Ultra High Definition HEVC DASH Data Set

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ABSTRACT
Ultra High Definition video is entering a phase of deployment tests, with first UHD services being launched in late 2013. Most on-air broadcast UHD services will not start until 4K display market penetration is high enough, which will not happen until at least 2018. Therefore, most initial services will be offered via IPTV services or Over-The-Top delivery technologies. On the other hand, the new HEVC video compression standard, with a 50% gain over its predecessor AVC|H.264, is the natural industry choice for compressing UHD content; at the transport level, MPEG-DASH offers a complete set of tools for broadcast and broadband convergence, and is one of the first candidates for HEVC preferred transport layer. In this context, deployment tests of MPEG-DASH and UHD HEVC content are expected to be a very important topic in the next two years. In this paper, we present a Ultra High Definition HEVC DASH dataset ranging from HD to UHD in different bit rates. This data set may be used to simulate UHD DASH services, whether on-demand or live, using real-life professional quality content.

Categories and Subject Descriptors
D.3.3 [**Programming Languages**]: Video

General Terms
Algorithms, Measurement, Standardization, Documentation.

Keywords
Ultra High Definition, HEVC, HFR, Dynamic Adaptive Streaming over HTTP, DASH, Dataset

1. Introduction
Ultra High Definition content has been a major research focus for audio-visual content providers during the past decade; recent evolutions of Digital TV infrastructure, ranging from camera capabilities at the capture side to display devices, are pushing this research into deployment test phases. 2013 has seen a growing numbers of high-resolution cameras and displays, typically achieving UHDTV resolutions, i.e. 3840x2160 pixels, as defined by the International Telecommunication Union in 2012. During the 2013 International Broadcasting Convention, UHDTV was massively represented with demonstrations covering the complete production chain: cameras, video production and monitoring tools, broadcast and broadband distribution and TV playback.

Since Q.2 2013, UHDTV panel manufacturers, especially in Asia, have followed very aggressive price policies, sometimes providing a UHDTV at 30 Hz for the same price as Full High Definition (FHD, 1920x1080) at 60 or 120 Hz. In a recent study from late October 2013, *Displaybank HIS* gave a market projection for UHDTV display panels, evaluating the market penetration by unit, giving an estimated market share of 4% in 2015 (~9 million units) and 8% in 2017 (~21 million units). This study illustrates the growing importance of UHD content, however with a large predominance of FHD displays.

Digital TV is not alone in this race for UHD: with the growing consumption of video content on personal devices such as smartphones or tablets, device manufacturer are also investigating packing more pixels into personal devices. The first prototypes of 4K tablets of 12-inch screen size have already been demonstrated in 2013, and manufacturers envision market production of 4K devices in 2016. Given such figures, there is no incentive for content providers to use broadcast channels to address less than 4 % of their customers, and it is safe to state that most content providers will target IPTV or HTTP streaming for UHDTV service deployments in the years to come.

Ultra High Definition is not just a matter of pixel resolution; image frequency also plays a major part here. The industry investigates higher frame rate (HFR) video, typically targeting between 50 frames per seconds (fps) up to 120 fps for content distribution; such broadcast content were also showcased during IBC 2013. Although most Digital TV panels support 60 Hz or 120 Hz display rate, most broadcasted services do not run at such frequencies: they usually provide 50/60 Hz services in interlace mode, for backward compatibility with existing infrastructure. Here again, the deployment of HFR services will likely use point-to-point distribution to the end user, like IPTV or OTT delivery.

Finally, Ultra High Definition is also a matter of color fidelity; most video services currently deployed use 8 bits per color component, usually subsampling part of the color information (as in YUV420, the most common raw video format used by broadcast encoders). Modern video standards however allow for non- or less-subsampled YUV formats (typically YUV422, supported by SDI standard). Broadcasters are currently investigating higher color bit depth, from 10 bits per component up to 16 bit per component for High Dynamic Range imaging. For the same backward compatibility issues as above, broadcast services do not use high bit depth, although HDMI 1.3 supports 10, 12 and 16 bits per component; consequently, deployment of

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HDR or high fidelity video services will also use point-to-point distribution to the end user, like IPTV or OTT delivery.

