AoI optimal dynamic power control for IoT networks: A DRDPG Approach

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INTRODUCTION

- Information freshness is critical for real-time IoT applications and hence, we need to design effective status update strategies to improve it.
- The age of information (AoI) has been proposed as a new metric to characterize the information freshness.
- AoI oriented status update strategies have been developed in recent studies, where the "generate-at-will" model is generally considered. However, in some practical scenarios, the update arrivals at the SNs are stochastic, which makes the dynamic status update problem more challenging.
- Due to the heterogeneity of SNs, the system spectrum efficiency can be improved by allowing multiple SNs to simultaneously transmit their packets under the adaptive power control policy.
- This paper considers an IoT network consisting of multiple SNs with stochastic status update arrivals, and aims to minimize the weighted average AoI at the BS by adaptively controlling the transmission power of SNs. We have formulated the problem as a POMDP with a continue action space and devised a deep recurrent deterministic policy gradient (DRDPG) -based power control (DRPC) algorithm to solve it.

MODELING

- Network model

(1) We assume that status update arrivals at different SNs follow the Bernoulli process. Besides, at each SN, only the freshest update packet is stored in the buffer.
(2) The BS can observe the information freshness of the update packet stored at the SN, only when whose packet has been delivered to the BS.
(3)We consider that the BS can adaptively control the SNs' transmission power for status update to improve the information freshness at the BS.

- AoI dynamic

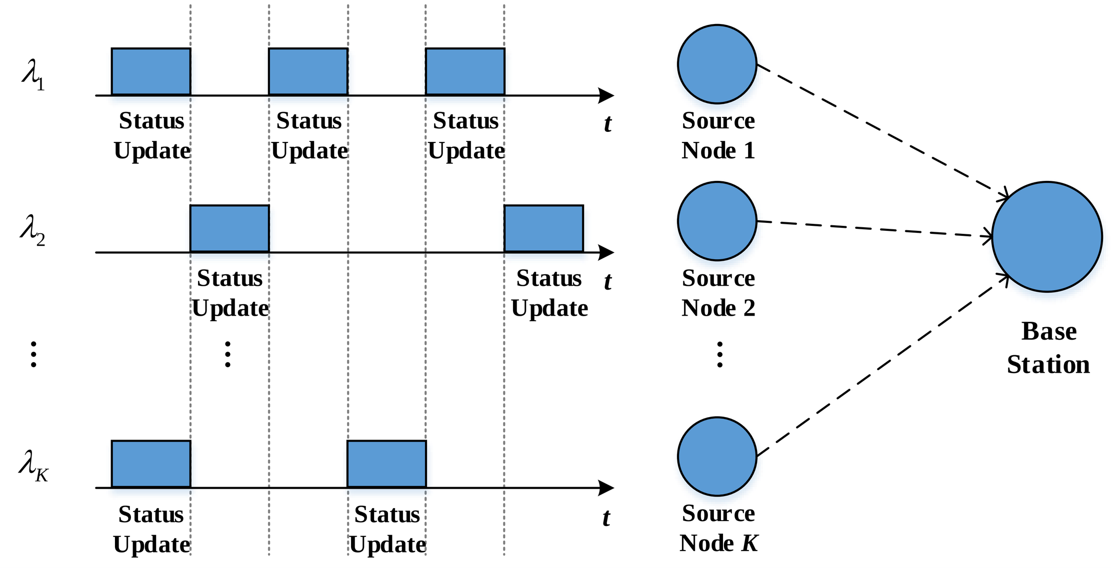
(1) AoI at the SN

$$Z_k(t+1) = \begin{cases} 1, & \text{if } \Lambda_k(t)=1 \\ \min\{Z_k(t)+1, \Delta_{max}\}, & \text{otherwise} \end{cases}.$$

(2)AoI at the BS

$$B_k(t+1) = \begin{cases} Z_k(t)+1, & \text{if } \Theta_k(t)=1 \\ \min\{B_k(t)+1, \Delta_{max}\}, & \text{otherwise} \end{cases}.$$

