PERFORMANCE OF SCHEDULING SCHEME FOR MU-MIMO BC SYSTEM WITH TWO-STAGE FEEDBACK

A Thesis Submitted in Fulfillment of the Requirement for the Award of the Degree of

MASTER OF ENGINEERING

in Electronics and Communication Engineering

Submitted By

Kanika Ralhan

801563011

Under Supervision of

Dr. Surbhi Sharma

Assistant Professor

ELECTRONICS AND COMMUNICATION ENGINEERING DEPARTMENT

THAPAR UNIVERSITY, PATIALA, PUNJAB

JUNE, 2017

DECLARATION

I, Kanika Ralhan hereby declare that the work presented in this thesis entitled "**Performance of Scheduling Scheme for MU-MIMO BC system with two-stage feedback"** in fulfillment of the requirement for the award of degree of Master of Engineering submitted at electronics and Communication Engineering, Thapar University, Patiala is an authentic record of work carried out under supervision of Dr. Surbhi Sharma (Assistant Professor, Electronics and Communication Engineering, Thapar University) from July 2015 to July 2017**.** The matter presented in this this has not been submitted either in part or full to any other university or institute for the award of any other degree.

Kanika

Date:…………………………… Kanika Ralhan

801563011

CERTIFICATE

It is certified that the work contained in the thesis titled **Performance of Scheduling Scheme for MU-MIMO BC system with two-stage feedback** by Kanika Ralhan[801563011] has been carried out under my/our supervision and that this work has not been submitted elsewhere for any other degree.

Surbhi 12/7/17

Dr. Surbhi Sharma
Assistant Professor
Electronics and Communication Engineering
Thapar Univeristy

Date: 12-07-17

ACKNOWLEDGEMENT

I would like to express my profound exaltation and gratitude to my mentor **Dr. Surbhi Sharma** for her candid guidance, constructive propositions and overwhelming inspiration in the nurturing work. It has been a blessing for me to spend many opportune moments under the guidance of the perfectionist at the acme of professionalism. The present work is testimony to her activity, inspiration and ardent personal interest, taken by her during the course of her work in its present form. I would like to express my sincere gratitude to all who directly or indirectly helped me for the successful completion of this report.

ABSTRACT

Multi-user Multiple Input Multiple Output (MU-MIMO) broadcast channel (BC) deployed with multiple transmit antennas at the base station (BS) and multiple receive antennas at each user is considered. The channel state information (CSI) from each user is quantized at the user side and the CSI at the transmitter (CSIT) required to obtain the throughput for the system is obtained in terms of the feedback bits only. The main objective is to reduce the feedback load. Transmitter architecture is proposed based on the zero-forcing beam forming (ZFBF) semi-orthogonal user selection (SUS) algorithm. In the proposed system, a two-stage feedback scheme is used along with the SUS scheduling algorithm so as to minimize the feedback load. The Maximum expected SINR combiner (MESC) is exploited so that only a limited number of users convey their feedback. These methods efficiently eliminate users from transmission in feedback and scheduling process, resulting in optimum use of scarce resources.The selected set of users are used for finding the BER and the ergodic capacity of the system. For this the CSIT (Channel State Information) is requires to obtain throughput using the feedback bits only. The MESC (Maximum Estimated SINR combiner) is calculated for the users to convey their feedback. The analytical result shows that the BER decreases with the increase in number of antennas which helps in increasing the efficiency of the system proposed. The ergodic capacity of the system increases with an increase in the number of feedback bits thus helping in accommodating more number of users.

TABLE OF CONTENTS

LISTS OF ABBREVIATIONS

MU-MIMO	Multiuser- Multiple Input Multiple Output
MAC	Multiple Access Channel
BC	Broadcast Channel
CSIT	Channel State Information at Transmitter
CDI	Channel Directional Information
SUS	Semi-orthogonal User Selection
BER	Bit Error Rate
SDMA	Space Division Multiple Access
TDMA	Time Division Multiple Access
FDMA	Frequency Division Multiple Access
CDMA	Channel Division Multiple Access
CSIR	Channel State Information at Receiver
SNR	Signal To Noise Ratio
SINR	Signal to Interference Noise Ratio
BS	Base Station
CSI	Channel State Information
ZFBF	Zero Forcing Beam Forming
QoS	Quality of Service
BD	Block Diagonalization
CQI	Channel Quality Information
TaS	Transmit Antenna Selection
EGT	Equal gain Transmission
VQ	Vector Quantization
SQ	Scalar Quantization
MISO	Multiple Input Single Output
DPC	Dirty Paper Coding

UTD	Uniform theory of Diffraction
NLOS	Non line of Sight
OSTBC	Orthogonal Space time Block Codes
ML	Maximum Likelihood
ZF	Zero Forcing
MRT	Maximum Ratio Theory
MRC	Maximum ratio Combining
FB	Feedback
LAN	Local area Network
TDD	Time Division Duplexing
FDD	Frequency Division Duplexing
EMOS	Eurecom's MIMO Openair Sounder
AWGN	Additive White Gaussian Noise
PDF	Probability Density Function
CDF	Cumulative Density Function

LISTS OF FIGURE

LISTS OF TABLE

CHAPTER 1
INTRODUCTION

1.1 Multiuser-MIMO system

MU-MIMO [1] upgrades for Multi-user Multiple Input Multiple Output which empowers autonomous radio terminals for getting to the framework where numerous clients get to a similar channel utilizing spatial degrees of flexibility. Multi-client MIMO or MU-MIMO is the updated sort the MIMO advancement in grabbing affirmation. MU-MIMO, Multi-user MIMO engages various self-ruling radio terminals for getting to a system updating the correspondence capacities of each individual terminal. As requirements are it is habitually considered as an extension for Space Division Multiple Access, SDMA [2]. MU-MIMO manhandle most outrageous structure restrain by booking various clients to have the ability to at the same time get to a comparative channel that uses spatial degrees of adaptability offered by MIMO system. For enabling MU-MIMO, there are a couple of procedures that can be gotten, and different applications/variations that are open.

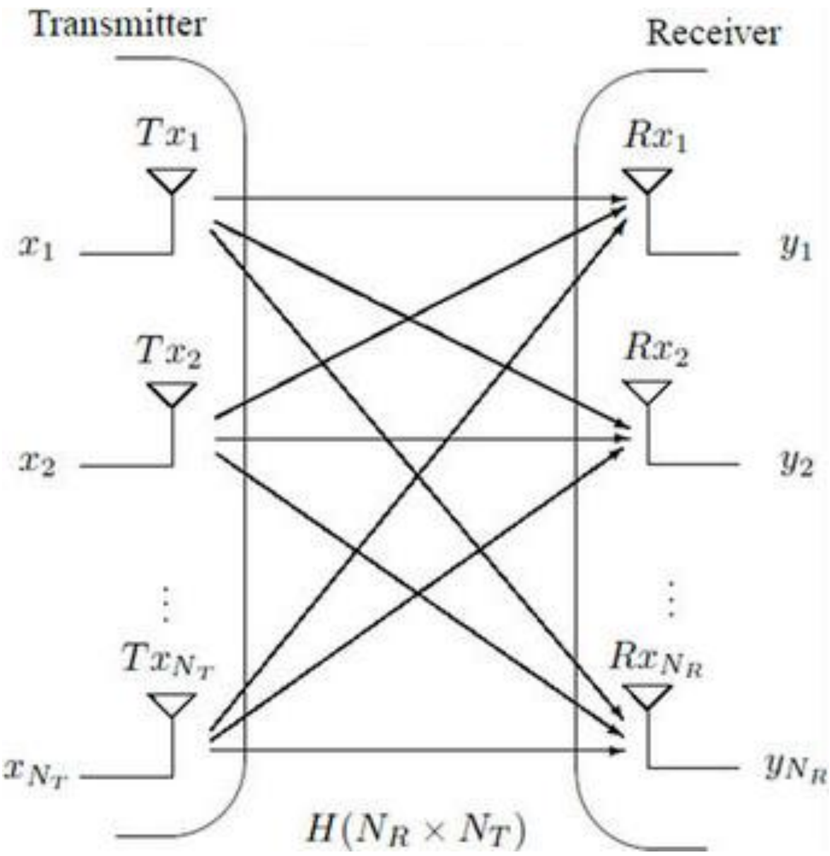

Figure 1.1 Multi-user MIMO system

MU-MIMO (Multi-client Multiple Input Multiple Output) gives higher get to rates to voice, video and information channels. This assists in adapting up to the difficulties that the expanding interest for administrations postures. For this numerous radio wires are conveyed at the transmission and gathering closes, known as the MIMO channel. With the potential for giving spatial multiplexing addition and assorted qualities pick up MUMIMO correspondence frameworks have tricked thought. It is considered as an idealistic approach for future remote system.

1.2 Preferences of MU-MIMO

MU-MIMO offers some basic ideal conditions over various techniques [3],[4],[5]:

- MU-MIMO structures enables a level of direct get to be gotten in a different get the opportunity to restrain rising up out of the multi-customer multiplexing plans. This relates to the amount of base station radio wires used.
- MU-MIMO appears, from every angle, to be affected less by some spread issues that impact single customer MIMO structures. These consolidate channel rank disaster and radio wire association - regardless of the way that channel relationship still impacts arranged qualities on a for every customer introduce, it is not a critical issue for multi-customer contrasts.
- MU-MIMO grants spatial multiplexing expansion to be expert at the base station without the prerequisite for various getting wires at the UE. This mulls over the making of unassuming remote terminals - the knowledge and cost is consolidated inside the base station.

The upsides of using multi-user MIMO, MU-MIMO incorporated some huge destruction of additional hardware - gathering mechanical assemblies and planning - and moreover gaining the channel state information which requires the usage of the available transmission limit.

1.3 Types of MU MIMO

MU-MIMO gives the framework whereby spatial sharing of the channels can be expert. This can be expert at the cost of the additional gear - channels and getting wires - yet the breaker does not go to the hindrance of the additional transmission limit like the circumstance when headways, for instance, FDMA, TDMA or CDMA are used.

While using the spatial multiplexing, MU-MIMO, the deterrent between the particular customers on a comparable channel is obliged by the use of additional getting wires, and additional dealing with the engages the spatial segment of the assorted customers.

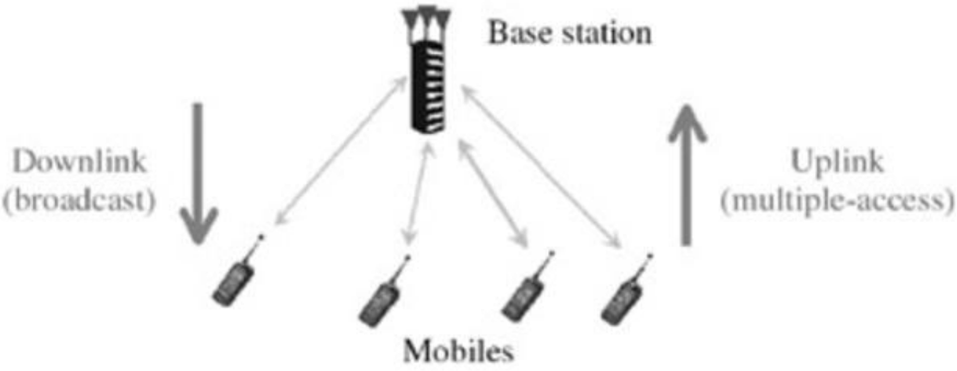

Figure 1.2 MU-MIMO types

There are two types related with MU-MIMO, Multi-user MIMO:

- Uplink-Multiple Access Channel, MAC [6]: The change of MIMO-MAC relies on upon the known single customer MIMO thoughts extended out for speaking to different customers.
- Downlink-Broadcast Channel, BC [7]: The MIMO-BC is the all the more troublesome circumstance. The perfect framework incorporates pre-impedance cancelation techniques known as "Dirty Paper Coding".

1.3.1 MIMO-MAC

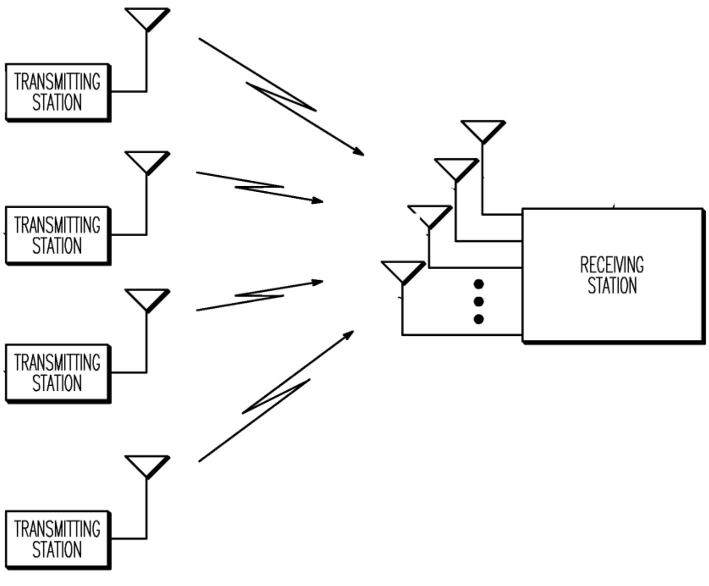

Figure 1.3 MIMO-MAC

This kind of MU-MIMO is accustomed for the substitute find the opportunity to channel - in this manner MIMO and it is utilized as a bit of uplink conditions. For the MIMO-MAC the gatherer plays out an amazing bit of the dealing with - here the recipient has to know the channel state and uses Channel Sate Information at the Receiver, CSIR. Picking CSIR is for the most part less asking for than picking CSIT, yet it requires fundamental levels of uplink ability to transmit the submitted pilots from every customer. However MIMO MAC frameworks vanquish exhibits point MIMO especially if the measure of recipient gathering gadgets is more detectable than the measure of transmit radio wires at every customer.