In order to compress at least 6 Gbps (3840x2160p60, YUV420), new compression tools are required for UHD. Since most early service deployment will be based on OTT delivery, an efficient combination of compression and transport layers will be needed, and test sequences should be made available in order to promote interoperability for UHD services and optimize clients and CDNs for next-generation video services, and help the academic and industrial community conduct their research experiments on professional quality content.

In this paper, we provide an Ultra High Definition dataset of real-life professional quality video content, using HEVC [1] and MPEG-DASH [2], featuring multiple encoding bitrates and packaging options; the dataset can be played with open-source tools. The rest of this paper is organized as follows. Section 2 gives a brief overview of HEVC and DASH for UHD services. Section 3 describes related work. Section 4 describes the proposed dataset. Finally, Section 5 gives some research challenge and future work while Section 6 concludes the paper.

2. HEVC and MPEG-DASH for UHD

HEVC[1], the new codec jointly developed by MPEG and ITU, is an answer to the compression challenge of UHD services. Subjective testing show performance gain of 50% over its predecessor AVC|H.264, and the codec has been specifically designed to target ultra high resolution with higher frame rates compared to AVC|H.264: new partitioning image scheme concept based on a quad-tree structures, as illustrated in Figure 1, using larger block size (up to 64x64), gathered in Coding Tree Units (CTUs).

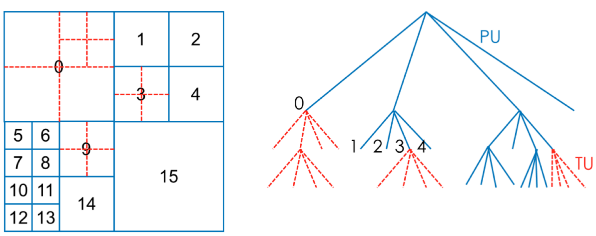

Figure 1 - HEVC Quad-tree Partitioning

HEVC also provides specific tools for efficient processing on parallels architectures, Tiles and Wavefront Parallel Processing (WPP), illustrated in Figure 2. WPP consists of resetting the CABAC probabilities of the first CTU in each line with the probabilities obtained after processing the second CTU of the line above (inter-block dependencies are maintained). CABAC encoding is flushed after the last CTU of each row, making the bitstream representing each row of CTU accessible using entry point defined in the slice header. Thus, it is possible to use any number of cores between one and the number of CTU rows in the frame, at the encoder or at the decoder side, resulting in performance increase with today's modern parallel hardware.

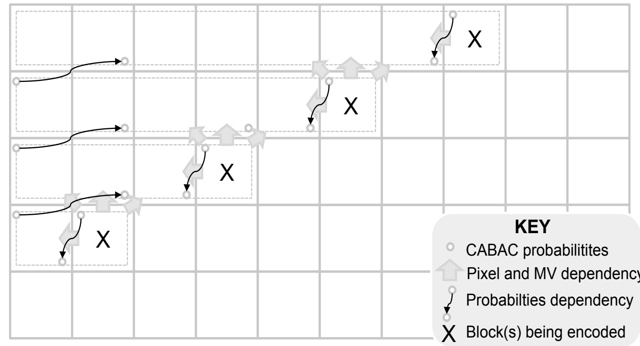

Figure 2 - Wavefront Parallel Processing

HEVC delivery over professional broadcasting networks has already been showcased several times in 2013, only a few months after the finalization of the specification; the 4Ever [5] project demonstrated, in early June 2013, the first live end-to-end transmission chain of HEVC video at the French Open Roland Garros 2013, featuring IPTV, DVB-T2 and MPEG-DASH transmissions of 720p60 content.

The MPEG-DASH standard [2] defines media formats and description for interoperable adaptive bitrate streaming service [3]. MPEG-DASH is codec and media format agnostic, however it also defines media formats based on the ISO Base Media File Format or the MPEG-2 Transport Stream; codecs are simply signaled through MIME type and associated codec parameters. The standard is targeting OTT delivery, mainly using HTTP and content delivery networks (CDN), but it is also used in some broadcast environments, such as eMBMS [4], as a replacement of MPEG-2 TS.

