RTP Payload Format for VC-2 HQ Profile Video
draft-ietf-payload-rtp-vc2hq-08

Abstract

This memo describes an RTP Payload format for the High Quality (HQ) profile of Society of Motion Picture and Television Engineers Standard ST 2042-1 known as VC-2. This document describes the transport of HQ Profile VC-2 in RTP packets and has applications for low-complexity, high-bandwidth streaming of both lossless and lossy compressed video.

The HQ profile of VC-2 is intended for low latency video compression (with latency potentially on the order of lines of video) at high data rates (with compression ratios on the order of 2:1 or 4:1).

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1. Introduction

This memo specifies an RTP payload format for the video coding standard Society of Motion Picture and Television Engineers ST 2042-1:2017 [VC2] also known as VC-2

The VC-2 codec is a wavelet-based codec intended primarily for professional video use with high bit-rates and only low levels of compression. It has been designed to be low-complexity, and potentially have a very low latency through both encoder and decoder: with some choices of parameters this latency may be as low as a few lines of video.

The low level of complexity in the VC-2 codec allows for this low latency operation but also means that it lacks many of the more powerful compression techniques used in other codecs. As such it is
suitable for low compression ratios that produce coded data rates
around half to a quarter of that of uncompressed video, at a similar
visual quality.

The primary use for VC-2 is likely to be in professional video
production environments.

2. Conventions, Definitions and Acronyms

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.

3. Media Format Description

The VC-2 specification defines a VC-2 stream as being composed of one
or more Sequences. Each Sequence is independently decodable,
containing all of the needed parameters and metadata for configuring
the decoder.

Each Sequence consists of a series of 13-octet Parse Info headers and
variable length Data Units. The Sequence begins and ends with a
Parse Info header and each Data Unit is preceded by a Parse Info
Header. Data Units come in a variety of types, and the type of a
Data Unit is signaled in the proceeding Parse Info Header. The most
important types are the Sequence Header, which contains configuration
data needed by the decoder, and several types of Coded Picture, which
contain the coded data for the pictures themselves. Each picture
represents a frame in a progressively scanned video Sequence or a
field in an interlaced video Sequence.

The first Data Unit in a Sequence as produced by an encoder is always
a Sequence Header, but Sequences can be joined in the middle, so this
should not be assumed.

The High Quality (HQ) profile for VC-2 restricts the types of Parse
Info Headers which may appear in the Sequence (and hence also the
types of Data Unit) to only:

- Sequence Headers (which are always followed by a Data Unit),
- High Quality Pictures (which are always followed by a Data Unit),
- High Quality Fragments (which are always followed by a Data Unit),
- Auxiliary Data (which are always followed by a Data Unit),
o Padding Data (which are always followed by a Data Unit), and
o End of Sequence (which are never followed by a Data Unit).

At time of writing there is currently no definition for the use of Auxiliary Data in VC-2, and Padding Data is required to be ignored by all receivers.

Each High Quality Picture data unit contains a set of parameters for the picture followed by a series of coded Slices, each representing a rectangular region of the transformed picture. Slices within a picture may vary in coded length, but all represent the same shape and size of rectangle in the picture.

Each High Quality Fragment data unit contains either a set of parameters for a picture or it contains a series of coded Slices. Fragments carry the same data as pictures, but broken up into smaller units to facilitate transmission via packet-based protocols such as RTP.

This payload format only makes use of fragments, not pictures.

4. Payload format

In this specification each RTP packet is used to carry data corresponding to a single Parse Info Header and its following data unit (if it has one). A single packet MAY NOT contain data from more than one Parse Info header or data unit. A single Parse Info Header and Data Unit pair MUST NOT be split across more than one packet, the sole exception to this rule is that an Auxiliary Data Unit MAY be split between multiple packets, using the B and E flags to indicate start and end.

