Visions of the Wireless Future: Insights into Emerging Technologies

Dina Katabi
Directory of Wireless@MIT

wireless @mit

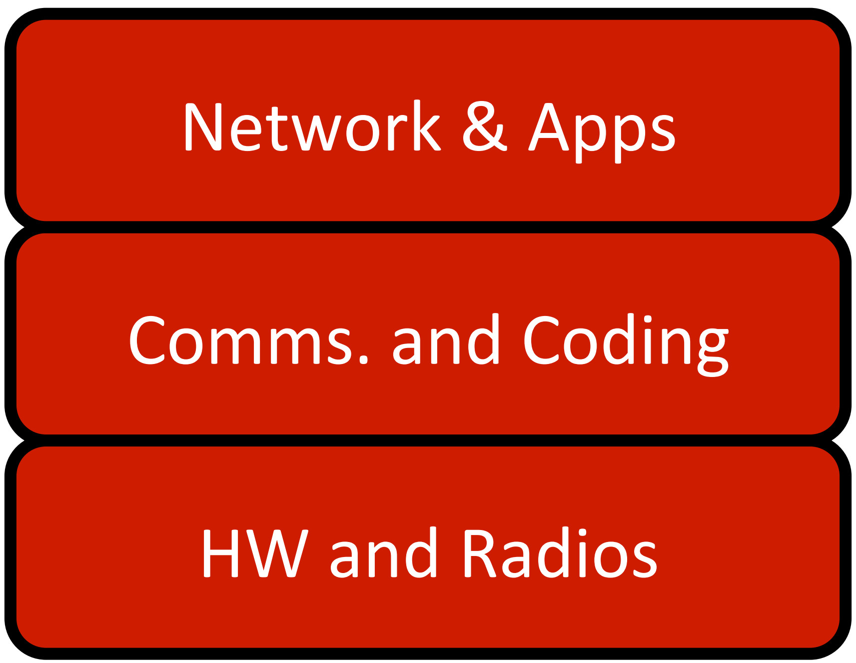
Over 20 PIs and 50 Graduate Students

Wireless@MIT Partners

Fundamental Architectural Change

Traditional Approach

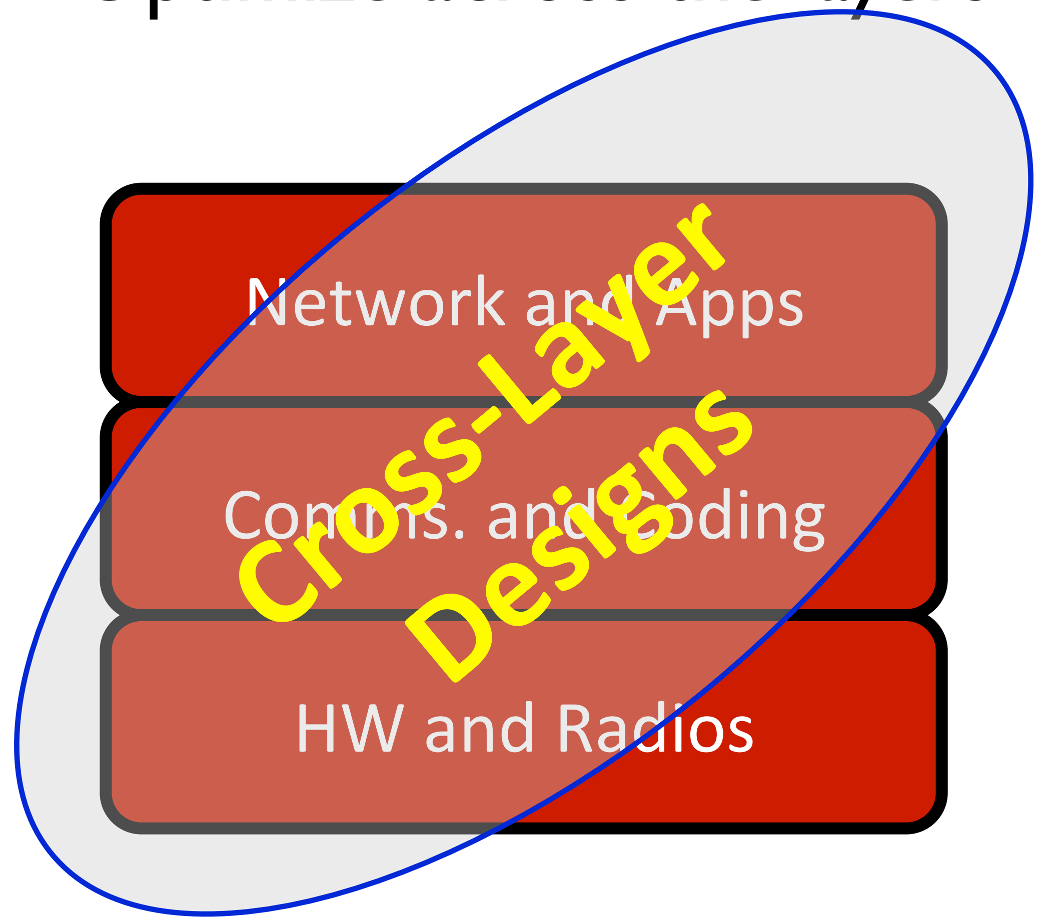
Optimize within isolated layers



Disruptive gains are unlikely

New Approach

Optimize across the layers

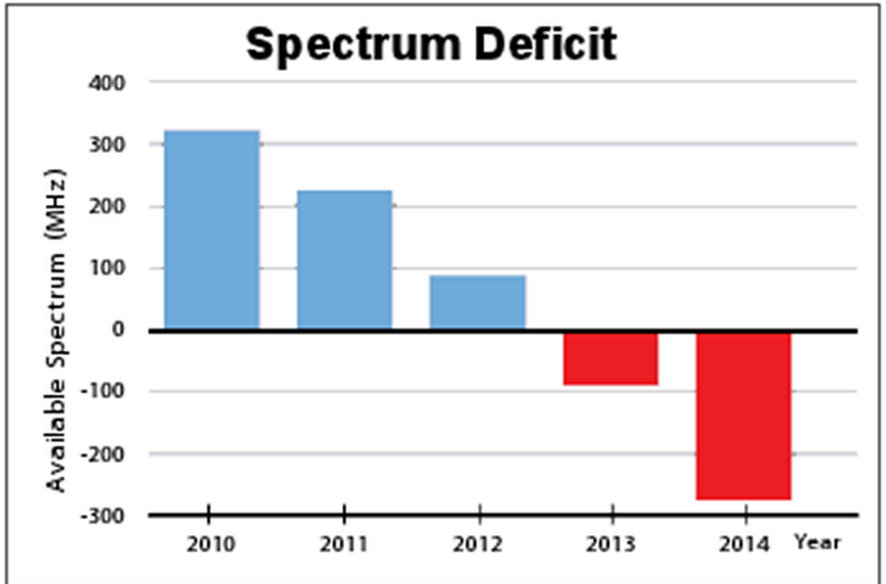


Major opportunities!

MegaMIMO

10x Higher Data Rates

Looming Wireless Capacity Crunch



The FCC projects a spectrum deficit by the year 2013

The FCC projects that the US will face a spectrum shortfall in 2013.

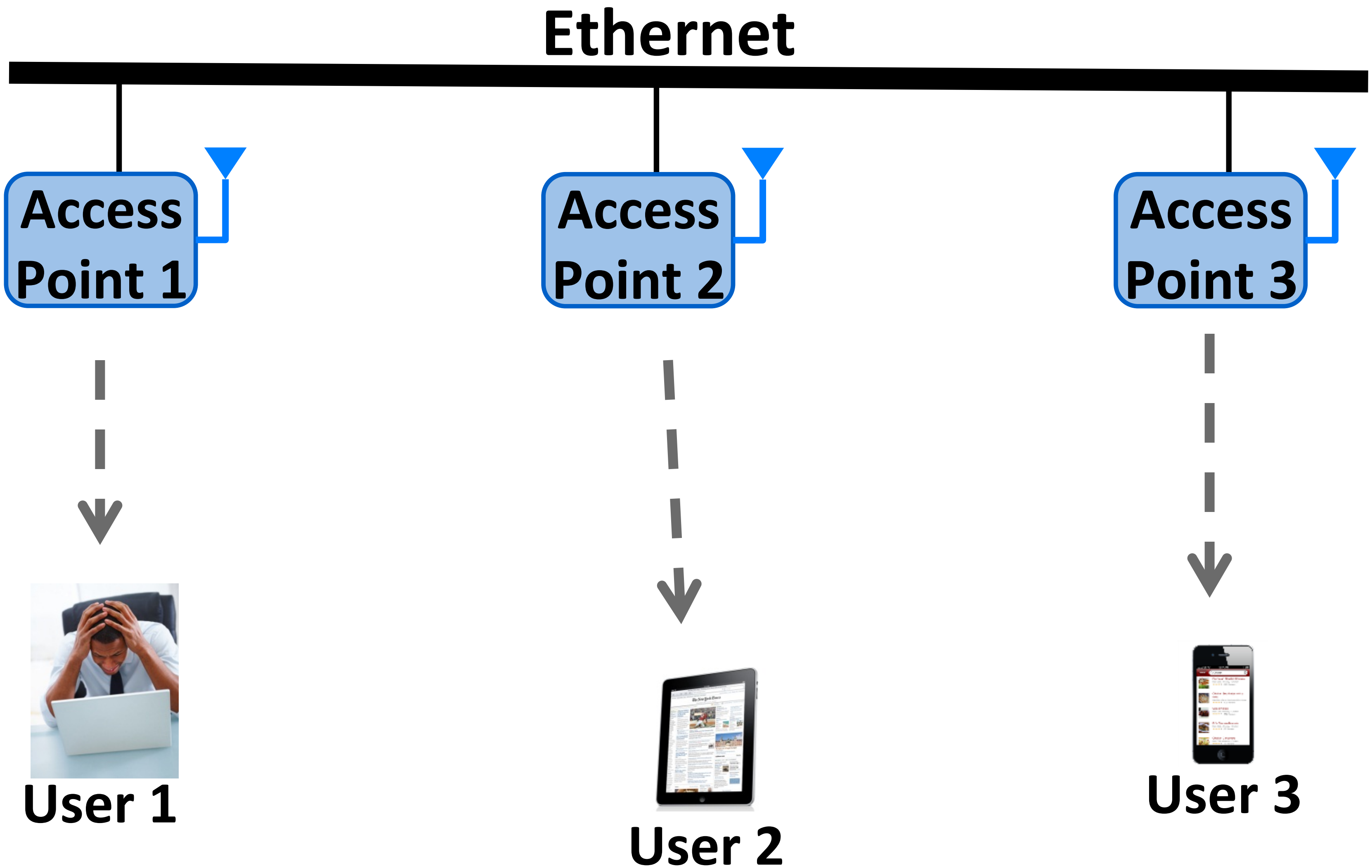
The iPhone 4 demo failed due to wireless congestion.