At the current time, most content providers use existing OTT proprietary technologies to address portable devices, however the growing integration of MPEG-DASH in CE devices (DTV, smartphones) turns it into a good candidate for future OTT deployments. MPEG-DASH opens the way for next-generation video services, such as UHDTV, 3D and Free Viewpoint TV, by providing an exhaustive description (MPD or Media Presentation Description) of media resources available in the service. This allows a client to decide which media fits best the user preferences, the terminal capabilities and the network characteristics, thereby guaranteeing the user's quality of experience. Typically, for UHD content, the DASH MPD will provide per media stream:

- Bandwidth requirements,
- Video resolution, allowing a client to select 4K versus Full HD,
- Frame rate and progressive/interlace information, allowing a client to go for 60 or 120 Hz progressive content,
- Media codec profiles, which are most of the time sufficient to determine bit depth and chroma sampling mode of the video.

These parameters are highlighted in Listing 1.

```xml
<MPD xmlns="urn:mpeg:dash:schema:mpd:2011" ...>
 <Period …>
  <AdaptationSet maxWidth="3840" maxHeight="2160"
maxFrameRate="60" par="16:9">
      <Representation mimeType="video/mp4"
codecs="hvc1.1.c.L120.90" width="1920" height="1080"
frameRate="30" bandwidth="3000000"/>
      <Representation mimeType="video/mp4"
codecs="hvc1.2.8.L123.90" width="1920" height="1080"
frameRate="60" bandwidth="8000000"/>
      <Representation mimeType="video/mp4"
codecs="hvc1.1.c.L153.90" width="3840" height="2160"
frameRate="60" bandwidth="15000000"/>
  </AdaptationSet>
 </Period>
</MPD>
```

Listing 1 - Sample DASH MPD for UHD

MPEG-DASH does not constraint the duration of media segments (continuous chunks of media at a given bandwidth), allowing the content provider to adjust this according to its use case. In most use cases, the longer the segment, the longer the latency of the chain (longer delay at the client side). Typically, short segments (one or a few seconds) will be used for live services, for which it is preferable to keep the client playback close to the live point, whereas longer segments will be used for other services (catch-up, Video on Demand).

3. Related Data Sets

Quality data sets are usually hard to track, since they are not always publically announced or even available. The most known data set for HEVC content is hosted at the BBC [6]; this data set was created during the development of the HEVC standard, to validate the different versions of HEVC Test Model (or HM), which is the reference implementation of the standard. However, this data set does not contain any ultra high definition content (quad full HD), the highest resolution of the test sequences available at time of writing this article being 2560x1600 at 60 fps. Moreover, these sequences are quite short, usually no more than 10 seconds, which is quite problematic for testing adaptive streaming in real-life conditions; concatenation of sequences is not viable for realistic simulation, since this would result in repeating patterns of bandwidth occupancy and coding complexity. This makes any optimization of OTT delivery for such content practically impossible. Most HEVC content publically available is usually another coded version of this data set; some data sets use synthetic graphics video content available under Creative Commons, but such content is not fully representative for real-life testing (such content is usually easier to encode than natural video). Other HEVC test material has to be obtained through membership to standard bodies or through private means.

Some data sets related to MPEG-DASH are also available. An early dataset was made available in [7], in order for implementations to test DASH support with a variety of resolution (from 320x240 to 1920x1080) and bitrates (from 50 kps to 8 mbps); the dataset provides different segment length, as well as the possibility to do byte-range requests to retrieve segments, rather than file-based. This paper also studies the impact of segment duration on the quality of experience for given network configurations, such as usage of persistent connections and network latencies. Another interesting data set was presented in [8], providing the first distributed data set over a large number of locations; this data set allows testing adaptation policies not only based on the different available media rates for the current server/CDN, but also based on the responsiveness and speed of other servers/CDNs.

While all these data sets are very useful, none of them provides means of testing Ultra High Definition services in Over-The-Top delivery networks. Furthermore, existing MPEG-DASH datasets only provide AVC|H.264 encodings in at most HD formats.

