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The Future of 4K UHDTV – Examining Methods to Acquire, Exchange and Distribute High Quality Content

A Technical Paper prepared for the Society of Cable Telecommunications Engineers
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Overview

The industry is in the midst of a seismic shift to an all-digital and all-HD world and the growing consumer desire for the highest TV image quality possible is creating increased market demand for new Ultra High Definition televisions (UHDTVs). More than half a million 4K UHDTVs are forecasted to ship worldwide in 2013, according to research from NPD DisplaySearch, and this number is projected to grow to more than 7 million by 2016. Ericsson's 2012 ConsumerLab report [2] showed that for viewers watching video on larger screens, high quality, HD content is particularly important for the overall TV experience, and this is a trend that is building in momentum. 41 percent of consumers are willing to pay for TV and video content which has higher picture quality, demonstrating that there is a significant readiness for UHDTV services. In preparation for this, methods through which UHDTV can be reliably and efficiently acquired, exchanged and distributed to consumers in the home are being investigated and trialed.

This paper will provide key insights into the technologies that will enable the acquisition, exchange and distribution of 4K UHDTV content today and tomorrow. First, "true" 4K UHDTV is defined and explained. Second, an overview of common scenarios for content acquisition, exchange, and distribution is given, followed by a discussion of some of the challenges to overcome in UHDTV workflow and end-to-end ecosystem readiness, and new technologies to improve the efficiency of satellite and fiber delivery. Lastly, an overview of the newly ratified High Efficiency Video Coding standard (HEVC/H.265) will be given and when it is projected to be viable for UHDTV workflows. The paper also will explore how to leverage the use of MPEG-4 AVC 4:2:2 10-bit technology today to cover major events, such as concerts or live sports, and build interest and demand for the 4K UHDTV, develop UHDTV workflow competence, as well as ingest a library of contribution quality 4K content.

Increasing TV Resolution

The resolution of consumer image displays and video screens has increased greatly in recent years. For almost 50 years, standard television resolution (known as standard definition TV or SDTV) was approximately 720 pixels by 480 lines or 576 lines (NTSC or PAL TV standards, respectively, for most 30Hz and 25Hz TV applications worldwide). When high definition TV (HDTV) was introduced in the late 1990s, the spatial resolution increased greatly, with two formats, 1280 pixels by 720 lines and 1920 pixels by 1080 lines. While personal computer and tablet displays may have slightly different resolutions due to screen size variance, it is common place in today's consumer electronic devices (tablets, smartphones, etc.) to have HD image resolutions.

With the ever increasing demand to have entertainment video approach human visual system reality, the Society of Motion Picture and Television Engineers (SMPTE) and The International Telecommunication Union Radiocommunication Sector (ITU-R) have standardized UHDTV at two levels, Level 1 being 3840x2160 (so called "4K") and Level 2 being 7680x4320 (so called "8K") [3,4].

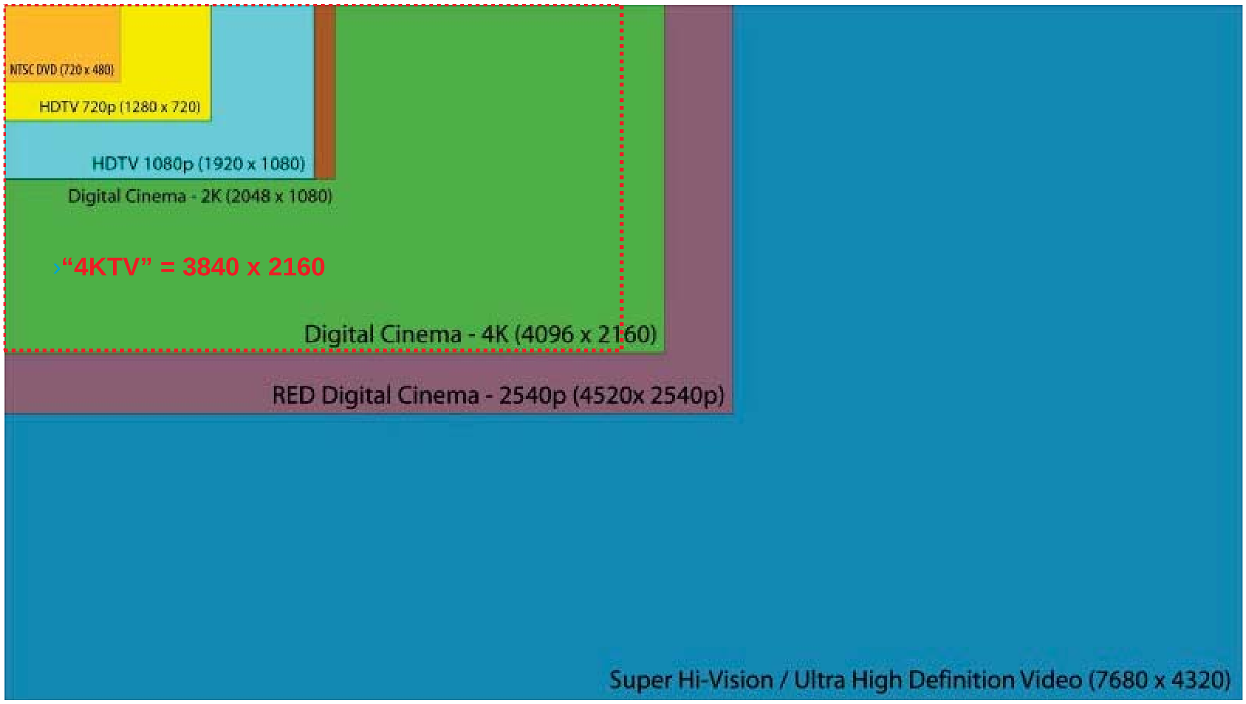

Figure 1. Comparison of image sizes, from standard definition to 8K ultra high definition.

Consumer TVs took a leap forward when 4K Ultra High Definition TV (UHDTV) displays, with four times the spatial resolution of HDTVs, were introduced at the 2012 International Consumer Electronics Show and became a "mainstream event" at the

2013 show. In October 2012, in an effort to “standardize” differing consumer electronics manufacturer terminology for the higher resolution displays, the Consumer Electronics Association (CEA) issued a release stating that “Ultra HD” or “UHDTV” would be the preferred term for 3840x2160 resolution displays. One can still see usage of “4KTV” and “QFHD” (quad full HD) in some manufacturer’s literature.

