Study on HDR/WCG Service Model for UHD Service

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Abstract— **In recent years, as people's interest in high-quality media services and technology development have increased, not only methods producing content supporting technologies such as High Dynamic Range (HDR) / Wide Color Gamut (WCG), but also converting technologies from existing contents to the one satisfying high-quality media standards is also widely studied and attracting attention. In this paper, we propose a HDR/WCG content service model for commercialized IPTV service based on head-end processing media conversion. We also suggest commercial high-quality media services over content-platform-network-device area.**

I. Introduction

With the development of large-screen display production technology and the development of broadcasting communication technology, high-quality ultra-high definition (UHD) contents are spreading to home beyond high definition (HD). The UHDTV service is characterized not only by increasing the resolution and frame rate, but also by implementing technologies that pursue color reproduction and faithful content reproduction. In recent years, interest in HDR and WCG-supporting technologies has been increasing, and related research and standardization are actively being carried out to faithfully reproduce the contents and to feel the same reality as the original content.

HDR and WCG technologies are collectively referred as technologies that dramatically increase the contrast ratio and color gamut of existing images so that they can express brightness and color close to the original image. In general terms, HDR / WCG images should support a contrast ratio of 1000: 1 or higher and be able to express the gamut defined in ITU-R BT.709 [1]. In order to provide seamless HDR / WCG video service, it is necessary to develop and supply equipment such as cameras and displays that can handle HDR / WCG signals as well as broadcasting / communication and compression standards. The existing standardization technology related to HDR / WCG is not suitable for providing highly immersive media service such as HDR / WCG since it was established only considering the technology level at that time. For addressing the need for high-quality media service, various organizations such as ITU-R, SMPTE, MPEG, ATSC have established standards for more efficient HDR / WCG media service while global TV manufacturers have developed HDR / WCG supporting products satisfying related standards.

However, a user's needs for high-quality media are rapidly growing, even though major content providers such as Netflix and Amazon are making plenty of content supporting HDR/WCG functionality. In addition, HDR / WCG conversion process is time and resource consuming, and therefore is not suitable for processing by the terminal devices. In order to deal with the limitations above, it is necessary to develop technology and equipment to convert existing Standard Dynamic Range (SDR) content into WCG / HDR contents and apply it to IPTV service system.

In this paper, we have developed a content conversion technology from SDR to HDR / WCG in head-end contents server and present the case of deploying them to commercial SK broadband (SKB) service [2]. Since metadata is enclosed and transmitted with converted content from server, the user can play the content without purchasing any additional equipment.

II. Related Works

In this paper, we extend our consideration from HDR/WCG technologies to high-quality media service. Therefore, it is necessary to review HDR/WCG technologies in terms of image processing, standardization, media service.

A. Image processing for HDR/WCG

Real-world scenes typically include a wide range of brightness variations. When the scene to be photographed includes bright and dark areas at the same time, a general digital camera having a low dynamic range (LDR) does not properly acquire the radiance of the scene and the details are lost. HDR imaging aims to better represent scenes by extending the limited dynamic range of imaging devices to overcome these limitations. Much research has been done on HDR imaging until now, and most methods have recovered HDR radiation radiance using several LDR images taken at different exposures for the same scene [3-8]. However, this method is not suitable for broadcasting system because it requires multiple exposure images for the same scene and generates visual distortions such as ghosting effect due to multiple exposures.

