UEP based on Proximity Pilot Subcarriers with QAM in OFDM

Tony Gladvin George
Research Scholar,
Vinayaka Mission University,
Salem, Tamilnadu, India

Dr.N.Malmurugan
Principal,
Kalaignar Karunanithi Institute of Technology,
Coimbatore, Tamilnadu

Abstract— **A novel UEP (Unequal Error Protection) method is proposed that utilizes the subcarrier positions relative to pilot subcarriers in an OFDM multicarrier frame along with QAM (Quadrature Amplitude Modulation) schemes. With the available physical layer techniques, a prioritized encoding strategy based on the characteristics of the channel fading effects on the proximity data subcarriers to the pilot subcarriers for layered video is developed. The strategy is to efficiently map the bit streams of various priorities into the subcarriers with assisted info on their individual error recovery probability. The proposed technology maintains a minimum QoS for all periods outside outage since the high priority layer is guaranteed to be transmitted under BER constraints. At lower SNR scenarios this difference between the pilot proximate subcarriers are more distinctive.**

Keywords-Video Transmission; Unequal Error Protection; Proximity Pilot Subcarriers; OFDM; QAM

I. INTRODUCTION

Compressed video bitstream transmission over wireless network is addressed in this paper. A new system that integrates video source coding and channel coding for broadband wireless transmission is attempted to explore. Specifically, **a system that integrates Orthogonal Frequency Division Multiplexing (OFDM) with unequal error protection channel coding on prioritized subcarriers with QAM** is proposed for robust video transmission.

The work proposes an Prioritized Subchannels Error Protection (PSEP) scheme by jointly considering the features of NAL layer in H.264/AVC and the characteristics of OFDM channels through sub-channel partitioning, in which a cross-layer allocator is used to allocate channel resources for different priority video data transmission for error resilient encoding. Various QAM schemes are used based on the subcarrier location. The strong impact of the proposed method in terms of video quality is evaluated for H.264 video transmission.

II. EXISTING UEP WITH QAM METHODS

In a multi-carrier system, such as OFDM, a natural way to implement UEP is based on forward error correction (FEC) [1]. Common approaches for UEP are based on channel coding, such as BCH (Bose and Ray-Chaudhuri) code, RS (Reed Solomon) code, rate-compatible punctured convolutional code (RCPC), Turbo coding etc. [2][3][4] . The basic idea is to employ different channel coding schemes to provide different levels of protection to video data with different priorities. Retransmission can also be combined with such schemes for prioritization [5] [3]. By employing different channel coding schemes, video data of high-priority (HP) is given more protection than low-priority (LP) data. UEP is classically performed at channel coding level, through convolutional and, more recently, turbo codes. In [1], an UEP method is proposed for an OFDM system by grouping sub-channels according to their channel gains, and power control is employed so that the subchannels belonging to the same group have the same signal-to-noise ratio (SNR).

Most OFDM systems use a fixed modulation scheme over all carriers for simplicity. However each carrier in a multiuser OFDM system can potentially have a different modulation scheme depending on the channel conditions. Any coherent or differential, phase or amplitude modulation scheme can be used including BPSK, QPSK, 8PSK, 16QAM, 64QAM, HQAM etc.

HQAM is an efficient modulation mode that achieves additional compression by assigning more than one bit to each transmission symbol. In the 64-QAM constellation (Fig 1), among the six bits of each symbol, as a result of the Gray bit distribution of the points, the two most significant bits (MSB) have the same value in each quadrant. Therefore, these two bits are more distinguishable and so have lower bit error rates than the four least significant bits (LSB) [10]. To provide UEP for video stream, this property of hierarchical QAM (HQAM) can be applied.

