

Review Paper on Massive MIMO Systems with Channel State Information

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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. 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. Depending on slow/fast channel fading conditions, several authors suggested adaptive LMS, RLS and NLMS based channel estimators, which either require statistical information of the channel or are not efficient enough in terms of performance or computations. In order to overcome the above effects, the work focuses on the QR-RLS based channel estimation method for cell free Massive MIMO systems.

Keywords: - Massive MIMO, Channel State Information, Square Root-Recursive Least Square (QR-RLS)

I. INTRODUCTION

The demand for wireless throughput has grown exponentially in the past few years, with the increase in a number of wireless devices and number of new mobile users. The throughput is the product of Bandwidth (Hz) and Spectral efficiency (bits/s/Hz) [1]. To increase the throughput, either Bandwidth or Spectral efficiency has to be increased. Since increasing the Bandwidth is a costly factor, the spectral efficiency has to be taken into consideration. It can be increased by using multiple antennas at the transmitter and receiver. Multiple-Input Multiple Output (MIMO) antennas enhance both communication reliability as well as the capacity of communication (by transmitting different data in different antennas). Generally MIMO systems are divided into two categories: Point-to-Point MIMO and Multi User - MIMO (MU-MIMO) [2], [3]. In Point-to-Point MIMO, both the transmitter and receiver are equipped with multiple antennas. The performance gain can be achieved by using the techniques such as beamforming and spatial multiplexing of several data streams. On the other hand, in MU-MIMO, the wireless channel is spatially shared among the users. The users in the cell transmit and receive data without joint encoding and joint detection among them. The Base Station (BS) communicates simultaneously with all the users, by exploiting the difference in spatial signatures at the BS antenna array. MIMO systems are incorporated in several new generation wireless standards like LTE - Advanced, Wireless LAN

etc. The main challenge in MU-MIMO system is the interference between the co-channel users. Hence, complex receiver technique has to be used, to reduce the co-channel interference. In [4], it is shown that by using an infinite number of antennas at the BS in comparison with the number of users in the cell, the random channel vectors between users and the BS become pair-wise orthogonal. By introducing more antennas at the BS, the effects of uncorrelated noise and intra cell interference disappear and small scale fading is averaged out. Hence, simple matched filter processing at BS is optimal. MU-MIMO system with hundreds of antenna at the BS which serves many single antenna user terminals simultaneously at same frequency and time is known as Massive MIMO system or large antenna array MU-MIMO system [5],[6]. One of the architectures proposed for 5G wireless communication is the massive MIMO system in which BS is equipped with a large number of antennas and serves multiple single antenna user terminals as shown in Fig 1.

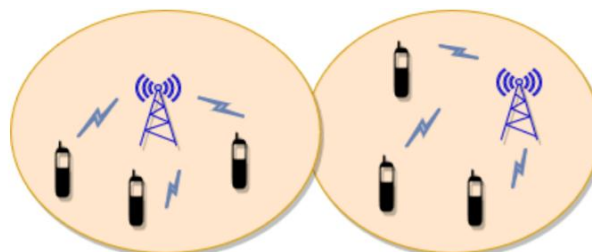


Figure 1: Multi-cell Massive MIMO System

Advantages of Massive MIMO System:-

High energy efficiency: If the channel is estimated from the uplink pilots, then each user's transmitted power can be reduced proportionally to $1/\sqrt{M}$ considering M is very large. If perfect Channel State Information (CSI) is available at the BS, then the transmitted power is reduced proportionally to $1/M$ [7]. In the downlink case, the BS can send signals only in the directions where the user terminals are located. By using the Massive MIMO, the radiated power can be reduced achieving high energy efficiency.

- **Simple signal processing:** Using an excessive number of BS antennas compared to users lead to the pair-wise orthogonality of channel vectors. Hence, with simple linear processing techniques both the effects of inter user interference and noise can be eliminated.
- **Sharp digital beamforming:** With an antenna array, generally analog beamforming is used for steering by adjusting the phases of RF signals. But in the case of Massive MIMO, beamforming is digital because of linear precoding. Digital beamforming is performed by tuning the phases and amplitudes of the transmitted signals in baseband.
- **Channel hardening:** The channel entries become almost deterministic in case of Massive MIMO, thereby almost eliminating the effects of small scale fading. This will significantly reduce the channel estimation errors.
- **Reduction of Latency:** Fading is the most important factor which impacts the latency. More fading will leads to more latency. Because of the presence of Channel hardening in Massive MIMO, the effects of fading will be almost eliminated and the latency will be reduced significantly.
- **Robustness:** Robustness of wireless communications can be increased by using multiple antennas. Massive MIMO have excess degrees of freedom which can be used to cancel the signal from intentional jammers.
- **Array gain:** Array gain results in a closed loop link budget enhancement proportional to the number of BS antennas.
- **Good Quality of Service (QoS):** Massive MIMO gives the provision of uniformly good QoS to all terminals in a cell because of the interference suppression capability offered by the spatial resolution of the array. Typical baseline power control algorithms achieve max-min fairness among the terminals.

