White Paper

QC Issues in UHD/HDR Video Delivered Over a Lossy Channel

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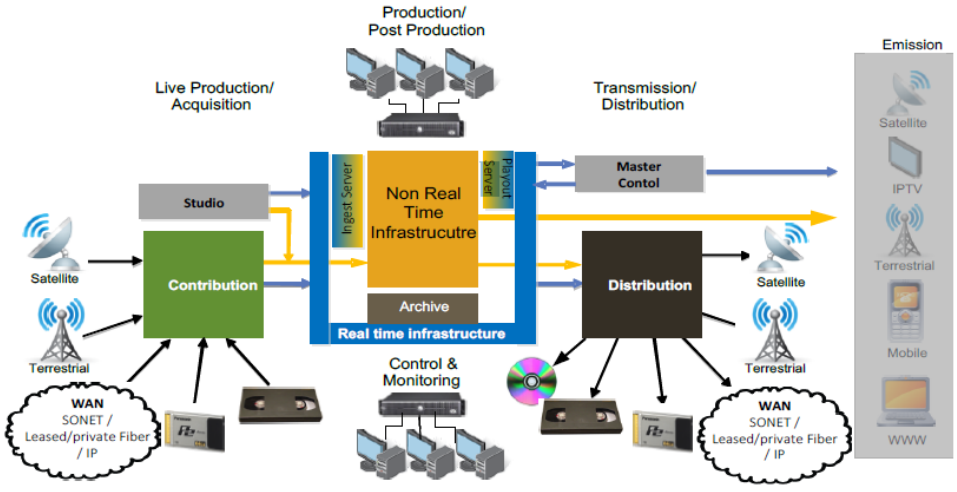
1. INTRODUCTION

The current drive towards High Dynamic Range (HDR) technology is primarily based upon the enhanced brightness and color depth or Wide Color Gamut (WCG) capability now available in displays. With multiple optical ←→ electrical transfer functions (OETF/EOTF) and WCG standards driving HDR content creation and display, along with issues of backwards compatibility with existing Rec 709/SDR displays, the issue of viewer experience in such an interoperable HDR environment clearly needs closer attention.

Furthermore, in conjunction with the work on HDR development, ATSC 3.0 is currently being developed as the next generation standard for Digital Television, wherein content provision is now being considered at Ultra High Definition (UHD) resolution, with HEVC (H.265) as the compression format. In this regard, Over-The-Top (OTT) compressed streaming content delivery in 4K/HDR is already being provided by Amazon and Netflix; while on the other hand, 4K Blu-ray compressed media storage/playback also has HDR support, as do most major display manufacturers. However, as it is well known, an increase in compression efficiency typically results in a corresponding decrease in coding redundancy. Subsequently, this results in a vulnerability to error propagation resulting from content transmission impacted by Packet Loss (PL), an issue that needs to be looked into as well.

2. A BRIEF OVERVIEW OF THE UHDTV ECOSYSTEM

First, we now take a quick overview of the current state of the art and in particular, how it ties in with the VQ issues subsequently discussed in Section 3. In this regard, a good starting point is the work done by SMPTE which has been captured in their 2015 report[1]. The following figure reproduced from the report illustrates the television production and broadcast flow.



SMPTE UHDTV Study Group Reference Diagram[1]

The implementation of High Frame Rate (HFR) video, HDR capture and a diversity of display capabilities in terms of color volume can challenge systems interoperability within the above flow. Now from a Video QC perspective, validation of various media

parameters is important because while there have been several 'customized' HDR offerings available commercially, implementation of standards at every stage of the video production pipeline makes interoperability and the monitoring of compliance viable in the future.

3. KEY ISSUES IN DEALING WITH HDR CONTENT

Implicit to legacy SDR TV Video *no-reference QC methodology* is the fact that the luminance ranges of video capture, as well as the color volume have been for several decades fixed, with legacy CRT displays being inherently compatible with the video capture and more contemporary LCD displays being equal to or exceeding the target video performance. This also enabled one to perform most of the video QC at either the compressed stream level or the decompressed component level. However, one set of primary issues currently driving optimal HDR viewing performance involve the challenge of interoperability between production and display. For example, when viewing a picture created in a WCG color palette on a legacy SDR display, picture wide contouring due to bit depth loss (global) or region based incorrect tone mapping (local); could be an issue if the conversion is not handled with care. In a similar vein, loss of contrast may occur due to target and actual EOTF mismatch, e.g. if viewed on a legacy BT709 compliant display. Additionally, the issue of possible enhancement of compression artifacts in brighter image regions viewed on a bright high contrast HDR panel needs to be monitored and quantified. Finally, the issue of whether the given content is indeed HDR needs verification. All of which is significant in order to assist content creators in monitoring and maintaining Video Quality (VQ) in a diverse (and at times 'mismatched') HDR ecosystem. These issues have been analyzed and described in detail by Interra[5].

