A Comparative Study of Different Channel Estimation Technique for A Massive MIMO Communication System.

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***Abstract* — The emerging fifth generation (5G) wireless communication system raises new requirements on spectral efficiency and energy efficiency. A massive multiple-input multiple-output (MIMO) system, equipped with tens or even hundreds of antennas, is capable of providing significant improvements to spectral efficiency, energy efficiency, and robustness of the system. For the design, performance evaluation, and optimization of massive MIMO wireless communication systems, realistic channel models are indispensable. Also, we compare channel characteristics of massive MIMO channel models, such as beam forming, capacity with respect to SNR. The upcoming data traffic growth created by the evolution of smart phones, tablet computers and Machine to Machine (M2M) communication outstrips the capacity increase of wireless communications networks. As a powerful countermeasure, in the case of full-rank channel matrices, MIMO techniques are potentially capable of linearly increasing the capacity or decreasing the transmit power upon increasing the number of antennas. Hence, the recent concept of large-scale MIMO (LS- MIMO) systems has attracted substantial research attention and been regarded as a promising technique for next-generation wireless communications networks. This paper considers pilot- based channel estimation in large-scale multiple-input multiple- output (MIMO) communication systems. Motivated by the fact that computational complexity is one of the main challenges in such systems, we tried to reduce the complexity of the system using different algorithms. The coefficients of the polynomial are optimized to minimize the mean square error (MSE) of the estimate. Finally we discussed the need of LS-MIMO with some of advantages and showed the difference between the capacity range of MIMO and Massive MIMO. By analyzing the results we can observe the changes that had been obtained and can decide the perfect algorithm for channel estimation which gives rise to a good communication system.**

Keywords— Large Scale MIMO (LS-MIMO), Co-channel interference (CCI), large-scale/massive MIMO, MIMO detection, Bandwidth efficiency (BE), Energy efficiency (EE), Self Interference Cancellation (SIC), Zero Forcing (ZF), Matched filter (MF), Machine to Machine (M2M) communication.

I. INTRODUCTION

MIMO techniques can bring huge improvements in spectral efficiency to wireless systems, by increasing the spatial reuse through spatial multiplexing [2]. While 8×8 MIMO transmissions have found its way into recent communication standards, such as LTE-Advanced [3], there is an increasing interest from academy and industry to equip base stations (BSs) with much larger arrays with several hundreds of antenna elements [4]–[9]. Such large-scale MIMO, or ―massive MIMO‖, techniques can give unprecedented spatial resolution and array gain, thus enabling a very dense spatial reuse that potentially can keep up with the rapidly increasing demand for wireless connectivity and need for high energy efficiency.

Massive MIMO is an emerging technology that scales up MIMO by possibly orders of magnitude compared to current state-of-the-art. With massive MIMO, we think of systems that use antenna arrays with a few hundred antennas, simultaneously serving many tens of terminals in the same time-frequency resource. The basic premise behind massive MIMO is to reap all the benefits of conventional MIMO, but on a much greater scale. Overall, massive MIMO is an enabler for the development of future broadband (fixed and mobile) networks which will be energy-efficient, secure, and robust, and will use the spectrum efficiently. As such, it is an enabler for the future digital society infrastructure that will connect the Internet of people, Internet of things, with clouds and other network infrastructure. Many different configurations and deployment scenarios for the actual antenna arrays used by a massive MIMO system can be envisioned [6].

Massive MIMO relies on spatial multiplexing that in turn relies on the base station having good enough channel knowledge, both on the uplink and the downlink. On the uplink, this is easy to accomplish by having the terminals send pilots, based on which the base station estimates the channel responses to each of the terminals. The downlink is more difficult. In conventional MIMO systems, like the LTE standard, the base station sends out pilot waveforms based on which the terminals estimate the channel responses, quantize the so-obtained estimates and feed them back to the base station. This will not be feasible in massive MIMO systems, at least not when operating in a high-mobility environment, for two reasons. First, optimal downlink pilots should be mutually orthogonal between the antennas. This means that the amount of time frequency resources needed for downlink pilots scales as the number of antennas, so a massive MIMO system would require up to a hundred times more such resources than a conventional system. Second, the number of channel responses that each terminal must estimate is also proportional to the number of base station antennas. Hence, the uplink resources needed to inform the base station about the channel responses would be up to a hundred times larger than in conventional systems. Generally, the solution is to operate in TDD mode, and rely on reciprocity between the uplink and downlink channels—although FDD operation may be possible in certain cases [12].

