// TECHNICAL GUIDE

UHD HDR Resource Kit

Part 1: The Current State of UHD HDR

A detailed review of the current HDR standards, HDR workflows and state of HDR deployments.

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The Current State of UHD HDR

TECHNICAL GUIDE

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Introduction

Shipments of consumer television sets supporting high dynamic range (HDR) in the United States are projected to reach more than 30 million units by 2020, according to market research by IHS Markit. As video content and service providers focus on delivering UHD HDR, gaining a greater understanding of HDR technology, including the relevant technologies, standards and ideal workflow implementations is essential.

Earlier, Harmonic released an UHD guide book primarily aimed at educating the market on UHD technologies, including HDR techniques. Now that our readers have a basic knowledge of HDR, we're upping the educational factor. This technical guide is devoted to helping service providers launch their own service and includes an overview of all the UHD HDR standards, including their status, readiness, and potential limitations and state of deployments.

Standardization Background

Although the industry has defined standards for HDR, it has gotten a little out of control. HDR standardization has happened on different fronts, including the:

- production side with the SMPTE standardization effort
- distribution side with the efforts in DVB, ATSC, ARIB in Japan and SARFT in China
- device side with the CTA organization in the U.S. and the Digital Europe initiative in Europe

In addition, there has been activity from CableLabs and its sister organization SCTE, as well as non Standards Developing Organizations (SDO) such as the Ultra HD Alliance and Ultra HD Forum, which are trying to navigate the HDR waters.

All of these organizations are loosely coupled and participate in an annual event, known as the "inter SDO meeting," where each SDO reports its progress and where concrete actions need to be taken to harmonize all of those activities.

Before we dive into the technical details of HDR, it's important to gain a background definition on the terms used throughout this guide.

In 2014, DVB defined UHD-1 Phase 1 as the first step in the UHD deployments, based on SDR technology. In November 2016, it standardized Phase 2, which includes HDR (HDR10/PQ10 and HLG), HFR (up to 2160p120) and NGA (object based).

The Ultra HD Forum has defined a staged approach for the introduction of high-quality UHD. Phase A is a subset of DVB UHD-1 Phase 2 and Phase B closely matches Phase 2 (staying within the MPEG Level 5.1 for video coding). The main motivation of those two phases is to enable the introduction of UHD deployments with HDR on existing deployed infrastructure. Phase A is considered as an entry-level, high-quality UHD experience. The second phase, Phase B, takes into account the requirement for new infrastructure, including decoders and displays, for a post-2019 commercial deployment that will provide the ultimate UHD experience.

Table 1: HDR Phases - A summary of the different elements of the phases defined by DVB and the Ultra HD Forum.

Standard	DVB	UHD Forum		ATSC 3.0
Version	UHD-1 Phase 2	Phase A	Phase B	A/341
Released in	2016	2016	2018	2018
Max resolution	3840x2160	3840x2160	3840x2160	3840x2160
Max frame rate	P120	P60	P120 (1)	P120
MPEG profile/ level	Main 10 / Level 5.2	Main 10 / Level 5.1	Main 10 / Level 5.1	Main 10 / Level 5.2
Color space	BT.2020	BT.2020	BT.2020	BT.2020
HDR	PQ10/HLG10 (2)	PQ10/HLG10	Dolby Vision SL-HDR1 (3)	PQ10/HLG10 A/341 SL-HDR1
Audio	NGA (object based) Dolby Atmos, MPEG-H, DTS-X (4)	Stereo or 5.1 multichannel audio Dolby Atmos (channel based)	NGA (object based): Dolby Atmos, MPEG-H(3)	NGA (object based) Dolby Atmos, MPEG-H
Audio codec	MPEG-H AC-4 DTS-X	AC-3, EAC-3, HE-ACC, AAC-LC	MPEG-H AC-4 (3)	MPEG-H AC-4
Backward compatibility for video	HDR: Phase 1 via HLG HFR: via temporal scalability	HDR : • Phase 1 via HLG • Receiver downconversion to SDR	HDR : • Dolby Vision has a HDR10 base layer • SL-HDR1 is BT.2020/709 compatible HFR: via temporal scalability	HDR : • HLG • Receiver downconversion to SDR • SL-HDR1 HFR: via temporal scalability

Table 1. HDR phases

Notes
(1) Max resolution allowed for HFR is 1080p120, (2) New HDR inclusions with metadata support being studied, (3) released at NAB'18, (4) Recently added (2017)

A Discussion on Standards and Standards Organizations

This section looks at the different aspects of HDR from standardization status to readiness and the limitations preventing commercial deployments.

Here's a summary of the different HDR versions at stake:

- HDR10 is a CTA standard that has an open specification.
- PQ10 was created from HDR10 for broadcasters planning to use HDR10 without any metadata.
- HLG10 was created by BBC and NHK, with the goal to make it backward compatible with SDR TVs (BT 2020 10 bits TVs).
- HDR10+ is a consortium created by Samsung aimed at improving the HDR10 specification with dynamic metadata. It is competing head to head with Dolby Vision on the distribution side.
- Dolby Vision is a specification developed by Dolby. The aim is to provide an end-to-end solution that can be used from content production to display. Dolby Vision can provide backwards compatibility with HDR10 receivers.
- SL-HDR1 is a specification developed by Technicolor initially to be backward compatible with SDR TVs (BT 709 8 bits).

Table 2: Different HDR Options - A summary of the known existing HDR specifications.

HDR standard name	Standard and interest group support	Transfer function	Metadata	HDMI
HDR10	CTA ITU-R UHDA	PQ	Static	2.0a
PQ10	CTA ITU-R SMPTE UHDF Phase A ATSC	PQ	Optional	2.0a
HLG10	CTA ITU-R UHDF Phase A ATSC	HLG	No	2.0b
HDR10+	Proposed standard candidate for ATSC SMPTE ST 2094-40 Proposed option for DVB UHD-1 Phase 2 UHDF Phase B	PQ	Dynamic	No public announcement yet, although some TV manufacturers claim they can support HDMI 2.0x TVs
Dolby Vision VOD	ITU-R BT.2100 SMPTE 2084 UHDA	PQ	Dynamic	1.4
Dolby Vision Live	A/341 SMPTE ST 2094-10 Proposed option for DVB UHD-1 Phase 2 UHDF Phase B	PQ	Dynamic	2.0
SL-HDR1	A/341 SMPTE ST 2094-30 and 20 Proposed option for DVB UHD-1 Phase 2 UHDF Phase B	PQ/HLG	Dynamic	2.1
China HDR	Under definition by SARFT	New	Static	Unknown

Table 2: Different HDR options

Let's move on to describing each HDR system, including the state of its standardization and signaling techniques applied. Note that because China HDR is still under discussion, this paper cannot provide any information on that specific system.

Table 3a: HDR10/PQ10

Type	Production		Compression	Transmission				Device
Standard body	ITU-R	SMPTE	MPEG/ITU-T	DVB	ATSC	ARIB	SARFT [1]	HDMI
Standard name	BT.2100	ST 2084 ST 2086	HEVC Main 10	TS 101 154 (PQ10)	A/341 (PQ10)	STD-B32	TBD	2.0a
Transfer function	PQ	ST 2084 (PQ)	Signaled	Signaled	Signaled	NA	TBD	Signaled
Transfer function signaling	NA	ST 2108-1	TF 16 (ST 2084/ PQ) in VUI of ES	Aligned with MPEG/ ITU-T	Aligned with MPEG/ ITU-T	NA	TBD	?
Static metadata	NA	ST 2086	Optional	Optional: aligned with MPEG/ ITU-T	Optional: aligned with MPEG/ ITU-T	NA	TBD	Optional: aligned with MPEG/ITU-T
Static metadata signaling	NA	ST 2108-1	In SEI messages (MDCV, CLL) of ES	Aligned with MPEG/ ITU-T	Aligned with MPEG/ ITU-T	NA	TBD	?
Dynamic metadata	NA	NA	NA	NA	NA	NA	NA	NA

Table 3a: HDR10 standard

Notes:

[1] SARFT is evaluating HDR options and should define a standard in 2018.