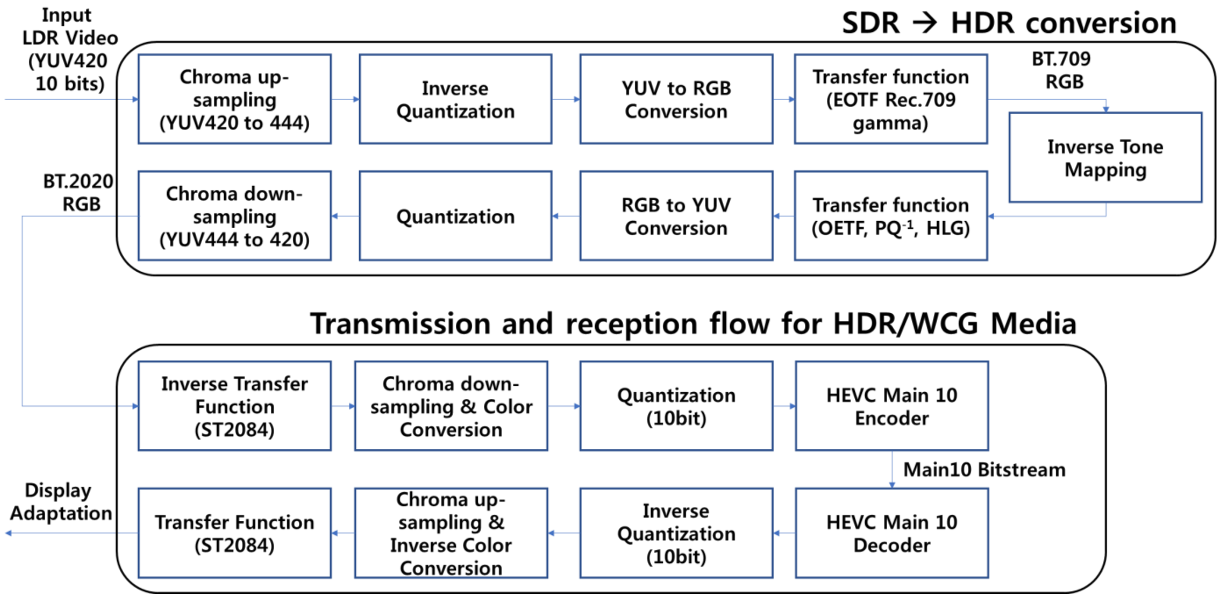

Fig.1 Proposed SDR to HDR conversion and transmission & reception flowchart for HDR/WCG media service [14]

B. Standardization for HDR/WCG

Current HDR/WCG related standards are mainly classified into HDR10 / Dolby Vision / Hybrid Log Gamma (HLG). HDR10 is an open standard adopted by service providers and manufacturers such as movie studios, Netflix, YouTube, and HDR TV. Dolby Vision is a technology developed by Dolby to combine Dolby Atmos sound with HDR video to maximize the visual and auditory effects of Dolby Cinema. HLG is a standard used mainly by satellite-based broadcasters, developed jointly by British BBC and Japan NHK, and standardized in ARIB.

Techniques for providing a seamless HDR/WCG image service include an Opto-Electrical Transfer Function (OETF) technique for converting an HDR/WCG signal acquired from a camera into an electronic signal required for pre / post processing and transmission, Electro-Optical Transfer Function (EOTF) technology for converting the optical signal into an optical signal to be expressed in a digital signal, and a metadata generation technique for pre and post-processing of the generated signal. The HDR conversion technique defined EOTF and OETF optimized for 100 nits in [9], which is not suitable for conversion of HDR signal of 1000 nits or more. To solve this problem, Perceptual Quantization (PE) - EOTF [11] is proposed, which defines a transform function optimized for maximum brightness of 10,000 nits based on Barten's cognitive and visual model [10]. [10] shows that if the EOTF curve is above the 'Visual Difference Threshold' based on the perceptual visual model, there may be degradation such as image blending. When the maximum brightness of the display used in the receiving end to which the EOTF is applied is smaller than the maximum brightness of the reference display, the Gamma function of BT.709 in the low gradation portion and the perceived visual characteristics in the high gradation portion are considered HLG-EOTF [12] was defined using the logarithmic function. The metadata for post processing includes additional information for correcting the maximum brightness of the display of the transmitting and receiving end. The static metadata includes the color primaries, white point, brightness range, and maximum content light level (MaxCLL) of the video signal defined in [14], And a maximum brightness average value (MaxFrame Average Light Level, MaxFALL) for each frame. If the dynamic range of the receiver display is less than the dynamic range of the display used in the mastering stage, color volume transfer technology is required to reproduce the HDR / WCG signal to match the color range of the receiver display. The dynamic metadata defines the necessary information at this time.

C. Media services for HDR/WCG

HDR / WCG functionality is one of the new requirements for new media service to be realized as ultra-high-quality media. Therefore, it is essential to analyze the readiness of contents (C), platform (P), network (N) and device (D). In this section, we describe trends in the C-P-N-D field as a whole.