Similarly, digital cinema has standardized on HD screens (note that cinema resolution is slightly different than TV) and the industry is in the process of deploying 4K Cinema. In recent years, NHK Science & Technology Research Laboratories has been demonstrating 8K UHDTV, which has 16 times the spatial resolution of HDTVs. However, there is a practical question of whether this high of a resolution will ever be needed in the home due to screen size.

It is interesting to note that the colloquial display nomenclature has shifted from vertical resolution to horizontal resolution. HDTV resolutions are commonly known as 720p and 1080i (where 720 and 1080 are the vertical number of lines of the display, with “p” representing progressive scanning and “i" interlaced scanning), while for UHDTV resolutions, 4K and 8K correspond to the horizontal number of pixels per line. Equivalently, HDTV could be known as 2K (for 1920 pixels per line) or 4K UHDTV as 2160p (2160 vertical lines). This switch in nomenclature has caused some industry confusion, but it likely will subside.

What is “True” 4K UHDTV?

With so much emphasis on the spatial resolution of the display, a lot of announcements in 2013 have been claiming first demonstrations of partial or complete 4K UHDTV delivery systems. However, the great advantage of 4K UHDTV has to do with its immersive TV viewing experience or realism. Spatial resolution is just one aspect; other enhancements to the content and display are required as well to realize the “True” 4K UHDTV viewing experience.

The proper TV viewing distance decreases as the display resolution increases. While the mathematics of human visual acuity are complex and account properly for angular resolution (both vertical and horizontal fields-of-view) in the computation of optimal viewing distance, this is outside the scope of this paper. A common, more basic rule-of-thumb (and therefore a bit more inaccurate) is to use the number of picture heights to estimate the approximate proper viewing distance. In this case, a distance of approximately six picture heights from the front of the screen is recommended for SDTV and three picture heights for HDTV. This number halves again for 4K UHDTV to one and one-half picture heights. Regardless of how the proper viewing distance is derived, if one sits closer than the minimum viewing distance, then the pixels themselves will begin to be recognized individually as opposed to the human visual system processing the entire picture as a whole, and most likely the viewer will feel uncomfortably close. If one sits further away than the maximum distance, then the increased resolution of the screen does not become discernible (loss of detail observed). The proper viewing distance is not a singular number, but rather is in a range of distances between the minimum and maximum stated above.

The decreased viewing distance coupled with the increased screen sizes offered results in the TV screen occupying more of the human central field-of-vision. Figure 2 demonstrates this, with HDTV occupying approximately a 30 degree field-of-view and 4K UHDTV occupying approximately 60 degrees [5] of the human central field-of-vision (which is approximately 80-90 degrees). This wider view angle, in combination with the higher spatial resolution, provides a greater sense of presence [6] or sensation of reality and hence a more immersive viewing experience [7].

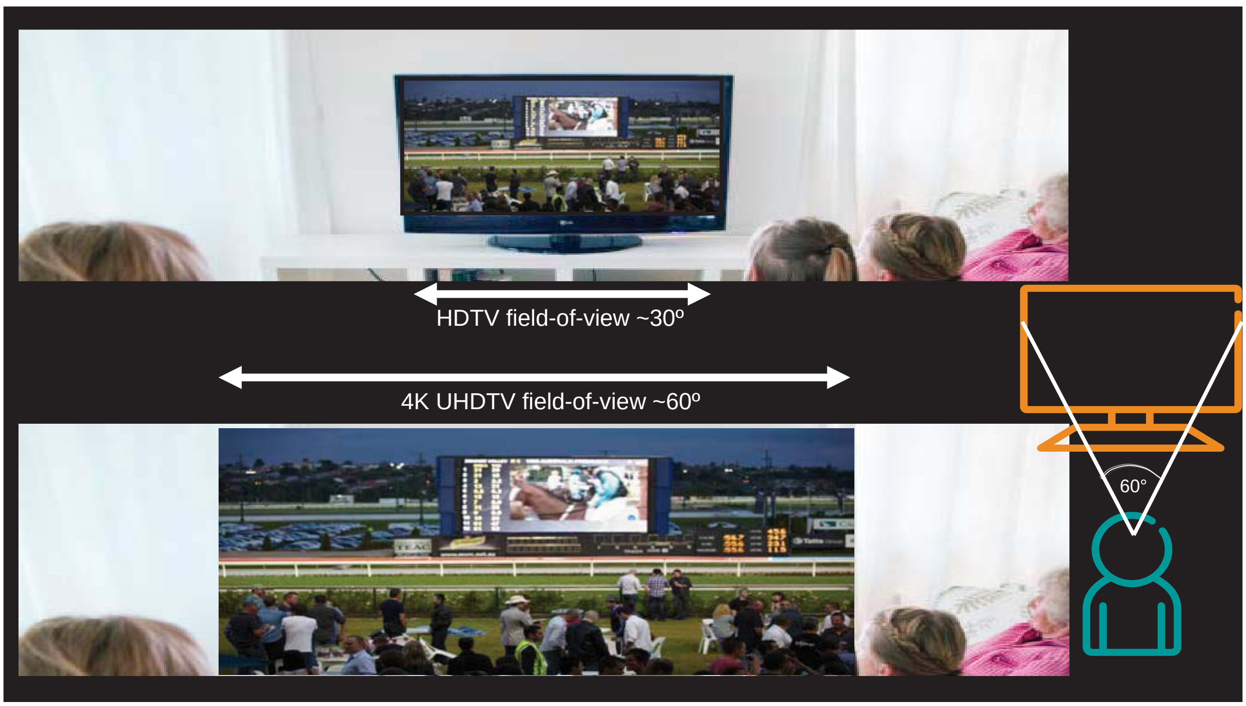

Figure 2. Comparison of 4K UHDTV and HDTV field of view within human central field-of-vision (approximately 90 degrees).

Since the TV now occupies more of the human central field-of-vision, images that move across the display cover a wider arc (greater angular change) in the field-of-view and therefore the human eye will be more sensitive to motion behavior. As such, higher frame rates are needed to represent fast motion across the greater angular change or a visual degradation will be caused when repeat images are not where they should be based on the motion vector assumed by the human visual system. This is called motion judder. Motion judder artifacts are observed commonly today when motion picture content (which is almost entirely produced at 24 frames per second) is converted to video (through a process called telecine or 2:3 pull-down; for example 24p to 29.97i). However, motion judder will be recognized more readily in the future with the more immersive viewing experience – the greater angular change of cross-screen motion – of

4K UHDTV. Live sports – which is often considered premium content – is very susceptible to this. Today's 25 and 30 frames per second (50-60 fields per second if interlaced) frame rate is far too low. This issue is currently under debate in several standards organization and industry forums, with frame rates as high as 120-150 fps being vetted. What's clear is that a minimum of 50-60 fps is required for true 4K UHDTV.

