Distributed Precoding for Network MIMO

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Outline

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Network MIMO Downlink

- Network MIMO is also known as multicell MIMO and CoMP.
- Base stations cooperate to increase the throughput.
- We discuss the network MIMO downlink.

Joint vs Distributed Precoding

- Joint
  - Multiple base stations act as a large virtual base station and transmit data to the users.
  - Optimal schemes are known.
- Distributed
  - Each base station is the processor that carries out its localized task.
  - Only the data destined for the inside-cell users need to be available at the base station.

Joint vs Distributed Precoding

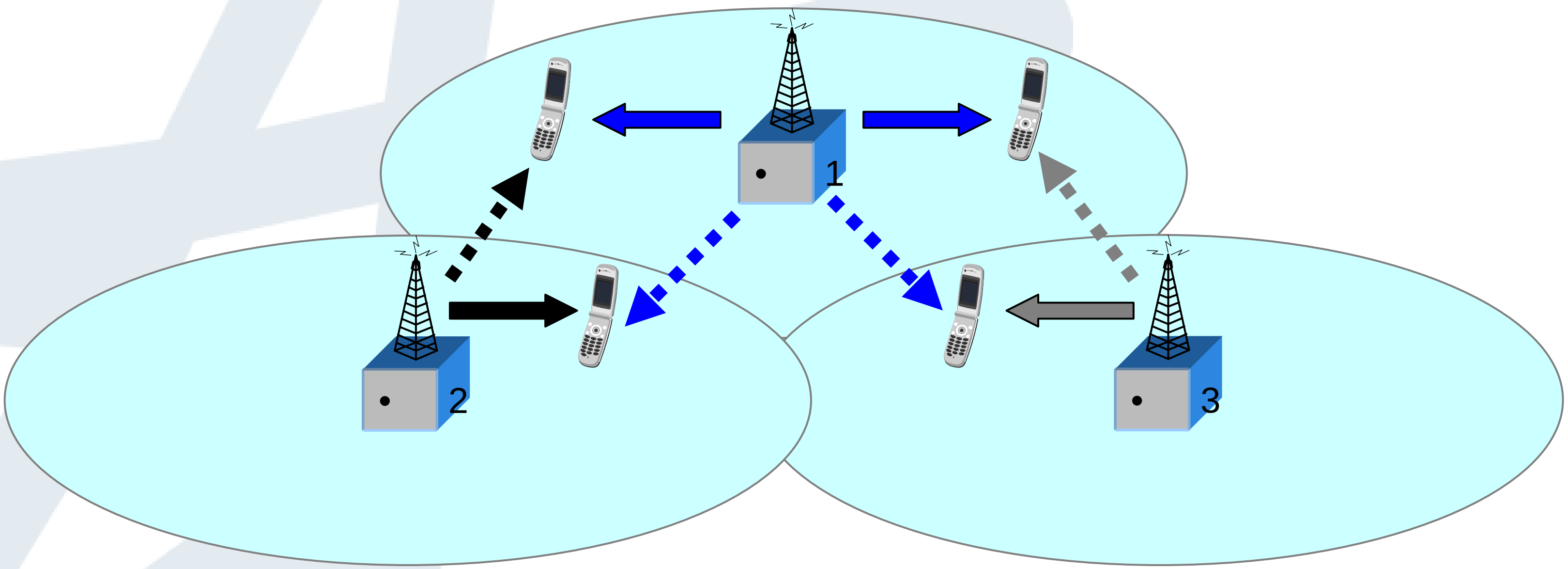
- Joint
  - The processor requires the combined downlink CSI from all base stations.
  - Co-channel interference helps transmission.
- Distributed
  - Each base station only requires the downlink CSI from itself.
  - Co-channel interference negatively affects transmission.

Problem Statement

- To find a distributed precoder that reduces the burden on the backhaul for CSI and data exchange.
- To handle multiple inside-cell and outside-cell users with one or more antennas.
- To provide high data rate for the users.

System Model

- $\mathbf{H}$ denotes channel to inside-cell users.
- $\overline{\mathbf{H}}$ denotes channel to outside-cell users.



Leakage Projected DPC

- The idea comes from the Golden Rule: Do to others what you want others to do to you.
- We maximize the inside-cell signal strength and minimize the outside-cell interference leakage.
- Dirty paper coding (DPC) is used for the inside-cell users to give high data rate.

