Not All 4k Is Created Equal: Finding Clarity, Reducing Costs

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Abstract

4K is the new leading television technology that will capture consumers' imagination. While the industry recognizes the potential, the processing, workflow, and delivery mechanisms must be re-defined for mass scale as subscribers embrace this exciting new viewing experience and 4K UHD devices proliferate.

As 4K unfolds, multichannel video programming distributors (MVPDs) will assume that files delivered by studios and content providers will conform to the optimal viewing experience across the multiscreen device landscape. In reality, all 4K is not created equal.

To prepare for 4K processing, workflows and distribution, MPVDs must sort through multiple issues to ensure that 4K-optimized content measures up to the requirements of a superior customer experience. In this paper, we will begin to frame the conversation to address the many questions that MPVDs will have to answer to distinguish true 4K-optimized quality content from everything else going by that name. We also consider steps operators can take to position themselves as leading providers of very high-quality content and the ways in which use of cloud-based management and storage can greatly reduce the costs of offering a 4K service.

INTRODUCTION

Faster than many experts anticipated, 4K Ultra High Definition (UHD) TVs are moving toward initial commercialization, bringing with it a new set of issues and requirements that will have to be addressed by MPVDs in preparing for and enabling distribution of 4K-optimized content.

These issues revolve around properties specific to two major areas of technology development: the 4K platform itself and the new encoding standard, High Efficiency Video Coding (HEVC) or H.265, which will be required to reduce the bandwidth constrains imposed by distribution of programming in the 4K format. Our goal here is to discuss the broad range of considerations that must be addressed as MPVDs set parameters essential to ensuring their 4K services deliver a quality of experience commensurate with market expectations, at costs commensurate with the pace of 4K UHD TV set penetration and consumer demand.

Fundamentally, it should be understood that there will be variations in the quality of 4K formatted titles from content providers and post-production houses. This is based on nuances having to do with parameters used in the preparation of content from sources that are either 4K native shot and mastered production or in the conversion, restoration, and re-mastering from film or High Definition (HD). Furthermore, to ensure that the playback experience is optimized on target devices, 4K files will need to undergo rigorous testing and quality

analysis of frame rates, bitrates, color gamut, bit depth, and decoding algorithms.

Operators, programmers and technology organizations such as CableLabs® will have to work together to determine what the thresholds should be across several parameters to ensure the Quality of Experience (QoE) targets are met. These include:

- Color gamut and depth
- Contrast depth
- Frame rate
- Mode of converting legacy content to 4K
- HEVC profile
- HEVC-encoded distribution bitrate

Beyond these core technical concerns, MPVDs 4K strategies will need to take into account a variety of business and cost-related issues. These include:

- The benefits and technical requirements associated with delivering a pre-4Kservice, where content formatted in 1080 progressive (1080p) HD can be up-scaled by 4K UHD TV sets for high-quality display;
- Determining the right balance between relying on HEVC-capable set-tops to support 4K pay TV delivery vs. IP-based distribution over broadband to HEVC-enabled IP-connected devices, including Smart TVs as well as smaller portable consumer electronic (CE) devices;
- The cost impact of accommodating workflow, ingest, storage and file management requirements of 4K-optimized content and the degree to which CapEx and OpEx might be alleviated through use of cloud-based management and storage.

EVALUATING PARAMETERS ESSENTIAL TO ACCEPTABLE QoE

Color Space

There remains some uncertainty within the industry's production circles over the definition of the ideal range of color gradations for4K, as expressed in three leading color space formats:

- the ITU's Recommendation BT.709 or rec.709, the foundation color depth standard for digital TV since 1992;
- rec. 2020, a new standard for next-generation TV, including 4K UHD;
- Dolby Vision, a proprietary system designed to comport with the requirements of High Dynamic Range (HDR) imaging.

Early iterations of 4K UHD TVs on display at leading events and trade shows in 2013 relied on rec. 709, which prescribes a bitrate of 8-bits per color with 256 gradations per primary color, for a total of approximately 16.8 million possible colors. The industry consensus was that the higher resolution enabled by 4K UHD at 3,840 x 2,160 pixels, twice the pixel width and height density of HD 1080p resolution, was not a strong enough differentiator to drive consumer demand for the new TV sets, given that the color gamut used with those early displays was the same used by HD.

