Dual Reconfigurable Intelligent Surfaces for Integrated Sensing and Communication

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Abstract

This study proposes the optimization of base station (BS) antenna beamforming to the dual reconfigurable intelligent surfaces (DRIS)-assisted integrated sensing and communication (ISAC) in dense urban environment scenario. The transmit antenna in the BS and DRIS can be utilized to increase the performance of both sensing and communication part of the system. In this study, the main consideration is the radar SNR (signal to noise ratio). From the simulation results, it can be seen that the proposed system offers higher SNR than the conventional one without the optimization.

Ⅰ. Introduction

Integrated sensing and communication (ISAC) has become the modernization of the previous separate sensing and communication system, since it allows unified waveforms to carry out communication and radar sensing functions concurrently [1]. ISAC is considered to be a supporting technology for the next-generation wireless networks which can be applied to smart home/factory, vehicular networks, etc., that demand both high-quality wireless communications and high-accuracy sensing. Until now, numerous study of ISAC for both theoretical and implementations have been investigated by academic and industry researchers [2].

Reconfigurable intelligent surface (RIS) is a low-cost and low-power device which is made of passive reflecting parts that can change channel realization to improve signal quality and has been regarded as one of the remarkable technologies for the sixth generation (6G) [3]. RIS can be attached to the internal space ceilings, building facades, etc which makes it suitable for dense urban environment. In [4], dual RISs (DRIS) are utilized to enhance the spectral efficiency in a challenging excessive pilot overhead ISAC systems. In [5], they exploit the single RIS to both detect targets and communicate with users. They designed algorithm to maximize the total sensing SNR while also maintaining to fulfill the communication quality requirements.

However, the previous work did not utilize dual RIS to enhance the radar SNR of the ISAC system. In this study, we try to enhance the previous existing works by optimizing the transmit beamforming of the BS antenna to enhance the radar SNR in a ISAC with dual RIS system.

Ⅱ. System Models

In Fig. 1, the transmitter sends the downlink signals to the RIS. The phase shift signals are reconfigured in RIS and then it reflects the signal to the receiver. The transmitted signal from the BS is denoted with

$$\mathbf{x} = \mathbf{W}_c\, \mathbf{s}_c + \mathbf{W}_r \boldsymbol{s}_r \qquad (1),$$

where the communication beamforming matrix and symbol are indicated by $\mathbf{W}_c$ and $\mathbf{s}_c$, respectively. The radar beamforming matrix and symbol vector are indicated by $\mathbf{W}_r$ and $\mathbf{s}_r$, respectively. The overall beamforming matrix is defined by $\mathbf{W} = [\mathbf{W}_c\, \mathbf{W}_r]$. The radar SNR of the target is written by

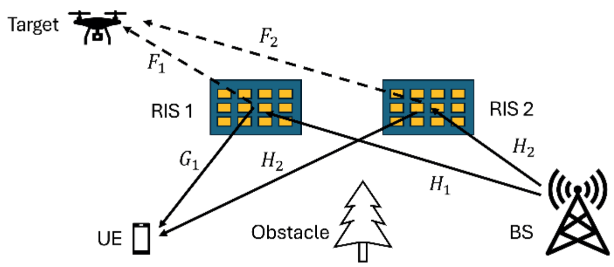

Figure 1. System model of the DRIS-ISAC.

$$SNR_t = Tr\frac{(W^H H_t^H H_t W)}{\sigma_r^2},$$

where σ_r^2 denotes the additive white Gaussian noise. H_t is the radar channel matrix and can be expressed more detail as below

$$H_t = H_1\varphi_1 F_1 + H_2\varphi_2 F_2$$

where $H_i, \varphi_{i,}$ and F_i the channel from BS to the i-th RIS, reflection matrix of the i -th RIS, and channel from the i -th RIS to the user, respectively.

III. Optimal Beamforming Matrix

In this study, the objective function can be expressed as,

$$\begin{aligned} &\max_{\mathbf{W}} \ \mathrm{Tr}(\mathbf{W}^H \mathbf{C}_1 \mathbf{W}) \\ &\text{s.t.} \ (1+\Gamma_c^{-1})\mathbf{h}_c^T \mathbf{w}_c \mathbf{w}_c^H \mathbf{h}_c^* \geq \mathbf{h}_c^T \mathbf{W}\mathbf{W}^H \mathbf{h}_c^* + \sigma_r^2, \\ &\quad \|\mathbf{W}\|_F^2 \leq P, \end{aligned}$$

where $\mathbf{C}_1 \triangleq \frac{\omega_t \mathbf{H}_t^H \mathbf{H}_t}{\sigma_r^2}$ and ω_t defines the weighted coefficient of the target. Γ_c is the communication SINR requirement that must be fulfilled. Referring to [5], this problem is a non-convex quadratically constrained quadratic programming (QCQP) problem that can be solved using semi-definite relaxation (SDR) strategy. In this study, CVX package of MATLAB app is used to optimize the beamforming matrix of the BS antenna.

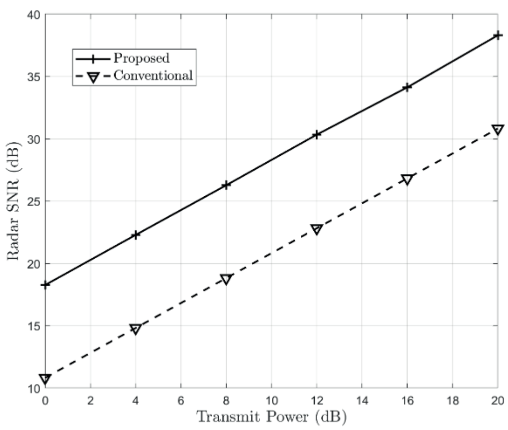

Figure 2. Radar SNR of DRIS-ISAC.

In Fig. 2, the comparison of DRIS-ISAC which BS beamforming matrix is shown and compared to the conventional system that does not consider the beamforming optimization. As expected, the optimization using SDR can leverage the radar SNR value.

IV. Conclusion and Future Work

In this study, the comparison of DRIS-ISAC with the conventional DRIS is shown. For the future work, the DRIS can use STAR-RIS to enhance the coverage of the transmission. Moreover, higher number of the existing nodes (BS, RIS, user equipment (UE), or target can also be considered.

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