Throughput Maximization Using TDMA-based NOMA Slot Allocation for UAV-ISAC System

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***Abstract*—Integrated sensing and communication (ISAC) is a promising 6G technology that is increasingly integrated with UAV platforms. This paper proposes a TDMA-based NOMA slot allocation scheme for UAV-ISAC systems. This scheme enforces power-domain superposition within a single beam in each scheduled slot, while maintaining the frame structure and the constraint of one illumination per target per frame. The proposed scheme is modeled and evaluated under the same UAV-ISAC configuration, sensing frequency, and power requirements as the TDMA baseline. Simulation results demonstrate that the proposed scheme achieves a higher average achievable rate than the baseline.**

***Index Terms*—Integrated sensing and communication, UAV, NOMA, beamforming, throughput maximization, slot allocation.**

I. Introduction

Integrated sensing and communication (ISAC) merges communication and sensing to reduce cost and improve spectral efficiency for 6G systems, emerging as a paradigm for UAV-enabled networks and resource-constrained deployments. In [1], dual-functional ISAC and beamforming trade-offs are surveyed. In particular, an UAV-enabled TDMA-based periodic sensing framework jointly optimizes trajectory, user association, and beamforming [2]. In [3], power-domain NOMA enlarges the broadcast region via superposition and SIC. In [4], coordinated trajectory and beamforming in UAV-ISAC systems are shown to improve end-to-end efficiency, motivating a multiuser slot design.

However, TDMA-based designs, such as [2] schedule only one communication user per slot, underusing communication time, and leaving multiuser spatial degree of freedom (DoF) idle. We propose a NOMA slot allocation scheme. In communication-only (CO) slots, two users are superposed with successive interference cancellation. In sensing-and-communication (SC) slots, one user is overlaid only when the sensing constraint is met. We benchmark against the straight-fly (SF), fly-hover-fly (FHF), and integrated periodic sensing and communication (IPSAC) mechanism design in [2]. We adopt NOMA design of [3] for the split of power and the decoding order. Performance is evaluated via simulations for throughput maximization using average achievable rate under identical sensing frequency and power requirement.

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No.2021R1A2C2007112).

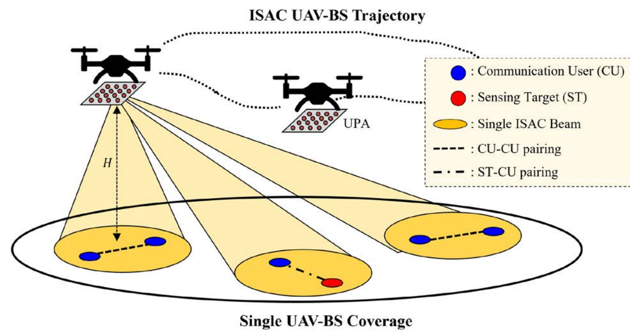

Fig. 1. Proposed system model for single UAV-ISAC system.

II. System Model and Proposed Scheme

A. System Model

As illustrated in Fig. 1, a single UAV with a uniform planar array executes a mission of duration T discretized into N slots of length δt and grouped into L equal ISAC frames with $N_L = N/L$ and frame length $T_L = T/L$; the sensing frequency is $f = 1/T_L$. Ground users $\{\mathbf{u}_k\}$ and sensing targets $\{\mathbf{v}_j\}$ are fixed while the UAV flies at altitude H with horizontal location $\mathbf{q}[n]$. Let $\mathbf{w}[n]$ denote the unit-norm transmit beam; the effective user and target gains are $g_k[n] = |\mathbf{h}_k^H[n]\mathbf{w}[n]|^2$ and $b_t[n] = |\mathbf{a}_t^H[n]\mathbf{w}[n]|^2$.Line-of-sight propagation, array steering, mobility constraints, and the periodic target sensing constraints follow the framework and sensing assumptions in [2]. As summarized in Fig. 2, a single ISAC beam per slot supports communication user pairing in CO slots and sensing target–communication user pairing in SC slots.

When slot n illuminates target j, the per-slot beampattern feasibility is

$$\big(p_s[n] + p_w[n]\big)\, b_t[n] \;\geq\; \Gamma_{\text{th}}\, d_t[n]^{\xi}, \tag{1}$$

where $p_s[n], p_w[n] \geq 0$ are the superposed powers for the strong user s and weak user w, $b_t[n]$ is the transmit gain toward the target, $d_t[n]$ is the UAV–target distance, and ξ is the sensing pathloss exponent. The cap $p_s[n]+p_w[n] \leq P_{\max}$ and the receiver noise power σ^2 apply. Frame-wise achievable-rate lower bounds from [2] can be imposed and naturally promote nonzero power to weaker users without exclusive slots.

