Channel Capacity of MISO or SIMO Systems in Multi-user Data Networks.

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1. Introduction

Recently, increasing demands for wireless services are driving the demand to increase system capacity. Multi-element antenna techniques and radio resource management by employing packet scheduling are the key techniques that increase system capacity in packet switched systems [1-3]. The capacity of multi-input mult-output (MIMO) systems has been studied mainly in link level model. Until now the interaction between packet scheduling and MIMO techniques has been studied in [2-5]. Most studies have analyzed the combined performance of MIMO techniques in accordance with scheduling by using a system level simulation model [3-4] while only a study has assessed the interactions between multiuser diversity and spatial diversity by using an analytical model [5]. However, [5] is confined to the analysis on the impact of a greedy scheduling algorithm that routes each transmission to the user along with the best instantaneous channel conditions on space-time block coding (STBC).

In this paper, expressions for the channel capacity of multi-input single-outpu (MISO) and single-input multi-ouput (SIMO) systems paired with a greedy scheduling algorithm are presented. Spectral efficiency is obtained from the distribution of the channel capacity combined by a greedy scheduler when the transmitter adapts to channel variations using a constant power variable rate strategy.

2. System Model and Distribution of System Capacity

In this paper we assume a multi-user MIMO system with no channel state information (CSI) at the transmitter, perfect CSI at the receiver, and employing equal power transmission over a frequency flat Rayleigh fading channel.

The n_R-dimensional signal $\mathbf{r}_k$ at the output of the receiving antennas for k th user in flat fading can be written as

$$\mathbf{r}_k = \mathbf{H}_k \mathbf{s}_k + \mathbf{n}_k , \quad (1)$$

where $\mathbf{s}_k$ is the n_T-dimensional transmitted vector for the k th user, and $\mathbf{H}_k$ is an $n_R \times n_T$

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complex channel gain matrix of the k th user. The AWGN vector of the k th user $\mathbf{n}_k$ consists of n_R independent noise components of modulus variance normalized to 1. The acheivable capacity the system with no CSI at the transmitter is given by [1-2]

$$C_k = \log_2\left[\det\left(\mathbf{I}_m + \frac{\rho_k}{n_T}\mathbf{W}\right)\right], \tag{2}$$

where ρ_k is the average signal-to-noise ratio (SNR) per recevie antenna of the k th user, $\mathbf{I}_m$ is the $m \times m$ identity matrix, $m = \min(n_R, n_T)$, $n = \max(n_R, n_T)$, and the $m \times m$ matrix $\mathbf{W}$ is given by

$$\mathbf{W} = \begin{cases} \mathbf{H}\mathbf{H}^H & n_R < n_T \\ \mathbf{H}^H\mathbf{H} & n_R > n_T \end{cases}, \tag{3}$$

where $(\cdot)^H$ denotes the conjugate transpose and the index k is omitted by the assumption of identical fading statistics for all mobile users. Let $\boldsymbol{\lambda} = [\lambda_1, \ldots, \lambda_m]^T$ denote the nonzero eigenvalues of the $\mathbf{W}$. Then, the capacity (2) can be written as

$$C_k = \sum_{i=1}^{m} \log_2\left(1 + \frac{\rho_k}{n_T}\lambda_i\right). \tag{4}$$

The joint probability density function (PDF) of the ordered eigenvalues, $\lambda_1 \geq \lambda_2 \cdots \geq \lambda_m$, of $\mathbf{W}$ is [1-2]

$$f_{\boldsymbol{\lambda}}(x_1, \ldots, x_m) = K \prod_{i=1}^{m} e^{-x_i} x_i^{n-m} \prod_{i<j}^{m} (x_i - x_j)^2, \tag{5}$$

where K is a normalizing constant given by

$$K = \frac{\pi^{m(m-1)}}{\tilde{\Gamma}_m(n)\tilde{\Gamma}_m(m)} \tag{6}$$

with $\tilde{\Gamma}_m(x) = \pi^{m(m-1)/2} \prod_{i=1}^{m} (x-i)!$.

In this paper, m is restricted to one, corresponding either to a MISO or SIMO system. Applying the required transformations, the PDF and the cumulative distribution function of C are given by

$$f_C(x) = \frac{\ln 2}{(\rho/n_T)(n-1)!} 2^x e^{-g(x)} g(x)^{n-1}, \qquad x \geq 0 \tag{7}$$

$$F_C(x) = 1 - e^{-g(x)} \sum_{i=0}^{n-1} \frac{g(x)^{n-i-1}}{(n-i-1)!}, \qquad x \geq 0 \tag{8}$$

where $g(x) = (2^x - 1)/(\rho/n_T)$.

