Near-Optimum Power Control for Two-Tier SIMO Uplink Under Power and Interference Constraints

Baris Yuksekkaya*, Hazer Inaltekin, Cenk Toker*, Halim Yanikomeroglu*****

**Department of Electrical and Electronics Engineering, Hacettepe University, Ankara, Turkey*
***Department of Electrical and Electronics Engineering, Antalya International University, Antalya, Turkey*
****Department of Systems and Computer Engineering, Carleton University, Ottawa, Ontario, Canada*

INTRODUCTION

- The demand of both society and industry for increasing data rates is currently growing.
- Earlier types of wireless networks are designed to minimize aggregate power consumption.
- Next generation communication networks needs power control policies that maximize information theoretic bit rates.
- Wireless systems such as CR networks and HetNets are expected to include multiple tiers of users.

PREVIOUS WORKS

- Ghasemi and Sousa found a modified water-filling solution where the water level is found using the interference constraint.
- Zhang extended these results to multiuser communication scenarios by considering multiple access and broadcast channels.
- Inaltekin established the optimality of the binary power control for the SISO single cell uplink.

OBJECTIVES

- Include multiple tiers of users operating in the same spectrum.
- Maximize information theoretic bit rates under appropriate system and technological constraints.
- Derive optimum transmit power allocation in a **two-tier SIMO uplink** network.

SYSTEM MODEL

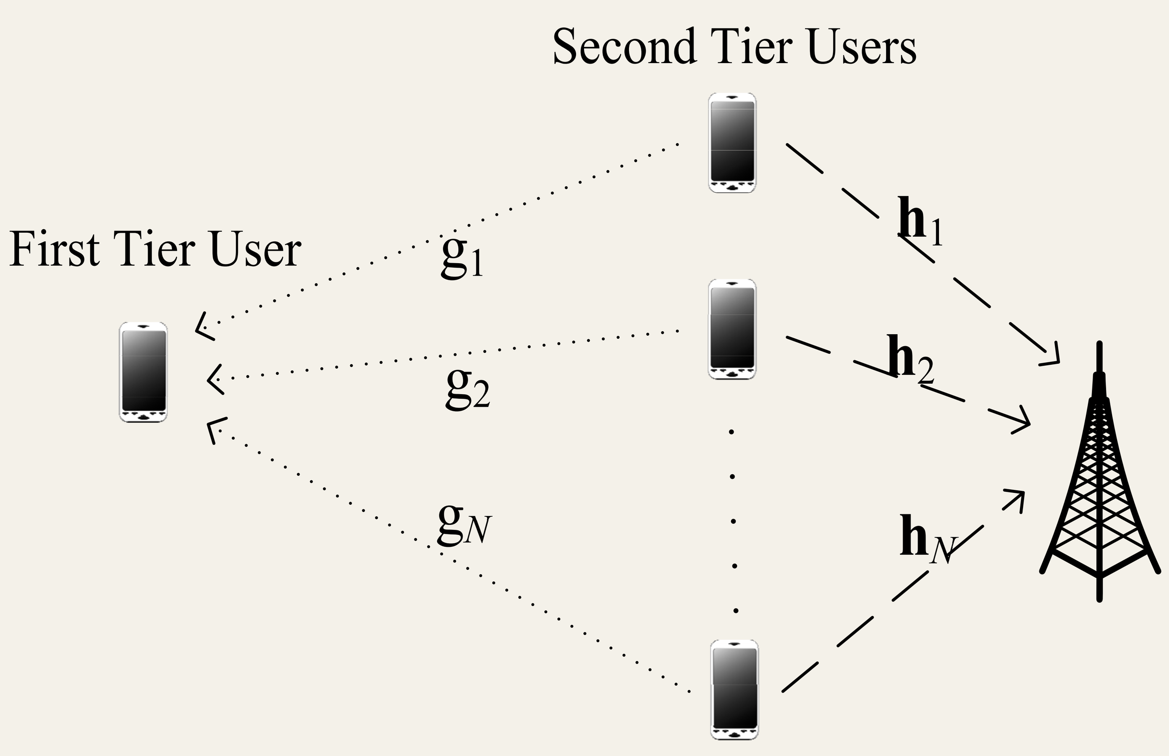


Fig. 1. System Model

- Two-tiers in the same spectrum.
- **Interference and noise** impaired system.
- SIC is not available, only linear receive filters are allowed at the STB.
- The optimization problem to solve is:

