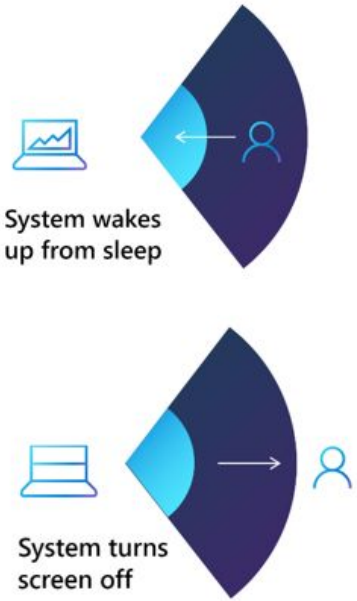
Desk Occupancy Sensing with Commercial UWB Devices and Low Power Backscatter Tags

Shanmu Wang

Embedded System - Midterm Checkpoint

Motivation and Objectives

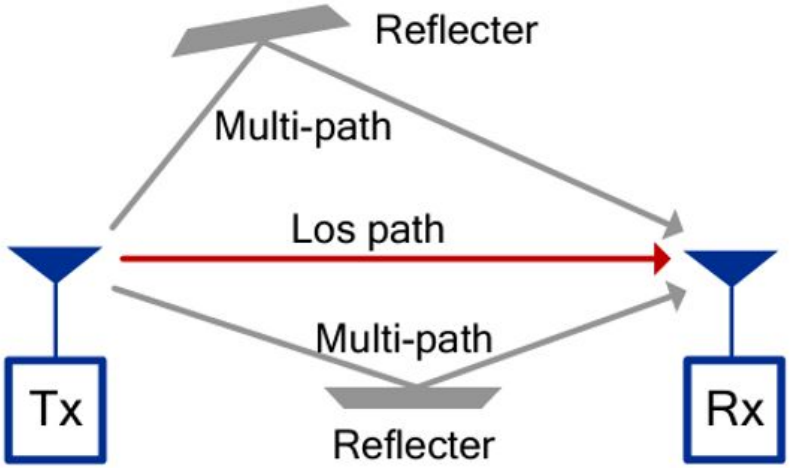
- Smart offices need desk-level occupancy data for applications such as wake-on-use networking
- Goals:
  - Device-free desk occupancy detection
  - Long lifetime, less maintenance
  - Generalizable framework that works for different room/desk layout

