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RTP Payload Format for ISO/IEC 21122 (JPEG XS)
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Abstract

This document specifies a Real-Time Transport Protocol (RTP) payload format to be used for transporting JPEG XS (ISO/IEC 21122) encoded video. JPEG XS is a low-latency, lightweight image coding system allowing for an increased resolution and frame rate, while offering visually lossless quality with reduced amount of resources such as power and bandwidth.

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1. Introduction

This document specifies a payload format for packetization of JPEG XS encoded video signals into the Real-time Transport Protocol (RTP) [RFC3550].

JPEG XS is a low-latency, lightweight image coding system allowing for an increased resolution and frame rate, while offering visually lossless quality with reduced amount of resources such as power and bandwidth.

2. Conventions, Definitions, and Abbreviations

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].

Application Data Unit:
The unit of source data provided as payload to the transport layer, and corresponding, in this RTP payload definition, to a JPEG XS frame.

EOC Marker
A marker that consists of the two bytex 0xff 0x10 indicating the start of a JPEG XS codestream.

JPEG XS codestream:
A sequence of bytes representing a compressed image formatted according to JPEG XS Part 1 [ISO21122-1].

JPEG XS frame:
The concatenation of a Video Support Box, as defined in JPEG XS Part 3 [ISO21122-3], and a JPEG XS codestream.

JPEG XS stream:
A JPEG XS stream is a sequence of frames, where each frame is coded independently of each other. For the purpose of RTP transport, each frame forms an Application Data Unit (ADU).

Marker:
A two-byte functional sequence that is part of a JPEG XS codestream starting with a 0xff byte and a subsequent byte defining its function.

Marker Segment:
A marker along with a 16-bit marker size and payload data following the size.

JPEG XS Header:
A sequence of bytes at the beginning of each JPEG XS codestream encoded in multiple markers and marker segments that does not carry entropy coded data, but metadata such as the frame dimension and component precision.

SOC Marker
A marker that consists of the two bytex 0xff 0x11 indicating the end of a JPEG XS codestream.

Video Support Box:

A ISO video support box in the sense of ISO/IEC 15444-1 [ISO15444-1] defined in ISO/IEC 21122-3 [ISO21122-3] that includes metadata required to play back a JPEG XS video stream, such as its color space, its maximum bitrate, its subsampling structure, its buffer model and its frame rate.

JPEG XS Header Segment:
The concatenation of a Video Support Box and JPEG XS header.

Slice:
The smallest independently decodable unit of a JPEG XS codestream, bearing in mind that it decodes to wavelet coefficients which still require inverse wavelet filtering to give an image.

Slice group:
A contiguous sequence of slices.

Fragment:
A fragment consists of one slice group, possibly preceded by a JPEG XS header segment (if the slice group is the first one of a JPEG XS frame), and possibly followed by the EOC marker (if the slice group is the last one of a JPEG XS frame).

3. Media Format Description

3.1. Image Data Structures

JPEG XS is a low-latency lightweight image coding system for coding continuous-tone grayscale or continuous-tone color digital images.

This coding system provides an efficient representation of image signals through the mathematical tool of wavelet analysis. The wavelet filter process separates each component into multiple bands, where each band consists of multiple coefficients describing the image signal of a given component within a frequency domain specific to the wavelet filter type, i.e. the particular filter corresponding to the band.

Wavelet coefficients are grouped into precincts, where each precinct includes all coefficients over all bands that contribute to a spatial region of the image.

One or multiple precincts are furthermore combined into slices consisting of an integral number of precincts. Precincts do not cross slice boundaries, and wavelet coefficients in precincts that are part of different slices can be decoded independently from each other. Note, however, that the wavelet transformation runs across

slice boundaries. A slice always extends over the full width of the image, but may only cover parts of its height.

Multiple contiguous slices are combined into slice groups. Slice groups along with preceding and/or following metadata form fragments. A fragment, and by that the corresponding slice group, is sized such that it is spread over at least two distinct RTP packets, except for the last fragment of an Application Data Unit.

Slice groups within a frame are enumerated from top to bottom by the slice group counter. That is, the first slice group of a frame is slice group #0, and the slice group counter increments by 1 from top to bottom for each slice group, and by that for each fragment.