This specification only covers the transport of Sequence Headers (together with their accompanying data unit), High Quality Fragments (together with their accompanying data unit), Auxiliary Data (together with their accompanying data unit), and (optionally) End Sequence Headers and Padding Data (for which no data unit it carried).

High Quality Pictures can be transported by converting them into an equivalent set of High Quality Fragments. The size of fragments should be chosen so as to fit within the MTU of the network in use.

For this reason this document defines six types of RTP packets in a VC-2 media stream:
o A VC-2 Sequence Header (Figure 1) (see Section 11 of the VC-2 specification [VC2]),

o A Picture Fragment containing the VC-2 Transform Parameters for a Picture (Figure 2) (see Section 14 of the VC-2 specification [VC2]),

o A Picture Fragment containing VC-2 Coded Slices (Figure 3) for a picture (see Section 14 of the VC-2 specification [VC2]),

o The end of a VC-2 Sequence (Figure 4) (see Section 10.5.2 of the VC-2 specification [VC2]),

o The contents of an auxiliary data unit (Figure 5) (see Section 10.4.4 of the VC-2 specification [VC2]), and

o An indication of the presence of a padding data unit (Figure 6) (see Section 10.4.5 of the VC-2 specification [VC2]).

These six packet-types can be distinguished by the fact that they use different codes in the "PC (Parse Code)" field, except for the two types of picture fragment which both use the same value in PC but have different values in the "No. of slices" field.

The choices of PC codes is explained in more detail in a following informative section (Section 4.3).
Figure 1: RTP Payload Format For Sequence Header
Figure 2: RTP Payload Format For Transform Parameters Fragment
Figure 3: RTP Payload Format For Fragment Containing Slices
Figure 4: RTP Payload Format For End of Sequence

Figure 5: RTP Payload Format For Auxiliary Data
All fields in the headers longer than a single bit are interpreted as unsigned integers in network byte order.

### 4.1. RTP Header Usage

The fields of the RTP header have the following additional notes on their usage:

**Marker Bit (M):** 1 bit  The marker bit MUST be set on any packet which contains the final slice in a coded picture and MUST NOT be set otherwise.

**Payload Type (PT):** 7 bits  A dynamically allocated payload type field that designates the payload as VC-2 coded video.

**Sequence Number:** 16 bits  Because the data rate of VC-2 coded streams can often be very high, in the order of gigabits rather than megabits per second, the standard 16-bit RTP sequence number can cycle very quickly. For this reason the sequence number is extended to 32-bits, and this field MUST hold the low-order 16-bits of this value.

**Timestamp:** 32 bits  If the packet contains transform parameters or coded slice data for a coded picture then the timestamp corresponds to the sampling instant of the coded picture. A 90kHz clock SHOULD be used. A single RTP packet MUST NOT
contain coded data for more than one coded picture, so there is no ambiguity here.

A Sequence Header packet SHOULD have the same timestamp as the next picture which will follow it in the stream. An End of Sequence packet SHOULD have the same timestamp as the previous picture which appeared in the stream.

The remaining RTP header fields are used as specified in RTP [RFC3550].

4.2. Payload Header

The fields of the extended headers are defined as follows:

Extended Sequence Number: 16 bits  MUST Contain the high-order 16-bits of the 32-bit packet sequence number. This is needed since the high data rates of VC2 Sequences mean that it is highly likely that the 16-bit sequence number will roll-over too frequently to be of use for stream synchronisation.

B: 1 bit  MUST be set to 1 if the packet contains the first byte of an Auxiliary Data Unit, and otherwise MUST be 0. If the recommendations of the Stream Constrants Section of this specification (Section 4.4) are followed then every Auxiliary Data Unit will be small enough to fit in a single packet and so this bit (where present) will always be 1.

E: 1 bit  MUST be set to 1 if the packet contains the final byte of an Auxiliary Data Unit, and otherwise MUST be 0. If the recommendations of the Stream Constrants Section of this specification (Section 4.4) are followed then every Auxiliary Data Unit will be small enough to fit in a single packet and so this bit (where present) will always be 1.

