Joint Optimization of Transmit and Reflect Precoding of Passive RIS

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Abstract

In this study, the optimization method is proposed to jointly optimize passive reconfigurable intelligent surfaces (RIS) and base station (BS) precoding. In contrast with other reference, we consider a direct link from BS to users. The main objective of the proposed system to enhance energy efficiency, where maximizing sum-rate and minimizing transmit power. The Dinkelbach transform method is selected over quadratic transform due to its faster converges. Simulation results show that proposed beamforming can achieve optimal result on various user distance.

Ⅰ. Introduction

Reconfigurable intelligent surfaces (RIS) are developed recently in order to seize the error rates by the principal of signal diversity and increase coverage by modifying signal phase [1,2,3]. RIS comprises of a finite length number of elements that can work and tuned independently [4]. However, in practical scenario, RIS phase shift can not be determined precisely, due to limitation of channel state information (CSI) at the receiver. Moreover, the precoding vector of multiple antenna base station (BS) is typically a challenge in determining optimal phase shifter of the RIS. In addition, in multiple user case, energy consumption of transmit power BS is a main issue, where multiple inter-user interference takes places.

In this study, the objective function to jointly optimize BS and RIS precoding is proposed. Noted that joint optimization is NP hard problem and non-convex, the alternate solution is proposed. In this study, Dinkelbach method is proposed, rather than quadratic transform because of its faster convergence rate [5]. In this study, we use the energy efficiency (EE) to measure the proposed system. This is because the main objective to maximize sum-rate and minimize power consumption of BS.

Ⅱ. System Model

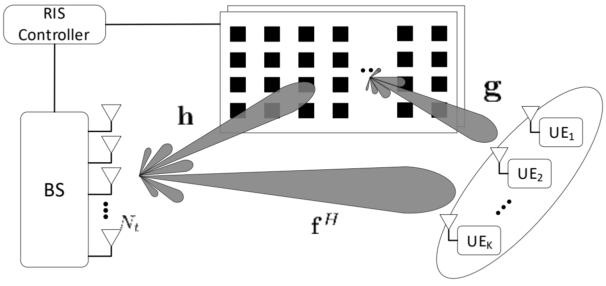

Fig.1. System Model of MISO-RIS Transmission.

Consider a downlink MIMO RIS UAV assisted system model as shown in Fig.1. In this scenario, base station equipped with N_t number of transmit antenna and single antenna K cluster users. Assume base station (BS) had a precoding vector $\boldsymbol{w}_j$, therefore the transmitted symbol is defined as:

$$s_{DL} = \sum_{j=1}^{K} \boldsymbol{w}_j s_j. \qquad (1)$$

where $\boldsymbol{s_{DL}}$ is the modulated user symbol. Therefore, the received signal of user is written as:

$$y_k^{DL} = (\boldsymbol{f}_k^{\mathrm{H}} + \boldsymbol{g}_k^{\mathrm{H}} \boldsymbol{P} \Theta \boldsymbol{h})\ s_{DL} + \boldsymbol{n}, \qquad (2)$$

In Eq. (2), $\boldsymbol{f}_k^H \in \mathbb{C}^{N_t \times 1}$ represents a direct channel between N_t antenna BS to user. $\boldsymbol{g}_k^H \in \mathbb{C}^{N \times 1}$ is channel between RIS and user. $\boldsymbol{h} \in \mathbb{C}^{N_t \times N}$ represents channel from BS to RIS. The RIS beamforming vector is denoted as $\boldsymbol{\Theta} \in \mathbb{C}^{N \times N}$. The notation $\boldsymbol{n}$ is additive white gaussian noise (AWGN). Therefore, the SINR of DL-MISO RIS can be written as:

$$\gamma_k^{DL} = \frac{|\tilde{\boldsymbol{H}}_k^H \boldsymbol{w}_k|^2}{\sum_{j=1, j\neq k}^{K} |\tilde{\boldsymbol{H}}_j^H \boldsymbol{w}_k|^2 + \sigma_n^2}. \qquad (3)$$

Furthermore, we can calculate sum-rate of the system as:

$$R_{sum}^{DL} = \sum_{k=1}^{K} (1 + \gamma_k^{DL}). \qquad (4)$$

The total power consumption is denoted by:

$$P = \xi \sum_{k=1}^{K} \|\boldsymbol{w}_k\|^2 + K W_{\mathrm{U}} + W_{\mathrm{BS}} + N W_{\mathrm{PS}}, \qquad (5)$$

where W is the dissipated power for BS (W_{BS}), phase shifter (W_{PS}), and user (W_U). In addition, to calculate EE, it can be written as:

$$EE = \frac{\mathrm{R}_k^{DL}}{P_{all}} \qquad (6)$$

where it is denoted that the total sum-rate of all users is divided with the total power consumption at the base station.

