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Digital Video Subcommittee

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ANSI/SCTE 281-2 2023

VVC Video Constraints for Cable Television
Part 2- Transport

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1. Introduction

1.1. Executive Summary

This document describes the constraints of carriage of a single VVC coded video elementary stream over an MPEG-2 transport stream.

1.2. Scope

This document defines the transport constraints on ITU-T Rec. H.266 | ISO/IEC 23090-3 [MPEG-VVC] video compression (hereafter called "VVC") for cable television. In particular, this document describes the transmission of a single VVC coded video elementary stream constrained per [SCTE 281-1] over MPEG-2 transport (ISO/IEC 13818-1 [MPEG-2 TS]) for linear delivery systems supporting ad insertion services [SCTE 35]. Beyond linear delivery with DPI, signaling is provided for segmentation of contents for xDVR applications.

NOTE 1: The carriage of video in the MPEG-2 service multiplex is described in [SCTE 54] .

1.3. Background (Informative)

This document specifies the transport of an VVC coded video elementary stream constrained per [SCTE 281-1] intended for cable video services. There are other applications such as time-shifting (e.g., PVR/DVR service), Video-on-Demand services, and splicing (e.g., Ad-insertion) that could employ the specifications in this document. However, constraints specific to those applications are outside of the scope of this document at this time.

2. Normative references

The following documents contain provisions which, through reference in this text, constitute provisions of this document. The editions indicated were valid at the time of subcommittee approval. All documents are subject to revision and, while parties to any agreement based on this document are encouraged to investigate the possibility of applying the most recent editions of the documents listed below, they are reminded that newer editions of those documents might not be compatible with the referenced version.

2.1. SCTE References

[SCTE 35]	ANSI/SCTE 35 2022, Digital Program Insertion Cueing Message for Cable.
[SCTE 54]	ANSI/SCTE 54 2020, Digital Video Service Multiplex and Transport System Standard for Cable Television.
[SCTE 128-1]	ANSI/SCTE 128-1 2020, AVC Video Constraints for Cable Television Part 1 – Coding.
[SCTE 128-2]	ANSI/SCTE 128-2 2018, AVC Video Constraints for Cable Television Part 2 – Transport.
[SCTE 281-1]	SCTE 281-1 2023, VVC Video Constraints for Cable Television Part 1 – Coding.

2.2. Standards from other Organizations

[ATSC A/65] ATSC A/65:2013 Program and System Information Protocol for Terrestrial Broadcast and Cable; Section 6.9.2.

[CICP 23091-2] ITU-T H.273 | ISO/IEC 23091-2:2022, Information technology-Coding independent code points – Part 2: Video

[CICP 23091-4] ITU-T H. Supplemental 19| ISO/IEC TR 23091-4 : 2021, Information technology-Coding independent code points – Part 4: Usage of video signal type code points.

[DVB-TS] ETSI TS 101 154 V2.7.1 Digital Video Broadcasting (DVB): Specification for the use of Video and Audio Coding in Broadcasting Applications based on the MPEG-2 Transport Stream, 2022.

[MPEG-2 TS] ISO/IEC 13818-1:2022, "Information Technology – Generic coding of moving pictures and associated audio – Part 1: Systems

[MPEG-2 TS/AMD1] ISO/IEC 13818-1:AMD1 Carriage of LCEVC and other improvements.

[MPEG-VSEI] ITU-T Rec. H.274 | ISO/IEC 23002-7:2022 – Versatile supplemental enhancement information messages for coded video bitstreams

[MPEG-VVC] ITU-T Rec. H.266 | ISO/IEC 23090-3:2022 – MPEG-I Part 3: Versatile Video Coding

3. Informative References

The following documents might provide valuable information to the reader but are not required when complying with this document.

3.1. SCTE References

[SCTE 07] ANSI/SCTE 07 2018, Digital Transmission Standard for Cable Television.

[SCTE 21] ANSI/SCTE 21 2017 (R2022), Standard for Carriage of NTSC VBI Data in Cable Digital Transport Streams.

