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Abstract

This document provides requirements for a video codec designed
mainly for use over the Internet. In addition, an evaluation
methodology needed for measuring the parameters (compression
efficiency, computational complexity, etc.) to ensure whether the
stated requirements are fulfilled or not.

Table of Contents

1. Introduction

In this document, the requirements for a video codec designed mainly for use over the Internet are presented. The requirements encompass a wide range of applications that use data transmission over the Internet including IPTV (broadcasting over IP-based networks), peer-to-peer video conferencing, video sharing, screencasting, and video monitoring/ surveillance. For each application, typical resolutions, frame-rates and picture access modes are presented. Specific requirements related to data transmission over packet-loss networks are considered as well. In this document, when we discuss data protection techniques we only refer to methods designed and implemented to protect data inside the video codec since there are many existing techniques that protect generic data transmitted over packet-loss networks. From the theoretical point of view, both packet-loss and bit-error robustness can be beneficial for video codecs. In practice, packet losses are a more significant problem than bit corruption in IP networks. It is worth noting that there is an evident interdependence between possible amount of delay and the necessity of error robust video streams:

o If an amount of delay is not crucial for an application, then reliable transport protocols such as TCP that resends undelivered packets can be used to guarantee correct decoding of transmitted data.

o If the amount of delay must be kept low, then either data transmission should be error free (e.g., by using managed networks) or compressed video stream should be error resilient.

Thus, error resilience can be useful for delay-critical applications to provide low delay in packet-loss environment.

2. Applications

In this chapter, an overview of video codec applications that are currently available on the Internet market is presented. It is worth noting that there are different use cases for each application that define a target platform, and hence there are different types of communication channels involved (e.g., wired or wireless channels) that are characterized by different quality of service as well as bandwidth; for instance, wired channels are considerably more error-free than wireless channels and therefore require different QoS approaches. The target platform, the channel bandwidth and the channel quality determine resolutions, frame-rates and quality or bit-rates for video streams to be encoded or decoded. By default,

color format YUV 4:2:0 is assumed for the application scenarios
listed below.

2.1. Internet Protocol Television (IPTV) / IP-based over-the-top (OTT) video transmission

This is a service for delivering television content over IP-based
networks. IPTV may be classified into two main groups based on the
type of delivery, as follows:

o unicast (e.g., for video on demand), where delay is not crucial
   and, hence, error resilience is not needed;

o multicast/broadcast (e.g., for transmitting news) where zapping,
   i.e. stream changing, delay is important and, therefore, error
   resilience is required in the case of unmanaged networks like the
   Internet.

The main difference between IPTV and IP-based OTT video transmission
is that traffic is transmitted over managed (QoS-based) and
unmanaged networks in the above cases, respectively. Typical content
used in this application is news, movies, cartoons, series, TV
shows, etc. One important requirement for both groups is Random
access to pictures, i.e. random access period (RAP) should be kept
small enough (approximately, 1-15 seconds). For the second group,
two further requirements should be met:

o Temporal (frame-rate) scalability;

o Error robustness (only for IP-based OTT video transmission).

For the first use case, the two above-mentioned requirements are
optional. Support of resolution and quality (SNR) scalability is
highly desirable for the both groups. For this application, typical
values of resolutions, frame-rates, and RAPs are presented in Table
1.

Resolution *	Frame-rate, fps	PAM
2160p (4K),3840x2160	60	RA
1080p, 1920x1080	24, 50, 60	RA
1080i, 1920x1080*	30 (60 fields per second)	RA

720p, 1280x720	50, 60	RA
576p (EDTV), 720x576	25, 50	RA
576i (SDTV), 720x576*	25, 30	RA
480p (EDTV), 720x480	50, 60	RA
480i (SDTV), 720x480*	25, 30	RA

Table 1. IPTV: typical values of resolutions, frame-rates, and RAPs

NB *: Interlaced content can be handled at the higher system level
and not necessarily by using specialized video coding tools. It is
included in this table only for the sake of completeness as most
video content today is in progressive format.

2.2. Video conferencing

This is a form of video connection over the Internet. This form
allows users to establish connections to two or more people by two-
way video and audio transmission for communication in real-time. For
this application, both stationary and mobile devices can be used.
The main requirements are as follows:

o Delay should be kept as low as possible (the preferable and
   maximum end-to-end delay values should be less than 100 ms [6]
   and 320 ms [1], respectively);

o Temporal (frame-rate) scalability;

o Error robustness.

