Survey of Control Methods in Multiple-Input-Multiple-Output Wireless Communication System

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Abstract: Multiple antennas play primary role in signal multiplexing and heterogeneous transmission in a broad range of communication applications. Modern high-speed 4G wireless communication technique is highly dependent on advanced design of multiple-input-multiple-output (MIMO) systems. The successful signal transmission is highly dependent on the control techniques of error rate. In this paper, an exploratory survey is presented regarding various error causing factor and their control methods in MIMO system. However, this paper also focuses to provide a comprehensive overview of MIMO transmission and future enhancements.

Keywords: Wireless Communication, MIMO, Error Rate, Root Mean Square Error.

1 Introduction

The explosive growth in the use of smart mobile devices such as smartphones and wireless modems has led to an exponentially increasing demand for wireless data services. Accordingly, substantial effort has been directed at improving the spectral efficiency and data throughput of wireless communication systems. In particular, multiple-input–multiple-output (MIMO) technologies promise to provide gains in multiplexing and/or diversity. By increasing the number of antennas at base stations and mobile terminals, communication systems can achieve better performance in terms of both system capacity and link reliability [1–4]. To date, MIMO technology has been adopted by the Long-Term Evolution (LTE) standard of the third-Generation Partnership Project (3GPP), IEEE 802.11n, and other wireless communication standards [5].

To this end, a 5G air interface is proposed, incorporating three basic technologies: massive MIMO, millimeter-wave, and small-cell. For millimeter-wave transmission, beamforming achieved with the use of large antenna arrays, including both analog and digital beamforming, can reduce propagation losses. Cell shrinking also requires the deployment of large conformal antenna arrays, the cost of which depends inversely on infrastructure density. Therefore, MIMO technology will continue to play an important role in upcoming 5G and other future wireless networks [6, 7]. Ad-hoc on demand multipath distance vector (AOMDV) protocol is capableto handled load by providing alternative path in MIMO also [8, 9]. An efficient selfish node detection and novel replica allocation technique are used to handle the MIMO selfish replica allocation suitably [10, 11].

2 MIMO Model

MIMO techniques were first investigated in point to point or SU-MIMO scenarios, that is, the Base Station (BS) or transmitter equipped with multiple transmit antennas and the User Equipment (UE) or receiver equipped with multiple receive antennas [12]. It is predicted that remarkable spectral efficiencies for wireless systems with multiple antennas when the channel exhibits rich scattering can be accurately obtained. SU-MIMO is one of the key techniques in Long Term Evolution (LTE) Release 8, which requires 300 Mb/s for Downlink (DL) and 75 Mb/s for Uplink (UL) throughput[13, 14].

2.1 MIMO Diversity

For a general MIMO system with N_r receive antennas and N_t transmit antennas, the maximum diversity order that can be achieved is by Equation 1

$$D = N_r \times N_t \tag{1}$$

where the channel between each transmit-receive antenna pair is assumed to fade independently.

2.2 MIMO Multiplexing

The strategy of SM transmission is to divide the data source into multiple parallel sub streams , where each sub-stream can be modulated and coded independently, and transmitted simultaneously[15]. Foschinihas shown that in the high-SNR regime, the capacity of a channel with independent and identically distributed Rayleigh fading between each transmit-receive antenna pair is given by Equation 2.

$$C(SNR) = min\{N_r, N_t\} \log(SNR) \tag{2}$$

The SM transmission offers a linear increase in the transmission rate for the same bandwidth and with no additional power expenditure[15]. SM is only possible in MIMO channels and compared with the spatial diversity transmission, the SM transmission aims to maximize the sum-rates. One typical SM transmission model is the Bell Laboratory

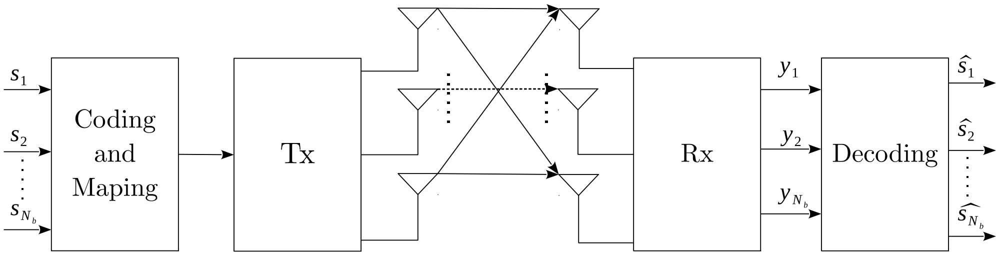

Figure 1: SU-MIMO Channel Model

Layered Space-Time (BLAST) system.The maximum multiplexing gain of the BLAST system is

$$r = min(N_r, N_t) \tag{3}$$

where r is the multiplexing gain. The SM configuration can also be applied in a multiuser format. This allows a capacity increase proportional to the number of transmit antennas and the number of users.