The greedy scheduler decides to send a packet to the user k^* who has the best supportable data rate. Thus, the scheduling algorithm can be expressed as:

$$k^* = \arg \max_{k \in \{1,2,\cdots,K\}} C_k . \tag{9}$$

Therefore, The PDF of the achievable channel capacity combined by the greedy scheduler, $\tilde{C}$, can be computed using order statistics [6] on the assumption of identical distribution of ρ_k.

$$f_{\tilde{C}}(x) = K f_C(x) \left(F_C(x)\right)^{K-1}, \qquad x \geq 0 \tag{10}$$

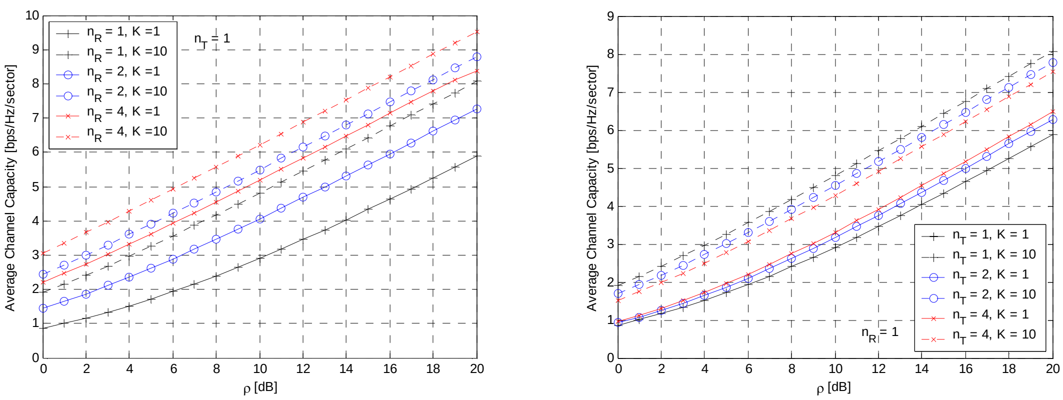
where K is the number of users in the sector.

3. Numerical result and Discussion

Figure 1 shows plots of average channel capacity per sector as a function of the average SNR for MISO and SIMO systems and figure 2 shows show the average channel capacity as a function of the number of users. The capacity results of MISO show that a larger number of transmit antennas increases space diversity gain at each link but decreases the system capacity, indicating that space diversity without array gain has a bad effect on multiuser diversity. Diversity gain not only reduces the severity of destructive fades but also the probability of encountering very high constructive fading peaks, which has destructive impacts on multiuser diversity. This result agrees well with the results of system level simulation in [3-4]. The capacity results of SIMO show that a larger number of transmit antennas increases the system capacity in spite of increased space diversity gain at each link, indicating that array gain of SIMO improves the system capacity even though space diversity gain reduces multiuser diversity gain.

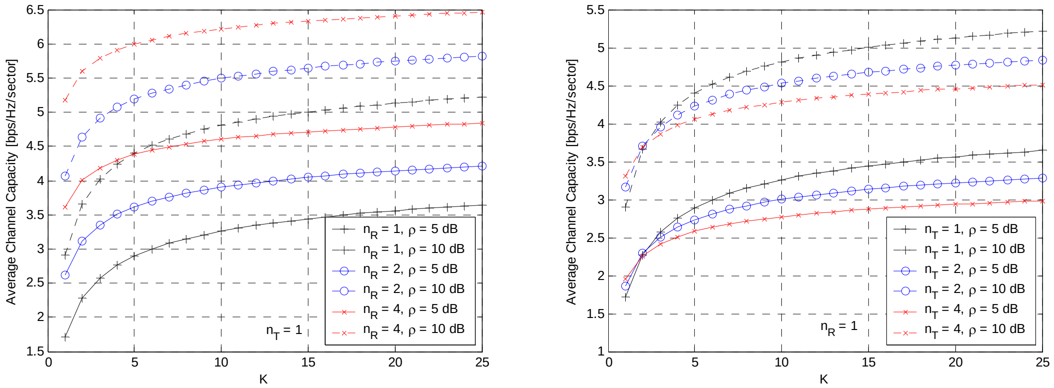
4. Conclusions

In this paper, we have derived expressions for the density and distribution function for channel capacity of MISO and SIMO systems paired with a greedy scheduling algorithm. Numerical results show that the MISO system provides full order diversity gain only shows destructive impact on multiuser diversity. On the other hand, the SIMO system which has an array gain provide an additional gain with multiuser diversity, even though a space diversity reduces multiuser diversity gain.



(a)SIMO (b)MISO

Fig.1. Average channel capacity vs. average SNR.



(a)SIMO (b)MISO

Fig.2. Average channel capacity vs. number of users.

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