Watermarking API for Encoder Integration

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Revision History

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1 PURPOSE AND SCOPE

Background knowledge about commercially deployed forensic watermarking systems has been presented in [1]. With a focus on integration, it helps stakeholders understanding what needs to be done.

In this document, for the specific use case of Adaptive Bitrate content, APIs are proposed. This allows an encoder and a watermarking system to process video content and output Variants. There are two flavours of the API, one for watermarking technologies that process baseband video content and one for watermarking technologies that process compressed video content.

2 DEFINITIONS, ACRONYMS AND REFERENCES

In addition to definitions, acronyms and references defined in [1], the following is added.

2.1 Acronyms

API	Application Programming Interface
EBP	Encoder Boundary Point
ENC	Encoder
HDR	High Dynamic Range
IDR	Instantaneous Decoder Refresh point
NALU	Network Access Layer Unit
RAP	Random Access Point
SEI	Supplemental Enhancement Information
VCL	Video Coding Layer
WMP	Watermark Pre-processor

The types ((**u)intN_t**) used in this document are defined in [2]. See also `<inttypes.h>` header, https://en.wikipedia.org/wiki/C_data_types#inttypes.h, and `<stdint.h>`.

2.2 References

[1] Ultra HD Forum Guidelines, Revision 2.4, 2020. https://ultrahdforum.org/guidelines/

[2] Information technology – Programming languages – C99, ISO/IEC 9899:1999.

[3] ITU-T Recommendation H.264 (01/2012): "Advanced video coding for generic audiovisual services" | ISO/IEC 14496-10:2010: "Information technology – Coding of audio-visual objects – Part 10: Advanced Video Coding".

[4] ITU-T Recommendation H.265 (04/2015): "Advanced video coding for generic audiovisual services" | ISO/IEC 23008-2:2015: "High Efficiency Coding and Media Delivery in Heterogeneous Environments – Part 2: High Efficiency Video Coding".

[5] ISO/IEC 13818-1:2019, Information technology — Generic coding of moving pictures and associated audio information — Part 1: Systems.

[6] OpenCable™ Specifications, Encoder Boundary Point Specification, 2013. OC-SP-EBP-I01-130118.

[7] AV1 Bitstream & Decoding Process Specification, *Last modified: 2019-01-08 11:48 PT,* Authors: Peter de Rivaz, Argon Design Ltd. Jack Haughton, Argon Design Ltd, Codec Working Group Chair: Adrian Grange, Google LLC, Document Design: Lou Quillio, Google LLC.

3 INTRODUCTION

For watermarking with Variants creation, video content is pre-processed and integration with the encoder is required, especially in the context of Live where latency is critical. The video encoder (ENC) will provide information about the stream, content and location and the Watermark pre-processor (WMP) will create Variants based on its own technology.

This document provides a generic C-language API for the WMP both for baseband and compressed watermarking technologies. Depending on implementation specifics, only a subgroup of these parameters may be required, and some functionality or parameters may be out of scope. This API is not limited to A/B use case only (generation of two Variants), it allows generating any number of Variants from the input frame.

This document extends the guidelines provided in [1]. For example, in the case of ABR content creation as shown in Figure 1 (DASH or HLS with two Variants), the API defined in this document is on the link between the ENC and WMP.

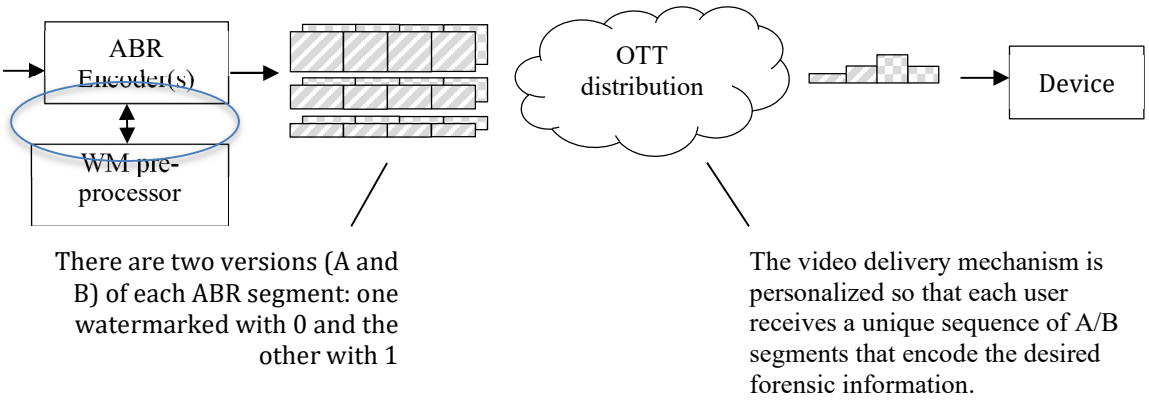


Figure 1: Scope of the API defined in this document.

3.1 WMP System Interfaces

From a system perspective, the WMP is a software component that accepts as input a video content and outputs one or several Variants, typically two in the case of A/B watermarking as shown in Figure 2.

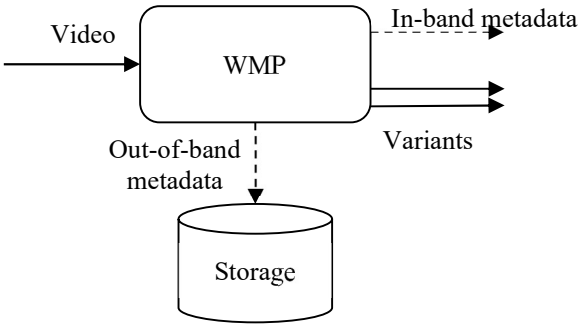


Figure 2: WMP interfaces.

This WMP needs to be integrated within the video processing pipeline of the ENC. Depending on the watermarking technology, it will be placed either before the encoding module of the ENC if the WMP processes baseband video content, or after the encoding module if it processes compressed video content. Although this document provides a generic API for both types of watermarking systems, the actual integration in the ENC will be de facto different. In both cases, the ENC is responsible for packaging the produced

Variants using relevant transport protocols. It is possible to configure the WMP to produce all the Variants of the watermarking system at once or, alternately, to produce only one of these Variants. In the latter case, several ENC will need to be deployed, each one producing a single Variant, in order to have all necessary Variants in the watermarking system.

In addition to the Variants, the WMP may also generate metadata and, more specifically, in-band and/or out-of-band metadata.

