IEEE 802.11ac wireless delivery of 4kUHD video: The impact of packet loss

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***Abstract*—This paper examines the 4kUHD video quality from streaming over an IEEE 802.11ac wireless channel, given measured levels of packet loss. Findings suggest that there is a strong content dependency to loss impact upon video quality but that, for short-range transmission, the quality is acceptable, making 4kUHD feasible on head-mounted displays.**

***Keywords*—4kUHD; head-mounted display; IEEE 802.11ac; Packet Loss Visibility; video streaming**

I. Introduction

The authors of [1] report a low-power High Efficiency Video Coding (HEVC) codec processor that is capable of delivering 4kUHD (Ultra High Definition) video (3840 × 2160p pixels/frame, 16 × 9 aspect ratio) at 30 fps to Long Term Evolution (LTE) and 5G portable devices. Portable devices are potentially better at displaying 4kUHD than traditional TV screens because 4kUHD is best viewed close-up. Alternatively, a 3m viewing distance would require an 80" screen. Though smart-phone 4kUHD displays already exist, even then users may find it hard to distinguish 1080p resolution from 4kUHD. However, head-mounted displays (HMD's) for (say) Augmented Reality (AR) can benefit from this resolution because the display is very close to the eyes.

In this paper, we consider another aspect to 4kUHD, which is the feasibility of streaming over 'lossy' wireless channels. Of potential wireless technologies, IEEE 802.11ac [2] provides a high-throughput wireless LAN in the unlicensed 5 GHz band. In theory, a single spatial channel has a maximum throughput of 867 Mbps. This is principally due to an increase in mandatory channel width to 80 MHz and up to 256-Quadrature Amplitude Modulation (QAM). However, when 256-QAM is selected, the impact of noise increases significantly. Moreover, the increased channel width that restricts 802.11ac operation to the 5 GHz band also results in shorter wavelengths at this frequency, affecting the propagation behavior. Thus, unless some form of HTTP Adaptive Streaming (HAS) is employed, leading to larger buffers and a significant risk of display stalls [3], packet loss visibility (PLV) (video quality after UDP-based streaming) becomes a concern for high-resolution video.

Our experiments firstly considered what levels of packet loss would occur in a number of indoor transmission scenarios and then determined the viewing quality after HEVC compression. Prior study by others has considered either the likely IEEE 802.11ac data-rates (Wave 1) in an indoor environment, as in [4], or the subjective video quality after error-free delivery, as in [5]. However, few researchers appear to have examined PLV within 4kUHD video, linking this to packet loss rates for an indoor environment. Since Wave 1, Wave 2 IEEE 802.11ac has introduced Multi-User (MU)-Multiple Input Multiple Output (MIMO) antennas (2×2 configuration), allowing high datarate streaming even when several AR devices are connected to the same access point (or for 3D display). As there are already commercial HD HMD's, including wireless HD, with applications such as personal digital cinema and gaming, the feasibility of streaming 4kUHD to HMD's should be explored.

II. Methodology

Four 4kUHD adaptations of well-known test sequences were employed. Table I records the characteristics of the sequences in terms of recommendation ITU-T P.910's Spatial Index (SI) and Temporal Index (TI). A Graphics Processing Unit (GPU)-assisted encoder was implemented based around enhancing the H.264/Advanced Video Coding (AVC) implementation of [6]. However, the encoding time was reduced to 5s (rather than 7s for [6]) for 500 frames of 4kUHD *Sintel*, with similar reductions for the other test sequences. This reduction was achieved by zero-copy memory transfer to the GPU rather than the memcpy mechanism in [6]. Streaming was at a Constant Bitrate (CBR) of 20 Mbps with the H.264/AVC High profile, with Group of Pictures (GoP) size 40 and frame structure IPPP… The aim was to assess packet loss rates (PLRs) in a typical indoor environment (average of 10 trials for each data point). The configuration of IEEE 802.11ac was similar to [4], using the high-throughput features present in the Broadcom BCM4360 chipset, as given in Table II.

III. Findings

Fig. 1 selects the packet losses at 10 m and 20 m within an office (mean of 20 tests). For the 10 m transmission there were no obstructions but for the 20 m experiment typical office furniture was present. It was also found that, when it was necessary to pass through intervening partition walls, there was a rapid fall off of available datarates. From Fig. 1, it may appear that up to 20 m PLRs are not distinguished by distance. However, the PLRs for higher-activity Sintel in particular are noticeably higher.

