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Energy Efficient Power Allocation for Distributed MIMO System

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Abstract

The rapid increasing demands of multi-media applications have busted the improvement of video transmission. By the increase of multimedia transmission, quality of experience (QoE) has become the hot topic of the wireless networks' research. This paper proposes a QoE-aware resource allocation algorithm in MIMO-OFDM Networks. The power allocation estimation is formulated to maximize according to QoE by considering the video transmission rate and the subcarrier schemes under the constraint of minimum power. In this paper, we will analyses the the performance of video transmission from transmission rate at the application layer to the power allocation at the physical layer. From simulation results, we can see that the proposed subcarrier allocation algorithm maximizes the video QoE by minimizing the sum distortion of multi-users in MIMO networks with power constraints.

Keywords

QoE, Cross Layer Design, Resource Allocation, MIMO

1. Introduction

The rapid increasing demands of multi-media applications have busted the improvement of video transmission [1]. The development of physical (PHY) layer transmission schemes, such as Multiple Input and Multiple Output (MIMO) antennas, as well as multiple access schemes, e.g., Orthogonal Frequency Division Multiple Access (OFDMA), has obviously changed everyday life. The concept of quality of experience (QoE) means that we can evaluate the performance of communication networks and services under the subjective opinions from application users [2]. Many researchers have proposed the equations of QoS-QoE, which could reflect the relation between QoS and QoE parameter [3] [4] [5]. In order to optimize the resource allocation during media video transmissions in next LET, it is necessary to propose an improved resource allocation driven by QoE parameter [5].

Meanwhile, new video compression techniques have dramatically improved the compression efficiency of video codecs. The H.264/ AVC (H.264 Advanced Video Coding) [6] has been shown to save up to 55% of the bits compared to prior MPEG standards. Most recently, the HEVC (High Efficiency Video Coding) [7] is 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 [8] [9].

Recently, many researchers have been proposed some scheme for videos transitions over LET systems, which both PHY layer and APP layer parameter are considered to improve QoE of users [10] [11]. The performance of QoS-aware system can be improved considering the channel condition and RD at APP layer. In [11], an optimal subcarrier allocation for minimizing RD over Massive-MIMO systems is proposed, where video quality and channel capacity are considered. In [12], authors proposed perspectives and research challenges for QoE in video transmission over wireless networks.

In this paper, we focus on QoE-aware 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 QoE 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**.

2.1. MIMO System 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). 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

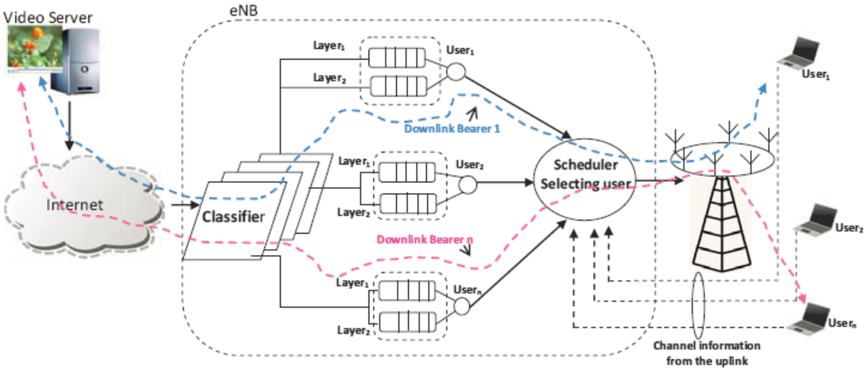

Figure 1. The structure of the proposed cross-layer transmission in MU-MIMO Communication systems.

