Massive Overloaded MIMO Signal Detection via Convex Optimization with Proximal Splitting

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Abstract

We propose a **signal detection** scheme for **massive overloaded** multiple-input multiple-output (MIMO) systems, where the number of receive antennas is less than that of transmitted streams. Using the idea of the sum-of-absolute-value (SOAV) optimization, we formulate the signal detection as a **convex optimization** problem.

To improve the performance, we also propose an **iterative approach**, referred to as iterative weighted-SOAV (IW-SOAV). It iteratively solves an optimization problem with weighting parameters update in the cost function. Simulation results show that the proposed scheme can achieve much better bit error rate (BER) performance than conventional schemes.

1. Introduction

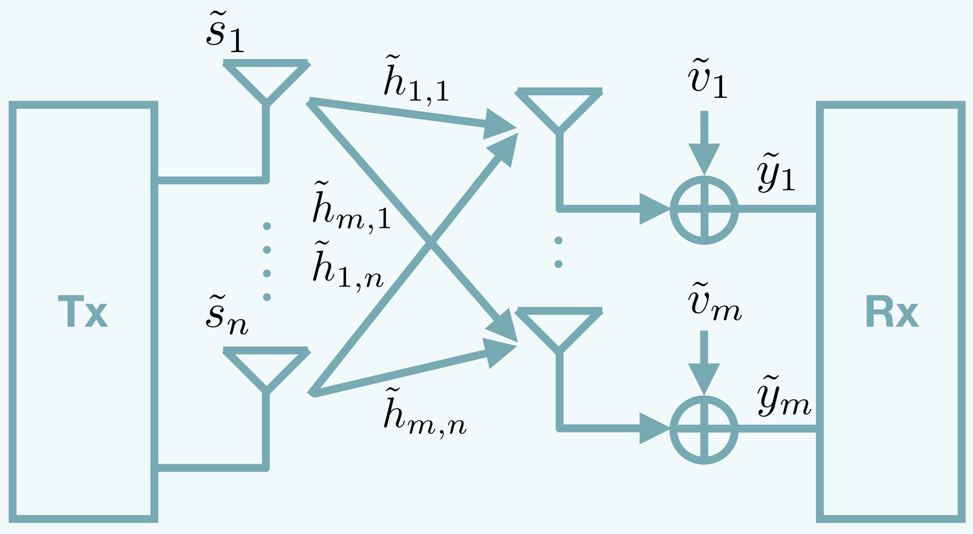
massive overloaded MIMO

- massive:
  - tens or hundreds of antennas are used to achieve very high spectral efficiency
- overloaded:
  - the number of receive antennas is **less** than that of transmitted streams due to **limits on size or weight of receiver**

Signal detection for massive overloaded MIMO is large-scale **underdetermined** problem

→ Performance of most detection schemes severely degrades

2. System Model



$\tilde{\boldsymbol{s}} \in \tilde{\mathbb{S}}^n$: transmitted signal vector
$\tilde{\boldsymbol{y}} \in \tilde{\mathbb{C}}^m$: received signal vector
$\tilde{\boldsymbol{H}} \in \tilde{\mathbb{C}}^{m \times n}$: channel matrix
$\tilde{\boldsymbol{v}} \in \tilde{\mathbb{C}}^m$: noise vector

$n > m$ (overloaded)

Complex Model → **Real Model**

$$\tilde{\boldsymbol{y}} = \tilde{\boldsymbol{H}}\tilde{\boldsymbol{s}} + \tilde{\boldsymbol{v}}$$

$$\boldsymbol{y} = \begin{bmatrix}\mathrm{Re}\{\tilde{\boldsymbol{y}}\} \\ \mathrm{Im}\{\tilde{\boldsymbol{y}}\}\end{bmatrix} \quad \boldsymbol{s} = \begin{bmatrix}\mathrm{Re}\{\tilde{\boldsymbol{s}}\} \\ \mathrm{Im}\{\tilde{\boldsymbol{s}}\}\end{bmatrix}$$

