International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

H.222.0

Amendment 3

(01/2014)

SERIES H: AUDIOVISUAL AND MULTIMEDIA SYSTEMS

Infrastructure of audiovisual services – Transmission multiplexing and synchronization

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Information technology – Generic coding of moving pictures and associated audio information: Systems

Amendment 3: Transport of HEVC video over MPEG-2 systems

Recommendation ITU-T H.222.0 (2012) – Amendment 3

International Telecommunication Union

ITU-T H-SERIES RECOMMENDATIONS

AUDIOVISUAL AND MULTIMEDIA SYSTEMS

CHARACTERISTICS OF VISUAL TELEPHONE SYSTEMS	H.100–H.199
INFRASTRUCTURE OF AUDIOVISUAL SERVICES	
General	H.200–H.219
Transmission multiplexing and synchronization	**H.220–H.229**
Systems aspects	H.230–H.239
Communication procedures	H.240–H.259
Coding of moving video	H.260–H.279
Related systems aspects	H.280–H.299
Systems and terminal equipment for audiovisual services	H.300–H.349
Directory services architecture for audiovisual and multimedia services	H.350–H.359
Quality of service architecture for audiovisual and multimedia services	H.360–H.369
Supplementary services for multimedia	H.450–H.499
MOBILITY AND COLLABORATION PROCEDURES	
Overview of Mobility and Collaboration, definitions, protocols and procedures	H.500–H.509
Mobility for H-Series multimedia systems and services	H.510–H.519
Mobile multimedia collaboration applications and services	H.520–H.529
Security for mobile multimedia systems and services	H.530–H.539
Security for mobile multimedia collaboration applications and services	H.540–H.549
Mobility interworking procedures	H.550–H.559
Mobile multimedia collaboration inter-working procedures	H.560–H.569
BROADBAND, TRIPLE-PLAY AND ADVANCED MULTIMEDIA SERVICES	
Broadband multimedia services over VDSL	H.610–H.619
Advanced multimedia services and applications	H.620–H.629
Ubiquitous sensor network applications and Internet of Things	H.640–H.649
IPTV MULTIMEDIA SERVICES AND APPLICATIONS FOR IPTV	
General aspects	H.700–H.719
IPTV terminal devices	H.720–H.729
IPTV middleware	H.730–H.739
IPTV application event handling	H.740–H.749
IPTV metadata	H.750–H.759
IPTV multimedia application frameworks	H.760–H.769
IPTV service discovery up to consumption	H.770–H.779
Digital Signage	H.780–H.789
E-HEALTH MULTIMEDIA SERVICES AND APPLICATIONS	
Interoperability compliance testing of personal health systems (HRN, PAN, LAN and WAN)	H.820–H.849
Multimedia e-health data exchange services	H.860–H.869

For further details, please refer to the list of ITU-T Recommendations.

INTERNATIONAL STANDARD ISO/IEC 13818-1
RECOMMENDATION ITU-T H.222.0

Information technology – Generic coding of moving pictures and associated audio information: Systems

Amendment 3

Transport of HEVC video over MPEG-2 systems

Summary

Amendment 3 to Recommendation ITU-T H.222.0 (2012) | ISO/IEC 13818-1:2013 specifies the transport of ITU-T H.265 | ISO/IEC 23008-2 high efficiency video coding (HEVC) bit-streams over MPEG-2 transport streams as defined in the Recommendation. This amendment does not include extensions for carriage of HEVC in program streams.

New stream types are specified to allow for the identification of elementary streams containing HEVC as a video codec. HEVC-specific descriptors are added to signal HEVC-specific properties such as profile and level. The amendment supports layered transport in case the HEVC bitstream contains more than one temporal sub-layer.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T H.222.0	1995-07-10	15	11.1002/1000/1071-en
1.1	ITU-T H.222.0 (1995) Amd. 1	1996-11-11	16	11.1002/1000/3834-en
1.2	ITU-T H.222.0 (1995) Amd. 2	1996-11-11	16	11.1002/1000/4096-en
1.3	ITU-T H.222.0 (1995) Technical Cor. 1	1998-02-06	16	11.1002/1000/4532-en
1.4	ITU-T H.222.0 (1995) Amd. 3	1998-02-06	16	11.1002/1000/4228-en
1.5	ITU-T H.222.0 (1995) Amd. 4	1998-02-06	16	11.1002/1000/4229-en
1.6	ITU-T H.222.0 (1995) Amd. 5	1999-05-27	16	11.1002/1000/4498-en
1.7	ITU-T H.222.0 (1995) Amd. 6	1999-05-27	16	11.1002/1000/4671-en
2.0	ITU-T H.222.0	2000-02-17	16	11.1002/1000/5142-en
2.1	ITU-T H.222.0 (2000) Technical Cor. 1	2001-03-01	16	11.1002/1000/5419-en
2.2	ITU-T H.222.0 (2000) Technical Cor. 2	2002-03-29	16	11.1002/1000/5675-en
2.3	ITU-T H.222.0 (2000) Amd. 1	2002-12-14	16	11.1002/1000/6190-en
2.4	ITU-T H.222.0 (2000) Amd. 1/Cor. 1	2003-06-29	16	11.1002/1000/6449-en
2.5	ITU-T H.222.0 (2000) Amd. 2	2003-06-29	16	11.1002/1000/6363-en
2.6	ITU-T H.222.0 (2000) Amd. 3	2004-03-15	16	11.1002/1000/7208-en
2.7	ITU-T H.222.0 (2000) Technical Cor. 3	2005-01-08	16	11.1002/1000/7435-en
2.8	ITU-T H.222.0 (2000) Amd. 4	2005-01-08	16	11.1002/1000/7436-en
2.9	ITU-T H.222.0 (2000) Amd. 5	2005-01-08	16	11.1002/1000/7437-en
2.10	ITU-T H.222.0 (2000) Technical Cor. 4	2005-09-13	16	11.1002/1000/8560-en
3.0	ITU-T H.222.0	2006-05-29	16	11.1002/1000/8802-en
3.1	ITU-T H.222.0 (2006) Amd. 1	2007-01-13	16	11.1002/1000/9024-en
3.2	ITU-T H.222.0 (2006) Amd. 2	2007-08-29	16	11.1002/1000/9214-en
3.3	ITU-T H.222.0 (2006) Cor. 1	2008-06-13	16	11.1002/1000/9471-en
3.4	ITU-T H.222.0 (2006) Cor. 2	2009-03-16	16	11.1002/1000/9692-en
3.5	ITU-T H.222.0 (2006) Amd. 3	2009-03-16	16	11.1002/1000/9691-en
3.6	ITU-T H.222.0 (2006) Cor. 3	2009-12-14	16	11.1002/1000/10621-en
3.7	ITU-T H.222.0 (2006) Cor. 4	2009-12-14	16	11.1002/1000/10622-en
3.8	ITU-T H.222.0 (2006) Amd. 4	2009-12-14	16	11.1002/1000/10623-en
3.9	ITU-T H.222.0 (2006) Amd. 5	2011-05-14	16	11.1002/1000/11287-en
3.10	ITU-T H.222.0 (2006) Amd. 6	2011-05-14	16	11.1002/1000/11288-en
4.0	ITU-T H.222.0	2012-06-29	16	11.1002/1000/11655-en
4.1	ITU-T H.222.0 (2012) Amd. 1	2014-01-13	16	11.1002/1000/12054-en
4.2	ITU-T H.222.0 (2012) Amd. 2	2014-01-13	16	11.1002/1000/12055-en
4.3	ITU-T H.222.0 (2012) Amd. 3	2014-01-13	16	11.1002/1000/12056-en
4.4	ITU-T H.222.0 (2012) Amd. 4	2014-01-13	16	11.1002/1000/12057-en

