Ph.D. Research Proposal

Doctoral Program in "Department Name"

Pilot Contamination Mitigation for Wideband Massive MIMO 5G Networks through Optimal Assignment and Network Construction

by

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I. INTRODUCTION / BACKGROUND

Massive MIMO also referred to as large-scale multi-user MIMO, has been recognized as one of the key technologies in 5G cellular network under the Mobile and Wireless Communications Enablers for the Twenty-twenty Information Society (METIS). Some of the advantages that have been identified in MIMO are: (a) increased energy (total number of bits transmitted per unit of radio spectrum consumed)and spectral (total number of bits transmitted per unit of radio spectrum consumed) efficiency, (b) expected cost reduction in RF power components, (c) latency reduction in air interface,(d) simplified multiple access layer, (e) robustness of wireless communications, and (f) when the number of BS antennas is much larger than UTs simpler linear precoders and detectors.

Cellular network is being widespread with the support of advanced technological growth. People adopt themselves over the use of newer advancements and hence this is the major reason to introduce high data rate 5G technology. 5G technology in telecommunication is applied for various applications [1]. To tolerate a huge number of users, 5G introduced Massive Multiple-Input-Multiple-Output (MIMO) with more number of antennas [2], [3]. Antenna plays a major role to perform communication, due to participation of more than one base station an issue of interference occurs. Massive MIMO includes the significant processing of precoding and mitigation of pilot contamination [4], [5] and [6]. Pilot contamination and precoding scheme is significant in Massive MIMO. In [7] Max-Min Fair Transmit precoding was proposed which used conventional linear precoding methods. The channel estimation was poor since, it ignores the effect of Peak-Average-Power-Ratio (PAPR) which is major problem in Massive MIMO. In precoding, pilot assignment plays a major role, since the edge users mostly retain performance degradation. A Cell-edge aware zero forcing precoding was proposed in Massive MIMO [8]. The network coverage area is partitioned based on voronoi diagram to concentrate edge users. However in this system, the deployment of base station is not advisable. Conventional precoding schemes were studied with base station cooperation [9]. Multi-cell environment was involved; in

which each cell was defined to be a group. Then Signal-to-Leakage-plus-Noise Ratio Precoding Scheme was proposed to increase spectral efficiency [10]. This method was capable to show better performance only which more number of antennas are used.

For precoding the conventional schemes are extended [11], where the users are separated into two types. The identification of user types is not easier, sine the pilot may be received by any user. Zero forcing precoding is a linear precoding which was analyzed in many papers to minimize pilot contamination [12], [13]. An Orthogonal Variable Spreading Factor was proposed with Zadoff-Chu sequences which minimized the effect of PAPR but was able to mitigate interference. Different types of filter were involved for mitigating pilot contamination as Wiener Filter and Kalman Filter [14], [15]. Using Wiener filter, the process include smoothing and then filtering which increases processing time. Filtering mostly consists of center users only that will degrade the network performance.

Pilot contamination mitigation was achieved by the design of channel zooming algorithm in Massive MIMO [16]. This algorithm was also performed based on conventional precoding, which was complex while a huge number of users are involved. Pilot contamination was also achieved by performing scheduling techniques [17], [18]. The major issues were inappropriate grouping for dynamic network environment and ignorance of significant network parameters. Pilot contamination was solved based on location-aided algorithm that operates on the basis of heuristic algorithm [19], [20].

1.1 Research Outline & Scope

Pilot contamination is mitigated based on grouping, precoding and channel estimatio. Several methods are discussed in each major process. In this research, the ideas of mitigating pilot contamination is established and solved accordingly.

1.2 Research Objectives

The main objective of this research work is to reduce the transmit power and also eliminates inter-user interference (IUI) and inter-stream interference (ISI).

II. RESEARCH GAPS

2.1 Common Problem Statement

However, massive MIMO systems are affected by pilot contamination, which influences the data rate of the system. This contamination is caused by the non-orthogonality of the pilot sequences transmitted by users in a cell similar to the neighboring cells.

2.2 Problem Definition

In [1] author proposes Maximum Ratio Combining precoding with base station cooperation (MRC-BSC) and Zero Forcing with Base Station Cooperation (ZF-BSC) schemes for precoding. In this work each cell is defined as a group and formulations are determined to reuse pilots among groups. The mathematical formulations are obtained for single cell and then for multi-cell. In multi-cell precoding, SINR is defined as a significant metric.

