JOINT ADAPTIVE MODULATION FOR IMAGE TRANSMISSION

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ABSTRACT

In this paper, we propose a Joint Adaptive Modulation scheme for image transmission over AWGN channels. More specifically, the scheme partitions the AC components of image information into different bit streams with unequal importance Then, it decides on the modulation level that meets a better symbol error rate than the 64 QAM Scheme. This SER is based on the Eb/No level as seen by the receiver and the sensitivity of the transmitted bit stream. Simulation results show that the proposed scheme provides significant improvement SER when compared to fixed-modulation based systems while maintaining relatively high peak signal-to-noise ratio (PSNR) and acceptable perceptual quality. Transmission of multimedia information over wireless channels has gained increasing attention because of its diversified applications. While wireless channels are characterized by their time-varying nature and limited bandwidth, multimedia applications demand reliable channels and high data rates.

Keywords: Image Transmission, AWGN Channels, RLE Image Compression, DPCM Etc

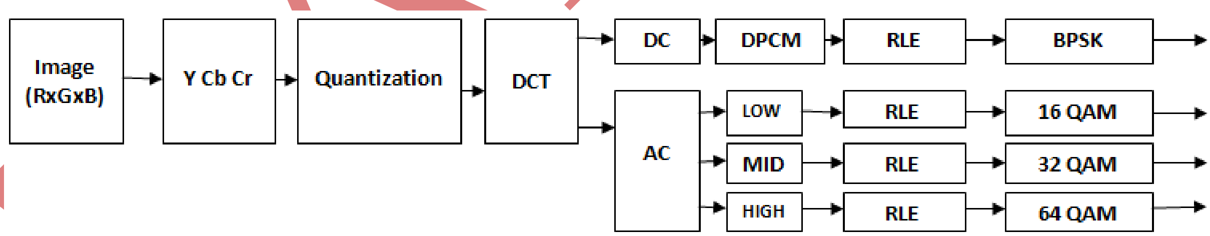
I INTRODUCTION

Recently, wireless multimedia applications and services have undergone enormous development due to the significant and continuing growth of wireless communications. These applications demand reliable channels and high data rates. On the other hand, wireless channels are characterized by their limited bandwidth and time varying conditions. The challenge raised by the wireless communication lies in the contradiction between the limited bandwidth offered by the channel and the large volume of multimedia data as well as the strict quality of service (QoS) parameters (such as bit error rate (BER), delay and latency) required by multimedia applications. The wireless channel might also delay, lose, or corrupt individual packets. Losses have significant impact on the perceived quality due to spatiotemporal error propagation. Thus, to achieve the required high data rates and acceptable BER, the channel must be efficiently used to guarantee a maximum level of perceptual quality from the end-user's perspective. [1]

In this study, we address the application of joint adaptive modulation and for multimedia transmission over wireless fading channels. We propose a new approach for selecting the appropriate modulation level which considers the perceptual quality and bandwidth efficiency. In this approach, the adaptation targets maximizing the bandwidth efficiency while maintaining high peak signal-to-noise ratio (PSNR) for an acceptable perceptual quality. Since not all portions of the coded bit stream are equally important, our framework partitions the bit stream into sub-streams with different quality and protects each sub stream based on its contribution to the final quality of the decompressed image. An algorithm is developed and used to select the appropriate modulation mode in order to efficiently protect the partitioned multimedia content against channel degradation. Simulation results show that adaptation according to the channel condition enhances the spectral efficiency and gives acceptable immunity against channel variations. While the adaptation according to the sensitivity of the compressed multimedia content proved to prevent the channel from introducing unrecoverable errors and improve the quality of the reconstructed data.[3]

This in turns allows more information to be transmitted which also allows the use of fine quantization that result in higher PSNR values. Recently, several studies considered the problem of adapting the source and channel code rates in the context of image and video transmission. Based on the channel conditions, the authors in [3] studied the impact of adapting the source code rate on transmission energy, latency, and the quality of the reconstructed image by varying the quantization parameters. Several JSCC schemes with different objectives were introduced in [1], [2], [5], [6], [7], [8] and the references there in. However, JSCC schemes have few limitations. For instance, the introduced JSCC schemes ignore the impact of entropy coding whereby the occurrence of any error leads to error propagation, the effect of which on the overall distortion cannot be estimated at the time of the encoding. Moreover, optimizations in JSCC schemes are performed on a per image basis; therefore the parameters derived for each image could be used to transmit that image only. The proposed scheme jointly considers the average energy-per-bit to noise power spectral density ratio (Eb/No) as seen by the receiver and the sensitivity of the compressed bit stream to achieve an optimal tradeoff between the image quality and the bandwidth efficiency.