1.3.2 MIMO-BC

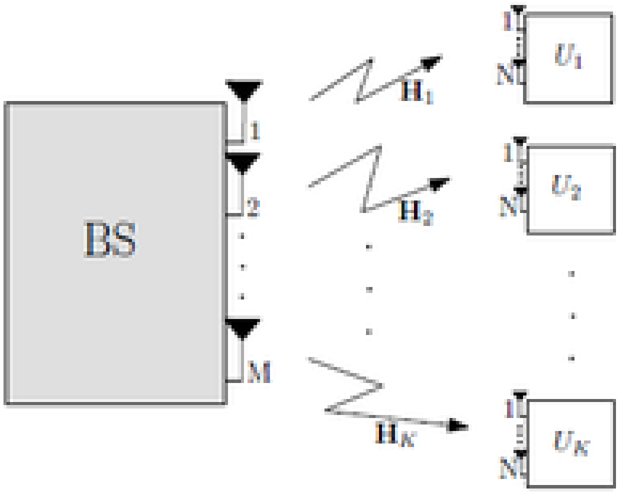

Figure 1.4 MIMO-BC

This kind of MU-MIMO is utilized by the MIMO grant channels, i.e. the downlink. Of the two channels, BC and MAC, it is the pass on channel that is the all the more troublesome inside MU-MIMO.

Transmit managing is guaranteed for this and it is normally as pre-coding and SDMA, Space Division Multiple Access based downlink client masterminding. For this the transmitter needs to know the Channel State Information at the Transmitter, CSIT. This enables enormous throughput improvement over that of customary demonstrate point MIMO structures, particularly when the measure of transmit radio wires beats that of the gathering contraptions at every recipient.

MIMO-BC addresses a downlink in which a single sender sends information to various authority remote frameworks. In MU-MIMO high throughput can be refined utilizing high SNR respect. Such systems have expansive access in remote structures. The occasions of utilization consolidate multi-cell structures with different get to channels where coordination among base station (BS) is set up. The guideline point is to co-ordinate and mitigates the effect of intruding cells.

1.4 Importance of CSIT and CDI

For transmit preparing of these signs, the channel state data at the transmitter (CSIT) [8] must be referred to in order to accomplish high throughput and change in multiplexing pick up. In the event that transmitter knows the downlink, channel state data at the transmitter (CSIT) splendidly, the limit can be proficient practically when there are huge quantities of clients. On the off chance that there is restricted CSIT then the exactness relies on upon precision of CSIT. These CSIT comes about assume a noteworthy part in throughput misfortune in light of obstruction variables. The codebook C is accessible at the transmitter and the collector. B bits per criticism interim are utilized in order to record the codebook with 2B vectors [9]. A very much characterized codebook contains code-words which traverse the arrangement of MIMO experience by the clients.

The expanded input partners with the quantity of clients and SNR values. The criticism is deciphered by two-arranges: the primary stage requires quantized CDI of client booking and the second stage aggregates CDI for client planning for beam forming. The aggregate rate execution depends upon the quantization legitimacy in outline and the measure of selected clients, input bits are satisfactorily relegated at each stage. For era of codebooks in importance to any radio wire outline for various spatial design, different profoundly versatile systems are accessible. To lessen the input, a small amount of clients which have their SNR higher than the framework characterized limit are approved to transmit their channel data. In the second stage; edge is a component of measure of clients, the measure of transmitting radio wires, quantization size and othogonality paradigm utilized. Ideal limit esteem is utilized with the goal that it diminishes the middle of the road criticism stack which is a necessity. We propose a planning calculation joined with the two-organize criticism for a Multi-user Multiple Input Multiple Output (MU-MIMO) which prior existed for Single client Multiple Input Multiple Output (SU-MIMO) system. The SUS calculation and the two-stage feedback consolidate together to perform better as the feedback [10] load is decreased. The input stack upgrades the throughput of the framework specifically. The need to consolidate these two frameworks began, for the quantity of clients wiped out in the SUS calculation is not huge. On consolidating the planning calculation with the criticism framework the quantities of clients are viably lessened.

For multi-client planning, the base station utilizes CSI (Channel State Information). The CSIT at the transmitter ought to be known impeccably, the execution up gradation should be possible for accomplishing most extreme limit, with expanding number of transmission and getting reception apparatuses. Limit pick up is hampered by variables, for example, data accessible at the transmitter and the collector side; channel SINR and co - connection between channels picks up. The CSIT as well as the CDI (Channel Directional Information) assumes a fundamental part. The CDI portrays the execution of MESC (Maximum assessed SINR Combiner) blend with ZFBF-SUS [17] (Zero driving Beam Forming Semi orthogonal Selection). In the SUS conspire, the clients are chosen on the orthogonality foundation. The favored clients are approved to transmit their data to the beneficiary. This aide in reducing the confusion from the ZFBF transmission. For a substantial number of clients this a successful technique that prompts ultra effective utilization of exposed assets. This paper contributes in reasoning the BER and expanding the limit of the MU-MIMO framework utilizing the SUS calculation.

1.5 Scheduling of users in MIMO system

Wireless Communication is a demanding network that has limited capacity and shared communication medium. The sharing of the spectrum among the users lead to a decrease in the access speed of the network which is a back step. Also because of the constant change in the user location, channel conditions and traffic patterns this needs to be taken care in a proper manner. The increasing demand for the wide variety of users mainly for data services leads to broad Quality of Service (QoS) hampering. Based on the applications the demand needs to be altered by the network as some applications are heterogeneous with hard constraints. These are the applications that require broad network for this the energy and delay constraints the design across the layers of the protocol stack. Depending on the various demands the users or the antennas can be scheduled using various algorithms or scheduling schemes.

1.6 Thesis Organization

The different chapters of the thesis are organized as

Chapter 1: Introduction discusses about Multi user Multiple Input Multiple Output systems and how they work. It also describes the various types of MIMO systems. The need for transmitting the CSIT and the CDI has also been discussed.

Chapter 2: Literature Survey briefs about the advancements in the Multiuser systems and also about the performance analysis of the system described.

Chapter 3: System Model describes the structure of the model implemented for decreasing the feedback load on the receiver side. Also the BER and the capacity of the system have been analyzed.

Chapter 4: Results and Discussions present the analytical results for the SUS implementation and the two-stage combined system, the BER and the capacity of the system.

Chapter 5: Conclusion summarizes the practical implementation of the proposed system and how well can it perform for real-time systems.

Chapter 2
LITERATURE SURVEY

M. Min, Y. Jeon, and G. Im *et al* [11]: This paper proposed the methods of user selection using block diagonalization (BD) and limited feedback. Channel state information at the transmitter (CSIT) is imperfectly transmitted, BD cannot reduce the effect of interference and thus leading to a lower throughput when compared to a perfect CSIT. When the number of users increase, the multi user diversity gain may be same because of the effect of the limited feedback based BD. The accurate CSIT must be transmitted for elimination of the expected rate taken in account over the precoding matrices unknown at the feedback stage. When CSIT accurately transmitted then it is advantageous for increasing number of users. Proper CSIT achieves a growth in the throughput combined with CQI, based on finite-rate feedback.

P. Lin and S. Tsai *et al* [12]: This paper proposes methods for reducing the feedback in the system caused by improper conditioning of the channel matrices. As a practical example the RF units are expensive, also degrade the performance of the system. To reduce the hardware cost, the RF units needs to be diminished. Based on the analytical results a simple TAS linearly pre-coded MU-MIMO system is proposed. The computational complexity is reduced using this technique and the performance is comparable with optimal selection scheme. Analytical results provide a better understanding of TAS effects which is considered appropriate for the hands on to be performed.

M. Torabi, D. Haccoun and W. Ajib *et al* [13] For the MRC MIMO systems the users are exploited for proper utilization of the antenna selection scheme. To overcome this channel hardening and the system performance needs to be improved. The closed form expression for Heterogeneous and Homogeneous cases BER and the capacity of the system is evaluated. The comparison of the results with the present scenario is made for the validation of these results.

C. R. Murthy and B. D. Rao *et al* [14] design for equal gain transmission (EGT) is considered for maximizing the channel capacity of a MISO system for finite rate feedback. The approaches used are vector and scalar quantization. Using the Vector quantization (VQ) the loss in the capacity of the system with respect to the EGT using perfect channel state information at the transmitter side is implemented. The iterative algorithm proposed using the Lloyd algorithm: for computing of the vector beamforming codebook. In the analytical approach, the Q-EGT performance and the expression in closed form for the loss in capacity and outage probability for i.i.d. Rayleigh flat fading channels. For the SQ, the uniform scalar quanitization and i.i.d Rayleigh flat fading channel. The high-resolution performance for the quantized EGT and performance contrast for VQ is derived. The same rate of convergence achieved for VQ and SQ as the number of feedback bits are increased, a fixed gap is encountered between the two.

M. Sharif and B. Hassibi *et al* [15] the time sharing, DPC and the beamforming is encountered for the MIMO system varying the number of transmitting antennas and the number of antennas per transmitter. This analysis is done for the best user possible for a bulky system. The average transmit power is fixed throughout. When a system is fixed with M transmit antennas and N user antenna equipped, the sum rate scales to M lognN. Whereas when M and N are fixed then the sum rate capacity scales to min (M;N)log log n. From the above results the time sharing for the sum rate of DPC and beam forming grows linearly to M, considering various multiplicative factors. Eventually the sum-rate capacity and the time-sharing scales to like N log log n.

A.Tajvidy and A. Ghorbani *et al* [16] keeping in mind the various fading factors in urban areas due to buildings, edges and mobility of the receivers. The uniform theory of diffraction (UTD) and Fresnel's reflection coefficient of the rays that strike the structure. The channel capacity is calculated rigorously, the use of the random variables and distribution functions is avoided. Therefore there is a significant improvement in the theoretical results obtained., for a realistic MISO system implemented for cellular mobile communication, as in this case the reflection form the buildings and the mobility of the receivers are also considered.

A.J.Paulraj , D.A.Gore, R.U. Nabar and H. Bolcskei *et al*[17] High information rate remote correspondences, nearing 1-Gb/s transmission rates, is of enthusiasm for developing remote neighborhood and home sound/visual systems. Outlining rapid remote connections that offer great nature of-administration and range capacity in non-viewable pathway (NLOS) situations constitutes a huge research and building challenge. Disregarding blurring in NLOS situations, we can, on a fundamental level, meet the 1-Gb/s information rate necessity with a solitary transmit single get reception apparatus remote framework if the result of data transmission (measured in hertz) and otherworldly productivity (measured in bits every second per hertz) is equivalent to 109. As we should plot in this paper, an assortment of cost, innovation and administrative requirements make such a savage compel arrangement ugly if not inconceivable. The utilization of various reception apparatuses at transmitter and beneficiary, famously known as numerous info different yields (MIMO) remote is a developing practical innovation that offers significant influences in making 1-Gb/s remote connections a reality. This paper gives an outline of MIMO remote innovation covering channel models, execution cutoff points, coding, and handset plan.

K. A. Saaifan and W. Henkel *et al* [18] A Middleton Class-A thickness is weil known to show indiscreet obstruction. The factual physical augmentation of this model for different get recieving wires is at present restricted to two reception apparatuses. An a1gebraic augmentation of the univariate MCA demonstrate prompts a muItivariate MCA dispersion, which can be utilized for a self-assertive number of get recieving wires. Since late reviews demonstrate a critical level of commotion relationship in a few remote frameworks, we create MIMO recipients for Rayleigh blurring directs within the sight of spatiaIly corresponded MCA obstruction. We infer upper bound pair wise mistake likelihood for orthogonal space time block codes (OSTBCs). We demonstrate that the execution change of OSTBCs is profoundly reliant on the motivation clamor condition and it ends up plainly minor as the number of transmit and get receiving wires increments. In the plan of MIMO beneficiaries, the most maximum likelihood (ML) identification has a high computational many-sided quality. Since the MCA model can be viewed as a multivariate Gaussian dissemination adapted on the information of commotion state, we acquaint a basic approach with gauge the condition of clamor at the collector, which in this way decreases the many-sided quality of the ML choice part.

C.-H. Chang and Y. Lee *et al* [19] Multiuser assorted qualities has pulled in critical consideration as of late. It makes utilization of the autonomous channel qualities for various clients through booking to enhance the execution of a remote cell correspondence framework. Sharp beamforming is a technique to upgrade the multiuser differing qualities pick up in a domain with constrained channel changes. In this paper, to make one stride assist, we explore the utilization of numerous radio wires at the collectors for astute beamforming frameworks. Distinctive differences consolidating systems are considered, and extra spatial assorted qualities can then be given. Recreation comes about demonstrate that the execution, including the normal throughput, normal greatest deferral and Jain's reasonableness list, can all be enhanced under various framework settings and channel situations.

