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Joint User and Receive Antenna Selection Algorithms for MU-MIMO Systems with Reduced Complexity

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Contents

Aims/Objectives

- The aim is to show that a joint user and receive antenna selection (**JURAS**) scheme potentially provides **significant sum capacity over a user selection (US) scheme.**

- **Two sub-optimal joint user and antenna selection algorithms** with dynamic data stream allocation are also going to analysed.

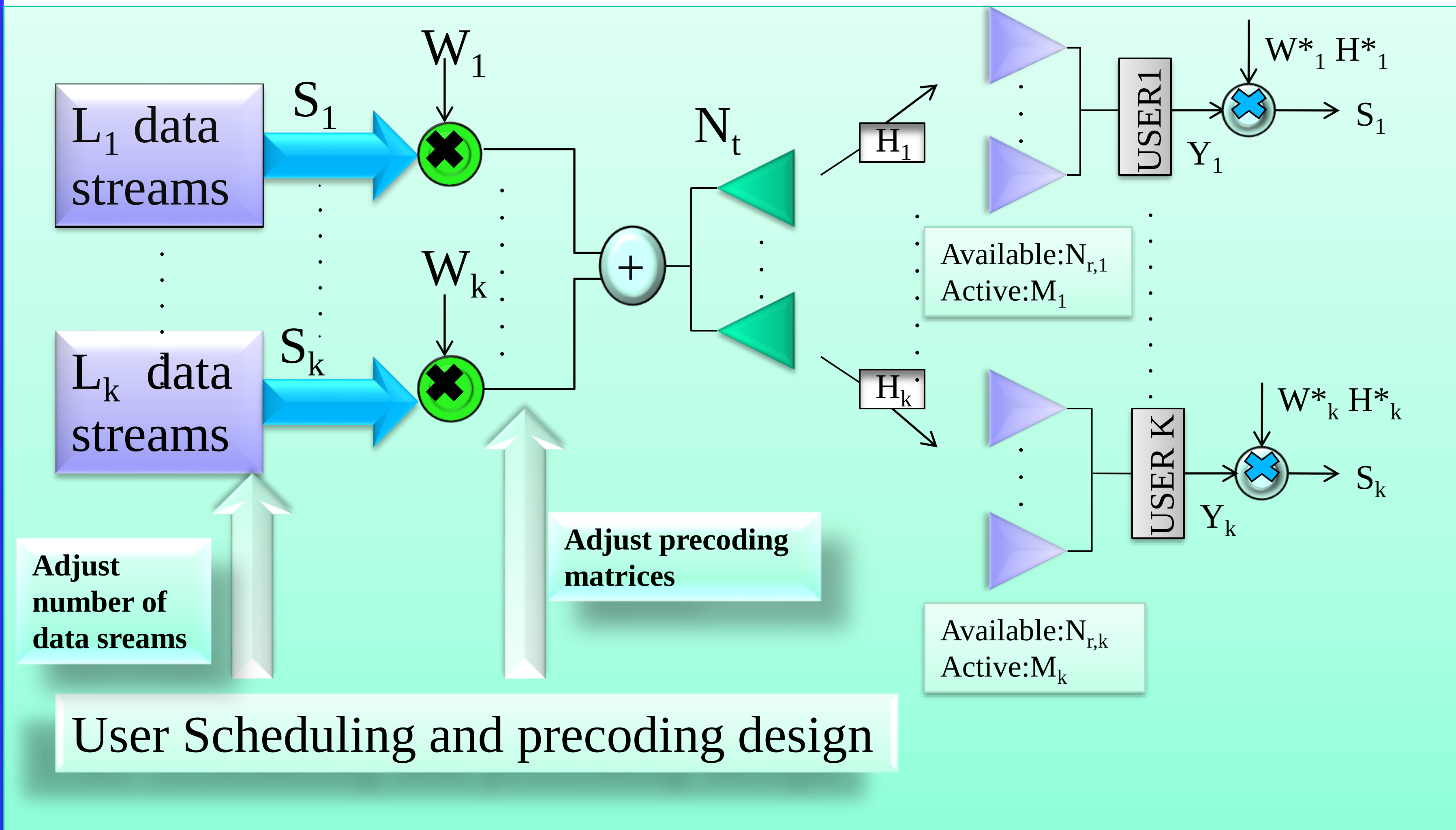
Introduction

- MU-MIMO schemes have recently attracted attention due to their capability of offering significant gain in **system capacity.**
- **When users are equipped with multiple antennas**, joint user and receive antenna selection may be performed and it potentially provide **superior performance**.
- There are some techniques which provide theoretical sum capacity are DPC (**Dirty Paper Coding**) ,ZF (**Zero Forcing**), BD (**Block Diagonalization**) but they suffer due to high complexity.

Introduction

- JURAS is used to achieve **high sum capacity** at high SNR.
- **sub optimal algorithms** are used to provide near theoretical sum capacity having **reduced complexity.**
- These algorithms will find the best combination of user and their receive antennas which will provide **maximum possible data rates or sum capacity** thereby increasing the data transfer rates.
- Although they are suboptimal but they are very useful when **number of receive antennas and users increase**.

System Model



System Model

- The model consists of a **single cell downlink MU MIMO** network.

- The Base Station has N_t number of transmitting antennas whereas there are **K users** having $\mathbf{N_r}$ **receiving antennas** with them where $\mathbf{M_k}$ **receiving antennas will be active at a time** for a particular user where $\mathbf{M_k <= Nr}$.

System Model

- Our **objective function i.e. sum capacity** is dependent on the SINR based precoding matrix which has been given in next slides.

- We will assume **equal power per data stream power scheme** while calculating the **SINR** for the system (**EPS**).