Production codecs such as Apple ProRes, Avid DNxHR, Sony XAVC and Panasonic AVC-Ultra now all support HDR10.

Aside from the HDR signaling over SDI, HDR10/PQ10 can be deployed.

Table 3b: HLG

Type	Production			Compression	Transmission				Device
Standard body	ITU-R	ARIB	SMPTE	MPEG/ITU-T	DVB	ATSC	ARIB	SARFT	HDMI
Standard name	BT.2100	STD-B67	ST.2036 (SDI) ST.2110 (IP)	HEVC Main 10	TS 101 154 (HLG10)	A/341	STD -B32	TBD	2.0b
Transfer function	HLG	HLG	ST 2108-1	Signaled	Signaled	Signaled	Signaled	TBD	Signaled
Transfer function signaling	NA	NA	ST 2108	First option: TF 18 (STD-B67/ HLG) in VUI of ES Second option (SDR Backward compatible): TF 14 in VUI of ES + SEI ATC message with TF 18 (STD-B67/ HLG)	Second option of MPEG/ ITU-T	First option of MPEG/ ITU-T	First option of MPEG/ ITU-T	TBD	?
Static metadata	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dynamic metadata	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 3b: HLG standard table

Notes:
SARFT is evaluating HDR options and should define a standard in 2018
HDR metadata carriage over SDI is scheduled to be a SMPTE standard in 1 2018

Production codecs such as Apple ProRes, Avid DNxHR, Sony XAVC and Panasonic AVC-Ultra now all support HLG.

It's important to note that HLG, from a production perspective, is only standardized by ITU-R. Except for the HDR signaling over SDI component, HLG can be deployed.

Table 3c: Dolby Standardized Imaging Technologies (Dolby Vision)

Type	Production		Compression	Transmission				Device
Standard body	ITU-R	SMPTE	MPEG/ITU-T	DVB	ATSC	ARIB	SARFT [1]	HDMI
Standard name	BT.2100	ST 2084 ST 2094-10	HEVC Main 10	TS 101 154 [3]	A/341	Optional	Optional	HDMI 2.0
Transfer function	BT.2100	ST 2084 (PQ)	Signaled	Signaled	Signaled	NA	TBD	Signaled
Transfer function signaling	NA	ST 2108 [2]	VUI TF-16	Aligned with MPEG/ ITU-T	Aligned with MPEG/ITU-T	NA	TBD	Yes
Static metadata	NA	ST 2086	ST 2086 Optional	TS 101 154	A/341	NA	TBD	HDMI 2.0a
Static metadata signaling	NA	ST 2108 [2]	In SEI message (MDCV) of ES	Aligned with MPEG/ ITU-T	Aligned with MPEG/ITU-T	NA	TBD	HDMI 2.0a
Dynamic metadata	NA	ST 2094-10	MPEG/ITU-T T-35 SEI message	CM phase	A/341	NA	TBD	HDMI 2.1
Dynamic metadata signaling	NA	ST 2108 [2]	Defined by SDO via registered SEI message	ETSI Draft TS 103 572	A/341	NA	TBD	HDMI 2.1

Table 3c: Dolby Vision in broadcast standards

Notes:
[1] SARFT is evaluating HDR options and should define a standard in 2018.
[2] HDR metadata carriage over SDI is now a SMPTE standard.
[3] DVB is defining a standard way to carry dynamic metadata in its Phase 2 extension specification.
Dolby Vision for broadcast is based on a single stream transport whereas in unicast and multicast applications (e.g., VOD) both single and dual layer stream (i.e. SDR (BT 709) base layer + enhancement layer) options are available.

Table 3d: SL-HDR1 (ETSI TS 103 433-1)[1]

Type	Production		Compression	Transmission				Device
Standard body	ITU-R	SMPTE	MPEG/ITU-T	DVB	ATSC	ARIB	SARFT	HDMI
Standard name	BT.2100 BT.709 BT.2020	ST 2084	HEVC Main 10	TS 101 154 [8]	A/341	NA	NA	1.4+ for SDR 2.1 for SL-HDR metadata[2]
Transfer function	Any HDR SDR[3]	ST 2084 (PQ) ST 274 (SDR)	BT.709 BT.2020	BT.709 BT.2020	BT.709 BT.2020	NA	NA	BT.709 BT.2020 any HDR[2]
Transfer function signaling	NA	ST 2108 [4]	BT.709 (SDR) BT.2020 (SDR)[5]	Aligned with MPEG/ ITU-T	Aligned with MPEG/ITU-T	NA	NA	EOTF=0 (SDR) EOTF=2 (PQ)[2]
Static metadata	NA	ST 2086	MDCV SEI message or encapsulated in SL-HDR message[6]	MDCV SEI message or encapsulated in SL-HDR message[6]	Encapsulated in SL-HDR message[6]	NA	NA	Static_metadata_ Type_1[2][6]
Static metadata signaling	NA	ST 2108	MDCV SEI message or encapsulated in SL-HDR message[6]	MDCV SEI message or encapsulated in SL-HDR message[6]	Encapsulated in SL-HDR message[6]	NA	NA	Static_metadata_ Type_1[2][6]
Dynamic metadata	NA	ST 2094-30 ST 2094-20[1]	ETSI TS 103 433-1	In process	ATSC 3.0 standard	NA	NA	ETSI TS 103 433-1
Dynamic metadata signaling	NA	ST 2108 [7]	SL-HDR message	SL-HDR message	SL-HDR message	NA	NA	Extended_ InfoFrame_Type = 0x0002

Table 3d: SL-HDR1

Notes:
[1] ETSI TS 103 433-1 is based on ST 2094-20 and ST 2094-20 and specifies the SL-HDR Information SEI message (herein, "SL-HDR message").
[2] If the HDMI sink is HDR capable, then the SL-HDR1 capable HDMI source can supply reconstructed HDR, otherwise the transmitted SDR signal is supplied. If the SDR signal is supplied by the source, HDMI 2.1 is used, and the sink is SL-HDR1 capable, then the HDMI source also supplies the SL-HDR1 metadata for use by the sink.
[3] Production may select any HDR transfer function (i.e., PQ, HLG, gamma, SLog3, LogC, etc.). SDR sources are inverse tone mapped to that HDR transfer function.
[4] Transfer function signaling is required in production if the transfer function is not fixed.
[5] Detection of the SL-HDR Information SEI message defined in ETSI TS 103 433-1 enables reconstruction of HDR signal to capable devices.
[6] Static metadata may be encapsulated throughout transmission in the SL-HDR Information SEI message and made available to the receiver with HDR reconstruction.
[7] Carriage of SL-HDR1 metadata in production is only required between a non-integrated SL-HDR1 pre-processor and the emission encoder. All production operations on the produced signal (e.g., graphics overlays) should take place in HDR.
[8] DVB is defining a standard way to carry dynamic metadata in its Phase 2 extension specification.