Support of resolution and quality (SNR) scalability is highly
desirable. For this application, typical values of resolutions,
frame-rates, and RAPs are presented in Table 2.

Resolution	Frame-rate, fps	PAM
1080p, 1920x1080	15, 30	JFPIC
720p, 1280x720	30, 60	JFPIC
4CIF, 704x576	30, 60	JFPIC

4SIF, 704x480	30, 60	JFPIC
VGA, 640x480	30, 60	JFPIC
360p, 640x360	30, 60	JFPIC

Table 2. Video conferencing: typical values of resolutions, frame-rates, and RAPs

2.3. Video sharing

This is a service that allows people to upload and share video data (using live streaming or not) and to watch them. It is also known as video hosting. A typical User-generated Content (UGC) scenario for this application is to capture video using mobile cameras such as GoPro or cameras integrated into smartphones (amateur video). The main requirements are as follows:

o   Random access to pictures for downloaded video data;

o   Temporal (frame-rate) scalability;

o   Error robustness.

Support of resolution and quality (SNR) scalability is highly desirable. For this application, typical values of resolutions, frame-rates, and RAPs are presented in Table 3.

Resolution	Frame-rate, fps	PAM
2160p (4K),3840x2160	24, 25, 30, 48, 50, 60	RA
1440p (2K),2560x1440	24, 25, 30, 48, 50, 60	RA
1080p, 1920x1080	24, 25, 30, 48, 50, 60	RA
720p, 1280x720	24, 25, 30, 48, 50, 60	RA
480p, 854x480	24, 25, 30, 48, 50, 60	RA
360p, 640x360	24, 25, 30, 48, 50, 60	RA

Table 3. Video sharing: typical values of resolutions, frame-rates [7], and RAPs

2.4. **Screencasting**

   This is a service that allows users to record and distribute
   computer desktop screen output. This service requires efficient
   compression of computer-generated content with high visual quality
   (up to visually and mathematically lossless) [8]. Currently, this
   application includes business presentations (powerpoint, word
   documents, email messages, etc.), animation (cartoons), gaming
   content, data visualization, i.e. such type of content that is
   characterized by fast motion, rotation, smooth shade, 3D effect,
   highly saturated colors with full resolution, clear textures and
   sharp edges with distinct colors [8]), virtual desktop
   infrastructure (VDI), screen/desktop sharing and collaboration,
   supervisory control and data acquisition (SCADA) display,
   automotive/navigation display, cloud gaming, factory automation
   display, wireless display, display wall, digital operating room
   (DiOR), etc. For this application, an important requirement is the
   support of a wide range of video formats (e.g., RGB) in addition to
   YUV 4:2:0 and YUV 4:4:4 [8]. For this application, typical values of
   resolutions, frame-rates, and RAPs are presented in Table 4.

Resolution	Frame-rate, fps	PAM
Input color format: RGB 4:4:4		
5k, 5120x2880	15, 30, 60	AI, RA, JFPIC
4k, 3840x2160	15, 30, 60	AI, RA, JFPIC
WQXGA, 2560x1600	15, 30, 60	AI, RA, JFPIC
WUXGA, 1920x1200	15, 30, 60	AI, RA, JFPIC
WSXGA+, 1680x1050	15, 30, 60	AI, RA, JFPIC
WXGA, 1280x800	15, 30, 60	AI, RA, JFPIC
XGA, 1024x768	15, 30, 60	AI, RA, JFPIC
SVGA, 800x600	15, 30, 60	AI, RA, JFPIC
VGA, 640x480	15, 30, 60	AI, RA, JFPIC

```
|                    Input color format: YUV 4:4:4              |
+----------------------+------------------------+---------------+
| 1440p (2K), 2560x1440|      15, 30, 60        | AI, RA, JFPIC |
+----------------------+------------------------+---------------+
| 1080p, 1920x1080     |      15, 30, 60        | AI, RA, JFPIC |
+----------------------+------------------------+---------------+
| 720p, 1280x720       |      15, 30, 60        | AI, RA, JFPIC |
+----------------------+------------------------+---------------+
```
Table 4. Screencasting for RGB and YUV 4:4:4 format: typical values
of resolutions, frame-rates, and RAPs