However, with the introduction of rec. 2020 on chipsets and in next-generation displays appearing at events in 2014, the consensus shifted to a thumbs-up on the appeal of 4K compared to HD, whether the display was on a large form factor TV or a small-screen handheld device. With a coding scheme of 10- or 12 –bits per color, rec. 2020 generates about 1.07 billion colors with 10-bit coding and a whopping 68.7 billion colors with 12-bit coding.

At this point, the market is increasingly focused on the 10-bit version of rec. 2020 with color depth of 1024 gradations per primary color. While 10-bit vs. 8-bit might seem to represent a 25 percent increase in encoding bit rate, the actual margin of increase is much lower, owing to compression methodologies and narrower gamut of legacy content. However, 10-bit does represent some increase in bit rate over 8-bit encoding.

Further boiling the waters is the emergence of Dolby Vision as a contender for adoption as the de facto 4K capture and display standard. This is based on what proponents and many objective observers believe to be a significantly better quality picture than seen so far with 4K. Dolby Vision uses the 12-bit version of the rec. 2020 color palette and introduces far greater contrast capabilities in line with HDR imaging.

Some vendors are touting HDR imaging capabilities as well. But Dolby appears to have gone much farther in gaining market penetration with leading Consumer Electronics (CE) manufacturers including Sharp, TCL and Vizio. They are already producing 4K UHD TV models based on Dolby Vision. Several Web video providers, including Amazon, Vudu and Microsoft X-box, have committed to producing HDR-caliber content using Dolby Vision, if and when a consumer market emerges for the format. While there's been much focus on Dolby's demonstration of a prototype display generating eight times the brightness of conventional displays, the real goal of HDR is not so much to increase luminance as it is to generate greater contrast across whatever the range of luminance might be for a given display.

At the present time, the best bet for driving consumer adoption of 4K is 10-bit rec. 2020-based display technology. That said, it's possible the baseline for 4K-optimized content could shift between now and when the threshold of 4K UHD TV set penetration reaches a point where it becomes necessary to introduce 4K services. The prudent thing will be to develop strategies on the assumption that quality parameters will revolve around a rec. 2020 baseline while being nimble enough to adjust should conditions change.

Frame Rate

Another factor that remains an open question is the optimal frame rate for 4K services. A common misconception is that 60 frames per second (fps) is a given requirement with 10-bit rec. 2020. In truth the optimal frame rate is a function of the need to minimize the number of transformations any content file goes through prior to staging it for distribution to consumers. Any time a file goes through a transformation, say, from 23.976 to 60 fps, the process introduces artifacts that far outweigh the benefit of moving to the higher frame rate.

Consequently, it's better to accept files natively captured at the standard film industry rate of 23.976 fps or the TV programming rate of 30 fps rather than insisting they be reconfigured to 60 fps. In any event, where natively stored 30 fps content is concerned, the frame rate can be increased to 60 fps in the distribution transcoding process, since it's a multiple of the native rate. The fact that 120 Hz is now the top frame rate supported by most 4K UHD TV sets greatly simplifies matters, since it is a multiple of all these lower rates. The fact that 120 Hz is a 5x multiple of 24 has contributed to the ability of 4K UHD TV

sets to work compatibly with Blu-ray, which is pegged to the 23.976 fps film rate, even to the point of performing upscale processing to enhance the quality of the Blu-ray HD content when displayed on 4K UHD TV sets.

MODES OF CONVERSION TO 4K

Another dimension in a MPVDs' search for baseline requirements is the impact of the various modes of format conversions from HD and film to 4K will have on the quality of content. Early on, most content licensed for network-delivered 4K will likely be content such as older movies that have been converted to 4K.

MPVDs will have to be vigilant in their acquisition of converted content insofar as some processes used in the conversion process won't produce 4K material that measures up to MPVD quality standards. The move to specialized 4K conversion capabilities is better understood by lab-based post-production houses who can address the right balance between quality and economics to build large 4K libraries.

Upscaling

The lowest-cost approach and therefore one that's received early market appeal involves upscaling of the original files. In its most basic form, upscaling does little more than quadruple the number of pixels. However, there are some versions of the upscaling process that attempt to augment the quality through algorithmic processes and add information by "guessing" what a rendering with deeper color depth and contrast would look like.