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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As of the date of approval of this Recommendation, ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

CONTENTS

INTERNATIONAL STANDARD
RECOMMENDATION ITU-T

Information technology – Generic coding of moving pictures and associated audio information: Systems

Amendment 3

Transport of HEVC video over MPEG-2 systems

1) Clause 1.2.2

Add the following references:

– Recommendation ITU-T H.265 (2013), *High efficiency video coding.*

ISO/IEC 23008-2:2013, *Information technology – High efficiency coding and media delivery in heterogeneous environments – Part 2: High efficiency video coding*.

2) Clauses 2.1.95 to 2.1.109

Add the following definitions after clause 2.1.94:

2.1.95 HEVC video stream: A byte stream as specified in Rec. ITU-T H. 265 | ISO/IEC 23008-2 Annex B.

2.1.96 HEVC access unit: An access unit as defined in Rec. ITU-T H.265 | ISO/IEC 23008-2 with the constraints specified in 2.17.1.

2.1.97 HEVC 24-hour picture (system): An *HEVC access unit* with a presentation time that is more than 24 hours in the future. For the purpose of this definition, *HEVC access unit* n has a presentation time that is more than 24 hours in the future if the difference between the initial arrival time $t_{ai}(n)$ and the DPB output time $t_{o,dpb}(n)$ is more than 24 hours.

2.1.98 HEVC slice: An *HEVC independent slice segment* and zero or more subsequent *HEVC dependent slice segments* preceding the next *HEVC independent slice segment* (if any) within the same *HEVC access unit*.

2.1.99 HEVC slice segment: A byte_stream_nal_unit with nal_unit_type in the range of 0 to 9 and 16 to 23, as defined in Rec. ITU-T H.265 | ISO/IEC 23008-2.

2.1.100 HEVC dependent slice segment: An *HEVC slice segment* with the syntax element dependent_slice_segment_flag in the slice header set to a value equal to 1, as defined in Rec. ITU-T H.265 | ISO/IEC 23008-2.

2.1.101 HEVC independent slice segment: An *HEVC slice segment* with the syntax element dependent_slice_segment_flag in the slice header set to a value 0 or inferred to be equal to 0, as defined in Rec. ITU-T H.265 | ISO/IEC 23008-2.

2.1.102 HEVC tile of slices: One or more consecutive *HEVC slices* which form the coded representation of a tile, as defined in Rec. ITU-T H.265 | ISO/IEC 23008-2.

2.1.103 HEVC still picture (system): An HEVC still picture consists of an *HEVC access unit* containing an IDR picture preceded by VPS, SPS and PPS NAL units, as defined in Rec. ITU-T H.265 | ISO/IEC 23008-2, that carry sufficient information to correctly decode this IDR picture. Preceding an HEVC still picture, there shall be another HEVC still picture or an end of sequence NAL unit terminating a preceding coded video sequence, as defined in Rec. ITU-T H.265 | ISO/IEC 23008-2.

2.1.104 HEVC video sequence (system): A coded video sequence as defined in Rec. ITU-T H.265 | ISO/IEC 23008-2.

2.1.105 HEVC video sub-bitstream: A subset of the NAL units of an HEVC video stream in their original order.

2.1.106 HEVC temporal video sub-bitstream: An *HEVC video sub-bitstream* that contains all VCL NAL units and associated non-VCL NAL units of the temporal sub-layer, as specified in Rec. ITU-T H.265 | ISO/IEC 23008-2, associated with TemporalId equal to 0 and which may additionally contain all VCL NAL units and associated non-VCL NAL units of all temporal sub-layers associated with a contiguous range of TemporalId from 1 to a value equal to or smaller than sps_max_sub_layers_minus1 included in the active sequence parameter set, as specified in Rec. ITU-T H.265 | ISO/IEC 23008-2.

2.1.107 HEVC temporal video subset: An *HEVC video sub-bitstream* that contains all VCL NAL units and the associated non-VCL NAL units of one or more temporal sub-layers, as specified in Rec. ITU-T H.265 | ISO/IEC 23008-2, with each temporal sub-layer not being present in the corresponding *HEVC temporal video sub-bitstream* and TemporalId associated with each temporal sub-layer forming a contiguous range of values.

NOTE – According to the constraints for the transport of HEVC specified in 2.17.1, each temporal sub-layer of an *HEVC video stream* is present either in the *HEVC temporal video sub-bitstream* or in exactly one *HEVC temporal video subset* which is carried in a set of elementary streams that are associated by hierarchy descriptors. This prevents the multiple inclusion of the same temporal sub-layer and allows aggregation of the *HEVC temporal video sub-bitstream* with associated *HEVC temporal video subsets* according to the hierarchy descriptors, as specified in 2.17.3.

2.1.108 HEVC highest temporal sub-layer representation: The sub-layer representation of the temporal sub-layer with the highest value of TemporalId, as defined in Rec. ITU-T H.265 | ISO/IEC 23008-2, in the associated *HEVC temporal video sub-bitstream* or *HEVC temporal video subset*.

2.1.109 HEVC complete temporal representation: A sub-layer representation as defined in Rec. ITU-T H.265 | ISO/IEC 23008-2 that contains all temporal sub-layers up to the temporal sub-layer with TemporalId equal to sps_max_sub_layers_minus1+1 as included in the active sequence parameter set, as specified in Rec. ITU-T H.265 | ISO/IEC 23008-2.

3) Clause 2.4.2.6

Replace the following two paragraphs:

Replace:

The delay of any data through the system target decoder buffers shall be less than or equal to one second except for still picture video data and ISO/IEC 14496 streams. Specifically: $td_n(j) - t(i) \leq 1$ second for all j, and all bytes i in access unit $A_n(j)$.

with:

The delay of any data through the system target decoder buffers shall be less than or equal to one second except for still picture video data, ISO/IEC 14496 and ISO/IEC 23008-2 streams. Specifically: $td_n(j) - t(i) \leq 1$ second for all j, and all bytes i in access unit $A_n(j)$.

Replace:

For ISO/IEC 14496 streams, the delay is constrained by $td_n(j) - t(i) \leq 10$ seconds for all j, and all bytes i in access unit $A_n(j)$.

with:

For ISO/IEC 14496 and ISO/IEC 23008-2 streams, the delay is constrained by $td_n(j) - t(i) \leq 10$ seconds for all j, and all bytes i in access unit $A_n(j)$.

