4K AND HDR, MORE THAN MORE PIXELS
How New Market and Technology Dynamics are Defining Next-Generation TV

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Abstract

As MVPDs shape their approaches to bringing 4K Ultra HD services to market, the emergence of High Dynamic Range (HDR) technology signals that they will soon have an opportunity to deliver a far more compelling viewing experience to their customers.

There's no longer any question that MVPDs must move sooner rather than later to address market pressures that mandate a near-term 4K UHD offering.

Going well beyond the immersive big-screen benefits of 4K, HDR supported TV sets combine greater luminosity, deeper contrast, and a broader color gamut to deliver a stunning picture unlike anything ever seen in mass market television. Just how important HDR is to accelerating 4K adoption can be ascertained simply by viewing a UHD set operating in basic 4K mode next to one equipped to support HDR.

Given market pressures and competitive dynamics, MVPDs can ill afford to wait for HDR to gain traction, even as 4K UHD services are in their nascent phases. Clearly, MVPDs must embrace a migration strategy that embraces the 4K UHD content that exists today, while allowing for the future potential of HDR.

Understanding the distinctions between the most prominent HDR modes and what's entailed in the preparation of content for each, is the first step toward factoring HDR into a UHD service migration strategy. As shall be seen, an appreciation of what's at stake and the attendant challenges, raises the question of what can be done to minimize time-to-market, lower the costs of delivering 4K services that meet consumer expectations, and futureproofing for HDR.

This paper begins with a brief overview of the UHD market, followed by a discussion on the bitrate impact on quality to enable MVPDs to offer 4K UHD content in this early state. We then cover the impact HDR technology is having on the quality of the UHD experience. Next, we turn to a detailed look at HDR technologies, the paths to market adoption and progress toward establishing the new workflow elements that will go into bringing this content to market.

UHD MARKET MOMENTUM

The Big-Screen Factor

Consumer demand for large-screen smart TVs is the greatest force behind the 4K UHD. Early sales are less driven by consumer demand for viewing UHD content, of which there are limited titles (although upscaling capabilities allowing 4K UHD sets to display Blu-ray 1080p HDTV at a higher level of resolution have been heavily promoted as a sales incentive).

A rapid drop in prices, rated by consumers in the CEA study as the biggest consideration in 4K set purchases, is fueling expectations for increased sales.[1] Top-tier brand suppliers are pricing 55-inch 4K sets at under $2,000, which is anywhere from $600 to $1,000 above the cost of a reasonably good quality 55-inch HD smart TV. This is a long way from the

thousands of dollars that separated them three years ago.

The Content Factor

Before long, content will begin to play a larger role in 4K UHD demand, thanks in part to the aggressive steps taken by OTT service providers. UHD services are already available to owners of 2014 or later LG, Samsung, Sony, and Vizio UHD sets. MVPDs are also making moves into the market, starting with Comcast and DirecTV, whose initial offerings are targeted to Samsung TVs.

Adding to the momentum, Dish Network announced it will roll out a new UHD set-top this summer that will work with UHD TV sets equipped with HDMI 2.0 and HDCP 2.2. Major pay TV networks may soon be contributing UHD content as well. A recent survey conducted by researcher FairmileWest found that at least six pay TV broadcasters plan to offer some UHD content online this year.[2]

MOVING AHEAD WITH 4K UHD

Launching a 4K UHD service is a major undertaking that cannot be accomplished merely by adding a new generation of transcoders. Acquiring and ingesting content for UHD is much more complicated than what MVPDs are accustomed to in the HD realm, where they typically receive content that has been pre-qualified with respect to basics like synchronization of video and audio, compilation of metadata, captioning, thumbnail art, etc.

Formatting content from various sources to a uniform level of 4K quality requires expertise in different conversion processes, depending on whether the content was originally shot in 35 mm film, 1080p HDTV or 4K cinematic profile. Unlike the highly automated processes attending format conversions in the HDTV realm, these 4K UHD conversions are resource intensive.