- **Autonomous operation of BS's:** The operation of BS's is improved because there is no requirement of sharing Channel State Information (CSI) with other cells and no requirement of accurate 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.

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.

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.

III. LITERATURE REVIEW

Bharti Katiyar et al. (2018, [1]), in this paper we consider pilot defilement issue in the uplink of a multi-cell enormous MIMO. Each base station (BS) is furnished with M (boundless) receiving wires serving K (substantial yet

limited) clients. Further, we let τ (pilot length) be a self-assertive however little esteem. Pilot pollution results from the re-utilization of a similar arrangement of pilot groupings in the distinctive cells of the framework. To moderate the underline issue in Massive MIMO framework, pre-set up calculation (APA) is audited and bit mistake rate is assessed over Weibull blurring situation utilizing APA calculation. The numerical outcome demonstrates critical improvement in BER and Spectral proficiency with expanding blurring seriousness.

Kai Liu et al. (2018, [2]), additionally create diagnostic limits on the SER and attainable rate execution of uplink huge MIMO structures with 1-bit quantization for the FTSR situation for the entirety SNR district. The proposed diagnostic bound holds not just for the FTSR case and is appeared to yield progressively precise outcomes contrasted with some other explanatory articulations in the writing. Our outcomes set up a tradeoff between worldly oversampling what's more, the quantity of get radio wires.

Ali Bulut et al. (2018, [3]), low goals simple to-advanced converters (ADC) pulled in much consideration recently for huge numerous information various yield (MIMO) correspondence and frameworks with huge data transfer capacity. Particularly, 1-bit ADCs are appropriate for such frameworks because of their low power utilization and cost. In this investigation, we delineate the advantages of utilizing quicker than image rate (FTSR) examining in an uplink monstrous MIMO framework with 1-bit ADCs in terms of image blunder rate (SER). We demonstrate that FTSR inspecting gives around 5 dB flag to-commotion proportion (SNR) advantage in terms of SER and attainable rate with a straight zero-compelling type recipient.

Dhanushka Kudathanthirige et al. (2018, [4]), the execution of multi-cell enormous various input numerous yield (MIMO) downlink (DL) with non-symmetrical numerous entrance (NOMA) is examined. An epic pilot task for NOMA clients is proposed to moderate intra-group pilot pollution and to ease the hindering effect of between group in the helpful working routine. The client hubs gathered into a similar bunch dependent on the spatial-heading data are doled out symmetrical pilots to alleviate intra group pilot tainting. These pilots are shared among the groups to decrease the preparation overhead. In any case, the between group pilot tainting is moderated by abusing the unmistakable spatial bearings of groups. This pilot task guarantees that the quantity of NOMA clients that can be served at the same time in a similar time-recurrence spatial asset square isn't restricted by the length of intelligibility interim. A maximum min reasonableness ideal transmit control portion calculation is proposed to ensure client decency.

Ahmed et al. (2018, [5]), the expanding remote information traffic requests have driven the need to investigate

reasonable range locales for gathering the anticipated necessities. In the light of this, millimeter wave (mmWave) correspondence has gotten extensive consideration from the examination network. Ordinarily, in fifth era (5G) remote systems, mmWave gigantic numerous information multiple output (MIMO) interchanges is acknowledged by the crossover handsets which consolidate high dimensional simple stage shifters and power intensifiers with lower-dimensional advanced flag preparing units. This crossover beamforming configuration lessens the expense and power utilization which is lined up with a vitality effective structure vision of 5G. In this paper, we track the advancement in half and half beamforming for monstrous MIMO correspondences with regards to framework models of the cross breed handsets' structures, the computerized and simple beamforming lattices with the conceivable radio wire design situations and the crossover beamforming in heterogeneous remote systems.

H. Q. Ngo et al. (2017, [6]), a Cell-Free Massive MIMO (numerous information various yield) framework includes an exceptionally huge number of circulated passages (APs), which all the while serve an a lot more modest number of clients over a similar time/recurrence assets dependent on straightforwardly estimated channel attributes. The APs and clients have just a single receiving wire each. The APs obtain channel state data through time-division duplex activity and the gathering of uplink pilot signals transmitted by the clients. The APs perform multiplexing/demultiplexing through conjugate beamforming on the downlink and coordinated separating on the uplink. Shut structure articulations for individual client uplink and downlink throughputs lead to max-min control calculations.