The ENC is responsible for encapsulating the in-band metadata in the video stream it outputs (see. Annex B). Depending on which component of the video delivery network shall consume WMP in-band metadata, it may be required to be encrypted or not. For instance, WMP in-band metadata may contain A/B redirection information to be used in the Edge servers of a CDN. In this case, the WMP in-band metadata shall be left in cleartext at the transport layer in order to be accessible at such locations. Alternately, WMP in-band metadata may contain information to perform just-in-time watermarking operations in the end-user device. In that case, the metadata shall be secured at the video transport layer in a way similar to the video content it is bound to.

The WMP may also produce out-of-band metadata that is required to perform watermark detection. This is watermarking vendor-specific metadata exchanged between the WMP and the watermark detector and is typically stored locally on disk by the WMP. The ENC shall then manage this data in a manner defined by the WMP provider. As an example, the WMP provider may request that the file is retrieved and pushed on an archive on a Cloud service on a regular basis. Another requirement can be on the file size that may not exceed a given value. All these elements are to be defined at integration time and are vendor specific.

3.2 Frame-based Processing

The WMP operates frame by frame: for each input video frame, the WMP returns Variants of the frame. Depending on whether the watermarking technology operates in the baseband or compressed domain, the content of a ‘frame’ will actually be different. In the case of baseband watermarking, a frame is a raw image represented by a buffer filled with pixel values and all frames have the same size. For compressed domain watermarking system, a frame is a portion of the encoded video stream e.g. an Access Unit (AU) using MPEG terminology. As a result, frames may have different sizes.

Another salient difference between baseband and compressed domain watermarking relates to the delivery schedule of the input frames. In baseband watermarking, the WMP is placed before the encoding module of the ENC and is therefore expecting input frames to be given in presentation order, typically at a regular pace depending on the frame rate of the input video feed. In contrast, with compressed domain watermarking systems, the WMP is typically placed after the encoding module of the ENC and expects input frames to be given in decoding order. In this setup, input frames may arrive in bursts according to the GOP structure.

For ABR distribution, the WMP may require knowing how the video bitstream will be eventually segmented for OTT delivery. This is the reason why dedicated signalling may be used to indicate if a given frame processed by the WMP will be the beginning of a segment at delivery time.

3.3 Shared Buffers

The WMP and the ENC have shared buffers for exchanging content (input frames and metadata and marked frames and metadata). The management of these buffers is under the ENC responsibility, the WMP is only responsible for managing its internal memory. Note that this internal memory could be a copy of these shared buffer, but it is not recommended for efficiency purposes. Depending on the operating modes that are expressed with several parameters, the ENC needs to release memory following the guidelines presented in Section 5. For example, when a shared buffer can be released depends on the use or not of a dedicated callback function.

Additional optimization of the memory management is possible with ad-hoc functions that are not defined in this document.

4 MAIN DATA STRUCTURES

This API uses a few data structures to describe (i) the video content that will be processed by a WMP instance, (ii) a video frame given in input to the WMP, and (iii) the Variants returned by the WMP.

4.1 Video Content Description

The description of the video content is encapsulated in a *fixed-size* data structure that contains the information listed below:

```
typedef struct {
  uint32_t width;                     // Width of a video frame in pixels
  uint32_t height;                    // Height of a video frame in pixels
  int32_t stride;                     // Number of pixels between consecutive lines
                                      // May be negative (for example for RGB space)
  wmp_yuv_format_t yuv_format;        // Raster format
  wmp_format_t format;                // Interlacing mode
  wmp_hdr_mode_t hdr_mode;            // HDR description
  uint32_t fps_num;                   // Numerator of the fps e.g. 30000
  uint32_t fps_den;                   // Denominator of the fps e.g. .1001 for 29.97
  wmp_codec_t codec;                  // Codec used to encode the video content
  uint32_t seg_min;                   // Min segment duration in frames
  uint32_t seg_max;                   // Max segment duration in frames
  wmp_mode_t enc_mode;                // Encoding mode
  int8_t content_identifier[256];     // Identifier of the content, null terminated
array
} wmp_content_description_t;
```

4.1.1 Raster Format

An exhaustive list of raster formats is defined in `ffmpeg` (`ffmpeg.exe -pix_fmts`). Note that it also includes the data size of pixels and bit depth. For example, a YUV 4:2:0 progressive video content with 8-bit depth is represented by `yuv420p`. The API of the WMP supports the following raster formats:

```
typedef enum {
  gray                =  0,
  yuv420p             =  1,
  yuv422p             =  2,
  yuv444p             =  3,
  yuv420p10le         =  4,
  yuv422p10le         =  5,
  yuv444p10le         =  6,
  yuv420p12le         =  7,
  yuv422p12le         =  8,
  yuv444p12le         =  9,
  yuv_format_undefined = 10
} wmp_yuv_format_t;
```

4.1.2 Interlacing

The API of the WMP supports the following modes of interlacing:

```
typedef enum {
  FF_INTERLACED_TOP_FIRST    = 0, // Interlaced format with odd/even indication
  FF_INTERLACED_BOTTOM_FIRST = 1, // Interlaced format with odd/even indication
  FF_PROG                    = 2, // Progressive mode
  FF_3DSBS                   = 3, // 3-D Side-by-Side
```

```
  FF_3DTB                    = 4  // 3-D Top-Bottom
} wmp_format_t;
```

4.1.3 Dynamic Range

The API of the WMP supports the following dynamic ranges:

```
typedef enum {
  SDR             = 1,
  HDR10           = 2,
  HDR10PLUS       = 3,
  HLG             = 4,
  DOLBYVISION     = 5,
  SL-HDR-1        = 6,
  range_undefined = 99
} wmp_hdr_mode_t;
```

This API does not make any assumption on clamping. If required, this can be added either when integrating the WMP and ENC or when deploying.

4.1.4 Video Codec

The API of the WMP supports the following video codecs:

```
typedef enum {
  RAW             = 0,
  AVC             = 1,
  HEVC            = 2,
  AV1             = 3,
  MPEG4           = 4,
  VP9             = 5,
  VP10            = 6,
  VVC             = 7,
  EVC             = 8,
  LCEVC           = 9,
  codec_undefined = 99
} wmp_codec_t;
```

This parameter is mandatory for watermarking technologies operating in the compressed domain. It is optional for watermarking technologies operating in the baseband domain, in which case the value `codec_undefined` shall be used. However, if in-band metadata is produced by the watermarking technology, this parameter shall be properly set to format the metadata accordingly (see Annex B).

4.1.5 ABR Segmentation

The parameters `seg_min` and `seg_max` define the boundaries length of any segment under any segmentation process. They enable the WMP to distribute the watermark embedding accordingly to guarantee maximum of a single variation per segment. Values should be as accurate as possible and setting `seg_min=seg_max` allows for the most efficient bit distribution. `seg_max` is an upper bound.

