Blind Pilot Decontamination

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joint work with

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HARP

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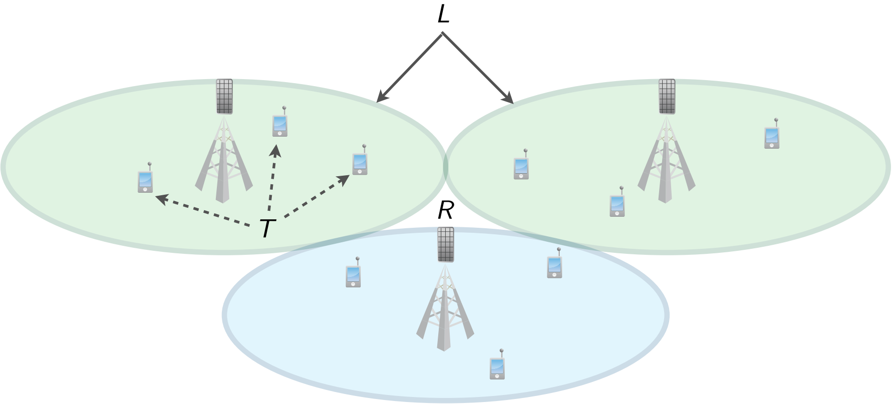
Both systems can operate in arbitrarily strong noise and interference.

Uplink (Reverse Link) System Model



$R \gg T$

$L \sim T$

Pilot (De-)Contamination

For T transmit antennas and R receive antennas, even for a static channel, RT channel coefficients must be estimated.

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How to estimate a massive MIMO channel appropriately?

Channel Reciprocity

We propose an uplink (reverse link)-based approach:

For a reciprocal channel, it suffices to utilize the array gain on the uplink.

Once, we have reliably detected the uplink data, we can use all uplink data to estimate the downlink (forward link) channel to high accuracy.

Blind Interference Rejection

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How to find the interference subspace or its orthogonal complement?

Matched Filter Projection

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- We would like to find a linear filter $\mathbf{m}$, such that $\mathbf{m}^\dagger \mathbf{Y}$ has high SNR.
- Then, we find

$$\mathbf{m} = \underset{\mathbf{m}_0}{\operatorname{argmax}} \frac{||\mathbf{m}_0^\dagger \mathbf{Y}||^2}{||\mathbf{m}_0||^2} = \underset{\mathbf{m}_0}{\operatorname{argmax}} \frac{\mathbf{m}_0^\dagger \mathbf{Y}\mathbf{Y}^\dagger \mathbf{m}_0}{\mathbf{m}_0^\dagger \mathbf{m}_0}$$

  is that eigenvector of $\mathbf{Y}\mathbf{Y}^\dagger$ that corresponds to the largest eigenvalue.

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We have utilized the array gain without estimating the channel.

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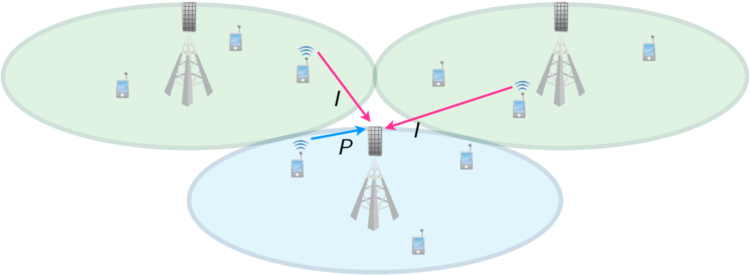
How to distinguish the signal of interest from interference?

Power Controlled Hand-Off

Consider power-controlled hand-off and perfect received power control.