4) Clause 2.4.2.11

Add the following new clause immediately after clause 2.4.2.10:

2.4.2.11 T-STD extensions for carriage of HEVC

T-STD extensions and T-STD parameters for the decoding of HEVC video streams are defined in 2.17.2 and 2.17.3. Program stream support including P-STD extensions and P-STD parameters are not specified for HEVC video streams.

5) Clause 2.4.3.5

In the paragraph specifying the discontinuity_indicator, add at the end of the bulleted list introduced by "For the purpose of this clause, an elementary stream access point is defined as follows":

- HEVC video streams or HEVC temporal video sub-bitstreams – The first byte of an HEVC access unit. The VPS, SPS and PPS parameter sets, as defined in Rec. ITU-T H.265 | ISO/IEC 23008-2, referenced in this and all subsequent HEVC access units in the HEVC video sequence shall be provided after this access point in the byte stream and prior to their activation.

In the paragraph specifying the elementary_stream_priority_indicator, add:

In the case of HEVC video streams or HEVC temporal video sub-bitstreams or HEVC temporal video subsets, this field may be set to '1' only if the payload contains one or more bytes from a slice with slice_type set to 2. A value of '0' indicates that the payload has the same priority as all other packets which do not have this bit set to '1'.

6) Clause 2.4.3.7

In Table 2-22, replace the following line:

1110 xxxx	Rec. ITU-T H.262 | ISO/IEC 13818-2, ISO/IEC 11172-2, ISO/IEC 14496-2 or Rec. ITU-T H.264 | ISO/IEC 14496-10 video stream number xxxx

with:

1110 xxxx	Rec. ITU-T H.262 | ISO/IEC 13818-2, ISO/IEC 11172-2, ISO/IEC 14496-2, Rec. ITU-T H.264 | ISO/IEC 14496-10 or Rec. ITU-T H.265 | ISO/IEC 23008-2 video stream number xxxx

At the end of the clause specifying the PTS (presentation time stamp), add:

For HEVC video streams, HEVC temporal video sub-bitstreams and HEVC temporal video subsets, if a PTS is present in the PES packet header, it shall refer to the first HEVC access unit that commences in this PES packet. To achieve consistency between the STD model and the HRD model defined in Annex C of Rec. ITU-T H.265 | ISO/IEC 23008-2, for each HEVC access unit the PTS value in the STD shall, within the accuracy of their respective clocks, indicate the same instant in time as the nominal DPB output time in the HRD, as defined in Annex C of Rec. ITU-T H.265 | ISO/IEC 23008-2.

At the end of the clause specifying the DTS (decoding time stamp), add:

For HEVC video streams, HEVC temporal video sub-bitstreams and HEVC temporal video subsets, if a DTS is present in the PES packet header, it shall refer to the first HEVC access unit that commences in this PES packet. To achieve consistency between the STD model and the HRD model defined in Annex C of Rec. ITU-T H.265 | ISO/IEC 23008-2, for each HEVC access unit the DTS value in the STD shall, within the accuracy of their respective clocks, indicate the same instant in time as the nominal CPB removal time in the HRD, as defined in Annex C of Rec. ITU-T H.265 | ISO/IEC 23008-2.

7) Clause 2.4.4.9

In Table 2-34, Stream type assignments, replace the following line:

0x24-0x7E	Rec. ITU-T H.222.0 | ISO/IEC 13818-1 Reserved

with:

0x24	HEVC video stream or an HEVC temporal video sub-bitstream
0x25	HEVC temporal video subset of an HEVC video stream conforming to one or more profiles defined in Annex A of Rec. ITU-T H.265 | ISO/IEC 23008-2
0x26-0x7E	Rec. ITU-T H.222.0 | ISO/IEC 13818-1 Reserved

8) Clause 2.6.1

Replace Table 2-45 with:

Table 2-45 – Program and program element descriptors

descriptor_tag	TS	PS	Identification
0	n/a	n/a	Reserved
1	n/a	X	Forbidden
2	X	X	video_stream_descriptor
3	X	X	audio_stream_descriptor
4	X	X	hierarchy_descriptor
5	X	X	registration_descriptor
6	X	X	data_stream_alignment_descriptor
7	X	X	target_background_grid_descriptor
8	X	X	video_window_descriptor
9	X	X	CA_descriptor
10	X	X	ISO_639_language_descriptor
11	X	X	system_clock_descriptor
12	X	X	multiplex_buffer_utilization_descriptor
13	X	X	copyright_descriptor
14	X		maximum_bitrate_descriptor
15	X	X	private_data_indicator_descriptor
16	X	X	smoothing_buffer_descriptor
17	X		STD_descriptor
18	X	X	IBP_descriptor
19-26	X		Defined in ISO/IEC 13818-6
27	X	X	MPEG-4_video_descriptor
28	X	X	MPEG-4_audio_descriptor
29	X	X	IOD_descriptor
30	X		SL_descriptor
31	X	X	FMC_descriptor
32	X	X	external_ES_ID_descriptor
33	X	X	MuxCode_descriptor
34	X	X	FmxBufferSize_descriptor
35	X		multiplexBuffer_descriptor
36	X	X	content_labeling_descriptor
37	X	X	metadata_pointer_descriptor
38	X	X	metadata_descriptor
39	X	X	metadata_STD_descriptor
40	X	X	AVC video descriptor
41	X	X	IPMP_descriptor (defined in ISO/IEC 13818-11, MPEG-2 IPMP)
42	X	X	AVC timing and HRD descriptor
43	X	X	MPEG-2_AAC_audio_descriptor
44	X	X	FlexMuxTiming_descriptor
45	X	X	MPEG-4_text_descriptor
46	X	X	MPEG-4_audio_extension_descriptor
47	X	X	Auxiliary_video_stream_descriptor
48	X	X	SVC extension descriptor
49	X	X	MVC extension descriptor
50	X	n/a	J2K video descriptor
51	X	X	MVC operation point descriptor

Table 2-45 – Program and program element descriptors

descriptor_tag	TS	PS	Identification
52	X	X	MPEG2_stereoscopic_video_format_descriptor
53	X	X	Stereoscopic_program_info_descriptor
54	X	X	Stereoscopic_video_info_descriptor
55	X	n/a	Transport_profile_descriptor
56	X	n/a	HEVC video descriptor
57-62	n/a	n/a	Rec. ITU-T H.222.0 | ISO/IEC 13818-1 Reserved
63	X	X	Extension_descriptor
64-255	n/a	n/a	User Private

9) Clause 2.6.7

In Table 2-50, replace the description for value 15 as shown below:

Table 2-50 – Hierarchy_type field values

Value	Description
15	Base layer or MVC base view sub-bitstream or AVC video sub-bitstream of MVC or HEVC temporal video sub-bitstream.

10) Clause 2.6.11

Add the following immediately after Table 2-54:

Table 2-54bis describes the alignment type for HEVC when the data_alignment_indicator in the PES packet header has a value of '1'.

