



Data Transmission Using Efficient FEC over CDMA Channel

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Abstract- Still Image/Video is one of the most important and also one of the most challenging types of traffic on communication networks. One of the challenges arises because communication networks can insert errors into still Image/Video, and also compressed image or compressed Video is fragile in the presence of errors; that are a single error can propagate over a large portion of the Image/Video. This thesis describes how to protect the content of still Image/Video during transmission by employing error correcting codes. It deals with the concept of transmitting packets with redundancy embedded in it for attempting error recovery and improving the quality at the receiver side. The effect of bit errors on the overall Image/Video quality has been studied. This thesis throws light on the importance of each bit in an Image/Video frame to the overall received quality. We have adopted BCH codes to improve the quality of image or Image/Video. Two types of FEC schemes have been implemented. In the first FEC scheme, data is not prioritized and various segments in the image or Image/Video stream are given equal importance. BCH (63, 51, 2) is used for this case. In the second scheme, a stronger FEC is applied to the first frame (the first I frame) as the important data is found in it. Hence BCH (63, 24, 7) is used for the first frame and BCH (63, 57, 1) is used for the rest inter frames. The main aim of the algorithm is to strengthen the Image/Video stream against most possible error cases and also reduce the percentage of the overhead bits arising because of BCH coding.

Keywords— spread spectrum, compression coding, channel control, Run length coding, convolutional code

I. INTRODUCTION

It is anticipated that the future will witness the next revolution through telecommunications technology to reach the ultimate goal of ubiquitous connectivity at anytime, anywhere, with anyone, and with any media. In recent years, the communications sector was one of the few constantly growing sectors in industry and a wide variety of new services were created. Two of the areas that have experienced a massive growth are multimedia communications and wireless communications. This work is primarily concerned with image coding and transmission over noisy channels, which is a small subset of wireless multimedia communications. With the rapid development of wireless communications, there are more and more plans to transmit multimedia content (image/video) over wireless channels. Typical wireless channels are noisy and of narrow bandwidth. Usually there is a 9.6kbps bandwidth for a customer using a digital wireless device like a code-division multiple-access (CDMA) cell phone. Even if the bandwidth increases up to 2Mbps for the coming 3G wireless, it is still not comparable to the bandwidth of broadband optical communication systems like ATM, which could allocate dozens of Mbps to end users. Thus for wireless multimedia applications, higher compression is required for both image and video signals.

II. IMAGE CODING IN WIRELESS

With the fast growing business in wireless access of multimedia information, visual communication over wireless channels has become an important service in multimedia communications. Spectrum is always at a premium and as demand takes off, there is a need for high signal compression for image transmission over wireless channels. As Figure 1.1 shows, most conventional approaches to image and video communications consist of a modular approach consisting of two stages: compression coding (or source coding), and channel coding

Two goals are generally considered in the design of image compression techniques:

- Maximizing compression or equivalently minimizing the bit rate.
- Maximizing the quality (acceptability and/or intelligibility) of the reconstructed data.

The primary role of the compression coder is to pack the maximum information into the smallest signal. The main problem in this approach is the fact that as the compression is higher, even a single bit in error may result in corruption of a wide range of decoded data.

A. Research aim

The primary objective of this work is to provide reliable transmission of low-bit-rate coded images over personal communications networks employing CDMA access. Therefore, our interest is in high compression coding with robust design and reliable transmission over the noisy channels. Moreover, when setting stringent constraints on reliability and

maximum delay in an environment characterized by bursts of errors, not only is robust source coding required, but also powerful channel error control. The domains of this research are error-resilient source coding and channel coding in general and robust low-bit-rate image transmission over wireless channels in particular.

Therefore, the focus of this work is twofold:

- Development of an error-resilient low-bit-rate image source coding scheme.
- Study of a source/channel coding system capable of providing reliable image transmission over wireless channels.

