Implementation of Adaptive Modulation and CAZAC Sequence in Power Effective Video Transmission Using OFDM Signals

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***Abstract*— A method is proposed to attain Quality of Service (QOS) Reliant Video transmission for a multi user OFDM system. Base station possesses the channel state information (CSI) and the rate distortion (RD) information of the video streams. The base station manages power and spectrum resources to users. The management is done by using CSI and RD information. Condition for the optimal resource allocation solution would be analyzed and realized in this attempt. Existing methods use physical layer optimization where channel strength alone is used for video resource allocation or application layer optimization where video complexity alone is analyzed. This is a novel attempt to combine the merits of both the schemes top form a cross layer optimization method. Addition of Constant Amplitude Zero Auto-correlation sequence (CAZAC) improves the method further. PSNR, MSE and throughput can be estimated by this method.**

Keywords*— Rate Distortion (RD), Channel State Information, Orthogonal Frequency Division Multiple Access, Peak Signal to Noise Ratio, CAZAC

I. INTRODUCTION

There are two important factors in the field of video transmission. One is the quality of wireless channel and the other is characteristics of video content. Orthogonal Frequency Division Multiplexing or OFDM is largely used in broadband multimedia communications. OFDM is a popular scheme for wide band digital communication, used in applications such as audio broadcasting, power-line networks, wireless networks, and 4G mobile communications. OFDM is a solution for inter-symbol interference (ISI) in wideband communication systems. In telecommunication, ISI is interference of one symbol with subsequent symbols. The previous symbol will interfere as noise and thus communication will become less reliable. The root cause of ISI is inherent non-linear frequency response of a channel causing successive symbols to distort together or multipath propagation. ISI causes errors at the receiver output. Minimization of ISI at transmitting and receiving filters is very much required in the transmission of the digital data. By scheduling different subcarriers to users according to CSI in a multiuser setting, Orthogonal Frequency Division Multiple Access (OFDMA) is a flexible and low-complex way of managing communication resources.

Different layers are used in the transmission of videos. The physical layer or the lowest layer gives information about the transmission medium, which is the channel used. The application layer, which is the highest layer, gives information about user's rate distortion curve. This curve helps to find the minimal number of bits per symbol, which is given by the rate R. This should be transmitted over a channel so that the input signal can be approximately reconstructed at the receiver without exceeding a given distortion D. Rate distortion curve basically reflects the complexity of video stream.

Here a technique has been proposed that combines the physical and application layer to transmit videos, while optimally allocating available resources to each user. Addition of Constant Amplitude Zero Auto Correlation Sequence (CAZAC) instead of cyclic prefix helps to reduce the mean square error. Zero auto correlation means the correlative variance between the users is zero, so there will be no interaction or interference between the users.

II. SYSTEM MODEL

A. Cross Layer Design

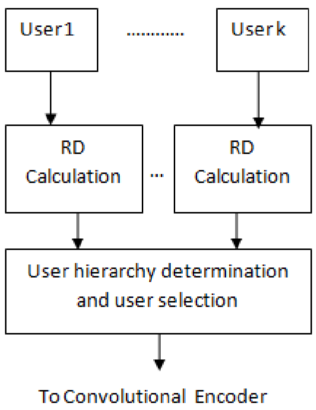

Fig. 1. User hierarchy determination

To minimize the sum of distortion at the receiver side, application layer rate distortion information and physical layer channel state information are allowed to interact. For this at first subcarriers are allocated based only on the channel information provided by the physical layer. Then considering the user who needs a greater bit rate, these subcarriers are reallocated to the user with the steepest distortion curve slope. This information is provided by the application layer. Fig 1 shows the hierarchy determination of the users. Block diagram of the transmitter is shown in Fig 2 and that of receiver is shown in Fig 3. Here the user's priority is selected from the given set of users, $k = \{1, 2, 3 \ldots K\}$. After that data is encoded convolutionally. The advantage of using convolutional encoder compared to the rest of encoders is the usage of the systems impulse response. Then the data is modulated adaptively, that is, for those signals with low signal to noise ratio, BPSK modulation is used and those with high signal to noise ratio, QPSK modulation is used. After this, subcarriers are allocated and inverse fast Fourier transform is taken after multiplying with square root of power. Cyclic prefix is added to avoid inter symbol interference. Then the OFDM signal is passed through the channel. At the receiver side fast Fourier transform is taken after subcarriers are reallocated. The signal is the demodulated adaptively, after which it is converted from parallel to serial data. Then the data is decoded convolutionally and its peak signal to noise ratio (PSNR), mean square error (MSE) and throughput is calculated. PSNR is calculated using the formula

$$\text{PSNR} = 10\log_{10}[(255 * 255)/\text{MSE}] \qquad (1)$$

Power is allocated by using water filling algorithm as the channel provides information regarding noise as the signals pass through it. Adding constant amplitude zero auto-correlation sequence (CAZAC) instead of cyclic prefix reduces mean square error