Derivation

- Initial precoder

$$\mathbf{V} \in \mathcal{C}^{N_\mathrm{T} \times N_\mathrm{V}}$$

$$\mathbf{y}^{\mathrm{sig}} = \mathbf{H}\mathbf{V}\sqrt{P/N_\mathrm{V}}\,\mathbf{s}.$$

$$\mathbf{y}^{\mathrm{leak}} = \overline{\mathbf{H}}\mathbf{V}\sqrt{P/N_\mathrm{V}}\,\mathbf{s}.$$

- Maximize cell signal to leakage plus noise ratio (SLNR)

$$\zeta_\mathrm{C} = \frac{\mathrm{Tr}\left(\mathbf{H}\mathbf{V}\mathbf{V}^H\mathbf{H}^H P/N_\mathrm{V}\right)}{\mathrm{Tr}\left(\overline{\mathbf{H}}\mathbf{V}\mathbf{V}^H\overline{\mathbf{H}}^H P/N_\mathrm{V}\right) + N_0 K N_\mathrm{R}} = \frac{\sum_{k=1}^{N_\mathrm{V}} \mathbf{v}_k^H \mathbf{G}_\mathrm{A} \mathbf{v}_k}{\sum_{k=1}^{N_\mathrm{V}} \mathbf{v}_k^H \mathbf{G}_\mathrm{B} \mathbf{v}_k}, \text{ where}$$

$$\mathbf{G}_\mathrm{A} = \rho\mathbf{H}^H\mathbf{H},\quad \mathbf{G}_\mathrm{B} = \rho\overline{\mathbf{H}}^H\overline{\mathbf{H}} + K N_\mathrm{R}\mathbf{I}_{N_\mathrm{T}}, \text{ and } \quad \rho = P/N_0.$$

Derivation

$$\zeta_{\mathrm{L}} = \min_{k=1,\ldots,N_{\mathrm{V}}} \frac{\mathbf{v}_k^H \mathbf{G}_{\mathrm{A}} \mathbf{v}_k}{\mathbf{v}_k^H \mathbf{G}_{\mathrm{B}} \mathbf{v}_k}. \text{ Consequently,}$$

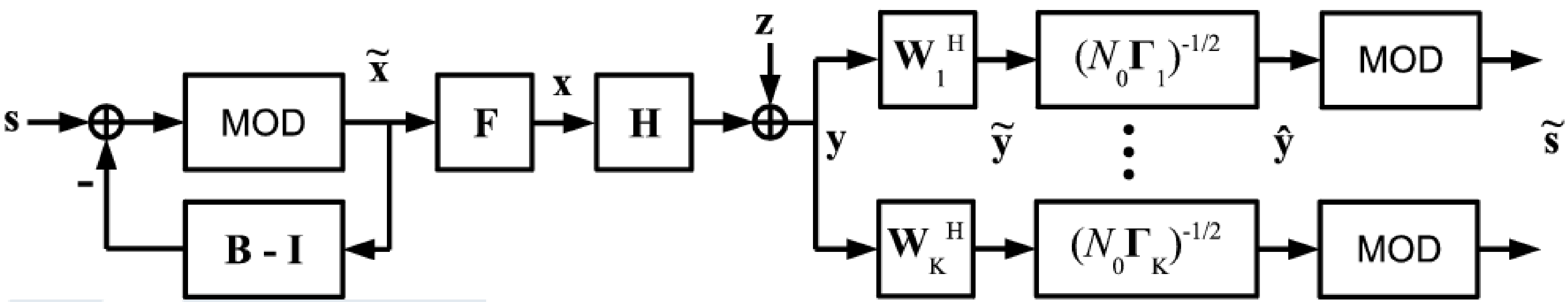
$$\zeta_{\mathrm{L,max}} = \max_{\mathbf{V}^H \mathbf{V} = \mathbf{I}_{N_{\mathrm{V}}}} \min_{k=1,\ldots,N_{\mathrm{V}}} \frac{\mathbf{v}_k^H \mathbf{G}_{\mathrm{A}} \mathbf{v}_k}{\mathbf{v}_k^H \mathbf{G}_{\mathrm{B}} \mathbf{v}_k} = \max_{\mathcal{V}:\dim(\mathcal{V})=N_{\mathrm{V}}} \min_{\mathbf{v}\in\mathcal{V}} \frac{\mathbf{v}^H \mathbf{G}_{\mathrm{A}} \mathbf{v}}{\mathbf{v}^H \mathbf{G}_{\mathrm{B}} \mathbf{v}}.$$

- The matrix **V** is given by the basis vectors spanning the dominant eigenvectors of $\mathbf{G}_S = \mathbf{G}_B^{-1} \mathbf{G}_A$, by the generalized Courant-Fischer max-min theorem.