SL-HDR1 is in the process of being standardized in both DVB (Phase 2 extension for metadata support only) and has been standardized in ATSC 3.0 (A/341 standard)

Table 3e: HDR10+

Type	Production		Compression	Transmission				Device
Standard body	ITU-R	SMPTE	MPEG/ITU-T	DVB	ATSC	ARIB	SARFT	HDMI
Standard name	BT 2100	ST 2084	HEVC Main 10	TS 101 154 [1]	A/341 [2]	NA	NA	[3]
Transfer function	PQ	ST 2084 (PQ)	Signaled	Signaled	Signaled	NA	NA	Signaled
Transfer function signaling	NA	ST 2108	TF 16 (ST 2084) in VUI of ES	Aligned with MPEG/ITU-T	Aligned with MPEG/ITU-T	NA	NA	?
Static metadata	NA	ST 2086	Optional As specified in ST 2086	Optional: aligned with MPEG/ITU-T	Optional: aligned with MPEG/ITU-T	NA	NA	Optional: aligned with MPEG/ITU-T
Static metadata signaling	NA	ST 2108	In SEI message (MDCV) of ES	Aligned with MPEG/ITU-T	Aligned with MPEG/ITU-T	NA	NA	?
Dynamic metadata	NA	ST 2094-40	Optional As specified in ST 2094-40	CM phase	Standard candidate	NA	NA	NA
Dynamic metadata signaling	NA	ST 2108 [4]	User-data registered SEI message	Under evaluation	Under evaluation	NA	NA	NA

Table 3e: HDR10+ standard table

Notes:
[1] DVB is defining a standard way to carry dynamic metadata in its Phase 2 extension specification

[2] Standard candidate status in ATSC 3.0 standard

[3] HDR10+ Technologies LLC can provide details

[4] HDR metadata carriage over SDI is now a SMPTE standard

HDR10+ is in the process of being standardized in both DVB (Phase 2 extension) and SARFT standards.

At the time of publication, no complete information was available on HDR10+. We will update this section when sufficient public information is available on HDR10+.

The Different Workflows for Each HDR Standard

This section describes the different workflows applied to each HDR standard. We've chosen to focus on a live/linear workflow, as this is the most complex one and because a VOD workflow uses different techniques for grading and metadata insertion.

PQ10 and HLG

For PQ10, let's assume there are no ST 2086 metadata, since it is a live environment. The workflow is quite similar to the HLG one. The only metadata passed between HDR grading, encoding, decoding and display is the signaling of the transfer function PQ10 or HLG. This is currently under work in SMPTE for baseband video and has been defined in MPEG for the compressed stream.

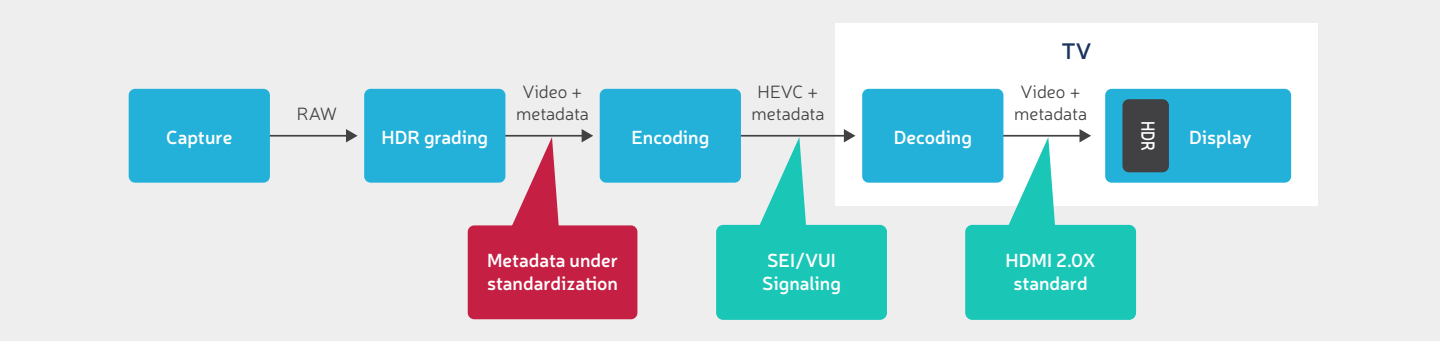

Figure 1.a: PQ10/HDR10/HLG workflow

Dolby Vision

Dolby Vision Live is a single-layer encoding scheme, with dynamic metadata generated in the last stage of distribution encoding. Therefore, metadata are created during the encoding process, either in or outside of the encoder. The only metadata passed between HDR grading and encoding is the signaling of the transfer function (ST 2084) and the mastering display color volume (ST 2086), which is optional.

The metadata passed between encoding and decoding are the specific dynamic metadata carried in the Dolby Vision system.

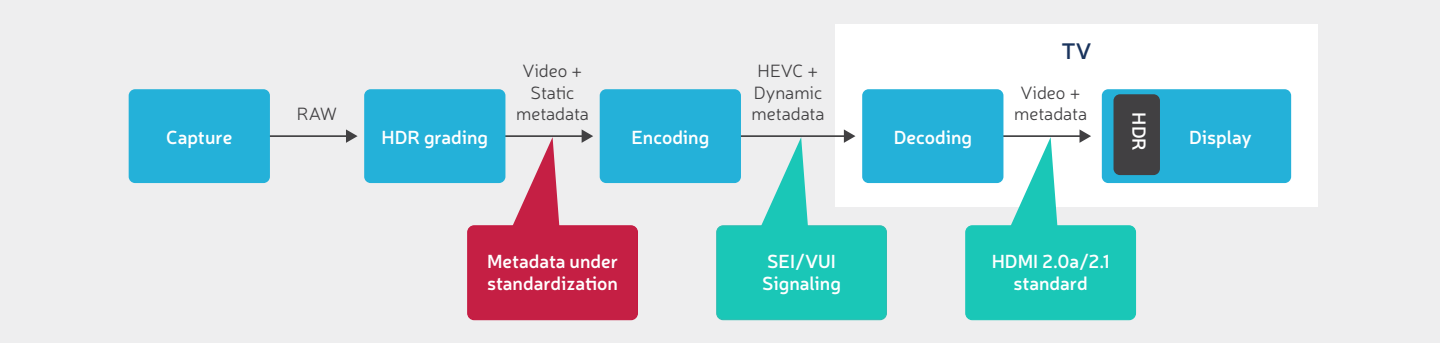

Figure 1.b: Dolby Vision workflow

SL-HDR1

SH HDR-1 is a single-layer encoding scheme, with dynamic metadata generated in the last stage of distribution encoding. Under this scheme, metadata are created during the encoding process, either in or outside of the encoder. The only metadata passed between HDR grading and encoding is the signaling of the transfer function (ST 2084) and the mastering display color volume (ST 2086), which is optional.

The metadata passed between encoding and decoding are the specific dynamic metadata carried in the SL-HDR1 system.

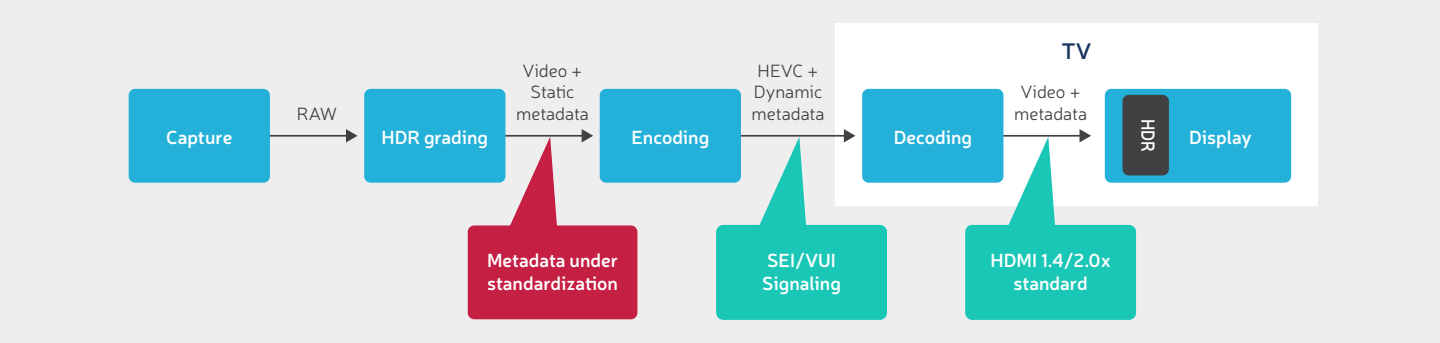

Figure 1.c: SL-HDR1 workflow

HDR10+

HDR10+ is a single-layer encoding scheme, with dynamic metadata generated in the last stage of distribution encoding. Therefore, metadata are created during the encoding process, either in or outside of the encoder. The only metadata passed between HDR grading and encoding is the signaling of the transfer function (ST 2084) and the mastering display color volume (ST 2086), which is optional.

