Image Transmission over Noisy Wireless Channels Using HQAM and Median Filter

Md. Abdul Kader, Farid Ghani, and R. Badlishah Ahmad

***Abstract*—This paper considers the use of unequal error protection and median filtering for transmission of images over poor wireless channels usually encountered over cellular mobile networks. Hierarchical Quadrature Amplitude Modulation (HQAM) that provides Unequal Error Protection (UEP) to the transmitted image data is used at the transmitter. In HQAM, non-uniform signal constellation is used to provide different degrees of protection to the significant and non-significant bits in the image data at lower channel Signal to Noise Ratio (SNR). Median filter is employed at the receiver to remove the impulsive noise present in the received image. Simulation results show that the use of HQAM and median filtering provides a gain of PSNR over the more conventional Quadrature Amplitude Modulation (QAM).**

***Index Terms*—HQAM, impulse noise, PSNR, unequal error protection, wireless channel.**

I. Introduction

The rapid growth of wireless communications has a demand for robust multimedia transmission with better quality, coverage, and more power and bandwidth efficiency. The restriction of the wireless communication channels like limited bandwidth increases the demand for more reliable image communication system that does not consume more bandwidth for achieving better image quality. Furthermore, real-time applications are important because it is wide spread. Implementation of reliable image communication with the real-time requirement needs low bit-rate, low power, low delay and low complexity maintaining good image quality. The solution of the problem of reliable real time transmission of high-quality images through wireless communication channels can be achieved by using Unequal Error Protection (UEP) techniques. Thus providing reliable image transmission with acceptable data rates and in the same time maintains the good image quality. UEP consists of two main parts; the first part is called *data partitioning* and the second part is applying UEP. Concerning with *data partitioning*, it is used to provide different levels of significance (importance) for the image source, so the data is classified into important and less important [1].

Concerning UEP, the degree of error-protection level will be assigned according to the significance of the image data; as the importance of data increases, the level of protection increases. UEP is performed in the channel coding stage. In particular, the more important data will be highly protected using high channel coding level (or rate) while the less important data will be channel coded by lower protection level.

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This paper proposes the use of an asymmetric modulation method known as Hierarchical Quadrature Amplitude Modulation (HQAM) for the transmission of images over erroneous wireless channels. This is a simple and efficient approach in which non-uniform signal-constellation is used to give different degrees of protection to the transmitted bits. The advantage of this method is that different degrees of protection are achieved without an increase in bandwidth in contrast to channel coding that increases the data rate by adding redundancy to the transmitted signal [2]-[4]. Median filtering is used to increase the PSNR by removing the impulse noise from the received image. PSNR analysis is presented for different values of the modulation parameter and performance comparison is carried out through computer simulation using 16-HQAM with gray image as test image.

The paper is organized as follows: In Section II, general model of the image transmission system is briefly described. Section III considers the effects of noise and distortion in image transmission. In the Section IV, overview of HQAM is given. Based on computer simulation results, the performance of HQAM is considered in Section V.

II. Model of Image Transmission System

The essentials of the image transmission system considered here are shown in Fig. 1.

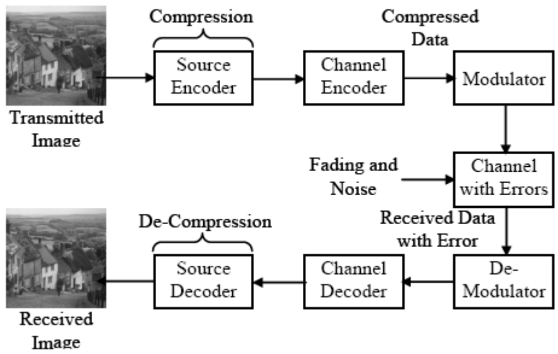

Fig. 1. Model of image transmission system

The source encoder encodes the source image using appropriate image compression technique. For the protection of coded image in Fig. 1 channel encoder adds redundancy to the coded image by using appropriate channel coding technique. Modulator modulates the coded image and transmits through the wireless channel. QAM is invariably used as the modulation technique [5]. The channel introduces noise and distortion to the transmitted image. The demodulator receives the image data with error and demodulates it. After channel decoding, the coded image is decompressed.

