Welcome!

CIS 7000: Special Topics on Mobile and IoT Sensing

Mingmin Zhao

Lecture 7

Penn
University of Pennsylvania

Objectives of the Three Lectures Series

Learn the fundamentals, applications, and implications of

IoT connectivity technologies

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Learn the fundamentals, applications, and implications of

IoT connectivity technologies

1. What is the overall IoT system architecture?
2. What are the various classes of connectivity technologies? And how do we choose the "right" technology for a given application?
3. What are various routing architectures for wireless networks & IoT systems?
4. How does energy impact IoT device design? And how do batteryless IoT systems work? **this lecture**

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BURBERRY
LONDON


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RFID
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Serial Number
ITEM : 1738390
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Restart
Scan Item
1. Ultra stretch jeans
Add Alteration
2. Fleece jacket
3. Sweat hoodie
4. K's HEATTECH cap
£39.90
£29.90
£34.90
£9.90
5 Items
BACK
Total £144.50
NEXT
PLEASE PLACE
ITEMS OR BASKET HERE
£5 welcome coupon*
for your first purchase

Forbes

Mar 8, 2021, 07:10am EST | 374 views

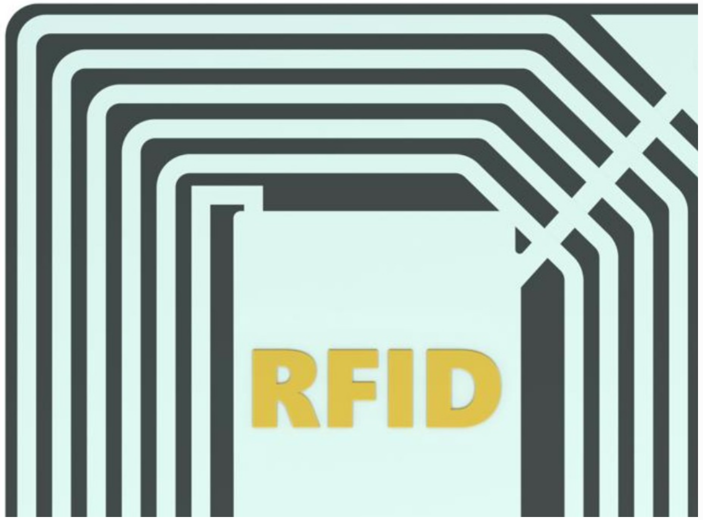
How RFID Helps Retail Companies Save Money

Walter Loeb

Walter Loeb Senior Contributor

Retail

I cover major developments in the retail industry.



Feb 26, 2019, 08:44pm EST | 7,451 views

Japan Aims To Automate All Convenience Stores By 2025 With A New RFID Technology

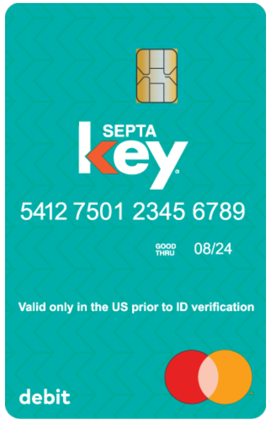
Akiko Katayama Contributor

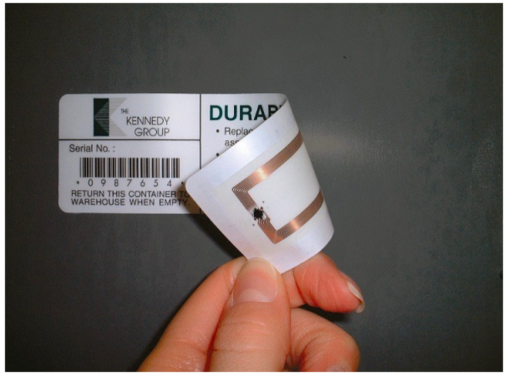
Food & Drink

This article is more than 2 years old.

RFID (Radio Frequency IDentification)

Access Control





Inventory control

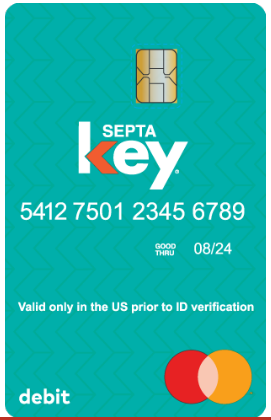
Security Sensitive Applications

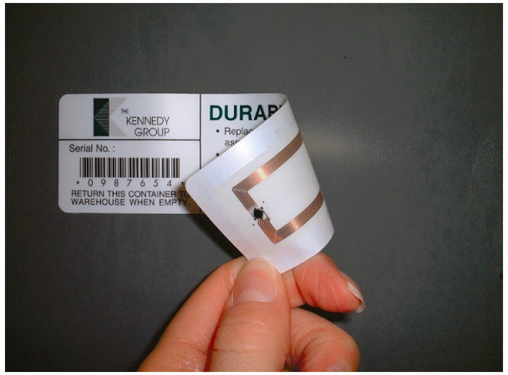
Tracking & Localization

Long-Range Payment Systems

RFID (Radio Frequency IDentification)

