RFC 9134
RTP Payload Format for ISO/IEC 21122 (JPEG XS)

Abstract

This document specifies a Real-Time Transport Protocol (RTP) payload format to be used for transporting video encoded with JPEG XS (ISO/IEC 21122). JPEG XS is a low-latency, lightweight image coding system. Compared to an uncompressed video use case, it allows higher resolutions and video frame rates while offering visually lossless quality, reduced power consumption, and encoding-decoding latency confined to a fraction of a video frame.

Status of This Memo

This is an Internet Standards Track document.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Further information on Internet Standards is available in Section 2 of RFC 7841.

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at https://www.rfc-editor.org/info/rfc9134.

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1. Introduction

This document specifies a payload format for packetization of video signals encoded with JPEG XS [ISO21122-1] into the Real-time Transport Protocol (RTP) [RFC3550].

The JPEG XS coding system offers compression and recompression of image sequences with very moderate computational resources while remaining robust under multiple compression and decompression cycles as well as mixing of content sources, e.g., embedding of subtitles, overlays, or logos. Typical target compression ratios ensuring visually lossless quality are in the range of 2:1 to 10:1 depending on the nature of the source material. The latency that is introduced by the encoding-decoding process can be confined to a fraction of a video frame, typically between a small number of lines down to below a single line.

2. Conventions, Definitions, and Abbreviations

The key words "**MUST**", "**MUST NOT**", "**REQUIRED**", "**SHALL**", "**SHALL NOT**", "**SHOULD**", "**SHOULD NOT**", "**RECOMMENDED**", "**NOT RECOMMENDED**", "**MAY**", and "**OPTIONAL**" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

Application Data Unit (ADU):
>   The unit of source data provided as payload to the transport layer. In this RTP payload definition, it corresponds to a single JPEG XS video frame.

Color Specification (CS) box:
>   An ISO color specification box defined in [ISO21122-3] (JPEG XS Part 3) that includes color-related metadata required to correctly display JPEG XS video frames, such as color primaries, transfer characteristics, and matrix coefficients.

End of Codestream (EOC) marker:
>   A marker that consists of the two bytes 0xff11 indicating the end of a JPEG XS codestream.

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

JPEG XS codestream header:
>   A sequence of bytes, starting with an SOC marker, 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 video frame dimension and component precision.

JPEG XS frame:
>   In the case of progressive video, a single JPEG XS picture segment. In the case of interlaced video, the concatenation of two JPEG XS picture segments.

JPEG XS header segment:
    The concatenation of a video support box [ISO21122-3], a color specification box [ISO21122-3], and a JPEG XS codestream header.

JPEG XS picture segment:
    The concatenation of a video support box [ISO21122-3], a color specification box [ISO21122-3], and a JPEG XS codestream.

JPEG XS stream:
    A sequence of JPEG XS frames.

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.

Packetization unit:
    A portion of an ADU whose boundaries coincide with boundaries of RTP packet payloads (excluding payload header), i.e., the first (or respectively, last) byte of a packetization unit is the first (or respectively, last) byte of an RTP packet payload (excluding its payload header).

SLH marker:
    A marker that represents a slice header, as defined in [ISO21122-1].

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.

Start of a Codestream (SOC) marker:
    A marker that consists of the two bytes 0xff10 indicating the start of a JPEG XS codestream. The SOC marker is considered an integral part of the JPEG XS codestream header.

Video Support (VS) box:
    An ISO video support box, as defined in [ISO21122-3], that includes metadata required to play back a JPEG XS stream; such metadata could include its maximum bit rate, its subsampling structure, its buffer model, and its frame rate.

3. Media Format Description

This section explains the terminology and concepts used in this memo specific to JPEG XS as specified in [ISO21122-1], [ISO21122-2], and [ISO21122-3].

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 integer number of precincts. Precincts do not cross slice boundaries, and wavelet coefficients in precincts that are part of different slices can be decoded independently of each other. However, note 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.

3.2. Codestream

A JPEG XS codestream is formed by (in the given order):

- a JPEG XS codestream header, which starts with a Start of Codestream (SOC) marker,
- one or more slices,
- an EOC marker to signal the end of the codestream.

The JPEG XS codestream format, including the definition of all markers, is further defined in [ISO21122-1]. It represents sample values of a single image, without any interpretation relative to a color space.

3.3. Video Support Box and Color Specification Box

While the information defined in the codestream is sufficient to reconstruct the sample values of one image, the interpretation of the samples remains undefined by the codestream itself. This interpretation is given by the video support box and the color specification box, which contain significant information to correctly play the JPEG XS stream. The layout and syntax of these boxes, together with their content, are defined in [ISO21122-3].

The video support box provides information on the maximum bit rate, the frame rate, the interlaced mode (progressive or interlaced), the subsampling image format, the informative timecode of the current JPEG XS frame, the profile, the level/sublevel used, and optionally the buffer model and the mastering display metadata.

Note that the profile and level/sublevel, specified respectively by the Ppih and Plev fields [ISO21122-2], specify limits on the capabilities needed to decode the codestream and handle the output. Profiles represent a limit on the required algorithmic features and parameter ranges used in the codestream. The combination of level and sublevel defines a lower bound on the required throughput for a decoder in the image (or decoded) domain and the codestream (or coded) domain, respectively. The actual defined profiles and levels/sublevels, along with the associated values for the Ppih and Plev fields, are defined in [ISO21122-2].

The color specification box indicates the color primaries, transfer characteristics, matrix coefficients, and video full range flag needed to specify the color space of the video stream.

3.4. JPEG XS Frame

The concatenation of a video support box, a color specification box, and a JPEG XS codestream forms a JPEG XS picture segment.

In the case of a progressive video stream, each JPEG XS frame consists of one single JPEG XS picture segment.

In the case of an interlaced video stream, each JPEG XS frame is made of two concatenated JPEG XS picture segments. The codestream of each picture segment corresponds exclusively to one of the two fields of the interlaced frame. Both picture segments **SHALL** contain identical boxes (i.e., concatenation of the video support box and the color specification box is byte exact the same for both picture segments of the frame).

Note that the interlaced mode, as signaled by the frat field [ISO21122-3] in the video support box, indicates either progressive interlaced top-field-first or interlaced bottom-field-first mode. Thus, in the case of interlaced content, its value **SHALL** also be identical in both picture segments.

4. RTP Payload Format

This section specifies the payload format for JPEG XS 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 synchronization source (SSRC) [RFC3550].

A JPEG XS stream is divided into Application Data Units (ADUs), each ADU corresponding to a single JPEG XS frame.

