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EEMA Scheme for Multi-User System

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Abstract: - In this paper we demonstrates development of the energy efficiency (EE) of multi-user multiple-input multiple-output (MIMO) orthogonal frequency-division multiple access (OFDMA) system, an Energy-efficient multiple access (EMA) scheme is proposed. It improves EE by selecting either time-division multiple access (TDMA) or space-division multiple access (SDMA) based on the no. of users or power consumption. Here, we introduced normalization process for power in OFDM system to improve the power gain. Numerical results verify that the EE and power gain can be significantly improved through the proposed EMA scheme.

Key Words- Energy efficiency (EE), channel access method, multiple access method, time-division multiple access (TDMA), space-division multiple access (SDMA), orthogonal frequency division multiple access (OFDMA).

1. INTRODUCTION

A multiple-input multiple-output (MIMO) system consists of multiple antennas at the transmitter and receiver. The energy efficient transmission in MIMO system has been paid increasing attention in recent years because multiple input multiple-output (MIMO) technology provides extra degrees of freedom and brings multiplexing and diversity gains. As a result, multiuser MIMO (MU-MIMO) transmission has attracted a lot of research interest in the past few decades. In the literature, significant efforts have been dedicated to improve the EE of wireless systems. A modulation strategy is introduced that minimizes the total energy consumption for transmitting a given number of bits in a single input and single output (SISO) AWGN channel [1]. A coordinated power allocation method is developed to balance the weighted SINR in a multi-cell massive multiple input single output (MISO) downlink system [2]. An energy-efficient pilot design in downlink system is studied for a single user (SU) case and the optimal overall transmit power and the power allocation between pilots and data symbols are investigated [3]. In SU communications, the quasiconcavity of EE over an achievable rate is well defined [4], [5], [6] but the trend of the MU communications over the rate is unclear.

2. CONCEPTUAL MODEL

Consider an antenna system with M transmitters and U receivers (users) with N orthogonal frequency sub-bands. Denote a channel matrix of sub-band n by Hn. The channel is assumed to be static for T slots and vary in every T slots independently. Each and every sub-band supports K users where K ≤ T. Throughout the paper, we assume that KN≥U. The EE of an EMA system is defined as

$$\mathrm{EE}_2 = \frac{UR}{c\sum_{n\in\mathcal{N}} P_{\mathrm{tx},n} + \max\{L_n\}P_{\mathrm{fix}}},$$

where R is a fixed target rate with allowing unlimited transmit power and ideal coding and decoding for each user; c represents system inefficiency (c > 1) that is caused by overhead PC at RF circuits; Ptx,n is transmit power on sub band n; Pfix is the fixed PC per time slot; Ln is the number of time slots used for transmission on sub-band n; and max{·} follows the fact that an RF chain should be turned on if there is at least one time slot to be transmitted over any sub-band. The first term of the denominator in (1) is a transmit power dependent (TPD) PC term and the second term is a transmit power independent (TPI) PC term. TDMA activates all T time slots which results in the high TPI PC, due to which EE significantly decreases. While the SDMA decrease the number of time slots by increasing the achievable rate for each time slot with higher TPD PC. This observation motivates us to propose a multiple access (MA) selection method between TDMA and SDMA, which is EMA for each sub-band. In the next section, we derive the PC of TDMA and SDMA precisely and propose three suboptimal EMA algorithms.

3. EMA ALGORITHMS

We find EMA algorithm that maximizes the lower bound of EE in (1) and it is realized by minimizing PC per sub-band n defined as

$$PC_n \triangleq cP_{tx,n} + L_n P_{fix}$$

We derive the minimum PC of (2) that achieves R for any user in a TDMA or SDMA mode to determine the MA for each sub-band.

A. PC of TDMA

We first derive the PC of TDMA with OFDMA. To allow the target rate R of user u through the sub-band with bandwidth Ω and variance ∑2 the power control factor pu is lower bounded as

$$p_u \geq \sigma^2\left(2^{\frac{R}{\Omega}}-1\right)g_u^{-1}\ \forall u\epsilon U$$

Where is the channel matrix Therefore, the minimum transmit power for achieving R is derived for the TDMA user u as

$$P_{tx,n}^{TDMA} = g_u \min\{p_u\} = \sigma^2\left(2^{\frac{R}{\Omega}}-1\right)$$

Since K users are supported through K time slots, the PC in (2) is derived for the TDMA as follows:

$$\begin{aligned} PC_n^{TDMA} &= c\textstyle\sum_{u\epsilon U_n} P_{tx,u}^{TDMA} + KP_{fix} \\ &= cK\sigma^2\left(2^{\frac{R}{\Omega}}-1\right) + KP_{fix} \end{aligned}$$