4. Dataset Description

4.1 Source Sequence

The sequences provided in the dataset are a professional edit of several sequences shot during the 4Ever [5] project. The sequences have been captured using a Sony F65 in raw mode, processed in BT.709 Gamut [9].

Figure 3 - Boat "Sedof" sequence

Figure 4 - "Manege" sequence

The edited sequence is an UHDTV 3840x2160 progressive video at 60 Hz, and lasts 8536 frames, which corresponds to 2 minutes, 22 seconds and 226 milliseconds (16 frames).

The sequence has been spatially down-sampled to generate HD (1280x720p60) and Full HD (1920x1080p60) sequences, which in turn have been temporally down-sampled at 30 Hz. The UHDTV sequence has not been temporally down-sampled, as most subjective viewing tests conducted by the 4Ever project on 4K materials at 30 Hz were not advocating for this.

A subpart of these sequences, as illustrated in Figure 3 and Figure 4, has been given to MPEG and ITU as test sequences for non-commercial use.

4.2 HEVC Coding

The sequences were encoded in HEVC in a variety of bitrates, as shown in Table 1, using a professional video encoder provided by Ateme.

Resolution	Frame Rate	bpp	Bit Rate
1280x720	30	8	1.8 Mbps
1280x720	30	8	2.76 Mbps
1280x720	60	8	2.75 Mbps
1280x720	60	8	3.7 Mbps
1920x1080	30	8	3.6 Mbps
1920x1080	30	8	5.51 Mbps
1920x1080	60	8	5.48 Mbps
1920x1080	60	8	7.45 Mbps
1920x1080	60	10	7.22 Mbps
3840x2160	60	8	10.9 Mbps
3840x2160	60	8	13.7 Mbps
3840x2160	60	8	18.6 Mbps
3840x2160	60	10	18 Mbps

Table 1

The encoded bitstream characteristics are:

- 1:1 sample aspect ratio
- 2 seconds GOP size
- Closed GOP (IDR every 2 seconds)
- Constant bitrate
- Coding Unit sizes: 8x8 16x16 32x32 64x64
- Transform Unit sizes: 4x4 8x8 16x16 32x32
- Wavefront Parallel Processing
- 1 slice per frame
- Hierarchical B-frames

The average PSNR over each GOP is shown in Figure 5, and is also available in the dataset as a separate spreadsheet.

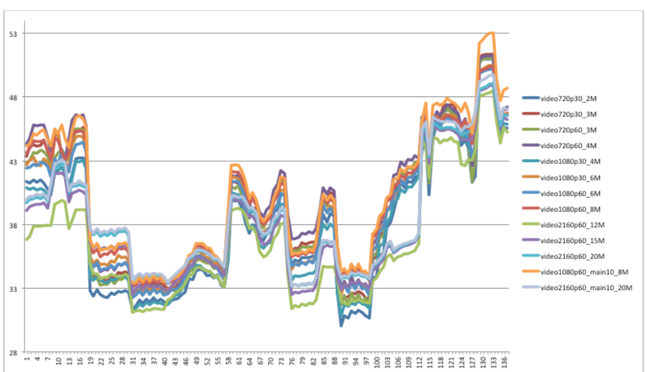

Figure 5 - Average PSNR per GOP in time

The choice for 2 seconds GOP was driven by the requirement of aligning all switching points on all resolutions and bitrates. With 4K content encoding, using too short GOPs is extremely costly and results in low quality (or high bitrates), which is obviously not interesting for high-quality UHD dataset. It could have been possible to use shorter GOPs at lower resolutions, typically half duration. Most implementations however only perform switching at MPEG-DASH segment boundaries and not inside the segment; therefore the in-between IDRs wouldn't have been very useful. The sequences have been crosschecked with the OpenHEVC decoder [10], in order to make sure that open-source implementations could validate the data set, and all sequences, including 10-bit video, can be visualized using GPAC[11].

The audio media is a single HE-AACv1 stream at 128 kbps.

