OPTIMAL CHANNEL FEEDBACK IN FDD MASSIVE MIMO SYSTEMS USING AN ANGLE-OF-DEPARTURE (AOD)

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FSKTM 2019 39

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By

BAKR MOHAMMED ABDULHADI AL-HAFIDH

Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Computer Science

July 2019

DEDICATION

"To my beloved father, mother and uncle, thank you for all your support in term of spiritual and encouragement"

"To all my fellow friends, laboratory colleagues and lecturers, thank you for all your support and help"

"To my supervisor who guided and help me, Assoc. Prof. Dr. Abdullah Muhammed"

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Computer Science

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July 2019

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ABSTRACT

Since channel feedback plays an increasingly important role in FDD massive MIMO systems, and MIMO, which is a key technology for 5G wireless communication systems, dramatically mitigates the inter-user interference with simple low complexity precoders and develops rapidly, more reliable and efficient channel feedback techniques are required to perform better forwarding. In FDD massive MIMO systems, due to the fact that feedback gain cannot be met without the knowledge of channel state information at the transmitter (CSIT), it is necessary to reduce feedback overhead reasonably to offer high spectral efficiency for next generation cellular systems. However, in the traditional techniques of channel feedback, the codebook is designed based on channel statistics and the feedback overhead scales linearly with the number of BS antennas to guarantee the capacity loss with an acceptable level. Therefore, as the number of BS antennas in massive MIMO systems is much larger than that of current

systems, the feedback overhead will be overwhelming. In order to balance and minimize the feedback overhead, a channel feedback based on AoD-adaptive subspace codebook in FDD massive MIMO systems is presented. In this research, collaborated with the concept of angle coherence time and the observation that path AoDs vary more slowly than path gains, the proposed technique utilizes the AoD information to accomplish the scalability and adaptability of the exactly distributed quantization vectors in the channel subspace. By providing the performance analysis of the proposed AoD-adaptive subspace codebook in a large-scale regime, the required number of feedback bits only scales linearly with the number of dominant paths, not with the number of BS antennas. Simulation was adopted using MATLAB. The simulation results show that the proposed codebook efficiently identifies the redundant antennas and users and is able to quantize the channel vector in a more accurate way while improving the performance and reducing the feedback overhead.

Key words: *channel feedback, FDD massive MIMO systems, feedback overhead, AoD, subspace codebook*

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Sarjana Sains Komputer

MAKLUM BALAS SALURAN OPTIMAL DALAM SISTEM MIMO BERSKALA BESAR FDD MENGGUNAKAN ANGLE-OF-DEEPARTURE (AOD)

Oleh

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ABSTRAK

Oleh kerana maklum balas saluran memainkan peranan yang semakin penting dalam sistem MIMO berskala besar FDD, dan MIMO, yang merupakan teknologi utama untuk sistem komunikasi tanpa wayar 5G, telah secara mendadak berupaya mengurangkan gangguan antara pengguna dengan precoder kerumitan rendah yang sederhana dan membangunkan teknik maklum balas saluran yang cepat, lebih dipercayai dan cekap yang diperlukan untuk melaksanakan penghantaran yang lebih baik. Dalam sistem MIMO berskala besar FDD, oleh kerana kebaikan maklum balas tidak dapat dipenuhi tanpa pengetahuan maklumat saluran saluran pada pemancar (CSIT), maka adalah perlu untuk mengurangkan overhead maklum balas dengan semestinya untuk menawarkan kecekapan spektrum tinggi untuk sistem selular generasi akan datang. Walau bagaimanapun, dalam teknik tradisional maklum balas saluran, buku kod direka