Some of the benefits of Massive MIMO are as follows:

- Massive MIMO can increase the capacity up to 10 times or more and simultaneously, improve the radiated energy-efficiency in the order of 100 times.
- Massive MIMO can be built with inexpensive of cost, low-power components.
- Massive MIMO enables a significant reduction of latency on the air interface.
- Massive MIMO simplifies the multiple-access layer.
- Massive MIMO increases the robustness both to unintended man-made interference and to intentional jamming.

Even with a lot of benefits, the Massive MIMO has some of the limiting factors that has to be concentrated, as follows:

- Channel Reciprocity.
- Pilot Contamination.
- Radio Propagation and Orthogonality of Channel Responses.

A. WHY ARE MASSIVE MIMO‘s IMPORTANT?

The multimedia data traffic conveyed by the global mobile networks has been increasing, and this trend is set to continue, as indicated by Cisco‘s visual networking index forecast. This explosive growth is mainly fuelled by the prevalence of smart phones, laptops and tablets, as well as by the emergence of machine-to-machine (M2M) communications. Additionally, the design of wireless communication systems is highly constrained by the radio spectrum, which is exemplified by the overcrowded frequency allocation chart of the United States. As a consequence of the combined effect of the mobile data traffic growth and the scarcity of favorable radio spectrum in the low-loss frequency range, the forthcoming fifth generation (5G) communication systems have to resort to the employment of massive/large scale multiple-input multiple-output (LS- MIMO) transmission techniques, which invoke a large number of antenna elements at the transmitter and/or receiver for achieving a high spectral efficiency and high energy-efficiency [18].

A range of other fundamental technologies conceived for 5G communications are closely related to LS-MIMO. For example, both millimeter wave communications and LSMIMOs may be regarded as enabling techniques facilitating high-dimensional physical-layer communication technologies. Their difference is that LS-MIMOs achieve high dimensionality in the spatial domain, while millimeter wave communication systems achieve a high dimensionality in the frequency domain by operating at frequencies ranging from about 30 GHz to 300 GHz, which is much higher than the operating frequencies of contemporary third generation (3G)/4G systems. All the above reasons tends to create a natural marriage amongst LS-MIMO, millimeter wave and Small-cell technologies [17].

B. APPLICATIONS

Large scale MIMO can be used in fields like cellular communication systems and broadband communication systems which are widely spreaded throughout the world for networking from one place to another and from one person to another person. This system architecture also provides bandwidth efficiency and energy efficiency for upcoming advanced wireless communication [12].

The cellular communication includes the applications like 5G mobile phones, high speed internet services, vehicle services, home solutions, and business applications involving big data.

The broadband communication includes the applications like Wi-Fi, WiMax, Email services, video based application and etc.

II. CHANNEL ESTIMATION

A known channel properties of a communication link (referred as Channel State Information (CSI)) describes how the signal propagates from transmitter to the receiver and represents the combined effect of it. This method is called as Channel Estimation. The CSI helps to adapt transmissions to present channel conditions which are used for achieving the reliable communication with high data rates in MIMO, OFDM systems. The CSI is estimated at the receiver and usually quantized and then fed back to the transmitter which gives rise to a technique called reverse link estimation. Therefore both transmitter and receiver can have different channel state information. The CSI at the transmitter and receiver are sometimes referred as Channel State Information Transmitter (CSIT) and Channel State Information Receiver (CSIR) respectively [15].

Basically there are two levels of CSI namely

- Instantaneous CSI (Short-term CSI).
- Statistical CSI (Long-term CSI).

Instantaneous CSI is a type of information that help us to know the current channel conditions which can be viewed as knowing the impulse response of a digital filter. This channel state information helps to achieve low bit error rates.

The statistical CSI is a type of information in which the statistical characterization of the channel is known. As with instantaneous CSI, the information can be used for transmission optimization [15].

A. WHY CHANNEL ESTIMATION?

Channel estimation has been implemented to obtain the transfer function of the real channel. We need channel estimation for the coherent detection of the transmitted data and the sub-channel frequency responses must be estimated and removed from the frequency samples. Normally in wireless systems the information that has been transmitted reaches receiver after passing through a radio channel.

For conventional coherent receivers, the effect of channel through on which the signal has been transmitted must be estimated to recover the transmitted information. As long as the receiver receives the accurate estimate how the channel modifies the transmitted signal it can recover the transmitted information.