Problems –

- Here each cell is defined to be each group, so reuse of pilot is insufficient when a single group has more number of users.
- Edge users are not separately considered

Proposed Solutions –

- Each cell is comprised with multiple groups
- Edge users are identified

In this [2] paper proposes a solution for pilot contamination based on Pilot Sequence Hopping with uncoordinated inter-cell. In pilot sequence hopping, the pilots are randomly shuffled and also it enables the user to randomly switch to a new pilot in the timeslot. Modified Kalman filter uses Autoregressive model, however this process increases more mathematical computations.

Problems –

- Random shuffle and assignment ignores the edge users and center users.

Proposed Solutions –

- Pilots are assigned optimally for users, for this purpose we use Particle Swarm Optimization with Fuzzy.

Pilot contamination in this work [3] is performed using Wiener-base filtering technique that includes Wiener Smoother and Wiener Predictor. The proposed Wiener based filtering technique involves filtering, smoothing and predicting. Block-data formulation is responsible for filtering followed by wiener smoother and wiener predictor. Based on the subframe, it is defined that it lacks in storage.

Problems –

- Lengthier process

Proposed Solutions –

- Simpler process to avoid pilot contamination

This paper proposes [4] an iterative algorithm defined as channel zooming algorithm in Massive MIMO systems. Channel zooming algorithm is formulated for two users based on antennas, noise and symbols. Bit error probability is determined only by assuming single contaminating user and in this paper author uses Maximum Ratio Combining in Base station.

Problems –

- Complex when more number of users participate in the network

Proposed Solutions –

- Base station rotation and pilot assignment mitigates pilot contamination

This paper proposes [5] a joint precoding and scheduling algorithm for the designed multi-cell network. Initially reference signals are transmitted by base station and from the user's feedback they are grouped. K-means clustering with chordal distance is used for grouping users. User scheduling is performed based on the data rate which is determined from Signal-to-Interference-Noise Ratio (SINR). The SINR is updated for second stage precoding matric.

Problems –

- Groups are defined based on points only and hence significant parameters are not involved.
- Difficult with dynamic environment.

Proposed Solutions –

- Groups are formed based on user parameters, this grouping is applicable for dynamic environment i.e. where users are movable.

III. RESEARCH CONTRIBUTIONS

In this work, we majorly focus on pilot contamination, Precoding and channel estimation over Massive MIMO in 5G environment. This process includes partitioning, group formation, pilot allocation to minimize pilot contamination, precoding and channel estimation. The network is deployed with dynamic user equipment and base station. Pilot contamination is mitigated by user scheduling and ***base station rotation***. Rotation is performed as Base station rotation is performed periodically with respect to the angle. Based on angle, we split into four quadrants between 0° – 360°. The base station is active only for two opposite quadrates at a particular time period. For efficient assignment of pilots, ***ring based partition*** is handled to partition users. These rings are formed based on the coverage area of base station and partitioning is performed only once. According to the number of rings, users are grouped using novel ***policy based*** algorithm that defines policies with respect to the following parameters: (1) *distance between neighbors*, (2) *user mobility* and (3) *position*. Grouped users are allocated with pilots, for which users are scheduled and then optimal pilots are allocated. Users are scheduled in accordance to

Neural Network using (1) *ring ID*, (2) *distance*, (3) *energy* and (4) *good count*. Higher prioritized user is provided with highly optimal pilots. Further to minimize pilot contamination, after grouping the users are allocated with time slots. So that the users are possible to communicate only during its timeslot