Table 2-54bis – HEVC video stream alignment values

Alignment type	Description
00	Reserved
01	HEVC access unit
02	HEVC slice
03	HEVC access unit or slice
04	HEVC tile of slices
05	HEVC access unit or tile of slices
06	HEVC slice or tile of slices
07	HEVC access unit or slice or tile of slices
08	HEVC slice segment
09	HEVC slice segment or access unit
10	HEVC slice segment or slice
11	HEVC slice segment or access unit or slice
12	HEVC slice segment or tile of slices
13	HEVC slice segment or access unit or tile of slices
14	HEVC slice segment or slice or tile of slices
15	HEVC slice segment or access unit or slice or tile of slices
16-255	Reserved

11) Clause 2.6.90

Replace Table 2-103bis with:

Table 2-103bis – Extension descriptor

Syntax	No. of bits	Mnemonic
Extension_descriptor () {		
descriptor_tag	**8**	**uimsbf**
descriptor_length	**8**	**uimsbf**
extension_descriptor_tag	**8**	**uimsbf**
if (extension_descriptor_tag == 0x02) {		
ObjectDescriptorUpdate()		
}		
else if (extension_descriptor_tag == 0x03) {		
HEVC_timing_and_HRD_descriptor()		
}		
else {		
for (i=0; i<N; i++) {		
reserved	**8**	**bslbf**
}		
}		
}		

12) Clause 2.6.91

Add the following immediately before Table 2-103ter:

HEVC_timing_and_HRD_descriptor() – This structure is defined in clauses 2.6.95 and 2.6.96.

Replace Table 2-103ter with:

Table 2-103ter – Extension descriptor tag values

Extension_descriptor_tag	TS	PS	Identification
0	n/a	n/a	Reserved
1	n/a	X	Forbidden
2	X	X	ODUpdate_descriptor
3	X	n/a	HEVC_timing_and_HRD_descriptor()
3-255	n/a	n/a	Rec. ITU-T H.222.0 | ISO/IEC 13818-1 Reserved

13) Clauses 2.6.95 to 2.6.98

Add the following new clauses immediately after clause 2.6.94:

2.6.95 HEVC video descriptor

For an HEVC video stream, the HEVC video descriptor provides basic information for identifying coding parameters, such as profile and level parameters of that HEVC video stream. For an HEVC temporal video sub-bitstream or an HEVC temporal video subset, the HEVC video descriptor provides information such as the associated HEVC highest temporal sub-layer representation contained in the elementary stream to which it applies.

Table 2-103sexiens – HEVC video descriptor

Syntax	No. Of bits	Mnemonic
HEVC_descriptor() {		
descriptor_tag	**8**	**uimsbf**
descriptor_length	**8**	**uimsbf**
profile_space	**2**	**uimsbf**
tier_flag	**1**	**bslbf**
profile_idc	**5**	**uimsbf**
profile_compatibility_indication	**32**	**bslbf**
progressive_source_flag	**1**	**bslbf**
interlaced_source_flag	**1**	**bslbf**
non_packed_constraint_flag	**1**	**bslbf**
frame_only_constraint_flag	**1**	**bslbf**
reserved_zero_44bits	**44**	**bslbf**
level_idc	**8**	**uimsbf**
temporal_layer_subset_flag	**1**	**bslbf**
HEVC_still_present_flag	**1**	**bslbf**
HEVC_24hr_picture_present_flag	**1**	**bslbf**
reserved	**5**	**bslbf**
if (temporal_layer_subset_flag == '1') {		
reserved	**5**	**bslbf**
temporal_id_min	**3**	**uimsbf**
reserved	**5**	**bslbf**
temporal_id_max	**3**	**uimsbf**
}		
}		

2.6.96 Semantic definition of fields in HEVC video descriptor

profile_space, tier_flag, profile_idc, profile_compatibility_indication, **progressive_source_flag, interlaced_source_flag, non_packed_constraint_flag, frame_only_constraint_flag, reserved_zero_44bits, level_idc** – When the HEVC video descriptor applies to an HEVC video stream or to an HEVC complete temporal representation, these fields shall be coded according to the semantics defined in Rec. ITU-T H.265 | ISO/IEC 23008-2 for *general_profile_space*, *general_tier_flag*, *general_profile_idc*, *general_profile_compatibility_flag[i]*, *general_progressive_source_flag*, *general_interlaced_source_flag*, *general_non_packed_constraint_flag*, *general_frame_only_constraint_flag*, *general_reserved_zero_44bits*, *general_level_idc*, respectively, for the corresponding HEVC video stream or HEVC complete temporal representation, and the entire HEVC video stream or HEVC complete temporal representation to which the HEVC video descriptor is associated shall conform to the information signalled by these fields.

When the HEVC video descriptor applies to an HEVC temporal video sub-bitstream or HEVC temporal video subset of which the corresponding HEVC highest temporal sub-layer representation is not an HEVC complete temporal representation, these fields shall be coded according to the semantics defined in Rec. ITU-T H.265 | ISO/IEC 23008-2 for *sub_layer_profile_space*, *sub_layer_tier_flag*, *sub_layer_profile_idc*, *sub_layer_profile_compatibility_flag[i]*, *sub_layer_progressive_source_flag*, *sub_layer_interlaced_source_flag*, *sub_layer_non_packed_constraint_flag*, *sub_layer_frame_only_constraint_flag*, *sub_layer_reserved_zero_44bits*, *sub_layer_level_idc*, respectively, for the corresponding HEVC highest temporal sub-layer representation, and the entire HEVC highest temporal sub-layer representation to which the HEVC video descriptor is associated shall conform to the information signalled by these fields.

NOTE 1 – In one or more sequences in the HEVC video stream the level may be lower than the level signalled in the HEVC video descriptor, while also a profile may occur that is a subset of the profile signalled in the HEVC video descriptor. However, in the entire HEVC video stream, only subsets of the entire bitstream syntax shall be used that are included in the profile signalled in the HEVC video descriptor, if present. If the sequence parameter sets in an HEVC video stream signal different profiles, and no additional constraints are signalled, then the stream may need examination to determine which profile, if any, the entire stream conforms to. If an HEVC video descriptor is to be associated with an HEVC video stream that does not conform to a single profile, then the HEVC video stream should be partitioned into two or more sub-streams, so that HEVC video descriptors can signal a single profile for each such sub-stream.

temporal_layer_subset_flag – This 1-bit flag, when set to '1', indicates that the syntax elements describing a subset of temporal layers are included in this descriptor. This field shall be set to 1 for HEVC temporal video subsets and for HEVC temporal video sub-bitstreams. When set to '0', the syntax elements temporal_id_min and temporal_id_max are not included in this descriptor.

HEVC_still_present_flag – This 1-bit field, when set to '1', indicates that the HEVC video stream or the HEVC highest temporal sub-layer representation may include HEVC still pictures. When set to '0', then the associated HEVC video stream shall not contain HEVC still pictures.

NOTE 2 – According to Rec. ITU-T H.265 | ISO/IEC 23008-2, IDR pictures are always associated with a TemporalId value equal to 0, Consequently, if the HEVC video descriptor applies to an HEVC temporal video subset, HEVC still pictures can only be present in the associated HEVC temporal video sub-bitstream.