Jobs's reaction: *"If you want to see the demos, shut off your laptops, turn off all these MiFi base stations, and put them on the floor, please."*

MegaMIMO

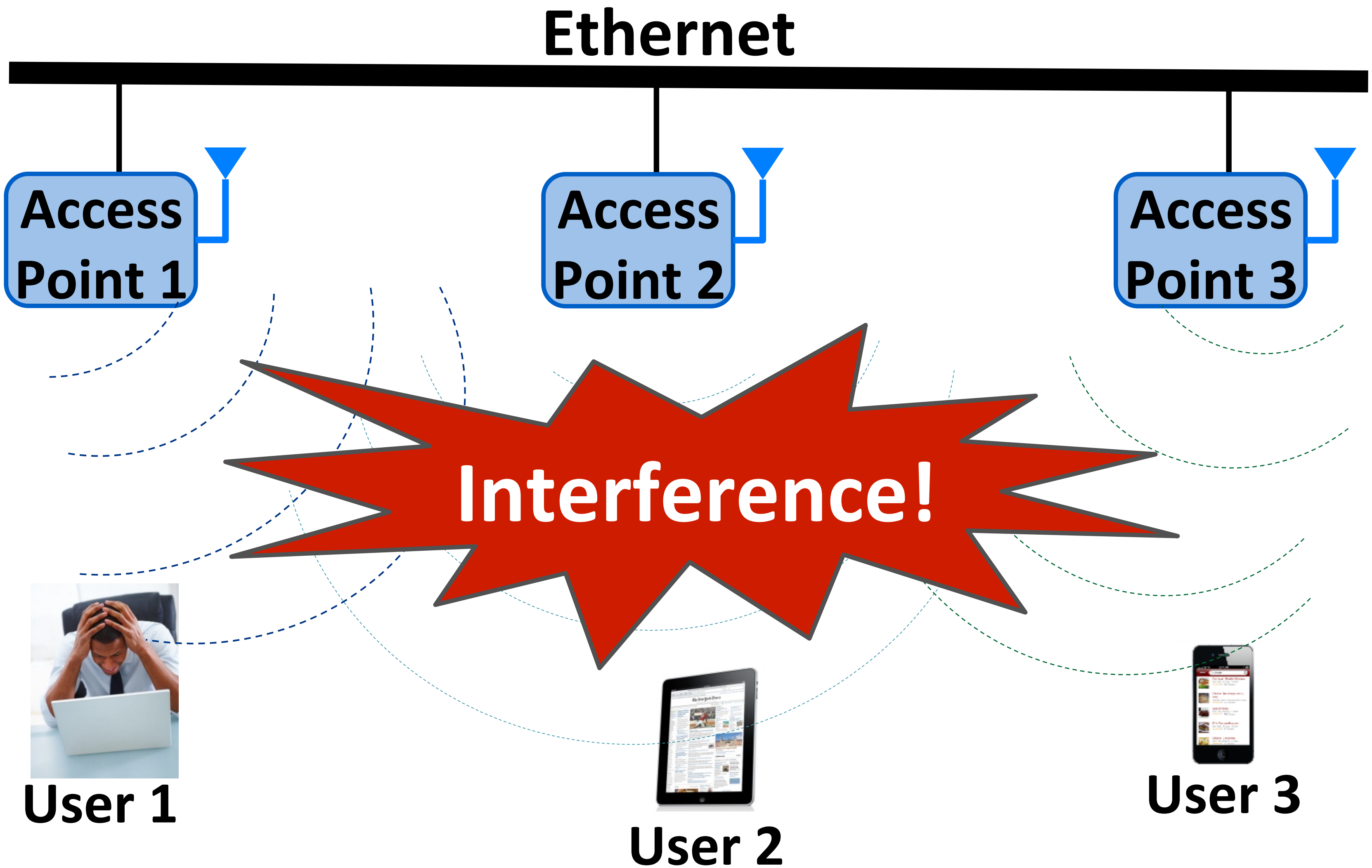
Alleviates the capacity crunch by transmitting more bits per unit of spectrum

Today's Wireless Networks



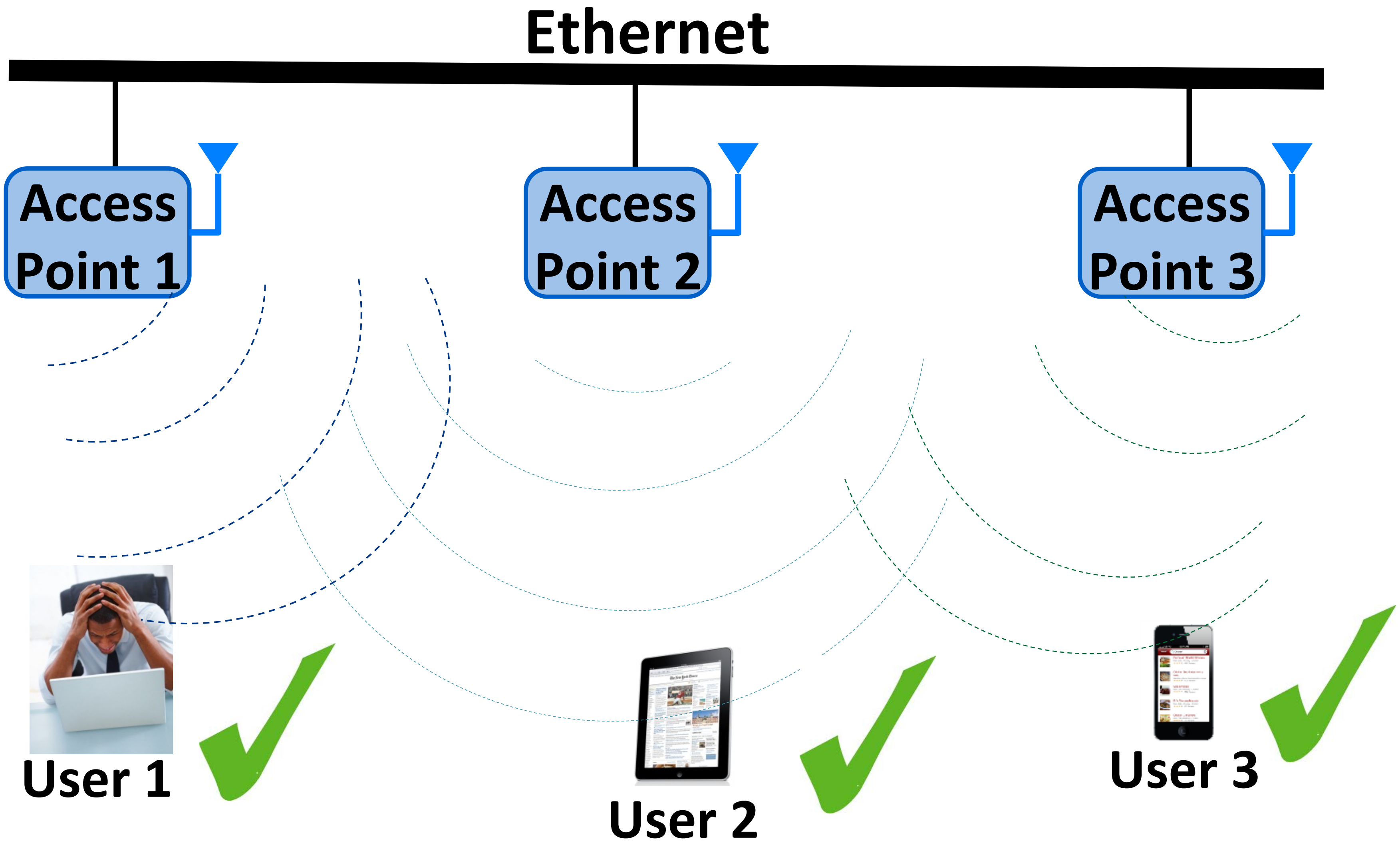
Today, Access Points Can't Transmit Together in the Same Channel