Note: This may be required for VOD content when every segment is not necessarily carrying watermark information and a certain number of bits must be embedded per a given duration (e.g. 10 bits for 5 minutes). These parameters are then helpful for proper calculation of the bit distribution.

4.1.6 Encoding Mode

As shown in Figure 3, in VOD content preparation workflow, the WMP may be used in two passes as are video encoders. The first pass is used to analyse the video content to be processed and the second pass actually

generates the Variants. For Live content preparation workflow, because of real-time constraints, there is no possibility to have a second pass.

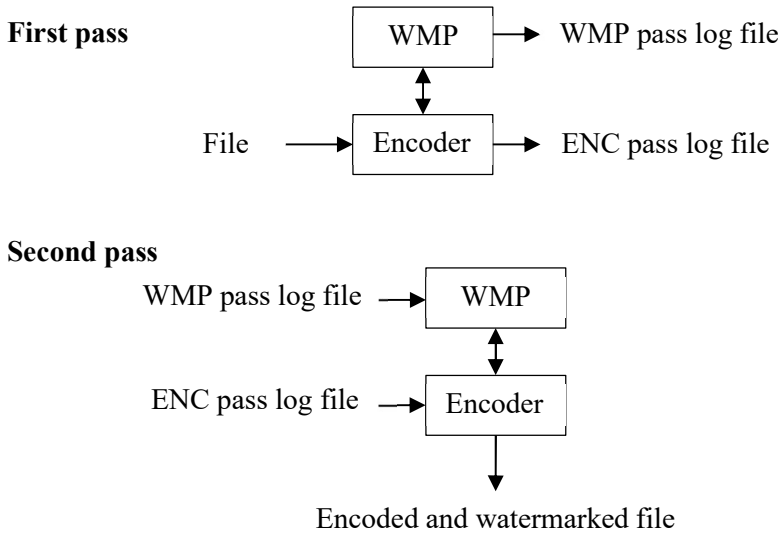


Figure 3: Two pass encoding workflow where `mode` = `ENC_TWO_PASS`.

The API of the WMP supports the following encoding modes:

```
typedef enum {
  ENC_ONE_PASS = 1, // VBR/CBR encoding using one pass
  ENC_TWO_PASS = 2, // VBR/CBR encoding using two passes
  ENC_LIVE     = 3  // Live encoding
} wmp_mode_t;
```

It is expected that the WMP instance manages internally the status of encoding a frame when in `ENC_TWO_PASS` mode. It means that the WMP knows whether this is the first or second pass when receiving a frame to process.

4.2 Video Frame Description

In essence, the WMP operates frame by frame. Each video frame that is fed to the WMP is described using a data structure that contains the information listed below:

```
typedef struct {
  wmp_frame_type_t   frame_type;        // Type of frame
  uint32_t           frame_number;      // Frame sequence number in presentation order
  uint64_t           PTS;               // Presentation Time Stamp (see [5])
  uint64_t           DTS;               // Decoding Time Stamp (see [5])
  uint32_t           encoder_id;        // ENC identifier
  uint32_t           seq_number;        // Sequence number
  uint8_t            frag_start;        // New EBP fragment indicator: 0 or 1
  uint8_t            seg_start;         // New EBP segment indicator: 0 or 1
  unit32_t           frame_buffer_len;  // Length of the frame buffer
  uint8_t           *frame_buffer;      // Frame in specified raster or codec format
  uint8_t           *enc_data;          // Blob containing ENC vendor-specific data
} wmp_frame_description_t;
```

4.2.1 Type of Frame

The WMP may adjust its watermarking strategy depending on the type of the video frame. The API of the WMP supports the MPEG types of frames listed below. If the ENC cannot provide this information, this field shall be set to the value `NN`. If an I-frame is also an IDR frame, then it shall be declared as an IDR frame.

```
typedef enum {
  NN  = 0,
  IDR = 1,
  I   = 2,
  P   = 3,
  B   = 4,
  b   = 5 // (non referenced B-frame)
} wmp_frame_type_t;
```

4.2.2 PTS and DTS

These parameters are not relevant for watermarking technologies operating in the baseband domain. In that case, they can be arbitrarily set to zero.

4.2.3 Encoder Identifier

A WMP instance may generate all the Variants of the watermarking system or, alternately, it may generate only one of them. In the latter case, several ENCs will run in parallel and the field `encoder_id` will let the WMP know which encoder it is interacting with and which Variant shall be generated. Examples are provided in Section 6.3.1.

4.2.4 Sequence number and ABR Segmentation

In addition to the high level ABR segmentation signalling defined in Section 4.1.5, the WMP may require to know if a video frame is the beginning of an ABR segment. This information can be inferred if the ENC can provide a sequence number (`seq_number`) for each frame. Alternately, the ENC can rely on Encoder Boundary Point (EBP) signalling such as defined in [5]. The binary flags `frag_start` and `seg_start` can be used to indicate the beginning of short fragments (typically a DASH 2 seconds segment) and long segments (typically an HLS 6 seconds segment) respectively[1].

When used, `seq_number` follows this rule: first = 1 (0 if unavailable).

4.2.5 Frame Buffer

If the WMP operates with baseband video, the buffer `frame_buffer` contains the pixel values of a video frame according to the pixel format defined in the content description (see Section 4.1). In contrast, if the WMP operates in the compressed domain, the buffer `frame_buffer` contains a portion of encoded video e.g. an MPEG Access Unit. In both cases, the length in bytes of the frame buffer is given by `frame_buffer_len`.

4.3 Watermarked Frames Description

The structure `wmp_mark_description_t` is composed of:

```
typedef struct {
  uint32_t                nb_variants;                    // Number of Variants
  wmp_frame_description_t variants[max_variants];         // Generated Variants
  uint8_t                 inband_metadata_size;           // Metadata size
  uint8_t    inband_metadata[max_inband_metadata_size];   // SEI to be added
```

[1] The 'fragment' and 'segment' terminology in the definition of `frag_start` and `seg_start` must be understood as defined in [6]. They are not CMAF fragments/segments.

```
} wmp_mark_description_t;
```

4.3.1 Number of Created Variants

For a given input video frame, the WMP may provide one or several Variants. If the frame is not watermarked, then the `nb_variants` variable will be set to zero (0); if it is watermarked, then there are several Variants (see examples in Section 6.3.1) and the number of Variants is given by the value of `nb_variants`, i.e. 1, 2… depending on the configuration. Note that `nb_variants` cannot take values higher than `max_variants` defined in `WMP_Open`. If parallel encoders are used, then each encoder will output one Variant and, in this case `nb_variants=1` is the maximum value.

