UHD FOR BROADCAST AND THE DVB ULTRA HD-1 PHASE 2 STANDARD

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ABSTRACT

Broadcasters and service providers are preparing for the launch of Ultra HD (UHD) using the upcoming DVB UHD-1 Phase 2 specification. This shift will be the biggest change that broadcasters face since the launch of HD. With this move, comes a new delivery specification, UHD-1 Phase 2, which will include Wide Color Gamut (WCG), High Dynamic Range (HDR), High Frame Rate (HFR) and Next-generation Audio (NGA), bringing the quality of the UHD experience to an entirely new level. This paper will describe how content can be created to accommodate the new specification and will provide reference architectures that are planned for deployment. The presentation will also highlight the work done by the Ultra HD Forum for the first commercial deployments of UHD-1 Phase 2 in 2016.

INTRODUCTION

The DVB UHD-1 Phase 2 standard is still being defined, and an introduction to the standard can be found in Table 1. The standard will consist of different elements.

Part	Details	Reference	Status
System	Transport stream	update from [0]	CRs closed, technical work due to complete October 2016 (limited changes expected)
	DVB DASH	update from [1]	Commercial Module closed
Video	Video codec with HDR	update from [0]	CRs closed, technical work due to complete October 2016
Audio	NGA codec	update from [0]	CRs closed, technical work due to complete October 2016
Subtitling	subtitling carriage with HDR	update from [2]	CR for text & bitmap closed, technical work due to complete October 2016

Table 1 - DVB UHD-1 Phase 2 at a glance

The primary focus of this paper is to describe the different video options that will be used for broadcast or unicast over HTTP.

The discussions around HDR are speculative, but aim to provide insight into the HDR decision process within DVB.

Audio aspects will not be included in this paper, as they imply different techniques.

The discussion will focus primarily on a video signal, with p60 as the maximum frame rate, as some DVB countries are using 60 Hz and thus imposing constraints on processing power.

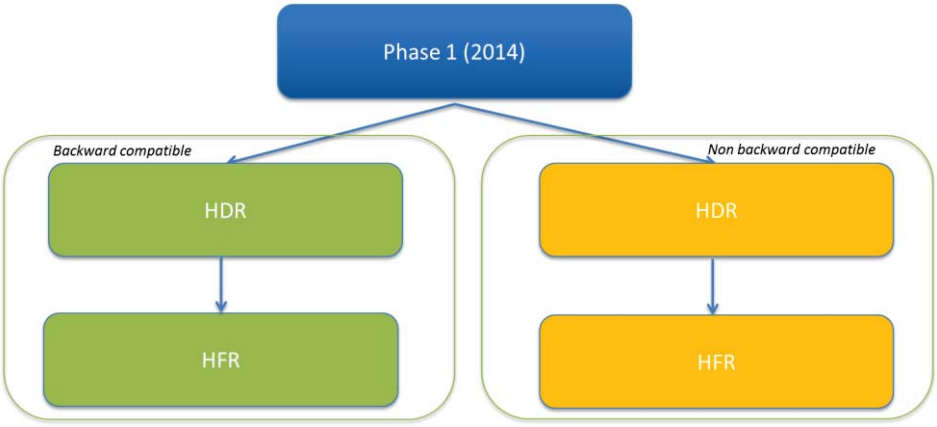

Figure 1 - Backward compatibility schemes

DVB BACKWARD COMPATIBILITY

DVB has defined a backward compatibility scheme against the Phase 1 IRD compliance requirement with UHD-1 Phase 1 bit stream specification [0] & [1]. A Phase 2 decoder will have to be backward compatible to enable delivery of video with HDR and HFR. Possible combinations are described in Figure 1.

As such, a backward compatible scheme is defined as that which supports HDR can be decoded by a Phase 1 decoder and support HFR when decoded by a Phase 1 decoder. A non-backward compatible scheme will not impose any backward compatibility constraints on Phase 1 decoders. Phase1 key parameters are summarized in Table 2.

Item	Details	Note
Deployment	2014 - 2015	
Codec	HEVC Main 10	
Maximum resolution	3840 x 2160 x 60	
Maximum MPEG level	5.1	
WCG	BT 709/2020	Decoder needed to ingest BT 2020
HDR	No	
HFR	No	
Backward compatibility	N/A	
NGA	No	5.1 HD codecs

Table 2 - DVB UHD-1 Phase1

MARKETBACKWARD COMPATIBILITY

This section will address the backward compatibility not only from a stream perspective but also from a display angle, i.e., how a Phase 1 display will have to be addressed by a Phase 2 STB. Since mostly SDR TV sets will be sold in the coming years, HDR backward compatibility with SDR sets will be a requirement. The following will look at the impacts of WCG, HDR and HFR on the backward compatibility of a DVB UHD-1Phase 2 system.

