Enhancing Spectral Utilization of 5G with Massive MIMO

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Acknowledgement

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Outline

- Massive MIMO Overview
- Problem Definition
  - Pilot Contamination
- Pilot Assignment
  - Based on Angle of Arrival Estimation
- Other Research Problems
- Chanel Estimation Based on the Temporal Properties Evaluation
  I. Kalman Filter Based Channel Estimation
  II. Correlation Matrix Estimation for MMSE Estimation
- Publications

Motivation

- Global mobile data traffic increased an estimated 63 percent in 2016 as in Fig (1) [1].
- So, a newer generation and more capable wireless network is required to satisfy the ever-increasing demand for data.
- Thus, to increase the data or throughput mainly either the bandwidth or spectrum efficiency must be increased.

  Throughput (bits/Hz). = Bandwidth (Hz) × Spectral efficiency (bits/s/Hz).
- Massive MIMO substantially increases the spectral efficiency [2].

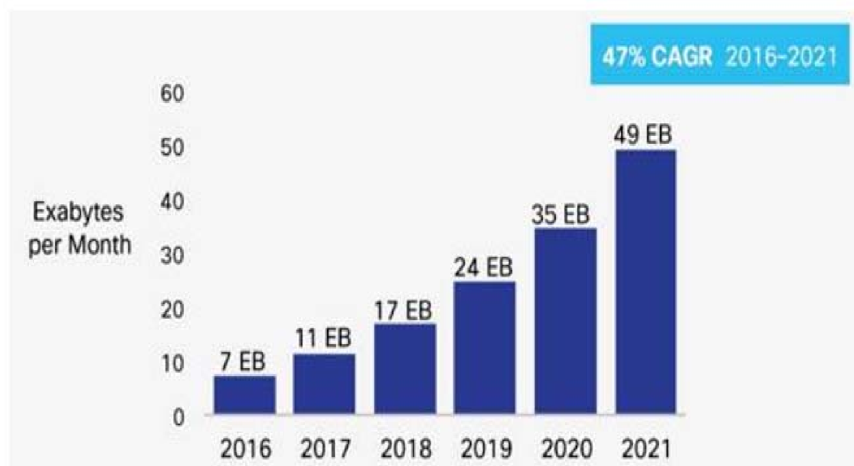


Fig (1) Data demand forecast for the next several years

Spectral Efficiency

- Defines the transmissions in a cell measured in bits/s/Hz
- MIMO improves the spectral efficiency by simultaneously transmitting to multiple users over the same bandwidth by space division multiplexing
- Universities of Bristol and Lund conducted Massive MIMO Experiments with:
  - 22 users; 256 QAM; a single cell indoor environment
- Demonstrated 145.6 bits/s/Hz spectral efficiency over 20 MZ bandwidth in 3.5 GHz band.
- Compare this with 3 bits/s/Hz for IMT Advanced requirement for 4G

Massive MIMO System Model

- We consider a model of multi-user massive MIMO system consisting of:
- *L* cells, a BS per each cell with M antennas.
- *K* single-antenna users; total of LK users
- We consider time division duplex TDD system.
- Assume the downlink and the uplink channels are reciprocal of each other and well calibrated.
- Within each cell, the pilots are considered orthogonal and reused in the adjacent cells.
- The number of the orthogonal pilots is equal to or more than the number of users