4.3.2 In-band Metadata

The ENC shall examine these two elements in order to determine whether it shall introduce extra metadata in the video bitstream:

1. `inband_metadata_size`: The effective size of `inband_metadata` in bytes.
2. `inband_metadata`: It is the concatenation of the `UUID` and `watermarking_metadata` of the payload for a Non-VCL units as described in Annex B depending on the codec.

This is optional, if no metadata is provided, the `inband_metadata_size` shall be explicitly set to zero (0). It contains vendor-specific data.

5 PROCESSING MODES

The following principles apply for the management of the shared buffers:

- The ENC is the owner of the memory buffers, namely `frame_description` (see section 4.2), representing the input frame, and `mark_description` (see section 4.3), representing the watermarked Variant. It means that ENC must pre-allocate these buffers before `WMP_ProcessFrame` is invoked.
- WMP sets the value of the `nb_variants` variable in `mark_description` to zero or a positive value (the maximum been defined by `max_variants`), in order to communicate "non-watermarked vs. number of Variants" frame, respectively – see the explanation of `nb_variants` in Section 4.3.1.

There are, theoretically, several processing modes that are possible with the parameters of the API defined in Section 6. The processing modes are governed by:

- The use of a callback function or not: If a callback function is used, the memory can only be released when the callback is invoked.
- The value of `nb_variant`: There are optimization cases allowing to use the `frame_description` content as replacement for the values for the `mark_description` and thereby avoid the need to copy full frame buffers.
- The values in `delay_description`: This allows the WMP to tell the ENC that WMP will add some delay, hence impacting when shared memory can be released and how much memory shall be budgeted by the ENC.

Based on the feedback from vendors with existing implementations, the three following cases are detailed as they represent models to be supported at the time of writing this document

- Without a callback function and an added delay of n frames (n could be equal to 0) and with the possibility that `nb_variant` can sometimes be equal to 0.
    - Because of the delay of n frames and the absence of a callback function, the ENC must keep the shared buffer of `frame_description` for n+1 calls of the processing function. It provides the WMP with an access to the input content as long as necessary for generating the Variants. When `nb_variant` is equal to 0, the ENC needs to get from the input `frame_description` the (non-modified) Variants that will be used in the next steps of the processing chain. Shared memory `mark_description` can always be released after exiting from the processing function and once the ENC has made use of it.
- Without a callback function and an added delay of n frames (n could be equal to 0) and `nb_variant` cannot be equal to 0
    - This case is very similar to the previous one, the ENC must keep the shared buffer `frame_description` for n+1 calls of the processing function. However, since `nb_variant` is always different from 0, Variants are always provided back in the `mark_description` that is part of the shared memory. As in the previous case, `mark_description` can always be released after exiting from the processing function and once the ENC has made use of it.
- With a callback function and an added delay of maximum t milliseconds and `nb_variant` cannot be equal to 0
    - The management of the memory is driven by the invocation of the dedicated callback function. When the ENC receives a corresponding callback call, any shared buffer `frame_description` and `mark_description` that is an argument of the callback function can be released as soon as the ENC made its own processing with the `mark_description` content. The ENC always get Variants in `mark_description` as `nb_variant` cannot be equal to 0.

6 APPLICATION PROGRAMMING INTERFACE

The WMP functionality is organized in five stateful API calls:

1. `WMP_Open`, which creates a WMP instance to be shared among all subsequent calls – see Section 6.1
2. `WMP_InitContent`, which initializes the earlier created instance with the content description (i.e. what content the instance is supposed to process) – see Section 6.2
3. `WMP_ProcessFrame`, which is called for each frame of the content to be processed by the WMP instance – see Section 6.3
4. `WMP_ClearContent`, which clears the content description of the WMP instance – see Section 6.4
5. `WMP_Close`, which destroys the WMP instance – see Section 6.5

All functions of the API return with one of the status codes defined in Section 6.6.

This document describes version 1.0 of the API.

6.1 WMP Instance Creation

This function is invoked to initialize the WMP. It takes in input several configurations parameters as well as pointers to callback functions that may be invoked by the WMP. If successful, this function returns a pointer to a data structure containing relevant information to operate the created WMP instance.

```
wmp_status_t WMP_Open(uint32_t          init_data_size,
                      const void       *init_data,
                      uint32_t          wm_id_length,
                      uint32_t          max_variants,
                      uint32_t          use_EBP_signal,
                      void             *log_message_callback,
                      void             *mark_ready_callback,
                      void            **instance)
```

Input parameter	Description
`init_data_size`	Size in bytes of the blob of data `init_data`.
`init_data`	Blob of data containing configuration parameters for the WMP. The exact structure of this blob of data depends of the watermarking vendor and could include, for example, the path for the file to be created by the WMP output (see Annex B). The ENC is responsible for allocating and filling this data structure with relevant information. This structure is unaltered by the function. The ENC obtains the data for filling this blob in a WMP vendor-specific manner.
`wm_id_length`	Number of symbols composing the watermarking identifier to be embedded at a later stage. This may be present in `init_data`, in this case, this must be the same value.
`max_variants`	Maximum number of Variants that this WMP instance shall create. This may be present in `init_data`, in this case, this must be the same value.
`use_EBP_signal`	Set to 1 if the EBP signalling in `frame_description` is used. Set to 0 otherwise. This may be present in `init_data`, in this case, this must be the same value.
`log_message_callback`	Callback function used by the WMP to escalate logs to the ENC.

mark_ready_callback	Optional callback function required for the WMP to operate in case Variants are not provided when WMP_ProcessFrame() returns. It shall be set to NULL if it is not used.
instance	The created WMP instance will be returned via this parameter. It will be set to NULL in case of error.