Figure 1 shows an example of packets, slices, slice groups and fragments. In this Figure, MDT indicates metadata preceding or following slice groups, SlcGrp the slice groups and Slc the slices. As seen there, a fragment may contain more than one slice if the slices are too short to fill up an entire packet, and fragment and packet boundaries need only to align at the start and the end of the ADU. Fragments may extend over more than two packets, depending on their size, but a packet never contains two entire fragments or more. Slice group and fragment boundaries coincide, except for the first and the last fragment, which include additional metadata. Unlike regularly sized packets, the fragment and the slice group size may vary.

```
<------------------- Application Data Unit (ADU) ------------------->

+-----------+-----------+-----------+-----------+-/ /-+-------------+
| Packet #0 | Packet #1 | Packet #2 | Packet #3 |     | Packet #n-1 |
+-----------+---+-------+-----------+---+-------+-/ /-+-------------+
|  Fragment #0  |      Fragment #1      |             Fragment #m-1 |
+---+-----------+-----------------------+---------/ /-----------+---+
|MDT| SlcGrp #0 |       SlcGrp #1       |           SlcGrp #m-1 | M |
+---+-----------+-----------------------+---------/ /-----------+---+
|MDT|Slc#0 Slc#1|         Slc #2        |             Slc #k-1  | M |
+---+-----------+-----------------------+---------/ /-----------+---+
```

Figure 1: Slice Groups and Fragments

3.2. Codestream

The overall codestream format, including the definition of all markers, is further defined in ISO/IEC 21122-1 [ISO21122-1]. It represents sample values of a single frame, bare any interpretation relative to a colorspace.

3.3. Video Support Box

While the information defined in the codestream is sufficient to reconstruct the sample values of one video frame, the interpretation of the samples remains undefined by the codestream itself. This interpretation, including the color space, frame rate and other information significant to play a JPEG XS stream are contained in the Video Support Box, which precedes each JPEG XS codestream. The syntax of the Video Support Box follows ISO/IEC 15444-1 [ISO15444-1]; it consists of multiple subboxes, each with a particular meaning. Its contents, in particular its subboxes are defined in ISO/IEC 21122-3 [ISO21122-3].

4. Payload Format

This section specifies the payload format for JPEG XS video streams over the Real-time Transport Protocol (RTP) [RFC3550].

In order to be transported over RTP, each JPEG XS stream is transported in a distinct RTP stream, identified by a distinct SSRC.

Each of those RTP streams is divided into Application Data Units (ADUs).

Each ADU is split into packets, depending e.g. on the Maximum Transmission unit (MTU) of the network. Every packet shall have the same size, except the last packet of every ADU which could be shorter. Packet boundaries shall coincide with ADU boundaries, i.e. the first (resp. last) byte of an ADU shall be the first (resp. last) byte of an RTP packet payload data.

The following figure illustrates the RTP payload header used in order to transport a JPEG XS stream.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---+-+-+-------+-+-------------+-------------------------------+
| V |P|X|  CC   |M|     PT      |       Sequence number         |
+---+-+-+-------+-+-------------+-------------------------------+
|                           Timestamp                           |
+---------------------------------------------------------------+
|           Synchronization source (SSRC) identifier            |
+===============================================================+
|            Contributing source (CSRC) identifiers             |
|                             ....                              |
+-----+-+-+---------+---------------------+---------------------+
| Ver |f|c| SlcGrp  |     SlcGrpOffset    |    Frame counter    |
+-----+-+-+---------+---------------------+---------------------+
|                             Data                              |
+---------------------------------------------------------------+
```

Figure 2: RTP and payload headers

4.1. Payload Header

The version (V), padding (P), extension (X), CSRC count (CC), sequence number, synchronization source (SSRC) and contributing source (CSRC) fields follow their respective definitions in RFC 3550 [RFC3550].

The timestamp should be based on a globally synchronized 90 kHz clock reference, and should correspond to the number of cycles since the SMPTE Epoch (as per defined in SMPTE ST 2059-1:2015 [SMPTE-ST2059]) modulo 2^32:

