Massive Notes 2.3 pp.226 - 228

Key Points : Uplink System Model; Downlink System Model.

1. Uplink System Model

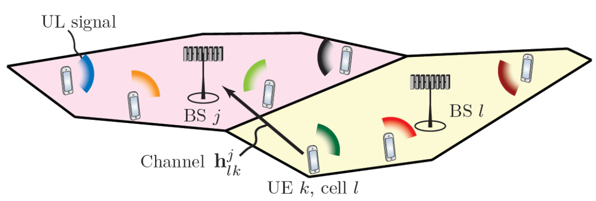


Figure 2.3: Illustration of the UL Massive MIMO transmission in cell j and cell l. The channel vector between BS j and UE k in cell l is called $\mathbf{h}_{lk}^{j}$.

1. As shown in figure 2.3 that the **received UL signal** $\mathbf{y}_j \in \mathbb{C}^{M_j}$ at BS j is modeled as

$$\begin{aligned}\mathbf{y}_j &= \sum_{l=1}^{L}\sum_{k=1}^{K_l}\mathbf{h}_{lk}^{j}s_{lk} + \mathbf{n}_j \\ &= \underbrace{\sum_{k=1}^{K_l}\mathbf{h}_{jk}^{j}s_{jk}}_{\text{Desired Signals}} + \underbrace{\sum_{l=1,l\neq j}^{L}\sum_{i=1}^{K_l}\mathbf{h}_{li}^{j}s_{li}}_{\text{Inter-cell Interference}} + \underbrace{\mathbf{n}_j}_{\text{Noise}} \end{aligned} \tag{2.5}$$

where $\mathbf{n}_j \sim \mathcal{N}_{\mathbb{C}}(\mathbf{0}_{M_j}, \sigma_{\text{UL}}^2\mathbf{I}_{M_j})$ is **Independent Additive Receiver Noise** with 0 mean and variance σ_{UL}^2. The UL signal from UE k in cell l is denoted by $s_{lk} \in \mathbb{C}$ and has power $p_{lk} = \mathbb{E}\{|s_{lk}|^2\}$.

2. During data transmission, the BS in cell j selects the **receive combining vector** $\mathbf{v}_{jk} \in \mathbb{C}^{M_j}$ to separate the signal from its kth desired UE from the interference as

$$\mathbf{v}_{jk}^{\text{H}}\mathbf{y}_j = \mathbf{v}_{jk}^{\text{H}}\sum_{l=1}^{L}\sum_{k=1}^{K_l}\mathbf{h}_{lk}^{j}s_{lk} + \mathbf{v}_{jk}^{\text{H}}\mathbf{n}_j$$

$$= \underbrace{\mathbf{v}_{jk}^{\mathrm{H}}\mathbf{h}_{jk}^{j}s_{jk}}_{\text{Desired Signal}} + \underbrace{\sum_{i=1,i\neq k}^{K_l}\mathbf{v}_{jk}^{\mathrm{H}}\mathbf{h}_{ji}^{j}s_{ji}}_{\text{Intra-cell Signals}} + \underbrace{\sum_{l=1,l\neq j}^{L}\sum_{i=1}^{K_l}\mathbf{v}_{jk}^{\mathrm{H}}\mathbf{h}_{li}^{j}s_{li}}_{\text{Inter-cell Interference}} + \underbrace{\mathbf{v}_{jk}^{\mathrm{H}}\mathbf{n}_j}_{\text{Noise}} \tag{2.6}$$

2. Downlink System Model

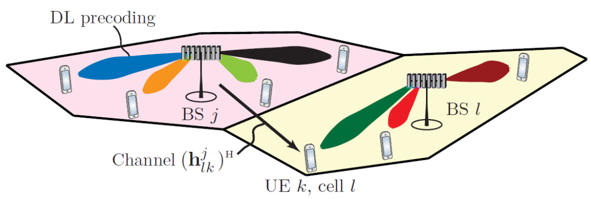


Figure 2.4: Illustration of the DL Massive MIMO transmission in cell j and cell l. The channel vector between BS j and UE k in cell l is called $\mathbf{h}_{lk}^{j}$.

3. As shown in figure 2.4 that the BS in cell l transmits the **DL signal** as follows

$$\mathbf{x}_l = \sum_{i=1}^{K_l} \underbrace{\mathbf{w}_{li}}_{\text{transmit precoding vector}} \overbrace{\zeta_{li}}^{\text{DL data signal}} \tag{2.7}$$

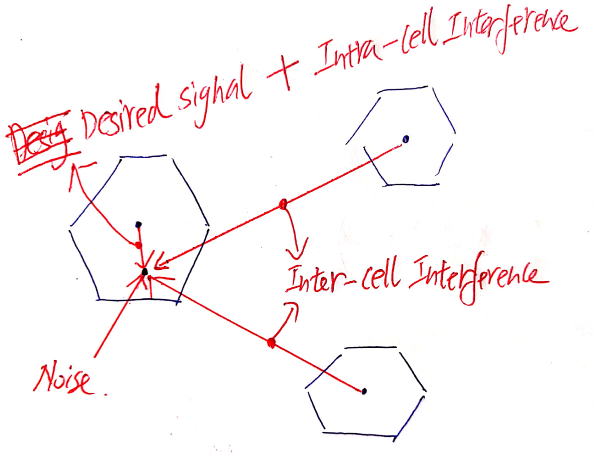
where $\zeta_{lk} \sim \mathcal{N}_{\mathbb{C}}(0,\rho_{lk})$ is the DL data signal intended for UE k in the cell and ρ_{lk} is the signal power. $\mathbf{w}_{lk} \in \mathbb{C}^{M_l}$ that determines the **spatial directivity** of the transmission, and $\mathbb{E}\{\|\mathbf{w}_{lk}\|^2\} = 1$. Therefore, $\mathbb{E}\{\|\mathbf{w}_{lk}\zeta_{li}\|^2\} = \rho_{lk}$ is the **transmit power allocated to this UE**.

4. The received signal $y_{jk} \in \mathbb{C}$ at UE k in cell j is modeled as

$$y_{jk} = \sum_{l=1}^{L}(\mathbf{h}_{jk}^{l})^{\mathrm{H}}\mathbf{x}_l + n_{jk} = \sum_{l=1}^{L}\sum_{i=1}^{K_l}(\mathbf{h}_{jk}^{l})^{\mathrm{H}}\mathbf{w}_{li}\zeta_{li} + n_{jk}$$

$$= \underbrace{(\mathbf{h}_{jk}^{j})^{\mathrm{H}}\mathbf{w}_{jk}\zeta_{jk}}_{\text{Desired Signal}} + \underbrace{\sum_{i=1,i\neq k}^{K_j}(\mathbf{h}_{jk}^{j})^{\mathrm{H}}\mathbf{w}_{ji}\zeta_{ji}}_{\text{Intra-cell Interference}} + \underbrace{\sum_{l=1,l\neq j}^{L}\sum_{i=1}^{K_l}(\mathbf{h}_{jk}^{l})^{\mathrm{H}}\mathbf{w}_{li}\zeta_{li}}_{\text{Inter-cell Interference}} + \underbrace{n_{jk}}_{\text{Noise}} \tag{2.8}$$

K_l is the total number of UEs in cell l.


~~Desig~~ Desired signal + Intra-cell Interference
Inter-cell Interference
Noise.