Optimal Deployment of UAV with Intelligent Reflecting Surface using Reinforcement Learning

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***Abstract*—Currently commercialized 5G is difficult to achieve perfect performance due to limitations of millimeter-wave. There must be many base stations for perfect performance, and the terrestrial base stations have geographical and economic limitations. This paper deals with the optimization of beamforming communication through Unmanned aerial vehicles (UAVs) equipped with the Intelligent Reflecting Surfaces (IRSs). We proposes a system to maximizing the received signal power of a moving user by optimizing the deployment of UAVs. For this optimization, the Soft Actor-Critic (SAC) algorithm is applied to set an optimal deployment with the maximum received signal power.**

I. Introduction

Beamforming is a technology that can support communication services for the corresponding part by concentrating communication in one place. The intelligent reflecting surface(IRS) used with beamforming is a plate that can reflect radio waves, and complements general beamforming to help focus communication services at a desired location [1].

- This paper proposes to provide beamforming communication to mobile users using UAV with IRS.
- Reinforcement learning was used to quickly and accurately derive the optimal location of UAV communication for the mobile user.

A. System model

This paper consists of one base station, one UAV, and one mobile user. At this time, the base station provides beamforming to the user through the UAV's IRS, and the UAV moves to the optimal communication position for the user's moved position. Reinforcement learning was used to find the optimal position.

1) Problem formulation: The problem can be defined as in Expression (1) as maximizing the user's received signal power over the time $\mathcal{N}$ the user is moving. Constraint (1b) implies the limit on the range $\mathcal{R}$ of the UAV. Constraint (1c) ensures that the angles of incidence and reflection of transmitter and receiver are greater than 0 degrees.

$$\max_{\mathcal{T}} \quad P^{total} \tag{1}$$

$$\text{s.t.} \quad P^{total} = \sum_{n \in \mathcal{N}} P_{r,n}, \tag{1a}$$

$$p_{u,n} \in \mathcal{R}, \forall n \in \mathcal{N}, \tag{1b}$$

$$0 < \theta_{r,n}, \theta_{t,n} < \frac{\pi}{2}, \forall n \in \mathcal{N} \tag{1c}$$

B. Reinforcement Learning Environments

The episodes of reinforcement learning are divided into certain times. The elements of reinforcement learning are designed to maximize the user's RSSI. The three basic elements of reinforcement learning are as follows.
In time slot n_j, state s_j is defined as

$$s_j = \{p_{b,j}, p_{u,j}, p_{t,j}\} \tag{2}$$

where $p_{b,j}$, $p_{u,j}$ and $p_{t,j}$ respectively denote the positions of the base station, the UAV, and the user at n_j at that time.
Action a_j is the amount of change in the position of the UAV.

$$a_j = \{\Delta x_u, \Delta y_u, \Delta z_u\} \tag{3}$$

The reward r_j is calculated at the end of the time slot n_j and is designed as

$$r_j = \begin{cases} -5, & \Delta P_{r,j} \leq 0 \vee p_{u,j} \notin \mathcal{R} \\ \Delta P_{r,j}, & \Delta P_{r,j} > 0 \end{cases} \tag{4}$$

There are two types of rewards. First, if the user's changed received signal power is reduced or the UAV is out of the given range $\mathcal{R}$, a penalty of -5 is imposed and the episode ends. If the received signal power of the user rises, the increased amount is added as a reward and the episode continues.

II. Conclusion

In this paper, we propose to provide beamforming communication to users moving through UAV with IRS. Reinforcement learning was applied to derive the optimal location of the UAV to maximize the user's received signal power. Reinforcement learning was done in a virtual environment through Unity [2]. As a result, through the proposed method, it was possible to quickly and accurately derive the optimal position of the UAV that can provide beamforming to the mobile user. We expect that the beamforming service through the combination of UAV and IRS is a way to complement the limitations of the current 5G.

References

[1] Wu, Qingqing, et al. "Intelligent reflecting surface aided wireless communications: A tutorial." arXiv preprint arXiv:2007.02759 (2020).
[2] Juliani, Arthur, et al. "Unity: A general platform for intelligent agents." arXiv preprint arXiv:1809.02627 (2018).