4.1. RTP Packetization

An ADU is made of several packetization units. If a packetization unit is bigger than the maximum size of an RTP packet payload, the unit is split into multiple RTP packet payloads, as illustrated in Figure 1. As seen there, each packet **SHALL** contain (part of) one, and only one, packetization unit. A packetization unit may extend over multiple packets. The payload of every packet **SHALL** have the same size (based, e.g., on the Maximum Transfer Unit of the network) with the possible exception of the last packet of a packetization unit. The boundaries of a packetization unit **SHALL** coincide with the boundaries of the payload of a packet (excluding the payload header), i.e., the first (or, respectively, last) byte of the packetization unit **SHALL** be the first (or, respectively, last) byte of the payload (excluding its header).

```
RTP          +-----+------------------------+
Packet #1    | Hdr | Packetization unit #1  |
             +-----+------------------------+
RTP          +-----+------------------------------------+
Packet #2    | Hdr | Packetization unit #2              |
             +-----+------------------------------------+
RTP          +-----+----------------------------------------------+
Packet #3    | Hdr | Packetization unit #3  (part 1/3)            |
             +-----+----------------------------------------------+
RTP          +-----+----------------------------------------------+
Packet #4    | Hdr | Packetization unit #3  (part 2/3)            |
             +-----+----------------------------------------------+
RTP          +-----+-------------------------------------------+
Packet #5    | Hdr | Packetization unit #3  (part 3/3)         |
             +-----+-------------------------------------------+
             ...
RTP          +-----+-----------------------------------------+
Packet #P    | Hdr | Packetization unit #N  (part q/q)       |
             +-----+-----------------------------------------+
```
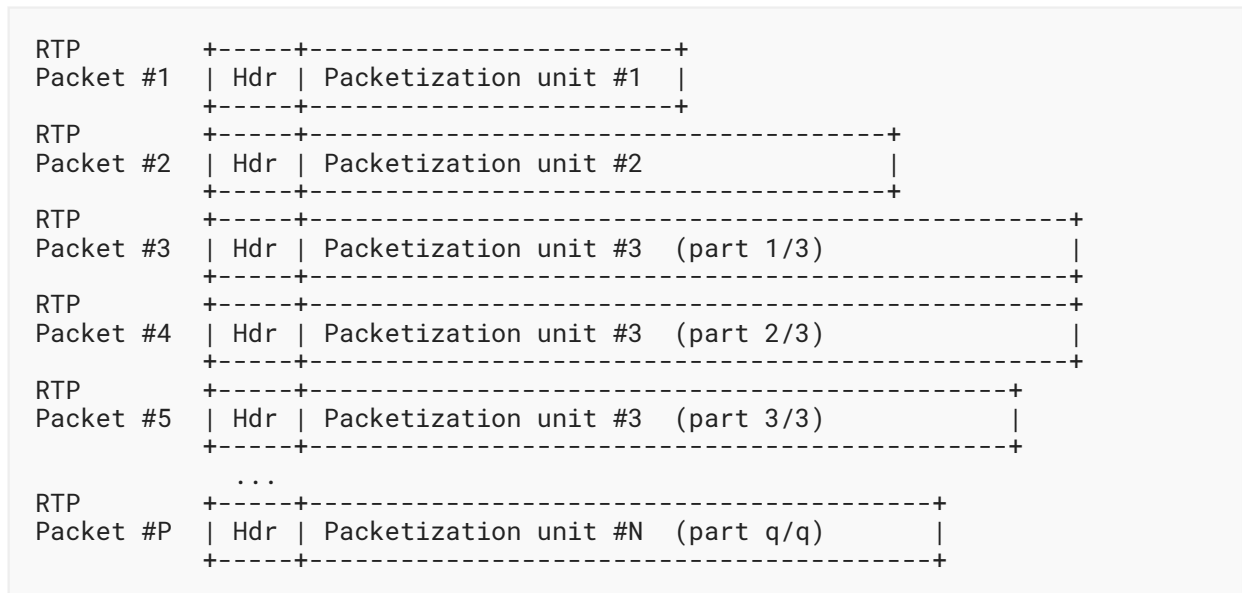
Figure 1: Example of ADU Packetization

There are two different packetization modes defined for this RTP payload format.

Codestream packetization mode:
> In this mode, the packetization unit **SHALL** be the entire JPEG XS picture segment (i.e., codestream preceded by boxes). This means that a progressive frame will have a single packetization unit, while an interlaced frame will have two. The progressive case is illustrated in Figure 2.

Slice packetization mode:
> In this mode, the packetization unit **SHALL** be the slice, i.e., there **SHALL** be data from no more than one slice per RTP packet. The first packetization unit **SHALL** be made of the JPEG XS header segment (i.e., the concatenation of the VS box, the CS box, and the JPEG XS codestream header). This first unit is then followed by successive units, each containing one and only one slice. The packetization unit containing the last slice of a JPEG XS codestream **SHALL** also contain the EOC marker immediately following this last slice. This is illustrated in Figure 3. In the case of an interlaced frame, the JPEG XS header segment of the second field **SHALL** be in its own packetization unit.

```
RTP          +-----+--------------------------------------------------+
Packet #1    | Hdr | VS box + CS box + JPEG XS codestream (part 1/q)  |
             +-----+--------------------------------------------------+
RTP          +-----+--------------------------------------------------+
Packet #2    | Hdr | JPEG XS codestream (part 2/q)                    |
             +-----+--------------------------------------------------+
             ...
RTP          +-----+------------------------------------------+
Packet #P    | Hdr | JPEG XS codestream (part q/q)            |
             +-----+------------------------------------------+
```