Usually transmitted signals are typically reflected and scattered, arriving at receivers along multiple paths. Also, due to the mobility of transmitters, receivers, or scattering objects, the channel response can change rapidly over time. Most important of all, the radio channel is highly random and the statistical characteristics of the channel are environment dependent. Multipath propagation, mobility, and local scattering cause the signal to be spread in frequency, time, and angle. These spreads, which are related to the selectivity of the channel, have significant implications on the received signal. Channel estimation performance is directly related to these statistics [25].

B. TYPES OF CHANNEL ESTIMATION

Channel estimation has a very long and rich history in single carrier communication systems. Here the CIR is typically modeled as an unknown time-varying FIR filter, whose coefficients has to be estimated. Many of the channel estimation approaches of single carrier systems can be applied to multi-carrier systems. These unique properties of multi- carrier transmission bring about additional characteristics that allow the development of new approaches for channel estimation of multi-carrier systems [9].
Channel estimation techniques can be categorized into two groups namely

1. Blind channel estimation.
2. Non blind channel estimation.

Blind channel estimation method destroys the statistical behavior of received signal and requires the large amount of data for distinguishing the transmitted signal. Hence this technique suffers from severe loss of performance in fast fading channels.

Non blind channel estimation method is one of the method in which the information of previous channel estimates or some portions of the transmitted signals are known to the receiver to be used for the channel estimation. In this project we are processing with a non blind channel estimation technique in order to estimate a better channel to transfer the information from transmitter and receiver in LS-MIMO systems which use same frequency and time without extending the bandwidth efficiency that result in reliable communication [16].

In order to achieve expected high capacity and gain in massive MIMO systems their exist another technique called Semi blind channel estimation. The semi-blind channel estimation technique combines the blind channel estimation and training- based channel estimation techniques, and can be implemented where information on the input signals i.e. transmit and training symbols are not available, the estimation proceeds using ‗unknown‘ factors that affect the channel characteristics.

III. METHODOLOGY

This section includes the different classes of channel estimation techniques for a Massive MIMO system which is as shown in the figure below.

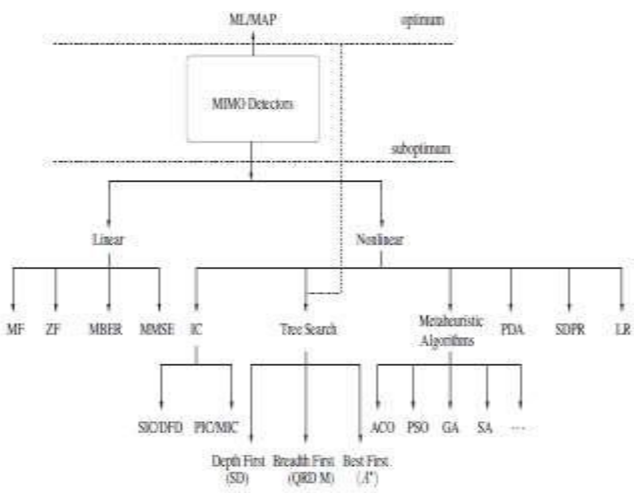

Fig 1: Overview of representative MIMO detectors.

In this paper, the Maximum Likelihood approach for MIMO detectors which has linear characteristics using Matched Filter and Minimum Mean Square Error are discussed.

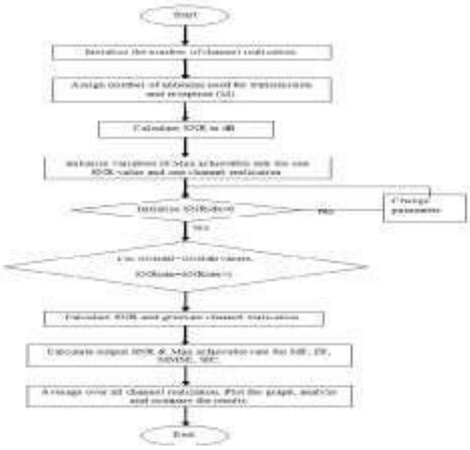

Fig 2: flowchart of design and implementation.

The achievable rates are averaged over channel realizations drawn from a identical and independent distributed Rayleigh distribution. In particular, we are comparing capacity with the SNR in order to evaluate with the Massive MIMO performance. In order to implement with the above flow chart first we had to calculate with the SNR, capacity, channel response and maximum achievable rate for MF, ZF, MMSE and SIC.