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. 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. QoE Evaluation of Multiuser

QoE is an option-related metric which is important factor for future LTE systems. We use utility functions to describe QoE for multi-users in varied applications. The QoE of user *i* can be expressed by $Q(\square)$ which is the quality function of systems. In this section, we use a QoE function, similar to [13]. It concludes a concave function of the rates. For a mutli-user *i* under the same base station, corresponding to the rate R_i, the QoE of user *i* can be described as:

$$Q_i(R_i) = \frac{\ln(1 + R_i)}{\ln(1 + R_i^{req})} \tag{4}$$

where R_i^{req} is t data rate of the *i* user requesting.

2.3. Video RD Characteristics

Because the video is expressed as GOPs, this RD function is described under a GOP-by-GOP. Set $D_i^k(\sigma)$ is the rate distortion function of user *i* in time slot *k*. For each GOP of user, the MSE distortion can be expressed as [14] [15]

$$D_i^k(\sigma) = \alpha_i + \frac{w_i}{B + \eta_i} \tag{5}$$

where α_i, w_i and η_i are constants, which will be jointly optimized by the PHY layer parameters by the cross layer design.

We put (4) into (5), then (5) can be written,

$$D_i^k(\sigma) = \alpha_i + \frac{\dfrac{w_i}{w \bullet T_s / T_0}}{\sum_{m=1}^{M} \mu R_i^m(P_i^m, H_i^m) + \dfrac{\eta_i}{\eta \bullet T_s / T_0}} \tag{6}$$

The QoE ignores the quality according to pricing $P_i(Q_i)$ from the users requirement in the MIMO-OFDMA network.

$$\max. \quad \sum_{n=1}^{N} \sum_{i \in I} Q(R_i^{t_n}) - \gamma \Phi(R_i^{t_n} - R_s)$$

$$s.t. \quad \sum_{i=1}^{N} \frac{1}{m_i r_i} R^i(q_i, l_f) \le R_s,$$

$$\sum_{i=1}^{N} P_i(Q_i) \le P_b$$

$$q_{\min} \le q_i \le q_{\max} \tag{7}$$

Note γ is a quality parameter from the user. $\Phi(\square)$ is a quadratic equation for rate restrict. Thus, the $Q_i = Q^i(q_i, l_f)$ and $R^i(q_i, l_f)$ express the QoE quality parameter corresponding to the quantization value q_i. We assume the same-length frame rate l_f and power constraint of P_b for each user. We also assume the adaptive modulation parameter is m_i.

We can see (7) is convex and convert it into a standard form convex optimization problem [14] by modifying the optimization function,

$$\min. \quad -\sum_{n=1}^{N} \sum_{i \in I} Q(R_i^{t_n}) - \gamma \Phi(R_i^{t_n} - R_s) \tag{8}$$

We can apply employ the Karush-Kuhn-Tucker (KKT) framework to (8). The Lagrangian function $L(\bar{q}, \lambda, \bar{\mu}, \bar{\delta})$ is,

$$\begin{aligned} L(\bar{q}, \lambda, \bar{\mu}, \bar{\delta}) = {} & -\sum_{i=1}^{N} n_i(\bar{\beta}_i q_i + \bar{\gamma}_i) \\ & + \lambda\Big(\sum_{i=1}^{N} k_i e^{d_i(1 - q_i/q_{\min})} - R_s\Big) \\ & + \sum_{i=1}^{N} \mu_i(q_i - q_{\max}) + \sum_{i=1}^{N} \delta_i(q_{\min} - q_i) \end{aligned} \tag{9}$$

where λ, μ_i, δ_i, $1 \le i \le N$ are Lagrange multipliers, $\bar{\beta}_i \,\square\, e_i Q_{\max}^i Q_t(l_f) \beta_i$, $\bar{\gamma}_i \,\square\, e_i Q_{\max}^i Q_t(l_f) \gamma_i$, We set $R_{\max}^i$ is the maximum rate of the i^{th} video transmission. The quantity k_i is as follow,

$$k_i \,\square\, \frac{R_{\max}^i}{m_i r_i}\Big(\frac{1 - e^{-c_t l_f / t_{\max}}}{1 - e^{-c_t}}\Big) \tag{10}$$

we obtain,

$$-n_i \bar{\beta}_i - \lambda k_i \left(\frac{d_i}{q_{\min}}\right) e^{d_i(1-q_i/q_{\min})} + \mu_i - \delta_i = 0 \tag{11}$$