Figure 2: Example of Codestream Packetization Mode

```
RTP          +-----+----------------------------+
Packet #1    | Hdr | JPEG XS header segment     |
             +-----+----------------------------+
RTP          +-----+-------------------------------------------+
Packet #2    | Hdr | Slice #1  (part 1/2)                      |
             +-----+-------------------------------------------+
RTP          +-----+------------------------------------------+
Packet #3    | Hdr | Slice #1  (part 2/2)                     |
             +-----+------------------------------------------+
RTP          +-----+-------------------------------------------+
Packet #4    | Hdr | Slice #2  (part 1/3)                      |
             +-----+-------------------------------------------+
             ...
RTP          +-----+--------------------------------------+
Packet #P    | Hdr | Slice #N  (part q/q) + EOC marker     |
             +-----+--------------------------------------+
```
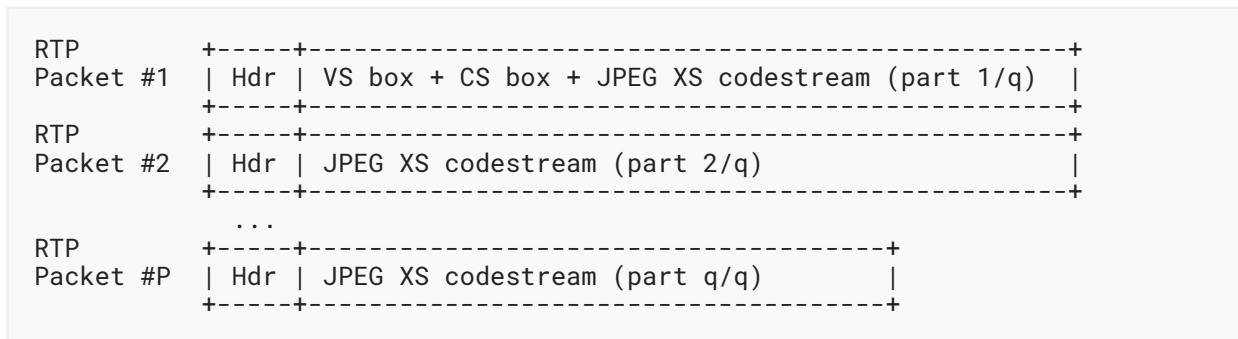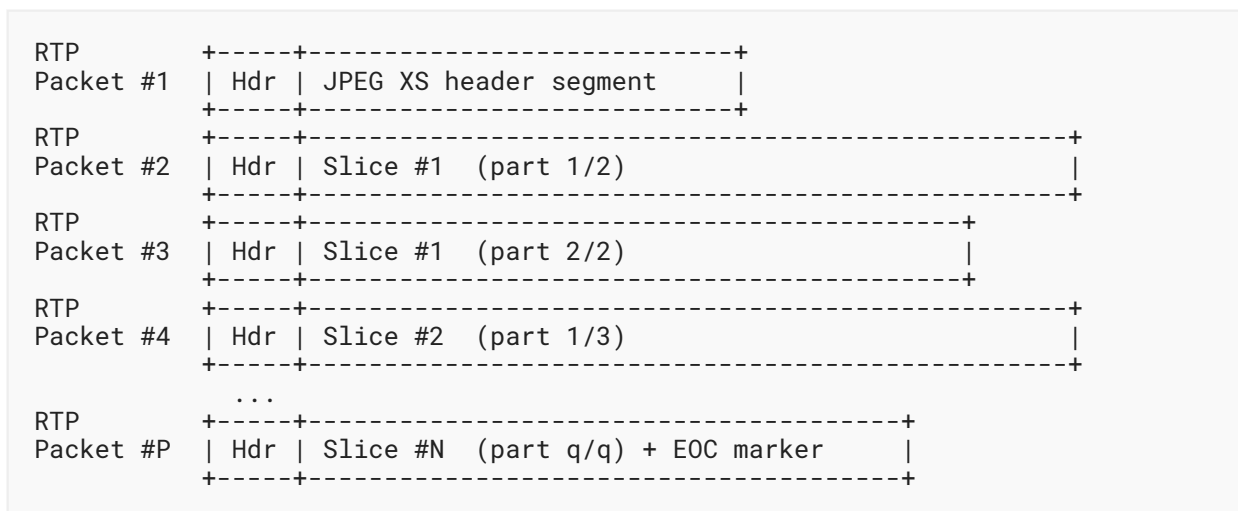
Figure 3: Example of Slice Packetization Mode

In a constant bitrate (CBR) scenario of JPEG XS, the codestream packetization mode guarantees that a JPEG XS RTP stream will produce both a constant number of bytes per video frame and a constant number of RTP packets per video frame. However, to provide similar guarantees with JPEG XS in a variable bitrate (VBR) mode or when using the slice packetization mode (for either CBR or VBR), additional mechanisms are needed. This can involve a constraint at the rate allocation stage in the JPEG XS encoder to impose a CBR at the slice level, the usage of padding data, or the insertion of empty RTP packets (i.e., an RTP packet whose payload data is empty). But, management of the amount of produced packets per video frame is application dependent and not a strict requirement of this RTP payload specification.

4.2. RTP Header Usage

The format of the RTP header is specified in [RFC3550] and reprinted in Figure 4 for convenience. This RTP payload format uses the fields of the header in a manner consistent with that specification.

The RTP payload (and the settings for some RTP header bits) for packetization units are specified in Section 4.3.

```
 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             |
|                            ....                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
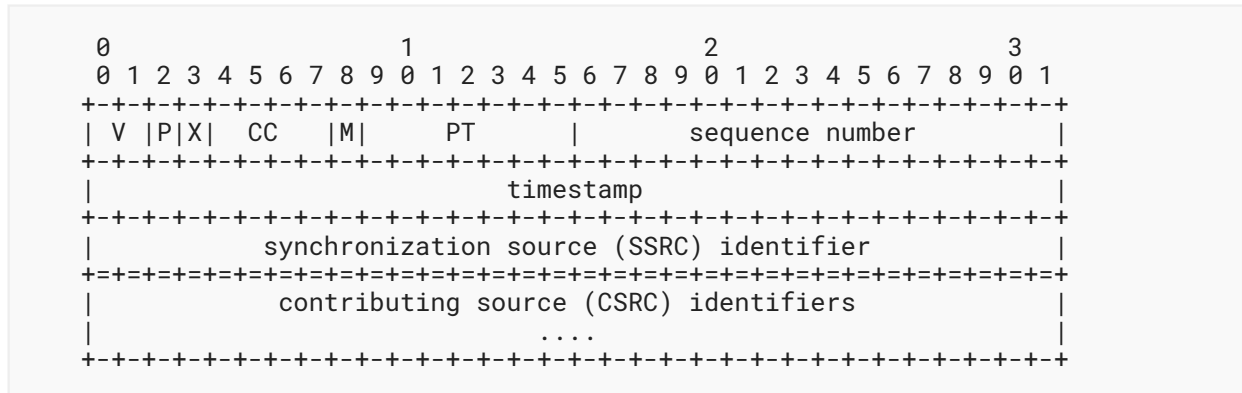
Figure 4: RTP Header According to RFC 3550

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 [RFC3550].

The remaining RTP header information to be set according to this RTP payload format is set as follows:

Marker (M) [1 bit]:
> If progressive scan video is being transmitted, the marker bit denotes the end of a video frame. If interlaced video is being transmitted, it denotes the end of the field. The marker bit **SHALL** be set to 1 for the last packet of the video frame/field. It **SHALL** be set to 0 for all other packets.

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

Timestamp [32 bits]:
> The RTP timestamp is set to the sampling timestamp of the content. A 90 kHz clock rate **SHALL** be used.

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

4.3. Payload Header Usage

The first four bytes of the payload of an RTP packet in this RTP payload format are referred to as the "payload header". Figure 5 illustrates the structure of this payload header.
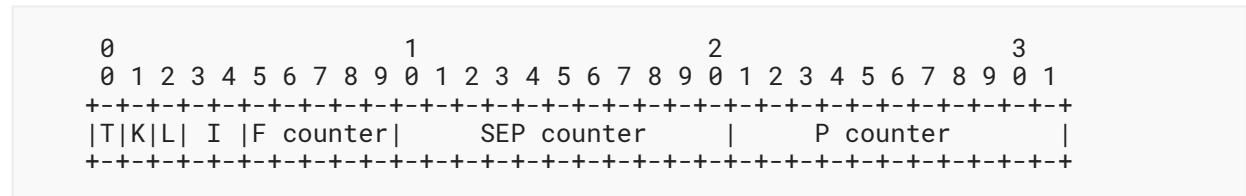
```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |T|K|L| I |F counter|    SEP counter    |    P counter         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 5: Payload Header