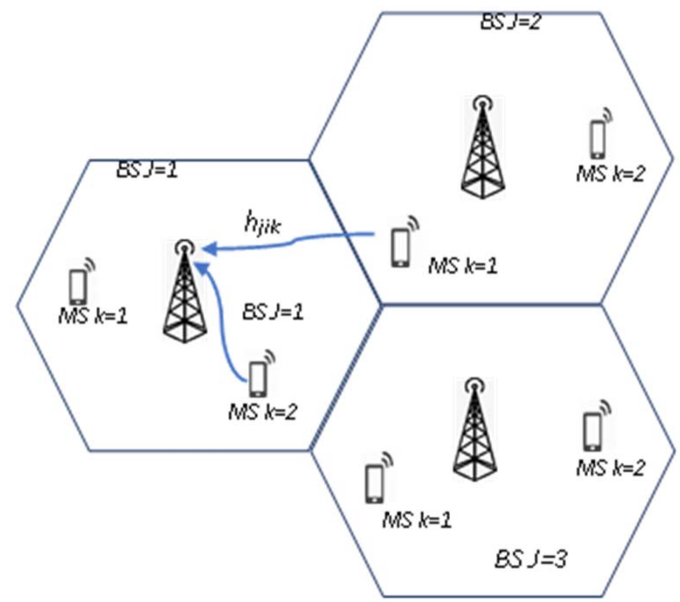


Figure (2) Multi Cell Multiuser massive MIMO System. The M-antennas of BS serve k single-antenna users within the same time-frequency resource.

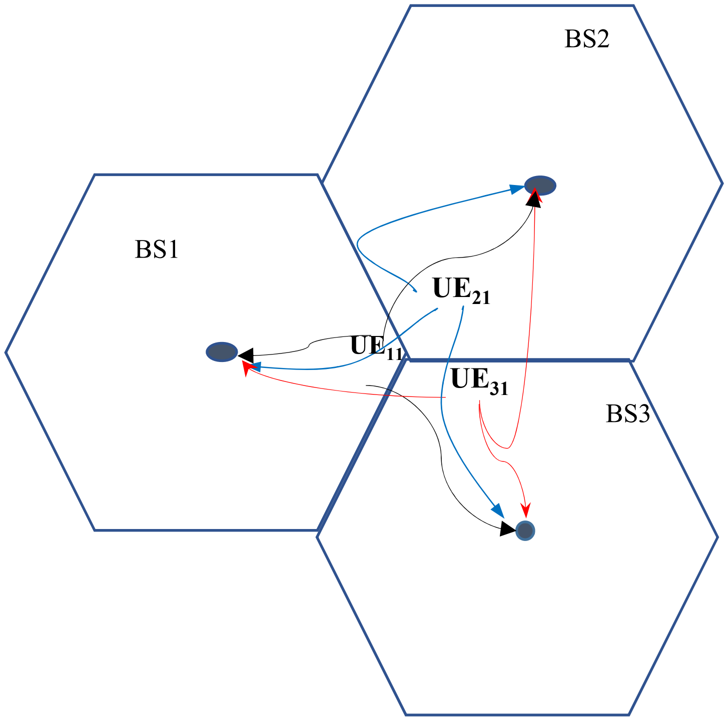
Pilot Contamination (PC)

Pilot Contamination is a fundamental challenge in the design of massive MIMO systems, a challenge that warrants further research.

- A problem that arises with pilot assignment in massive (MIMO) systems is due to inter-cell interference.
- When the interfering signals are pilot signals, the problem is known as pilot contamination.
- This work focuses on decreasing the inter-cell interference that results from spatial correlation based on signal arrival parameters.
- Assume the use of a cylindrical antenna array. The signal parameters are used to estimate user location.
- An algorithm is developed for allocating the pilot sequences to decrease the inter-cell interference and enhance the spectral efficiency based on estimated signal parameters .

Problem Definition

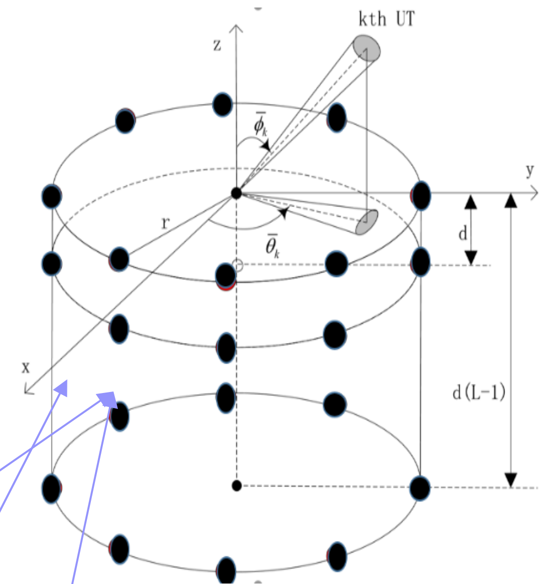
- Consider the multi cell multi user massive MIMO system as shown in the figure
- We assume that the system is synchronized such that all the users send their pilots to the serving BS at the same time
- Using conventional random assignment of pilots, there exists a high likelihood that adjacent users may be assigned the same pilot sequence. This leads to pilot sequence interference, known as pilot contamination
- Accordingly, each UE sends a pilot to the surrounding cells and each cell estimates the desired channel and the interfering channel.
- For example, BS1 estimates the black channel (desired) in addition to the blue and red (the interference channels).

