Capstone Project: Networked Millimeter Wave Radar for Autonomy and Safety

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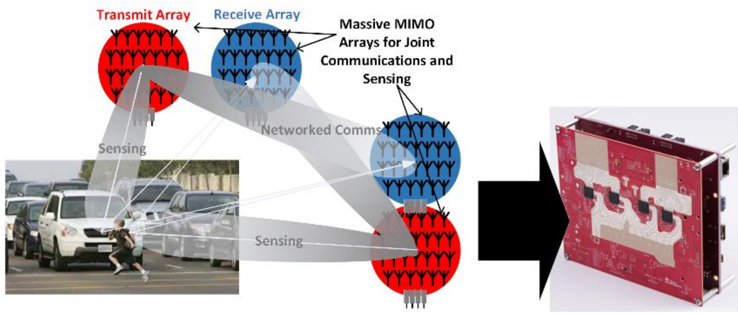
The goal is to demonstrate a network of radar nodes that could be integrated into future autonomous systems and instantaneously generate a comprehensive RF map of objects and activities in indoor or outdoor environments. This project will require a cohesive team of students with interests in radio, signal processing, and computer engineering.



Background: Rapid advances in millimeter-wave electronics have made commercially available radar systems that operate at 77 GHz available at low cost. These radars offer resolution at centimeter scales have applications ranging from perception for vehicular autonomy to privacy-preserving sensing for eldercare. An example of a commercially available multi-antenna millimeter-wave radar is the TI TIDEP-01012 shown in the adjacent figure. These components offer RF interfaces as well as powerful on-chip signal processing capability, and a powerful sensing infrastructure can be built by networking such radar units. A parallel development is the concept of Joint Communication and Sensing envisioned for NextG millimeter-wave cellular, in which reflections from signals emitted by base stations are employed for networked sensing.

Problem: Millimeter-wave radar offers excellent range resolution and coupled with multi-input/multi-output (MIMO) signal processing techniques can improve the resolution and flexibility to produce an instantaneous map of an indoor or outdoor environment. However, millimeter-wave radar systems do not see around corners or function well in non-line-of-sight conditions which limits the safety and robustness of relying on such as radar system.

Proposed Solution: By employing a distributed network of radar transmitters and receivers, the project will improve the resolution and reliability of RF imaging and inference. The project will explore fundamental building blocks for scaling to large distributed radar sensing systems. Depending on the interests and skillset of the team, this could include hardware/signal processing co-design for networked sensing, and/or development of a software framework for networked sensing with existing TI radar boards.

Suggested Tasks: There are two complementary directions that could be explored (a large enough team could be organized into subgroups for pursuing both of these directions.

A) Connected outdoor sensing with existing MIMO radar boards: Integrate GPS (for self-localization), WiFi (for communication to central server) and millisecond-level timing synchronization (this enables frame-level synchronization across boards) into TI radar evaluation hardware at 77 GHz. Stream radar point clouds to a centralized server, and develop and implement server algorithms for scene inference based on data received from multiple sensors. These algorithms are layered on top of the radar signal processing already performed by the TI boards. In order to accomplish this, the team must first develop a basic understanding of the fundamentals of MIMO radar, and become familiar with hardware programming tools and signal processing tools provided by TI, applying them to extract radar point clouds.

B) Hardware/signal processing design and prototyping for networked multistatic radar: Build programmable millimeter-wave transceivers which can generate a variety of waveforms. Develop and demonstrate the ability to receive reflections from targets at receivers which are *a priori* unsynchronized with the transmitter, and to estimate synchronization and target parameters jointly. This is the fundamental building block for nextG Joint Communication and Sensing (JCAS) systems leveraging the cellular infrastructure. Once this is accomplished, demonstrate target tracking using a network of one transmitter and two receivers.