[SCTE 43] ANSI/SCTE 43 2015 (R2021), Digital Video Systems Characteristics Standard for Cable Television.

[SCTE 67] ANCI/SCTE 67 2017, Recommended Practice for SCTE 35 Digital Program Insertion Cueing Message for Cable.

[SCTE 172] ANSI/SCTE 172 2017, Constraints on AVC Video Coding for Digital Program Insertion.

3.2. Standards from other Organizations

[ATSC A/53] ATSC A/53, Part 3, "Service Multiplex and Transport Subsystem Characteristics".

[CTA-CEB16] CTA-CEB16: Active Format Description (AFD) & Bar Data Recommended Practice.

[CTA 861-H] CTA-861-H “A DTV Profile for Uncompressed High Speed Digital Interfaces”.

[ITU-R BT.601-6] ITU-R BT.601-6 Encoding parameters of digital television for studios.

[ITU-R BT.709-6] ITU-R BT.709-6, Basic Parameter Values for the HDTV Standard for the Studio and for International Programme exchange.

[ITU-R BT.2022-2] ITU-R BT.2020-2, Parameter values for ultra-high definition television systems for production and international Programme exchange.

[ITU-R BT.2100-2] ITU-R BT.2100-2, Image parameters values for high dynamic range television for use in production and internal programme exchange.

[ITU-T J.83] ITU-T J.83, Digital Video Transmission Standard for Cable Television.

[MPEG-2 Audio] ISO/IEC 13818-2, Information Technology – Generic coding of moving pictures and associated audio -Part 2: Video.

[SMPTE ST 125] SMPTE ST 125, Standard for television, Component Video Signal 4:2:2, Bit Parallel Digital Interface.

[SMPTE ST 170] SMPTE ST 170, Television – Composite Analog Video Signal – NTSC for Studio Applications.

[SMPTE ST 267] SMPTE ST 267, Standard for television, Bit Parallel Digital Interface- Component Video Signal 4:2:2 16x9 Aspect Ratio.

[SMPTE ST 274] SMPTE ST 274 Standard for television, 1920 x 1080 Scanning and Interface.

[SMPTE ST 293] SMPTE ST 293, Standard for television, 720x483 Active Line at 59.95 Hz Progressive Scan Production, Digital Representation.

[SMPTE ST 296] SMPTE ST 296, Standard for television, 1280 x 720 Scanning, Analog and Digital Representation, and Analog Interface.

4. Compliance notation

shall	This word or the adjective "***required***" means that the item is an absolute requirement of this document.
shall not	This phrase means that the item is an absolute prohibition of this document.
forbidden	This word means the value specified ***shall*** never be used.
should	This word or the adjective "*recommended*" means that there *may* exist valid reasons in particular circumstances to ignore this item, but the full implications *should* be understood and the case carefully weighed before choosing a different course.
should not	This phrase means that there *may* exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications *should* be understood and the case carefully weighed before implementing any behavior described with this label.
may	This word or the adjective "*optional*" indicate a course of action permissible within the limits of the document.
deprecated	Use is permissible for legacy purposes only. Deprecated features *may* be removed from future versions of this document. Implementations *should* avoid use of deprecated features.

This document contains symbolic references to syntactic elements used in the video and transport coding subsystems. These references *may* contain the underscore character (e.g., constraint_set0_flag) and *may* consist of character strings that are not English words (e.g., pic_width_in_mbs_minus1).

5. Abbreviations and Definitions

5.1. Abbreviations

ATSC	Advanced Television Systems Committee
AU	Access Unit
AVC	Advanced Video Coding
CPB	Coded Picture Buffer
DPI	Digital Program Insertion
DTS	Decoding Time Stamp
DTV	Digital Television
DVB	Digital Video Broadcasting
DVS	Digital Video Subcommittee
ESPI	Elementary_Stream_Priority_Indicator
ETSI	European Telecommunications Standards Institute
HDR	High Dynamic Range
HDTV	High Definition Television
HRD	hypothetical reference decoder
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
MPEG	Moving Picture Experts Group
NAL	Network Abstraction Layer
NCG	Narrow Color Gamut
PCR	Program Clock Reference
PES	Packetized Elementary Stream

