Journal Watch

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1. Joint Power Allocation and Beamforming for Non-Orthogonal Multiple Access (NOMA) in 5G Millimeter Wave Communications

Authors: Zhenyu Xiao , Lipeng Zhu, Jinho Choi , Pengfei Xia, and Xiang-Gen Xia

Goal: To find the beamforming vector to steer towards the two users simultaneously subject to an analog beamforming structure, while allocating appropriate power to them.

- It considers a typical problem, i.e., maximization of the sum rate of a 2-user mm-wave NOMA system.
- As the problem is non-convex and may not be converted to a convex problem with simple manipulations, it proposes a suboptimal solution to this problem.
- It decomposes the original joint beamforming and power allocation problem into two sub-problems which are relatively easy to solve: one is a power and beam gain allocation problem, and the other is a beamforming problem under a constant-modulus constraint.

1. Problem Formulation

$$
\begin{aligned}
s &= \sqrt{p_1}s_1 + \sqrt{p_2}s_2 \\
y_1 &= \mathbf{h}_1^H\mathbf{w}(\sqrt{p_1}s_1 + \sqrt{p_2}s_2) + n_1 \\
y_2 &= \mathbf{h}_2^H\mathbf{w}(\sqrt{p_1}s_1 + \sqrt{p_2}s_2) + n_2
\end{aligned}
$$

- Case 1 is to decode s_1 first and Case 2 is to decode s_2 first.

$$
\begin{aligned}
\max_{p_1, p_2, w} \; & R_1 + R_2 \\
s.t. \; & R_1 \geq r_1 \\
& R_2 \geq r_2 \\
& p_1 + p_2 = P \\
& |[\mathbf{w}]_k| = \frac{1}{\sqrt{N}}, \;\; k = 1, 2, \ldots N \\
& |\mathbf{h}_1^H\mathbf{w}|^2 \geq |\mathbf{h}_2^H\mathbf{w}|^2
\end{aligned}
$$

1. Solution of the Problem

- Let $c_1 = |\mathbf{h}_1^H \mathbf{w}|^2$ and $c_2 = |\mathbf{h}_2^H \mathbf{w}|^2$ denote the beam gain for user 1 and user 2 respectively.
- With the ideal beamforming, the beam gains satisfy

$$\frac{c_1}{|\lambda_1|^2} + \frac{c_2}{|\lambda_2|^2} = N$$

  where N is the number of antennas.
- First we will solve the power allocation problem and then the optimal value of the gain constraints is used to satisfy the constant modulus constraint.

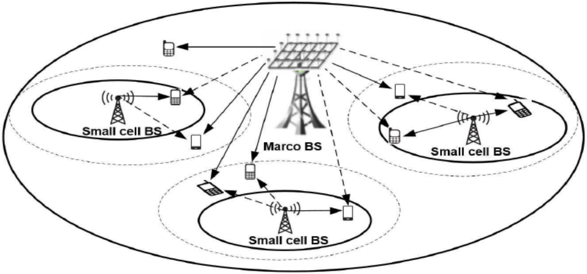
2. Downlink Beamforming for Energy-Efficient Heterogeneous Networks With Massive MIMO and Small Cells

Authors: Long D. Nguyen, Hoang Duong Tuan, Trung Q. Duong , Octavia A. Dobre, and H. Vincent Poor

Goal: Beamforming design at the base stations to optimize the network EE under the QoS constraints and a transmit power budget.

- A heterogeneous network (HetNet) of a macrocell base station equipped with a large-scale massive MIMO antenna array overlaying a number of SBS can provide high QoS to multiple users under low transmit power budget.
- It is also found that, for a given number of antennas, HetNet is more energy efficient than massive MIMO when considering the overall energy consumption.

