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Research Article

Analysis and Evaluation of Multicast Video Streaming Over IEEE 802.11n/ac

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Abstract

There is an ever-growing interest for video applications. It is well-known that video applications have very stringent quality of service (QoS) requirements and require high data rates. To meet ever growing demands for mobile video streaming applications and stringent QoS requirements, it is required to optimise the current networks. IEEE 802.11 is one of the most widely deployed networks in the world. Therefore, this paper investigates the performance of multicast video streaming over IEEE 802.11n/ac in a mobile outdoor scenario. To this end, an end-to-end system level simulator is developed to evaluate the performance of the perceived video quality at the receiver in terms of peak signal to noise ratio (PSNR) and resource efficiency in terms of total transmission times for different application layer - forward error correction (AL-FEC) and medium access control (MAC) layer parameters. Results show that without AL-FEC protection the legacy IEEE 802.11n/ac provides very poor quality of experience. However, the perceived video quality can be significantly improved by adding some extra repair symbols. Since video applications have very challenging QoS requirements, changing only MAC parameters are unable to meet these QoS requirements thus additional AL-FEC protection is required. Moreover, it is observed that with the use of the frame aggregate mechanism at the MAC layer, the total transmission times can be significantly reduced and hence the resource consumptions.

Keywords: Video streaming, Multicasting, IEEE 802.11n/ac, PSNR.

IEEE 802.11n/ac Üzerinden Çoklu Video Yayını Analizi ve Değerlendirilmesi

Öz

Video uygulamalarına ilgi giderek artıyor. Video uygulamalarının çok katı hizmet kalitesi (QoS) gereksinimleri olduğu ve yüksek veri hızları gerektirdiği iyi bilinmektedir. Mobil video uygulamaları için giderek artan talepleri ve katı QoS gereksinimlerini karşılamak için mevcut ağları optimize etmek gerekir. IEEE 802.11, dünyadaki en yaygın kullanılan ağlardan biridir. Bu nedenle, bu makale, mobil bir dış mekan senaryosunda IEEE 802.11n/ac üzerinden çoklu video gönderim performansını araştırmaktadır. Buna amaçla, alıcıda algılanan video kalitesinin performansını tepe sinyal gürültü oranı (PSNR) açısından ve kaynakların verimli kullanılmasını toplam iletim süresi açısından, farklı uygulama katmanı ileri hata düzeltme kodları (AL-FEC) ve orta erişim denetimi (MAC) katmanı parametreleri için değerlendirmek üzere uçtan uca bir sistem seviyesi simülatörü geliştirilmiştir. Sonuçlar, AL-FEC koruması olmadan geleneksel IEEE 802.11n/ac'nin çok düşük kalitede deneyim sağladığını göstermiştir. Bununla birlikte, bazı ekstra onarım sembolleri göndererek, video kalitesi önemli ölçüde iyileştirilebilir. Video uygulamalarının çok zorlu QoS gereksinimleri olduğundan, yalnızca MAC parametrelerini değiştirmek bu QoS gereksinimlerini karşılayamaz, bu nedenle ek AL-FEC koruması gerekir. Ayrıca, MAC'de çerçeve kümeleme mekanizmasının kullanılmasıyla, toplam iletim sürelerinin ve dolayısıyla kaynak tüketimlerinin önemli ölçüde azaltılabildiği gözlemlenmektedir.

Anahtar Kelimeler: Video gönderme, Çoklu gönderim, IEEE 802.11n/ac, PSNR.

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1. Introduction

Wide deployment of mobile phones and tablet PCs has led to increasing demands for mobile multimedia traffic. Especially, the video traffic constitutes a significant portion (around 82%) of global internet traffic (Cisco, 2017). Currently the IEEE802.11 standard is one of the widely deployed networks in the world used for video streaming applications (IEEE Std 802.11, 2016). In order to meet the increased traffic load and higher quality of service (QoS) requirements of video streaming services, the IEEE 802.11 standard has been evolved during the last decade. Many new IEEE802.11standards have been developed to increase the capacity, quality, and networks utilisations of the legacy system. Nowadays, IEEE802.11n operates at 2.4 GHz and 5 GHz bands and IEEE802.11ac operates at 5 GHz are widely used versions of the standard (IEEE Std 802.11, 2016) both amendments implement multiple input multiple output (MIMO) technology to increase the throughput. However, the higher throughput provided by MIMO technology is not well utilised, due to the high contention overhead and using lower data rates for control signalling. To improve the channel usage, frame aggregation mechanism at the medium access control (MAC) layer was proposed. Frame aggregation mechanisms are supported in both IEEE 802.11n and 11ac standards.