PID	Packet Identifier
PMT	Program Map Table
PPS	Picture Parameter Set
PTS	Presentation Time Stamp
PVR	Personal Video Recorder
QAM	Quadrature Amplitude Modulation
RAI	Random_Access_Indicator
RF	Radio Frequency
SDR	Standard Dynamic Range
SGOP	SCTE Group Of Pictures (see definitions in 5.2)
SVRAP	SCTE VVC Random Access Point (see definitions in 5.2)
T-STD	Transport Stream System Target Decoder
TS	Transport Stream
VBI	Vertical Blanking Interval
VVC	Versatile Video Coding
WCG	Wide Color Gamut
xDVR	Generic Digital Video Recorder (see definitions in 5.2)

5.2. Definitions

VVC	ITU-T Rec. H. 266 | ISO/IEC 23090-3, Versatile Video Coding [MPEG-VVC]
VVC Receiver	The term "VVC Receiver" in this standard for transport means a receiver having at least the additional attributes (in no particular order) listed below: 1. Able to support Video coding related attributes for an VVC Receiver definition found in DVS 1552-1 (Coding). 2. Able to parse and decode all the normative elements from ISO/IEC 13818-1 [MPEG-2 TS] that are normatively included and/or constrained by this standard; 3. Not adversely affected by the presence or absence of optional elements from ISO/IEC 13818-1 [MPEG-2 TS] (such as data in adaptation fields) that are specified with constraints in this standard;
Program	An ISO-IEC 13818-1 MPEG-2 Program [MPEG-2 TS]
SGOP	A SCTE Group Of Pictures (SGOP) is the group of pictures spanning two consecutive SVRAPs including the prior SVRAP AU but not including the subsequent SVRAP AU.
SVRAP	An SCTE VVC Random Access Point (SVRAP) is an VVC access unit as defined in [SCTE 281-1] that allows for the decoding process to start at a specific point in a bitstream.
SVRAP Picture	As defined in [SCTE 281-1], this is an Intra picture that is part of an SVRAP AU
xDVR	Generic DVR implementation. This could be ‘Cloud DVR (cDVR)’, ‘Network DVR (nDVR), local DVR or any other generic DVR.

Numerical formats are defined in Table 1.

Table 1: Numerical Format Definitions

Example Values	Description
12345	Example of a decimal value format
0x2A	Example of a hexadecimal value format
'10010100'	Example of a string of binary digits

6. MPEG-2 Multiplex and transport constraints for VVC

This section and its subsections describe MPEG-2 System details pertaining to VVC that extends the specifications of [SCTE 54].

6.1. Services and Features

This section describes additional services and features details pertaining to VVC.

NOTE 2: As described in [SCTE 54] and other SCTE standards, the MPEG-2 Transport provides services and features enabled by information carried at the MPEG-2 Transport multiplex level and not at the video elementary stream component level. Some of these services are System Information and Program Guide, Emergency Alerts, and Specification of Private Data Services.

NOTE 3: The bitrate value for the VVC Bitstream [SCTE 281-1] is application dependent and limited by the contiguous bandwidth of the transmission channel. In the application of VVC transmission [SCTE 281-1] over a 64-QAM channel, bitrate value in combination with other bitstreams in the MPEG-2 Transport multiplex, conforms to a channel bitrate of less than or equal to 26.97 Mbps; in transmissions over a 256-QAM channels to less than or equal to 38.81 Mbps [SCTE 07].

6.2. MPEG-2 Systems Standard

6.2.1. Video T-STD

Video T-STD for VVC ***shall*** be based on section 2.14.3.1 of ISO/IEC 13818-1 [MPEG-2 TS] and ***shall*** follow the constraints for the profile and level encoded in the video elementary stream in Appendix A of VVC [MPEG-VVC].

6.3. Assignment of Identifiers

This section describes additional identifiers relevant to VVC video elementary stream components.