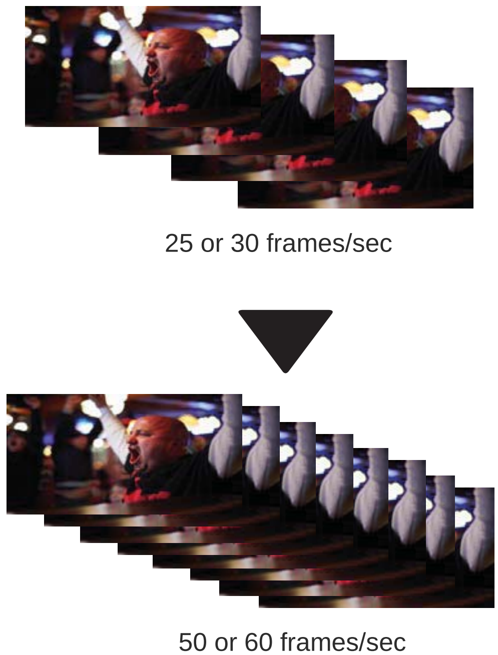

Figure 3. Higher frame rates are required to minimize motion judder for sports and other content with complex motion.

While the spatial resolution of 4K UHDTV is four times that of HDTV, if data values are still represented with 8-bit precision (as all direct-to-home compressed digital video is done today), only the same 2^8 or 256 levels of gradient is possible. With the more immersed viewing experience (larger display sizes and closer viewing distance), another artifact will be noticed more readily. Commonly seen in TV today, particularly in night scenes and other large areas of similar backgrounds and low motion, and during fades, is chrominance and luminance (color and brightness, respectively) banding or posterization. In Figure 4, notice the circular banding in the rays of the sunset on the left side. This is caused by not having sufficient numbers of different levels for chroma/luma to represent smooth gradients; clearly quantization steps are noticeable. On the right side, however, 10-bit depth data precision is used – with 2^{10} or 1024 levels of gradient – resulting in much smoother contouring of the sun's rays.

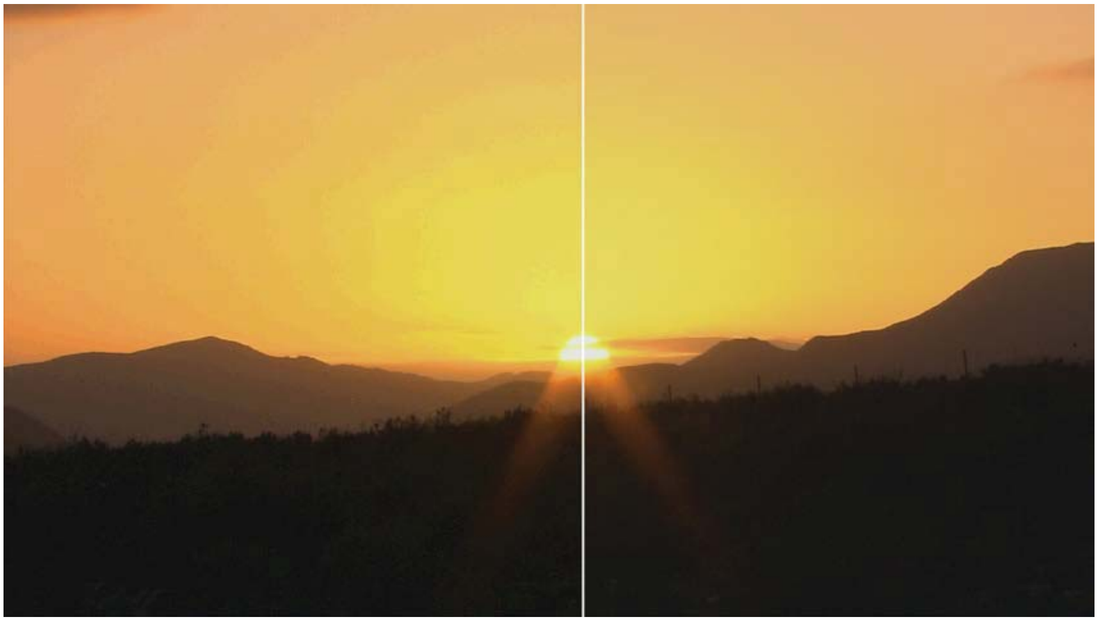

Figure 4. On left, Banding (posterization) artifacts due to insufficient data precision with 8-bit data values. On right, smoother contouring with 10-bit data values.

Both the ITU-R and SMPTE UHDTV specifications define 10-bits as the minimum data precision values for this reason. The Joint Collaborative team for Video Coding -- ISO/IEC Moving Pictures Experts Group (MPEG) and ITU-T Visual Coding Experts Group (VCEG) – created a Main 10 Profile in the first version of the recently ratified High Efficiency Video Coding (HEVC) standard [8] for this reason (more on HEVC later in this paper). While previous compressed digital video standards (such as MPEG-2 Video and AVC/H.264 [9]) defined profiles that included 10-bit precision, these were for professional applications only. HEVC is the first to include a profile that supports 10-bit precision for direct-to-home applications.

With large HDTV displays becoming more prominent – even before the entry of UHDTV – some industry experts are considering introducing 10-bit values into HDTV content to extend its dynamic range as well. Although, this would not be backward compatible with existing HDTV displays and ecosystem.

UHDTV also has an expanded color space defined [10], versus that used by HDTV or SDTV. In Figure 5, note the greatly expanded region of greens and the inclusion of more reds. This will give UHDTV an even more realistic color pallet than HDTV, which in turn would take advantage of the 10-bit precision described previously.

