Reinforcement Learning Based RIS-Assisted UAV ISAC Systems with Secrecy Considerations

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***Abstract*—Integrated sensing and communication (ISAC) enables spectrum-efficient joint sensing and data transmission, but its broadcast nature makes it vulnerable to eavesdropping and jamming, especially in UAV-enabled networks. In this paper, we study a learning-based problem for a RIS-assisted UAV ISAC system, where secrecy performance is evaluated under adversarial interference. The problem is addressed using a deep deterministic policy gradient (DDPG) based learning approach. Simulation results demonstrate that the proposed method exhibits improved secrecy performance compared with RIS-free schemes, although secrecy is evaluated as a performance metric rather than explicitly optimized.**

***Index Terms*—Reconfigurable intelligent surface, UAV communications, integrated sensing and communication, physical layer security, deep reinforcement learning.**

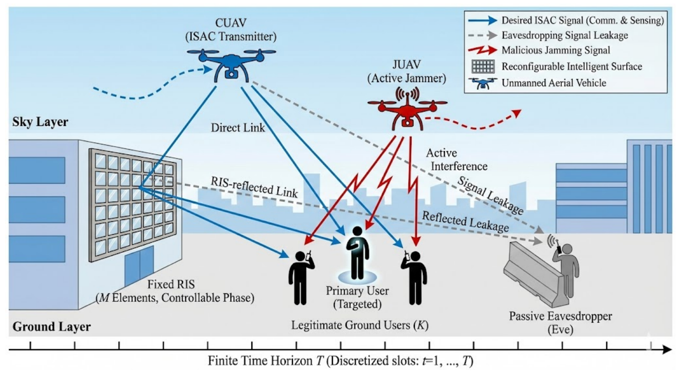

Fig. 1. Overall scenarios for RIS-Assisted UAV ISAC System.

I. Introduction

Integrated Sensing and Communication (ISAC) enables the joint use of communication signals for data transmission and sensing, but suffers from security threats such as jamming and eavesdropping, especially in UAV-enabled dynamic environments. Reconfigurable Intelligent Surfaces (RIS) can enhance wireless propagation and improve communication reliability when combined with UAV platforms, which also has the potential to benefit communication security.

However, jointly controlling UAV mobility and RIS configuration in dynamic and adversarial environments remains highly challenging, particularly when sensing, communication, and secrecy performance must be jointly considered [1].

This paper investigates a learning-based control framework for RIS-assisted UAV ISAC systems, where UAV trajectories and RIS phase shifts are optimized using deep reinforcement learning [2].

II. System Model

We consider a RIS-assisted UAV-enabled integrated sensing and communication (ISAC) system operating over a finite time horizon T, which is discretized into T equal-length time slots. As shown in Fig. 1 a communication UAV (CUAV) serves K legitimate ground users, while a cooperative jamming UAV (JUAV) mitigates potential eavesdropping by interfering with a passive eavesdropper. To enhance the wireless propagation environment, a reconfigurable intelligent surface (RIS) with M passive reflecting elements is deployed at a fixed location.

We adopt a RIS-assisted composite channel model. For an arbitrary receiver k, which can represent a legitimate user, the sensing target, or the eavesdropper, the effective channel between the CUAV and receiver k consists of a direct link and an RIS-assisted reflected link. Specifically, let $h_{c,k}$ denote the direct complex channel coefficient from the CUAV to receiver k, $\mathbf{h}_{c,r} \in \mathbb{C}^M$ denote the channel vector from the CUAV to the RIS, and $\mathbf{g}_{r,k} \in \mathbb{C}^M$ denote the channel vector from the RIS to receiver k. The RIS is modeled by a diagonal phase-shift matrix

$$\mathbf{\Phi} = \mathrm{diag}\left(e^{j\theta_1}, \dots, e^{j\theta_M}\right), \tag{1}$$

where $\theta_m \in [0, 2\pi)$ is the adjustable phase shift of the m-th reflecting element.

Accordingly, the RIS-assisted effective channel from the CUAV to receiver k is given by

$$h_{c,k}^{\mathrm{eff}} = h_{c,k} + \mathbf{g}_{r,k}^{\mathrm{H}} \mathbf{\Phi}\, \mathbf{h}_{c,r}, \tag{2}$$

and the corresponding effective channel power gain is

$$G_{c,k}^{\mathrm{eff}} = \left|h_{c,k}^{\mathrm{eff}}\right|^2. \tag{3}$$

Using the effective channel gains, the received signal-to-interference-plus-noise ratio (SINR) at legitimate user k is expressed as

$$\gamma_k = \frac{P_c G_{c,k}^{\mathrm{eff}}}{P_j G_{j,k}^{\mathrm{eff}} + \sigma^2}, \tag{4}$$

where P_c and P_j denote the transmit powers of the CUAV and the JUAV, respectively, $G_{j,k}^{\mathrm{eff}}$ denotes the effective channel gain from the JUAV to user k, and σ^2 is the noise power. For simplicity, the JUAV is assumed to interfere through both direct and RIS-assisted links.

