Clustering-Beamforming Algorithm for Security Performance in Multiple Flying RISs-supported Systems

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***Abstract*—This paper introduces an algorithm for improving the security performance in a system by combining unmanned aerial vehicles (UAVs) and reconfigurable intelligent surfaces (RISs), which are emerging technologies in the context of 6G networks. Multiple flying RISs are utilized in this approach. Among them, a DNN-based algorithm is presented to deploy flying RISs in appropriate locations to cover the maximum number of users possible. Through simulation experiments, the superiority of the proposed algorithm is confirmed in terms of accuracy and execution time. In the future, research will be conducted on algorithms optimizing beamforming from the perspective of the base station (BS) and achieving active beamforming within the RIS to further enhance the security performance.**

Keywords— Deep neural network; Reconfigurable intelligent surface; Secrecy rate; Unmanned aerial vehicles.

I. INTRODUCTION

UAVs, characterized by their flexible movements and high altitudes, have gained attention as efficient means to extend wireless coverage in mobile communication systems. RISs, known for their energy-efficient and cost-effective nature, are emerging technologies in the context of 6G networks that can enhance the performance of received signals and mitigate interference by adjusting the propagation environment [1-2]. Research on RISs with various applications is underway, and this paper focuses on improving the physical-layer security performance as a primary objective. Using a standalone fixed RIS has limitations when supporting multiple users in unfavorable receiving environments. Therefore, this paper introduces an algorithm that leverages flying RISs, combining UAVs and RISs, to cover multiple users and enhance the physical-layer security performance in large-scale systems.

Since the research is still ongoing. In [3], the author introduces an algorithm that increases the security rate by optimizing beamforming vectors and paths using the aerial RIS in a single system. Further, in [4], it is considered a small-scale system consisting of a single user, EVE, and aerial RIS an algorithm that maximizes security performance by optimizing the position and phase shift for aerial RISs. However, above algorithms are not suitable for bulk systems because of short resources. Therefore, this paper proposes an algorithm for deploying multiple flying RISs that combine UAV and RIS to support the bulk system consisting of multiple users and EVEs. In the future, research will be conducted on algorithms optimizing beamforming from the perspective of the Base

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Station (BS) and achieving active beamforming within the RIS to further enhance the security performance.

II. SYSTEM MODEL

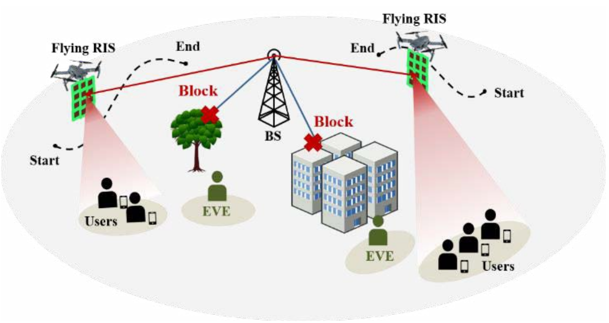

Fig. 1. Flying RISs-supported system model.

This paper considers a large-scale system where one BS supports multiple ground users, as illustrated in Fig. 1. The scenario is taken into account multiple flying RISs and eavesdroppers (EVEs) positioned in the environment, assuming that the line-of-sight (LOS) paths between the BS and users are obstructed by obstacles. For flying RISs, as the altitude increases, the LOS probability also increases. Therefore, it is assumed that there are only LOS paths between the BS and flying RISs, flying RISs and users, and EVEs.

To cover a large number of users with a small number of flying RISs, it is necessary to cluster the users appropriately. In this paper, a set is used to represent the flying RISs, denoted as set $\boldsymbol{L} = \{1, 2, \dots, L\}$, and a set to represent the EVEs, denoted as set $\boldsymbol{E} = \{1, 2, \dots, E\}$. The users are represented as set $\boldsymbol{K} = \{1, 2, \dots, K\}$, where the *l*th flying RIS can cover a set of users, denoted as set $\boldsymbol{K_l} = \{1, 2, \dots, K_l\}$. It is assumed that each cluster contains one EVE. Moreover, to ensure system efficiency, there is a limit to the number of users that can be covered within each cluster represented by K_l^{max}.

