Video Transmission for Third Generation Mobile Communication Systems

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ABSTRACT

This paper presents a method of transmitting video over the cdma2000 mobile system. In this method, the video bit-stream after splitting, is transmitted via the supplemental channels of the cdma2000 reverse link. The method takes advantage of the direct spread multiplexing structure of the supplemental channels to transmit divided video at differing priority classes. This is accomplished by adopting the relative gain adjustment strategy where the most error sensitive video information is transmitted via a channel with higher power. The most challenging aspect of this investigation has been to maintain full compatibility with the cdma2000 standard. In particular, for the reverse link where the power allocation is tightly controlled, this strategy has been successfully deployed by taking advantage of the flexibility of its link budget. Finally, we will demonstrate that this strategy can result in a significantly higher quality of the reconstructed video data when transmitted over time-varying multipath fading of IMT-2000 channels.

INTRODUCTION

Third generation (3G) wireless systems are expected to provide high bit rate data services suitable for transmitting multimedia information. At the same time, they are to operate reliably in different types of environments: macro, micro, and pico cellular; urban, suburban, and rural; indoor and outdoor. In other words, the 3G systems are expected to offer better quality and coverage, be more power and bandwidth efficient, and be deployed in diverse environments. Nevertheless, 3G systems, despite their enhanced features, are still severely bandwidth-constrained - particularly for handling video communication traffic. Whilst current methods of video compression accelerate transmission by reducing the number of bits to be transmitted over the network, they have the unfortunate trade-off of increasing signal sensitivity to transmission errors. One effective method of protecting the compressed video signal is to split the coded video signal into a number of separate bitstreams where each can be transmitted via a separate channel having a different degree of error protection [1]. The bitstream splitting can be accomplished by taking into consideration the perceptual significance of coded video, where better protection is provided for the transmission of the more error-sensitive bits. In this paper, the ITU-T H.263 video coding standard has been used to compress the video signal. The splitting of the compressed video bit-stream is based on a separation of the video header information as well as some of the Variable Length Coded (VLC) data that represent the Discrete Cosine Transform (DCT) coefficients within each block. Figure 1 shows a general block diagram of the video splitting and re-synchronization process.

In our previous investigation [1], a video splitting strategy was considered for the other 3G system known as WCDMA. It was shown that an unequal error protection scheme with a simple repetition code could be applied to protect the most error sensitive video data. Since the structure of the cdma2000 system is substantially different from its competitor (WCDMA), we have proposed a different approach that suits the cdma2000 physical layer structure. As will be discussed in the following section, the cdma2000 physical layer is based on a Direct Spread (DS) multi code channel structure where power for each channel is allocated separately but under certain restrictions. Therefore, unlike the unequal error protection approach, for cdma2000 we have considered a different dual priority strategy which is based on exploiting the flexibility of the relative power allocation in its link budget. Here we have mainly concentrated on the reverse link due to its more sophisticated power budget specifications.

In this paper, after an overview of the cdma2000 physical layer, its reverse-link budget specifications are briefly discussed. We then present the proposed priotrization strategy than can be specifically applied to cdma2000. Finally, the simulation results, which include the transmission of two layer-streamed video, are presented.