The payload header consists of the following fields:

Transmission mode (T) [1 bit]:
> The T bit is set to indicate that packets are sent sequentially by the transmitter. This information allows a receiver to dimension its input buffer(s) accordingly. If T=0, nothing can be assumed about the transmission order and packets may be sent out of order by the transmitter. If T=1, packets **SHALL** be sent sequentially by the transmitter. The T-bit value **SHALL** be identical for all packets of the RTP stream.

pacKetization mode (K) [1 bit]:
> The K bit is set to indicate which packetization mode is used. K=0 indicates codestream packetization mode, while K=1 indicates slice packetization mode. In the case that the Transmission mode (T) is set to 0 (out of order), the slice packetization mode **SHALL** be used and K **SHALL** be set to 1. This is required because only the slice packetization mode supports out-of-order packet transmission. The K-bit value **SHALL** be identical for all packets of the RTP stream.

Last (L) [1 bit]:
> The L bit is set to indicate the last packet of a packetization unit. As the end of the video frame also ends the packet containing the last unit of the video frame, the L bit is set whenever the M bit is set. In the codestream packetization mode, the L bit and M bit get an equivalent meaning, so they **SHALL** have identical values in each packet.

Interlaced information (I) [2 bits]:
> These two I bits are used to indicate how the JPEG XS frame is scanned (progressive or interlaced). In case of an interlaced frame, they also indicate which JPEG XS picture segment the payload is part of (first or second).

> 00:   The payload is progressively scanned.

> 01:   This value is reserved for future use.

10:     The payload is part of the first JPEG XS picture segment of an interlaced video frame. The height specified in the included JPEG XS codestream header is half of the height of the entire displayed image.

11:     The payload is part of the second JPEG XS picture segment of an interlaced video frame. The height specified in the included JPEG XS codestream header is half of the height of the entire displayed image.

F counter [5 bits]:
The Frame (F) counter identifies the video frame number modulo 32 to which a packet belongs. Frame numbers are incremented by 1 for each video frame transmitted. The frame number, in addition to the timestamp, may help the decoder manage its input buffer and bring packets back into their natural order.

Slice and Extended Packet (SEP) counter [11 bits]:
The SEP counter is used differently depending on the packetization mode.

  • In the case of codestream packetization mode (K=0), this counter resets whenever the Packet counter resets (see Section 4.4) and increments by 1 whenever the Packet counter overruns.
  • In the case of slice packetization mode (K=1), this counter identifies the slice modulo 2047 to which the packet contributes. If the data belongs to the JPEG XS header segment, this field **SHALL** have its maximal value, namely 2047 = 0x07ff. Otherwise, it is the slice index modulo 2047. Slice indices are counted from 0 (corresponding to the top of the video frame).

P counter [11 bits]:
The Packet (P) counter identifies the packet number modulo 2048 within the current packetization unit. It is set to 0 at the start of the packetization unit and incremented by 1 for every subsequent packet (if any) belonging to the same unit. Practically, if codestream packetization mode is enabled, this field counts the packets within a JPEG XS picture segment and is extended by the SEP counter when it overruns. If slice packetization mode is enabled, this field counts the packets within a slice or within the JPEG XS header segment.

4.4. Payload Data

The payload data of a JPEG XS RTP stream consists of a concatenation of multiple JPEG XS frames. Within the RTP stream, all of the video support boxes and all of the color specification boxes **SHALL** retain their respective layouts for each JPEG XS frame. Thus, each video support box in the RTP stream **SHALL** define the same sub boxes. The effective values in the boxes are allowed to change under the condition that their relative byte offsets **SHALL NOT** change.

Each JPEG XS frame is the concatenation of one or more packetization unit(s), as explained in Section 4.1. Figure 6 depicts this layout for a progressive video frame in the codestream packetization mode, Figure 7 depicts this layout for an interlaced video frame in the codestream packetization mode, Figure 8 depicts this layout for a progressive video frame in the slice

packetization mode, and Figure 9 depicts this layout for an interlaced video frame in the slice
packetization mode. The Frame counter value is not indicated because the value is constant for
all packetization units of a given video frame.

```
+=====[ Packetization unit (PU) #1 ]====+
|            Video support box          |  SEP counter=0
|   +--------------------------------+  |  P counter=0
|   :      Sub boxes of the VS box   :  |
|   +--------------------------------+  |
+- - - - - - - - - - - - - - - - - - -+
|         Color specification box       |
|   +--------------------------------+  |
|   :       Fields of the CS box     :  |
|   +--------------------------------+  |
+- - - - - - - - - - - - - - - - - - -+
|            JPEG XS codestream         |
:               (part 1/q)              :  M=0, K=0, L=0, I=00
+---------------------------------------+
|            JPEG XS codestream         |  SEP counter=0
|               (part 2/q)              |  P counter=1
:                                       :  M=0, K=0, L=0, I=00
+---------------------------------------+
|            JPEG XS codestream         |  SEP counter=0
|               (part 3/q)              |  P counter=2
:                                       :  M=0, K=0, L=0, I=00
+---------------------------------------+
:                                       :
+---------------------------------------+
|            JPEG XS codestream         |  SEP counter=1
|              (part 2049/q)            |  P counter=0
:                                       :  M=0, K=0, L=0, I=00
+---------------------------------------+
:                                       :
+---------------------------------------+
|            JPEG XS codestream         |  SEP counter=(q-1) div 2048
|               (part q/q)              |  P counter=(q-1) mod 2048
:                                       :  M=1, K=0, L=1, I=00
+=======================================+
```

