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HYBRID PRECODING DESIGN FOR MILLIMETER WAVE MASSIVE MIMO SYSTEM VIA CUA

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Abstract:

Millimeter wave (mmWave) communication in the 60 GHz band requires large antenna arrays at both the transmit and receive terminals to achieve beam forming gains, in order to counteract the high pathloss. Fully digital techniques are infeasible with large antenna arrays due to hardware constraints at such frequencies, while purely analog solutions suffer severe performance limitations. Hybrid analog/digital beam forming is a promising solution, especially when extended to a multi-user scenario. This paper conveys three main contributions: (i) a Kalman-based formulation for hybrid analog/digital precoding in multi-user environment is proposed, (ii) an analytical expression of the error between the transmitted and estimated data is formulated, so that the Kalman algorithm at the base station (BS) does not require information on the estimated data at the mobile stations (MSs), and instead, relies only on the precoding/combining matrix, (iii) an iterative solution is designed for the hybrid precoding scheme with affordable complexity. Simulation results confirm significant improvement of the proposed approach in terms of both BER and spectral efficiency- achieving almost 7 bps/Hz, at 20 dB with 10 channel paths with respect to the analogonly beamsteering, and almost 1 bps/Hz with respect to the hybrid minimum mean square error (MMSE) precoding under the same conditions.

Index terms: Hybrid beamforming, Kalman filter, Millimiter Wave, massive MIMO.

1. INTRODUCTION

Millimeter wave (mmWave) band communication is a key enabling technology for solving the spectrum crunch in future 5G systems [1]–[7]. Due to limited available spectrum in the sub-6GHz band, conventional cellular and WiFi-based solutions cannot be scaled up to meet the ever-growing data demands of network densification, and emerging applications associated with data centers and mobile devices. While innovative solutions such as utilizing licensed spectrum on an opportunistic basis have been proposed [8], such approaches are still subjected to frequent disruption and are limited by the channel bandwidth available in the licensed bands, such as the TV bands. Millimeter wave (mmWave) band communication in the recently opened up contiguous block of unlicensed spectrum in the 57-71GHz range is an opportunity for achieving gigabit-per-second data rates [9]. Indeed, existing standards like the IEEE 802.11ad operating in these bands allow up to 2GHz-wide channels for short-distance communications. Due to the high path loss characterizing mmWave bands, directional beamforming exploiting large antenna arrays at both base station (BS) and mobile stations (MSs) is required This enables high quality and long-distance communication links, and increases the signal power concentrated at the receiver end. The high frequency of operation also supports massive multi-antenna architectures

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from a design viewpoint, while reducing the size of each antenna and allowing many of them to be packed in a small area. While the hardware support from large antenna arrays for beamforming functions is already available, the high frequency of operation, expected sampling rates and channel bandwidths make it difficult to deploy traditional fully digital beamforming solutions However, analog solutions cannot use adaptive gain control.

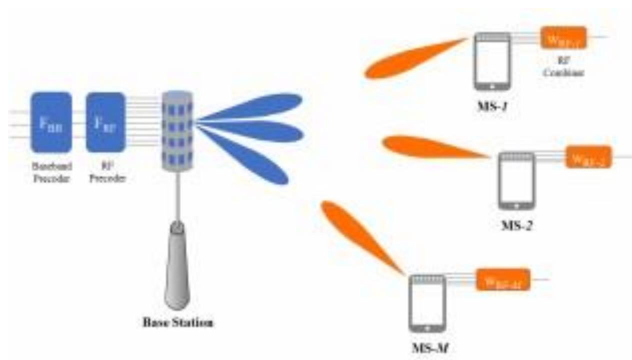
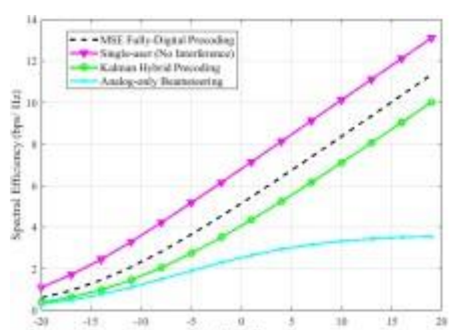


Fig.1.System

Moreover, phase shifters can be digitally controlled with only quantized phases thus limiting the possibility of advanced processing and resulting in poor performance.