The metadata passed between encoding and decoding are the specific dynamic metadata carried in the HDR10+ system.

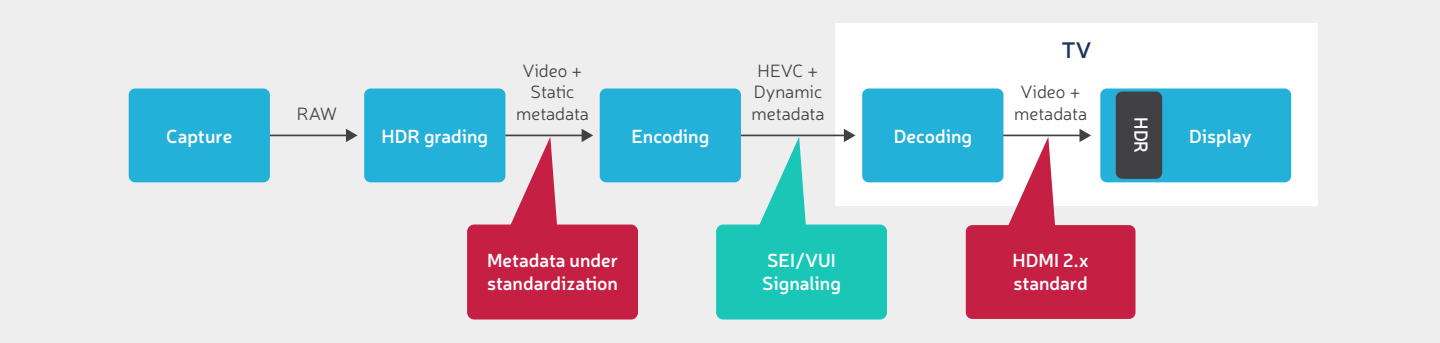

Figure 1.d: HDR10+ workflow

SDR Backward Compatibility of HDR signals

Different HDRs have been created to fulfill various use cases, with a strong constraint on the timing of introduction, the overall performance of the system, the availability of authoring tools, the capability to address UHD-1 Phase 1 STB (SDR), support on STBs and TVs, and licensing terms. IHS Markit expects that nearly all of the 112 million 4K TVs shipped worldwide will be compatible with HDR in 2020, but only 30 percent will have true HDR performance capabilities. This section synthetizes the status of the different types of HDR, specifically with regards to SDR backward compatibility. Stream backward compatibility is when an SDR decoder can decode an HDR stream. Display backward compatibility is when an HDR decoder can decode an HDR stream and send it to an SDR display.

Table 4: Backward Compatibility

	Application backward compatibility		Backward compatibility features		
HDR	**Live**	**VOD**	**SW upgrade of legacy SDR STBs**	**Stream backward compatibility**	**Display backward compatibility**
HDR10	No	No	Yes	No	Yes with some external decoders (*)
PQ10	No	No	Yes	No	Yes with some external decoders (*)
HDR10+	No	No	Yes (****)	No (only HDR10 decoders)	Maybe with some external decoders
HLG10	Yes	Yes	Yes	With UHD SDR BT.2020 sets	Yes with some decoders (**) for BT 709 displays
Dolby Vision VOD	Abandoned	Dual layer encoding	No	With SDR BT 709 set	Yes
Dolby Vision Live	No	NA	No	No (only with HDR10 sets)	Yes with VS10 devices
SL-HDR1	Yes	Yes	No	With SDR BT 709 & BT.2020 sets	No need for specific decoder

Table 4: SDR backward compatibility of HDR

(*) Explicit in the Ultra HD Forum and ATSC specifications.
(**) At the discretion of the decoder manufacturer.
(***) Decoder will do the conversion to TV set capability.
(****) Pending the additional HDMI related information.

The next section takes a detailed look at the backward compatibility for each HDR system, according to the Ultra HD Forum definition.

Ultra HD Forum Perspective on HDR

In order to avoid market confusion, reduce delays and to enable fast HDR deployments on the existing installed base of SDR UHD STB and TVs, the Ultra HD Forum has defined two phases for the HDR introduction:

- Phase A is based on deployment in 2017 using existing infrastructure. HDR10 and PQ10 were both selected for this phase.
- Phase B is intended for deployment in 2019 and beyond, which would require new infrastructure. This is the case for Dolby Vision, SL-HDR1, HDR10+ and possibly China HDR.

Figure 2 illustrates the different phases developed by the Ultra HD Forum.

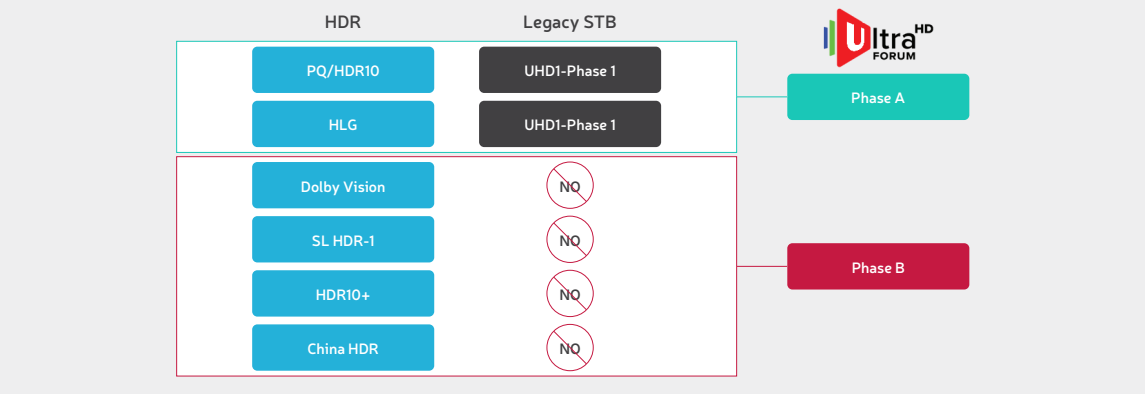

Figure 2: Ultra HD Forum phases

In conclusion a UHD Phase 1 STB can potentially be upgraded in software only for HDR10/PQ10 and HLG. Any other HDR (Phase B) schemes will require a new STB.

Figure 3 shows different compatibility levels for each HDR system of Phase A.

