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Review on Massive MIMO based on Channel Estimation for mm-wave Communication

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ABSTRACT: In a cellular network, the demand for high throughput and reliable transmission is increasing in large scale. One of the architectures proposed for 5G wireless communication to satisfy the demand is Massive MIMO system. The massive system is equipped with the large array of antennas at the Base Station (BS) serving multiple single antenna users simultaneously i.e., number of BS antennas are typically more compared to the number of users in a cell. This additional number of antennas at the base station increases the spatial degree of freedom which helps to increase throughput, maximize the beamforming gain, simplify the signal processing technique and reduces the need of more transmit power. The advantages of massive MIMO can be achieved only if Channel State Information (CSI) is known at BS uplink and downlink operate on orthogonal channels - TDD and FDD modes.

KEYWORDS: Massive MIMO, Channel State Information, FDD, TDD

I. INTRODUCTION

The interest for remote throughput has developed exponentially in the previous hardly any years, with the expansion in various remote gadgets and number of new versatile clients. The throughput is the result of Bandwidth (Hz) and Spectral productivity (bits/s/Hz) [1]. To expand the throughput, either Bandwidth or Spectral productivity must be expanded. Since expanding the Bandwidth is an expensive factor, the ghastly productivity must be mulled over. It very well may be expanded by utilizing numerous radio wires at the transmitter and recipient. Numerous Input Multiple Output (MIMO) reception apparatuses improve both correspondence unwavering quality just as the limit of correspondence (by transmitting various information in various receiving wires). For the most part MIMO frameworks are separated into two classes: Point-to-Point MIMO and Multi User - MIMO (MU-MIMO) [2], [3]. In Point-to-Point MIMO, both the transmitter and collector are furnished with numerous radio wires. The presentation increase can be accomplished by utilizing the systems, for example, beamforming and spatial multiplexing of a few information streams. Then again, in MU-MIMO, the remote channel is spatially shared among the clients. The clients in the cell transmit and get information without joint encoding and joint discovery among them. The Base Station (BS) discusses all the while with every one of the clients, by misusing the distinction in spatial marks at the BS radio wire exhibit. MIMO frameworks are consolidated in a few new age remote gauges like LTE - Advanced, Wireless LAN and so forth.

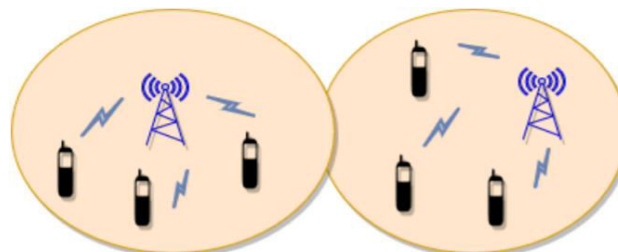


Figure 1: Multi-cell Massive MIMO System

The principle challenge in MU-MIMO framework is the obstruction between the co-channel clients. Subsequently, complex recipient strategy must be utilized, to diminish the co-channel impedance. In [4], it is demonstrated that by utilizing an unending number of reception apparatuses at the BS in examination with the quantity of clients in the phone, the irregular channel vectors among clients and the BS become pair-wise symmetrical. By presenting more reception apparatuses at the BS, the impacts of uncorrelated commotion and intra cell obstruction vanish and little scale

blurring is arrived at the midpoint of out. Henceforth, basic coordinated channel preparing at BS is ideal. MU-MIMO framework with several radio wire at the BS which serves many single reception apparatus client terminals all the while at same recurrence and time is known as Massive MIMO framework or huge receiving wire exhibit MU-MIMO framework [5],[6]. One of the structures proposed for 5G remote correspondence is the enormous MIMO framework in which BS is furnished with countless radio wires and serves different single receiving wire client terminals as appeared in Fig 1.

Advantages of Massive MIMO System:-

High vitality productivity: If the channel is assessed from the uplink pilots, at that point every client's transmitted force can be decreased relatively to $1/\sqrt{M}$ considering M is huge. On the off chance that ideal Channel State Information (CSI) is accessible at the BS, at that point the transmitted force is diminished relatively to $1/M$ [7]. In the downlink case, the BS can impart signs just in the ways where the client terminals are found. By utilizing the Massive MIMO, the emanated force can be diminished accomplishing high vitality effectiveness.

