NEW ENERGY-EFFICIENT-USER CLUSTERING AND POWER ALLOCATION FOR NOMA IN 5G MILLIMETER-WAVE MASSIVE MIMO

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To my beloved family, thank you.

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ABSTRACT

In wireless communications, designing Data Rate (R) and Energy Efficient (EE) Beamspace-Multiple Inputs Multiple Outputs (BS-MIMO) for the millimetre wave communications are challenging research problems from the last decade. There are different solutions presented such as Fully-Digital (FD), BS-MIMO, and BS-MIMO Non-Orthogonal Multiple-Accesses (BS-MIMO NOMA). To address these problems, a novel mm-Wave communication is proposed with a user clustering approach called BS MIMO C-NOMA. It combines the advantages of NOMA and BS-MIMO at first then combines user-clustering to enhance throughput of BS-MIMO NOMA downlink-multi-user NOMA. The efficient users cluster has been proposed to improve the spectral, power efficiency, and the quantity of upheld clients can be bigger than the quantity of Radio Frequency (RF) chains in the time frequency assets as well compared to existing solutions. Iterative power optimization methods with less complexity have been designed to use a dynamic power allocation in order to achieve EE performance. In this thesis, a lens antenna was used in the experiment to assess the lens's effectiveness in maximizing the signal. The simulation outcomes demonstrate the R and EE in C-NOMA are much higher than in NOMA by a percentage of 4.2 % and 26 % respectively, It means R is increased 6 % with a maximum of 50 users in C-NOMA compared to NOMA, and an increase of 3.92 % with a maximum 100 users. Then, EE results with a maximum 50 users for FD, MIMO, NOMA and C-NOMA are 1.172, 7.249, 10.879 and 13.72, respectively. Therefore, EE effects against SNR with 32 users in C-NOMA is 10.11 the highest compared to FD, MIMO and NOMA with 1.23, 6.58 and 7.58, respectively. The EE results of maximum 100 users for FD, MIMO, NOMA and C-NOMA are 1.29, 4.08, 7.85 and 10.82, respectively. The results of EE in C-NOMA show an increase of 37 % compared to NOMA with a maximum of 100 users. Signal strength result is increased from -18 dBm to -11 dBm by using the lens. We believe the proposed C-NOMA method can achieve higher result of R and EE compared to NOMA.

ABSTRAK

Dalam komunikasi tanpa wayar, mereka bentuk Kadar Data (R) dan Kecekapan Tenaga (EE) Ruang alur-Masukan Berbilang Keluaran Berbilang (BS-MIMO) untuk komunikasi gelombang milimeter (mm-Wave) merupakan masalah penyelidikan yang mencabar sejak sedekad yang lalu. Terdapat penyelesaian berbeza yang dibentangkan seperti Digit-Sepenuhnya (FD), BS-MIMO dan BS-MIMO Capaian Berbilang Tidak-Ortogon (BS-MIMO NOMA). Untuk menangani masalah ini, komunikasi mm-Wave novel baru telah dicadangkan dengan pendekatan pengelompokan pengguna cekap yang dipanggil BS MIMO C- NOMA. Pada awalnya, ia menggabungkan kelebihan NOMA dan BS-MIMO kemudian menggabungkan pengelompokan pengguna untuk meningkatkan daya pengeluaran BS-MIMO NOMA pautan bawah-berbilang-pengguna NOMA. Pengelompokan pengguna yang cekap telah dicadangkan untuk membantu meningkatkan spektrum, kecekapan kuasa dan kuantiti pelanggan yang disokong boleh menjadi lebih besar daripada kuantiti rantaian Frekuensi Radio (RF) dalam aset masa-frekuensi berbanding dengan penyelesaian sedia ada. Kaedah pengoptimuman kuasa berulang dengan kerumitan yang rendah telah direkabentuk dengan menggunakan peruntukan kuasa dinamik bagi mencapai prestasi EE. Dalam tesis ini, antena kanta telah digunakan dalam eksperimen untuk menilai keberkesanan kanta dalam memaksimumkan isyarat. Hasil simulasi menunjukkan R dan EE dalam C-NOMA jauh lebih tinggi berbanding NOMA dengan peratusan masing-masing 4.2 % dan 26 %. Ini bermakna R ditingkatkan 6 % dengan maksimum 50 pengguna dalam C-NOMA berbanding NOMA, dan peningkatan sebanyak 3.92 % dengan maksimum 100 pengguna. Kemudian, keputusan EE bagi maksimum 50 pengguna FD, MIMO, NOMA dan C-NOMA masing-masing 1.172, 7.249, 10.879 dan 13.72. Oleh itu, kesan EE terhadap SNR dengan 32 pengguna dalam C-NOMA adalah 10.11 tertinggi

