Max-min Rate Optimization of RIS-enabled Downlink Fluid Antenna System using Proximal Policy Optimization

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Abstract

The increasingly demanding quality-of-service (QoS) requirements for next generation communication systems have led to the development of a number of innovative key enabling technologies. In recent years, fluid antenna systems (FAS) have attracted significant attention owing to their ability to dynamically adjust their antenna characteristics. Reconfigurable intelligent surfaces (RISs) have also been studied extensively and have been shown to provide considerable performance improvement through channel reconfiguration. We aim to study the combined effects of these two technologies for min rate maximization using proximal policy optimization (PPO) and show that the utilization of fluid antenna systems significantly enhances system performance by raising the minimum rate as compared to traditional MIMO in the presence of RIS.

Ⅰ. Introduction

Successive generations of wireless communication technologies have aimed to provide higher rates in order to support the developing application scenarios enabled by wireless communications. The demand for higher rates has magnified the effects of channel scarcity, therefore novel technologies are being developed that aim to fulfill the QoS requirements expected the be present in future applications.

RISs owing to their light-weight, cost effective and energy efficient operation, have been studied as one of the promising technologies for the construction of a smart radio environment. They function by passively changing the electromagnetic properties of the impinging waves in a controlled fashion in order to enhance signal reception at the receiver [1]. They have been studied in conjunction with a number of other technologies such as non-orthogonal multiple access (NOMA) [2] and unmanned aerial vehicles (UAVs) [3] etc., where they have been shown to significantly enhance system performance.

FAS are software-controlled entities capable of adjusting their antenna characteristics like gain, radiation pattern and operating frequency etc., by dynamically reconfiguring the shape and position of their antenna elements [4]. The antenna reconfiguration capabilities allow for diversity and multiplexing gains unprecedented in traditional antenna systems with the same number of antennas [5].

Ⅱ. System Model

In this article, we consider a multiple input single output downlink communication system with multiple users. The base station serving the users consists of a N port FAS with N_t fluid antenna elements such that N > N_t. d is the distance between each of the individual ports, making the total length of the FAS equal to d(N-1).

An M element reflective RIS is present such that the RIS has a line-of-sight channel with the base station. And finally, the users are present in the space between the RIS and the base station, as shown in Fig. 1.

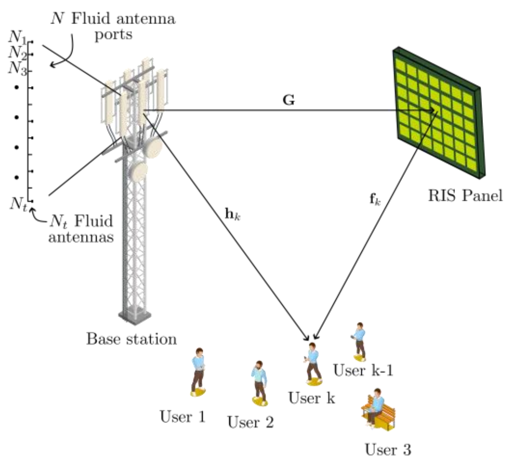

Fig. 1. System Model

Ⅲ. Signal Model & Optimization

The line-of-sight channel G is an N_t×M channel from the base station to the RIS, while the channel from the base station to the user k is given by hk where hk is modelled as a Rician fading channel, given by a Nt×1 complex channel vector. Finally the channel from the RIS to the user is also modelled as a Rician fading channel, given by a M×1 complex channel vector.

We maximize the minimum rate by designing the beamforming and antenna position vectors at the base station and the reflection matrix at the RIS utilizing the PPO algorithm. The neural networks of PPO consist of two hidden layers of neurons given by (128,64). The learning rate is set to 0.0004 and the episode length is set to 100 with a batch size of 64.

IV. Results

The results of max-min optimization of RIS aided FAS system are compared with an RIS aided static antenna system.

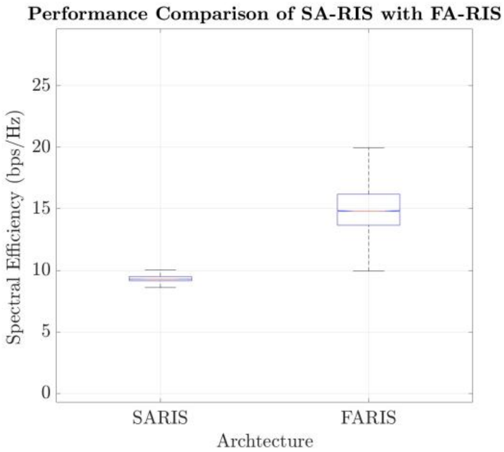

Fig. 2. Mean rate performance comparison of FARIS and SARIS system

It can be seen in Fig. 2. that the fluid antenna RIS (FARIS) system greatly outperforms the static antenna RIS (SARIS) system in terms of mean spectral efficiency, measure using 10,000 Monte Carlo simulations. This indicates that for the same amount of bandwidth, the FARIS system can provide higher rates as compared to the SARIS system.

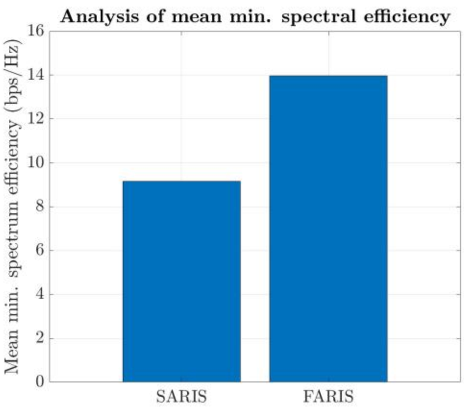

Fig. 3. Mean min graph for FARIS and SARIS

It can be seen from Fig. 3. that the mean min rate in the case of FARIS is much higher as compared to a traditional SARIS system. This performance improvement in the case of mean and min spectral efficiency can be attributed to the additional degree of freedom provided to the base station antennas in the case of FARIS due to the presence of ports. The optimal selection of the ports in the case of FARIS is essential for maximizing the gains provided by the FAS.

IV. Conclusion

In this article we analyzed and compared the performance of an FARIS system with its traditional counterpart using PPO. Rician channels were assumed to be from the base station and RIS to the users. The optimal position of the antennas was selected by the PPO algorithm along with the beamformers at the base station and reflection matrix at the RIS. Our results show that utilizing the extra degrees of freedom offered by the fluid antenna, we obtain an approximately 40% increase in the mean spectral efficiency and approximately 35% increase in the minimum data rate compared to a traditional SARIS system.

ACKNOWLEDGMENT

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