Let's define s as the transmitted signal and w as the transmitted beamforming vector. Similarly, we define $\boldsymbol{h}_{rt}$ as the channel vector between the transmitter and receiver. The received signals at the *k*th user and *e*th EVE can be expressed as equations (1) and (2) respectively. Here, $x_{l,k} \in \{0, 1\}$ represents an index indicating whether the *k*th user is included in the cluster covered by the *l*th RIS. For example, if $x_{l,k}$ is 1, it means that the *k*th user is included in the *l*th RIS cluster. Additionally, $\boldsymbol{h}_{kl}$ means the channel vector between *k*th user and *l*th RIS. Similarly, $\boldsymbol{h}_{el}$ means the channel vector between *e*th EVE and *l*th RIS and $\boldsymbol{h}_{lB}$ means the channel matrix between *l*th RIS and BS. $\boldsymbol{Q}_l$ means the phase-shift matrix of *l*th RIS. And n_l, n_k and n_e are noise of *l*th RIS, *k*th user, and *e*th EVE.

$$y_k = \sum_{l=1}^{L}\{(x_{l,k}\boldsymbol{h}_{kl}\boldsymbol{Q}_l\boldsymbol{h}_{lB})w_k s + x_{l,k}\boldsymbol{h}_{kl}\boldsymbol{Q}_l n_l\} + n_k \qquad (1)$$

$$y_e = \sum_{l=1}^{L}\{(x_{l,e}\boldsymbol{h}_{el}\boldsymbol{Q}_l\boldsymbol{h}_{lB})w_k s + x_{l,e}\boldsymbol{h}_{el}\boldsymbol{Q}_l n_l\} + n_e \qquad (2)$$

If we denote the achievable rate for the *k*th user and *e*th EVE as $R_{l,k}$ and $R_{l,e}$, respectively, the secrecy rate can be expressed as shown in equation (3) where $[x]^+ = \max(0, x)$. The ultimate goal of this study is to maximize the secrecy rate $R_{s,avg}$ by optimizing the positions of flying RISs, beamforming at the BS, and active beamforming at the RIS. Since the research is still ongoing, this paper focuses only on optimizing the positions of flying RISs and does not cover the aspects of beamforming at the BS and active beamforming at the RIS.

$$R_{s,avg} = \frac{1}{K}\sum_{l=1}^{L}\sum_{k=1}^{K_l}[R_{l,k} - R_{l,e}]^+ \qquad (3)$$

III. PROPOSED CLUSTERING ALGORITHM FOR FLYING RISS PLACEMENT

The main objective in optimizing the placement of flying RISs is to strategically position them in locations that can cover as many users as possible, while keeping the cost low and maximizing system efficiency. Based on this concept, we can formulate a mixed-integer binary programming problem as shown in equation (4). In this equation, $d_{l,k}$ represents the Euclidean distance between the *l*th flying RIS and *k*th user, γ_l represents an arbitrary value that maximizes the coverage range of the *l*th flying RIS, which we specify as 165 m in this paper. q_l represents the position of the *l*th flying RIS, which should be within the range of minimum and maximum values denoted by q_l^{min} and q_l^{max}, respectively.

$$\begin{aligned} &\max_{q,x} \sum_{l=1}^{L}\sum_{k=1}^{K_l} x_{l,k} \\ \text{s.t. } & d_{l,k}^2 \le \left(D_{l,cov}^{max}\right)^2 + \gamma_l(1 - x_{l,k}) \\ & q_l \in [q_l^{min}, q_l^{max}] \\ & x_{l,k} = \{0, 1\} \\ & K_l \in \mathbb{Z}^+, K_l \le K_l^{max} \\ & l \in \boldsymbol{L} \end{aligned} \qquad (4)$$