While upscaling may offer a fast track to library building, operators will have to decide whether any of the upscaling methods will meet the higher quality expectations that subscribers expect and demand.

A special case in addressing this question is how to convert content originally shot in 4K but which has been down-scaled to 2K to accommodate the prevalence of 2K projectors in theaters. Here, the gap to be closed in the scaling process is smaller, but operators will have to decide based on technical analysis of scaled content whether such techniques will be sufficient for processing this type of content.

Scanning

MPVDs will be on much more solid ground to the extent they can rely on suppliers of 4K content who use more advanced conversion methods such as scanning to convert 2K and film to 4K. But there are nuances that will impact quality with these methods as well.

One approach involves scanning each frame individually to create a sequence of uncompressed discreet image files, usually in the Digital Picture Exchange (DPX) format, which in turn are processed with various restoration imaging applications, including applications that bring the 4K color palette into play. An alternative approach involves continuous scanning, basically an enhancement of the old Telecine restoration process, which scans the frames as the film runs through the scanner - slower than real time but faster than the one-second-per-frame speed of the intermittent frame scanning process. Either way, the processing procedure also repairs defects in old films such as scratches and removes dust and other materials, leaving a pristine, very large master file which must then be compressed for storage.

No matter what the scanning methodology might be, it's important to recognize that additional steps must be taken when it comes to encoding the converted content for storage to avoid introducing excessive graininess into the completed file. Older film stock, being grainier than newer films, is especially problematic in this regard.

While film converted and encoded digitally for display on today's HD TV sets has not posed much of a problem, use of HEVC and the higher resolution of 4K UHD TVs will display the picture more accurately than has been possible in the past. HEVC, by virtue of the more advanced processing techniques used with this encoding protocol, captures the graininess with greater clarity than was the case with H.264 or MPEG-2, and 4K makes any graininess far more apparent to viewers. Whether and to what extent this intensification of graininess needs to be remedied through filtering or other additional processing in the conversion process is another issue that content owners will have to address prior to releasing content to MVPDs.

Beyond scanning, there's an even more expensive and comprehensive conversion method where computer generated imaging (CGI) is used to recreate the film digitally in 4K. Experience shows – and is reflected in 4K conversion choices being made by motion picture studios – that a properly administered advanced scanning process can achieve quality levels comparable to native 4K-originated content.

For example, Deluxe Media Services is applying continuous scanning, film grain filtering, artifact removal and related processes to the 4K conversion of growing numbers of movies with outstanding results. As techniques evolve and more usage generates more feedback, Deluxe will continue to refine the parameters to meet MPVDs' requirements.

BITRATES AND HEVC

How MPVDs work through the issues raised in the foregoing discussion will greatly impact their approach to setting transmission bitrates for delivery of HEVC-encoded 4K-optimized content. There has been a lot of discussion in the 4K space that has emphasized how little bandwidth will be needed to deliver a compelling user experience, with some citing 15 mbps as a target rate for its 4K rollout.

Over time, HEVC, as was the case with previous codecs, will become more efficient, allowing bitrates to fall for delivering content at any given level of quality. But at s point, the quality level that MPVDs will likely want to support will require the setting of bitrates for 4Kcontent well above the rates cited by some in the industry.

Early on a key choice to be made is what profile – Main 10 or Main – operators will require for HEVC encoding. Main, the original profile set with the approved standard, was designed to support 8-bit color with a sampling depth of 256 levels – in other words the parameters used with rec. 709. Late last year, Main 10 was added to the standard to enable encoding of content utilizing 10-bit color with 1,024 sampling levels – specifically, the parameters employed with rec. 2020.

At this point both Main and Main 10 limit chroma subsampling to 4:2:0, but extensions are scheduled to be added in 2014 that will raise the levels to 4:2:2 and 4:4:4, along with introducing multi-view video coding for 3D applications. All of this will require additional bandwidth headroom

should operators decide to adopt such extensions. Frame rates, too, will be a factor in setting transmission bitrates.