$$R_{total} = \sum_{i=1}^{N} \log_2 \left(\frac{\det\left[P_i \mathbf{h}_i \mathbf{h}_i^H + \mathbf{I} + \sum_{j \neq i} P_j \mathbf{h}_j \mathbf{h}_j^H \right]}{\det\left[\mathbf{I} + \sum_{j \neq i} P_j \mathbf{h}_j \mathbf{h}_j^H \right]} \right)$$

- The optimization problem to solve is:

$$\begin{aligned} \overline{\mathbf{P}}^* = \ & \arg\max_{\overline{\mathbf{P}}} R_{total} \\ \text{s.t.} \quad & P_i \geq 0, \quad \forall i \\ & P_i \leq P_{\max}, \quad \forall i \\ & \sum_{i=1}^{N} |g_i|^2 P_i \leq Q \end{aligned}$$

CHALLENGES

- This problem is **non-convex**.
- The cost function is in **vector form** as a result of multiple antennas at the base station.
- The **interference** terms in the denominator of the cost function complicates the problem.

NEAR-OPTIMUM POWER ALLOCATION

- **Channel Diagonalization**:

$$\hat{\mathbf{H}}_k = \left[\mathbf{h}_1 \ \cdots \ \mathbf{h}_{k-1} \ \ \mathbf{h}_{k+1} \ \cdots \ \mathbf{h}_N \right]$$

$$\hat{\mathbf{H}}_k = \left[\hat{\mathbf{U}}_k^1 \ \ \hat{\mathbf{U}}_k^0 \right] \begin{bmatrix} \hat{\mathbf{\Sigma}}_k \\ \mathbf{0} \end{bmatrix} \hat{\mathbf{V}}_k^H$$

$$\mathbf{U} = \left[\mathbf{u}_1 \ \cdots \ \mathbf{u}_{N \cdot N_{STU}} \right] \rightarrow$$ kth column is a vector taken from $\hat{\mathbf{U}}_k^0$

$$\mathbf{H}_{eff} = \mathbf{U}^H \mathbf{H} = \begin{bmatrix} \mathbf{u}_1^H \\ \vdots \\ \mathbf{u}_N^H \end{bmatrix} \left[\mathbf{h}_1 \ \cdots \ \mathbf{h}_N \right] = \begin{bmatrix} \mu_1 & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & \mu_N \end{bmatrix}$$

- User-by-user detection is now possible.
- Power allocation problem after diagonalization is:

$$\begin{aligned} \overline{\mathbf{P}}^* = \ & \arg\max_{\overline{\mathbf{P}}} \sum_{i=1}^{N} \log_2 \left(1 + P_i |\mu_i|^2 \right) \\ \text{s.t.} \quad & P_i \geq 0, \quad \forall i \\ & P_i \leq P_{\max}, \quad \forall i \\ & \sum_{i=1}^{N} |g_i|^2 P_i \leq Q \end{aligned}$$