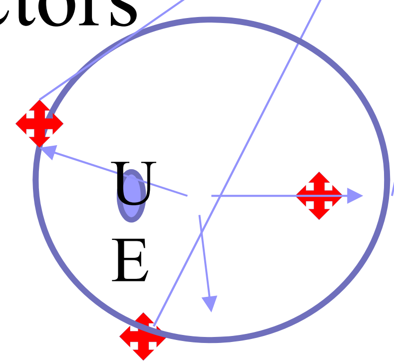


Channel Model

The channel between BS j and a UE $_k$ is

- $\widehat{\boldsymbol{h}}_{jk} = \sum_{j=1}^{j=L} \sum_{p=1}^{P=j} b_{jkp}\,(\theta_{jkp}, \emptyset_{jkp})\ \boldsymbol{a}_{jkp}$ (15)
- $\boldsymbol{a}_{jkp}$ is a function of $(\theta_{jkp}, \emptyset_{jkp})$
- A one ring spatial correlation model with 10 reflectors is adopted .



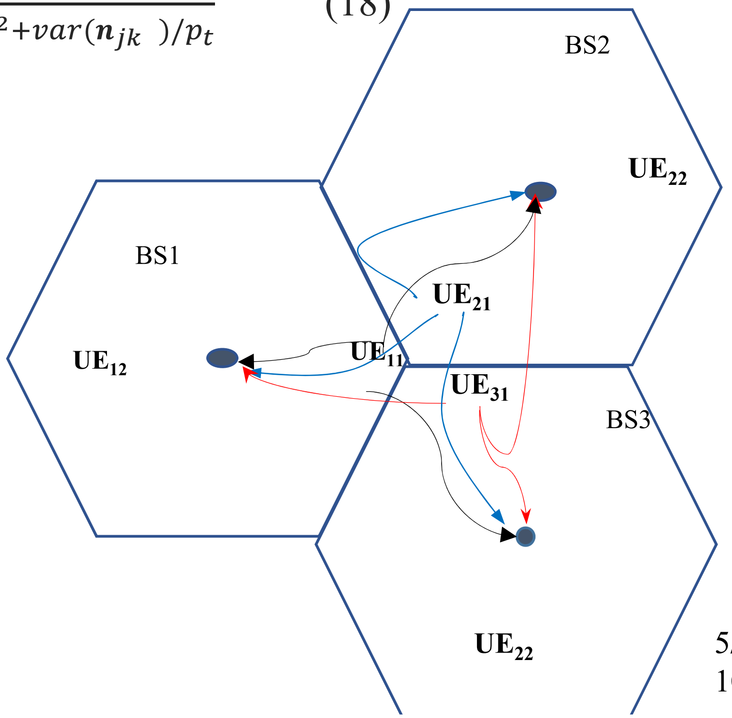


Channel Model

$$\hat{\boldsymbol{h}}_{jk} = \sum_{p=1}^{Pj} \frac{p_t}{Pj} b_{jkp}\, \boldsymbol{a}_{jkp}(\theta_{jkp}, \emptyset_{jkp}) + \left(\sum_{j=1}^{j=L} \sum_{p=1}^{Pj} \frac{p_t}{Pj}\, b_{jkp}\,(\theta_{jkp}, \emptyset_{jkp})\, \boldsymbol{a}_{jkp}(\theta_{jkp}, \emptyset_{jkp}) \right. {}_{+} \boldsymbol{n}_{jk}\ /(pt) \qquad (16)$$

$$CAPACITY\ Sum\ rate_{\ j} = \textstyle\sum_{k=1}^{K} \log(1 + SNIR_{jk}) \qquad (17)$$

$$SNIR_{jk} = \frac{||\, \boldsymbol{h}_{jk}^{H} \boldsymbol{h}_{jk}\ ||^2}{\sum_{j1\neq j,k1\neq k}^{J} ||\, \boldsymbol{h}_{jk}^{H} \boldsymbol{h}_{j1k1}||^2 + var(\boldsymbol{n}_{jk}\ )/p_t} \qquad (18)$$