B. Research strategy

The incorporation of low-bit-rate image coders into emerging wireless communication systems presents problems which previous communication systems have never encountered. One of the most important of these problems is the degradation experienced in image quality as a result of corruption of the transmitted image information by channel errors. To meet the quality requirements of these systems, efficient techniques have to be employed to control the impact of channel errors on the received images. In order to improve performance of spatial coding, we are proposing a promising analysis-by-synthesis coding technique called two-dimensional coded excited linear predictive (2D-CELP) coding, with block-adaptive prediction and variable block-size (VB) quantization. The proposed technique is shown to have the potential of reducing the block effects of the DCT method while having low decoder complexity. Our VB 2D-CELP coding scheme is shown to yield better image quality reconstruction and higher compression ratio than conventional CELP methods. When compared with the JPEG standard, the VB 2D-CELP scheme yields better performance in terms of image quality and low complexity. Wireless communication radio channels suffer from burst errors in which a large number of consecutive bits are lost or corrupted by the fading channel. Typically, the bit error rate (BER) in a wireless channel ranges from 10^{-1} to 10^{-6} while the BER for a fixed channel ranges from 10^{-6} to 10^{-9} or less. Accordingly, the channel-fading effect is an obstacle.

C. Performance evaluation: is comparison possible?

Image transmission services should be supported with a high wireless transmission bit rate within a wider allowable bandwidth. However, due to limited spectrum, only a limited number of radio communication channels can be shared by mobile users. As a result, image data should be compressed before transmission in order to efficiently use the radio channel.

D. Effects of channel errors

The effect of channel errors on the image coded bit-stream varies according to the compression method used. Before discussing coding methods that are resilient to channel errors or approaches to provide reliable or acceptable image communication over noisy channels, an understanding of the error sensitivity of the different types of compression methods is necessary.

III. APPROACH FOR IMAGE TRANSMISSION

Using one or more of the above mentioned methods, many coding schemes have been proposed for image transmission over mobile channels in specific wireless transmission environments often with a predefined multiple access technique. Many of the schemes investigated deal with spatial coding. In fact, spatial coding is known to be capable of providing robustness to transmission errors. It is even proposed to not use inter-frame coding of image sequences, but rather intra (spatial) coding to prevent error propagation. As a standard technique in spatial coding is block-DCT with Huffman and run-length coding, many authors have investigated the deployment of the JPEG codec for image transmission over wireless channels. Others have employed sub-band coded schemes, discrete wavelet transform based systems, fractal based or other modified discrete cosine transformed systems.

• CDMA Systems:

Code-division multiple-access (CDMA) is a multi-user access scheme that uses different long pseudo-noise (PN) binary sequences to either multiply each user's information sequence which is called direct sequence CDMA (DS-CDMA), or control each user's carrier frequency hopping pattern which is called frequency hopped CDMA (FH-CDMA). In either case, the overall frequency bandwidth used by each user is much larger than the user's information bandwidth so CDMA channel is a kind of spread spectrum (SS) channel. Another aspect of CDMA is that multiple users are using the same frequency band meaning that users are co-channel interference to each other.

• CDMA Signals and Channel:

We first give a mathematical formula description of DS-CDMA BPSK (binary phase shift keying) signals and channel. Let's assume that the k^{th} user's signal comes out from the transmitter with initial transmit power A_k , carrier frequency of ω_c and initial phase of θ_k , and can be described as:

$$d_k(t) = \sqrt{2A_k} s_k(t) b_k(t) \cos(\omega_c t + \theta_k) \quad (2.1)$$

Where $bk(t)$ and $sk(t)$ are the data sequence and spreading sequence respectively with

$$b_k(t) = \sum_{i=-\infty}^{+\infty} b_k[i]P_{T_b}(t - iT_b) \quad (2.1)$$

$$s_k(t) = \sum_{i=-\infty}^{+\infty} s_k[i]P_{T_c}(t - iT_c) \quad (2.2)$$

and $P_T(t)$ is a pulse waveform of duration T , T_c and T_b are spreading bit duration and data bit duration respectively, $s_k[i]$ and $b_k[i]$ are spreading bit and data bit respectively with value of either 1 or -1. A bit of the spreading sequence is usually called a chip, and the chip period T_c is much smaller than T_b so that, after spreaded by $s_k(t)$, the spectrum of the product $s_k(t)b_k(t)$ is much wider than the spectrum of the original data sequence $b_k(t)$.