The optimization of energy efficiency can be formulated as:

$$\max_{\boldsymbol{W},\boldsymbol{\Theta}} \quad \eta = \frac{R}{P}$$
$$\text{s.t. } \mathrm{C}_1: \ \xi \sum_{k=1}^{K} \|\boldsymbol{w}_k\|^2 + W_{\mathrm{BS}} \leq P_{\mathrm{BS}}^{\max}, \qquad (7)$$
$$\mathrm{C}_2: \ |\theta_n| \leq 1, \ \forall n \in [N],$$

In Eq. (4) it can be seen that C1, guarantee the BS precoding vector is under maximum power of BS. C2 satisfy RIS phase optimization constraint, where there is no power amplification. By utilizing Dinkelbach method, we can alternate the problem as:

$$\max_{\boldsymbol{W},\boldsymbol{\Theta}} \quad D(\boldsymbol{W},\boldsymbol{\Theta}) = R - \eta^* P \qquad (8)$$
$$\text{s.t. } \mathrm{C}_1, \ \mathrm{C}_2, \ \mathrm{C}_3.$$

In Eq. (7) we can solve the EE coefficient by maximizing sum-rate of the MISO-BS RIS. However, the problem is still non-convex, therefore we applied auxiliary variables to guarantee concavity/ convexity and convergence. The alternated problem can be written as [6]:

$$\max_{\boldsymbol{W},\boldsymbol{\Theta},\boldsymbol{\mu},\boldsymbol{\nu}} \quad z(\boldsymbol{W},\boldsymbol{\Theta},\boldsymbol{\mu},\boldsymbol{\nu}) \qquad \text{s.t. } \mathrm{C}_1, \ \mathrm{C}_2, \ \mathrm{C}_3,$$
$$= \sum_{k=1}^{K} \Big[\ln(1+\mu_k) - \mu_k + 2\sqrt{1+\mu_k} \mathrm{Re}\{\nu_k^* \boldsymbol{H}_k^H \boldsymbol{w}_k\} \qquad (9)$$
$$- |\nu_k|^2 \Big(\sum_{j=1}^{K} |\boldsymbol{H}_k^H \boldsymbol{w}_j|^2 + \sigma^2 \Big) \Big] - \eta P.$$

Ⅲ. Simulation Result

The parameters set for the simulation results are mentioned as follows: frequency carrier is 5GHz; N_t = 6; P_{BS} = 9dB; WBS = 9dB; WUE = WPS = -20 dB; Rayleigh fading with zero mean and variance; BS coordinates (0, -20) and RIS is in (100, 5).

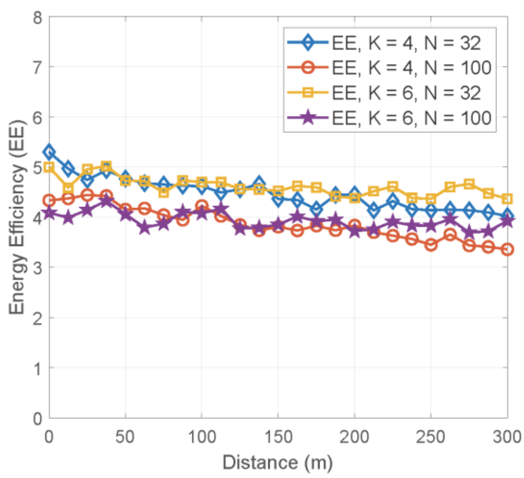

Fig.2. Energy efficiency of the proposed system over different distance of the user cluster.

Fig.2 depicts that the proposed system can give an advantage for all K user, because of its equal EE for all user distances. It can be seen that when K is similar to N_t, gives more performance to the energy efficiency. However, the tradeoff of the proposed minimization is when N is getting bigger, will be resulting in degrading performance. This is because the higher number of elements, will be resulting in higher dissipated power of RIS phase shift.

IV. Conclusion

The proposed algorithm of BS and RIS precoding vector to minimize power consumption and maximizing sum-rate can achieved similar EE to all distance of the users. However, the tradeoff of the proposed system is the lower EE for higher number of RIS elements. Further research direction is considering user mobility and multi cluster case.

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