Q. H. Spencer , L. Swindlehurst and M. Haardt *et al*[20] The utilization of space-division various get to (SDMA) in the downlink of a multiuser different info, numerous yield (MIMO) remote interchanges system can give a generous pick up in framework throughput. The test in such multiuser frameworks is planning transmit vectors while considering the co-channel impedance of different clients. Run of the mill advancement issues of intrigue incorporate the limit issue—augmenting the whole data rate subject to a power limitation—or the power control issue—limiting transmitted power with the end goal that a specific nature of-administration metric for every client is met. Neither of these issues have shut frame answers for the general multiuser MIMO channel, yet the burden of specific limitations can prompt shut shape arrangements. This paper presents two such compelled arrangements. The main, alluded to as "square diagonalization," is a speculation of channel reversal when there are different reception apparatuses at every collector. It is effortlessly adjusted to enhance for either most extreme transmission rate or least power and methodologies the ideal arrangement at high SNR. The second, known as "progressive enhancement," is an option strategy for explaining the power minimization issue one client at any given moment, and it yields predominant outcomes in a few (e.g., low SNR) circumstances. Both of these calculations are constrained to situations where the transmitter has a bigger number of reception apparatuses than all get receiving wires joined. To suit more broad situations, we likewise propose a structure for composed transmitter-recipient preparing that sums up the two calculations to cases including more get than transmit receiving wires. While the proposed calculations are imperfect, they prompt less complex transmitter and recipient structures and take into consideration a sensible tradeoff amongst execution and multifaceted nature.

E. Bala, K. J.-L. Pan, R. Olesen and D. Grieco *et al* [21] Zero-driving (ZF) beamforming, a productive strategy for multiuser MIMO frameworks, requires culminate channel state data to be accessible at the base station. This is accomplished by quantizing the channel and encouraging back the data with a set number of bits. A test of this strategy is the huge downlink flagging overhead, which is because of the extensive size of the codebook that can be utilized at the base station for ZF beamforming. In this paper, we initially investigate this issue and after that present a method outlining codebooks with lessened size and insignificant execution corruption. We likewise characterize the related techniques required for the framework usage. Recreation comes about demonstrate that the measure of the eNodeB codebook can be significantly diminished with just a little (5 %) punishment in execution.

M. Min, D. Kim, H.-M. Kim, and Gi-H. Im *et al* [22] a sharp two-stage feedback and booking calculation that depends on zero-driving beamforming with semi-orthogonal user selection (ZFBF-SUS) to decrease its feedback stack. In a SUS calculation, a base station plans semi-orthogonal users utilizing the feedback of all users' channel data. In any case, such feedback overhead essentially increments with the quantity of users. To lessen the feedback heap of ZFBF-SUS frameworks, the proposed two-stage feedback plot sharply and independently misuses the flag to impedance in addition to commotion proportion and orthogonality in each stage with the end goal that lone a small amount of users input their channel data. In light of this entrepreneurial feedback conspire; we decouple the whole procedure of the SUS into two sub-forms. The proposed two-stage feedback and booking plan successfully avoid the unseemly users for ZFBF transmission in both feedback and planning periods, and accordingly spare the rare assets expended for the feedback procedure. We infer a scientific expression for the normal number of feedback bits of the proposed framework and improve it in a found the middle value of sense. Promote, the total rate of the proposed framework is hypothetically explored. Both systematic and reproduction comes about demonstrate that the proposed calculation accomplishes the execution of traditional ZFBF-SUS frameworks with a fundamentally lessened number of feedback bits.

M. Trivellato, F. Boccardi, and H. Huang *et al* [23] the MIMO communicate channel where both the transmitter and beneficiaries are outfitted with different radio wires. Channel state information at the transmitter (CSIT) is acquired through restricted (i.e., limited data transfer capacity) input from the beneficiaries that file an arrangement of precoding vectors contained in a predefined codebook. We propose a novel handset engineering in view of zero-constraining beamforming and direct recipient joining. The recipient consolidating and quantization for CSIT criticism are mutually planned keeping in mind the end goal to expand the normal SINR for every client. We give an explanatory characterization of the achievable throughput on account of numerous clients and show how extra get reception apparatuses or higher multiuser assorted qualities can decrease the required criticism rate to accomplish an objective throughput. We likewise propose a plan approach for generating codebooks custom fitted for discretionary spatial correlation statistics. The subsequent codebooks have a tree structure that can be used in time-correlated MIMO channels to essentially lessen input overhead. Simulation comes about demonstrate the viability of the general handset plan strategy and codebook outline philosophy contrasted with earlier systems in an assortment of correlation conditions.

D. Gesbert , M.-S. Alouini *et al* [24] Remote planning calculations can extricate multi-client differing qualities through organizing the clients with best current channel conditions. One disadvantage of MUDiv is the required input conveying the momentary channel rates from every single dynamic endorser of the get to point/base station. This paper demonstrates that this input load is, generally, unjustified. To mitigate this issue, we propose a strategy permitting to significantly lessen the input (by up to 90%) needs while saving the basic of the plan execution. We give a hypothetical investigation of the criticism stack as capacity of the framework's ergodic and blackout limit with respect to both the conventional MUDiv plot and the new plan.

Taesang Yoo and A. Goldsmith *et al* [25] the limit of multiple-input/multipleoutput (MIMO) communicate channels (BCs) can be accomplished by filthy paper coding (DPC), it is hard to execute in commonsense frameworks. This paper explores if, for a substantial number of clients, less complex plans can accomplish a similar execution. In particular, we demonstrate that a zero-forcing beamforming (ZFBF) procedure, while for the most part problematic, can accomplish an indistinguishable asymptotic whole limit from that of DPC, as the quantity of clients goes to boundlessness. In demonstrating this asymptotic outcome, we give a calculation to figuring out which clients ought to be dynamic under ZFBF. These clients are semiorthogonal to each other and can be gathered for concurrent transmission to upgrade the throughput of planning calculations. In light of the client gathering, we propose and analyze two reasonable booking plans in round-robin ZFBF and relative reasonable ZFBF. We give numerical outcomes to affirm the optimality of ZFBF and to think about the execution of ZFBF and proposed reasonable planning plans with that of different MIMO BC procedures.

Y-G. Lim, C-B. Chae and G. Caire *et al* [26] monstrous different input– various yield frameworks for both downlink and uplink situations, where three radio units associated by means of one computerized unit bolster different client supplies at the cell-limit through a similar radio asset, i.e., a similar time–frequency opening. For downlink transmitter alternatives, the review considers zero forcing (ZF) and maximum ratio transmission (MRT), while for uplink collector choices, it considers ZF and maximum ratio combining (MRC). For the entirety rate of each of these, we determine basic shut frame equations. In the straightforward however for all intents and purposes important situation where uniform power is allotted to all downlink information streams, we watch that, for the downlink, vector standardization is better for ZF though network standardization is better for MRT. For a given radio wire and client configuration, we additionally diagnostically infer the flag to-clamor ratio level beneath which MRC ought to be utilized rather than ZF. Numerical recreations affirm our explanatory outcomes.

N. Benvenuto, E. Conte, S. Tomasin and M. Trivellato *et al* [27] For the downlink of a remote cell framework where the base station (BS) utilizes numerous receiving wires in a beamforming arrangement for a multiuser transmission (broadcasting), we examine two methods for quantizing the channel state data at the versatile terminal and bolstering it back to the BS. In both cases quantization of channel vectors and feedback flagging are together composed with a specific end goal to get a low-rate feedback (FB). Specifically, we initially consider a tree structure vector quantizer (VQ) of the channel vector with a novel metric, as a contrasting option to the traditional mean square mistake. It is seen that the tree seek allows to lower the FB flagging rate likewise in a period differing condition. As an option, a prescient VQ is proposed. These two and other FB strategies were broadly looked at in a run of the mill cell condition for various versatile rates and FB rates.

H. Huh, A. M. Tulino,, and G. Caire *et al* [28] the downlink of a multicell framework with multiantenna base stations and single radio wire client terminals, optional base station cooperation groups, isolate ward expansion pathloss, and general "tolerability" necessities. Base stations in a near interest assemble utilize joint transmission with straight zero driving beamforming, subject to indicate or per-base station control goals. Intercluster impedance is managed as disturbance at the client terminals. Logical articulations for the structure heavenly profitability are found in the colossal framework bind where both the measures of clients and radio wires per construct station keep an eye in light of boundlessness with a given extent. In particular, for the per-base station control impediment, we find new outcomes in self-assertive cross section hypothesis, yielding the squared Frobenius standard of submatrices of the Moore–Penrose pseudo-banter for the sorted out non-i.i.d. channel lattice coming to fruition due to the joint effort bunch, client flow, and way debacle coefficients. The examination is extended to the event of nonideal Channel State Information at the Transmitters overcome unequivocal downlink channel planning and uplink input. Specifically, our outcomes illuminate the trade off between the benefit of a more noteworthy number of teaming up social event gadgets and the cost of surveying higher dimensional channel vectors. Also, our examination prompts another streamlined downlink booking course of action that preselects the clients as shown by probabilities gotten from the liberal structure happens, dependent upon the pined for sensibility establishment. The proposed plot performs near the perfect (restricted dimensional) sly client decision while requiring in a general sense less channel state contribution, since just a little segment of preselected clients must feedback their channel state information.

V. Hassel, D. Gesbert, M.-S. Alouini and G. E. Øien *et al* [29] a channel state input calculation that uses different criticism limits to diminish the quantity of clients transmitting input to a base. The clients are surveyed with lower and lower edge values and just the clients that are over a limit esteem transmit criticism to the base station. We demonstrate how this input calculation can be utilized for any planning calculation and show how shut frame expressions for the ideal edge qualities can be acquired for two understood booking calculations. At long last, we propose a two-step optimization technique for advancing the input calculation for genuine cell principles. Another channel state criticism calculation for present day cell systems. Contrasted with already distributed works, our calculation depends on two novel ideas, to be specific, (i) adjusting the criticism limit an incentive to the planning calculation executed in the framework, and (ii) utilizing numerous input edges to diminish the quantity of clients transmitting input to a base. Our criticism calculation prompts a huge diminishing in the power utilization of the portable clients and furthermore in the time used to gather input for some frameworks. The proposed criticism calculation can be actualized for any booking metric, however much of the time the ideal edge values must be discovered numerically. Be that as it may, for the MCS and the NCS calculations we acquired exquisite shut shape expressions for the ideal limit values. At long last, we proposed a two-stage improvement strategy for acquiring the edge values and the quantity of edges, in actuality, remote systems.

Q. H. Spencer, C. B. Peel and M. Haardt *et al* [30] Multiple-input multiple-output (MIMO) correspondence procedures have been an essential territory of center for cutting edge remote frameworks due to their potential for high limit, expanded differing qualities, and impedance concealment. For applications, for example, remote LANs and cell communication, MIMO frameworks will probably be conveyed in conditions where a solitary base must speak with numerous clients all the while. Thus, the investigation of multi-client MIMO frameworks has developed as of late as an essential research subject. Such frameworks can possibly consolidate the high limit achievable with MIMO handling with the advantages of space-division multiple get to. In this article we audit a few calculations that have been proposed in light of this objective. We portray two classes of arrangements. The main uses a flag preparing approach with different sorts of transmitter beamforming. The second uses "dirty paper" coding to defeat the impedance a client sees from signs proposed for different clients. We close by portraying future regions of research in multi-client MIMO correspondences.

M. Rim *et al* [31] The cutting edge cell radio systems require high information rate transmission and substantial framework limit. To meet these necessities, numerous radio wires can be utilized at the base and portable stations, shaping different information, various yield (MIMO) channels. Downlink limit is imperative for versatile multimedia benefits and can be enhanced by expanding the quantity of portable station reception apparatuses. Notwithstanding, it is not practical to utilize an enormous number of reception apparatuses at a portable station because of the imperatives of its size, cost, and power utilization. Then again, base stations have generally free imperatives and we may pick the expansion in the quantity of base station radio wires. In this Letter, we consider downlink MIMO systems with M and N component radio wire clusters at the base and versatile stations, respectively. Assumes an expansive M, a little N, and level blurring, semi stationary, and rich-dispersing channel situations. We likewise accept that a base station can have the channel state data by uplink divert estimation in time-division duplexing (TDD) mode or by input from portable stations in frequency-division duplexing (FDD) mode.

Wei Yu and Tian Lan ***et al*** **[32]** transmitter enhancement issue for a multiuser downlink channel with various transmit radio wires at the base-station. Rather than the regular whole power imperative on the transmit reception apparatuses, this paper embraces a more reasonable per-radio wire control limitation, in light of the fact that in functional executions every receiving wire is outfitted with its own energy intensifier and is constrained independently by the linearity of the speaker. Expecting impeccable station learning at the transmitter, this paper explores two distinctive transmission plots under the per-receiving wire control imperative: a base power beamforming outline for downlink stations with a solitary reception apparatus at every remote client and a limit accomplishing transmitter plan for downlink stations with various radio wires at every remote client. It is demonstrated that in both cases, the per-radio wire downlink transmitter enhancement issue might be changed into a double uplink issue with an unverifiable commotion. This sums up past uplink–downlink duality comes about and changes the per-radio wire transmitter streamlining issue into a comparable minimax enhancement issue. Promote, it is demonstrated that different ideas of uplink–downlink duality might be brought together under a Lagrangian duality system. This new elucidation of duality offers ascend to productive numerical advancement methods for tackling the downlink per-receiving wire transmitter streamlining issue.