To determine the clustering range of flying RISs, we need to define the coverage area they can provide. If we assume that a flying RIS can cover a circular area with a radius $D_{l,cov}^{max}$ around its center, we can express it in terms of altitude (H_l) as shown in equation (5).

$$H_l = D_{l,cov}^{max}\tan(\theta) \qquad (5)$$

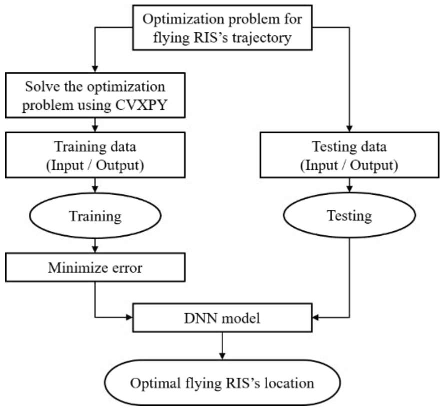

Fig. 2. Proposed DNN structure for optimization of flying RIS's location.

Since equation (4) is in the form of Convex, it can be easily solved with CVXPY. However, this method has the disadvantage of taking a long time and is not suitable for large-scale systems that consider multiple users. Therefore, we propose a DNN-based algorithm as shown in Fig. 2 [6]. The proposed algorithm is largely divided into three stages. 1) It is a step to optimize the problem, 2) create data for training and testing, and 3) use the data to learn and evaluate the DNN model. To obtain data from step 2, we repeatedly solved the problem of Equation (4) using CVXPY for 200 scenarios and obtained the optimal position of flying RISs as a solution. Accordingly, the DNN model was learned with the user's location as the input of the DNN model and the optimal location of flying RISs as the output of the model.

The DNN model consisted of a total of three hidden layers, each of which consisted of 200, 80 and 80 neurons. The fully-connected form was considered, and the "sigmoid" function was applied to the hidden layer as an activation function, and the "linear" function was applied to the output layer. For compiling of the model, the SGD (Stochastic Gradient) method considering mean square error (MSE) was used.

IV. SIMULATION RESULTS

A. Simulation setup

In this paper, a carrier-frequency system of 28 GHz was considered, and to obtain 200 scenarios, the commonly used external ray-tracing scenario "O1" DeepMIMO dataset was used [7]. BS has an 4×4 planar antenna arrangement structure, and both users and EVEs have a single antenna. And as expressed in equation (5), to calculate the coverage of the lth flying RIS, θ is set to 54.62° [5].

B. Performance Evaluation

Table I. Performance comparison Conv. versus proposed DNN-based approach among different scenarios.

Scenarios	**Conv. OPT**	**DNN**	**Accuracy**
$L = 3, K_l = 10$	6.00064s	0.11612s	98.81%
$L = 3, K_l = 20$	7.77566s	0.11313s	96.26%
$L = 3, K_l = 30$	9.31059s	0.11114s	89.89%

Table I shows the time and accuracy taken when solving equation (4) with proposed DNN-based algorithms and general CVXPY methods in various scenarios. It can be seen that the proposed DNN technique predicts the location of flying RISs with high accuracy and short time compared to the existing method. In addition, the existing method increases the execution time as the number of users in the cluster that flying RISs should be in charge of increases, but the proposed method is almost constant and it can be confirmed that it is a suitable algorithm for large-scale systems.

V. CONCLUSION

The goal of this study is to develop an algorithm to improve security rate performance in systems that support multiple users using multiple flying RISs. Since it is still under study, this paper only mentions the placement optimization part of flying RISs, and demonstrates in simulations that it is possible to predict the location of flying RISs with high accuracy and speed by proposing a DNN-based method. In the future, research will be conducted on algorithms that can improve security rate performance by optimizing beamforming on the BS side and active beamforming on RIS.

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