Today's Wireless Networks



Today, Access Points Can't Transmit Together in the Same Channel

MegaMIMO



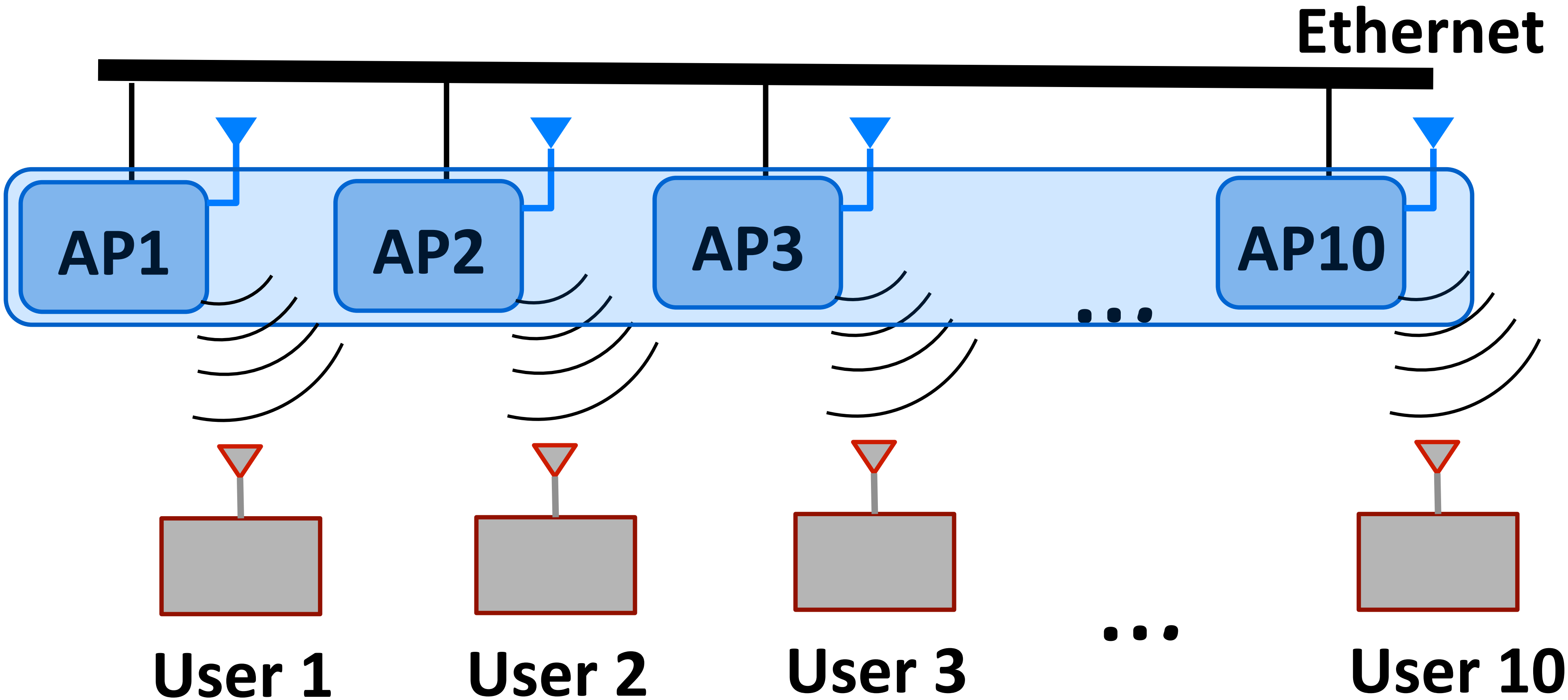
Interference: $d_2+d_3 \approx 0$
Data: d_1 <u>*survives*</u>