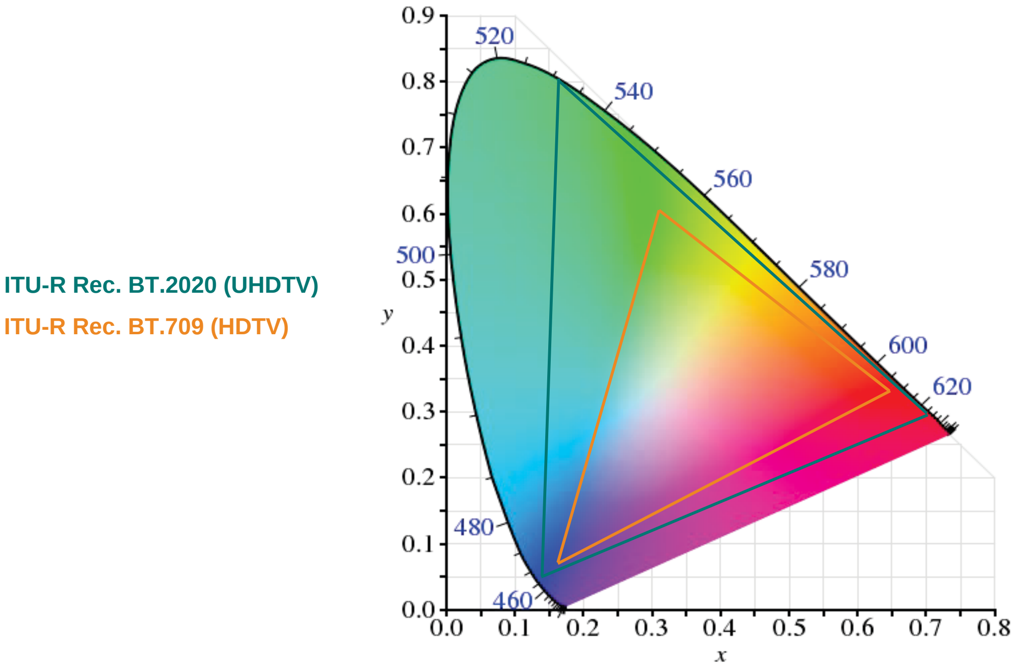

Figure 5. The expanded colorimetry of UHDTV.

In summary, True 4K UHDTV consists of four times the spatial resolution of HDTV, at least two times the temporal resolution of 1920x1080 HDTV, at least 10-bit depth precision for data values (vs. 8-bit for direct-to-home applications) and an expanded color space. This creates an immersive viewer experience, providing a greater sense of presence and sensation of reality than possible with today's best HDTV.

Content Acquisition, Exchange & Distribution

Now that True 4K UHDTV has been defined, what unique requirements does it impose on the content acquisition, exchange, and distribution ecosystems already in use by HDTV?

Figure 6 depicts typical scenarios for live content acquisition. Until recently, almost all venue (sports, concerts, etc.) acquisition done for contribution/archiving/mastering quality required backhaul over satellite. Increasingly, however, high bandwidth fiber is available at major venues. In many situations, both fiber and satellite backhauls are used simultaneously.

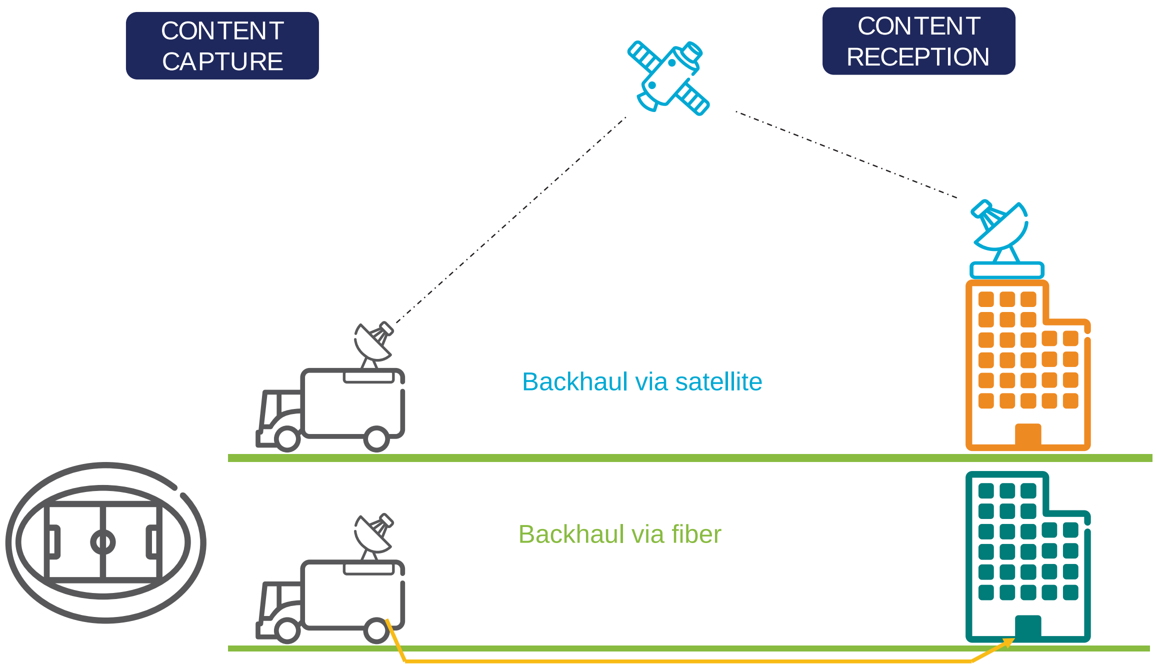

Figure 6. Typical content acquisition scenarios.

Figures 7 depicts typical scenarios for both content exchange and primary distribution.

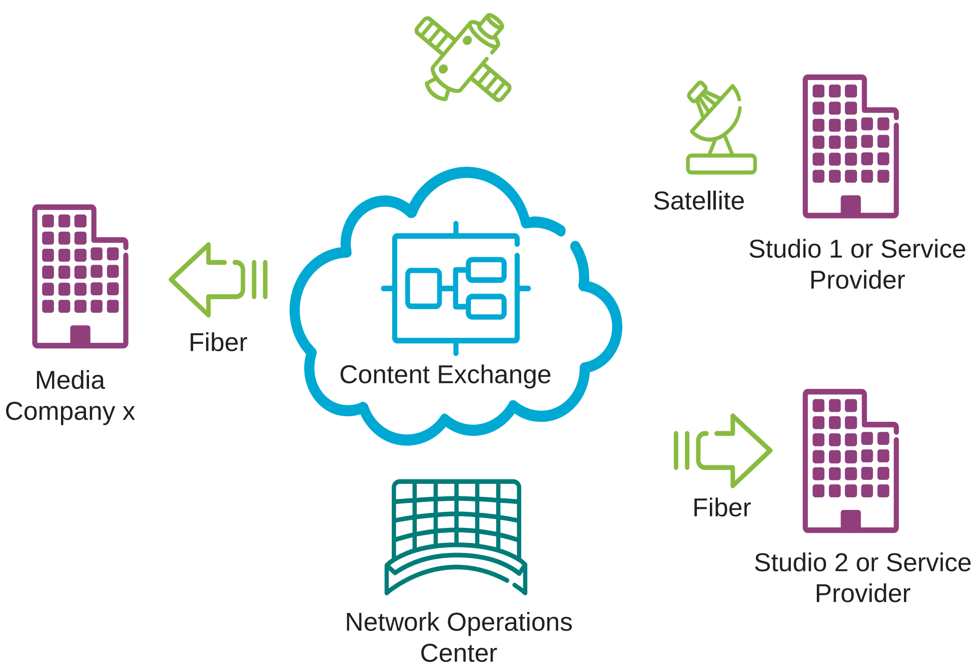

Figure 7. Typical content exchange and distribution scenarios.