UHD TV Types

It is important to understand what types of UHD displays have been deployed so far and what displays will come in the future. Seven classes of UHD TV types have been identified based on the criteria described in Table 3.

Class 0 represents the first generation of UHD TV sets sold. As it can only support p30, it cannot be used for a DVB UHD system, unless a spatial scalable scheme is implemented. This scenario is not highly probable since it would sacrifice QoE.

Class	HDMI	color space	HEVC Level	Max Resolution	Max Frame Rate	HDR support
0	1.4	BT 709	5.1	3840x2160	p30	No
1	2.0	BT 709	5.1	3840x2160	p60	No
2	2.0	BT 2020	5.1	3840x2160	p60	No
3	2.0a	BT 2020	5.1	3840x2160	p60	Yes
4	2.0a	BT 2020	5.0	1920x1080	p120	Yes
5	New	BT 2020	5.1	2560x1440	p120	Yes
6	New	BT 2020	5.2	3840x2160	p120	Yes

Table 3 – UHD TV Classes

Class 1 is the second generation of UHD TV sets deployed with full frame rate support, BT 709 color space support, but no HDR. This class imposes the most constraints on backward compatibility. To address this type of set, the industry needs an HDR scheme that can create a BT 709 signal. The HDR section will discuss the possible HDR options.

Class 2 is the third generation of UHD TV sets deployed with full frame rate support, BT 2020 color space support, but no HDR. This class imposes fewer constraints on backward compatibility, as the color space is wider than for Class 2. To address this type of set, the industry needs an HDR scheme that can create a BT 2020 signal. The HDR section will discuss the possible HDR options.

Class 3 is the first generation of UHD TV set that supports HDR. The frame rate is still limited to p60.

Class 4 is the first generation of UHD TV set that supports HDR and HFR in p120 but with an HD resolution (1920 x 1080). It is important to note that the signal can be carried in HDMI 2.0a.

Class 5 is the first generation of UHD TV set that supports HDR and HFR in p120 but with improved resolution vs Class 4 (4 x 720p resolution of 2560 x 1440). It is important to note that the signal needs a new HDMI specification, but that the pixel rate is within the boundaries of MPEG HEVC Main 10 Level 5.1, meaning that a Main 10 decoder, in principle, has the capability to decode this HFR profile.

Class 6 is the ultimate goal of 3840 x 2160 x 120 with HDR. As this requires a new decoder and encoder infrastructure (two times the pixel rate versus Class 3), it is expected to come at a later stage when technology is available at a reasonable cost.

WCG and HDR

MPEG, SMPTE, ITU-R, CTA, DVB and ATSC are all working on standardizing HDR for broadcast applications. Since no standard has been defined internationally yet for broadcast, this paper will list all the documented options and will refer to the SMPTE HDR paper [4] for details. Table 4 provides the list of all the different HDR options that will be discussed further.

HDR	Codec	Codec layers	EOTF	Meta data	Backward compatibility	Standard reference
HDR 10	HEVC Main 10	single	ST 2084	ST 2086	decoder based (1)	SMPTE CTA
Dolby Vision	HEVC Main 10	dual	ST 2084	ST 2086/ETSI	stream based	BDA ETSI
		single	ST 2084	ST 2086/Prop	decoder based (2)	
Technicolor /Philips	HEVC Main 10	single	ST 2084	Prop	stream based decoder based (2)	BDA
HLG	HEVC Main 10	single	hybrid log Gamma	No	Native	ITU-R ARIB
SHVC	SHVC	dual	ST 2084	being defined	decoder based (1)	ETSI

(1) Decoder based w/o meta data, does not guarantee the quality of the restitution of SDR
(2) *Decoder based w/ meta data, does guarantee the quality of the restitution of SDR*

Table 4 – HDR options

HDR options

HDR 10

Figure 2 shows the HDR solution that has been specified by BDA [3] for the encoding format, as well as by CTA [4] for the HDMI transmission. Metadata are passed via ST 2086 for static metadata, and ST 2094 will define dynamic metadata. As this is the only published HDR standard today, all chips (i.e., decoders and TVs) support HDR 10. HDR 10 was designed as a non-backward compatible scheme at the beginning, but there are implementations in Blu-ray players that will be able to tone map it to an SDR BT 709 color space on the receiver side. Some TV manufacturers and STB chipsets were also showing similar capabilities at CES 2016. The first broadcast demonstration of HDR 10 was made by Sky Germany, which conducted live trials of HDR 10 in August 2015 [5]. At IBC2015, Harmonic was also showing a joint HDR 10 demonstration of a live end-to-end workflow with the Ultra HD Forum.