- **Simple signal processing:** Using an extreme number of BS radio wires contrasted with clients lead to the pair-wise symmetry of channel vectors. Henceforth, with basic straight preparing strategies both the impacts of bury client impedance and clamor can be disposed of.
- **Sharp digital beamforming:** With a receiving wire exhibit, by and large simple beamforming is utilized for guiding by changing the periods of RF signals. Be that as it may, on account of Massive MIMO, beamforming is computerized in light of direct precoding. Computerized beamforming is performed by tuning the stages and amplitudes of the transmitted signals in baseband. Without guiding genuine shafts into the channels, signals include in stage at the proposed clients and out of stage at different clients. With the expansion in various receiving wires, the sign quality at the planned clients gets higher and gives low impedance from different clients. Advanced beamforming in gigantic MIMO gives an increasingly adaptable and forceful method for spatial multiplexing. Another preferred position of computerized beamforming is that it doesn't require exhibit alignment since correspondence is utilized.
- **Channel solidifying:** The channel passages become practically deterministic in the event of Massive MIMO, in this way nearly killing the impacts of little scale blurring. This will fundamentally diminish the channel estimation mistakes.
- **Reduction of Latency:** Fading is the most significant factor which impacts the dormancy. Additional blurring will prompts more dormancy. As a result of the nearness of Channel solidifying in Massive MIMO, the impacts of blurring will be nearly disposed of and the dormancy will be diminished altogether.
- **Robustness:** Robustness of remote correspondences can be expanded by utilizing different reception apparatuses. Huge MIMO have overabundance degrees of opportunity which can be utilized to drop the sign from purposeful jammers.
- **Array gain:** Array gain brings about a shut circle interface spending improvement corresponding to the quantity of BS radio wires.
- **Good Quality of Service (QoS):** Massive MIMO gives the arrangement of consistently great QoS to all terminals in a cell as a result of the obstruction concealment capacity offered by the spatial goals of the cluster. Run of the mill gauge power control calculations accomplish max-min decency among the terminals.
- **Autonomous activity of BS's:** The activity of BS's is improved on the grounds that there is no necessity of sharing Channel State Information (CSI) with different cells and no prerequisite of exact time synchronization.

II. CHALLENGES

Propagation Model: In most of the Massive MIMO related works, the assumption that made was: as the BS antennas grow the user channels are uncorrelated and the channel vectors become pair-wise orthogonal. But in real time propagation environment, antenna correlation comes into the picture. If the antennas are highly correlated, then the channel vectors cannot become pair-wise orthogonal by increasing the number of antennas. This means that users location is an important factor in Massive MIMO systems.

Modulation: For the construction of a BS with a large number of antennas, cheap power efficient RF amplifiers are needed.

Channel Reciprocity: TDD operation depends on channel reciprocity. There seems to be a reasonable consensus that the propagation channel itself is basically reciprocal unless the propagation is suffering from materials with strange



magnetic properties. Between the uplink and the downlink, there is a hardware chain in the base station and terminal transceivers may not be reciprocal.

Channel Estimation: To perform detection at the receiver side, we need perfect CSI at the receiver side. Due to the mobility of users in MU case, channel matrix changes with time. In high mobility case, accurate and time acquisition of CSI is very difficult. FDD Massive MIMO induces training overhead and TDD Massive MIMO relies on channel reciprocity and training may occupy a large fraction of the coherence interval.

Low-cost Hardware: Large number of RF chains, Analog-to-Digital converters, Digital-to-Analog converters are needed.

Coupling between antenna arrays: At the BS side, several antennas are packed in a small space. This causes mutual coupling in between the antenna arrays. Mutual coupling degrades the performance of Massive MIMO due to power loss and results in lower capacity and less number of degrees of freedom. When designing a Massive MIMO system, the effect of mutual coupling has to be taken into account [8], [9].

Mobility: If the mobility of the terminal is very high, then the coherence interval between the channel becomes very less. Therefore, it accommodates very less number of pilots. • **Pilot Contamination:** Pilot contamination is a challenging problem for multicell massive MIMO is to be resolved. In multicell system, users from neighboring cells may use non-orthogonal pilots that result in pilot contamination. This causes inter-cell interference problem which further grows with the increase in a number of BS antennas.

III. LITERATURE REVIEW

Rifat Hasan et al. [1],the next major step in mobile communications technology beyond the current LTE-A is 5G wireless technologies. With the rapid progression of 5G, massive MIMO innovation has turned out to be one of the most significant advances in 5G networks by facilitating beamforming technology. In this paper, we have simulated and analyzed the statistical propagation channel model for 5G massive MIMO millimeter-wave (mmWave) cellular communication in the ultra-wideband unlicensed spectrum of 60 GHz. This investigation is based on IR (impulse response) channel model named NYUSIM which is a geometrical based channel modeling tool developed by NYUWireless. We have used the drop based mode to determine the propagation channel coefficients. We investigated the network performance by considering the directional, omnidirectional power delay profiles (PDPs) and path loss. Analyzing the propagation channel is fundamental to define the actions of the channel response of the wireless stream link in the specific environment to reach the 5G expectations.