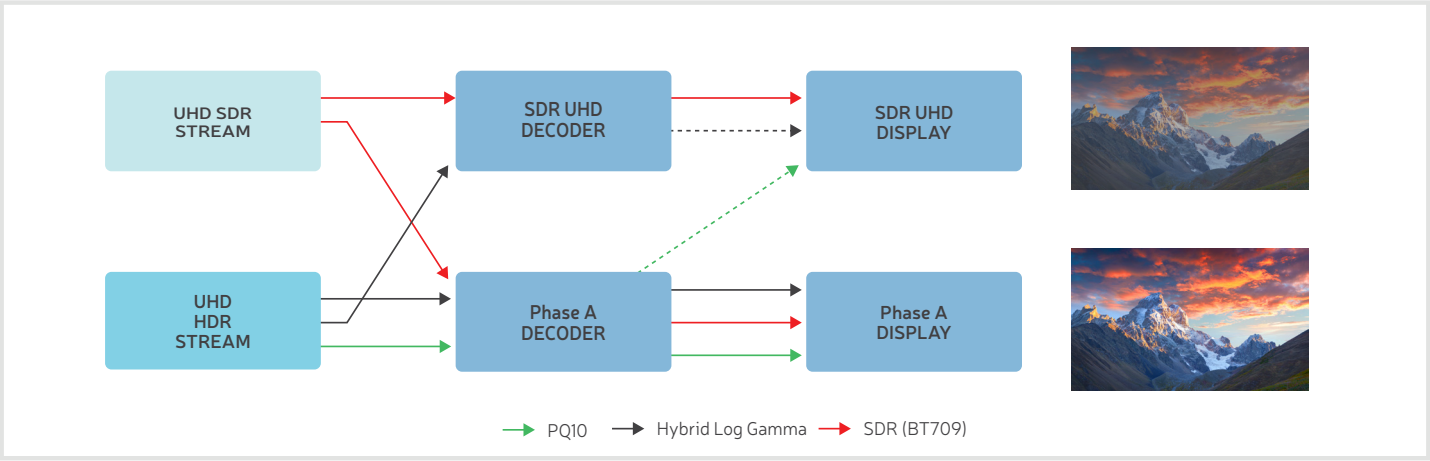

Figure 3: HDR backward compatibility schemes for Phase A

An HDR10/PQ10 signal can only be displayed by a PQ TV set. This is a non-backward scheme. Meanwhile some HDR10/PQ10 receivers (i.e., STBs and TVs) can ingest PQ signals and output SDR (in BT.2020 or BT.709) to address SDR TVs. To that extent, PQ can be made backward compatible to SDR TV sets. This is a recommended practice by the Ultra HD Forum Phase A Guidelines, the ATSC 3.0 specification as well as the upcoming China HDR standard. The dotted lines show an option that the decoder might implement in PQ10.

An HLG signal can be sent at the same time to an HDR TV and an SDR TV, provided it is BT.2020. This does not address BT.709 displays, which were the first sets to be commercialized in 2014.

For the Phase B, the new standards of HDR introduced (Dolby Vision, SL-HDR1, HDR10+ and possibly China HDR) will have to be backward compatible with Phase A receivers. Figure 4 illustrates the different compatibility levels of each HDR system of Phase A.

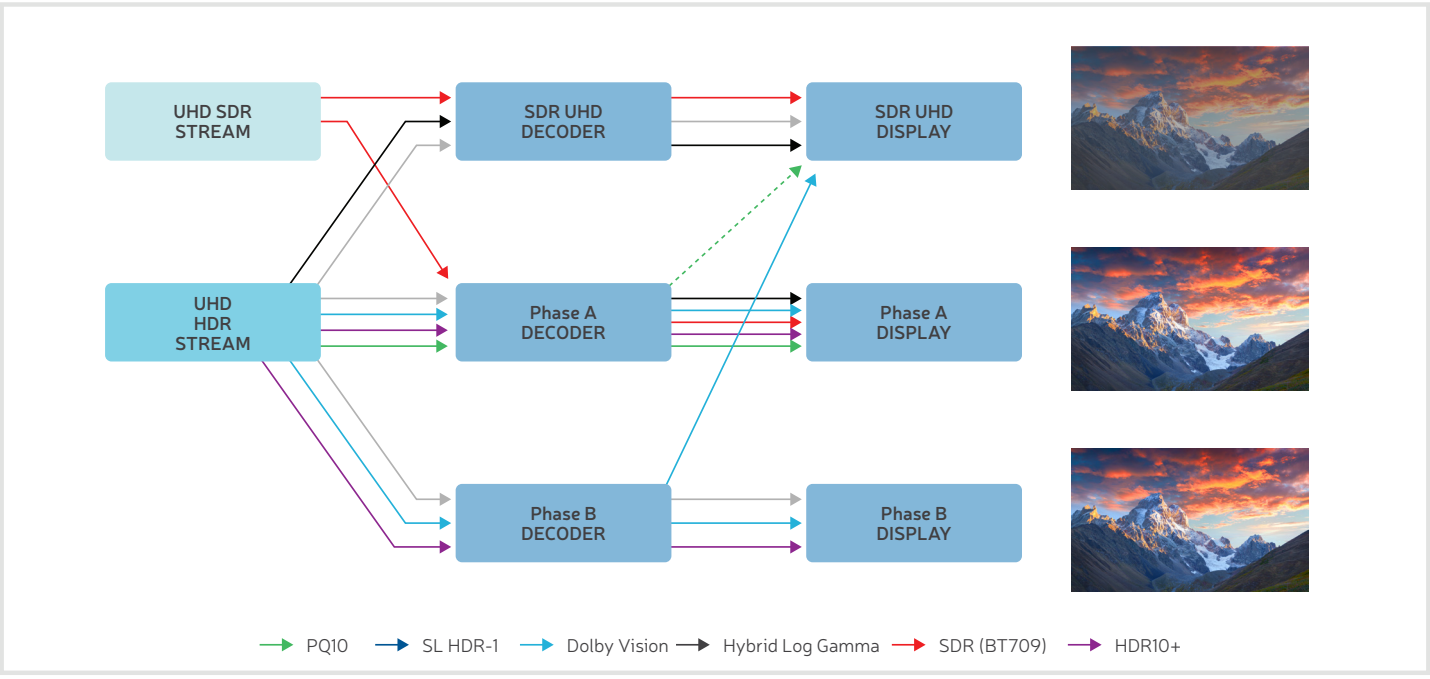

Figure 4: HDR backward compatibility schemes for Phase A

A Dolby Vison Live system enables the full Dolby Vision experience to a Phase B decoder. The same stream sent to a Phase A decoder connected to a Phase A display will only reproduce the HDR10 experience. Note that all Dolby Vision decoders can output an SDR signal toned mapped from any HDR source, including HLG. This system is backward compatible with HDR10 (stream wise) and SDR (from the decoder output) systems.

An SL-HDR1 system will send the full SL-HDR1 experience to a Phase B decoder and the SL-HDR1 stream sent to an SDR decoder/display will produce an SDR experience. This system is backward compatible with any SDR system, from a streaming perspective.

An HDR10+ system will enable the full HDR10+ experience to a Phase B decoder. The same stream can be sent to a Phase A decoder connected to a Phase A display, but it will only reproduce the HDR10 experience.

HDR is a Reality: The State of HDR Deployments

TV HDR ecosystem

Thus far, HDR has been dominated by TVs as the end-user rendering device. The reason is TV is the last element in the chain to render the HDR signal. Therefore, it conditions the HDR experience as opposed to playout, encoder or even decoder systems that are just passing the metadata to reconstruct the HDR signal in the TV. Table 4 shows that different TV models that support HDR as of 2017.

Table 5: HDR Support

TV Manufacturer	HDR10	Dolby Vision	HLG	HDR10+	SL-HDR1
lg	x	x	x		1
loewe	x	x	x		
sony	x	x	x		
TP Vision	x		x	x	
toshiba	x	x	x		
vizio	x	x	x		
tcl	x	x			
le eco	x	x			
hisense	x	x	x		
skyworth	x	x			
changhong	x	x			
panasonic	x		x	x	
konka	x	x			
Philips USA	x	x			
Sharp	x				
jvc	x		x		
B&O	x	x	x		
Grundig	x	x	x		
samsung	x		x	x	
magnavox	x				
rca	x				
Polaroid	x				
Westinghouse	x				

Table 5: HDR support in TVs

Based on the @UHD4K chart of supported HDR devices communicated at IBC 2018, Figure 5 outlines the market share for HD in TV sets at the end of 2017. (These percentages are derived from brand support as opposed to shipped volume or revenue).