*Figure 6: Example of JPEG XS Payload Data (Codestream Packetization Mode, Progressive Video
Frame)*

```
+=====[ Packetization unit (PU) #1 ]====+
|          Video support box            |   SEP counter=0
+- - - - - - - - - - - - - - - - - - - -+   P counter=0
|        Color specification box        |
+- - - - - - - - - - - - - - - - - - - -+
|     JPEG XS codestream (1st field)    |
:             (part 1/q)                :   M=0, K=0, L=0, I=10
+---------------------------------------+
|     JPEG XS codestream (1st field)    |   SEP counter=0
|             (part 2/q)                |   P counter=1
:                                       :   M=0, K=0, L=0, I=10
+---------------------------------------+
:                                       :
+---------------------------------------+
|     JPEG XS codestream (1st field)    |   SEP counter=1
|            (part 2049/q)              |   P counter=0
:                                       :   M=0, K=0, L=0, I=10
+---------------------------------------+
:                                       :
+---------------------------------------+
|     JPEG XS codestream (1st field)    |   SEP counter=(q-1) div 2048
|             (part q/q)                |   P counter=(q-1) mod 2048
:                                       :   M=1, K=0, L=1, I=10
+==============[ PU #2 ]===============+
|          Video support box            |   SEP counter=0
+- - - - - - - - - - - - - - - - - - - -+   P counter=0
|        Color specification box        |
+- - - - - - - - - - - - - - - - - - - -+
|     JPEG XS codestream (2nd field)    |
|             (part 1/q)                |
:                                       :   M=0, K=0, L=0, I=11
+---------------------------------------+
|     JPEG XS codestream (2nd field)    |   SEP counter=0
|             (part 2/q)                |   P counter=1
:                                       :   M=0, K=0, L=0, I=11
+---------------------------------------+
:                                       :
+---------------------------------------+
|     JPEG XS codestream (2nd field)    |   SEP counter=(q-1) div 2048
|             (part q/q)                |   P counter=(q-1) mod 2048
:                                       :   M=1, K=0, L=1, I=11
+=======================================+
```
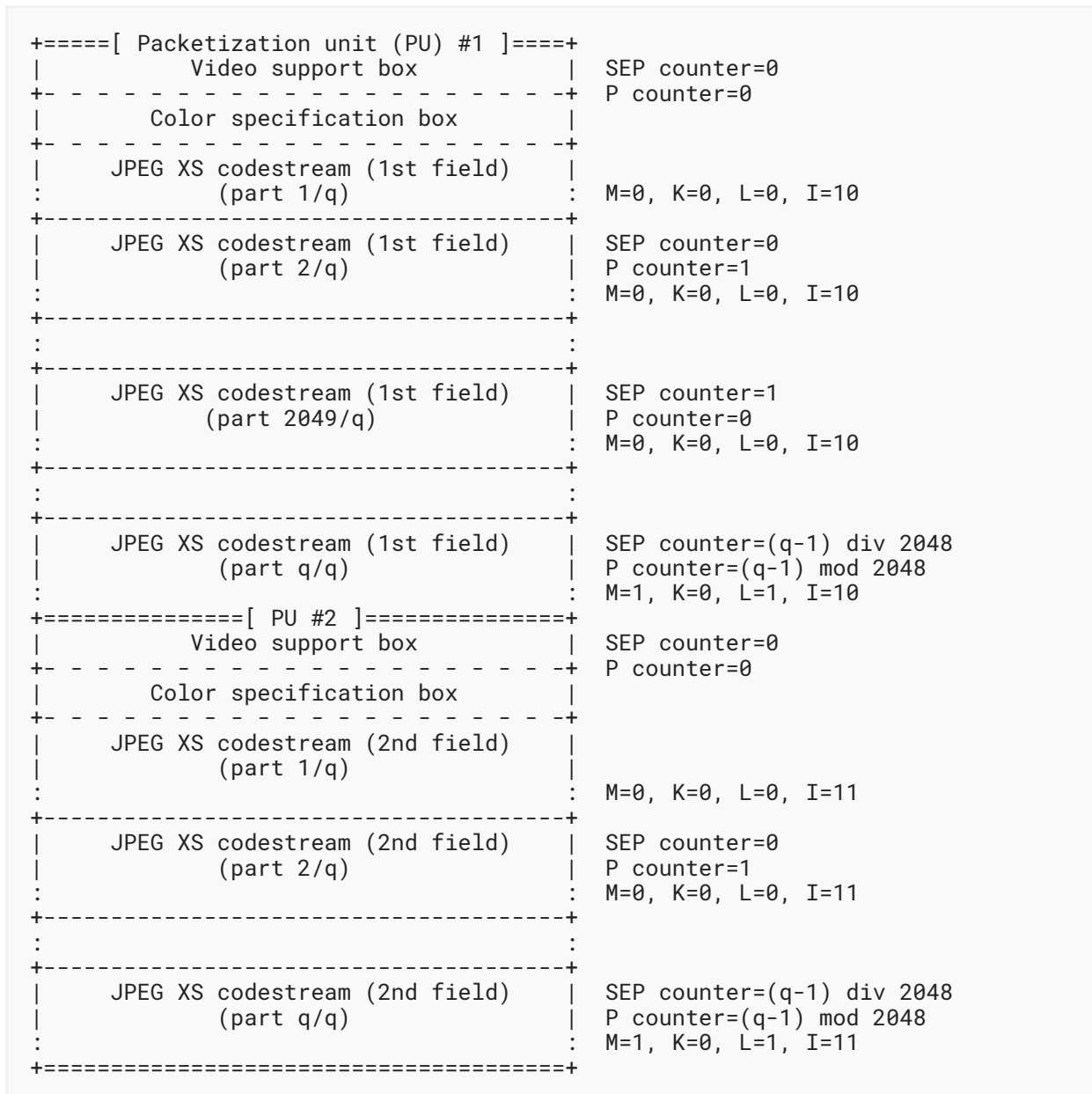
Figure 7: Example of JPEG XS Payload Data (Codestream Packetization Mode, Interlaced Video Frame)

```
+===[ PU #1: JPEG XS Header segment ]===+
|             Video support box         |  SEP counter=0x07FF
+- - - - - - - - - - - - - - - - - - -+  P counter=0
|         Color specification box       |
+- - - - - - - - - - - - - - - - - - -+
|        JPEG XS codestream header      |
|   +-------------------------------+   |
|   :  Markers and marker segments  :   |
|   +-------------------------------+   |  M=0, T=0, K=1, L=1, I=00
+==========[ PU #2: Slice #1 ]==========+
|   +-------------------------------+   |  SEP counter=0
|   |           SLH Marker          |   |  P counter=0
|   +-------------------------------+   |
|   :       Entropy Coded Data      :   |
|   +-------------------------------+   |  M=0, T=0, K=1, L=1, I=00
+==========[ PU #3: Slice #2 ]==========+
|               Slice #2                |  SEP counter=1
|               (part 1/q)              |  P counter=0
:                                       :  M=0, T=0, K=1, L=0, I=00
+---------------------------------------+
|               Slice #2                |  SEP counter=1
|               (part 2/q)              |  P counter=1
:                                       :  M=0, T=0, K=1, L=0, I=00
+---------------------------------------+
:                                       :
+---------------------------------------+
|               Slice #2                |  SEP counter=1
|               (part q/q)              |  P counter=q-1
:                                       :  M=0, T=0, K=1, L=1, I=00
+=======================================+
:                                       :
+========[ PU #N: Slice #(N-1) ]========+
|              Slice #(N-1)             |  SEP counter=N-2
|               (part 1/r)              |  P counter=0
:                                       :  M=0, T=0, K=1, L=0, I=00
+---------------------------------------+
:                                       :
+---------------------------------------+
|              Slice #(N-1)             |  SEP counter=N-2
|               (part r/r)              |  P counter=r-1
:              + EOC marker             :  M=1, T=0, K=1, L=1, I=00
+=======================================+
```

