3D-MIMO With Massive Antennas In 5G Technology

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Abstract - *This paper presents role of 3D-MIMO with massive antennas in 5G Technology. Multiple-input–multiple-output (MIMO) techniques by using massive antennas in wireless systems and has been considered important in future fifth-generation(5G) mobile communications system for sending and receiving data with high data rate. Considering the limitation of antenna panel size, placing the massive antennas in 2-D grid is an effective way for its commercialization, which is termed as "3D-MIMO". the performance of 3D-MIMO with massive antennas by system-level simulation using practical assumption and 3-D channel model and test the 3D-MIMO in field trial with commercial terminal and networks. 3D-MIMO is evaluated and analyzed by exploiting a system-level simulation platform and the well-established 3D channel model. The simulation results showing that 3D-MIMO with 64 antennas can enhance the cell-average and cell-edge throughput by 117% and 228%, respectively, which verifies the promised gains to be brought by 3D-MIMO for future 5G systems. finally, we comparing the Downlink Precoding for TDD Systems with 3D-MIMO of SU-MIMO Transmission and MU-MIMO Transmission with respect to 200m and 500m.*

Key Words: 2D, 3D-Beamforming, MIMO, 5G, Massive Antennas.

1.Introduction:

MIMO technologies can significantly improve the capacity and reliability of wireless systems, and have been widely applied in current cellular mobile communication systems, such as long-term evolution (LTE) systems. In order to meet the demand for higher spectrum efficiency in 5G systems, more antennas can be deployed at base stations (BS) to increase capacity, which is referred to as massive MIMO in academia. Specifically, the current commercialized antenna products have a limited number of active antennas: usually 2, 4 or a maximum of 8. To exploit the benefit of more antennas in future 5G systems, the number of active antennas can be increased to 64, 128 or more. Considering that the antenna panel size is proportional to the number of antennas, if the massive antennas are deployed in a horizontal line, the integrated antenna panel will be quite large. Placing the antenna in a two-dimensional grid is an effective way to reduce the antenna panel size, an approach that is termed 3D-MIMO and which has been studied in the Third Generation Partnership Project (3GPP) for possible future applications. 3D-MIMO not only can exploit the degree of freedom of massive transmit antennas, but can also adjust the direction of the transmit beam in both the horizontal and vertical dimensions, which helps in enhancing the spatial resolution in the third dimension, so improving the signal power and reducing intercell interference.

2. Methodology

Massive MIMO technology: The concept of massive MIMO in the context of multiple cells and TDD scenario. Thus, some different features of the limited number of antennas in single cell were found. massive MIMO technology refers to that the base station is equipped with a large number of antennas, usually a hundred or several hundred antennas, which is several orders of magnitude higher than the number of antennas in the existing communication system. It serves multiple users simultaneously on the same time-frequency resource, and mobile terminals generally adopt the communication mode of single antenna reception. The basic model of massive MIMO is shown in figure Modern communication systems rely upon multiple antennas at the transmitter and/or receiver to enhance link performance. This class of techniques, known as multiple input, multiple output (MIMO), exploits the spatial dimension by employing spatial encoding and/or decoding. MIMO techniques can be extended beyond point-to-point to multi-user applications with multi-user MIMO (MU-MIMO). MU-MIMO can be used to separate users by their spatial position, allowing for further network densification and increased capacity. MU-MIMO provides higher guarantees for spatial multiplexing than a point-to-point system but inherits challenges in near-far power control and time/frequency synchronization. MU-MIMO modes have been provisioned as part of the LTE and LTE-A standards.

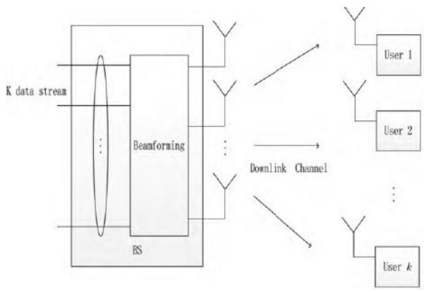

Fig -1: Basic model of Massive

Radically departing from existing MIMO is a new generation of large antenna array techniques, commonly referred to as "Massive MIMO", where the number of antennas at the base station is increased drastically (by an order of magnitude or more over current MIMO systems) to harvest further gains. Massive MIMO theory has promised vast gains in spectral efficiency, increase in energy efficiency, and reduction in network interference, all of which are key to address the demands of a data-centric world where spectrum and energy are increasingly precious.