Similarly, the sensing performance is characterized by the sensing signal-to-noise ratio (SNR) at the target, given by

$$\gamma_s = \frac{P_c G_{c,s}^{\mathrm{eff}}}{\sigma^2}, \tag{5}$$

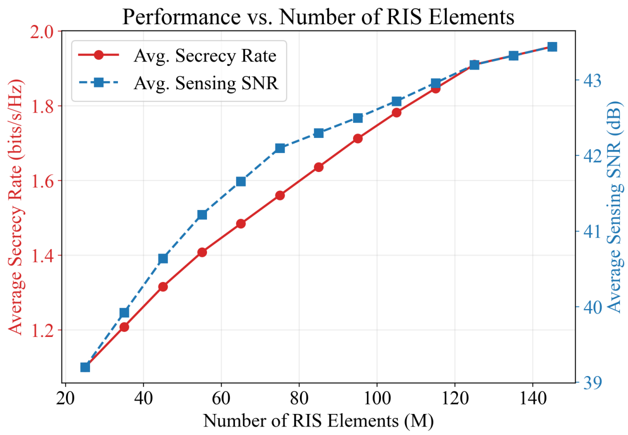

Fig. 2. Impact of the Number of RIS Elements on Secrecy and Sensing Performance.

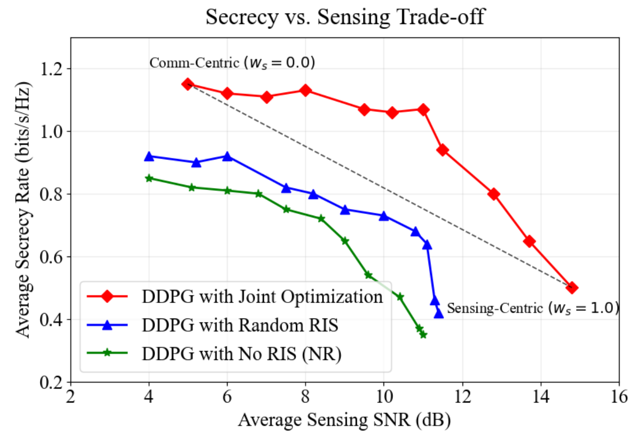

Fig. 3. Secrecy–Sensing Trade-off under Different RIS Configurations.

where $G_{c,s}^{\text{eff}}$ denotes the RIS-assisted effective channel gain between the CUAV and the sensing target.

The SINR at the eavesdropper is expressed as

$$\gamma_e = \frac{P_c G_{c,e}^{\text{eff}}}{P_j G_{j,e}^{\text{eff}} + \sigma^2}, \quad (6)$$

where $G_{c,e}^{\text{eff}}$ and $G_{j,e}^{\text{eff}}$ denote the effective channel gains from the CUAV and the JUAV to the eavesdropper, respectively.

Based on the above physical-layer characterization, the system performance can be controlled through the UAV mobility and RIS phase configuration. Accordingly, the CUAV and JUAV aim to jointly optimize their trajectories and RIS phase shifts to balance communication and sensing performance over the mission duration

$$\max_{\{\mathbf{v}_c(t), \mathbf{v}_j(t), \boldsymbol{\theta}(t)\}} \sum_{t=1}^{T} \Big((1 - w_s)\, R_c(t) + w_s \log\big(1 + \gamma_s(t)\big) \Big), \quad (7)$$

subject to UAV mobility constraints, where the UAV positions evolve over time according to their velocity control actions. Here, $\mathbf{v}_c(t)$ and $\mathbf{v}_j(t)$ denote the velocity vectors of the CUAV and the JUAV, respectively, and $w_s \in [0, 1]$ controls the communication–sensing trade-off. Moreover, $R_c(t)$ denotes the instantaneous sum communication rate of all legitimate users. The UAV control and RIS phase configuration are learned using a DDPG agent, where the UAV positions and sensing SNR are treated as the state, and the UAV velocity vectors together with RIS phase shifts are treated as the action.

III. Simulation Results and Disscussion

The secrecy performance is evaluated using the instantaneous secrecy rate defined as

$$R_s = \big[\log_2(1 + \gamma_0) - \log_2(1 + \gamma_e)\big]^+, \quad (8)$$

where $[x]^+ \triangleq \max\{x, 0\}$ and γ_0 denotes the SINR of the primary user.

Fig. 2 illustrates the impact of the number of RIS reflecting elements M on the average secrecy rate and sensing SNR. It is observed that both metrics increase monotonically with M, due to the enhanced passive beamforming gain provided by a larger RIS.

Fig. 3 shows the trade-off between the average secrecy rate and sensing SNR under different system configurations. By varying the weighting factor w_s, the system transitions from a communication-centric design ($w_s = 0$) to a sensing-centric design ($w_s = 1$). The proposed DDPG-based joint optimization consistently outperforms both random RIS and no-RIS baselines across the entire trade-off region, confirming the effectiveness of jointly optimizing UAV trajectories and RIS phase shifts.

IV. Conclusion

This paper investigates a learning-based framework for RIS-assisted UAV ISAC systems under adversarial interference. By leveraging deep reinforcement learning, RIS phase shifts are optimized to balance communication and sensing performance, while secrecy is evaluated as a key performance indicator.

Simulation results demonstrate that the proposed method achieves improved secrecy performance compared with RIS-free and random RIS baselines, while effectively capturing the trade-off between secrecy and sensing performance.

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