Assuming there are K users and each user's signal goes through L different paths, then the received signal at the cellular base station will be:

$$r_e(t) = \sum_{k=1}^K \sum_{l=1}^L \sqrt{2A_k} c_{kl}(t) s_k(t - \tau_{kl}) b_k(t - \tau_{kl}) \cos(\omega_e t + \phi_{kl}) + n_e(t) \quad (2.4)$$

Where c_{kl} is the fading coefficient for the l th path of k th user, τ_{kl} is the path time delay and ϕ_{kl} is the composite phase which is:

$$\phi_{kl} = \theta_k - \omega_e \tau_{kl} - \phi_{kl} \quad (2.5)$$

Where ϕ_{kl} is the path phase delay, and $wc(t)$ is the white noise in the bandwidth of the wireless channel.

Interference in CDMA that Limits its Capacity:

when the receiver in the cellular base station dispreads a user's signal with its PN codes, there will be interference caused by the cross-correlation with other users' PN codes. This kind of interference is called multiple access interference (MAI). It happens in the uplink of CDMA systems, where mobile users transmit their signal to the base station, and there is no way to control their synchronization so that their PN codes are orthogonal. This thesis will assume MAI is impulsive by arbitrarily inducing the maximum cross-correlation of different users' PN codes. To improve the limits of the PN codes this thesis will work.

IV. ERROR CONTROL METHOD

Transmission Environment and Channel Error Control

A DSCDMA system has been accepted as a digital cellular standard (IS-95) and is operating in North America. Transmitting images with high reliability over a system patterned after the IS-95 standard has been one of the motivations of this research. In this chapter we first provide a brief description of CDMA system operation with an emphasis on the IS-95 communication system.

A. DS-CDMA transmission environment

The system operation for CDMA cellular systems, such as IS95, is based on Direct-Sequence (DS) spread-spectrum signal, whereby each message bit is represented by a large number of coded bits called chips. Direct-Sequence spread spectrum begins with digital modulation of the signal using standard methods, e.g. Quadrature Phase-Shift Keying (QPSK) modulation. This modulated digital signal is further modulated by a spreading code, for which the chip rate is much greater than the bit rate of the signal. As a result, the narrow-band digital signal is spread out to become a wide-band signal, with a bandwidth typically greater than 1 MHz

- **Forward error correction in fading channels:**

With every transmission/modulation technique, there is an associated error probability, which is dependent on the transmitted signal energy per bit (E_b), and the noise encountered (NO) [Y2]. Increasing the signal energy to noise ratio per bit (E_b/N_o) reduces the probability of error in transmission. However, practical considerations place a limit on E_b/N_o . For a fixed E_b/N_o , the only way to lower the probability of error is to use coding. The use of coding techniques introduces coding gain which is defined as the reduction in the required signal power for a given error probability when coding is in use, compared to the signal power required for the same error probability without coding.

B. Automatic Repeat re-Quest schemes

ARQ schemes are an alternative form of error control to FEC, and can be more reliable than FEC schemes where data applications in the mobile radio channel are concerned [89], but at the expense of greater delay. ARQ protocols employ an error detection code and a feedback channel so that the receiver can request retransmission of the erroneous packets, or it can use the feedback channel to acknowledge the correctly received packets

- **Non-continuous Repeat re-Quests:**

The non-continuous Repeat re-Quest protocol is the Stop-And-Wait ARQ. In a SAW ARQ data transmission system, the transmitter sends a single frame ' to the receiver and waits for an acknowledgment. A positive acknowledgment (ACK) from the receiver signals that the frame has been successfully received (i.e., no errors being detected), and the transmitter sends the next block. A negative acknowledgment (NAK) from the receiver indicates that the frame has been detected in error, and the transmitter resends the same frame. Retransmissions continue until an ACK is received by the transmitter.