```
timestamp = floor(time_since_epoch*90000) % 2^32
```

where time_since_epoch is the time elapsed since the SMPTE Epoch, expressed in seconds as a real number, and floor indicates rounding to the next lower integer.

As per specified in RFC 3550 [RFC3550] and RFC 4175 [RFC4175], the RTP timestamp designates the sampling instant of the first octet of the frame to which the RTP packet belongs. Packets shall not include data from multiple frames, and all packets belonging to the same frame shall have the same timestamp. Several successive RTP packets will consequently have equal timestamps if they belong to the same frame (that is until the marker bit is set to 1, marking the last packet of the frame), and the timestamp is only increased when a new frame begins.

If the sampling instant does not correspond to an integer value of the clock, the value shall be truncated to the next lowest integer, with no ambiguity.

The remaining fields are defined as follows:

Marker (M) [1 bit]:
The marker bit is used to indicate the last packet of a frame. This enables a decoder to finish decoding the frame, where it otherwise may need to wait for the next packet to explicitly know that the frame is finished.

Payload Type (PT) [7 bits]:
A dynamically allocated payload type field that designates the payload as JPEG XS video.

Ver [3 bits]:
This field indicates the version number of the payload header. The value of this field shall be 0 for the purpose of this edition of the RFC.

f [1 bit]:
The f field shall be set if a new fragment is started within this packet, i.e. if this packet contains the first byte of a fragment.

NOTE: The JPEG XS header segment and the first slice group form a fragment. For that reason, the f-bit remains unset in the packet that contains the first byte of slice group 0 but does not also contains the first byte of the Video Support box. All other slice groups form fragments of their own. The f bit allows a quick identification of packets that start a fragment. The SlcGrpOffset field (see below) can be used to identify the start of a slice group.

c [1 bit]:
The c field is a one-bit field that is set if the fragment to which the first byte of the packet belongs extends througout a subsequent packet.

SlcGrp [5 bits]:
The SlcGrp (Slice Group) field contains the slice group index modulo 32 that is contained in the fragment that is started in this packet. If no fragment starts in this packet, it contains the slice group index modulo 64 of the slice group that is contained in the fragment to which the first byte of the payload data of this packet belongs.

SlcGrpOffset [11 bits]:

This field indicates the byte offset of the slice header marker (SLH, hex 0xff20, see ISO/IEC 21122-1 [ISO21122-1]) of the slice group that starts in this packet, relative to the Ver field. If no slice group starts in this packet, this field shall be 0.

NOTE: Since the payload data has a non-zero offset within a packet, this field can also be used to identify whether a slice group starts in a packet. If 0, no slice group starts in this packet. Consequently, for all slice groups in a frame except the first one, this field will be non-zero if and only if the f-field is set.

Frame counter [11 bits]:
Counter indicating the current frame number modulo 2^11. The frame number is incremented by one at the beginning of each frame, and stays constant throughout all packets that contribute to to the same frame.

4.2. Payload Data

The payload data of a JPEG XS transport stream consists of a concatenation of multiple JPEG XS Frames.

Each JPEG XS frame is the concatenation of multiple fragments where each fragment contains one and only one slice group. The first fragment of a frame also contains the Video Support box and the JPEG XS header, the last fragment also contains the EOC marker. Figure 3 depicts this layout.

```
 ^     +--------------------------------------------+    ^
 |     |             Video Support Box              |    |
 |     |  +--------------------------------------+  |    |
 |     |  |  Sub boxes of the Video Support Box  |  |    |
Frag-  |  +--------------------------------------+  |  JPEG
ment   |  : additional sub-boxes of the VE-Box   :  |   XS
 #0    |  +--------------------------------------+  |  Header
 |     |                                            |   Seg-
 |     +--------------------------------------------+   ment
 |     |              JPEG XS Header                |    |
 |     |  +--------------------------------------+  |    |
 |     |  |             SOC Marker               |  |    |
 |     |  +--------------------------------------+  |    |
 |     |  :      Additional Marker Segments      :  |    |
 |     |  +--------------------------------------+  |    |
 |     |                                            |    |
 |     +--------------------------------------------+    v
 |     |             Slice Group #0                 |
 |     |  +--------------------------------------+  |
```