HEVC_24_hour_picture_present_flag – This 1-bit flag, when set to '1', indicates that the associated HEVC video stream or the HEVC highest temporal sub-layer representation may contain HEVC 24-hour pictures. For the definition of an HEVC 24-hour picture, see clause 2.1.97. If this flag is set to '0', the associated HEVC video stream shall not contain any HEVC 24-hour pictures.

temporal_id_min – This 3-bit field indicates the minimum value of the *TemporalId*, as defined in Rec. ITU-T H.265 | ISO/IEC 23008-2, of all HEVC access units in the associated elementary stream.

temporal_id_max – This 3-bit field indicates the maximum value of the *TemporalId*, as defined in Rec. ITU-T H.265 | ISO/IEC 23008-2, of all HEVC access units in the associated elementary stream.

2.6.97 HEVC timing and HRD descriptor

For an HEVC video stream, an HEVC temporal video sub-bitstream or an HEVC temporal video subset, the HEVC timing and HRD descriptor provides timing and HRD parameters, as defined in Annex C of Rec. ITU-T H.265 | ISO/IEC 23008-2, for the associated HEVC video stream or the HEVC highest temporal sub-layer representation thereof, respectively.

Table 2-103septiens – HEVC timing and HRD descriptor

Syntax	No. Of bits	Mnemonic
HEVC_timing_and_HRD_descriptor() {		
hrd_management_valid_flag	**1**	**bslbf**
reserved	**6**	**bslbf**
picture_and_timing_info_present_flag	**1**	**bslbf**
if (picture_and_timing_info_present_flag == '1') {		
90kHz_flag	**1**	**bslbf**
reserved	**7**	**bslbf**
if (90kHz_flag = = '0') {		
N	**32**	**uimsbf**
K	**32**	**uimsbf**
}		
num_units_in_tick	**32**	**uimsbf**
}		
}		

2.6.98 Semantic definition of fields in HEVC timing and HRD descriptor

hrd_management_valid_flag – This 1-bit flag is only defined for use in transport streams. When the HEVC timing and HRD descriptor is associated with an HEVC video stream or with an HEVC highest temporal sub-layer representation carried in a transport stream, then the following apply.

If the *hrd_management_valid_flag* is set to '1', then Buffering Period SEI and Picture Timing SEI messages, as defined in Annex C of Rec. ITU-T H.265 | ISO/IEC 23008-2, shall be present in the associated HEVC video stream or HEVC highest temporal sub-layer representation. These buffering period SEI messages shall carry coded *nal_initial_cpb_removal_delay* and *nal_initial_cpb_removal_delay_offset* values and may additionally carry *nal_initial_alt_removal_delay* and *nal_initial_alt_cpb_removal_delay_offset* values for the NAL HRD. If the *hrd_management_valid_flag* is set to '1', then the transfer of each byte from MB_n to EB_n in the T-STD as defined in 2.17.2 or the transfer from $MB_{n,k}$ to EB_n in the T-STD as defined in 2.17.3 shall be according to the delivery schedule for that byte into the CPB in the NAL HRD, as determined from the coded *nal_initial_cpb_removal_delay* and *nal_initial_cpb_removal_delay_offset* or from the coded *nal_initial_alt_cpb_removal_delay* and *nal_initial_alt_cpb_removal_delay_offset* values for *SchedSelIdx* equal to *cpb_cnt_minus1,* as specified in Annex C of Rec. ITU-T H.265 | ISO/IEC 23008-2. When the *hrd_management_valid_flag* is set to '0', the leak method shall be used for the transfer from MB_n to EB_n in the T-STD as defined in 2.17.2 or the transfer from $MB_{n,k}$ to EB_n in the T-STD as defined in 2.17.3.

picture_and_timing_info_present_flag – This 1-bit flag when set to '1' indicates that the *90kHz_flag* and parameters for accurate mapping to a 90-kHz system clock are included in this descriptor.

90kHz_flag – This 1-bit flag when set to '1' indicates that the frequency of the HEVC time base is 90 kHz.

N, K – For an HEVC video stream or HEVC highest temporal sub-layer representation , the frequency of the HEVC time base is defined by the syntax element *vui_time_scale* in the VUI parameters, as defined in Annex E of Rec. ITU-T H.265 | ISO/IEC 23008-2. The relationship between the HEVC *time_scale* and the STC shall be defined by the parameters N and K in this descriptor as follows.

$$time\_scale = (N \times system\_clock\_frequency) / K$$

If the *90kHz_flag* is set to '1', then N equals 1 and K equals 300. If the *90kHz_flag* is set to '0', then the values of N and K are provided by the coded values of the N and K fields.

NOTE – This allows mapping of time expressed in units of *time_scale* to 90 kHz units, as needed for the calculation of PTS and DTS timestamps, for example in decoders for HEVC access units for which no PTS or DTS is encoded in the PES header.

num_units_in_tick – This 32-bit field is coded exactly in the same way as the *vui_num_units_in_tick* field in VUI parameters in Annex E of Rec. ITU-T H.265 | ISO/IEC 23008-2. The information provided by this field shall apply to the entire HEVC video stream or HEVC highest temporal sub-layer representation to which the HEVC timing and HRD descriptor is associated.

14) Clause 2.17

Add the following new clause after clause 2.16:

2.17 Carriage of HEVC

2.17.1 Constraints for the transport of HEVC

For HEVC video streams, HEVC temporal video sub-bitstreams or HEVC temporal video subsets, the following constraints additionally apply:

- Each HEVC access unit shall contain an access unit delimiter NAL unit.

  NOTE 1 – HEVC requires that an access unit delimiter NAL unit, if present, is the first NAL unit within an HEVC access unit. Access unit delimiter NAL units simplify the ability to detect the boundary between HEVC access units.

- An HEVC video stream or HEVC temporal video sub-bitstream shall be an element of an ITU-T H.222.0 | ISO/IEC 13818-1 program and the *stream_type* for this elementary stream shall be equal to 0x24.

- The video parameter sets, sequence parameter sets and picture parameter sets, as specified in Rec. ITU-T H.265 | ISO/IEC 23008-2, that are necessary for decoding an HEVC video stream or HEVC temporal video sub-bitstream shall be present within the elementary stream carrying that HEVC video stream or HEVC temporal video sub-bitstream.

- For each HEVC temporal video subset that is an element of the same Rec. ITU-T H.222.0 | ISO/IEC 13818-1 program, the *stream_type* for this elementary stream shall be equal to 0x25.

- When a Rec. ITU-T H.222.0 | ISO/IEC 13818-1 program includes more than one HEVC temporal video subset, or more than one HEVC temporal video sub-bitstream and at least one HEVC temporal video subset, a hierarchy descriptor as defined in 2.6.7 shall be present for all associated elementary streams with *stream type* equal to 0x24 or 0x25. The hierarchy descriptors shall be used to indicate the dependencies of all HEVC temporal video sub-bitstreams and all HEVC temporal video subsets.

- In each elementary stream with *stream_type* equal to 0x24 with a hierarchy descriptor, the *hierarchy_type* in the hierarchy descriptor shall be equal to 15.

- In each elementary stream with *stream_type* equal to 0x25 with a hierarchy descriptor, the *hierarchy_type* in the hierarchy descriptor shall be equal to 3.