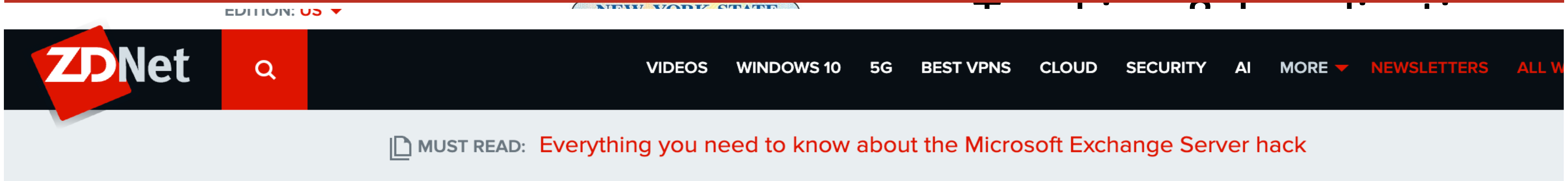
Access Control





Inventory control

> 100 Billion in the world



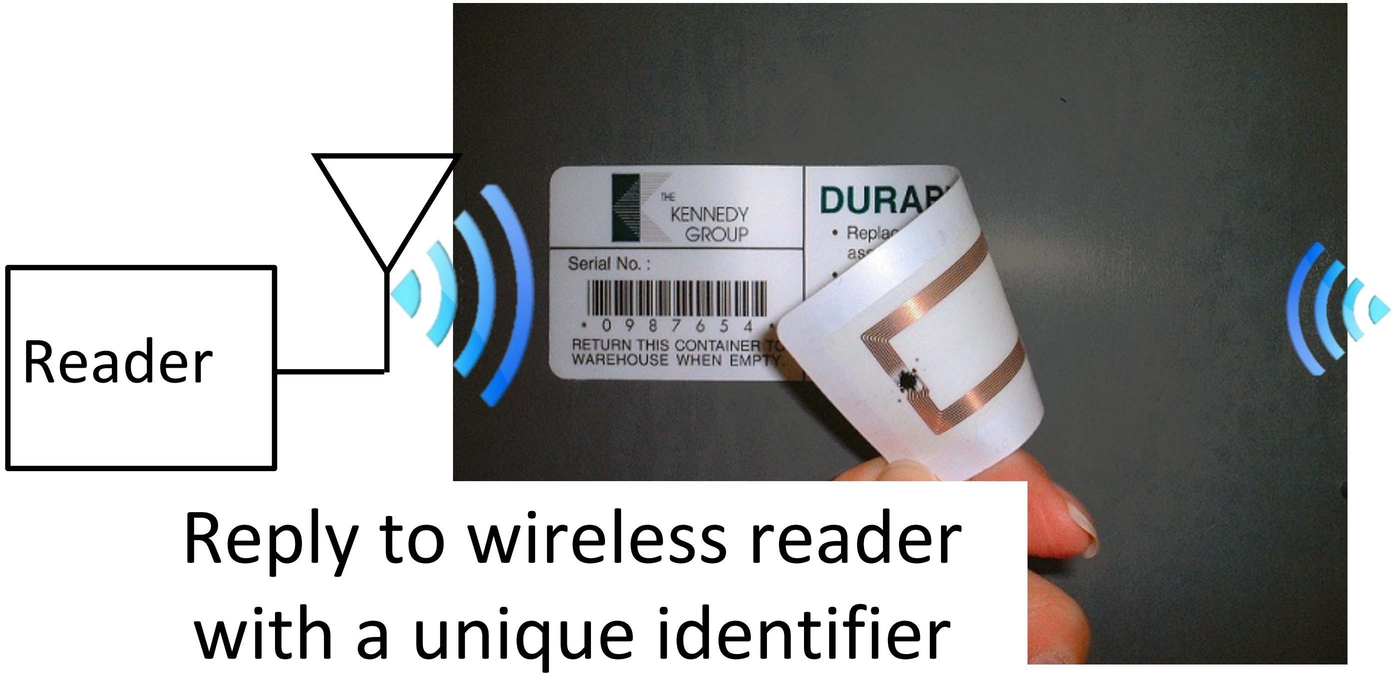
PART OF A ZDNET SPECIAL FEATURE: CORONAVIRUS: BUSINESS AND TECHNOLOGY IN A PANDEMIC

Humble hero: How RFID is helping end the pandemic

A common technology takes on an uncommon mission: Distributing vaccines around the globe.

Basic Principle of Operation

RFID: cheap battery-free stickers



Reply to wireless reader
with a unique identifier

History of RFIDs

- WWII: Aircraft IFF Transponder
  - Identify Friend or Foe, Transmitter-Responder

- 1945: “The Thing” or “The Great Seal Bug”
  - “Gift” given by the Soviets to American ambassador

- 1980s: development of E-Toll transponders

- 2004: Auto-ID lab at MIT led to the birth of modern battery-free RFIDs
  - Goal: supply chain chain optimization
  - Paper: “Towards the 5 cent tag”

How are RFIDs different from standard wireless devices (e.g., WiFi, cellular)?

RFID Requirements

- Small form factor
- Massive scale
- Lifetime

RFID Constraints

- No battery
- Ultra-low cost
- Simple circuitry

Types of RFIDs

Frequency Range

UHF (~900MHz)

HF (13.56MHz)

LF (120-150kHz)

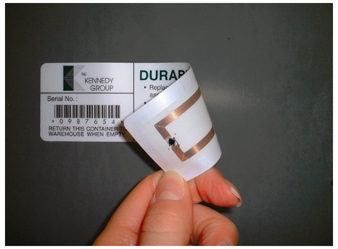
long range (few m)

short range (few cm)

Range of Operation

“need to tap”

Where do these fall?



Types of RFIDs

Frequency Range

UHF (~900MHz)

HF (13.56MHz)

LF (120-150kHz)

the vast majority of RFIDs

Cost

few cents

10s to 100s of $

Power consumption

Passive (battery-free)

Semi-Passive or Semi-Active

Active (with battery)

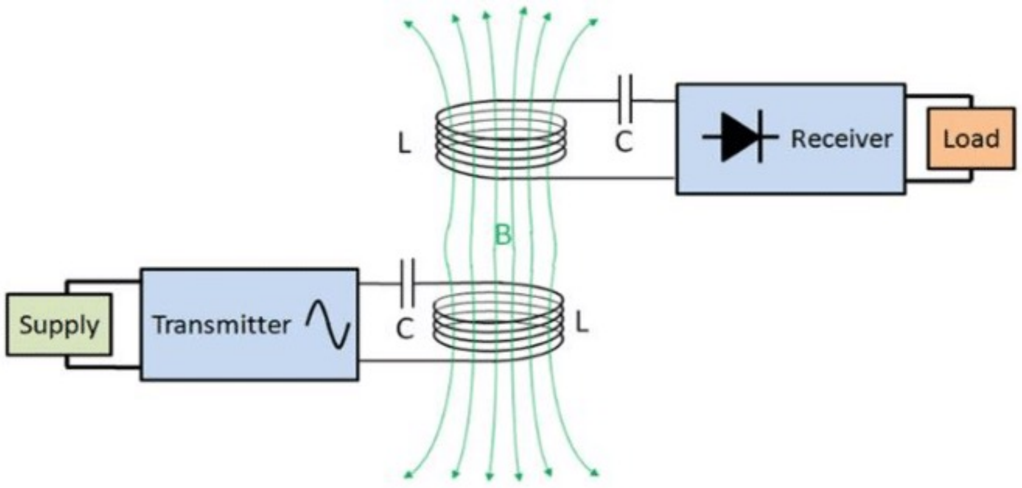
Other less common versions: 2.4GHz, UWB (3-10GHz), etc.

How does an RFID power up?

Harvests Energy from Reader's Signal

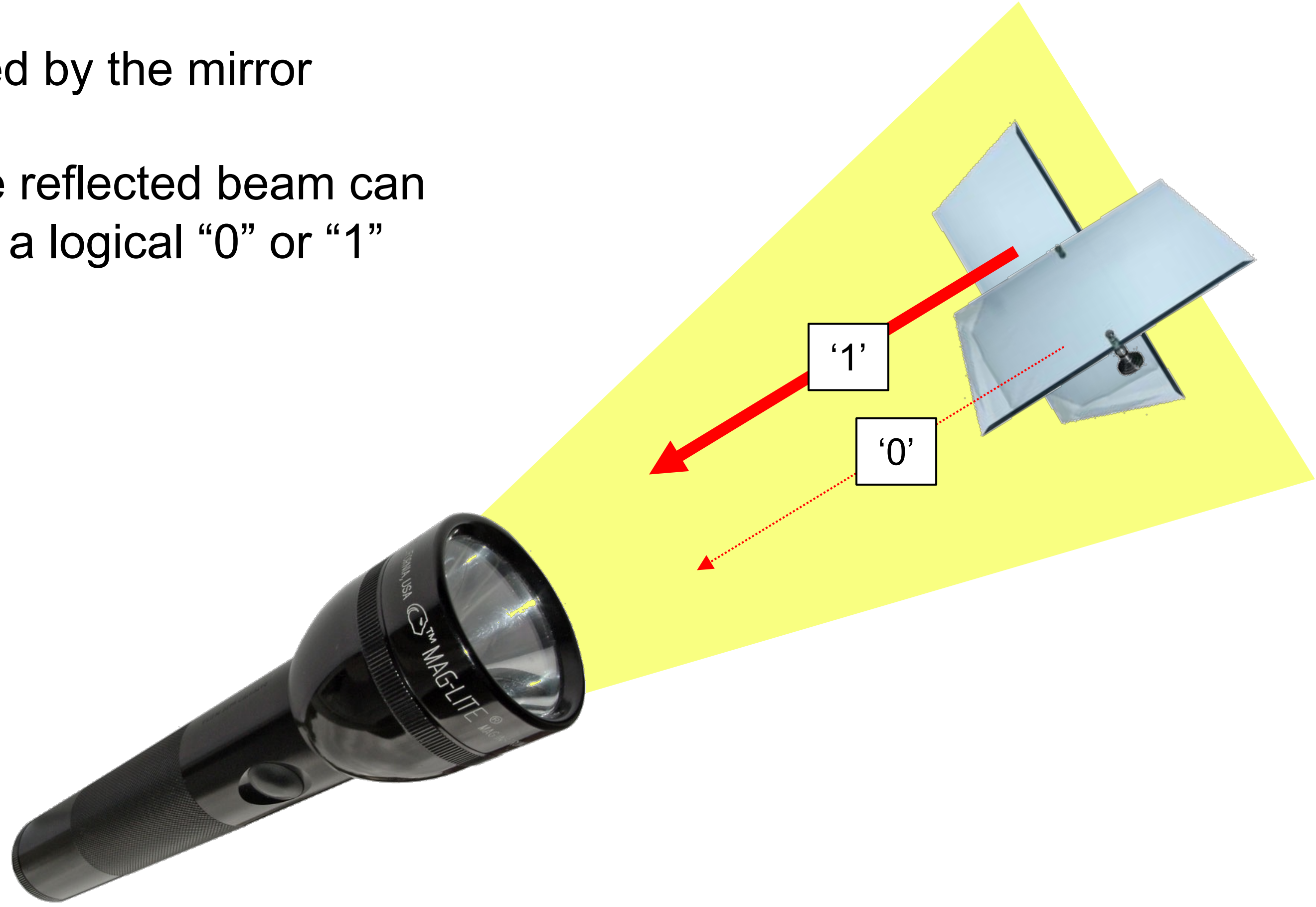
Inductive Coupling		Radiative
LF (120-150kHz)	HF (13.56MHz)	UHF (~900MHz)
Magnetic (Near Field)		Electromagnetic (Far Field)
Coil		Antenna