The state of the art in encoding, notwithstanding some aggressive claims, appears to require something on the order of 25 mbps or above for rec. 2020-compatible 4K transmissions from stored content delivered at 60 fps. Live feeds are likely to require higher rates, especially in sports programming. Supporting the chroma subsampling extensions will increase the optimal bitrates as well.

In light of all this, MPVDs will probably want to look at new approaches to QAM allocations, where 4K might use the majority of the 38 mbps available on a 256 QAM while allocating the remainder to other HEVC-encoded or even MPEG-2 or H.264 encoded content. The picture, of course, will change with the coming of 1024 QAM, a feature of the DOCSIS 3.1 spec. By the time 1024 QAM goes into wide use, there will likely have been considerable gains in HEVC efficiency, allowing operators to pack two or three 4K channels per QAM in tandem with the need to introduce more 4K feeds.

PREPARING THE MARKET

Meanwhile, in the run-up to introduce true 4K and HEVC, MPVDs may want to consider adjusting QAM allocations along these lines sooner than later. This is necessary to support a move to 1080p HD as a way of gaining competitive differentiation as providers of extraordinarily high quality content to 4K UHD TV set owners. In other words, by dedicating more QAM bandwidth to transmitting higher bitrate 1080p content, operators would be able to provide content amenable to upscaling on 4K UHD TV sets to quality levels approaching 4K while providing non-4K households a quality of HDTV that offers a 10 to 20 percent or better improvement over customary lower bitrate 1080 interlace (1080i) content.

Upscaling of 1080p by 4K UHD TV sets has become a key selling point, given the improvement upscaling delivers to Blu-ray 1080p content. Operators offering1080p HD to 4K UHD TV set owners would be helping to satisfy those subscribers' hungry for high-quality content, while making them aware that the cable company will be their source for true 4K-optimized content as it becomes available.

The emergence of HEVC opens additional possibilities for cable services, including the opportunity to consume lower bandwidth in unicast deliveries of premium content to IP devices that are equipped to decode HEVC. Many researchers have noted that, given the fast turnover rate and rapid increase in processing power of CE devices like smartphones and tablets, HEVC decoding capabilities will rapidly populate these markets. Multimedia Research Group, for example, says one billion devices capable of decoding HEVC were in the market by year-end 2013.[1] But, the researcher says, penetration of the set-top market will take much longer.

This advantage on the broadband side also applies to 4K UHD TV sets, which are Smart TVs equipped to access IP premium content directly without the need for a set-top box. Opening this conduit for 4K distribution by delivering pay TV service apps to such device would allow operators to expand their 4K service reach faster than they could by relying solely on the introduction of HEVC-capable set-tops.

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[1] "HEVC Decoding in Consumer Devices," Multimedia Research Group, March 2013

Cable operators will gain another advantage over competitors as they obtain licenses to first run releases for distribution in4K. The motion picture industry is introducing new security requirements for this extremely high-value content, including forensic watermarking that will associate each unicast of an on-demand file with the viewing household. Operators are likely to be in a far better position to implement advanced security requirements over their managed networks and devices versus those who operate in the open security provisioning environment of the Internet.

LEVERAGING THE CLOUD TO REDUCE COSTS

Whatever approaches MPVDs take to bring 4K-optimized content to market, it's inevitable that most of this content will be delivered from storage in an on-demand mode in the early stages. It will take a considerable amount of time for an end-to-end HEVC/4K ecosystem capable of supporting live 4K programming to emerge. In sports programming, which is seen as the initial driver to live 4K broadcasting, "just at the field" production level will require a new system to be implemented to run in parallel with the legacy system. This is needed to support different degrees of scene panning, approaches to slow-motion replay and other elements affecting the picture and the textual and graphics trappings.

Of course, as the editing systems, distribution pipelines to head-ends and beyond, and equipment in the home are installed to accommodate live 4K programming, the volume of 4K-optimized files positioned for on-demand access will grow, eventually reaching the quantities common to today's HDTV-based video on demand (VOD) systems. The infrastructure and storage burden alone, adding to costs already incurred with expansion of on-demand service into the multiscreen domain, will be immense. This raises the natural question of whether operators can sustain legacy approaches to amassing VOD content.