Interference: $d_1+d_3 \approx 0$
Data: d_2 <u>*survives*</u>

Interference: $d_1+d_2 \approx 0$
Data: d_3 <u>*survives*</u>

MegaMIMO = Distributed MIMO

Access Points act as a huge distributed MIMO transmitter with sum of antennas

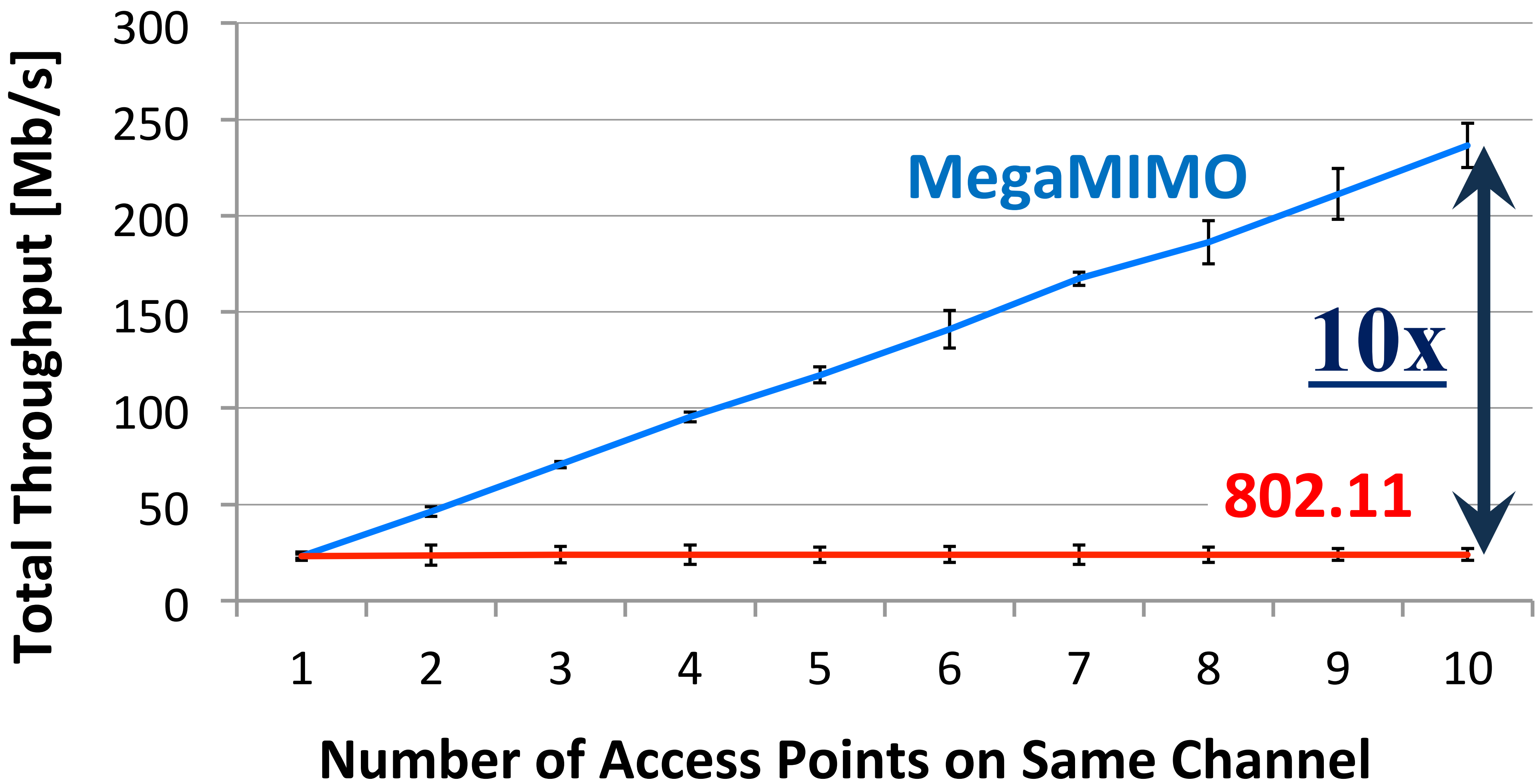


10 Access Points → 10x Higher Throughput

Testbed of Software Radios

Dense Conference Room Like Deployment

Results from Prototype



10x throughput gain over existing Wi-Fi

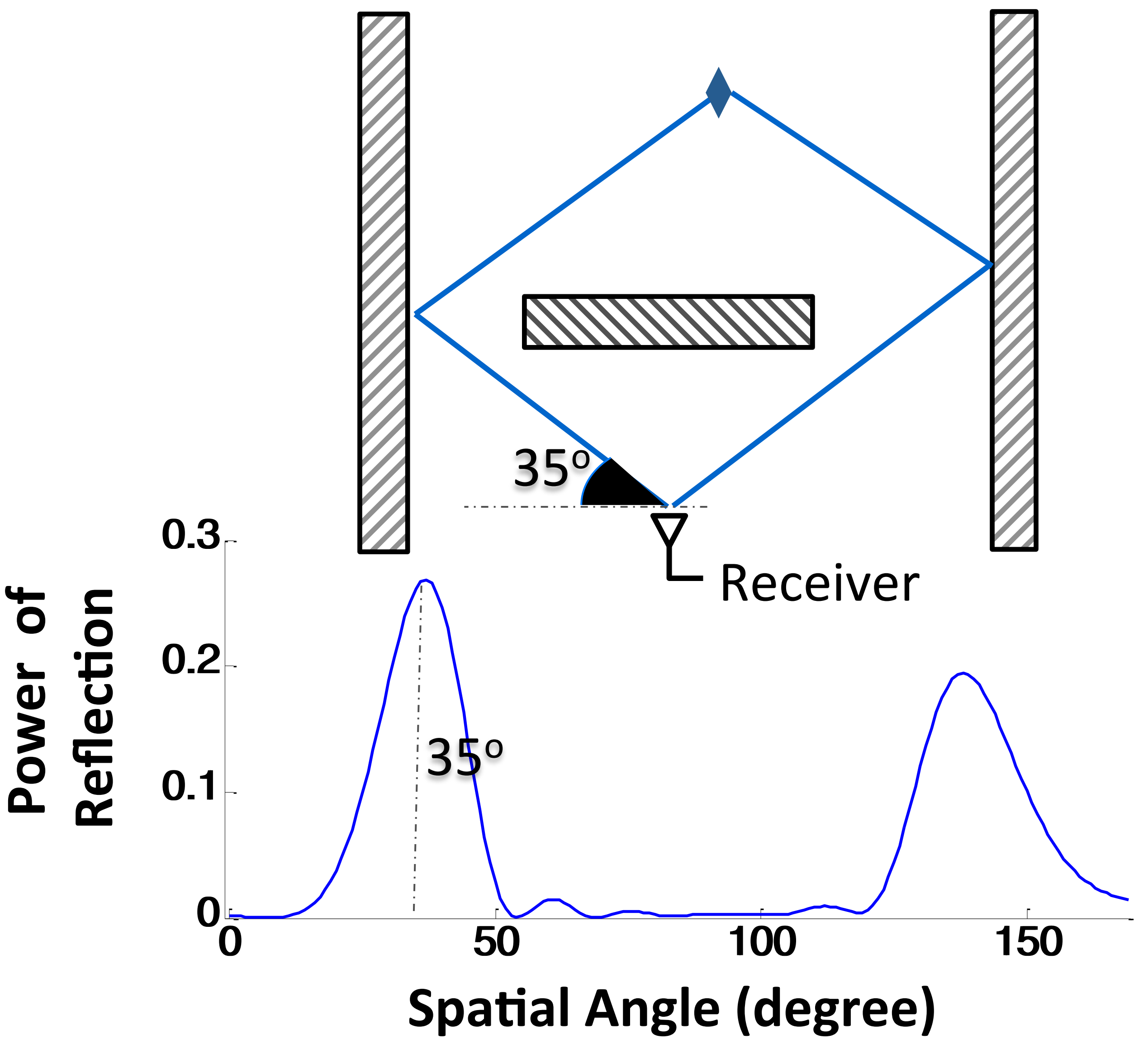
Centimeter-Scale Localization

Today, RF-based localization has about one meter accuracy

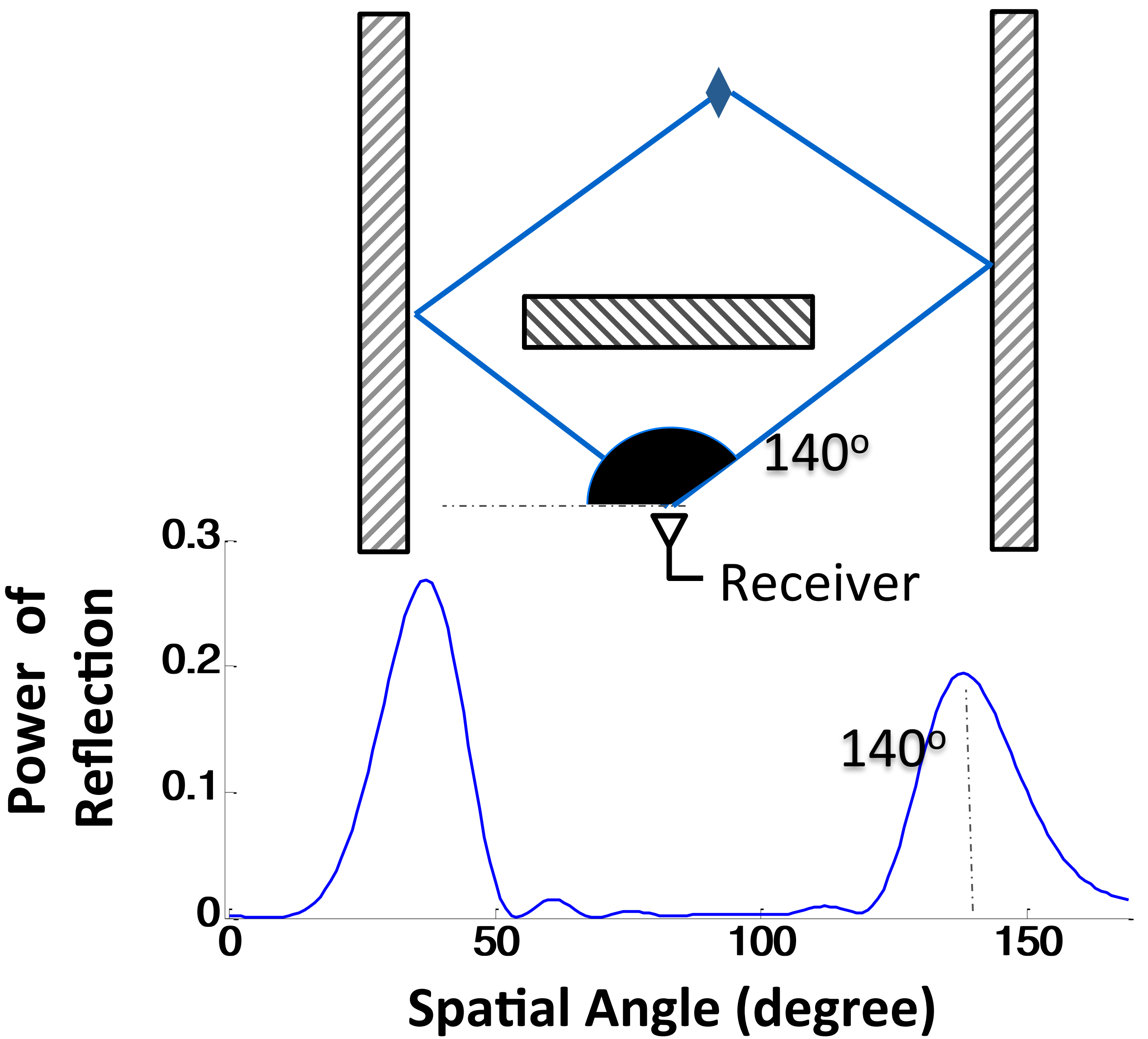
Challenge: Multipath effects confuse the localization system