As with content acquisition, both satellite and high bandwidth fiber is used.

Uncompressed Digital Video

For the contribution and distribution scenarios depicted above, the highest practical picture quality is required for mastering, archiving, and post production needs. In addition to the minimum requirements for True 4K UHDTV discussed earlier – that is, 3840x2160p59.94 10-bit (p50 in 25Hz parts of the world) – the chrominance format 4:2:2 is required to maintain the color fidelity through multiple encode/decode/re-encode cycles. Chrominance signals typically are encoded with less resolution than luminance signals to take advantage of the human visual system's lower acuity for color [11]). Contribution and primary distribution scenarios use at least the 4:2:2 format, which indicates that there are four luminance data points for every two chrominance data points for each of the two color difference signals. In direct-to-home scenarios, the need for the lowest possible bitrate is much more important than the need for the content to survive multiple encode/decode cycles and, therefore, direct-to-home applications use the 4:2:0 format (indicating there are four luminance data points for every one chrominance data point for each of the two color difference signals) with acceptable results. The uncompressed video bitrate equates to approximately 12 Gigabits per second (Gbps). In comparison, uncompressed 720p and 1080i HDTV requires 1.5 Gbps, while "full" HDTV 1080p60 (p50 in 25Hz parts of the world) requires 3 Gbps.

System Nomenclature	Horizontal Pixels	Vertical Pixels	Frames per Second	Total Payload	
				10-bit 4:2:0 10-bit 4:2:2	12-bit 4:2:0 12-bit 4:2:2 12-bit 4:4:4 10-bit 4:4:4:4
4320p60 / 59.94	7680	4320	60	48Gbps	96Gbps
4320p50	7680	4320	50		
4320p30 / 29.97	7680	4320	30	24Gbps	48Gbps
4320p25	7680	4320	25		
4320p24 / 23.98	7680	4320	24		
2160p60 / 59.94	**3840 / 4096**	**2160**	**60**	**12Gbps**	24Gbps
2160p50	3840 / 4096	2160	50		
2160p48	4096	2160	48		
2160p30 / 29.97	3840 / 4096	2160	30	6Gbps	12Gbps
2160p25	3840 / 4096	2160	25		
2160p24 / 23.98	3840 / 4096	2160	24		
1080p60 / 59.94	1920 / 2048	1080	60	3Gbps	6Gbps
1080p50	1920 / 2048	1080	50		
1080p48	2048	1080	48		

Table 1. Formats and interfaces for real-time uncompressed digital video.

There is already a "bandwidth crunch" with existing HDTV services. Requiring four to eight times the bandwidth over HDTV to deliver uncompressed 4K UHDTV services presents a challenge. The highest bitrate single link professional video interface available today is 3 Gbps, 3G-SDI [12]. Four of these need to be linked together to carry a single live uncompressed True 4K UHDTV signal. As shown in Table 1, the amount of data for transporting UHDTV can be significant. And if stereoscopic 3D video is desired, this would be twice the payload rates shown in the table.

While multi-link interfaces operate well, new production facilities being built to support UHDTV would prefer a single link interface for practical operational reasons. SMPTE does specify single and multi-link 10 Gbps interfaces [13]. However, a single link still does not support True 4K UHDTV and with higher bandwidth requirements on the horizon (see Table 1 plus potential stereoscopic 3D needs), many consider using multiple links of 3G-SDI to be a non-starter. There are higher bandwidth interfaces being developed within the SMPTE, but none are ready to be used as of yet.

The issue is not just with professional interfaces. In the consumer world, the near ubiquitous HDMI (High Definition Multimedia Interface) does not yet support True 4K UHDTV signals. The latest HDMI (version 1.4) does support 4K motion picture releases (2160p24), such as those provided on Blu-ray® Discs, but not the 2160p50/60 UHDTV format. The next generation HDMI (as of the writing of this paper) is purported to be called HDMI 2.0 and claims to support True 4K UHDTV and beyond, but it's not published yet. What this means is that, with a few exceptions, none of the currently shipping consumer 4K UHDTVs are capable of accepting a real-time True 4K UHDTV signal! This, of course, is believed to be a temporary situation as the HDMI 2.0 is supposed to be published this year, but this has caused a bit of confusion among consumers and video professionals alike.

There are many other issues that need to be resolved to enable the UHDTV ecosystem and workflows to work seamlessly. Conversion between HDTV and UHDTV color space (ITU-R Rec. BT.709 and BT.2020, see Figure 5) needs to be defined. The current discussions on frame rates higher than 60 fps needs to be concluded and documented (100, 120, 150 and even higher frame rates are being vetted). Lastly, lightly compressed or so called "mezzanine" video compression formats are possible that cause little picture quality degradation while conserving significant bandwidth. There are many compression standards options available as well as defining interoperability points within a subset of those standards to garner industry support.

SMPTE has launched a Study Group on UHDTV Ecosystem [14] to recommend courses of action to address the end-to-end UHDTV ecosystem.

Advances in Satellite Transmission

One way to reduce the burden of the higher bandwidth required for UHDTV is to improve the content delivery channel. For satellite, there is a new modulation technology that is scheduled to be standardized and published in September 2013, under the auspices of the Digital Video Broadcasting project (DVB).

