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Low RF-Difficulty knowledges to AllowMillimeter-Wave MIMO with Antenna Collection for 5G Wireless Communications

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ABSTRACT:

Millimeter-wave (mmWave) MIMO with a large antenna array has involved arge interests from abstract and industry communities, as it can provide larger bandwidth and higher spectrum efficiency. However, with hundreds of antennas,the number of radiofrequency(RF)chains vital by mmWave MIMO is also huge, leading to unreasonable hardware cost and power feeding in practice. In this paper, we in-low RF-difficulty technologies to solve this bottleneck. We firstreview the evolution of low RF-complexity skills from microwave frequencies to mm Wave frequencies. Then, we discuss two promising low RF-complexity skills for mm Wave MIMO systems in detail, i.e., phased array based hybrid precoding (PAHP)and lens array based hybrid precoding (LAHP), including their principles, advantages, challenges, and recent results. We compare the performance of these two skills to draw some insights about how they can be arranged in practice. Finally, we conclude this paper and point out some future research directions in this part.

I.INTRODUCTION:

Millimeter wave (mm Wave) (30-300 GHz) multiple input multiple output (MIMO) with big antenna array has been considered as a promising resolution to meet the one thousand times increase in data traffic hand predicted for further 5G wireless communications. On one, mm Wave can provide nearly 2 GHz bandwidth , which is much larger than the 20 MHz bandwidth in current 4G wireless communications without transporter aggregation. On the other hand, the short wavelengths associated with mm Wave frequencies enable a big antenna array to be crowded in a insignificant carnal size, which means that MIMO with a big antenna array is thinkable at mm Wave frequencies to excellently recompense the high path loss induced by high frequencies and significantly improve the spectrum efficiency. However, realizing mm Wave MIMO in practice is not a trivial task. One exciting problematic is that each antenna in MIMO system usually need one enthusiastic radio-frequency (RF) cable including digital-to-analog converters (DACs), mixers and soon. This will result in extreme hardware cost and power consumption in mm Wave MIMO systems, as the number of antennas is huge (e.g., 256 compared with 8) and the power consumption of RF cable is high (e.g., 250 mw at mm Wave frequencies related with 30 mw at microwave frequencies) .

We give complete overview for these two skills including their principles, advantages, challenges, and recent results; ii) We propose a novel adaptive selecting network for LAHP with low hardware cost and power consumption. For data communication, it can select rays like the old one, while for channel estimate, it can voice the ray space channel estimate as a light signal recovery problem and estimate the ray space channel with considerably summary pilot overhead; iii) We provide the

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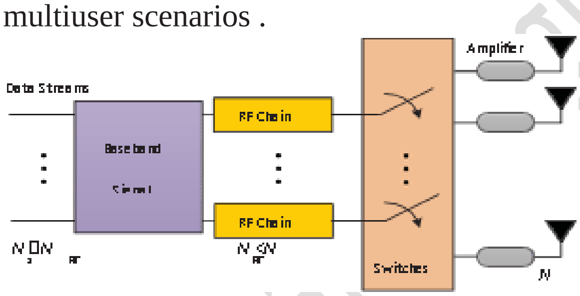
sum rate and power efficiency contrasts between PAHP and LAHP in a practical outdoor mm Wave MIMO system, where the channel estimation error and inter-cell intrusion are also included. Then, we draw some visions about how these two skills can be organized in practice

II.TRADITIONAL LOW KNOWLEDGES

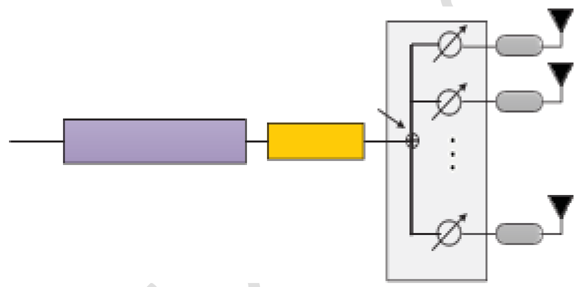
We first evaluation two typical low RF complexity skills, i.e., antenna collection and analog ray forming. Antenna selection may be measured as the most classical low RF complexity skill for microwave MIMO systems. By contrast, analog ray forming is the most commonly used lowRF complexity skill for indoor mm wave transportations. These two skills can be regarded as the basics of PAHP and LAHP loss. More importantly, analog ray forming can only support single water course broadcast, which cannot be used in multi-watercourse or multiuser scenarios .



ANTENNA SELECTION

The key feature of antenna selection is that there is one choosing network between N_{RF} RF cables and N antennas. Based on the channel state information (CSI), the goal of antenna selection is to select N_{RF} best antennas out of total N antennas for data communication to maximize the doable sum-rate.

An exciting result of antenna selection is that when the number of RF cablesN_{RF} is bigger than the number of communicated data water courses N_s, the presentation loss induced by antenna choice is insignificant under independent identically distributed (IID) Rayleigh fading channels. However, when channels are very correlated, the doable sumrate of antenna selection will lessening drastically , as antenna selection invites more channel information loss in this case.