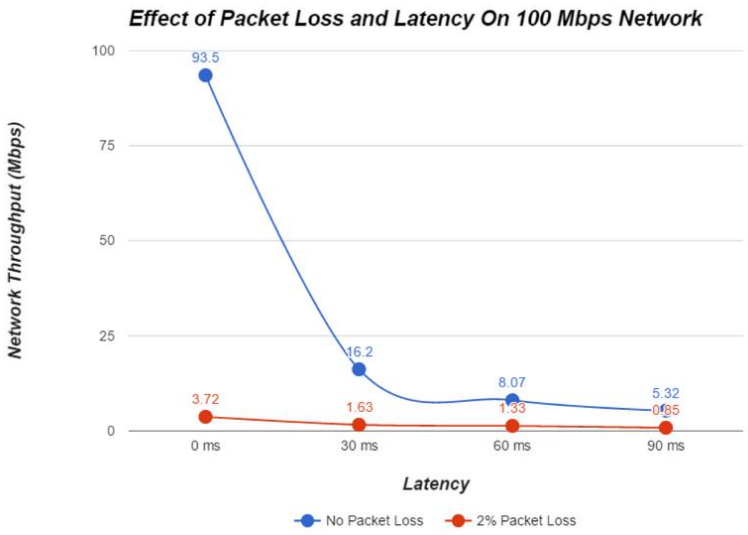
4. EFFECT OF LATENCY AND PACKET LOSS (PL)

Now taking a step back and looking at SMPTE UHDTV Group reference diagram described in Section 2, we note the information flow within the network occurring between a succession of devices or modules. In each case, there is a finite time or delay for a packet to travel from one device to the next. The cumulative effect on the time taken from the start of an information packet, to its final delivery at the receiving device, is termed as the overall latency.

Network routers, packet queuing due to heavy network congestion, satellite communication delay (if applicable), all contribute significantly to latency and its effect can be studied in terms of retrievable and non-retrievable packets, as follows[2]:

4.1 RETRIEVABLE PACKET DELIVERY

- Commonly used protocols like TCP (Transmission Control Protocol) govern the packet traffic flow within a network. TCP for example, is supposed to ensure or guarantee media information packet delivery.
- This involves a handshaking process wherein the device sending the media packet gets an acknowledgement from the receiving end.
- If such an acknowledgement is not received within a specified time period the packet is deemed 'lost', and then that particular media packet is resend.
- We note that as the latency becomes larger, the media packet providing device spends a commensurately increased amount of time in waiting for an acknowledgement.
- This negatively impacts the actual throughput; as shown in the following figure[2]:



Network Throughput versus Latency

As Maniscalco[2] succinctly puts it: "To put this into perspective, Netflix recommends 25 Mbps in order to get a single stream of 4K HDR quality video (1.5Mbps is the minimum recommended). This means that with just a 30ms round trip time, users will be BELOW the recommendation!" So keeping this in mind and considering the issues described in the previous section, the effect of a lossy channel (with retrievable packet delivery) on viewer experience, can then be summarized thus:

- Effective throughput would be lower than the peak specified, depending upon the system latency / PL characteristics.
- This in turn may result in the content provider delivering media at a *lower* effective bitrate. So for a native 4K/UHD HDR content being originally provided, this could manifest itself as:
    - Lowering the bit-depth → resulting in the possibility of banding or posterization type artifacts.
    - The above may happen in conjunction with a reduction of the color volume (e.g. going from BT.2020 → BT.709), which in turn would reduce the viewer QoE.
    - Increasing the QP → Results in a higher degree of compression artifacts. These in turn could get enhanced at the HDR receiver, depending upon their intensity and local contrast.
    - Format down conversion UHD → HD/SD and/or HDR → SDR, in order to cater to an effectively reduced BW due to PL; clearly leading to some of the QC issues mentioned in the previous section, as well as a potential drop in viewer QoE.
    - Lowering the frame rate → In an immersive viewing UHD environment, this could leave the viewer with a diminished QoE (Quality of Experience); especially when viewing high motion content like sports and so on.