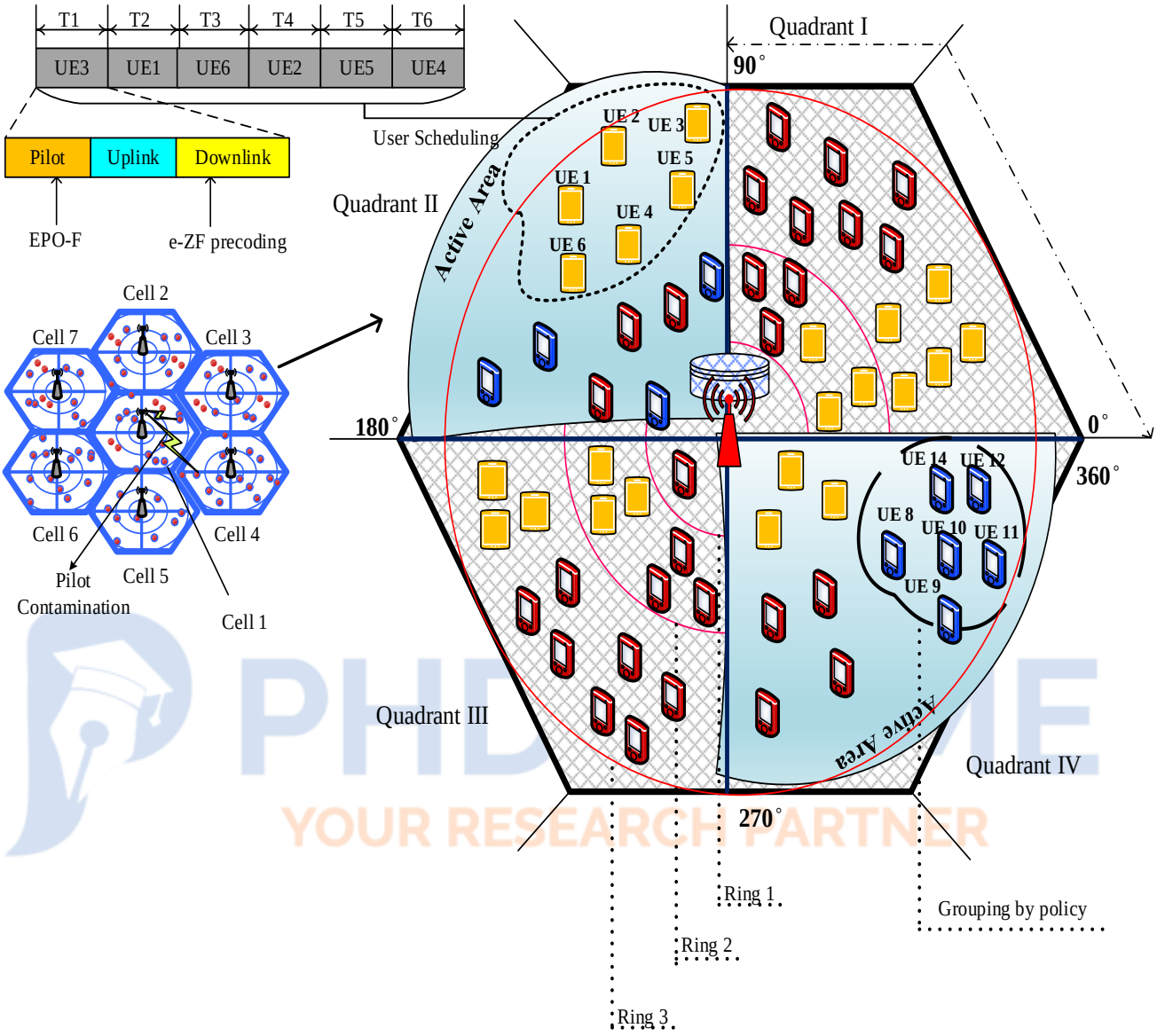
Optimal pilots are chosen and firstly assigned for edge users and other pilots for center users present in the network. A Novel ***Emperor Penguin OPtimization with Fuzzy*** (PSO-F) is designed to estimate optimal pilots. The output from fuzzy is considered to be the fitness value in PSO for each user. In fuzzy, the significant parameters that are taken into account are *channel quality* and AWGN. Based on the determined fitness values, the optimal pilots are assigned. Further an ***enhanced Zero Forcing*** (e-ZF) precoding is proposed. Usually the involvement of *Peak-to-Average-Power-Ratio* (PAPR) is one of the major problem that degrades the performance of the network. PAPR was not significantly taken in account for precoding schemes. The proposed e-ZF includes Signal to Noise Ratio and PAPR and effectively estimates the channel.