6.3.1. VVC Stream Type Codes

The value of stream_type for a VVC video stream is 0x33 as per 13818-1 [MPEG-2 TS]. The value of 0x34 for stream_type is forbidden.

6.3.2. Descriptors

6.3.2.1. Video Descriptor

Information associated with the VVC video stream *may* be signaled by the VVC_video_descriptor() in accordance with ISO/IEC 13818-1 [MPEG-2 TS]. This descriptor, when present, ***shall*** be placed in the descriptor loop for the video program element of the PMT with a descriptor tag value of '57' or '0x39'.

When the VVC_video_descriptor() is present it ***shall*** be associated with a single VVC stream that conforms to a single profile within the MPEG transport stream, and the following constraints ***shall*** apply:

- All temporal sublayers layers ***shall*** be carried in a single PID with appropriate signaling in VVC descriptor
- The associated VVC video stream ***shall*** not contain any VVC 24-hour pictures. VVC_24_hour_picture_present_flag ***shall*** be set to '0'.
- HDR_WCG_idc value parameters and the video_properties_tag value parameters ***shall*** be set for each type of content in the manner designated in this subsection. For informational purposes, Table 2-134 (Semantics of HDR_WCG_idc) in 13818-1 [MPEG-2 TS] is reproduced here as Table 2.

Table 2: Semantics of HDR_WCG_idc [MPEG-2 TS]

HDR_WCG_idc	Description
0	SDR (i.e., SDR video) is based on the Rec. ITU-R BT.709 OETF using BT.709 color primaries with a corresponding reference EOTF for flat panel displays as specified in BT.1886 (see Note 1)
1	WCG only, i.e., video color gamut in a Rec ITU-R BT.2020 container that exceeds Rec. ITU-R BT.709 (see Note 2)
2	Both HDR and WCG are to be indicated in the stream (see Note 3)
3	No indication is made regarding HDR/WCG or SDR characteristics of the stream

NOTE 1: An example where it would be desirable to set HDR_WCG_idc to 0 would be when the colour_description_present_flag, as defined in Rec. ITU-T H.274 | ISO/IEC 23002-7, is set to '0', with colour_primaries and transfer_characteristics not present in the video stream.

NOTE 2: An example where it would be desirable to set HDR_WCG_idc to 1 would be when colour_primaries as defined in Rec. ITU-T H.274 | ISO/IEC 23002-7(which refers to the ColourPrimaries parameter in Rec. ITU-T H.273 | ISO/IEC 23091-2) is equal to 9 to indicate Rec. ITU-R BT.2020 [ITU-R BT.2022-2]

NOTE 3: An example where it would be desirable to set HDR_WCG_idc to 2 would be when transfer_characteristics as defined in Rec. ITU-T H.274 | ISO/IEC 23002-7 (which refers to the TransferCharacteristics parameter in Rec. ITU-T H.273 | ISO/IEC 23091-2) is equal to 16 to indicate BT.2100 PQ EOTF or equal to 18 to indicate BT.2100 HLG EOTF, and when colour_primaries as defined in ISO/IEC 23002-7 is equal to 9 to indicate Rec. ITU-R BT.2020.

- SDR indicated video streams ***shall*** be signaled with an HDR_WCG_idc value set to '0'. For informational purposes, Table 2-135 (SDR widely used video property combinations) in 13818-1 [MPEG-2 TS] is reproduced here as Table 3.

Table 3: SDR widely used video property combinations

video_properties_tag	CICP Values - System Identifier [ColourPrimaries, TransferCharacteristics, MatrixCoefficients, VideoFullRangeFlag]
0	Video property CICP combination not specified or unknown
1	[1,1,1,0]- BT709_YCC
2	[1,1,0,0]- BT709_RGB
3	[6,6,6,0]- BT601_525
4	[5,6,5,0]- BT601_625
5	[1,1,0,1]- FR709_RGB
6-15	Reserved

- HDR indicated video streams ***shall*** be signaled with an HDR_WCG_idc value set to '2'. For informational purposes, Table 2-136 (WCG widely used video property combinations) in 13818-1 [MPEG-2 TS] is reproduced here as Table 4.