- **Continuous Repeat request:**

Continuous Repeat request (RQ) systems such as GBN and SR, send information frames continuously before receiving any acknowledgments. These systems are more efficient than SAW, but there must be a limit on the number of frames transmitted or the buffers required will overflow.

- **Hybrid ARQ:**

ARQ methods are indispensable in providing highly reliable communications in data transport systems. However, when channel conditions are poor, systems that use only ARQ suffer degradation in throughput performance due to an increase in the frame error rate. Accordingly, in recent years, research has been successfully performed to merge FEC coding and ARQ into Hybrid ARQ systems to provide reliable communications with high throughput.

- Hybrid ARQ systems are divided into two main classes called type-I hybrid ARQ and type-II hybrid ARQ systems.

C. FEC scheme over memory-less channel

- **BER performance:**

The convolutional encoder under consideration is combined with orthogonal Walsh signaling and non-coherent detection. Squarclaw metrics are employed in the decoder. This is optimal for Rayleigh fading with symbol interleaving [100]. The bit error probability is upper bounded by 1921:

$$P_b < \frac{2^{k-1}}{2^k - 1} \sum_{d=d_f}^{\infty} \beta_d p_2(d) \quad (3.3)$$

Where $k = \log_2 M$ for M-ary modulation. The free distance of the convolution coder d_f is the minimum weight, in terms of the number of nonzero Walsh symbols, of the nonzero path. P_d is the total number of nonzero information bits for all the paths that have path weight equal to d . On the Rayleigh fading channel, assuming full interleaving is obtainable to make successive symbols independent in the fading variable, the probability of error in pair wise comparison of the all-zero path with a path that has d nonzero symbols (6 bits/symbol for $M=64$) is given by 1921:

$$p_2(d) = p^d \sum_{i=0}^{d-1} \binom{d+i-1}{i} (1-p)^i \quad (3.4) \quad p = \frac{1}{(2+\gamma)}$$

Where, p is the error probability for binary decisions between orthogonal signals on the (non-coherent) Rayleigh channel. It corresponds to the probability of error for binary orthogonal signaling on a fading channel without diversity. For m -branch spatial diversity employed to mitigate the effect of fading, $P_2(d)$ is given by

$$p_2(d) = \frac{1}{(\gamma_m + 2)^{md}} \sum_{i=0}^{md-1} \binom{md+i-1}{i} \left(\frac{\gamma_m + 1}{\gamma_m + 2} \right)^i \quad (3.5)$$

where $\gamma_m = \frac{E_c}{mN_o}$, E_c is the total energy per orthogonal signal from all diversity branches, and $\gamma = \frac{E_c}{N_o} = m\gamma_m$ is the total

SNR.

In order to test the performance of our transmission model, we compare simulations and analytical bounds on BER for the fading channel with infinite interleaving with no RS coding and for one and two-branch diversity. BER results are provided as function of E_b/N_o , that is the total bit-energy to noise spectral density on one receive antenna. Figure 5.1 illustrates the bit error probability obtained through simulations and the upper bounds based on (5.3) with and without antenna diversity.

- **Concatenated coding scheme performance:**

Consider the performance of maximum distance separable (MDS) codes when they are used for error detection in coding schemes with retransmissions. The most important MDS codes are q-ary RS codes of length $n = q - 1$. The RS codes make highly efficient use of redundancy, and block lengths and symbol sizes can be readily adjusted to accommodate a wide range of frame sizes. RS codes also provide a wide range of code rates that can be chosen to optimize performance.