Content. For content readiness, since the specifications for content creation, editing, transmission, and playback have been made through the UHD Alliance at CES in 2016, a variety of products have been released for HDR / WCG content creation. Through NAB 2018, Sony and Sharp exhibited workflows and camera and camcorder lines that

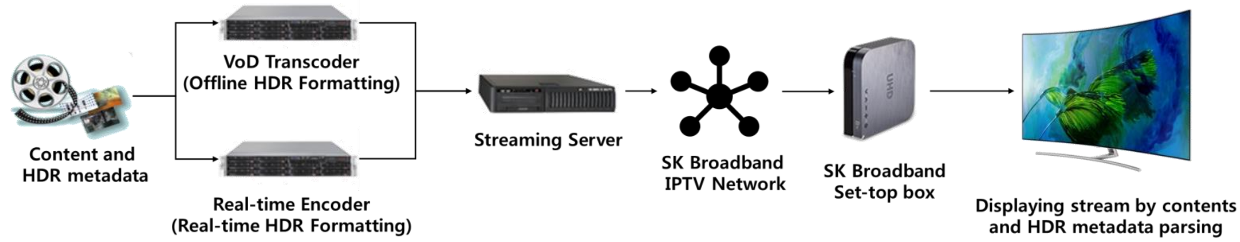

Fig.2 Proposed SDR to HDR conversion and transmission & reception flowchart for HDR/WCG media service [14]

support 4K HDR, and Apple has introduced ProRes RAW, which allows high-quality UHD images to be handled in relatively low- Format. In addition, it has introduced products that support related formats such as the camera unit of ground, aerial photographing equipment, DJI, and video equipment of Atmos.

Platform. Since the start of UHD IPTV and Giga Internet service in 2014, HDR10/HDR10+ based UHD IPTV service has demonstrated in 2017 and will be commercialized in 2018. In case of UHD terrestrial broadcasting, HLG based UHD broadcasting is planned and its contents is being produced. OTT service providers such as YouTube, Netflix, and Amazon which launched UHD service are getting increased HDR10/10+ video service fields through partnership with device and OS manufacturers.

Network. Ultra-high quality video supporting HDR/WCG is applied to 4K UHD contents firstly, and it needs infrastructure such as Giga Internet and UHD Set-Top Box to receive 4K stream. In Korea, after deployment of Giga Internet and UHD IPTV service in 2014, 2.5G premium service started in May, 2018 and 10Gbps speed Internet will be commercialized in the end of 2018 as well. In addition, HDR enabled IPTV Set-Top Boxes have been launched from 2016, and the HDR function over commercial Set-Top Boxes is trialed in the VoD service.

Device. When it comes to device readiness, high-end displays supporting 4K resolution and HDR are being sold through TV makers such as Samsung and LG since 2015. HDR functions are also being sold in some low-end models starting in 2017 following the expansion of all high-end models in 2016. It is mainly supported by SMPTE standard such HDR10, but HDR10 + which is Dolby Vision and Dynamic HDR is also installed from the end of 2017. Therefore, it is necessary to support various contents formats to provide HDR in the device when providing contents.

The ecosystem for supporting ultra-high-definition media services is being created and it is expected that it will evolve into next-generation home entertainment through various developments in terms of CPND. However, the change cycle of each value chain differs, and in particular, ultra-high-definition media service supports only high-end devices and contents. In terms of transmission and playback, the content providing method is variously supported by HLG, Dolby, HDR10/10+ depending on the device. Therefore, it is necessary to develop media conversion technology that can play HDR / WCG contents in various legacy devices in accordance with various standards.

III. PROPOSED HDR/WCG SERVICE MODEL

In this section, we describe the case of HDR/WCG media conversion system on the IPTV service. Fig.1 schematically shows entire process of SDR to HDR/WCG conversion with HEVC main 10 profile (HDR10) defined in [CES2015] that our HDR/WCG content service model is based on. In order to provide HDR/WCG contents to encoder, our method converts non-linear lights in YUV 420 format to linear RGB in BT.709 color representation. Then we perform inverse tone-mapping in color conversion from BT.709 to BT.2020. Then input of encoder is HDR contents in color with BT.2020. In the encoder side, transfer function commonly referred to as SMPTE ST 2084:2014 EOTF [11] and inverse-EOTF digitizes a linear light signal and expresses ti as non-linear RGB. In Chroma sampling and Color Conversion step, RGB signal is converted into YCbCr signal which is easy to compress, and down-sampling is performed in 4: 4: 4 format to 4: 2: 0 described in BT.2020 [14]. In the quantization step, the number of colors that can be expressed in one pixel is defined as 2^{10} to have 10 bit depth. Also HDR10 is defined as the combination of the container above and coding characteristics as metadata. According to SMPTE ST 2086 [13], the proposed system delivers MaxFall and MaxCLL as metadata information referring mastering display color volume supporting high luminance and WCG to Supplemental Enhancement Information (SEI) and color map information and transfer function information to Video Usability Information (VUI).