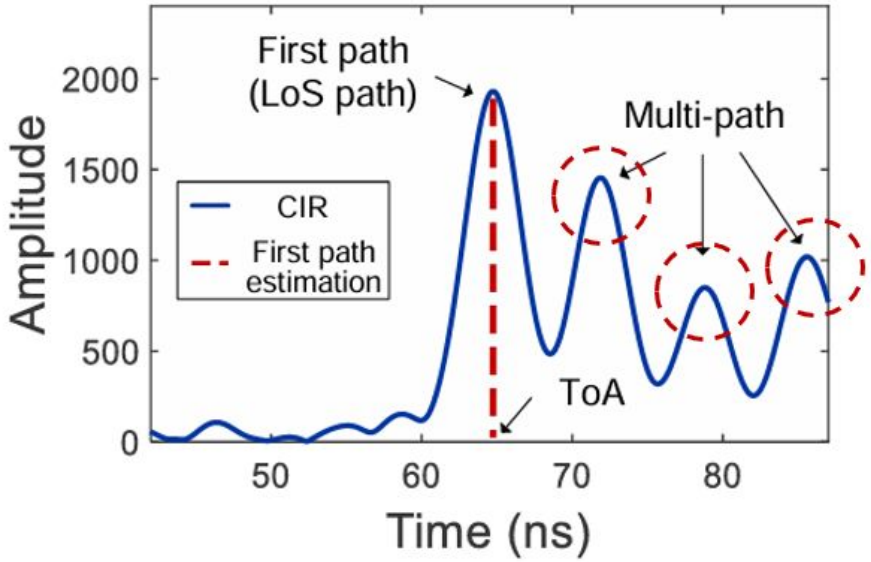


Technical Approach and Novelty

- Device-based:
  - Infrared sensor, pressure pads: drains the battery, increased maintenance
- Device-free:
  - Camera-based: Risk of privacy
  - WiFi-based: ubiquitous, but with limited resolutions -> Room-level occupancy estimation; desk-level needs fingerprinting
- Next Generation Wi-Fi APs by CISCO, will equip Ultra-Wideband (UWB) radios
  - UWB provides much higher resolution, enabling precise tracking capabilities
  - Their potential in sensing is less explored

Multipath Effects in UWB Radios:

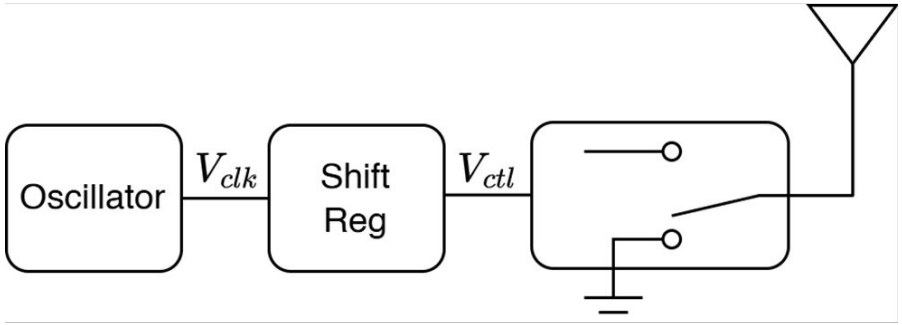


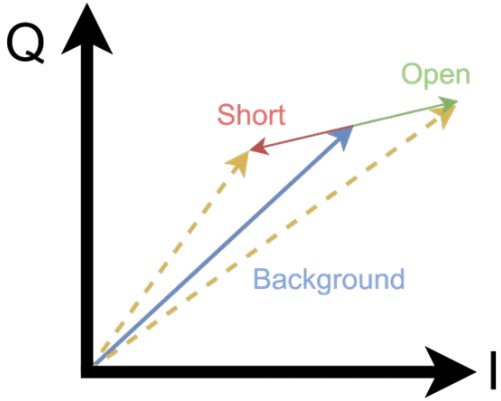


- Desk location and room layout vary a lot
- We need to calibrate the desk identities and locations