2.5. Game streaming

This is a service that provides game content over the Internet to
different local devices such as notebooks, gaming tablets, etc. In
this category of applications, server renders 3D games in cloud
server, and streams the game to any device with a wired or wireless
broadband connection [9]. There are low latency requirements for
transmitting user interactions and receiving game data in less than
a turn-around delay of 100 ms. This allows anyone to play (or
resume) full featured games from anywhere in the Internet [9]. An
example of this application is Nvidia Grid [9]. Another category
application is broadcast of video games played by people over the
Internet in real time or for later viewing [9]. There are many
companies such as Twitch, YY in China enable game broadcasting [9].
Games typically contain a lot of sharp edges and large motion [9].
The main requirements are as follows:

o Random access to pictures for game broadcasting;

o Temporal (frame-rate) scalability;

o Error robustness.

Support of resolution and quality (SNR) scalability is highly
desirable. For this application, typical values of resolutions,
frame-rates, and RAPs are similar to ones presented in Table 4.

2.6. Video monitoring / surveillance

This is a type of live broadcasting over IP-based networks. Video
streams are sent to many receivers at the same time. A new receiver
may connect to the stream at an arbitrary moment, so random access
period should be kept small enough (approximately, ~1-5 seconds).
Data are transmitted publicly in the case of video monitoring and
privately in the case of video surveillance, respectively. For IP-
cameras that have to capture, process and encode video data,

complexity including computational and hardware complexity as well
as memory bandwidth should be kept low to allow real-time
processing. In addition, support of high dynamic range as well as
resolution and quality (SNR) scalability is an essential requirement
for video surveillance. For this application, typical values of
resolutions, frame-rates, and RAPs are presented in Table 5.

Resolution	Frame-rate, fps	PAM
2160p (4K),3840x2160	12	RA, JFPIC
5Mpixels, 2560x1920	12	RA, JFPIC
1080p, 1920x1080	25	RA, JFPIC
1.3Mpixels, 1280x960	25, 30	RA, JFPIC
720p, 1280x720	25, 30	RA, JFPIC
SVGA, 800x600	25, 30	RA, JFPIC

Table 5. Video monitoring / surveillance: typical values of
resolutions, frame-rates, and RAPs

3. Requirements

Taking the requirements discussed above for specific video
applications, this chapter proposes requirements for an internet
video codec. The most basic requirement is coding efficiency, i.e.
compression performance. It should be better than for state-of-the-
art video codecs such as HEVC/H.265 and VP9. Levels to be supported
by the new codec are presented in Table 6.

Level	Example picture resolution at highest frame rate
1	640x360(230,400*)@60.0
2	640x360(230,400*)@60.0 960x540(518,400*)@30.0
3	720x576(414,720*)@75.0 960x540(518,400*)@60.0 1280x720(921,600*)@30.0

```
|             |                 1,280x720(921,600*)@68.0            |
|      4      |                 2,048x1,080(2,211,840*)@30.0        |
+-------------+-----------------------------------------------------+
|             |                 1,280x720(921,600*)@120.0           |
|      5      |                 2,048x1,080(2,211,840*)@60.0         |
+-------------+-----------------------------------------------------+
|             |                 1,920x1,080(2,073,600*)@120.0       |
|      6      |                 3,840x2,160(8,294,400*)@30.0         |
|             |                 4,096x2,160(8,847,360*)@30.0         |
+-------------+-----------------------------------------------------+
|             |                 1,920x1,080(2,073,600*)@250.0       |
|      7      |                 4,096x2,160(8,847,360*)@60.0         |
+-------------+-----------------------------------------------------+
|             |                 1,920x1,080(2,073,600*)@300.0       |
|      8      |                 4,096x2,160(8,847,360*)@120.0        |
+-------------+-----------------------------------------------------+
|             |                 3,840x2,160(8,294,400*)@120.0       |
|      9      |                 8,192x4,320(35,389,440*)@30.0        |
+-------------+-----------------------------------------------------+
|             |                 3,840x2,160(8,294,400*)@250.0       |
|     10      |                 8,192x4,320(35,389,440*)@60.0        |
+-------------+-----------------------------------------------------+
|             |                 3,840x2,160(8,294,400*)@300.0       |
|     11      |                 8,192x4,320(35,389,440*)@120.0       |
+-------------+-----------------------------------------------------+
```
Table 6. Codec levels

