DELIVERING THE NEXT GENERATION OF CONTENT: TECHNOLOGIES TO SUPPORT ULTRA HIGH DEFINITION TELEVISION

Wade Wan
Broadcom Corporation

Abstract

Ultra High Definition Television (UHDTV) technology, also known as UltraHD or 4KTV, is already being embraced by content producers in both film and television. As broadcasters begin to investigate UHDTV as a way to significantly improve the viewer experience, operators will need a way to deliver premium content at higher resolutions than possible with current services.

This paper will discuss recent technical advances that will allow cable providers to efficiently and cost-effectively deploy UHDTV offerings in the near term. It describes how new technologies and industry standards, such as HEVC/H.265 video compression, BT.2020 color gamut, HDMI 2.0 digital interface, and HDCP 2.2 content protection must be supported in next-generation set-top boxes to enable cable providers to deliver next generation content.

INTRODUCTION

Generally, UHDTV refers to doubling the horizontal and vertical resolutions, as compared to the 1080p and 1080i High Definition Television (HDTV) formats. In addition to increased image resolution, increased pixel density enlarges the end user's field of vision and promises a more realistic and immersive viewer experience.

Within the industry, there is general agreement that UHDTV services should increase both the bit depth and frame rate of video to further differentiate it from current HDTV services, both technically and commercially [1]. Increasing the bit depth enables the transmission and display of more brightness levels and colors, and increasing the frame rate reduces motion judder artifacts that appear when high motion video is transmitted at insufficient frame rate.

Encoder and decoder implementers have started supporting an UHDTV format of progressive scanned video with 3840x2160 pixels, 60 frames/second, and 10-bit pixel depth, which is a significant quality improvement over current HD formats such as interlaced scanned video format with 1920x1080 pixels, 60 fields/second, and 8-bit pixel depth.

As shown in Table 1, the uncompressed pixel rate of this new UHDTV format is a 10x increase over existing HDTV formats. It would be inefficient, if not impractical, to deploy UHDTV services using the existing methods used for HDTV services.

Table 1: Comparison of HDTV and UHDTV Formats and Uncompressed Pixel Rates

Parameter	HDTV Format	UHDTV Format
Spatial Resolution (pixels/frame)	1920x1080	3840x2160
Pixel Depth (bits/pixel)	8	10
Frame Rate (frames/sec)	30	60
Uncompressed Pixel Rate (Mbits/sec)	497.664	4,976.640

VIDEO COMPRESSION

The significant increase in the video data rate poses a key challenge to new UHDTV service offerings, since transmission bandwidth is a valued and costly resource. The resulting increase in the compressed bit rate does not scale by the same 10x factor as the uncompressed pixel rate, with the exact ratio being content and operating-point dependent.

To address this challenge, the HEVC/H.265 video compression standard [2-4], ratified in January 2013, provides a 2x improvement in coding efficiency compared to the AVC/H.264 video compression standard and a 4x improvement compared to the MPEG-2 video compression standard.

The example bit rates in Table 2 show how compressed bit rates scale for UHDTV formats. Note these examples are estimates with actual bit rates in practice depending on the content and encoding complexity. As the table indicates, there is an approximate 150% to 250% increase in compressed bit rate for each UHDTV bitstream as compared to an HDTV bitstream, even after incorporating the 2x increased coding efficiency provided by the HEVC/H.265 video compression standard for the UHDTV formats. While there have been UHDTV demonstrations using AVC/H.264, it is generally accepted that any realistic UHDTV service cannot use AVC/H.264 and must utilize HEVC/H.265 for the increased coding efficiency it provides.

Table 2: Bit Rate Examples

Resolution	Codec	Bit Rate
HDTV 8 bit 1920x1080p30	AVC	6 Mbps
UHDTV 10 bit 3840x2160p24	HEVC	10 Mbps
UHDTV 10 bit 3840x2160p60	HEVC	15 Mbps

COLOR GAMUT

Modern display capabilities already exceed current color gamut standards such as ITU-R Rec. BT.709 chromaticity standard used for HDTV [5]. To effectively support the color reproduction capabilities of future display technologies like OLED, an expanded color gamut is needed. ITU-R Rec. BT.2020 was announced in August 2012 to define such a color gamut [6].

