UEP based on Proximity Pilot Subcarriers in OFDM

Tony Gladvin George, N.Malmurugan

***Abstract*— A novel Unequal-Error-Protection method is proposed that utilizes the subcarrier positions relative to pilot subcarriers in an OFDM multicarrier frame. With the available physical layer techniques, a prioritized encoding strategy based on the characteristics of the channel fading effects on the data subcarriers, those are in close proximity 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 information 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 data subcarriers are more distinctive.**

***Index Terms*— Video Transmission, Unequal Error Protection, Proximity Pilot Subcarriers, OFDM.**

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 OFDM with unequal error protection channel coding on prioritized subcarriers** is proposed for robust video transmission.

The work proposes an Prioritized-Subchannels-Error-Protection 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. The strong impact of the proposed method in terms of video quality is evaluated for H.264 video transmission.

II. EXISTING UEP SYSTEMS

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. [1][2][3] . 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 [4] [2].

UEP can also be realized based on modulation. Different modulation schemes have different BER performances for the same signal to noise ratio (SNR). On the other hand, for a certain modulation scheme, different points on the signal constellation have different error resistance [5] [6] [7]. The advantage of modulation-based UEP is that different degrees of protection are achieved without an increase in bandwidth requirement, which is generally required by a channel coding based scheme. Optimization of the rate allocation in such a scheme was addressed by [8] [9].

Wireless image transmission using turbo codes and optimal unequal error protection is proposed by Thomos et al. [10]. They proposed a novel scheme based on the SPIHT source coder applied in conjunction with the application of the turbo codes [11]. Their methodology, termed turbo-coded SPIHT (TCS) was implemented and tested in conjunction with two protection strategies, one using equal error protection (EEP) and the other using UEP. The TCS with successive decoding (terms TCSD) was also implemented and evaluated in this work.

However, channel estimation has not been exploited for the transmission of prioritized multimedia data. In this work, the problem of UEP over OFDM will be studied from a different view considering the channel estimation and the relative position of data-subcarriers with pilot-subcarriers.

III. PROPOSED METHOD

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

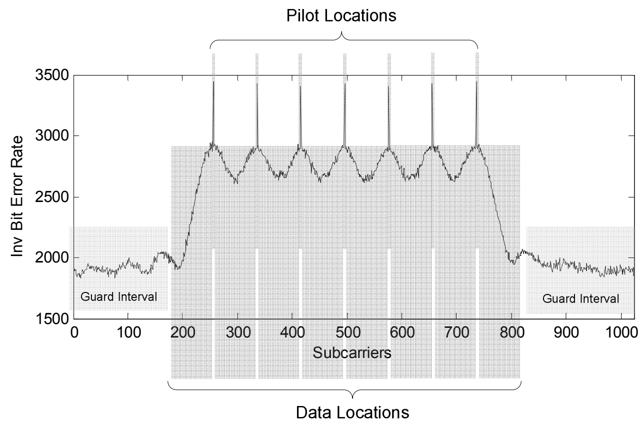

Fig 1: OFDM BPSK bit location error response

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Tony Gladvin George, Research Scholar, Vinayaka Mission University, Salem, Tamilnadu, India. (e-mail: ewizlab@gmail.com).
Dr. N. Malmurugan, M.Tech., PhD, Principal, Kalaignar Karunanithi Institute of Technology, Coimbatore (e-mail: n_malmurugan@yahoo.com).

A. *Channel Effect Recovery of Proximity Pilot Carriers*

The error response on the 1024 bit locations of a 1024 subcarrier OFDM after reception & channel-estimation is as shown in Fig 1. 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 1. 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 2. 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.

The following BER diagram Fig 3 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.

The 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 two 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. The following section will detail the mapping of prioritized data.

B. *NAL Prioritized Packer*

H.264/AVC entropy coding uses three main tools to allow a high data compression: Exp-Golomb coding, Context Adaptive Variable Length Coding (CAVLC) and Context Adaptive Binary Arithmetic Coding (CABAC). The main innovation of the entropy coding is the use of a context adaptive coding. In this case, the coding process depends on the element that will be coded, on the coding algorithm phase, and on the previously coded elements.