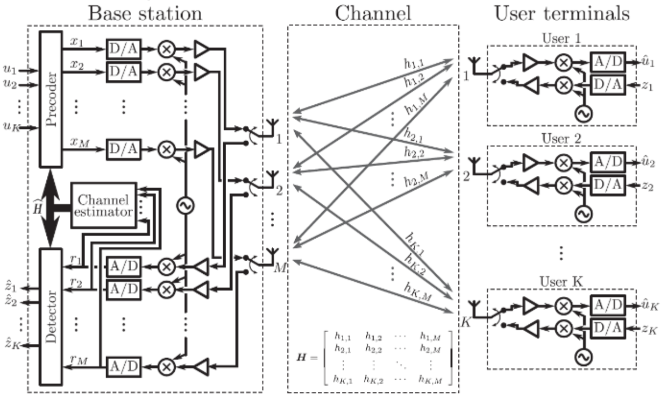

Fig -2: Simplified Massive Model, assuming time-division &duplex channel reciprocity

The basic concept of Massive MIMO is shown in figure 2, where a base station is using M antennas to spatially multiplex K<<M single-antenna terminals. The success of such a spatial multiplex, in both uplink and downlink, relies on several important concepts. One of the most important requirements is that the base station should have sufficiently good knowledge of the propagation channel in both directions, on which efficient downlink precoders and uplink detectors can be based. horizontal line, the integrated antenna panel will be quite large. Placing the antenna in a two-dimensional grid is an effective way to reduce the antenna panel size, an approach that is termed 3D-MIMO. See below figure 3, that comparison between 2D-MIMO with limited Antennas with 3D-Massive Antennas.

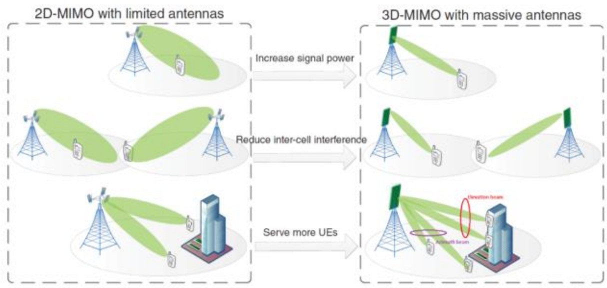

Fig - 3: 2D-MIMO vs 3D-MIMO with massive antennas

2D & 3D Beamforming: Beamforming is a technique that focuses a wireless signal towards a specific receiving device, rather than having the signal spread in all directions from a broadcast antenna, as it normally would. The resulting more direct connection is faster and more reliable than it would be without beamforming. Multi-antenna technologies such as massive Multiple-Input Multiple-Output (massive MIMO) and beamforming are key features to enhance performance, in terms of capacity and coverage, by using a large number of antennas intelligently. With the upcoming 5G New Radio (NR), FD-MIMO (Full Dimension MIMO) will play a major key role. FD-MIMO consists in arranging a large number of antennas in a 2D array, which enables to use 3D beamforming i.e., beamforming in both horizontal and vertical dimensions. The present paper provides a 3D beamforming model where beam steering depends on the random spatial distribution of users. We attempt to derive some analytical results regarding the probability distribution of antenna beamforming radiation pattern. Also, through system level simulations, we show how 3D beamforming can reduce interference impact, compared to the traditional 2D beamforming, and enhances system performance in terms of the coverage probability and user's throughput.

Fig - 4.a **Fig – 4.b** **Fig – 4.c**

comparison of different beamforming of 2D-MIMO & 3D-MIMO beamforming with Massive Antennas. Here Fig-4.a: Azimuth 2D beamforming from a horizontal uniform linear array (ULA), Fig-4.b: Elevation 2D beamforming from a vertical ULA, Fig-4.c 3D beamforming from a planar array with Massive Antennas.

3. Application Scenarios of 3D-MIMO with Massive Antennas:

the benefits of 3D-MIMO are mainly based on the beamforming scenario three types. those are explained below

I) macro and micro coverage scenario: Considering the urgent requirement for cell throughput enhancement in current cellular systems, one promising scenario of 3D-MIMO with massive antennas is the macro-cell and micro-cell coverage scenario. By exploiting horizontal and vertical domain beamforming to simultaneously serve more UEs by multi-user MIMO (MU-MIMO) transmission, cell throughput can be greatly improved. By forming narrower and more directional beams, the signal power can be increased and intercell interference is more likely to be avoided, which helps in promoting spectral efficiency.

II) high-rise scenario: The height of buildings can be vastly different around the world. One typical urban environment sees some higher buildings (around thirty floors) surrounded by many lower buildings (4–8 floors). Nonetheless, the UEs in the high-rise scenario (more than 8 floors) cannot be covered properly by typical macro-BSs, because these normally use down tilt antennas. In such scenarios, 3D-MIMO can solve the coverage problem of UEs in higher floors by flexibly adjusting the beam direction in the elevation domain. In addition, it is possible to apply elevation-domain MU-MIMO between UEs at lower and higher floors due to the large elevation angular separation, which should greatly improve spectral efficiency.

