3-D Position Optimization of Solar Energy Hovering UAV Relay in Optical Wireless Backhaul

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I. Introduction and Motivation:

This research presents a 3-D position optimization of solar-powered hovering unmanned aerial vehicles (UAVs) for efficient communication in optical wireless backhaul. The UAVs simultaneously receive sensor data and harvest solar energy while hovering. Once a sufficient energy reserve is attained, the collected sensor data is transmitted to a ground base station. However, both solar energy collection and laser signal transmission by UAVs are subject to attenuation when passing through clouds. To enhance system performance and flexibility under different conditions, we explore various attenuation coefficients and parameters to determine the UAV's optimal location.

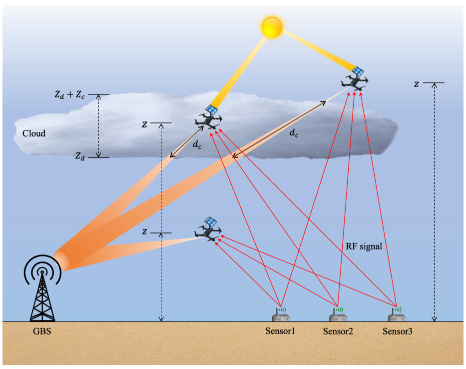

Fig. 1. Hovering UAVs wireless communication backhaul system model

II. System Model:

The Solar Energy Model is given by

$$P_H(z) = \begin{cases} \eta_0 A G_r \alpha_0(z), & z > Z_d + Z_c \\ \eta_0 A G_r \alpha_0(z)\alpha_c(Z_d + Z_c - z), & Z_d < z < Z_d + Z_c \\ \eta_0 A G_r \alpha_0(z)\alpha_c(Z_c)\alpha_d(Z_d - z), & z < Z_d \end{cases}$$

The received signal at the GBS Z is

$$Z = \eta \mathbb{h} Y + N = \eta \mathbb{h} G X + N = \eta \mathbb{h} G(S_X + N_X) + N$$

The end-to-end rate for AF scheme with channel gain $\mathbb{h}$ is

$$C = \int_0^\infty C(h) f_{\mathbb{h}}(h)\, dh\,, \text{ where } C(h) = \ln\left(1 + \frac{(\eta h G S_X)^2}{(\eta h G \sigma_X)^2 + \sigma_N^2}\right)$$

III. Optimization problems and simulation results:

$$\begin{aligned} \underset{x,y,z}{\text{maximize}} \quad & C \\ \text{subject to} \quad & i)\ 0 < x, y < D \\ & ii)\ z > z_0 \end{aligned}$$

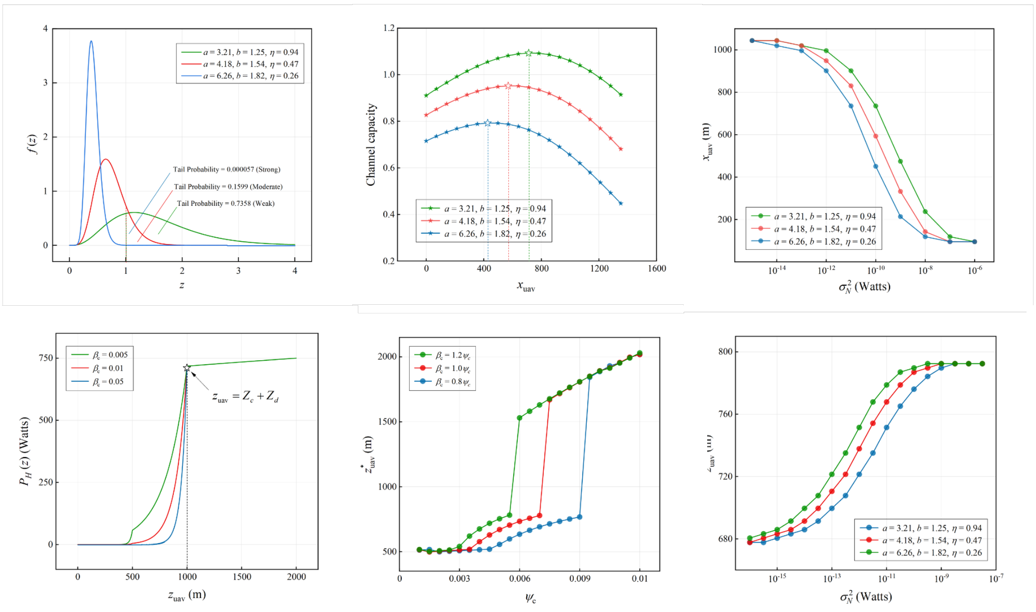

Fig. 2. 3-D UAVs position optimization problem under different environment conditions

IV. Summary

The first curve depicts variations in atmospheric fading channel conditions. Subsequently, the second and third curves reveal that severe atmospheric turbulence or reduced Signal-to-Noise Ratio (SNR) results in a lower optimal UAV positioning in the x-y plane, indicating closer proximity to the ground base station.

Conversely, the fifth curve illustrates that increasing laser signal energy or altering solar energy attenuation factors (ψ_c and β_c) raises the optimal UAV altitude, indicating a tendency for UAVs to move closer to the sun. Similarly, the sixth curve follows an inverse trend observed in the third curve, with deteriorating SNR leading to an increase in the optimal UAV altitude.

References

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[2] M. S. Bashir and M. -S. Alouini, "Energy Optimization of a Laser-Powered Hovering-UAV Relay in Optical Wireless Backhaul," in IEEE Transactions on Wireless Communications, vol. 22, no. 5, pp. 3216-3230, May 2023, doi: 10.1109/TWC.2022.3216797.