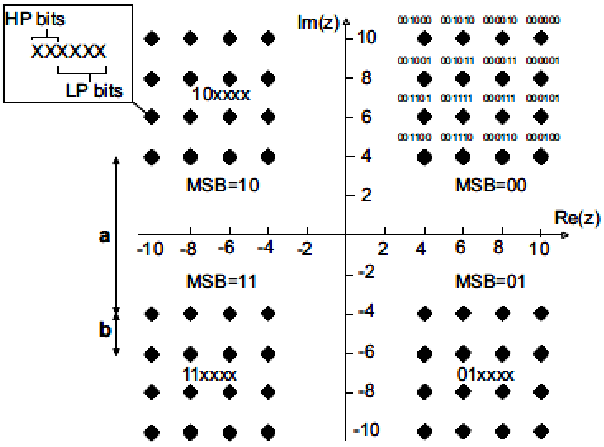

Fig 1: A non-uniform 64-QAM mapping with alpha = a/b = 4

HQAM is a simple and efficient approach in which a non-uniform signal space constellation is used to give different degrees of protection [11], [12]. 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.

One major drawback of conventional HQAM (as in the digital video broadcasting standard for example) is that there are fixed allocated capacities for the HP and LP video layers. However in data partitioning, the corresponding parts of the coded data do not necessarily produce a constant bit-rate ratio. Therefore, conventional HQAM is not well suited to such application without either accepting delay or losing HP protection.

In systems that use a fixed modulation scheme the carrier modulation must be designed to provide an acceptable BER under the worst channel conditions. This results in most systems using BPSK or QPSK. These give a poor spectral efficiency (1-2 bits/s/Hz) and provide an excess link margin most of the time.

III. Proposed Method

In the proposed technique, the channel estimation in conjunction with error probability of subcarriers proximate to pilot subcarriers had been explored achieved higher UEP.

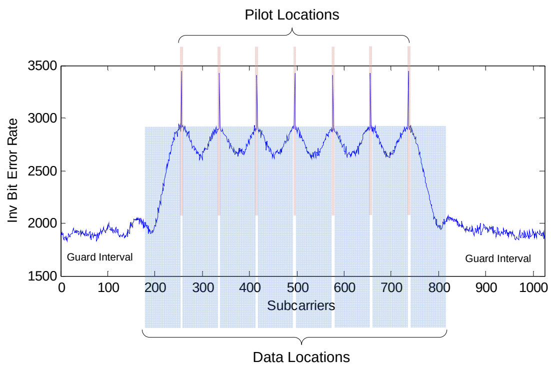

Fig 2: OFDM BPSK bit location error response

A. *Channel Effect Recovery of Proximity Pilot Carriers*

The error response on the 1024 bit locations of a 1024 subcarrier OFDM after reception and channel estimation is as shown in Fig 2. The pilots are placed in an interval of 80 subcarriers, excluding the guard interval to form 7 pilots. The Pilot locations, Data locations and Guard intervals are shaded for better visibility in Fig 2. After channel estimation the pilot subcarriers will have comparatively lesser distortion from the channel effects and hence the sharp peaks of BER.

The subcarrier response of data subcarriers excluding the pilot subcarriers are shown in Fig 3. The peaks and troughs are formed in relation with the position of the pilot subcarriers. The data subcarriers near to the pilot subcarriers have lower BER. As the data subcarriers located further from the pilot subcarriers, it is prone to more errors and has higher BER.

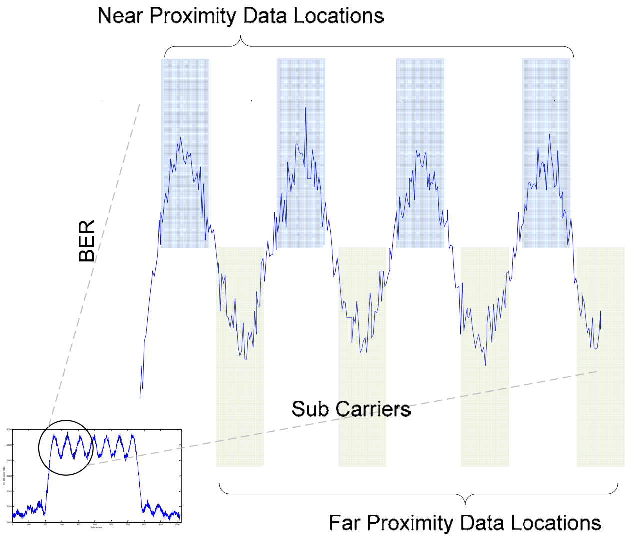

Fig 3: Proximity subcarrier BER

The following BER diagram Fig 4 shows the channel responses for near proximity subcarriers and far proximity subcarriers. Any kind of error correction mechanisms including the FEC is not used with the intention of focusing on the study of the channel response with proximity subcarriers.

