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Qos-Based Optimal Resource Allocation for Multimedia Transmission in Wireless Networks

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Abstract

In this paper, aiming to improve the quality of multimedia transmission while satisfying the quality of service (QoS) requirements, we propose an optimal subcarrier allocation by jointly considering the video coding rate and the available power resource. We jointly analyses the effects on the performance of multimedia transmission from video coding rate at the application layer as well as the power control at the physical layer. This proposed joint power and subcarrier allocation algorithm in MIMO OFDM systems enables us both to overcome the challenge of full CSI (channel state information) with RD (the rate-distortion) to make minimum of the distortion of each users under delay and power constraints. Simulation results show that the proposed optimal subcarrier allocation algorithm improves the multimedia transmission quality considerably through the comparison with the resource allocation algorithms only use a single layer of information.

Keywords

QoS, Cross Layer Design, Resource Allocation, Wireless Networks

1. Introduction

Over the past two decades or so, the wireless communication industry has been experiencing a huge technological revolution. The development of physical (PHY) layer transmission schemes, such as Multiple Input and Multiple Output (MIMO), Orthogonal Frequency Division Multiple Access (OFDMA), has obviously changed everyday life. OFDM makes a frequency access wideband channel into flat fading multiple sub-carriers, therefore drastically decreases the whole period of processing receiver. Thus, these flat subcarriers are located to each user and group in multicast or unicast networks respectively for transmission periods of time.

Meanwhile, new video compression techniques have dramatically improved the compression efficiency of video codecs. The u H.264/AVC (H.264 Advanced Video Coding) [1] has been shown to save up to 55% of the bits compared to prior MPEG standards. Most recently, the HEVC (High Efficiency Video Coding) [2] s proposed to the improvement over the coding efficiency for the H.264.

Along with the increasing demands on multimedia application, multimedia transmission is becoming one of the most popular services in future wireless networks [3] [4]. For multimedia transmission, the quality of service (QoS) is an important parameter to measure the system performance. QoS can be peak signal to noise ratio (PSNR) or video distortion [5] [6], etc. And QoS performance can be affected by the transmit power, the channel fading at the PHY layer, corresponding to the coding rate for media video at the APP layer. Therefore, in order to improve the quality of video transmission, all these factors from different protocol layers should be taken into consideration. For cellular network systems, research on cross-layer design across PHY and APP layer has effective improved video quality and increased network capacity. cross layer design across PHY and APP layer for the video transmission in wireless networks [7] [8], UEP (unequal error protection) [9] [10] and these error channel coding [11] [12] have been developed, The results of these works show that the quality of received video can be significantly enhanced by protecting the video data with different levels according to the more importance of the bits.

In this paper, we focus on cross layer optimization in a multiple access environment. We investigate the resource allocation strategy by jointly considering the physical layer information and the application layer information, With the goal of optimizing the overall system video performance, the PHY layer communication resources are allocated to the video users according to the demand of the multi-users.

The rest of the papers are written as following: Section II presents PHY layer and APP layer scheme, the same as the cross layer optimization. We will propose cross layer resource allocation in Section III, In Section IV Simulation results are showed, and in Section V, we will draw the conclusions.

2. System Model

We consider a MIMO OFDM network, where there are users transmitting their video streams to one access point (AP) through single hop route as shown in **Figure 1**. Assume that the network works in a steady state and each user transmits one video stream. The transmission process of video packet of each user can be modeled as a queueing process.

The arrival video packets from video encoder are first buffered in a queue, where they are waiting to be transmitted over the wireless channel. Since the video transmission process of each user involves multiple parameters (e.g., delay, video bit rate, transmission rate) from different protocol layers, we propose a cross layer transmission scheme to improve the performance of multimedia transmission system. The information exchanges among different layers are modeled as follows.