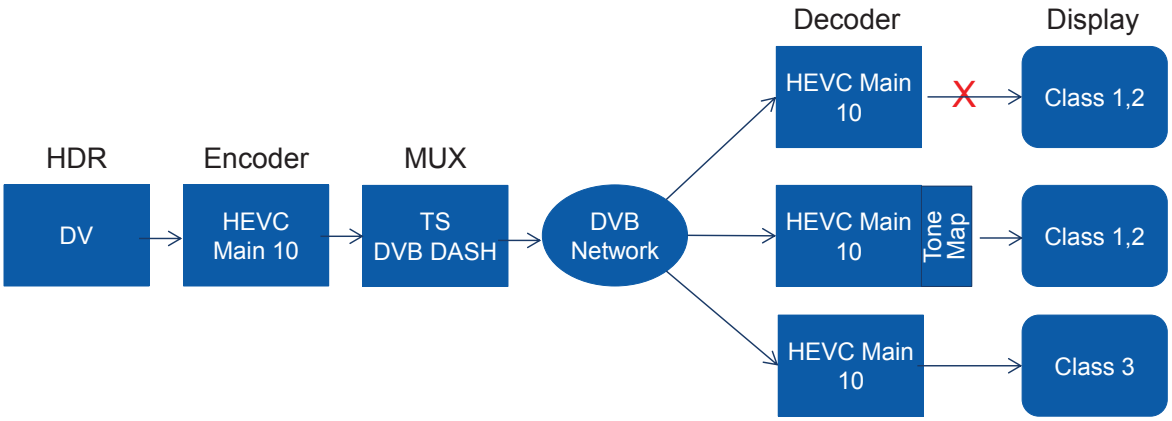

Figure 2 - HDR 10

Dolby Vision dual layer

Dolby Vision dual layer is solution that will transmit BT 709 to Class 1 TVs and can also address Class 2 TVs with BT 2020. Through an enhancement layer, it can provide an HDR experience on a Dolby Vision consumer playback solution that will display to a Class 3 and above TV. Note that in the BDA specification, the base layer is not BT 709 but HDR 10, so a different specification is required for broadcast application. In that respect, Dolby has started a standardization effort with ETSI to specify a broadcast dual layer scheme. Metadata is defined in SMPTE ST2086, ST2094 and ETSI ISG CCM. Dolby Vision has already been endorsed by several silicon TV decoder chipsets, including Mediatek, MStar, Sigma, Realtek, and HiSilicon.

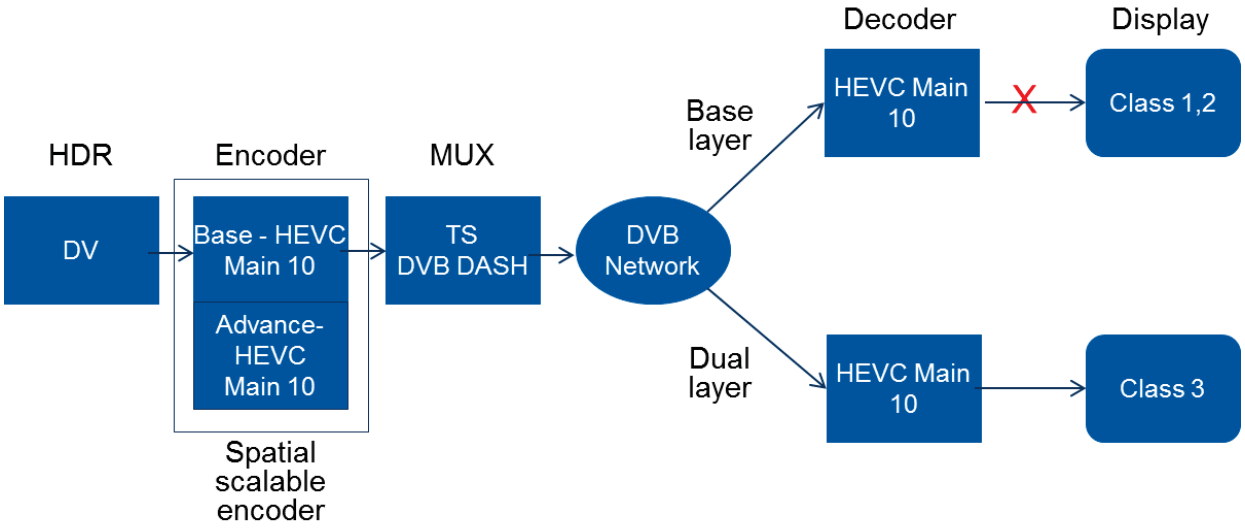

Figure 3 –Dolby Vision dual layer

Dolby Vision single layer

Dolby Vision single layer is proposed for standardization in DVB. It is a non-backward compatible solution that will only address BT 2020 HDR sets of Class 3 TVs and above. The Dolby Vision consumer playback solution can accept a BT 2020 HDR signal and map it to a BT 709 color space. Dolby was demonstrating a preview of this solution with Harmonic at IBC2015 [6].

