Yang LIU, Kui XU, Xiaochen XIA, Wei XIE, Nan MA, Jianhui XU, 2023. Joint power control and passive beamforming optimization in RIS-assisted anti-jamming communication. *Frontiers of Information Technology & Electronic Engineering*, 24(12):1791-1802. https://doi.org/10.1631/FITEE.2200646

Joint power control and passive beamforming optimization in RIS-assisted anti-jamming communication

Key words: Reconfigurable intelligent surface (RIS); Power control; Anti-jamming; Reinforcement learning (RL)

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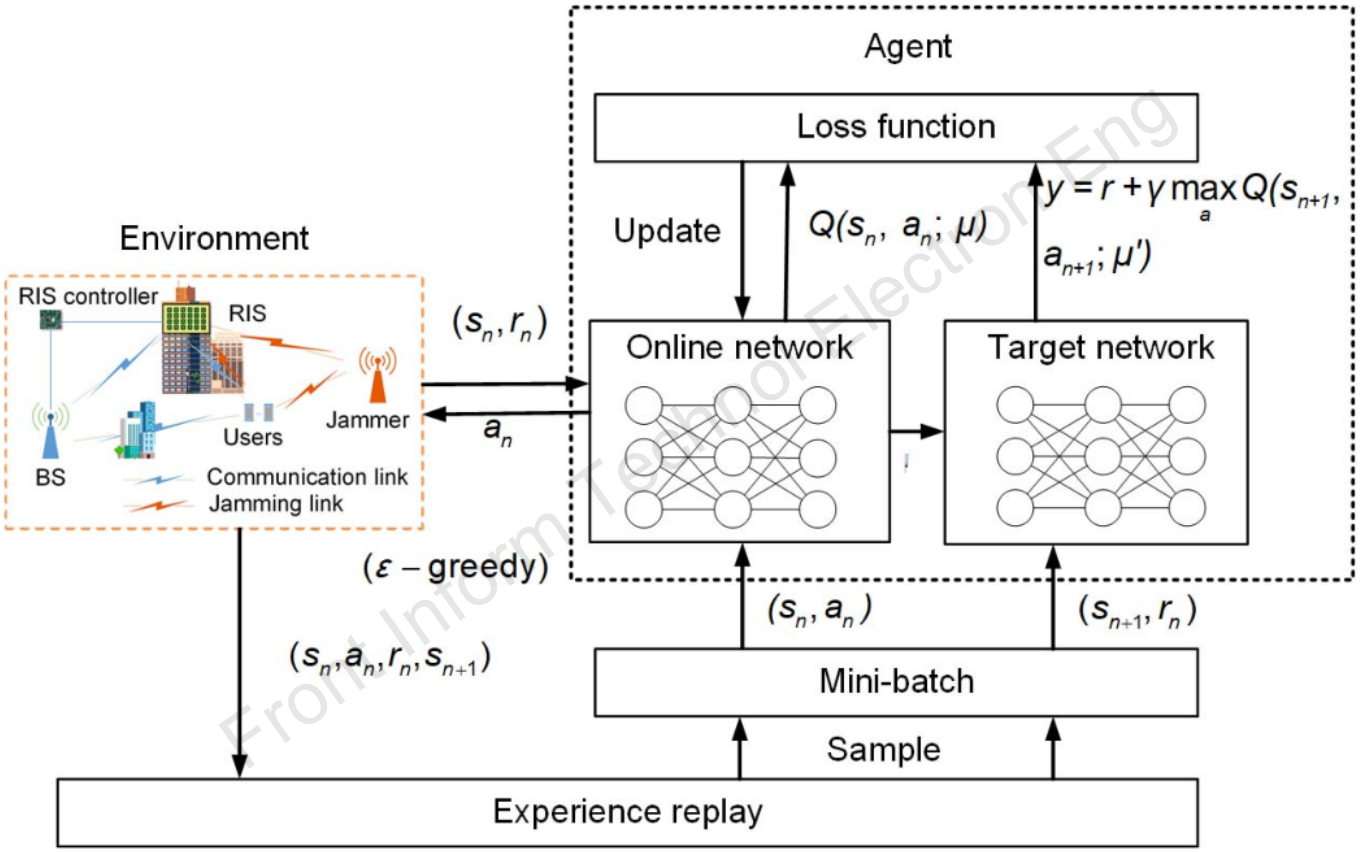
Motivation

- Due to the openness of the wireless propagation environment, wireless networks are highly susceptible to malicious jamming. Taking into account the dynamic and unpredictable nature of a smart jammer, the problem of joint optimization of transmitting power and RIS reflection coefficients is modeled as a Markov decision process (MDP).
- Unlike most power-domain jamming mitigation methods that require information on the jamming power, the proposed double deep Q-network (DDQN) algorithm is better able to adapt to dynamic and unknown environments without relying on the prior information about jamming power.