• **New proposed code generation:**

The binary sample space for the design of New Proposed Code set will comprise only two properties, i.e., zero mean and linear phase (either symmetric or asymmetric about the middle of the code). Hence, for the case of 8-bit (length 8) codes, binary sample space consists of 22 unique codes, and for 16-bit codes there are only 326 candidate codes, and similarly, for 32-bit codes there are about 38,000 potential codes. From this binary sample space, the orthogonal code sets are iteratively searched as per following algorithm:

Algorithms:

- (1) Select the first basis function of the orthogonal set from the corresponding integer in the sample space. Represent the integer number in binary representation and convert to bipolar notation.
- (2) Select the next basis function by sequentially converting the integers in the sample space into binary codes and checking for orthogonality of codes with the first basis function.
- (3) Repeat this process n-1 times to get n-1 orthogonal codes, checking each time for the orthogonality. Lastly the DC code is added in order to make it a (n-dimensional) complete binary set.
- (4) By choosing a different integer number as first basis function, number of independent orthogonal code sets can be generated.

Using the above said algorithm, I have made a MATLAB simulation program for 32-bit code. Firstly, I found the binary sample space from 2^{32} available values by checking each number for linear phase and zero mean condition. From this available binary sample space, for any corresponding number 31-orthogonal pairs were found and the DC code is added. Thus, by using a different number as the first basis function, a number of different orthogonal pairs can be formed.

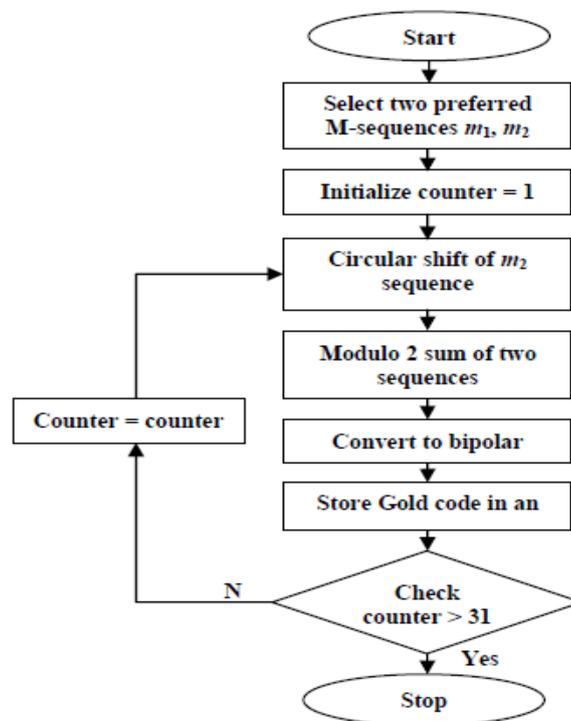


Fig 3.1 Flow chart 32-bit gold code generator

• **Image Coding:**

The image coded bit-stream is separated into two types of information: type-I and type-II: type-I contain the side information and type-II contains the rest of the image data which is the entropy-coded code-vector data. We suppose that type-I data is perfectly recovered at the decoder. Therefore, predictor information is available at the decoder side. In order to analyze the error sensitivity of the block-size index and code-vector index, the image coding scheme is summarized in the form of an algorithm for each of the previously proposed cases. For simplicity, we still assume that two coding block sizes are used (4 x 4 and 2 x 2). First, K predictors corresponding to block size 4 x 4 are used whether the block is coded using 4 x 4 size or split into four 2 x 2 blocks. In algorithm-I, the coding block-size is part of type-I data. For algorithm-2, only predictor information is sent as side information.

Algorithm-1

For each 4 x 4 image block,

1. select the predictor $H_k^{(4)}$ that results in the MMSPE.
2. Based on the comparison of the MMSPE value with threshold Δ , check if the block can be classified as low-activity block,

- (a) If yes, Indicate this by sending a low level-activity one-bit flag as type-1 data, and the codewords of the code-vector in sub-codebook $C_k^{(4)}$ and results in MMSRE as type-11 data.
- (b) If no, send the high- activity one bit flag as type-1, data, decompose the block into 2x2 sub-blocks, and for each block:
 - 1 select the code-vector in sub-codebook C_k^2 , that results in the MMSRE and send the codewords

Algorithm-2

For each 4 x 4 image block,

1. Select the predictor $H_k^{(4)}$ that results in MMSPE.
2. Based on the comparison of the MMSPE value with threshold Δ , check if the block can be classified as low-activity block,
 - (a) If yes, select code-vector in sub-codebook $C_k^{(4)}$ that results in MMSRE
And send the codewords as type-11 data.
 - (b) If no, decompose the block into 2x2 sub-blocks, and for each block:
 - 1 select the code-vector in sub-codebook C_k^2 , that results in the MMSRE and send the codewords to type-11 data.

