Hybrid Beam Forming In Millimeter Wave MIMO Systems

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Abstract- *The increasing wireless data traffic demands have driven the need to explore suitable spectrum regions for meeting the projected requirements. In the light of this, millimeter wave (mm Wave) communication has received considerable attention from the research community. Typically, in fifth generation (5G) wireless networks, mm Wave massive multiple-input multiple output (MIMO) communications is realized by the hybrid transceivers which combine high dimensional analog phase shifters and power amplifiers with lower-dimensional digital signal processing units. This hybrid beam forming design reduces the cost and power consumption which is aligned with an energy efficient design vision of 5G.*

Conventional MIMO systems utilize digital beam forming where every antenna component is furnished with one radio recurrence (RF) chain. At the point when the quantity of the antennas are scaled up, the expense and power utilization of massive MIMO systems additionally increment essentially.So hybrid analog-and-digital beam formers have pulled in a great deal of consideration as a economically efficient way to deal with profit by the benefits of massive MIMO. In hybrid structure, few RF chains are associated with countless antennas through a system of phase shifters. The general target is to give basic and compelling hybrid beamforming answers for narrowband point-to-point and multiuser huge MIMO situations. Hybrid beamforming (HBF) incorporates analog beamforming with phase shift array in RF domain and digital beam forming in baseband domain. Phase shift array is normally made up with a lot of phase shifters.

The theoretical and simulation results indicate that the degradation of the performance is serious with the existence of phase shifting error and gain error and will be limited to the ceiling in the high SNR regime. The focus is recognizing the bit error rate in mm wave range with hybrid beamforming.

I. INTRODUCTION

Engineers and researchers in the telecommunication industry have been working on new technology to meet the need for higher data rates and more efficient communication. This necessitates making significant improvements to current systems and consumer equipment. Massive multiple-input multiple-output (MMIMO) is one of the innovations that will be used in the fifth generation (5G) of cellular communication systems. Massive MIMO can boost efficiency by allowing for more spatial multiplexing and diversity. Small-scale fading and noise disappear, and low-complexity linear beamforming techniques like zero forcing (ZF) and matched filtering (MF) achieve near-optimal efficiency in multiuser scenarios. Despite the advantages of large MIMO systems, their implementation is difficult and requires high power consumption. Research on fifth-generation (5G) wireless networks ,which aims to meet and solve various technical requirements and challenges, has recently received profound attention from academia and industry..In addition, the traffic demand of users has also increased dramatically over the years and this is due to the advent of a broad range of bandwidth-hungry applications such as three dimensional video games, car-to-x (Car2X) communications, high resolution augmented reality video streams (not only for gaming but also in factories-of-future). In order to accommodate such communications, the cellular network has to dramatically increase its capacity. In this regard, in order to accommodate such massive communications, it is forecasted that 5G network has to provide 1000 times higher capacity than the current system. This ambitious goal will become an inevitable energy crunch problem and thus it is very important to provide energy efficient solutions while maintaining the technical requirements. More than 70% of the mobile operator electricity bills come from the radio part. In addition, the increased extension of mobile networks contributes significantly to the carbon dioxide emission, which is a major concern nowadays. In order to meet these stringent 5G requirements and simultaneously maintain the energy efficient design, hybrid beamforming for millimeterwave (mmWave) is envisioned as an integral part of the 5Gwireless networks.

II. METHODOLOGY

The ideal mmWave massive MIMO hardware realization requires number of RF chains equal to the number of antennas. The RF chain consists of hardware components such as ADC/DAC, mixer, etc. On the other hand mmWave wireless channel does not encourage multipath reflections and offers a sparse channel between TX and RX. These two conditions motivates the design of hybrid beamforming with the number of RF chains as low as the required data streams. The increase of energy consumption in massive MIMO antennas technology adopted for 5G wireless communication systems is mainly due to the large number of antennas and RF chains. Large antenna arrays will be intensively used in the future mmWave cellular networks, and different possible antenna architectures and MIMO techniques will be needed. Instead of implementing a fully digital beamforming, which requires one distinct RF chain for each antenna, a two-stage hybrid linear precoding and combining scheme is a possible solution. Hybrid analog and digital beamforming is an emerging technique for large-scale MIMO systems since it can reach the performance of the conventional fully digital beamforming schemes, with much lower hardware implementation complexity and power consumption. The green design of the RF chains, the use of simplified TX/RX structures, and the energy-efficient design of power amplifiers are among the hardware solutions to improve the EE, especially in systems with many antennas such as massive MIMO systems and mmWave systems. The Hybrid beamforming architecture provides sharp beams with phase shifters (PSs) at analog domain and flexibility of digital domain.