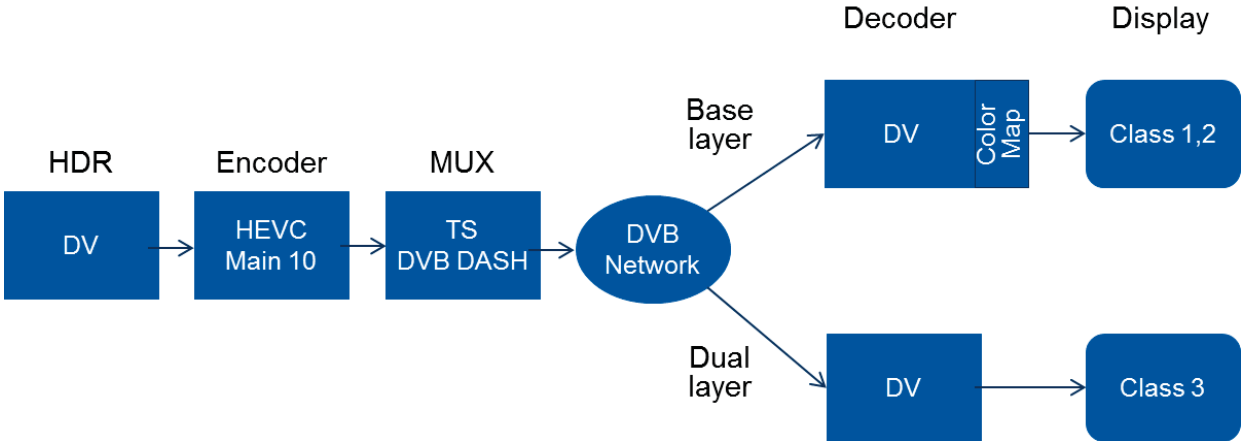

Figure 4 - Dolby Vision single layer

Technicolor/Philips

Technicolor and Philips announced at CES 2016 they would merge their solutions. A single-layer codec solution that is natively compatible with BT 709 UHD decoders is expected. The additional metadata will be used by the decoder to reconstruct an HDR signal. The main characteristic of this solution is that the base layer is compatible with legacy UHD decoders (e.g., DVB Phase 1 decoders) and therefore Class 1 and 2 displays. The drawback is that a new decoder is required to decode the metadata needed to

reconstruct the HDR signal. At CES 2016, STM, Marvell, MStar and Sigma Designs announced their next-generation silicon would support Technicolor.

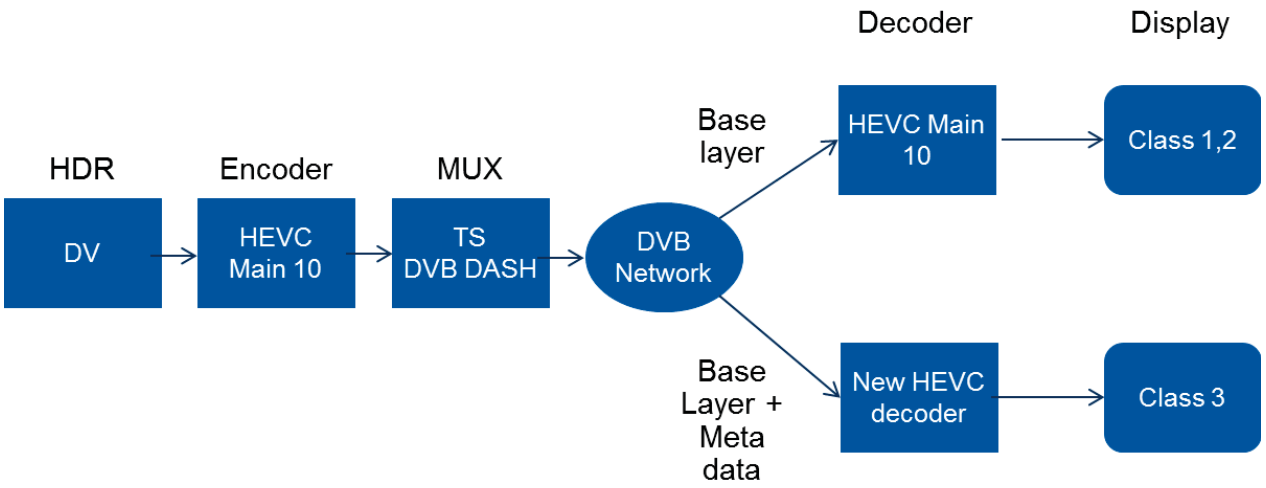

Figure 5 - Technicolor/Philips merged solution

HLG (Hybrid Log Gamma)

HLG is a solution jointly promoted by BBC and NHK. They have agreed on the OETF (Optical Electrical Transfer Function) within the ITU-R [7]. The main feature of HLG is that the same stream goes to legacy TVs (Class 1 and 2) and to HDR TVs (Class 3 and above). The main advantage is that HLG can work on existing infrastructure via a software upgrade of the decoder, the HDMI link and the TV set. There is no certainty that HLG will be standardized for Class 1 TVs, as tests are still underway at the time of writing of this paper. Live HLG demonstrations have already been done by SES [8] in May 2015, Sky Germany in August 2015 [5], and Sky PerfecTV [9] in November 2015. As HLG is now being standardized by ITU-R, it is anticipated that there will be more traction for this format for broadcast applications.