ANALOGRAY FORMING

The key idea of analog ray forming is to use only one RF cable to communicate single data watercourse, and employ the phase shifter network to control the phases of unique signals to maximize the array increase and effective signal-to-noise ratio (SNR). Structure the ray forming vectors (include the relative generosities and phases applied to the diverse antenna essentials to figure the signal asset at a specific way in the far field) involves ray training, which includes an iterative and joint design between the spreader and receiver. For example, in IEEE 802.11ad, a multi resolution ray forming codebook (consists of several pre-defined ray forming vectors) is adopted to progressively refine the selected ray forming vectors.

The advantage of analog ray forming is that it only requires one RF cable leading to rather low hardware cost and power consumption. However, the analog ray forming can only adjust the phases of the signals, which means that all the elements of ray forming vector have the same largeness. Such design constriction will in cur some routine.Based on these facts, we know that antenna range is not

Journal of Engineering Sciences
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appropriate for mm wave MIMO systems, since it suffers from thoughtful act loss with highly correlated channels. Moreover, although analog ray forming is established for mm wave transportations, it can only support single watercourse transmission without multiplexing gains. This means that analog ray forming cannot fully exploit the possible of mm wave MIMO in range efficiency , Next, we will investigate two promising low RF complexity skills future recently for mm wave MIMO systems, i.e., PAHP and LAHP.

III.PHASED COLLECTION BASED MIXTURE PRECODING

A. Principle

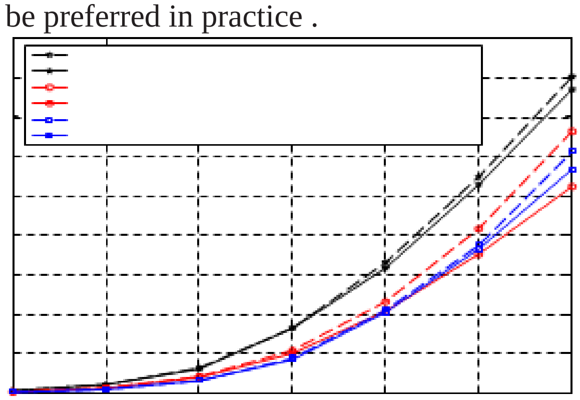
Precoding is used to adjust the weights of transmitted signals to maximize the reachable sum-rate. the conventional fully digital precoding can casually adjust the profusions and phases of the unique signals. It can achieve multiplexing gains, and enjoys higher design autonomy than analog ray forming. However, it needs one dedicated RF chain for each antenna, which brings extreme hardware cost and power eating when the number of antennas is large. Fusion precoding can be slow as a capable concession among the optimal fully digital precoding and the low-cost analog ray forming. Its key idea is to divide the big-size digital precoder into a big size analog ray former (realized by the analog circuit) and a small-size digital precoder (requiring a small number of RF cables).

PAHP is one of the realization of combination precoding, where the referend ray earlier is realized by phase shifters. Accept there are N_s single-antenna users to be assisted. As shown in Fig. 2, the established signal coursey for $N_s$workers in the downlink can be standing as

$$y = HADs+n,(1)$$

where H of size $N_s \times N$, s of size $N_s \times 1$, and n of size $N_s \times 1$denotethemmWaveMIMOchannelmatrix,transmitted signal vector, and noise vector, respectively, A of size $N \times N_{RF}$ is the analog ray former, and D of size $N_{RF} \times N_s$ is the digital precoder. Note that PAHP has two designs, i.e., full-PAHP and sub-PAHP .

In full-PAHP, each RF cable is related to all N feelers via phase shifters, and the analog ray previous A is a full medium. It can attain filling act, but usually needs a large amount of NN_{RF}phase shifters (e.g., NN_{RF}= 256 × 16 = 4096), composed with the difficult control splitters/combiner sand signal/control lines. By contrast, in sub-PAHP, each RF cable is only linked to a subset of feelers, leading A to be a block slanting matrix. Perceptibly, sub-PAHP can reduce the sum of phase shifters from NN_{RF} to N and avoid using power combiners. Therefore, although sub-PAHP suffers from a loss in array advances by a factor of $1/N_{RF}$, it may be preferred in practice .



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Advantages

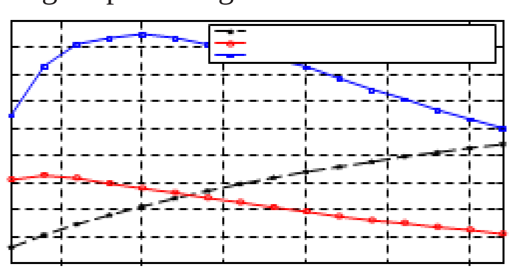
PAHP can achieve a better tradeoff between the hardware cost/power feeding and the sum-rate act. It can suggestively lessen the number of essential RF chains from N (e.g., $N = 256$) to N_s (e.g., $N_{RF}= N_s= 16$), principal to lower power feeding. Besides, as explained above, the outdoor mm Wave MIMO channel matrix is usually low- rank. This indicates that the all-out number of data watercourses that can be concurrently conveyed by such channel is limited. Therefore, as long as the number of RF cables is bigger than the rank of network matrix, the small-size digital precoder is still able to fully achieve the multiplexing gains and obtain the near-optimal performance likened to the fully digital precoding .