Derivation

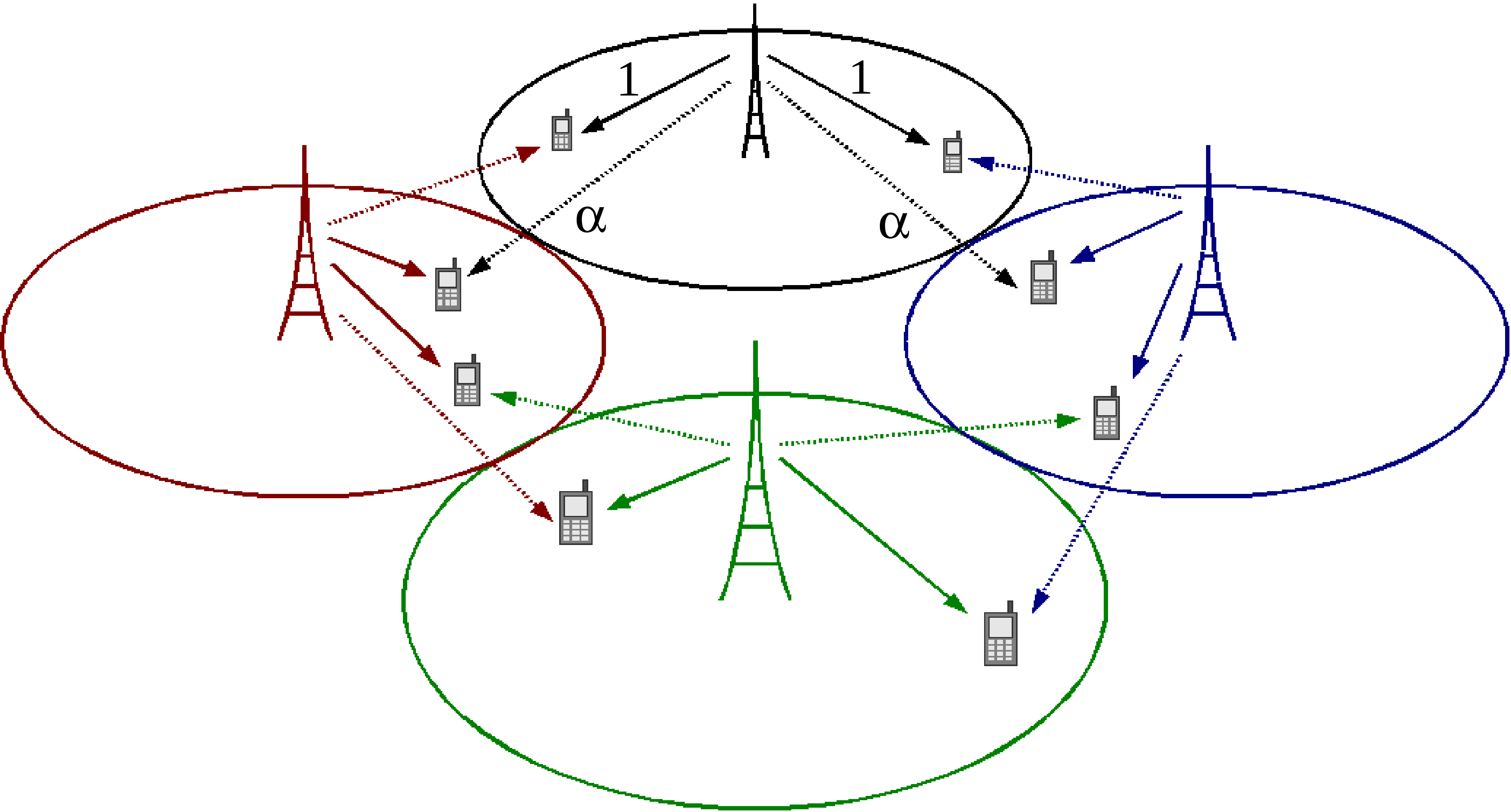
- Block diagonal DPC processing
  - e.g. block diagonal geometric mean decomposition (BD-GMD) is applied.

$$\mathbf{H}_{\perp} = \mathbf{H}\mathbf{V}\mathbf{V}^{H} \qquad \mathbf{P}^{H}\mathbf{H}_{\perp}\mathbf{Q} = \mathbf{L}$$



Simulations

- Figure 2: Circular Wyner Model with *M*=4 cells and *K* users per cell.