With the frame aggregation mechanism, multiple UDP/IP data packets arrived from the transport/application layer (AL) can be combined to form a larger aggregated data frame. In this way, when an AP/client gets access the medium to transmit a number of frames can combine them into an aggregate frame to avoid contenting the channel many times. This allows reducing the contention times (overhead requires transmitting every frame) and utilising the channel efficiently.

Two types of frame aggregation mechanisms are proposed in the standard: Aggregated MAC service data unit (A-MSDU) and aggregated MAC protocol data unit (A-MPDU). In A-MSDU, multiple logical link control (LLC) frames, namely MSDUs are combined to build a single A-MSDU. The aggregated frame contains one MAC header and has a maximum size of 7935MSDU bytes. In A-MPDU, MAC header is added to each MSDU to form an MPDU then multiple MPDUs are combined to create an A-MPDU. An A-MPDU has the maximum of 65535 bytes in size. Since an A-MSDU contains only one MAC header, if a part of an A-MSDU is lost then all aggregated MSDUs will be lost. However, in A-MPDU mechanism, each MSDU has a separate MAC header even if some parts of an A-MPDU is lost some MSDUs can be still recovered. Therefore, in this work, the A-MPDU mechanism is considered for multicast video streaming. Since for multicast data transmission, IEEE 802.11 does not provide any reliable solution, multicast packets are delivered without getting any feedback from users. Therefore, packet loss rate would be very high and that of video streaming applications cannot tolerate higher packet losses or longer delays. Although MAC aggregation can enhance channel utilisation and save networks resources, it cannot provide reliable multicasting of videos. Thus, additional mechanism, which is AL-FEC (application layer forward error correction) based on Raptor code (Shokrollahi, 2006), is proposed by 3GPP in multimedia broadcast multicast services (MBMS) to protect the video packets from channel losses (3GPP TS 26.346 V8.0.0, 2008). AL-FEC scheme based on Raptor codes employs transmitting redundant packets along with the original packets to allow the receiver (video decoder) to recover the corrupted source packets by using the redundant ones.

In literature, works have studied the performance of MAC aggregation schemes (Daldoul et al., 2011; Charfi et al., 2017) and AL-FEC based on Raptor codes for multicast video streaming over IEEE 802.11 (Shin et al., 2017; Osunkunle, 2018; Bulut, 2020). However, as far as author`s knowledge, there is no work that considers the IEEE 802.11 system performance by employing both RaptorQ at AL and frame aggregation mechanism at the MAC. To this end, this paper presents the realistic simulation studies on the impact of frame aggregation and AL-FEC based on RaptorQ codes (Shokrollahi and Luby, 2011) on multicast video streaming performance. We believe that these insights on MAC frame aggregation and AL-FEC parameters are helpful to develop new enhancements for multicast video streaming in IEEE 802.11n/ac networks.

The rest of the paper is organised as follows. Section 2 provides materials and methods used in the work. Section 3 presents simulation results and discussion and finally Section 4 concludes the paper.

2. Material and Method

An advanced cross-layer simulator was developed in order to evaluate the end-to-end video streaming performance of the system for different cross-layer system parameters. To reduce the computational complexity and time, the cross-layer simulator was divided into four sub-systems: 1) H.264/AVC codec, 2) RaptorQ, 3) IEEE 802.11n/ac MAC-PHY, and 4) the channel simulators. Each of these MATLAB simulators was developed individually and results obtained from on sub-system were used as inputs to other in order to calculate the final performance evaluation metrics, which are peak signal to noise ratio (PSNR), the average (mean) PSNR over a number of video sequence realisations (100 times) and total transmission times, defined in this work. PSNR is a statistical objective measure and in literature it is mostly implemented to quantify the quality of received videos. The PSNR for a given video frame is computed by taking the mean square error (MSE) of the received version (frame) and comparing it with a reference frame which is the error free version of the frame generated at the encoder. The transmission times are calculated using the procedure defined in IEEE 802.11 standard (IEEE Std 802.11, 2016).