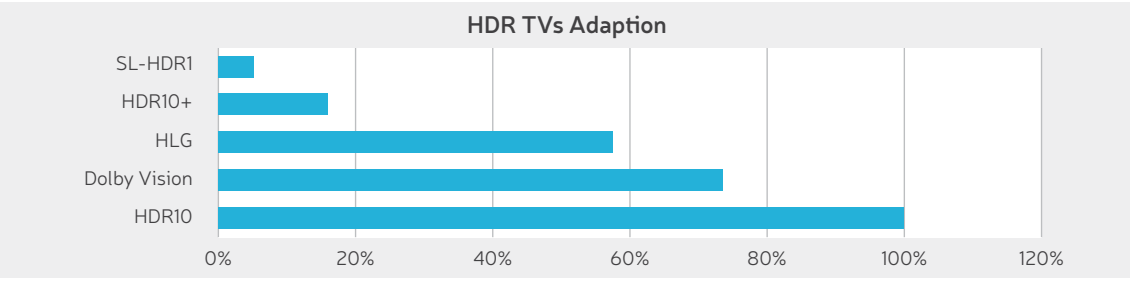

Figure 5: TV manufacturer HDR market share

Figure 6 shows the different players in the video ecosystem that support HDR. As this is a moving target, the diagram might not be accurate at the time of its publication.

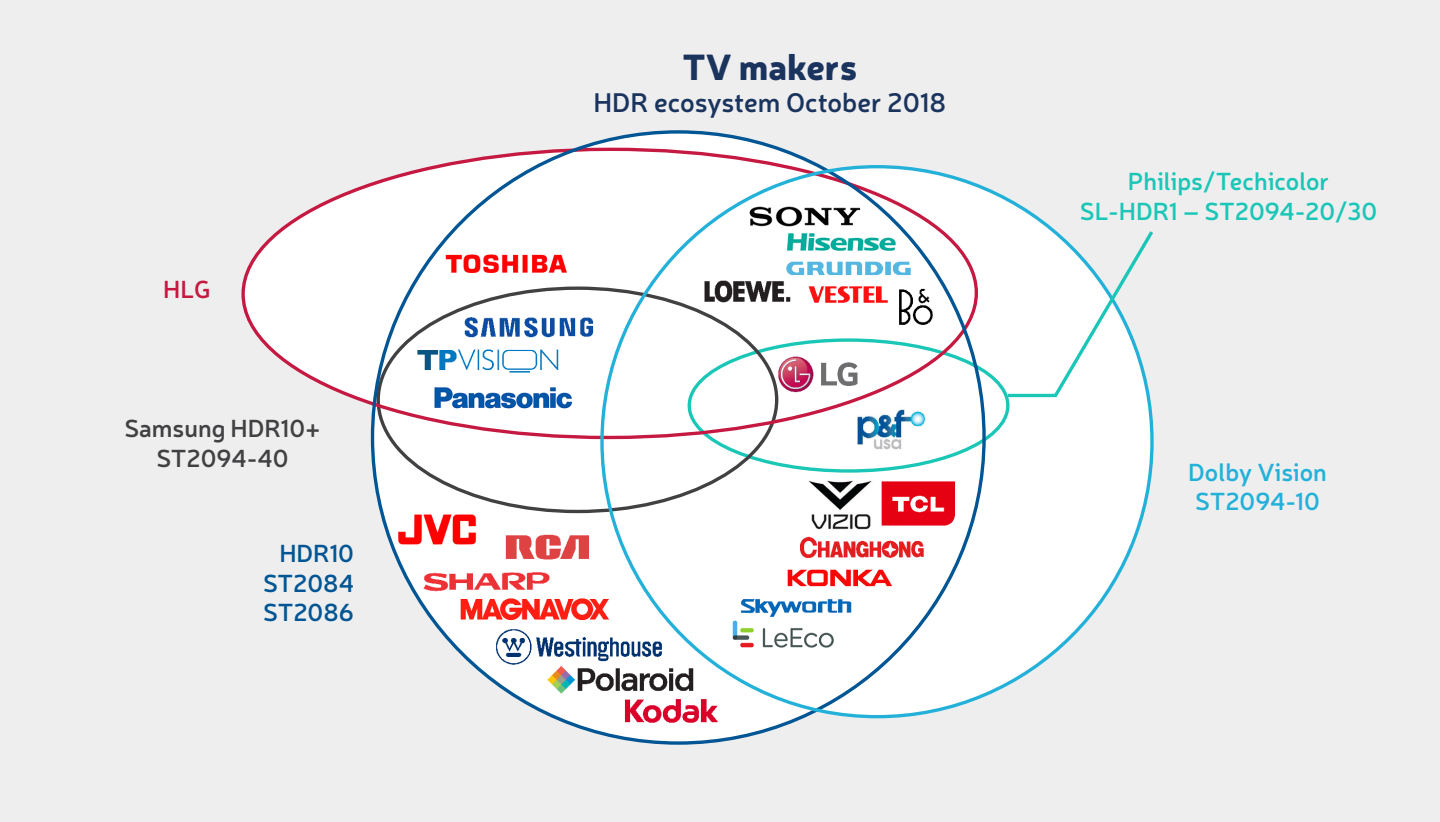

Figure 6: HDR ecosystem, Courtesy @UHD4K

Harmonic's take on the different HDR formats :

- HDR10 is now supported by all TV manufacturers. Therefore, we consider it to be the de facto standard.
- Dolby Vision (VOD and Live for TVs) is the second leading standard. This standard is the frontrunner for delivering a premium VOD experience.
- HLG is the third leading format supported, with 50 percent of the brands backing it. A handful of live HLG services are available. Meanwhile, all four of the major global TV makers (Samsung, LG, Sony and Panasonic) have announced support for HLG in their 2016 and 2017 HDR models. This format is the leading format for live applications, as it also supports the installed base of BT.2020 TV sets produced in 2015 and after.
- HDR10+ (ST 2094-40) only has limited support, which is normal since the standard has only been ratified on the production side with SMPTE. It has not yet been approved for transmission by the ATSC or DVB. Today, only Samsung, Panasonic and TP Vision support this standard.

TV HDR deployments

So far, HDR has mostly been deployed for VOD OTT services, starting in 2016. By the end of 2016, HDR was beginning to be deployed for live.

Table 6 shows the list of deployed UHD HDR services as per April '18. More information, including updates, are provided at **https://ultrahdforum.org/resources/list-of-commercial-uhd-or-4k-services-that-are-live/**