3 SU-MIMO Channel Model

The typical SU-MIMO [16, 17] channel is showed as follows in Figure 1.

Soft computing based radio resource management technique for base station (BS) power management can be applied to MIMO based base stations [18, 19]. It is assumed that the transmit antenna number is N_b , the receive antenna number is N_u and the maximum number of multipaths between the BS and UE is L. The channel statistical model can be expressed as

$$H(\tau, t) = \Sigma_{(l=0)^{L-1}} A_t(t)\delta(\tau - \tau_1) \tag{4}$$

Where the quantity $A_(t) \in C^{N_u \times N_b}$ represents the l^{th} path between transmitter and receiver. If we adopt $H_{i,j}(\tau, t)$ to represent the impulse response between the j^{th} transmit and i^{th} receive antenna, the channel matrix of SU-MIMO can be represented as

$$H(\tau, t) = \begin{bmatrix} h_{1,1}(\tau, t) & h_{1,2}(\tau, t) & \dots & h_{1,N_b}(\tau, t) \\ h_{2,1}(\tau, t) & h_{2,2}(\tau, t) & \dots & h_{1,N_b}(\tau, t) \\ \vdots & \vdots & \ddots & \vdots \\ h_{N_{u,1}}(\tau, t) & h_{N_{u,2}}(\tau, t) & \dots & h_{N_u,N_b}(\tau, t) \end{bmatrix} \tag{5}$$

Where $H_i, j(\tau, t)$ is the function of time, delay and location of receiving antenna? And also includes the amplitude gain and phase rotation. If the transmitted signal vector is $s(t) \in C^{N_b \times 1}$ and the received signal vector is obtained as

$$y(t) = H(\tau, t) * s(t) + n(t) \tag{6}$$

Where $n(t) \in C^{N_u}$ is the Gaussian noise with i.i.d. entries of zero mean and variance σ_n^2. In the flat fading channel, since the output at any instant of time is independent of inputs at previous time, the received signal can be expressed as

$$y = Hs + n \tag{7}$$

Another factor that we should take into account is the spatial correlation caused by the scattering and insufficient spacing between adjacent antennas. A correlated channel matrix can be obtained using Kroneker model [20].

$$H_c = R_u^{1/2} H R_b^{1/2} \tag{8}$$

Where R_u and R_b are the receive and transmit covariance matrices with $tr(R_u) = N_u$ and $tr(R_b) = N_b$. Both R_u and R_b are positive semi definite Herrmitian matrices. In the presence of receive and transmit correlation, the rank of H_c is constrained by $min\,(r(R_u), r(R_b))$. Therefore, the system will suffer from both BER and sum rate performance loss because of rank deficiency. For the case of an urban wireless environment, the UE is always surrounded by rich scattering objects and the channel is most likely independent Rayleigh fading at the receive side. From the transmitter's point of view, however, the spatial structure of the channel is governed by remote scattering objects and will most likely result in a highly spatially correlated scenario. Hence, we assume $R_u = I_{N_u}$ and we have

$$H_c = H R_b^{1/2} \tag{9}$$

To study the effect of antenna correlations, random realizations of correlated channels are generated according to the exponential correlation model such that the elements of R_b are given by

$$R_b(i, j) = \begin{cases} r^{j-i} \; i \le j & |r| \le 1 \\ r_{j,i}^* \; i > j & otherwise \end{cases} \tag{10}$$

Where 'r' is the correlation coefficient between any two neighboring antennas. Thus correlation model is in practice suitable since the correlation between neighboring channel s is higher than that of distant channels.

4 Related Works

Techniques for multi-user MIMO downlink and uplink processing can be implemented in various way as described by researchers.

Hong *et al.* [21] obtained analytical expressions for the average (Bit Error Rate) BER of MIMO systems in transmit-correlated Rayleigh flat-fading channels with or without precoding and with MMSE receivers. These expressions, whose accuracy even for small dimensions has been proved by comparison with numerical results, can be used to optimize the transmitter for a given target BER or, in general, as a useful tool for the system design. the average BER for the k^{th} signal can be obtained as

$$\bar{P}_e(\alpha,\theta)=\int_0^{\infty}P_e(s)\frac{s^{\alpha-1}e^{-s/\theta}}{\Gamma(\alpha)\theta^{\alpha}}ds \tag{11}$$

where $\Gamma(\cdot)$ is the complete Gamma function, and $P_e(\cdot)$ is the instantaneous BER function for the corresponding scalar signal (s), which depends on the modulation scheme used at the transmitter.

Cerone *et al.* [22] proposed an algorithm for computing tight bounds on the system parameters, through the formulation of a suitable polynomial optimization problem, where the uncertainty affecting the data is properly handled. More precisely, the intrinsic correlation between successive occurrences of the same uncertain variables in the constraints that implicitly describe the feasible parameter set. The problem is then solved through a computationally efficient convex relaxation approach, by exploiting the peculiar sparsity structure of the problem. The effectiveness of the proposed approach is shown by means of a simulation example, where the percentage relative estimation error is quite small (typically less than 15%) also for a significantly large amount of noise (SNR = 15 dB).