There are two major constraints in transmission of images over wireless channels. First, there are fluctuations in the channel bandwidth for this reason the image data must be compressed. Second, there is a high probability of channel error for this reason the image data must be protected from errors in order to maintain image quality.

III. Effects of Noise and Distortion in Image Transmission

The most common type of noise that is encountered in the image transmission system is the Salt and pepper noise (special case of impulse noise) [6], [7], where a certain percentage of individual pixels in digital image is randomly digitized into two extreme intensities (maximum and minimum). Faulty memory locations or transmission through erroneous channels can result in the received image being corrupted with this type of noise [8]. The effect of salt and pepper noise on the received image is shown in Fig. 2(a).

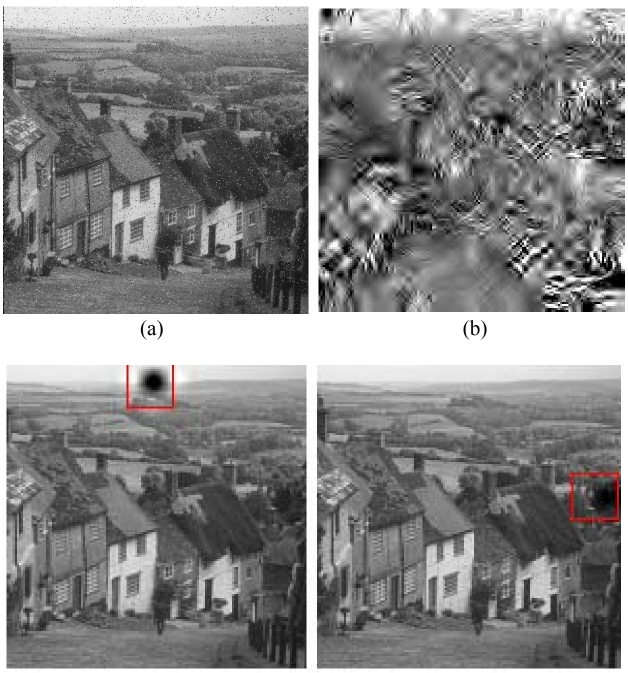

Fig. 2. (a) Effects of Salt & pepper noise (b) Effects of error in critical bits (c) Effects of error in sign bit (non-critical bit) and (d) Effects of error in refinement bits

Distortion in images occurs when errors cause local variations in image scale and coordinate location of the image pixels. The distortion is more severe when the errors occur in critical (significant/high priority) bits of the received signal. For errors in non-critical bits (sign bits/low priority bits and refinement bits/low priority bits) the distortion is not that severe. This can be seen from Fig. 2(b), 2(c) and 2(d). Fig. 2(b) corresponds to the case when the errors are in significant bits while the Fig. 2(c) and 2(d) result when the error is in sign or refinement bits. Thus in image transmission it is necessary to give more protection to significant bits as compared to the insignificant bits rather than giving equal protection to all the bits.

IV. Hierarchical Quadrature Amplitude Modulation

Hierarchical Quadrature Amplitude Modulation (HQAM) is the more spectrally efficient and dc-free modulation scheme [9]. It provides the different degree of protection to the transmitted data bits, in which the high priority (HP) data bits are mapped to the most significant bits (MSB), and the low priority (LP) data bits are mapped to the least significant bits (LSB) of the modulation constellation points. Using HQAM will, therefore, a result in improved image quality specially at low channel SNR conditions, since the highly sensitive HP data bits are mapped to the MSBs with low bit error rate (BER) in HQAM. For the sake of simplicity only 16-HQAM is considered in this paper.

In Hierarchical QAM, it is possible to give higher protection to the most important data (significant bits) by changing the value of the modulation parameter α. α is the ratio of the distance b between quadrants to the distance c between the points within a quadrant [10]. In the constellation diagram referring to Fig. 3(a) the modulation parameter $\alpha = b/c$. For a given transmitted signal power the sum of b and c should remain constant. The value of the should not exceed the square root of the carrier power p_c. Otherwise, the constellation points of the same quadrant will overlap.