For example, MVPDs must be able to implement quality assurance procedures at every stage of the workflow, from ingest to final staging for distribution. Critical to delivering a superior consumer experience is the ability to take high quality content and make it playable across multiple formats and devices, while also testing that content across the vast range Consumer Electronic companies to ensure the intended playback experience.

Bitrate Impact On Quality

Supporting 4K UHD to both large form factor TVs and lower resolution formats on mobile devices is a balancing act, with the need to minimize bitrates without sacrificing quality in the HEVC transcoding process. This is dependent on the relationship between the source material, size of the master file and the quality of output in the transcoding process.

While there is much fanfare about 4K natively shot content, a significant portion of the libraries will likely be available utilizing the very best 1080p ProRes HQ master source materials available at bitrates of 600-700 Mbps or higher, that can be up-converted to 4K UHD. High bitrate source material, >100 Mbps, is key to achieving high-quality outputs in the HEVC transcoding process. Lower bitrates typically delivered to the MVPD, <15 Mbps, is not a sufficient source for up-converting and transcoding a 4K UHD output.

When using higher quality source material, MVPDs are able to deliver 4K UHD-caliber content that has been up-converted from 1080p masters with output maximum bitrate settings of just 10 Mbps. Furthermore, this content can be delivered as adaptive bitrates (ABR) in lower HEVC transcode outputs of

1080p 7.5 Mbps and 720p 3.8 Mbps to ensure the adaptive bitrate video stream will continue uninterrupted in instances where congestion or other events momentarily cut a user's bandwidth throughput to below 10 Mbps.

Results Using Episodic 1080p Masters

Deluxe OnDemand recently conducted tests with video camera captured, episodic 1080p material with the following source specifications: ProRes HQ 422 10-bit 600 to 700 Mbps. Through advanced "up-res" processing, Deluxe was able to produce content that looks better on a 4K TV than on an HD TV from standard AVC and MPEG2 ready to play 1080p material. Results showed:

- When objects move through the screen, UHD provides more pixels to smooth the motion and reduce image ghosting across multiple frames compared to HD.
- Edges are distinct providing clear separation from backgrounds and other objects in UHD – edges will be slightly fuzzy on HD.
- Static backgrounds do not exhibit blocking or compression artifacts – with less bits HD may mush pixels together to save bits for areas of motion, resulting in macro blocking.
- Straight lines are clean and crisp in UHD – HD may exhibit stair stepping across pixels.
- Skin complexion is more readily apparent in UHD, with greater detail than HD.
- UHD is capable of displaying individual hairs - HD tends to lose thin line details.
- Static backgrounds do not exhibit blocking or compression artifacts – with less bits HD may mush pixels together to save bits for areas of motion, resulting in macro blocking.
- Small details on fabrics are captured in UHD – HD detail will average fine patterns, looking less clear.

Results Using Studio 4K Native Shot Maters

Deluxe OnDemand conducted additional tests on 4K native shot footage that had all of the challenging elements that video compression technology struggles with -- motion, dark footage, water, reflection, skin, hair and CGI.

The content was presented in two bitrates and from two source masters:

Output Bitrate	**Source**
20 Mbps	UHD Master, 8 Gbps, v210 AVI
15 Mbps	UHD Master, 8 Gbps, v210 AVI
20 Mbps	1080p Master, 600-700 Mbps, ProRes HQ
15 Mbps	1080p Master, 600-700 Mbps, ProRes HQ

Clearly, the output based on the UHD master at 20 Mbps yielded the best experience. However, consumers would see discernable improvements from the UHD master source at 15 Mbps and the1080p master source at 20 Mbps.

THE HDR FACTOR

Now there's a new development that could make a big difference in UHD penetration and service expectations – HDR.

As the name implies, High Dynamic Range goes beyond the spatial resolution benefits of 4K by breaking with the long-standing Standard Dynamic Range (SDR or

ITU REC 709) specifications that have defined how TV content is presented since the dawn of the HD era 20 years ago. The various HDR modes now vying for market acceptance all have in common (a) support for a much wider color gamut,(b) much greater contrast dynamics with deeper levels of black in the darker pictorial elements and (c) far greater luminance in the brightest white and color elements.