Inductive Coupling

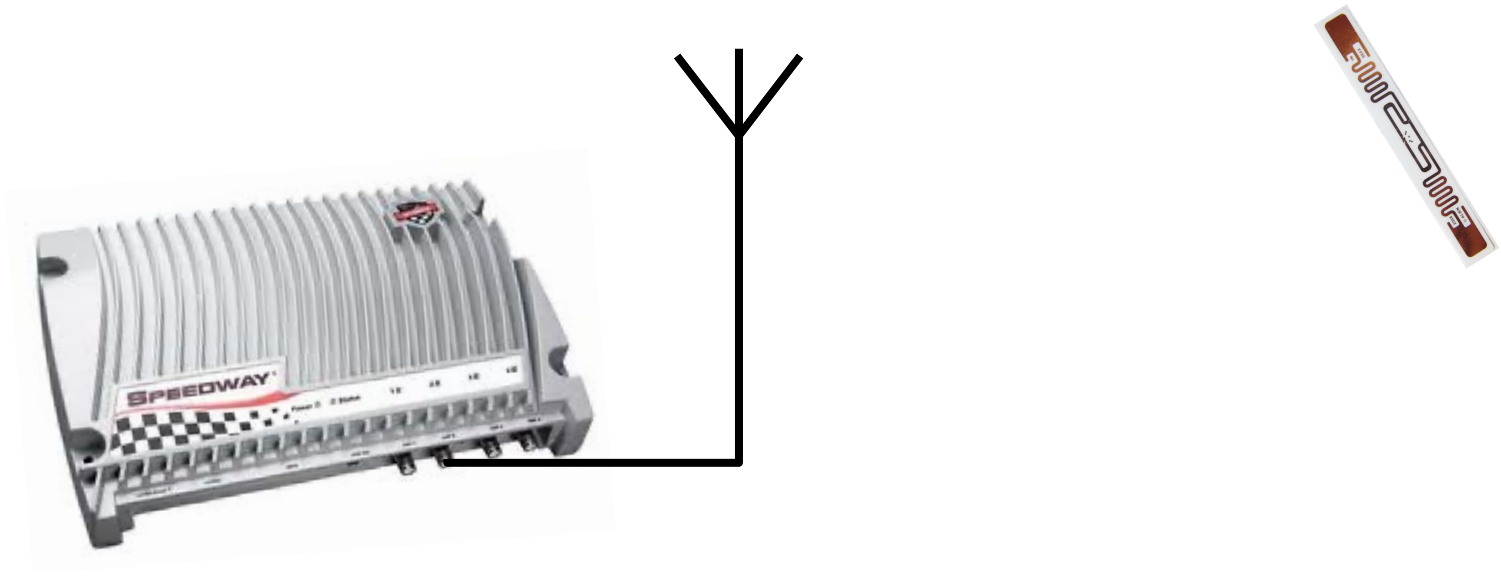


UHF Backscatter Communication

- A flashlight emits a beam of light
- The light is reflected by the mirror
- The intensity of the reflected beam can be associated with a logical “0” or “1”