System Model

- The **received signal** at the mobile station is given as,

$$\underbrace{\mathbf{y_j}}_{\text{Received signal}} = \underbrace{\mathbf{H_j W_j s_j}}_{\text{Desired signal}} + \underbrace{\mathbf{H_j} \sum_{\mathbf{k \in U_j k \neq j}} \mathbf{W_k s_k}}_{\text{Interfering undesired signals}} + \underbrace{\mathbf{v_j}}_{\text{White zero mean complex gaussian noise}}$$

JURAS Scheme for MU-MIMO

- **JURAS means the joint user and receive antenna selection scheme** which is being implemented in this project using two suboptimal algorithms.

- **Suboptimal algorithm-1** works by updating the user's precoding matrices and evaluate sum capacity(**time complexity is somewhat more**).

- **Suboptimal algorithm-2** works by considering each receiving antenna as a single user during user selection process and then computes the precoding matrices used for data transmission (**time complexity is reduced**) .

Suboptimal Algorithms

1. Suboptimal algorithm 1

- This suboptimal algorithm can be divided into two phases. The **first phase** extends the ideas of the **capacity-based iterative user selection algorithm.**
- It selects a receive antenna with the highest capacity. Then, from the remaining unselected antennas, it finds the next receive antenna providing the largest sum capacity.

Suboptimal Algorithms

- This phase terminates when the **sum capacity would reduce as a result of adding one more receive antenna** (equivalent to one more data stream).
- In the **second phase**, the algorithm researches the remaining unselected antennas of the selected users without increasing the number of allocated data streams.
- The algorithm terminates when no extra sum capacity is achieved by the receive beamforming.

Suboptimal Algorithms

- This suboptimal algorithm selects receive antenna of user having highest capacity and so on and use the below formula to calculate the sum capacity,

$$C_{\text{sum}} = \sum_{j \in U} \sum_{l=1}^{L_j} log_2 \left(1 + \frac{\left[D_j D_j^* \right]_{ll}}{\left[\left(L\sigma_j^2 / E_{BS} \right) D_j + Q_j \widetilde{W}_j \widetilde{W}_j^* Q_j^* \right]_{ll}} \right)$$

- The complexity of the suboptimal algorithm 1 is more .

