Performance Evaluation of Massive MIMO in terms of capacity

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Abstract— Massive MIMO (also known as large-scale antenna systems, hyper MIMO, full-dimension MIMO and hybrid MIMO) makes a clean break with current practice through the use of a large number of service antennas over active terminals and provide large network capacities in multi-user scenarios. With this, one can measure the channel matrix and compute the achievable rate of the massive MIMO system. The measured channel capacity is linearly increasing with the number of antennas of the base station. The Vandermonde channel model is more realistic to describe the massive MIMO architecture in terms of capacity. By adjusting the range for angle of arrival 'θ' and the base station antenna distance 'd' during the simulation, the Vandermonde channel model capacity also varies.

Key words: Massive MIMO, very-large MIMO, multi-user MIMO (MU MIMO), BS- Base Station. Channel model

I. INTRODUCTION

Massive multiple-input multiple-output (MIMO) is an emerging technology that scales up MIMO by orders of magnitude compared to the current state of the art. Multiple-input multiple-output (MIMO) technology is a topic of concern from the past two decades because it is proved to be efficient in terms of reliability and capacity of the wireless systems. With massive MIMO, we consider multi-user MIMO (MU-MIMO) systems [1] where base stations are equipped with a large number (say, tens to hundreds) of antennas. As a comparison, the LTE standard only allows for up to 8 antennas at the base station [2]. In this way, massive MIMO scales conventional MIMO by an order or two in magnitude. Typically, a base station with a large number of antennas serves several single-antenna users in the same time-frequency resource.

While initial work on the problem focused on point-to-point MIMO links where two devices with multiple antennas communicate with each other, focus has shifted in recent years to more practical multi-user MIMO (MU-MIMO) systems, where typically a base station (BS) with multiple antennas simultaneously serves a set of single-antenna users and the multiplexing gain can be shared by all users. In this way, expensive equipment is only needed on the BS end of receivers large adjacent channel interference are produced. That adjacent channel interference is helpful to achieve higher strength of signal at receiver side due to use of MIMO diversity repetition coding technique. Furthermore, due to multi-user diversity, the performance of MU-MIMO systems is generally less sensitive to the propagation environment than in the point-to-point MIMO case. As a result, MU-MIMO has become an integral part of communications standards, such as 802.11 (Wi-Fi), 802.16 (WiMAX), LTE, and is progressively being deployed throughout the world. For most MIMO implementations, the BS typically employs only a few (i.e., fewer than 10) antennas, and the corresponding improvement in spectral efficiency, while important, is still relatively modest.

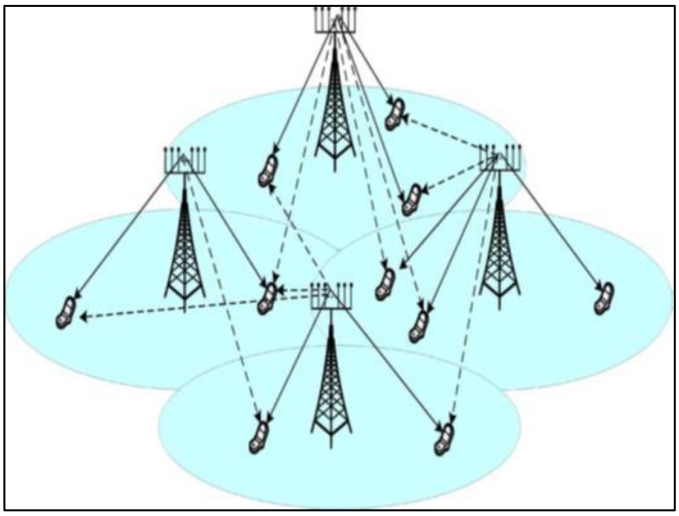

Fig. 1: Illustration of Massive MU-MIMO systems [5]

In a recent effort to achieve more dramatic gains as well as to simplify the required signal processing, massive MIMO systems or large-scale antenna systems (LSAS) have been proposed in [3], [4], where each BS is equipped with orders of magnitude more antennas, e.g., 100 or more. A massive MU-MIMO network is depicted in Fig. 1. Asymptotic arguments based on random matrix theory [4] demonstrate that the effects of uncorrelated noise and small-scale fading are eliminated, the number of users per cell are independent of the size of the cell, and the required transmitted energy per bit vanishes as the number of antennas in a MIMO cell grows to infinity [5].