R. Hasan et al. [2],in recent years, an increasing interest in the millimeter wave (mmWave) communications plays a vital solution for the growing demands of the data and speed. As a vast unused spectrum, mmWave is expected to handle a key role in the access network of the fifth generation (5G) mobile technologies. Despite its ability to provide higher transmission rate and spread spectrum capability, mmWave suffers from several major drawbacks such as high attenuation and sensitivity due to its weather dependency which causes the modeling of an mmWave channel to be very challenging. In this research, we investigate a statistical analysis of an outdoor channel in 73 GHz for access network of an urban micro cell. A well-known mmWave channel modeling simulator NYUSIM is used for both LOS and NLOS scenarios. Simulation scenarios consider some crucial network parameters such as angle of arrival, angle of departure, power delay profiles, and path loss to characterize an mmWave channel in the 73 GHz E band. These investigations may be utilized to demonstrate the potential of 73 GHz mmWave band and its suitability for the 5G outdoor networks.

R. Hasan et al. [3],millimeter wave (mmWave) is perceived as an essential innovation so as to meet the rapid increment of wireless mobile traffic request utilizing its massive bandwidth. However, channel modeling is still difficult for its high weather dependency and antenna positioning for line-of-sight (LOS) communication. Co-polarization and cross polarization(X-pol) are two main incidents of radiation pattern direction for transmitting wave; where the desired direction of transmitting wave indicates co-pol and orthogonal propagation of the desired direction represents X-pol. This paper presents an extensive analysis of polarization impact on a statistical channel modeling for two definite front-runners of mmWave bands (28 GHz & 73 GHz) by a novel simulator NYUSIM. We simulate a realistic urban microcell scenario using the 3-D statistical spatial channel model (SSCM) that is adopted by time cluster and spatial beam approach. Simulation results present 3-D channel characteristics (AoA, AoD, and path loss) and

various power delay profiles (directional, omnidirectional, and small scale) for Co-pol and X-pol in 28 GHz and 73 GHz.

M. Khatun H et al. [4], this paper presents a large scale fading channel model at the 60 GHz band. This model is based on the measurement campaign that our team conducted at Boise Airport and Boise State University. The close-in reference path loss and floating-intercept path loss models with both statistical and stochastic approaches are investigated for these environments. The measurements were collected at several different locations in line-of-sight (LOS) and non-line-of-sight (NLOS) scenarios using high gain directional antenna. The path loss exponent and shadowing factor are determined based on the measurement results and compared with recent work at this frequency. Both the stochastic gradient descent algorithm and the statistical least-square technique are used to analyze the floating-intercept path loss model. The results show that the path loss exponents in the outdoor scenarios are higher than the indoor environment due to the RF noise caused by the sunny and dry climate in the Boise area. Finally, a good agreement is found between the measurement results and the prior work results presented in the literature.

Supraja Eduru et al. [5], in massive Multiple Input Multiple Output (MIMO) systems, spatial correlation is one of the factors, which significantly affects the bit error rate (BER) performance. Therefore, in this paper, linear detection is employed with different decomposition techniques to improve the performance. It is observed that there is 10 dB degradation in channel gain for 10% increment in correlation coefficient. At a BER of 10^{-3} , with Zero Forcing (ZF) using Singular Value Decomposition (SVD), the channel gain is doubled by doubling the order of the MIMO system when compared to Cholesky and QR decomposition. Further, the BER remains unchanged for Minimum Mean Square Error (MMSE) detection irrespective of the type of decomposition techniques used. However, it is also observed that for 32×32 MIMO system, at a BER of 10^{-3} , MMSE provides nearly 10 dB to 15 dB channel gain when compared to ZF.