berdasarkan statistik saluran dan skala overhead maklum balas secara linear dengan bilangan antena BS untuk menjamin kehilangan kapasiti dengan tahap yang boleh diterima. Oleh itu, kerana bilangan antena BS dalam sistem MIMO besar-besaran jauh lebih besar daripada sistem semasa, overhead maklum balas akan menjadi sangat menggalakkan. Untuk mengimbangi dan meminimumkan overheaad maklum balas, maklum balas saluran berdasarkan buku kod subspace AoD-adaptif dalam sistem MIMO besar-besaran FDD dipaparkan. Dalam penyelidikan ini, konsep masa penggabungan sudut dan pemerhatian bahawa laluan AoDs berubah dengan lebih perlahan daripada keuntungan laluan telah digunakan, ini telah menggunakan teknik yang dicadngkan; menggunakan maklumat AoD untuk mencapai kebolehan berskala dan penyesuaian vektor kuantisasi yang teragih dalam ruang kecil saluran. Dengan menyediakan analisis prestasi buku kod subspace sub-AoD yang dicadangkan dalam rejim berskala besar, bilangan bit maklum balas yang diperlukan hanya bersisik secara linear dengan bilangan laluan yang dominan, bukan dengan bilangan antena BS. Simulasi dijalankan menggunakan MATLAB. Hasil simulasi menunjukkan bahawa buku kod yang dicadangkan cekap dalam mengenalpasti antena dan pengguna yang berlebihan, dan mampu mengkuantisasi vektor saluran dengan cara yang lebih tepat sambil meningkatkan prestasi dan mengurangkan overhead maklum balas.

Kata kunci: *rangkaianmaklum balas saluran, maklum balas overhead, sistem MIMO besar-besaran FDD, AoD, buku kod subspace*

ACKNOWLEGEMENT

First and foremost, I would like to show my deepest gratitude to my supervisor, Assoc. Prof. Dr. Abdullah Muhammed, a respectable, responsible and resourceful scholar, who has provided me with valuable guidance in every stage of the writing of this thesis.

Not forgotten, I would like to thank Dr. Mohamed Alrshah who have helped me to give me lots of useful advice and improve my thesis and presentation. Moreover, I would like express my gratitude towards my seniors under Dr. Hazlina, who direct or indirectly lend their helping hands in this study.

Last but not least, I' d like to thank all my friends and my family for their unceasing love, encouragement and support.

APPROVAL

I certify that this thesis was submitted to the Faculty of Computer Science and Information Technology, Universiti Putra Malaysia and has been accepted as partial fulfilment of the requirement for the degree of Master of Computer Science.

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DECLARATION

Declaration by graduate student

I hereby confirm that:

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This is to confirm that:

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LIST OF ABBREVIATIONS

MIMO	Multiple-Input Multiple-Output
BS	Base Station
AoD	Angle of Departure
SIMO	Single-Input-Multiple-Output
MISO	Multiple-Input-Single-Output
SISO	Single-Input-Single-Output
SU-MIMO	Single-User Multiple-Input Multiple-Output
MU-MIMO	Multi-User Multiple-Input Multiple-Output
TDMA	Time Division Multiple Access
CDMA	Code Division Multiple Access
SDMA	Space Division Multiple Access
MUD	Multiple User Detection
NI	National Instruments
TDD	Time Division Duplexing
FDD	Frequency Division Duplexing
CSI	Channel State Information

PMI	Precoding Matrix Index
ACM	Adaptive Coded Modulation
CQI	Channel Quality Information
CSIT	Channel State Information at the Transmitter
DPC	Dirty Paper Coding
ZFBF	Zero-Forcing Beamforming
CDI	Channel Direction Information
SINR	Signal to Interference plus Noise Ratio
SLNR	Signal Leakage plus Noise Ratio
OWA	Open Wireless Architecture
CoA	Care of Address
FA	Foreign Agent
ZF	Zero Forcing
BD	Block Diagonalization
MMSE	Minimum Mean Square Error
THP	Tomlinson-Harashima Precoding
VP	Vector Precoding
ISI	Inter Symbol Interference

