# New Error Resilience Method for Video Transmission in DS-CDMA Systems


**Mario R. Hueda**

Digital Communications Research Laboratory - National University of Cordoba
Casilla de Correo 755 – Correo Central - Córdoba (5000) - Argentina
mhueda@com.uncor.edu



## Abstract

*This paper introduces a new error resilience method for reliable video transmission in DS-CDMA systems. The new scheme is designed to stop error propagation in the decoded video sequence originated by residual channel errors. Although our technique is general, we focus here on the problem of providing reliable video communication from wired users to mobile users in slow fading environments. This scenario has been shown to be the most critical due to long block error bursts present in the forward link of CDMA systems [8], and the inability of error resilience approaches incorporated in wired video codecs to guarantee an acceptable video quality in wireless transmissions [2]. Numerical results show that our approach achieves important improvements in the quality of the decoded video.*



## Keywords

Robust video transmission, CDMA, error resilience.


## INTRODUCTION

Video transmission and videoconferencing are among the most important multimedia services that can be provided on direct sequence code division multiple access (DS-CDMA) cellular networks. In these systems, video transmission must be limited to low bit rates to allow an adequate capacity for voice users [1].

Coded video data are extremely sensitive to channel errors, so additional protection schemes must be incorporated [2]. Three types of schemes have been used to improve the video quality in transmission over error-prone channels: *error concealment*, *error correction*, and *error resilience*. *Error concealment* techniques refer to those error post-processing methods where the video decoder, recognizing that an *uncorrectable* error has occurred, seeks to hide or minimize the glitch as observed by the viewer, so that a more visually pleasing rendition of the decoded video can be obtained [12]. *Error correction* methods are used to decrease the packet losses owing to transmission over error-prone channels, while *error resilience* approaches attempt to curtail the spread and severity of the damage originated by the transmission errors. The video quality achieved at the decoder in transmission over error-prone channels depends critically on both error correction and error resilience techniques. The ability of the latter to improve video quality in DS-CDMA wireless transmission at low rates requires further considerations. For example, increasing even more the frequency of refresh with an *intra-coded* frame (i.e., a coded video frame that can be decoded by itself) to stop error propagation is not a proper solution because this frame has low compression efficiency and significant additional bandwidth is required to reduce time delays. This not only affects the overall video quality and system capacity (it increases interference), but it also requires elaborate bandwidth allocation algorithms. On the other hand, adjusting the percentage of *intra-coded macroblocks* (*I*-MBs) [10] cannot be achieved without suffering high distortion, because video transmission at low bit rates is assumed. A possible solution to improve video quality in CDMA transmissions consists in combining an error resilience method with an error correction scheme.

This paper presents a new scheme to stop error propagation in the decoded sequence originated by residual channel errors. The new scheme is called the *centralized video quality recovery* (CVQR) scheme. In CVQR, a base station improves the video quality achieved at a mobile station transmitting a video frame especially coded to stop error propagation in the decoded sequence. Although our architecture is general, we focus here on the problem of providing reliable video communication from users belonging to a wired network to mobile users in slow fading environments. This scenario has been shown to be the most critical due to long block error bursts present in the forward link of most existing DS-CDMA systems where closed-loop power control is not used [8], and the inability of error resilience approaches incorporated in wired video codecs to guarantee an acceptable video quality in wireless transmissions [2]. Numerical results show that the proposed technique can achieve important improvements on the quality of decoded video. Furthermore, we show that the new technique outperforms previous error protection schemes with low additional complexity.

## BACKGROUND

Without loss of generality, in this work we analyze H.263 based video transmission [7]. H.263 is a compression standard developed to transmit video using the telephone network at data rates less than 64 kbps. The picture resolution is often QCIF (Quarter Common Intermediate Format, 176x144 pixels). At QCIF resolution, each picture is di-

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vided into 11x9 macroblocks (MBs), which comprise 16x16 luminance samples, and two corresponding 8x8 blocks of chrominance samples. A fixed number of successive MBs is usually grouped into a group of blocks (GOBs). A typical H.263 video stream is composed of *intra-coded* frames (*I*-frames) and *predictive-coded* frames (*P*-frames). An *I*-frame is an independently coded video frame that can be decoded by itself. A *P*-frame is composed of changes in the current image of the video stream relative to the last *I*-frame encoded. An H.263 video stream is usually an *I*-frame followed by many *P*-frames, with an *I*-frame re-introduced to restore image quality in case of transmission errors.