Solution: Use the multipath reflection pattern as a signature of the location

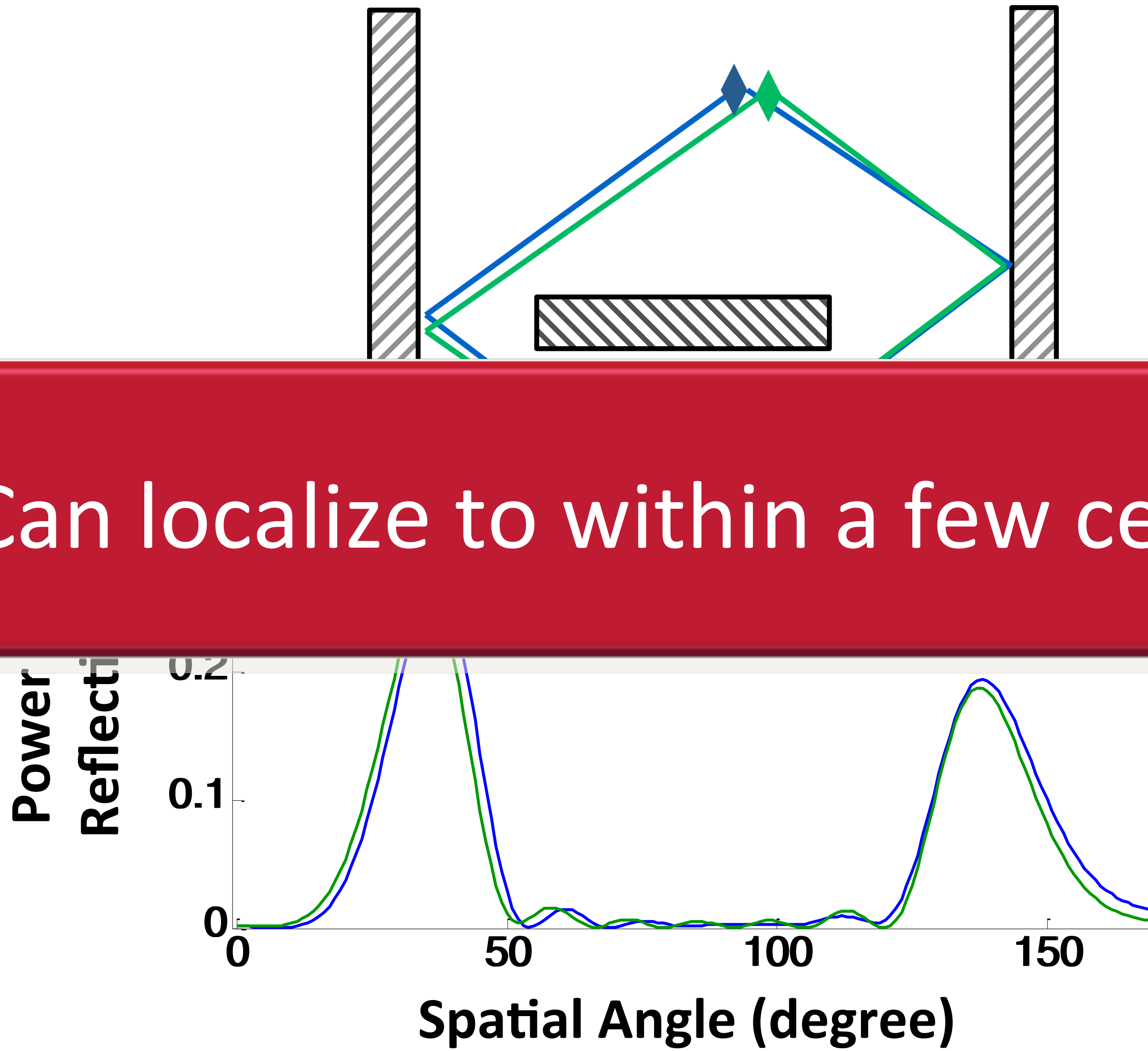
Use Multipath Reflections



Use Multipath Reflections



Use Multipath Reflections



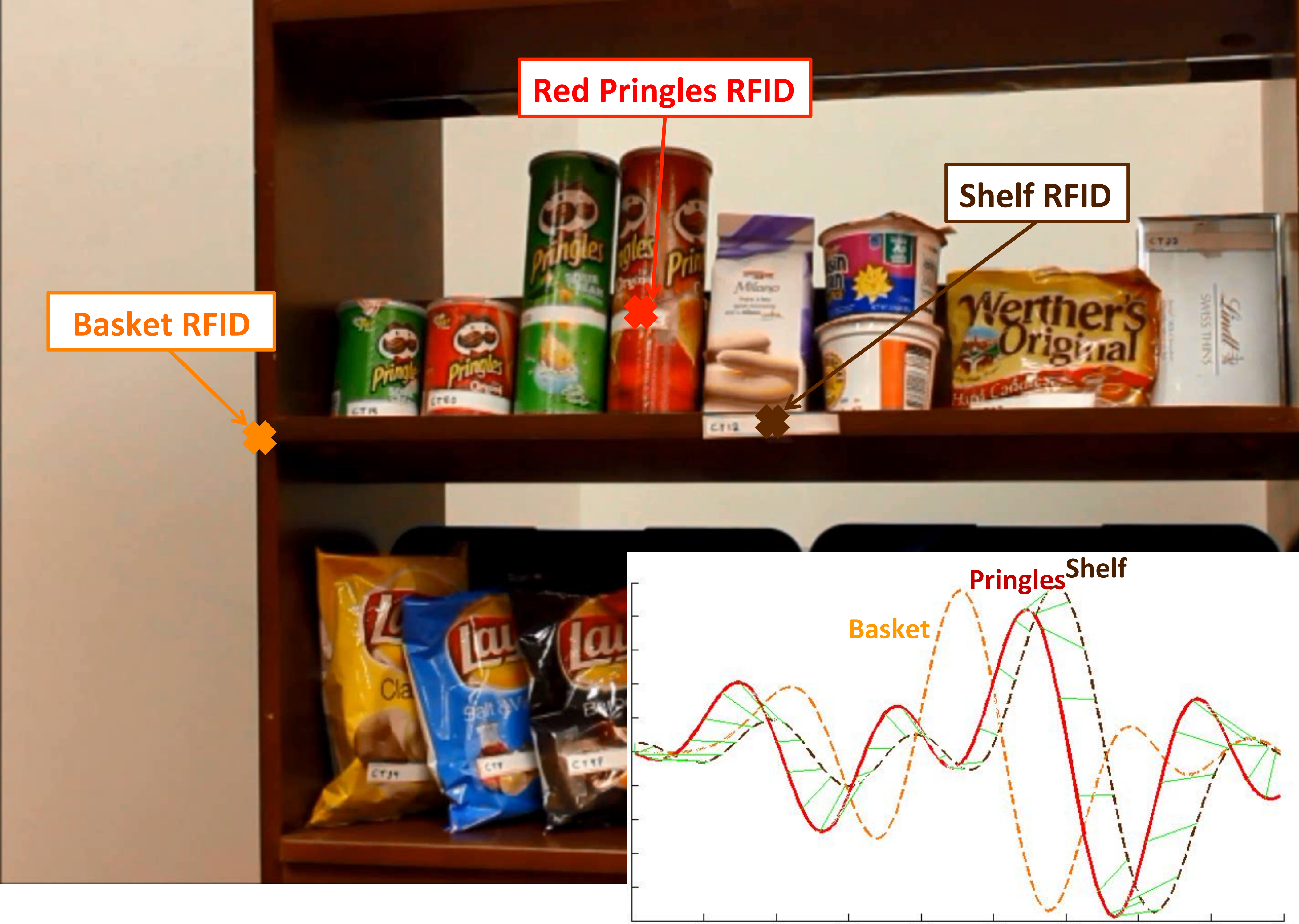
Can localize to within a few centimeters

Works even with RFIDs

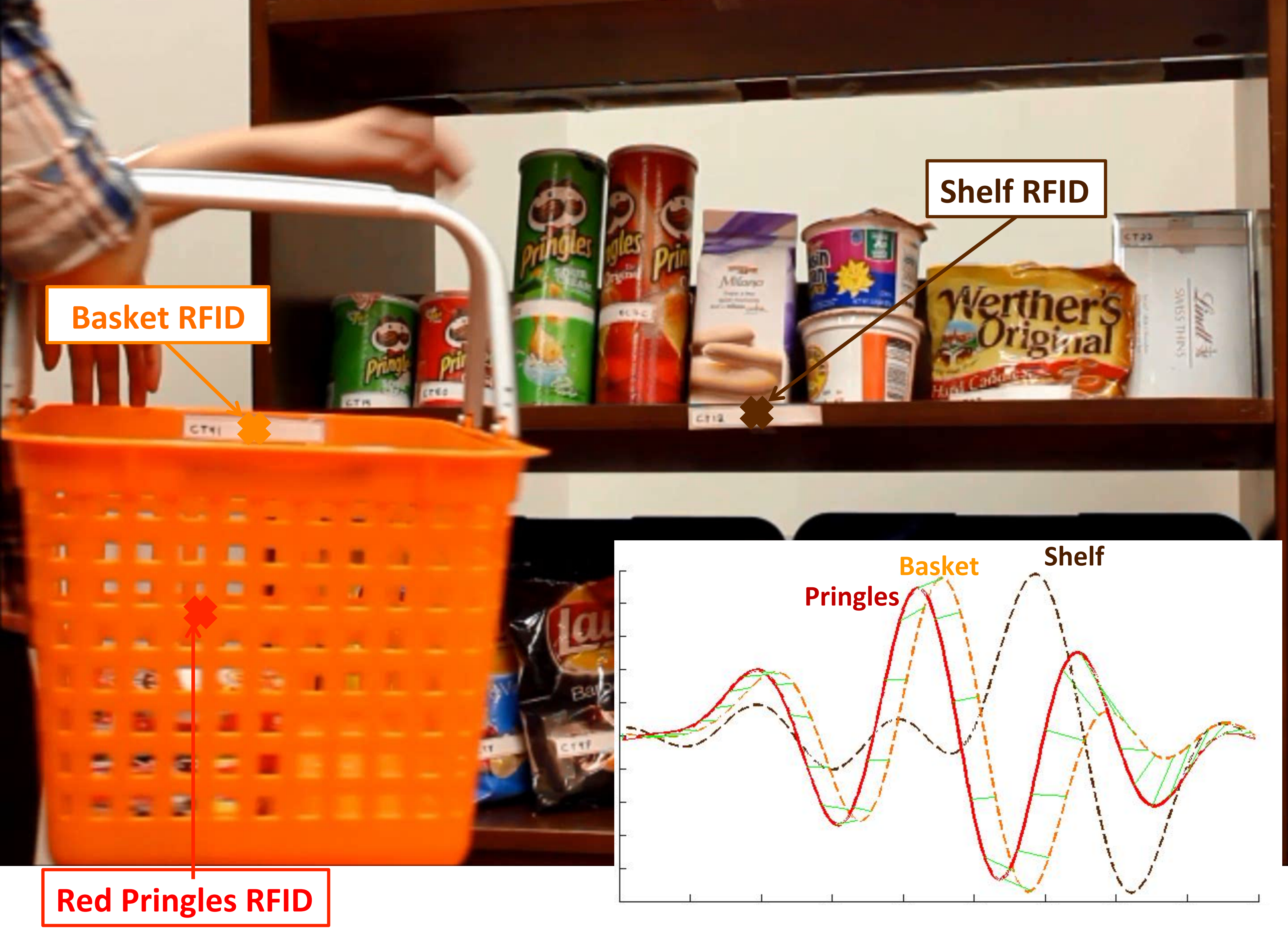
Battery-free stickers to tag any and every object

