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QoS Optimization of MPEG-2 Video Transmission over ADSL Channels using Hierarchical Modulations

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Abstract: - We propose in this paper an original system to optimize the received video quality within the framework of digital video transmission over ADSL. The system is first based on a bi-resolution transcoding scheme using the data partitioning mode of the MPEG-2 standard to adapt the source video bit rate according to the quality of subscriber's line. The second part of the system consists of the transmission of the bi-resolution video bit streams on a hierarchical DMT modulation to achieve unequal error protection. The hierarchical DMT modulation is realized using hierarchical QAM on each sub channel and applying a bit and power loading algorithm designed for such a system. This hierarchical transmission system is described in detail in the paper. Finally we present experimental results that evaluate the performances of the two parts of the system in terms of weighted mean squared error (WMSE) of the compressed digital video sequences, before and after transmission. In particular, this analysis show the advantages of the proposed solution compared to classical transmission schemes.

Key-Words: - MPEG-2 transcoding, data partitioning, hierarchical QAM, DMT, bit and power loading

1 Introduction

Today DSL technologies [1] are widely spread on the market allowing user to access data up to 20 Mbps on their phone lines. Thus, the users benefit from many applications such as Internet access, TV over ADSL or IP telephony. In this context, many multimedia applications and more particularly Video on Demand (VoD) become possible.

However, real-time video transmission over ADSL channels remains a challenging research field [2]. The aim of our study is to optimize these transmissions. We propose in this paper a transmission scheme that optimizes the quality of the video received by each ADSL subscriber depending on its line quality. Indeed, video quality depends directly on the transmitted bit stream rate. When the quality of the line decreases, the error rate increases, leading to unacceptable visual degradations. It is necessary to find the optimal transmission bit rate depending on the bit rate of the compressed video bit stream as shown in figure 1 where D/D_{tot} represents the ratio between the really transmitted bit rate and the total bit rate before transmission. The system we propose here optimizes the quality of services (QoS) of the transmitted video by first adapting the video bit rate according to the quality of the subscriber's loop then applying a transmission scheme based on hierarchical modulations. The video bit rate adjustment is realized with a bi-resolution MPEG-2 transcoding using data partitioning [3] that guarantees a minimal QoS for all subscribers.

The paper is organized as follow. The first section describes in a detailed way the optimisation method of the video QoS. We first present the video transcoding by describing its main characteristics and then we explain how the transcoded video bit streams are transmitting using unequal error protection (UEP) achieved with hierarchical modulations. Section 3 presents the experimental study of the visual degradations due to transcoding and transmission. These distortions are expressed with a simple perceptual quality assessment metric, the weighted mean squared error (WMSE), as a function of the video bit rate. Finally, we reconsider the actual characteristics of our system and we evoke our prospects for improvement.

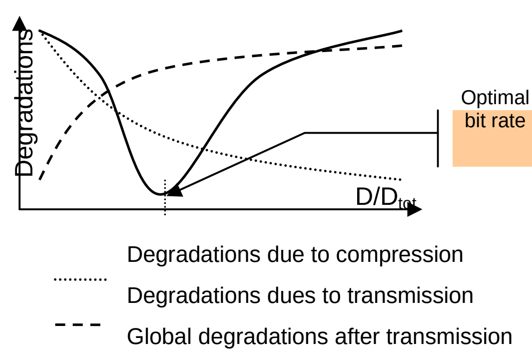

Fig. 1: Video degradations after transmission depending on the video bit rate

2 QoS optimization using transcoding and hierarchical modulations

2.1 Real-time MPEG-2 transcoding using Data Partitioning

In order to adjust the video bit rate in real-time, we use a scalable transcoding scheme based on MPEG-2 Data Partitioning [3] that divides the MPEG-2 initial bit stream into a base layer (BL) containing the most important data and an enhancement layer (EL) containing detail information. Here we consider that the enhancement layer contains only high frequency coefficients of the video. That corresponds in the particular case of a Priority Break Point (PBP) equal or higher than 64, as described in the standard [4] allowing the base layer to transmit a single-decodable video at a minimum QoS. Note that this PBP is called "PBP1" in the following of this paper for clarity. Then, we introduce, in an artificial way, a new PBP called "PBP2" in order to cut the enhancement layer as shown in figure 2. Thus, a reduced part of the enhancement layer is kept and transmitted to the subscriber; the other part being discarded so that the total bit rate decreases.

