Joint Antenna Selection and Power Allocation (JASPA) for an Energy-efficient Massive MIMO System

Youngwoo Oh

Department of Computer Engineering,

Chosun University.

CONTENTS

1-1 INTRODUCTION

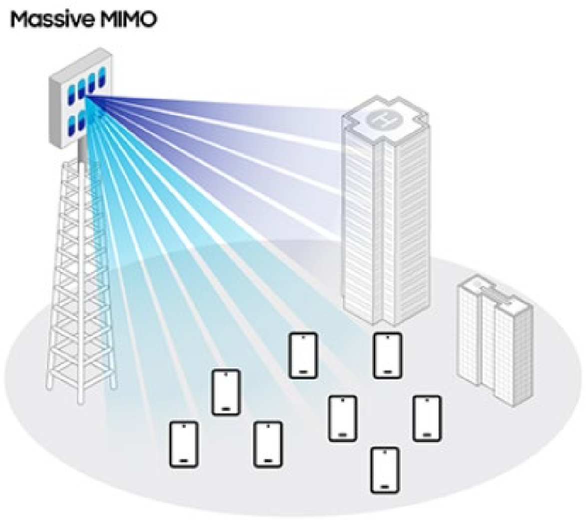
Massive MIMO

Has been recognized as potential candidate technology for 5G networks that use multiple base-station antennas to serves a large of single antenna users.

In fact, Massive MIMO can significantly improve performance such as spectral efficiency and maximum transmission rate compared to conventional systems.

However, the energy consumption in Massive MIMO systems has also increased significantly since the total power consumption is proportional to the number of antennas.

Therefore, some paper has been studied to improve in this problems.



- Massive MIMO technology is a promising for 5G and next-generation wireless communication.
- However, there are several constraints, and research is required to improve them.

1-2 INTRODUCTION

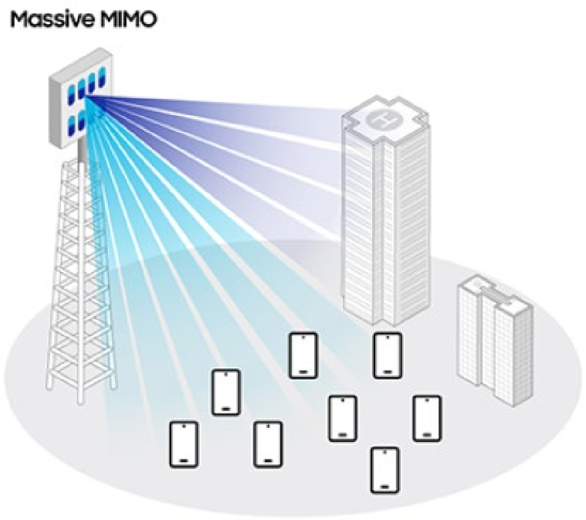
Existing literature

Several researchers have investigated and proposed the resource allocation problem of Massive MIMO systems.

They mainly focused on sum-rate maximization, minimization of power consumption and maximum energy efficiency by considering outage capacity.

The above works considered the antenna selection and/or power allocation separately to optimize energy efficiency.

However, to maximize energy efficiency, both antenna selection and power allocation must be considered.



- Several papers have conducted studies to improve energy efficiency.
- However, in order to maximize energy efficiency, several techniques must be considered simultaneously.

1-3 INTRODUCTION

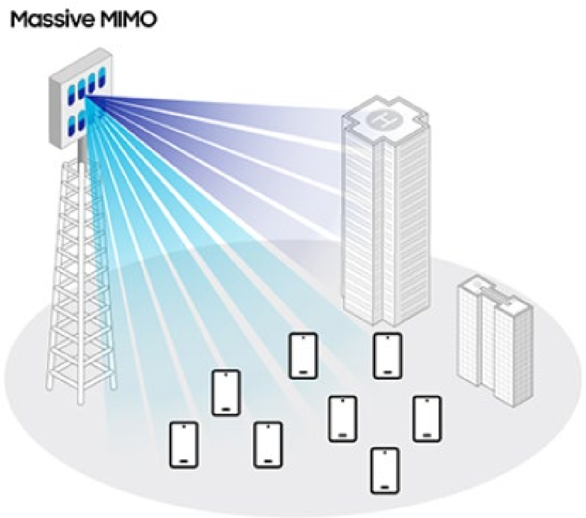
Objective

A joint antenna selection and power allocation (JASPA) scheme that maximizes energy efficiency has not been well studied before.

