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1 System Model

1.1 System Configuration

Like most scenarios adopts a single user massive MIMO system in a single cell, in which the base station equips $N_t > 1$ transmitting antennas as well as the UE with a single receiving antennas. An orthogonal frequency division multiplexing (OFDM) system with N_c sub-carriers for FDD downlink massive MIMO is examined. In the OFDM-MIMO system considered in this work, the subcarriers are assumed to maintain orthogonality.

1.2 Channel Model

The time-domain channel impulse response between the i-th transmit antenna and UE follows Rayleigh fading:

$$h_i(\tau) = \sum_{l=1}^{L} \alpha_{i,l}\delta(\tau - \tau_l), \quad \alpha_{i,l} \sim \mathcal{CN}(0, \sigma_l^2)$$

where $\alpha_{i,l}$ is the complex gain and τ_l is the delay of the l-th path. The frequency-domain channel matrix for subcarrier n is:

$$\mathbf{H}_n = [H_{1,n}, H_{2,n}, \dots, H_{N_t,n}] \in \mathbb{C}^{1\times N_t}$$

with elements derived from:

$$H_{i,n} = \sum_{l=1}^{L} \alpha_{i,l} e^{-j2\pi n\tau_l/N_c}$$

1.3 Pilot Transmission

We will assume base station sends orthogonal pilots for each subcarrier to the UE $n = 1, ..., N_c$: let pilot matrix $\mathbf{X}_{p,n} \in \mathbb{C}^{N_t\times T_p}$ be orthogonal ($T_p \geq N_t$). We will assume on n^{th} sub-carriers the received signal at UE will be equal to:

$$\mathbf{Y}_{p,n} = \mathbf{H}_n\mathbf{X}_{p,n} + \mathbf{Z}_n$$

where $\mathbf{Y}_{p,n} \in \mathbb{C}^{1\times T_p}$ $(N_r = 1)$ is received pilot at n^{th} subcarrier, $\mathbf{H}_n \in \mathbb{C}^{1\times N_t}$ is the MIMO channel matrix for subcarrier n and $\mathbf{Z}_n \in \mathbb{C}^{1\times T_p}$ is AWGN noise with variance σ^2.

1.4 Channel Estimation

Let's assume UE uses Least Squares (LS) to estimate $\mathbf{H}_n$:

$$\hat{\mathbf{H}}_n = \mathbf{Y}_{p,n}\mathbf{X}_{p,n}^{\dagger}$$

where $\hat{\mathbf{H}}_n \in \mathbb{C}^{1\times N_t}$ and $\mathbf{X}_{p,n}^{\dagger} = \mathbf{X}_{p,n}^{H}(\mathbf{X}_{p,n}\mathbf{X}_{p,n}^{H})^{-1}$. The pilot matrix $\mathbf{X}_{p,n}$ satisfies $\mathbf{X}_{p,n}\mathbf{X}_{p,n}^{H} = \mathbf{I}_{N_t}$ for $T_p \geq N_t$.

1.5 CSI Feedback

For each subcarrier estimated CSI matrices is $\{\hat{\mathbf{H}}_1, ..., \hat{\mathbf{H}}_{N_c}\}$. For simplicity we stack and reshape the channel matrix into:

$$H_{\text{freq}} = \left[\hat{\mathbf{H}}_1^H, \hat{\mathbf{H}}_2^H, ..., \hat{\mathbf{H}}_{N_c}^H\right]_{N_c\times N_t}^{H}$$

$H_{\text{freq}} \in \mathbb{C}^{N_c\times N_t}$ is the stacked CSI matrix across subcarriers. Evidently, $H_{\text{freq}} \in \mathbb{C}^{N_c\times N_t}$ has $2 \times N_c \times N_t$ float numbers, which is too big for direct feedback in a massive MIMO system and this feedback is required for creating the precoding to be built by base station.

H_{freq} is the spatial-frequency domain equivalent of the CSI. We use the 2D discrete Fourier transform (DFT) and transfer H_{freq} into the angle-delay domain as follows to extract the CSI features:

$$\tilde{\mathbf{H}} = \mathbf{F}_d H_{\text{freq}} \mathbf{F}_a^H$$

where $\mathbf{F}_d \in \mathbb{C}^{N_c\times N_c}$ is delay DFT and $\mathbf{F}_a \in \mathbb{C}^{N_t\times N_t}$ is angular DFT and both of them are unitary DFT matrices.

CSI shows sparsity in the delay domain, with $\tilde{\mathbf{H}}$ having significant values only in the first N_i rows because the time of arrival (TOA) between multipaths is limited in duration. Like aforementioned researches, we select first N_i rows of $\tilde{\mathbf{H}}$ to create a new channel matrix $\tilde{\mathbf{H}}_f$ as

$$\tilde{\mathbf{H}}_f = \left[\tilde{\mathbf{H}}\right]_{1:N_i}$$

$\tilde{\mathbf{H}}_f$ as is still too heavy for feedback, though, because in a massive MIMO system, N_t is a big number. Our goal is to further compress matrix $\tilde{\mathbf{H}}_f$ in order to minimize the weight of the feedback.

1.6 Deep Learning Compression

In an effort to lower transmission overheads, DL-based algorithms have recently been used in CSI feedback. An encoder at UE first compresses the CSI data into a codeword:

$$s = f_{\text{enc}}(\tilde{\mathbf{H}}_f)$$

and after that, a feedback channel is used to send the codeword to the BS. A decoder at the BS can recreate the CSI as:

$$\hat{\tilde{\mathbf{H}}}_f = f_{\text{dec}}(s)$$

The compression ratio can be obtained as:

$$\gamma = \frac{N_s}{2 \times N_i \times N_t}$$

where γ, N_s, N_i and N_t are compression ratio, codeword length, selected rows from $\widetilde{H}$ and number of transmit antenna.