As for the predictor side information, the block-size information is appended to type-I data. Suppose that with high error protection this information is perfectly recovered at the decoder side. In decoding the index bit-stream, once the erroneous region is delimited, the ZIR reconstructed block can be obtained with the appropriate block size since this information is available. In Algorithm-2, once the erroneous region is delimited at the decoder side, ZIR reconstructed blocks have to be generated considering a block size of 4 x 4 since no information about the effective coding block-size is available at this stage. Hence, the main difference between the algorithms regarding PSNR performance would result from the fact that ZIR reconstructed blocks in Algorithm-:we do not correspond to what can actually be generated according to the coding process.

Algorithm-3

For each 4 x 4 image block,

1. Select the predictor $H_k^{(4)}$ that results in MMSPE.
2. Based on the comparison of the MMSPE value with threshold Δ , check if the block can be classified as low-activity block,
 - a. If yes, send the predictor index code to type-1 data and the codeword of the s code-vector index sub-codebook $C_k^{(4)}$ that results in MMSRE to the type-11 data.
And send the codewords as type-11 data.
 - b. If no, decompose the block into 2x2 sub-blocks, and for each sub block
 - 1 selects the code-vector in sub-codebook C_k^2 , that results in the MMSRE and send the codewords to type-11 data.
3. Send four the codewords to type-11 data.

V. SIMULATION AND PARAMETERS

A data rate of 76.8 Kbps is considered. The data frame duration has to be chosen so that it is sufficiently short to allow rapid retransmission but not too short in order to avoid the retransmission occurring during the same fade. Examination of the distribution of the length of error bursts in the Micro-cellular CDMA channel at 2 GHz reveals that the mean fade duration is less than 30 msec for portables moving at 1 Kmlh. Considering the same portables speed, a data frame duration of 5 msec is considered herein, and a shortened RS code with 48 data bytes that can correct up to 7 bytes is used. We consider a CDMA system with closed-loop power control only. The power controls are generated at the rate of 800 bps. The mobile adjusts its transmit power by a fixed stepsize of 0.5 dB depending on the received power control bit. The performance of the transceiver was studied for two power control step sizes 0.5 dB and 1 dB. The 0.5 dB power control step size was found to result in smaller required SNR for the slowly fading channel considered here. The impact of possible channel errors on the performance of the power control scheme is not considered. In considering the required SNR (per antenna), the effect of fast power control gain is not taken into account. In other words, the signal power used in computing the SNR is taken before the fast power control gain.

In order to express the delay in seconds, practical values of the delay components are needed. For convenience, we make the following numerical assumptions for the computation of delay. The propagation delay, depends on the entire system including the network. However, as our motivation is in studying the effect of varying the maximum number of retransmissions and the outer interleaving depth, we neglect the propagation delay. The acknowledgment time T_a is considered as the time taken to decode a frame and generate a NAK or ACK, without including deinterleaving delays. We assume $T_a=20$ msec.