The H.264/AVC video simulator enables modelling transmissions of H.264 video sequences over the MAC and PHY layers of IEEE 802.11n/ac. The H.264/AVC video encoder processes incoming video frames in order to form fixed size network abstraction layer units (NALUs) (ITU-T Recommendation H.264, 2009). One or more NALUs can be encapsulated into one RTP/UDP/IP packet.

The RaptorQ encoder constructs source blocks by collecting the incoming RTP/UDP/IP packets which are basically called source symbols. Each source block has k source symbols each T bytes in size. Then, the RaptorQ encoding process over each source block is implemented to generate some repair symbols r for each block (Shokrollahi and Luby, 2011). As RaptorQ is a systematic FEC code, the first k encoded symbols are called the original symbols. The number of repair symbols generated depends on the RaptorQ code rate which is defined as $CR=k/(k+r)=k/n$.

The 802.11n/ac MAC-PHY layer simulator was developed based on the standard (IEEE Std 802.11, 2016). It enables aggregation and fragmentation of MAC MSDUs and creates the packet loss pattern for a sequence of MAC frames based on the time varying channel model. This process is performed for different modulation and coding schemes (MCS)/MIMO modes, m_j, $m_j \in M = \{8, \ldots, 11\}$ and different RaptorQ code rates, $CR = \{0.4 < CR \leq 1\}$. Simulation parameters and MCS/MIMO modes used in this work are presented in Table 1 and Table 2, respectively. More detailed information about the cross-layer simulator can be found in our previous work (Bulut, 2020).

At the receiver side, the RaptorQ decoder waits to gather all packets to form a given source block. When the number of received symbols k' (source and repair) for a source block is $k' \geq (\varepsilon + 1)k$ (for real $\varepsilon > 0$), then the RaptorQ decoder can successfully decode the source block and all packets are delivered to video codec. But, if the decoder fails, only the correctly received source UDP packets are delivered to the video decoder.

Table 1. Simulation Parameters

Parameter	**Value**
Raptor symbol size, T	1400 bytes and 500 bytes
Source block length, K	200, 560
Video bit rate	5 Mbps
I frame interval/period	5
BS height	2.5 m
MS height	1.5 m
Number of antennas at the BS and MS	2
Channel frequency	5 GHz
Channel bandwidth	20 MHz
GI	800 ns

Table 2. IEEE 802.11n/ac Transmission Modes

MCS index, m_j	**Spatial streams**	**Modulation**	**Coding rate**	**Data rate (Mbit/s)**
8	2	BPSK	1/2	13
9	2	QPSK	1/2	26
10	2	QPSK	3/4	39
11	2	16-QAM	1/2	52

3. Results and Discussion

In terms of simulation scenarios, it is assumed that a mobile user moves in a non-line-of-sight (NLOS) large outdoor environment. To evaluate the system performance, the Rush hour video sequence with a resolution of 720p is used. The video was encoded with a bit rate (λ) of 5 Mbps. The test video sequence has 200 frames encoded at 25 frames per second, and I frames are transmitted at every 5th frame intervals. The video quality is evaluated in terms of PSNR and average PSNR for different RaptorQ source symbol sizes (T=1400 bytes and T=500 bytes), block sizes (k = 200 and k = 560), RaptorQ code rates ($CR = \{0.4 < CR \leq 1\}$) and MCS modes m_j ($m_j \in M = \{8, \ldots, 11\}$). The results were repeated for 100 times (channel realisations) in order to provide statistical results.

Figure 1 presents a snapshot of the received packet loss trace consisting of 6000 NALUs. The packet loss trace is used as an input to the RaptorQ decoder. Decoding is performed over the received packet loss trace and correctly received packets are delivered to video codec in order to calculate the PSNR values. Figure 2 shows the PSNR per frame results for legacy system (no RaptorQ) and RaptorQ code rates of 0.8 and 0.6. The error free PSNR ranges between 40 dB – 44 dB. It is seen that without AL-FEC most of the received frames are in error, i.e., their PSNR values are less than 40 dB thus the legacy system provides very poor QoE. However, by adding 25% (CR=0.8) and 33% (CR=0.6) of repair symbols, the numbers of received error free frames (and hence the user QoE) are increased by 234% and 442%, respectively. The benefits of using AL-FEC scheme to deliver error free videos is obvious and comes at the expense of additional bandwidth requirements (25% and 33% in this specific case).