However, the degradation of QoE (and the challenge of capturing it within the VQ assessment space), can become even more severe when lost packets cannot be retrieved, as we shall see in the subsequent section.

4.2 IRRETRIEVABLE PACKETS – INFORMATION LOSS

Now, if lost packet retransmission is not ensured, then this leads to a loss of information or content. The QoE under such circumstances depends upon the receiver error concealment (if any), the efficacy of which in turn would depend on the specific media content – i.e. its spatial and temporal 'busy-ness', amongst other considerations. This issue has been analyzed by Interra with a variety of HEVC encoded test sequences[3].

5. LOOKING AHEAD

As of this writing, it has been announced that NBC is pushing for the distribution of 4K HDR to cable, satellite and telco providers[4] for their 2018 Winter Olympics coverage. It turns out that this will be the first offering of Olympic coverage in 4K HDR in the U.S.

So looking ahead, while HDR offerings appear to expand and provide the consumer with a more enriching and satisfying viewing experience, they also pose challenges in the interim wherein standards are still being developed and all the components of the production and broadcast flow as described in Section 2 may not always be on the same page. As aptly stated in the SMPTE report[1]: "Displays, image processors, up/down color convertors will all need to detect the HDR encoding and colorimetry in use to correctly process and display the signal. Compression and image processing is an increased part of many production and distribution systems, and the interaction of HDR signals with standard methods have not been fully explored".

Therefore, development and adaption of viable video QC is crucial in the evolving ecosystem, where issues with interoperability could impact optimal viewing performance and therefore where metadata capture, interpretation and application is key.

6. INCORPORATION OF HDR IN BATON® QC

Interra Systems provides software and services for the digital media industry. The company's solutions include its flagship product BATON, an automated verification system that ensures media content readiness.

BATON™ QC flow

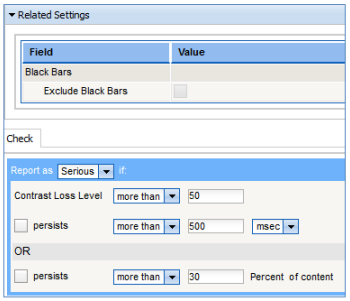
The releases of this product will have HDR support that includes the VQ checks described earlier in Sections 3 and 4. In this respect, the new cluster of HDR checks currently offered comprise of monitoring the following:

- Frame-Maximum Light Level
- Frame-Average Light Level
- Light Level over the entire content
- Contouring, local (due to tone mapping issues) or global (due to bit depth loss)
- Contrast Loss due to panel mismatch
    - Enhancements in of existing checks for Compression Artifacts

For example, a snapshot of the GUI proposed for the new HDR related Contrast loss check has been exemplified below:

- **Contrast Loss**

There can be a loss in perceived contrast if an HDR Video is displayed on a Low Dynamic Range (LDR) Display or on a display with inconsistent Transfer characteristics.



Example Scenario 1
*An error will be reported for a video sequence with **duration** more than **500 msecs** and with Frames having **Contrast loss Level** more than **50***

Example Scenario 2
*An error will be reported for the entire video content if more than **30%** of the content is having **Contrast loss Level** more than **50**.*

Note that the HDR related items are subject to change and will evolve within the Video QC flow, as more clarity is achieved over time on the standardization (and hence interoperability) aspects within the HDR ecosystem described in Section 2.

In addition to BATON, Interra Systems also offers VEGA, a family of audio/video analyzers that accelerate media product development and ORION, a real-time content monitoring solution.

Interra Systems is headquartered in Cupertino, CA. For more information, please visit http://www.interrasystems.com.

REFERENCES

1. Study Group Report High-Dynamic-Range (HDR) Imaging Ecosystem, SMPTE 2015.

2. Maniscalco, M., "*Buffering, Poor Video Quality, Signal Loss – How Network Latency And Packet Loss Kill Your Networks*", IHIJI Blog, February 14, 2017, taken from http://www.ihiji.com/buffering-poor-video-quality-signal-loss-network-latency-packet-loss-kill-networks/

3. Kumar, B., et. al. "*Perceptual Video Quality Analysis for HEVC in Packet Loss Environment*", SMPTE 2014 Annual Technical Conference and Exhibition, Los Angeles, CA, October 20-23, 2014.

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5. Mogre, A., Kumar, B., and Madnani, S., "*Analyzing and Monitoring Video Quality a Diverse HDR Ecosystem*", SMPTE Motion Imaging Journal, Vol. 126 No. 6, pp 54-63, Aug. 2017.