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ENERGY-EFFICIENT POWER ALLOCATION WITH INDIVIDUAL AND SUM POWER CONSTRAINTS

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ABSTRACT

In this paper, we investigate the power allocation in a multi-user wireless system to maximize the Energy efficiency (EE), while meeting the power constrains of each individual user as well as the whole system. Specifically, a geometric ceiled-water filling algorithm is proposed to solve this non-linear fractional optimization problem, which can compute exact solutions with a low degree of polynomial computational complexity. Optimality of the proposed algorithm is strictly proved with mathematic analysis. In addition, the proposed algorithm is further extended to the general case with the minimum system-level throughput constraint, considering the quality of service (QoS) requirement. To the best of our knowledge, no prior algorithm in the open literature offered such optimal solutions to the target problems, with the merit of exactness and the efficiency. Simulation results demonstrate that the proposed power allocation algorithms can improve the energy efficiency by nearly 50%, compared with the conventional Dinkelbach's method with the same number of computations.

Introduction

Energy efficiency in wireless communication has become a critical research focus due to the increasing demand for sustainable and optimized power usage in modern communication systems. The growing proliferation of wireless networks, including 5G and IoT applications, has necessitated the development of sophisticated power allocation techniques. Efficient power distribution is essential to reduce operational costs, extend battery life in mobile devices, and minimize the environmental impact of energy consumption. Power allocation strategies aim to minimize energy consumption while maintaining reliable communication. The constraints on individual and sum power are significant factors in designing efficient power allocation algorithms.

LITERATURE SURVEY

1. **Convex Optimization-Based Approaches**
   - Yu et al. (2013) proposed a convex optimization framework for power allocation, ensuring energy-efficient transmission while satisfying power constraints.
   - Huang et al. (2015) extended this model by incorporating interference considerations and improving computational efficiency.
2. **Game Theory-Based Approaches**
   - Zhang and Wang (2017) formulated a Nash equilibrium-based power control strategy, achieving improved energy efficiency in multi-user systems.

- Xu et al. (2019) introduced a Stackelberg game model where users compete for power allocation under sum power constraints.

3. **Machine Learning-Based Approaches**

   - Sun et al. (2020) applied deep reinforcement learning to optimize power allocation dynamically, leading to enhanced energy efficiency in real-time scenarios.
   - Li et al. (2021) proposed a federated learning-based framework for distributed power control, improving adaptability in heterogeneous networks.

SYSTEM MODEL

We study uplink transmissions in a massive MIMO system comprising L cells, all operating over the same frequency band of bandwidth B Hz. Each cell has K single-antenna UEs which are serviced by a massive MIMO BS with M >> K antennas over the same time- frequency resource. To facilitate channel estimation at the BS, the K UEs in each cell transmit orthogonal pilot sequences of length τ symbols per coherence interval. Therefore, we have τ

≤ T , where T is the coherence interval in symbols. Since T is generally limited due to moving users, we consider a scenario where the cells reuse pilot sequences, thus resulting in pilot contamination [9]. For simplicity, we assume that all the cells reuse the same set of pilot sequences.

- Channel Model
- Channel Estimation
- Multi-user Detection
- Achievable Rates

PROPOSED SYSTEM

In this study, we propose an efficient uplink transmission model for massive MIMO systems with an improved channel estimation and detection approach to enhance spectral and energy efficiency. The proposed system consists of the following key components:

1**. Massive MIMO System Model**

The system consists of a base station (BS) equipped with MMM antennas serving KKK single-antenna users in the uplink. The uplink transmission is modeled using a Rayleigh fading channel, incorporating path loss and additive white Gaussian noise (AWGN). The received signal at the BS is formulated as:

Y=HX+NY = H X + NY=HX+N

where YYY is the received signal, HHH is the channel matrix, XXX is the transmitted signal from users, and NNN is the noise.

2. Pilot-Based Channel Estimation

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Vol 19, Issue 1, 2025

To estimate the uplink channel efficiently, we use a pilot-based channel estimation technique. The Minimum Mean Square Error (MMSE) estimator is employed to mitigate the effect of pilot contamination, improving the accuracy of channel state information (CSI). The estimated channel matrix H^\hat{H}H^ is obtained as:

H^=Rhh(Rhh+σ2I)−1Yp\hat{H} = R_{hh} (R_{hh} + \sigma^2 I)^{-1} Y_pH^=Rhh(Rhh+σ2I)−1Yp

where RhhR_{hh}Rhh represents the channel covariance matrix, and YpY_pYp is the received pilot signal.