The authors focused on the energy efficiency optimization problem for a downlink single-cell Massive MIMO system.

To achieve further improvements in energy efficiency and derive the closed-form solutions for optimal transmit antenna and power allocation.

To tackle this problem, transform the non-convex function into a convex subtractive form and develop a feasible two-layer iterative algorithm by employing the Lagrangian dual method.



- The author proposes joint antenna selection and power allocation to maximize energy efficiency.
- Used a two-layer iterative algorithm to transform a non-convex function into a convex form.

2-1 SYSTEM MODEL

Considered scenario

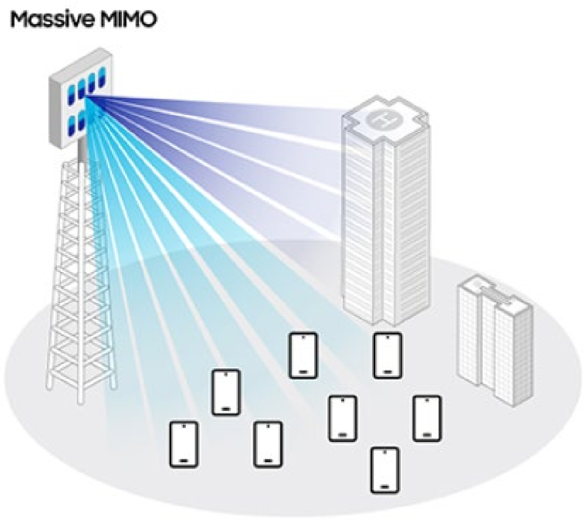
The authors considered a downlink of a single-cell Massive MIMO system, in which the base station(BS) is located in the center of the single cell with all user terminals (UTs) are uniformly distributed in the cell.

Assume that the BS is installed with M transmit antennas and it communicated with K single-antenna UTs. $(M \gg K \gg 1)$

$$\mathbf{G} = \mathbf{H}\mathbf{D}^{1/2} \in \mathbb{C}^{M \times K} \tag{1}$$

$$h_{mk} = [\mathbf{H}]_{mk} \quad h_{mk} \sim \mathcal{CN}(0,1)$$

$$\mathbf{D}_{\beta}^{1/2} = \mathrm{diag}\left(\sqrt{\beta_1}, \cdots, \sqrt{\beta_K}\right)$$



- In this paper, considered a downlink of a single cell Massive MIMO systems.
- Assumed perfect CSI channel and Zero-forcing (ZF) linear precoding is adopted at BS.

2-2 SYSTEM MODEL

Considered scenario

In this paper, small and large-scale fading, path loss δ, and transmission power $p_{d,k}$ are considered.
Thus, the received signal $y_{d,k}$ at the K-th UT is

$$y_{d,k} = \sqrt{\alpha p_{d,k}} \mathbf{g}_k^H \mathbf{a}_k q_k + \sqrt{\alpha} \sum_{i=1, i \neq k}^{K} \sqrt{p_{d,i}} \mathbf{g}_k^H \mathbf{a}_i q_i + n_k \qquad (2)$$

Based in the Shannon's capacity formula, the ergodic achievable downlink rate (in bits/s/Hz) of K-th UT is given by

$$R_k = \mathbb{E}\left\{ \log_2 \left(1 + \frac{\alpha p_{d,k} \left| \mathbf{g}_k^H \mathbf{a}_k \right|^2}{\alpha \sum_{i=1, i \neq k}^{K} p_{d,i} \left| \mathbf{g}_k^H \mathbf{a}_i \right|^2 + 1} \right) \right\} \qquad (3)$$