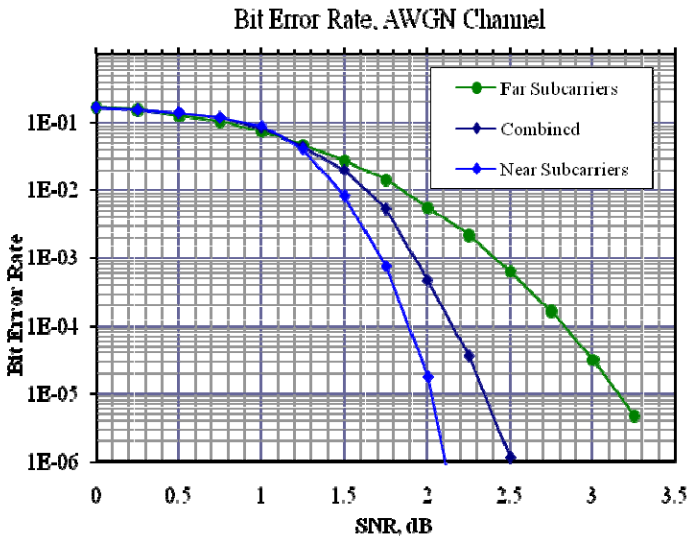

Fig 4: Proximity subcarrier BER

This property of lower probability of BER on proximity sub carriers is extended to use for the Unequal Error Protection for prioritized video transmission. The data subcarriers are categorized into three groups based on the proximity of with the pilot subcarriers. The prioritized data from the NAL layer is mapped into the grouped data-subcarriers accordingly.

B. Near Field and Far Field Channel Response

Extensive tests had been carried out to opt for the best ratio between the allocation in Near Field Subcarriers and Far Field Subcarriers. Fig 5 shows the PSNR in two different ratios of 30% vs 60%. A ratio of 30% is utilized which in all cases gives a graceful degradation as channel SNR decreases. Since the probability of the BER is different for Near Field Data Carriers (NFDC) and Far Field Data carriers (FFDC), the FEC rate should be considered according to the bit mapping on the subcarrier locations.

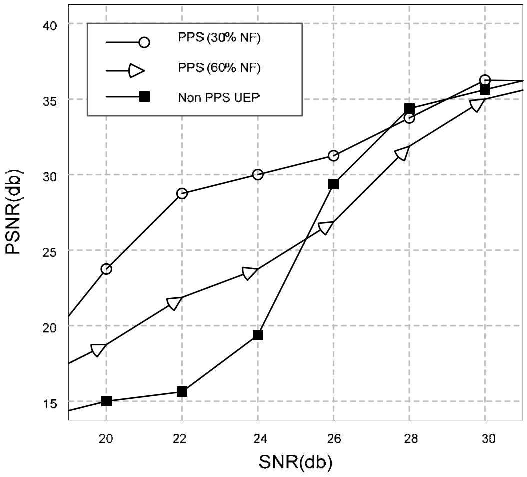

Fig 5: Ratio of Near Field and Far Field in 64kbps

Actual video quality depends on PER (Packet Error Rate). In video encoding, even if a single bit in a packet is lost the entire packet shall not be used and is assumed lost. Assuming a packet size of 1000 bits and a BER of 10-3, then on an average only 1 bit in a packet will be lost. A very simple but high rate coding mechanism (convolution coding with veterbi decoding) with low complexity that can correct a few bits will be sufficient to further bring down the PER to an acceptable value. Effectively, the FEC ratio will be different for packets with different priorities.