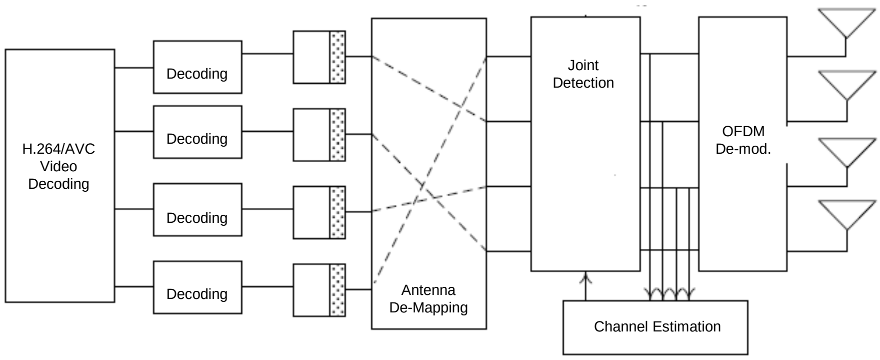

Figure 1. The structure of the proposed cross-layer MU-MIMO with Multimedia Communication systems.

2.1. Physical Layer Transmission Model

In this Section, we consider a central-controlling cellular OFDMA multimedia communication networks. We set the users as $k = \{1, 2, 3, \cdots, K\}$ where to the base station went to communicate media. The M is the number subcarrier. We can see $m = \{1, 2, \cdots, M\}$. We can occupy a total frequency factors as W(Hz). It is equal divide into each bandwidth of the main lobe. Every subcarriers is $\Delta W = W/M$ (Hz). The arrival video packets from video encoder are first buffered in a queue, where they are waiting to be transmitted over the wireless channel. To protect this information data, but it is possible for one user to obtain much more sub-carrier. All users adapt alphabet size of this modulation format, and adoptive QAM modulation is determined in the resource allocation scheme.

The user k transmits the video packet with power P_k under the maximum power constraint $P_k^{\max}$. The signal to interference plus noise ratio (SINR) for user k is expressed as

$$SINR_k = \frac{\gamma_k P_k G_k}{\Omega_K^2 + \sum_{i \neq k} P_j G_j} \tag{1}$$

where γ_k represents the spreading gain and G_k is the channel gain such as the large scale and small scale fading. Ω_K^2 expresses the noise power of user k. The corresponding link capacity of user is given as

$$C_k = B \log_2 \left(1 + SINR_k\right) \tag{2}$$

where B is the channel bandwidth. To improve the quality of multimedia transmission, same assumption as made in [13] that the network works in the high SINR region. This is reasonable since the large spreading gain is provided by the wireless networks. Therefore, the link capacity in (2) can be approximated as

$$C_k \approx B \log_2 \left(\frac{\gamma_k P_k G_k}{\Omega_K^2 + \sum_{i \neq k} P_j G_j} \right) \tag{3}.$$

2.2. Application Layer Model

Let T is the duration of data in GOP. H_k^m can be the complex channel. The rate can be express by u. The time slot is s for each sub-carrier. For the data duration in each GOP, then transmission rate of user k can be expressed:

$$\tilde{R}_k = \sum_{m=1}^{M} R_k^m \left(P_k^m, H_k^m\right) \Big/ T \tag{4}$$

Because the channel time slot is same to the duration. The data rate in each PHY layer link can be express:

$$R_k = \mu \sum_{m=1}^{M} R_k^m \left(P_k^m, H_k^m\right) \Big/ T \tag{5}$$

In Section 3, we will next needn't the channel errors and use (5), and increase the throughput for the whole system and scheme design, The performance for next wireless networks will be calculated and be simulated in Section 4.