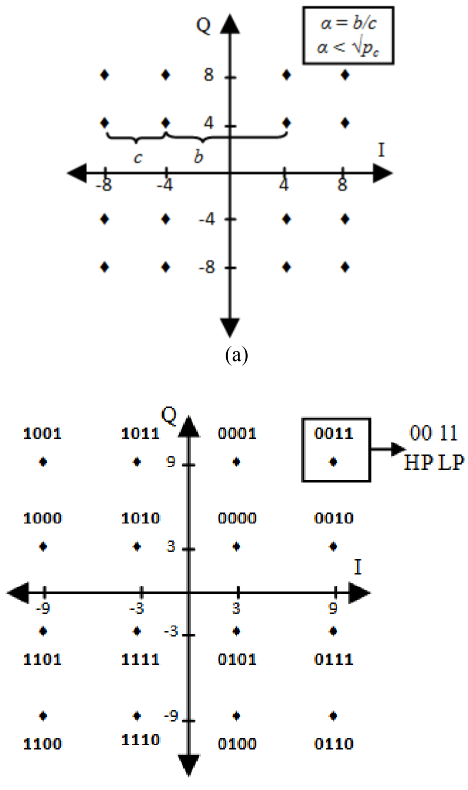

Fig. 3. Constellation diagram of 16-HQAM for (a) $\alpha = 2$ and (b) $\alpha = 1$

When $\alpha = 1$, *i.e.* b=c then HQAM results in QAM as can be seen from Fig. 3 (b). Referring to Fig. 3 (b), the two MSB represents the HP bits which have lower BER than the two

LSB bits. LSB bits are representing LP bits. It can be seen that the four symbols in every quadrant have the same HP bits but different LP bits; this is also called constellation overlapping and ensure that the HP bits to be transmitted correctly [5].

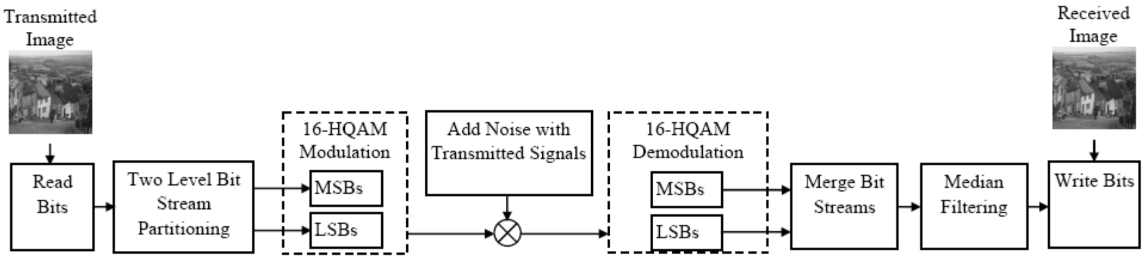

Fig. 4. Simulation of image transmission and reception using 16-HQAM

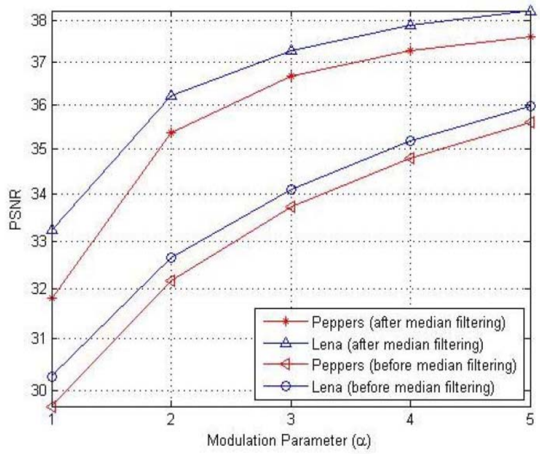

Fig. 5. PSNR vs. modulation parameter α = 1 to 5

V. Simulation and Results

A simulation for gray scale image transmission and reception was carried out using 16-HQAM and Median filter is used for suppression of impulsive noise in the image to improve the PSNR. The flow diagram of the proposed simulation is shown in Fig. 4 and simulated using MATLAB 7.8 (R2009a). This simulation transmits and receives grayscale images through the wireless erroneous channel and calculates the PSNR of the image.

Fig. 5 shows the PSNR vs. modulation parameter curves for before and after median filtering (over AWGN channel) using hierarchical 16-QAM for α = 1 to 5. There are two different images (Peppers and Lena) used to be transmitted. It is seen that as expected by increasing the value of α, PSNR of the received images increase when the median filtering is used. However, HP (significant) data of the images are highly protected for the larger value of α for lower channel SNR and also improve the image quality (higher PSNR).