As depicted in **Figure 1**, the impact of HDR is obvious.

Figure 1: Impact of HDR

The goal is to more closely match the dynamic range of the human visual experience in the natural world. HDR specifications were tied to the limitations of the cathode ray tube (CRT), which can render the darkest scenes at no lower than .117 nits and top out with the brightest white at 100 nits and color brightness ceilings at various levels below 10 nits.

The human eye can detect a luminance range from one millionth (0.000001) of a nit to about 100 million nits. For formulating HDR displays, the goal of course, isn't to match this range but rather, to operate within a dynamic contrast range that is closer to what the eye experiences in the natural world as a person's gaze moves from bright to dark backgrounds – in other words, the instantaneous dynamic range available to human perception as a function of pupil dilation and other opto-physiological processes in real-world situations.

THE TECHNICAL ELEMENTS OF HDR

Contrast Ratio

One way to measure dynamic range in video imaging is to derive a contrast ratio across the entire luminance range based on exposure value or stops, which originated with the f-stops used in camera settings for still photography. One stop is equivalent to a doubling of light value, so that with each stop the luminance increases by a power of 2.

The dynamic range of SDR, at about seven stops, represents a contrast ratio of 128:1. HDR, at the baseline value incorporated in some emerging standards, is about 11 stops, which represents a contrast ratio of 2,048:1, or about 16 times that of SDR. The contrast ratios enabled through enhancements used with templates supported by Dolby, Philips and others go up from there. With everyday experience in the natural world, the maximum contrast ratio registered by the human eye in a given instant with minimal adaptation is about 20 stops, which equates to a 1,048,576:1 contrast ratio.

Dolby, in ascertaining with focus groups the ideal dynamic range that its Dolby Vision enhanced HDR technology should support to create the most realistic human experience possible without producing contrasts that would be jarring to viewers, found that consumers chose as the optimum a range of 0 to 10,000 nits. But while a 10,000-nit dynamic range became the foundation specification for Dolby Vision, the company has settled on 4,000 nits, equating to between 17 and 18 stops or a contrast ratio of 200,000:1, for the initial commercial iteration.

Color Space

Where color gamut is concerned, the goal is to set a benchmark for production that minimizes the amount of color lost from original camera capture, such as occurs when producing content that maps to the REC 709 standard. The ITU has developed REC 2020 as the successor to REC 709, thereby providing a standardized palette for use in video imaging that comes closer to the full color range in nature. Where, with 8-bit encoding, REC 709 encompasses 16.78 million colors, REC 2020 with 10-bit encoding offers 1.07 billion colors. With 12-bit encoding the REC 2020 color count tops out at an incomprehensible 68.7 billion colors.

But a more reasonable target to shoot for is the color gamut devised by the Society of Motion Picture and Television Engineers (SMPTE) with the DCI P3 standard, which is the color range that cinema projectors are pegged to and which, therefore, is the color range used in the filmmaking postproduction process. With 10-bit encoding DCI P3 encompasses a range of 756.6 million colors. See **Figure 2.**

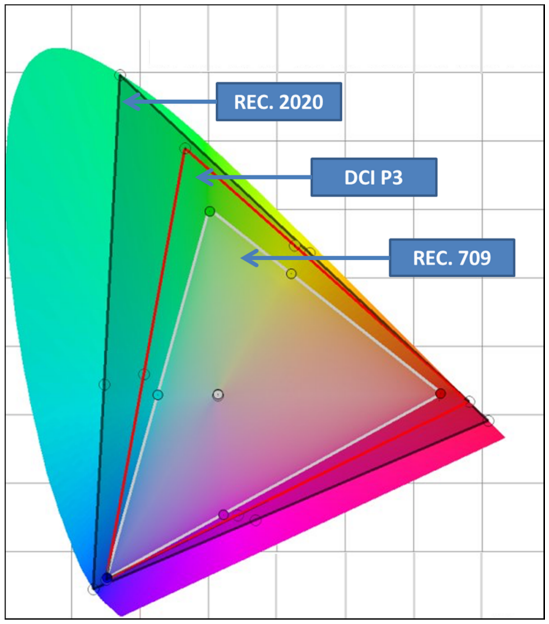

Figure 2: Color Gamut Comparison

Deluxe, which has been working closely with Dolby to set post-production parameters for content to be viewed on Dolby Vision-enabled TV sets, has set the color gamut target to the DCI P3 specifications. This provides a uniform post-production gamut which will also be more than enough to meet the requirements of "baseline" HDR TV sets.