III) indoor scenario: According to published statistics, 70% of current cellular traffic is indoors: at home or in an office. In the near future, this figure is envisioned to increase to 90% or more. In indoor scenarios, the scatters are rich, which makes it suitable for exploiting the multiplexing gain of MIMO transmission. As shown in Figure 5, by placing the 3D-MIMO array under the roof, the forming of beams in different directions, together with the rich scatters, allows more UEs to be served, so as to meet the explosive growth of traffic in indoor.

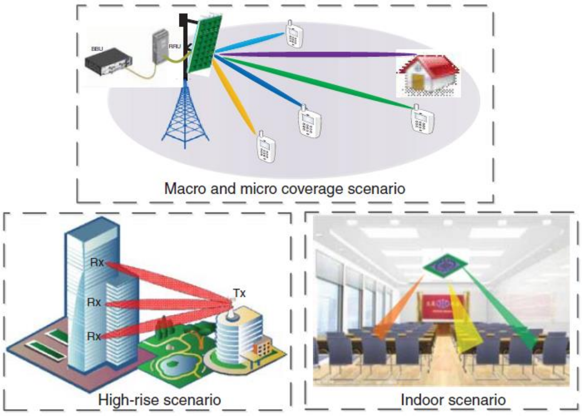

Fig - 5: Deployment scenarios for 3D-MIMO with massive antennas

4. 3D-MIMO Gain Based on Techniques in Current Standards:

In current LTE standards, MIMO transmission can be achieved in two different manners: codebook-based and non-codebook-based transmission. Codebook-based solutions aim at solving the feedback problems in frequency division duplexing (FDD) systems. Although 3D-MIMO with massive antennas can inherently use such codebook-based transmission, the codebooks in current standards do not exploit the characteristics of 3D-MIMO well.

System Model: The comparison of traditional 2D-MIMO with 8 antenna ports and 3D-MIMO with 16, 32 and 64 antenna ports are shown below figure. The number of antenna elements in the four structures shown is the same, namely 64. The difference lies in the number of antenna ports Nt. Regarding traditional 2D-MIMO with 8 antenna ports, one port is mapped to 8 vertical antenna elements in a column. 3D-MIMO with 16, 32 and 64 antenna ports is constructed by mapping one antenna port to 4, 2 and 1 vertical antenna elements, respectively.

The received signal of UE*m* served by the *n*th BS is:

$$y_{m,n} = H_{m,n} W_{m,n} P_{m,n}^{1/2} s_{m,n} + \sum_{l=1, l\neq m}^{M} H_{m,n} W_{l,n} P_{l,n}^{1/2} s_{l,n} + \mathbf{Inf}_{m,n} + z_{m,n}$$

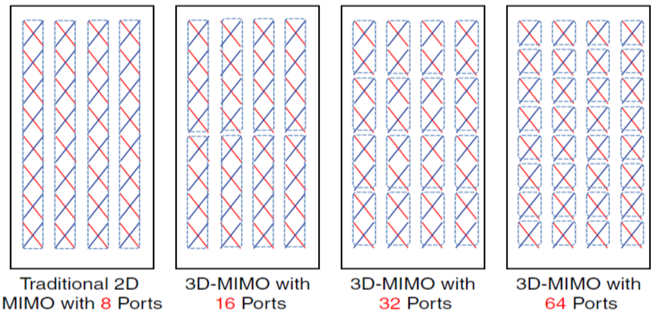

Fig - 6: Comparison of traditional 2D-MIMO with 8 antenna ports and 3D MIMO with 16, 32 and 64 antenna ports

where Hm,n∈ $C^{Nr \times Nt}$ is the equivalent channel between the UE_m and the transceivers of the nth BS. It worthwhile to note that when Na > Nt, the channel matrix includes the mapping from transceivers to antenna elements. $W_{m,n}$∈ $C^{Nt \times S}$ is the precoding matrix for the data transmission to UEm with the norm of each column as 1, $P_{m,n}$ is the power allocation matrix, and $s_{m,n}$ is data intended for UEm.

The part of $\sum_{l=1,l\neq m}^{M} H_{m,n} W_{l,n} s_{m,n}$ is represents the intra-cell interference,

while the term $Inf_{m,n}$ represents the inter-cell interference received by UE_m. zm,n is additive white Gaussian noise (AWGN) with zero mean and covariance σ^2_z.

SU-MIMO Transmission: SU-MIMO transmission trans -mits a signal to a single UE on each subcarrier, so M = 1. Then the intracell interference part in $y_{m,n}$ does not exist, and intercell interference $Inf_{m,n}$ and receive AWGN noise $z_{m,n}$ dominate the performance. The precoding on each carrier of the BS can be designed to achieve the channel capacity by eigen-beamforming and water-filling power allocation. Considering the complexity of water-filling power allocation in practical systems, we assume equal power allocation between the S streams of UE_m, so $P_{n,m}$ = (P_0/S) I_S, where I_S ∈ $C^{S \times S}$ is the identity matrix, and P0 is the total transmit power of the BS.