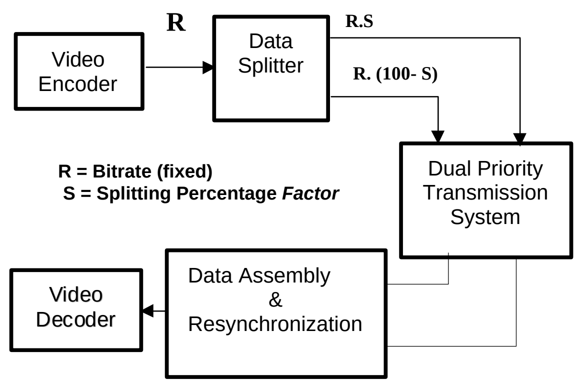

Figure 1. A general block diagram of the video splitting process

TRAFFIC CHANNEL

The voice and data information can be transported via cdma2000 by utilizing one fundamental channel (FCH), and up to two supplemental channels (SCHs) in both the forward and reverse links [2,3]. The FCH provides a basic rate of 9.6 kbps (rateset 1) or 14.4 kbps (rateset 2). In addition, the FCH is capable of providing variable data rates of *1.5*, *2.7. 4.8*, and up to *9.6* kbps for rateset *1* and *1800*, *3600*, *7200*, up to *14400* for rateset 2 where the rates can be changed on a frame by frame basis. The use of SCH1 and SCH2 offers two additional higher rate channels, which will be considered here for the transmission of video signals. Both the forward and reverse link can operate at a chipset of *N*1.2288* Mcps where *N* is defined as the spreading rate and can have a value of *1, 3, 6,* etc. For operational purposes, the selection of different spreading rates (e.g. *N=1* or *N=3*), the ratesets, or the possible information rates are classified as Radio Configurations (RC). For instance, Radio Configurations 1 and 2 are designed for backward compatibility with the existing IS-95 CDMA system. As our main objective is to evaluate the transmission of audiovisual information over the reverse link of the cdma2000 system, the following provides a brief overview of its traffic channel characteristics.

A. Reverse Link

The traffic signal in the reverse link consists of five direct spread (DS) channels [2]. These are the Reverse Pilot Channel (R-PCH), Reverse Fundamental Channel (R-FCH), Optional Reverse Supplemental Channel-1 (R-SCH1), Optional Reverse Supplemental Channel-2, and Reverse Dedicated Control Channel (R-DCCH). In addition, a total of six radio configurations (RC) have been specified so far for the reverse link (this number may rise with future expansion of the IS-2000). For our video conferencing application we have considered RC=5. This configuration corresponds to a chip rate of 3.68 Mcps and is based on rateset-1 (i.e., basic rate of 9.6 kbps). The coding structure of the R-FCH and R-SCH are similar and their detailed specifications can be found in [3]. Table 1 depicts some of their most important parameters.

Input Data rate (kbps)	Convolutional Rate	Puncturing pattern	Coded Symbol Rate (ksps)
(1.5)	1/4	1 of 5	76.8
(2.7)	1/4	1 of 9	76.8
(4.8)	1/4	None	76.8
(9.6)	1/4	None	76.8
(19.2)	1/4	None	76.8
(38.4)	1/4	None	153.6
(76.8)	1/4	None	307.2
(153.6)	1/4	None	614.4
(307.2)	1/3	None	921.6
(614.4)	1/3	None	1,8432

Table 1. Important parameters and data information of the R-FCH and R-SCH for RC = 5

For transmission, the reverse channel signals are orthogonally spread and combined using quadrature spreading. Orthogonal codes are employed to multiplex the reverse channels using the Walsh function. Figure 2 shows the spreading, combining and modulation characteristics of the reverse link for RC = 5. As shown in this Figure, the spread reverse channels are scaled by their relative gains, which are set in accordance with the reverse link budget.

For the transmission channel we have considered the IMT-2000 Vehicular Model A, as specified by the standard [3]. This model takes into account both slow and frequency selective fast fading. The frequency selective fast fading is modeled by the superposition of multiple single flat faded paths with different arrival times and average powers. The relative average power and arrival times are assumed to be fixed and are determined by the channel impulse response. Each path has a Rayleigh distribution, with the power spectrum suggested by Jakes [4]. For instance, for RC = 5, the fading channel consists of a six-path. After the fading channel, white Gaussian noise (WGN) is added to simulate the effect of overall interference in the system, including thermal noise and inter-cell interference.