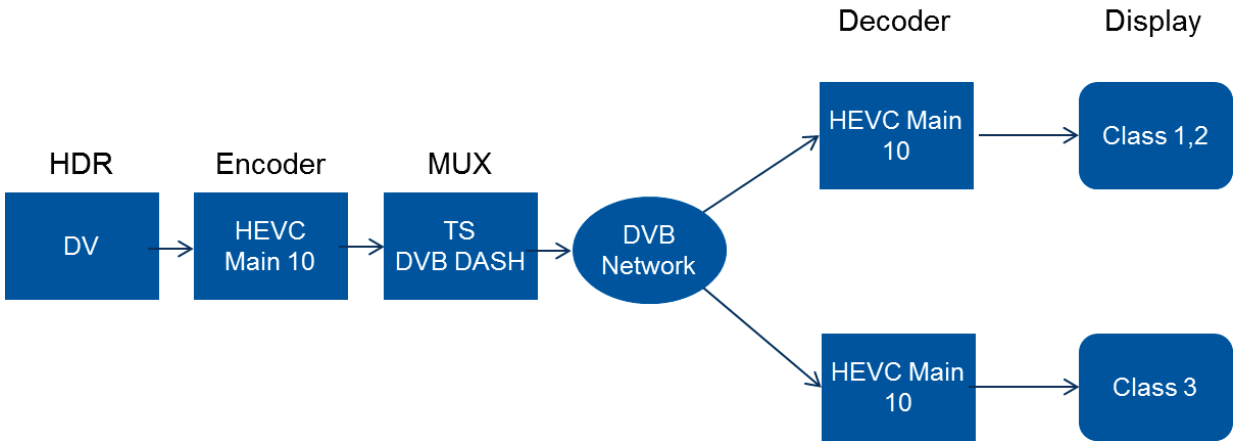

Figure 6 - HLG

SHVC (Scalable High Efficiency Video Codec)

SHVC is a solution that will transmit BT 709 to Class 1 TVs and can also address Class 2 TVs with BT 2020. Through the SHVC enhancement layer, it can provide an HDR experience on a SHVC playback solution that will display to a Class 3 and above TV. This solution will require an SHVC-capable decoder which so far has not been announced by any semiconductor company, so chances to be adopted by the market are low, although this is a fully standards-based solution. Metadata is defined in SMPTE ST2086, ST2094.

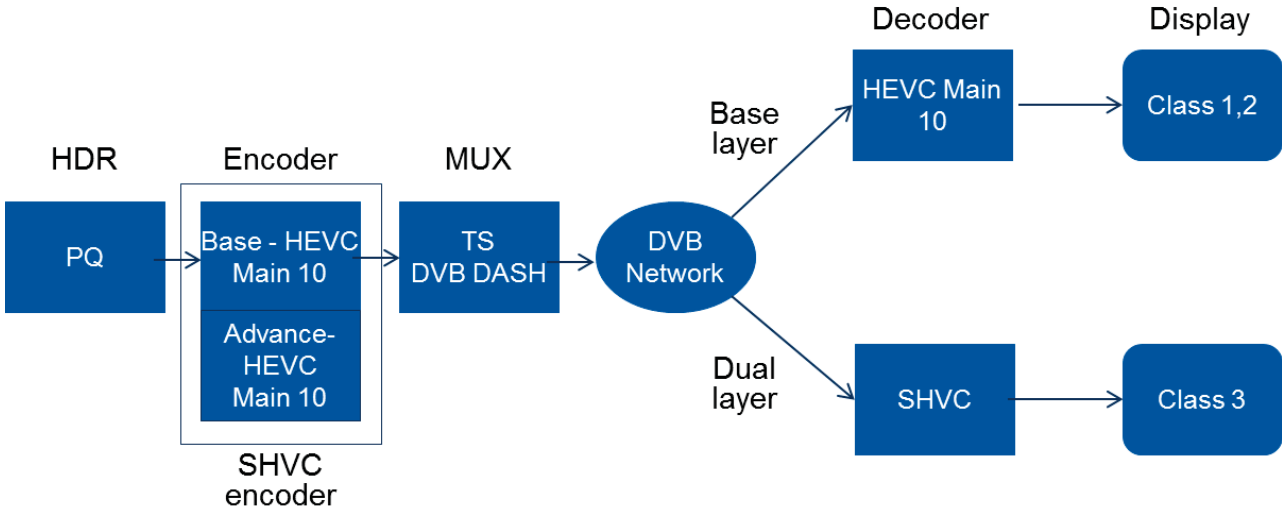

Figure 7 - SHVC

Standardization outlook

In terms of standardization, DVB is currently evaluating all of the technologies discussed throughout this paper and should come to a decision in the summer 2016. One important element in the discussion is ITU-R standardization for HDR. So far HDR10 and HLG (single EOTF) are the only ones selected for standardization by ITU-R.