Denote the estimation of $H_{m,n}$ at the BS as $H_{m,n}$. The SVD decomposition of $H_{m,n}$ can be expressed as

$$\hat{H}_{m,n} = U_{m,n} \Lambda_{m,n} V_{m,n}^{H}$$

MU-MIMO Transmission: MU-MIMO transmission transmits signals to multiple UEs simultaneously on each subcarrier, which means M >1. By exploiting massive antennas for MU-MIMO transmission, the performance can be improved by low-complexity linear precoding. The basic idea is to transmit multiple data streams to UE_m at the null-space of the channel of all the other co-schedule UEs. Denote the estimated composed channel matrices of all UEs except UE_m as

$$\overline{H}_{m,n} = [\hat{H}^T_{1,n}, \dots, \hat{H}^T_{m-1,n}, \hat{H}^T_{m+1,n}, \dots, \hat{H}^T_{M,n}]^T$$

5. Performance of 3D-MIMO with Massive Antennas:

The four antenna structures illustrated in Figure 5 are considered in simulation, with an antenna panel equipped with 64 antenna elements. The first one is the traditional 2D-MIMO with 8 antenna ports. The other three are 3D-MIMO with 16, 32 and 64 antenna ports, where one transceiver is mapped to 4, 2 and 1 vertical antenna elements, respectively. Figures 7 and 8 show the simulation results of the four antenna structures under Uma and UMi scenarios. Both SU-MIMO and MU-MIMO are evaluated by system-level simulation, where up to two-UE pairing and up to dual-layer transmission per UE are considered for MU-MIMO. The performance metric is the UE perceived throughput (UPT), which is defined as

$$\text{UPT} = \frac{\text{amount of data (file size)}}{\text{time needed to download data}}$$

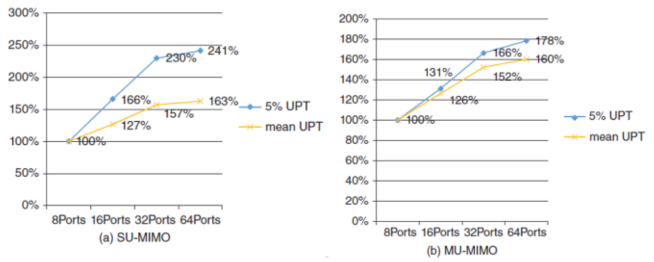

Fig - 7: Performance comparison of different numbers of ports under UMa scenarios, where one port corresponds to one transceiver Distance = 500m

From the simulation results we can observe that 3D-MIMO significantly improves system performance. In the UMa scenario, the performance gains of 3D-MIMO with 64 antenna ports compared with 2D-MIMO with 8 antenna ports are

- 63% and 141% for mean UPT and 5% UPT when SU-MIMO is considered
- 60% and 78% for mean UPT and 5% UPT when 2UE-MU-MIMO is considered

By contrast, the performance gain in the UMi scenario is larger:

- 125% and 299% for mean UPT and 5% UPT when applying SU-MIMO
- 117% and 228% for mean UPT and 5% UPT when employing MU-MIMO.

By analyzing the simulation results, we can observe that the capability of 3D-MIMO can be best exploited by MU-MIMO transmission, since more UEs can be spatially multiplexed.

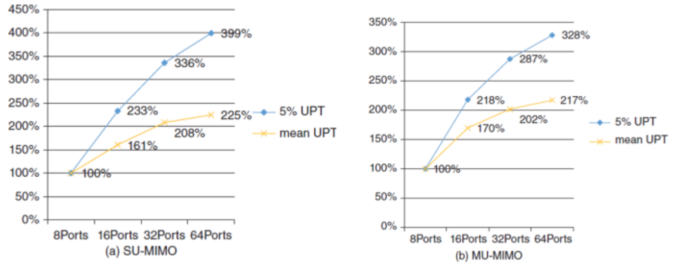

Fig - 8: Performance comparison of different numbers of ports under UMi scenarios, where one port corresponds to one transceiver. Distance = 200m

3. CONCLUSIONS

In this paper, 3d-MIMO technologies and structure of 2D 3D antenna Beamforming have been introduced. A dynamic beamforming algorithm for 3D MIMO in LTE-Advanced networks is proposed, which can be proved as an effective method to reduce intercell interference. Simulation results for 3D MIMO with different down tilt angle parameters and sector radius parameters are presented. Compared with 2D beamforming, 3D dynamic beamforming can improve both the cell edge UE throughput and the whole system's performance significantly. The simulation results showing that 3D-MIMO with 64 antennas can enhance the cell-average and cell-edge throughput by 117% and 228%, and the performance differences of different scenarios are analyzed in this paper.

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