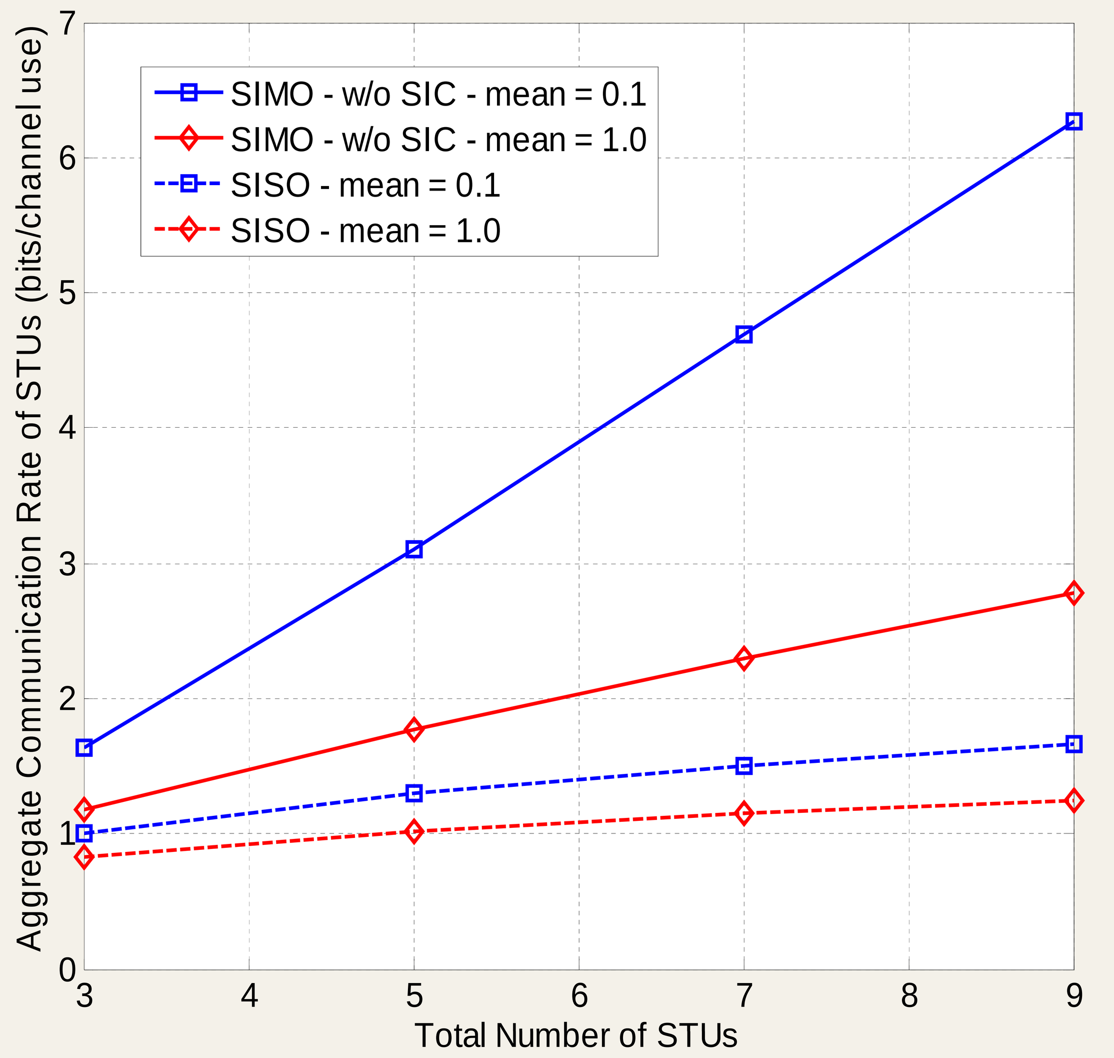
- **Optimum power allocation** for the simplified problem is a **modified water-filling** algorithm.

$$P_i^* = \min \left[\left(\frac{1}{\ln 2 \cdot \lambda |g_i|^2} - \frac{1}{|\mu_i|^2} \right)^+, P_{\max} \right]$$