Challenges and recent results

Optimal design of hybrid precoder: Maximizing the achievable sum-rate by designing the hybrid precoder P = AD is the main target of PAHP. However, this optimization problem imposes new challenges, since there are several non-convex hardware constraints on the analog beam former A. For ex- ample, all the nonzero elements of A should share the same amplitude due to the constant modulus constraint on phase shifter. To this end, one feasible way is to approximate the unique optimization problematic as a convex one to obtain a near-optimum hybrid precoder with low complexity.

Following this idea, some unconventional schemes have been anticipated recently. In a spatially scarce scheme is pro- posed for single-user full-PAHP. It approximates the sum- rate optimization problem as the one curtailing the distance between the optimum fully digital precoder and the hybrid precoder. Then, a different of the orthogonal matching pursuit (OMP) algorithm is established to obtain the near-optimal hybrid precoder. In full-PAHP is lengthy to multi-user scenario, where a two-stage multi-user scheme is proposed. In the first stage, the optimal analog ray former is examined from a pre-definite codebook to maximize the desired signal power of each user. In the second stage, the standard zero forcing (ZF) precoder is used to cancel multi-user meddling. In a successive interfering dissolution (SIC)-based scheme is proposed for sub-PAHP. It first decomposes the sum-rate optimization problem into a series of simple and convex sub- problems, each of which only considers one sub-phased array. Then, inspired by the standard SIC multi-user signal gage, the near-optimal hybrid precoder for each sub-phased collection is gotten in an one-by-one fashion.

Channel estimation: The maximum gain of PAHP can be only achieved with perfect CSI, which is difficult to obtain in mm Wave MIMO systems. Firstly, due to the lack of array gains before the founding of the spread link, the SNR for network estimate in PAHP is quite low. Secondly, the number of RF cables in PAHP is frequently much reduced than the number of probes. Therefore, we cannot directly detect the network matrix like that in fully digital precoding.



Two typical solutions have been future to solve this tricky. The first divides the network approximation tricky into two steps. In the first step, the BS and users

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will achieve ray exercise like analog beam forming to control A. In the second step, the operative frequency matrix HA with smaller size $N_s \times N_{RF}$ ($N_{RF} \ll N$) is assessed by classical systems, such as least quadrangles(LS).

PRESENTATIONASSESSMENT

In this section, we compare the presentation of full-PAHP, LAHP with the planned adaptively selecting network, and fully digital precoding. We first contemplate an outdoor multi- user mm Wave MIMO in single-cell scenario, where the BS services N = 256 projections to concurrently serve N_s= 16 single-antenna users. The extensively used Saleh-Valenzuela multi- path model is adopted to capture the physiognomies of mmWave MIMO networks. Each user has one Loss path and two Nalos paths. The improvement of loss path is normalized to 1,whilethegainofeachNalospathisexpectedtofollowCN (0, 0.1). The instructions of all paths of users are expected to follow the IID uniform delivery within [$-\pi/2$, $\pi/2$].Fig. 4 shows the comparison of achievablesum-rateagainst the SNR for data broadcast. For full-PAHP with N_{RF}= N_s= 16 RF chains, we use the adaptive CS based channel approximation scheme proposed in (the number of initial direction grids is set as 1024) to approximation the three-dimensional channel, and employ the two-stage multi-user arrangement proposed in (4-bit phase shifters are used) to convey data. For LAHP also with N_{RF}= N_s= 16 RF cables, we utilize the proposed adaptive selecting network to estimate the ray space network as illustrated above, and adopt the Array collection scheme to communicate data.

CONCLUSIONS

In this paper, we have introduced two promising low RF- complexity technologies for mmWave MIMO with large antenna array, i.e., PAHP and LAHP, in detail. We have also proposed an adaptive selecting network for LAHP with low hardware cost and power consumption, which can formulate the beam space channel estimation as a sparse signal recovery problem, and considerably reduce the pilot overhead. Finally, we have provided the complete and systematic performance comparison between PAHP and LAHP. It shows that PAHP achieves higher achievable sum-rate than LAHP when the channel is perfectly known, but LAHP is more robust to the channel estimation error. It also shows that LAHP enjoys higher power efficiency than PAHP, since the phase shifter network is replaced by the low-cost lens array and switches. Besides the deliberations above, there are still some open is- sues on low RF-complexity knowledge for outdoor mm Wave MIMO systems. For example, most of the current low RF- complexity knowledge are designed for the narrowband and time-invariant networks. However, due to the large bandwidth and the high frequency, the mm Wave MIMO networks are more possible to be broadband and time-varying, which incurs new encounters. Take the PAHP for example, "broadband" means that the similarity ray previous cannot be adaptively adjusted conferring to the frequency, leading to more difficulties in signal processing design, while. Therefore, conniving low RF-complexity technologies for broadband time-varying networks will be an influence problematic to solve.

Vol 10, Issue 10, Oct /2019
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