Suboptimal Algorithms

❑ SA-1 PSEUDOCODE

1. **Initialization:**
2. UsrId = mapping between rx antenna id and user id
3. $\mathcal{R} = \{1, \dots, N_r\}, \delta = \emptyset, u = \emptyset, l = 0, \widetilde{H} = \emptyset$
4. $C_{\max} = 0$, flag $= 1$, phase $= 1$
5. **Do while flag $= 1$**
   a. **for every $r \in \mathcal{R}$**
      i. Let $\delta_{\text{tmp}} = \delta + \{r\}, W = \emptyset, H = \widetilde{H}, l_{\text{tmp}} = l$
      ii. **Find the candidate user:**

      $$u = Usrld(r), u_{\text{tmp}} = u \cup \{u\}, H_u = H[u\} = [H[u]; h_r]$$

      iii. **If phase $= 1$,**

      $$l_{\text{tmp}}(u) += 1;$$

      iv. **End**

Suboptimal Algorithms

v. $L_{\mathrm{tmp}} = \mathrm{sum}(l_{\mathrm{tmp}})$

vi. Find precoding $\boldsymbol{W_j}$ for every user $\boldsymbol{j} \in \boldsymbol{U}_{\mathbf{tmp}}$

$$M_j = \mathrm{size}(H_j, 1), E_j = L_j \cdot E_{BS}/L_{tmp}$$

$$W_j \propto \mathrm{eigvec}_{L_j}\left(H_j^* H_j, \left(\frac{M_j \sigma_j^2}{E_j}\right)\mathbf{I} + \tilde{H}_j^* \tilde{H}_j\right), \mathrm{Tr}(W_j^* W_j) = L_j$$

$$W\{j\} = W_j$$

vii. Calculate sum capacity, denoted as $\boldsymbol{C_r}$

$$C_r = \sum_{j \in U_{\mathrm{tmp}}} \sum_{i=1}^{M_j} \log_2\left(1 + \frac{\left[D_j D_j^*\right]_{ll}}{\left[\left(L_{tmp}\,\sigma_j^2/E_{BS}\right)D_j + Q_j \overline{W}_j \overline{W}_j^* Q_j^*\right]_{ll}}\right)$$

b. End

c. $\bar{r} = \mathrm{argmax}_{r \in R} C_r$

d. if $\boldsymbol{C_{\vec{r}}} > \boldsymbol{C}_{\mathbf{max}}$

i. if phase $= \mathbf{1}$

$$l(\bar{u}) += 1;$$

ii. End

Suboptimal Algorithms

e. elseif phase $= 1$

$i.$ $\mathcal{R} =$ remaining antennas of users in u,

not been selected in δ phase $= 2$

f. Else

i. flag $= 0$

g. End

h. End

Output: $\mathcal{S}, \mathcal{U}, \mathbf{l}$

Suboptimal Algorithms

2. Suboptimal algorithm 2

- It is seen that the **main computational burden of SA1** focuses on **updating users' precoding matrices and evaluating the sum capacity**.
- Thus, the algorithm is only required to compute the beamforming vector of **the candidate antenna without updating the precoding matrices of the selected ones.**

Suboptimal Algorithms

- Treating each receive antenna as an individual user provides **more robustness to the errors** from outdated precoding matrices than considering multiple antennas at each user.
- By treating each antenna as a separate user, no receive beamforming can be exploited. Thus, procedures in the second phase are excluded from SA2 and **the number of data streams is always equal to the number of selected antennas.**

Suboptimal Algorithms

- This suboptimal algorithm selects receive antenna of user having highest capacity and so on and use the below formula to calculate the sum capacity,

$$C_{sum} = \sum_{r=Stmp} log_2\left(1 + \frac{\|h_r w_r\|^2}{\left(\frac{L\sigma_r^2}{E_{BS}}\right) + \Sigma_{q\in\delta,q\neq r}\|h_r w_q\|^2}\right)$$

- The complexity of the suboptimal algorithm 2 is less.