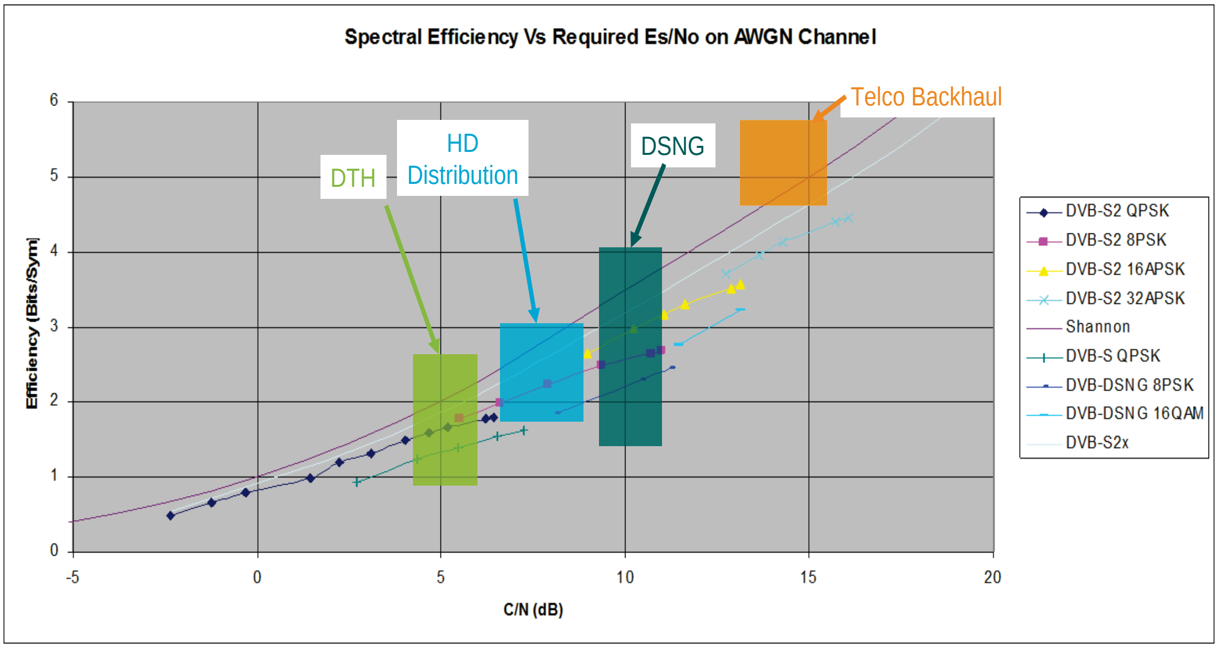

Figure 8. DVB-S2 Extensions spectral efficiency, with areas of gains by application.

The DVB-S2 Extensions include enhancements to the worldwide-used DVB-S2 standard, with the expected performance to be efficiency gains in the range of 20 to 35%, in many cases close to the Shannon Limit of channel capacity (see Figure 8), the maximum rate at which information can be transmitted over a communications channel of a specified bandwidth in the presence of noise [15]. There are no fundamental changes to the structure of DVB-S2. Better efficiency, higher bitrates, and improved service robustness are achieved by:

- Increased granularity in modulation and coding (MODCODs)
  - 87 vs. 28 in DVB-S2
- Tighter roll-offs
- Linear and non-linear MODCODs
- Higher modulation schemes, up to 64-level amplitude phase shift keying (64APSK)
- Advanced filtering for improved carrier spacing
- Wideband support up to 72 Mbaud

Silicon chips based off of the new standard are expected shortly thereafter, with system replacements possible by mid-2014. Projected deployment timeline and bitrate gains with AVC and HEVC compression are shown in Figure 9.

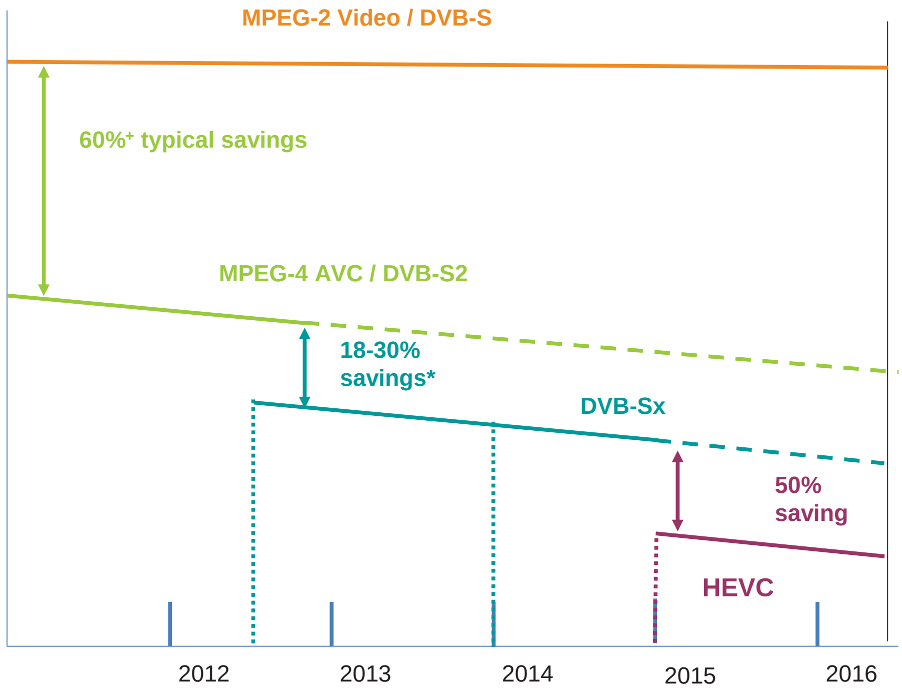

Figure 9. Estimated deployment timeline and bandwidth gains for DVB-S2 Extensions.

High Quality Real-Time Video over IP Networks

To aid in the delivery of high quality real-time video over IP networks, there is a new family of SMPTE standards, ST 2022-x. Defining Forward Error Correction (FEC) codes to improve the underlying quality of service of the network, these standards also specify the transport format for various video compression algorithms encapsulated in the near ubiquitous MPEG-2 Transport Stream format [16], both constant and variable bitrate. They also define the carriage of uncompressed video streams (referred to as High Bit Rate Media Transport or HBRMT), from SD (270 Mbps) to 1080p HD (3 Gbps). In all cases, RTP/UDP/IP protocol layers [17] are required as they provide the standard header for the data essence and FEC streams. The list of 2022 standards is given in the bibliography [18,19,20,21,22,23].

Current work within the SMPTE is to define a standard for seamless reconstruction of a stream of SMPTE ST 2022 RTP datagrams, based on transmission of two streams of identical content over potentially diverse paths. This will be Part 7 of the 2022 family when published, *Seamless Protection Switching of SMPTE ST 2022 IP datagram*.

High Efficiency Video Coding

In January 2013, High Efficiency Video Coding (HEVC) became an international standard for video compression, officially known as ITU-T Recommendation H.265 and

ISO/IEC 23008-2 MPEG-H Part 2. Almost 20 years have passed since the standardization of MPEG-2 Video (ITU-T Recommendation H.262 | ISO/IEC 13818-2) revolutionized TV and entertainment video by ushering in the age of digital video for consumers. Subsequently, 10 years have passed since the standardization of AVC (ITU-T Recommendation H.264 | ISO/IEC 14496-2), which extended the application of digital video to the Internet and for worldwide HDTV adoption.