### Error Resilience Techniques

Residual transmission errors cannot be avoided in a mobile radio channel. Additional schemes to stop the error propagation have to be considered. Numerous error resilience techniques have been proposed in the literature to improve video quality in transmissions over error-prone channels [9], [10], [13], [14]. Among them, the *error tracking* (ET) approach has been shown to achieve a good tradeoff between video quality and complexity [9]. ET utilizes *I*-MBs refresh to stop interframe error propagation. Using a feedback channel, the temporal and spatial occurrence of an error is reported to the transmitter. Thus, the location and extent of propagated errors are reconstructed at the encoder. In practical situations, quality degradation is experienced because:

- to maintain constant bit rate, only a fraction of MBs corresponding to severely affected image regions are coded in *I*-mode;
- the video source coding distortion increases as a result of the higher number of *I*-MBs;
- packet losses between the last frame for which acknowledgment was received and the current frame, are not considered by the transmitter.

Better results than ET can be achieved with the error resilience technique described by R. Zhang et al. in [14]. In this case, however, modifications of H.263 video encoders and heavy numerical computation are required (it works at the pixel level). All these inconveniences can be overcome by our *centralized video quality recovery* (CVQR) scheme.

## NEW ERROR RESILIENCE METHOD *CVQR*

We assume that error protection is based on a retransmission protocol. Thus, analyzing the ACKs/NACKs provided by the retransmission protocol, the base station (BS) is able to reconstruct the video decoded at the mobile station (MS). Then, taking into account the error concealment technique used by the MS, the decoded video can be reconstructed at the BS. On the other hand, the original video transmitted from the far user (FU) can be decoded at the BS. Then, since the original and reproduced *video frames* (VFs) are known at the BS, it is possible to obtain a measure of the video degradation level at the MS. When this value is larger than a certain threshold, the BS transmits a new frame called *correction frame* (CF), which is coded based on the difference between the original and reproduced video frames. To reduce delays, the transmission of the CF corresponding to instant *t*-1 and the actual video frame at instant *t* ($VF_t$) is achieved increasing the user's bandwidth. At the MS, the CF is decoded first and *then* the actual video frame is decoded. Assuming that there is no information loss in the coding process of CF, the actual frame will be decoded with the same reference utilized by the FU's video encoder; therefore the error propagation will be stopped (see Figure 1).

### Implementation of CVQR in Slow Fading Environments

We assume that the BS is able to reconstruct at instant $t$ the video frame decoded by the MS at instant $t$-$\delta$ (Figure 2). Since the round trip delay ($N$) and the frame rate are small (e.g., $N \leq 6$ slots and 6 frames per second (fps), respectively), it can be verified that $\delta$ is around 2-3 VFs (the block duration ($T_B$) is around 20 msec.). On the other hand, since the channel varies slowly, the MS can estimate the channel state with good accuracy (e.g., using the pilot signal), and report it to the BS. Based on this information, the video quality recovery process is achieved as follows (see Figure 3). If the BS detects at $t_0$ that: (*i*) the BS→MS link is good (i.e., a strong signal level at the MS), and (*ii*) the degradation of the decoded video is significant, the CVQR process is started.