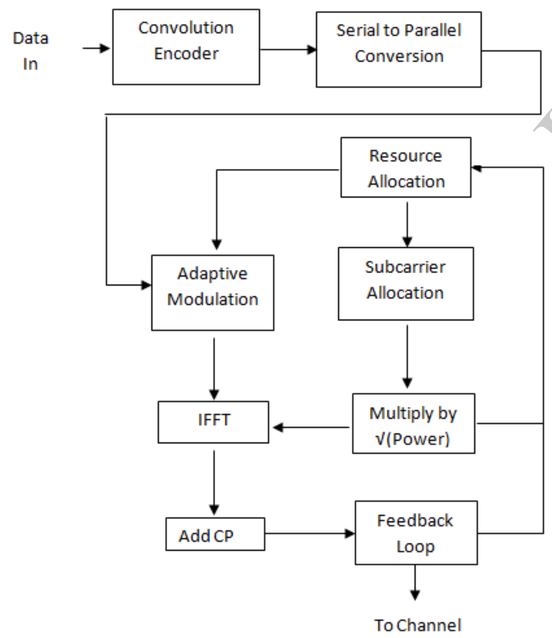

Fig. 2. Block diagram of Transmitter

(MSE) as the energy of adding redundant bits are saved. In this case the block transmission unit consists of a preamble and a number of sub-frames. This will be identical for every user. The sub-frame is equivalent to one OFDM symbol, and the number of sub-frames can be flexibly designed according to the channel's coherent time, i.e., a higher Doppler spread leads to a smaller number of sub-frames and vice versa. Here the preamble consists of a prefix, postfix and user specific N_p training sequence or CAZAC sequence. The CAZAC sequence $c_{m,0}$ can be chosen as

$$c_{m,0} = e^{j\frac{\pi r n^2}{N_p}}, \quad 0 \le n \le Np - 1,\ 1 \le m \le K \qquad (2)$$

where r is relatively prime to N_p[2].

B. Baseline Algorithms

1) Physical Layer: Suppose $[H_{1,m}, H_{2,m} \ldots\ldots H_{K,m}]$ is the vector of channel gains of users {1,2...K} at subcarrier m. Similar to conventional resource allocation based on multi-user diversity (MUD) , subcarrier m is assigned to user k* , where

$$k^* = \text{argmax}\ \{|H_{K,m}|^2 / |H_K|^2\} \qquad (3)$$

and $$|H_K|^2 = 1/M \sum_{m=1}^{M} |H_{K,m}|^2 \qquad (4)$$

After subcarrier assignment, every user would apply water filling to allocate power to each assigned subcarrier [1].

2) *Application Layer:* Here the channel state information or the CSI is not used. Instead the application layer provides the rate distortion information of the video streams of the users. While making the allocation decision, all the subcarriers are given the same importance. But the user's hierarchy is taken at first. After the resource allocation decision is done, modulation and coding scheme is selected. Similar to the cross layer algorithm, user k conducts a water filling calculation for transmission power assignment, and the modulation format is chosen for each subcarrier [1].

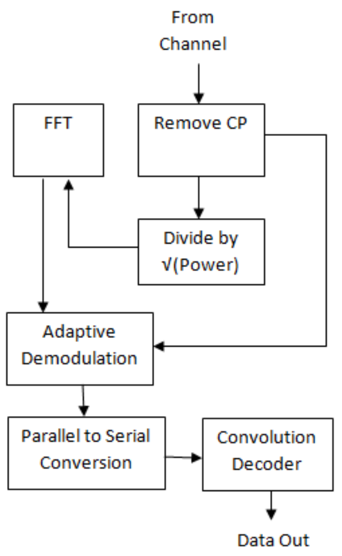

Fig. 3. Block diagram of Receiver

III. SIMULATIONS FOR PERFORMANCE EVALUATION

The available resources are optimally allocated. The power allocation is done based on water filling algorithm whose basic principle is that more power is allotted to channels with less noise. That is, when channel conditions are good more power and a higher data rate is sent over the channel. As channel quality degrades, less power and data rate is sent over the channel. If the instantaneous channel SNR falls below a cut off value, the channel is not used [3]. Figure 4 shows the power allocation using water filling algorithm. Here the signal to noise ratios (SNR) has been fixed for each sub channels. As it changes power allocation also changes. Figure 5, 6 and 7 shows the MSE, PSNR and the throughput plot for the physical layer. Figure 8, 9 and 10 shows the MSE, PSNR and the throughput plot for the application layer. Figure 11, 12 and 13 shows the MSE, PSNR and the throughput plot for the cross layer.

