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Long-Lasting UAV-aided RIS Communications based on SWIPT

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Introduction

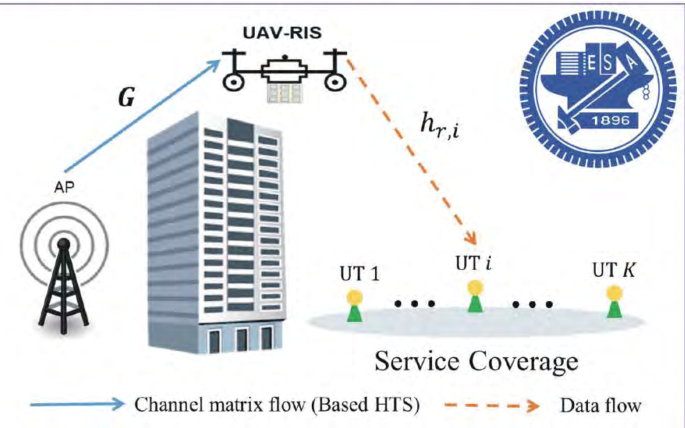

Figure 1. The UAV-aided RIS communications.

Key Words

- Sustainable & Green Communications;
- Energy Harvesting (EH);
- Unmanned Aerial Vehicle (UAV);
- Reconfigurable Intelligent Surface (RIS);
- User Terminals (UTs).

Background

❖ RIS can transmit signal without any energy loss.

❖ UAV-RIS can provide on-demand deployment services.

Motivation

❖ RIS has the capability of harvesting energy from the received radio-frequency (RF) signal for UAV endurance.

Contribution

❖ Enhanced the service coverage of UAV-RIS communications.

❖ Enhanced the endurance capability of UAV-RIS.

❖ Improved the energy-efficient of 5G wireless networks.

Problem Statement

➢ **Problem:** The on-board battery capacity of UAVs still essentially limits the performance and endurance of UAV-assisted RISs communications.

➢ **Objective:** Maximizing the total harvested energy from the received RF signal while satisfying the required minimal communication QoS causality constraints.

$$E = \max_{\tau(t),p,\lambda} \sum_{t=1}^{T} \hat{E}(t), \qquad SNR_k = \frac{|h_{r,k}^H \Theta Z V_k|^2}{\sigma_k^2}, k\epsilon\mathcal{K}$$

$$s.t.\ C1: SNR_k(t) \geq SNR_{min}, \forall k \in \mathcal{K}, t \in \mathcal{T},$$

$$C2: 0 \leq \tau(t) \leq 1, \forall t \in \mathcal{T},$$

$$C3: 0 \leq p = \sum_{k\in\mathcal{K}} \|V_k\|^2 \leq p_{max},$$

$$C4: 0 \leq \lambda \leq 1.$$

Technique Statement

A Novel Energy Harvest Scheme

Architecture

Consists of two main models:

➢ Resources allocation-based HTS model;

➢ AP-RIS-UT channel model.

Novelty & originality

➢ Harvesting energy on both the time and space domains of RIS.

Advantage

➢ The proposed EH scheme outperformed the conventional time-domain EH method in energy-efficient.

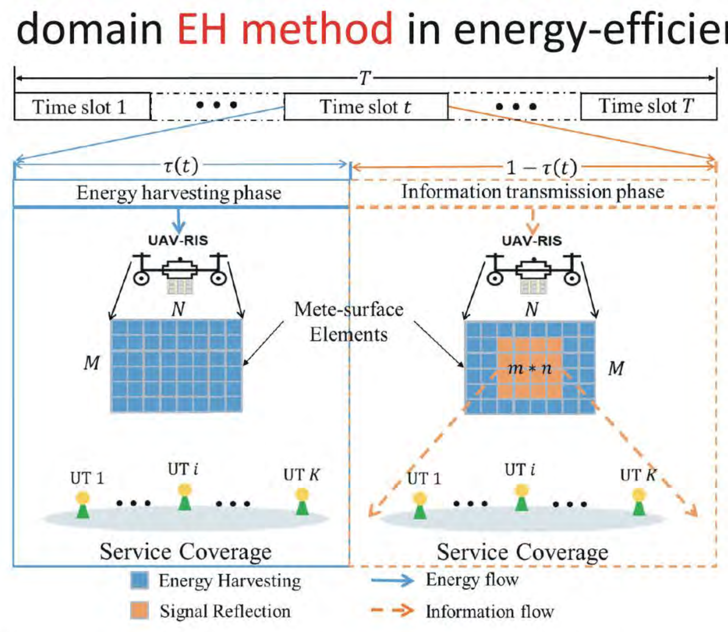

Figure 2. The proposed energy harvest scheme.