Table 4: WCG widely used video property combinations

video_properties_tag	CICP Values - System Identifier [ColourPrimaries, TransferCharacteristics, MatrixCoefficients, VideoFullRangeFlag]
0	Video property CICP combination not specified or unknown
1	[9,14,9,0]- BT2020_YCC_NCL
2	[9,14,0,0]- BT2020_RGB
3	[9,14,0,1]- FR2020_RGB
4	[12,1,6,1]- FRP3D65_YCC
5-15	Reserved

- All other video streams where no indication is made ***shall*** be signaled with an HDR_WCG_idc value set to '3'. For informational purposes, Table 2-137 (WCG widely used video property combinations) in 13818-1 [MPEG-2 TS] is reproduced here as Table 5.

Table 5: HDR/WCG widely used video property combinations

video_properties_tag	CICP Values - System Identifier [ColourPrimaries, TransferCharacteristics, MatrixCoefficients, VideoFullRangeFlag]
0	Video property CICP combination not specified or unknown
1	[9,16,9,0]- BT2100_PQ_YCC
2	[9,18,9,0]- BT2100_HLG_YCC
3	[9,16,14,0]- BT2100_PQ_ICTCP
4	[9,16,0,0]- BT2100_PQ_RGB
5	[9,18,0,0]- BT2100_HLG_RGB
6-15	Reserved

- HDR_WCG_idc value of '1' is SCTE reserved.
- Changes in the HDR_WCG_idc parameter ***shall*** only occur at SVRAPs.

Certain services *may* include video elementary streams that contain one or more VVC still pictures that conform to the still picture model of ISO/IEC 13818-1 [MPEG-2 TS]. Any elementary stream containing still pictures ***shall*** include a VVC_video_descriptor() with VVC_still_present_flag set to "1" in accordance with section 2.6.129 of 13818-1 [MPEG-2 TS]. In addition, maximum value of Temporal**I**d and minimum value of Temporal**I**d ***shall*** be set to '0'. Constraints for transmitting VVC still pictures are defined in section 6.6.2 of this document.

6.3.2.2. Caption Service Descriptor

This ***shall*** comply with the requirements of SCTE 128-2 [SCTE 128-2] section 6.3.2.2.

NOTE 4: Receivers rendering captions and/or other types of graphics overlays need to be aware of both the stream format and end device display capabilities to avoid mismatches in video presentation.

6.3.2.3. SCTE Adaptation Field Data Descriptor

This ***shall*** comply with the requirements of [SCTE 128-2] section 6.3.2.3

6.3.3. Media Service Kind Descriptor

The media service kind descriptor ***shall*** be placed at the program stream level in the program map section for programs encapsulated in the transport stream. If a single elementary stream is carried in the transport stream, then the media service kind descriptor ***shall*** be placed in the program map section containing the elementary stream. An identifier for the program or stream *should* be used in the descriptor [MPEG-2 TS/AMD1].

6.4. VVC Program Constraints

MPEG-2 Programs ***shall*** be constrained to carry at most one VVC video elementary stream component with a stream_type value of 0x33; as defined in ISO/IEC 13818-1 [MPEG-2 TS].

6.4.1. SCTE VVC Random Access Point (SVRAP) Access Unit Composition

An **SCTE VVC Random Access Point** access unit (SVRAP) demarcates a location within an VVC bitstream where an VVC Receiver is able to begin decoding video. The spacing of successive random access points is an important contributor to channel change time, but is not the only factor contributing to channel change time. Other factors that contribute to channel change time include physical device tuning constraints, RF tuning, or conditional access operations. Picture coding constraints for low delay mode are found in SCTE VVC Coding Constraints [SCTE 281-1].

6.4.2. SVRAP Transport Constraints

An SVRAP ***shall*** meet the following transport constraints.