Kim *et al.* [23] proposed a new adaptive iterative learning controller (AILC) approach for uncertain MIMO nonlinear systems in the normal form. The proposed AILC learns the system and input gain parameters as well as the desired input. Compared with the existing results in AILC, the AILC with input learning is first developed for the uncertain MIMO nonlinear systems in the normal form; the input learning rule is simple, and so it can be easily implemented in industrial applications. The tracking error and desired input error signal asymptotically converge to zero, and the error signals are bounded in the learning control system. Single-link and two-link manipulators are presented as simulation examples to demonstrate the validity of the proposed controller.

Sugimoto *et al.* [24] proposed a new MIMO FEL scheme and showed a proof of zero convergence of tracking error. Numerical simulation shows effectiveness of the proposed scheme over the conventional one. Our future work would be experimental validation of the proposed scheme.

5 Proposed Model for MU-MIMO System

Consider K independent users in the multiuser MIMO system. We assume that BS and each MS are equipped with N_B and N_M antennas, respectively. Figure 3.4shows the uplink channel, known as a multiple access channel (MAC) for K independent users. Let $x_u \in C^{N_M\times 1}$ and $y_{\text{MAC}} \in C^{N_B\times 1}$ denotes the transmit signal from the u^{th} user, $u=1,2,\ldots,K$, and the received signal at the BS, respectively. The channel gain between the u^{th} user MS and BS is represented by $H_u^{UL} \in C^{N_B\times N_m}$, $u=1,2,\ldots,K$. The received signal is expressed as

$$\begin{aligned} y_{\text{MAC}} &= H_1^{UL}x_1+H_2^{UL}x_2+\ldots.+H_k^{UL}x_k+Z \\ &= \begin{bmatrix} H_1^{UL} & H_2^{UL} & \ldots & H_k^{UL} \end{bmatrix}\begin{bmatrix} x_1 \\ \vdots \\ x_K \end{bmatrix} \\ &= H^{UL}\begin{bmatrix} x_1 \\ \vdots \\ x_K \end{bmatrix}+z \end{aligned} \tag{12}$$

Where $z \in C^{N_B\times 1}$ is the additive noise in the receiver and it is modeled as a zero mean circular symmetric complex Gaussian (ZMCSCG) random vector.

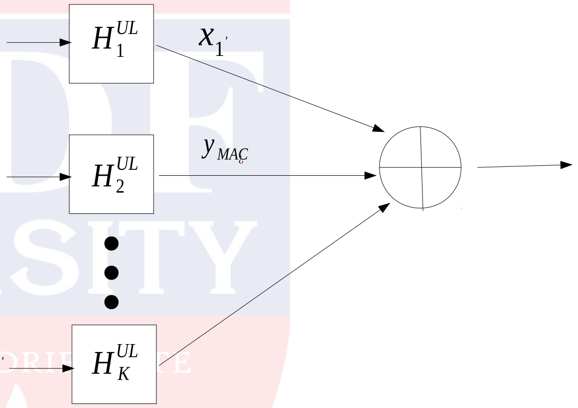

Figure 2: Uplink channel model for multiuser MIMO system: multiple access channel (MAC)

On the other hand, figure 3.5 shows the downlink channel, known as Broadcast Channel (BC) in which $x \in C^{N_B\times 1}$ is the transmitted signal from the BS and $y_u \in C^{N_M\times 1}$ is the received signal at the u^{th} user,$u=1,2,\ldots,K$. Let $H_u^{DL} \in C^{N_M\times N_B}$ represents the channel gain between BS and the u^{th} user. In MAC, the received signal at the u^{th} user is expressed as

$$y_u = H_u^{DL}x+z_u \tag{13}$$

where $u=1,2,\ldots,k$ Where $z_u \in C^{N_M\times 1}$ is the additive ZMCSCG noise at the u^{th} user. Representing all the signals by a single vector, the overall system can be represented as

$$\begin{bmatrix} y_1 \\ \vdots \\ y_k \end{bmatrix} = \begin{bmatrix} H_1^{DL} \\ \vdots \\ H_k^{DL} \end{bmatrix} x + \begin{bmatrix} z_1 \\ \vdots \\ z_K \end{bmatrix} \tag{14}$$

6 Conclusion

This paper has surveyed wireless techniques for Multiuser MIMO broadcast channel following a system perspective and has proposed novel precoding algorithm that can offer an improved performance while requiring a lower complexity than existing methods. This final Chapter summarizes the contributions of the thesis and outlines some directions for future work. Conventionally, for the algorithm design, there is always a dilemma between performance and computational complexity. In order to achieve an optimal performance a design often requires a higher computational complexity, whilst if the goal is an easy implementation and efficiency this is inevitably associated with a loss in performance. In this paper, the art of novel efficient error correcting algorithms has been explored with a comparable performance as the optimal one.

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