Operator	Country	Type	Service	Network	WCG	HDR	NGA	Delivery	Specification	Deployed	Client
Amazon	US	service	VoD	OTT	BT 2020	HDR10 DV HDR10+	No	Unicast ABR	Proprietary	2014	TV
Astro	Malaysia	service	Live	DTH	BT 709	Soon	No	broadcast	DVB ?	2018	STB
BT	UK	service	Live	IPTV	BT 709	No	Atmos	Multicast	DVB	2015	STB
BT	UK	trial	Live	IPTV	BT 2020	HDR10	Atmos	Multicast	DVB	2017	STB
BT	UK	trial	Live	OTT	BT 2020	HDR10	No	unicast	DVB ?	2018	Mobile
canal+	France	service	Live	OTT	BT 709	No	No	Unicast ABR	HLS	2017	Apple TV
canal+	France	service	Live	DTH	BT 709	No	No	broadcast	DVB	2018	STB
Comcast	US	service	Live	Cable	BT 2020	HDR10	No	unicast	Cablelabs ?	2018	STB
Comcast	US	service	VOD	Cable	BT 2020	HDR10	No	unicast	Cablelabs ?	2018	STB
Comcast	US	service	Live	Cable	BT 2020	HDR10	No	unicast	Cablelabs ?	2016	TV
Comcast	US	service	VOD	Cable	BT 709	No	Atmos	unicast	Cablelabs ?	2014	TV (samsung)
Dalian Tiantu	China	service	TS Playout	Cable	BT 709	No	No	?	DVB	2015	?
Digiturk	Turkey	service	Live	DTH	BT 709	No	No	broadcast	DVB	2016	STB
DirecTV	US	service	VoD	DTH	BT 709	No	No	Push VoD	DVB	2014	Tv (samsung)
DirecTV	US	service	Live	OTT	BT 709	No	No	unicast	?	2016	TV (samsung)
DirecTV	US	service	Live	DTH	BT 709	No	No	broadcast	DVB	2015	Tv (samsung)
DirecTV	US	service	Live	DTH	BT 2020	HLG	No	broadcast	DVB	2018	STB
DISH	US	service	Live	DTH	BT 2020	HLG	No	broadcast	DVB	2018	STB
EPB	US	service	Live	IPTV	BT 709	No	No	Multicast	Mediaroom	2016	STB
Fransat	France	service	TS Playout	DTH	BT 709	No	No	broadcast	DVB	2014	TV
Fransat	France	service	Live	DTH	BT 709	No	No	broadcast	DVB		
Free	France	service	TS Playout	IPTV	BT 709	No	No	Multicast	DVB	2015	STB
Inspur	China	service	Live	Cable	BT 709	No	No	?	DVB	2015	?
KBS	Korea	service	Playout	Terrestrial	BT 709	No	No	broadcast	ASTC3.0	2014	TV
KPN	Netherland	service	Live	IPTV	BT 2020	HLG	No	Multicast	DVB	2016	STB
KT	Korea	service	Live	IPTV	BT 709	No	No	Multicast ?	Korea	2014	STB
LG Uplus	Korea	service	VoD / Live ?	IPTV	BT 709	No	No	Multicast ?	DVB	2014	STB
MBC	Korea	service	Playout	Terrestrial	BT 709(2020)	No	No	broadcast	ATSC 3.0	2014	TV
MBC OB-van	Korea	service	Live	DTH	BT 709	No	No	broadcast	Korea	2017	Internal
Netflix	US	service	VoD	OTT	BT 2020	HDR10 DV	No	Unicast ABR	Proprietary	2014	Various TVs
NHK	Japan	service	Live	ISDB-T	BT 709	No	No	broadcast	4k-8K ARIB	2014	TV
NOS	Portugal	service	Live	IPTV	BT 709	No	No	broadcast	DVB	2016	STB
NTT	Japan	service	Live	IPTV	BT 709	No	No	Multicast	4k-8K ARIB	2014	TV
Orange	France	service	Live	IPTV	BT 709	No	Atmos	Multicast	DVB	2016	STB
SFR	France	service	Live	IPTV	BT 709	No	No	Multicast	DVB	2016	STB
SKBB	Korea	service	Live	IPTV	BT 709	No	No	Multicast ?	DVB	2014	STB
SKY	UK	service	Live	DTH	BT 709	No	No	broadcast	DVB	2016	STB
SKY	Germany	service	Live	DTH	BT 709	No	No	broadcast	DVB	2016	STB
SKY	Germany	service	Push VoD	DTH	BT 709	No	No	broadcast	DVB	2016	STB
SKY	Italy	announced	Live	DTH	BT 2020	HLG	No	broadcast	DVB	2018	STB
SkyLife	Korea	service	Live	DTH	BT 709	No	No	broadcast	Korea	2015	STB
SkyPerfecTV	Japan	service	Live	DTH	BT 2020	HLG	No	broadcast	4k-8K ARIB	2015	STB
Sony	US	service	VoD	OTT	BT 709	No	No	Unicast ABR	Proprietary	2015	Sony TV
Sony	US	service	VoD	OTT	BT 2020	HDR10	No	Unicast ABR	Proprietary	2017	Sony TV
Swisscom	Swittzerland	service	Live	IPTV	BT 709	No	No	Multicast	DVB	2016	STB
tata Sky	India	service	Live	DTH	BT 709	No	No	broadcast	DVB	2015	STB
Tricolor	Russia	service	Live	DTH	BT 709	No	No	broadcast	DVB	2016	STB
UMAX	Korea	service	TS Playout	Cable	BT 709	No	No	broadcast	Korea	2014	TV
Virgin Media	UK	service	Live	Cable	BT 709?	No	No	broadcast	DVB	2018	STB
Videocon	India	service	Live	DTH	BT 709	No	No	broadcast	DVB	2015	STB
Vodafone	Portugal	service	Live	IPTV	BT 709	No	No	Multicast	Mediaroom	2016	STB
Vodafone	Spain	service	Live	IPTV	BT 709	No	No	Multicast	Mediaroom	2016	STB
Vudu	US	service	VoD	OTT	BT 2020	DV	No	Unicast ABR	Proprietary	2015	TV
Telus	Canada	service	Liv & VoD	IPTV		Yes					
waiki tv	France	service	VoD	OTT	BT 709	No	No	Unicast ABR	Proprietary	2015	STB
MolotovTV	France	service	Live	OTT	BT 709	No	No	Unicast ABR	HEVC (DASH+HLS)	2017	Android - Apple TV - Samsung
MöödsTV	France	service	SVoD	OTT	BT 709	No	No	Unicast ABR	DASH+HLS	2017	Android - Apple TV - PC

Table 6. Current HDR deployments

The 2018 premiere soccer tournament held in Russia was produced in different UHD HDR formats: Slog3, HDR10 and HLG, which are sent from the International Broadcast Center to the 24 distributors that will make then available to consumers in their respective countries. Each distributor is then in charge to deliver them in the selected format after conversion to SDR (BT 709), HDR10 or HLG, depending on the devices they want to target.

Below is the percentage of HDR implementation of currently deployed UHD services, as well as the split between the HDR technologies deployed. Source: Ultra HD Forum (April 2018)

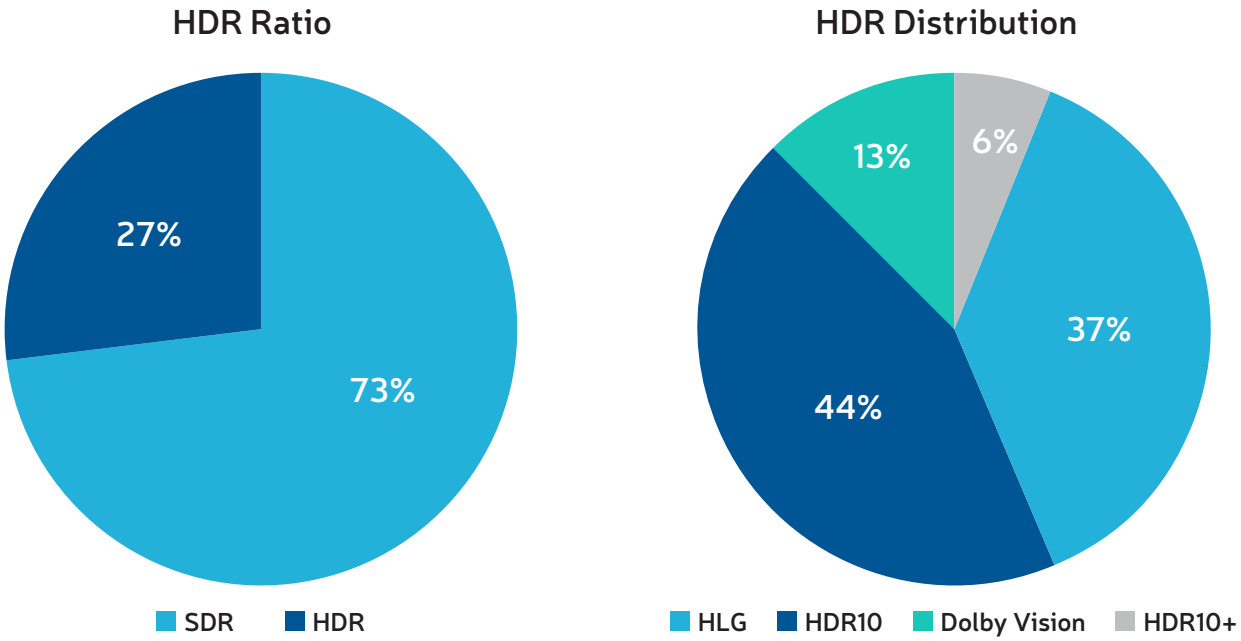

Figure 7: HDR Ratio/Distribution

HDR is clearly getting deployed more often with HDR10 and HLG, which are both part of the DVB UHD-1 Phase 2 and Ultra HD Forum Phase A Guidelines, and are dominating the market with a share of 83% of deployed services.