2. Signal Model



Complex baseband signal received by MUE k is

$$y_k = \underbrace{\sqrt{\beta_k} h_k^H f_k x_k}_{\text{desired signal}} + \underbrace{\sum_{i \in \mathcal{K}_M \setminus \{k\}} \sqrt{\beta_k} h_k^H f_i x_i}_{\text{inter-MUE interference}} + \underbrace{\sum_{s \in \mathcal{N}_k} \sum_{j=1}^{K_s} \eta_{s,k}^H f_{s,j} x_{s,j}}_{\text{SBS interference}} + n_k$$

2. Solutions

Complex baseband signal received by SUE (s, l) is

$$y_k = \underbrace{h_{s,l}^H f_{s,l} x_{s,l}}_{\text{desired signal}} + \underbrace{\sum_{i=1}^{M} \sqrt{\beta_{s,l}} \chi_{s,l}^H f_i x_i}_{\text{MBS interference}} + \underbrace{\sum_{j' \in \mathcal{K}_s \setminus \{l\}} h_{s,l}^H f_{s,j'} x_{s,j'}}_{\text{inter SUE interference}} + n_{s,l}$$

- Zero-Forcing Inter-MUE Interference based Beamforming (MZF)

$$\begin{aligned} H &= [h_1, h_2, \dots, h_M] \\ \bar{F}_M &= [\bar{f}_1, \bar{f}_2, \dots, \bar{f}_M] = H(H^H H)^{-1}, \\ I &= H^H \bar{F}_M = [h_1^H \bar{F}_M; \dots; h_M^H \bar{F}_M] \\ &= [h_i^H \bar{f}_j]_{(i,j) \in \mathcal{K}_M \times \mathcal{K}_M} \end{aligned}$$

2. Solutions

- Zero Forcing Co-Tier Interference Based Beamforming (MZF+SZF)
- Zero-Forcing Inter-MUE and MBS and Inter-SUE Interference Beamforming (ZMI+SZF)
- Adaptively Suppressed Co-Interference Based Beamforming (AZMI+SZF)
- It compares the energy-efficiency zero forcing HetNet beamforming with massive MIMO.

3. Content Placement in Cache-Enabled Sub-6 GHz and Millimeter-Wave Multi-Antenna Dense Small Cell Networks

Authors: Yongxu Zhu , Gan Zheng , Lifeng Wang, Kai-Kit Wong, and Liqiang Zhao

Goal: Study the performance of cache enabled dense small cell networks consisting of multi-antenna sub-6 GHz and millimeter-wave base stations.

- It first derives the successful content delivery probability by accounting for the key channel features at sub-6 GHz and mm-wave frequencies.
- It then develops another simple yet effective heuristic probabilistic content placement scheme, termed two-stair algorithm, which strikes a balance between caching the most popular contents and achieving content diversity.

3. System Model

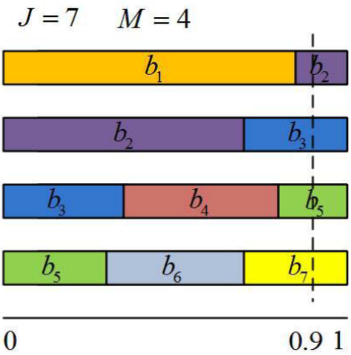


Figure: Probabilistic Content Placement Strategy

- a_j is the request probability of the jth content.
- b_j is the probability that the jth content is cached at a SBS.

3. Downlink Transmission

$$\sum_{j=1}^{J} a_j = 1$$

$$\sum_{j=1}^{J} b_j \leq M,\ 0 \leq b_j \leq 1, \forall j$$

- The positions of μ-wave SBSs are modeled by by a homogeneous Poisson point process.
- In the μ-wave tier, the maximum-ratio transmission beamforming is adopted at each SBS.
- In the mm-wave tier, we assume that the directional beamforming is adopted at each mm-wave SBS and small-scale fading is neglected, since small-scale fading has little change in received power.