- The video parameter sets, sequence parameter sets and picture parameter sets, as specified in Rec. ITU-T H.265 | ISO/IEC 23008-2, that are necessary for decoding the HEVC highest temporal sub-layer representation of an HEVC temporal video subset shall be present within the elementary stream carrying the HEVC temporal video sub-bitstream associated by a hierarchy descriptor.

- The aggregation of the HEVC temporal video sub-bitstream with associated HEVC temporal video subsets according to the hierarchy descriptors, as specified in 2.17.3, shall result in a valid HEVC video stream.

  NOTE 2 – The resulting HEVC video stream contains a set of temporal sub-layers, as specified in Rec. ITU-T H.265 | ISO/IEC 23008-2, with TemporalId values forming a contiguous range of integer numbers.

Carriage in PES packets

ITU-T H.265 | ISO/IEC 23008-2 video is carried in PES packets as *PES_packet_data_bytes*, using one of the 16 *stream_id* values assigned to video, while signalling the ITU-T H.265 | ISO/IEC 23008-2 video stream by means of the assigned stream-type value in the PMT (see Table 2-34). The highest level that may occur in an HEVC video stream, as well as a profile and tier that the entire stream conforms to should be signalled using the HEVC video descriptor. If an HEVC video descriptor is associated with an HEVC video stream, an HEVC temporal video sub-bitstream, an HEVC temporal video subset, then this descriptor shall be conveyed in the descriptor loop for the respective elementary stream entry in the program map table. This Recommendation | International Standard does not specify the presentation of ITU-T H.265 | ISO/IEC 23008-2 streams in the context of a program.

For PES packetization, no specific data alignment constraints apply. For synchronization and STD management, PTSs and, when appropriate, DTSs are encoded in the header of the PES packet that carries the ITU-T H.265 | ISO/IEC 23008-2 video elementary stream data. For PTS and DTS encoding, the constraints and semantics apply as defined in 2.4.3.7 and 2.7.

DPB buffer management

Carriage of an HEVC video stream, an HEVC temporal video sub-stream or an HEVC temporal video subset over an ITU-T H.222.0 | ISO/IEC 13818-1 stream does not impact the size of the buffer DPB. For decoding an HEVC video stream, an HEVC temporal video sub-bitstream or an HEVC temporal video sub-bitstream and its associated HEVC temporal video subsets in the STD, the size of a DPB is as defined in Rec. ITU-T H.265 | ISO/IEC 23008-2. The DPB shall be managed as specified in Annex C of Rec. ITU-T H.265 | ISO/IEC 23008-2 (clauses C.3 and C.5). A decoded HEVC access unit enters the DPB instantaneously upon decoding the HEVC access unit, hence at the CPB removal time of the HEVC access unit. A decoded HEVC access unit is presented at the DPB output time. If the HEVC video stream, HEVC temporal video sub-bitstream or HEVC temporal video subset provides insufficient information to determine the CPB removal time and the DPB output time of HEVC access units, then these time instants shall be determined in the STD model from PTS and DTS timestamps as follows:

1) The CPB removal time of HEVC access unit n is the instant in time indicated by DTS(n) where DTS(n) is the DTS value of HEVC access unit n.
2) The DPB output time of HEVC access unit n is the instant in time indicated by PTS(n) where PTS(n) is the PTS value of HEVC access unit n.

NOTE 3 – HEVC video sequences in which the *low_delay_hrd_flag* in the syntax structure *hrd_parameters()* is set to 1 carry sufficient information to determine the DPB output time and the CPB removal time of each HEVC access unit. Hence for HEVC access units for which STD underflow may occur, the CPB removal time and the DPB output time are defined by HRD parameters, and not by DTS and PTS timestamps.

NOTE 4 – An HEVC video stream may carry information to determine compliance of the HEVC video stream to the HRD, as specified in Annex C of Rec. ITU-T H.265 | ISO/IEC 23008-2. The presence of this information can be signalled in a transport stream using the HEVC timing and HRD descriptor with the *hrd_management_valid_flag* set to '1'. Irrespective of the presence of this information, compliance of an HEVC video stream to the T-STD ensures that HRD buffer management requirements for the CPB are met when each byte in the HEVC video stream is delivered to and removed from the CPB in the HRD at exactly the same instant in time at which the byte is delivered to and removed from EB_n in the T-STD.

2.17.2 T-STD Extensions for single layer HEVC

When there is an HEVC video stream or HEVC temporal video sub-bitstream in an ITU-T H.222.0 | ISO/IEC 13818-1 program and there is no HEVC temporal video subset associated with this elementary stream of stream_type 0x24 in the same ITU-T H.222.0 | ISO/IEC 13818-1 program, the T-STD model as described in 2.4.2 is extended as illustrated in Figure 2-18 and as specified below.

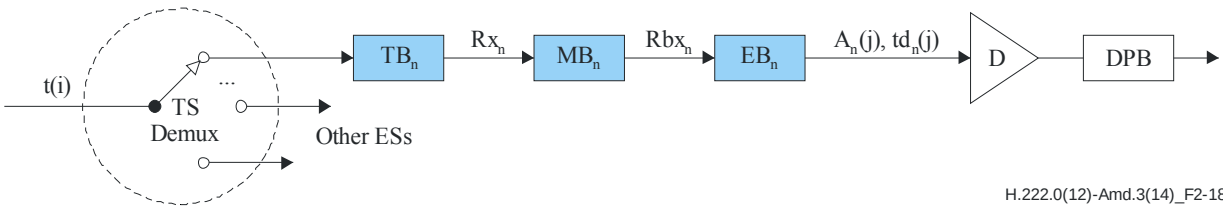

Figure 2-18 – T-STD model extensions for single layer HEVC

TB_n, MB_n, EB_n buffer management

The following additional notations are used to describe the T-STD extensions and are illustrated in Figure 2-18 above.

t(i) indicates the time in seconds at which the i-th byte of the transport stream enters the system target decoder

TB_n is the transport buffer for elementary stream n

TBS is the size of the transport buffer TB_n, measured in bytes

MB_n is the multiplexing buffer for elementary stream n

MBS_n is the size of the multiplexing buffer MB_n, measured in bytes

EB_n is the elementary stream buffer for the HEVC video stream

j is an index to the HEVC access unit of the HEVC video stream

$A_n(j)$ is the j-th access unit of the HEVC video bitstream

$td_n(j)$ is the decoding time of $A_n(j)$, measured in seconds, in the system target decoder

Rx_n is the transfer rate from the transport buffer TB_n to the multiplex buffer MB_n as specified below.

Rbx_n is the transfer rate from the multiplex buffer MB_n to the elementary stream buffer EB_n as specified below.