Performance Evaluation

Finally, the proposed Massive MIMO in 5G environment shows better performances in terms of the following metrics:

- Achievable Rate with respect to SNR
- Achievable Rate with respect to # of antennas
- Received SINR
- Spectral Efficiency with respect to SNR
- Spectral Efficiency with respect to # of antennas

SYSTEM ARCHITECTURE



IV. RESEARCH NOVELTIES

V. PREVIOUS WORKS & LIMITATIONS

Paper 1

Title – A New Joint TSPA/WGC Pilot Contamination Reduction Strategy Based on Exact Graph Coloring Grouping Algorithm

Concept –

In this paper, two different pilot assignment approaches are jointly proposed to reduce pilot contamination effect. A time-shifted pilot assignment (TSPA) approach is used, where a cellular network is divided into exclusive groups, wherein users in the same group send their uplink-pilots simultaneously, while other users receive their downlink-data. Through the uplink-pilot phase, a heuristic weighted graph coloring-based pilot assignment (WGC-PA) approach is used to reduce intra-group interference caused by pilot contamination. Different uplink-pilots are allocated to the users in the same group having the largest pilot contamination severity (PCS), whereas other users with the smallest PCS share the same uplink-pilots. To divide the cellular network into exclusive groups, we propose a cells grouping technique based on the adjacent distance between cells.

Paper 2

Title – A Comprehensive Survey of Pilot Contamination in Massive MIMO – 5G Systems

Concept –

This paper explains the merits on using Massive MIMO such as energy efficiency, spectral efficiency, linear processing, reliability and more. Pilot schemes and channel estimation methods are studied in this article. The major sources of pilot contamination is discussed, therefore this intimates the importance of pilot contamination in 5G systems using Massive MIMO. Some pilot contamination techniques are elaborated.

Paper 3

Title – Pilot contamination mitigation strategies in massive MIMO systems

Concept –

This paper reviews four categorize of pilot contamination as multi-cell cooperation, data-aided channel estimation, interference suppression and pilot alignment. These four categorizes of pilot contamination are studied and their limitations are discussed.

Paper 4

Title – Max-Min Fair Transmit Precoding for Multi-Group Multicasting in Massive MIMO

Concept –

This paper focuses on channel estimation, pilot contamination and multi-group multicasting using Massive MIMO. The traditional Maximum Ratio Transmission (MRT) and Zero Forcing (ZF) are used for precoding. Channel estimation is handled with dedicated pilot assignment and co-pilot assignment.

Limitations

- PAPR is not significantly considered
- Entire system is complex due to the involvement of complex mathematical equations.

Paper 5

Title – Cell-Edge-Aware Precoding for Downlink Massive MIMO Cellular Networks

Concept –

This paper proposed a cell-edge aware – zero forcing precoder that discusses the importance of scheduling. In this work the cells are split based on voronoi diagram in first order and second order. Signal-to-Interference Ratio is estimated by user equipment from their origin location. Then coverage probability is determined, which is enabled to analyze the information of Signal-to-Interference Ratio.

Limitations

- Using voronoi diagram based cells, leads to installation of base station very closer.

Paper 6

Title – Spectral and Energy Efficiency Analysis for SLNR Precoding in Massive MIMO Systems with Imperfect CSI

Concept –

The authors of this paper have proposed Signal-to-Leakage-plus-Noise Ratio Precoding Scheme (SLNR-PS). SLNR is formulated based on different entities as transmit power of user, transmit power level of base station and noise. This work achieves optimal energy efficiency only when the numbers of antenna are in large number. The entire procedure of this proposed scheme involves with multiple mathematical formulations.

Limitations

- Poor performance with minimum number of antennas.

Paper 7

Title – Downlink Precoding with Mixed Statistical and Imperfect Instantaneous CSI for Massive MIMO Systems

Concept –

This paper proposed extended Zero-Forcing (eZF) and extended Maximum Ratio Transmission (eMRT) precoding methods for the purpose of increasing signal power for serving users. Here users are classified into type-S and type-C, in which the users sending uplink pilot comes under type-C and other under type-S. This work also involves in avoiding mutual interference between type-C and type-S users.

Limitations

- Received signal power degrades due to scarification of channel statistical information.
- PAPR is not focused and hence it is high.