Channel Model

- The first term is the desired channel and the second is the undesired channel which is between the desired BS and UEs under neighboring BSs. So, our goal is to minimize the second term.
- Assuming the AoA is known by each BS, we propose an algorithm with reduced complexity that prevents any adjacent users in close proximity to each other being assigned the same pilot.
- Let $(\theta_{jk}, \emptyset_{jk})$ be the AoA of UE_k of BS_j. Then the distance between UE_k of BS_j and the other terminals could be calculated easily.
- An optimization model for solving pilot signals assignments with several constraints is then proposed.

Pilot Assignment

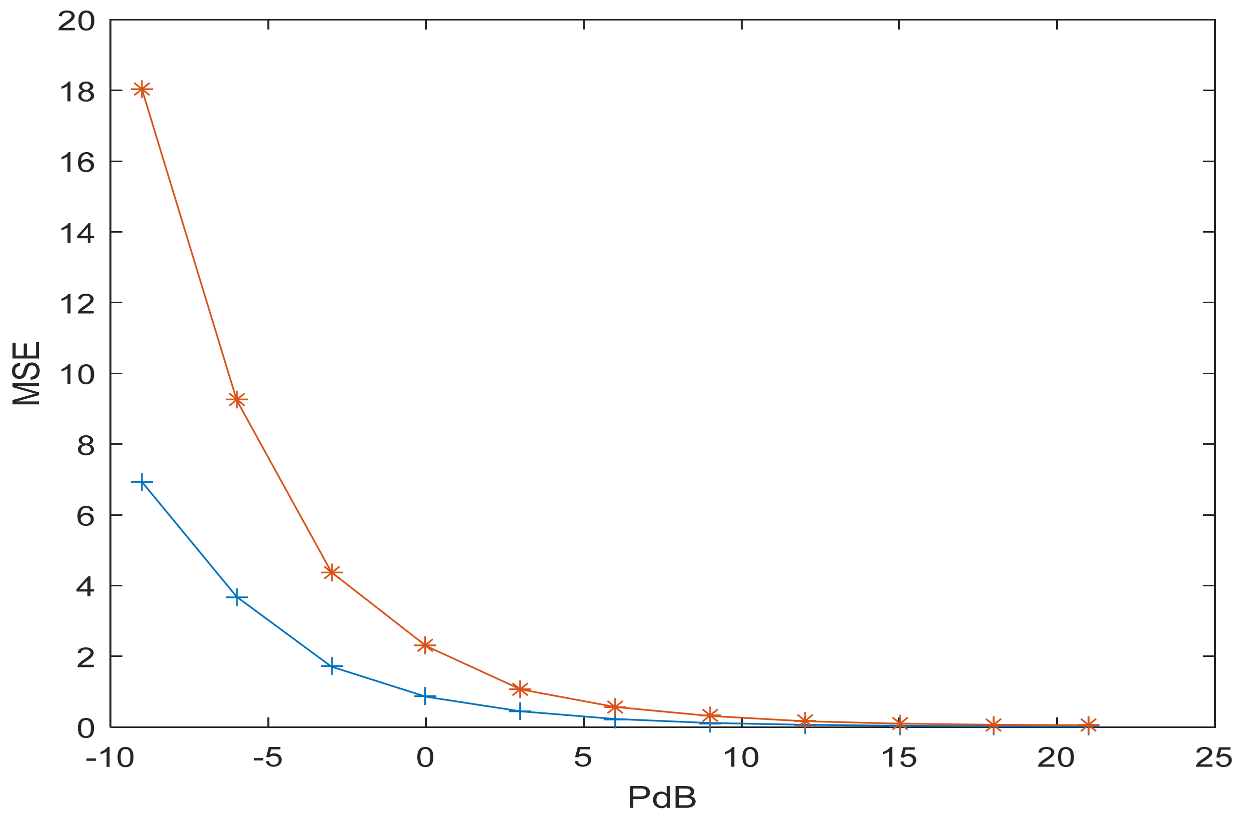
- We propose a pilot assignment algorithm that assigns the same pilot to the users who are separated the most.
- In this case, the channel correlation decreases since the pilots take different paths.
- The algorithm aims to increase the AoA spread.