TABLE I Test video sequences content type

Video sequence	SI	TI	Motion classification
Coast	10.84	16.92	Moderate
News	17.52	21.24	Moderate
Foreman	19.71	38.29	High
Sintel	16.39	72.26	High

TABLE II Settings for IEEE 802.11ac measurements

Setting	Value
Channel bandwidth	80 MHz
Channel number	36 (5.180 GHz)
No. of spatial channels	3 (3 × 3 MIMO)
Transport protocol	UDP
Datagram size	1472 B
Modulation	256-QAM

Inspection of the output frame rates of the hardware-assisted encoder, Fig. 2, showed that the coding complexity reduced Sintel's output to 15 fps, whereas Coast's output approached 20 fps, with the other two clip's rate between that in order of motion activity (Table I). We, therefore, surmise that the total time during which a video was transmitted exposed the video to more packet loss events, despite the fact that channel 36 (Table II) was chosen to avoid external interference and transmission was at night. Nonetheless, Fig. 1 appears to show likely PLRs, which might be reduced for less active sequences to about 0.1% with application-layer channel coding.

Video quality in Fig. 3 was assessed with the well-known Structural Similarity (SSIM) index which more than PSNR reflects the response of the Human Visual System but approaches PSNR's computation speed. To bring the results more in line with contemporary developments, the HEVC codec, FFmpeg implementation, was configured in its Main profile, to output at a CBR of 13.5 Mbps (approximately equivalent in quality to an H.264/AVC rate of 20 Mbps). The GoP size was 25 with an IBBPBBP… frame structure at 25 fps. From Fig. 3's plots, particularly for PLRs between 0.2% and 0.5%, it is clear that motion activity is a strong determinant of the packet loss impact. *Coast* in particular benefits from its lower activity. Certainly, one would not want to stream 4kUHD video in this configuration if the PLR was above 0.5%. However, Fig. 1 implies that a PLR above 0.5% may not often occur. SSIM does not assess temporal quality and a frame rate of 60 fps rather than 25 fps may eventually be required.

IV. Conclusion

Wireless IEEE 802.11ac seems a likely way to transmit compressed 4kUHD. Provided the transmission range is not

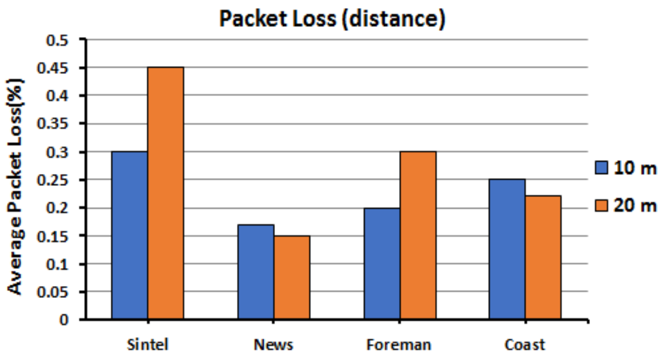

Fig. 1. Packet loss at different distances during IEEE 802.11ac transmission of 4kUHD video

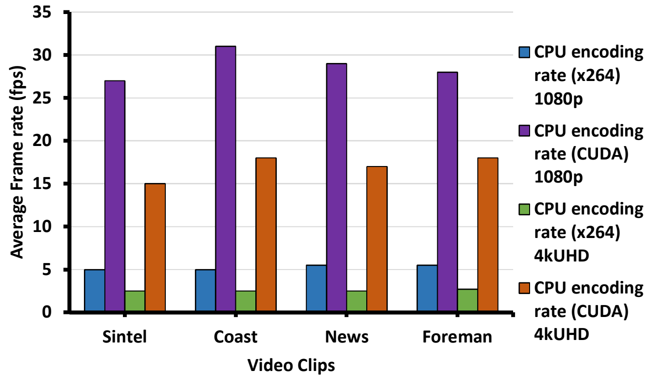

Fig. 2. Comparison of achievable framerates for HD and 4kUHD video

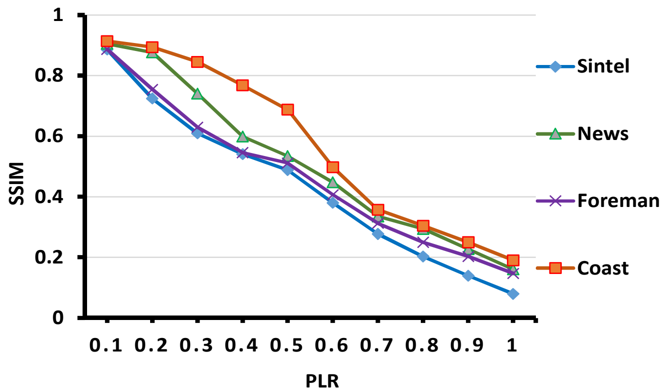

Fig. 3. SSIM video quality assessment for a range of PLR percentages with HEVC codec encoding and 4kUHD resolution

much greater than 10 m, PLRs of less than 0.2% may be acceptable. However, high motion activity within a video, e.g. a TI over 30 in Table I, will strongly influence the perceived quality. As it is easy to classify video by such activity, content-selective streaming may be possible. However, what FEC overhead will be needed requires further investigation before a real-time HMD application such as AR is achieved.

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