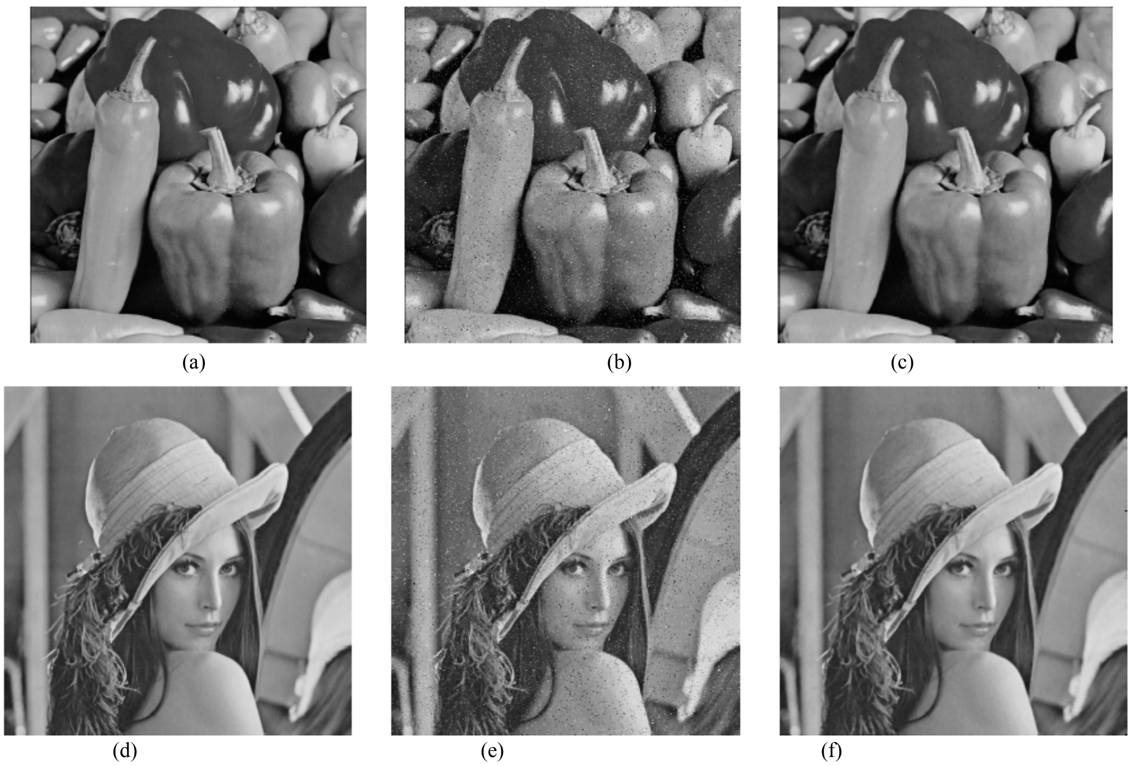

Fig. 6. (a) Original image (peppers) (b) Received image (peppers-before filtering) (c) Receive image (peppers-after filtering) (d) Original image (lena) (e) Received image (lena-before filtering) (f) Receive image (lena-after filtering)

Gray scale test images shown in Fig. 6(a) and 6(d) were used to obtain the performance of 16-HQAM using

MATLAB. Different values of the modulation parameter α were used to see the improvement in the distortion of the received image with α before and after median filtering. The SNR was kept at a fixed value of 14 dB. The results are shown in Fig. 6(b) and 6(e) before filtering and Fig. 6(c) and 6(f) after filtering when $\alpha = 5$. It has been seen that the best-quality images are received by proposed simulation when $\alpha = 5$ and SNR=14dB by using the median filter.

VI. Conclusion

In image transmission over erroneous wireless channels, if the sensitive data of transmitted image is corrupted then it is difficult to recover that image for low channel SNR. Hierarchical QAM (HQAM) overcomes this disadvantage by providing more protection to the higher-priority bits and less protection to the lower-priority bits of the image data. To increase the PSNR of reconstructed median filter is used. Thus HQAM being a simple technique provides a more efficient means of image transmission over the erroneous wireless channel with low SNR.

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