A Low Complexity Antenna Selection Algorithm for MIMO System

Sasmita Padhy¹, M. Santhi Sri Rukmini², Susanta Kumar Das³, and Swadhin Mishra⁴

¹Department of Computer Science and Engineering, GIIT, Berhampur, Odisha, India, E-mail: pinky.sasmita@gmail.com
²Department of ECE, Vignan’s Lara Institute of Technology and Science, Guntur, A.P., India, E-mail: mssrukmini@yahoo.co.in
³Department of Computer Science and Engineering, Berhampur University, Odisha, India, E-mail: dr.dassusanta@yahoo.co.in
⁴Department of Electronics and Telecomm Engineering, NIST, Berhampur, Odisha, India, E-mail: swadhin.mishra@gmail.com

Abstract: The performance of Multiple-input multiple-output (MIMO) system can be improved by employing a large number of antennas than actually used and selecting the optimal subset based on the channel state information at receiver. Antenna selection is used for increasing the channel capacity of MIMO systems and reducing the systems complexity and cost of RF chains. In this paper we propose an effective antenna selection algorithm which minimizes computational time when calculating channel capacity. Simulation result of proposed algorithm achieves high performance in calculating channel capacity.

Keywords: MIMO, Computational complexity, Antenna selection, Channel capacity.

1. INTRODUCTION

A MIMO system is an intelligent antenna technology in wireless mobile communication, which can improve the system performance by increasing the system capacity and improving the link quality of wireless transmission [1–3] without increasing the bandwidth of the channel. In typical MIMO systems, the transmitter and receiver employ the same number of antennas, also RF chains (consists of A/D transceiver, amplifier, modulator, etc.) which causes high implementation cost. The numbers of RF chains used are less then the number of antennas as RF chains are more cost then antennas. Therefore an optimal subset of available antennas is chosen to fit RF chains. The main aim of antenna selection algorithm is to maximize the channel capacity. We know that, a measure of how much information that can be transmitted and received with a negligible probability of error is called the channel capacity. The selection of optimum antenna requires an exhaustive search of all possible combinations but it has high computational complexity according to obeying exponential quality [4, 5]. Zhibin Xie Jinkuan [6, 7]. Wang Yun Wang proposed a novel antenna selection algorithm based on complex Householder QR factorization in wireless MIMO systems. Therefore it is quite impractical even though it can achieve optimum result. Removing and adding antennas sequentially are suboptimum algorithm under the largest Shannon Capacity. Both of them minimizes computational complexity and achieves nearly optimal capacity. But when the number of antennas increasing, then the computational complexity is considerable. In this paper, we propose an algorithm with low computational complexity based on the element characteristics of the channel capacity in MIMO systems.

2. PRESENT WORK

2.1 Channel Model

There are M transmitter and N receiver antennas in a MIMO system. We consider the channel state information at receiver, thus water filling cannot be used. The selection is implemented at the receiver and the selected antenna subset is fed back to the transmitter so that the transmitter can equally allocate energy among the selected antennas. Assume that the channel is a flat Rayleigh fading and remains constant over a block of symbols and changing independently to a new realization. So the channel matrix H of size $M \times N$ can be characterized by the following matrix:

$$H = \begin{bmatrix}
h_{11} & h_{12} & \cdots & h_{1M} \\
h_{21} & h_{22} & \cdots & h_{2M} \\
& & \cdots \cdots \cdots \cdots \cdots \cdots \\
& & & h_{N1} & h_{N2} & \cdots & h_{NM}
\end{bmatrix}$$

here $h_{ij} \sim CN(0, 1)$ is the channel gain from the $j$th ($j = 1, 2, \ldots, M$) transmit antenna to the $i$th ($i = 1, 2, \ldots, N$) receive
antenna. Denote $h_j = [h_{1j}, h_{2j}, \ldots, h_{Nj}]$ where $j = 1, 2, \ldots, M$, the columns of channel matrix $H$.