Mobile HDR ecosystem

Until recently HDR was reserved to TV sets; however, at Mobile World Congress 2018, Sony and LG announced their support of HDR, Samsung S8 announced support for HDR10, and Apple declared that Apple X would support HDR10 and Dolby Vision. As a result, in 2018 a critical number of mobile devices will support HDR, as summarized in Table 7.

	HDR10	Dolby	HLG
Sony	Yes		
LG	Yes	Yes	
Samsung	Yes		
Apple	Yes	Yes	

Table 7: Mobile phone HDR support

There are two significant conclusions to make from the information in Table 6. First, HDR10 is supported on all the phones, as it is on TVs. Second, there are no phones that support HLG, despite its universal support on TVs. If a service provider wants to address smartphones with HDR, it will have to simulcast HDR10 and SDR in BT.709 color space, because there are no phones that support BT.2020 in SDR mode.

Below is an example of the ideal deployment architecture for addressing HDR content on smartphones.

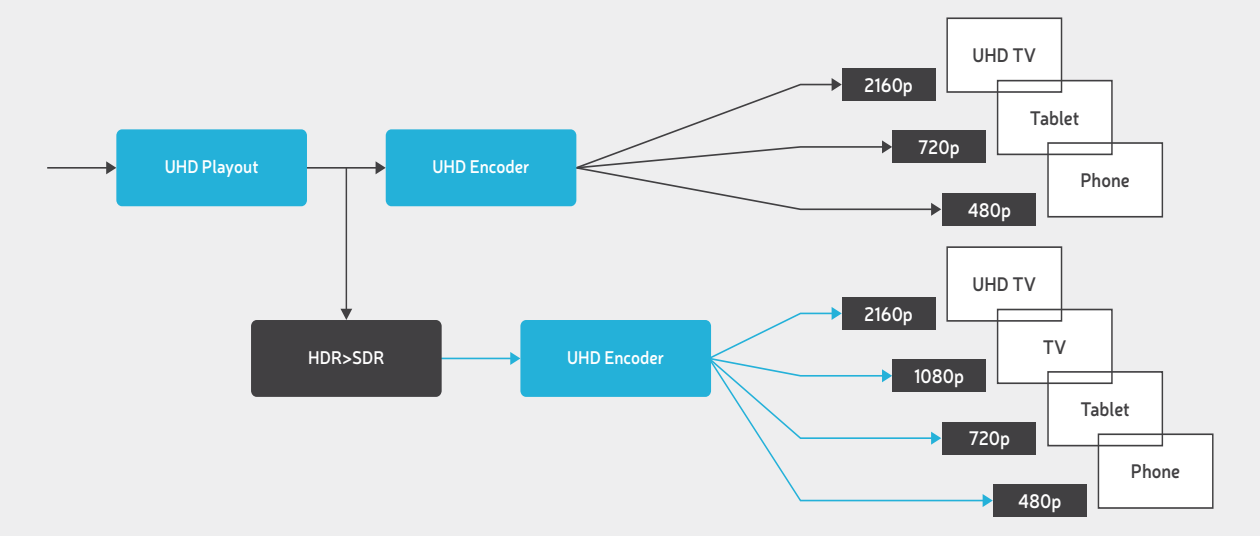

Figure 8. Deployment model for HDR delivery on smartphones

HDR licensing models

The goal of this section is to provide high-level, publically disclosed information. Any licensing term commercial discussions need to be made with the technology provider.

HDR standard	Specification	Licensing term	Sources	Notes
HDR10	CTA/ ITU-R/ DVB / ATSC	Supposed to be royalty free	No formal source	Several articles mention it is royalty free
PQ10	CTA/ ITU-R/ DVB / ATSC	Supposed to be royalty free	Subset of HDR10	
HLG10	CTA/ ITU-R/ DVB / ATSC	BBC has stated it would be royalty free	http://www.bbc.co.uk/rd/projects/high-dynamic-range	
HDR10+	Need to sign licensing agreement with HDR10+ LLC	Set up fee yearly, no per device licensing	https://advanced-television.com/2018/01/08/momentum-grows-for-hdr10	More announcements to come after CES
Dolby Vision	ETSI / ATSC specifications available. For implementation, need to sign an agreement with Dolby	Per Dolby commercial terms		
SL-HDR1	ETSI / ATSC specifications available. For implementation, need to sign an agreement with Technicolor	Per Technicolor commercial terms		
China HDR	Undefined yet			

Table 8: HDR licensing terms

In summary, HDR10 and HLG are the two standards that are easiest to implement and with reasonable licensing terms. Other HDR systems are more complex and require a more expensive investment on the licensing side.

Now that we have analyzed the capabilities of each HDR solution that exists on the market from a standard, feature set, TV and mobile device compatibility perspective, let's look at which option makes the most sense to deploy.

Table 9 provides a summary of all the different HDR solutions that exist today in the market.

HDR10	Dolby	HLG
HDR10	Yes	Royalty free
PQ10	Yes	Royalty free
HDR10+	No	Licensing (setup fee)
HLG10	No	Royalty free
Dolby Vision VOD	Yes	Licensing (per device)
Dolby Vision Live	Yes	Licensing (per device)
SL-HDR1	No	Licensing (per device)

Table 9: Summary of HDR main features

There are a couple of different deployment cases for HDR, including TV-only in a broadcast scenario and a combined TV and mobile service using unicast. When it comes to the TV-only scenario, for an operator that has already deployed an SDR (UHD-1 Phase1) STB, the most attractive choice is to deploy PQ10 or HLG10, depending on the backward-compatibility requirements.

As of today, all deployed broadcast systems are using HLG10. For unicast, PQ10 Live is an option being considered. It should be noted that in a unicast (VOD or live) scheme, with HDR10, a simulcast SDR will have to be provided to the legacy device. This doubles the production, encoding, ingest to CDN and CDN storage costs. In this scenario, it is also possible to deploy a backward compatible scheme such as HLG or SL-HDR1 system, but only newly deployed STBs will benefit from SL-HDR1, while legacy UHD1 Phase 1 STBs can be upgraded to HLG. Legacy STBs will only be able to deliver SDR.

For a green-field scenario, the operator can add Dolby Vision to address the HDR10 and SDR TVs, resolving backward-compatibility issues in the STB. The operator can also deploy an SL-HDR1 system. In this case, only the new STB will take advantage of the SL-HDR1 standard.

For a combined TV and mobile scenario, the safe format to use is HDR10, as opposed to PQ10, which could be a challenge for live workflows, as it is supported on all HDR devices, with an option to move to Dolby Vision Live for new STB deployments or directly to connected TVs.

Conclusion

This technical guide was our attempt to describe the current state of UHD HDR and the attributes of the different HDR technologies. So far, HLG has emerged as the deployment leader for live applications. In 2018, we expect to see PQ10 deployments in unicast to address mobile devices. Due to the large support of TV manufacturers and mobile devices, combined with the complete ecosystem that Dolby has developed around Dolby Vision, we foresee Dolby Vision being deployed in unicast for both TV and mobile use cases. Other HDR techniques like SL-HDR1 and HDR10+ are still in the standardization process and might see increased market interest in coming years.