6.1.1 Log Callback Function

This callback function is invoked by the WMP to provide log information (error, warning, info, debug) to the ENC. The ENC shall incorporates these log messages as part of its general logs. This callback function shall return one of the status code defined in Section 6.6 to indicate whether or not the log message has been successfully processed by the ENC or not.

```
typedef wmp_status_t (*log_message_callback)(wmp_logs_level_t     log_level,
                                             char               *log_message)
```

The log_level values are in descending order, meaning that the lower the value is, the higher the importance of the log information is. The different log level values are:

```
typedef enum {
  ERROR = 0,
  WARNING,
  INFO,
  DEBUG,
  MAX_LOGS
} wmp_logs_level_t;
```

6.1.2 Mark Ready Callback Function

This callback function is invoked when the Variants generated by the WMP are not provided when WMP_ProcessFrame() returns. In that case, the WMP invokes this callback to notify the ENC that a frame has been fully processed. The ENC shall then push the generated Variants further downstream. Moreover, invoking this callback indicates that the WMP will no longer reference the original input frame as well as the watermarked frames and that the ENC can reuse the underlying shared memory buffers. This callback function shall return one of the status code defined in Section 6.6 to indicate whether or not the ENC has successfully processed the provided frames and Variants.

```
Typedef

wmp_status_t (*mark_ready_callback)(wmp_frame_description_t *frame_description,
                                    wmp_mark_description_t *mark_description)
```

6.2 Content Initialization

This function takes in input the description of the video content to be processed and attaches it to a created WMP instance. The WMP returns information about its processing delay and the amount of in-band metadata that may need to be incorporated to the output video content.

```
wmp_status_t WMP_InitContent(const wmp_content_description_t *content_description,
                                   wmp_delay_description_t   *delay_description,
                                   uint16_t                 *max_inband_metadata_size,
                                   void                      *instance)
```

Input parameter	Description

`content_description`	Pointer to a data structure containing the description of the video content to be processed by the WMP instance (see Section 4.1). The ENC is responsible for allocating and filling this structure. It is unaltered by the function.
`delay_description`	Pointer to a data structure containing information about the processing delay introduced by the WMP (see below). The ENC is responsible for allocating this structure and the WMP fills it with relevant information.
`max_inband_metadata_size`	This is the maximum size in bytes of `inband_metadata` part of the `mark_description` structure. This value is returned by the WMP so that the ENC can properly pre-allocate the memory buffers of Variants.
`instance`	Pointer to a created WMP instance that shall process the frames of `content_description`.

6.2.1 Processing delay

When the WMP processes video content, it may introduce some delay in the video processing pipeline. Such delay may be dependent on some characteristics of the video content, e.g. the resolution, the video codec, the video bitrate, etc. To notify the ENC of this processing delay, the WMP fills a data structure previously allocated by the ENC.

```
typedef enum {
  NO_DELAY = 0, // No delay is added (delay value shall be set to 0)
  TIME     = 1, // Time delay expressed in milliseconds
  FRAME    = 2  // Frame delay expressed in number of frames
} wmp_delay_type_t;


typedef struct {
  delay_type_t delay_type; // Type of delay
  uint32_t     value;      // Effective delay introduced by the WMP (in ms or frames)
} wmp_delay_description_t;
```

The data structure `wmp_delay_description_t` first indicates if the introduced delay will be expressed in milliseconds (time delay) or in number of frames (frame delay). Usually, when the WMP provides the Variants when `WMP_ProcessFrame()` returns, the delay is a number of frames whereas it is rather expressed in milliseconds if a callback function is used. Such information is expected to help the ENC to properly provision buffers that will be shared with the WMP.

If the WMP does not introduce any delay, the type of delay shall be set to `NO_DELAY` and the value set to 0.

6.3 Frame Processing

This method is called repeatedly to process successive frames of the video content and produce Variants. For baseband watermarking technologies, frames should be passed in presentation order. Conversely, for compressed domain watermarking technologies, frames shall be passed in decoding order.

```
wmp_status_t WMP_ProcessFrame(const wmp_frame_description_t      *frame_description,
                                    wmp_mark_description_t       *mark_description,
                                    void                         *instance)
```

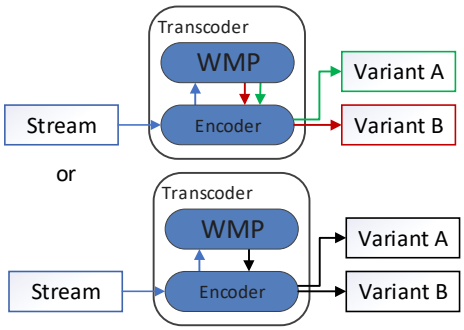
Input parameter	Description
`frame_description`	Data structure containing the description of the frame to be processed by the WMP (see Section 4.2). The ENC is responsible for allocating and filling this structure with relevant information. It is unaltered by the function. The ENC is also responsible for deallocating this data structure after its use.

`mark_description`	Data structure containing the description of the watermarked frames generated by the WMP (see Section 4.3). The ENC is responsible for allocating this structure. WMP fills it with relevant information. It is provided for every frame.
`instance`	Instance of the WMP to be used for processing the input frame.

6.3.1 Examples of WMP Parameters Settings

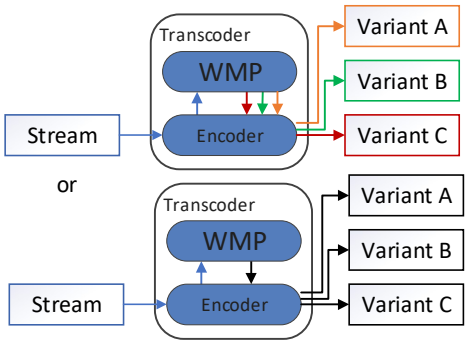
The following are examples of setting some parameters in the `frame_description` and `mark_description` structures.

Example 1: An ENC receives one frame and outputs two Variants created by the WMP. Optionally, the WMP may decide to output no Variant or only one Variant if there is no difference between A/B (for example if adding only a time stamp).



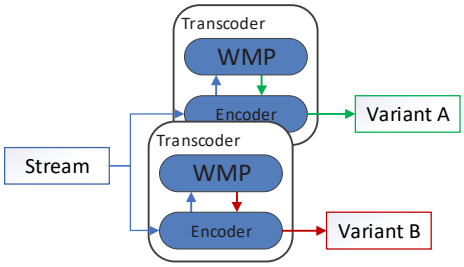
- `max_variants = 2`
  `// General parameter of the instance.`
- `nb_variants = 0, 1 or 2`
  `// If equal to 0, the WMP does not watermark the frame. If equal to 1, the WMP produced a single Variant and the ENC can overlook the content of variants[1].`
- `encoder_id = 1`

Example 2: An encoder receives one frame and outputs three Variants created by the WMP. Optionally, the WMP may decide to output no Variant or only one Variant if there is no difference between A/B/C.



- `max_variants = 3`
  `// General parameter of the instance.`
- `nb_variants = 0, 1 or 3`
  `// If equal to 0, WMP does not watermark the frame. If equal to 1, the WMP produced a single Variant and the ENC shall overlook the content of variants[1] and variants[2].`
- `encoder_id = 1`

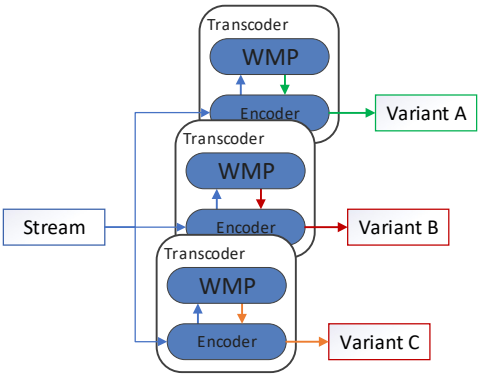
Example 3: Two ENCs are used in parallel, both receive the same frame and each encoder outputs one Variant.