No more customer checkout lines

No more customer checkout lines

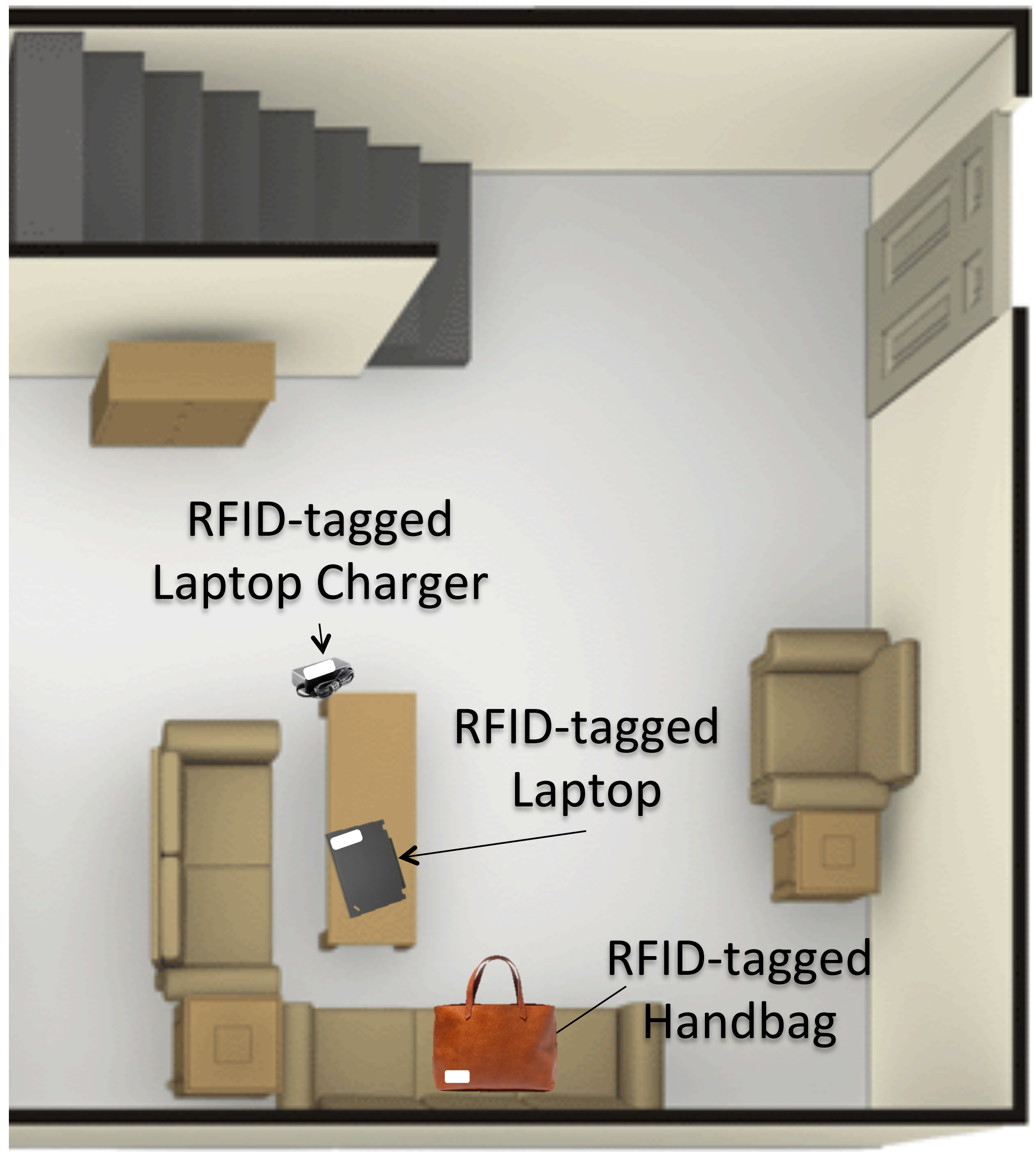


Red Pringles RFID
Shelf RFID
Basket RFID
Pringles
Shelf
Basket
Werther's Original

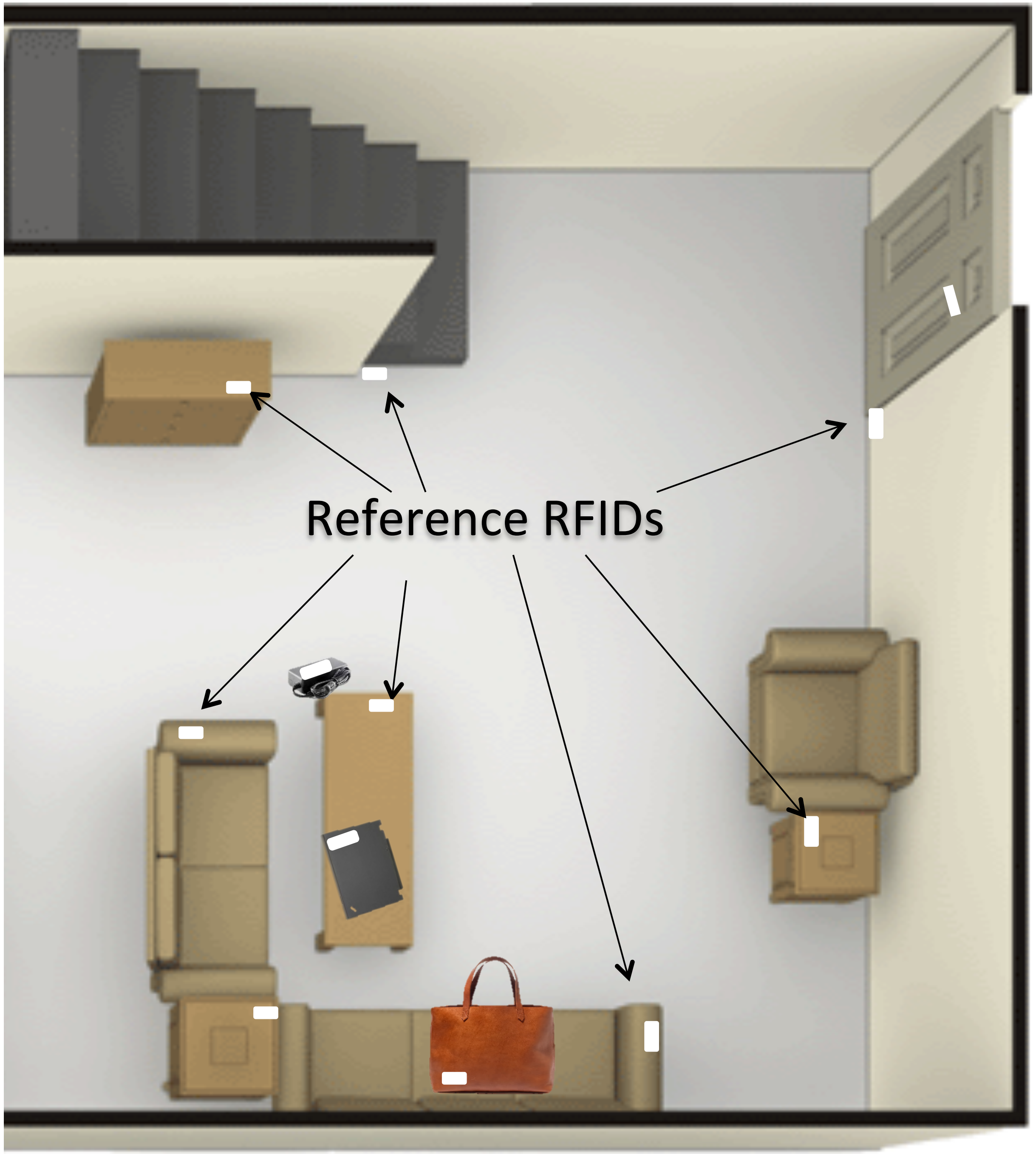

Shelf RFID
Basket RFID
Red Pringles RFID
Basket
Shelf
Pringles


Pringles
Milano
Werther's
Original
Lay's
wavy
ORIGINAL
CHEDDAR & SOUR CREAM
Lay's
Classic