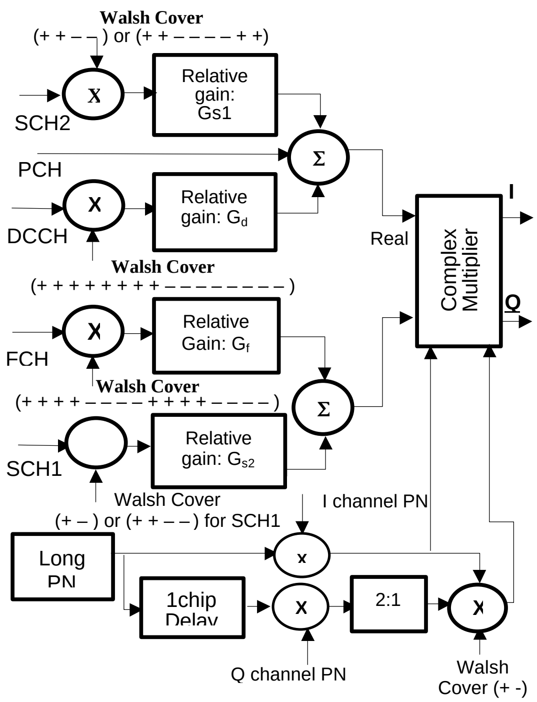

Figure 2. Spreading and modulation characteristics of the reverse link for RC=5

As for the receiver, we have considered a six-finger rake receiver. The rake receiver is a coherent receiver that attempts to collect signal energy from all received signal paths that carry the same information. The rake receiver therefore can significantly reduce fading caused by these multiple paths. The channel despreader takes the outputs from the rake receivers and recovers the channel data, by despreading the outputs using the appropriate Walsh function.

B. Link Budget

As shown in Figure 2, the spread channels are added together (including the pilot) as the chip rate is the same after spreading. The spread, summed data is then complex multiplied with the pilot PN (short) sequence, and filtered.

The channel powers, are determined by the link budget. The reverse link power budget is based on the equations specified in the Cdma2000 physical layer [3]. The output power of each Code Channel (e.g., R-FCH, R-SCHs, R-DCCH) is set by the mobile station relative to the output power of the Reverse Pilot Channel (*R-PCH*). Therefore, the first task is to determine the output power of the *R-PCH* (*Ppilot*) using open loop power estimation. Then, the output power of every Code Channel, *Pcode*, can be calculated based on P_{pilot} and stored parameters in the mobile station. The calculated P_{code} is then applied to the Relative Gain block shown in Figure 2, so that every Code Channel can be adjusted to its desired output power for transmission. In our strategy, the relative gain adjustment for mean pilot output power is calculated assuming that there are no closed loop power corrections.

CHANNEL PRIORITIZATION STRATEGY

For dual priority video streaming we have considered both supplemental channels where each is used to transport one of the partitioned video bitstreams. The fundamental channel, however, can be used for transporting the audio portion of the video conferencing information.

To impose prioritization on the supplemental channels, a power allocation strategy has been proposed. This strategy can be easily incorporated into the cdma2000 reverse link budget. For instance, the stored parameters in the link budget consist of a parameter, which is defined as [3]:

RLGAIN_SCH_PILOT[i]s

The function of *RLGAIN_SCH_PILOT[i]s* is to perform a gain adjustment of the R-SCH[i] (i.e., i=0 or 1) relative to the reverse pilot channel (R-PCH).

In order to maintain the same total transmission power of the reverse link, the power increase in the high priority R-SCH (e.g., R-SCH1) should be compensated by the same amount for the lower priority R-SCH (e.g., R-SCH2). We should emphasize that the power allocation also depends on the data rate operated on that Code Channel. If the same data rate is selected for both supplemental channels, their relative powers should be increased and compensated by exactly the same linear amount. It should be noted that, in accordance with the IS-2000 link budget specifications, the code channel powers could go up or down by the steps of 0.125 dB. This may slightly change the total transmit power but the effect would be marginal. For selecting differing data rates for R-SCHs, a new parameter is added to the link budget to appropriately control the power allocations for both supplemental channels.

EXPERIMENTAL RESULTS

Recently at NIST, we have designed and developed generic simulation models and libraries for cdma2000 using Signal Processing Worksystem (SPW) tools[1]. These models include all the radio configurations defined by the IS-2000 standard [5] for both forward and reverse links. In addition, the link budget for the reverse link has been fully implemented in accordance with IS-2000 specifications for test and performance evaluations. For this investigation, transmission of partitioned video using the cdma2000 reverse link with radio configuration 5 (RC = 5), has been considered. This configuration corresponds to a chip rate of 3.68 Mcps and rateset 1. For both supplemental channels an information rate of 19.2 kbits/s was selected and the fixed 9.6 kbits/s was considered for the fundamental channel.

