Interference Alignment on MIMO X Channel with Synergistic CSIT

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Contribution ①

- To derive an achievable scheme for asymmetric MIMO X channel with synergistic CSIT that generalized the results presented in [1]
- The parameters of this scheme are optimized and the DoF value is shown to be greater than the value with outdated CSIT and equal to that of outdated CSIT with transmitter cooperation
- The deployment of outdated and instantaneous CSIT are being analyzed

Introduction ②

- The DoF in the SISO X channel with outdated CSIT is less than that in the SISO X channel with transmitter cooperation, viz. $6/5$ vs $4/3$
- The outdated and instantaneous CSIT can be synergistically utilized, if feedback delay is less than channel coherence time
- In the SISO case, the DoF $(4/3)$ with synergistic CSIT is greater than that of outdated CSIT $(6/5)$, and is the same as the DoF with outdated CSIT and transmitter cooperation

System Model ③

- DoF definition:
  - Degrees of freedom (DoF) denotes the maximal multiplexing gain, and can be derived from the approximation of capacity in high SNR regime
  - DoF measures the maximal number of independent channels utilized by the system

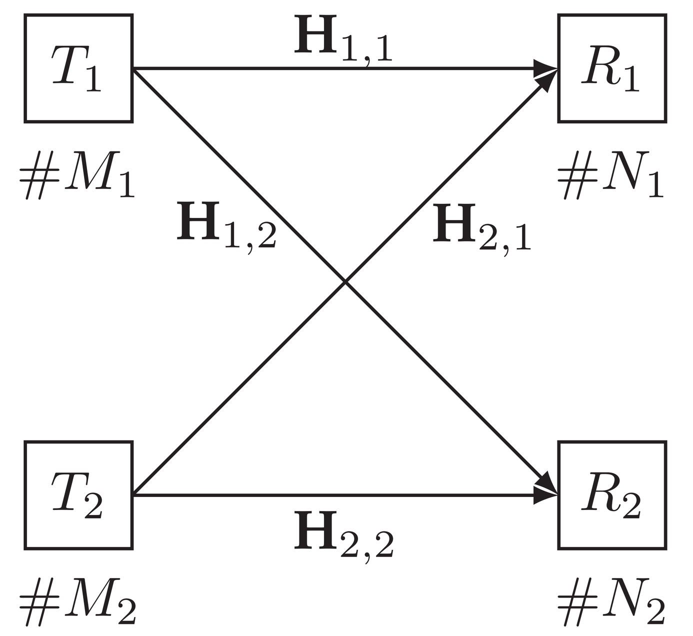
$$C = \text{DoF}\,\log(\text{SNR}) + o(\log(\text{SNR}))\ \text{bps/Hz}$$

where

$$o(\log(\text{SNR})) = \lim_{\text{SNR}\to\infty} \frac{C}{\log(\text{SNR})} = 0$$

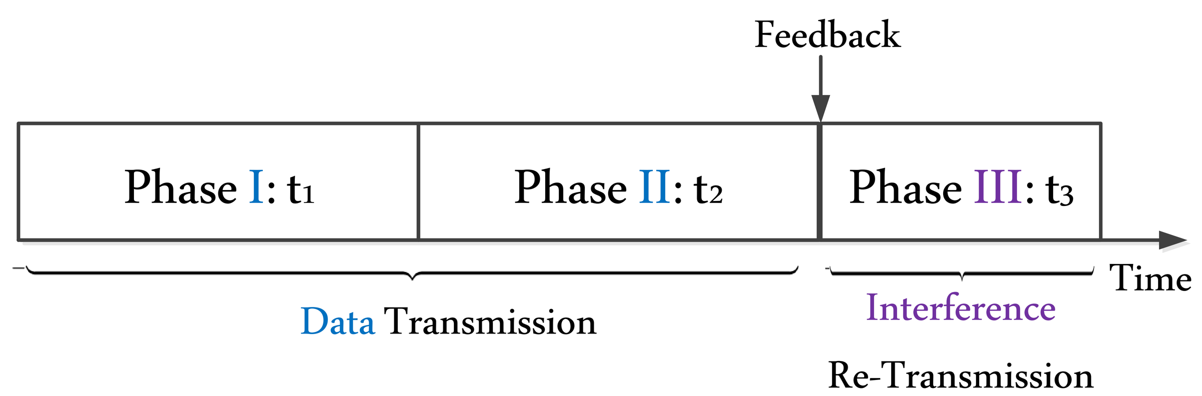
- X channel:

Channel matrices from transmitter $T_i, i \in \{1,2\}$ to receiver $R_j, j \in \{1,2\}$: $\mathbf{H}_{ij}$. Each transmitter sends messages to both receiver



- Synergistic CSIT:
  - Synergistically alternating the instantaneous, delay and no CSIT to provide DoF gains compared to simple delayed and no CSIT cases
  - Our model uses a kind of synergistic CSIT, where at the last phase of the CSIT is updated to the present one [1]. This results from the fact that the channel coherence time can be longer than feedback delay

Methods ④



- A 3-phase transmission scheme is applied
- Phase-I and II are used to send symbols to receivers R_1 and R_2, respectively
- In Phase-III, we re-transmit the interference, where beamforming matrices are designed to align interference together so it can be canceled by the phase-I and II interference

$$\mathbf{H}_{1,1}\mathbf{V}_1^{[2]} = \mathbf{H}_{2,1}\mathbf{V}_2^{[2]}, \quad \mathbf{H}_{1,2}\mathbf{V}_1^{[1]} = \mathbf{H}_{2,2}\mathbf{V}_2^{[1]}$$

- An optimization problem is established to obtain the optimal time slots required in achieving maximum DoF

$$\max_{\{t_1,t_2\}} \frac{(M_1+M_2)t_1 + (M_1+M_2)t_2}{t_1 + t_2 + \max\{\alpha t_1, \beta t_2\}}$$
$$\text{s.t.}\quad 0 < N_2\alpha t_1 \le N_1 t_2, \quad 0 < N_1\beta t_2 \le N_2 t_1$$

- Optimal solution: $t_1^* = N_1(M_1+M_2-N_2)$, $t_2^* = N_2(M_1+M_2-N_1)$ and $t_3^* = (M_1+M_2-N_1)(M_1+M_2-N_2)$
- In phase III, to efficiently utilize the retransmission, both receivers need equal time to acquire their desired equations

Results ⑤

The achievable DoF for asymmetric MIMO X channel with synergistic CSIT is given as follows:

$$\text{Case A}: M_1 + M_2,$$

$$\text{Case B}: \frac{N_1(M_1+M_2-N_2) + N_2(M_1+M_2-N_1)}{M_1+M_2-\frac{N_1N_2}{M_1+M_2}}$$

$$\text{Case C}: \frac{N_1^2(N_1+N_2) + N_2^2(N_1+N_2)}{N_1^2+N_2^2+N_1N_2}$$

where Case A, B and C denote $M_1 + M_2 \le N_1$, $N_1 < M_1+M_2 \le N_1+N_2$ and $N_1+N_2 < M_1+M_2$