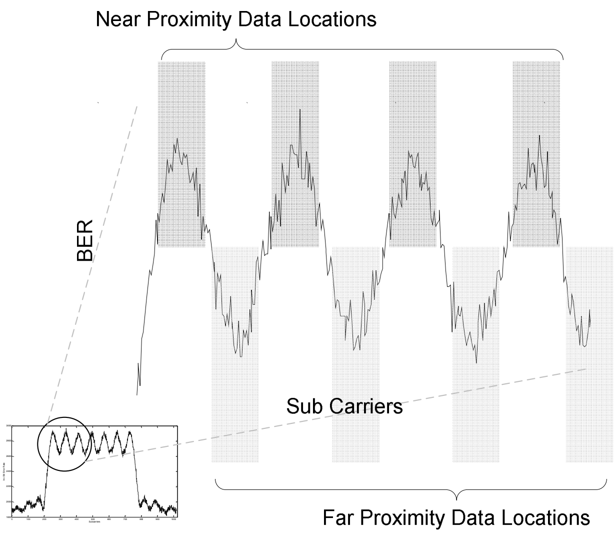

Fig 2: Proximity subcarrier BER

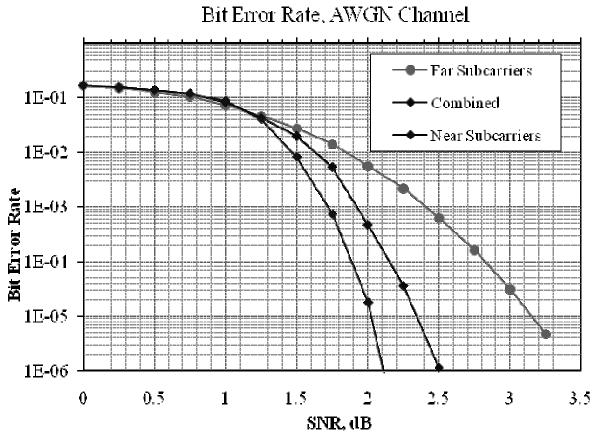

Fig 3: Proximity subcarrier BER

Entropy coding process defines that the residual information (quantized coefficients) is entropy coded using CAVLC or CABAC, while the other coding units are coded using Exp-Golomb codes. The Exp-Golomb compression in H.264 basically handles the header information and the CAVLC handles the payload.

The NAL Prioritized packer will pack the NAL stream into three, according the error sensitivity of the streams. The output from the Exp-Golomb will be mapped into Stream-1 (PC1), Stream-2 that is basically consists of the residuals of Intra pictures are mapped into PC2 and Stream-3 that consists mainly P and B residual data are mapped to PC3 (Fig 4).

C. *System Diagram*

The implemented system diagram of UEP, based on PSP is given in Fig 5. The chain of modules in the Tx & Rx incorporated in the system can be broadly classified into bit level blocks, symbol level blocks and video processing blocks. The bit-level blocks include randomization, FEC, interleaving, and mapping to quadrature phase shift keying (QPSK) and QAM functions on the transmit side. The corresponding receive processing bit-level blocks are symbol de-mapping, de-interleaving, FEC decoding, and de-randomization. All bit-level functions except FEC decoding are relatively straightforward and not computationally intensive.