Figure 8: Example of JPEG XS Payload Data (Slice Packetization Mode, Progressive Video Frame)

```
+====[ PU #1: JPEG XS Hdr segment 1 ]===+
|            Video support box          |    SEP counter=0x07FF
+- - - - - - - - - - - - - - - - - - -+    P counter=0
|          Color specification box      |
+- - - - - - - - - - - - - - - - - - - -+
|        JPEG XS codestream header 1    |
|   +-------------------------------+   |
|   :   Markers and marker segments  :  |
|   +-------------------------------+   |    M=0, T=0, K=1, L=1, I=10
+====[ PU #2: Slice #1 (1st field) ]====+
|   +-------------------------------+   |    SEP counter=0
|   |             SLH Marker         |  |    P counter=0
|   +-------------------------------+   |
|   :        Entropy Coded Data      :  |
|   +-------------------------------+   |    M=0, T=0, K=1, L=1, I=10
+====[ PU #3: Slice #2 (1st field) ]====+
|               Slice #2                |    SEP counter=1
|               (part 1/q)              |    P counter=0
:                                       :    M=0, T=0, K=1, L=0, I=10
+---------------------------------------+
|               Slice #2                |    SEP counter=1
|               (part 2/q)              |    P counter=1
:                                       :    M=0, T=0, K=1, L=0, I=10
+---------------------------------------+
:                                       :
+---------------------------------------+
|               Slice #2                |    SEP counter=1
|               (part q/q)              |    P counter=q-1
:                                       :    M=0, T=0, K=1, L=1, I=10
+=======================================+
:                                       :
+==[ PU #N: Slice #(N-1) (1st field) ]==+
|              Slice #(N-1)             |    SEP counter=N-2
|               (part 1/r)              |    P counter=0
:                                       :    M=0, T=0, K=1, L=0, I=10
+---------------------------------------+
:                                       :
+---------------------------------------+
|              Slice #(N-1)             |    SEP counter=N-2
|               (part r/r)              |    P counter=r-1
:               + EOC marker            :    M=1, T=0, K=1, L=1, I=10
+=======================================+
+===[ PU #N+1: JPEG XS Hdr segment 2 ]==+
|            Video support box          |    SEP counter=0x07FF
+- - - - - - - - - - - - - - - - - - -+    P counter=0
|          Color specification box      |
+- - - - - - - - - - - - - - - - - - - -+
|        JPEG XS codestream header 2    |
|   +-------------------------------+   |
|   :   Markers and marker segments  :  |
|   +-------------------------------+   |    M=0, T=0, K=1, L=1, I=11
+===[ PU #N+2: Slice #1 (2nd field) ]===+
|   +-------------------------------+   |    SEP counter=0
|   |             SLH Marker         |  |    P counter=0
|   +-------------------------------+   |
|   :        Entropy Coded Data      :  |
|   +-------------------------------+   |    M=0, T=0, K=1, L=1, I=11
```

```
+===[ PU #N+3: Slice #2 (2nd field) ]===+
|             Slice #2                  | SEP counter=1
|             (part 1/s)                | P counter=0
:                                       : M=0, T=0, K=1, L=0, I=11
+---------------------------------------+
|             Slice #2                  | SEP counter=1
|             (part 2/s)                | P counter=1
:                                       : M=0, T=0, K=1, L=0, I=11
+---------------------------------------+
:                                       :
+---------------------------------------+
|             Slice #2                  | SEP counter=1
|             (part s/s)                | P counter=s-1
:                                       : M=0, T=0, K=1, L=1, I=11
+=======================================+
:                                       :
+==[ PU #2N: Slice #(N-1) (2nd field) ]=+
|             Slice #(N-1)              | SEP counter=N-2
|             (part 1/t)                | P counter=0
:                                       : M=0, T=0, K=1, L=0, I=11
+---------------------------------------+
:                                       :
+---------------------------------------+
|             Slice #(N-1)              | SEP counter=N-2
|             (part t/t)                | P counter=t-1
:             + EOC marker              : M=1, T=0, K=1, L=1, I=11
+=======================================+
```
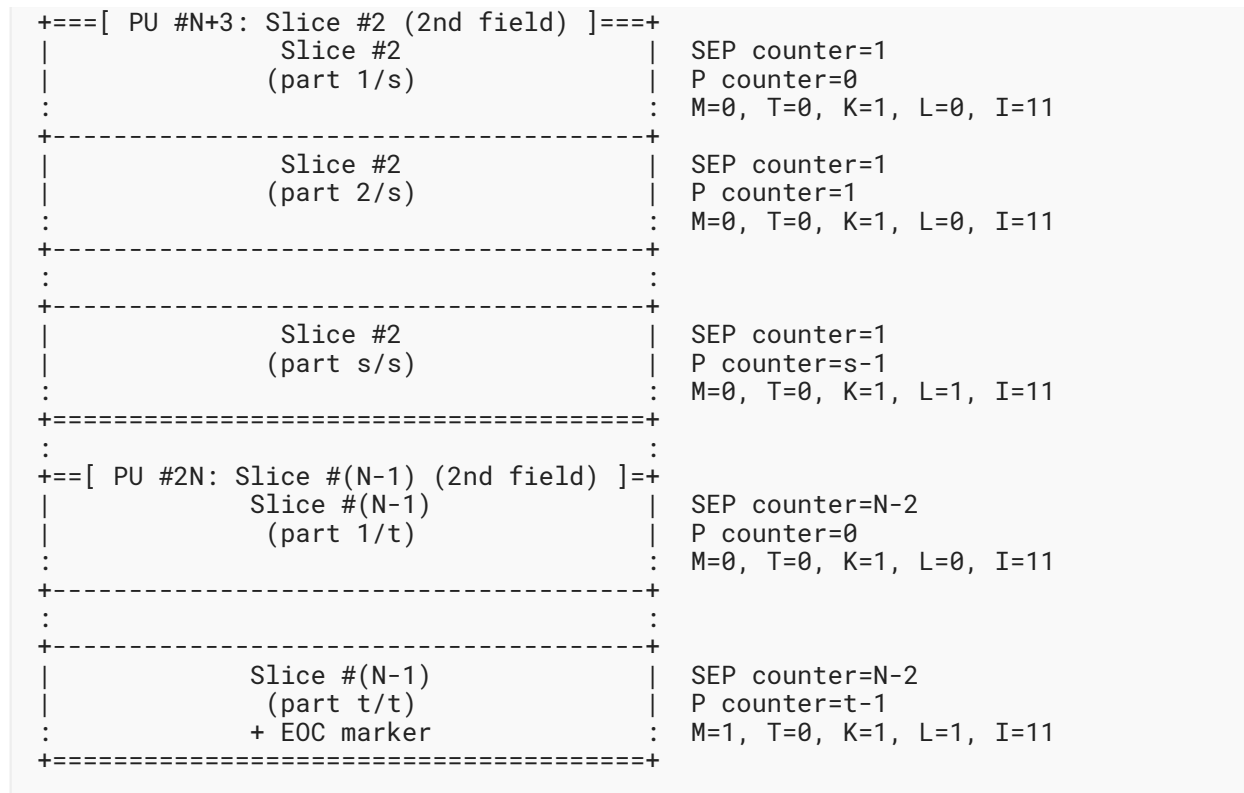
Figure 9: Example of JPEG XS Payload Data (Slice Packetization Mode, Interlaced Video Frame)