3-1 FORMULATION

Energy efficiency optimization problem

The maximum energy efficiency optimization problem with respect to the number of transmit antennas and allocated power

$$\max_{M,\mathbf{p}_d} \eta = \frac{\sum_{k=1}^{K} \widetilde{R}_k}{\sum_{k=1}^{K} \frac{p_{d,k}}{\rho} + Mp_r} = \frac{\sum_{k=1}^{K} \log_2\left(1+\alpha p_{d,k}\right)}{\sum_{k=1}^{K} \frac{p_{d,k}}{\rho} + Mp_r} \tag{4}$$

Constraints 1 is guaranteeing the minimum achievable downlink rate of per UT;
Constraints 2 is the total transmit power constraint at BS;

$$s.t.\ C1: \widetilde{R}_k \geq R_{min}, \forall\ k, \quad C2: \sum_{k=1}^{K} p_{d,k} = P_s \tag{5}$$

3-2 FORMULATION

Convert to convex optimization

The existence of combinatorial logarithmic function leads to high complexity.
So, convert problem (4) into the following convex optimization problem.

$$\max_{M,\widetilde{\mathbf{R}}} \sum_{k=1}^{K} \left(\widetilde{R}_k - \frac{\eta \left(2^{\widetilde{R}_k} - 1\right)}{\rho\alpha} \right) - \eta M p_r \tag{6}$$

$$s.t.\ C1,\ C2: \sum_{k=1}^{K} \frac{2^{\widetilde{R}_k} - 1}{\alpha} = P_s.$$

After then, equation (6) is a convex optimization by using Lagrangian dual method.

$$\mathcal{L}\left(M, \widetilde{\mathbf{R}}, \boldsymbol{\mu}, \theta\right) = \sum_{k=1}^{K} \left(\widetilde{R}_k - \frac{\eta \left(2^{\widetilde{R}_k} - 1\right)}{\rho\alpha} \right) - \eta M p_r + \sum_{k=1}^{K} \mu_k \left(\widetilde{R}_k - R_{min}\right) + \theta \left(P_s - \sum_{k=1}^{K} \frac{2^{\widetilde{R}_k} - 1}{\alpha} \right) \tag{7}$$

$$\widetilde{\mathbf{R}} = \left\{\widetilde{R}_1, \cdots, \widetilde{R}_K\right\}$$

3-3 FORMULATION

Optimal solutions of JASPA

The maximum energy efficiency optimization problem with respect to the number of transmit antennas and allocated power

$$\mathring{M} = \min\left\{\left\lceil\frac{\Psi + \sqrt{\Psi^2 - 4(\ln 2)^2 \rho\eta p_r K\Omega}}{2\rho\eta p_r \ln 2} + K\right\rceil, M_{max}\right\}$$

$$\mathring{p}_{d,k} = \left\lfloor\frac{\rho\left(\mu_k + 1\right)}{\Omega \ln 2} - \frac{\sum_{k=1}^{K} 1/\beta_k}{\left(\mathring{M} - K\right)}\right\rfloor \tag{8}$$

$$\Psi = \rho \sum_{k=1}^{K} (\mu_k + 1), \qquad \Omega = (\eta + \rho\theta) \sum_{k=1}^{K} 1/\beta_k,$$