Smart Homes

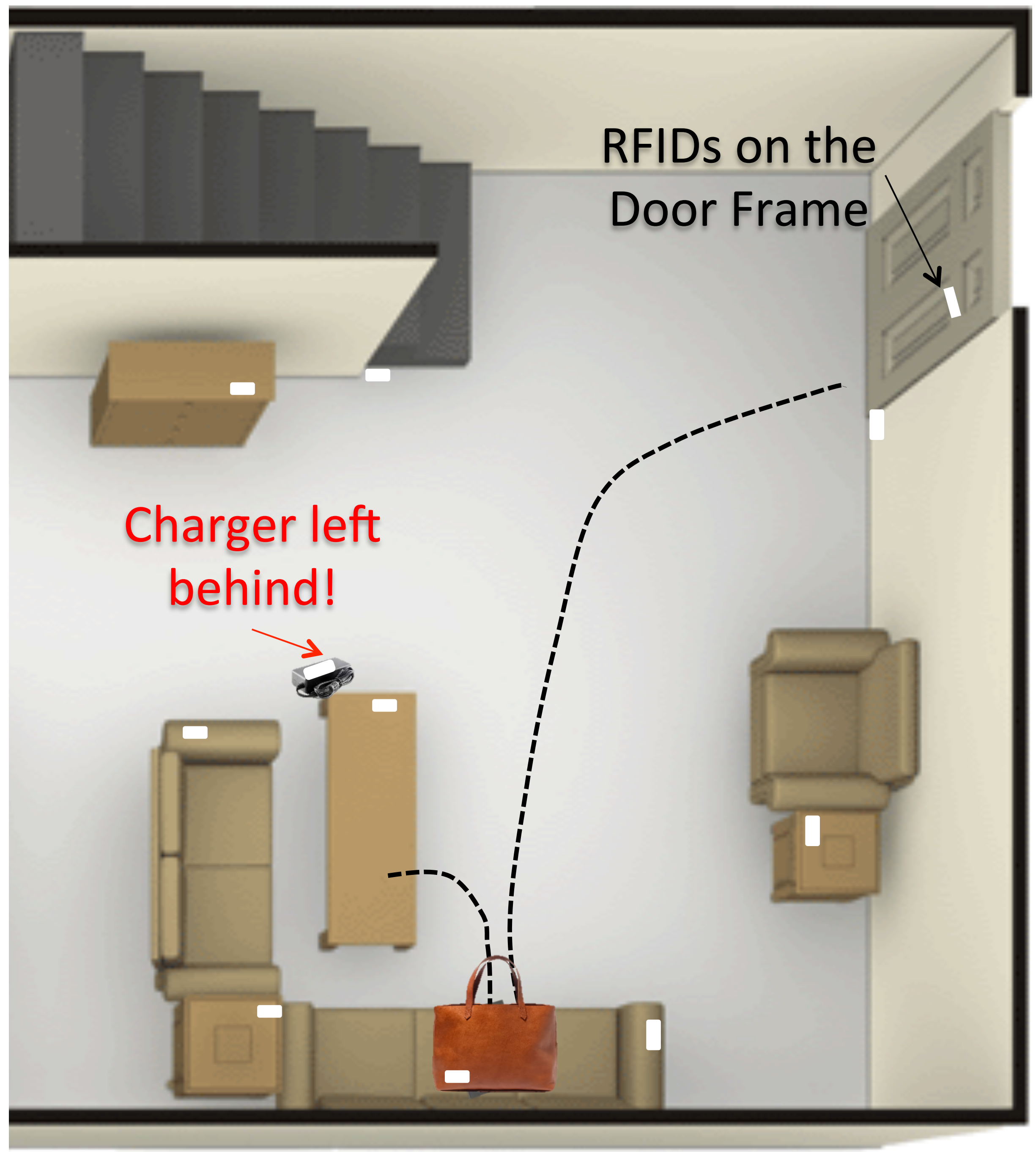

RFID-tagged
Laptop Charger
RFID-tagged
Laptop
RFID-tagged
Handbag

Smart Homes



Smart Homes

Smart Homes



Can your cellphone give you X-ray vision?

WiVi: See through-walls with WiFi

- WiFi signals traverse walls and reflect off objects
- Challenge: reflections off the separating wall are 10,000x higher than off a human behind the wall
- Solution: use two transmit antennas and one receive antenna; the two transmitted waves cancel each other for static objects but not animated objects
- See video on YouTube

https://www.youtube.com/watch?v=uJkQzLjYBFI

Low-power Realtime GHz-Wide Spectrum Sensing

Imagine

A low-power cheap sensor that captures GHz-wide spectrum in realtime

- → Thousands of sensors to map spectrum usage
- → Very efficient dynamic spectrum sharing
- → Can detect fleeting signals like radar

Realtime GHz Spectrum Sensing is Difficult

- Today, sequential scanning of tens of MHz

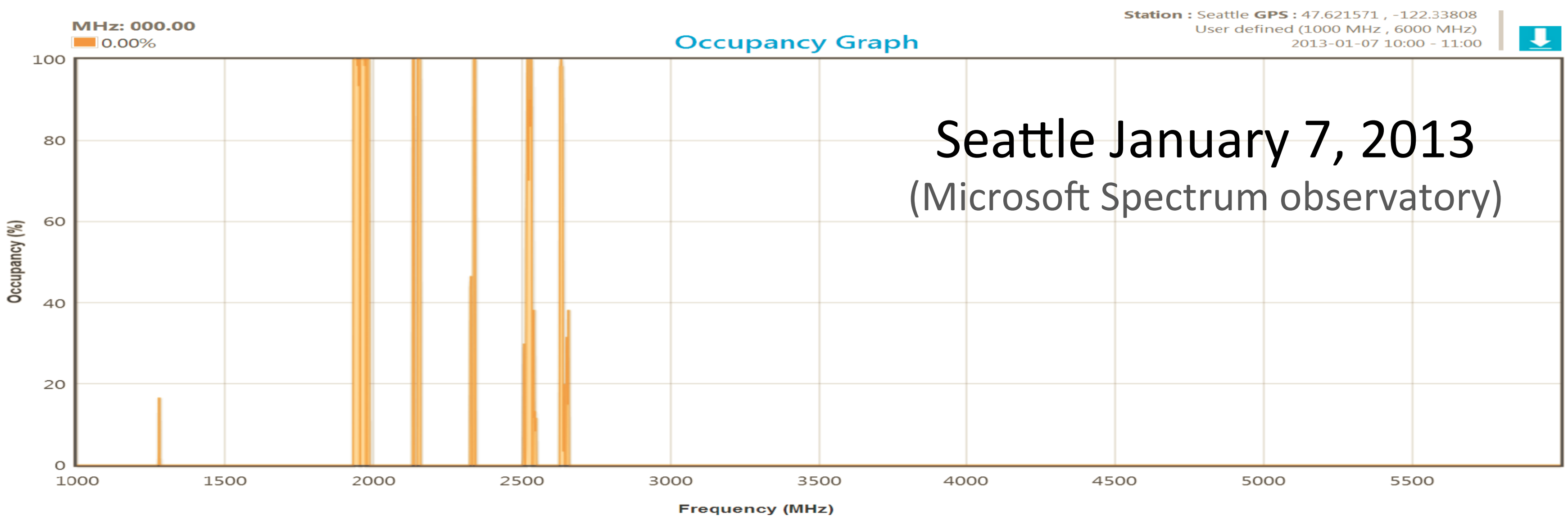
  ➔ Can easily miss radar signals

- Key Challenge: high-speed ADCs

Tens of MHz ADC
< a dollar
Low-power
High resolution

A Few GHz ADC
Hundreds of dollars
10x more power
Poor resolution

Idea: Leverage Sparsity



Sparse recovery show that one can acquire sparse signals using sub-Nyquist sampling

Sparse FFT

No random sampling → can use low-speed ADCs

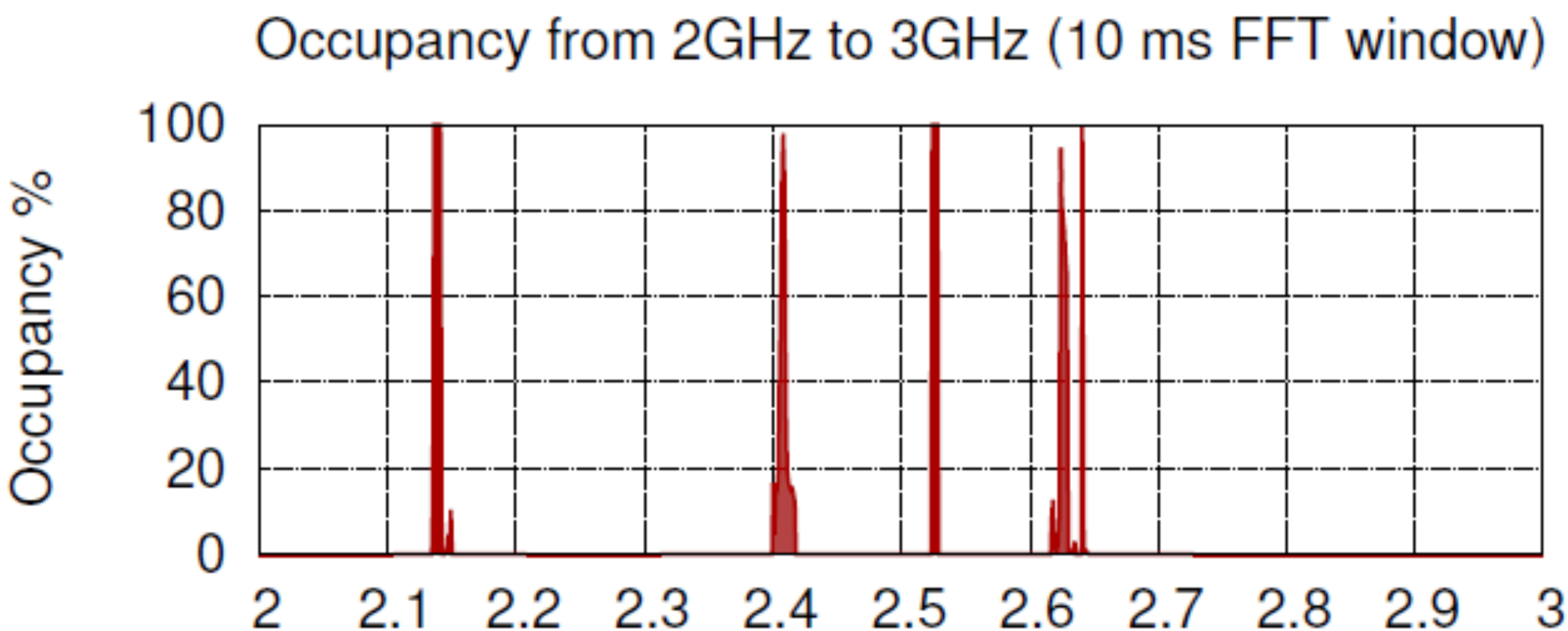
Benefits of Sparse FFT

- Sub-sample the data → Can use low-speed ADCs
- Very fast algorithm → Lower-power consumption