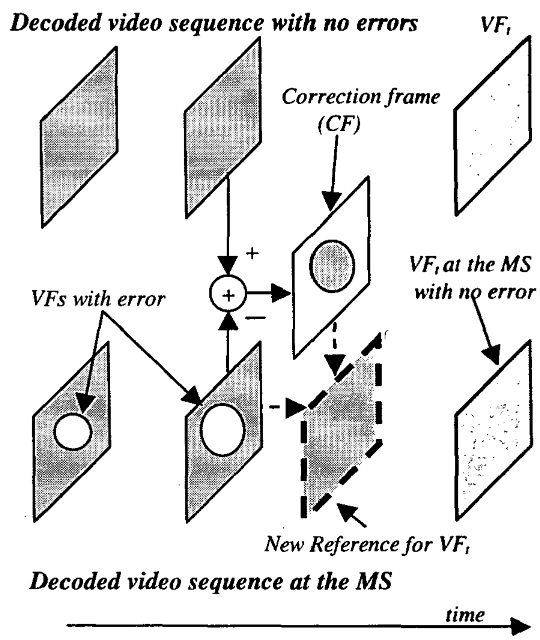


**Figure 1. Error resilience method CVQR.**

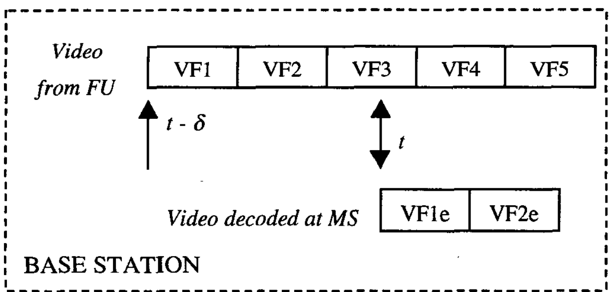


**Figure 2. Reconstruction at the BS of video received from FU and decoded at MS.**

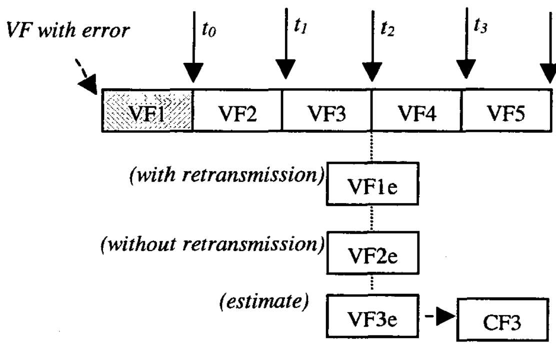


**Figure 3. Estimates of correction frame (CF).**

BS knows at instant $t_2$ how the data packets corresponding to VF1 (and the previous) were received at the MS after the retransmission process. In addition, the BS can determine if there were errors in the original transmission of VF2 (i.e., with no retransmission). In this case, it is expected that the data blocks with information of VF2 are received with no errors because of the good quality of the BS→MS link. Thus, the BS can reconstruct exactly the VFs decoded at MS corresponding to VF1 and VF2, which will be denoted by $VF1_e$ y $VF2_e$, respectively. Furthermore, at instant $t_2$ a good estimate of $VF3_e$ can be obtained. Towards this end, we assume that the data blocks with information of VF3 will be transmitted with no errors. This is based on the facts that (*i*) the signal level at the MS is good and (*ii*) the channel varies slowly. This way, the BS can estimate at instant $t_2$, the correction frame (CF) required to stop error propagation (i.e., $CF3 = VF3\text{-}VF3_e$). Then CF3 is encoded and the BS increases the user's bandwidth to transmit both CF3 and VF4 with low delay. In the MS, the video decoder will process CF3 first and then VF4 (note that the delay introduced is negligible). Assuming that the coding of CF3 is ideal (i.e., there is no information loss), VF4 will be decoded with the same reference used by the FU's video encoder, and thus, the error propagation will be stopped. When the CVQR process finishes, the system returns to the normal operation (e.g., at instant $t_3$).

## Effectiveness of CF to Stop Error Propagation

In practical situations, the CF is coded with loss, therefore a residual degradation will be observed in the decoded sequence. However, this degradation is not important for video sequences with low/medium motion as a result of: (*i*) the low recovery time delay $T_{CVQR}$ (CVQR takes place between an MS and its BS), (*ii*) the use at MS of an error concealment method, (*iii*) and the fact that CF is coded from the difference between two frames (i.e., a *P*-frame). In sequences with heavy motion, the transmission of CF requires extra bandwidth to achieve an acceptable degradation level. When this extra bandwidth is not available, the CVQR process can be repeated several times to gradually reduce video distortion.