4-1 ANALYSIS

Energy efficiency versus the number of UTs

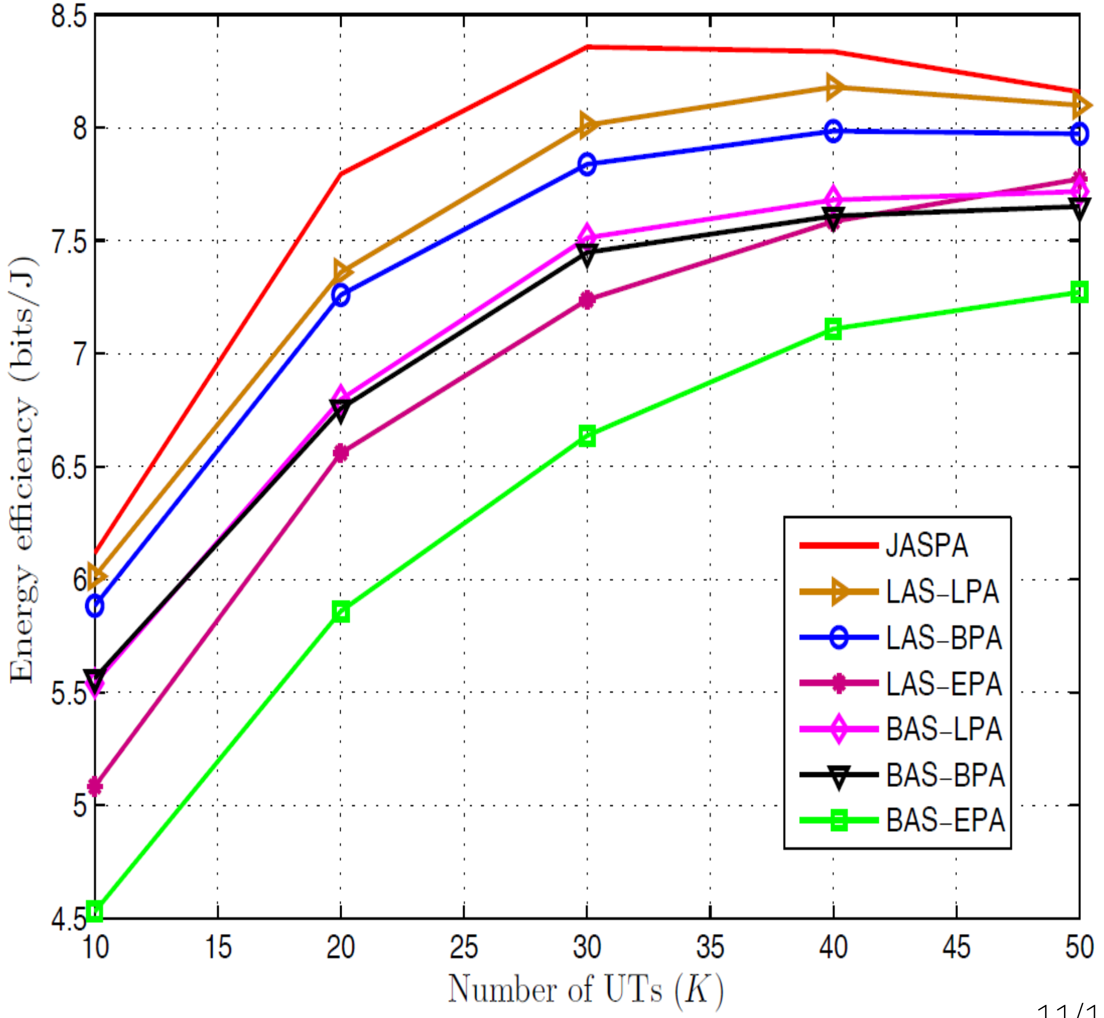
In this figure presented for the proposed JASPA algorithm, and the algorithms Is compared with other schemes (antenna selection and power allocation).

The proposed JASPA algorithm increases with the number of UTs, But the growth rate of the energy efficiency becomes slower.

Also proposed JASPA algorithm achieves better energy efficiency Performance than the reference schemes.

Where LAS is determined the antenna selection by Lagrangian method.
BAS is determined the antenna selection by bisection.

LPA, BPA, and EPA allocate power by the Lagrangian dual method, the bisection and the equal power allocation method.