The following apply:

- There is exactly one transport buffer TB_n for the received HEVC video stream or HEVC temporal video sub-bitstream where the size TBS is fixed to 512 bytes.
- There is exactly one multiplexing buffer MB_n for the HEVC video stream or HEVC temporal video sub-bitstream, where the size MBS_n of the multiplexing buffer MB is constrained as follows:

  $MBS_n = BS_{mux} + BS_{oh} + CpbBrNalFactor \times MaxCPB[tier, level] - cpb\_size$

  where BS_{oh}, packet overhead buffering, is defined as:

  $$BS_{oh} = (1/750) \text{ seconds} \times \max\{ CpbBrNalFactor \times MaxBR[tier, level], 2\,000\,000 \text{ bit/s}\}$$

  and BS_{mux}, additional multiplex buffering, is defined as:

  $$BS_{mux} = 0.004 \text{ seconds} \times \max\{ CpbBrNalFactor \times MaxBR[tier, level], 2\,000\,000 \text{ bit/s}\}$$

  MaxCPB[tier, level] and MaxBR[tier, level] are taken from Annex A of Rec. ITU-T H.265 | ISO/IEC 23008-2 for the tier and level of the HEVC video stream or HEVC temporal video sub-bitstream. cpb_size is taken from the HRD parameters, as specified in Annex E of Rec. ITU-T H.265 | ISO/IEC 23008-2, included in the HEVC video stream or HEVC temporal video sub-bitstream.
- There is exactly one elementary stream buffer EB_n for all the elementary streams in the set of received elementary streams associated by hierarchy descriptors, with a total size EBS_n

  $$EBS_n = cpb\_size \text{ (measured in bytes)}$$

  where cpb_size is taken from the HRD parameters, as specified in Annex E of Rec. ITU-T H.265 | ISO/IEC 23008-2, included in the HEVC video stream or the HEVC temporal video sub-bitstream.
- Transfer from TB_n to MB_n is applied as follows:

  When there is no data in TB_n then Rx_n is equal to zero. Otherwise:

  $$Rx_n = bit\_rate$$

  where bit_rate is CpbBrNalFactor/CpbBrVlcFactor x BitRate[SchedSelIdx] of data flow into the CPB for the byte stream format and BitRate[SchedSelIdx] is as defined in Annex E of Rec. ITU-T H.265 | ISO/IEC 23008-2 when NAL hrd_parameters() is present in the VUI parameters of the HEVC video stream.

  NOTE – Annex E also specifies default values for BitRate[SchedSelIdx] based on profile, tier and level when NAL HRD parameters are not present in the VUI. .
- Transfer from MB_n to EB_n is applied as follows:

  If the *HEVC_timing_and_HRD_descriptor* is present with the *hrd_management_valid_flag* set to '1' for the elementary stream, then the transfer of data from MB_n to EB_n shall follow the HRD defined scheme for data arrival in the CPB of the elementary stream as defined in Annex C of Rec. ITU-T H.265 | ISO/IEC 23008-2.

Otherwise, the leak method shall be used to transfer data from MB_n to EB_n as follows:

$$Rbx_n = CpbBrNalFactor \times MaxBR[tier, level]$$

where MaxBR[tier, level] is taken from Annex A of Rec. ITU-T H.265 | ISO/IEC 23008-2 for the tier and level of the HEVC video stream or HEVC temporal video sub-bitstream.

If there is PES packet payload data in MB_n, and buffer EB_n is not full, the PES packet payload is transferred from MB_n to EB_n at a rate equal to Rbx_n. If EB_n is full, data are not removed from MB_n. When a byte of data is transferred from MB_n to EB_n, all PES packet header bytes that are in MB_n and precede that byte are instantaneously removed and discarded. When there is no PES packet payload data present in MB_n, no data is removed from MB_n. All data that enters MB_n leaves it. All PES packet payload data bytes enter EB_n instantaneously upon leaving MB_n.

STD delay

The STD delay of any ITU-T H.265 | ISO/IEC 23008-2 data other than HEVC still picture data through the system target decoders buffers TB_n, MB_n, and EB_n shall be constrained by $td_n(j) - t(i) \leq 10$ seconds for all j, and all bytes i in access unit $A_n(j)$.

The delay of any HEVC still picture data through the system target decoders TB_n, MB_n, and EB_n shall be constrained by $td_n(j) - t(i) \leq 60$ seconds for all j, and all bytes i in access unit $A_n(j)$.

Buffer management conditions

Transport streams shall be constructed so that the following conditions for buffer management are satisfied:

- Each TB_n shall not overflow and shall be empty at least once every second.
- Each MB_n, EB_n and DPB shall not overflow.
- EB_n shall not underflow, except when VUI parameters are present for the HEVC video sequence with the *low_delay_hrd_flag* set to '1'. Underflow of EB_n occurs for HEVC access unit $A_n(j)$ when one or more bytes of $A_n(j)$ are not present in EB_n at the decoding time $td_n(j)$.

2.17.3 T-STD extensions for layered transport of HEVC temporal video subsets

When there is an HEVC video sub-bitstream and at least one associated elementary stream of type 0x25 in an ITU-T H.222.0 | ISO/IEC 13818-1 program, the T-STD model as described in 2.4.2 is extended as illustrated in Figure 2-19 and as specified below.

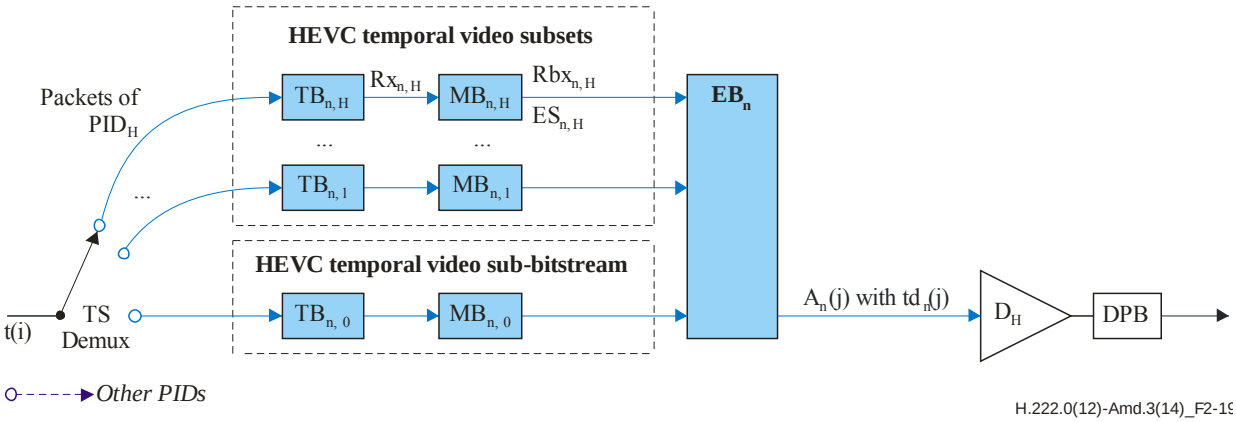

Figure 2-19 – T-STD model extensions for layered transport of HEVC temporal video subsets

The following additional notations are used to describe the T-STD extensions and are illustrated in Figure 2-19 above.

t(i) indicates the time in seconds at which the i-th byte of the transport stream enters the system target decoder.