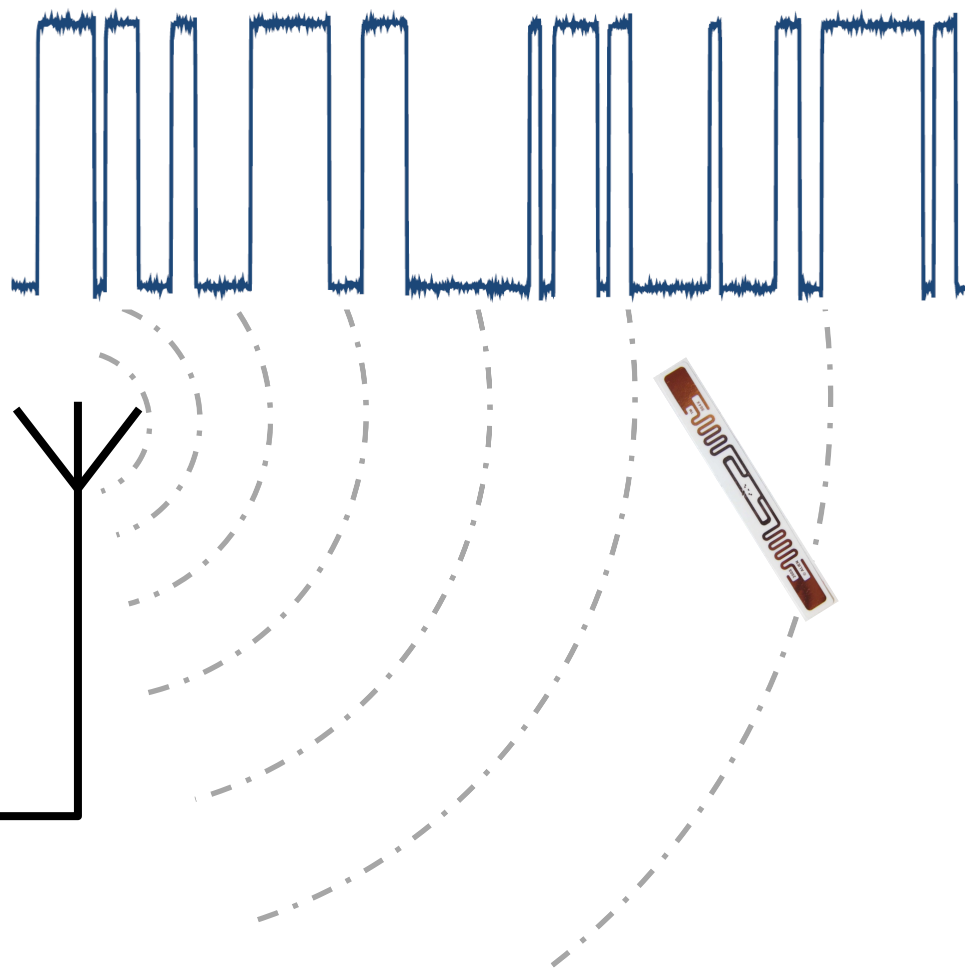


Backscatter Communication



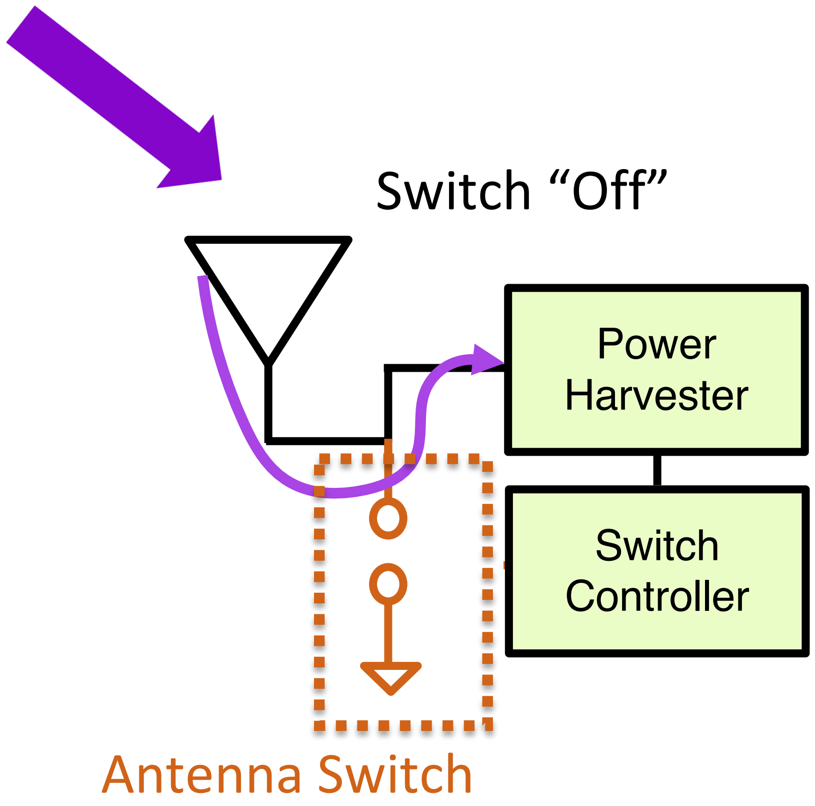
Backscatter Communication

Tag reflects the reader's signal using ON-OFF keying



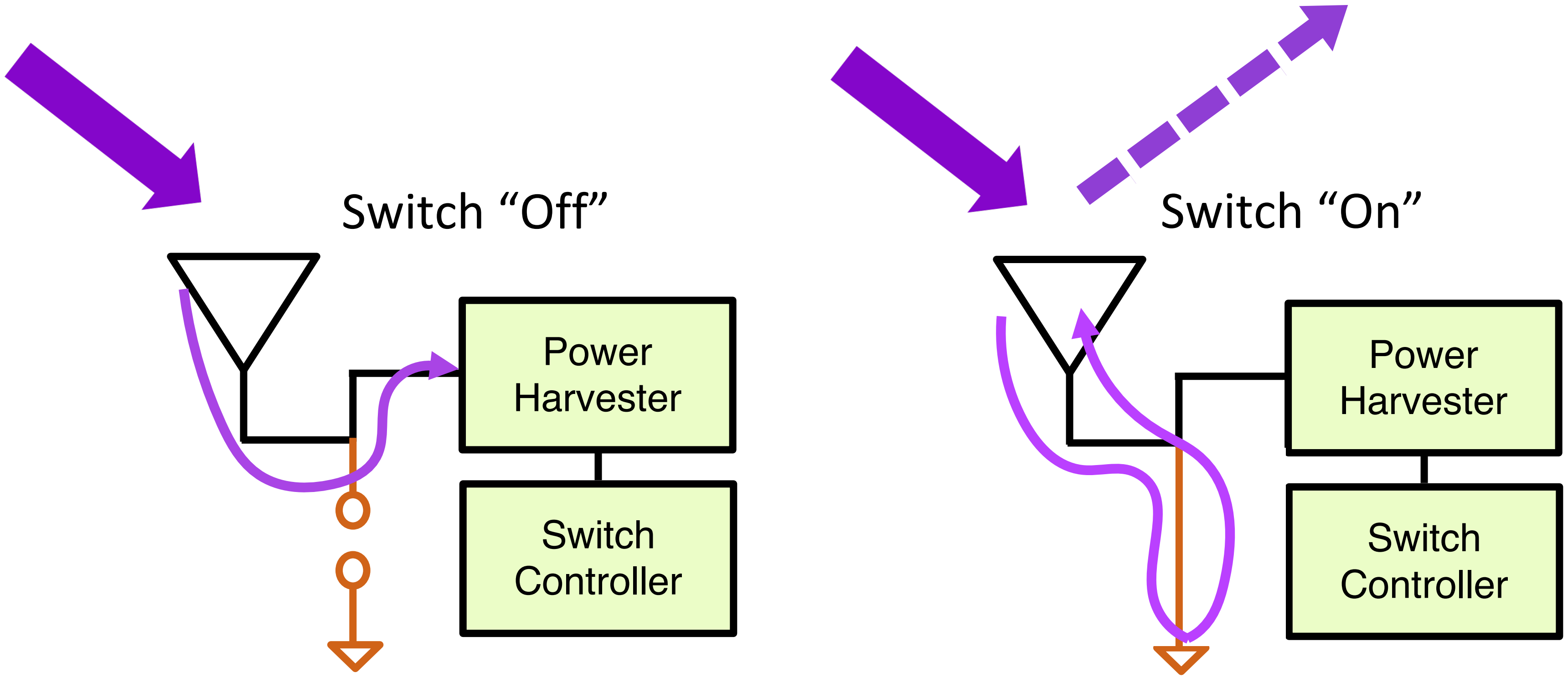
Reader shines an RF signal on nearby RFIDs