HFR Solution

The sports community is demanding an increase in the frame rate, namely 120p. In order to achieve that, a new 120fps workflow needs to be created. As none of this exists today, even for HD resolution, it will take some time to be deployed. On the receiver side, HDMI 2.0 is only capable of supporting 1980 x 1080 x 120 10 bit 4:2:2, so if broadcasters want to reuse existing infrastructure, they will have to limit the resolution. A common perception is that the existing Main 10 Level 5.1 decoder should be able to decode 2540 x 1440 x 120 4:2:0 10 bit, as this is a pixel rate included in Level 5.1. The problem is that most of the existing chips were designed for a p60 output, and moving to p120 will require a redesign of the silicon.

Of course, there is always the option to transmit 3840 x 2160 x 60 and have the TV do the frame rate conversion in the TV. Harmonic and Sigma Designs demonstrated this at IBC2014, and the audience was impressed by the result. Orange, a partner of the 4EVER

Project, has also compared this method to a native 120p transmission and came to the conclusion this FRC was acceptable in terms of video quality for most content.

DVB is looking at HFR as a long-term deployment and plans to have it available in the 2019 timeframe. The proposed scheme for backward compatibility should be based on a temporal scalable approach with a base layer being SDR. Another option would be to have a base layer that is HDR. Table 5 lists all the options for HFR.

Option	HDMI	Layer Coding	HEVC Level	Max Resolution	max frame rate
1	2.0	single	4.1	1080p120	p120
2	New	single	5.1	1440p120	p120
3	New	single	5.2	3840x2160	p120
4	2.0/ New	dual	5.2	3840x2160	p120

Table 5 – HFR Options

Option 1 is what exists today, and that can work on some decoders and TVs that support HDMI 2.0 (See Figure 8).

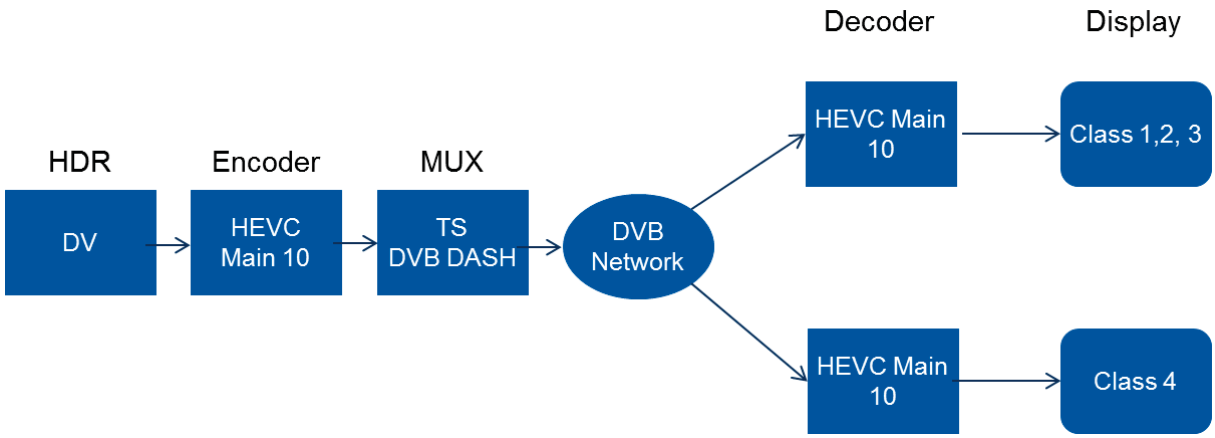

Figure 8 – HFR 1080p120

Option 2 is based on existing decoder technology, the biggest problem being the display refresh rate at 120 Hz for the TV. This is a solution that could find some traction as it has a nice trade-off between resolution and frame rate (See Figure 9).