The data set only contains HEVC-encoded video material. Although the UHD adoption phase will witness cohabitation of AVC HD and HEVC HD/UHD services, current deployment recommendations do not support mixing AVC and HEVC; publishing yet another AVC HD data set does not offer more than existing datasets. The authors considered that until scalable extensions of HEVC are finalized, providing a hybrid HEVC/AVC data set has little interest.

4.3 MPEG-DASH

The data set uses ISO Base Media File Format segments. This format was preferred over the MPEG-2 TS format, since most MPEG-DASH deployment recommend usage of ISO Base Media Files. Each media stream is encapsulated in its own file and there are no multiplexed segments (i.e. mixing audio and video in one file) in the dataset.

All media streams are split into segments with the following characteristics:

- same segment duration: presentation time of the first frame in any K media segment of a media stream is exactly the same as the presentation time of the first frame of the K media segment in any other media stream. Note however that due to the variable frame rate, the number of frames per segment will vary between representations.
- each media stream starts with an IDR.

Different types of encapsulation are provided, in order to test different distribution use cases:

- <u>*Live profile*</u>

This packaging features one or several complete GOPs per segment, with each segment carried in its own file referenced in the MPD using template mechanism for segment name construction. This is the most common way of deploying MPEG-DASH for live or on-demand services. In this packaging format, each video stream has its own initialization segment carrying all parameter sets used in the sequence, and is signaled with ***hvc1*** codec type. All sequences are prefixed with ***dashevc-live-.***

- <u>*Live profile with bitstream switching*</u>

This packaging format is a variation of the previous one. The only difference is that all video streams share the same initialization segment, which carries the parameter sets of the 720p30@2Mbps sequence but marked as 'incomplete' to signal that more parameters will come later. Each IDR sample in the file format carries the associated SPS, PPS and VPS for the sequence, as is usually the case in live broadcast environment. The advantage of this method is that it does not require the client to reload any initialization data at each switching point, which is therefore transparent for the file format demultiplexer. This is signaled using the ***hev1*** codec type. All sequences are prefixed with ***dashevc-live-bs-***

- <u>*OnDemand profile*</u>

This packaging features one or several complete GOPs per sub segment, with all sub segment carried in a single file with a top-level index describing all sub segments in the file. This is one possible way of deploying MPEG-DASH for on-demand services. All sequences are prefixed with ***dashevc-ondemand-***

- <u>*Main profile*</u>

This packaging features one or several complete GOPs per segment, with all sub segments carried in a single file. Each segment has an index describing the GOP start offset, and is referred to in the MPD through a segment list using byte-range

URLs. All sequences are prefixed with ***dashevc-main-.*** Unfortunately, files conforming to the main profile do not conform to the onDemand profile, because segment indexes shall not be placed at the same position in the file; this implies that segment byte-ranges cannot describe media segments compatible with both profiles; we therefore had to "duplicate" the files, although the structure is almost identical since only segment index changes.

Live and onDemand profile in this dataset have been generated to conform to the latest version of the DASH-IF recommendation for DASH+HEVC services[13]; the constraints on the MPD and media segments are respected, and the HEVC profile used is compatible with all requested profiles in this draft specification.

Live, catch-up or on demand video services have different requirements in terms of latency. Typically, live services require the overall delay of the transmission chain to be roughly the same as the delay of a satellite or terrestrial broadcast chain, usually 10 seconds maximum. With players buffering usually up to 3 segments to build their bitrate adaptation strategies, live services typically require short duration segments to stay below 10-second delays. In order to a variety of network configurations, different segment lengths are provided in the dataset:

- 2 seconds (1 GOP) segments, which is more dedicated for live and very low latency testing;
- 4 and 6 seconds segments, which are provided for live use-cases testing adaptive switching in the middle of segments,
- 10 and 20 seconds (5 and 10 GOPs) segments, which is common in on demand scenarios;

The duration of the segment (***2s, 4s, 6s, 10s or 20s***) is appended to the sequence prefix.

In order to have a coherent switching between the different video media for existing file format parsers, especially in bitstream switching mode where a single initialization segment is used for the whole sequence, the media timescale of all video files is set to 60. This allows switching to and from 30 and 60 Hz versions of the material regardless of the encapsulation method. The segments were generated using MP4Box tool from the GPAC [11] project, both for importing the raw HEVC content into media files, and creating the media segments.