A comparison of the BT.2020 and BT.709 color gamuts is shown in Figure 1. Both color gamuts have the same reference white but BT.2020 has a wider gamut to represent more colors, and thus requires a larger bit depth to properly sample/represent the range of colors within the gamut, which is one reason why BT.2020 is defined for higher bit depths (10-bit and 12-bit) than BT.709 (8-bit and 10-bit). The transition to 10-bit coding enables the use of a wider color gamut. Until now, this would not have been possible without most likely generating artifacts from a sparse sampling of a larger color gamut with 8-bit coding.

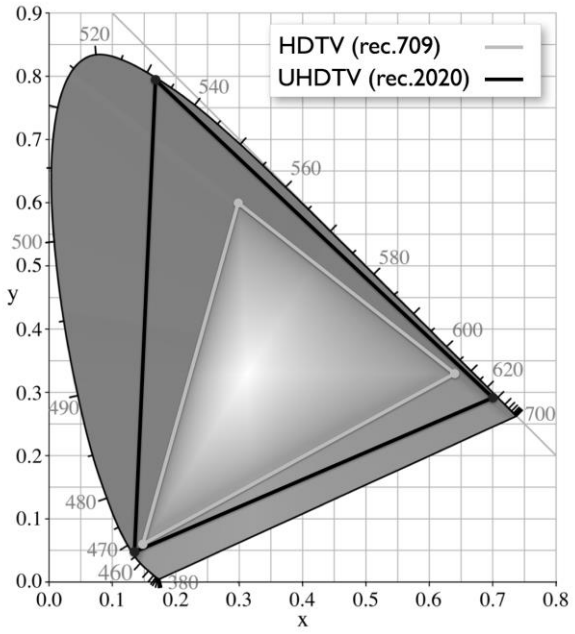

Figure 1: HDTV and UHDTV Color Gamuts

DIGITAL INTERFACE

The increase in the uncompressed or decompressed data rate of UHDTV video is quite significant, especially when using a digital interface to connect two devices, such as a set-top box and a display. While other alternatives are available, such as DisplayPort developed by the Video Electronics Standards Association (VESA), High Definition Multimedia Interface (HDMI) is still the most natural and prevalent interface for connecting high definition components.

Until recently, HDMI interfaces had limited UHDTV format support. More specifically, because the maximum throughput across the interface was limited to 10.2 Gbps [7], a single HDMI 1.4b interface was only capable of supporting UHDTV formats when the pixel data was 8-bit and the frame rate was less than 30 frames per second.. Conceptually, this limitation could be overcome by using multiple HDMI interfaces. However, this soulution would be technically problematic since it could possibly lead to synchronization issues between the interfaces and problems due to the increased cost of duplicating cables and connectors.

To address this limitation, the HDMI 2.0 specification announced in September 2013, increased the bandwidth supported across the interface to 18 Gbps [7]. A comparison of the 4K formats supported by the previous (1.4b) and new (2.0) versions of the HDMI specification is shown in Table 3. Note that the new specification adds support for UHDTV resolutions at 50/60 Hz over a single interface, thereby potentially avoiding implementers and end users struggling to use multiple cables and connectors to handle the increased throughput of UHDTV services.

Table 3: 4K Formats Supported By HDMI 2.0

4K formats	Previous HDMI 1.4b	New HDMI 2.0
8 bit 24/25/30 Hz RGB/4:4:4	YES	YES
10 bit 24/25/30 Hz RGB/4:4:4	NO	YES
8 bit 50/60 Hz RGB/4:4:4/4:2:0	NO	YES
10 bit 50/60 Hz 4:2:0	NO	YES

CONTENT PROTECTION

High-bandwidth Digital Content Protection (HDCP) is a digital copy protection and

digital rights management specification for securing audiovisual content between devices. HDCP version2.2, which can be mapped to HDMI interfaces [8], was released in February 2013. It is important to note that this version was made "clean" by not being backward compatible to previous HDCP versions 2.0 and 2.1, which were identified as possibly having a security breach in August 2012.