I: 1 bit  MUST be set to 1 if the packet contains coded picture parameters or slice data from a field in an interlaced frame, and to 0 if the packet contains data from any part of a progressive frame.

F: 1 bit  MUST be set to 1 if the packet contains coded picture parameters or slice data from the second field of an interlaced frame, and to 0 if the packet contains data from the first field of an interlaced frame or any part of a progressive frame.

Parse Code (PC): 8 bits  Contains a Parse Code which MUST be the value indicated for the type of data in the packet.
Data Length: 32 bits  For an auxiliary data unit this contains the number of bytes of data contained in the payload section of this packet. If the recommendations of the Stream Constraints Section of this specification (Section 4.4) are followed then no Auxiliary Data Unit will be large enough to cause a packet to exceed the MTU of the network.

Picture Number: 32 bits MUST contain the Picture Number for the coded picture this packet contains data for, as described in Section 12.1 of the VC-2 specification [VC2].

The sender MUST send at least one transform parameters packet for each coded picture and MAY include more than one as long as they contain identical data. The sender MUST NOT send a packet from a new picture until all the coded data from the current picture has been sent.

If the receiver does not receive a transform parameters packet for a picture then it MAY assume that the parameters are unchanged since the last picture, or MAY discard the picture. Choosing between these two options is left up to the implementation as it will be dependent on intended use, the former may result in malformed pictures, the latter will result in dropped frames. Such an occurance is an indication either of packet loss, joining a stream mid-picture, or of a non-compliant transmitter.

Slice Prefix Bytes: 16 bits MUST contain the Slice Prefix Bytes value for the coded picture this packet contains data for, as described in Section 12.3.4 of the VC-2 specification [VC2].

In the VC-2 specification this value is not restricted to 16 bits, but the constraints on streams specified in this document (Section 4.4) do require this.

Slice Size Scaler: 16 bits MUST contain the Slice Size Scaler value for the coded picture this packet contains data for, as described in Section 12.3.4 of the VC-2 specification [VC2].

In the VC-2 specification this value is not restricted to 16 bits, but the constraints on streams specified in this document (Section 4.4) do require this.

Fragment Length: 16 bits MUST contain the number of bytes of data contained in the coded payload section of this packet.

No. of Slices: 16 bits MUST contain the number of coded slices contained in this packet, which MUST be 0 for a packet.
containing transform parameters. In a packet containing coded slices this number MUST be the number of whole slices contained in the packet, and the packet MUST NOT contain any partial slices.

Slice Offset X: 16 bits MUST contain the X coordinate of the first slice in this packet, in slices, starting from the top left corner of the picture.

Slice Offset Y: 16 bits MUST contain the Y coordinate of the first slice in this packet, in slices, starting from the top left corner of the picture.

4.3. The Choice of Parse Codes (Informative)

The "PC" field in the packets is used to carry the Parse Code which identifies the type of content in the packet. This code matches the value of the Parse Code used to identify each data unit in a VC-2 stream, as defined in the VC-2 specification, and each packet contains the entire data unit.

The table below lists all of the parse codes currently allowed in a VC-2 Sequence. The final column indicates whether the code in question can be present in a stream transmitted using this specification.

<table>
<thead>
<tr>
<th>PC (hex)</th>
<th>Binary</th>
<th>Description</th>
<th>Valid</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x00</td>
<td>0000 0000</td>
<td>Sequence Header</td>
<td>Yes</td>
</tr>
<tr>
<td>0x10</td>
<td>0001 0000</td>
<td>End of Sequence</td>
<td>Yes</td>
</tr>
<tr>
<td>0x20</td>
<td>0010 0000</td>
<td>Auxiliary Data</td>
<td>Yes</td>
</tr>
<tr>
<td>0x30</td>
<td>0011 0000</td>
<td>Padding Data</td>
<td>Yes</td>
</tr>
<tr>
<td>0xC8</td>
<td>1100 1000</td>
<td>LD Picture</td>
<td>No</td>
</tr>
<tr>
<td>0xE8</td>
<td>1110 1000</td>
<td>HQ Picture</td>
<td>No</td>
</tr>
<tr>
<td>0xEC</td>
<td>1110 1100</td>
<td>HQ Picture Fragment</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Figure 7: Parse Codes and Meanings

4.4. Stream Constraints

There are some constraints which a Sequence needs to conform to in order to be transmissible with this specification.