For each transcoder:

- `max_variants = 1`
  // General parameter of the instance.
- `nb_variants = 0 or 1`
  // If equal to 0, the WMP does not watermark the frame. Each transcoder outputs only one Variant.
- `encoder_id = 1 or 2`
  // Each encoder has a different ID.

Example 4: Three ENCs are used in parallel; each one receives the same frame and outputs one Variant.



For each transcoder:

- `max_variants = 1`
  // General parameter of the instance.
- `nb_variants = 0 or 1`
  // If equal to 0, the WMP does not watermark the frame. Each transcoder output only one Variant.
- `encoder_id = 1 or 2 or 3`
  // Each encoder has a different ID.

6.4 Content Purge

The ENC invokes this function to purge a WMP instance prior to its termination or its reconfiguration to process another video content having possibly different characteristics. Once this function has returned, the WMP will never invoke the `mark_ready_callback` function if a callback function is defined and will never reference shared buffers provided previously. Before exiting, several callback could be triggered, if used, in order to flush the shared buffer in the pipeline. If no callback function is used, it is the responsibility of the ENC to release shared memory, as a consequence, few frames may not be marked at the end of the content.

```
wmp_status_t WMP_ClearContent(void *instance)
```

Input parameter	Description
`instance`	Instance of the WMP for which the content descriptor is reset.

6.5 WMP Instance Termination

The ENC invokes this function to terminate a running WMP instance.

```
wmp_status_t WMP_Close(void *instance)
```

Input parameter	Description
`instance`	Instance of the WMP to be terminated.

6.6 API Return Status Codes

The following status code are defined as part of this API:

```
typedef enum {
  WMP_SUCCESS = 0,
  WMP_E_MEM_ALLOC = 1,           // Error during the memory allocation
  WMP_E_MEM_FREE = 2,            // Error during the memory release
  WMP_E_INIT_FORMAT = 3,         // Error during the processing of init_data
  WMP_E_CONTENT_FORMAT = 4,      // Error during the processing of content_description
  WMP_E_WM_ID_LENGTH_RANGE = 5,  // wm_id_length is out of supported range
  WMP_E_MAX_VARIANTS_RANGE = 6,  // max_variants value is out of supported range
  WMP_E_MARK_READY_CALLBACK_MISSING = 7, // Callback pointer is mandatory
  WMP_E_INIT = 8,                // Error other than those specified above during init
  WMP_E_FRAME_FORMAT = 8,        // Error occurred during reading frame_description
  WMP_E_GENERIC = 99             // Generic error code
} wmp_status_t;
```

Additional error codes can be defined by any WMP provider. These error codes must be above 99. These error codes are then specific to this WMP provider and to its implementation.

ANNEX A CALL SEQUENCE DIAGRAM

A.1 INTRODUCTION

The following exemplifies two reference WMP flows and associated sequence calls with main parameters. Both examples assume that an A/B version of the input video content is expected and that a single WMP instance is created for creating these Variants (example 1 in the previous section). The flow presented in section A.2 is typically for a WMP working in the baseband space while the flow presented in section A.3 is for a WMP working in the compressed domain.

A.2 WITHOUT A CALLBACK FUNCTION

Figure 4 is a typical flow when no callback function is defined. The watermarked frames are provided back when the function `WMP_ProcessFrame()` returns. In Figure 4, the function `WMP_ProcessFrame()` is blocking and `ENC` waits for `WMP` to end its processing before the next call of `WMP_ProcessFrame()`. Note that, in this flow, the data in the returned `mark_description` may correspond to a video frame provided in a previous call in `frame_description`. This delay is expressed using the structure `delay_description` returned by the function `WMP_InitContent()`.

For example, with a delay of two frames, `mark_desc_3` contains the watermarked frames for the frame provided in `frame_desc_1`. Assuming that the content is SDR 1080p at 24 fps, the relevant parameters in the API calls would be:

`WMP_Open()`

`init_data_size`	`Variable`
`init_data`	`Variable`
`wm_id_length`	`Variable`
`max_variants`	`2 – creation of A/B Variants`
`use_EBP_signal`	`Variable`
`log_message_callback`	`Pointer to a function`
`mark_ready_callback`	`NULL – no callback function`
`instance`	`Pointer to WMP`

`WMP_InitContent()`

`content_description`	`width=1920;`
	`height=1080;`
	`stride=1920;`
	`yuv_format=1;`
	`format=2,`
	`hdr_mode=1;`
	`fps_num=24;`
	`fps_den=1;`
	`codec=99; // Irrelevant parameter for baseband`
	`seg_min=48;`
	`seg_max=48;`
	`mode=2;`

`delay_description`	`delay_type=2;` `value=2; // mark_desc_(n+2) contains watermarked frames for the frame provided in frame_desc_(n)`
`max_inband_metadata_size`	`Variable`
`instance`	`Pointer to WMP`

WMP_ProcessFrame()

frame_description	All parameters are different per frame
mark_description	All parameters are different per frame
instance	Pointer to WMP