- System Model



- Problem Formulation

$$\lim_{T\to\infty}\frac{1}{T}\sum_{t=1}^{T}\sum_{k=1}^{K}\theta_k B_k(t)$$

- POMDP Formulation

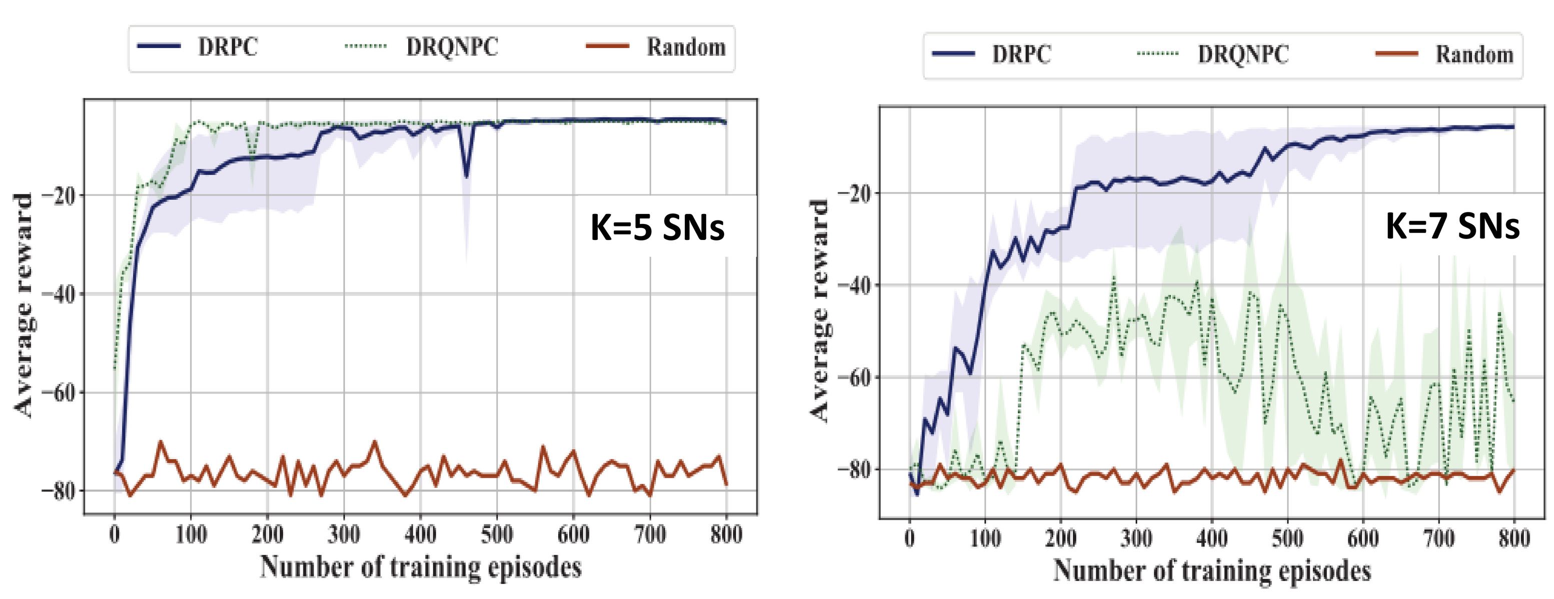
$$< \mathbb{S}, \mathbb{O}, \mathbb{A}, U(\cdot,\cdot) >$$

State space $\mathbb{S}$: $\mathcal{S}(t) = \{\boldsymbol{Z}(t), \boldsymbol{B}(t)\}$
Observation space $\mathbb{O}$: $\mathcal{O}(t) = \{\widehat{\boldsymbol{Z}}(t), \boldsymbol{B}(t)\}$
Action space $\mathbb{A}$: $\boldsymbol{A}(t) = \boldsymbol{p}(t)$
Reward function $U(\cdot,\cdot)$:

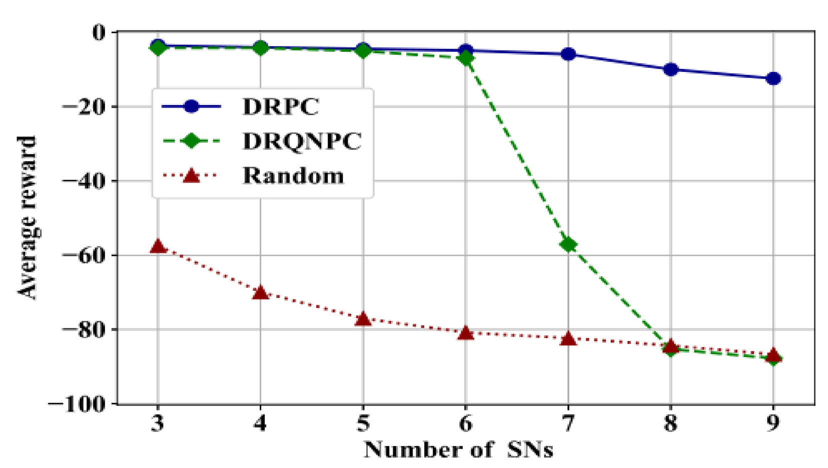
$$U(\mathcal{S}(t), \boldsymbol{A}(t)) = -\sum_{k=1}^{K}\theta_k B_k(t+1)$$

SIMULATION RESULTS

Convergence Comparison



Performance Comparison



CONCLUSION

- This paper has proposed a DRDPG-based power control algorithm to improve the information freshness for IoT networks, where the status update arrivals at SNs are stochastic.
- One of the possible extensions is to study the AoI optimal update strategy for mobile SNs.

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