H is the number of received HEVC temporal video subsets, associated by hierarchy descriptors with the same HEVC temporal video sub-bitstream.

k is an index identifying the H+1 received elementary streams which contain exactly one HEVC temporal video sub-bitstream and H HEVC temporal video subsets associated by hierarchy descriptors. The index value k equal to 0 identifies the elementary stream which contains the HEVC temporal video sub-bitstream and index values k ranging from 1 up to H identify the associated HEVC temporal video subsets.

$ES_{n,k}$ is the received elementary stream which contains the k-th HEVC temporal video subset or the HEVC temporal video sub-bitstream if k equals 0.

$ES_{n,H}$ is the received elementary stream containing the highest HEVC temporal video subset present in the set of received elementary streams.

PID_H is the packet identifier value which identifies $ES_{n,H}$.

j is an index to the output access units.

$A_n(j)$ is the j-th access unit of the HEVC complete temporal representation.

$td_n(j)$ is the decoding time of $A_n(j)$ in the system target decoder.

$TB_{n,k}$ is the transport buffer for elementary stream k.

$TBS_{n,k}$ is the size of the transport buffer $TB_{n,k}$, measured in bytes.

$MB_{n,k}$ is the multiplexing buffer for elementary stream k.

$MBS_{n,k}$ is the size of the multiplexing buffer $MB_{n,k}$, measured in bytes.

EB_n is the elementary stream buffer for the received HEVC temporal video sub-bitstream $ES_{n,0}$ and the received HEVC temporal video subsets $ES_{n,1}$ to $ES_{n,H}$.

EBS_n is the size of elementary stream buffer EB_n, measured in bytes.

$Rx_{n,k}$ is the transfer rate from the k-th transport buffer $TB_{n,k}$ to the k-th multiplex buffer $MB_{n,k}$ as specified below.

$Rbx_{n,k}$ is the transfer rate from the k-th multiplex buffer $MB_{n,k}$ to the elementary stream buffer EB_n as specified below.

NOTE – The index n, where used, indicates that the received elementary streams and associated buffers belong to a certain HEVC temporal video sub-bitstream and its associated HEVC temporal video subsets, distinguishing these elementary streams and associated buffers from other elementary streams and buffers, maintaining consistency with the notation in Figure 2-18.

$TB_{n,k}$, $MB_{n,k}$, EB_n buffer management

The following apply:

- There is one transport buffer $TB_{n,k}$ for each received elementary stream $ES_{n,k}$, where the size $TBS_{n,k}$ is fixed to 512 bytes.
- There is one multiplex buffer $MB_{n,k}$ for each received elementary stream $ES_{n,k}$, where the size $MBS_{n,k}$ of the multiplex buffer $MB_{n,k}$ is constrained as follows:

  $MBS_{n,k} = BS_{mux} + BS_{oh} + CpbBrNalFactor \times MaxCPB[tier, level] – cpb\_size$ (measured in bytes)

  where

  BS_{oh}, packet overhead buffering, and BS_{mux}, additional multiplex buffering, are as specified in 2.17.2;

  MaxCPB[tier, level] and MaxBR[tier, level] are taken from the tier and level specification of HEVC for the tier and level of the HEVC highest temporal sub-layer representation associated with $ES_{n,k}$;

  cpb_size is taken from the HRD parameters, as specified in Annex E of Rec. ITU-T H.265 | ISO/IEC 23008-2, included in the HEVC highest temporal sub-layer representation associated with $ES_{n,k}$.
- There is exactly one elementary stream buffer EB_n for the H + 1 elementary streams in the set of received elementary streams $ES_{n,0}$ to $ES_{n,H}$, with a total size EBS_n

  $EBS_n = cpb\_size$ (measured in bytes)

  where cpb_size is taken from the HRD parameters, as specified in Annex E of Rec. ITU-T H.265 | ISO/IEC 23008-2, included in the HEVC highest temporal sub-layer representation associated with $ES_{n,H}$.
- Transfer from $TB_{n,k}$ to $MB_{n,k}$ is applied as follows:

  When there is no data in $TB_{n,k}$ then $Rx_{n,k}$ is equal to zero. Otherwise:

  $Rx_{n,k} = bit\_rate$

  where bit_rate is as specified in 2.17.2.

- Transfer from $MB_{n,k}$ to EB_n is applied as follows:

  If the HEVC_timing_and_HRD_descriptor is present with the hrd_management_valid_flag set to '1' for the HEVC video sub-bitstream, then the transfer of data from $MB_{n,k}$ to EB_n shall follow the HRD defined scheme for data arrival in the CPB of elementary stream $ES_{n,H}$ as defined in Annex C of Rec. ITU-T H.265 | ISO/IEC 23008-2.

  Otherwise, the leak method shall be used to transfer data from $MB_{n,k}$ to EB_n as follows:

  $$Rbx_{n,k} = CpbBrNalFactor \times MaxBR[tier, level]$$

  where MaxBR[tier, level] is defined for the byte stream format in Annex A of Rec. ITU-T H.265 | ISO/IEC 23008-2 for the tier and level of the HEVC video stream or the HEVC highest temporal sub-layer representation associated with $ES_{n,k}$.

  If there is PES packet payload data in $MB_{n,k}$, and EB_n is not full, the PES packet payload is transferred from $MB_{n,k}$ to EB_n at a rate equal to $Rbx_{n,k}$. If EB_n is full, data are not removed from $MB_{n,k}$. When a byte of data is transferred from $MB_{n,k}$ to EB_n,, all PES packet header bytes that are in $MB_{n,k}$ and precede that byte are instantaneously removed and discarded. When there is no PES packet payload data present in $MB_{n,k}$, no data is removed from $MB_{n,k}$. All data that enters $MB_{n,k}$ leaves it. All PES packet payload data bytes enter EB_n instantaneously upon leaving $MB_{n,k}$.

At the output of the elementary stream buffer EB_n, the elementary streams are aggregated by removing all HEVC access units in ascending DTS order and transferring them to the HEVC decoder D_H, irrespective of which elementary stream $ES_{n,k}$ each HEVC access unit belongs to.

STD delay

The STD delay of any ITU-T H.265 | ISO/IEC 23008-2 data other than HEVC still picture data through the system target decoders buffers $TB_{n,k}$, $MB_{n,k}$, and EB_n shall be constrained by $td_n(j) - t(i) \leq 10$ seconds for all k, all j, and all bytes i in access unit $A_n(j)$.

The delay of any HEVC still picture data through the system target decoders $TB_{n,k}$, $MB_{n,k}$, and EB_n shall be constrained by $td_n(j) - t(i) \leq 60$ seconds for all k, all j, and all bytes i in access unit $A_n(j)$.

Buffer management conditions

Transport streams shall be constructed so that the following conditions for buffer management are satisfied:

- Each $TB_{n,k}$ shall not overflow and shall be empty at least once every second.
- Each $MB_{n,k}$, EB_n, and DPB shall not overflow.
- EB_n shall not underflow, except when VUI parameters are present for the HEVC video sequence with the *low_delay_hrd_flag* set to '1'. Underflow of EB_n occurs for HEVC access unit $A_n(j)$ when one or more bytes of $A_n(j)$ are not present in EB_n at the decoding time $td_n(j)$.

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Printed in Switzerland
Geneva, 2014