1.1 System Model



To evaluate the performance of the proposed joint adaptive modulation scheme, we simulated the transmission of the 512x512 bitmap RGB image. The bit stream of the encoded image is divided into three priority-levels bit streams. Each bit stream is modulated according to the proposed scheme and transmitted over a AWGN channel. At the receiver, the signal is demodulated, decoded and combined to reconstruct the received image

Figure 1 depicts the block diagram of the proposed end-to end image transmission scheme. The output of the source encoder is divided into three different quality bit streams (i.e. with unequal importance). The first bit stream contains the DC coefficients, which represents the average luminance of the 8 x 8 blocks of the image and hence is considered the most important bit stream. The second bit stream contains the low-frequency AC coefficients which are concentrated in the upper left parts of each of the 8 x 8 blocks of the image. With the low-frequency AC coefficients, most of the details of the image could be recovered, however they are less important than the DC coefficients. The third bit stream carries the high-frequency AC coefficients which generally represent the fine details of the image. Since the human visual system is less sensitive to the information contained in the high frequency AC coefficients (i.e. fine details), they are considered to be the least significant data. Whether the transmission systems use fixed or 64 Quadrature Amplitude modulations, these systems do not take into consideration the channel condition jointly with the importance of the transmitted bit stream. When a fixed modulation level is used, independent of the channel state, the modulation level as set by the transmission algorithm is typically decided to be for the worst-case scenario. This is true since this modulation level should achieve an acceptable SER for the lowest possible Eb/No value. This is simply explained by the fact that using a lower modulation level during the "good" channel conditions will hinder the transmission at higher rates that would have been possible should the proper modulation level have been used. Thus, in the proposed transmission scheme, adaptive modulation is adopted to improve the tradeoff between the Eb/No and the achieved PSNR as the channel conditions vary with time.

The discrete cosine transform (DCT) is a technique for converting a signal into elementary frequency components. We have defined functions to compute the DCT of a list of length n = 8 and the DCT of an 8 x 8 array. We have restricted our attention to this case partly for simplicity of exposition, and partly because when it is used for image compression, the DCT is typically restricted to this size.

Rather than taking the transformation of the image as a whole, the DCT is applied separately to 8 x 8 blocks of the image. We can partition each row into lists of length 8, apply the DCT to them, rejoin the resulting lists, and then transpose the whole image and repeat the process.

FDCT

$$S_{uv} = \frac{1}{4} C_u C_v \sum_{i=0}^{7} \sum_{i=0}^{7} S_{ij} \cos\frac{(2i+1)u\pi}{16} \cos\frac{(2j+1)v\pi}{16}$$

IDCT

$$S_{ij} = \frac{1}{4} \sum_{i=0}^{7} \sum_{i=0}^{7} C_u C_v S_{uv} \cos\frac{(2i+1)u\pi}{16} \cos\frac{(2j+1)v\pi}{16}$$

$$C_u C_v = \begin{cases} \frac{1}{\sqrt{2}} & u, v = 0 \\ 1 & otherwise \end{cases}$$

Where S_{ij} is the value of the pixel at position (i,j) in the block and S_{uv} is the transformed (u,v) DCT coefficient.

II PERFORMANCE ANALYSIS

Figure 1 compares the two modulation schemes (Fixed 64 QAM Vs Joint adaptive modulation scheme). The figure indicates the plot between SER & Eb/No. It shows the performance of the proposed scheme is comparable to the performance of 64 QAM at low Eb/No values while the SER decreases at higher Eb/No values. This behavior is simply explained by the fact that at low Eb/No values, the result (value of SER) of both schemes are almost same.

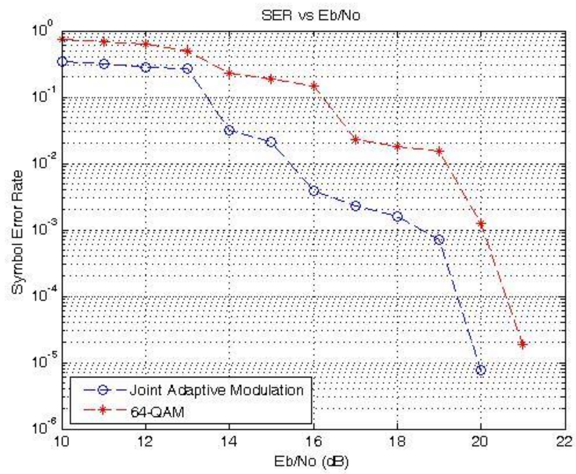


Figure1: SER Vs Eb/No

Figure 2: demonstrates the impact on the subjective (visual) quality of transmitted image using joint adaptive modulation. In addition, and for the sake of comparison, the 64 QAM fixed modulation scheme with different Eb/No values was used for the transmission of the same image.