- The sequence MUST NOT contain Parse Info Headers with a Parse Code which is not 0x00 (Sequence Header), 0x10 (End of Sequence), 0x20
(Auxiliary Data), 0x30 (Padding Data) and 0xEC (High Quality Picture Fragment). Some other streams MAY be convertible to meet this restriction (see below).

- Every High Quality Picture Fragment MUST be no longer than 65535 bytes. This can usually be ensured by splitting large fragments into several smaller fragments, except in the case where an individual slice is too large, in which case see the notes below on conversion.

- Informative note: this requirement ensures that every High Quality Picture Fragment will always contain no more than 65535 slices.

- Every High Quality Picture Fragment SHOULD be small enough that the RTP packet carrying it will fit within the network MTU size. This can usually be ensured by splitting large fragments into several smaller fragments, except in the case where an individual slice is too large, in which case see the notes below on conversion.

- Every High Quality Picture Fragment MUST be encoded using values for Slice Prefix Bytes and Slice Size Scaler no greater than 65535.

If a Sequence intended for transmission does not conform to these restrictions then it MAY be possible to simply convert it into a form that does by splitting pictures and/or large fragments into suitably sized fragments. This can be done provided that the following (weaker) constraints are met:

- The sequence does not contain Parse Info Headers with a Parse Code which is not 0x00 (Sequence Header), 0x10 (End of Sequence), 0x20 (Auxiliary Data), 0x30 (Padding Data), 0xE8 (High Quality Picture), and 0xEC (High Quality Picture Fragment).

- Every High Quality Picture or High Quality Picture Fragment contains no slices which are individually longer than 65535 bytes. Note: When this is the case the values of Slice Prefix Bytes and Slice Size Scaler will necessarily also be smaller than 65535.

- Every High Quality Picture or High Quality Picture Fragment contains no slices which are individually so large that an RTP packet carrying a Fragment containing that single slice will fit within the network MTU size.

Sending a Stream which does not meet the above requirements via this mechanism is not possible unless the stream is re-encoded by a VC-2 Encoder so as to meet them.
In addition every Auxiliary Data Unit SHOULD be small enough that a single RTP packet carrying it will fit within the network MTU size. Since there is currently no specification for the format of Auxiliary Data in VC-2 the mechanism for ensuring this with an encoder implementation that includes Auxiliary Data Units will be dependent upon the implementation's use for them.

When encoding VC-2 video intended to be transported via RTP a VC-2 profile and level which ensures these requirements are met SHOULD be used.

4.5. Payload Data

For the Sequence Header packet type (PC = 0x00) the payload data MUST be the coded Sequence Header exactly as it appears in the VC-2 Sequence.

For the Transform Parameters packet type (PC = 0xEC and No. Slices = 0) the payload data MUST be the variable length coded transform parameters. This MUST NOT include the fragment header (since all data in the picture header is already included in the packet header).

For the Auxiliary Data packet type (PC = 0x20) the payload data MUST be a portion of the auxiliary data bytes contained in the Auxiliary data unit being being transmitted. The B flag MUST be set on the packet which contains the first byte, the E flag MUST be set on the packet which contains the last byte, the bytes MUST be included in order, and the packets MUST have contiguous sequence numbers.

