Joint Power and Backhaul Bits Allocation for Coordinated Multi-Point Transmission

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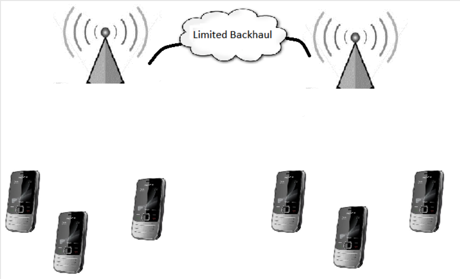
Introduction

In this paper, we study the problem of backhaul sharing in Network MIMO. Considering a backhaul of limited number of bits, we investigate how to allocate these bits jointly with the base-stations power among users in order to maximize the sum-rate under fairness constraints.

System Model



- We consider a Wyner channel model in the downlink mode.
- Two base-stations, N users per cell.
- Each base-station has M=2N antennas, all users are single antenna.
- Zero-forcing pre-coders are used at the base-stations.
- The two base-stations share a backhaul of maximum number of quantization bits = D bits.

Optimization Problem

The rate of each user can be expressed as:

$$SINR_i^t = \frac{Pt_{1,i}\,(l_{ii,1})^2 \left|\mathbf{h}_{1,i}^H \mathbf{w}_{1,i}\right|^2}{\sigma^2 + \sum_{1\le j\le N} Pt_{2,j}\,(l_{ii,2})^2 \left|\mathbf{h}_{2,i}^H \mathbf{w}_{2,j}\right|^2}$$

As the backhaul has a limited number of bits, the average SINR for user I can be rewritten as:

$$SINR_i = \frac{P_{1,i,i}}{\sigma^2 + \sum_{1\le j\le N} P_{2,i,j} \times Q_i}$$

where Qi is the average power of the quantization noise.

The objective is to choose the power transmitted and the backhaul bits allocated for each user in order to maximize the sum-rate of the users in the system defined as:

$$\sum_{1\le i\le N} r_i = \sum_{1\le i\le N} \log_2\left(1 + SINR_i\right)$$

Single user per cell - A: equal distances

The two-cell sum-rate is defined as:

$$R_{sum} = \sum_{\substack{\forall i,j\in\{1,2\}\\ i\neq j}} \log_2\left(1 + \frac{P_i \times l_{i,i}}{\sigma^2 + P_j \times l_{i,j} \times Q_i}\right)$$

The optimum power and backhaul bits allocation that maximizes this sum-rate is the binary allocation of the power according to the following cases:

$$P_1, P_2 = \begin{cases} P_{max}, P_{max} & \text{if } Q_{min} < Q_{critical} \\ P_{max}, 0 & \text{if } Q_{min} > Q_{critical} \end{cases}$$

As it is shown, the binary power allocation is adjusted depending on the relation between the min quantization noise precipitated by the backhaul, and a critical value for this quantization noise Qcritical which is determined by the different parameters in the system.

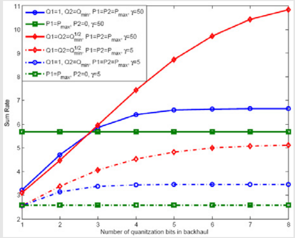
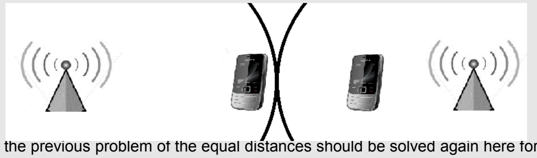


Fig. 1. This figure shows how the optimal modes, both power and backhaul, switch at Qcritical.

Single user per cell - B: Unequal distances



In this case, the previous problem of the equal distances should be solved again here for the minimum distance. If the solution indicates that switching one of the base-station on and switching the other base-station off is the optimum solution, then this will be also the optimum solution for the unequal distances case.

If switching the two base-stations on is the optimum solution, then this will be also the optimum solution here, but the backhaul bits allocation will not be binary in general.

In the 1st case, as the difference of the distances between each user and its base-station, is smaller than certain threshold, switching one of the base-stations on and the other one off will be optimum. After this threshold, the optimum power allocation will be switching the two base-stations on.

The threshold distance is defined as:

$$d_{th} = 2\left(\left(\left(\frac{Q_2^*\left(1 + P_{max}/\sigma^2\right)}{1 + \frac{P_{max}K\left(\frac{d_1}{d_o}\right)^{-\beta}}{\sigma^2 + P_{max}K\left(\frac{2-d_1}{d_o}\right)^{-\beta} Q_1^*}} - Q_2^*\right)^{\beta} + 1\right)^{-1}$$

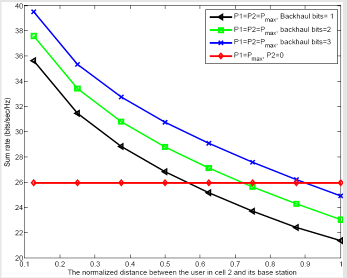


Fig. 2 This figure shows the sum-rate versus normalized distance for several numbers of quantization bits for the unequal distance case

Case 2: Cells with Multiple Users

Cells with multiple users approximate N-user sum-rate for large SINR and $\sigma^2 \ll I_{qi}$

$$\sum_{1\le i\le N} r_i = \log_2\left(\frac{\prod_{1\le i\le N} P_{1,i,i}}{\prod_{1\le i\le N}\left(\sum_{1\le j\le N} P_{2,i,j} \times Q_i\right)}\right)$$

Then

$$\sum_{1\le i\le N} r_i = \log_2\left(\frac{\prod_{1\le i\le N} P_{1,i,i}}{\prod_{1\le i\le N} (l_{ii,2})\, P_{max} \times C \times 2^{2D}}\right)$$

The Sum-Rate depends only on total quantization bits (D) rather than on their distribution. Therefore fairness is a better optimization objective.

Fairness Optimization Problems

Maximize the minimum SINR subject to a limited total number of quantization bits

$$\max_{b_i} \min_i \; SINR_i \quad \text{s.t.} \sum_{1\le i\le N} b_i = D$$

Maximize the minimum SINR subject to a limited total number of quantization bits and that the resulting sum-rate is greater than a certain value R.

$$\max_{b_i} \min_i \; SINR_i \quad \text{s.t.} \sum_{1\le i\le N} b_i = D, \quad \sum_{1\le i\le N} r_i \ge R$$

Convex problems can be numerically solved.

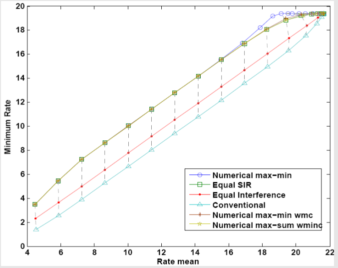


Fig. 3 This figure illustrates the minimum rate versus mean rate for several fairness schemes.