Suboptimal Algorithms

❑ SA-2 PSEUDOCODE

1. **Initialization:**

   $\mathcal{R} = \{1, \ldots, N_r\}, \delta = \emptyset, L = 0, \mathbf{H} = \emptyset, \mathbf{W} = \emptyset$
   $C_{\max} = 0, \text{flag} = 1$

2. **Do while flag $= 1$**

   a. **for every $r \in \mathcal{R}$**

      i. Let $\delta_{\text{tmp}} = \delta + \{r\}$

      ii. $L_{tmp} = L + 1$

      iii. **Find precoding only for the candidate antenna**

      iv. $\mathbf{w}_r \propto$ max. eigenvector $\left(\left((L_{\text{tmp}}\, \sigma_r^2 / E_{BS})\mathbf{I} + \widetilde{\mathbf{H}}^* \, \widetilde{\mathbf{H}}\right)^{-1} \mathbf{h}_r^* \mathbf{h}_r\right)$

      v. $\mathrm{Tr}(w_r^* w_r) = 1$

      vi. $W_{\text{tmp}} = [W, w_r]$

      vii. **Calculate sum capacity, denoted as C_r**

$$C_r = \sum_{i \in \delta_{tmp}} \log_2 \left(1 + \frac{\|\mathbf{h}_i \mathbf{W}_{\text{tmp}}(:, i)\|^2}{(L_{tmp}\, \sigma_i^2 / E_{BS}) + \sum_{i \in \delta_{tmp}, i \pm i} \|h_i W_{tmp}(:, \tilde{\imath})\|^2}\right)$$

   b. **End**

Suboptimal Algorithms

c. $\bar{r} = \text{argmax}_{r \in \mathcal{R}} C_r$

d. if $\boldsymbol{C}_{\mathbf{fr}} > \boldsymbol{C}_{\mathbf{max}}$

$$C_{\max} = C_{\bar{r}}, \delta = \delta + \{\bar{r}\}, \mathcal{R} = \mathcal{R} - \{\bar{r}\}$$
$$L = L + 1$$
$$W = [W, w_{\bar{r}}], \widetilde{H} = [\widetilde{H}\,; h_{\bar{r}}]$$

e. else

i. $\text{flag} = 0$

f. End

3. End

Output: $\boldsymbol{\delta}(\boldsymbol{u}, \boldsymbol{l}$ are derived from $\boldsymbol{\delta})$