The Case B result does not hold in

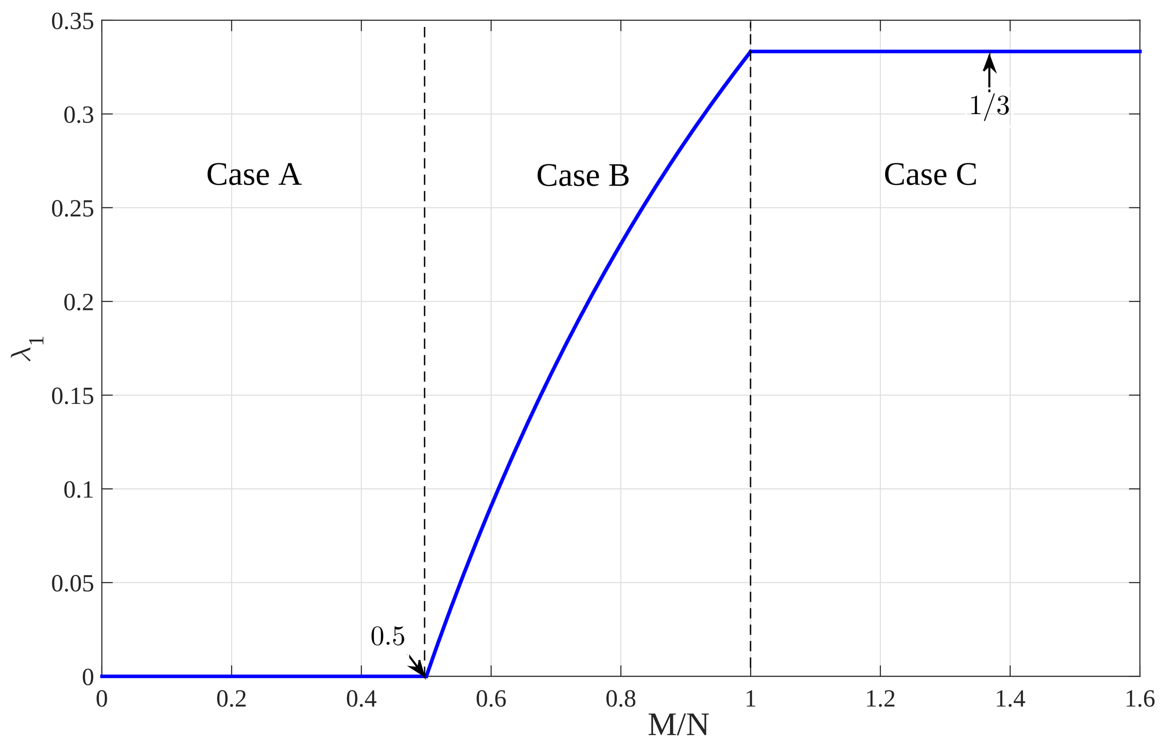
$$\begin{cases} M_2 \le N_2 \le M_1, M_1+2M_2 < N_1+N_2, \\ \text{or } M_1 \le N_2, M_1+M_2 < N_2+N_1/2 \end{cases}$$

and

$$\begin{cases} M_2 \le N_1 \le M_1, M_1+2M_2 < N_1+N_2, \\ \text{or } M_1 \le N_1, M_1+M_2 < N_1+N_2/2 \end{cases}$$

Some beamforming matrices cannot satisfy the alignment condition and provide enough rank of the desired signal space simultaneously

Discussion ⑥



Define λ_1 and λ_2 as the ratios of instantaneous CSIT time to total time and outdated CSIT time to total time, respectively

$$\text{Case A}: \lambda_1 = 0, \lambda_2 = 0$$

$$\text{Case B}: \lambda_1 = \frac{(M_1+M_2-N_2)}{N_1\frac{M_1+M_2-N_2}{M_1+M_2-N_1} + (M_1+M_2)}$$

$$\text{Case C}: \lambda_1 = \frac{N_1N_2}{N_1^2+N_2^2+N_1N_2}$$

In symmetric antenna setting, instantaneous CSIT time to total time ratio λ_1 is not more than $1/3$

References

[1] N. Lee, R. Tandon, and R. W. Heath, "Distributed space-time interference alignment with moderately delayed csit," *IEEE Transactions on Wireless Communications*, vol. 14, no. 2, pp. 1048–1059, Feb 2015.

Future Research

- Derive a tight upper DoF bound
- Consider imperfect CSIT conditions
- Extend to K-user X networks with synergistic CSIT

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