Simulations

MATLAB R14 was used to perform the simulations.
The results were averaged over 1000 trials.

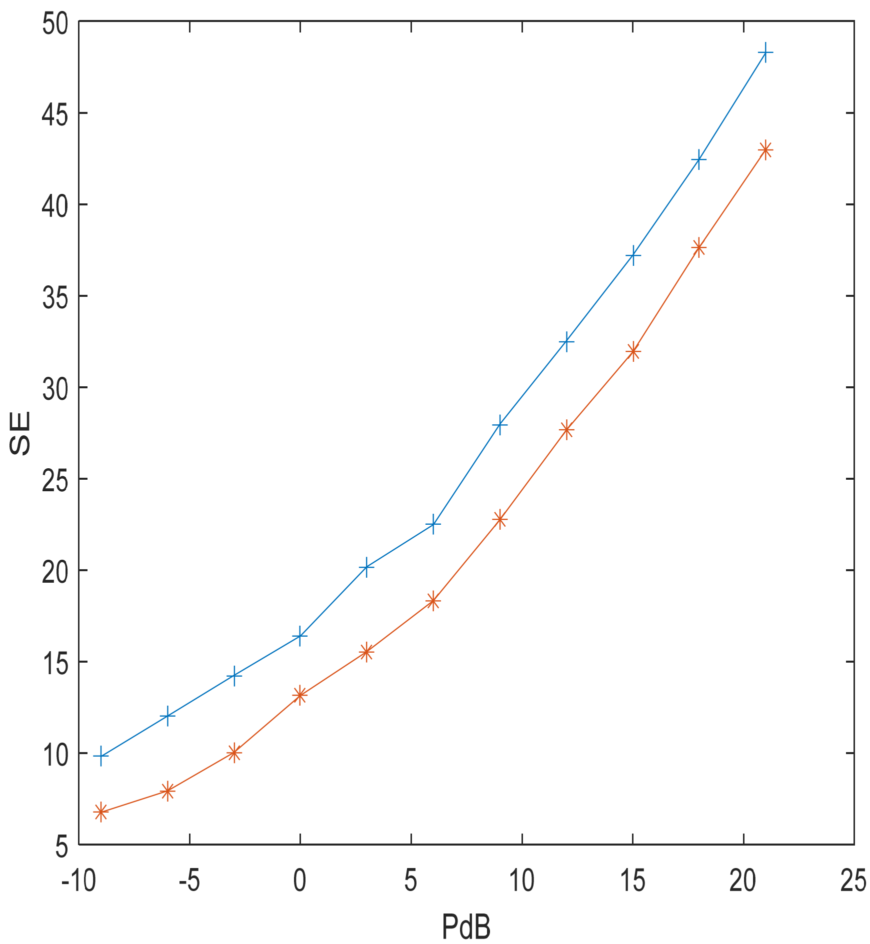
Terminals per BS	8
Number of BS	7
Forbidden radius	100m
BS height	25m
Inter-site distance	1000m
Frequency	2 GHz
Sigma Shadow	8
Path loss exponent	3
Antenna spacing	$\lambda/2$
Radius of reflectors	100m

Results



Channel Estimation MSE vs Signal Power. The blue color is the proposed . The red color is the conventional random assignment method .