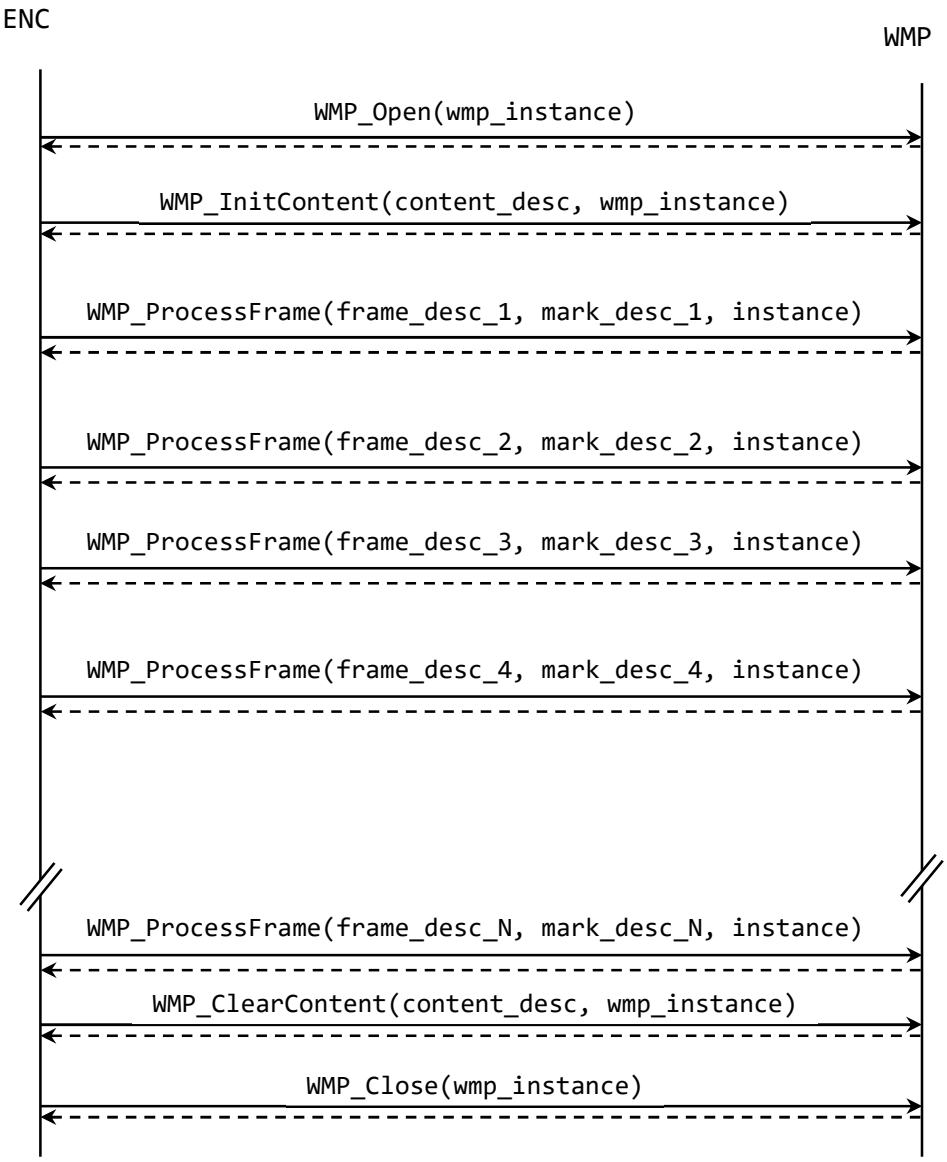


Figure 4: Illustration of the calls sequence diagram when the WMP operates without a callback function.

A.3 WITH A CALLBACK FUNCTION

Figure 5 depicts a similar flow when a dedicated callback function is used to output watermarked frames.

In Figure 5, the function WMP_ProcessFrame() returns almost immediately and ENC can rapidly push several video frames to WMP if needed. WMP then invokes the callback mark_ready_callback() to notify ENC that it

produced Variants for an input frame and that it will no longer reference the specified `frame_description` and `mark_description`. `ENC` can then reuse the memory allocated to these structures once watermarked content is pushed further in the content preparation pipeline.

In this example, assuming content is SDR 1080p at 24 fps encoded with AVC, the relevant parameters in the calls would be

`WMP_Open()`

`init_data_size`	`Variable`
`init_data`	`Variable`
`wm_id_length`	`Variable`
`max_variants`	`2 – creation of A/B Variants`
`use_EBP_signal`	`Variable`
`log_message_callback`	`Pointer to a function`
`mark_ready_callback`	`Pointer to a function`
`instance`	`Pointer to WMP`

`WMP_InitContent()`

`content_description`	`Width=1920;`
	`Height=1080;`
	`Stride=1920;`
	`yuv_format=1;`
	`format=2,`
	`hdr_mode=1;`
	`fps_num=24;`
	`fps_den=1;`
	`codec=1;`
	`seg_min=48;`
	`seg_max=48;`
	`mode=2;`

`delay_description`	`delay_type=1;` `value=50;  // The callback function provides watermarked data with 50 ms delay`
`max_inband_metadata_size`	`Variable`
`instance`	`Pointer to WMP`

`WMP_ProcessFrame()`

`frame_description`	`All parameters are different per frame`
`mark_description`	`While been present and memory is allocated, watermarked data is not provided in this call`

`mark_ready_callback()`

`frame_description`	`All parameters are different per frame`
`mark_description`	`All parameters are different per frame`