Figure 4 shows the PSNR obtained with our approach for video test sequences "*Mother & Daughter*" (1-stage CVQR) and "*Foreman*" (1 and 2-stage CVQR). The transmission environment is detailed in next section. From Figure 4 it can be verified that the residual video degradation is negligible. Note also that owing to the heavy motion contained in sequence "*Foreman*", a 2-stage CVQR process is required to achieve an acceptable video quality without requiring extra bandwidth. Figure 5 shows the ability of CF to stop error propagation with $P_B = 0.041$. Note that the residual video degradation is negligible.

## Observations

1) CVQR does not use intra-coded MBs, thus the source video quality from the FU is not affected.
2) Although a video decoder is continuously used by the BS, its complexity is small. Therefore, CVQR can be easily incorporated into existing BSs.

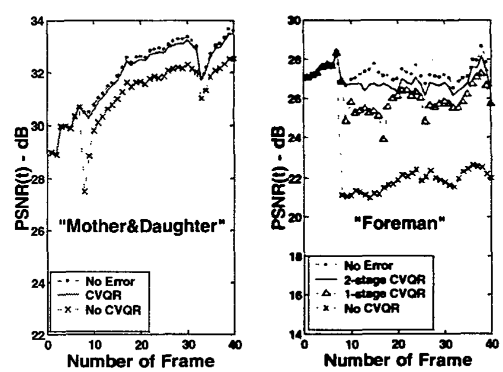


**Figure 4. Effectiveness of CF to recover video quality.**

**Figure 5. Frame 38 of sequence "*Foreman*". Left: original (no errors). Right: no CVQR. Middle: CVQR.**

3) Video quality recovery is successful if VF3 and CF3 are received correctly. On the other hand, we have verified that the average length of the sequence of video frames without errors in transmissions over slow fading channels is higher than 5 (this study is not included in this paper). Therefore, it can be inferred that the probability that VF3 and CF3 are correctly received is high since the CVQR takes place when the channel state is good. If VF3 or CF3 are received with error, it is just required to start the CVQR process at $t_3$ or $t_4$, respectively (see Figure 3).

4) The additional complexity required at the MS is minimal. Only a modest increase of memory is necessary to store several *coded* video frames. In addition, a simple scheme to control and order data blocks is required. Note that, with suitable control logic at the MS, it is not necessary to modify existing video decoders.

5) BS can reconstruct video frames reproduced at the MS using ACKs/NACKs provided by a feedback error control scheme. Therefore, it is important to protect this information in order to assure their correct reception at the BS. Nevertheless, since the FU transmits an *I*-frame refresh frequently (e.g., each 132 coded frames), it is possible to prevent propagation of long error events of indeterminate duration caused by incorrect ACKs/NACKs. Furthermore, this problem can be overcome by means of transcoding at the BS [3], and using CVQR to reduce the video distortion caused by the transcoding process.

## PERFORMANCE OF CVQR

In this section we investigate performance of CVQR. Our performance studies are based on computer simulations and theoretical analysis using the model introduced in [4].

### Simulation Environment

To perform our simulation experiments, we use the University of British Columbia's H.263+ Reference codec. Moreover, we utilize the rate control method discussed in TMN-8 [6]. We also assume that GOB sync words are inserted at the beginning of each macroblock row. This is exploited by the error concealment technique employed in the decoder, which discards corrupted GOBs and replaces the corresponding image content with data from the previously decoded frame. All the results represent around 160 coded pictures of test sequences having QCIF resolution, coded at 6 frames per second (fps). Although numerous simulations have been performed, only a few results are discussed in this paper because of space constraints. We use the parameters, interleaver/deinterleaver, and convolutional code of the downlink of the IS-95B standard [11]. Furthermore, we use soft-decision decoding of the rate ¾, constraint length 9, convolutional code (i.e., rate set 2 of IS-95B). We use the retransmission scheme described in [5]. We set the number of RAKE fingers, $L$, to four ($L$ =4). We assume that RAKE fingers have equal power. Coherent demodulation at the RAKE receiver is used. The Rayleigh channel is simulated using Jakes' model. The block duration is $T_B = 20$ msec and the fading rate is $f_m T_B = 0.04$ ($f_m$ is the maximum Doppler frequency). We set the number of multicodes to two. Fundamental (FCC) and a suplemental (SCC) channel code are used to transmit video. The rate of SCC is 14.4 kbps. The transmission rate of FCC is 3.6 kbps, thus 10.8 kbps are reserved for retransmissions (14.4 kbps is its maximal rate). 2.4 kbps are spent for overhead (packet headers + CRC + tail block) and the video net bit rate results in 15.6 kbps. The round trip delay is $N$ =6 and the recovery time delay $T_{CVQR}$ is considered constant (i.e., it does not depend on the video degradation level at the MS), with $T_{CVQR} = 1$ sec. The bandwidth required to transmit the correction frames is provided by the retransmission channel (i.e., 10.8 kbps). Three values of the SCC average block error probability ($P_B$) are considered: 0.08, 0.041 and 0.02.