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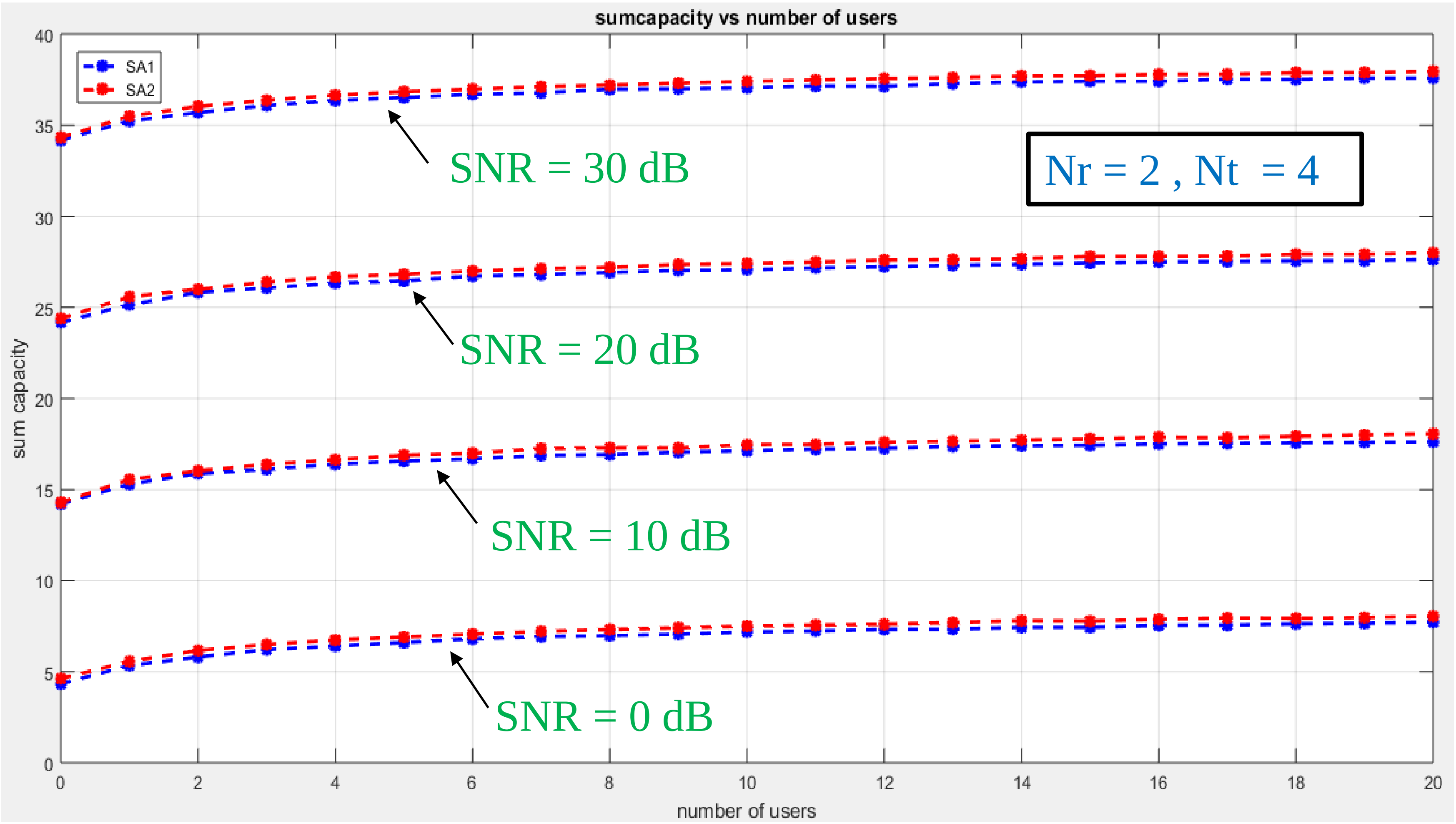
Outputs