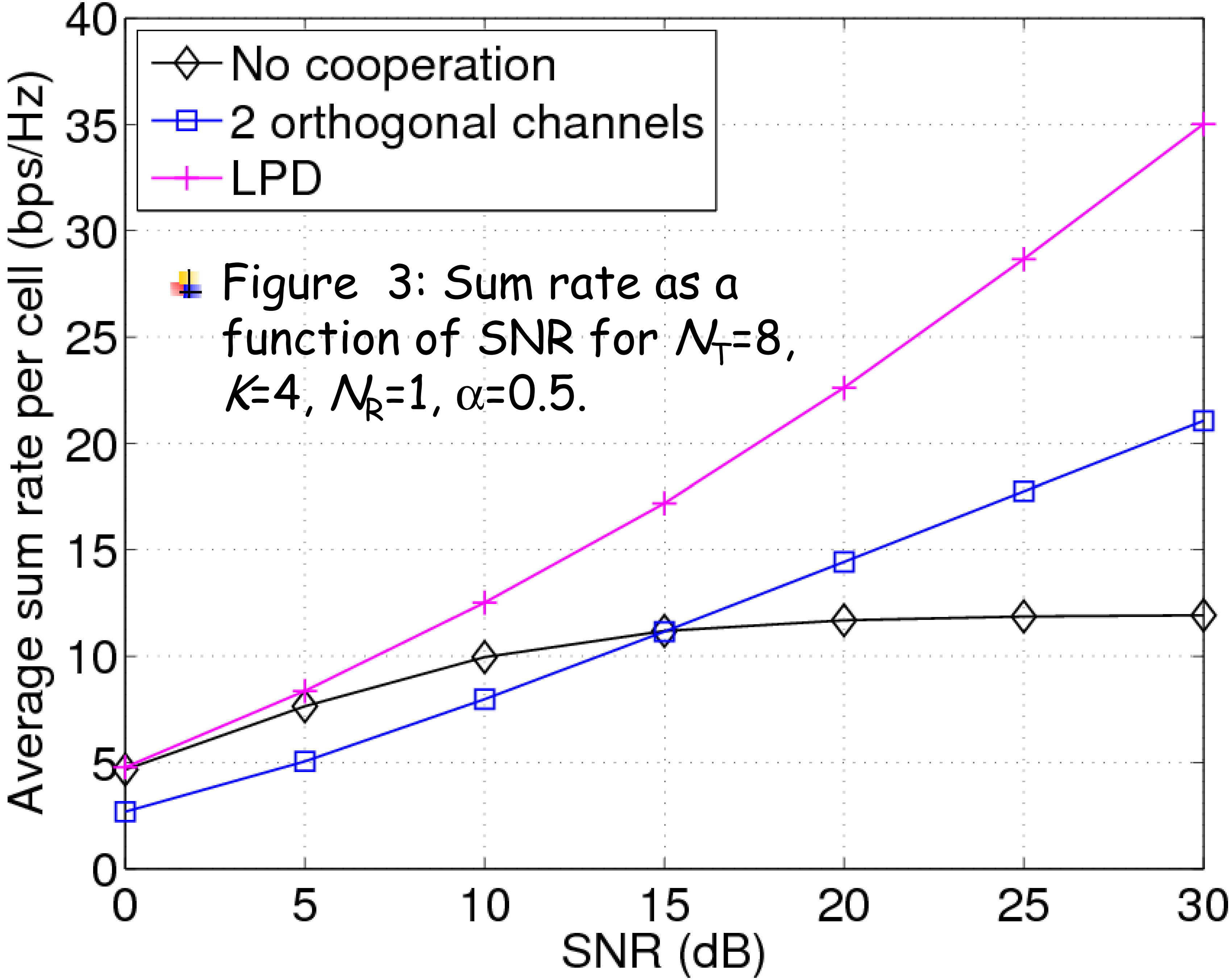


Figure 3: Sum rate as a function of SNR for N_T=8, K=4, N_R=1, α=0.5.