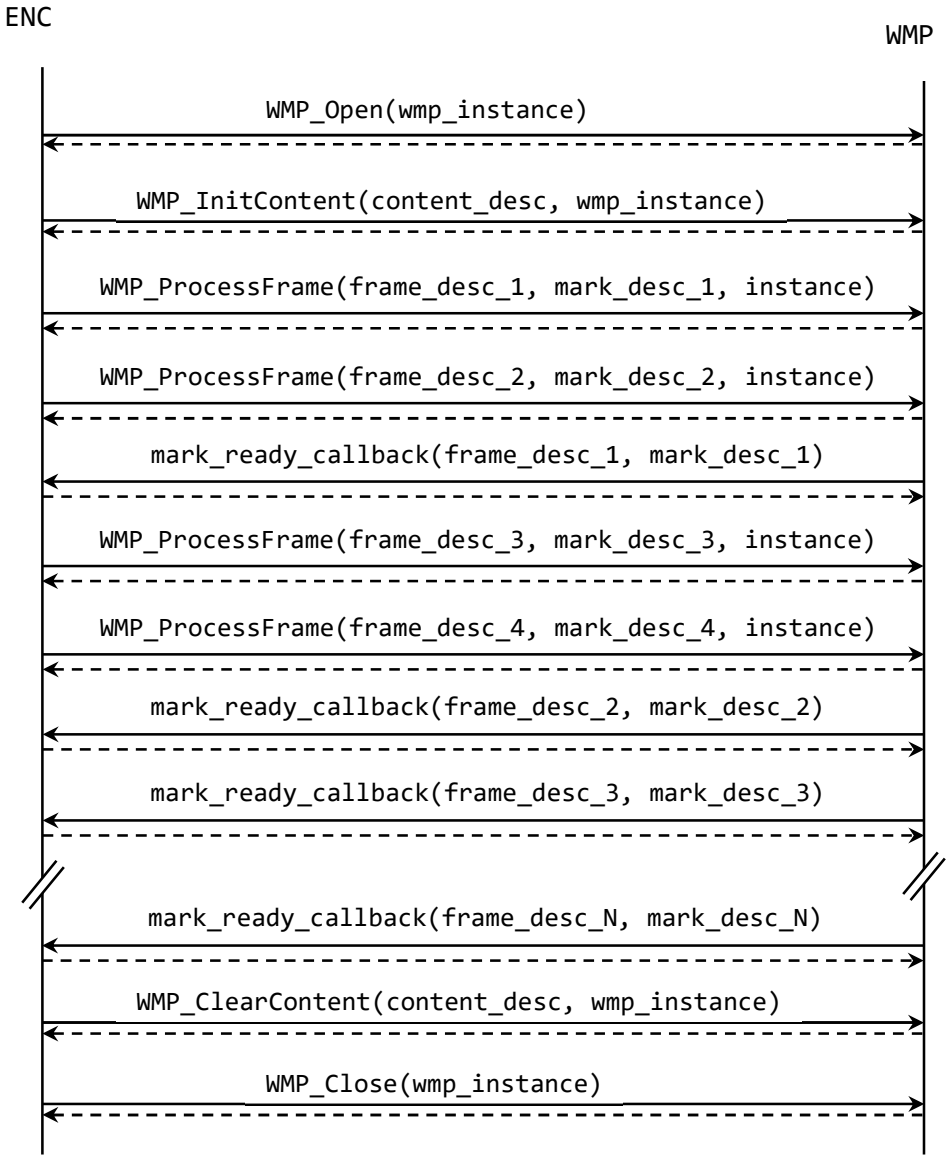


Figure 5: Illustration of the calls sequence diagram when the WMP operates with a callback function.

ANNEX B IN-BAND METADATA

B.1 INTRODUCTION

Encoders produce formatted streams in order to be compliant with the ingest format of the next in-line components or systems. In case of OTT, these next in-line can be Origins or JiT (Just-in-Time) Packagers. Encoders also make some initial formatting decisions (e.g. EBP, RAP, IDR, etc.). To avoid two information channels between an upstream component and a downstream component in the Live flows, where one channel is the video stream and the other channel is out-of-band metadata with locations, Encoders can introduce in-band metadata located within the encoded video bitstream.

When an Encoder calls `WMP_ProcessFrame,` it submits the `frame_description` structure with the metadata such as: `frame_number` or `seq_number`. In order to enable proper switching between Variants in the downstream components, an out-of-band embed locations file can be constructed. While this may work for VOD deployments, it is risky and introduces significant (repetitive) overhead in terms of out-of-band file copies for Live deployments.

The same effect can be achieved by an in-band artifact collocated with the actual video frames, where the switching between Variants can be recovered by quick scan of the final (formatted) stream while avoiding out-of-band synchronization challenges. Therefore, instead of having two channels and potential misalignments between them in Live deployments, a single channel carries all necessary information and metadata "piggy-backs" the existing infrastructure.

B.2 AVC METADATA INCLUSION

Metadata is added in the stream as non-VCL NALUs (user data unregistered SEI NAL) as described in Section 7.3.1 and Annex D of [3]. These NALUs are interleaved with VCL NALUs, which are carrying video frames data. Watermarking metadata can be seamlessly carried with other video bitstream Non-VCL data.

Table 1 gives the format of the SEI NALU that carries watermarking metadata.

Table 1: Watermarking metadata SEI NAL for AVC.

Name	Descriptor	Value	Description
`forbidden_zero_bit`	f(1)	0	
`nal_ref_idc`	u(2)	0	
`nal_unit_type`	u(5)	6	SEI NAL
`payloadType`	u(8)	5	user_data_unregistered
`payloadSize`	u(8x)		SEI payload size
`uuid_iso_iec_11578`	u(128)		UUID
`user_data_payload_byte`	u(n)		Watermarking metadata

`uuid_iso_iec_11578`: It shall have a value specified as a UUID according to the procedures of ISO/IEC 11578:1996 Annex A. Its value is vendor dependent e.g. `0x4062b69958c7442081fa091040882077.`

B.3 HEVC METADATA INCLUSION

Metadata is added in the stream as non-VCL NALUs (user data unregistered SEI NAL) as described in Section 7.3.1.1 and Annex D of [4]. As in the case of the AVC codec, these NALUs are interleaved with VCL NALUs, which are carrying video frames data. Watermarking metadata can be seamlessly carried with other video bitstream Non-VCL data.

Table 2 gives the format of the SEI NALU that carries watermarking metadata.

Table 2: Watermarking metadata SEI NAL for HEVC.

Name	Descriptor	Value	Description

forbidden_zero_bit	f(1)	0	Always zero
nal_unit_type	u(6)	39	SEI NAL
layer_id	u(6)	0	Layer id
temporal_id_plus1	u(3)	1	Temporal identifier
payloadType	u(8)	5	SEI payload unregistered data
payloadSize	u(8x)	26	SEI payload size
uuid_iso_iec_11578	u(128)		UUID
user_data_payload_byte	u(n)		Watermarking metadata

uuid_iso_iec_11578: It shall have a value specified as a UUID according to the procedures of ISO/IEC 11578:1996 Annex A. Its value is vendor dependent.

B.4 AV1 METADATA INCLUSION

The AV1 codec is packetized in so called "Open Bitstream Units" (OBU), which purpose matches the one of NAL units in codecs such as AVC and HEVC. Moreover, the purpose of Reserved OBU (obu_type = 0) is similar to the purpose of SEI and user data. According to the Alliance for Open Media, AV1 codec and Section 5.4 of [7]: "*Reserved OBUs do not have a defined syntax. The obu_type reserved values are reserved for future use. Decoders should ignore the entire OBU if they do not understand the obu_type. Ignoring the OBU can be done based on obu_size*." Consequently, watermarking metadata can be added in the stream as the payload of a Reserved OBU.

Table 3: Watermarking metadata and Reserved OBU for AV1.

Name	Descriptor	Value	Description
obu_forbidden_bit	f(1)	0	Always zero for all OBUs
obu_type	f(4)	0	Reserved OBU enumeration
obu_extension_flag	f(1)	0	No extensions for this instance
obu_has_size_field	f(1)	1	Read "leb128" encoded size
obu_reserved_bit1	f(1)	0	Reserved bit set to 0 for all OBUs
obu_size	leb128	e.g. 0x1e	Watermark metadata size as leb128
uuid_iso_iec_11578	u(128)		UUID
metadata	u(n)		Watermarking metadata

AV1 stream must include the obu_size inside the Reserved OBU, and it must be encoded as unsigned integer represented by a variable number of little-endian bytes – for the explanation see Section 4.10.5 of [7]. The obu_size includes both uuid_iso_iec_11578 and metadata.

uuid_iso_iec_11578: It shall have a value specified as a UUID according to the procedures of ISO/IEC 11578:1996 Annex A. Its value is vendor dependent.