4.4 Dataset Distribution

The dataset is made available at the following URL:

http://download.tsi.telecom-paristech.fr/gpac/dataset/dash/uhd

More information on the dataset license is available at the download page.

For each encapsulation format, several MPDs, each containing both audio and video, are provided:

- MPD featuring all representation:

$SEQ_PREFIX/$SEQ_PREFIX.mpd

- MPD featuring only 60p from 720p to 1080p:

*$SEQ_PREFIX/$SEQ_PREFIX**-p60***.mpd

- MPD featuring only 4K content:

*$SEQ_PREFIX/$SEQ_PREFIX**-4k***.mpd

- MPD featuring only 10 bit content:

*$SEQ_PREFIX/$SEQ_PREFIX**-main10***.mpd

For example, the live MPD for 4K using 10s segments with bitstream switching will be ***http://download.tsi.telecom-paristech.fr/gpac/dataset/dash/uhd/dashevc-live-bs-10s/dashevc-live-10s-4k.mpd***. The complete set of MPDs is also described on the dataset web page.

All MPDs included in this dataset are conformant to the first edition of the MPEG-DASH standard, and have been validated using the online MPEG-DASH validator [12].

Using the media representations available in *dashevc-ondemand-2s/,* it is possible to simulate a live UHD HEVC DASH session using MP4Box, as shown in Listing 2.

```
MP4Box -dash-live 2000 -subdur 2000 -out
dashsession.mpd -profile live
 -segment-name
live$RepresentationID$$Number$
 -bs-switching no
 FILE1.mp4:id=V1 … FILEN.mp4:id=Vn
```

Listing 2 - Live DASH from off-line content

This will generate a live session where each segment is 2 seconds long and produced every two seconds. By setting `-bs-switching` to `yes`, files will be compliant to hev1 codec point, as explained in the previous section. More information on MP4Box as a live MPEG-DASH simulator can be found GPAC[11] web site.

4.5 Dataset performance

The dataset can be played back using GPAC[11] player, either locally with manual quality switching, or using HTTP 1.1 servers. The video decoding is done using the OpenHEVC decoder [10], an open-source implementation of the HEVC standard. The decoder was tested on a workstation computer running Linux (Intel Xeon 16 cores at 2.4 GHz) and on a laptop computer running OSX (Mac Book Pro 4 cores hyper-threaded at 2.8 GHz). The tests were done with several threading configurations:

- CFG1: single thread used.
- CFG2: 8 threads for frame-level parallelization: one thread is allocated per frame and decoding starts as early as possible. No WPP processing.
- CFG3: WPP processing only, using 8 threads per frame
- CFG4: WPP processing using 4 threads per frame, and frame-level parallelization using (NbCores hyperthreaded / NbWPPThreads) threads.

For each of these configurations, the decoding frame rate over the overall sequence was computed. The results in frames per seconds are given in Table 2 for the Xeon machine, and in Table 3 for the Mac Book Pro.

Sequence@bitrate	CFG1	CFG2	CFG3	CFG4
1280x720p30@2M	138	330	256	527
1280x720p30@3M	111	239	216	446
1280x720p60@3M	153	371	277	572
1280x720p60@4M	142	299	238	507
1920x1080p30@4M	57	176	170	333
1920x1080p30@6M	48	148	155	283
1920x1080p60@6M	65	203	218	363
3840x2160p60@12M	18	86	87	130
3840x2160p60@15M	17	66	74	152
3840x2160p60@20M	16	66	73	138

Table 2 - OpenHEVC performances over the dataset on 16 cores Xeon 2.4 GHz

Sequence@bitrate	CFG1	CFG2	CFG3	CFG4
1280x720p30@2M	200	488	530	676
1280x720p30@3M	165	425	445	565
1280x720p60@3M	229	597	602	758
1280x720p60@4M	196	511	532	656
1920x1080p30@4M	85,4	254	261	334
1920x1080p30@6M	71	205	215	275
1920x1080p60@6M	96	280	289	359
1920x1080p60@8M	81	235	218	298
3840x2160p60@12M	26	86	85	102
3840x2160p60@15M	26	74	92	103
3840x2160p60@20M	23	81	85	93