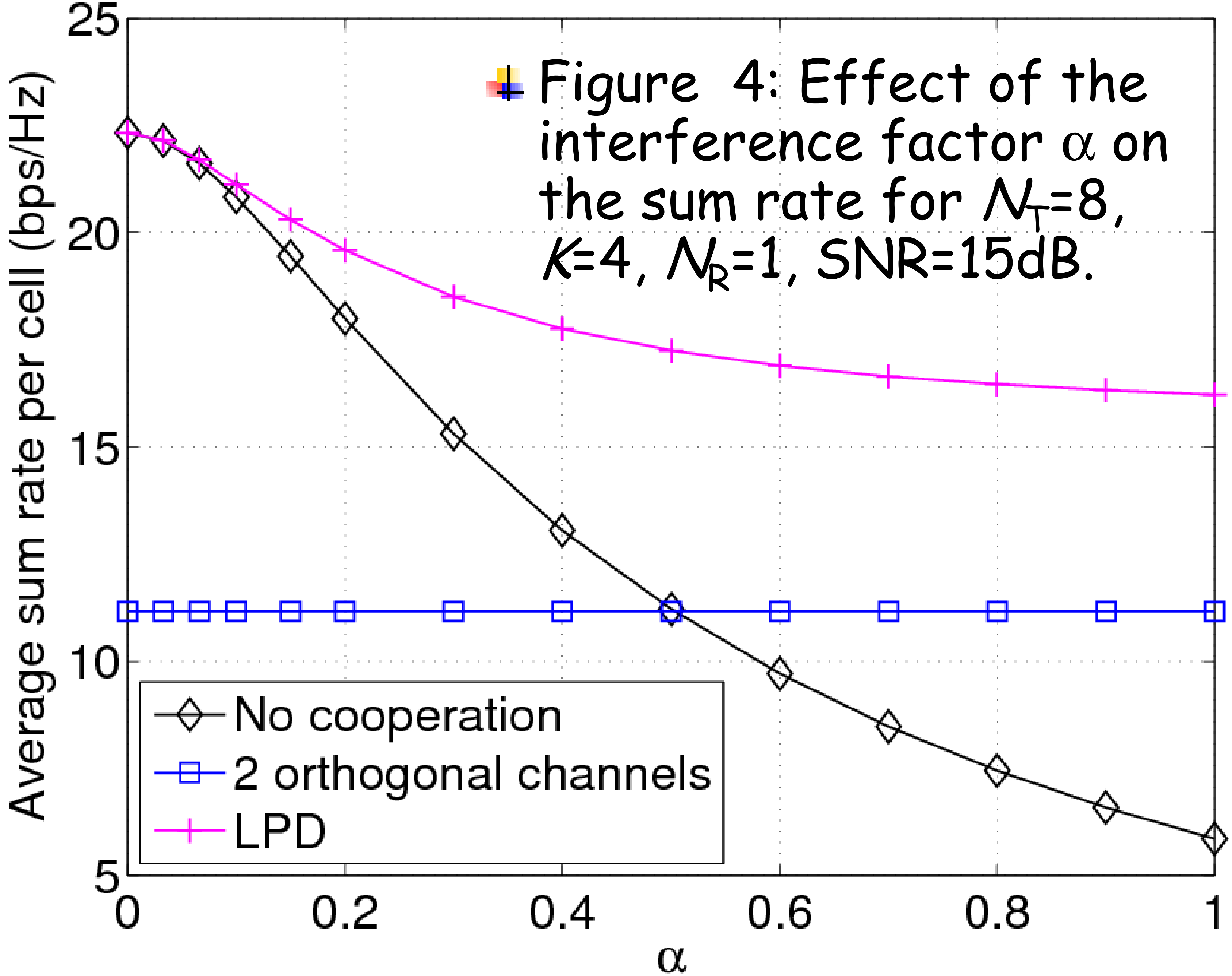


Figure 4: Effect of the interference factor α on the sum rate for N_T=8, K=4, N_R=1, SNR=15dB.