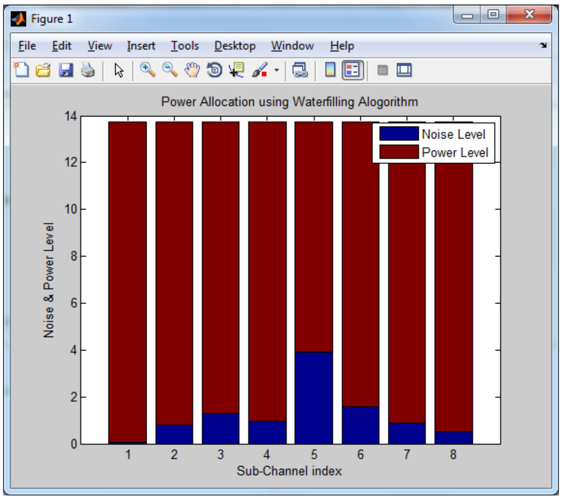

Fig. 4. Power allocation using water filling algorithm

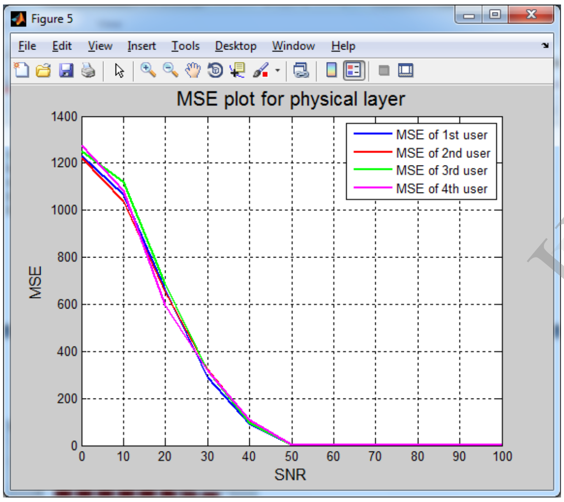

Fig. 5. MSE plot for physical layer

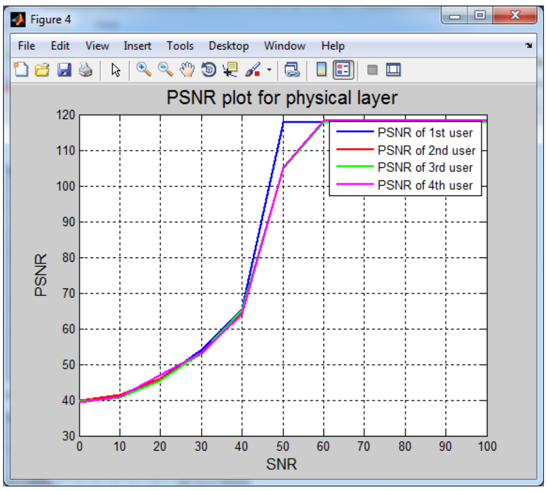

Fig. 6. PSNR plot for physical layer

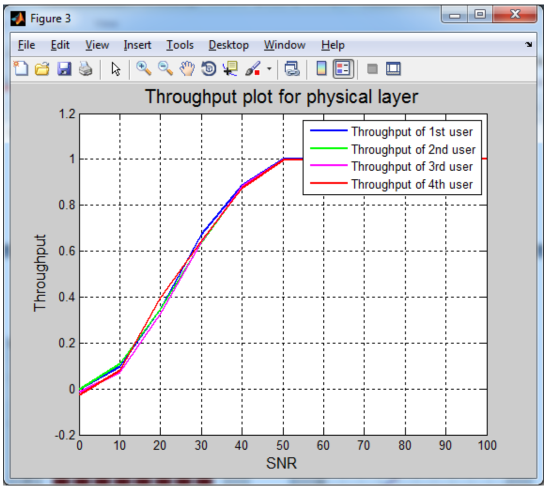

Fig. 7. Throughput plot for physical layer

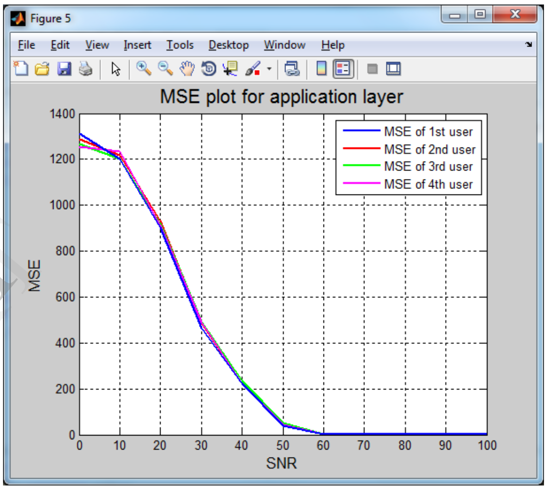

Fig. 8. MSE plot for application layer

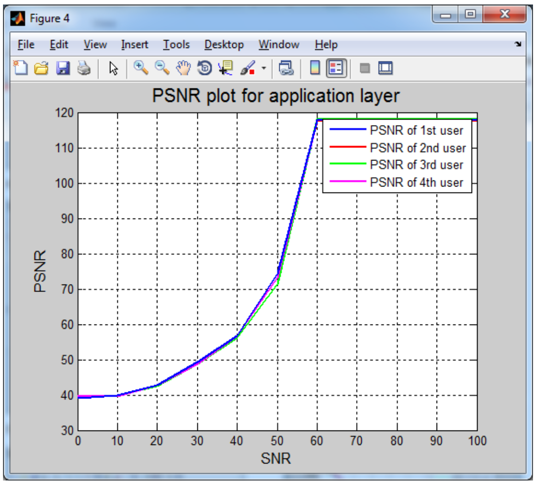

Fig. 9. PSNR plot for application layer

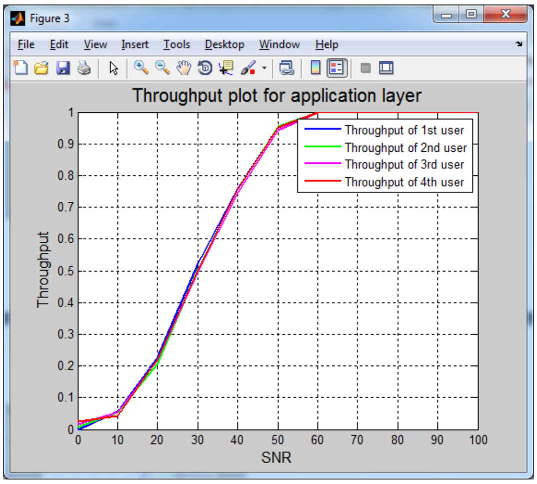

Fig. 10. Throughput plot for application layer

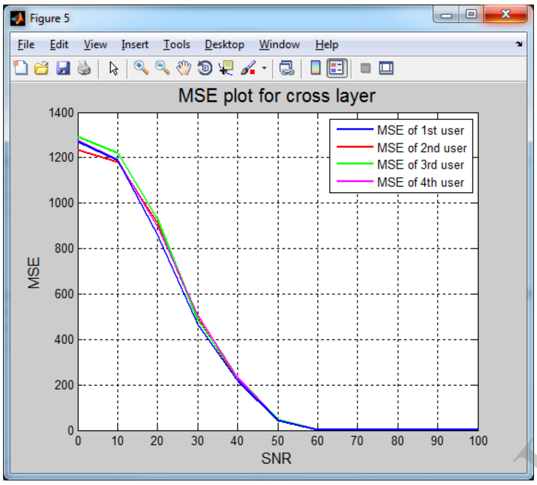

Fig. 11. MSE plot for cross layer

IV. CONCLUSION

A method is described for optimally allocating available resources while transmitting videos between users. The power allocation and subcarrier assignment strategy are jointly decided by each user's channel state information (CSI) and rate distortion (RD) characteristics. The simulation results show that the optimal allocation is achieved only if the product of the rate distortion slope and a physical layer metric related to the water filling solution is minimized for each band and each user. Mean Square Error (MSE) gets further reduced by addition of constant amplitude zero auto-correlation sequence (CAZAC) sequence.

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