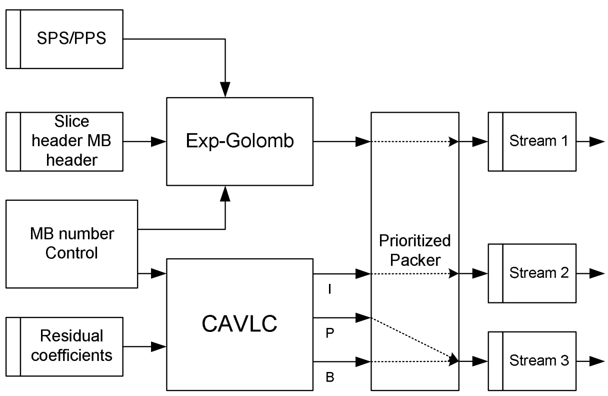

Fig 4: Prioritized Subcarrier Channel Response

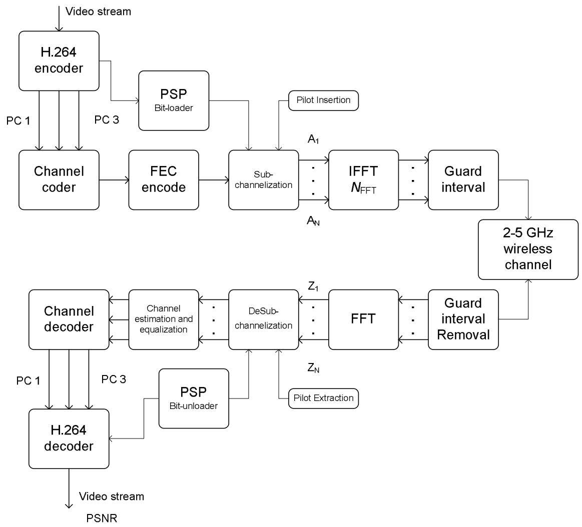

Fig 5: UEP based on PPS

Symbol-level functions in OFDM systems include sub-channelization and de-sub-channelization, channel estimation, equalization and cyclic prefix insertion, and removal functions. The time-to-frequency domain conversion and vice-versa are implemented using FFT (fast Fourier transform) and IFFT, respectively.

D. BIT loading and decoding

The Bit loader will make the frame for each OFDM symbol according to the priority. In order to create the OFDM symbol in the frequency domain, the modulated symbols are mapped on to the subchannels that have been allocated for the transmission of the data block. Active (data PC1, PC2, PC3 and pilot) sub-carriers are grouped into subsets of sub-carriers called subchannels.

The minimum frequency-time resource unit of sub-channelization is one slot. The number and exact distribution of the subcarriers that constitute a subchannel decide by Bit loader based on the subcarrier permutation mode. The number of subchannels allocated for transmitting a data block depends on various parameters, such as the size of the data block, the modulation format, and the coding rate.

Then several NAL units with different priorities are generated and the information about the priorities is sent to the allocator. The source coded video data is encapsulated before transmitted by the PHY (Physical) layer, which is OFDM channel in our consideration.

A cross-layer allocator is used as the controller (Fig 6). It collects the segmentation & priority information about the video source data & SNR of subchannels, and informs the coding rate and video-data-to-subchannels map to PHY layer and the transmission status of video data back to video encoder. Along with the video data, the coding rate and the video-data-to-sub-channel map are also been transmitted to the receiver. The PHY layer of the receiver, which is also OFDM receiver, estimates the sub-carrier's SNR and feedback them to the transmitter.

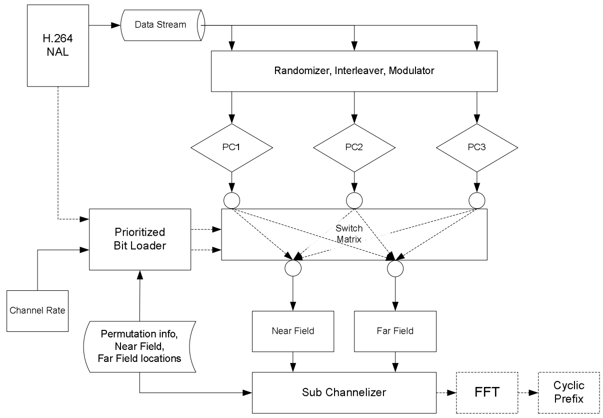

Fig 6: UEP based on PPS

IV. RESULTS AND COMPARISON

Software simulations were carried out for the proposed UEP on H.264/AVC coded video transmission using PPS. A 30-frame video sequence in Quarter-Common-Intermediate-Format (QCIF) of spatial resolution 176 x 144 pixels compressed to 64 Kbit/s and 200 Kbit/s were used in the simulation. The encoded frame sequence has I-frame is inserted every fifteen frames. The periodical insertion of I-frame in every fifteen frames is to prohibit the temporal error propagation when errors occur during transmission.

It is anticipated that other combinations of I-frames and P-frames will lead to similar results for the proposed UEP system. The transmitted signal was subject to AWGN. Results of twenty simulations, performed with different AWGN seeds, were averaged in order to obtain more reliable results. The average PSNR, is thus given by

$$Average\_PSNR = \frac{1}{20}\sum_{s=1}^{20} PSNR(s) \qquad (1)$$

Fig 7 and Fig 9 compare the performance of the proposed UEP using Proximity Pilot Subcarriers.

