Communication in Massive MIMO: Challenges

- Higher carrier frequencies, larger number of antennas
- Large MIMO systems have large channel estimation overhead
- What can we do without CSI at either transmitter or receiver?

Our Previous Results

- Estimate the transmitted symbol as: \( \hat{x} \)

- Low encoding and decoding complexity

- Robust constellation design if statistics of \( h \) are not perfectly known

- Coherent (pilot based) schemes:
  - FDD: Impractical due to the large number of antennas
  - TDD: Pilot Contamination

- Multiuser Grassman manifold codebook optimization is tough for moderate SNRs
- Encoding complexity and decoder complexity

Proposed Approach

- Use only the knowledge of the channel statistics in the system model and the asymptotics of \( n \)

- Energy measurements at the receiver:
  - \( y = hx + \nu \), where \( y \in \mathbb{R}^n \), \( h, \nu \) i.i.d. \( \sim f(h), \nu \) i.i.d. \( \sim N(0, \sigma^2) \) \(, x \in \mathcal{P}\)

- Non-intersecting decoding intervals: \( \{I_p\}_{p \in \mathcal{P}} \)

- Estimate the transmitted symbol as: \( \hat{x} \in \{p : \|y\|_n^2 \in I_p\} \)

System Model

1 receiver with \( n \) antennas and 1 transmitter with single antenna:

\[ y = hx + \nu, \]

where \( y \in \mathbb{R}^n \), \( h, \nu \) i.i.d. \( \sim f(h), \nu \) i.i.d. \( \sim N(0, \sigma^2) \), \( x \in \mathcal{P} \)

Useful Lemma

The rate function \( I_p(d) \) satisfies

\[ \lim_{d \rightarrow 0} \frac{I_p(d)}{d^2} = \frac{1}{s(p)} \]

Perfect Knowledge of Channel Statistics

The rate function \( I_p(d) \) is upper bounded by \( e^{-nI_p(d)} \) where \( I_p(d) \) is the rate function

Constellation Design Problem

Find maximum \( t^* \) such that:

\[ \frac{d^2_{R,p}}{s(p)} \geq t^*, \quad \frac{d^2_{L,p}}{s(p)} \geq t^*, \quad \forall p \in \mathcal{P} \]

Number of Antennas needed: Perfect Channel Statistics

Intuition: Solve a weighted minimum distance problem

\[ \min_{p \in \mathcal{P}} \sum_{i=1}^{L} \rho_i \leq 1, \quad 0 \leq \rho_i \]

\[ d_{R,1} \leq d_{R,2} \leq \ldots \leq d_{R,L} \leq d_{L,2} \leq \ldots \leq d_{L,L} \]

\[ p_1 + \sigma^2 \leq p_2 + \sigma^2 \leq \ldots \leq p_L + \sigma^2 \]

Conclusions

- Simple scheme for non coherent communication in SIMO channels with simple encoding, simple decoding (lookup table) and simple receiver architecture (energy measurements only)
- "Asymptotics" kick in even with 50-100 antennas
- Valid for general fading statistics (e.g. Rician, Nakagami) and to block fading models
- Extensions: multiple users
- Current work: large coherence times, phase, downlink

References


Main takeaway

With 128 receive antennas, we can design a 3-bit constellation that achieves uncoded symbol error probability less than \( 10^{-4} \) in Rician Fading with \( K = 10 \) and \( \text{SNR} = 10 \text{ dB} \) without any CSI knowledge.