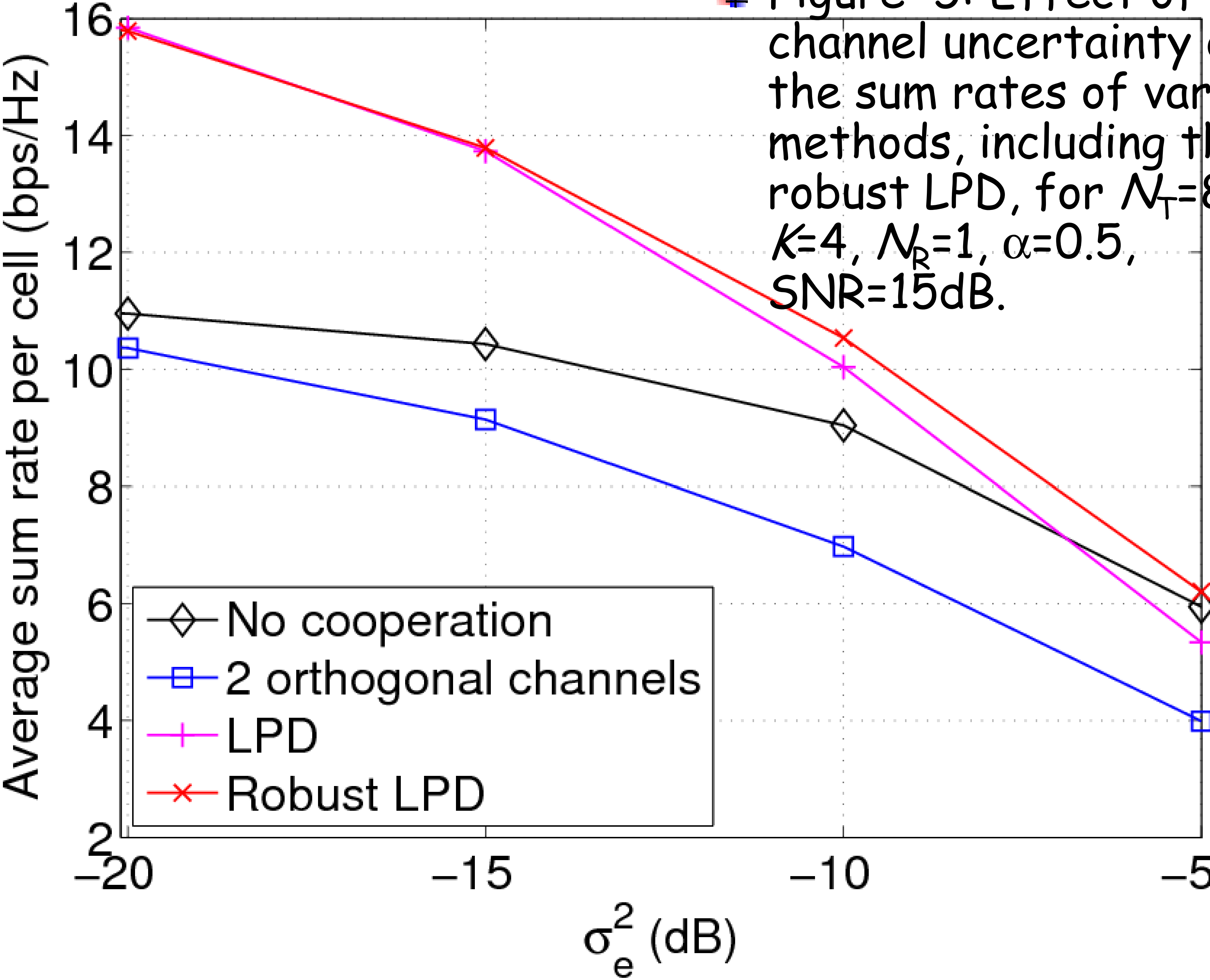


Figure 5: Effect of channel uncertainty on the sum rates of various methods, including the robust LPD, for N_T=8, K=4, N_R=1, α=0.5, SNR=15dB.

Conclusion

- Network MIMO is an attractive technology to tackle interference and increase spectral efficiency.
- Leakage Projected DPC is a distributed precoder that reduces the burden on the backhaul for CSI and data exchange.
- It provides high data rate for the users.