- Used sparse FFT to build a GHz receiver from three 50 MHz ADCs
- Both senses and decodes sparse spectrum

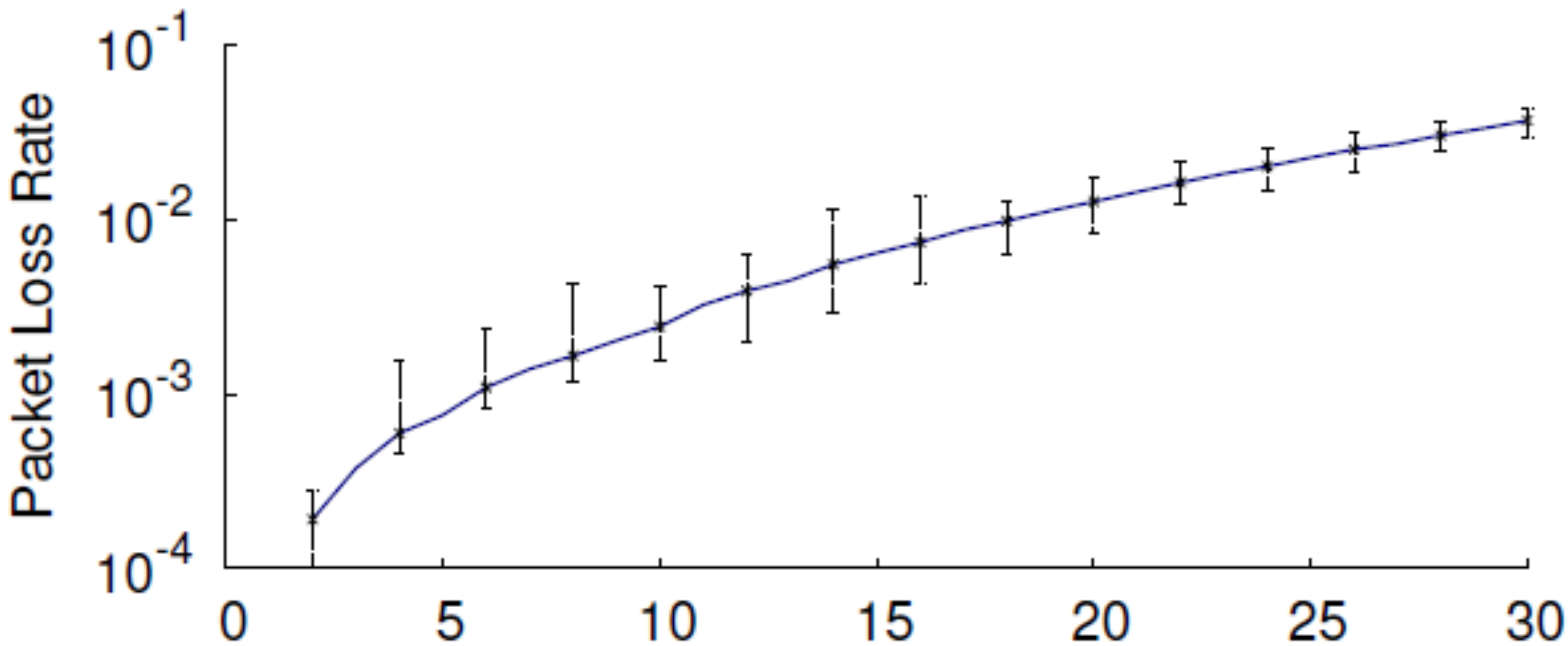
Realtime GHz Spectrum Sensing

Cambridge, MA January 18 2013



Sense GHz using 3 tens of MHz ADCs

Decoding Senders Randomly Hopping in a GHz



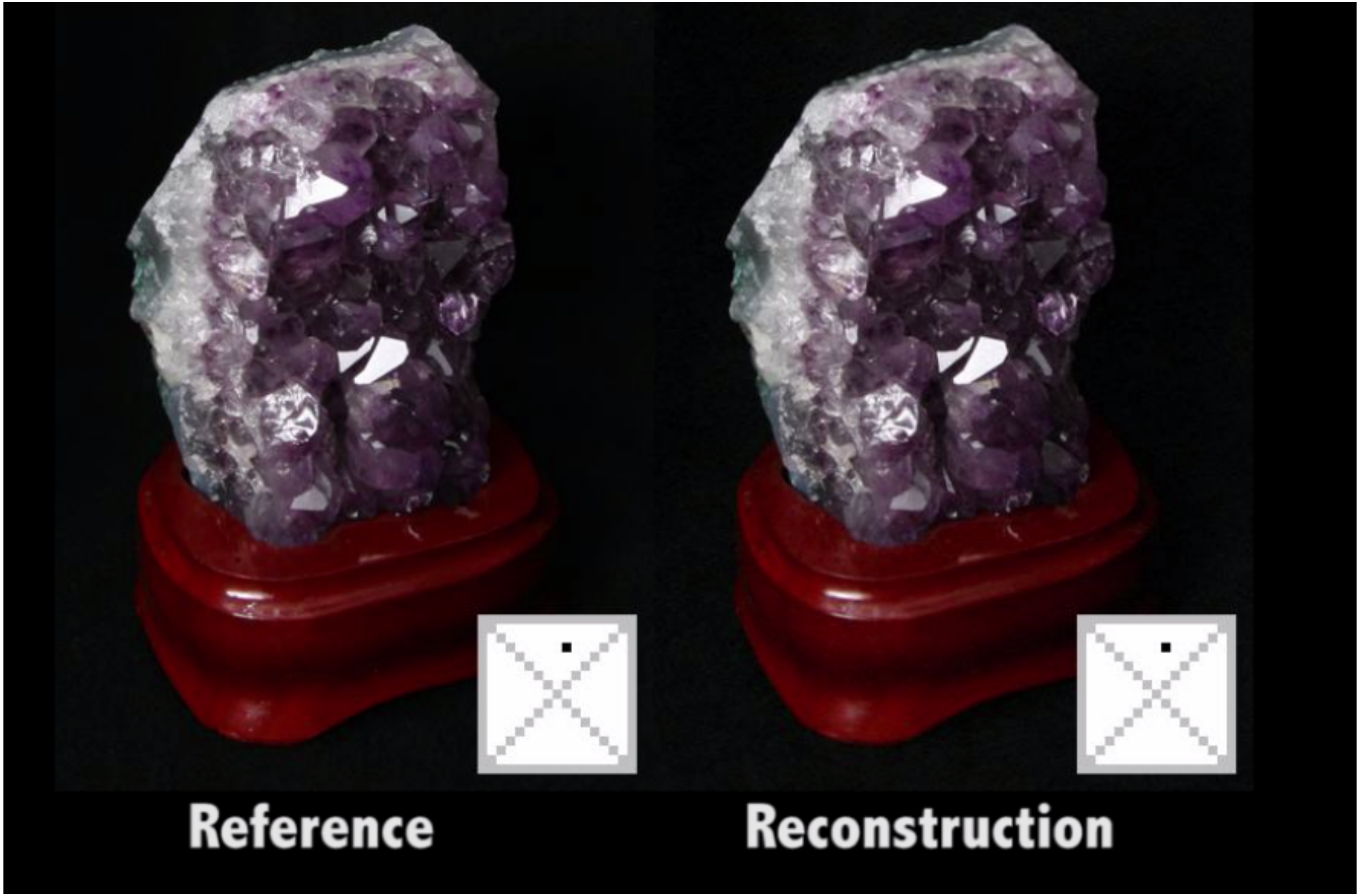
Number of MHz Senders Randomly Hopping in in 0.9 GHz

Both Senses and Decodes

3D Photography Using Sparse FFT

- Generate depth and perspective using a camera array
- Images are correlated →4D frequencies are sparse
- Goal: reduce the number of camera elements to enable implementation in a hand-held device
- Solution: Camera images are correlated →Use sparse FFT

Results show that we can accurately reconstruct unsampled camera outputs



Conclusion

The future will be full of amazing wireless technologies that will change our life

wireless @mit