Reinforcement Learning-based Method

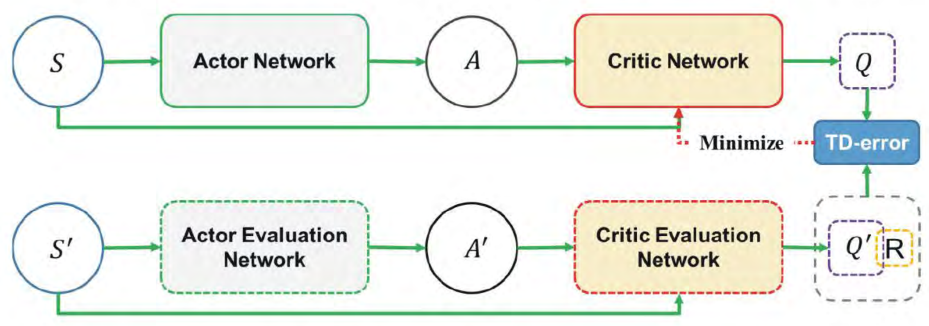

Figure 3. The proposed RL-based approach.

Advantage

❖ Convergence fast and stable;

❖ Low Complexity;

❖ High performance in continuous & high-dimension action space.

Partial Technical Architecture

❖ Reward function

$$\mathcal{R}_t \begin{cases} \hat{E}(t), SNR_k(t) \geq SNR_{min}, \forall k \in \mathcal{K}. \\ 0, SNR_k(t) < SNR_{min}, \forall k \in \mathcal{K}. \end{cases}$$

❖ Loss function of critic evaluation net

$$L(\delta^Q) = \frac{1}{N_B}\sum_{j=1}^{N_B}(y_j - Q(s_j, a_j|\delta^Q))^2$$

Partial Simulation Results

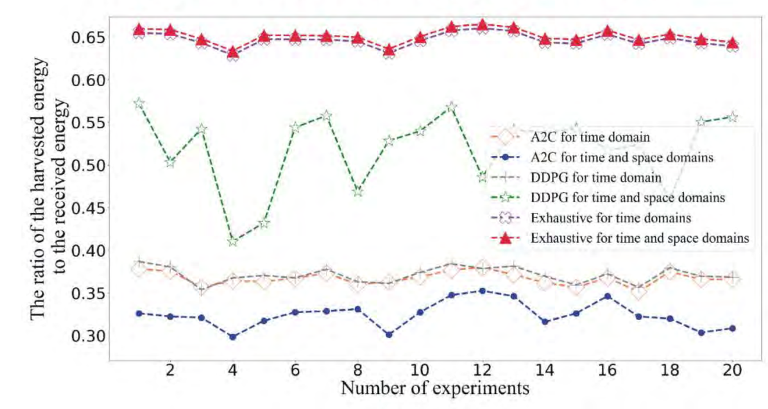

Figure 4. The harvest energy to the received RF signal.

Simulation results demonstrate the efficient and favorable performance of the proposed RL-based optimization method for harvesting energy in UAV-assisted RIS networks.

	Conventional EH	The proposed EH
DDPG	37.1%	51.9%
A2C	32.3%	36.7%
Exhaust	64.7%	65.1%

Table 1. The harvest energy of different methods.

❖ The proposed two-domains EH scheme outperformed the conventional EH on different optimization approaches, such as DDPG, A2C, and exhaustive algorithm.

Conclusion & Discussion

➢ This work investigates the **energy-efficient optimization** and **endurance enhancement** issue of UAV-aided RIS communications for **cutting carbon dioxide emissions** in 5G networks.

➢ This work proposed a **novel long-endurance scheme** via allocating resources of passive reflect-arrays to **harvest energy on both time and space dimensions** for UAV-aided RIS communications.

➢ The proposed RL-based approach can **harvest 51.9% and 21.1% of the energy** from received RF signals with an **acceptable time complexity** in the single UT and multiple UTs cases, respectively.

Publications

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[2] **Haoran Peng**, Chao Chen, C. Lai, Li-Chun Wang, and Zhu Han, "A Predictive On-Demand Placement of UAV Base Stations Using Echo State Network," in IEEE/CIC Int. Conf. Commun. China (ICCC),Changchun, China, Aug. 2019.

[3] Li-Chun Wang, **Haoran Peng**, Cheng-Sen Huang, and Ang-Hsun Tsai, "Latest Advances in Spectrum Management for 6G Communications", in IEEE Wireless Opt. Commun. Conf. (WOCC), Taipei, Taiwan, Oct. 2021.

[4] **Haoran Peng,** Li-Chun Wang, Geoffrey Ye Li, and Ang-Hsun Tsai "Long-Lasting UAV-aided RIS Communications based on SWIPT", has submitted to IEEE Wireless Commun. Netw. Conf. (WCNC), Austin, TX, Apr. 2022.

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