerations

Technique presented in Section 5.1 allows for DoS. A malicious site may send packet with a fake source address matching an address that belongs to a victim site. The compressor gateway upon receiving such malicious packet may be fooled about the recipient gateway and thus the intended packet may not be received by victim site once it goes through the wrong ROHC channel.

To mitigate this problem, compressor gateway that receives such suspicious packets with similar source address coming from different frontends of DVB receiver should disable compression and send all packets uncompressed via uncompressed channel when transmitting packets with the destination address.
11. References

11.1. Normative References


11.2. Informative References


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