### Numerical Results and Discussion

The average peak signal-to-noise ratios (PSNRs) for the video test sequences "*Mother & Daughter*" ("*M&D*") and "*Foreman*" are presented in Figures 6 and 7, respectively. Two error resilience methods are analyzed: CVQR and a theoretical *ideal error tracking* (I-ET) [5]. The latter approach is similar to the one presented in [9]. However, unlike [9], I-ET assumes that the video source coding distortion is not affected by *I*-MBs refresh. In both cases (CVQR and I-ET), we assume that the error signal at $t = 0$ is *successfully* canceled at $t = T_{CVQR}$. We present results from entire system simulations and theoretical values derived from the model we introduced in [4] (details of this study will be reported in a future work). To obtain results from simulation of the entire system, the coded sequences were transmitted 300 times using different starting points in the fading simulator. The average over all the runs is presented. Compared with a system without error resilience technique, a significant gain can be observed. This gain depends on the residual block error rate and the amount of motion present in the sequence. Furthermore, it can be verified that CVQR outperforms I-ET in all the range of $P_B$. This is because I-ET does not consider packet losses between the last frame for which acknowledgment was received, and the current frame [14]. Finally, it is important to realize that the important improvements achieved by our technique are obtained with low additional complexity and *without modifying* H.263 video codecs.

## CONCLUDING REMARKS

This work has introduced a new error resilience technique for robust interactive video transmission in DS-CDMA cellular networks. Our results have shown that the new protection method significantly improves the reliability of video transmission over CDMA cellular systems. Furthermore, we showed that our approach outperforms previous protection schemes with small additional complexity.

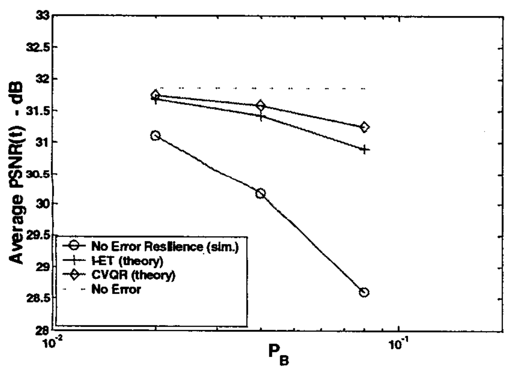


**Figure 6. Average PSNR of sequence "*M&D*".**

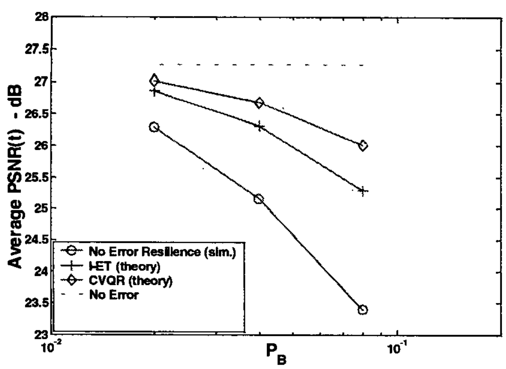


**Figure 7. Average PSNR of sequence "*Foreman*".**

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