Dynamic Dual-Domain Resource Allocation for Integrated Sensing, Communication, and Powering (3D-ISCAP)

CHEDDAR

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Background & Motivation

- ISCAP is a compelling setup to improve energy and spectrum efficiency while reducing deployment and maintenance costs in 6G networks.
- ISCAP cater for multiple applications and scenarios.
- SotA Resource allocation approaches in ISAC systems tend to focus on frequency domain, assuming time-invariant channels, prefixed power budgets, and resource cardinalities.
- The environment in several ISCAP scenarios can be dynamic: (Wireless-powered sensors on moving/rotating machines, moving communication users, sensing targets, and scatters)

⇨ We need adaptive resource allocation mechanisms that balance the various competing QoS requirements.

Use cases & Applications

ISCAP for smart manufacturing and Industrial IoT

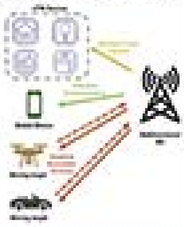
ISCAP for smart cities applications

- Sensing moving robots, vehicles, and machines.
- Wirelessly powering vibration/temperature/rotation/humidity sensors in harsh, difficult-to-access/replace battery locations
- Sending downlink data to users, control packets to machines,...

Scenario Description & System Model

- A multi-functional BS equipped with single TX antenna and single RX antenna simultaneously serve communication users, energy receivers and act as monostatic radar to sense targets in the environment.
- Dual-domain mapping matrices are used to track the mutual-exclusive resources.
- The compound multi-functional OFDM signal is:

$$\mathbf{X} = \mathbf{A} \odot \left(\mathbf{R}^s \odot \mathbf{S}^s + \sum_{i=1} \mathbf{R}_i^c \odot \mathbf{S}^c + \sum_{j=1} \mathbf{R}_j^e \odot \mathbf{S}^e \right) \in \mathbb{C}^{N \times M}$$



Approach & Methodology

- Leverages OFDM flexibility across different degrees of freedom to propose adaptive resource allocation schemes for multi-functional ISCAP networks.
- Propose multiple allocation designs, based on the service priority requirements (Sensing-First Design (SFD), Comm-First Design (CFD), and Power-First Design (PFD).
- Dual sensing metrics to cover the whole AF properties (Resolution and ambiguities CRB and PSL).

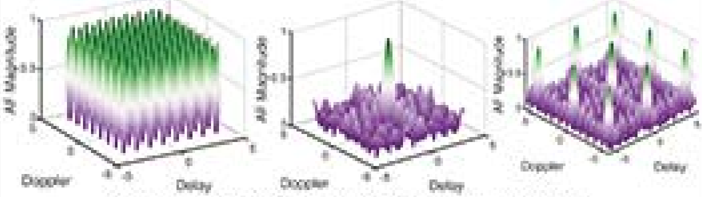
Performance Metrics:

Communication

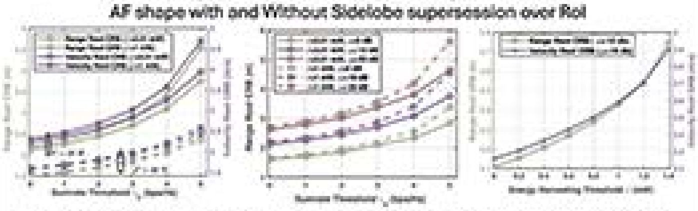
Sensing

Powering

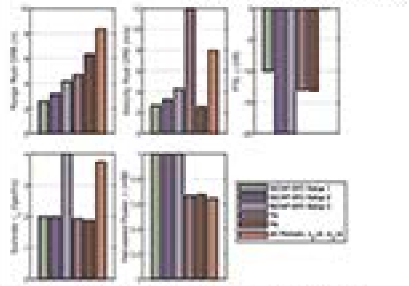
Highlighted Results



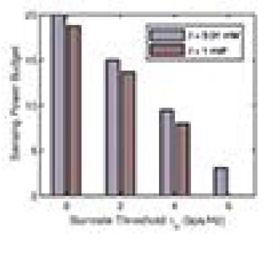
AF shape with and Without Sidelobe supersession over RoI



Three-way inter-function (Sensing-Comm-Powering) Tradeoffs and Inra-Sensing Function (Resolution-Ambiguity) Tradeoff



Adaptive Allocation Versus Static Allocation



Sensing Power Budget Evolution

Main Contributions

- Proposed adaptive joint subcarrier-power allocation designs for ISCAP taking into account delay-doppler resolution and ambiguity of sensing tasks, energy demands of IoT devices and QoS requirements of communication users.
- Analyzed three-way inter-function and intra-sensing function (Resolution-Ambiguity) tradeoffs, and spotted regimes where the system would fail to accommodate the conflicting demands.

Future Extensions

- Extend to non-orthogonal ISCAP setup

⇨ Cross-function interference mitigation

- Multifunctional-RIS meets Multifunctional-OFDM:

⇨ Design passive, active beamforming and RIS elements partitioning to support multiple functions.

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