VI. RESULT ANALYSIS AND DISCUSSION

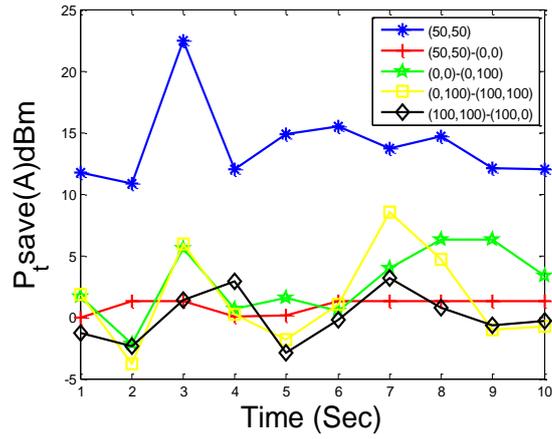


Fig 1

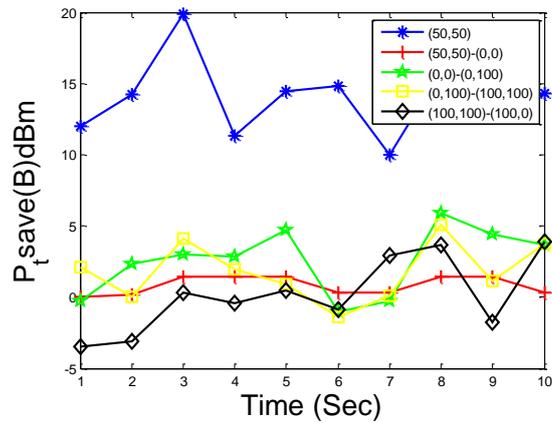


Fig 2

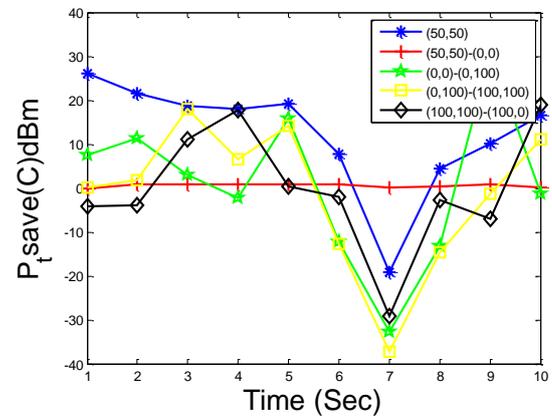


Fig 3

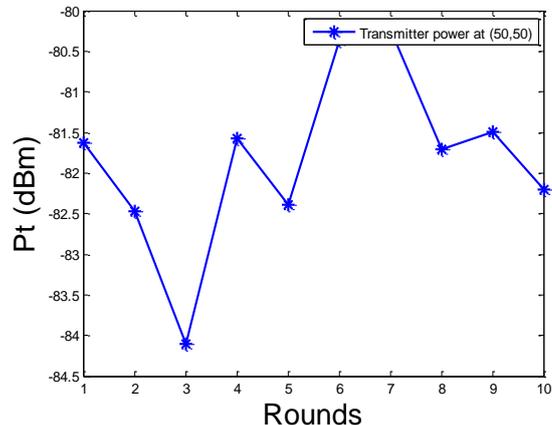


Fig 4

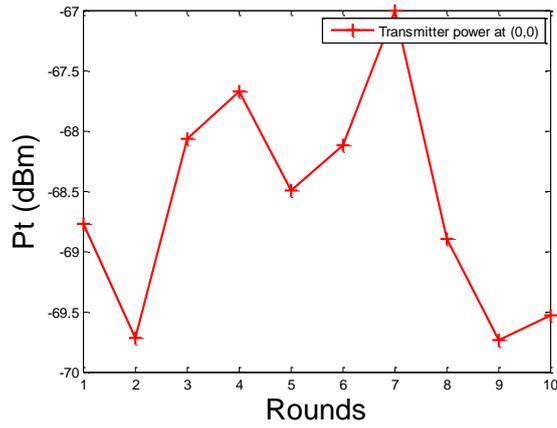


Fig 5

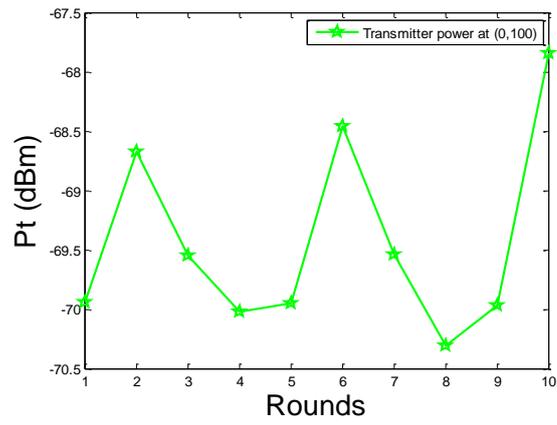


Fig 6

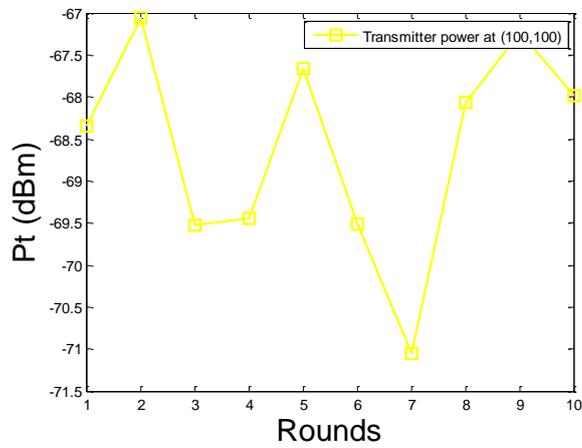


Fig 7

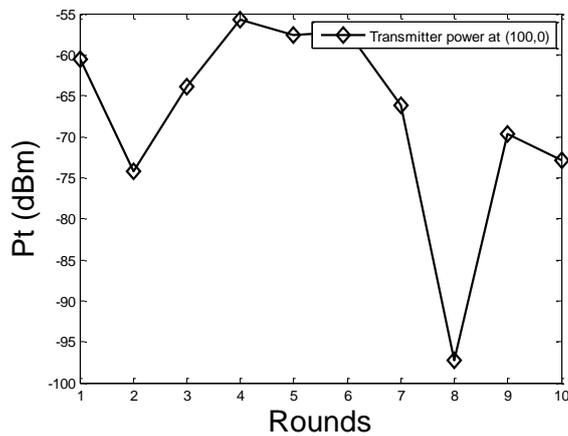


Fig 8

VII. CONCLUSION

In this thesis we tried to provide better quality for transmission of bulky data over wireless CDMA channels, in the fast growing business in wireless multimedia communication, visual communication over wireless channels is becoming an important service in mobile communications. Due to limited spectrum resources and a severe wireless environment, advanced processing techniques such as source coding and channel coding must be developed and applied for robust and flexible service provision. A source coding scheme can be optimal according to rate-distortion theory but fail to yield high performance over noisy channels. Therefore, combined strategies based on a priori information such as source error sensitivity and Quality of Service (QoS) requirements are a necessity in realistic implementations. The theme of this study is robust transmission of images over wireless channels. The research addressed three major issues: (i) the proposal of a new analysis-by-synthesis coding scheme, (ii) the evaluation of the performance of a truncated type-I hybrid ARQ protocol using concatenated coding in DSCDMA Rayleigh fading channels, and (iii) an investigation of strategies that combine error-resilient source coding and channel error control for the purpose of providing robust transmission of images over wireless channels.

VIII. FUTURE WORKS

This research can be extended in different directions. In the following, we offer ideas for further research. It is expected that type-4 hybrid ARQ protocol will yield better performance, but at the expense of additional complexity and delay. In our study, the effect of errors on the feedback channel has been neglected for simplicity. However, performance of the error control protocol taking into consideration the effect of feedback errors is to be evaluated. The performance analysis of the RS/CC type-1 ARQ protocol suggests that the transmission delay and the protocol error probability of an ARQ-based protocol can be greatly reduced by incorporating a Reed-Solomon code into the protocol. The emphasis of this work has been given to the performance aspects of a transmission system using an outer RS code with fixed error correction capability, a constant signaling bit rate, and two extreme transmission channel models.

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