Framework



Structure of DDQN-based joint design of power control and passive beamforming

Method

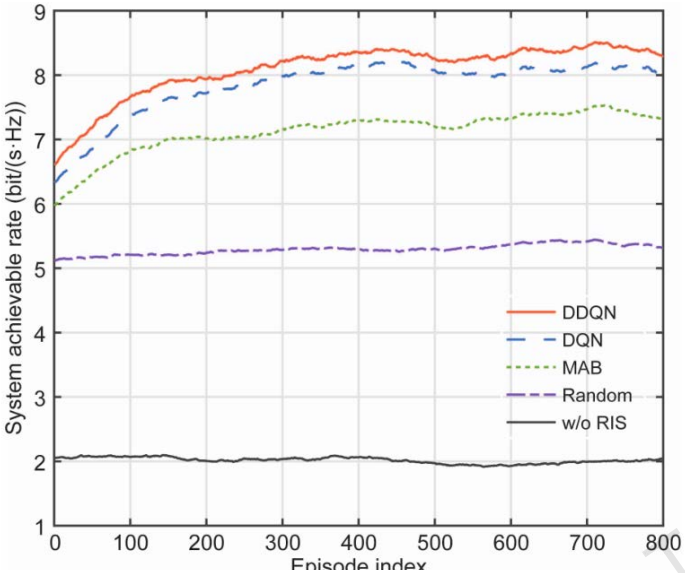
- We model the optimization problem as an MDP and present the proposed DDQN-based algorithm for joint design of power control and passive beamforming.
- DDQN learning algorithm needs to use the evaluation network to determine the action and the target network to determine the action value when estimating the reward.
- Moreover, phase-shift dithering is introduced to enhance the effectiveness of phase shifting and improve the flexibility and performance of the RIS-assisted anti-jamming scheme.

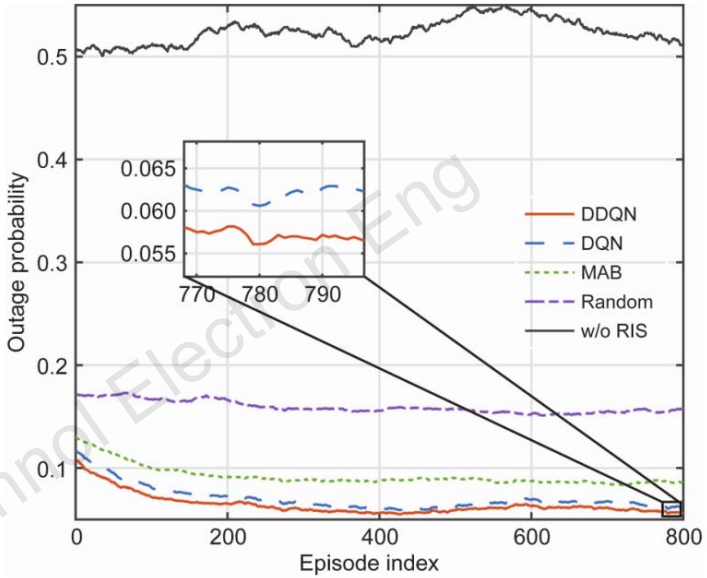
Method

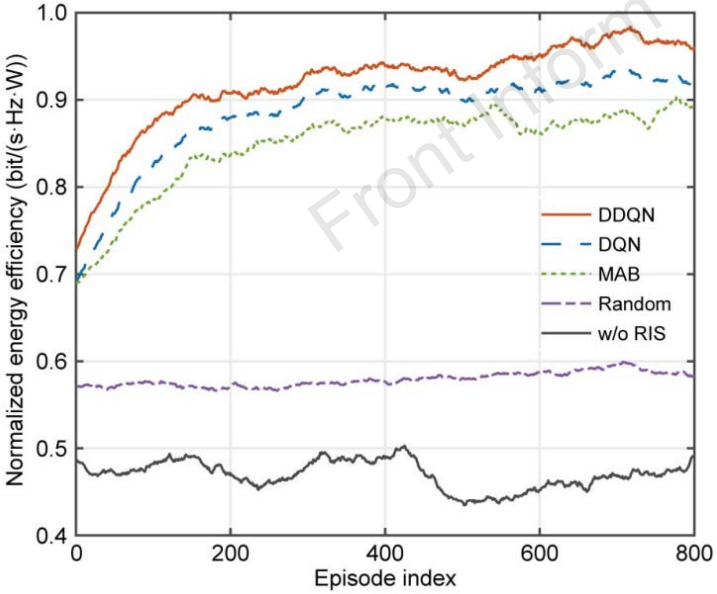
Algorithm 1 DDQN-based joint design of power control and passive beamforming