B. PC of SDMA Next, the PC of SDMA with OFDMA is derived. Since the SDMA can be implemented with Ln time slots (1 ≤ Ln ≤ T), each sub-band supports the K users with less time slots in fair comparison with TDMA. To allow the target rate R of user u ∈Un with Ln SDMA slots through the bandwidth Ω, the minimum required transmit power on each sub-band is derived for one SDMA time slot as follows:

$$\begin{aligned} PC_{tx,n}^{SDMA} &= \min\{\textstyle\sum_{m\epsilon M}\|w_{mn}^{r}\sqrt{Q_n}\|^2\} \\ &= \sigma^2\left(2^{\frac{R}{L_n\Omega}}-1\right)\|W_n\|_F^2 \end{aligned}$$

where||.||F is the Frobenius norm of a matrix and Wn is the pseudo-inverse of the channel matrix. Since Ln SDMA time slots are used, the PC in (2) is derived for the SDMA as (1 ≤ Ln ≤ T)

$$PC_n^{SDMA} = cL_n PC_{tx,n}^{SDMA} + L_n P_{fix}$$
$$= cL_n \sigma^2 \left(2^{\frac{R}{L_n \Omega}} - 1\right) ||W_n||_F^2 + L_n P_{fix}$$

C. EMA Algorithm for each sub-band:

To find the optimal MA for each sub-band n, we need to compare PC_n^{SDMA} in (5) and PC_n^{SDMA} in (7), which requires Õ(TN) time complexity. For large N, as the complexity is more, we find the optimal number of SDMA slots for each sub-band n, denoted by. This can be obtained by l_n assuming a floating value l_n instead of Ln in (7). Now we get a differentiable function over as

$$f(l_n) = cl_n \sigma^2 \left(2^{\frac{R}{l_n \Omega}} - 1\right) ||W_n||_F^2 + l_n P_{fix}$$

Now make the first derivative of $f(l_n)$ with respect to l_n be zero to find the minimum value of. l_n^*.Thus,

$$l_n^* = \frac{R \ln 2}{\Omega\left(W\left(\frac{1}{\exp(1)} \frac{P_{fix}}{c\sigma^2 ||W_n||_F^2 - 1}\right) + 1\right)}$$

To guarantee EE improvement, we further compare the EE of a pure TDMA with EE of the EMA algorithm for each sub-band, and then determine the MA technique that achieves the higher EE.

D. EMA Algorithm

For the whole sub-band In this algorithm, we consider an EMA algorithm that selects either pure TDMA or SDMA for the whole sub-band. This further reduces the complexity. The total PC of SDMA for all sub-bands is defined from (8) as

$$f(\{L_n\}) = c \sum_{n \in N} L_n \sigma^2 \left(2^{\frac{R}{L_n \Omega}} - 1\right) ||W_n||_F^2 \max\{L_n\} P_{fix}$$

Now make the first derivative of $f(\{Ln\})$ with respect to Ln be zero to find the optimal {. The optimal Ln's that minimize (10) are identical to one another, i.e., =L*. This allows one-dimensional line search from 1 to T to find L* optimally, which requires Õ(T) time complexity.

E. Normalized EMA algorithm: The general communication system is depicted as

Based on the transmit power ST and receive power SR, the channel power gain is defined as SR /ST. For a non-ISI channel, using a flat transmit power spectrum, the channel power gain is defined as

$$\frac{S_R}{S_T} = \int_{-\infty}^{\infty} |H(f)|^2 \, df$$

Which is usually normalized to unity? One should be aware that the channel gain can be greater than unity in frequency ranges near the peak of the frequency response. When dealing with real channels, it is common to normalize the frequency response so that the maximum value is unity. Thus, we shall also normalize the power frequency to unity. This ensures that the minimum Eb/N0 is always -1.6 dB. That is, we shall normalize the frequency response such that the - 3 dB bandwidth is 1 Hz. We shall call this as peak bandwidth normalization. For an m-tap channel with unit energy normalization |H(f)|2 , the frequency response with peak bandwidth normalization is given as

$$|G(f)|^2 = \frac{1}{M} \left|H\left(\frac{f}{n}\right)\right|^2 \quad \text{----12}$$

Where M is the maximum value of |H(f)| 2 and n is the scaling factor which makes the -3 dB bandwidth of |G(f)| 2 equal to 1. Normalization by the maximum value ensures the channel maximum power gain is unity. Thus, no particular channel has a gain over another channel in the frequency ranges where the transmit power is concentrated.

5. CONCLUSION

In this paper, we have proposed energy efficiency (EE)- aware multiple access (EMA) scheme. Based on the required power consumption to achieve the fixed feasible target rates, the EMA chooses either a time-division multiple access or spatial-division multiple access (SDMA) for each sub-band. For the EE-aware SDMA, optimal number of SDMA slots has been derived. It has been shown that the SDMA is most likely selected if

i) The target rate is high,

ii) The transmit-power-independent power consumption is high or

iii) The channel quality is good. Simple EMA algorithms have been devised and their impact on EE and gain improvement has been verified by simulation. The results have provided valuable insight to extend EE-aware system with the consideration of

i) the uncertainty of channel state information and ii) power consumption of uplink communications.

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