C. QAM Prioritization scheme

Each modulation scheme of BPSK, QPSK, 8PSK, 16QAM, 64QAM, HQAM provides a tradeoff between spectral efficiency and the bit error rate as shown in Fig 6. The prioritization efficiency can be maximized by choosing the highest modulation scheme that will give an acceptable BER. In a multipath radio channel, frequency selective fading can result in large variation in the received power of each carrier.

For a channel with no direct signal path this variation can be as much as 30 dB in the received power resulting in a similar variation in the SNR. Using prioritized modulation the carrier modulation is matched to the SNR, maximizing the overall packet protection.

Thus the priority of the packet decreases the modulation can be increased from 1 bits/s/Hz (BPSK) up to 4-6 bits/s/Hz (16QAM - 64QAM), significantly increasing the spectral efficiency and transmission rate of the overall system. Preliminary results show that for a cellular network the system capacity can potentially be doubled using prioritized modulation.

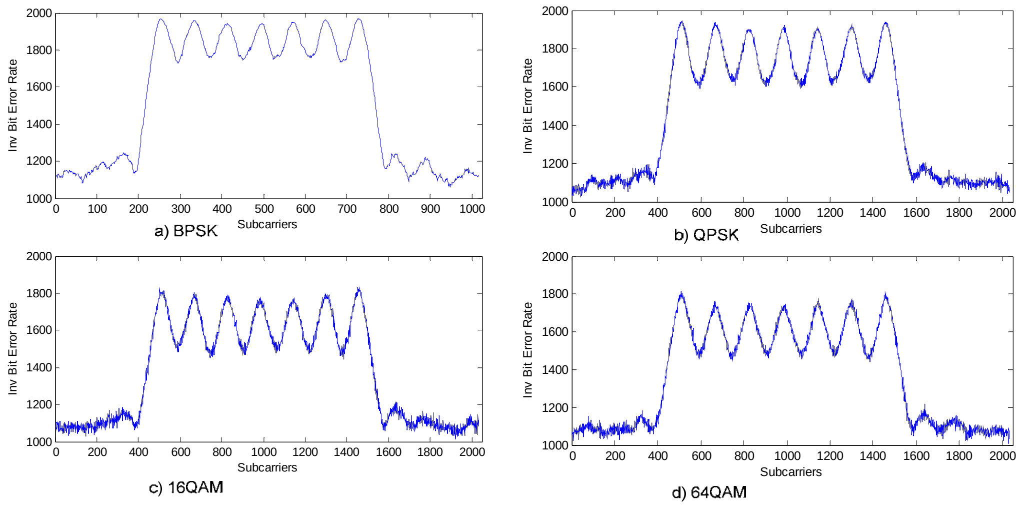

Fig 6: QAM vs BER. a) BPSK b) QPSK c) 16 QAM d) 64 QAM

Using prioritized modulation, the remote stations can use a much higher modulation scheme according to the priority of the video packet. Fig 7 depicts such as system where Prioritized Bit Loader module switches between various modulation to achieve the PQAM scheme.

