Interference Alignment on MIMO X Channel with Synergistic CSIT

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Contribution
- 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- The parameters of this scheme are optimized and the DoF value is shown to be greater than the value with outdated CSIT and equal to that of outdated CSIT with transmitter cooperation
- The deployment of outdated and instantaneous CSIT are being analyzed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
- The DoF in the SISO X channel with outdated CSIT is less than that in the SISO X channel with transmitter cooperation, viz. 6/5 vs 4/3
- The outdated and instantaneous CSIT can be synergistically utilized, if feedback delay is less than channel coherence time
- In the SISO case, the DoF (4/3) with synergistic CSIT is greater than that of outdated CSIT (6/5), and is the same as the DoF with outdated CSIT and transmitter cooperation

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

Case A: \( M_1 + M_2, \)

\[
\begin{align*}
\text{Case B:} & \quad \frac{N_1(M_1 + M_2 - N_2) + N_2(M_1 + M_2 - N_1)}{M_1 + M_2 - \frac{N_1N_2}{M_1M_2}} \\
\text{Case C:} & \quad \frac{N_1^2(N_1 + N_2) + N_2^2(N_1 + N_2)}{N_1^2 + N_2^2 + N_1N_2}
\end{align*}
\]

where Case A, B and C denote \( M_1 + M_2 \leq N_1, N_1 < M_1 + M_2 \leq N_1 + N_2 \) and \( N_1 + N_2 < M_1 + M_2 \)

The Case B result does not hold in

\[
\begin{align*}
M_2 & \leq N_2 < M_1, M_1 + 2M_2 < N_1 + N_2, \\
\text{or} \quad M_1 & \leq N_2, M_1 + M_2 < N_1 + N_2/2 \\
\text{and} \quad M_2 & \leq N_1 < M_1, M_1 + 2M_2 < N_1 + N_2, \\
\text{or} \quad M_1 & \leq N_1, M_1 + M_2 < N_1 + N_2/2
\end{align*}
\]

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

System Model
- 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 \( R_j \), \( j \in \{1, 2\} \): \( H_{ij} \). Each transmitter sends messages to both receiver

Methods
- 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

\[
\begin{align*}
H_{11}V_{11} &= H_{12}V_{21} \\
H_{12}V_{12} &= H_{22}V_{22}
\end{align*}
\]

- Extends to K-user X networks with synergistic CSIT

References

Future Research
- Derive a tight upper DoF bound
- Consider imperfect CSIT conditions

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