NB *: The quantities of pixels are presented for such applications
where a picture can have an arbitrary size (e.g., screencasting)

3.1. Basic requirements

3.1.1. Input source formats:

o Bit depth: 8- and 10-bits per color component;

o Color sampling formats: YUV 4:2:0, YUV 4:4:4

o Support of arbitrary resolution such applications where a picture
   can have an arbitrary size (e.g., screencasting)

3.1.2. Coding delay:

o Support of "low-delay" configurations (end-to-end delay should be
   up to 320 ms [1] but it's preferable value should be less than
   100 ms [6])

3.1.3. Complexity:

o Feasible real-time implementation of both an encoder and a
   decoder for hardware and software implementation based on a wide
   range of state-of-the-art platforms

3.1.4. Scalability:

o Temporal (frame-rate) scalability

3.1.5. Error resilience:

o Error resilience tools that are complementary to the error
   protection mechanisms implemented on transport level.

3.2. Optional requirements

3.2.1. Input source formats

o Bit depth: up to 16-bits per color component;

o Color sampling formats: RGB 4:4:4 and YUV 4:2:2;

o Auxiliary channel (e.g., alpha channel) support;

o Support of high dynamic range

3.2.2. Scalability:

o Resolution and quality (SNR) scalability;

o Computational complexity scalability, i.e. computational
   complexity is decreasing along with degrading picture quality

3.2.3. Complexity:

Tools that enable parallel processing (e.g., slices, tiles, wave
front propagation processing) at both encoder and decoder sides are
highly desirable for many applications.

o High-level multi-core parallelism: encoder and decoder operation,
   especially entropy encoding and decoding, should allow multiple
   frames or sub-frame regions (e.g. 1D slices, 2D tiles, or
   partitions) to be processed concurrently, either independently or
   with deterministic dependencies that can be efficiently pipelined

   o Low-level instruction set parallelism: favor algorithms that are
      SIMD/GPU friendly over inherently serial algorithms

4. Evaluation methodology

4.1. Compression performance evaluation

   As shown in Fig.1, compression performance testing is performed in 3
   ranges that encompass 12 different bit-rate values:

   o Low bit-rate range (LBR) is the range that contains the 4 lowest
      bit-rates of the 12 specified bit-rates;

   o Medium bit-rate range (MBR) is the range that contains the 4
      medium bit-rates of the 12 specified bit-rates;

   o High bit-rate range (HBR) is the range that contains the 4
      highest bit-rates of the 12 specified bit-rates.

   To avoid any rate control mechanisms that can significantly impact
   evaluation results, just nominal values of bit-rates should be
   specified in a separate document on Internet video codec testing.
   The deviation between nominal and actual values of bit-rates
   obtained for both reference and tested codecs should be less than
   the threshold value defined in the above-mention document on
   Internet video codec testing. This deviation is calculated as
   follows:

$$D = abs((BRa - BRn)/ BRn)*100\%,$$

   where BRn is a nominal value of bit-rate, BRa is an actual value of
   bit-rate obtained for either reference or tested codecs.

```
                                               Bit-rate
    ------------------------------------------------------------->
    BR0   BR1    BR2   BR3   BR4   BR5    BR6   BR7   BR8   BR9   BR10   BR11
     ^                  ^     ^                  ^     ^                  ^
     |------LBR------|     |------MBR------|     |------HBR------|
```
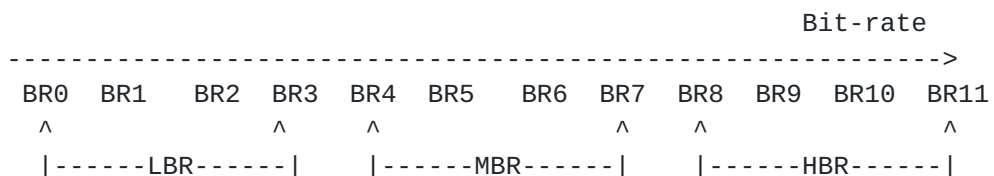
                Figure 1 Bit-rate ranges for the CBR mode