The Transfer Function

A key parameter affecting the ability of manufacturers to repurpose current generation LCD/LED displays to support HDR is what is known as the "gamma function," which is a non-linear transfer function that maps the grey scale signal strength of the display system to the color gamut and dynamic range of the post-production master. Originally set to the display dynamics of CRTs, the gamma function has been enhanced to accommodate the capabilities of LED/LCD displays.

SMPTE 2084 defines an Electro-Optical Transfer Function (EOTF) that is meant to replace the gamma function in order to extend the range of the color gamut and contrast transfer into the realms defined by REC 2020.

SMPTE 2084, using an encoding system known as Perceptual Quantization (PQ), also serves to compress the transferred information in order to reduce the number of bits per color that would otherwise be required to execute the new parameters. For example, without PQ Dolby Vision would probably require 16- rather than 12-bit encoding to signal the high dynamic range and wider color gamut to the display decoder.

Baseline 10-bit HDR systems at luminance levels in the 1,000-nit range and with color a gamut significantly below the full scope of the 12-bit version of REC 2020 or DCI P3, can use the enhanced gamma function. However, Dolby Vision and the enhanced HDR system developed by Philips rely on the more expansive EOTF to enable the display systems to reach the higher color and dynamic ranges achieved with 12-bit encoding. The dividing line between the levels of HDR performance that can rely on the gamma function versus performance levels that require use of SMPTE 2084 may well be a key factor in efforts to define a common baseline HDR standard and a "premium" standard.

Display Systems

Another key factor in setting HDR parameters is the need to minimize costs by leveraging the current generation of SoCs (systems on a chip) used in TV sets. These chipsets have enough processing power to handle the Dolby Vision luminance, color and contrast enhancements. These enhancements, utilizing 12-bit encoding, are conveyed in a metadata overlay, which the SoC decoding processes combine with the regular REC 709 video feed to deliver an integrated signal to Dolby Vision display systems.

This bifurcated overlay approach ensures that content mastered to Dolby Vision specifications will also be viewable on traditional displays, where the SDR decoder does not interact with the metadata. But, from a bandwidth perspective, it adds about 20 percent in bandwidth overhead to the bitstream.

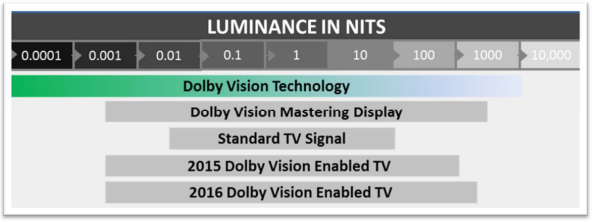

Figure 3: Display Luminance in Nits

As shown in **Figure 3**, the big difference between Dolby Vision, and more basic HDR systems when it comes to manufacturing requirements, is in the displays themselves. Dolby Vision uses individually modulated LED semiconductors that can be switched across multiple steps of luminance from 0 nits to the chosen peak level of brightness, which, as mentioned, is about 4,000 nits for the first-generation Dolby Vision. This requires production of all-new display systems, whereas the current generation of LCD displays, particularly those with better local back-lit contrast controls, can be repurposed with firmware upgrades of current-generation SoCs at the factory to support HDR platforms operating in the 1,000-nit range.

STANDARDIZING HDR

At CES 2015, most of the major brands had prototype HDR sets on display with a bewildering potpourri of labels such as Wide Color LED from LG Electronics, Dynamic Range Remaster from Panasonic, X-tended Dynamic Range from Sony and SUHD from Samsung. Prototypes supporting Dolby Vision were on offer from Toshiba, Hisense, Philips and Vizio.