berbanding FD, MIMO dan NOMA masing-masing 1.23, 6.58 dan 7.58. Keputusan EE bagi maksimum 100 pengguna FD, MIMO, NOMA dan C-NOMA masing-masing 1.29, 4.08, 7.85, dan 10.82. Keputusan EE dalam C-NOMA menunjukkan peningkatan sebanyak 37 % berbanding NOMA dengan maksimum 100 pengguna. Keputusan kekuatan isyarat telah ditingkatkan daripada -18 dBm kepada -11 dBm dengan menggunakan kanta. Kami percaya dengan kaedah C-NOMA yang dicadangkan ini boleh mencapai R dan EE yang lebih tinggi berbanding NOMA.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

AOA	–	Angle of Arrival
AOD		Angle of Departure
ABF	–	Analogy Beamforming
AF	–	Average Frequency
AWGN	–	Additive White Gaussian Noise
BBF	–	Broadband Forum
BER	–	Bit Error Rate
BB	–	Branch and Bound
BS	–	Base Station
BF	–	Beamforming
CoMP	–	Coordinated Multi-Point
CSIT	–	Channel State Information at the Transmitter
C	–	Cluster
CCMs	–	Channel Covariance Matrices
C-NOMA	–	Clustering - NOMA
CMOS	–	Complementary Metal-Oxide-Semiconductor
CSI	–	Channel State Information
CIR	–	Channel Impulse Response
DFT	–	Discrete Fourier Transform
D2D	–	Device-to-Device
DACs	–	Digital-to-Analogue Converters
DL	–	Downlink
DRL	–	Deep Reinforcement learning
DST	–	Discrete Sine Transform
dB	–	Decibel
EE	–	Energy Efficiency
FD	–	Full-Duplex

FDD	–	Frequency Division Duplex
FXCM	–	Exponential Fuzzy Clustering Methods
GK	–	Rayleigh Fading Channel Information
5G	–	Fifth Generation
4G	–	Fourth Generation
GHz	–	Giga Hertz
GA	–	Genetic Algorithm
G	–	Vector of Rayleigh Fading Channel
HB	–	Hybrid Beam
HPS	–	Hierarchical Power Separation
ISI	–	Inter-Symbol Interference
IEEE	–	Institute of Electrical and Electronics Engineers
IF	–	Impediment Frequency
IUs	–	Interference Users
IP	–	Internet Protocol
IDMAs	–	Integrated Document Management and Analysis System
IA	–	Interference Aware
LK	–	Pathloss Component Information
LOS	–	Line of Sight
LLHR	–	Low Latency and High Reliability
LAHB	–	Lens Array Hybrid Beam
LTE	–	Long-Term Evolution
LDD	–	Lagrange Dual Decomposition
L	–	Vector of Pathloss Component
K	–	Number of users
MIMO	–	Multiple Input Multiple Output
mm-Wave	–	Millimeter-Wave
MISO	–	Multiple Input Single Output
MMSE	–	Minimum Mean Square Error
MN	–	Antenna Elements in Transmitter and Receiver
MB	–	Multi-Beam
MM	–	Maximum Magnitude