Q. Huang et al. (2017, [7]), in this paper, we consider the uplink of sans cell gigantic MIMO frameworks, where an extensive number of conveyed single radio wire passageways (APs) serve an a lot more modest number of clients all the while by means of restricted backhaul. Out of the blue, we research the execution of figure and-forward (C&F) in such a ultra-thick system with a reasonable channel model (counting blurring, pathloss and shadowing). By using the normal for pathloss, a low intricacy coefficient choice calculation for C&F is proposed. We likewise give a voracious AP choice strategy for message recuperation. Furthermore, we think about the execution of C&F to some other promising direct systems for conveyed gigantic MIMO, for example, little cells (SC) and most extreme proportion joining (MRC). Numerical outcomes uncover that C&F decreases the backhaul load, yet additionally fundamentally expands the framework throughput for the symmetric situation.

F. Molisch et al. (2017, [8]), the expanding remote information traffic requests have driven the need to investigate appropriate range locales for gathering the

anticipated necessities. In the light of this, millimeter wave (mmWave) correspondence has gotten significant consideration from the exploration network. Regularly, in fifth era (5G) remote systems, mmWave huge different info multiple output (MIMO) interchanges is acknowledged by the half breed handsets which consolidate high dimensional simple stage shifters and power enhancers with lower-dimensional computerized flag preparing units.

F. Sohrabi et al. (2016, [9]), the capability of utilizing of millimeter wave (mmWave) recurrence for future remote cell correspondence frameworks has spurred the investigation of huge scale receiving wire clusters for accomplishing exceedingly directional beamforming. Be that as it may, the customary completely advanced beamforming strategies which require one radio recurrence (RF) chain per radio wire component isn't practical for huge scale receiving wire exhibits because of the surprising expense also, high power utilization of RF chain parts in high frequencies.

M. Liu et al. (2016, [10]), in this paper, a downlink various info multiple output (MIMO) non-symmetrical numerous entrance (NOMA) situation is considered. We research a dynamic client bunching issue from a decency viewpoint. So as to fathom this streamlining issue, three imperfect calculations, to be specific top down A, top-down B, and base up, are proposed to figure it out diverse tradeoffs of intricacy and throughput of the most noticeably terrible client. What's more, for each given client grouping case, we enhance the power allotment coefficients for the clients in each group by embracing a separation look based calculation.

Z. Ding et al. (2016, [11]), in this letter, a low-input non-symmetrical numerous entrance (NOMA) conspire utilizing huge various info different yield (MIMO) transmission is proposed. Specifically, the proposed plan can disintegrate a monstrous MIMO-NOMA framework into different isolated single-input single-yield NOMA channels, and scientific outcomes are created to assess the execution of the proposed plan for two situations, with flawless client requesting and with one-piece input, individually.

H. Q. Ngo et al. (2015, [12]), we consider the downlink of Cell-Free Massive MIMO frameworks, where countless access focuses (APs) all the while serve an a lot more modest number of clients. Each AP utilizes neighborhood channel gauges acquired from gotten uplink pilots and applies conjugate beamforming to transmit information to the clients. We determine a shut structure articulation for the feasible rate. This articulation empowers us to plan an ideal max-min control conspire that gives equivalent quality of administration to all clients.

E. Nayebi et al. (2015, [13]), Cell-Free Massive MIMO frameworks contain a vast number of circulated, minimal

effort, and low power passage reception apparatuses, associated with a system controller. The quantity of reception apparatuses is altogether bigger than the quantity of clients. The framework isn't apportioned into cells and every client is served by all passage radio wires at the same time. In this paper, we characterize sans cell frameworks and dissect calculations for power advancement and straight pre-coding. Contrasted and the customary little cell plot, Cell-Free Massive MIMO can yield more than ten times improvement as far as 5%-blackout rate.

L. Lu et al. (2014, [14]), we start with a data theoretic investigation to represent the guessed favorable circumstances of enormous MIMO, and after that we address usage issues identified with channel estimation, identification and precoding plans. We especially center around the potential effect of pilot tainting caused by the utilization of non-symmetrical pilot successions by clients in contiguous cells. We likewise investigate the vitality effectiveness accomplished by huge MIMO frameworks, and exhibit how the degrees of opportunity given by monstrous MIMO frameworks empower proficient single-bearer transmission. At long last, the difficulties and openings related with actualizing monstrous MIMO in future remote interchanges frameworks are talked about.

O. E. Ayach et al. (2014, [15]), enormous various info numerous yield (MIMO) remote correspondences alludes to the thought preparing cell base stations (BSs) with countless, and has been appeared to possibly take into consideration requests of extent improvement in otherworldly and vitality productivity utilizing generally straightforward (direct) handling. In this paper, we present a far reaching outline of cutting edge examine on the theme, which has as of late pulled in extensive consideration.

IV. CHANNEL ESTIMATION

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.