Efforts to set standards have made significant headway, but there are many initiatives underway that will have to be brought together on the road to true

standardization. These include the ITU's pursuit of a global UHD standard; the U.S. broadcast industry's development of ASTC 3.0; the Blu-ray Disc Association's (BDA's) Ultra-HD Blu-ray platform; the end-to-end UHD agenda at the Ultra HD Forum, and the efforts of the new UHD Alliance.

The UHD Alliance, which was launched at CES, is the latest undertaking, fueled by Samsung's proposal of an open HDR solution. This initiative has brought together some key players from across the consumer electronics, OTT, MVPD, content and studio sectors.

At this early stage, while there may be refinements to Samsung's proposal through contributions from other UHD Alliance members, it appears that open HDR will prevail as a "basic" HDR format, while Dolby Vision could well emerge as a "premium" format. Where the first generation of Dolby Vision has been pegged to a 4,000-nit range in luminance, Samsung's version of open HDR supports a 1,000-nit range.

Meanwhile, the BDA has revealed basic parameters of the Ultra-HD Blu-ray standard scheduled for release later this year. According to press reports, the specs will support an open HDR standard using 10-bit HEVC encoding and SMPTE 2084 signalling while making provisions for two optional solutions, Dolby Vision and the Philip's proposal, that can be layered onto the basic platform. The BDA also includes means by which 10-bit encoding and the wider color gamut can be applied in the presentation of SDR content.

It remains to be seen how all this plays out. While the goal is to deliver products that can be branded with an HDR label guaranteeing a consistent quality of experience on all displays, the industry must reach consensus on basic questions such as what the minimum nit threshold should be, at what point does the nit count exceed viewers' comfort levels, how much contrast is too much and how broad the color palette must be to qualify as HDR compliant.

THE COMMECIALIZATION OF HDR

Whatever comes of the standardization efforts, one thing is certain: HDR when combined with the high resolution offered by 4K UHD, delivers a powerful viewing experience that truly differentiates UHD. While today's LED/LCD TVs deliver luminance at up to 300 to 500 nits, which is sufficient to enable viewing in a brightly lit room, these levels of brightness are achieved with display enhancement techniques applied to content that has been mapped to the contrast and color range of REC 709.

There's no improvement when it comes to fidelity to color or better contrast. For example, there's still no ability to accurately render Coca-Cola Red or the green used on Caltrans highway signs in California. In fact, these brightness enhancements introduce distortions that often take the viewer farther away from the creator's intent with heightened emphasis on "out-of-gamut" colors. And without sufficient contrast, the increased brightness can produce a wash-out effect across color gradations on the limited REC 709 scale.

HDR from OTT Providers

Consequently, buyers of HDR-enabled 4K UHD TV sets will look for 4K content sources that can deliver the far superior experience of HDR. Judging by plans publicized so far by various content providers, HDR set owners won't have long to wait.

One OTT provider, for example, has publicly committed to begin streaming HDR-caliber content this year. While the company has been a vocal proponent of Dolby Vision, executives have said it will be able to support other formats as well. Dolby has announced

commitments from many OTT providers at the present time.

The motion picture studios are beginning to react to the HDR potential as well. Some are already formatting movies for viewing on Dolby Vision displays while others have announced exclusive deal to make some of its movies available for viewing on displays using Samsung's open HDR.

While we don't know how soon HDR-enabled 4K UHD TV sets and the availability of HDR content from OTT sources will begin shaping the expectations of cable subscribers, the fact that early adopters will most likely come from the ranks of MVPDs' highest paying subscribers means their expectations will carry special weight in determining how HDR factors into UHD service strategies. Thus, it's likely MVPDs will need to begin supporting HDR sooner than later, well before the standards issues are fully resolved.

MEETING THE MVPD CHALLENGES

Expediting the Move to HDR

The advent of HDR introduces new challenges for MVPDs. The ability of OEMs to quickly move from 4K UHD to HDR attests to the fact that the systems on chips (SoCs) used in today's television sets are so powerful that new levels of viewing experience can be achieved through advances in software, without having to wait for new generations of hardware.

