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ECE 250 - Wireless Communication and Networking

Final Project Abstract

Exploring Integrated Sensing and Communication (ISAC) for MIMO Architecture

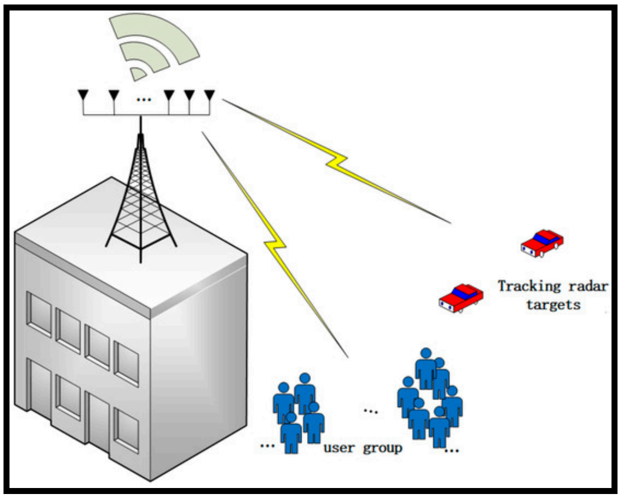

Fig: NOMA-Assisted ISAC Systems[3]

Introduction

Wireless communication and radar sensing have been studied separately for a long time. 6G marks a paradigm shift in next-generation wireless systems by combining the two efforts, known as Integrated Sensing and Communication (ISAC), by designing the signal covariance matrix or the precoding matrix considering both sensing and communication performance requirements[1]. Leveraging Multiple-Input Multiple-Output (MIMO) technology, ISAC systems can exploit the spatial degrees of freedom to simultaneously transmit communication data and extract environmental sensing information using a shared hardware and spectral resource[2]. This dual use opens up promising avenues for applications such as autonomous vehicles, smart environments, gesture recognition, industrial automation, and joint vehicular communication-radar systems.

A range of available literature explores novel beamforming strategies[2], waveform design[4], and spatial resource allocation[5] for MIMO-enabled ISAC systems. Key challenges include optimizing trade-offs between sensing accuracy and communication throughput, robust beam alignment in dynamic environments, and hardware constraints such as phase noise and synchronization. We aim to identify optimal trade-off points via simulation frameworks that model both communication and radar performance metrics, enabling early-stage prototyping of ISAC systems in MIMO architectures.

Simulation Methods Planned

The initial plan of action we have is to utilize the crowd-sourcing dataset available in the lab website, and integrate that in a simplified MIMO setup. We further want to design theoretical framework and try to simulate more experiments in the following direction (with decreasing priority):

- **Joint Beamforming for ISAC** - Designing a transmit beam that optimizes generation of a sufficiently high minimum communication SNR, while maintaining an accurate angle/range estimation.
- **Resource Allocation Strategies** - Optimize power, bandwidth, and spatial degrees of freedom between sensing(Range/Doppler Resolution, Detection Probability) and communication (BER, SNR, Throughput) tasks.
- **Statistical CSI-Based Beamforming Design** – Evaluating a scalable, low-complexity ISAC method based on long-term channel statistics, serving as a practical benchmark when real-time CSI is limited or unavailable
- **Waveform Design for Dual Use** - Investigating OFDM-based radar-communication waveforms to use wifi signals to perform the same task.

Simplified System Description

Communication Part: Uses a K×M MIMO channel with flat fading (Rayleigh).

Sensing Part: Uses beam steering to simulate radar-like object detection via phased arrays.

Objective: Simplified crowd analytics by sensing multiple targets. Demonstrate coexistence of data transmission and object detection (ISAC concept).

Simulation Platforms: MATLAB + Phased Array System Toolbox and Sionna (TensorFlow).

References

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