F. Kaltenberger, D. Gesbert, R. Knopp and M. Kountouris ***et al*** **[33]** In multi-client numerous info different yield (MUMIMO) frameworks, spatial multiplexing can be utilized to expand the throughput without the requirement for various reception apparatuses and costly flag handling at the client types of gear. In principle, MU-MIMO is additionally more resistant to a large portion of engendering constraints tormenting single-client MIMO (SU-MIMO) frameworks, for example, channel rank misfortune or radio wire connection. In any case, in this paper we demonstrate this is not generally genuine. We think about the limit and the relationship of measured MU-MIMO channels for both open air and indoor situations. The estimation information has been procured utilizing Eurecom's MIMO Openair Sounder (EMOS). The EMOS can perform continuous MIMO channel estimations synchronously over numerous clients. The outcomes demonstrate that in many situations MU-MIMO gives a higher throughput than SU-MIMO likewise in the deliberate channels. Be that as it may, in open air situations with an observable pathway, the limit drops fundamentally when the clients are near one another, because of high relationship at the transmitter side of the channel. In such a case, the execution of SU-MIMO and MU-MIMO is practically identical.

U. Erez and S. T. Brink *et al* [34] The "written work on dirty paper"- channel show offers an information theoretic structure for precoding techniques for intersection out self-decisive obstacle known at the transmitter. It demonstrates that lossless precoding is theoretically possible at any banner to-commotion extent (SNR), and along these lines soiled paper coding may fill in as a basic building hinder in both single-customer and multiuser correspondence structures. We layout a conclusion to-end coding affirmation of a system rising an important piece of the ensured gets. We use multidimensional quantization in light of trellis trim at the transmitter. Coset disentangling is realized at the recipient using "virtual bits." Combined with iterative unwinding of farthest point pushing toward codes we fulfill a change of 2 dB over the best scalar quantization scheme. Code setup is done using the EXIT chart strategy.

G. Caire and S. Shamai *et al* [35] the point of confinement of a couple channels whose unforeseen yield probability allotment depends on upon a state technique independent of the channel input and where channel state data (CSI) signs are open both at the transmitter (CSIT) and at the collector (CSIR). At whatever point the channel state and the CSI signs are as one free and unclearly passed on (i.i.d.), the channel reductions to a case considered by Shannon. For this circumstance, we show that when the CSIT is a deterministic limit of the CSIR, perfect coding is particularly essential. Exactly when the state strategy has memory, we give a general point of confinement formula and we give some more restrictive conditions under which the cutoff has still a fundamental single-letter depiction, allowing essential perfect coding. Finally, we swing to the additional substance white Gaussian disturbance (AWGN) channel with obscuring likewise, we give a theory of a couple of results about point of confinement with CSI for this channel. In particular, we show that variable rate coding (or multiplexing of a couple codebooks) is not required as far as possible and, despite when the CSIT is not impeccable, the breaking point achieving power task is of the water filling sort.

K.V.Bindra,S. Sharma and R.Khanna *et al* [36] multiuser various data different yield, scholarly radio (CR) structure has been poor down with transmit receiving wire decision (TAS) at CR base station transmitter and summed up decision merging GSC (Nr, Nc) at each CR customer. Multiuser grouped qualities get is gotten by picking best

CR customer on the preface of prompt post arranged banner to-commotion extent (SNR) at the CR-Rx. The improved typical post arranged SNR and ergodic point of confinement of proposed TAS/GSC system is a component of best picked beneficiary branches. The proposed TAS/GSC structure is constrained by deterrent temperature limit "Q" at basic customer (PU) Rx, which debases general throughput therefore peak control (Pp) of CR base station is set to be not as much as 'Q'. We in like manner gather interpretive expressions for ergodic breaking point and ordinary post arranged SNR. The reenactment result endorses with logical result.

M. Torabi, D. Haccoun and W. Ajib *et al* [37] an execution examination for the customer booking for the multiuser MRC MIMO structures abusing the customer and recieving wire diversities. We consider two planning arranges including preeminent SNR-based booking and standardized SNR-based booking arranges. We propose the use of a radio wire determination plan to overcome the downside of direct solidifying in multiuser MIMO systems and to enhance the structure execution. We determine new closedform expressions for the ordinary piece screw up rate of the displayed plans for two situations: Heterogeneous (free non-identically disseminated SNRs-i.i.d.) and Homogeneous (autonomous indistinguishably circulated SNRs-i.i.d.) cases. Utilizing scientific investigation and numerical reenactments, we break down the displayed plans.

Y. Jing and H. Jafarkhani *et al* [38] beamforming in remote transfer networks with impeccable channel information at the transfers, receiver, and transmitter if there is an immediate connection between the transmitter and recipient. It is expected that each hub in the network has its own energy limitation. A two-step amplify-and-forward protocol is utilized, in which the transmitter and transfers not just utilize coordinate channels to shape a pillar at the beneficiary additionally adaptively change their transmit powers as indicated by the channel quality information. For networks with no immediate connection, a calculation is proposed to systematically locate the correct arrangement with straight (in network estimate) many-sided quality. It is demonstrated that the transmitter ought to dependably utilize its maximal power while the ideal energy of a transfer can take any an incentive in the vicinity of zero and its maxima. Likewise, this esteem relies on upon the nature of every single other channel notwithstanding the hand-off's own. In spite of this coupling actuality, distributive procedures are proposed in which, with the guide of a low-rate collector communicate, a transfer needs just its own particular channel information to actualize the ideal power control. At that point, beamforming in networks with an immediate connection is considered. At the point when the immediate connection exists amid the initial step just, the ideal power control is the same as that of networks with no direct link. For networks with an immediate connection amid the second step just and both steps, recursive numerical calculations are proposed. Recreation demonstrates that network beamforming accomplishes the maximal differing qualities arrange and outflanks other existing plans.

Giuseppe Caire, Sean A. Ramprashad and H. C. Papadopoulos *et al* [39] the downlink throughput of different cell models with multi-receiving wire base stations and numerous single-reception apparatus clients per cell, by considering various inborn physical layer issues, for example, path-misfortune and time and recurrence specific blurring. Specifically, we concentrate on Multiuser MIMO (MU-MIMO) downlink strategies that require channel state information at the transmitter (CSIT). Our examination assesses the cost of CSIT estimation and illuminates the tradeoffs between CSIT, estimation mistake, and framework asset dedicated to preparing. This tradeoff demonstrates that the quantity of receiving wires that can be together coordinated (either on a similar base station or over various base stations) is naturally constrained not simply by "outside variables, for example, many-sided quality and rate of the spine wired system, however by the inalienable time and recurrence fluctuation of the blurring channels. Our investigation, in concurrence with various late simulation comes about, demonstrates that customary MU-MIMO cell structures may beat plans in light of coordinated transmission from base stations (alluded to as Network MIMO plans, NW-MIMO), at the insignificant cost of a couple of additional receiving wires per station. In light of these outcomes, it gives the idea that the natural bottleneck of NW-MIMO frameworks is not the spine arrange (which here is expected perfect with endless limit) however the inherent dimensional limitation of estimating the channels.

J. Fan, Z. Xu, and G. Y. Li *et al* [40] achievable total rates of a multiuser numerous info different yield (MU-MIMO) interface with maximal proportion transmission (MRT) and zero-constraining (ZF) precoders for downlink cell circumstances. We use Gamma movement to construe tight lower and maximum cutoff points of the achievable aggregate rates. From the logical results, the whole rates of the MRT and ZF precoders are extended with the amount of the transmit gathering devices and transmit control, and there exists a perfect number of served customers for the most hoisted achievable aggregate rates while using the ZF precoder.

J. Mao, J. Gao, Y. Liu and G. Xie *et al* [41] the outstanding semiorthogonal user selection (SUS) calculation for the multi-user numerous information different yield (MU-MIMO) framework with zeroforcing beamforming (ZFBF). Contrasted and the first SUS calculation, the proposed user selection calculation accomplishes a similar execution, however with essentially less multifaceted nature. Recreation comes about demonstrate that the proposed calculation can make a decent tradeoff amongst execution and many-sided quality for the MUMIMO framework with ZFBF.

CHAPTER 3

SCHEDULED USERS WITH SUS AND TWO-STAGE FEEDBACK COMBINED

The multi-antenna broadcast (BC) channel in a MU-MIMO system is considered with K users. The base station (BS) consists N_t transmit antennas and each user has N_r number of receive antennas with the assumption that $K \times N_r >> N_t$. The complex base-band received signal is represented as

$$\mathbf{y}_k = \mathbf{H}_k \mathbf{x} + \mathbf{n}_k$$

where $\mathbf{H}_k$ is the N_r x N_t channel matrix of kth user, **x** is the transmitted signal vector of size N_t x 1 and n_k is the complex Gaussian noise component for the k^{th} user. Individual components h_{ij} of the channel matrix **H** are assumed to Rayleigh fading coefficients, i.e. they are complex Gaussian random variable with zero mean and unit variance ~ CN(0,1).The assumption is taken that the channel information is known to each user. In case of multiple receiver antennas, each user has spatial data stream. We assume a equal power allocation mechanism, i.e each selected user is allocated a power of P/N_t where P is the total transmit power. In practical cellular systems where $K>>N_t$, this restriction is through empirical observation under ideal CSIT, limiting the feedback per user provides justification for the restriction done.

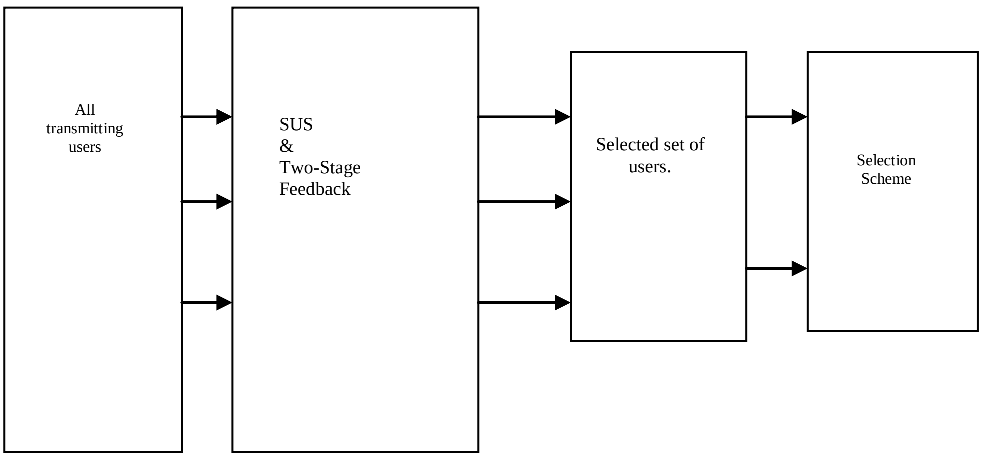

Figure 3.1: Block Diagram for the proposed system

The base station (BS) serves a particular set of users i.e S ϵ_{1,2…….K}. This set of users is selected using the zero-forcing beam-forming (ZFBF) with semi-orthogonal user selection (SUS) combined with two-stage feedback which attains both the multiplexing and multi-diversity gains. The channel directional information (CDI) is also combined with this scheme. Because of limited degrees of freedom, the numbers of users are restricted $S \leq N_t$. The limited feedback ZFBF-SUS system needs both CQI (Channel Quality Information) and CDI to attain the sum capacity growth rate for perfect CSIT. The scheme was deployed for different feedback bits and the performance was monitored. An optimum threshold was used so as to minimize the intermediate feedback load. This threshold is considered as a function of number of transmit antennas, number of users, the number of quantization size, and the orthogonality criterion in the second stage. With this the feedback load is reduced significantly without hampering the performance of the ZFBF-SUS algorithm. Combined

3.1 Scheduling and User Selection

3.1.1 Combined Scheduled Two-stage Feedback

Before deploying the SUS algorithm for all the users we need to calculate the expected SINR value. For the CQI feedback, the expected SINR is:-

$$\gamma_k = \frac{\rho \left| \mathbf{u}_k \mathbf{H}_k \hat{\mathbf{v}}_k \right|^2}{1 + \rho \left\| \mathbf{u}_k^H \mathbf{H}_k - (\mathbf{u}_k^H \mathbf{H}_k \hat{v}_k) \hat{v}_k^H \right\|^2} \tag{1}$$

with ρ=P/Nt.

where $\mathbf{u}_k = (I + \mathbf{B}_k)^{-1} \sqrt{\rho} \mathbf{H}_k \mathbf{c}_i$; where $\mathbf{u}_k$ represents N dimensional unit norm vector and $\mathbf{c}_i$ represents the codebook of the system.

$$\mathbf{A}_k = \rho (\mathbf{H}_k \mathbf{c}_i \mathbf{c}_i^H) \mathbf{H}_k^H ; \tag{2}$$

$$\mathbf{B}_k = \rho [\mathbf{H}_k (I - \mathbf{c}_i \mathbf{c}_i^H) \mathbf{H}_k^H] . \tag{3}$$

The CQI is expected using the Maximum expected SINR combiner (MESC).