For the Picture Fragment packet type (PC = 0xEC and No. Slices > 0) the payload data MUST be a specified number of coded slices in the same order that they appear in the VC-2 stream. Which slices appear in the packet is identified using the Slice Offset X and Slice Offset Y fields in the payload header.

For the End of Sequence packet type (PC = 0x10) there is no payload data.

4.5.1. Reassembling the Data
To reassemble the data in the RTP packets into a valid VC-2 Sequence the receiver SHOULD:

- Take the data from each packet with a Parse Code of 0x00 and prepend a valid VC-2 Parse Info Header (Figure 8) with the same parse code to it. The resulting Sequence Header Parse Info Header and data unit MUST be included in the output stream before any coded pictures which followed it in the RTP stream unless an identical Sequence Header has already been included, and MAY be repeated (with appropriate modifications to the next and previous header offsets) at any point that results in a valid VC-2 stream.

- Take the data from each packet with a Parse Code of 0xEC and No. of Slices set to 0 (which together indicates that this packet contains the transform parameters for a coded picture) and prepend a valid VC-2 Parse Info Header (Figure 8) followed by the picture number, fragment data length, and slice count (0) to it with the same parse code.

- Take the data from each packet with a Parse Code of 0xEC and No. of Slices not set to 0 (which together indicates that this packet contains coded slices) and prepend a valid VC-2 Parse Info Header (Figure 8) followed by the picture number, fragment data length, slice count, x offset and y offset taken from the packet header to it with the same parse code.

- A receiver MAY combine all fragment data units (with parse code 0xEC) and the same picture number into a single picture data unit with parse code 0xE8. If the stream is required to comply with major versions 1 or 2 of the VC-2 Spec then this MUST be done.

- Take the data from each packet with a Parse Code of 0x20 and the B bit set and prepend a valid VC-2 Parse Info Header (Figure 8) with the parse code 0x20 and then take each subsequent packet with
parse code 0x20 without the B bit set and append their payload to the growing data unit. When all packets for a particular data unit have been received it SHOULD be included in the output stream. The final packet for a data unit will have the E bit set.

- Once a data unit has been assembled, whether a Sequence Header, Coded Picture Fragment, Coded Picture, or Auxiliary Data Unit, the next parse offset and previous parse offset values in its Parse Info Header SHOULD be filled with the offset between the start of the header and the start of the next or previous.

- An End of Sequence Parse Info Header MAY be inserted when a packet with parse code set to 0x10 is encountered, or at any other time that is allowed in a valid VC-2 stream. After an End of Sequence Parse Info Header is included in the output stream either the stream must end or it MUST be followed by a Sequence Header indicating the start of a new Sequence. The next parse offset of the End of Sequence header MUST be set to 0, and the previous parse offset SHOULD be filled with the offset from the start of the previous parse info header in the stream.

- A Padding Data Parse Info Header MAY be inserted when a packet with parse code set to 0x30 and the B bit set is encountered, or at any other time that is allowed in a valid VC-2 stream. The length of the accompanying data unit MAY have any value, and its contents MUST be set to a series of zero bytes. The next parse offset and previous parse offset values in its Parse Info Header SHOULD be filled with the offset between the start of the header and the start of the next or previous.

5. FEC Considerations

VC-2 provides no underlying protection against data loss, so it may be useful to employ forward error correction to the stream. A mechanism for doing this to a generic RTP stream is specified in RFC5109 [RFC5109]. If making use of this mechanism to provide multi-level protection then the packets SHOULD be assigned to layers based upon their packet type, with the packet types in order of importance being:

1. Sequence Headers
2. Fragments containing Transform Parameters
3. Fragments containing coded slices
4. Auxiliary Data and end of Sequence
5. Padding

It is RECOMMENDED that if multi-level protection is to be used then
one layer will protect all Sequence Header packets, and a second will
protect Sequence Headers and all Fragments. If desired a third layer
MAY protect Auxiliary Data and End of Sequence packets. Padding data
SHOULD NOT be protected by FEC.