Uplink Communication

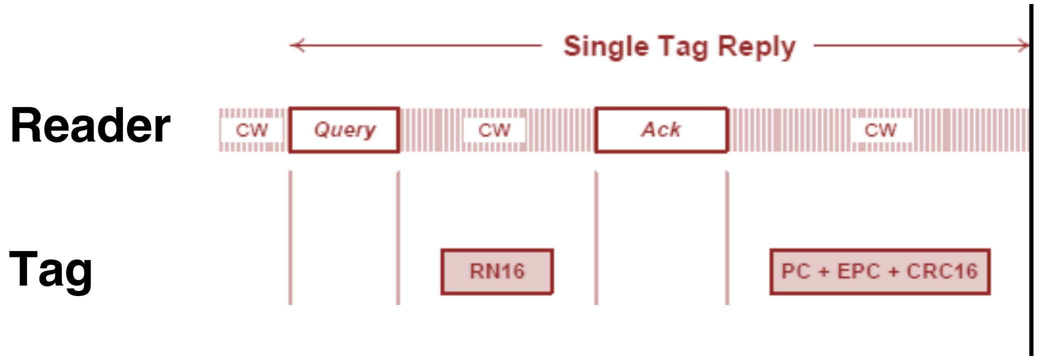


Simplified RFID schematic

Uplink Communication



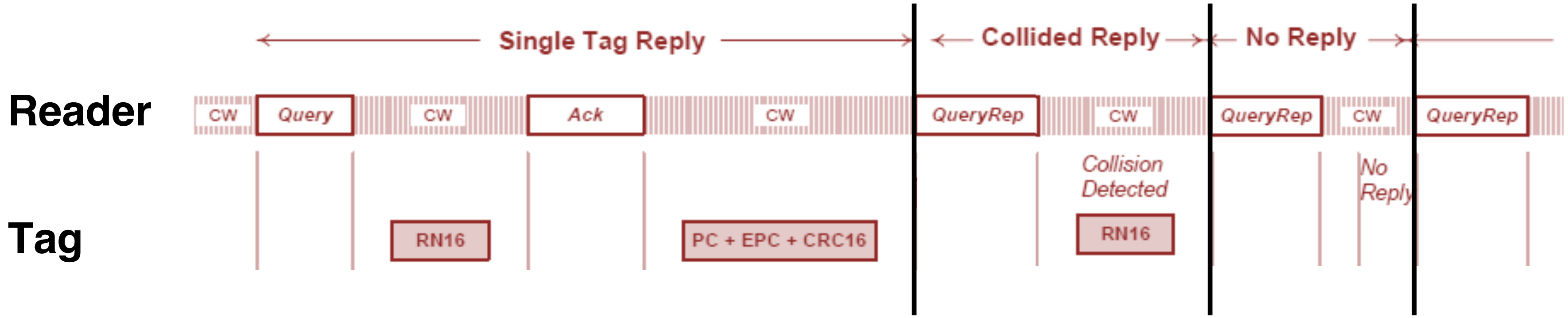
EPC Gen2 Standard – MAC



Slotted Aloha:

- Reader allocates Q time slots and transmits a query at the beginning of each time slot
- Each tag picks a random slot and transmits a 16-bit random number
- In each slot:
  - RN16 decoded → Reader ACKs → Tags transmits 96-bit ID
  - Collision → Reader moves on to next slot
  - No reply → Reader moves on to next slot

EPC Gen2 – MAC

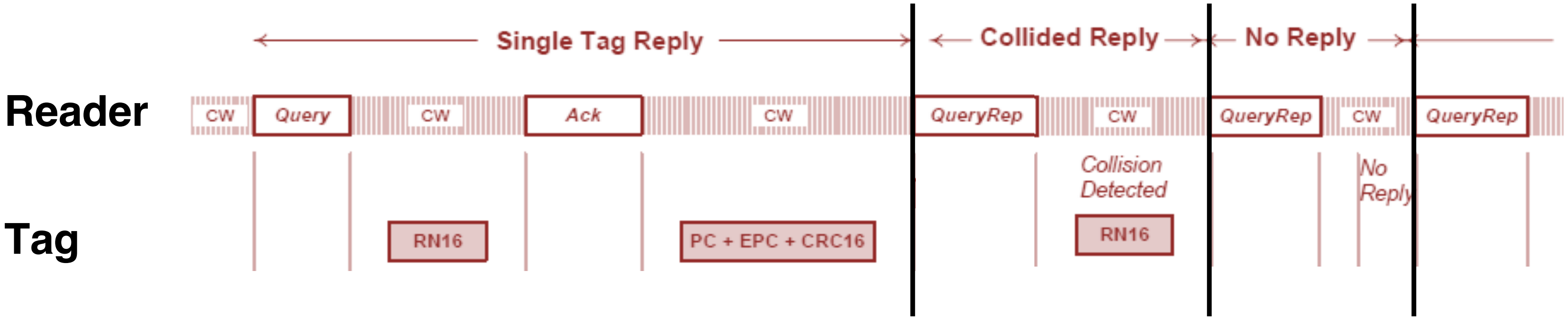


Let's consider an example with Q=4, no tag; and Q=4, 1 tag

Inefficient:

- If reader allocates large number of slots → Too many empty slots
- If reader allocates small number of slots → Too many collisions

EPC Gen2 – MAC



Inefficient:

- If reader allocates large number of slots → Too many empty slots
- If reader allocates small number of slots → Too many collisions
- If reader knows number of tags = N → Allocate K=N slots → 37% efficiency
- Downlink overhead

Significant work on "spanning trees", efficient scanning, decoding with collisions, etc.

MobiCom 2018, New Delhi, India

Challenge:
RFID Hacking for Fun and Profit

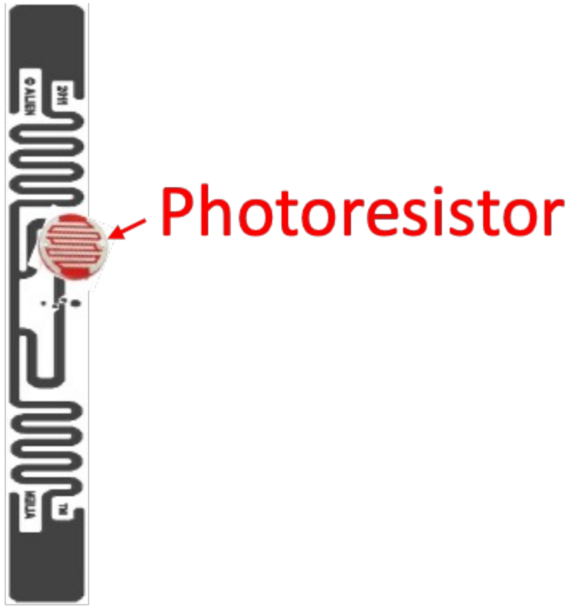
Ju Wang, Omid Abari and Srinivasan Keshav

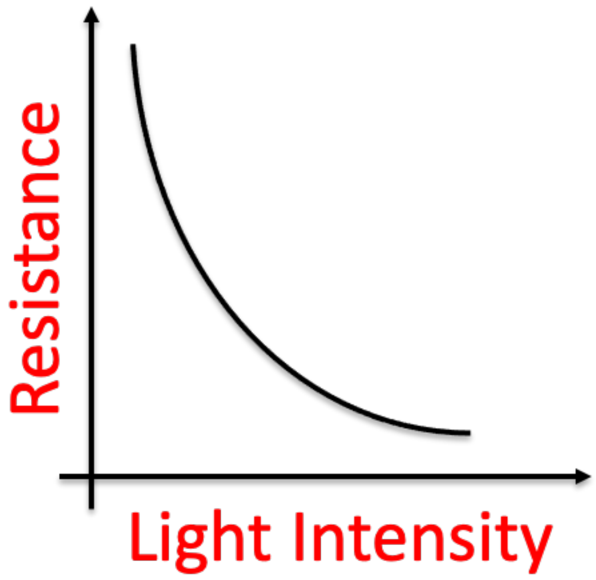
{ju.wang,omid.abari,keshav}@uwaterloo.ca

UNIVERSITY OF WATERLOO

ICONLAB.ca

What’s the basic approach?