In this paper, first we discuss about system model of Massive MIMO. Then system channel capacity is calculated using vondermonde channel. Vandermonde channel depends on two parameters: the range for angle of arrival ‘θ’ and the base station antenna distance‘d’. By varying one parameter at time and remaining one parameter fixed at time, the result is different. In simulation, first the base station distance between two antenna‘d’ has been varied for fixed value of the range for angle of arrival ‘θ’. Secondly, the range for angle of arrival ‘θ’ has been varied for fixed value of the base station distance between two antenna‘d’

II. System Overview

Consider massive MIMO and MU-MIMO technology in cellular systems, where a base station is equipped with tens to hundreds of antennas, and communicates with many users simultaneously through spatial multiplexing. Fig. 2 illustrates the MU-MIMO system model in both downlink and uplink transmissions, for a single cell. MIMO with a large number of antennas, however, should not be limited to multi-user scenarios. It can also be used in single-user scene

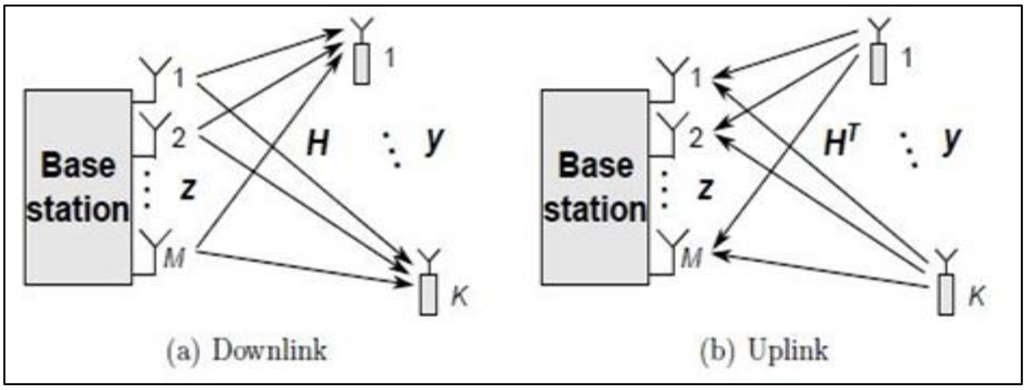

Fig. 2: An MU-MIMO system model, in the (a) downlink and (b) uplink [7]

An M-antenna base station serves K single-antenna users in a spatial-multiplexing manner. Channel reciprocity is assumed, so the relation between the downlink and uplink channel matrices is simply the matrix transpose [7].The downlink signal model for each time-frequency resource is,

$$Y_l = \sqrt{\rho_{dl}} H z_l + n_l \quad (1)$$

Where H_l is a K*M the propagation channel matrix, z_l is normalized vector across the M antennas Assume that$E\{||z_l||^2\} = 1$, y is the receive signal vector at the K users, and n is the white-noise vector with i.i.d. circularly-symmetric complex Gaussian, CN (0; σn2), elements, so $\sqrt{\rho_{dl}}$ contains the total transmit power in the downlink. Two power-scaling factors ($\rho_{dl} = \rho K/M$) , where ρ is an SNR factor. We scale up to transmit power with the number of users K, and choose to 1) keep it constant or 2) scale it down with the number of antennas M. From the term$\rho K/M$, we increase the transmit power with the number of users and reduce it as the number of base station antennas grows [7]. As K Increases, we keep the same transmit power per user. With increasing M the array gain increases and we choose to harvest this as reduced transmit power instead of increased receive SNR at the users

Due to reciprocity, the uplink channel matrix isH_l^T, and the signal model becomes

$$Z_l = \sqrt{\rho_{ul}} H_l^T y_l + n_l \quad (2)$$

The total transmit power from all users is ρ_{ul} and $\rho_{ul} = \rho K/M$ depending on used power-scaling scheme.

A. Capacity and achievable rates:

Under the assumption that the receiver has perfect knowledge of channel matrix H, the capacity of the $N_t * N_r$ MIMO channel is computed by [17]

$$C = log_2 \det\left(I_{N_r} + \frac{\rho}{Nt} H H^H\right) \quad (3)$$

Where $I_{N_r}$the identity matrix and the H means Hermitian transposition.

B. Vandermonde channel model:

The Vandermonde random matrix is given as following:

$$\begin{bmatrix} 1 & \cdots & 1 \\ e^{-j2\pi\frac{d}{\lambda}\sin(\theta_1)} & \cdots & e^{-j2\pi\frac{d}{\lambda}\sin(\theta_N)} \\ \vdots & \ddots & \vdots \\ e^{-j2\pi\frac{d}{\lambda}(M-1)\sin(\theta_1)} & \cdots & e^{-j2\pi\frac{d}{\lambda}(M-1)\sin(\theta_N)} \end{bmatrix}$$

The Vandermonde random matrix is introduced to describe the channel model for a base station receiver with M antennas and N mobiles, where d is the antenna spacing and λ is the wavelength. The angles of arrival are supposed to be uniformed distributed within (-θ; θ). The elements of the Vandermonde matrix can also have phases with uniform distribution for comparison. The received signal at the base station is given by

$$y = VP^{\frac{1}{2}}s + n \quad (4)$$

Where y, s, n are respectively the M *1 received vector, the N*1 transmit vector, and the M*1 additive noise, V is the Vandermonde channel matrix, P is the power gain matrix which can be set as identity matrix in simulation. The Vandermonde model, compared with Gaussian channel model, is close to the real massive MIMO system from the architecture point of view.