```
    |     |  |    Slice #0 of Slice Group #0      |  |
    |     |  |  +-------------------------------+ |  |
    |     |  |  |          SLH Marker           | |  |
    |     |  |  +-------------------------------+ |  |
    |     |  |  :     Entropy Coded Data        : |  |
    |     |  |  +-------------------------------+ |  |
    |     |  +------------------------------------+  |
    |     |  |    Slice #1 of Slice Group #0      |  |
    |     |  :                                    :  |
    |     |  +------------------------------------+  |
    |     |  |    Slice #n-1 of Slice Group #0    |  |
    |     |  :                                    :  |
    v     |  +------------------------------------+  |
    ^     +------------------------------------------+
    |     |            Slice Group #1                |
   Frag-  :                                          :
   ment   :                                          :
    #1    :                                          :
    |     :                                          :
    v     +------------------------------------------+
          :                                          :
    ^     +------------------------------------------+
    |     |            Slice Group #n-1              |
   Frag-  :                                          :
   ment   :                                          :
   #n-1   +------------------------------------------+
    |     |             EOC Marker                   |
    v     +------------------------------------------+
```

Figure 3: JPEG XS Payload Data

4.3. Traffic Shaping and Delivery Timing

The traffic shaping and delivery timing shall be in accordance with the Network Compatibility Model compliance definitions specified in SMPTE ST 2110-21 [SMPTE-ST2110-21] for either Narrow Linear Senders (Type NL) or Wide Senders (Type W).

NOTE: The Virtual Receiver Buffer Model compliance definitions of ST 2110-21 do not apply.

5. Congestion Control Considerations

Congestion control for RTP SHALL be used in accordance with RFC 3550 [RFC3550], and with any applicable RTP profile: e.g., RFC 3551 [RFC3551]. An additional requirement if best-effort service is being used is users of this payload format MUST monitor packet loss to ensure that the packet loss rate is within acceptable parameters.

Circuit Breakers [RFC8083] is an update to RTP [RFC3550] that defines criteria for when one is required to stop sending RTP Packet Streams and applications implementing this standard MUST comply with it. RFC 8085 [RFC8083] provides additional information on the best practices for applying congestion control to UDP streams.

6. Payload Format Parameters

6.1. Media Type Definition

Type name: video

Subtype name: jpeg-xs

Required parameters:

rate: The RTP timestamp clock rate. Applications using this payload format SHOULD use a value of 90000.

Optional parameters:

profile: The JPEG XS profile in use, as defined in JPEG XS Part 2 [ISO21122-2].

level: The JPEG XS level in use, as defined in JPEG XS Part 2 [ISO21122-2].

sublevel: The JPEG XS sublevel in use, as defined in JPEG XS Part 2 [ISO21122-2].

sampling: Signals the color difference signal sub-sampling structure.

Signals utilizing the non-constant luminance Y'C'B C'R signal format of Recommendation ITU-R BT.601-7, Recommendation ITU-R BT.709-6, Recommendation ITU-R BT.2020-2, or Recommendation ITU-R BT.2100 shall use the appropriate one of the following values for the Media Type Parameter "sampling":