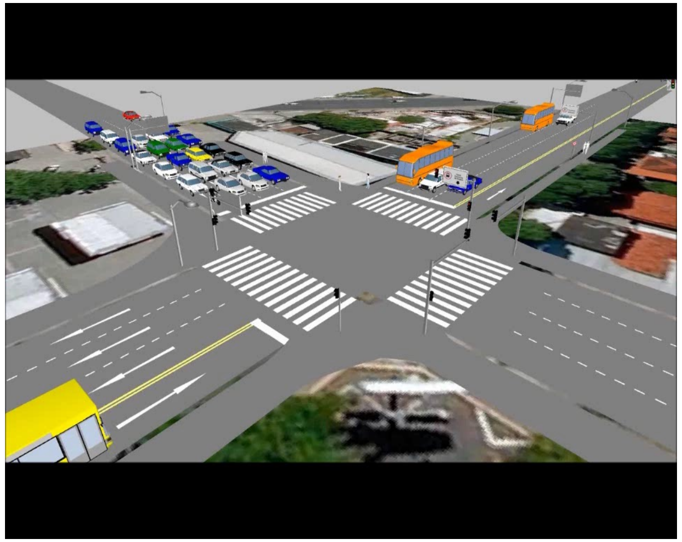




An E-Toll Transponder Network for Smart Cities

Smart City Services

Traffic Management

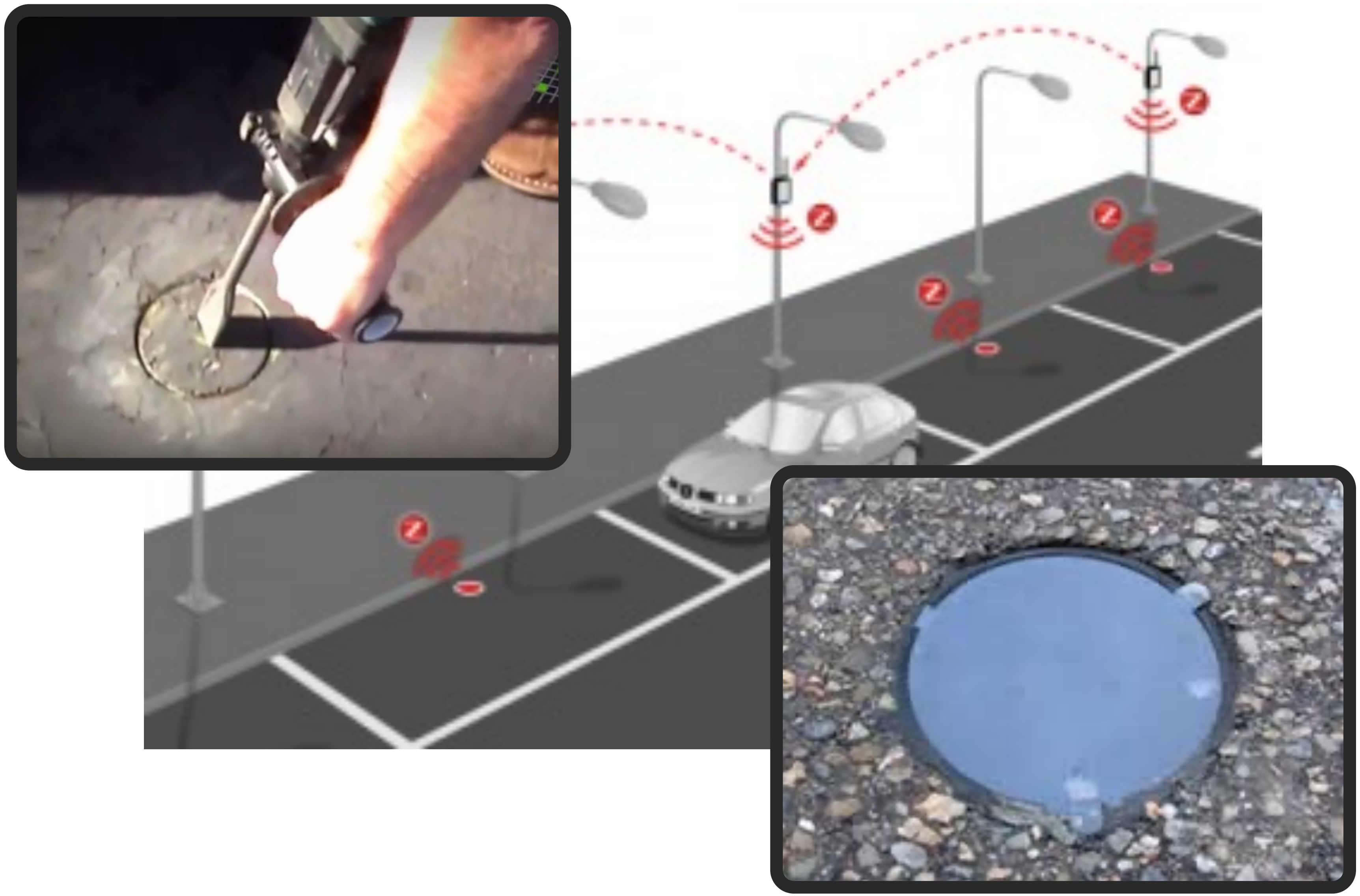


Detect
Red-Light Runner

Smart
Parking

Key Problem: each service needs a new infrastructure

Smart Parking



Traffic Management

Ideally…

1) ONE Infrastructure

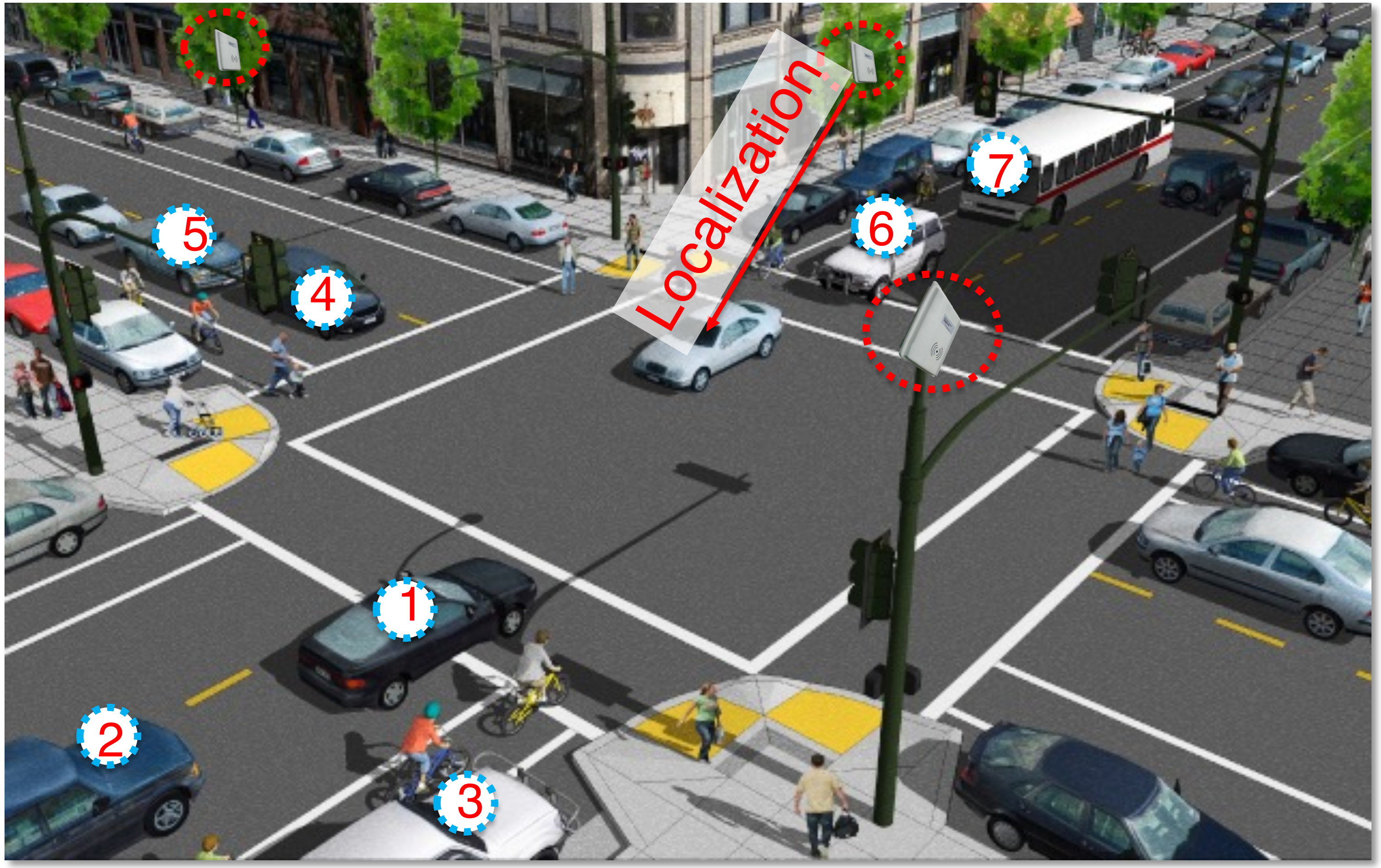
2) Ease of Maintenance

3) We don’t want to add new devices to cars

Electronic Toll Transponders