The carrier frequency was set at 1.9 GHz. In our experiments, the mean output channel powers were calculated by the reverse link model in accordance with our modified link budget. All the initial values and relative gain adjustments in the link budget were set in such a way that R-SCH1 was transmitted with higher power relative to R-SCH2. As discussed earlier, the mean pilot channel power was first calculated by our SPW model link budget. This was done in accordance with the user specified Received Power Spectral Density (PSD) at the mobile station's antenna connector. The initial results are presented in Figure 3 in terms of the BER versus the power spectral density (PSD) of the band limited white noise, I_{oc}.

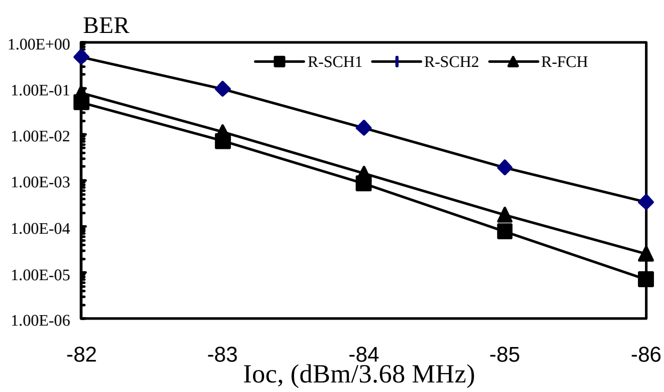

Figure 3. BER performance of the R-FCH, R-SCH1, and R-SCH2 with unequal power allocation for the supplemental channels

[1] Signal Processing Work System and SPW are registered trademarks of Cadence Design Systems, Inc. The SPW is identified in this paper to foster understanding. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that this product is necessarily the best available for the purpose.

I_{oc} parameter is defined to represent the total received noise (interference + thermal) in dBm/3.68 MHz. These results are based on the unequal power allocation for the supplemental channels. In the simulation model, the vehicular speed was set at 100 km/s. Other important parameters with which these results were obtained are tabulated in Table 2.

The final stage of our experiments was concerned with the transmission aspects of the partitioned video signal over the cdma2000 reverse link. Two video sequences known as "Clair" and "Carphone" with the Quadrature Intermediate Format (QCIF), that correspond to the spatial resolution of 172-pel by 144 lines, were used.

Both sequences were coded at a frame rate of 15 frames/second and a bitrate of 35.6 kbit/s. Together with the additional synchronization bits, the total bitrate for each partitioned video bitstream was set at 18 kb/s. Subsequently, each bitstream was then transported via one supplemental channel with a service rate being set to 19.2 kbits/s. Under the these conditions, a partitioning percentage factor of about 52% (see Figure 1) was required. This is to allow additional synchronization bits for the second partition to help reassemble the two bitstreams at the receiver via a predecoder block. The pre-decoder is designed to perform error-detection and concealment at the bitstream level prior to the standard H.263 decoder. Thus, an important function of the predecoder was to resynchronize and align the corrupted bitstreams into a single bitstream in full compliance with the H.263 syntax. In these experiments, the quality of the received reconstructed video sequences was evaluated under the same transmission environments shown in Table 2 and Figure 3. Figure 4 displays two consecutive reconstructed video frames of the "Clair" sequence after being transmitted over the cdma2000 reverse link. In this Figure, the first, second, third, and forth rows correspond to I_{oc} = -86, -85, -84, and –83 (please note that the predecoder was unable to handle I_{oc} = -82 due to excessive number of errors) .