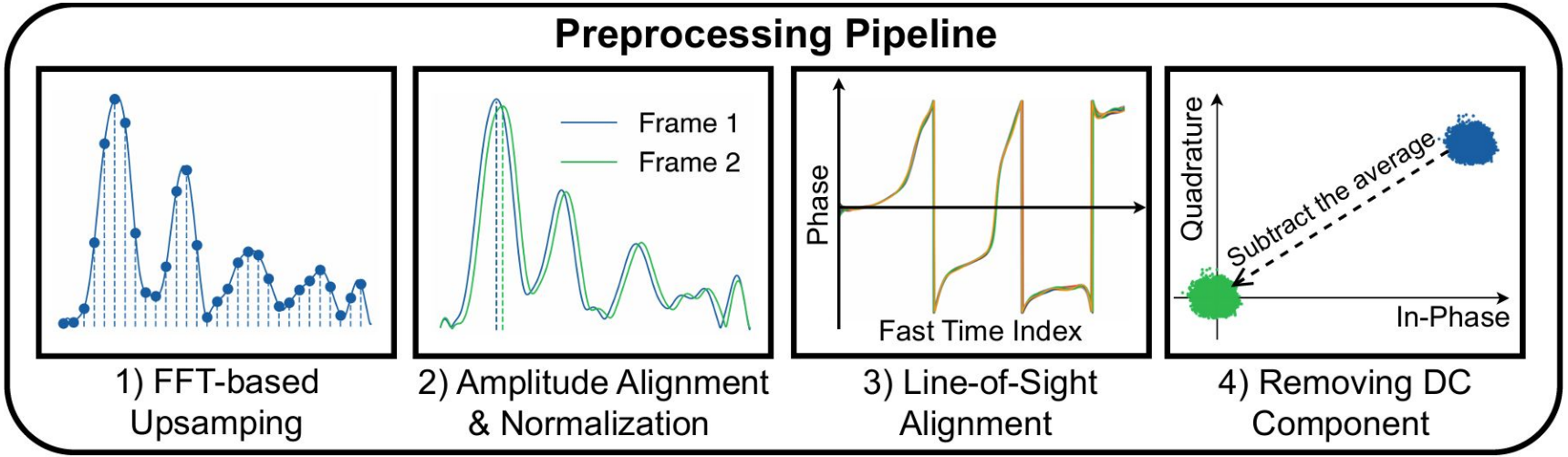
Methods

- Use **backscattered tags** for desk localization and identification
- An RF antenna receives incoming signal and reflects it back
- A switch that switching the load of the antenna between open or short, modulating the reflection with 180/0 degrees shift
- Make such reflections in a pseudo-noise pattern, which provides high auto-correlation and low cross-correlation





Tag Detection with Commercial Off-the-Shelf Devices



range resolution:

~ 30 to ~ 1 cm

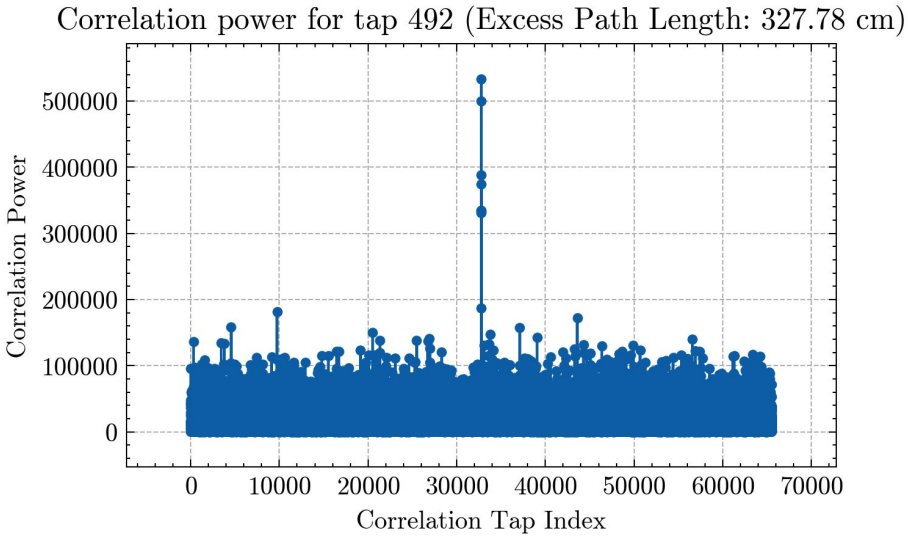
preamble accumulation number & hardware imperfection