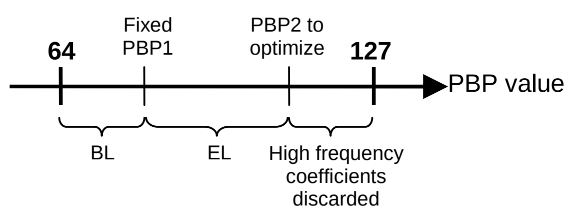

Fig. 2: Principle of the hierarchical transcoding with two PBP values.

As to ensure the same minimum QoS for all subscribers, we fix the PBP1 at 66 corresponding to a good compromise between visual quality of the base layer and the D_{BL}/D_{tot} ratio (approximately 2/3 for a video sequence at 6 Mbps). The choice of the PBP2 value depends on the quality of the line and also on the inherent quality of the video. The lower the video bit rate is (i.e. the lower the PBP2 is), the less the video bit stream is affected by transmission errors, but on the other hand, the inherent quality of the video signal decreases because several high frequency coefficients have been discarded. The ideal PBP2 is the one that guarantees the best global quality at the receiver. The optimization of quality of the received video signal has to take into account limits of transcoding, on the one hand in term of bit rate and on the other hand in term of error generated by transcoding. Indeed, as shown in figure 3, a video encoded at 6 Mbps and transcoded with a PBP2 value of 64 reaches an average bit rate of 2.8 Mbps. This corresponds to the minimum data that have to be transmitted so that the video may be decoded by a subscriber. Subscribers who have a line with a too low quality could not receive the video. As for the error generated by transcoding, also known under the name of "drift error" [5], it is due to the fact that reconstructed frames at the encoder and reconstructed ones at the decoder are not the same. Then, visual artifacts may occur, especially when there is a lot of movement in the video. The lower the PBP2 is, the more the drift error is likely to occur.

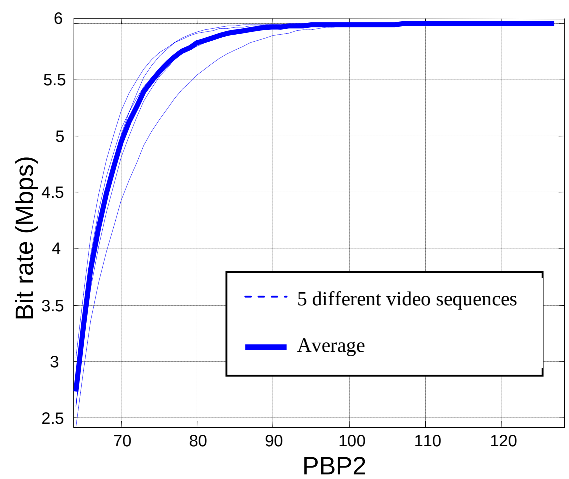

Fig. 3: Video bit rate after transcoding as a function of the PBP2 (for source coding at 6 Mbps)

Once the video has been transcoded in a bi-resolution way, the two resulting bit streams have to be transmitted using two priority levels : the base layer has a high priority level resulting in a low BER requirement, while the enhancement layer has a low priority level resulting in a higher BER requirement. In order to achieve the two priority level transmission, we combine hierachical Quadrature Modulation (QAM) with the multicarrier scheme as described in the next subsection.

2.2 Hierarchical DMT scheme

It is well known that DMT modulation used in DSL technologies is based on Multi-Carrier Modulation (MCM), a parallel data transmission scheme in which there are *L* parallel data streams modulating *L* separate sub-carriers using QAM. A typical bi-resolution transmission scheme over MCM consists of using frequency division multiplex [2]: the "best" sub carriers are assigned to the high priority (HP) bit stream and the other ones are assigned to the low priority (LP) bit stream. Another way to achieve UEP is to modulate each sub carrier using hierarchical QAM so that HP bits and LP bits can be transmitted over the same sub carrier with different levels of protection. This is the principle of what we call here "hierarchical DMT".