The received signal vector can be written as
\[ Y = (SNR/M) H^* X + n \]  
\[ \text{... (2)} \]

Where $X = [x_1, x_2, \ldots, x_M]$, is the $(M \times 1)$ transmitted signal vector and $Y = [y_1, y_2, \ldots, y_N]$, is the $(N \times 1)$ received signal vector, $n$ additive noise matrix with independent and identical distributed, i.e iid entries of $CN(0, 1)$ with zero mean and variance is unity. Thus the channel capacity can be expressed as
\[ C = \log \left| \det (IM + (SNR/M) H^* H) \right| \]  
\[ \text{... (3)} \]

Where $\det ()$ and $\det ()^*$ denote the matrix determinant and conjugate transpose operation respectively. IM stands for the $M \times M$ identity matrix.

2.2 Proposed Algorithm

Let $L$ number of RF chains are available. So, $L$ ($L \leq M$) transmit antennas out of the $M$ candidates were selected and connected to the available RF chains. We assume that receiver is having the knowledge of channel state information so that it is possible to select the best antennas at the receiver and the selected antenna subset is fed back to the transmitter. Then the transmitter can equally locate its energy among the selected antennas. The channel between the selected antenna elements is then described by the matrix $HL = [h_1, h_2, \ldots, h_L]$. $N \times L$ size sub-matrix of the channel matrix $H$ and the capacity can be denoted as
\[ CL = \log \left| \det (IL + (SNR/L) HL^* HL) \right| \]  
\[ \text{... (4)} \]

Denoting $S$ is a Hermitian matrix it is equal to $H^* H$, where $H = [h_1, h_2, \ldots, h_L]$ and
\[ S = H^* H = [h_1, h_2, \ldots, h_M]^* [h_1, h_2, \ldots, h_M] \]
\[ H = \begin{bmatrix} h_{1,1} & h_{1,2} & \cdots & h_{1,M} \\ h_{2,1} & h_{2,2} & \cdots & h_{2,M} \\ \cdots & \cdots & \cdots & \cdots \\ h_{N,1} & h_{N,2} & \cdots & h_{N,M} \end{bmatrix} \]  
\[ \text{... (5)} \]

Now we can find the diagonal entries of $S$ from the matrix expression (5) which represents the channel gains of the transmit antennas. To maximize channel capacity, the channel gains of the selected antennas should be maximized and correlations between them should be minimized.

Effective antenna selection algorithm:
1. Initialize $M$ transmit antennas and $N$ receive antennas for a MIMO system and calculate channel gain matrix $H$ for it.
2. Select $L$, which is the subset of $S$ transmit antennas ($L \leq M$).
3. Find $S = H^* H$ for channel gain matrix $H = [h_1, h_2, \ldots, h_M]$.
4. Select $j$th transmit antenna which have maximum diagonal element of $S$ into the subset and set the $j$th diagonal element of $S$ to zero.
5. Repeat Steps 3 and 4 for $L$ times to select $L$ transmit antennas from $M$ transmit antennas.
6. Then calculate channel capacity for different SNR values and plot SNR Vs Channel Capacity.

The above proposed algorithm maximizes the channel capacity by minimizing the correlation between the selected antennas. No matrix inverse operation and no matrix decomposition operation performed like $G$-circle algorithm, only multiplication and addition of matrix operations are performed over here. Therefore it reduces computational complexity of the channel capacity. The matrix $S$ can be used in both way: in calculating channel capacity if antenna selection is implemented and vice-versa. We can also implement this antenna selection algorithm at the receiver by calculating $S’$ instead of $S$.

3. RESULT AND DISCUSSION

In the proposed algorithm we assume that the MIMO system with $M = 8$ and $N = 4$ and $L = 4$. We consider Rayleigh Fading channels, BPSK modulation and maximum likelihood signal detection. In the simulation result, capacity achieved by antenna selection algorithm is based on instantaneous channel state information (CSI).

4. CONCLUSIONS

A low complexity antenna selection algorithm has been proposed in wireless MIMO systems. This method achieves similar capacity as that of the random search algorithm. But it takes less computational time to calculate channel capacity as it is having only multiplication and addition of matrix.
REFERENCES