Table 3 - OpenHEVC performances over the dataset on a 4 cores hyperthreaded Mac Book Pro 2.8 GHz

5. Future work and Research challenges

During the years 2012-2013, there has been a lot of interest in quality-based rate adaptation inside the MPEG-DASH community, using streaming of quality metrics for each segment but sent in different files or HTTP requests. In order for the research community to further investigate this topic, average PSNR per GOP for each sequence is provided in the dataset as a single spreadsheet. In the future, these metrics will be made available as complementary DASH streams, in conformance to the ongoing work done at MPEG; this is not integrated in the current dataset since the complete MPEG solution design is not yet frozen.

The dataset presented in this article is the first data set mixing different temporal resolutions and bit depth per videos, with multiple adaptation paths; it is not yet clear from the literature how switching to lower SNR versus lower temporal or bit depth resolution affect the perceived quality of the session, and we intend to investigate this aspect. Combined with the associated PSNR metrics, this dataset can be used to optimize switching policies in adaptive streaming of UHD services.

6. Conclusion

In this paper, we presented the market conditions and deployment challenges of UHD services and explained how the combination of HEVC and MPEG-DASH could be the major enabler for such services. We have explained why the lack of real-life professional quality UHD content is problematic for fine optimization of bitstream switching strategies in adaptive streaming environments. We propose a data set made of real-life professional content ranging from HD to UHDTV at high frame rates, with a duration long-enough to simulate both on-demand and live services, encoded using optimizations for parallel processing. Additionally, we provide average PSNR metrics per GOP to allow researchers investigate quality-driven switching. The dataset can be played using existing open-source software, and we give performance results of such tools over the dataset for different hardware configurations. In the near future, we will promote this dataset to the academic and industrial research community, and based on this, investigate switching policies for high frame-rate and high bit depth video services.

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8. REFERENCES

[1] G. J. Sullivan, J.-R. Ohm, W. Han, and T. Wiegand, "Overview of the High Efficiency Video Coding (HEVC) Standard," IEEE Trans. Circuits Syst. Video Techn., vol. 22, no. 12, pp. 1649–1668, 2012.

[2] ISO/IEC DIS 23009-1.2, *Information technology — Dynamic adaptive streaming over HTTP (DASH) — Part 1: Media presentation description and segment formats*

[3] Stockhammer, T. 2011, Dynamic Adaptive Streaming over HTTP – Design Principles and Standards, In Proceedings of the second annual ACM conference on Multimedia systems (MMSys11), ACM, New York, NY, USA

[4] Lecompte, D., & Gabin, F. (2012). Evolved multimedia broadcast/multicast service (eMBMS) in LTE-advanced: overview and Rel-11 enhancements. *Communications Magazine, IEEE*, *50*(11), 68-74.

[5] 4Ever Project http://www.4ever-project.com/

[6] http://ftp.kw.bbc.co.uk/hevc/

[7] Lederer, S., Mueller, C., and Timmerer, C. 2012. Dynamic adaptive streaming over HTTP dataset. In Proceedings of the 3rd Multimedia Systems Conference (MMSys '12). ACM, New York, NY, USA, 89-94.

[8] Lederer, S., Mueller, C., Timmerer, C., Concolato, C., Le Feuvre, J., & Fliegel, K. (2013, February). Distributed DASH dataset. In *Proceedings of the 4th ACM Multimedia Systems Conference* (pp. 131-135). ACM.

[9] BT.709 Gamut, http://www.itu.int/rec/R-REC-BT.709/

[10] OpenHEVC, https://github.com/openhevc/openhevc

[11] J.Le Feuvre, C. Concolato and J.C. Moissinac 2007 GPAC: open source multimedia framework. In Proceedings of the 15th international Conference on Multimedia (Augsburg, Germany, September 25 - 29, 2007). MULTIMEDIA '07.

[12] http://www-itec.uni-klu.ac.at/dash/?page_id=605

[13] DASH-HEVC/265 Interoperability Points