Multi-agent Deep Deterministic Policy Gradient for Secrecy Rate Maximization in Double Faced Active RIS-Assisted Wireless Networks

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Abstract

The focal point of our research study is to engineer a Reconfigurable Intelligent Surfaces (RIS) framework that seamlessly integrates both reflective and refractive signal amplification techniques, designed to enhance the secrecy rate in an environment susceptible to proactive eavesdropping while concurrently optimizing the quality of service for legitimate users. These advancements are to be realized within the constraints of imperfect channel state information. To address the intricacies of achieving optimal outcomes in a dynamic mobile environment, which inherently poses a challenging non-convex optimization problem, we propose the application of a reinforcement learning approach. Specifically, we adopt a multi-agent deep deterministic policy gradient to improve the learning rate and secrecy rate of legitimate users in the presence of multiple eavesdroppers with maximum quality of service under imperfect channel state informaiton.

1. Motivation

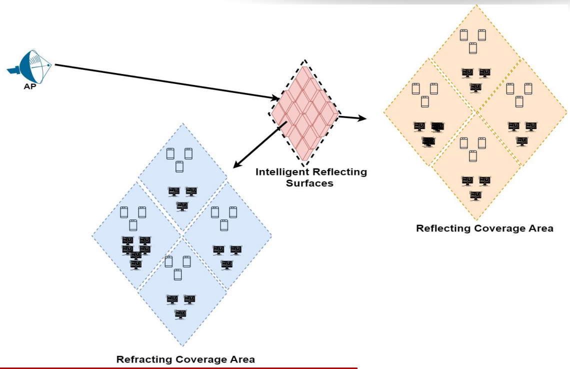
- From a security point of view, physical layer is considered as the cornerstone for the next-generation wireless communication networks, securing radio signals from different attacks for example eavesdropping, wiretapping etc.
- RIS stands alone with minimal cost and complexity as compared to other physical layer technologies, such as relays etc.
- Traditional programming approaches have convergence issues and not considered as most suitable for dynamic environments.
- We will leverage recent advancements in the Reinforcement Learning domain and deploy a Multi-Agent Deep Deterministic Policy Gradient approach, where multiple agents are deployed to maximize the cumulative reward.

1.1 Applications of RIS in 6G

2.1 System Model and Reinforcement Learning

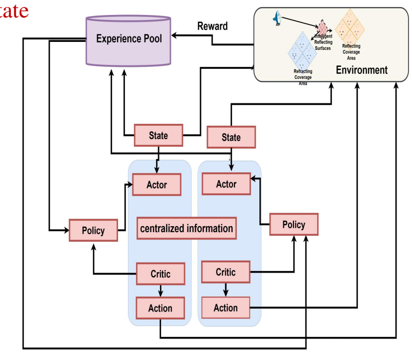
2.2 Signal Model

- From Access Point to Intelligent Reflection Surfaces: $\mathbf{G} \in \mathbf{C}^{M \times N}$
- From Access Point to legitimate users: $h_{d,k} \in \mathbf{C}^{N \times 1}$
- From Access Point to Eves: $g_{d,l} \in \mathbf{C}^{N \times 1}$
- From Intelligent Reflecting Surfaces to legitimate users: $h_{r,k} \in \mathbf{C}^{M \times 1}$
- From Intelligent Reflecting Surfaces to Eves: $g_{r,l} \in \mathbf{C}^{M \times 1}$



2.3 MADDPG

- State : The state provides information about the environment to the RL agents to make decisions about their actions.
  Action : Possible Action in Environment
- Reward : It is possible action ($a \in A$) the RL agents can take in a given environment.
- Next State : It is the probability of transitioning to the next state



3. Conclusion

In 6G, different networks will merge or integrate to achieve maximum output and generate higher revenue than the previous stand-alone networks. With this merger, they will cope with security risks from their counterparts and from newly integrated networks. The Connection and Service layers are not viewed as effective solutions for such a hybrid environment, and the only option is to improve security at the physical layer. Recently, due to the hard work of researchers and engineers, a new technology has garnered attention, named Reconfigurable Intelligent Surfaces. Because of this technology, telecom or wireless network operators will have more control over the physical environment to bypass attacks, such as eavesdropping on wireless signals. Artificial intelligence has already made its impact on different sectors and changed the shape of business. Traditional techniques have not provided effective solutions to security breaches. As an alternative, we will deploy Reinforcement Learning, more specifically the Multi-Agent Deep Deterministic Policy Gradient Algorithm, to bypass eavesdropping attacks on wireless signals and generate Quality of Service under Imperfect Channel State information.

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