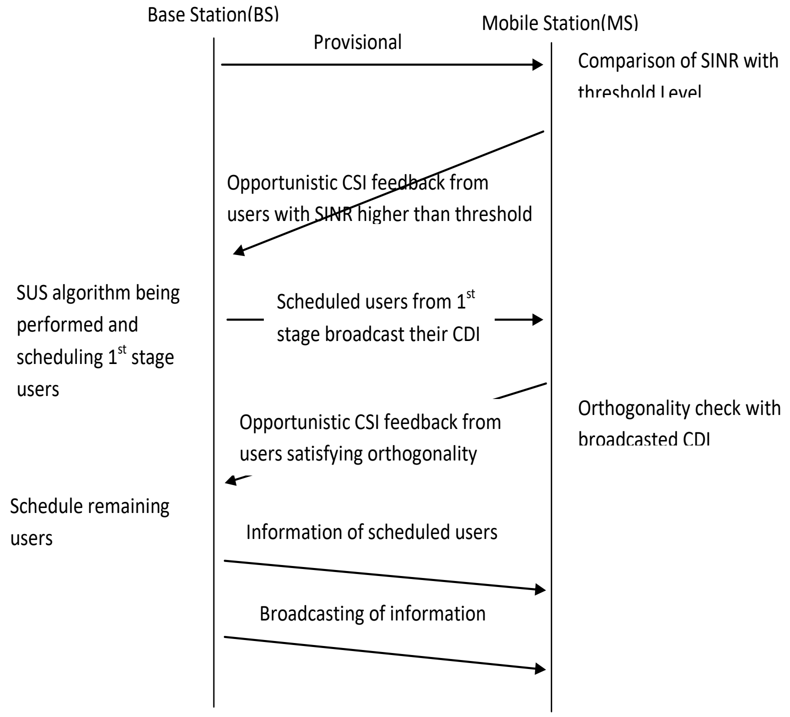

Figure 3.2 Proposed scheme timing diagram

3.1.2 SUS Algorithm

For selection of the adequate number of users, the BS executes the SUS Algorithm is performed as follows:-

Step 1) Initialize U_o with the index of all the users

U_o=[1,2…….k] .

Step 2) A user is selected on the basis of the given condition

$$\phi(i) = \arg\max_{k \in k_{i-1}} \gamma_k \tag{4}$$

The set of users satisfying this condition are collected.

Step 3) The remaining user-set is updated which satisfy

$$U_i = \{ j \in k_{i-1} : \left| \hat{\mathbf{v}}_k^H \hat{\mathbf{v}}_{\phi(i)} \right| \leq \in \} \tag{5}$$

Step 4) Repetition of 2) and 3) is done until the user reaches N_t .Considering U_i should not be an empty matrix.

The selected users are quantized using he quantization vectors, in S = {ϕ(1),ϕ(2)………..ϕ(M)}; where $M \leq N_t$ and the ZFBF vectors as:-

$$\hat{\mathbf{H}} = [\hat{h}_{\phi(1)}\hat{h}_{\phi(2)}.............\hat{h}_{\phi(M)}]$$

$$W(s) = \hat{\mathbf{H}}(\hat{\mathbf{H}}^H\mathbf{H})^{-1} \quad (6)$$

On normalizing W(s), the beam forming vector $\hat{W}_k$ is obtained for k € S. The selected users from the SUS algorithm are the appropriate users which will be used for the ZFBF-based transmission having low complications from steps 2) and 3). Since all the users are not appropriate for the ZFBF, the unwanted users are excluded from the SUS algorithm. K feedback bits are required for CDI for a perfect CQI. The procedure has disadvantages as it consumes important resources such as bandwidth, time and transmission energy as we increase the number of users i.e K. For reduction in the transmission load and the computational load, we exclude users before the feedback and scheduling process. The feedback strategy is proposed so as to avoid the unwanted ZFBF transmission, of the users from reporting the CDI and CQI. The users using approximate SINR γ_k and orthogonality are the ones selected for the ZFBF transmission. For this we use both the CQI and CDI for the feedback considers the feedback. The two stage feedback considers the feedback from SINR during the 1st stage and orthogonality criterion at the 2nd stage.

3.1.3 Two-stage feeback system

Stage 1: SUS combined with SINR-based appropriate feedback

The exploitation of the SINR feedback is done, to reduce the overhead feedback. Each user transmits its CQI and CDI and the CQI value γ_k is compared to the threshold value. Comparison is done by each user, it compares the SINR value i.e. γ_k with γ_t and decides the transmission of the CSI (CQI and CDI) or not. From this, the selected users are collected as:-

$$\mathbf{M}_1 = \{k \in K : \gamma_k > \gamma_t\} \quad (7)$$

Where k={1,2………K} .

On reception of selected users in M_1, the SUS is partially performed on these by the selected users. ϕ(1), ϕ(2)……….ϕ() using the steps of SUS algorithm. The initialization of the SUS algorithm is swiped from U_o to M_1. If in case =N_t, the BS skips the second stage and jumps to the downlink. Else the numbers of selected users are sent to the feedback stage for further processing.

Stage 2: SUS combined with orthogonality criterion

To diminish the complexness of user selection, the orthogonality criterion is implemented on the user. Step 3) of SUS algorithm is used to exploit the orthogonality criterion in second stage. The non orthogonal users are eliminated in this stage. The orthogonality is calculated between the quantization vector and the broadcast codeword vectors, the users satisfying this condition transmit their CSI. Using the above criterion, the selected users are collected as:

$$\mathbf{M}_2 = \{k \in K - \mathbf{M}_1 : \left|\hat{h}_k^H \hat{h}_{\phi(j)}\right| \leq \in, 1 \leq \forall j \leq N_s^1\} \tag{8}$$

If N_s^1=0; all users transmit their CSI. Also, we can minimize the number of feedback bits. Codebook indices for both BS and the users are known; thus the codebooks do not satisfy this orthogonality criterion is eliminated. Thus now the codebook is reduced to:-

$$C_2 = \{\mathbf{c} \in \mathbf{C} : \left|\mathbf{c}^H \hat{\mathbf{h}}_{\phi(j)}\right| \leq \in, 1 \leq \forall j \leq N_s^1\} \tag{9}$$

C_2 is known to the BS and selected users of stage 2 i.e. M_2 can quantize CDI with reduced codebook C_2 and feedback quantization index.

On performing the SUS algorithm partially the set of selected user S={ϕ(1),ϕ(2)…………….ϕ(M)}. Now the BS constructs the ZFBF vectors and the broadcasting is done. Since the two-stages are related as ⌈M_2⌈ is subset of ⌈M_1⌈ as it depends on the selected users in stage 1).

3.2 Performance Analysis Using Theory of Order of Statistics

Using the pdf (probability density function) and the cdf (cumulative density function) respectively for the best codeword is given in (10) and (11). For deploying the SUS algorithm with the two-stage feedback, the expected SINR value is calculated for all users. The users with orthogonal CDI are selected at the transmitter and the effective MESC for the kth user is considered. The pdf (probability density function) and the cdf (cumulative density function) respectively for the best codeword is

$$f_{\gamma_k}(z) = \binom{N_t - 1}{N_r - 1} 2^B e^{-z/\rho}(-1/\rho) + \binom{N_t - 1}{N_r - 1} 2^B e^{(=z/\rho)}(1+z)^{N_t - N_r - 2} \tag{10}$$

$$F_{\gamma_k}(z) = 1 - \frac{\binom{N_t - 1}{N_r - 1} 2^B e^{(-z/\rho)}}{(1+z)^{N_t - N_r}} \quad (11)$$

Where B represents the number of feedback bits and $\rho = P/N_t$, P=power transmitted**.**

The given steps need to be followed for finding the best transmitting antenna and best user from the pdf and cdf of the best codeword:

Step 1: From the cdf of the best code word, the pdf is calculated by integrating.

Step 2: Using the pdf, the best transmitting antenna is selected using the theory of order of statistics stated in 3.1.4 The pdf and cdf of the best transmitting antenna can be found out.

Step 3: From the pdf and cdf of the best transmitting antenna, the best user is selected using the theory of order of statistics stated in 3.1.5.

Step 4: Using the pdf of the best user, the BER can be found out as in 3.2.

Step 5: Using the pdf and cdfof the best user, the capacity of the system can also be calculated by finding the first and the second moment of the system as in 3.3.

The above steps are implemented as follows:

3.2.1 Best transmitting antenna

In order to select best transmitting antenna, by using the theory of order statistics, the pdf and cdf of best transmitting antenna is

$$f_{\gamma bt,t}(\gamma) = L f_{\gamma_k}(z)[F_{\gamma_k}(z)]^{L-1} \quad (12)$$

$$F_{\gamma bt,t}(\gamma) = [F_{\gamma_k}(z)]^{L} \quad (13)$$

Substituting the values of (10) and (11) in (12) and (13); the cdf and the pdf for the best transmitting antenna obtained are:

$$F_{\gamma bt,t}(z) = \left[1 - \frac{\binom{N_t - 1}{N_r - 1} 2^B e^{(-z/\rho)}}{(1+z)^{N_t - N_r}} \right]^L \quad (14)$$

$$f_{\gamma bt,t}(z) = L\left[\binom{N_t - 1}{N_r - 1} 2^B e^{-z/\rho}(-1/\rho) + \binom{N_t - 1}{N_r - 1} 2^B e^{(=z/\rho)}(1+z)^{N_t - N_r - 2} \right] \left[1 - \frac{\binom{N_t - 1}{N_r - 1} 2^B e^{(-z/\rho)}}{(1+z)^{N_t - N_r}} \right]^{L-1} \quad (15)$$

Where L is the number of users in the multi-user system.

3.2.2 Best user selection

The best user from the best transmitting antenna can be found again by using the theory of order statics

$$F_{\gamma bu,u}(z) = [F_{\gamma bt,t}]^k \quad (16)$$

$$f_{\gamma bu,u}(z) = k f_{\gamma bt,t}(z)[F_{\gamma bt,t}(z)]^{k-1} \quad (17)$$

On substituting the substituting the values of (14) and (15) in (16) and (17), the equations for best user are as follows:

$$F_{\gamma bu,u}(z) = \left[1 - \frac{\binom{N_t - 1}{N_r - 1} 2^B e^{(-z/\rho)}}{(1+z)^{N_t - N_r}} \right]^{LXk} \quad (18)$$

$$f_{\gamma bu,u}(z) = kL\left[\binom{N_t - 1}{N_r - 1} 2^B e^{-z/\rho}(-1/\rho) + \binom{N_t - 1}{N_r - 1} 2^B e^{(=z/\rho)}(1+z)^{N_t - N_r - 2} \right] \left[1 - \frac{\binom{N_t - 1}{N_r - 1} 2^B e^{(-z/\rho)}}{(1+z)^{N_t - N_r}} \right]^{L-1} \left(\left[1 - \frac{\binom{N_t - 1}{N_r - 1} 2^B e^{(-z/\rho)}}{(1+z)^{N_t - N_r}} \right]^{L} \right)^{k-1} \quad (19)$$

3.3 Bit Error Rate (BER)

The average bit error rate is used for accessing telecomm, radio and network systems which transmit data from one location to another. The general expression for BER is as follows:

$$P_e = \frac{1}{2} \int_0^{\infty} erfc\left(\sqrt{z}\right)\ f_{\gamma_{bu,u}}(z)\, dz \tag{20}$$

It qualifies the channel carrying data by counting the number of errors present in the data string. The factors affecting BER are transmit power, interference, modulation and bandwidth of the signal. This identifies the performance of system which is directly proportional to operational performance. Using the pdf for the best user the bit error rate is as follows:

$$P_e = \frac{1}{2} \times k \times L \int_0^{\infty} erfc(\sqrt{z}) \left[\binom{N_t - 1}{N_r - 1} 2^B e^{-z/\rho} (-1/\rho) + \binom{N_t - 1}{N_r - 1} 2^B e^{(=z/\rho)} (1+z)^{N_t - N_r - 2} \right]$$
$$\left[1 - \frac{\binom{N_t - 1}{N_r - 1} 2^B e^{(-z/\rho)}}{(1+z)^{N_t - N_r}} \right]^{L-1} \left(\left[1 - \frac{\binom{N_t - 1}{N_r - 1} 2^B e^{(-z/\rho)}}{(1+z)^{N_t - N_r}} \right]^{L} \right)^{k-1} dz \tag{22}$$

3.4 Ergodic Capacity

Maximum mutual information averaged over all channel states is known as Ergodic Capacity. This can be achieved by varying the transmit power. To derive the expression for capacity we need to find out the first moment, therefore

$$E\left\{ f_{\gamma bu,u} \right\} = \int_0^{\infty} \gamma f_{\gamma bu,u}(\gamma) d\gamma \tag{23}$$

where E{.} is an expectation operator and the value of $f_{\gamma bu,u}$ .The above evaluation is evaluated using Wolfram Mathematica. The ergodic capacity $C_{\gamma bu,u}$ of the system model is determined by averaging the instantaneous capacity over all possible channels

$$C_{\gamma bu,u} \cong \log_2(1 + \gamma E\{ f_{\gamma\, bu,u} \}) - \frac{\gamma^2 (\sigma_{\gamma bu,u})^2}{2(1 + \gamma E\{ f_{\gamma bu,u} \})^2} \tag{24}$$

Where σ^2 is variance.

Our prime focus is to reduce the feedback load, for this we analyze the average number of feedback bits. Analyzing the performance for B=4 and 8 when N_t=4 and N_r=4 and also with N_t=4 and N_r=1 was done. This system can be implemented by changing the values of N_t and N_r also. Primarily the SUS algorithm was implemented solely and the results were recorded. Then further the two-stage feedback scheduling was combined with the SUS algorithm and the results were recorded.