6.4.2.1. TS Packet Header and Adaptation Field Constraints

A TS packet containing the first byte of a PES packet header of an SVRAP ***shall*** have an adaptation field. The payload_unit_start_indicator bit ***shall*** be set to ‘1’ in the TS packet header and the adaptation_field_control bits ***shall*** be set to ‘11’(as per ISO/IEC 13818-1 [MPEG-2 TS]). In addition, the random_access_indicator bit in the adaptation field of the TS packet that contains the first byte of the PES packet header containing the SVRAP ***shall*** be set to '1' and ***shall*** follow the constraints as specified in ISO/IEC 13818-1 [MPEG-2 TS] in subclause 2.4.3.5.

Per ISO/IEC 13818-1 [MPEG-2 TS], the elementary_stream_priority_indicator bit ***shall*** be set to ‘1’ in the adaptation field of the TS packet that contains the first slice start code of the SVRAP Picture.

The first byte of the PES Packet Header containing an SVRAP and the first byte of the first slice start code of the SVRAP picture ***shall*** occur either in the same TS packet or in successive TS packets of the same PID. If both occur in the same TS packet, then both the random_access_indicator and elementary_stream_priority_indicator bits ***shall*** be set to ‘1’ in the adaptation field of this TS packet. If the first byte of the PES header and the first slice start code of the SVRAP picture occur in successive TS packets of the same PID, then both TS packets ***shall*** contain adaptation fields. The first TS packet adaptation field ***shall*** contain random_access_indicator = 1. The second TS packet ***shall*** contain elementary_stream_priority_indicator = 1.

NOTE 5: Setting of both a random_access_indicator and elementary_stream_priority_indicator bits for the access unit signifies an SVRAP access unit.

NOTE 6: Multiple PPSs may be present in an SVRAP access unit. The number of PPSs that may be present in an SVRAP access unit is constrained by the TS packet restrictions above (requiring both RAI and ESPI bits set in either the same TS packet or of successive TS packets). According to MPEG-2 Systems 13818-1 [MPEG-2 TS], this requires all the bytes between the access unit delimiter NAL Unit and the start of the first slice of the SVRAP Picture to be part of the payload of either the same TS packet or two successive TS packets.

6.4.2.2. SVRAP Picture Decoding Time Stamp and SVRAP Picture Presentation Time Stamp Constraints

The VVC Bitstream ***shall*** contain necessary elements such that all pictures with PTS greater than or equal to DTS_{SVRAP} + 0.5 seconds (where DTS_{SVRAP} represents the decoding time stamp of an SVRAP Picture) are fully reconstructable and displayable when decoding starts at the SVRAP picture.

NOTE 7: This implies that any picture that has a PTS >= [DTS_{SVRAP} + 0.5 seconds] cannot be predicted directly or indirectly from reference pictures that were transmitted prior to the SVRAP (i.e., with a lower value of DTS than DTS_{SVRAP}). This also implies that any picture that was transmitted prior to the SVRAP as well as any partially reconstructed pictures in the time interval [DTS_{SVRAP}, DTS_{SVRAP} + 0.5 seconds], cannot have a PTS that is greater than or equal to [DTS_{SVRAP} + 0.5 seconds].

NOTE 8: This also implies that the PTS of the first clean displayed picture output is less than or equal to [DTS_{SVRAP} + 0.5 seconds]

The time difference between the receipt of an SVRAP (actual value of PCR if present in the transport packet or computed value of PCR for the transport packet containing SVRAP) and the DTS/PTS of its SVRAP Picture is another key component in determining channel change time. The time difference between the receipt of an SVRAP and the DTS of its SVRAP Picture is also known as the initial video buffering delay of the VVC Bitstream in the CPB.

The initial video buffering delay ***shall not*** be greater than 3 seconds. For applications requiring fast channel change or small initial delay after random access, the initial video buffering delay *should* be limited to one second or less.

NOTE 9: The maximum initial video buffering delay for a given bitrate is not permitted to have a value that exceeds the maximum CPB size permissible in VVC [MPEG-VVC].

6.4.2.3. Constraints on Decoding Time Stamps

The maximum time interval between the decoding time stamp of successive SVRAP Pictures ***shall*** be less than or equal to 3 seconds.