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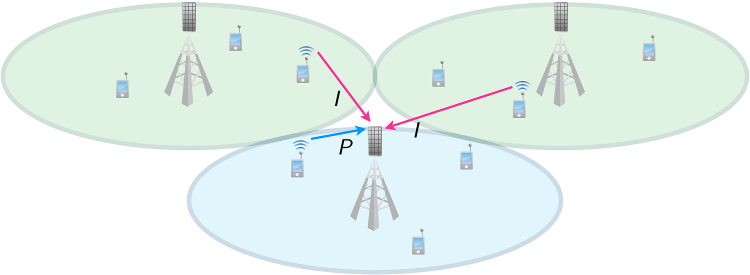

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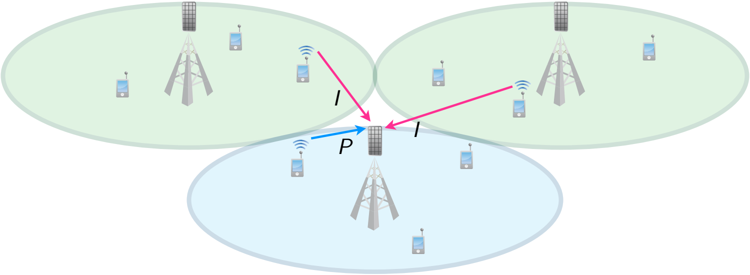

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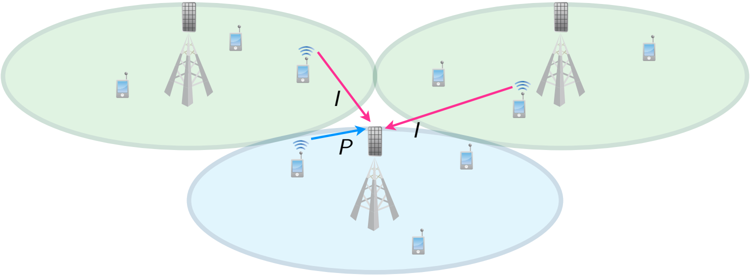

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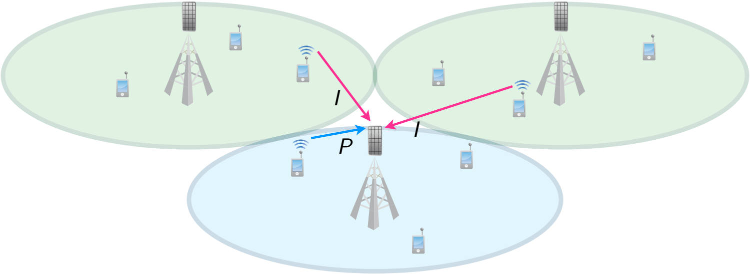

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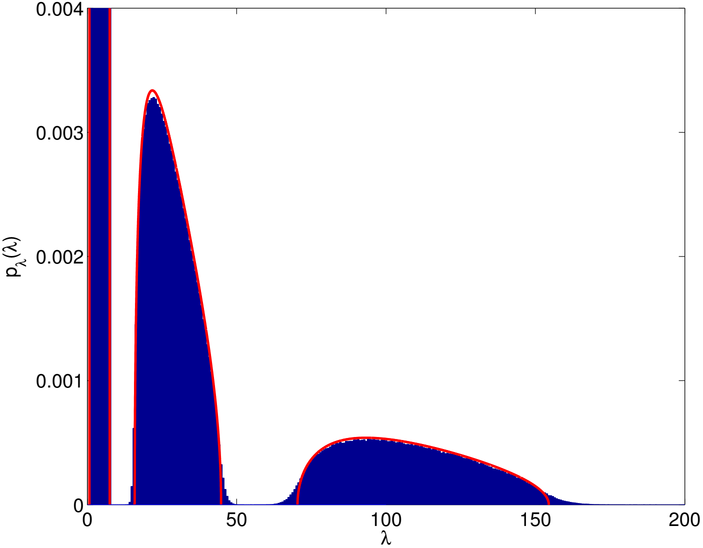
What if the load is small, but not vanishing?

Empirical Eigenvalue Distribution



$$\begin{aligned} R &= 300 \\ T &= 10 \\ C &= 1000 \\ L &= 2 \\ W &= 1000 \\ P &= 100 \\ I &= 25 \end{aligned}$$

Eigenvalue Spread

Assume an i.i.d. channel matrix and $R \gg T \to \infty$.