Some states have made it mandatory

Opportunities



One infrastructure for many smart services

Challenge: Interference

Wireless query

One car responds

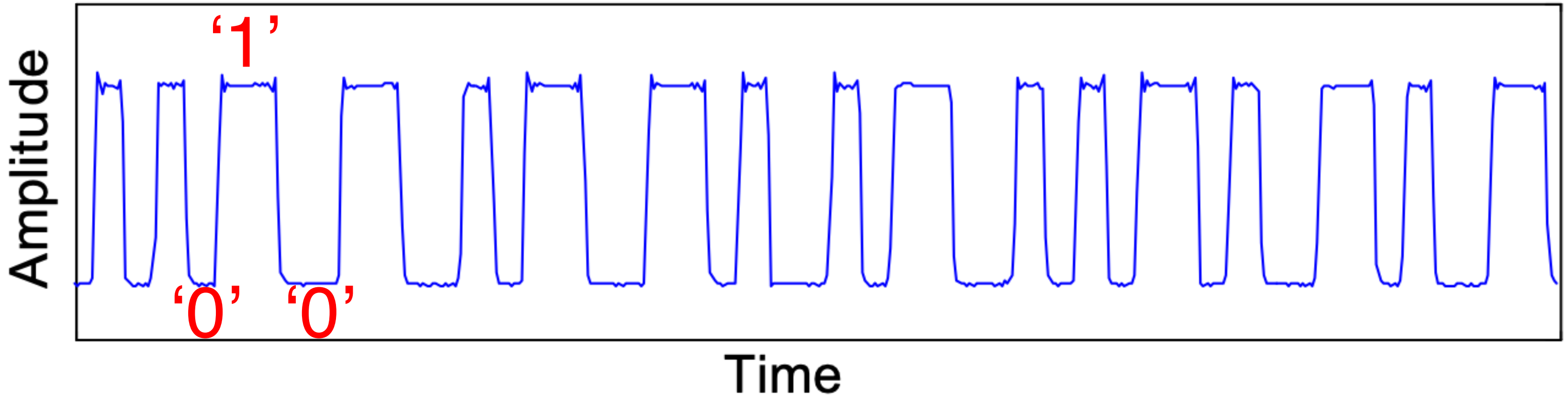
Wireless query

All cars respond

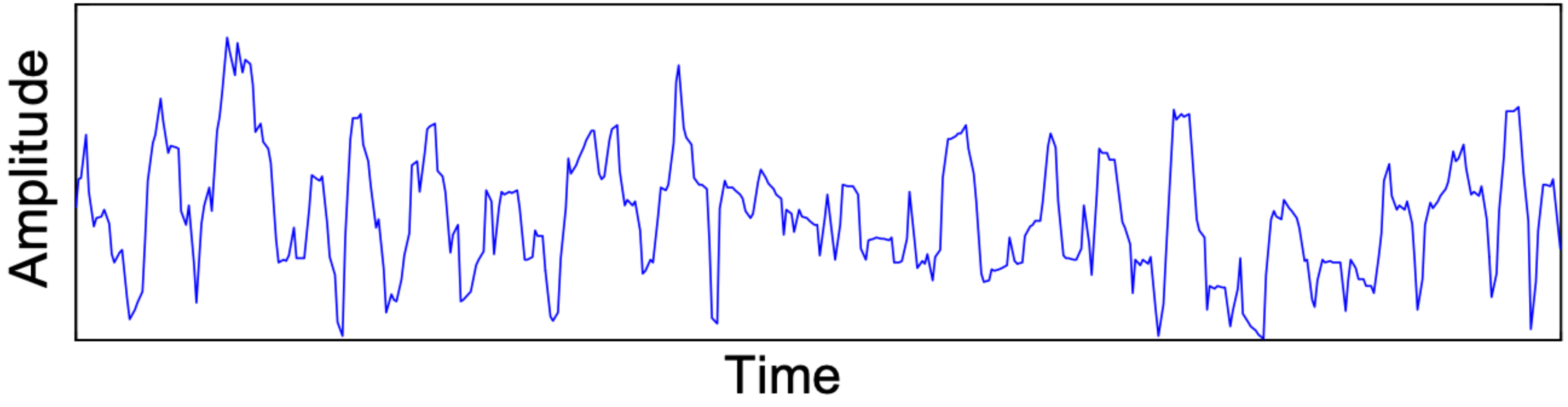
How can we decode transponders despite Interference?

How can we decode transponders despite Interference?

One Transponder Responds → Decodable



Multiple Transponders Respond



Count cars: How to count despite interference?