T. Abbas F. et al. [6], this paper examines the physical layer security issue of psychological decipher and forward hand-off systems over Nakagami-m fading channels. We consider the handing-off correspondence between one auxiliary client (SU) source and one SU goal by utilizing a pioneering transfer choice from numerous SU transfers and sharing the authorized range of different essential clients (PUs) in the underlay arrange. While the transmission between the SUs forces impedance on every PU, the handed-off transmission is caught by one SU meddler. Without the busybody's channel state data, the hand-off determination depends on the biggest channel addition of transfer to-goal connect, which is thought to be obsolete because of input delay. We infer the definite likelihood of non-zero mystery limit and the precise mystery blackout likelihood (SOP) in the shut structure. Besides, we determine the asymptotic SOP in two distinct cases, and unequivocally demonstrate the impacts of framework parameters on the mystery decent variety request and the mystery assorted variety gain, individually. Both asymptotic investigation and reenactment results demonstrate that the mystery execution can be improved by expanding either the quantity of transfers or the Nakagami parameter of the authentic hand-off channels, while the mystery decent variety addition disintegrates as the quantity of the PUs increments.

S. Sun G. R. et al. [7], in future functional organizations of gigantic multi-input multi-output (MIMO) frameworks, the quantity of radio-recurrence (RF) chains at the base stations (BSs) might be a lot smaller than the quantity of BS receiving wires to lessen the general use. In this correspondence, we propose a novel structure for joint information and counterfeit commotion (A) precoding in a multiuser enormous MIMO framework with predetermined number of RF chains, which improves the remote security execution. With defective channel state data (CSI), we logically determine an attainable lower bound on the ergodic mystery rate of any versatile terminal (MT) for both simple and half breed precoding plans. The shut structure lower bound is utilized to decide ideal power part among information and AN expands the mystery rate through basic 1-D search. Diagnostic and numerical outcomes together uncover that the proposed cross breed precoder, albeit experiencing diminished mystery rate contrasted and the hypothetical full-dimensional precoder, is free of the high computational multifaceted nature of enormous scale framework reversal and invalid space counts and to a great extent decreases the equipment cost.

IV. FDD AND TDD

In order to achieve the benefits of a large antenna array, accurate and timely acquisition of Channel State Information (CSI) is needed at the BS. The need for CSI is to process the received signal at BS as well as to design a precoder for optimal selection of a group of users who are served on the same time-frequency resources. The acquisition of CSI at the BS can be done either through feedback or channel reciprocity schemes based on Time Division Duplex (TDD) or

Frequency Division Duplex (FDD) system. The procedure for acquiring CSI and data transmission for both systems is explained in the subsequent sections [10, 11].

Channel Estimation and Data Transmission in TDD System

In TDD system, the signals are transmitted in the same frequency band for both uplink and downlink channel but in different time slots. Hence, uplink and downlink channels are reciprocal. The estimation of the uplink channel is preferred, as the number of pilots used to estimate the channel is less compared to the downlink channel. Most published research works have considered the rich scattering propagation environment in uplink TDD mode (i.e., number of scatterers tend to be infinity or more than the number of BS antenna and users in the cell). Under rich scattering condition, the channel vector seen by any two users are orthogonal. However, in realistic condition, the number of scatterers is finite. In this thesis, the finite scattering propagation environment is considered for the uplink TDD mode channel estimation problem. In finite scattering scenario, it is assumed that the number of scatterers is less than the number of BS antenna and users. Also, the scatterers are fixed and all users are facing the same scatterers. When same scatterers are shared by all users, the correlation among the channel vectors increases and correspondingly increase the spread of Eigen values of the channel matrix. Hence, the high dimensional massive MIMO system is likely to have a low-rank channel.

