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Rate control for unbalanced multiple description video streaming

Pedro Correia [a,b,*], Pedro Assuncao [a,c], Vitor Silva [a,d]

[a] Instituto de Telecomunicacoes, Polo de Coimbra, 3030-290 Coimbra, Portugal
[b] Polytechnic Institute of Tomar, EST, Tomar, Portugal
[c] Polytechnic Institute of Leiria, ESTG, Leiria, Portugal
[d] University of Coimbra, DEEC, Coimbra, Portugal

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ABSTRACT

Unbalanced multiple description coding (U-MDC) of video signals aims to obtain different coding rates for transmission over channels with asymmetric available bandwidth. This paper proposes a new rate control method, based on Multiple Description Scalar Quantisation (MDSQ), to generate unbalanced descriptions for asymmetric multipath video streaming. A new set of index assignment tables combined with an extension of the ρ model is devised to generate two unbalanced descriptions with controlled rate, using U-MDC under the general coding framework of H.264/AVC. This work demonstrates that a linear relationship between the rate and percentage of zeros in the transform coefficients of each description is maintained across different description domains, i.e., when moving from the single description domain (SDC) into the MDC domain. The simulation results show that rate–distortion performance of U-MDC is better than its equivalent balanced MDC. The proposed rate control algorithm exhibits high accuracy in achieving different target bitrates and unbalanced ratios between two descriptions. Improved performance is also achieved in video streaming over asymmetric transmission paths, where each description rate can be adapted according to different channel conditions.

1. Introduction

It is known that most of the current communication networks cannot ensure a predefined level of quality of service (QoS). For instance, wireless networks always suffer from fading and multipath interference, leading to inevitable packet loss and variable delays. Multiple Description Coding (MDC) can be used as an efficient approach to improve the video quality in lossy channels, particularly those providing multiple paths between the sender and the receiver. In MDC, several streams (i.e., descriptions) are produced by the video encoder and each one comprises an independent coded representation of the same source signal. The interesting characteristics of MDC is that any single description can be independently decoded and joint decoding of all descriptions yields higher signal quality than individual decoding of any single one [1].

In general, most of the existing MDC architectures use $N=2$ descriptions with approximately the same rate, *i.e.* balanced. However, in order to cope with non-stationary characteristics of channel conditions in terms of available bandwidth and packet error rates, it is better to dynamically match the MDC rate of each description to each different channel in order to minimize the distortion at decoder. Such requirement implies that MDC schemes

* Corresponding author at: Instituto de Telecomunicacoes, Polo de Coimbra, 3030-290 Coimbra, Portugal. Tel.: +351 239796236; fax: +351 239796293.
E-mail addresses: pcorreia@co.it.pt, pcorreia@ipt.pt (P. Correia), amado@co.it.pt (P. Assuncao), vitor@co.it.pt (V. Silva).

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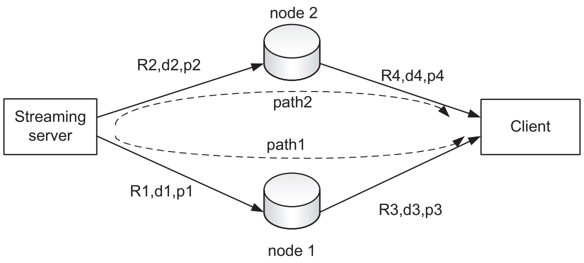

Fig. 1. Unbalanced MDC application scenario.

should be able to produce asymmetric bitrate for each description as necessary, *i.e.* unbalanced MDC (U-MDC).