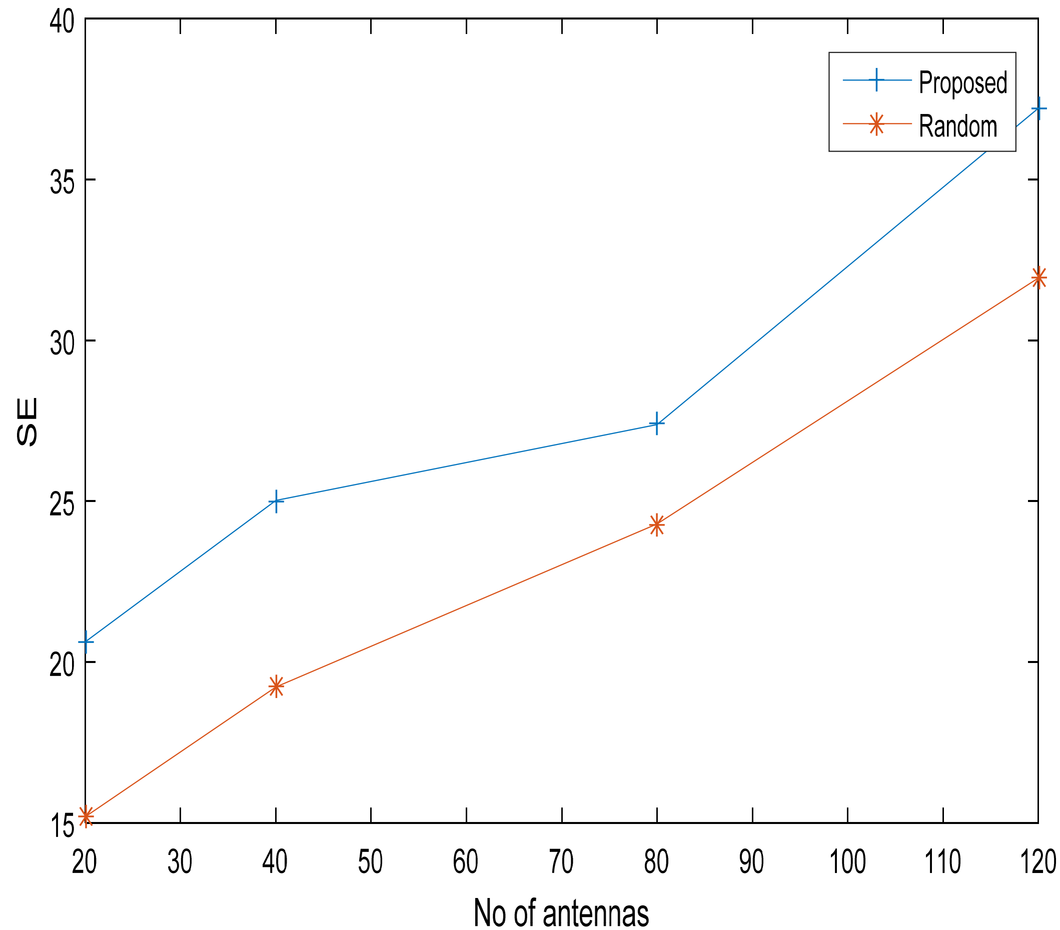
The proposed algorithm improves the spectral efficiency by about 38% at 0dB and by about 17% at 10dB.



Spectral efficiency vs the Power. The blue color is the proposed.

Results

With 40 antennas, the spectral efficiency improves by about 39% and with 100 antennas by about 18.5%



Spectral efficiency Vs the Number of Antennas. The blue color is the proposed.

SUMMARY

- A pilot assignment algorithm was proposed based on the estimated parameters of user terminals of multi-user massive MIMO systems.
- Exploit the AoA information obtained for each terminal to separate any terminals close to each other from being assigned the same pilot.
- The channel model used in the simulation and analysis is the one ring model.
- The algorithm keeps the distance between terminals with the same pilot approximately the inter-base stations distance.
- The simulation results show about 5dB improvement over conventional random pilot assignment.

Publications

1- A. Almamori and S. Mohan, "Estimation of channel state information for massive MIMO based on received data using Kalman filter," *2018 IEEE 8th Annual Computing and Communication Workshop and Conference (CCWC)*, Las Vegas, NV, 2018, pp. 665-669.
2- A. Almamori and S. Mohan, "A spectrally efficient algorithm for massive MIMO for mitigating pilot contamination," *2017 IEEE 38th Sarnoff Symposium*, Newark, NJ, 2017, pp. 1-5.
3- A. Almamori and S. Mohan, "Improved MMSE channel estimation in massive MIMO system with a method for the prediction of channel correlation matrix," *2018 IEEE 8th Annual Computing and Communication Workshop and Conference (CCWC)*, Las Vegas, NV, 2018, pp. 670-672.

THANK YOU