```
YCbCr-4:4:4 (4:4:4 sampling)
YCbCr-4:2:2 (4:2:2 sampling)
YCbCr-4:2:0 (4:2:0 sampling)
```

Signals utilizing the Constant Luminance Y'C C'BC C'RC signal format of Recommendation ITU-R BT.2020-2 shall use the appropriate one of the following values for the Media Type Parameter "sampling":

CLYCbCr-4:4:4 (4:4:4 sampling)
CLYCbCr-4:2:2 (4:2:2 sampling)
CLYCbCr-4:2:0 (4:2:0 sampling)

Signals utilizing the constant intensity I CT CP signal format of Recommendation ITU-R BT.2100 shall use the appropriate one of the following values for the Media Type Parameter "sampling":

ICtCp-4:4:4 (4:4:4 sampling)
ICtCp-4:2:2 (4:2:2 sampling)
ICtCp-4:2:0 (4:2:0 sampling)

Signals utilizing the 4:4:4 R' G' B' or RGB signal format (such as that of Recommendation ITU-R BT.601, Recommendation ITU-R BT.709, Recommendation ITU-R BT.2020, Recommendation ITU-R BT.2100, SMPTE ST 2065-1 or ST 2065-3) shall use the following value for the Media Type Parameter sampling.

RGB   RGB or R' G' B' samples

Signals utilizing the 4:4:4 X' Y' Z' signal format (such as defined in SMPTE ST 428-1) shall use the following value for the Media Type Parameter sampling.

XYZ   X' Y' Z' samples

Key signals as defined in SMPTE RP 157 shall use the value key for the Media Type Parameter sampling. The Key signal is represented as a single component.

KEY   samples of the key signal

depth: Determines the number of bits per sample. This is an integer with typical values including 8, 10, 12, and 16.

width: Determines the number of pixels per line. This is an integer between 1 and 32767.

height: Determines the number of lines per frame. This is an integer between 1 and 32767.

exactframerate: Signals the frame rate in frames per second. Integer frame rates shall be signaled as a single decimal number (e.g. "25") whilst non-integer frame rates shall be signaled as a ratio of two integer decimal numbers separated by a "forward-slash" character (e.g. "30000/1001"), utilizing the numerically smallest numerator value possible.

colorimetry: Specifies the system colorimetry used by the image samples. Valid values and their specification are:

BT601-5	ITU Recommendation BT.601-5
BT709-2	ITU Recommendation BT.709-2
SMPTE240M	SMPTE standard 240M
BT601	as specified in Recommendation ITU-R BT.601-7
BT709	as specified in Recommendation ITU-R BT.709-6
BT2020	as specified in Recommendation ITU-R BT.2020-2
BT2100	as specified in Recommendation ITU-R BT.2100 Table 2 titled "System colorimetry"
ST2065-1	as specified in SMPTE ST 2065-1 Academy Color Encoding Specification (ACES)
ST2065-3	as specified for Academy Density Exchange Encoding (ADX) in SMPTE ST 2065-3
XYZ	as specified in ISO 11664-1 section titled "1931 Observer"

Signals utilizing the Recommendation ITU-R BT.2100 colorimetry should also signal the representational range using the optional parameter RANGE defined below.

interlace: If this OPTIONAL parameter name is present, it indicates that the video is interlaced. If this parameter name is not present, the progressive video format shall be assumed.

TCS: Transfer Characteristic System. This parameter specifies the transfer characteristic system of the image samples. Valid values and their specification are:

SDR	(Standard Dynamic Range) Video streams of standard dynamic range, that utilize the OETF of Recommendation ITU-R BT.709 or Recommendation ITU-R BT.2020. Such streams shall be assumed to target the EOTF specified in ITU-R BT.1886.
PQ	Video streams of high dynamic range video that utilize the Perceptual Quantization system of Recommendation ITU-R BT.2100
HLG	Video streams of high dynamic range video that utilize the Hybrid Log-Gamma system of Recommendation ITU-R BT.2100

RANGE: This parameter should be used to signal the encoding range of the sample values within the stream. When paired with ITU Rec BT.2100 colorimetry, this parameter has two allowed values NARROW and FULL, corresponding to the ranges specified in table 9 of ITU Rec BT.2100. In any other context, this parameter has three allowed values: NARROW, FULLPROTECT, and FULL, which correspond to

the ranges specified in SMPTE RP 2077. In the absence of this parameter, NARROW shall be the assumed value in either case.

Encoding considerations:
This media type is framed and binary; see Section 4.8 in RFC 6838 [RFC6838].

Security considerations:
Please see the Security Considerations section in RFC XXXX

6.2. Mapping to SDP

6.2.1. General

A Session Description Protocol (SDP) object shall be created for each RTP stream and it shall be in accordance with the provisions of SMPTE ST 2110-10 [SMPTE-ST2110-10].

The information carried in the media type specification has a specific mapping to fields in the Session Description Protocol (SDP), which is commonly used to describe RTP sessions.

6.2.2. Media type and subtype

The media type ("video") goes in SDP "m=" as the media name.

The media subtype ("jpeg-xs") goes in SDP "a=rtpmap" as the encoding name. The RTP clock rate in "a=rtpmap" MUST be 90000, which for the payload format defined in this document is a 90 kHz clock. The remaining parameters go in the SDP "a=fmtp" attribute by copying them directly from the MIME media type string as a semicolon-separated list of parameter=value pairs.

A sample SDP mapping for JPEG XS video is as follows:

```
m=video 30000 RTP/AVP 112
a=rtpmap:112 jpeg-xs/90000
a=fmtp:112 sampling=YCbCr-4:2:2; width=1920; height=1080;
           depth=10; colorimetry=BT709; TCS=SDR; RANGE=FULL
```

In this example, a dynamic payload type 112 is used for JPEG XS video. The RTP sampling clock is 90 kHz. Note that the "a=fmtp:" line has been wrapped to fit this page, and will be a single long line in the SDP file.

6.2.3. Traffic shaping

The SDP object shall include the TP parameter and may include the CMAX parameter as specified in SMPTE ST 2110-21 [SMPTE-ST2110-21].

6.2.4. Offer/Answer Considerations

The following considerations apply when using SDP offer/answer procedures [RFC3264] to negotiate the use of the JPEG XS payload in RTP:

- o The "encode" parameter can be used for sendrecv, sendonly, and recvonly streams. Each encode type MUST use a separate payload type number.

- o Any unknown parameter in an offer MUST be ignored by the receiver and MUST NOT be included in the answer.

7. IANA Considerations

This memo requests that IANA registers video/jpeg-xs as specified in Section 6.1. The media type is also requested to be added to the IANA registry for "RTP Payload Format MIME types" [1].

8. Security Considerations

RTP packets using the payload format defined in this specification are subject to the security considerations discussed in the RTP specification [RFC3550] and in any applicable RTP profile such as RTP/AVP [RFC3551], RTP/AVPF [RFC4585], RTP/SAVP [RFC3711], or RTP/SAVPF [RFC5124]. This implies that confidentiality of the media streams is achieved by encryption.

However, as "Securing the RTP Framework: Why RTP Does Not Mandate a Single Media Security Solution" [RFC7202] discusses, it is not an RTP payload format's responsibility to discuss or mandate what solutions are used to meet the basic security goals like confidentiality, integrity, and source authenticity for RTP in general. This responsibility lies on anyone using RTP in an application. They can find guidance on available security mechanisms and important considerations in "Options for Securing RTP Sessions" [RFC7201]. Applications SHOULD use one or more appropriate strong security mechanisms.

This payload format and the JPEG XS encoding do not exhibit any substantial non-uniformity, either in output or in complexity to perform the decoding operation and thus are unlikely to pose a

denial-of-service threat due to the receipt of pathological datagrams.

It is important to note that HD or UHDTV JPEG XS-encoded video can have significant bandwidth requirements (typically more than 1 Gbps for ultra high-definition video, especially if using high framerate). This is sufficient to cause potential for denial-of-service if transmitted onto most currently available Internet paths.

Accordingly, if best-effort service is being used, users of this payload format MUST monitor packet loss to ensure that the packet loss rate is within acceptable parameters. Packet loss is considered acceptable if a TCP flow across the same network path, and experiencing the same network conditions, would achieve an average throughput, measured on a reasonable timescale, that is not less than the RTP flow is achieving. This condition can be satisfied by implementing congestion control mechanisms to adapt the transmission rate (or the number of layers subscribed for a layered multicast session), or by arranging for a receiver to leave the session if the loss rate is unacceptably high.

This payload format may also be used in networks that provide quality-of-service guarantees. If enhanced service is being used, receivers SHOULD monitor packet loss to ensure that the service that was requested is actually being delivered. If it is not, then they SHOULD assume that they are receiving best-effort service and behave accordingly.

9. RFC Editor Considerations

Note to RFC Editor: This section may be removed after carrying out all the instructions of this section.

RFC XXXX is to be replaced by the RFC number this specification receives when published.

10. References

10.1. Normative References

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[RFC8085] Eggert, L., Fairhurst, G., and G. Shepherd, "UDP Usage Guidelines", BCP 145, RFC 8085, DOI 10.17487/RFC8085, March 2017, <https://www.rfc-editor.org/info/rfc8085>.

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