From (11), we can obtain the KKT complementary condition given as,

$$\lambda \sum_{i=1}^{N} k_i e^{d_i(1-q_i/q_{\min})} - R_s = 0 \tag{12}$$

From (12), we set $\mu_i = 0$ and $\delta_i = 0$, the Lagrangian multiplier λ^* can be expressed as,

$$\lambda^* = -\frac{q_{\min}}{R_s}\left(\sum_{j=1}^{N} \frac{\bar{\beta}_j n_j}{d_j}\right) \tag{13}$$

We substitute the above expression for the optimal quantization parameter q_i^* and then,

$$\begin{aligned} q_i^* &= \frac{q_{\min} - q_{\min} \ln\left(\dfrac{q_{\min} \bar{\beta}_{ii} m_i r_i}{\lambda^* k_j d_j}\right)}{d_j} \\ &= \frac{q_{\min} - q_{\min} \ln\left(\dfrac{R_s}{k_i} \dfrac{n_i \bar{\beta}_i (d_i)^{-1}}{\sum_{j=1}^{N} n_j (d_i)^{-1}}\right)}{d_j} \end{aligned} \tag{14}$$

The above expression can obtain the optimal quantization parameter q_i^* for resource allocation. The (14) has low computational complexity scheme for optimal video transmission for both unicast and multicast surrounding. This proposed joint power and subcarrier allocation algorithm in MIMO OFDM systems enables us both to overcome the challenge of full CSI. We can get optimal subcarrier and power allocation by iterative as **Table 1**.

Table 1. Iterative Subcarrier and Power Allocation.

Algorithm 1. Iterative Subcarrier and Power Allocation

```
Input the QoE of user i according to (4);
Initialize $p_i$, $q_i$
procedure ITERATION
    repeat
        $\mu_i = 0$ and $\delta_i = 0$
        for $k = 1 : M$ do
            repeat
                Calculate $q_i$ according to (14);
            until $q_i$ reaches the QoE of user $i$;
        end for
        Update $\lambda^*$, k_i according to(10) and (13);
        Update $p_i$, $q_i$, Which are used in the next iteration;
    until Convergence;
end procedure
```

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 −120 dB/Hz.. Under the given power constraint in each bandwidth, power can be expressed as Pt = 200 mW, of which has each bandwidth of 100 kHz. We can denote the path-loss con-strain 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 the number of users. **Figure 2** describe a set of 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 PSNR is about 40% toward to SER. In one word, to obtain the target PSNR under 16QAM, the rate allocation is bigger than the result of the other OFDMA system.

When the transmission power is decrease, the result can be shown will be made. This simulation can be shown in **Figure 3 Figure 4**, where the PSNR is applied under this value. When the value of power 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.

Our simulation results show that the optimal cross-layer design is achieved highly performance according to the curve of QoE. Compared to a resource algorithm using either only PHY layer or only APP layer, the cross layer optimization significantly improved the performance of the sys-tem. It is also achieved highly throughout and low delay in this numerical results.