MNLIP	–	Mixed Nonlinear Integer Programming
MU	–	Multi Users
MEF	–	Metro Ethernet Forum
MS	–	Mobile Station
MAC	–	Media Access Control
NLoS	–	Non-Line of Sight
NOMA	–	Non-Orthogonal Multiple Access
NIUs	–	Non-Interference Users
NU	–	Near-User
NGMN	–	Next Generation Mobile Networks
OMA	–	Orthogonal Multiple Access
OFDM	–	Orthogonal Frequency Division Multiplexing
PDF	–	Possibility Density Function
PAPR	–	Peak-to-Average Power Ratio
PD	–	Power Distribution
PA	–	Power Allocation
PF	–	Proportional Fairness
QoS	–	Quality of Service
QAM	–	Quadrature Amplitude Modulation
RX	–	Receive Signal
RA	–	Rate Adaptive
RF	–	Radio - Frequency
SIMO	–	Single Input Multiple Output
SNR	–	Signal-to-Noise Ratio
SU	–	Single User
SVD	–	Singular Value Decomposition
SIC	–	Successive Interference Cancellation
SC	–	Superposition Codes
SI	–	Self-Interference
SARSA	–	State–Action–Reward–State–Action
SINR	–	Signal-to-Interference and Noise Ratio
SISO	–	Single Input and Single Output
SOP	–	Secure Outage Probability

SER	–	Symbol Error Rate
R	–	Data Rate
Tx	–	Transmit Signal
TDD	–	Time Division Duplex
THP	–	Timescale Hybrid Pre-coding
TWDP	–	Two-Wave with Diffuse Power
TAS	–	Transmission Antenna Selection
UE	–	User Equipment
U	–	Vector of users belongs to a particular cluster
UTHM	–	University Tun Hussein Onn Malaysia
WPAN	–	Wireless Personal Area Network
WGC	–	Weighted Graph Coloring
WHT	–	Walsh-Hadamard Transform
ZF	–	Zero-Forcing

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Overview

The Multiple Input Multiple Output (MIMO) frameworks convey immense advantages to remote communication networks like Fifth generation (5G) when contrasted with conventional remote communication frameworks. To develop mobile data traffic of 5G communication, we need to grow the required channel capacity. It can use different methods, including creating a NOMA to achieve that development. Many kinds of research provided studies in other sites, such as joining MIMO technology, which increases the channel capacity by transmitting various signals over multiple antennas and Orthogonal Frequency Division Multiplexing (OFDM). Therefore, it distributes a radio channel into a high number of closely spaced sub channels to give more reliable connections at high speed. In addition, this system is expected to increase data rate (R) and channel capacity by a combination of these methods. Therefore, this section describes both MIMO and NOMA. In addition, the diversity of these techniques is likely to boost overall system channel capacity. Before examining the notion of C-NOMA, this part covers the concept of NOMA and related technologies that can integrate with NOMA to provide accessible features.

1.2 Problem Statement

To alleviate the problems of the traditional MIMO system, the recent concept of beamspace-MIMO has been proposed, which uses a lens antenna to drastically reduce the number of RF chains required in mm-wave MIMO systems without noticeable loss of performance.

Therefore, nowadays, there are challenges regarding the 5G requirements of wireless communication methods. These requirements are expected to be satisfied with the vast growth of mobile internet access, where it is likely that the traffic of the global mobile data will grow on an average of 10 to 100 times in the coming ten years. The emerging mm-Wave communications, operating in a range between 30 and 300-GHz, afford scope to meet such a high channel capacity demand of 5G [1] [2].

The beamspace-MIMO NOMA system can reduce the RF chain required in broad wave MIMO systems without losing visible performance. However, the beamspace-MIMO cannot select the same beam for different users with different requirements [3]. Therefore, there are several issues in the MIMO system. One of the issues in the traditional beam selection of beamspace-MIMO NOMA schemes is suffering from high interferences between the users in one beamspace.