3. Cross Layer Optimization Problem Formulation

The QoS ignores initially scheme the quality based pricing $P_i(Q_i)$ from the users content providers in the OFDMA network. The above symbolic rate allocation can be formulated as a basis for rate maximization expressions,

$$\begin{aligned} &\max . \sum_{i=1}^{N} n_i P_i\left(Q_i\right) \\ &s.t. \ \sum_{i=1}^{N} \frac{1}{m_i r_i} R^i\left(q_i, l_f\right) \le R_s, \\ &\sum_{i=1}^{N} P_i\left(Q_i\right) \le P_b \\ &q_{\min} \le q_i \le q_{\max} \end{aligned} \tag{6}$$

where R_s means the total symbol rate of the OFDMA system and n_i, $1 \le i \le N$ increasing to the optimal media video frame quantization the i^{th} media group. The quantities $Q_i = Q^i(q_i, l_f)$ and $R^i(q_i, l_f)$ denote the QoS and Ratio of the i^{th} media serial corresponding to the QoS parameter q_i and total bit rate l_f. N means the sum groups number. Let us assume that the maximum power constraint is P_b under the same subcarrier, and one carrier can only allocate to one user. The automatic modulation parameter m_i is the number of frames per bit and r_i as coding rate of the i^{th} media video frames, which is transferred automatically by the transmitter as channel coding. It can be only seen that the former question is convex in question and the optimization system can be automatically transferred to a standard from convex optimization question [14] by revising the optimization parameter as,

$$\min . -\sum_{i=1}^{N} n_i P_i\left(Q_i\right) \tag{7}$$

The all forever equation of convex optimization curve can be adaptively solved applying auto convex optimization storages which apply Karush-Kuhn-Tucker (KKT) solution. The Lagrangian function $L\left(\bar{q}, \lambda, \bar{\mu}, \bar{\delta}\right)$ for the former optimal maximization question is given as,

$$L\left(\overline{q},\lambda,\overline{\mu},\overline{\delta}\right)=-\sum_{i=1}^{N}n_i\left(\overline{\beta}_i q_i+\overline{\gamma}_i\right)$$
$$+\lambda\left(\sum_{i=1}^{N}k_i \mathrm{e}^{d_i\left(1-q_i/q_{\min}\right)}-R_s\right) \tag{8}$$
$$+\sum_{i=1}^{N}\mu_i\left(q_i-q_{\max}\right)+\sum_{i=1}^{N}\delta_i\left(q_{\min}-q_i\right)$$

where λ,μ_i,δ_i, $1 \leq i \leq N$ are Lagrange equations, $\overline{\beta}_i \triangleq e_i Q_{\max}^i Q_t\left(l_f\right)\beta_i$, $\overline{\gamma}_i \triangleq e_i Q_{\max}^i Q_t\left(l_f\right)\gamma_i$, and $R_i^{\max}$ is the maximum results increasing to the i^{th} video frame. The parameter k_i is defined as follow,

$$k_i \triangleq \frac{R_{\max}^i}{m_i r_i}\left(\frac{1-\mathrm{e}^{-c_t l_f/t_{\max}}}{1-\mathrm{e}^{-c_t}}\right) \tag{9}$$

Applying the KKT parameters for the former Lagrangian optimization function and letting with $\lambda \geq 0$, $\overline{\mu}_i \geq 0$, $\overline{\delta}_i \geq 0$, we can see,

$$-n_i\overline{\beta}_i-\lambda k_i\left(\frac{d_i}{q_{\min}}\right)\mathrm{e}^{d_i\left(1-q_i/q_{\min}\right)}+\mu_i-\delta_i=0 \tag{10}$$

From (6), the KKT maximum condition increasing to the rate maximization constraint is as follow,

$$\lambda\sum_{i=1}^{N}k_i \mathrm{e}^{d_i\left(1-q_i/q_{\min}\right)}-R_s=0 \tag{11}$$

Therefore, the Lagrangian maximization λ^* is increased as the optimal media video frame quantization setting $\mu_i=0$ and $\delta_i=0$ value adaptation (corresponding to above parameter maximization constraints) taken by obtain be obtained as,

$$\lambda^*=-\frac{q_{\min}}{R_s}\left(\sum_{j=1}^{N}\frac{\overline{\beta}_j n_j}{d_j}\right) \tag{12}$$