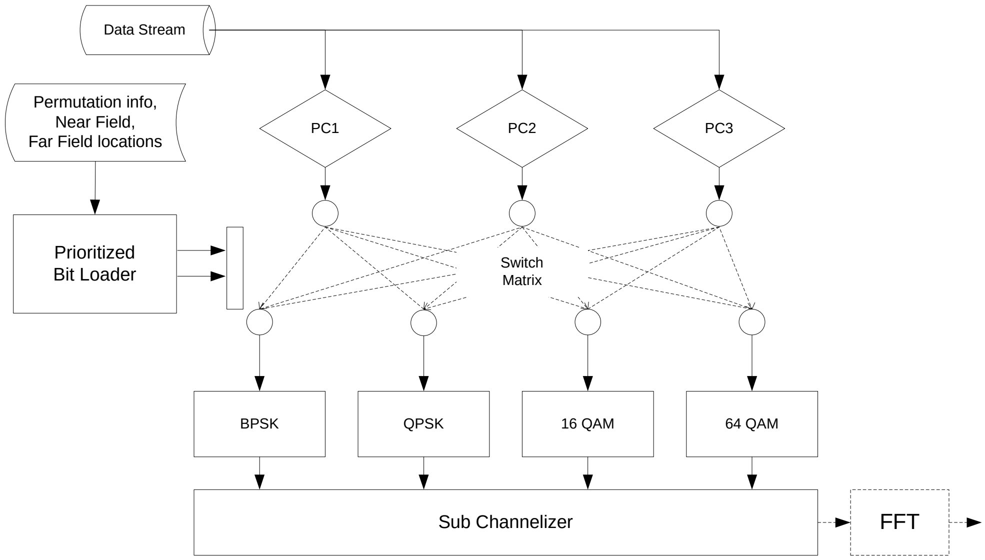

Fig 7: Prioritized QAM Bit Loader

Prioritized modulation doesn't require knowledge of the radio channel since it is not working on feedback based system, where in which Adaptive modulation requires accurate knowledge of the radio channel. The modulation scheme is based on the priority of the video packet and the proximity to the pilot sub carrier.

RESULTS AND COMPARISON

The prioritized modulation shows significant gain in BER even in poor SNR. Fig 8(c) shows the BER after mapping QPSK in Far-Field and 64QAM in Near-Field. The BER of the Far-Field is considerably improved from BER-L3 to BER-L2.

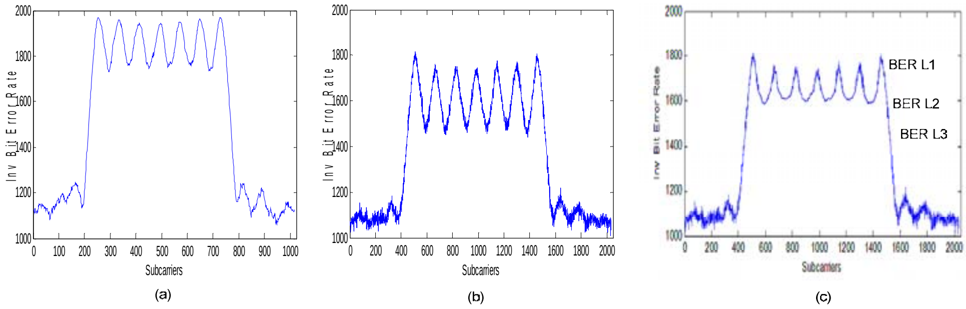

Fig 8: BER of the Far Field for prioritized modulation

The UEP-PPS-PQAM transmission of data-partitioned coded video have been simulated in Gaussian and fading environments with a constant total channel rate, ch = 64 kbps and 200kbps. The Fig 9 and Fig 11 shows the PSNR performance comparisons between scheme Non-PSP-UEP1[7], Non-PSP-UEP2[8], UEP-PSP[13], UEP-PPS-FEC[14] and UEP-PPS-QAM.