Channel	Information Rate (kbit/s)	Power (dBm)	RLGAIN_ SCH_PILOT	Received PSD (dBm)
R-PICH	Unmodulated	-3.0	-	-76.5
R-FCH	9.6 Fixed	-.625	-	"
R-SCH1	19.2	5.5	15	"
R-SCH2	19.2	3.375	-10	"
R-DCCH	9.6	-0.625	-	"

Table 2. Test Parameters and mean power values

In terms of signal to interference noise ratio, Figures 5 and 6 show the average peak-to-peak signal to reconstruction noise ratio, SRNR, versus I_{oc} for the "Clair" and "Carphone" sequences, respectively. The reconstruction noise in this case corresponds to the difference between the transmitted video frames (i.e., after being locally decoded) and the received video frames (corrupted by transmission errors). In addition, in these Figures, the SRNR results of the video without bitstream splitting are included. In this case, the video was encoded at a rate of 36 kb/s and was transmitted using one supplemental channel at a rate of 38.4 kb/s (please note that the second supplemental channel was turned off). This experiment was carried out using the same transmit power.

Figure 4: Two consecutive received video frames for Ioc values of -86 (first row), -85 (second row), -84 (third row), and - 83 (forth row)

We should point out that for this case, the predecoder was designed to perform error recovery and concealment on a single bitstream before being forwarded to the standard H.263 decoder. As can be observed from these Figures, in both cases the SRNR rapidly drops as the interference noise increases. This is mainly the result of excessive errors which make it impossible for the predecoder to properly track the corrupted bitstream. (Please note that by increasing the predecoder memory, it is possible to improve error recovery but at the expense of increasing the delay). Under such conditions, the predecoder removes the undecodable data from the bitstream and replaces it with new header information. This is done in such a way that the proceeding data will be considered uncoded with respect to the last successfully decoded frame and continues until the next intraframe data has been detected. Although this arrangement helps the continuity of the decoding process, it also increases the distortion of those corrupted frames that became undecodable. As a result, this causes a considerable reduction in SRNR, as indicated in Figures 5 and 6. Nevertheless, these results clearly indicate that the splitting process with unequal power allocation, can significantly improve the performance of video transmission over mobile channels.

CONCLUSION

This paper has presented the feasibility of transmitting compressed video information over the cdma2000 reverse link. In the approach presented, two direct spread supplemental channels were considered to transport highly compressed video signals with two layer partitioning. This strategy was implemented by allocating a different power to each supplemental channel in accordance with the parameters specified in the link budget. The supplemental channel with the higher allocated power was used to carry the partitioned video bitstream. This channel carried more error-sensitive data information. It was shown that such a strategy can be effectively applied to the cdma2000 system for videoconferencing applications.

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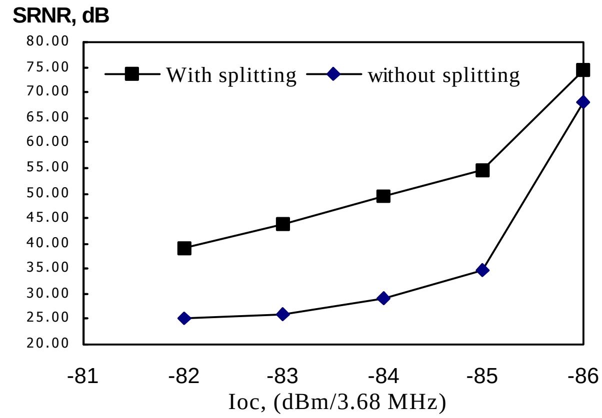

Figure 5. Average signal to noise ratio of the reconstructed frames of the "Clair" Sequence

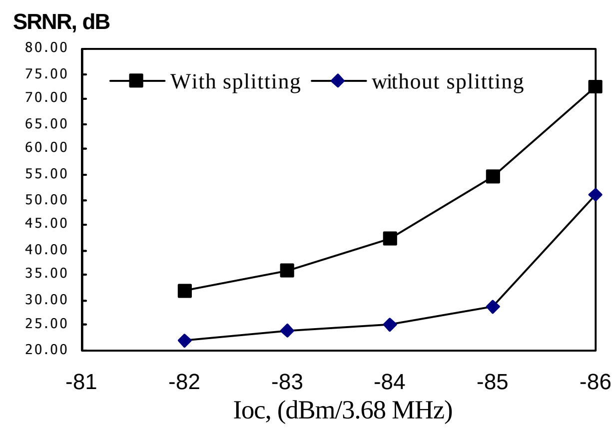

Figure 6. Average signal to noise ratio of the reconstructed frames of the "Carphone" Sequence

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