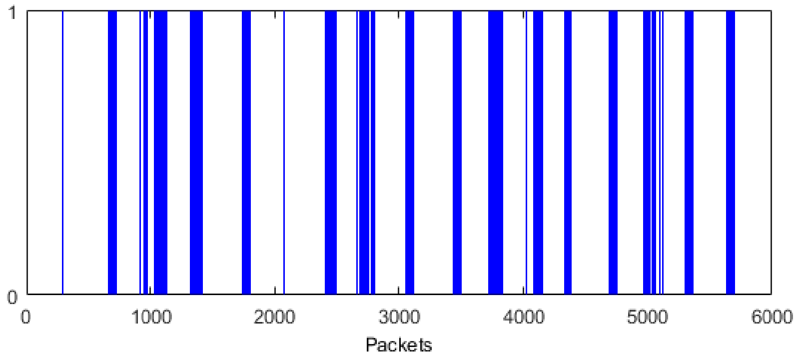


Figure 1. Received packet loss trace (1: lost packet, 0: received packet), MCS 8.

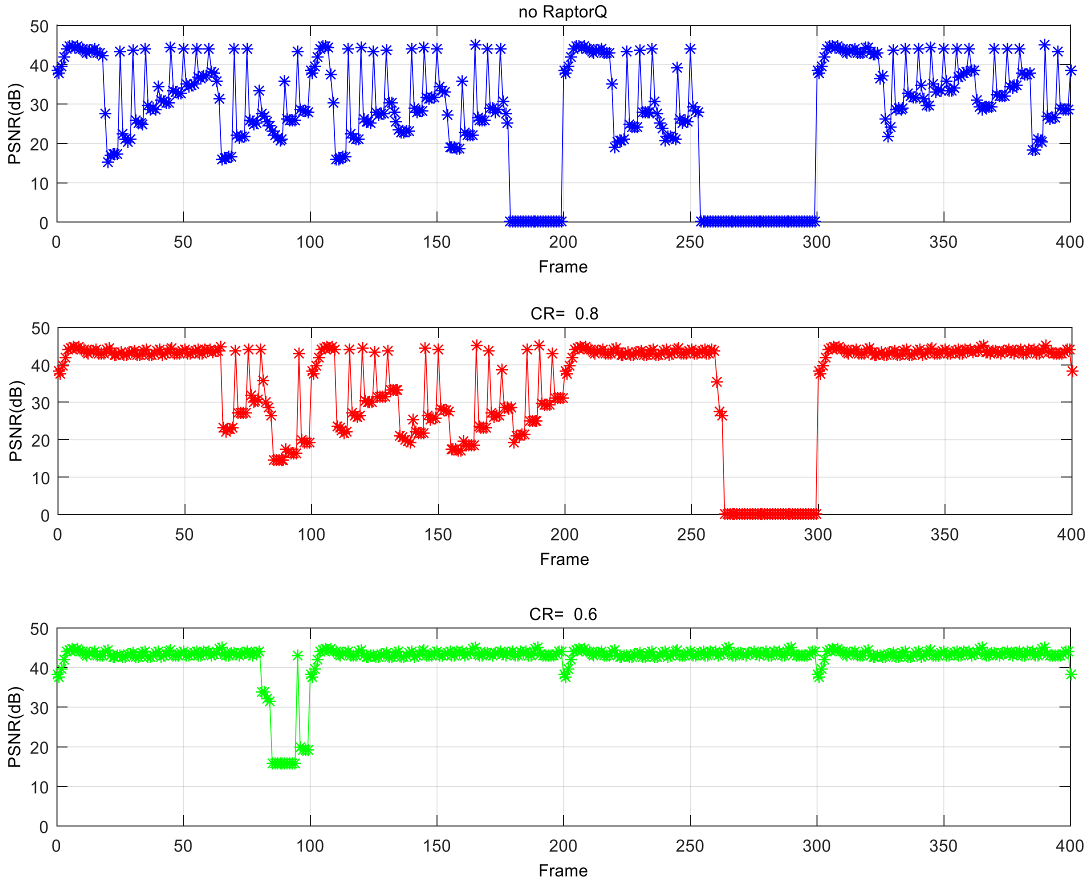
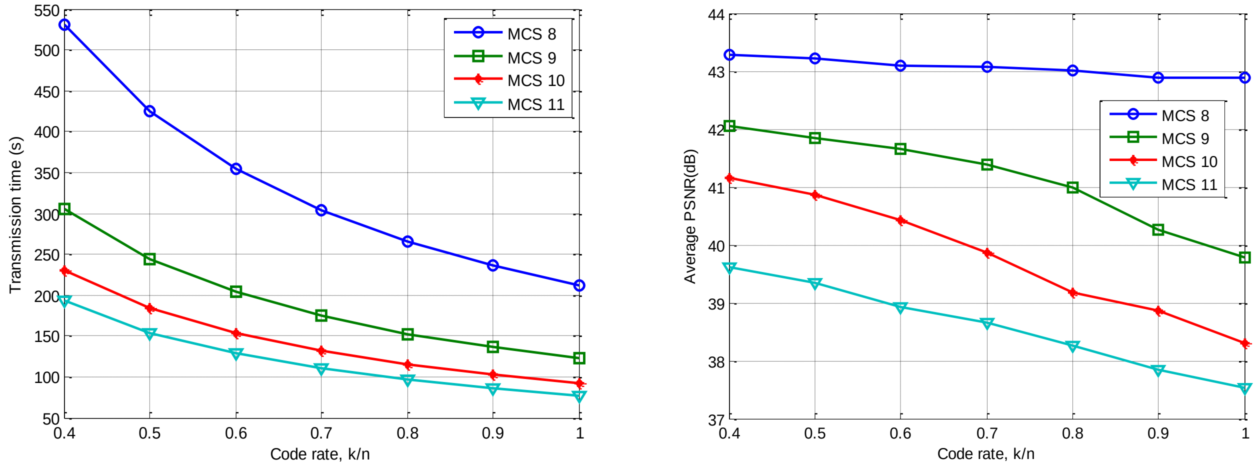