We transferred the above equations for λ^* in (10) increasing to the optimal media video frame quantization parameter q_i^* as,

$$q_i^*=\frac{q_{\min}-q_{\min}\ln\left(\dfrac{q_{\min}\overline{\beta}_{ii}m_i r_i}{\lambda^* k_j d_j}\right)}{d_j}$$
$$=\frac{q_{\min}-q_{\min}\ln\left(\dfrac{R_s}{k_i}\dfrac{n_i\overline{\beta}_i\left(d_i\right)^{-1}}{\sum_{j=1}^{N}n_j\left(d_i\right)^{-1}}\right)}{d_j} \tag{13}$$

The above equation obtains the optimal quantization parameter q_i^* of the media video frame maximization and time sub-carrier allocation of media video maximization. Thus the former video form allocation obtains an effective. With low computation complexity system to applying convex senders and are applicable of compared of optimal media video automatic both multicast and unicast systems.

Further, the proposed optimal framework for the code constrained time-frequency allocation conspiring reverse maximization not constricted to linear bidding models and can be mainly applied for a large store of utility equations. The corresponding framework for auction based reverse maximization will be formulated at,

$$
\begin{aligned}
&\max . \sum_{i=1}^{N} n_i \log_{10}\left(Q_i\right) \\
&s.t.\ \sum_{i=1}^{N} \frac{1}{m_i r_i} R^i\left(q_i, l_f\right) \le R_s \\
&\sum_{i=1}^{N} \log_{10}\left(Q_i\right) \le P_b \\
&q_{\min} \le q_i \le q_{\max}
\end{aligned}
\tag{14}
$$

The simulation results as following describe the proposed algorithms performance of media video rate allocations.

4. Simulation Results

In this section, we simulate the performance results for the MU-MIMO OFDM systems with an amount of 32 subcarriers. and the system power constrain is −150 dB/Hz.. Under the given power constraint in each bandwidth, power can be expressed as $P_t = 200$ mW, of which has each bandwidth of 100 kHz. We can denote the path-loss constrain is $\gamma = 2.45$. Moreover, α is a Rayleigh fading variable. For each time slot i the optimization system can be automatically transferred.

In simulation, the aim of the allocations is to be outputted to the rate and subcarrier allocation corresponding to SER. **Figure 2** describe a set of simulate results. The figure allocate to the $\text{SER}_t = 0.2$ of these simulate results. From **Figure 2**, we can see, with cross layer design, requirement of the packet loss in APP layer varying with the channel fading. Hence the power control coefficients can be made independent of frequency and their effect on the data rate obtained by QAM. The valid raw SER is about 40% toward to SER. In one word, to obtain the target SER under 16QAM, the rate allocation is bigger than the result of the other OFDMA system.

We choose subcarriers from 2 to 16 in a system of 64 users, and compare the PSNR with channel fading. When serving mobile users, there is a finite limit to the users that can be served simultaneously because of the unknown required for CSI acquisition. From the figure, the simulation of the algorithm is increase under this value. That is to say, when the SER is becoming low, the **Figure 2** shows mainly sensitive limit to the users, which is resulting in too much video media frames being allocated.

When the value of SER is decrease, the result can be shown will be made. This simulation to can be shown in **Figure 3**, where the PSNR is applied f under this value. That is to say 8 users computing for resources which here are 64 sub-carriers are obtained. We can see the users SER and compare the performance of the encoder one and the decoder one. From the figure, we can see the perform-