4.1 Implementation of the SUS algorithm

The comparison of the results for the feedback bits 4 and 8 when the SUS algorithm was implemented for N_t=4 and N_r=1 is as follows:-

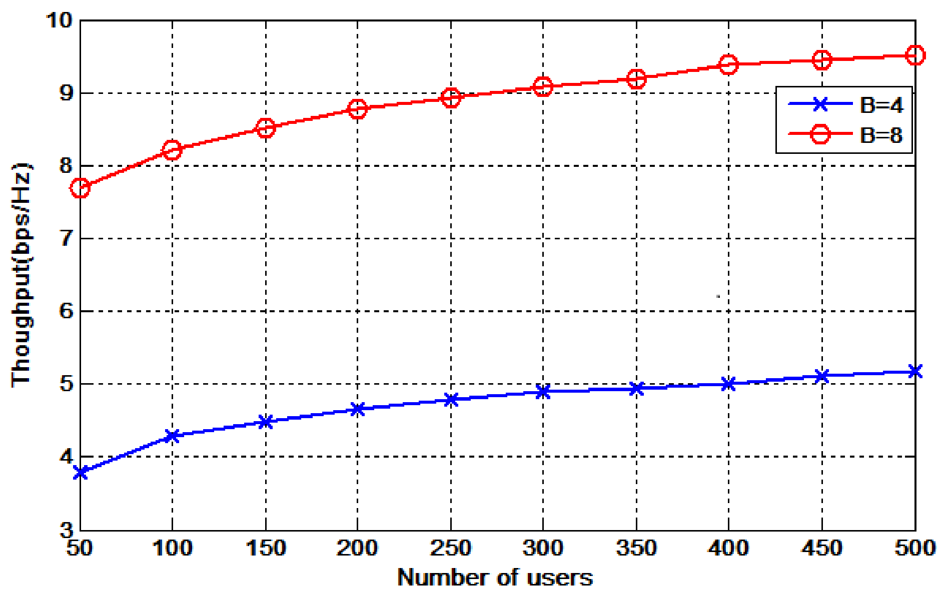

Figure 4.1: Comparison of achieved throughput for B=4 and B=8 with Nt=4 and Nr=1 using SUS user selection algorithm.

The comparison of the results for the feedback bits 4 and 8 when the SUS algorithm was implemented for N_t=4 and N_r=4 is as follows:-

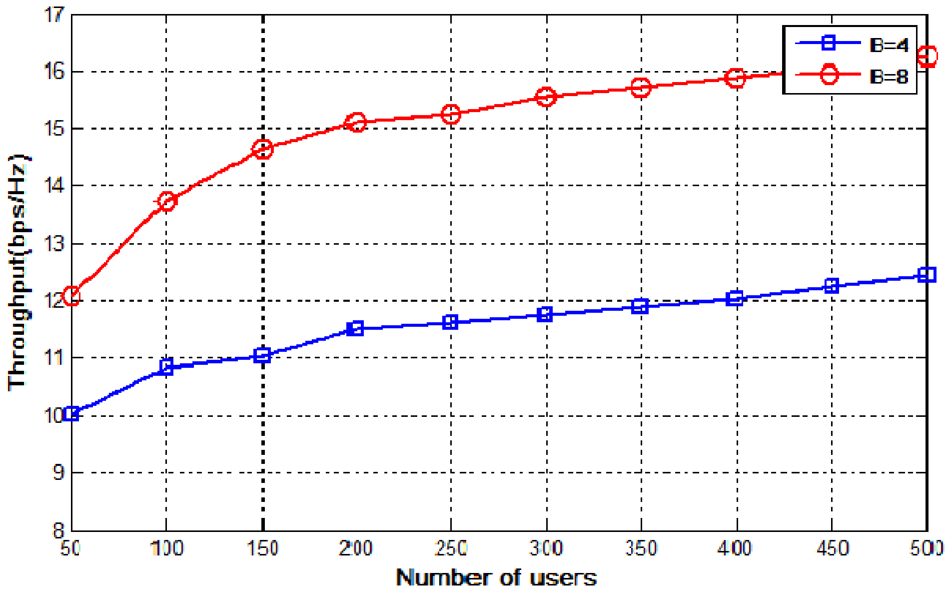

Figure 4.2 Comparison of achieved throughput for B=4 and B=8 with Nt=4 and Nr=4 using SUS user selection algorithm.

The comparison of results when the SUS algorithm was combined with the two-stage feedback was implemented for feedback bits 4 and 8 for N_t=4 and N_r=1 is as follows:-

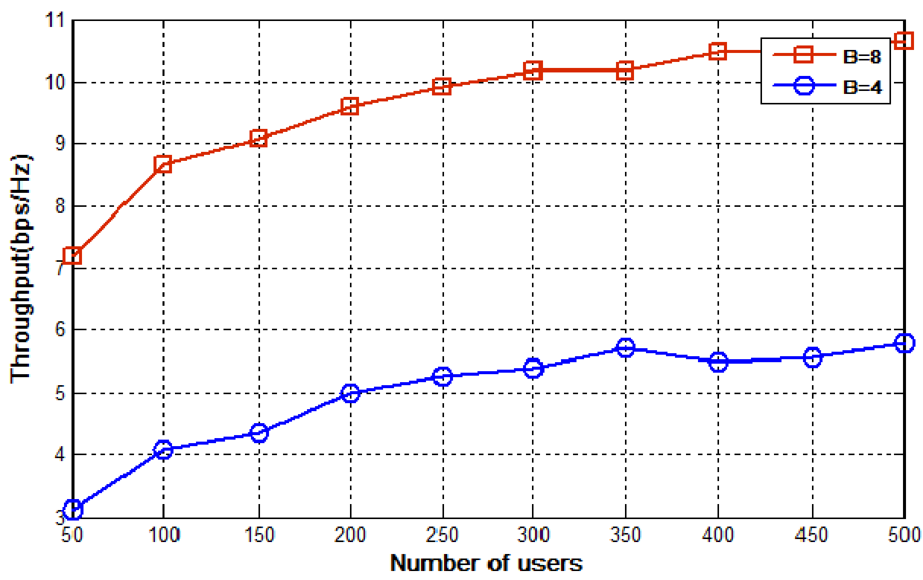

Figure 4.3 Comparison of achieved throughput for B=4 and B=8 with Nt=4 and Nr=1 using SUS user selection algorithm combined with two-stage feedback.

4.2 Implementation of SUS and two-stage feedback combined

The comparison of results when the SUS algorithm was combined with the two-stage feedback was implemented for feedback bits 4 and 8 for N_t=4 and N_r=4 is as follows:-

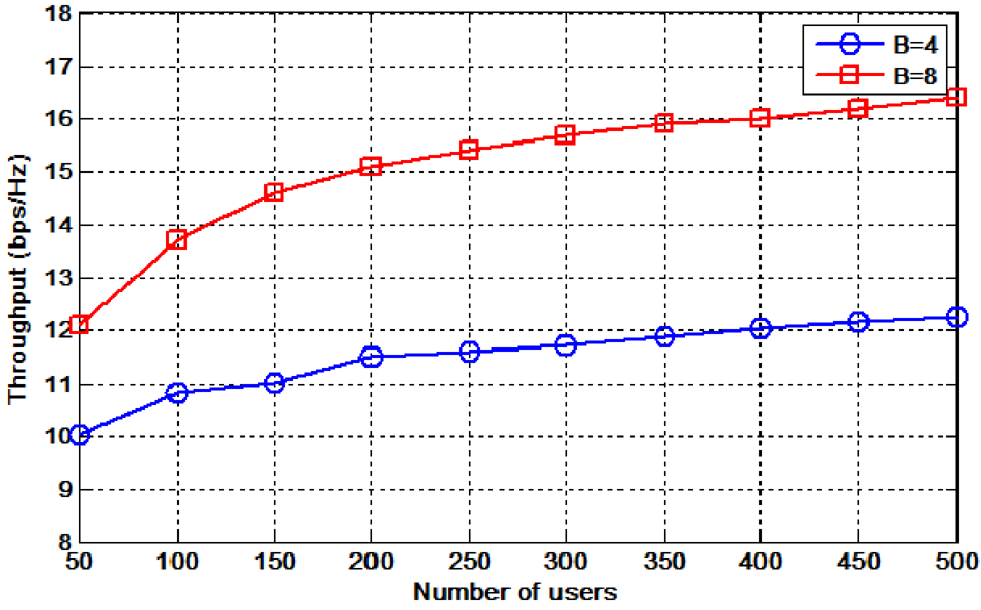

Figure 4.4 Comparison of achieved throughput for B=4 and B=8 with Nt=4 and Nr=4 using SUS user selection algorithm combined with two-stage feedback.

When we compare the results of SUS user selection algorithm and the two-stage feedback then, we come up to a conclusion that the feedback bit 8 has better results when compared with 4 feedback bits. This is due to the fact that when we increase the number of quanization bits then the quantization error is reduced. Similarly, if we implement it for 12 feedback bits then the results will be much better as compared to 8 feedback bits.

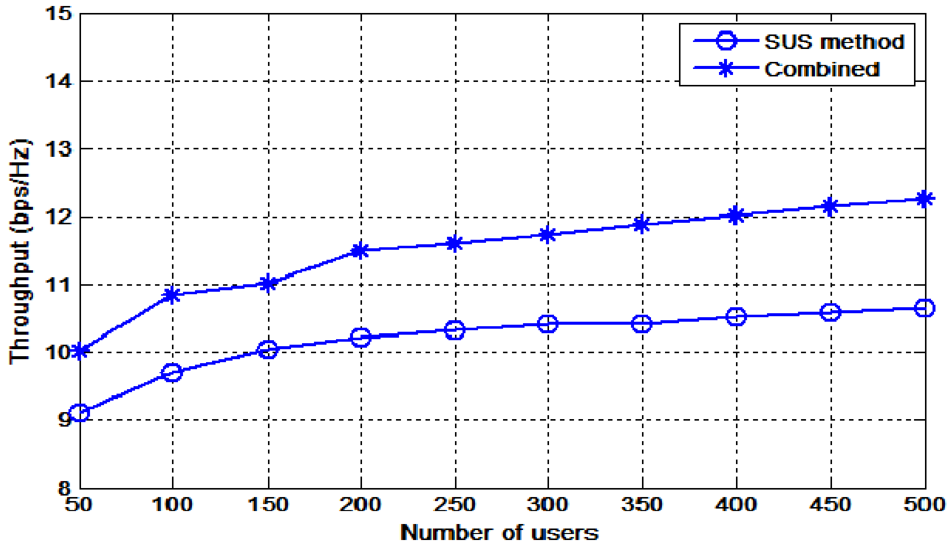

Figure 4.5 Comparison of results for B=4, when SUS user selection algorithm was implemented and when SUS was combined with two-stage feedback system where Nt=4 and Nr=4.

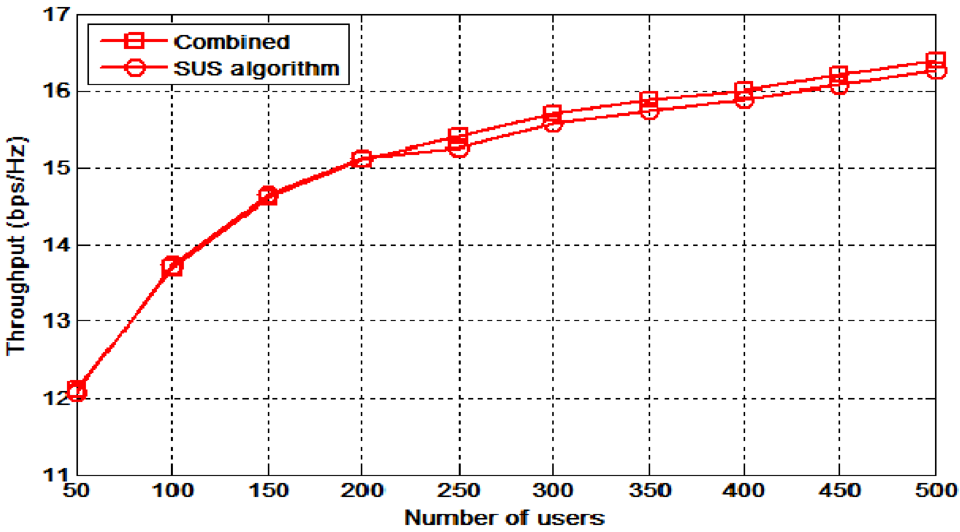

Figure 4.6 Comparison of results for B=8, when SUS user selection algorithm was implemented and when SUS was combined with two-stage feedback system where Nt=4 and Nr=4.

The analysis of the derived results has been validated using monte carlo simulations for varying number of transmit and receive antennas. It is also observed that by changing the number of feedback bits, the system performs better. Results obtained with varying the number of feedback bits from B=2 ,4 and 8 are shown in Figure 4.7-4.12.

4.3 Bit Error Rate for varying transmit and receive antennas

Case 1: When N_t=2 and N_r=2

From the Figure 4.7 it is evident that the BER increases with a symbolic increase in the number of feedback bits. When the numbers of feedback bits are less i.e 2 and 4 then the difference between the error rate is less.