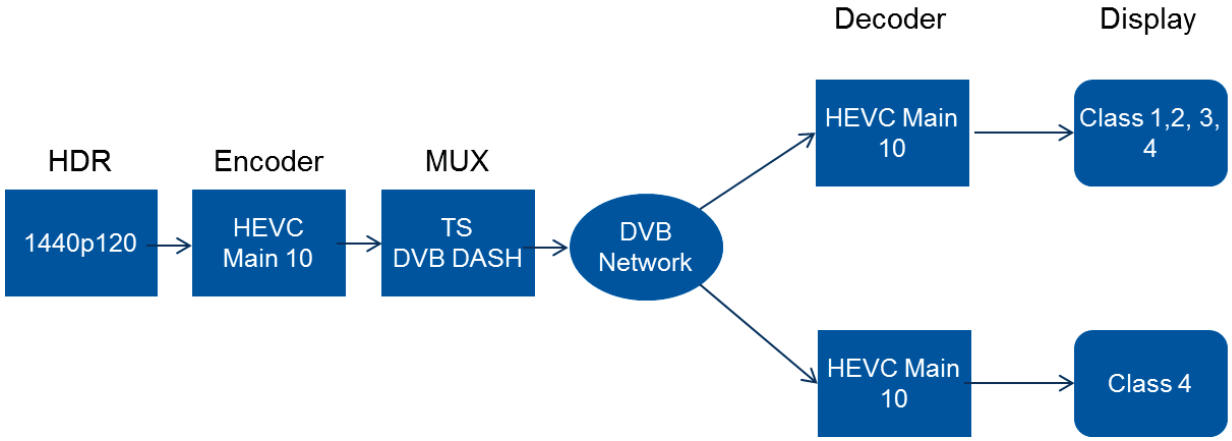

Figure 9 – HFR 1440p120

Option 3 requires a brand new design for the decoder, display and encoder. This type of solution will likely be more expensive, and the adoption will be gated by the technology maturity. 2019 seems a reasonable target to launch such a service (See Figure 10).

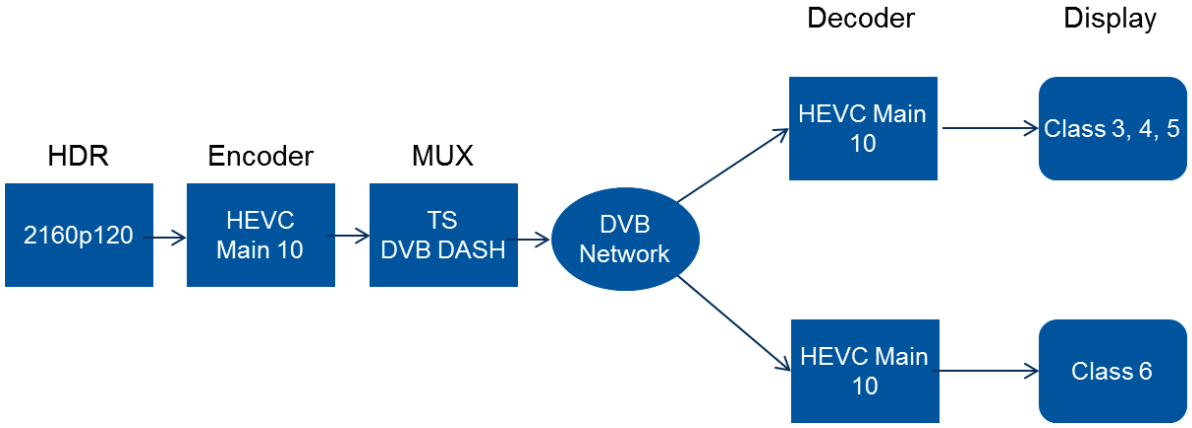

Figure 10 – HFR 2160p120

Option 4 is a temporal scalable solution that will have a base layer either in SDR (Class 1 and 2) or HDR (Class 3). While this solution is complex, the fact that it offers backward compatibility could be appealing (See Figure 11).