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

In particular it should be noted that the expected data rate for RTP
sessions which use this profile is likely to be in the range of
gigabits per second. If used on a closed network which has been
correctly provisioned for the expected data rates this might not pose
a problem, but there is always the risk of data getting out onto the
open internet.

7. Payload Format Parameters

This RTP payload format is identified using the video/vc2 media type
which is registered in accordance with RFC 4855 [RFC4855] and using
the template of RFC 6838 [RFC6838].

7.1. Media Type Definition

Type name:

  video

Subtype name:

  vc2

Required parameters:

  rate: The RTP timestamp clock rate. Applications using this
        payload format SHOULD use a value of 90000.
profile: The VC-2 profile in use, the only currently allowed value is "HQ".

Optional parameters:

version: the VC-2 specification version in use. The only currently allowed value is "3" since all Sequences transported using this mechanism will contain HQ Picture Fragment data units, which the VC-2 specification [VC2] defines as requiring version 3.

level: The VC-2 level in use. Any integer may be used.

Encoding considerations:

This media type is framed and binary, see section 4.8 in RFC6838 [RFC6838].

Security considerations:

Please see security consideration in RFCXXXX

Interoperability considerations: N/A

Published specification:

RFC XXXX

Applications that use this media type:

Video Communication.

Fragment Identifier Considerations: N/A

Additional information: N/A

Person & email address to contact for further information:

james.barrett@bbc.co.uk

Intended usage:

COMMON

Restrictions on usage:

This media type depends on RTP framing, and hence is only defined for transfer via RTP [RFC3550]. Transport within other framing protocols is not defined at this time.
7.2. Mapping to SDP

The mapping of the above defined payload format media type and its parameters SHALL be done according to Section 3 of RFC 4855 [RFC4855].

- The type name ("video") goes in SDP "m=" as the media name.
- The subtype name ("vc2") goes in SDP "a=rtpmap" as the encoding name, followed by a slash ("/") and the rate parameter.
- The required parameter profile and the optional parameters version and level, when present, are included in the "a=fmtp" attribute line of SDP as a semicolon-separated list of parameter=value pairs.

Version and level SHALL be specified in decimal when present.

For example, a sample SDP mapping for VC-2 could be as follows:

```sdp
m=video 30000 RTP/AVP 112
a=rtpmap:112 vc2/90000
a=fmtp:112 profile=HQ;version=3;level=0
```

In this example, a dynamic payload type 112 is used for vc-2 data. The 90 kHz RTP timestamp rate is specified in the "a=rtpmap" line after the subtype. In the "a=fmtp:" line, profile HQ, version 3, and level 0 (unknown or non-standard level) are specified.

7.3. Offer/Answer Considerations

All parameters are declarative.

8. IANA Considerations

This memo requests that IANA registers video/vc2 as specified in Section 7.1. The media type is also requested to be added to the
IANA registry for "RTP Payload Format MIME types" (http://www.iana.org/assignments/rtp-parameters).

9. 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/SAVF [RFC3711] or RTP/SAVPF [RFC5124]. However, as "Securing the RTP Protocol 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 with 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. The rest of this security consideration section discusses the security impacting properties of the payload format itself.

This RTP payload format and its media decoder do not exhibit any significant non-uniformity in the receiver-side computational complexity for packet processing, and thus are unlikely to pose a denial-of-service threat due to the receipt of pathological data. Nor does the RTP payload format contain any active content.

To avoid buffer overruns when processing these packets the receiver MUST consider both the reported fragment length and the actual received size of a packet containing slice data.

In some cases the transmitter may need to decode variable length coded headers in order to extract some data from the VC-2 bitstream before assembling packets. This process is potentially subject to buffer overruns if not implemented carefully.

10. RFC Editor Considerations

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

RFCXXXX is to be replaced by the RFC number this specification receives when published.
11. References

11.1. Normative References


11.2. Informative References


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