2.2.1 Hierarchical QAM

The principle is to transmit HP bits and LP bits in a same QAM symbol. Figure 4 shows some example of hierarchical QAM constellations. Here, HP bits are assigned to the clouds and the LP bits to the satellites. The distances d_1 and d_2 are unequal and are adjusted to meet the desired BERs. In what follows, we consider the use of hierarchical N/M QAMs, with $N = 2^n$, n being equal to the number of HP bits, and $M = 2^{m+n}$, m being equal to the number of LP bits. The parameters n and m can take odd or even values. The parameters n and m can take odd or even values. In the latter case, we consider as a first approach that the N/M QAM corresponding constellations are rectangular.

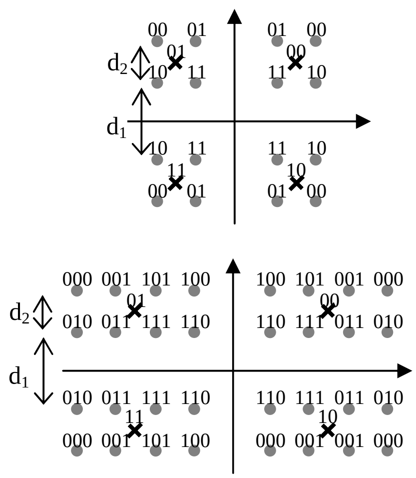

Fig. 4: Examples of hierarchical QAM constellations

2.2.2 Bit and power loading

The bit and power allocation over hierarchical DMT consists of minimizing the transmitted power while maintaining constant HP and LP throughputs (respectively, R_H and R_L) and target HP and LP BERs (respectively B_H and B_L). The bi-resolution allocation is realized in two steps. The first one consists of the power and bit loading of the HP bits and the second step consists of the power and bit loading of the LP bits over the HP bits as shown in figure 4. The bit-loading algorithm should be computationally efficient and reflects the well-known water-filling principle, where more bits are allocated to the sub channels having lowest noise power. An example of such an algorithm is given in [6].

3. Experimentations

At the receiver side, the video quality is degraded because of losses due to transcoding on one hand, and losses due to transmission errors on the other hand. As we want to find the optimal bit rate that minimizes the visual degradations for a subscriber line , we analyze the evolution of the video quality depending on the bit rate. We have seen in section 2.1 that the function relating the PBP2 to the bit rate has little variations depending on the type of video source. We will thus study video quality losses as a function of the PBP2 instead of as a function of the bit rate. The major advantage is the capability to control this parameter at the transcoder side.

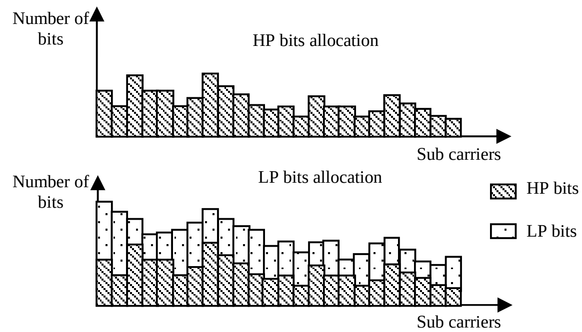

Fig. 5: illustration of the bit and power loading algorithm framework

3.1 Visual image quality assessment metric employed : the WMSE

In the proposed system, the video bitstream is real-time transcoded at the central side of the ADSL transmission. As the choice of the bit rate is based on the evaluated video quality, the visual quality assessment metric is implemented in the central. Thus, the metric has to be very simple to compute. The mean squared error (MSE) is the metric the most used to assess visual quality of images. Indeed, this objective metric is very simple to implement. However, it has been shown that the MSE does not match with the visual response of human observers [7]. Numerous quality assessment metrics that take into account the human visual system have been proposed in the literature. However, they are not as simple as the MSE to compute. The main characteristic of the human eye is its frequency sensitivity: when watching an image, the human eye is more sensitive to low frequency components (uniform areas) than high frequency components (edges, fine details,…). This characteristic has been modeled as a contrast sensitivity function. This function is used here to weight frequency components of the squared error image in order to achieve a metric that is more suited with human visual response. This corresponding weighted MSE (WMSE) metric is a good compromise between computation simplicity and human perceptual relevance. Moreover, we compute the WMSE of the sequence in the DCT domain based on statistical characteristics of the different frames as in [8]. This WMSE metric is used in our experimentations to evaluate the visual degradations due to transcoding and transmission.