Inverse tone-mapping converting BT.709 to BT.2020 is the core process of SDR to HDR conversion in our HDR/WCG contents service model. Linear conversion of color space results in serious color distortion especially in human skin color. In order to eliminate the above visual distortion, the proposed method reduces the color distortion and increases the detail of the image by applying a predetermined mapping function according to the color intensity characteristic of the input image. The input and output of the mapping function are both normalized luminance, and the input luminance range is from 0.05 to 100 nits corresponding to the dynamic range of existing SDR contents and the output is 0.0005 to 1000 nit.

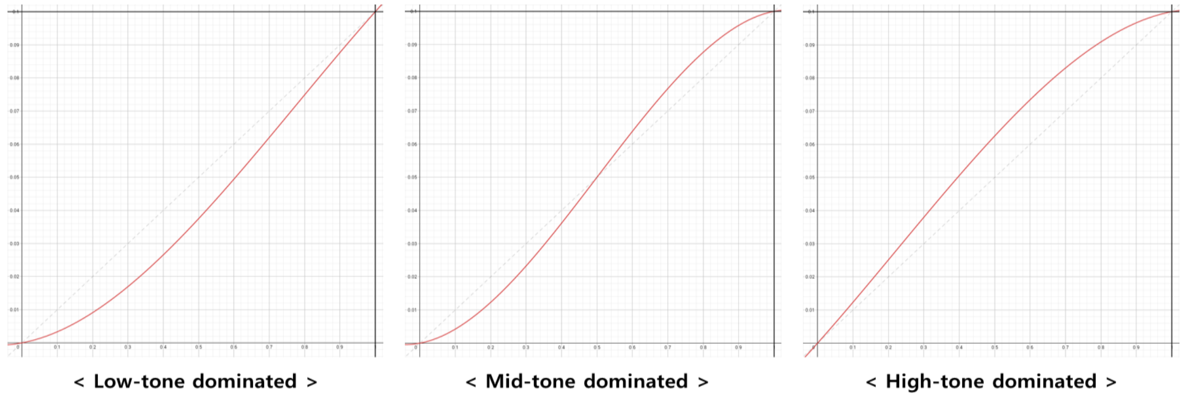

Fig.3 Inverse tone-mapping curve of the proposed HDR/WCG conversion

Fig.4 SDR to HDR/WCG conversion result
(Left: converted HDR/WCG content, Right: SDR content)

The input image is classified into low-tone, mid-tone, and high-tone dominated images through histogram analysis [15] and different mapping functions are applied as shown in the Fig.3. The mapping function estimates the piece-wise linear relation between the specular and diffuse regions for the three types of input images and generates the fourth-order normalized Beier Curve corresponding to piece-wise linear relation and color mastering theme.

Fig.2 shows the flow of high-quality media service based on HDR / WCG contents conversion technology applied to Btv, SK Broadband's IPTV service. The SKB Btv service transmits both offline VoD content and online real-time content together with HDR metadata after HDR formatting and plays the stream from the display through HDR / WCG content and metadata parsing in the set-top box. HDR content has been completed with color tone mapping corresponding to the TV manufacturer and model. The HDR / WCG conversion of the proposed legacy SDR contents is performed in the head-end content server. The proposed head-end conversion has the following advantages / disadvantages compared to performing the same operation on a displaying device such as a set-top box or a TV.

Head-end conversion can guarantee conversion quality. For TV and set-top box conversion, only the user can check the conversion result. In other words, when the quality of the conversion is poor, the demand for quality assurance from the user increases. Head-end conversion, on the other hand, provides a guaranteed conversion result because it can validate and master the quality of the converted content. In addition, in the case of terminal conversion, high quality conversion process is required for each user for the same content. In the case of head-end conversion, processing due to repetition can be reduced because a single conversion can serve multiple users. As the content size increases due to high-quality conversion, the amount of data required for content streaming increases, which is a financial burden on the user. However, the financial burden of increasing data volume will decrease rapidly as wireless networks are about to commercialize 5Gbps, wired networks at 10Gbps, and wired and wireless operators offer unlimited rate plans at lower prices.

IV. FUTURE WORKS AND CONCLUSION

In this paper, we have developed a head-end HDR / WCG conversion technology for high-quality media services and introduced a commercial IPTV service. To expand high-quality media services, we have focused on developing media codec technology standards, media solutions such as encoders and HDRs. However, since each C-P-N-D has a different cycle of change, it is necessary to support not only individual development of C-P-N-D ecosystem but also balance of each to provide universal ultra-high quality media service. For this purpose, we implemented HDR / WCG automatic conversion of SDR system and deployed HDR/WCG service over IPTV to increase the number of high quality contents. For expanding ultra-high quality video, we will improve various media conversion technologies such as upscaling and HFR.

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