A Novel Approach to Joint User Selection and Precoding for Multiuser MISO Downlink Channels

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Objective

Joint design of user selection (US) and precoding for the design criteria of weighted sum rate (WSR) maximization s.t total power constraint

System Model

- Single cell MISO system; Down link scenario
- full frequency and time resources reuse
- M Tx ants; $N(\geq M)$ single antenna users (UEs)
- Independent data to selected UEs; Utmost M selected UEs
- Rx signal of all UEs, $\mathbf{y}$, is

$$\begin{bmatrix} y_1 \\ \vdots \\ y_N \end{bmatrix} = \begin{bmatrix} \dots \mathbf{h}_1^H \dots \\ \vdots \\ \dots \mathbf{h}_N^H \dots \end{bmatrix} \begin{bmatrix} \vdots & & \vdots \\ \mathbf{w}_1 & \dots & \mathbf{w}_N \\ \vdots & & \vdots \end{bmatrix} \begin{bmatrix} x_1 \\ \vdots \\ x_N \end{bmatrix} + \begin{bmatrix} \vdots \\ \mathbf{n} \\ \vdots \end{bmatrix}$$

- y_i, $\mathbf{h}_i$, $\mathbf{w}_i$, x_i, n_i are the received signal, downlink channel and precoding vector, data and noise of user i.

Prior work and contribution

Prior work:

- US and precoding as two decoupled problems
- Joint problem formulation with disjoint update of US and precoding variables

Scope of improvement: US and precoding are coupled → the joint solution outperforms aforementioned techniques

Contribution: Joint solution to joint problem

Weighted sum rate maximization

$$\max_{\mathbf{W},\mathcal{S}} \sum_{i\in\mathcal{S}} \beta_i \log(1+\gamma_i)$$

$$\text{s.t. } C_1: \sum_{i=1}^{N} \|\mathbf{w}_i\|_2^2 \leq P_T;\ C_2: |\mathcal{S}| \leq M$$

where β_i and $\gamma_i = \dfrac{|\mathbf{h}_i^H\mathbf{w}_i|^2}{\sigma^2 + \sum_{j\neq i}|\mathbf{h}_i^H\mathbf{w}_j|^2}$ are the weight and SINR of user i, and $\mathcal{S}$ is the set of selected users, and P_T is the total power.

Joint formulations with binary variables in literature

$$\max_{\mathbf{W},\boldsymbol{\eta}} \sum_{i=1}^{N} \eta_i\beta_i \log(1+\gamma_i) \ \text{ or } \ \sum_{i=1}^{N} \beta_i \log(1+\eta_i\gamma_i)$$

$$\text{s.t } C_1: \eta_i \in \{0,1\},\ \forall i$$

$$C_2: \sum_{i=1}^{N} \eta_i \leq M;\ C_3: \sum_{i=1}^{N} \|\mathbf{w}_i\|_2^2 \leq P_T$$

Drawbacks

- Multiplication $\implies$ Coupled formulation
- Alternative update of $\mathbf{W}$ and $\boldsymbol{\eta}$

Proposed formulation

Key: $\|\mathbf{w}_i\|_2^2 = \begin{cases} 0; \text{Not selected} \\ \neq 0; \text{selected} \end{cases}$

Reformulation with binary slack variable

$$\mathcal{P}_1: \max_{\mathbf{W},\mathbf{P},\boldsymbol{\eta}} \sum_{i=1}^{N} \beta_i \log(1+\gamma_i)$$

$$\text{s.t. } C_1: \eta_i \in \{0,1\},\ \forall i,$$

$$C_2: \|\mathbf{w}_i\|_2^2 \leq \eta_i P_i, \forall i$$

$$C_3: \sum_{i=1}^{N} \eta_i \leq M;\ C_4: \sum_{i=1}^{N} P_i \leq P_T$$

Novelty: Decoupling of $\mathbf{W}$ and $\boldsymbol{\eta}$

Usefulness: Amenable to joint optimization

Remark: Nonconvex obj and $\boldsymbol{\eta} \implies$ MINLP

WSR as DC problem

Addressing non-convexity: Epigraph form

$$\mathcal{P}_2: \max_{\mathbf{W},\mathbf{P},\boldsymbol{\eta},\boldsymbol{\zeta}} \sum_{i=1}^{N} \beta_i \log(\zeta_i)$$

$$\text{s.t.} C_1, C_2, C_3, C_4$$

$$C_5: 1+\gamma_i \geq \zeta_i,\ \forall i$$

$$C_6: \gamma_i \geq 1,\ \forall i$$

C_5 as a DC constraint:

$$1+\gamma_i \geq \zeta_i \implies \frac{\sigma^2+\sum_{j=1}^{N}|\mathbf{h}_i^H\mathbf{w}_j|^2}{\sigma^2+\sum_{j\neq i}|\mathbf{h}_i^H\mathbf{w}_j|^2} \geq \zeta_i$$

$$\implies \underbrace{\frac{\sigma^2+\sum_{j=1}^{N}|\mathbf{h}_i^H\mathbf{w}_j|^2}{\zeta_i}}_{\text{jointly convex in } \mathbf{W},\zeta_i \text{ for } \zeta_i>0} \geq \underbrace{\sigma^2+\sum_{j\neq i}|\mathbf{h}_i^H\mathbf{w}_j|^2}_{\text{convex}}$$