DFE	Decision Feedback Equalizer
CS	Compressive Sensing
CIR	Channel Impulse Response
DCT	Discrete Cosine Transform
MP	Match Pursuit
OMP	Orthogonal Match Pursuit
SP	Subspace Pursuit
BP	Basis Pursuit
BOMP	Block Sparse Orthogonal Matching Pursuit
VQC	Vector Quantization Codebook
VQ	Vector Quantization
RVQ	Random Vector Quantization
ULA	Uniform Linear Array
UPA	Uniform Planar Array
MUSIC	MUltiple SIgnal Classification
API	Application Program Interface

CHAPTER 1

INTRODUCTION

1.1 Research Background

With the development of wireless communication, people have basically realized three "W" (Wherever, Whenever, Whoever), that is, instant communication can be achieved with any user at any place, at any time. However, at present, its development is gradually constrained by the existing bottleneck - the shortage of wireless spectrum resources. And how to improve the transmission quality and speed in complex and harsh channel environments (multipath fading and Doppler frequency shift) and limited bandwidth has become the key point of the development of wireless communication technology.

With the introduction of MIMO communication system in the 1990s, multi-antenna technology of space-time processing provides a new solution to the problem of bandwidth and quality of mobile Internet. The scheme of transmit diversity and space-division multiplexing realized by space-time coding has become a focus in the field of wireless communication. As we all know, the new technology can no longer increase the burden in frequency domain, and the combination of space-time coding and spatial diversity (MIMO) technology is to transform the unfavorable factors of the signal in the channel transmission process into favorable factors without occupying additional spectrum resources.

MIMO wireless communication system is a further expansion of the array antenna communication system and the smart antenna communication system. In general, it has not changed much on the original system, but has made minor improvements in the air interface. So MIMO technology has become the first choice of the third-generation communication technology and the third-generation evolution communication technology, and the key of future mobile communication.

1.2 Problem Statement

In order to guarantee the capacity loss within an appropriate and applicable level, the feedback overhead scales linearly with the number of the BS antennas. Therefore, based on these issues, in this study the problems are summarized:

1) The traditional channel codebooks are statistics-based, which is unable to scale up with the massive MIMO system due to the large amount of BS antennas, therefore, as the number of BS antennas is much larger than that of current systems, the feedback overhead will be overwhelming;
2) The performance analysis in the traditional statistics-based codebook is based on the correlation matrix of the exact channel, which is not efficient in large-dimension regime, especially when the number of BS antennas is sufficiently large.

1.3 Objectives

The main objective of this research is to re-implement the angel-of-departure (AoD) adaptive subspace codebook for channel feedback to reduce the feedback overhead. Below are the details of this research objectives:

1) to exploit the concept of the angle coherence time to estimate easily the AoD information with lower codebook size and overhead;
2) to develop the AoD subspace codebook by utilizing the constant AoD information to achieve better channel feedback quality;
3) to analyse the performance of this proposed algorithm based on the AoD estimate in the large scale systems when the number of the BS antennas grows large.

1.4 Research Scope

The scope of this project is to re-implement the AoD-adaptive subspace codebook that was proposed by Wenqian et al. (2018), which will achieve better channel feedback quality in FDD massive MIMO systems.

This simulation is in MATLAB and results are generated with graphs to provide the performance analysis of the proposed codebook.

1.5 Thesis Organization

Five chapters are consisted in this thesis:

- Chapter 1 (Introduction): contains the research background and the problem statements, which describe the research issues. Based on the issues, the objectives are listed corresponding to each objective. Then the research scope is given.
- Chapter 2 (Literature Review): gives overview of the MIMO systems and existing typical algorithms in MIMO systems. Especially, the related work is described briefly and different algorithms are compared.
- Chapter 3 (Research Methodology): illustrates the methodology used to develop the AoD-adaptive subspace codebook and describe the whole process. How to design and implement this research are explicated in detail.
- Chapter 4 (Results and Discussions): consists of the output produced by the simulation and discussions about the results. Residual energy and energy consumption are analyzed in this chapter.
- Chapter 5 (Conclusion and Future Work): summarizes this research and gives the future works.

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