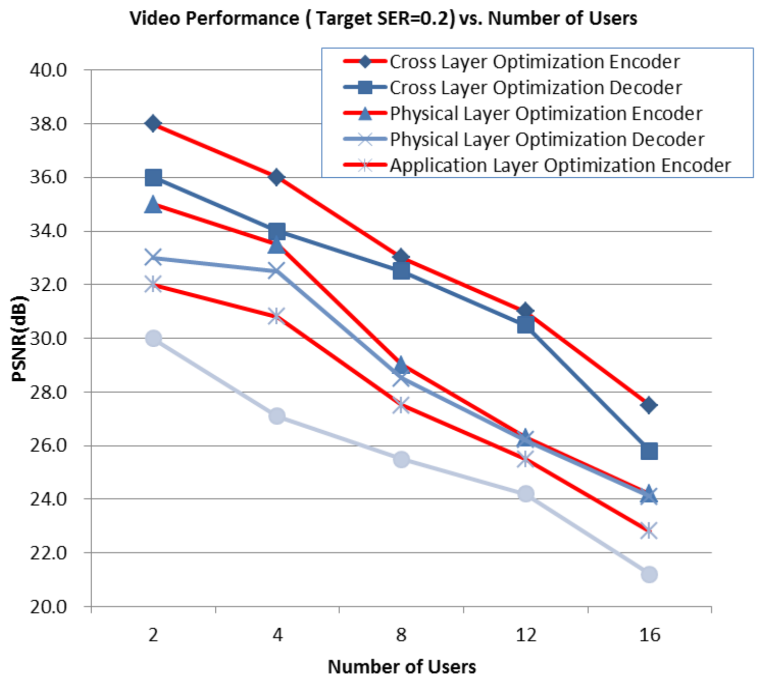

Figure 2. Average media video quality vs. number of users

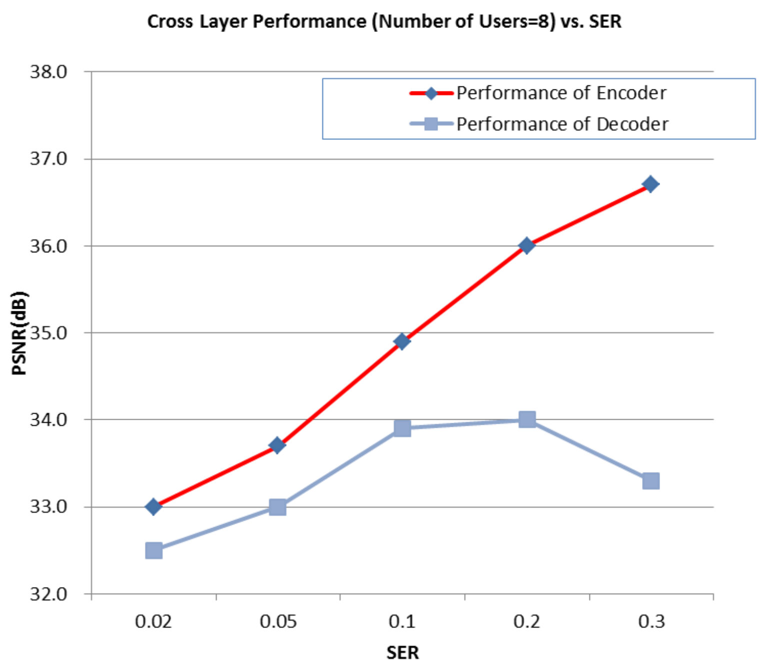

Figure 3. User Performance Comparison Cross layer approach and the baseline approach based on iterative water-filling.

ance of system will adaptively increasing as the target SER in the system would compare a resource algorithm under the target SER is showed to improve. When the performance shows with $SER_t = 0.2$. Because of increasing, fact SERs are adaptively decreased with target SERs.

Our simulation results show that the optimal cross-layer design is achieved highly performance according to the curve of RD. With the channel fading in a

PHY layer, we use the water filling algorithm to obtain the throughput for every user. Compared to a resource algorithm using either only PHY layer or only APP layer, the cross layer optimization significantly improved the performance of the system. It is also achieved highly throughout and low delay in this numerical results.

5. Conclusion

In this paper, aiming to improve the quality of multimedia transmission while satisfying the quality of service (QoS) requirements, we propose an optimal subcarrier allocation by jointly considering the video coding rate and the available power resource. We jointly analyses the effects on the performance of multimedia transmission from video coding rate at the application layer as well as the power control at the physical layer. This proposed joint power and subcarrier allocation algorithm in MIMO OFDM systems enables us both to overcome the challenge of full CSI (channel state information) with RD (the rate-distortion) to make minimum of the distortion of each users under delay and power constraints. Simulation results show that the proposed optimal subcarrier allocation algorithm improves the multimedia transmission quality considerably through the comparison with the resource allocation algorithms only use a single layer of information.

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