2. RELATED WORK

For example, our experiments prove that analog beamforming may achieve at most a spectral efficiency around 3 bps/Hz at 20 dB, while our proposed hybrid analog/digital beamforming gets 10 bps/Hz under the same conditions. In summary, hybrid schemes are promising candidate solutions that overcome the limitations of pure digital or analog beamforming, as they incorporate the advantages of both methods Hybrid schemes reduce the training overhead compared to analog-only architectures by leveraging multiple simultaneous beam transmissions.



In hybrid solutions, the number of RF chains may be much lower than the number of antennas. Also other solutions include minimum mean square error (MMSE) as a part of the approach. In particular, an

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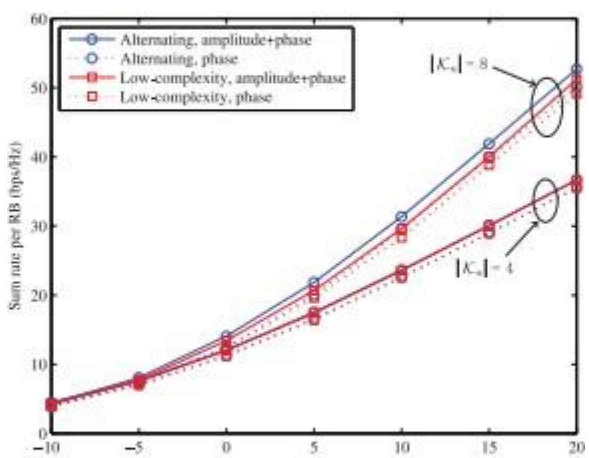
iterative algorithm for joint precoding and combining is proposed in [30]. At the initial step, the analog precoder/combiner is selected through an orthogonal matching pursuit (OMP) algorithm to enhance the channel gain, while mitigating the multi-user interference, and the digital combiner is obtained via MMSE criterion. Then, the iterative procedure is applied to improve the performance. the authors first develop the digital precoder/combiner leveraging minimum sum-mean-square-error (min-SMSE) criterion to minimize the BER, and then design an over-sampling codebook (OSC) based analog precoder/combiner scheme to further reduce the SMSE handles the inter-user interference at both analog and digital beamforming levels as follows: the analog beamforming matrix is calculated through the low complexity Gram-Schmidt algorithm and the digital matrix is obtained by the MMSE method with a low dimensional effective channel.

3. PROPOSED SYSTEM

The signal-to-noise ratio (SNR) of all users is 10 dB. All the results are averaged over 100 random drops. To analyze the impact of frequency-domain scheduling, we divide all RBs into B groups and schedule the same users for the RBs in each group. If B = 1, all RBs schedule the same users and the system operates in SDMA-OFDM manner; otherwise, the system is in SDMA-OFDMA manner. We consider two frequency-domain scheduling methods, random scheduling that selects users randomly for each group and greedy scheduling that selects users providing the maximal sum rate for each group. Note that when greedy scheduling is applied, the achieved multiuser diversity gain increases with B, and the largest multiuser diversity gain is obtained when B = N, where every RB can schedule its own favourite users. In Fig. 1, we compare the performance of the proposed algorithms, where L = 8 RF chains, B = 16 groups and random scheduling are considered.