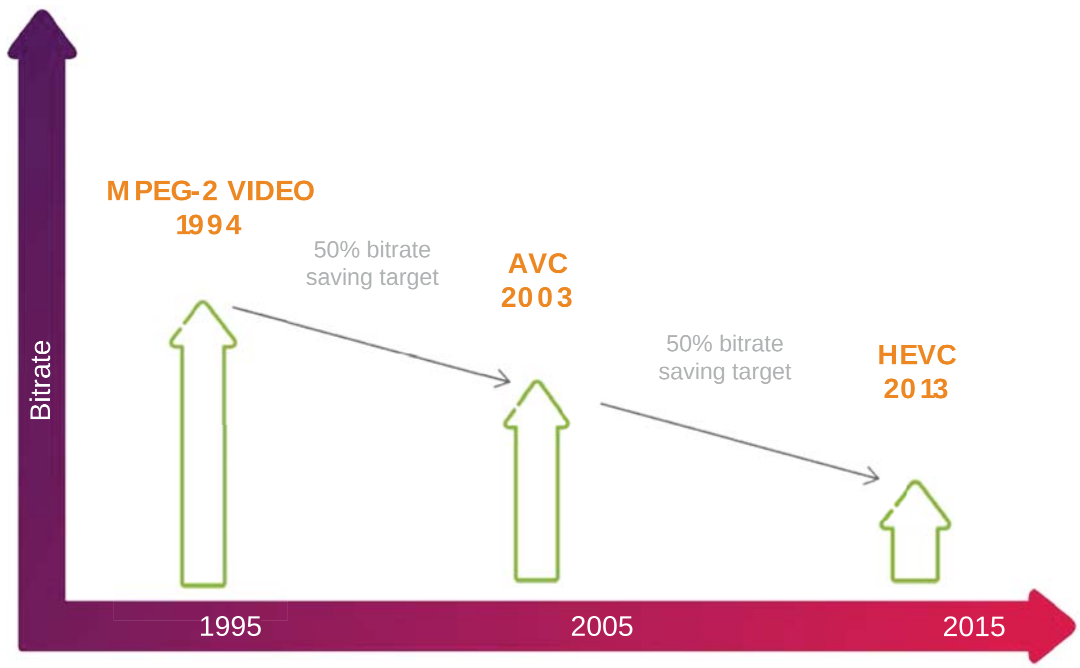

Figure 10. Video compression evolution.

For direct-to-home scenarios, such as cable television, HEVC has the potential to reduce the bandwidth required for a given picture quality by half – 50% bitrate reduction or twice as bitrate efficient – vs. AVC, or four times as bitrate efficient as MPEG-2 Video (one-fourth the bandwidth) [24]. For 4K UHDTV, the bitrate reduction may exceed 50% [25]. While what constitutes acceptable picture quality is literally in the “eyes of the beholder”, Table 2 contains a comparison of typical bitrates for MPEG-2 Video, AVC and HEVC, for direct-to-home scenarios, with the assumption that the picture quality is equivalent in each compression technology. Note that when HEVC implementations mature, 4K UHDTV can be conveyed in the same bandwidth as that used today for HDTV. Table 3 is a similar comparison for content acquisition, exchange and distribution scenarios.

	MPEG-2 Video	AVC	HEVC
SD	3 - 5 Mbps	1.5 - 2.5 Mbps	0.8 - 1.5 Mbps
HD	12 - 18 Mbps	6 - 9 Mbps	3 - 4.5 Mbps
4K UHDTV (2160p60 10b)	N/A	16 – 30 Mbps (theory)	8 – 15 Mbps

Table 2. Typical direct-to-home bitrates for equivalent picture quality.

	MPEG-2 Video 4:2:2 8b	AVC 4:2:2 10b	HEVC 4:2:2 10b
HD	35 - 60 Mbps	20 - 40 Mbps	14 - 28 Mbps**
4K UHDTV (2160p60)	N/A	100 - 200 Mbps*	50 - 100 Mbps**

****4 x 1080p60***
*****Estimated; HEVC Range Extension profiles not yet standardized***

Table 3. Typical content acquisition, exchange and distribution bitrates for equivalent picture quality.

The HEVC codec contains a set of advanced coding tools that together make HEVC significantly more compression efficient compared to AVC. Figure 11 depicts a high level tool comparison between AVC and HEVC. With the advancements in integrated circuit technology – processing power, transistor and memory density, etc. – that have occurred in the past decade, HEVC includes a superset of functions over that provided in AVC. These include a coding unit with block sizes that range from 8x8 to 64x64 (AVC and MPEG-2 Video have a fixed 16x16 macroblock size); hierarchical block coding, in a quad-tree structure, with independent Transform Unit and Prediction Unit; 35 intra prediction modes (vs. 9 in AVC and 1 in MPEG-2); more precise intra prediction filters; advanced motion vector prediction; in-loop de-blocking and sample adaptive offset filters (AVC includes in-loop de-blocking only and MPEG-2 does not support either); four transform block sizes, from 4x4 to 32x32 (AVC has 4x4 and 8x8 transform blocks only, while MPEG-2 uses 8x8 only); and wavefront parallel processing [25].