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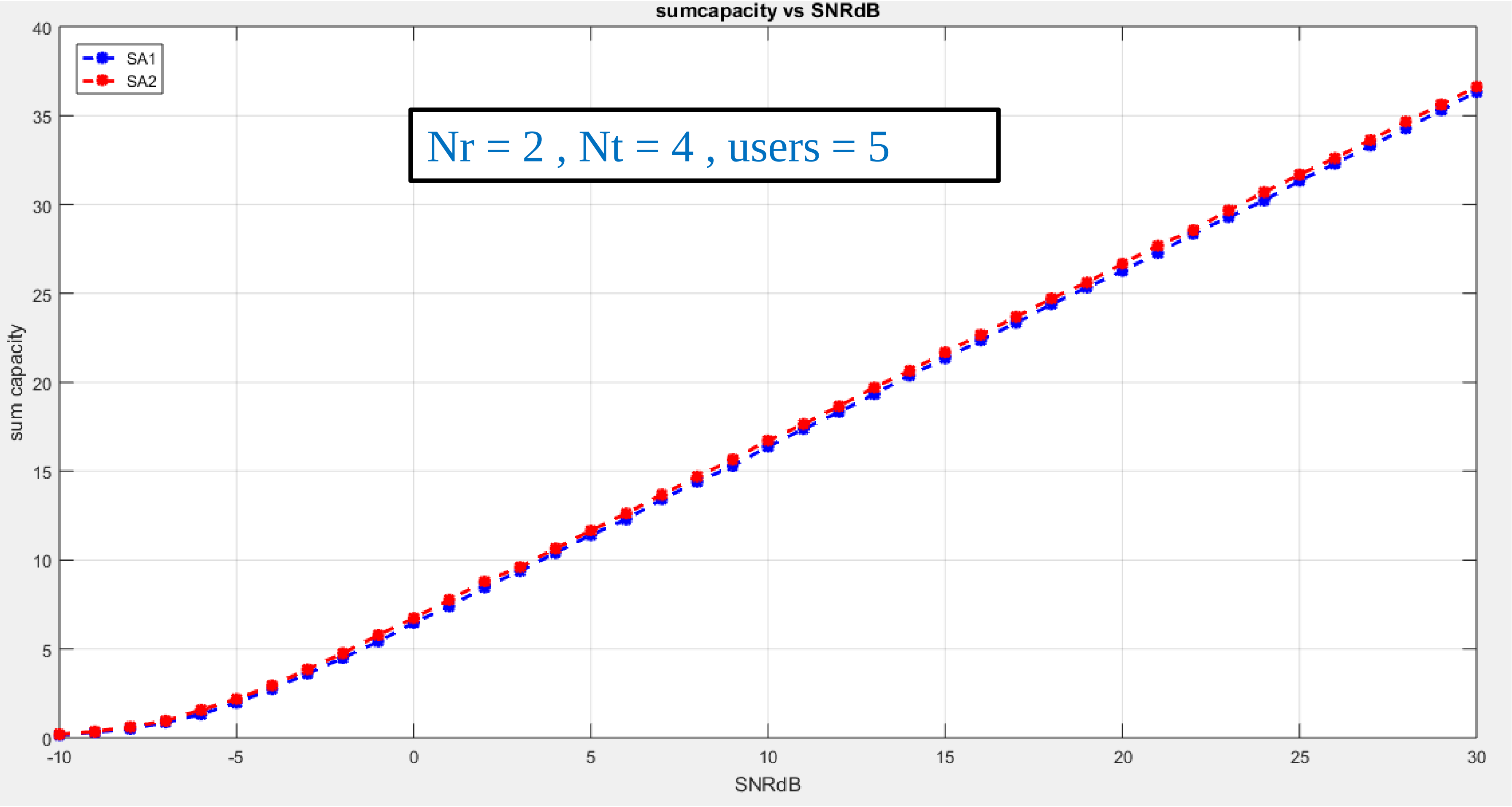
Outputs



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Outputs

Time Complexity Analysis

Profile Summary

Generated 21-Mar-2021 09:53:28 using performance time.

Function Name	Calls	Total Time	**Self Time***	Total Time Plot (dark band = self time)
SuboptimalAlgorithm1Final	125000	2144.908 s	1198.561 s	
SuboptimalAlgorithm2Final	125000	3045.033 s	757.932 s	
unique	14298016	790.469 s	517.341 s	
eigs	4391000	1753.271 s	498.944 s	
eigs>checkInputs	4391000	839.749 s	497.746 s	
eigs>fullEig	4391000	414.579 s	414.579 s	
union	14048015	1399.702 s	358.936 s	
unique>uniqueR2012a	14298016	273.128 s	273.128 s	
eigs>checkInputs/LUfactorB	4391000	269.290 s	269.290 s	
union>unionR2012a	14048015	1040.766 s	265.714 s	
cell.ismember	4391000	61.071 s	61.071 s	
ismember>ismemberR2012a	2383021	37.611 s	29.110 s	
ismember	2383021	50.781 s	13.170 s	
...(arraytoconvert)int64(arraytoconvert)	4391000	11.642 s	11.642 s	
ScriptFileForSAPlotFinal	1	5201.805 s	10.264 s	
ismember>ismemberBuiltinTypes	2383000	8.487 s	8.487 s	
setdiff	250001	38.004 s	7.760 s	

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Conclusions

- The JURAS scheme enhances the **sum capacity** when the number of users increases.
- The JURAS scheme **sum capacity** is **significant at high SNR.**
- The two JURAS suboptimal algorithms **reduced the complexity of computation.**

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Thank You