3.2 Analysis of the distortions due to MPEG-2 transcoding

We present, in this subsection, results acquired with several video sequences encoded at 6 Mbps. These sequences have been selected among the ones provided by the working group VQEG [9]. They have been chosen for their representative characteristics in terms of movements and details. We relate here distortions due to transcoding to the video quality losses occurring after the suppression of high frequency DCT coefficients.

Transcoding distortions are evaluated by the WMSE as a function of the PBP2, as shown in figure 6. The WMSE is computed between MPEG-2 reconstructed frames before and after transcoding, respectively.

As we have seen previously, few frequency coefficients are present above a PBP2 value equal to 90 because there are only few frequency coefficients in the bit stream for a PBP2 value higher than 90 as shown in figure 3. The WMSE then reaches its minimum quickly.

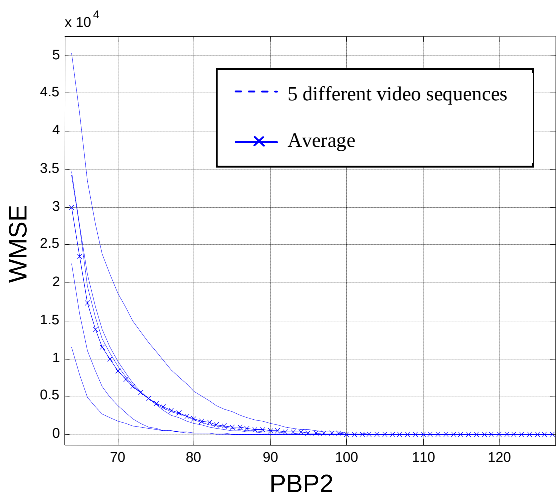

Fig. 6: Distortions due to transcoding as a function of the PBP2

3.3 Analysis of the distortions due to transmission

We suppose that the base layer is transmitted in a lossless way. To realize this safe transmission, we apply Reed Solomon codes with parameters (255,239) on the base layer and we transmit the protected bit stream with a BER requirement equal to 10^{-6} that corresponds to a BER lower than 10^{-11} after decoding the RS codes. Thus, only the enhancement layer is transmitted in an error prone environment. We define its BER to be equal to 10^{-3}.We compute the WMSE of the enhancement layer between the reconstructed images of the transcoded bit streams and the reconstructed one of the same bit streams with the introduction of errors. We suppose that the errors appear independently in the bitstream because of the interleaving of the ADSL system. We present in figure 7 the results in term of WMSE as a function of the PBP2.

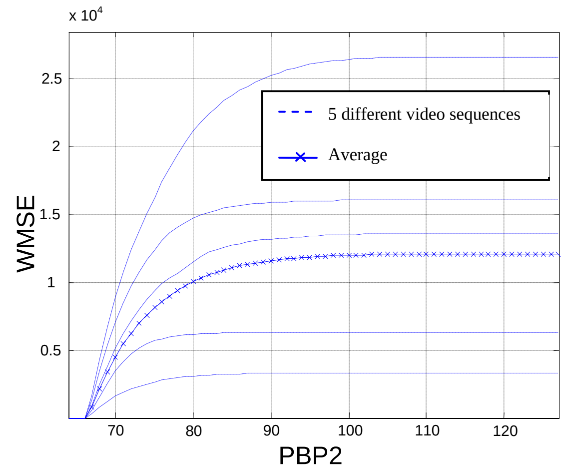

Fig. 7: Distortions due to transmission as a function of the PBP2

It is noted that for a PBP2 value lower than 90, the WMSE increases quickly depending on the PBP2. This was expected for the reason that, if we refer to figure 3, the video bit rate also increases very quickly depending on the PBP2. Indeed, the energy of the video signal is concentrated in the low frequency components and a video encoded at 6 Mbps contains few high frequency information that are likely to exceed a PBP2 value of 90. It is thus normal that the video bit rate and the WMSE which jointly evolve reach quickly their maximum threshold.