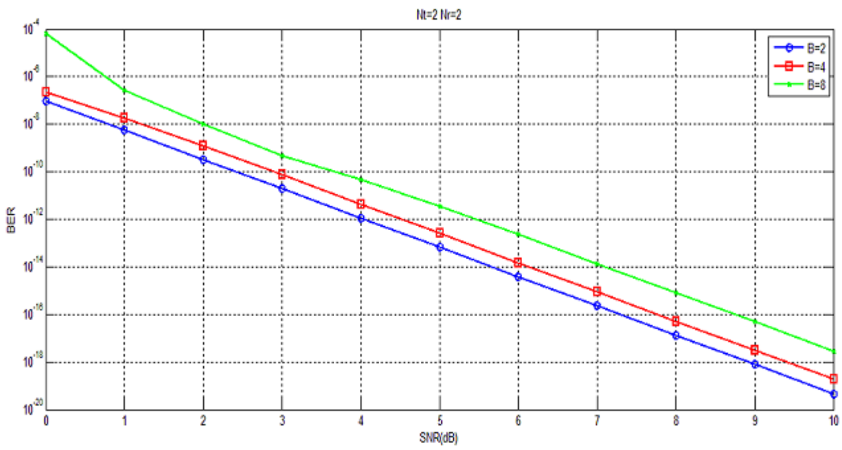

Figure 4.7 BER for N_t=2 and N_r=2 are constant and changing number of feedback bits.

Case 2: When N_t=4 and N_r=2

From the Figure 4.8 it is evident, the BER increases with a symbolic increase in the number of feedback bits from 2 to 8. With the increase in number of antennas it can be seen that the error rate decreases for increasing SNR values.

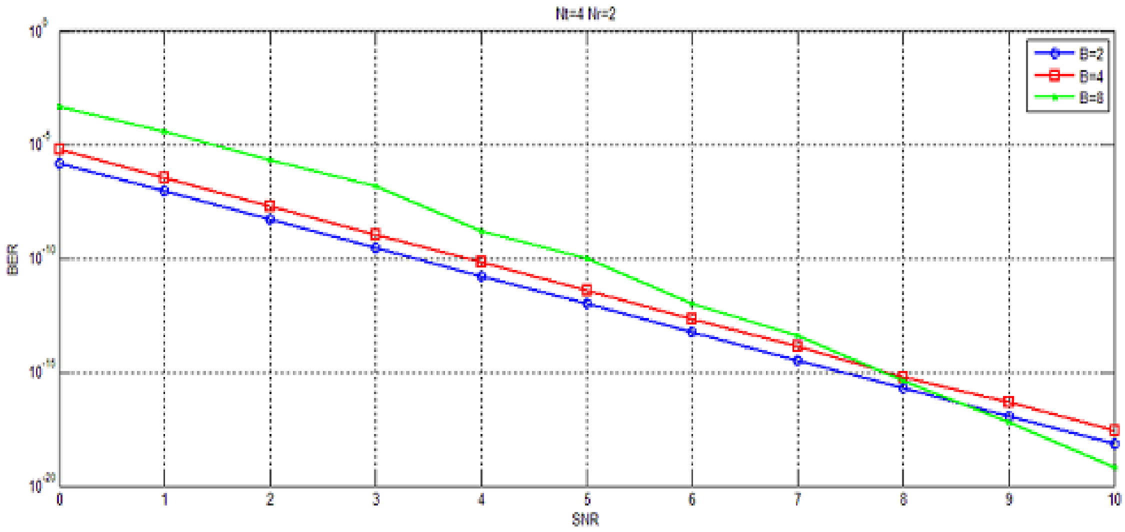

Figure 4.8 BER for N_t=4 and N_r=2 are constant and changing number of feedback bits.

Case 3: When N_t=4 and N_r=4

From Figure 4.9, it is clearly seen that the error rate is less for less number of feedback bits. With the increase in number of antennas the error rate decreases for less number of feedback bits. This helps in increasing the efficiency of the system.

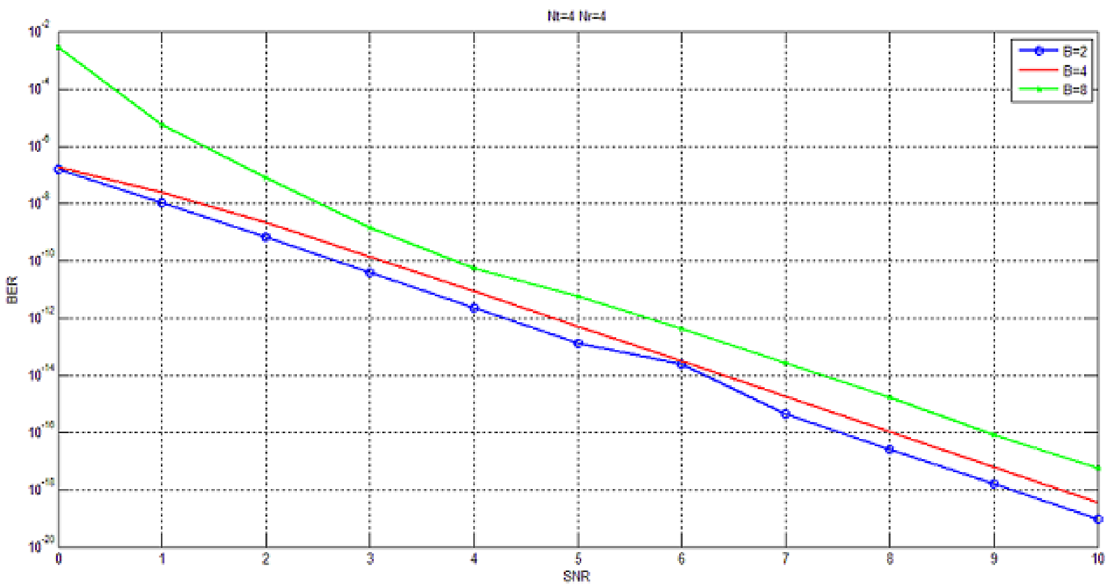

Figure 4.9: BER for N_t=4 and N_r=4 are constant and changing number of feedback bits.

4.4 Ergodic capacity for varying transmit and receive antennas

Case 1 when N_t=2 and N_r=2

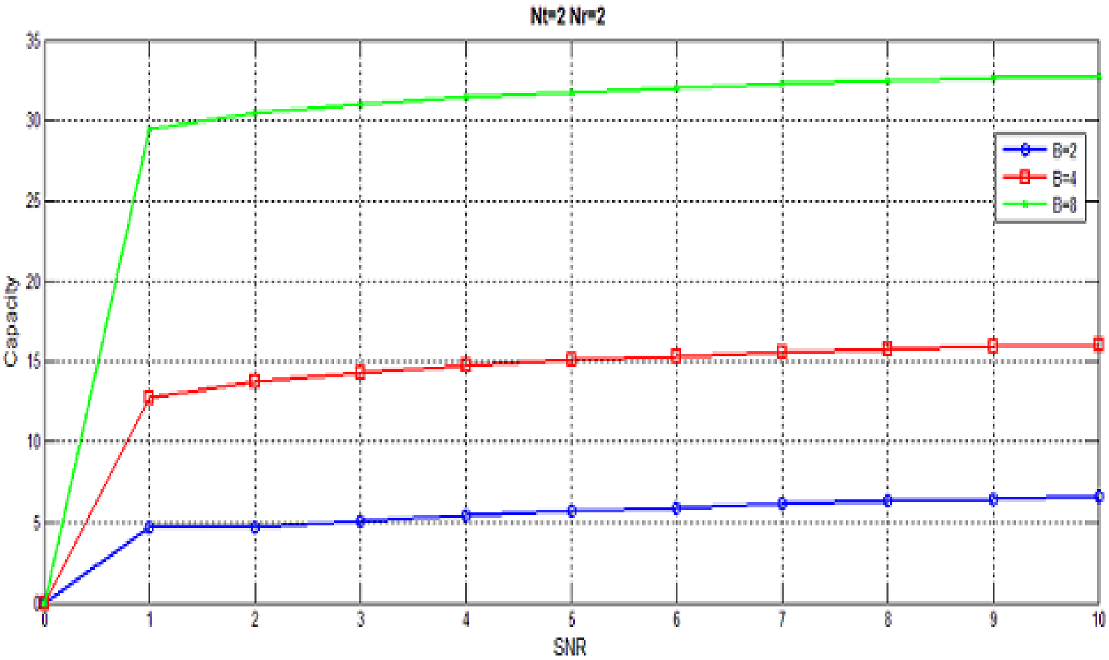

Figure 4.10: Ergodic Capacity of Multiuser MIMO system with feedback for N_t =N_r=2 and changing number of feedback bits.

The Figure 4.10 shows us varying capacity for varying feedback bits when the numbers of transmitting and receiving antennas are 2. From the Table 4.1 it is clearly evident that there is a significant increase in the capacity of the system from 6.61741 for B=2 to 32.7952 for B=8.

Table 4.1: When N_t=2 and N_r=2 are fixed and the number of feedback bits are changing from 2 to 8.

N_t (Transmitting Antennas)	N_r (Receiving Antennas)	B (Number of feedback bits)	Capacity
2	2	2	6.61741
2	2	4	16.0833
2	2	8	32.7952

Case 2: When N_t=4 and N_r=2

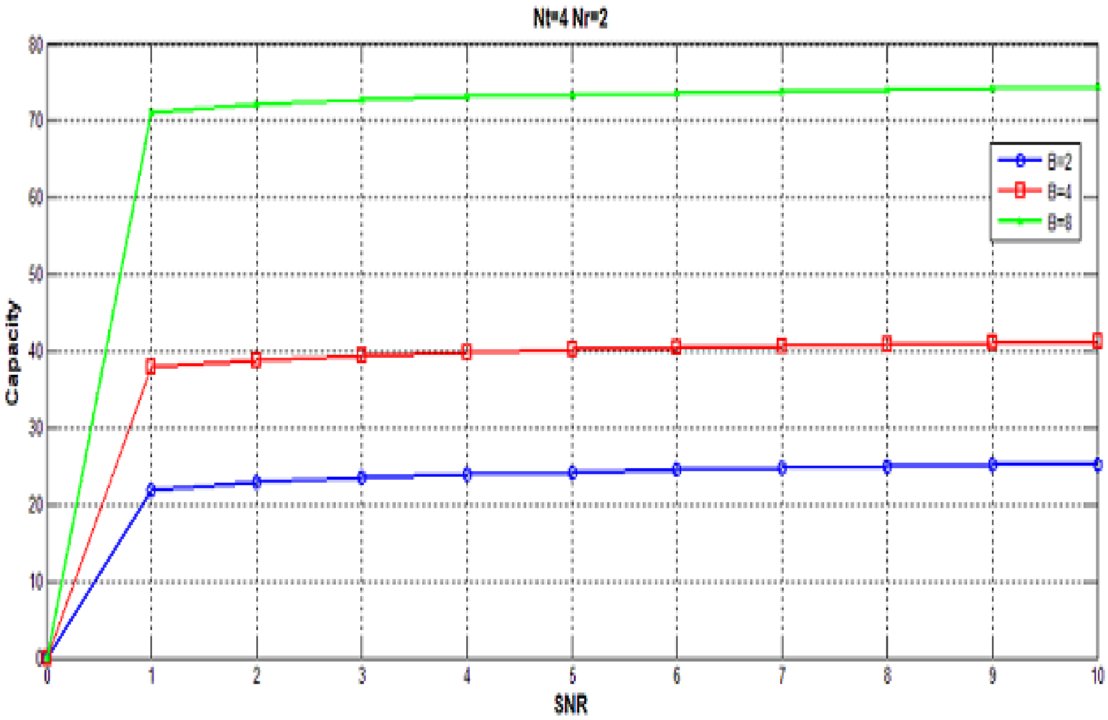

Figure 4.11: Ergodic Capacity of Multiuser MIMO system with feedback for N_t =4 and N_r=2 and changing number of feedback bits.

The Figure 4.11 shows varying capacity for varying feedback bits when there are 4 transmitting antennas and 2 receiving antennas. From the Table 4.2 is clearly evident that there is a significant increase from 25.225 for B=2 to 74.4320 for B=8.

Table 4.2: When N_t=4 and N_r=2 are fixed and the number of feedback bits are changing from 2 to 8.