A second issue is a limited number of users that support one beam, which leads to the use of a high number of RF chains with high energy consumption [4]; all these issues affect the data rate. Using Interference Aware (IA) and beam selection in mm-Wave massive MIMO NOMA system can null multiuser interference by using Zero-forcing pre-coding methods [5][6]. Therefore, reducing the number of antennas can reduce the required number of RF at the BS, which leads to a high transmission data rate and low energy consumption in the system [7]. Another issue concerning the current beamspace-MIMO NOMA system and the limitation of the number of supported users in one beamspace leads the system not to exceed the number of RF chains in the same frequency source. This means that BS MIMO NOMA is not scalable when the supported number of users is less than the number of RF chains at the same time and frequency resources.

Therefore, using the beamspace-MIMO technique increases network channel capacity and reduces complexity and interference [8]. The NOMA technology has recently proven a practical solution for mm-Wave communications [6]. Though the use of the spatial MIMO with NOMA together has been extensively studied, it only concentrated on traditional MIMO more than mm-Wave massive MIMO [9],[10]. The current MIMO-NOMA system has not taken into account the transmission features, such as not checking numbers for conflicting users of beamspace-MIMO and channel sparsity [8].

The main goal of this research is to design user clustering with a power allocation algorithm to enhance the performance of the EE in the 5G mm-Wave massive MIMO system and reduce the required number of the RF chains by using lens antenna technology in addition to enhancing the maximum throughput of the worst user among all users in one beamspace mm-Wave massive MIMO system and to improve scalability and reduce complexity. Practically, the power allocation and pre-coding method should be designed to reduce the interferences when increasing the achievable sum rate. The problem of power allocation in the research we took up is convex optimization to intra-cluster power allocation, providing optimal power allocation to any group size. Power allocation is the same in each of the traditional BS MIMO NOMA and BS MIMO C-NOMA, and dynamic allocation is the main demonstrator in both cases. About dynamic power allocation, multi-user beamforming and MIMO communication have been extensively studied as a potential technology to achieve significant benefits throughout. Achieving the balance between R and EE is the key research challenge for future communication technologies.

1.3 Objectives of Research

The R and EE user power allocation technique for future wireless communications is the main aim of this research. The objectives are:

i. To design the novel user clustering and power allocation algorithm in BS MIMO NOMA in order to enhance the performance of the EE and data rate of the worst user among all the users in one beamspace mm-Wave massive MIMO in a 5G system.
ii. To investigate the signal strength based on the experiment using the lens antenna to reduce the required number of RF chains, in addition, to evaluating the near-optimal beam selection by proposing the Interference Aware (IA) of NOMA with user cluster in the beamspace mm-Wave massive MIMO in 5G system.

iii. To evaluate a high data rate and maximize EE based on the optimal power allocation by improving the channel estimation for clustering the users based on mean squared error (MSE) and channel equalization.

1.4 Scope of Work

The research focuses on improving the R and EE for future wireless communications systems by using mm-Wave. Therefore, this research is bounded by the following:

i. The scope of this work is limited to simulation and evaluation of future wireless communications by using the novel proposed users clustering and power allocation algorithm in each beam in the downlink system, by exploiting the scatter natural of the wireless communication network.
ii. Specifically, our work is in the beamspace-MIMO system combined with the NOMA method. Two groups of users are used at the first maximum of 50 and then 100 users in each cell which covered three sectors with 120 degrees for each sector. The number of transmit antennas is 256 antennas, and the number of paths per user is 3.
iii. User clustering algorithm is used based on an iterative power allocation algorithm, and the benefits of lens antenna technology of beamspace-MIMO NOMA method. In our work, the number of iterations is 50.
iv. The user clustering algorithm represents the collection of users of the same properties by using the Rayleigh fading channel and pathloss component.
v. The number of users in each cluster depends on the upper band.
vi. Using a lens antenna to reduce the number of radio frequency channels.
vii. An equivalent channel vector is determined for each beam to realize pre-coding based on the principle of ZF, which means the limitation of our work to remove the interference by using ZF pre-coding.
viii. Derived the maximize EE by designing the user clustering with different numbers of users. The maximum EE is 26 % more than the traditional method.
ix. Using intra-beam Successive Interference Cancellation (SIC) and Superposition Coding (SC) within each cluster to support more than one user in one cluster.

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APPENDIX C

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