Additional content protection measures, such as watermarking, might be implemented to protect high-value UHDTV content. However, securing the HDMI digital interface with HDCP 2.2 is expected be the minimum requirement for securing the transmission of UHDTV content and satisfying the distribution requirements of content providers. As an example, MovieLabs has published a content protection specification listing HDCP 2.2 (or better) as a link control/protection requirement [9].

CONCLUSION

The promise of delivering UHDTV services offers an exciting opportunity to provide viewers with a new, immersive experience. The original concept of doubling horizontal and vertical resolution from current HDTV services has expanded to also include increasing the bit depth and frame rate to differentiate UHDTV services from HDTV services.

A key challenge has been the increased bit rates that result from the UHDTV pixel rates. The HEVC/H.265 video compression standard represents a technological milestone for video coding with its 2x improvement in coding efficiency as compared to the previous state of the art AVC/H.264 video codec. With transmission bit rate being a key consideration, the practical solution is for UHDTV deployments to use HEVC/H.265 to minimize bit rates.

The challenge with delivering UHDTV services is not limited solely to the video codec. It also requires advances in other parts of the system pipeline. This paper has highlighted three new technologies and industry standards that were developed for use in UHDTV systems. The BT.2020 color gamut expands the color gamut to better match the capabilities of current as well as future capture and display equipment. The HDMI 2.0 digital interface can better support 4K formats. HDCP 2.2 content protection can secure the HDMI interface in order to protect UHDTV content.

Now that these technologies have matured into industry standards, cost-effective, single System-on-Chip (SoC) solutions have been designed and are being used to power next-generation set-top boxes [10,11]. This will allow cable providers to efficiently and cost-effectively deploy UHDTV equipment and services in the near future.

REFERENCES

[1] ITU-R, "The present state of ultra-high definition television", Recommendation BT.2246-2, Nov. 2012.

[2] ITU-T, "High Efficiency Video Coding", Recommendation H.265, Apr. 2013.

[3] G.J. Sullivan, J.-R. Ohm, W.-J. Han and T. Wiegand, "Overview of the High Efficiency Video Coding (HEVC) Standard", IEEE Trans. Circuits Syst. Video Technol., Vol. 22, No. 12, Dec. 2012.

[4] J.-R. Ohm, G.J. Sullivan, H. Schwarz, T.K. Tan and T. Wiegand, "Comparison of the Coding Efficiency of Video Coding Standards—Including High Efficiency Video Coding (HEVC)", IEEE Trans.

Circuits Syst. Video Technol., Vol. 22, No. 12, Dec. 2012.
[5] ITU-R, Recommendation ITU-R BT.709-5 : Parameter values for the HDTV standards for production and international programme exchange, Apr. 2002.
[6] ITU-R, Recommendation ITU-R BT.2020 : Parameter values for ultra-high definition television systems for production and international programme exchange, Aug. 2012.
[7] FAQ for HDMI 2.0, http://www.hdmi.org/manufacturer/hdmi_2_0/hdmi_2_0_faq.aspx
[8] Digital Content Protection LLC, "High-bandwidth Digital Content Protection System - Mapping HDCP to HDMI", Revision 2.2, Feb. 2013.
[9] MovieLabs Specification for Enhanced Content Protection, v1.0, 2013.
[10] Broadcom Unveils World's First UltraHD TV Home Gateway Chip, Press Release, http://www.broadcom.com/press/release.php?id=s732069, Jan. 2013.
[11] Broadcom Proliferates UltraHD Set-top Box Availability with New HEVC Chipsets, Press Release, http://www.broadcom.com/press/release.php?id=s790302, Sep. 2013.