A. VIDEO AT 64KBPS

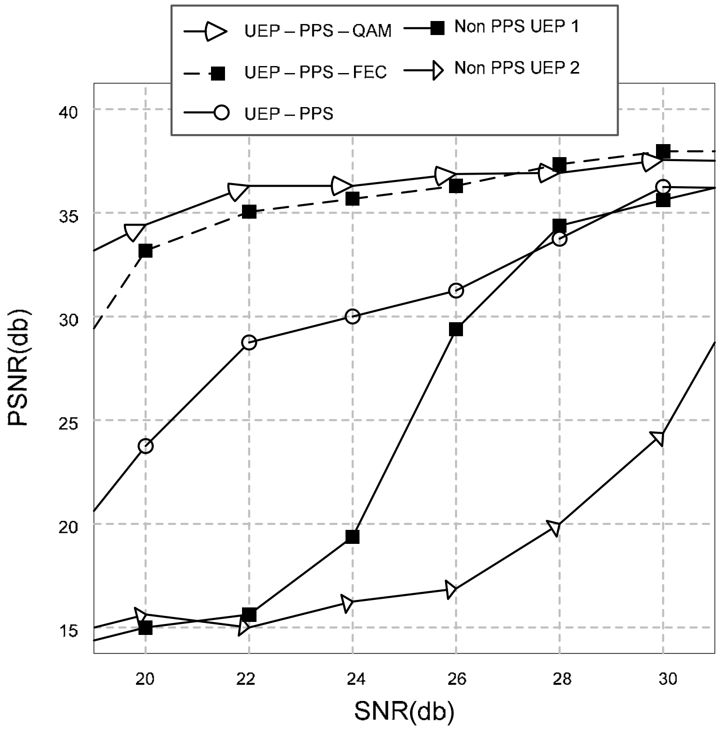

Fig 9: Video Quality in 64kbps

From the PSNR plot of Fig 9 it is inferred that the PPS-QAM outperforms other schemes during the SNR is very poor (Fig 10). But when the SNR improves, the difference between the PPS-PQAM and other schemes are similar. This shows the specific capability of PPS-QAM to perform well during low SNR in wireless channel.

Fig 10: Comparison of subjective reconstructed video quality for Carphone video sequence at SNR=22.0dB in 64kbps; (a) UEP-PPS-QAM the proposed scheme; (b) Non-PPS-UEP-1 scheme from [8];

B. VIDEO AT 200KBPS

For 200 kbps at low SNRs (Fig 11), the PPS-PQAM system is not much of difference than the UEP-FEC[14] system. This is because at this bit rate, the PC1 stream can have enough protection required. In all cases, the PPS-PQAM method gives a graceful degradation as channel SNR decreases.

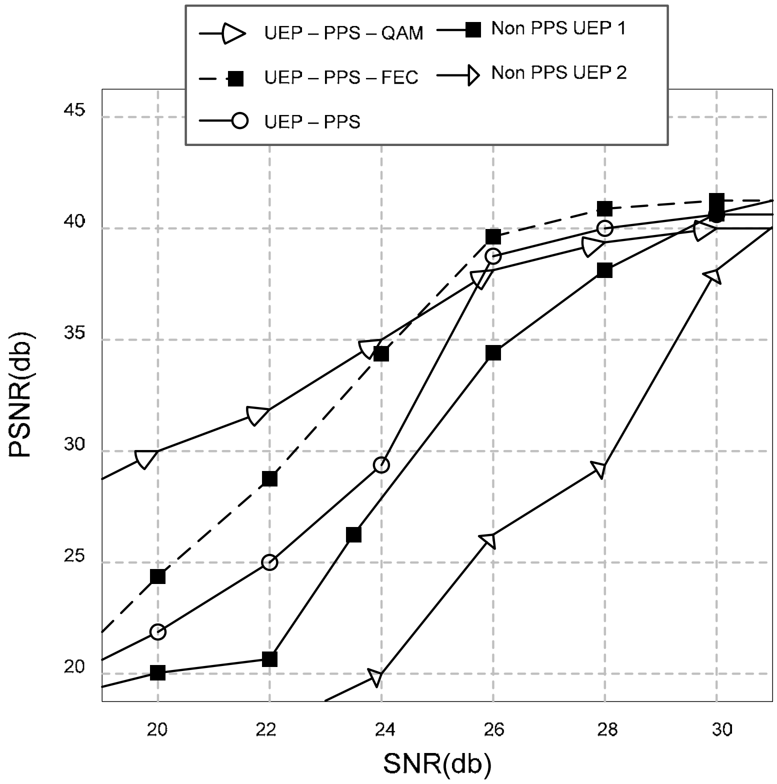

Fig 11: Video Quality in 200kbps

It is also understood that the Prioritized modulation doesn't require knowledge of the radio channel since it is not working on feedback based system, where in which Adaptive modulation requires accurate knowledge of the radio channel. This property forms a definite advantage over Adaptive modulation schemes.

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