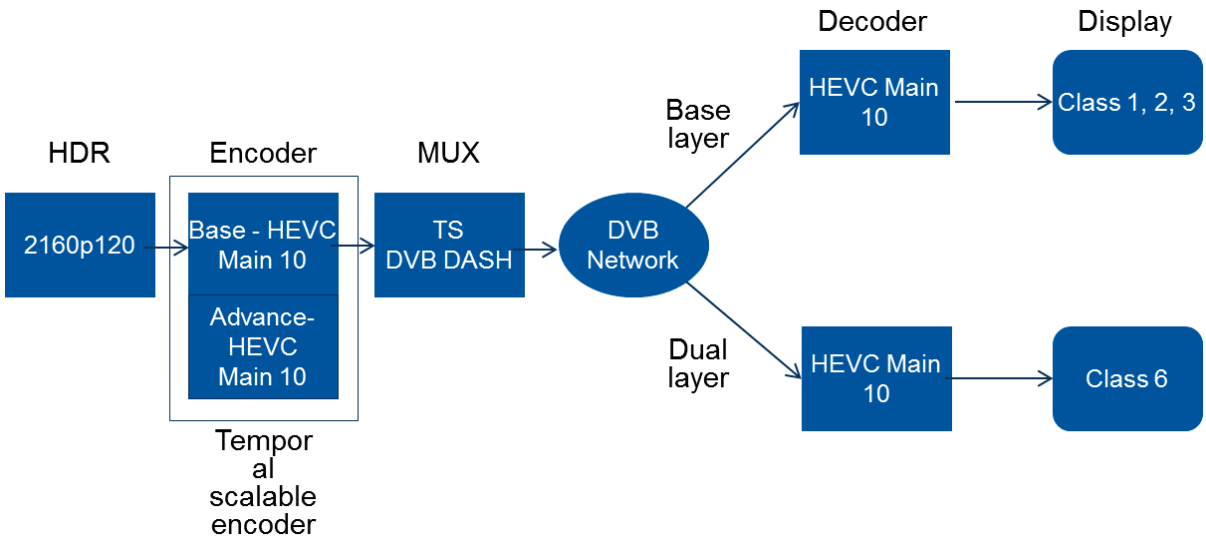

Figure 11 – Temporal scalable

In conclusion on HFR, multiple technology options are possible. Due to the fact that on the production side p120 is not yet ready and that on the display side 2160p120 displays are not yet mainstream, HFR is expected to come in a second phase. As many 2160p60 UHD TVs will be deployed, a temporal scalable scheme makes a lot of sense.

RECOMMENDATIONS AND GUIDELINES

In addition to the SDO defining standards for Ultra HD, there are other industry groups providing recommendations for the deployment of UHD. Those recommendations will have an impact on the definition of DVB UHD-1 Phase 2.

At CES, the UHD Alliance presented its guidelines [12], which will be accompanied by an UltraHD Premium certification program. Table 6 provides a high-level summary of the UHD Alliance recommendations.

Item	UHD Alliance
Publication	CES'16
Application	Disc / VoD Push & OTT
Deployment	2016
Codec	HEVC Main 10
Minimum resolution	3840 x 2160 x 24
Maximum resolution	3840 x 2160 x 60
WCG	BT 2020
Display	90% of P3 colors
HDR EOTF	ST 2084*
HDR meta data	not specified
Peak brightness /black levels (nits)	1000/0.05 or 540/ 0.0005
Backward compatibility	Receiver based
Audio	NGA recommended

**enables HDR 10, Dolby Vision, Technicolor/Philips*

Table 6 - UHD Alliance Recommendations

At CES 2016, Samsung, LG and Panasonic all announced they had certified UHD Premium TVs. Sony announced a 4000 nits (vs 1000 nits for the Premium certification) TV, and did not make any public comment.

The Ultra Forum has released at NAB 2016 its Phase A Guidelines for service providers looking at deploying live applications either in a broadcast or unicast environment [11], to be deployed in 2016. Those guidelines are described in Table 7.

Item	Ultra HD Forum
Publication	NAB'16
Application	Live Broadcast & Unicast
Deployment	2016
Codec	HEVC Main 10
Minimum resolution	1920 x 1080 x 60
Maximum resolution	3840 x 2160 x 60
Frame rate	24, 25, 50, 60 +
WCG	BT 2020 / BT 709
HDR EOTF	SDR / PQ10 * /HLG10 **
HDR meta data	not needed
Backward compatibility	Head End & decoder based
Audio channels	Stereo or 5.1 multi-channel audio
Audio codec	AC-3, EAC-3, HE-ACC, AAC-LC
subtitling	CTA-608/708, ETSI 300 743, ETSI 300 472, SCTE-27, IMSC1
Transport	TS (broadcast) DASH ISO BMFF (unicast)
backward compatibility	PQ10 : simulcast or decoder based HLG 10 : built in

+ Fractional frame rate accepted
* PQ10 is HDR10 w/o metadata
** HLG10 is HLG with BT2020 Main 10

Table 7 - Ultra HD Forum guidelines preview for live Phase A deployments

It is important to note that no metadata is used in the broadcast workflow, and there is no possibility to insert metadata in a live production from an economic standpoint.

The Phase A Guidelines will be reviewed by various SDOs (e.g., SMPTE, ITU-R, CTA, DVB, EBU, ATSC, CableLabs, SCTE) involved in the standardization of Ultra HD. Based on the feedback, a new version will be released. Following that, interoperability plug fests will be performed where those guidelines will be tested, and a new iteration of the guidelines will be created to provide confidence to operators.

Phase B will cover all types of broadcast and unicast deployments for 2017 and beyond that extend the current defined HDR (PQ10 and HLG10), and will also introduce HFR and NGA.

Out of the two guidelines of the UHD Alliance and the Ultra HD Forum, there's a clear trend in terms of deployable technology, which will influence the first UHD-1 Phase 2 deployments.

ABR SCENARIO

In an ABR deployment scenario, there are fewer constraints on backward compatibility, and it serves different devices with different HDR and HFR requirements. Indeed, as the transmission is expected to be unicast, various implementations of HDR will be used for different devices. That is already happening today with VOD OTT services using diverse HDR for different devices.

CONCLUSION

While there are still a lot of moving parts, ITU-R recommendations and the Ultra HD Forum Guidelines provide some ground for UHD services to be deployed on existing infrastructure (i.e., encoders, STBs, TVs) in 2016. IBC2016 demonstrations will very likely help broadcasters understand where the technology stands.

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