III. SIMULATION RESULT

The simulations have been done for the capacity under the Vandermonde channel model, by adjusting two parameters d and θ. The simulation frequency is 926MHz, the corresponding wavelength is λ = 32.4cm. Selection of the parameter d in {λ, λ/2, 3λ/2} and the simulation has been carried out for Vandermonde model by adjusting λ for each fixed d.

Firstly, Demonstration of the linearity of the capacity with the number of antennas by the measured channel capacity in Fig. 3 is done. The capacity of the system increases linearly with the number of antennas, for both the simulated Gaussian channels, Vandermonde channels and the measured channels. From simulation it has been observed that:

- The capacity of Vandermonde channel decreases when θ is getting smaller for fixed d.
- The capacity of Vandermonde channel increases when d is bigger for fixed θ

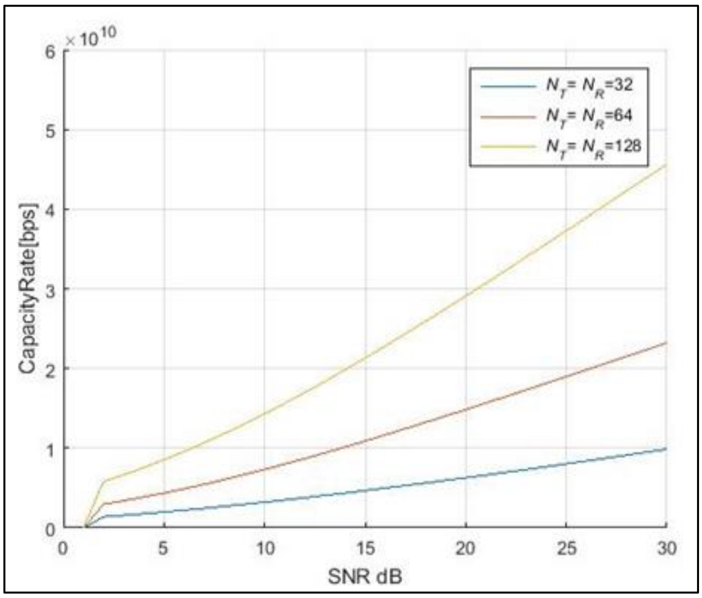

Fig. 3: Capacity of massive MIMO (d = λ/2, θ=35)

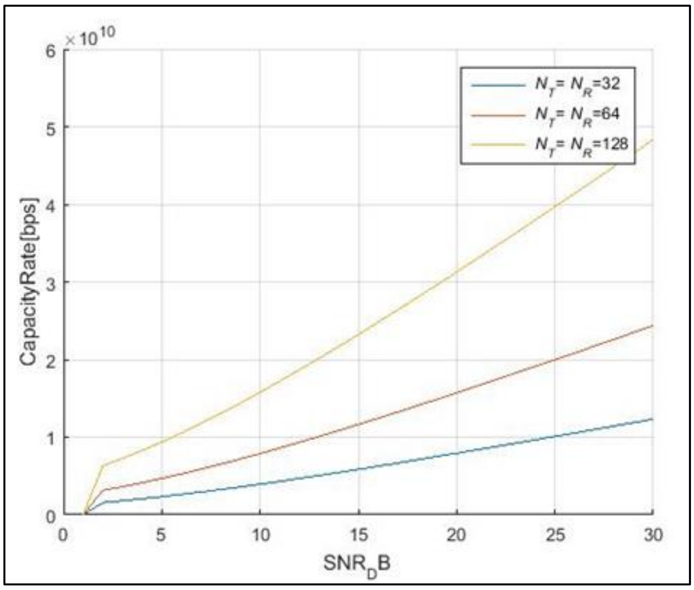

Fig. 4: Capacity of massive MIMO (d = λ, θ=35)