As a result, MVPDs face a protracted period of transition to mass market adoption, during which they will want to be able to support multiple permutations of HDR without incurring untenable costs. In addition to all the steps associated with ingesting, storing and processing content for higher resolution, MVPDs must be able to establish the workflows essential to ingesting and converting content that can be mapped to the higher color gamut, luminance and contrast ratios of each HDR mode.

Thus, the benefits of the outsource option increase with the addition of support for HDR, which may only be of interest to a small proportion of their subscriber bases. By utilizing an outsource service that is able to support any commercially viable HDR mode, MVPDs will avoid the pain of any format wars preceding industry agreement on standards.

The new procedures start with establishing relationships and a means for acquiring source material that has not been processed in post-production for SDR distribution. In other words, MVPDs want to be able to use source materials that have not lost their original colors, contrast range and brightness in a mastering process. In so doing, they will be able to add value even to old films, which will be converted for TV viewing at a quality level that rivals the original theatrical experience.

MVPDs will need to be able to adopt conversion processes essential to supporting whichever HDR modes gain traction in the marketplace. This will require new expertise, new tools, and in the case of an enhanced HDR service such as Dolby Vision, support for 12-bit encoding and processing steps related to creating the metadata for transmitting enhancements to the baseline REC 709 formats.

Adding to the challenges is the fact that, at this early stage of HDR development, the details of how to execute on all these requirements must be worked out through close working relationships with providers of HDR technology. For example, just as it took time for Deluxe OnDemand to work out all the details that have allowed it to create a fast-to-market launch pad for 4K UHD services, it will take time to develop the optimal HDR platform for baseline and enhanced levels of HDR distribution.

Deluxe, working closely with Dolby and other HDR platform providers, is moving rapidly on this path. As a result, MVPDs can proceed with launching and scaling 4K UHD services in tandem with market demand without waiting until they're ready to support HDR.

When they are ready to add HDR to their UHD options, they will be able to avoid the long delays they would incur by having to climb the learning curve in-house. With the workflows, tools and practices already in place, they will be able to get underway as soon as they determine market conditions have reached the point where they stand to gain by offering their customers the unprecedented viewing experience of HDR.

CONCLUSION

The prospects for consumer adoption of 4K UHD have been increased by virtue of commercial introduction of HDR technology as a major enhancement to the viewing experience. With 4K UHD penetration outpacing earlier industry projections and ever more 4K UHD content entering the market, MVPDs already have ample reason to launch a 4K UHD service, but it won't be long before the same can be said of HDR.

By delivering a quality of experience far beyond that of SDR-formatted content, HDR promises to drive consumer expectations even higher as 4K UHD takes hold. Already, leading OTT suppliers, who were first to market with 4K UHD content, are preparing to introduce HDR content before year's end.

Just as MVPDs cannot afford to cede the 4K UHD viewing advantage to OTT competitors, they cannot ignore the implications of HDR for service development. The question is, with 4K UHD just getting off the ground and so many HDR formats in play, how can these emerging market imperatives be accommodated without spending immense sums on the staffing, workflows, tools and storage capacity these new technologies require, long before the market for these services will grow large enough to generate a reasonable ROI.

The answer can be found in leveraging the shared-cost environment of an outsource supplier for the heavy lifting to launch and scale 4K UHD in the near term, with expectations that similar benefits will accrue when the time comes to introduce HDR services. Companies such as Deluxe OnDemand are already playing the role of the outsource workflow supplier of 4K UHD services to MVPDs, with all the processes essential to delivering a superior 4K UHD service at minimal costs. Furthermore, the outsource strategy has an inherent futureproof component for HDR support. As a result, customers can be assured they will have the opportunity to introduce HDR services whenever they determine the timing is right to enter this next phase in the transition to next-generation TV.

Footnotes:

[1] Consumer Electronics Association, 4K Ultra HD Update: Consumer Adoption & Awareness, January 2015

[2] The Digital TV Group, "At Least Six Pay TV Broadcasters Set to Launch UHD Services this year," January 2015