N_t (Transmitting Antennas)	N_r (Receiving Antennas)	B (Number of feedback bits)	Capacity
4	2	2	25.2225
4	2	4	41.1504
4	2	8	74.4320

Case 3: When N_t=4 and N_r=4

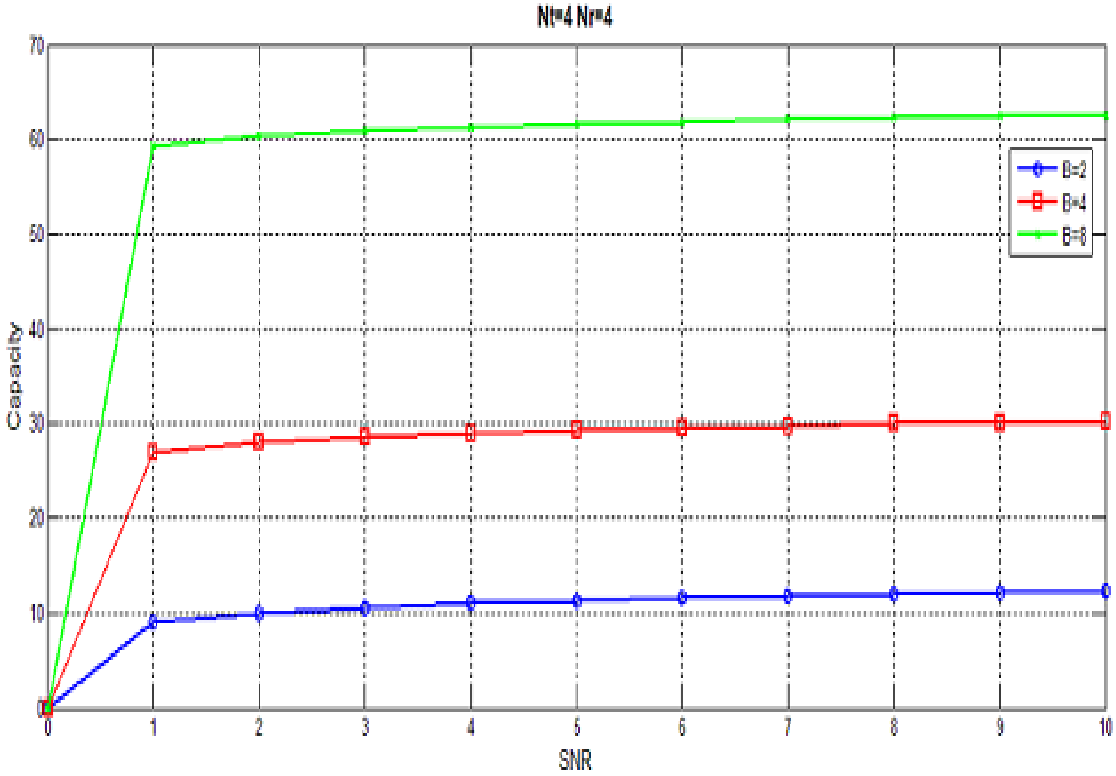

Figure 4.12: Ergodic Capacity of Multiuser MIMO system with feedback for N_t =4 and N_r=4 and changing number of feedback bits**.**

The Figure 4.12 shows variable capacity for variable feedback bits for 4 transmitting antennas and 4 receiving antennas. From the table we can interpret that the capacity has increased from 12.3273 for B=2 to 62.6618 for B=8.

Table 4.3: When N_t=4 and N_r=4 are fixed and the number of feedback bits are changing from 2 to 8.

N_t (Transmitting Antennas)	N_r (Receiving Antennas)	B (Number of feedback bits)	Capacity
4	4	2	12.3273
4	4	4	30.2982
4	4	8	62.6618

Chapter 5
CONCLUSION

The proposed MU-MIMO scheduling scheme allows that the SUS user selection method is a better method to achieve the required throughput. In case of SUS user selection method we use the entire feedback and then the algorithm is performed on it. But this is not in case of the two-stage feedback system. In the two-stage feedback system the reduction in feedback bits lead to a significant reduction in the information at the transmitter. This lesser information at the transmitter side helps in simulating the things in faster and a better way. When the two schemes are combined the system performance is better since the feedback load is reduced in this case. The BER and the capacity of the system have been analytically analyzed using the pdf and the cdf of the best codeword. This is mainly done keeping in mind the number of feedback bits. The increase in number of feedback bits when increase lead to a significant increase in the capacity of the system, which is needed for the increasing number of users in the present time. This scenario leads to the evident need of MU-MIMO system to be implemented as the number of users in the radio spectrum is increasing day-by-day.

REFERENCES

[1] Gesbert, D., Kountouris, M., Heath Jr, R.W., Chae, C.B. and Salzer, T., 2007. Shifting the MIMO paradigm. *IEEE signal processing magazine*, *24*(5), pp.36-46.

[2] Fuchs, M., Del Galdo, G. and Haardt, M., 2007. Low-complexity space–time–frequency scheduling for MIMO systems with SDMA. *IEEE Transactions on Vehicular Technology*, *56*(5), pp.2775-2784.

[3] Wang, B.H., Hui, H.T. and Leong, M.S., 2010. Global and fast receiver antenna selection for MIMO systems. *IEEE Transactions on Communications*, *58*(9), pp.2505-2510.

[4] Daum, F. and Huang, J., 2008, October. MIMO radar: Snake oil or good idea?. In *Signals, Systems and Computers, 2008 42nd Asilomar Conference on* (pp. 183-187). IEEE.

[5] Gesbert, D., Shafi, M., Shiu, D.S., Smith, P.J. and Naguib, A., 2003. From theory to practice: An overview of MIMO space-time coded wireless systems. *IEEE Journal on selected areas in Communications*, *21*(3), pp.281-302.

[6] Ngo, H.Q., Larsson, E.G. and Marzetta, T.L., 2013. The multicell multiuser MIMO uplink with very large antenna arrays and a finite-dimensional channel. *IEEE Transactions on Communications*, *61*(6), pp.2350-2361.

[7] Spencer, Q.H., Peel, C.B., Swindlehurst, A.L. and Haardt, M., 2004. An introduction to the multi-user MIMO downlink. *IEEE communications Magazine*, *42*(10), pp.60-67.

[8] Vu, M. and Paulraj, A., 2007. On the capacity of MIMO wireless channels with dynamic CSIT. *IEEE Journal on Selected Areas in Communications*, *25*(7).

[9] Vaisey, J. and Gersho, A., 1988, April. Simulated annealing and codebook design. In *Acoustics, Speech, and Signal Processing, 1988. ICASSP-88., 1988 International Conference on* (pp. 1176-1179). IEEE.

[10] Hassel, V., Gesbert, D., Alouini, M.S. and Oien, G.E., 2007. A threshold-based channel state feedback algorithm for modern cellular systems. *IEEE Transactions on Wireless Communications*, *6*(7), p.2422.

[11] Min, M., Jeon, Y.S. and Im, G.H., 2016. On Achievable Rate of User Selection for MIMO Broadcast Channels With Limited Feedback. *IEEE Transactions on Communications*.

[12] Lin, P.H. and Tsai, S.H., 2012. Performance analysis and algorithm designs for transmit antenna selection in linearly precoded multiuser MIMO systems. *IEEE transactions on Vehicular Technology*, *61*(4), pp.1698-1708.

[13] Torabi, M., Haccoun, D. and Ajib, W., 2009, November. BER performance analysis of multiuser diversity with antenna selection in MRC MIMO systems.

In *Global Telecommunications Conference, 2009. GLOBECOM 2009. IEEE* (pp. 1-6). IEEE.

[14] Murthy, C.R. and Rao, B.D., 2007. Quantization methods for equal gain transmission with finite rate feedback. *IEEE transactions on signal processing*, *55*(1), pp.233-245.

[15] Sharif, M. and Hassibi, B., 2007. A comparison of time-sharing, DPC, and beamforming for MIMO broadcast channels with many users. *IEEE Transactions on Communications*, *55*(1), pp.11-15.

[16] Tajvidy, A. and Ghorbani, A., 2015, September. MISO uniform theory of diffraction based channel model for mobile wireless communications in urban areas. In *Antennas and Propagation in Wireless Communications (APWC), 2015 IEEE-APS Topical Conference on* (pp. 795-798). IEEE.

[17] Paulraj, A.J., Gore, D.A., Nabar, R.U. and Bolcskei, H., 2004. An overview of MIMO communications-a key to gigabit wireless. *Proceedings of the IEEE*, *92*(2), pp.198-218.

[18] Saaifan, K.A. and Henkel, W., 2012, December. A receiver design for MIMO systems over rayleigh fading channels with correlated impulse noise. In *Global Communications Conference (GLOBECOM), 2012 IEEE* (pp. 2481-2486). IEEE.

[19] Chang, C.H. and Lee, Y., 2009, December. Opportunistic beamforming systems with diversity combining. In *Information, Communications and Signal Processing, 2009. ICICS 2009. 7th International Conference on* (pp. 1-5). IEEE.

[20] Spencer, Q.H., Swindlehurst, A.L. and Haardt, M., 2004. Zero-forcing methods for downlink spatial multiplexing in multiuser MIMO channels. *IEEE Transactions on Signal Processing*, *52*(2), pp.461-471.

[21] Bala, E., Pan, K.J.L., Olesen, R. and Grieco, D., 2008, September. Zero-forcing beamforming codebook design for MU-MIMO OFDM systems. In *Vehicular Technology Conference, 2008. VTC 2008-Fall. IEEE 68th* (pp. 1-5). IEEE.

[22] Min, M., Kim, D., Kim, H.M. and Im, G.H., 2013. Opportunistic two-stage feedback and scheduling for MIMO downlink systems. *IEEE Transactions on Communications*, *61*(1), pp.312-324.

[23] Trivellato, M., Boccardi, F. and Huang, H., 2008. On transceiver design and channel quantization for downlink multiuser MIMO systems with limited feedback. *IEEE Journal on Selected Areas in Communications*, *26*(8).

[24] Gesbert, D. and Alouini, M.S., 2004, June. How much feedback is multi-user diversity really worth?. In *Communications, 2004 IEEE International Conference on* (Vol. 1, pp. 234-238). IEEE.

[25] Yoo, T. and Goldsmith, A., 2006. On the optimality of multiantenna broadcast scheduling using zero-forcing beamforming. *IEEE Journal on Selected Areas in Communications*, *24*(3), pp.528-541.

[26] Lin, P.H. and Tsai, S.H., 2012. Performance analysis and algorithm designs for transmit antenna selection in linearly precoded multiuser MIMO systems. *IEEE transactions on Vehicular Technology*, *61*(4), pp.1698-1708.

[27] Benvenuto, N., Conte, E., Tomasin, S. and Trivellato, M., 2007, September. Joint low-rate feedback and channel quantization for the MIMO broadcast channel. In *AFRICON 2007* (pp. 1-7). IEEE.

[28] Huh, H., Tulino, A.M. and Caire, G., 2012. Network MIMO with linear zero-forcing beamforming: Large system analysis, impact of channel estimation, and reduced-complexity scheduling. *IEEE Transactions on Information Theory*, *58*(5), pp.2911-2934.

[29] Hassel, V., Gesbert, D., Alouini, M.S. and Oien, G.E., 2007. A threshold-based channel state feedback algorithm for modern cellular systems. *IEEE Transactions on Wireless Communications*, *6*(7), p.2422.

[30] Spencer, Q.H., Peel, C.B., Swindlehurst, A.L. and Haardt, M., 2004. An introduction to the multi-user MIMO downlink. *IEEE communications Magazine*, *42*(10), pp.60-67.

[31] Rim, M., 2002. Multi-user downlink beamforming with multiple transmit and receive antennas. *Electronics Letters*, *38*(25), pp.1725-1726.

[32] Yu, W. and Lan, T., 2007. Transmitter optimization for the multi-antenna downlink with per-antenna power constraints. *IEEE Transactions on Signal Processing*, *55*(6), pp.2646-2660.

[33] Kaltenberger, F., Gesbert, D., Knopp, R. and Kountouris, M., 2008, September. Correlation and capacity of measured multi-user MIMO channels. In *Personal, Indoor and Mobile Radio Communications, 2008. PIMRC 2008. IEEE 19th International Symposium on* (pp. 1-5). IEEE.

[34] Erez, U. and Ten Brink, S., 2005. A close-to-capacity dirty paper coding scheme. *IEEE Transactions on information theory*, *51*(10), pp.3417-3432.

[35] Caire, G. and Shamai, S., 1999. On the capacity of some channels with channel state information. *IEEE Transactions on Information Theory*, *45*(6), pp.2007-2019.

[36] Bindra, K.V., Sharma, S. and Khanna, R., Performance Analysis of Scheduled TAS Cognitive Radio System with Generalized Selection Combining. *Wireless Personal Communications*, pp.1-16.

[37] Torabi, M., Haccoun, D. and Ajib, W., 2009, November. BER performance analysis of multiuser diversity with antenna selection in MRC MIMO systems. In *Global Telecommunications Conference, 2009. GLOBECOM 2009. IEEE* (pp. 1-6). IEEE.

[38] Jing, Y. and Jafarkhani, H., 2009. Network beamforming using relays with perfect channel information. *IEEE Transactions on Information Theory*, *55*(6), pp.2499-2517.

[39] Caire, G., Ramprashad, S.A. and Papadopoulos, H.C., 2010, January. Rethinking network MIMO: Cost of CSIT, performance analysis, and architecture comparisons. In *Information Theory and Applications Workshop (ITA), 2010* (pp. 1-10). IEEE.

[40] Fan, J., Xu, Z. and Li, G.Y., 2015. Performance analysis of MU-MIMO in downlink cellular networks. *IEEE Communications Letters*, *19*(2), pp. 223-226.

[41] Mao, J., Gao, J., Liu, Y. and Xie, G., 2012. Simplified semi-orthogonal user selection for MU-MIMO systems with ZFBF. *IEEE Wireless Communications Letters*, *1*(1), pp. 42-45.

LIST OF PUBLICATIONS

1. Ralhan K. and Sharma S. 2017. On the performance of the scheduling scheme for MU-MIMO BC system with two-stage feedback. MID International Conference of Technology & Applied Sciences-17.

2. Ralhan K. and Sharma S. 2017. Performance Analysis of MU-MIMO BC system with reduced feedback and selection scheme. Pertanika Journal of Applied Sciences & Technology.

ORIGINALITY REPORT