To assess the quality of output (decoded) sequences, two indexes,
PSNR [2] and MS-SSIM [2,10], should be separately calculated for
each color plane. For obtaining an integral estimation, BD-rate [11]
should be computed for each range and each quality index. Finally,
18 values should be obtained for a color format, which contains 3
color planes (e.g., for YUV or RGB). A list of video sequences that
should be used for testing as well as the 6 values of bit-rates are
defined in a separate document. Testing processes should use the
information on the codec applications presented in this document. As
the reference for evaluation, the HEVC/H.265 codec [3,4] must be
used. The reference source code of the HEVC/H.265 codec can be found
at [5]. The HEVC/H.265 codec must be configured according to [12]
and Table 9.

```
+---------------------+---------------------------------------------+
| Intra-period, second | HEVC/H.265 encoding mode according to [12]|
+---------------------+---------------------------------------------+
|         AI          |         Intra Main or Intra Main10          |
+---------------------+---------------------------------------------+
|         RA          |            Random access Main or            |
|                     |            Random access Main10             |
+---------------------+---------------------------------------------+
|        JFPIC        |              Low delay Main or              |
|                     |              Low delay Main10               |
+---------------------+---------------------------------------------+
```

Table 9. Intra-periods for different HEVC/H.265 encoding modes
according to [12]

In addition to the objective quality measures defined above,
subjective evaluation must also be performed before adopting any new
tool and a final codec standard. For subjective tests, the MOS-based
evaluation procedure must be used as described in section 2.1 of
[2]. For perception-oriented tools that primarily impact subjective
quality, additional tests may also be individually assigned even for
intermediate evaluation, subject to a decision of the NETVC WG.

5. Security Considerations

This document itself does not address any security considerations.
However, it is worth noting that a codec implementation (for both an
encoder and a decoder) should cover the worst case of computational
complexity, memory bandwidth, and physical memory size (e.g., for
decoded pictures used as references). Otherwise, it can be
considered as a security vulnerability and lead to denial-of-service
(DoS) in the case of attacks.

[6](). Conclusions

In this document, an overview of Internet video codec applications and typical use cases as well as a prioritized list of requirements for an Internet video codec are presented. An evaluation methodology for this codec is also proposed.

[7](). References

[7.1](). Normative References

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[2]   ISO/IEC PDTR 29170-1: Information technology -- Advanced image coding and evaluation methodologies -- Part 1: Guidelines for codec evaluation.

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Appendix A.   **Abbreviations used in the text of this document**

```
+--------------+----------------------------------------------------+
| Abbreviation |                    Meaning                         |
+--------------+----------------------------------------------------+
|      AI      | All-Intra (each picture is intra-coded)            |
|    BD-Rate   | Bjontegaard Delta Rate                             |
|     GOP      | Group of Picture                                   |
|     HBR      | High Bit-rate Range                                |
|     PAM      | Picture Access Mode                                |
|      RA      | Random Access                                      |
|     RAP      | Random Access Period                               |
|     IPTV     | Internet Protocol Television                       |
|    JFPIC     | Just the First Picture is Intra-Coded              |
|     LBR      | Low Bit-rate Range                                 |
|     MBR      | Medium Bit-rate Range                              |
|     MOS      | Mean Opinion Score                                 |
|    MS-SSIM   | Multi-Scale Structural Similarity quality index    |
|     OTT      | Over-The-Top                                        |
|     PSNR     | Peak Signal-to-Noise Ratio                         |
|     QoS      | Quality of Service                                 |
|     UGC      | User-Generated Content                             |
|     VDI      | Virtual Desktop Infrastructure                     |
+--------------+----------------------------------------------------+
```

Appendix B.   **Used terms**

```
+-----------------+----------------------------------------------+
|     Term        |                 Meaning                      |
+-----------------+----------------------------------------------+
|  Random access  | is the period of time between two closest    |
|  period         | independently decodable frames (pictures).   |
|                 |                                              |
| Visually        | is a form or manner of lossy compression     |
| lossless        | where the data that are lost after the file  |
| compression     | is compressed and decompressed is not        |
|                 | detectable to the eye; the compressed data   |
|                 | appearing identical to the uncompressed      |
|                 | data [13].                                   |
+-----------------+----------------------------------------------+
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