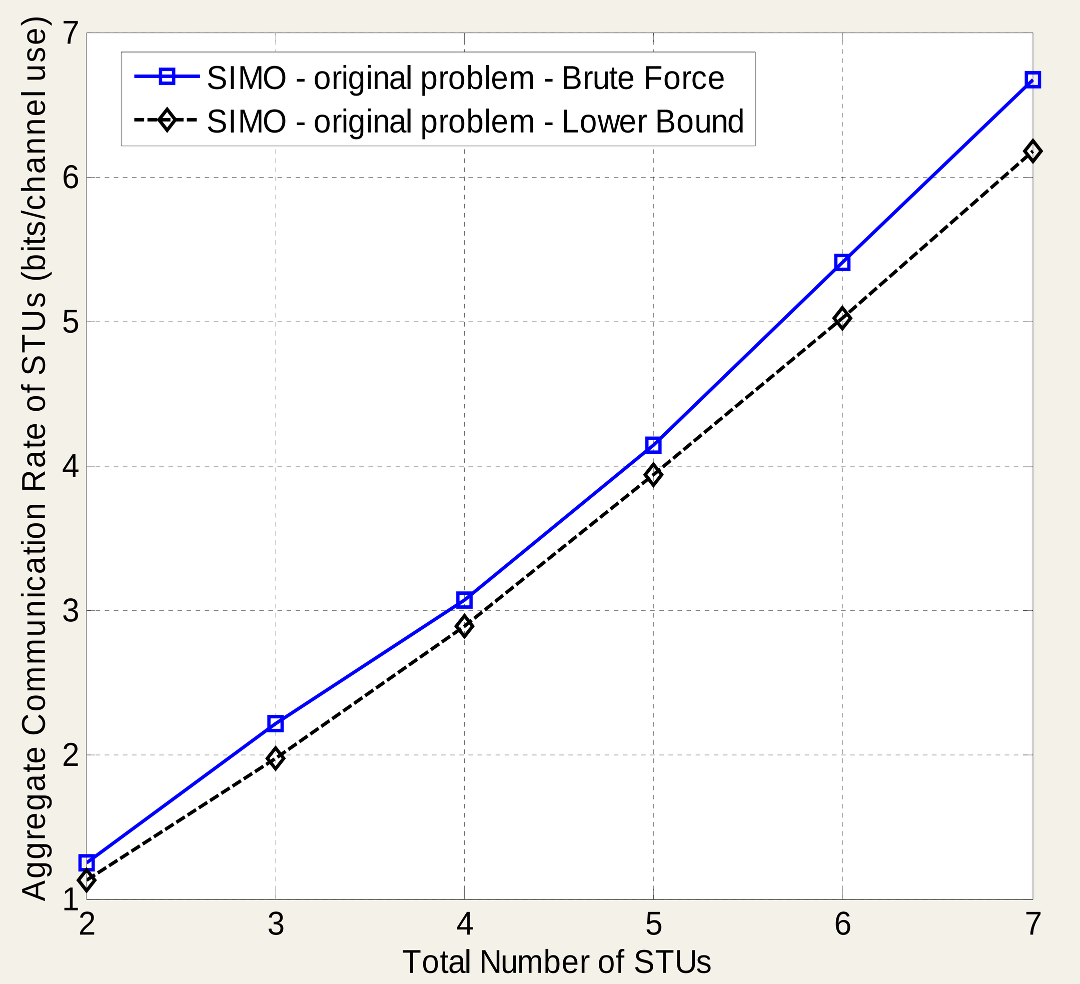
$$\sum_i P_i^* |g_i|^2 = \sum_i \left(\frac{1}{\ln 2 \cdot \lambda} - \frac{|g_i|^2}{|\mu_i|^2} \right)^+ = Q$$

- Interference-filling rather than power-filling.
- Water level has an additional multiplier.
- Transmit power of each antenna is upper limited.
- Solution is optimum for the simplified problem.

RESULTS AND CONCLUSIONS



- Multiple antennas do not only eliminate the interference, but also increase the data rate.



- A tight lower bound to the original problem is also found.

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