Paper 8

Title – Eradication of pilot contamination and zero forcing precoding in the multi-cell TDD massive MIMO systems

Concept –

In this paper, the authors have proposed Orthogonal Variable Spreading Factor (OVSF) and Zadoff-Chu sequences to increase performance of the network. This works begins with estimation of OVSF codes and then ZC sequence is performed. Mathematical formulations are defined but the significant network parameters are not involved. In this work the authors insisted that, to minimize the complexity, a pilot assignment technique is required.

Limitations

- However OVSF reduces PAPR, it is not able to mitigate interference between users.

Paper 9

Title – Low-Complexity Linear Precoding for Pilot Contamination Mitigation in Multi-Cell Massive MIMO Systems

Concept –

This paper proposes Truncated Polynomial Expansion precoding for minimizing intra-cell interference. Here the Regularized Zero-Forcing is involved, which includes the power control factor. The defined transmission power is required to be satisfied by base station participating in that particular cell. Intra –cell interference is controlled by the base station present in each cell, since it is responsible for the particular cell.

Paper 10

Title – Pilot contamination reduction in massive MIMO based on pilot scheduling

Concept –

The authors of this paper have proposed scheduling scheme for allocating optimal pilot sequence. The proposed pilot scheduling scheme is operated based on degradation performance and grouping. Pilot scheduling scheme based on grouping involves scheduling based on different levels of contamination. Users are grouped in accordance to the channel quality and identify edge users and center users.

Limitations

- Channel quality detection needs establishment of link and channel quality is a metric which also varies due to other technical factors (interference, malicious node interruption, obstacle, etc.).

Paper 11

Title – Location-Aided Pilot Contamination Avoidance for Massive MIMO Systems

Concept –

This paper proposes pilot contamination which is performed based on the location of the target user. A heuristic approach is proposed for user assignment and the user Angle of Arrival information is estimated. SINR is the parameter that is involved, by using heuristic algorithm the pilots are randomly assigned. Cost function is required for attaining distance and position.

Paper 12

Title – Reduction of Pilot Contamination in Massive MIMO System

Concept –

The main aim of this article is to maximize spectral efficiency by mitigating pilot contamination. This takes in account of received signal-to-interference-noise ratio and this work also support cell edge aware data transmission.

Paper 13

Title – Achievable Downlink Rates of MRC and ZF Precoders in Massive MIMO with Uplink and Downlink Pilot Contamination

Concept –

In multicell environments, adjacent cells using the same spectrum cause a pilot contamination problem and degrade CSI quality. Under such practical environments, it is important to assess achievable rate of the system for a proper system design. There exist achievable rate bounds of uplink (UL) systems in the literature, but general closed-form rate bounds for downlink (DL) systems are not available yet. This paper studies a practical massive MIMO DL system with or without pilot-aided coherent detection under the scenario of pilot contamination, and derives closed-form approximate achievable DL rate expressions for both maximum ratio combining (MRC) and zero forcing (ZF) precoders.

Paper 14

Title – Resource Allocation Optimization in Multi-user Multi-cell Massive MIMO Networks Considering Pilot Contamination

Concept –

In this paper, we study the joint pilot assignment and resource allocation for system energy efficiency (SEE) maximization in the multi-user and multi-cell (MU-MC) massive multi-input multi-output (MIMO) network. We explicitly consider the pilot contamination effect during the channel estimation in the SEE maximization problem, which aims to optimize the power allocation, number of activated antennas, and pilot assignment. To tackle the SEE maximization problem, we transform it into a subtractive form, which can be solved more efficiently. In particular, we develop an iterative algorithm to solve the transformed problem where optimization of power allocation and number of antennas is performed then pilot assignment optimization is conducted sequentially in each iteration.

Paper 15

Title – Pilot Decontamination Based on Superimposed Pilots Assisted by Time-Multiplexed Pilots in Massive MIMO Networks

Concept –

In this work, authors propose a novel pilot decontamination approach in a massive MIMO network where the time division duplex operation is assumed. In our proposed approach, user equipments are allowed to use superimposed (SP) pilots in combination with time-multiplexed (TM) pilots to estimate the CSI prior to downlink data transmission. Specifically, the contaminated channel estimates obtained by TM pilots are used to reduce the amount of interference caused by transmitting pilots together with uplink data, which is a typical problem in SP pilots-based channel estimation.

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