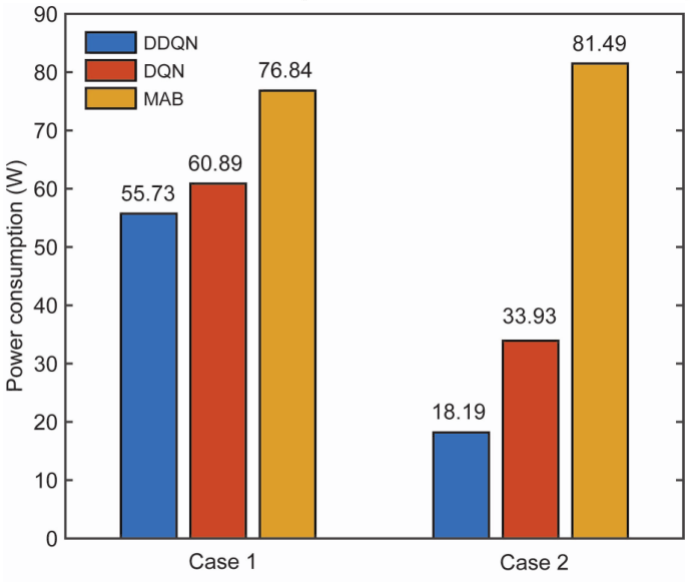
1: Initialize experience memory and parameters M_{e}, N_{b}, γ , ε;
2: Initialize online network with a random weight and biases $\boldsymbol{\mu}$;
3: Initialize the target network as a copy of primary network weights and biases $\boldsymbol{\mu}'$;
4: **for** $n = 1, 2, 3, ...$ **do**
5: Intput state s_n to the DQN and obtain the state-action value $Q_{\psi}(s_n, a_n)$;
6: Select an action a_n based on the $\varepsilon-$greedy policy:
$$\psi(s,a) = \begin{cases} \arg\max\limits_{a} Q(s,a), & p_r > \varepsilon, \\ a_{\mathrm{random}}, & p_r \leq \varepsilon; \end{cases}$$
7: Obtain immediate reward r_n and observe next state s_{n+1};
8: Store experience (s_n, a_n, r_n, s_{n+1}) into memory M_{e};
9: Randomly sample a mini-batch of N_{b} experience tuples from memory;
10: Calculate the target Q-value in the target deep network;
11: Set target:
$T_n = r_n + \gamma Q(s_{n+1}, \arg\max\limits_{a^*} Q(s_{n+1}, a^*; \boldsymbol{\mu}); \boldsymbol{\mu}')$;
12: Train online network to minimize the loss function:
$L(\boldsymbol{\mu}) = E\left[(T_n - Q(s_n, a_n; \boldsymbol{\mu}))^2\right]$;
13: Update the weights of the target network $\boldsymbol{\mu}'$;
14: **end for**

Major results









Conclusions

- By employing RL, the optimal anti-jamming strategy is explored to enhance the anti-jamming communication performance, even without knowledge of the jamming power. Specifically, a DDQN learning algorithm is proposed to jointly optimize power control and RIS passive beamforming, aiming to improve the system's communication performance.
- Simulations are conducted to compare the performance of the DDQN, DQN, MAB, and random algorithms in terms of the system achievable rate, outage probability, and energy efficiency. The results demonstrate that the proposed DDQN learning algorithm outperforms the other algorithms in terms of performance and energy efficiency.

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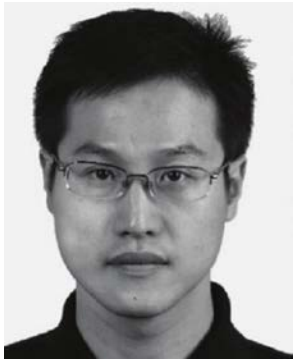

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