5. Traffic Shaping and Delivery Timing

In order to facilitate proper synchronization between senders and receivers, it is **RECOMMENDED** to implement traffic shaping and delivery timing in accordance with the Network Compatibility Model compliance definitions specified in [SMPTE-ST2110-21]. In such a case, the session description **SHALL** signal the compliance with the media type parameter TP. The actual applied traffic shaping and timing delivery mechanism is outside the scope of this memo and does not influence the payload packetization.

6. Congestion Control Considerations

Congestion control for RTP **SHALL** be used in accordance with [RFC3550] and with any applicable RTP profile, e.g., RTP/AVP [RFC3551] or RTP/AVPF [RFC4585].

While JPEG XS is mainly designed to be used in controlled network environments, it can also be employed in best-effort network environments, like the Internet. However, in this case, the users of this payload format **SHALL** monitor packet loss to ensure that the packet loss rate is within acceptable parameters. This can be achieved, for example, by means of RTP Control Protocol (RTCP) Feedback for Congestion Control [RFC8888].

In addition, [RFC8083] is an update to [RFC3550] that defines criteria for when one is required to stop sending RTP Packet Streams and for when applications implementing this standard **SHALL** comply with it.

[RFC8085] provides additional information on the best practices for applying congestion control to UDP streams.

7. Payload Format Parameters

This section specifies the required and optional parameters of the payload format and/or the RTP stream. All parameters are declarative, meaning that the information signaled by the parameters is also present in the payload data, namely in the payload header (see Section 4.3) or in the JPEG XS header segment [ISO21122-1] [ISO21122-3]. When provided, their respective values **SHALL** be consistent with the payload.

7.1. Media Type Registration

This registration is done using the template defined in [RFC6838] and following [RFC4855].

The receiver **SHALL** ignore any unrecognized parameter.

Type name:
   video

Subtype name:
   jxsv

Clock rate:
   90000

Required parameters:
   rate: The RTP timestamp clock rate. Applications using this payload format **SHALL** use a
      value of 90000.

   packetmode: This parameter specifies the configured packetization mode as defined by the
      pacKetization mode (K) bit in the payload header of Section 4.3. This value **SHALL** be equal
      to the K-bit value configured in the RTP stream (i.e., 0 for codestream or 1 for slice).

Optional parameters:
   transmode: This parameter specifies the configured transmission mode as defined by the
      Transmission mode (T) bit in the payload header of Section 4.3. If specified, this value
      SHALL be equal to the T-bit value configured in the RTP stream (i.e., 0 for out-of-order-
      allowed or 1 for sequential-only). If not specified, a value 1 (sequential-only) **SHALL** be
      assumed and the T bit **SHALL** be set to 1.

   profile: The JPEG XS profile [ISO21122-2] in use. Any white space in the profile name **SHALL**
      be omitted. Examples of valid profile names are 'Main444.12' or 'High444.12'.

level: The JPEG XS level [ISO21122-2] in use. Any white space in the level name **SHALL** be omitted. Examples of valid levels are '2k-1' or '4k-2'.

sublevel: The JPEG XS sublevel [ISO21122-2] in use. Any white space in the sublevel name **SHALL** be omitted. Examples of valid sublevels are 'Sublev3bpp' or 'Sublev6bpp'.

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, inclusive.

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

exactframerate: Signals the video 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.

interlace: If this parameter name is present, it indicates that the video is interlaced, or that the video is Progressive segmented Frame (PsF). If this parameter name is not present, the progressive video format **SHALL** be assumed.

segmented: If this parameter name is present, and the interlace parameter name is also present, then the video is a Progressive segmented Frame (PsF). Signaling of this parameter without the interlace parameter is forbidden.

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":

Option 1: spacing=compact

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":

blah blah blah blah blah blahblah blah blahblah blah blahblah blah blahblah blah blahblah blah blahblah blah blah 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":

Option 2: spacing=compact and empty <t>

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":

**Option 3: spacing=compact and
**

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)

Signals utilizing a color sub-sampling other than what is defined here **SHALL** use the following value for the Media Type Parameter "sampling":

UNSPECIFIED   (Sampling signaled by the payload)

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

BT601-5:   ITU-R Recommendation BT.601-5.
BT709-2:   ITU-R Recommendation BT.709-2.
SMPTE240M: SMPTE ST 240M.
BT601:   ITU-R Recommendation BT.601-7.
BT709:   ITU-R Recommendation BT.709-6.
BT2020:   ITU-R Recommendation BT.2020-2.
BT2100:   ITU-R Recommendation BT.2100, Table 2 titled "System colorimetry".
ST2065-1:   SMPTE ST 2065-1 Academy Color Encoding Specification (ACES).
ST2065-3:   SMPTE ST 2065-3 Academy Density Exchange Encoding (ADX).