Binary to continuous: Penalization method

$$\mathcal{P}_4: \max_{\mathbf{W},\mathbf{P},\boldsymbol{\eta},\boldsymbol{\zeta}} \underbrace{\sum_{i=1}^{N} \left(\beta_i \log(\zeta_i) + \lambda P(\eta_i)\right)}_{\text{difference of concave}}$$

$$\text{s.t. } C_1: 0 \leq \eta_i \leq 1,\ \forall i$$

$$C_5: \underbrace{\sigma^2+\sum_{j\neq i}|\mathbf{h}_i^H\mathbf{w}_j|^2 - \frac{\sigma^2+\sum_{j=1}^{N}|\mathbf{h}_i^H\mathbf{w}_j|^2}{\zeta_i}}_{\text{difference of convex functions}} \leq 0,\ \forall i,$$

$$C_2, C_3, C_4, C_6$$

Remarks:

- $P(\eta_i) \triangleq \eta_i \log\eta_i + (1-\eta_i)\log(1-\eta_i)$ is convex
- Maximization of $P(\eta_i)$ yields $\eta_i \in \{0,1\}$ for appropriate λ
- $\mathcal{P}_4$ is a DC problem: DC objective s.t DC and convex constraints
- Efficient than SDP based DC formulation: No rank ambiguity and less complex
- $\mathcal{P}_4$ is solved using Convex-concave procedure (CCP)
- Feasible initial point $\implies$ convergence to a stationary point for CCP based solution

SAJSP a CCP based Solution

Execute the following two steps untill convergence:

- Convexify $\mathcal{P}_4$ around previous point using affine approximations of nonconvex parts
- Solve the convexified problem globally

Simulation Results

- $\{\beta_i\}_{i=1}^{N} = 1$, $\lambda = 1$, $P_T = 10$ dB
- Results are averaged over 500 iterations
- SUS-ZF/MMSE: Channel orthogonality based user selection followed by ZF/MMSE precoding
- SUS-ZF is used as a initial feasible point

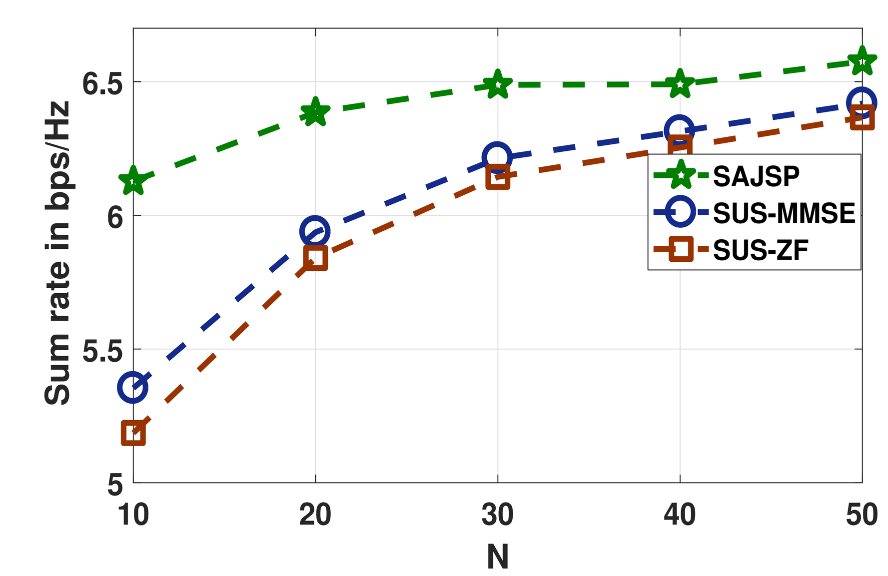

Figure 1: WSR versus N for M =4 and $N = [10:10:50]$

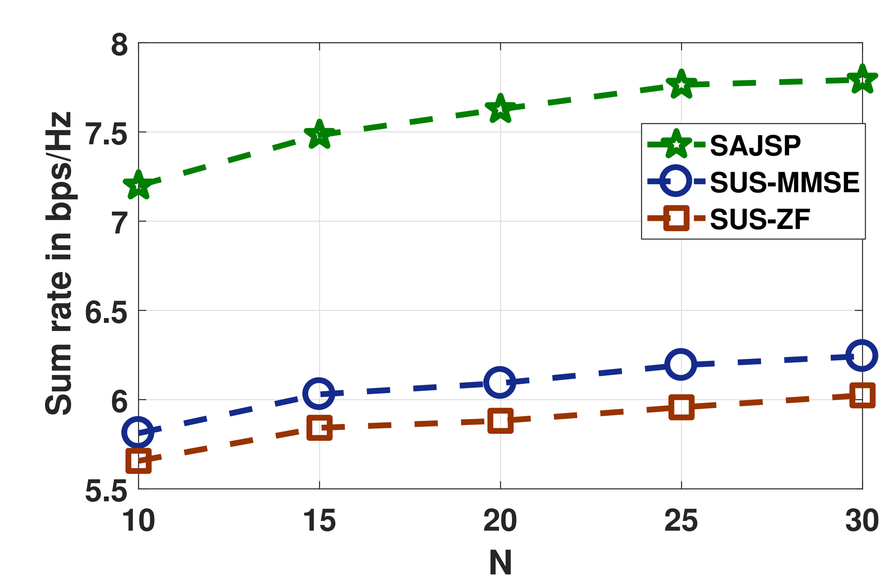

Figure 2: WSR versus N for M =8 and $N = [10:5:30]$.

Conclusions

Novel formulation → DC reformulation → CCP based solution → efficacy through simulations