Hybrid Beamforming for Point-to-Point Systems.

In this scenario, which is also called single-user MIMO, both transmitter and the receiver are equipped with a hybrid beamformer. In general, the capacity of MIMO channels is achieved when the transmitter and receiver have full channel state information(CSI), and both of them are equipped with a fully-digital system. However, this requires a dedicated RF chain per antenna element. Digital beamforming, where each antenna element is equipped with a dedicated RF chain, can provide a higher degree of freedom to improve the system performance. Due to the complexity of mixed signal circuits and high level of power consumption, however, the implementation of a large number of RF chains can become very expensive. Alternatively, analog beam formers can be implemented with a single RF chain and a phased array antenna. Although they are cheaper to implement and to operate; analog systems provide a lesser degree of freedom in comparison to digital beam formers resulting in poorer performance. A third approach is to use a combination of the previous techniques, known as hybrid beamforming that can provide a trade-off between performance and cost.

It is assumed that the rich and sparse scattering channels follow Rayleigh fading and geometry based models, perfect CSI is available at the transmitter and the number of the antennas are large. The following issues will be discussed to derive and analyze the asymptotically optimal beam former:

1. The performance of the digital beam formers is achievable when the number of the RF chains is two times larger than the number of the transmitted symbols.
2. In order to calculate the hybrid beamformer for the independent and identically distributed Rayleigh fading scenario when the number of the RF chains and symbols are equal, the distribution of the elements of the singular vectors of the large channel matrix are derived which, to the best knowledge of the authors has not been previously reported. Based on this distribution, the asymptotically optimal hybrid beamforming schemes for both the point-to-point scenarios are derived.
3. It is shown that the asymptotically optimal RF beamforming matrix is achieved when the phase shifters are set according to the phase of the elements of thesingular vectors of the channel matrix. Then, the closed-form expressions of the spectral efficiencies achieved by the proposed hybrid beamformers are calculated.
4. When digital phase shifters are used, a simple but effective hybrid beamforming scheme is proposed and its performance lower-bound is derived. The advantages of the proposed approach over the stat-of-the-art are simplicity, low computational delays and asymptotically optimal behavior.

Hybrid Beamforming for Multiuser Scenario:

The wireless channels tend to have favorable conditions when the number of the base station antennas grows large. Using the asymptotic behaviors of the channel matrix, the asymptotically optimal hybrid beam former for the point-to-point multiple-input multiple-output (MIMO) system was derived. In this scenario, the capacity of the channel is achieved when the transmission scheme is based on singular value decomposition (SVD) and water_lling. In the multiuser scenario, however, calculation of SVD on both side is not feasible as there is no collaboration between the user equipment.

In general, the capacity of the broadcast channels is derived by dirty paper coding which is difficult to implement. Hence, in practice the suboptimal linear precoding algorithms with low complexity such as zero-forcing (ZF) are preferred. It has been shown that the performance of ZF converges to optimal sum-capacity for the Rayleigh channel when the number of the base station antennas goes large.

III. SIMULATION RESULTS.

The hybrid structure at the base station is capable of transmitting multiple multiplexed data streams to multiple UEs. Hybrid beam-formers use a combination of analog and digital beamforming while keeping the number of RF up/down conversion chains within reasonable limits and hence reduces the cost to a great extent. The below figure shows the effect of noise and bit error rate and hence performance of the hybrid beamforming in massive MIMO systems can be improved.