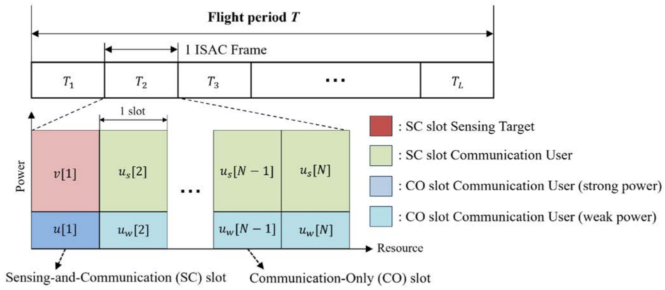

Fig. 2. Proposed TDMA-based NOMA slot allocation structure.

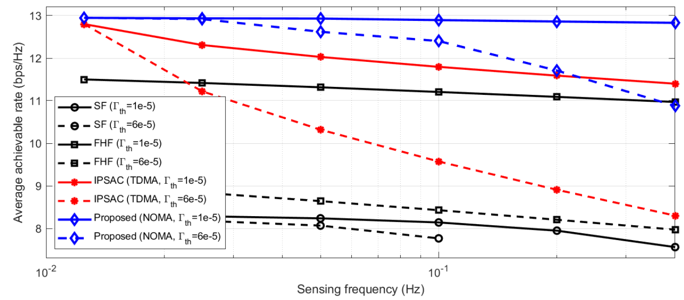

Fig. 3. Comparison of achievable rate between the baseline schemes and the proposed scheme.

B. Proposed Scheme

In CO slots a NOMA pair (s, w) is served with one transmit beam chosen in the span of the paired users' steering vectors, inducing effective gains $g_s[n]$ and $g_w[n]$. In SC slots exactly one target is illuminated per frame, and one communication user is overlaid only if the same beam satisfies (1). For a chosen beam, the per-slot achievable rates are

$$\begin{aligned} R_s[n] &= \log_2\Big(1 + \frac{g_s[n]\, p_s[n]}{\sigma^2}\Big), \\ R_w[n] &= \log_2\Big(1 + \frac{g_w[n]\, p_w[n]}{g_w[n]\, p_s[n] + \sigma^2}\Big), \end{aligned} \tag{2}$$

with $p_s[n]+p_w[n] \le P_{\max}$. From (1), any SC slot must satisfy

$$p_{\min}[n] = \frac{\Gamma_{\text{th}}\, d_t[n]^{\xi}}{b_t[n]}, \qquad p_s[n] + p_w[n] \in \big[p_{\min}[n],\, P_{\max}\big]. \tag{3}$$

Given the total slot power $S[n] = p_s[n] + p_w[n]$, the achievable rate per slot is

$$R_{\text{sum}}[n] = R_s[n] + R_w[n] \tag{4}$$

is optimized by selecting $p_s[n] \in [0, S[n]]$. When $g_s[n] \ge g_w[n]$ and no additional per-user constraints are active, the unconstrained maximizer of (4) occurs at $p_s^{\star}[n] = S[n]$; nonzero $p_w[n]$ becomes optimal under frame-level bounds of [2] or feasibility-coupled beamforming. The interior stationary point, when it exists, satisfies

$$\frac{g_s[n]}{\sigma^2 + g_s[n]\, p_s^{\star}[n]} = \frac{g_w[n]}{\sigma^2 + g_w[n]\, p_s^{\star}[n]}\,, \tag{5}$$

During the mission, we maximize the average achievable rate.

$$\bar{R} = \frac{1}{N}\sum_{n=1}^{N}\sum_{k=1}^{K} R_k[n], \tag{6}$$

subject to illumination per target per frame, feasibility per slots (1), power cap $p_s[n]+p_w[n] \le P_{\max}$, optional user/frame min-rate bounds, and constraints on UAV mobility in [2]. Within these constraints, the proposed NOMA slot allocation scheme exploits two-user superposition to optimize (6), and in our evaluations attains values comparable to or exceeding the TDMA-based baseline schemes under identical frame and feasibility constraints.

III. Simulation Results

Using the baseline geometry, propagation, and array settings in [2], we sweep the sensing frequency by varying the frame length T_L and test two beampattern thresholds $\Gamma_{\text{th}} = 10^{-5}$ and 6×10^{-5}. Fig. 3 plots average achievable rate for baseline schemes, and the proposed NOMA slot allocation scheme. At the lower threshold our design exceeds baselines when CO slots dominate and two-user superposition is feasible. As sensing frequency rises all curves drop since CO time shrinks, yet our scheme keeps a margin by pairing users with asymmetry and reusing the beam. At the higher threshold rates drop due to (1) yet the advantage persists across UAV geometries, confirming throughput gains under identical sensing frequency and power requirement.

IV. Conclusion

In this paper, we propose a TDMA-based NOMA slot allocation scheme for UAV-enabled ISAC that preserves the frame design and one illumination per target each frame, while changing only the per slot access rule. In CO slots, two users are superposed with SIC, and in SC slots one user is overlaid only when the beam meets the sensing constraint. With one beam per slot and optimized pairing and power split, the scheme maximizes the average achievable rate. Simulations show that under the same sensing frequency and power budgets as the baseline schemes, the proposed scheme yields higher average achievable rates in the UAV-ISAC system. Future work will consider multi-UAV operation, more realistic channels, and trade-offs involving QoS and energy efficiency.

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