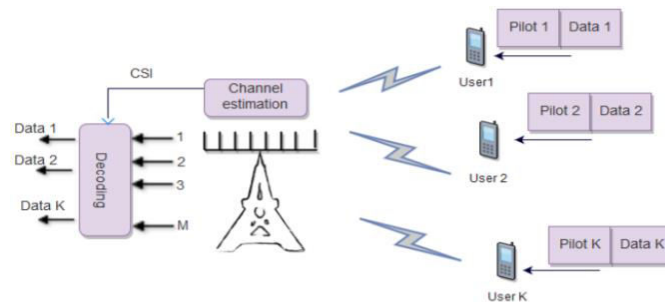


Figure 2: Uplink transmission in a TDD Massive MIMO system

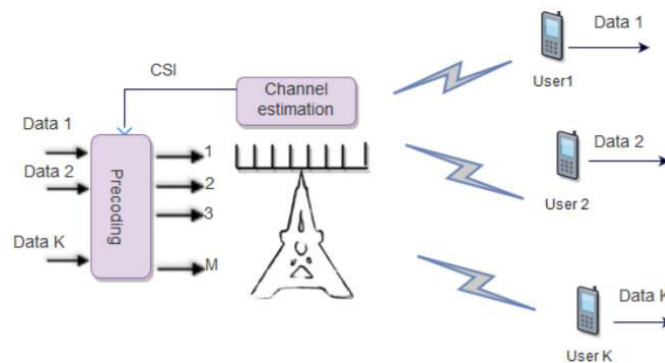


Figure 3: Downlink transmission in a TDD Massive MIMO system

Channel Estimation and Data Transmission in FDD System

On the other hand, the current cellular network is dominated by FDD system. Hence, it is of importance to explore channel estimation of massive MIMO system in FDD Mode also. In FDD systems, every user obtains CSI by sending the pilot signal and the obtained CSI is fed back to the BS for precoding. The number of pilots required for downlink channel estimation is proportional to the number of BS antennas, while the number of pilots required for uplink channel estimation is proportional to the number of users. Therefore, to estimate the downlink channel, the pilot overhead is in the order of the number of BS antenna which is prohibitively large in Massive MIMO system and the corresponding CSI feedback is high overhead for uplink. Hence, it is of importance to explore channel estimation in the downlink than that in the uplink, which can facilitate massive MIMO to be backward compatible with current FDD dominated cellular networks [12].

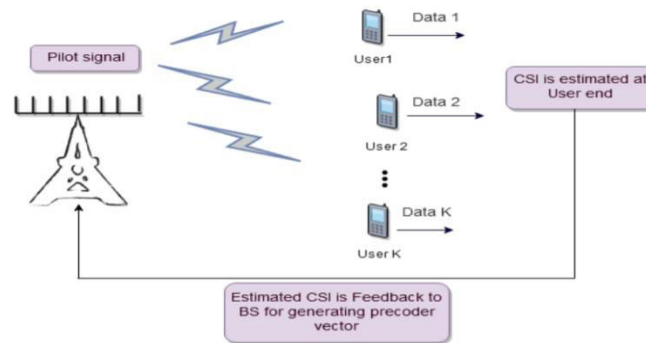


Figure 5: Downlink transmission in an FDD Massive MIMO system

V. mm-WAVE COMMUNICATION

Communication at mmWave provides multi-gigabit communication services with the use of frequency band from 30 GHz to 300 GHz. At mmWave, available spectrum is supreme to cellular and WLAN microwave systems that operate at frequencies below 10 GHz. The unlicensed spectrum at 60 GHz mmWave band offers 10 to 100 more spectrum than is available for conventional unlicensed WLAN in the Industrial, Scientific, and Medical (ISM) bands and 4G (Fourth Generation) or earlier cellular systems that operate at carrier frequencies below 6 GHz. In particular, it is possible to achieve higher data rates for comparable modulation techniques and provide more resources to be shared among multiple users using large amount of spectrum. However, there are fundamental differences between mmWave communications and other communication systems operating in the microwaves band. There are challenges in physical, medium access control, and routing layers for mmWave communications to make a big impact in the 5G wireless networks [13, 14].

MmWave Challenges

Despite the high carrier frequency and wide bandwidth of mmWave band, there are several technical challenges in the design of circuit components and antennas for mmWave communications.

Integrated circuits and system design:- The high transmit power and wide bandwidth cause severe nonlinear distortion of power amplifiers. Also, phase noise and In-phase and Quadrature (IQ) imbalance are the challenging problems in Radio Frequency (RF) integrated circuits. There are also problems on integrated circuits including on-chip and inpackage antennas, RF power amplifiers, low-noise amplifiers, voltage controlled oscillators, mixers, and analog-to-digital converters.

Interference management:- The interference between links is less due to the directivity of transmission. Thus, simultaneous transmissions can be fully exploited to enhance the network capacity. The coordination mechanism becomes important in the medium access control design [15]. In the indoor environments, it is required to deploy large number of Access Points (APs) to provide seamless coverage, due to the limited range. The interference within each Basic Service Set (BSS) and interference among different BSSs need to be considered. Thus, power control, transmission coordination and concurrent transmission using spatial reuse should be applied to manage interference.

VI. Conclusion

This paper has dealt with channel estimation for single cell Massive MIMO system with no interference from other cells. However, it is necessary to estimate the channel of a single cell, when the signal from other cells interferes with the signal of the desired cell. Consider the case, where BS estimates not only the channel parameters of desired links in a given cell but also, those of the interference links from adjacent cells. In multi-cell case, it is necessary to study the interference links, in order to have interference coordination. In such scenarios, BS has to collect information regarding CSI of both the desired links within the cell and interference links from its neighboring cells. Under undesirable finite scattering scenario, the combined channel matrix can be modeled as low-rank matrix. Therefore, the analysis presented in this work can be extended to a multi-cell scenario.

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