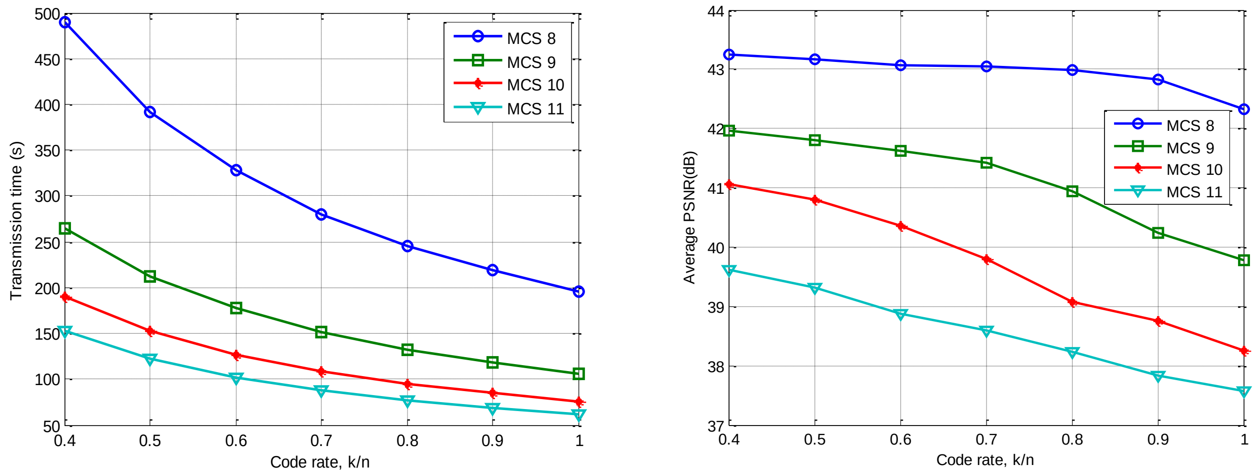
Figure 2. PSNR per video frame for k=200, T=1400 bytes, MCS 8.