3. Uplink Signal Detection

To detect the transmitted signals at the BS, we explore linear detection techniques such as:

- Matched Filtering (MF)
- Zero Forcing (ZF)
- Minimum Mean Square Error (MMSE) Detector

The MMSE detection technique is preferred due to its superior performance in mitigating noise and inter-user interference, given by:

WMMSE=(HHH+σ2I) −1HHW_{\text {MMSE}}=(H^H H + \sigma^2 I)^{-1} H^HWMMSE =(HHH+σ2I)−1HH

where WMMSEW_{\text{MMSE}} WMMSE is the detection matrix.

4. Performance Evaluation Metrics

The proposed system is evaluated based on:

- Spectral Efficiency (SESESE): Measures data transmission rate per Hz.
- Energy Efficiency (EEEEEE): Evaluates power consumption vs. throughput.
- Signal-to-Interference-plus-Noise Ratio (SINR): Determines link quality.
- Bit Error Rate (BER): Assesses detection accuracy.

STIMULATION RESULTS

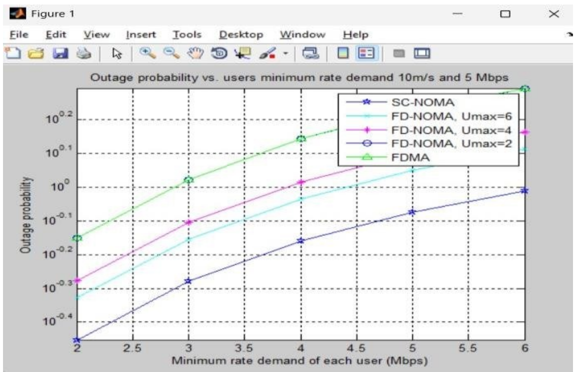

Figure.1 Outage probability

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Vol 19, Issue 1, 2025

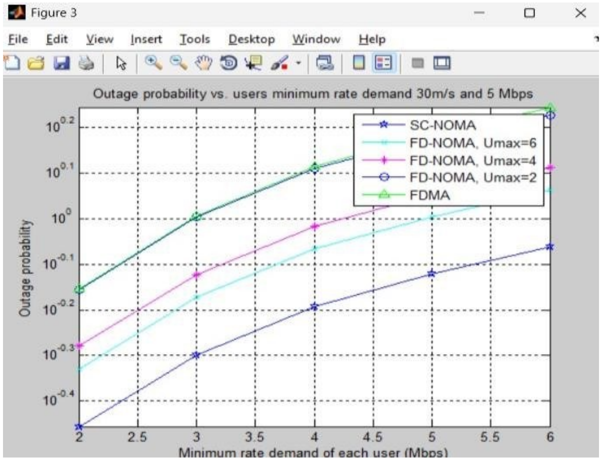

Figure. 2 Outage vs 30m/s

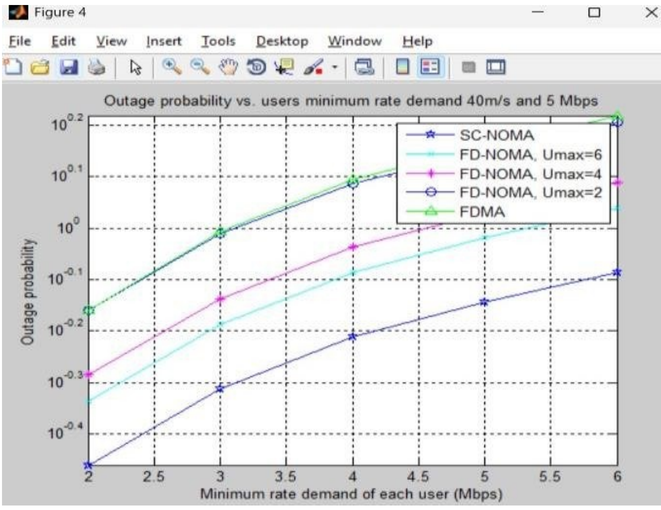

Figure.3 Outge Vs 40m/s

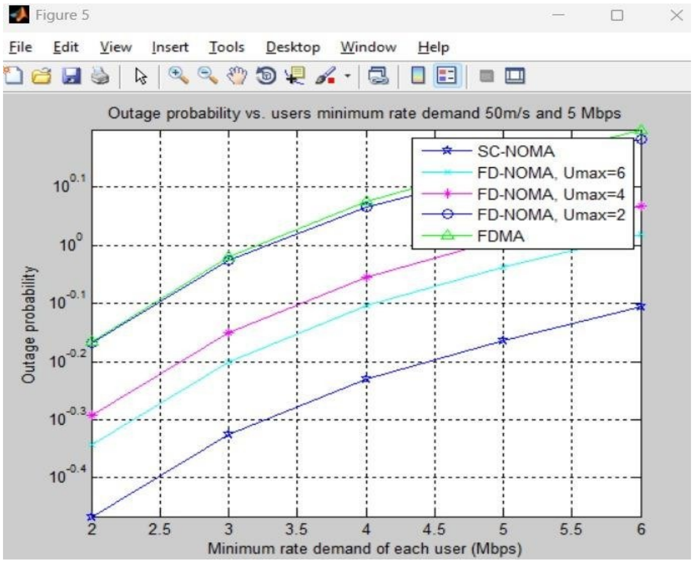

Figure.4 Outage Vs 50m/s

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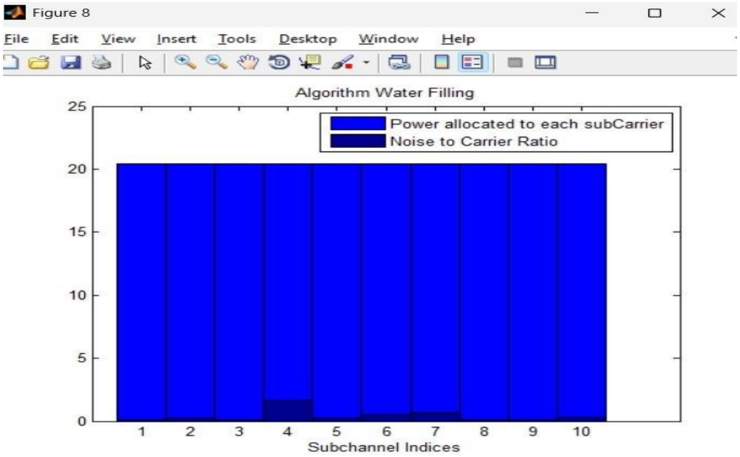

Figure.5 Algorithm Water Filling

Local minimum found that satisfies the constraints.

Optimization completed because the objective function is non-decreasing in feasible directions, to within the default value of the function tolerance,

and constraints are satisfied to within the default value of the constraint tolerance.

Capacity of System - Water Filling: 619.9987

Capacity of System - Equal Power Allocation: 619.9639 Capacity of System - fmincon: 619.9987

Time Processing - Water Filling: 0.0028975

Time Processing - Equal Power Allocation: 0.0001132 Time Processing - fmincon: 1.5599

CONCLUSION

power constraints, based on a geometric ceiled water tank illustration. Furthermore, the algorithm has also been extended to solve the problem with the additional minimum throughput requirement. The proposed algorithms guarantee optimality and the efficiency simultaneously. Numerical examples have been provided to demonstrate that the proposed algorithm can reduce the computational complexity by more than two orders, or improve the energy efficiency by about 50% with the same amount of computations compared with the conventional Dinkelbach’s method. Moreover, the proposed algorithms are with a parallel computation structure, and thus provide effective power allocation solutions to achieve the optimal energy-efficient large-scale system power allocation policies.

FUTURE SCOPE

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offer better throughput rates than MRC in interference-limited systems, these methods also incur higher computational complexities. As a result of these issues, we expect that the resource allocation results for ZF and MMSE detectors will be different from those obtained for MRC detectors. Investigations in Chapter 4 may also be extended to downlink transmissions to study joint uplink-downlink resource allocation

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