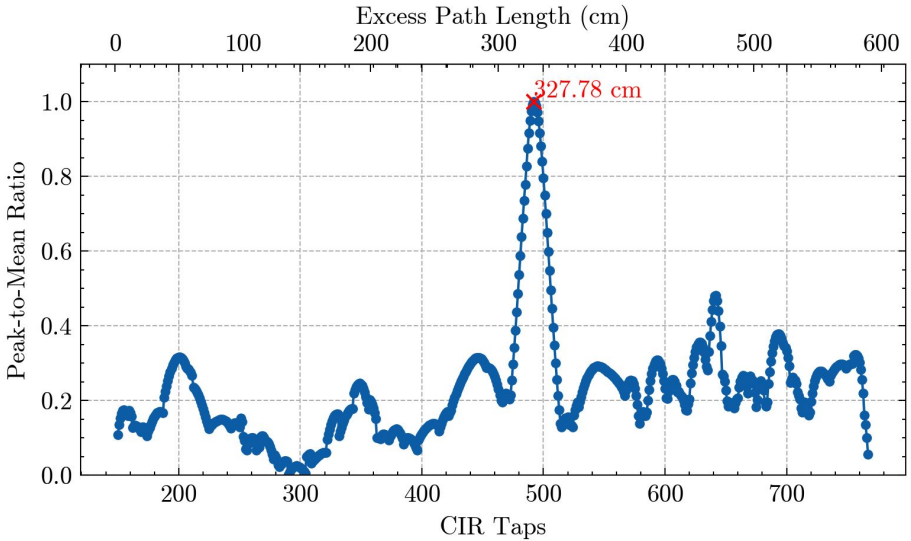
CFO between TX & RX

remove the background clutter

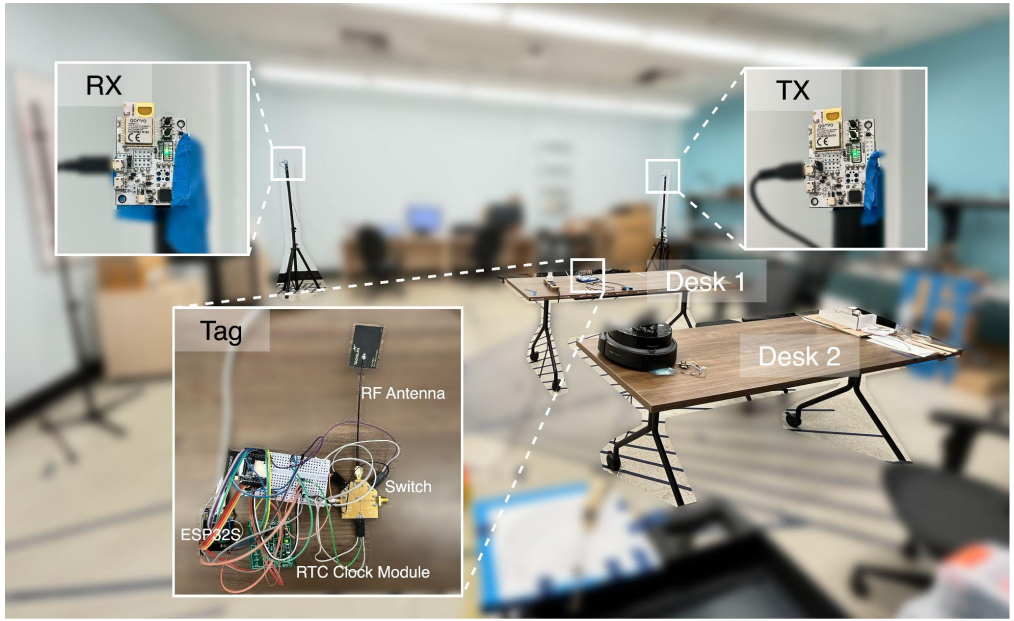
Tag Localization Algorithm

- Get each tap's time series data, correlate with the known PN code, identify the strongest peak





Evaluation and Metrics



- UWB module from Qorvo, working on channel 9 (7.9GHz with 500MHz bandwidth)
- Build a tag with a switch evaluation board, a RTC clock module, and a MCU
- First evaluate the localization performance

Tag detection results (5 experiments):

Closer Desk (GT: 285 cm)

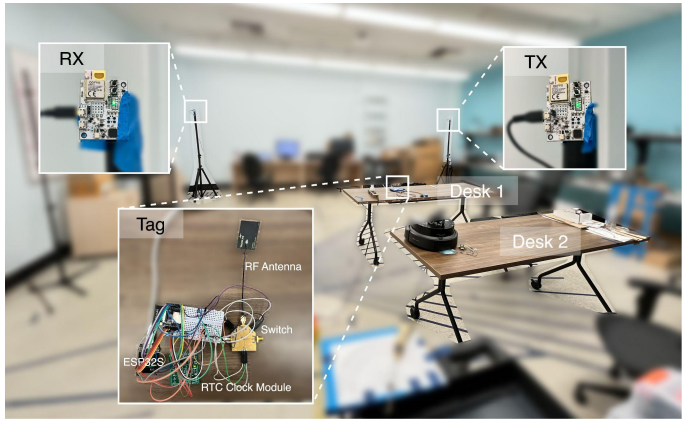
	Peak-to-Mean Ratio	Estimated Excess Path Length (cm)
exp1	26.38	284.74
exp2	25.54	282.14
exp3	30.35	283.24
exp4	29.55	281.44
exp5	34.16	286.87