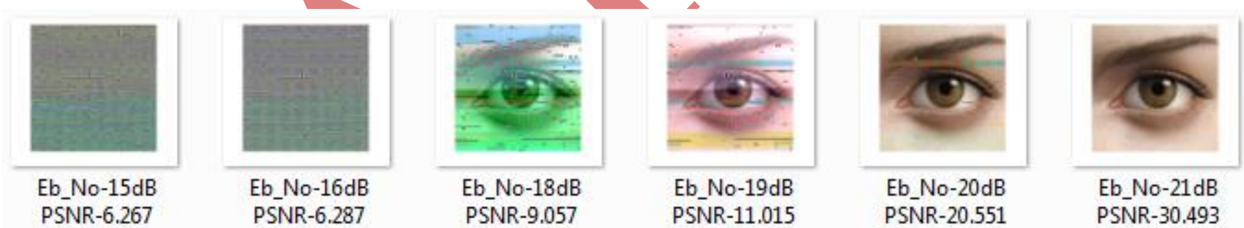


Figure 2(a) For 64 QAM

Figure 2(b) For Joint Adaptive Modulation

The quality degradation in the reconstructed image can be seen by comparing Figure 2-(a) & (b), the PSNR of the image in case of 64 QAM is 6.287 while in case of Joint adaptive modulation is 11.477when Eb/No is 16 dB (Same for both schemes). PSNR of 64 QAM is less than the Joint Adaptive Modulation for all Eb/No. It is good and acceptable quality. So it can be summarized that Joint Adaptive Modulation is better than 64 QAM.

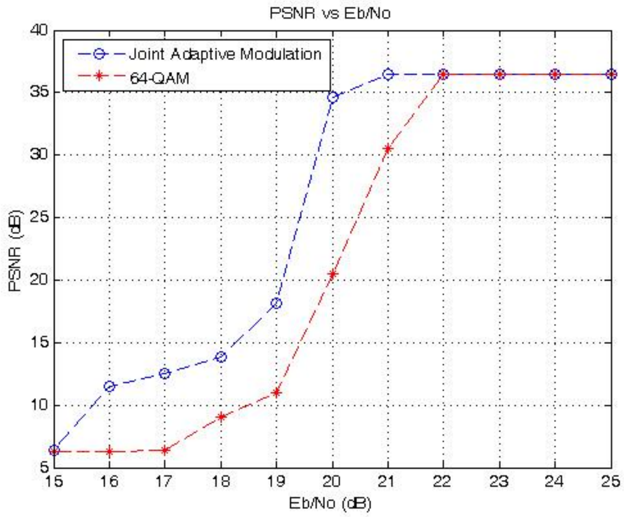


Figure 3: PSNR Vs Eb/No

Figures 4.3 compares the PSNR for the proposed joint adaptive scheme with that of the 64 QAM fixed modulation scheme. PSNR is an objective quality measure used to judge the quality of the reconstructed image. It measures the difference between the original and the reconstructed image. The proposed joint adaptive scheme achieves PSNR values that are higher than those of the fixed QAM system. While this drop in the achieved PSNR is of a major impact on the achieved perceptual quality, it must be noted that the achieved data rates is much higher than the case of 64 QAM.

III CONCLUSIONS

Based on the concept of unequal protection, we used different modulation schemes for different AC components (high, mid, low). For High, Mid and low frequency component we use 64-QAM, 32-QAM and 16-QAM respectively. DC Part is modulated by BPSK. Same Image is modulated by 64 QAM simply; the plot between SER & Eb/No is compared. The adaptation attempts to maximize the bandwidth efficiency while maintaining an acceptable perceptual quality.

Results demonstrate that combining Joint adaptive modulation for image transmission provides a graceful trade-off between image quality and SER. A significant improvement in the PSNR was achieved over a wide range of channel states while maintaining a good perceptual quality both subjectively and objectively. In future work, the proposed adaptive modulation scheme will be extended through the adaptation of channel codes based on the channel conditions as well as the sensitivity of the bit stream. Furthermore, it will also be extended to take into consideration the sensitivity and the spatiotemporal redundancies of the video streams.

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