$$\boldsymbol{H} = \begin{bmatrix}\mathrm{Re}\{\tilde{\boldsymbol{H}}\} & -\mathrm{Im}\{\tilde{\boldsymbol{H}}\} \\ \mathrm{Im}\{\tilde{\boldsymbol{H}}\} & \mathrm{Re}\{\tilde{\boldsymbol{H}}\}\end{bmatrix} \quad \boldsymbol{v} = \begin{bmatrix}\mathrm{Re}\{\tilde{\boldsymbol{v}}\} \\ \mathrm{Im}\{\tilde{\boldsymbol{v}}\}\end{bmatrix}$$

$$\boldsymbol{y} = \boldsymbol{H}\boldsymbol{s} + \boldsymbol{v}$$

3. Proposed Signal Detection Scheme

Assumption (for simplicity): $\boldsymbol{s} \in \{1, -1\}^{2n}$ (QPSK modulation)

Basic idea: $\boldsymbol{s}$ is discrete-valued vector composed of 1 and -1

$$\sum_{j=1}^{2n} \left(\frac{1}{2}|s_j - 1| + \frac{1}{2}|s_j + 1| \right) \text{ is small } -(*)$$

SOAV optimization

from $(*)$ from $\boldsymbol{y} = \boldsymbol{H}\boldsymbol{s} + \boldsymbol{v}$

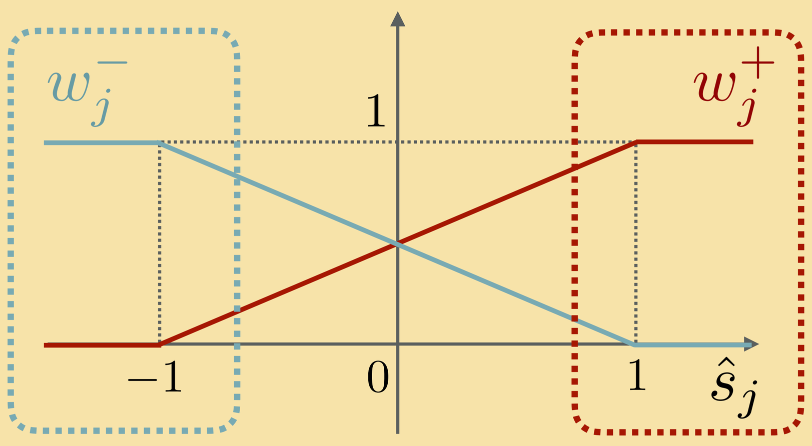
$$\underset{\boldsymbol{z} \in \mathbb{R}^{2n}}{\text{minimize}} \sum_{j=1}^{2n} \left(\frac{1}{2}|z_j - 1| + \frac{1}{2}|z_j + 1| \right) + \frac{\alpha}{2}\|\boldsymbol{y} - \boldsymbol{H}\boldsymbol{z}\|_2^2 \quad (\alpha > 0)$$

↓ $\hat{\boldsymbol{s}}$

weight update

Calculate w_j^+, w_j^- $(j = 1, \ldots 2n)$

rough approximation of $\Pr(s_j = 1), \Pr(s_j = -1)$



$w_j^+ < w_j^-$ $w_j^+ > w_j^-$

↓ w_j^+, w_j^-

weighted-SOAV optimization

detection with prior information w_j^+, w_j^-

$$\underset{\boldsymbol{z} \in \mathbb{R}^{2n}}{\text{minimize}} \sum_{j=1}^{2n} \left(w_j^+|z_j - 1| + w_j^-|z_j + 1| \right) + \frac{\alpha}{2}\|\boldsymbol{y} - \boldsymbol{H}\boldsymbol{z}\|_2^2$$

