

Learning-based Robust and Secure Transmission for Reconfigurable Intelligent Surface Aided Millimeter Wave UAV Communications

Xufeng Guo, Ying Wang, *Member, IEEE*, and Yuanbin Chen

Abstract—In this letter, we study the secure transmission in the millimeter-wave (mmWave) unmanned aerial vehicle (UAV) communications assisted by the reconfigurable intelligent surface (RIS) under imperfect channel state information (CSI). Specifically, the active beamforming of the UAV, the coefficients of the RIS elements and the UAV trajectory are jointly designed to maximize the sum secrecy rate of all legitimate users in the presence of multiple eavesdroppers. However, the formulated problem is intractable mainly due to the complex constraints **result** from the intricate coupled variables and the time-related issue caused by outdated CSI. To tackle these difficulties, by leveraging the deep deterministic policy gradient (DDPG) framework, a novel and effective twin-DDPG deep reinforcement learning (TDDRL) algorithm is proposed. Simulation results demonstrate the effectiveness and robustness of the proposed algorithm, and the RIS can significantly improve the sum secrecy rate.

Index Terms—Deep reinforcement learning, reconfigurable intelligent surface, secure communication, UAV communication, millimeter-wave communications.

I. INTRODUCTION

Millimeter-wave (mmWave) communications with multi-gigahertz bandwidth availability boost much higher capacity and transmission rate than conventional sub-6GHz communications. Unmanned aerial vehicles (UAVs), which are featured by their high mobility and flexible deployment, are promising candidates to compensate most of the deficiencies of mmWave signals, preserve its advantages, and provide more opportunities [1]. However, the mmWave signals transmitted by UAVs are prone to deteriorate due to their high sensitivity to the presence of spatial blockages, especially in the complex propagation environment (such as in urban areas), which thus degrades the reliability of the communication links. As a result, a more powerful and novel solution is more than essential.

Recently, the reconfigurable intelligent surface (RIS) composed of a large number of passive reflecting elements has become a revolutionary technology to achieve high spectral and energy efficiency in a cost-effective way [2]. By appropriately tuning the reflection coefficients, the reflected signal can be enhanced or weakened at different receivers. Since the RIS has significant passive beamforming gain, it can be incorporated into the mmWave UAV communication system to

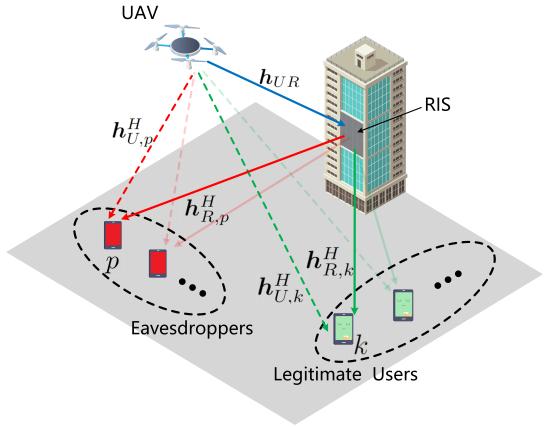


Fig. 1. RIS-aided Millimeter Wave UAV Communications.

generate virtual LoS links, thereby achieving directional signal enhancement, expanding coverage area and reducing the need for radio frequency (RF) chains [3]. In addition, broadcasting and superposition, as two basic properties of the wireless communication, make wireless transmissions inherently susceptible to security breaches [4]. Hence, secure transmission is also a pivotal issue in UAV communication systems which attracted extensive interest of researches [5], [6].

A crucial issue in the RIS-aided mmWave UAV communication system is to jointly design the active and passive beamforming, and the UAV trajectory. However, unlike the general RIS-aided wireless communication model, the UAV mobility-induced variation of **angles of arrival/departure (AoAs/AoDs)** render the channel gains of all links (including direct links and cascaded links) to be optimization variables that need to be well-designed. Such variables are intricately coupled together with the active and passive beamforming matrix [7], which greatly increases the difficulty of the design. To circumvent this issue, several researches have been investigated in [5], [6], [8]–[10], some of which, in particular, leverage alternating optimization (AO) method [5], [6], [8], [9] to tackle the coupled variables, and adopt the phase alignment technique [8] for the single-user system. In [10], a deep reinforcement learning approach is utilized to jointly optimize the passive beamforming and the UAV trajectory, in which, however, the active beamforming is not considered in this approach. It should be pointed out that the above literature [5], [8]–[10] are based on the assumption of the perfect channel state information (CSI), which weakens the versatility and

Corresponding author: Ying Wang.

X. Guo, Y. Chen, and Y. Wang are with the State Key Laboratory of Networking and Switching Technology, Beijing University of Posts and Telecommunications, Beijing, China 100876 (e-mail:brook1711@bupt.edu.cn; wangying@bupt.edu.cn; chen_yuanbin@163.com).