Fig. 1 shows an application scenario using U-MDC with two descriptions transmitted over different paths. The streaming server sends the coded streams (i.e., descriptions) to the client over two paths. Each path is defined by distinct network branches between client and server, passing through intermediate network nodes. In such type of scenario, each branch is usually characterized by the available bandwidth, delay and packet loss rates, represented by R_i, d_i and p_i. Whenever the streaming server needs to match the MDC output rates to different available bandwidth in each channel, U-MDC provides the necessary solution to cope with such network conditions. In general this is accomplished by using rate control schemes including rate-redundancy distortion models. Furthermore, since available bandwidth and packet loss can differ in each network branch, the intermediate nodes can also perform rate adaptation in each description using MDC transrating systems.

Distinct approaches can be used in U-MDC to achieve asymmetric coded rates, such as adapting quantisation, temporal or spatial resolution. For instance, an U-MDC scheme was proposed in [2] based on different frame rates for each description, while maintaining the quality of individual frames. In this case, the redundancy introduced at lower rate descriptions can be high because of increased temporal distance between frames. In [3,4], U-MDC video coding with rate–distortion optimization is proposed to generate two descriptions maintaining the original temporal resolution. In particular, one description is obtained by encoding the sequence with high resolution (HR) while the other is encoded with low resolution (LR). The main problem of such approach is that the full quality obtained from decoding both descriptions is the same as that obtained from decoding the HR description on its own. Thus, the LR description is totally redundant, which means that the LR description does not improve the signal quality when jointly decoded with HR. Therefore, such approaches cannot be considered true MDC schemes because the overall quality is not improved when both descriptions are available at the receiver.

Unbalanced rates can be obtained by adapting the amount of redundancy encoded and transmitted in each description. For instance, in [5], an U-MDC framework is proposed for wavelet-based coders. The proposed method groups with different wavelet coefficient trees in each sub-stream, based on the available rate for source coding in each sender, and then each group is independently encoded. The work shows that U-MDC combined with an efficient rate allocation algorithm achieves higher performance than conventional balanced MDC. In [6] an asymmetric rate control scheme is proposed for H.264/AVC, where the MDC redundancy is adaptively allocated, based on an end-to-end distortion model. The overall rate is controlled by jointly setting the central and side distortions. Although the resultant redundancy rate is controlled according to channel conditions, this method does not allow changes in each description rate without severe degradation in the central distortion. How to generate efficient unbalanced descriptions without losing error resilience capabilities remains an open research issue.

This paper proposes a rather new approach for MDSQ-based U-MDC. Taking the concept of index assignment for symmetric descriptions as reference [7,8], a new U-MDC scheme based on MDSQ for video streaming is devised. The rate of each description is asymmetrically allocated by changing the index assignment tables of MDSQ and the overall rate control method is capable of producing two descriptions with different rates. From our knowledge this is the first practical implementation of U-MDC using MDSQ applied to video streaming.

The paper is organized as follows. Section 2 presents the necessary background of balanced MDSQ to support the proposed U-MDSQ described in Section 3. Section 4 briefly describes the MDSQ video coding architecture used in this work. In Section 5 the ρ model proposed for U-MDC is presented while Section 6 describes the rate control method. Section 7 presents and discusses performance evaluation results and, finally, Section 8 concludes the paper.

2. Balanced MDSQ

Multiple Description Scalar Quantisation (MDSQ) was firstly proposed by Vaishampayan [9] to generate two independent descriptions from the same source signal, based on two functions: *scalar quantisation* and *index assignment*. Scalar quantisation is generally applied to transform coefficients x such that an index i_0 is produced for each one. Then index assignment relies on an *index assignment matrix* (Table 1) to produce a side index pair (i_1, i_2) from each central index i_0. Each side index corresponds to a quantisation cell containing several possible

Table 1
Balanced MDSQ, $k=1$.

i1 (description 1)	i2 (description 2)									
	−4	−3	−2	−1	0	1	2	3	4	5
−4	…	…								
−3	−10	−9	−11							
−2		−8	−6	−7						
−1			−4	−3	−1					
0				−2	0	1				
1					2	3	5			
2						4	6	7		
3							8	9	11	
4								10	12	13
5									…	…