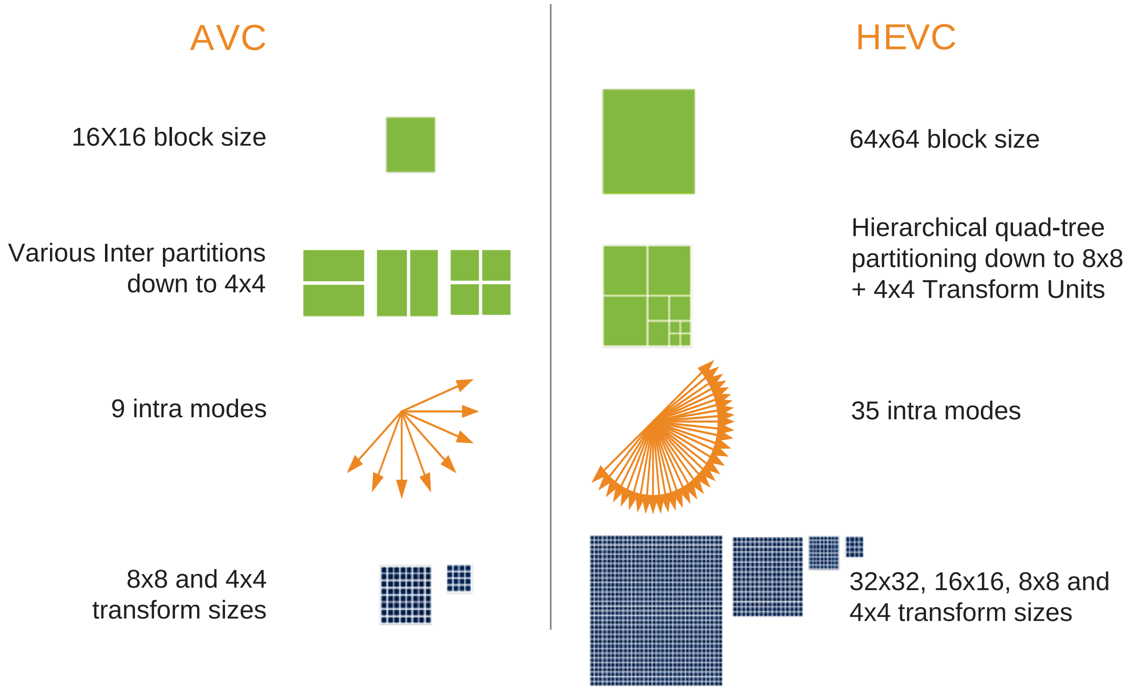

Figure 11. A high level tool comparison of AVC and HEVC.

Up to ten times more encode and three times more decode processing power than AVC is required to perform the calculations required by the new tools, as well as to execute many of the calculations in parallel. Direct-to-home profiles – Main Profile and Main 10 Profile – were standardized in the initial version of the specification. Professional profiles to support content acquisition, exchange and distribution (such as Main 4:2:2 10-bit) are scheduled to be completed in January 2014.

4K UHDTV Contribution and Distribution

With four times the spatial resolution and twice the temporal resolution (frame rate), True 4K UHDTV (3840x2160p59.94 10-bit) is estimated to require 80 times the processing power to encode with HEVC over that required to encode HDTV (1920x1080i30 8-bit) with AVC. High performance, live, real-time UHDTV HEVC encoders likely will not be available until late 2014 or mid-2015, due to the processing power required, which in turn requires new hardware-based designs to be built. In order to jumpstart consumer interest in UHDTV today, content acquisition, exchange and distribution may be performed by launching a live 4K UHDTV ecosystem using AVC technology. Such a system is shown in Figure 12 and has been deployed in the field. As noted earlier in this paper, four 3G-SDI interconnects are required to transport the 12 Gbps True 4K UHDTV signal as there is no single-wire interface defined currently. Each of the four 3 Gbps signals represents one 1080p quadrant (1920x1080p59.94 4:2:2 10-bit), whether from the live output of a camera or play-out from a server. The four encoders that each receive one of the quadrant signals are frame synchronized by using a common video clock across all four 3G-SDI inputs.

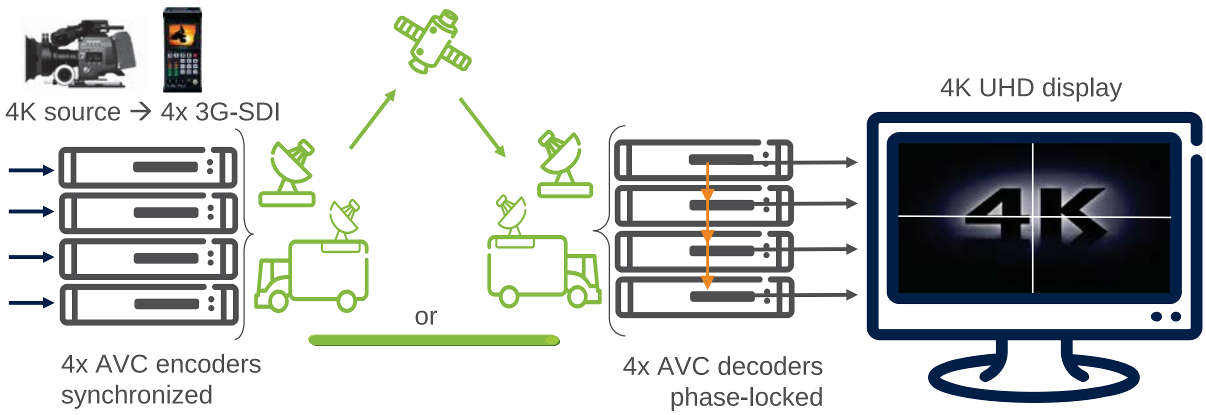

Figure 12. Until HEVC is ready … 4K Ultra HD Contribution using AVC.

During video compression, a MPEG-2 Multi-Program Transport Stream (MPTS) is produced, using a common clock (Program Clock Reference) in order to keep the four quadrants in phase-lock [16]. The MPTS is then transmitted or transported over satellite or fiber to its destination. At the receive site, four professional receivers decode the four quadrants back to baseband video signals. The clocks in the four receivers must be phase-locked to guarantee quadrant synchronization. The output video signals are then delivered to a 4K UHDTV for live viewing and/or sent into a video processing system (master control or video server or similar).

Conclusion

4K UHDTV has the potential to be an exciting new viewing experience. To be compelling and immersive, True 4K UHDTV is not only four times the spatial resolution of HDTV, but also at least twice the temporal resolution and uses 10-bit data value precision. The end-to-end ecosystem for 4K UHDTV is not yet mature and several issues need to be addressed, such as having a single-wire interface that supports 12 Gbps minimum. With UHDTV's higher bandwidth requirements and picture quality, more efficient data transmission (such as DVB-S2 Extensions satellite modulation technology) and quality of service protection (such as the SMPTE ST 2022 series of video over IP standards) are most welcome. The new HEVC video compression standard provides a mechanism through which 4K UHDTV to the home may be realized over the same bandwidth used by today's HDTV. Because it will be a few years before high performance live 4K UHDTV HEVC encoders will be available, a contribution ecosystem built around AVC-based 4K UHDTV encoders will jumpstart the nascent demand for UHDTV for major events such as live sports and music concerts.

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Abbreviations and Acronyms

AVC	Advanced Video Coding
DVB	Digital Video Broadcasting project
FEC	Forward Error Correction
fps	Frames per second
Gbps	Gigabits per second
HBRMT	High Bit Rate Media Transport (SMPTE)
HDTV	High Definition TV
HEVC	High Efficiency Video Coding
ISO/IEC	International Standards Organization / International Electrotechnical Commission
ITU-R	International Telecommunication Union Radiocommunication Sector
ITU-T	International Telecommunication Union Telecommunication Sector
Mbps	Megabits per second
MPEG	Moving Pictures Experts Group (ISO/IEC)
MPTS	Multi-Program Transport Stream (MPEG)
SDTV	Standard Definition TV
SMPTE	Society of Motion Picture and Television Engineers
TV	Television
UHDTV	Ultra HDTV
VCEG	Visual Coding Experts Group (ITU-T)