In contemplating what can be done to alleviate these costs, it's important to recognize what the true costs of sustaining current approaches would be. A thorough analysis of what goes into building an in-house VOD library must include operating expenses, initial capital outlays and ongoing capital investments across a task list that encompasses workflow system development and management, ingest processes, metadata and content processing, quality control, storage, distribution and reporting.

At the same time, further analysis will reveal how much can be saved through a strategic approach that exploits the cost-savings benefits of a sophisticated cloud-based asset storage and management system. For example, in the instance of mounting multiscreen on-demand services, operators are discovering that whether they rely on such a service to process, store and deliver their entire portfolio or use such a service to build on the existing in-house infrastructure, they can cut the costs of operations by hundreds of dollars per title.

Such savings will apply as well to the use of the cloud to support expansion into 4K distribution, especially as that service, too, requires multiple formatting and encodes to reach multiple types of connected devices. To the extent such costs can be shared across multiple users of the cloud, the per-title costs accruing to each operator will be a fraction of what they would be if all these processes had to be performed individually for each pay TV distributor. Moreover, beyond cutting costs, the opportunity to rely

on best practices developed by experts in content management, processing and storing 4K-optimized content for access in the cloud will help operators sort through the complex issues that go into establishing benchmarks for delivering a superior 4Kexperience to their customers.

Companies addressing these issues via the cloud include Deluxe Digital Distribution. Through decades of managing master source files for Hollywood studios, they have developed critical know how in meeting the requirements of the new content supply chain including management, ingest, processing, storage and distribution of content. Such best-of-breed cloud solutions eliminate the need for heavy investments in storage and processing infrastructures and workflows while providing operators affordable, easy access to libraries of UHD-optimized titles.

CONCLUSION

While 4K is widely regarded as the inevitable next stage in the evolution of television technology, there are many questions yet to be resolved between now and when 4K content and services enter the cable TV service mix. This starts with issues related to minimum requirements to ensure the movies and TV programming offered on-demand to subscribers meet expectations for a superior viewing experience and delivered at the highest quality and optimal bitrate for bandwidth, transport and storage efficiencies across the multiscreen landscape.

There is and will continue to be great variation in the fundamental characteristics of content rendered and labeled as 4K in postproduction, including differences in color gamut and depth, contrast, frame rate and degrees to which artifacts are removed and film grain levels are matched to the original work of art. It will take time to determine what the minimum parameters should be for cable-caliber service and to identify the types of conversion methods that can be trusted to produce acceptable 4K-optimized content. In tandem with resolution of these issues, service providers will have to determine the amount of bandwidth to be allocated to 4K in the context of setting optimal bitrates for HEVC encoding to address the congestion and capacity issues at the network core and edge.

Clearly, these issues will have to be addressed in the context of a competitive environment. As more subscribers purchase 4K UHD TV sets, operators will be pressured to satisfy demand for higher quality content suited to viewing on large-screen 4K UHD TVs. Consequently, operators may want to begin planning for allocation of QAMs to support delivery of a high-quality HD service in 1080p that can be upscaled on 4K UHD TV sets to provide a superior viewing experience in advance of true 4K-optimized content. Operators will also need to address the question of they want to expand the reach of 4K service by introducing 4Kover IP broadband for direct access on connected TVs and other devices, in parallel with reliance on use of HEVC-capable set-top boxes.

Underlying all these preparations is the cost question. The need to create a support infrastructure, including workflows, ingestion, asset management, storage and other processes for 4K on top of ongoing expansion of resources for traditional VOD and TV Everywhere, imposes cost burdens that will be hard to sustain using old approaches to building VOD libraries. The logical alternative will be reliance on cloud-managed services where the costs of

building and maintaining 4K libraries can be shared among multiple operators.

Acronym List

Computer Generated imaging (CGI)
Consumer Electronics (CE)
Digital Picture Exchange (DPX)
Frames per Second (fps)
High Definition (HD)
High Dynamic Range (HDR)
High Efficiency Video Coding (HEVC)
Mutichannel Video Programming Distributors **(**MVPDs**)**
Over-the-Top (OTT)
Quality of Experience (QoE)
Ultra High Definition (UHD)
Video on Demand (VOD)
1080 progressive (1080p)
1080 interlace (1080i)