$w_j^+ > w_j^-$ ⟹ z_j becomes close to 1

$w_j^+ < w_j^-$ ⟹ z_j becomes close to -1

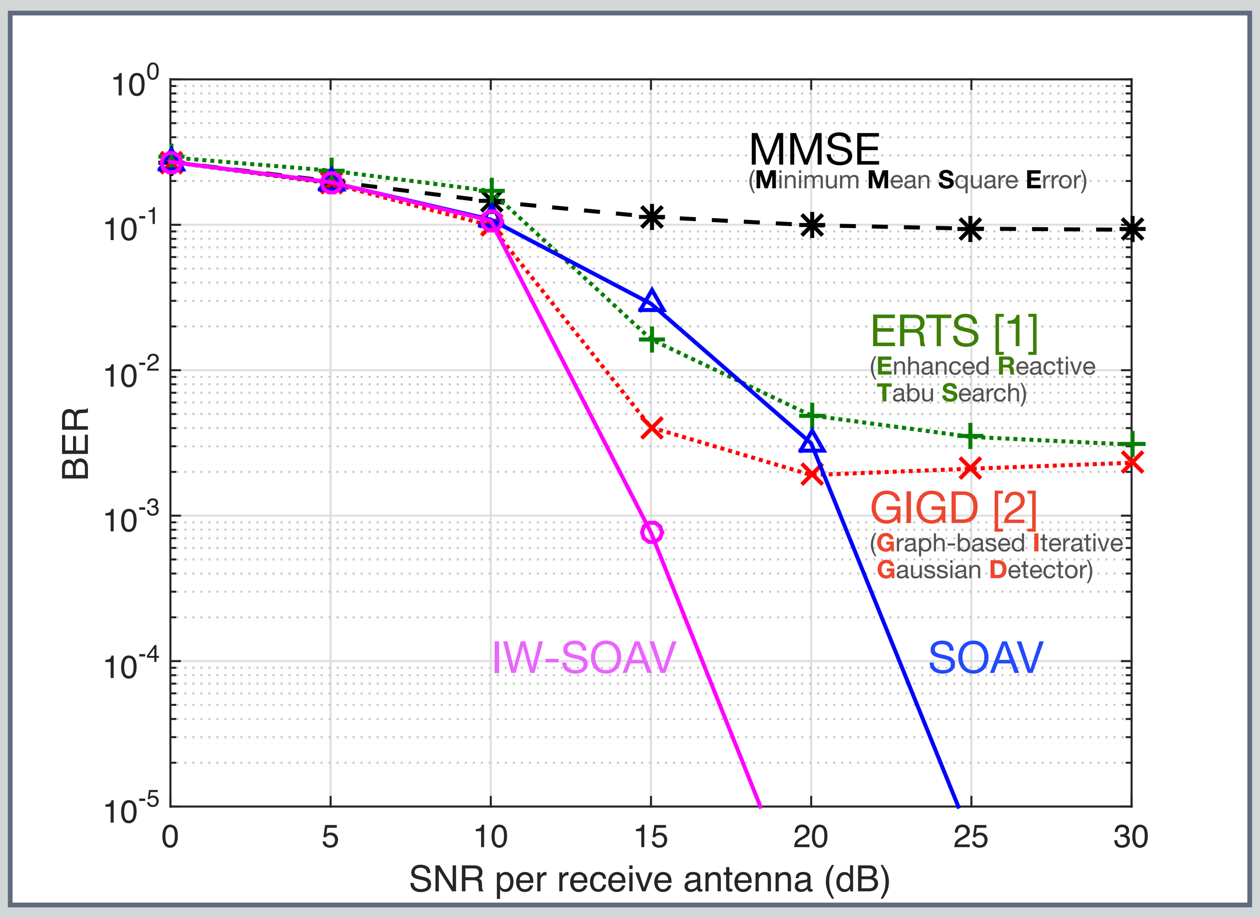
↓ $\hat{\boldsymbol{s}}$ (fed back to weight update)