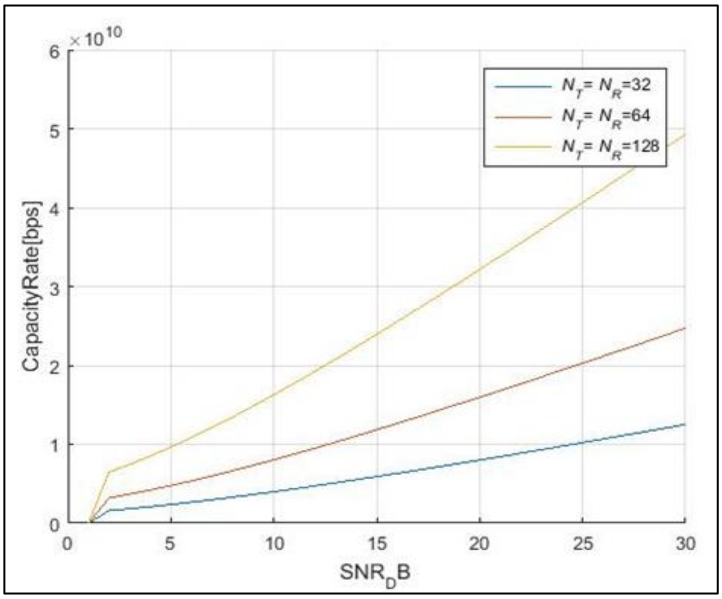

Fig. 5: Capacity of massive MIMO (d =3λ/2, θ=35)

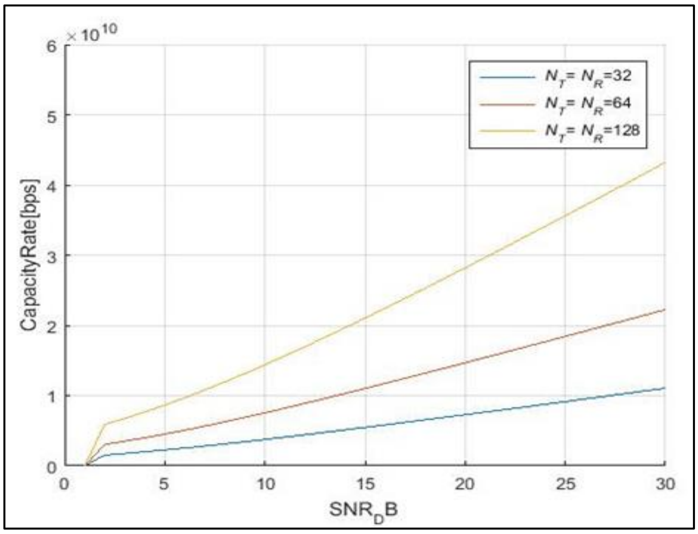

Fig. 6: Capacity of massive MIMO (d = λ/2, θ=26)

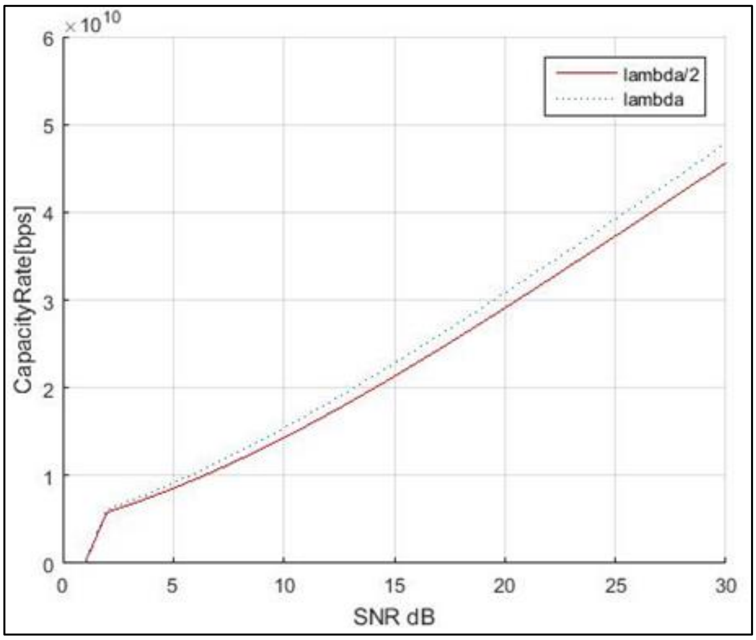

Fig. 7: Capacity of massive MIMO (d = λ/2, d = λ)

IV. CONCLUSION

This paper presents simulation of a vandermonde channel. The system capacity is increased from the measured channel matrix in terms of Gbps. It has been observed that the measured channel capacity agrees with that of the Vandermonde channel model with the optimal parameters: the range of the arrival angles and the base station antenna distance. It is recommend the Vandermonde channel model to be used in future research, as it is more realistic than the current widely used Gaussian model.

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