3.4 Analysis of the global distortions

This final result is obtained by summing the distortions due to transcoding and the distortions due to transmission. Note that we have normalized the WMSE to compare the different sources of disturbances in the signal. As previously done, we express the results in terms of WMSE as a function of the PBP2, as shown in figure 8. The curves on the figure are the ones resulting from the averaging of the WMSE of the different video sequences.

This result does not clearly show that there is on optimal bit rate to transmit video in the suggested conditions. Indeed, the global distortions curve is monotone decreasing and thus does not reach a minimum value in the PBP2 range of [70;90]. Nevertheless, it is possible to find the minimum value of the PBP2 that ensure the optimal WMSE. Here, this optimal PBP2 is around 76 for a WMSE value that could not be under 1.25×10^4. This means that for a PBP2 value higher than 76, the decoded video would not have a higher visual quality because of transmission errors. And with a PBP2 value under 70, the video quality is not good enough because of the degradations due to transcoding.

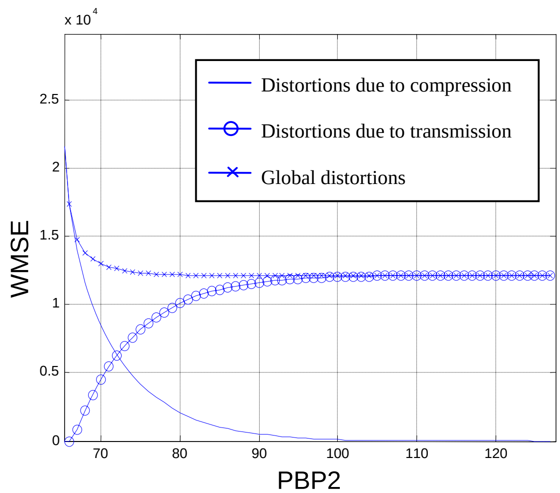

Fig. 8: Global distortions due to transcoding and transmission as a function of the PBP2

4 Conclusion

We have verified the efficiency of the MPEG-2 transcoding scheme described in this paper. We have seen that this transcoding is limited by a minimum bit rate corresponding to a PBP value equal to 64 and by a possible appearance of the drift error phenomenon. To mitigate these drawbacks, it should be possible to emit the video source at three different bit rates: 2, 4 and 6 Mbps. The bit rate should be thus chosen depending on the quality of the subscriber's line and should be adapted using the proposed transcoding scheme.

Our current research concerns the implementation of the total video transmission scheme, from the transcoding to the transmission using hierarchical QAMs. Such experiments would prove the advantage of the hierarchical DMT.

Finally, as our transcoding scheme has been validated on enough video sequences, further work is to determine an algorithm in order to automatically calculate the optimal PBP1 and PBP2 values depending on the quality of the subscriber's line and based on the bit and power loading algorithm used for the hierarchical DMT.

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References:

[1] J.M. Cioffi, T.Starr, P.J. Silverman, Understanding Digital Subscriber Line Technology, *Prentice Hall Communications Engineering and Emerging Technologies Series*, 1999

[2] H. Zheng, K.J. Ray Liu, Multimedia Services Over Digital Subscriber Lines, *IEEE Signal Processing Magazine*, vol. 17, no. 4, 2000, p.44-60.

[3] R. Matthew, J.F. Arnold, Efficient Layered Video Coding using Data Partitioning, *Signal Processing: Image Communication*, No. 14, 1999, pp. 761-782.

[4] ISO/IEC 13818/H.222: Information Technology - Generic Coding of Moving Pictures and Associated Audio Information - Part 2: Video

[5] J.Youn and M-T. Sun, Video Transcoding with H.263 Bit-Streams, *JVCIR 11*, 2000, pp. 385-404

[6] N. Paprandeou, T. Antonakopoulos, A New Computationally Efficient Discrete Bit-Loading Algorithm for DMT Applications, *IEEE Trans. On Commun.*, vol 53, no 5, pp. 785-789, May 2005

[7] B. Girod, What's wrong with mean-squared error, *Digital Images and Human Vision* (A. B. Watson, ed.), the MIT press, 1993, pp. 207–220.

[8] D. Turaga, Y. Chen and J. Caviedes, , No Reference PSNR Estimation for Compressed Pictures, *Signal Processing: Image communication*; vol. 19, 2000, pp. 173-184

[9] http://www.vqeg.org