A. Video at 64KBPS

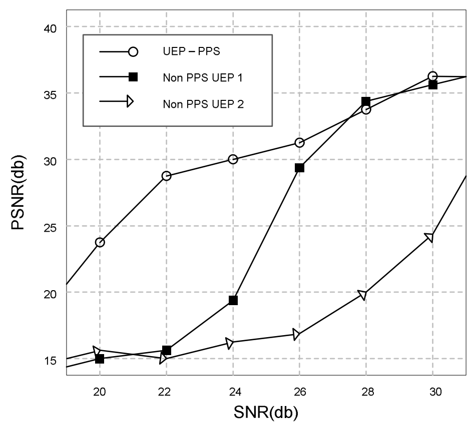

Fig 7: Video Quality in 64kbps; Non-PPS-UEP-1 scheme from [12]; Non-PPS-UEP-2 scheme from [13]

(a) (b)

Fig 8: Comparison of subjective reconstructed video quality for Carphone video sequence at SNR=20.0dB, 64kbps; (a) UEP scheme in [12] ; (b) Proposed UEP scheme.

In Fig 7 it can be seen that in terms of Average PSNR, the proposed UEP scheme using PPS outperforms Non-PPS-UEP-1 scheme from [12] and Non-PPS-UEP-2 scheme from [13] by up to ~10.2dB during low SNR condition (SNR = 20dB to 24.5 dB) and low bit rate of 64Kbps.

In other words, the proposed UEP scheme has highly improved the visual quality when the SNR of the channel is low. Fig 8 is a frame captures of the carphone sequence at a low bit rate of 64kbps. Fig 8 (a) shows the output of the UEP scheme described in [12], where as Fig 8 (b) shows the output of the proposed method in this paper.

These results can be attributed to the fact that when the channel SNR is low, the probability of errors occurring to the I-frames and earlier P-frames are much lower, since the PC1 packets are better protected against channel noise than PC2 and PC3 streams.

B. Video at 200KBPS

When the bit-rate is higher, such as 200Kbps, the proposed UEP scheme result has only slight improvement in visual quality (Fig 9). This is because, when the bit-rate is higher, due to the inherent higher BER of Channel, the difference between all the schemes is not very significant.

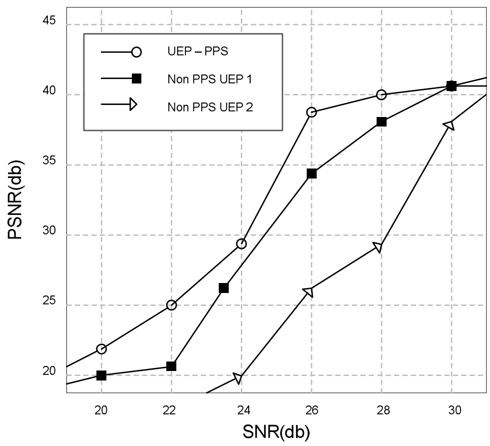

Fig 9: Video Quality in 200kbps; Non-PPS-UEP-1 scheme from [12]; Non-PPS-UEP-2 scheme from [13]

C. Near Field and Far Field Subcarriers

Extensive tests had been carried out to opt for the best ratio between the allocation in Near-Field-Subcarriers and Far-Field-Subcarriers. Fig 10 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.

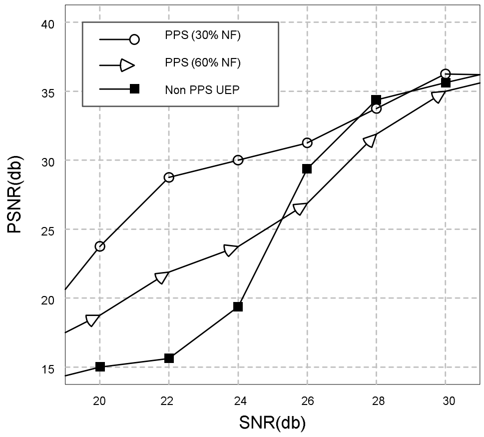

Fig 10: Ratio of Near Field and Far Field in 64kbps

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