Further Desk (GT: 500 cm)

	Peak-to-Mean Ratio	Estimated Excess Path Length (cm)
exp1	22.77	498.72
exp2	20.09	493.65
exp3	22.25	499.42
exp4	20.42	495.19
exp5	23.66	496.64

- Less than 5 cm error

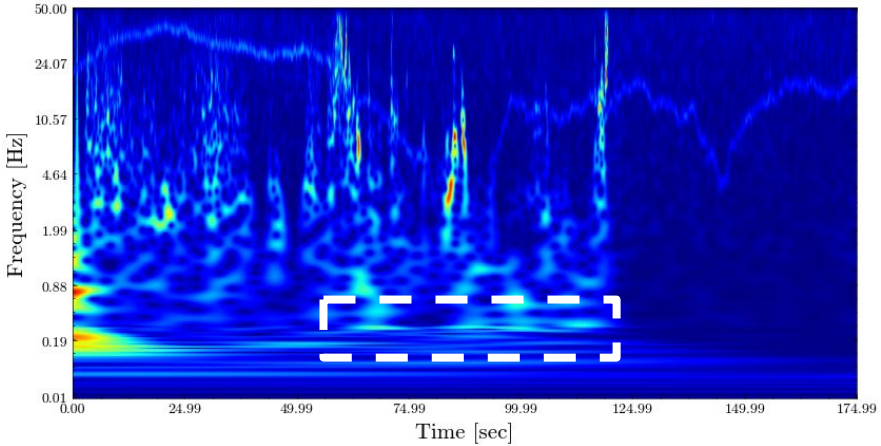
Desk Occupancy Investigation



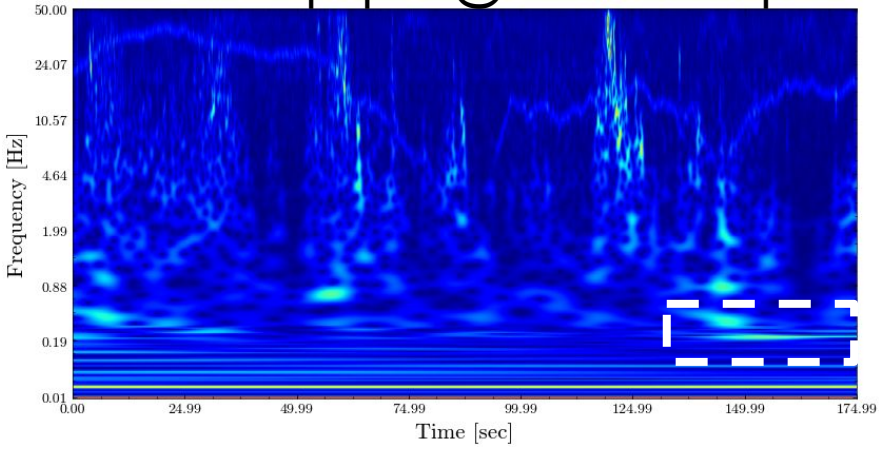
First occupy Desk 1, then Desk 2

- Freq. component @ 0.2~0.3Hz
- Most likely the breathing pattern: 12~18 breath per minute

Time-Freq Spec @ Desk 1's Tap



Time-Freq Spec @ Desk 2's Tap



Next Steps

- Design and fabricate PCB boards for tags, evaluate multi-tag localization
- Verify the end-to-end occupancy estimation