↓ $\hat{\boldsymbol{s}}$

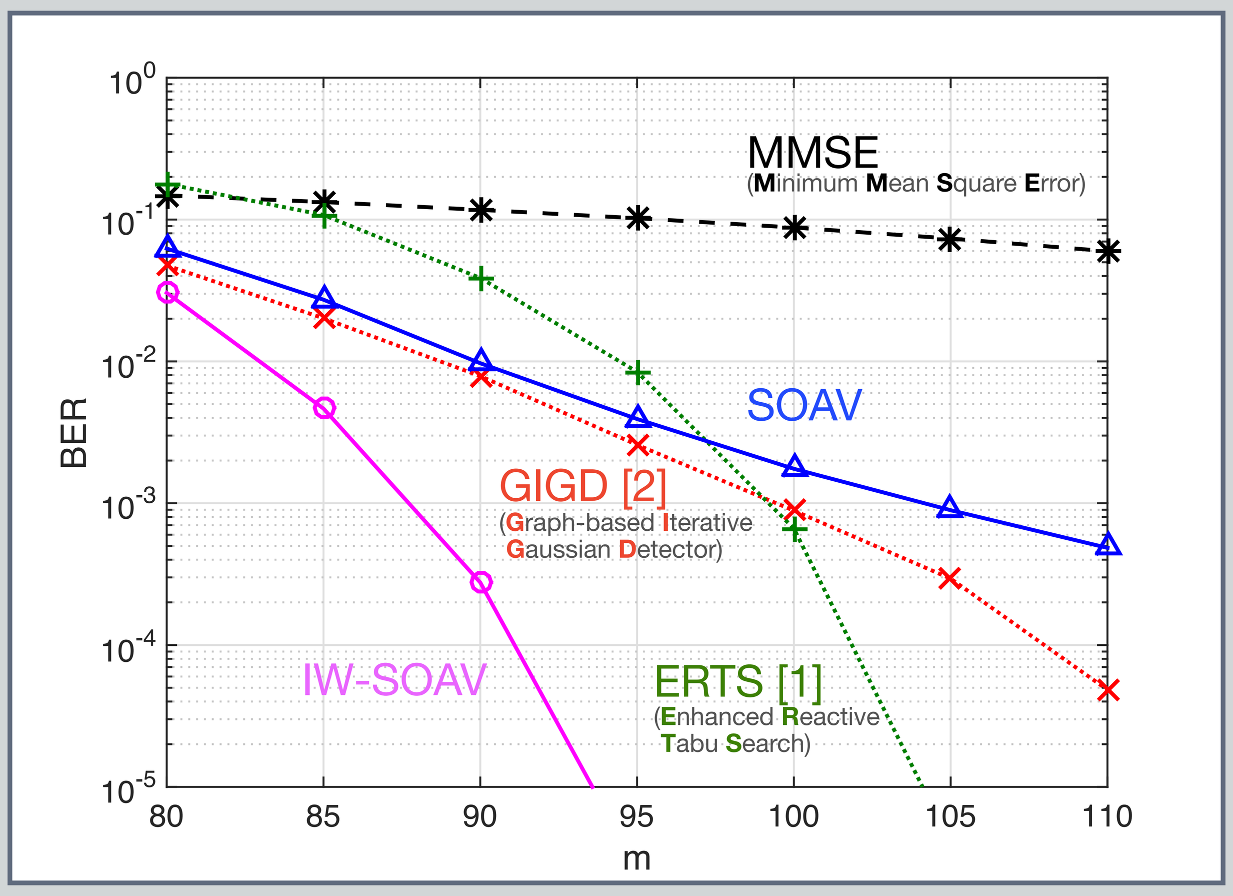
4. Simulation Results

Our proposed scheme (IW-SOAV) outperforms the conventional schemes

number of transmit antennas: $n = 150$
number of receive antennas : $m = 96$



number of transmit antennas: $n = 150$
SNR per receive antenna : 20dB



[1] T. Datta, N. Srinidhi, A. Chockalingam, and B. S. Rajan, “Low-complexity near-optimal signal detection in underdetermined large-MIMO systems,” Proc. NCC 2012, pp. 1–5, Feb. 2012.
[2] T. Wo and P. A. Hoeher, “A simple iterative Gaussian detector for severely delay-spread MIMO channels,” Proc. IEEE ICC 2007, pp. 4598–4563, Jun. 2007.