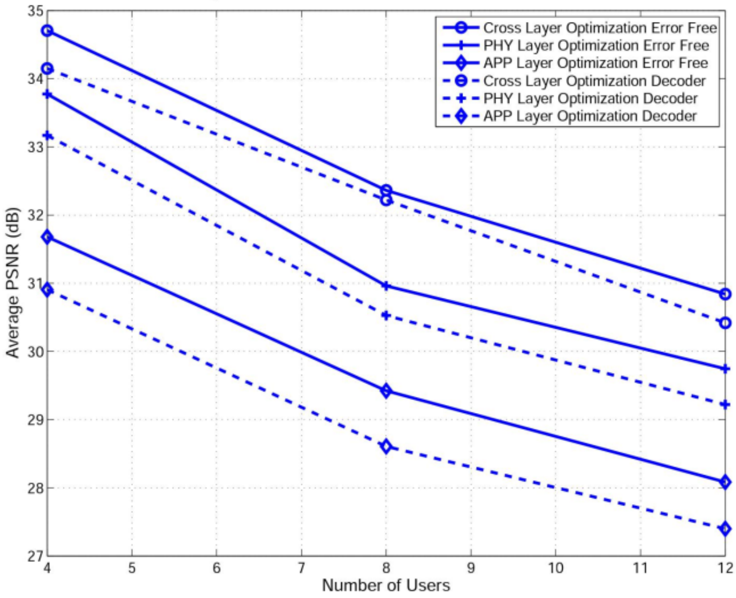

Figure 2. Average media video quality vs. number of users.

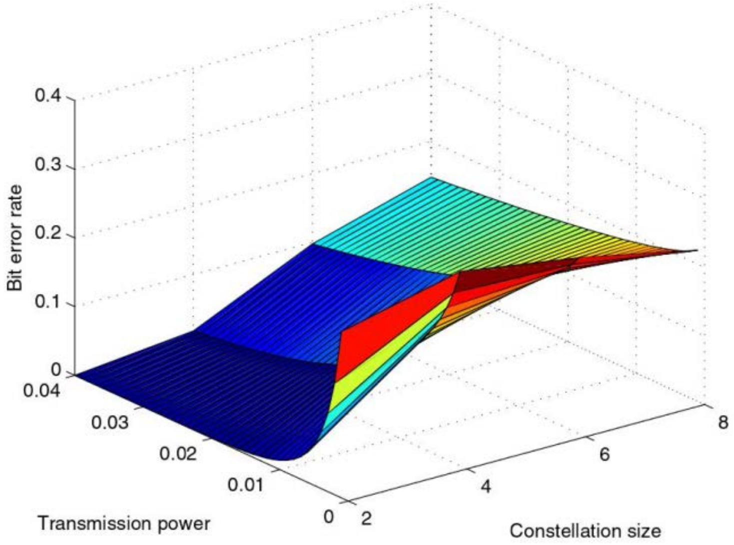

Figure 3. Bit error rate under different power and constellation size.

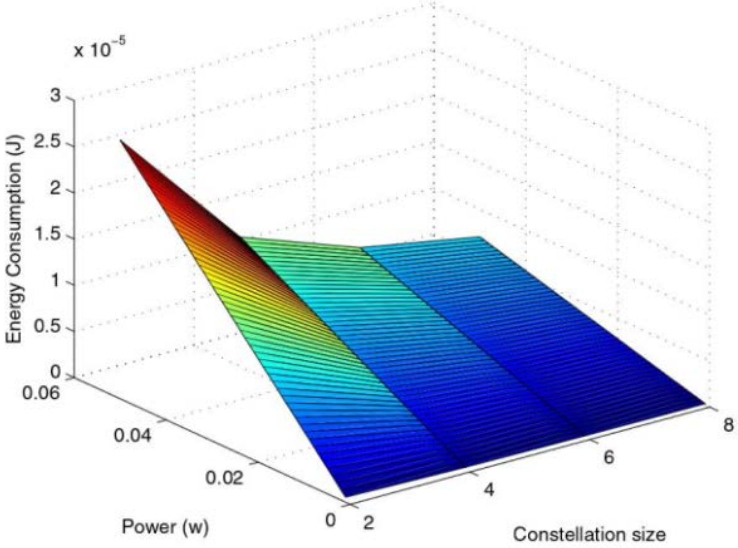

Figure 4. Energy consumption with different power and constellation size.

5. Conclusion

In this paper, aiming to improve the quality of multimedia transmission while satisfying the QoE 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 to make minimum of the distortion of each users under delay and power constraints. Simulation results show that the proposed optimal power 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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