3. Successful Content Delivery Probability

- In the μ-wave tier,

$$\mathcal{P}^{\mu}_{SCD} = \sum_{j=1}^{J} a_j \mathcal{P}^{\mu}_{j,SCD}(b_j),$$

- In the mm-wave tier,

$$\mathcal{P}^{mm}_{SCD} = \sum_{j=1}^{J} a_j \mathcal{P}^{mm,L}_{j,SCD}(b_j) + \sum_{j=1}^{J} a_j \mathcal{P}^{mm,N}_{j,SCD}(b_j),$$

To maximize the Successful Content Delivery Probability we propose two algorithms,

- It is developed based on the CEO method that can achieve near-optimal performance.
- Other is a two-stair scheme is based on the combination of MPC and CD content placement schemes with reduced complexity.

4. Hybrid Precoding for Millimeter Wave MIMO Systems: A Matrix Factorization Approach

Authors: Juening Jin , Yahong Rosa Zheng , Wen Chen , and Chengshan Xiao

Goal: To design a hybrid precoder for mm-wave MIMO with finite-alphabet inputs.

This paper has three main contributions.

- First, it presents a sufficient condition and a necessary condition for hybrid precoding schemes to realize unconstrained optimal precoders exactly when the number of data streams N_s satisfies $N_s = min\{rank(H), N_{rf}\}$.
- Second, it shows that the coupled power constraint in our matrix factorization problem can be removed without loss of optimality.
- Third, it proposes a Broyden-Fletcher-Goldfarb-Shanno-based algorithm to solve our matrix factorization problem using gradient and Hessian information.

4. System Model

Consider a point-to-point mm-wave MIMO system,

$$y = HF_{RF}F_{BB}x + n$$

$$\mathcal{I}(x;y) = N_s \log M - \frac{1}{M^{N_s}} E_n\{\log \sum_{k=1}^{M^{N_s}} e^{-d_{mk}}\}$$

where $d_{mk} = \sigma^{-2}(\|HF_{RF}F_{BB}(x_m - x_k) + n\|^2 - \|n\|^2)$,

$$\max_{F_{RF}\in\mathcal{U}, F_{BB}} \mathcal{I}(x;y)$$
$$s.t.\ tr(F_{BB}^H F_{RF}^H F_{RF} F_{BB}) \leq P$$

To overcome the difficulties in solving above problem, the problem is reformulated as

$$\min_{F_{RF}\in\mathcal{U}, F_{BB}} \|F_{opt} - F_{RF}F_{BB}\|_{\mathcal{F}}^2$$
$$s.t.\ tr(F_{BB}^H F_{RF}^H F_{RF} F_{BB}) \leq P.$$

4. Hybrid Precoding Schemes

- **Optimality of Hybrid Precoding Schemes**:- When the number of data streams N_s satisfies $N_s \leq \frac{1}{2} N_{rf}$, we can construct analog and digital precoders to realize any unconstrained optimal precoder.
- To achieve the maximum degrees of freedom $N_s = min\{rank(H), N_{rf}\}$.
- If $(\hat{F}_{RF}, \hat{F}_{BB})$ is a KKT point of problem, then it satisfies $tr(F_{BB}^H F_{RF}^H F_{RF} F_{BB}) \leq P$.
- **Constant modulus matrix factorization**:-

$$\min_{F_{RF} \in \mathcal{U}} f(F_{RF}) = \|F_{opt} - F_{RF} F_{RF}^{+} F_{opt}\|_F^2.$$

- The complex gradient and hessian matrices of $f(F_{RF})$ is used to solve the problem.

Other Papers

- Novel 3-D Non-Stationary Wideband Models for Massive MIMO Channels ... *Carlos F. Lpez and Cheng-Xiang Wang*
- Achievable Throughput of Energy Harvesting Fading Multiple-Access Channels Under Statistical QoS Constraints ... *Deli Qiao and Jingwen Han*
- Wireless Backhaul: Performance Modeling and Impact on User Association for 5G ... *Mona Jaber, F. Javier Lopez-Martinez, Muhammad Ali Imran, Andy Sutton, Anvar Tukmanov, and Rahim Tafazolli*
- Heterogeneous Networks With Power-Domain NOMA: Coverage, Throughput, and Power Allocation Analysis ... *Chun-Hung Liu and Di-Chun Liang*