XYZ: ISO/IEC 11664-1, section titled "1931 Observer".

UNSPECIFIED: Colorimetry is signaled in the payload by the color specification box of
[ISO21122-3], or it must be manually coordinated between sender and
receiver.

Signals utilizing the Recommendation ITU-R BT.2100 colorimetry **SHOULD** also signal the
representational range using the optional parameter RANGE defined below. Signals
utilizing the UNSPECIFIED colorimetry might require manual coordination between the
sender and the receiver.

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

SDR: Standard Dynamic Range video streams that utilize the Optical Electrical
Transfer Function (OETF) of ITU-R Recommendation BT.709 or ITU-R
Recommendation BT.2020. Such streams **SHALL** be assumed to target the
Electro-Optical Transfer Function (EOTF) specified in ITU-R
Recommendation BT.1886.

PQ: High dynamic range video streams that utilize the Perceptual Quantization
system of ITU-R Recommendation BT.2100.

HLG: High dynamic range video streams that utilize the Hybrid Log-Gamma
system of ITU-R Recommendation BT.2100.

UNSPECIFIED: Video streams whose transfer characteristics are signaled by the payload
as specified in [ISO21122-3], or that must be manually coordinated
between sender and receiver.

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, and for all but the UNSPECIFIED colorimetry, NARROW
SHALL be the assumed value. When paired with the UNSPECIFIED colorimetry, FULL
SHALL be the default assumed value.

Encoding considerations:
    This media type is framed in RTP and contains binary data; see Section 4.8 of [RFC6838].

Security considerations:
    See the Security Considerations section of RFC 9134.

Interoperability considerations:
    None

Published specification:
    See the References section of RFC 9134.

Applications that use this media type:
    Any application that transmits video over RTP (like SMPTE ST 2110).

Fragment identifier considerations:
    N/A

Additional information:
    None

Person & email address to contact for further information:
    S. Lugan <rtp@intopix.com> and T. Richter <jpeg-xs-techsupport@iis.fraunhofer.de>.

Intended usage:
    COMMON

Restrictions on usage:
    This media type depends on RTP framing; hence, it is only defined for transfer via RTP
    [RFC3550].

Author:
    See the Authors' Addresses section of RFC 9134.

Change controller:
    IETF Audio/Video Transport Working Group delegated from the IESG.

8. SDP Parameters

A mapping of the parameters into the Session Description Protocol (SDP) [RFC8866] is provided
for applications that use SDP.

8.1. Mapping of Payload Type Parameters to SDP

The media type video/jxsv string is mapped to fields in the Session Description Protocol (SDP)
[RFC8866] as follows:

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

   The media subtype ("jxsv") goes in SDP "a=rtpmap" as the encoding name, followed by a slash
   ("/") and the required parameter "rate" corresponding to the RTP timestamp clock rate (which
   for the payload format defined in this document **SHALL** be 90000).

   The required parameter "packetmode" and any of the additional optional parameters, as
   described in Section 7.1, go in the SDP media format description, being the "a=fmtp" attribute
   (Format Parameters), by copying them directly from the media type string as a semicolon-
   separated list of parameter=value pairs.

All parameters of the media format **SHALL** correspond to the parameters of the payload. In case
of discrepancies between payload parameter values and SDP fields, the values from the payload
data **SHALL** prevail.

The receiver **SHALL** ignore any parameter that is not defined in Section 7.1.

An example SDP mapping for JPEG XS video is as follows:

```
m=video 30000 RTP/AVP 112
a=rtpmap:112 jxsv/90000
a=fmtp:112 packetmode=0;sampling=YCbCr-4:2:2;
           width=1920;height=1080;depth=10;
           colorimetry=BT709;TCS=SDR;RANGE=FULL;TP=2110TPNL
```

In this example, a JPEG XS RTP stream is to be sent to UDP destination port 30000, with an RTP dynamic payload type of 112 and a media clock rate of 90000 Hz. Note that the "a=fmtp:" line has been wrapped to fit this page and will be a single long line in the SDP file. This example includes the TP parameter (as specified in Section 5).

8.2. Usage with SDP Offer/Answer Model

When JPEG XS is offered over RTP using SDP in an offer/answer model [RFC3264] for negotiation for unicast usage, the following limitations and rules apply:

The "a=fmtp" attribute **SHALL** be present specifying the required parameter "packetmode" and **MAY** specify any of the optional parameters, as described in Section 7.1.

All parameters in the "a=fmtp" attribute indicate sending capabilities (i.e., properties of the payload).

An answerer of the SDP is required to support all parameters and values of the parameters provided by the offerer; otherwise, the answerer **SHALL** reject the session. It falls on the offerer to use values that are expected to be supported by the answerer. If the answerer accepts the session, it **SHALL** reply with the exact same parameters values in the "a=fmtp" attribute as it was offered.

The same RTP payload type number used in the offer **SHOULD** be used in the answer, as specified in [RFC3264].

9. IANA Considerations

IANA has registered the media type registration "video/jxsv" as specified in Section 7.1. The media type has also been added to the IANA registry for "RTP Payload Format Media Types" <https://www.iana.org/assignments/rtp-parameters>.

10. Security Considerations

RTP packets using the payload format defined in this memo are subject to the security considerations discussed in [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.

Implementations of this RTP payload format need to take appropriate security considerations into account. It is important for the decoder to be robust against malicious or malformed payloads and ensure that they do not cause the decoder to overrun its allocated memory or otherwise misbehave. An overrun in allocated memory could lead to arbitrary code execution by an attacker. The same applies to the encoder, even though problems in encoders are typically rarer.

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; thus, they are unlikely to pose a denial-of-service threat due to the receipt of pathological datagrams.

This payload format and the JPEG XS encoding do not contain code that is executable.

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 **SHALL** 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.

11. References

11.1. Normative References

[ISO21122-1]

International Organization for Standardization (ISO) - International Electrotechnical Commission (IEC), "Information technology - JPEG XS low-latency lightweight image coding system - Part 1: Core coding system", ISO/IEC IS 21122-1.

[ISO21122-2] International Organization for Standardization (ISO) - International Electrotechnical Commission (IEC), "Information technology - JPEG XS low-latency lightweight image coding system - Part 2: Profiles and buffer models", ISO/IEC IS 21122-2.

[ISO21122-3] International Organization for Standardization (ISO) - International Electrotechnical Commission (IEC), "Information technology - JPEG XS low-latency lightweight image coding system - Part 3: Transport and container formats", ISO/IEC IS 21122-3.

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11.2. Informative References

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Acknowledgments

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