I. RESULTS.

After design and implementation steps are completed with the coding and checked with the error free code. The code is compiled and run to get the desired output. Here we have compared with some of the parameters like capacity, beam forming and by increasing number of antenna with respect to signal to noise ratio (SNR). The results are as follows

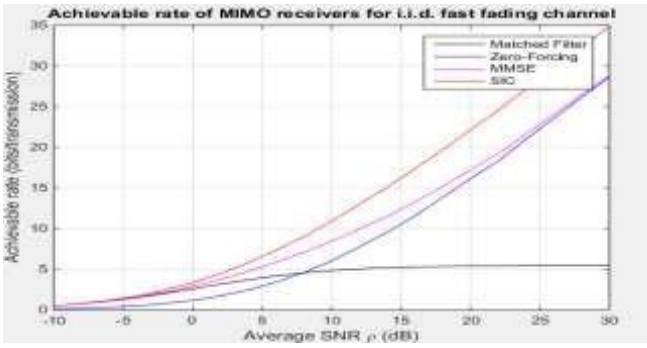

Fig 3: Achievable rate of MIMO receivers for a fast fading channel.

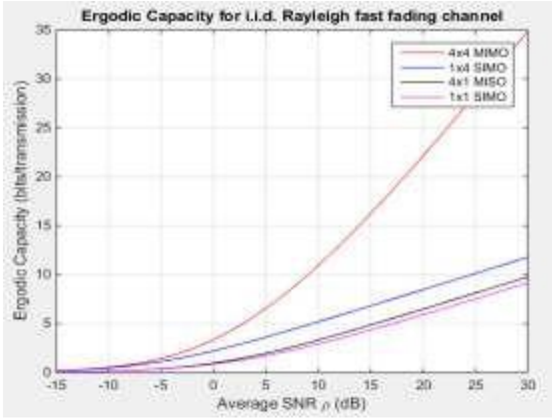

Fig 4: Capacity vs SNR.

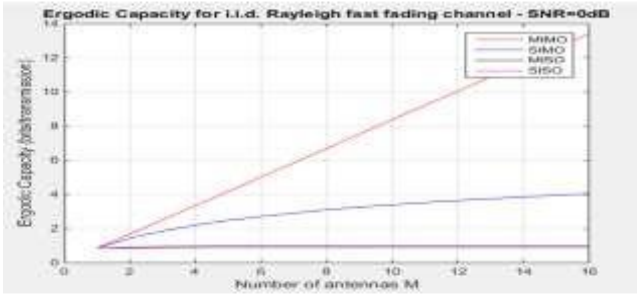

Fig 5: Ergodic capacity vs Number of antennas for different configuration antennas.

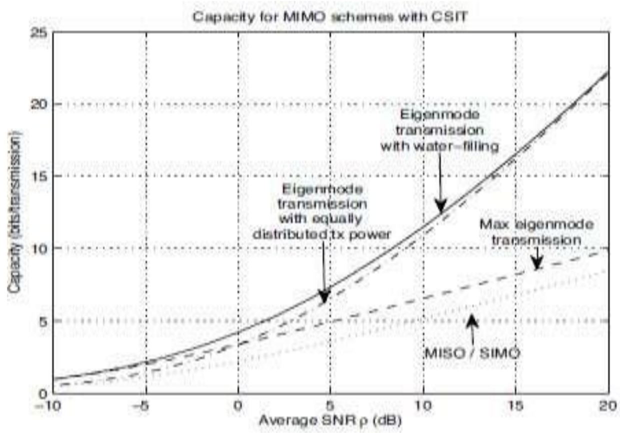

Fig 6: Achievable rate of beam forming schemes averaged over channel realization.

II. CONCLUSION

The concept of LS-MIMO systems are regarded as a paradigm shift in the wireless communication and signal processing community. In this paper we tried the readers to understand with a basic knowledge of Large scale MIMO. This includes what is Massive MIMO, need of Massive MIMO, needs for Channel estimation. Massive MIMO channel characteristics such as the spherical wave front effect and non stationary properties on the antenna array have significant impacts on channel models. These models aim to capture key characteristics of various scenarios emerging in 5G communication networks and provide different trade-off between model accuracy and complexity.

Therefore, Massive MIMO antennas finally results in high data rate, high directivity, high bandwidth efficiency and energy efficiency that help to clear the upcoming scarcity of data rate with enormous amount of traffic services.

By observing the experimental results we can conclude that

- Increase in data rate which helps in fast communication for Massive MIMO systems.
- Better spectral utilization.
- Low power consumption.
- Greatly decreases the computational complexity of the communication system.
- LS MIMO with pre-coders at the transmitter further increases the efficiency of the system.

III. FUTURE SCOPE

- ✓ In future we can also make advanced improvement for massive MIMO in terms of increasing the throughput by increasing the number of pre-coders at the transmitter region.
- ✓ Pilot contamination of symbols can be avoided.

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