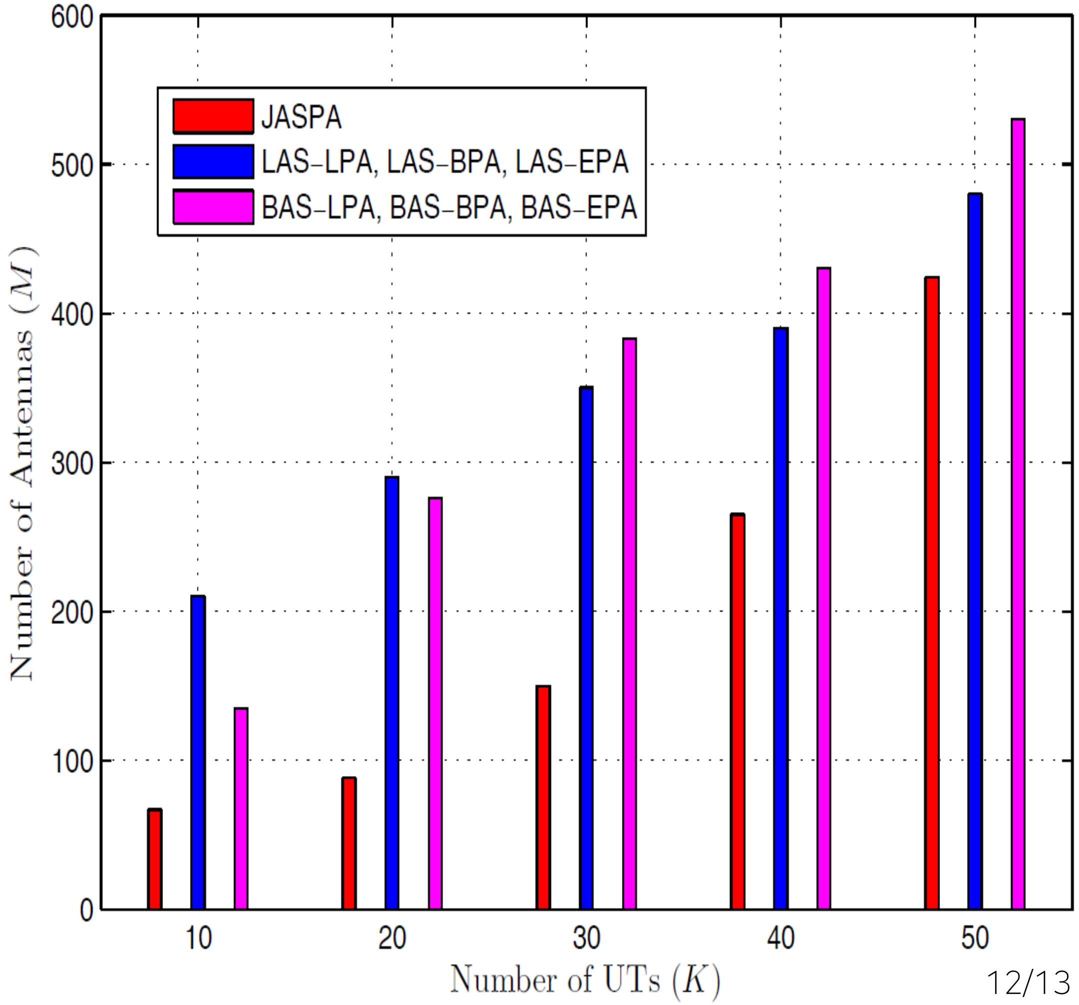
4-2 ANALYSIS

Number of antennas versus the number of UTs

In this figure can see that, regardless of the reference scheme,
The number of antennas will increase as the number of UTs increases.

Given the number of UTs, the proposed JASPA has the least number of BS transmit antennas compared to the other schemes.

Experimental results show that this will reduce the total power consumption.



5 CONCLUSION

Number of antennas versus the number of UTs

The authors investigated a JASPA scheme for a downlink single-cell Massive MIMO system with sum power constraints and QoS requirements.

And developed an iterative algorithm to achieve the maximum energy efficiency.

Simulation results showed that the energy efficiency performance of the proposed iterative JASPA algorithm outperforms the existing schemes.

Reference

H. Li, J. Cheng, Z. Wang and H. Wang, "Joint Antenna Selection and Power Allocation for an Energy-efficient Massive MIMO System", in *IEEE Wireless Communication Letters*, vol. 8, no. 1, pp. 257-260.

PRESENTATION END

THANK YOU