For applications where fast channel change or random access is important, the maximum time interval between the decoding time stamp of successive SVRAP Pictures *should* be less than or equal to 1.2 seconds.

NOTE 10: The frequency at which SVRAP access units are inserted into an VVC Bitstream is one of the key components in determining the channel change time and may simplify splicing and trick mode operations. If the interval between the Decoding Time Stamps of two successive SVRAP Pictures is too small, compression efficiency might be lowered significantly. On the other hand, if the interval between the Decoding Time Stamps of two successive SVRAP Pictures is too large, the time to effect a channel change or the initial delay after random access may be longer.

6.4.3. Adaptation Field Private Data

The signaling of adaptation field private data is described in [SCTE 128-2] section 6.4.3. Tag Values for VVC ***shall*** be as described in the Table 6.

Table 6: Tag Values

Tag Values	Description
0x00	*Forbidden*
0x01	Used by DVB
0x02	Reserved
0x03	Reserved
0x04-0xDE	Reserved for future standardized use. See ATSC Code Points Registry in addition to this standard.
0xDF	Registered Private Data
0xE0-0xFE	User Private (unmanaged, therefore collisions between different users or applications *may* occur, except perhaps in totally closed systems)
0xFF	Reserved for future extensions

NOTE 11: This standard places no constraint on the definition of new tag values that conform to the structure defined herein. The syntax and semantics for other tag values, when defined, may be found in other SCTE or other standards.

6.4.3.1. Optional Transport Adaptation Layer Information

Multiple tag values *should not* be used in the same program. Use of tag values 0x02 and 0x03 is *deprecated*. VVC Receivers *may* ignore tag values 0x02 and 0x03 and their corresponding information.

6.5. PES constraints

Each PES packet ***shall*** contain exactly one VVC access unit, as defined in sections 2.1.150 and 2.23.1 of 13818-1 [MPEG-2 TS]. The VVC access unit start ***shall*** occur in the same TS packet as contains the corresponding payload_unit_start_indicator==1 or in the next TS packet with the same PID. Each PES packet header ***shall*** contain a PTS. Each PES packet header also ***shall*** contain a DTS if DTS differs from the PTS. PES packetization ***shall*** comply to ISO/IEC 13818-1 [MPEG-2 TS] even under system time base or continuity counter discontinuities signaled by setting discontinuity_indicator to '1' in the adaptation header.

NOTE 12: Per 13818-1 [MPEG-2 TS], the payload_unit_start_indicator bit is set to '1' in the TS packet header of a TS packet containing a PES packet header. The payload of this TS packet will commence with the first byte of the PES packet.

6.6. Constraints on Alternative Application Modes

6.6.1. Low Delay Mode

Low Delay mode is signaled by low_delay_hrd_flag[i] = '1' in the HRD Parameters (per SCTE VVC Coding Constraints [SCTE 281-1] Table 8). Low Delay mode ***shall*** satisfy all of the following transport constraints.

Picture coding constraints for low delay mode are found in SCTE VVC Coding Constraints [SCTE 281-1] section 8.1.5.

1. The PTS of each picture ***shall*** be equal to or inferred equal to its DTS. The DTS *may* or *may* not be present in the PES packet header
2. Each picture in the bitstream ***shall*** be greater than the PTS of the prior picture.

6.6.2. Support for VVC Still Pictures

VVC still pictures *may* be used in the transport multiplex and when used ***shall*** comply with the following transport constraints. Picture coding constraints for VVC still pictures are found in SCTE VVC Coding Constraints [SCTE 281-1] section 8.3.3.

1. A PES packet ***shall*** contain one and only one complete access unit with a still picture, which ***shall*** be aligned to the PES packet header. The PES packet header ***shall*** contain a coded PTS value.
2. The still picture coding ***shall*** comply with section 2.1.155 of 13818-1 [MPEG-2 TS].
3. The PMT for this program element ***shall*** include the VVC_video_descriptor with the VVC_still_present_flag set to '1'.