It is shown that the proposed low-complexity algorithm performs very close to the alternating optimization algorithm no matter when |Kn| = 4 or 8 users are scheduled in each RB. We can see that the phaseonly constraint on analog precoder leads to slight performance loss for both algorithms. performance gap is enlarged when more users are scheduled (i.e., larger B) because random scheduling provides no multiuser diversity gain and serving more users only degrades the effectiveness of analog

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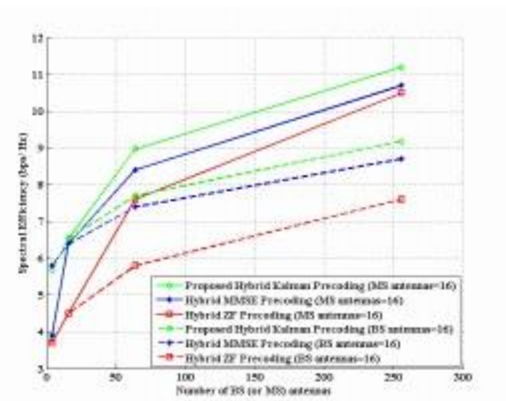
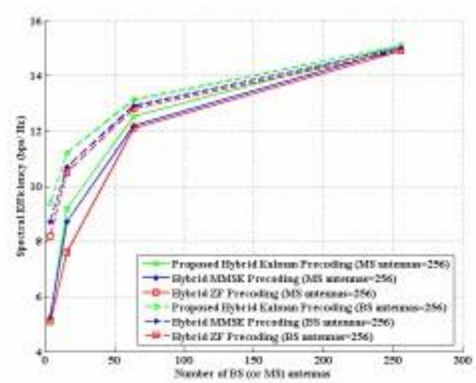
precoder on providing large array gain. Nevertheless, the results change when greedy scheduling is applied due to the presence of multiuser diversity gain. Now scheduling more users (i.e., increasing B) has twofold impacts, which increases the multiuser diversity gain but reduces the array gain obtained by analog precoder as mentioned before. However, the array gain loss for analog precoder can be well compensated by digital precoders when the number of RF chains L is large. Therefore, when both B and L are large, the achieved multiuser diversity gain will be greater than the array gain loss, and then the performance can be improved. It is shown in Fig.2(b) that when $L \geq 16$, scheduling more users in frequency domain can improve the performance, and the wideband hybrid precoder can perform as well as the narrowband hybrid precoder when $B = 16$.

4. RESULT ANALYSIS

The error between the transmitted and estimated data. The method uses a specially designed formulation of the error, and following this, a two-step procedure is carried out to first calculate the RF precoding/combining matrix, and then design the digital baseband precoder at the BS. Simulation results show that the proposed algorithm outperforms existing solutions, in terms of both spectral efficiency and BER, due to its ability to better adjust the precoding matrix in hybrid architectures.





Analysis

In future work, we will incorporate a channel estimation scheme in the Kalman hybrid precoding algorithm, and extend the proposed solution to mobile scenarios. Moreover, we will focus on extending the proposed solution to joint precoders/combiners iterative optimization when user devices employ multiple streams. based on which the necessity of frequency-domain scheduling and the effectiveness of hybrid structure in wideband systems are analyzed. Aimed at maximizing the sum rate of all served users, we first derive an alternating optimization algorithm to optimize the wideband hybrid precoder, then an efficient low-complexity non-iterative hybrid precoder is proposed, in both of which the phaseonly constraint are considered for analog precoder. Simulation results show that both the necessity of frequency scheduling and the effectiveness of wideband hybrid precoder depend on the employed scheduling method and the number of available RF chains.

CONCLUSION

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We first derived an alternating optimization algorithm, which requires the iteration between analog precoder and digital precoders, then an efficient noniterative algorithm was proposed to reduce the complexity. Simulation results show that both the necessity of frequency scheduling and the effectiveness of wideband hybrid precoder depend on the employed scheduling method and the number of available RF chains. When random scheduling is used, frequency scheduling degrades the performance and wideband hybrid precoder has a larger performance gap from full digital precoder compared to narrowband hybrid precoder.

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