The eigenvalues of the signal of interest are confined in an interval centered at the received power P with width

$$4P\sqrt{\frac{T}{R} + \frac{T}{C}}.$$

For massive MIMO, the width is quite small.

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The eigenvalues of the sole interference spread around the interference power (which for sake of simplicity is assumed to be unique).
They are confined in an interval centered at the interference power I with width

$$4I\sqrt{\frac{LT}{R}+\frac{LT}{C}}$$

where L denotes the number of interfering cells.

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Eigenvalue Separation

The two intervals do not overlap if

$$\frac{P}{I} > \frac{1 + 2\sqrt{\frac{LT}{R} + \frac{LT}{C}}}{1 - 2\sqrt{\frac{T}{R} + \frac{T}{C}}}.$$

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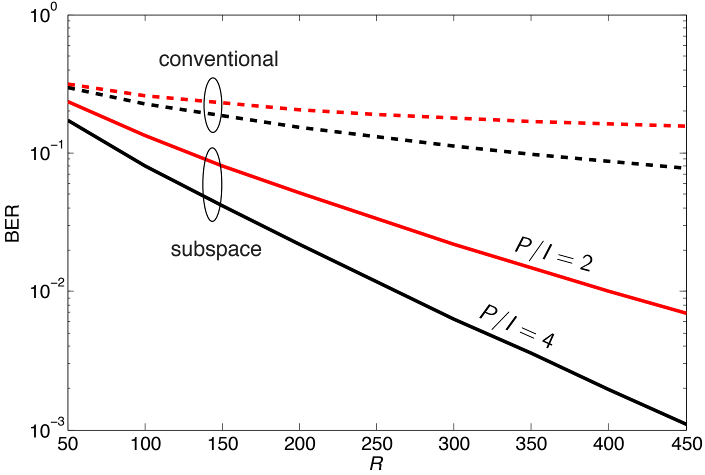
For finite number of receive antennas, the interval boundaries are not sharp, but have exponentially decaying tails.

BER vs. Array Size



$T = 3$

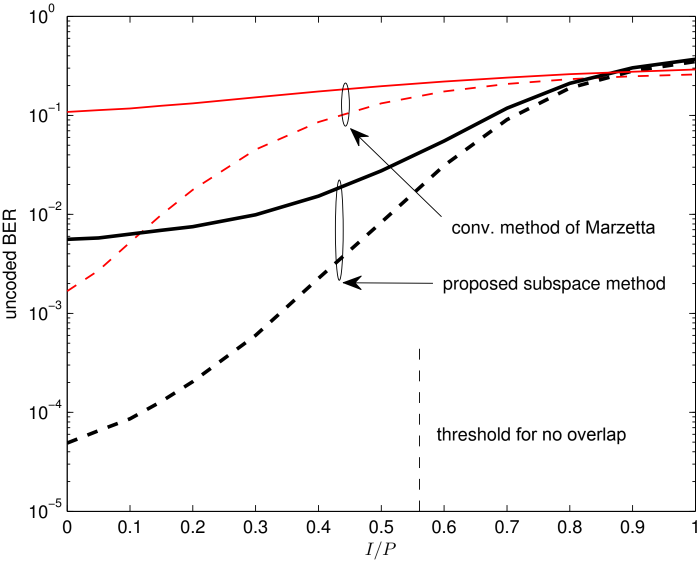
$C = 1000$

$L = 2$

$\text{SNR} = -10\text{dB}$

1 pilot symbol per transmit antenna and cell

BER vs. Power Margin



$$R = 200$$
$$T = 2$$
$$C = 400$$
$$L = 2$$
$$W = 1$$
$$P = 0.1$$

1 (–) or 10 (- -) pilot symbols per transmit antenna and cell

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Pro: A sufficient power margin can be established (with high probability).
Con: Users at cell boundaries may suffer from reduced data rate.

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- The algorithm requires real-time eigenvalue or singular value decompositions.

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