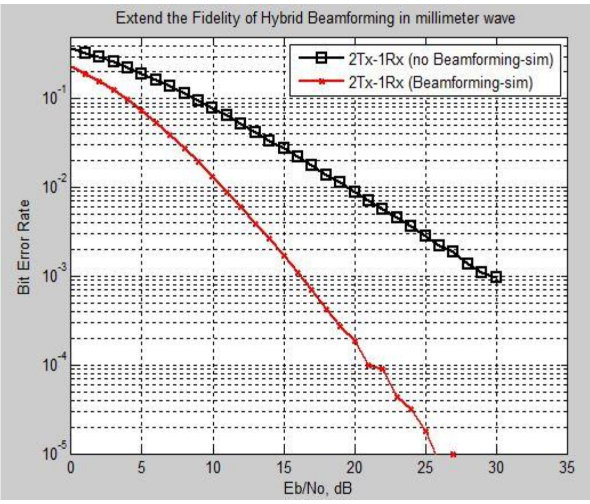

Figure 3: Beamforming BER output plotfor N = 10^6

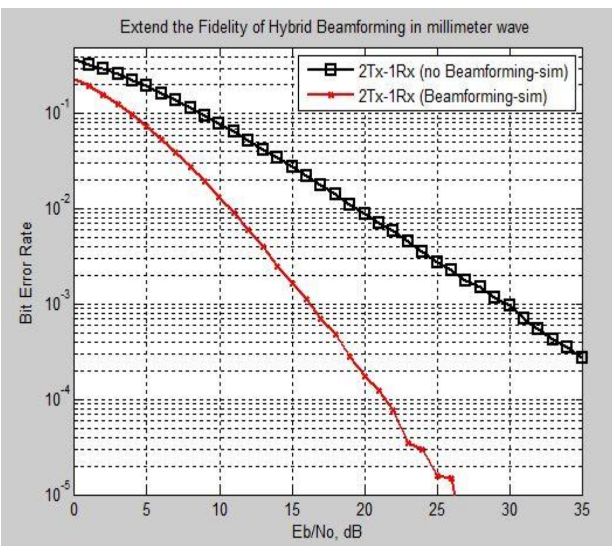

Figure 4: Beamforming BER output plotfor N = 10^5

Figure 4,5 shows system performance in terms of bit error rate versus E_b/N_o with 2Tx and 1Rx. E_b/N_o is basically a normalized signal to noise ratio measure and also indicates the power efficiency of the system. Two different figures are obtained for different values of N in MATLAB code. These results are obtained under White Gaussian Noise channel and 0dB variance. Also it's worth mentioning that Rayleigh channel is used to perform coding in MATLAB. The simulated BER (with beam forming) and simulated BER (no beamforming) gives the best illustration for understanding the performance of hybrid beamforming using MATLAB code. As it is evident from figures as we perform beamforming simulation the performance gets better when compared with no-beamforming simulation.

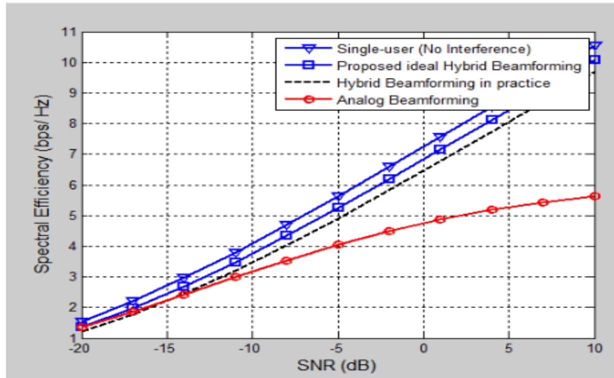

Figure5: Performance comparison for hybrid beamforming

As it is evident from the figure 6, that hybrid beamforming performance is better that the rest. Also single user with no interference is performing well under our MATLAB code because of almost negligible interference and ideal conditions for communication.

IV. CONCLUSION

Hybrid beamforming techniques were invented more than 10 years ago, but have seen a dramatic uptick in interest in the past 3 years due to their importance in making massive MIMO systems cost- and energy-efficient. They use a combination of analog and digital beamforming to exploit the fine spatial resolution stemming from a large number of antenna elements, but keep the number of (expensive and energy-hungry) RF up/down conversion chains within reasonable limits.. The ever-increasing demand of mobile data requires paradigm shift towards larger bandwidth available in mm Wave frequency band, larger number of antennas and hence, the hybrid beamforming to save the capital and operation cost. From the power consumption point of view, bit resolution of ADC in DB and PS in AB plays the key role.
The mm Wave massive MIMO system is only feasible with hybrid beamforming having low-dimension digital beam former and low-dimension analog beam former **.**

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