Figure 3 - Figure 5 compare the video quality in terms of average PSNR and transmission time, which are calculated aver all video frames and 100 realisations, for different MCS modes, RaptorQ source block sizes of k = 200 and k = 560, RaptorQ code rates of $CR = \{0.4 < CR \leq 1\}$ and RaptorQ source symbol sizes of T=1400 bytes and T=500 bytes with and without the MAC aggregation. It is seen that (in Figure 4) the aggregate MAC schemes provides the lower total transmission times thus consumes less radio and network resources at the expense of slight reduction in the received PSNR due to the bust of errors encountered in aggregate MAC mechanism compared to the legacy MAC schemes in Figure 3. Especially, the performance gap increases when the code rate decreases since the number of transmitted packets increases and MCS mode decreases. For example, for MCS 8 and CR=1(implies no RaptorQ), the total transmission times are around 210 s and 196 s for legacy and aggregate MAC schemes respectively, i.e., there is around 6.6% reduction in the total transmission times. For CR=0.4, the total transmission times are around 535 s and 492 s for legacy and aggregate MAC schemes respectively, i.e., there is around 8% reduction in the total transmission times. It should be noted that since IEEE 802.11 MAC scheme is based on time sharing it is very important to reduce the transmission times thus other users can access the channel. It is further observed from the figures that adding more repair symbols can yield better PSNR (video quality) however, it consumes immense radio and network resources (increased total transmission times). When higher MCS modes are implemented, the resource consumption is significantly reduced. However, higher MCS modes result in lower average PSNRs thus poor QoEs. Performance of the higher MCS modes can be significantly improved with the use of AL-FEC as seen in the figures there is up to 3 dB improvement in the PSNR values.



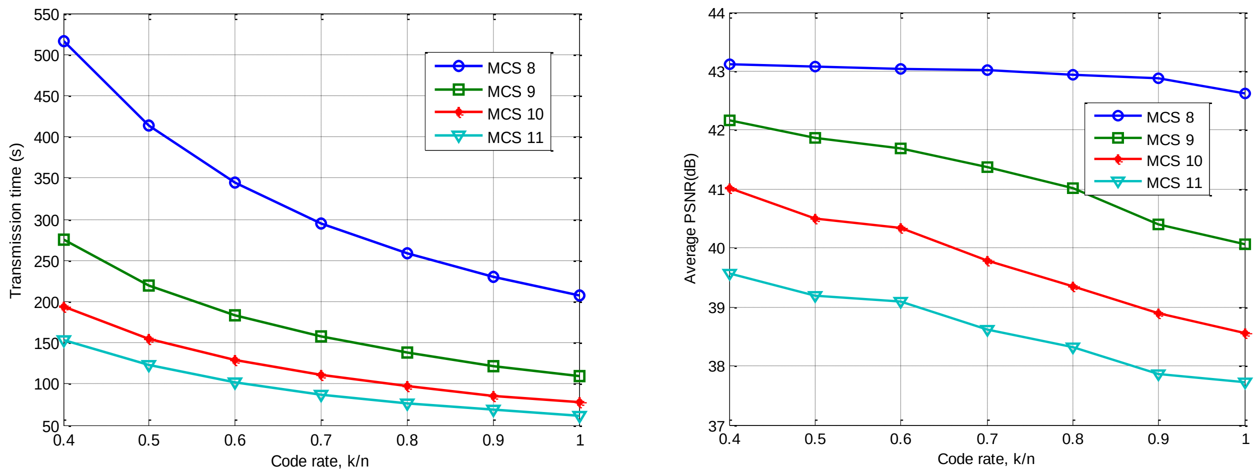
(a) **(b)**

Figure 3. System performance with respect to *CR*, *k*=200, *T*=1400 bytes: **a)** Total transmission time, **b)** Average PSNR.



(a) **(b)**

Figure 4. System performance with respect to *CR* with aggregate MAC, *k*=200, *T*=1400 bytes: **a)** Total transmission time, **b)** Average PSNR.



(a) **(b)**

Figure 5. System performance with respect to *CR* with aggregate MAC, *k*=560, *T*=500 bytes: **a)** Total transmission time, **b)** Average PSNR.