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 transmissions but at different time slots. Hence, uplink and downlink channels are reciprocal. During uplink transmission, all the

users in the cell synchronously send the pilot signal to the BS. The antenna array receives the modified pilot signal by the propagation channel. Based on the received pilot signal, BS estimate the CSI and further, this information is used to separate the signal and detect the signal transmitted by the users as shown in Fig 2. In downlink transmission, due to channel reciprocity, BS uses the estimated CSI to generate precoding/beamforming vector. The data for each user is beam formed by the precoded vector at the BS and transmitted to the user through propagation channel as shown in Fig 3.

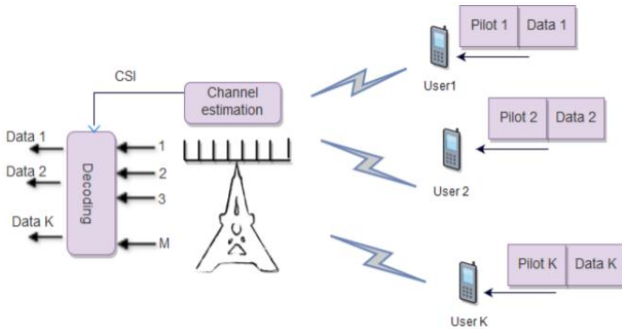


Figure 2: Uplink transmission in a TDD Massive MIMO system

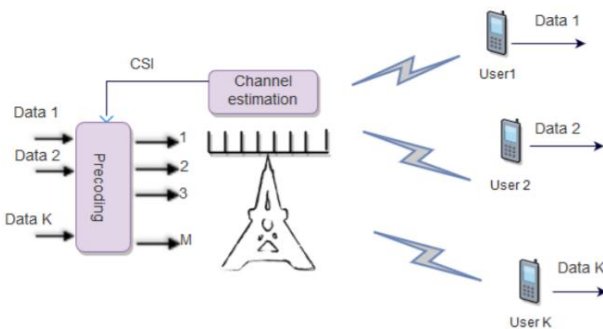


Figure 3: Downlink transmission in a TDD Massive MIMO system

Channel Estimation and Data Transmission in FDD System

In FDD system, the signals are transmitted at different frequency band for uplink and downlink transmission. Therefore, CSI for the uplink and downlink channels are not reciprocal. Hence, to generate precoding/beamforming vector for each user, BS transmits a pilot signal to all users in the cell and then all users feedback estimated CSI of the downlink channels to the BS as shown in Fig. 4. During uplink transmission, BS needs CSI to decode the signal transmitted by the users. To detect the signal transmitted by the user, CSI is acquired by sending pilot signal in the uplink transmission.

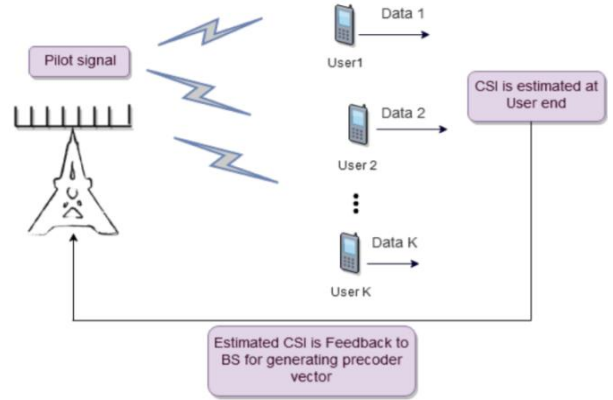


Figure 4: Downlink transmission in an FDD Massive MIMO system

Mathematical Equation

Be that as it may, because of the wide data transfer capacity and diminished flag vitality, UWB beats experience extreme heartbeat twisting.

Consider the received signal at q^{th} receive antenna represented in matrix form as

$$Y(n) = (U(n).H(n)) + V(n) \tag{1}$$

The posteriori error is given by the difference between the received preamble symbol and its corresponding estimate at time n on q^{th} receiving antenna

$$e(q, n) = y(q, n) - \tilde{y}(q, n) \tag{2}$$

$$e(q, n) = y(q, n) - X_{pre}(n)\tilde{H}_q \tag{3}$$

Where \tilde{H} has the same dimensionality as H . The weighted Square-root error at time n is given by

$$e(q, n) = \sum_{i=0}^n \lambda^{n-i} (|e(q, i)|)^2 \tag{4}$$

Where λ is weigh factor, whose value lies between (0, 1) depending on channel fading conditions is present. Solution of the above equation gives the optimum value for the estimated channel coefficients H at time n . The optimum solution

$$H_{opt}(n) = R^{-1}_x(n) \times R_{yx}(n) \tag{5}$$

Where $R_{yx}(n)$ is the autocorrelation matrix of the preamble signal, $R^{-1}_x(n)$ is the cross correlation matrix between received signal and the preamble signal at time n .

V. 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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