When incoming video NALUs are divided into more UDP/IP packets with a smaller size as seen in Figure 5 (symbols size is reduced but RaptorQ source block size increases), the system performance in terms of PSNR gets slightly better compared to Figure 4 at the expense of slight increase in the total transmission times due to upper layers` overheads. Using small packets especially beneficial when there is no AL-FEC mechanism and higher MCS modes are implemented. This is due to the fact that small packets are less susceptible to the PER since they are scattered over time it is less likely to have long busts of PERs. It is also worth noting that dividing NALUs into more packets with smaller size (higher source block sizes *k*) results in more encoding and decoding processing and hence more energy consumptions at the transmitter and the receiver. Considering that mobile devices have limited processing capabilities it would not be practical to divide NALUs more and smaller packets when AL-FEC is implemented.

Overall, in terms of practical implementation scenarios, it is beneficial to use bigger packet sizes (e.g., *T*=1400 bytes) and to reduce the resource consumption and allow more users to access the network, it is necessary to use MAC aggregation mechanism to stream videos over IEEE 802.11n/ac.

4. Conclusions and Recommendations

This paper investigated performance of multicast video streaming over IEEE 802.11n/ac in an NLOS scenario. To this ed, an end-to-end system level simulator was developed to evaluate the received video quality in terms of PSNR and resource efficiency in terms of total transmission times for different AL-FEC and MAC layer parameters. It was shown that without AL-FEC protection the legacy system provides very poor QoE. However, adding some extra repair symbols, the perceived video quality can be significantly improved. Since video applications have very stringent QoS requirements, changing only MAC parameters are unable to meet these QoS requirements thus additional AL-FEC protection is crucial. Moreover, it was observed that using aggregate MAC mechanism, significantly reduce the total transmission times and hence the resource consumptions. However, the perceived video quality in terms of PSNR gets slightly worse due to the bust of errors encountered in aggregate MAC mechanism. Further that when different packets sizes were evaluated, it was shown that dividing the incoming NALUs into smaller packets led higher total transmission and comparable PSNR values compared to the bigger packet sizes.

References

3GPP TS 26.346 V8.0.0, 2008. Universal mobile telecommunications system (UMTS); multimedia broadcast/multicast service (MBMS); Protocols and codecs.

Bulut B, 2020. Reliable Video Multicasting over WLANs. Journal of the Institute of Science and Technology, 10 (1): 118-127.

Charfi E, Gueguen C, Chaari L, Cousin B, Kamoun L, 2017. Dynamic Frame Ag-gregation Scheduler for Multimedia applications in IEEE 802.11n Networks. Transactions on emerging telecommunications technologies, Wiley-Blackwell, pp.1 - 17.

Cisco Visual Networking Index: Forecast and Trends, 20172022. [On-line] Available: http://www.cisco.com/

Daldoul Y, Ahmed T , Meddour D, 2011. EEE 802.11n aggregation performance study for the multicast. 2011 IFIP Wireless Days (WD), Niagara Falls, ON, October 10-12, 2011, pp: 1-6.

H.264/AVC reference software, 2015. http://iphome.hhi.de/suehring/tml/ (Date of access: 11 September 2015).

IEEE 802.11-2016 - IEEE Standard for Information technology—Telecommunications and information exchange between systems Local and metropolitan area networks—Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications.

ITU-T Recommendation H.264, 2009. Advanced Video Coding for Generic Audio visual Services. ISO/IEC 14496-10 (2009): Information Technology - Coding of Audio-visual Objects - Part 10: Advanced Video Coding.

Osunkunle I, 2018. AL-FEC Wireless Rate Adaptation for WiFi Multicast. IEEE Canadian Conference on Electrical & Computer Engineering (CCECE), Quebec City, QC, May 13-16, 2018, pp: 1-5.

Shokrollahi A, 2006. Raptor codes. IEEE Transactions on Information Theory, 52(6): 2551–2567.

Shokrollahi A., Luby M, 2011. Raptor Codes. Foundations and Trends in Communications and Information Theory, 6(3), 213–322.

Shin Y, Lee G, Choi J, Koo J, Lee S, Choi S, 2017. InFRA: Interference-Aware PHY/FEC Rate Adaptation for Video Multicast over WLAN. 14th Annual IEEE International Conference on Sensing, Communication, and Networking (SECON), San Diego, CA, June 12-14, 2017, pp: 1-9.