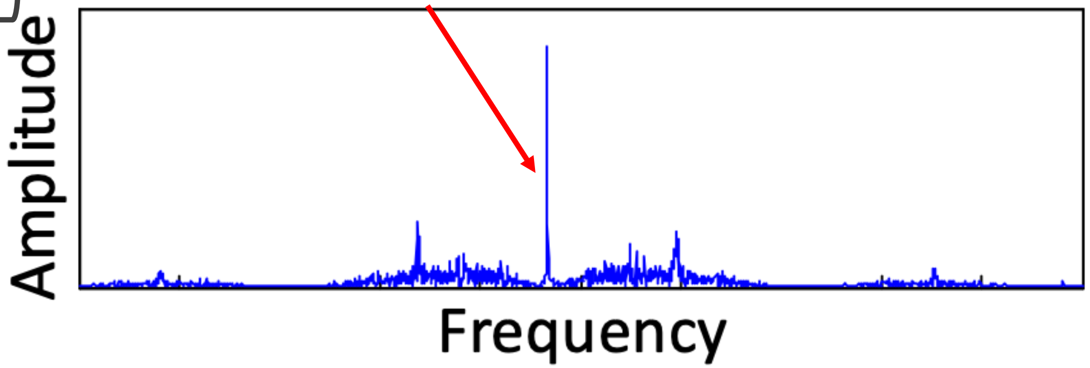
Structure of the Signal

Time-Domain

$\times \underbrace{(\sin 2\pi f_c t)}_{\text{Carrier}}$

Freq-Domain

Spike



Variability due to manufacturing process

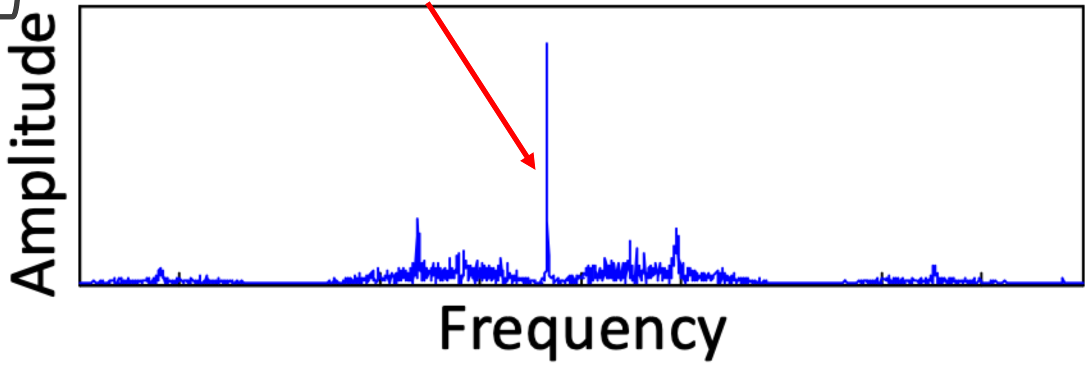
Structure of the Signal

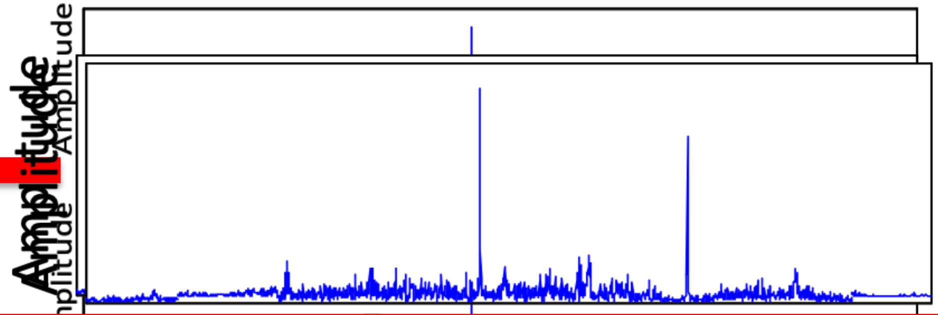
Time-Domain

 x $\underbrace{(\sin 2\pi f_c t)}_{\text{Carrier}}$

Freq-Domain

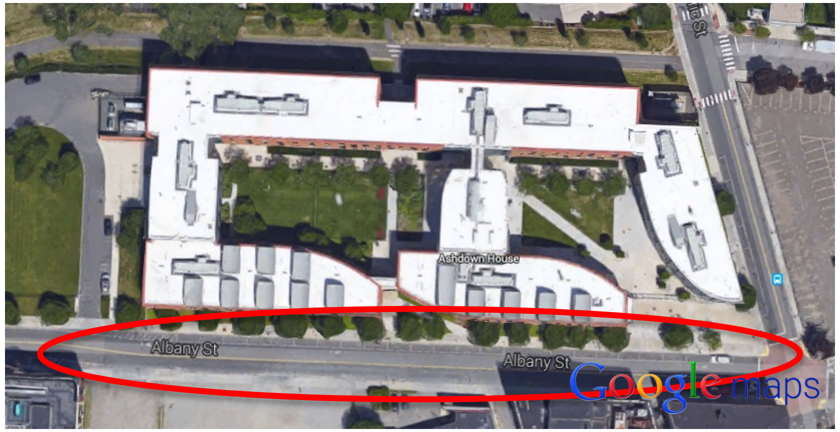
Spike





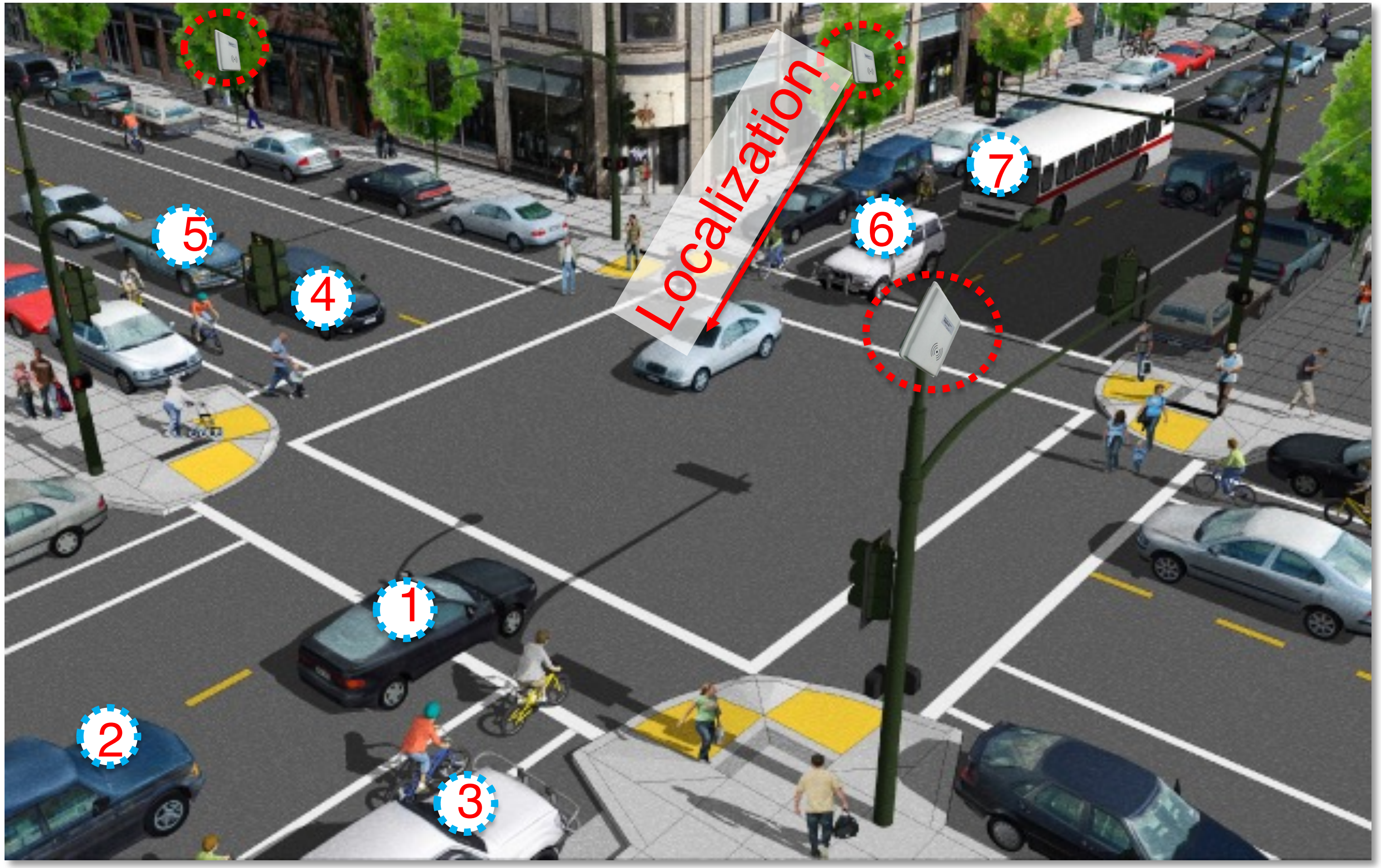
Can count despite interference

Evaluation



- MIT campus- four streets
- Caraoke readers were placed on 12.5-feet poles
- Standard E-ZPass transponders on the cars

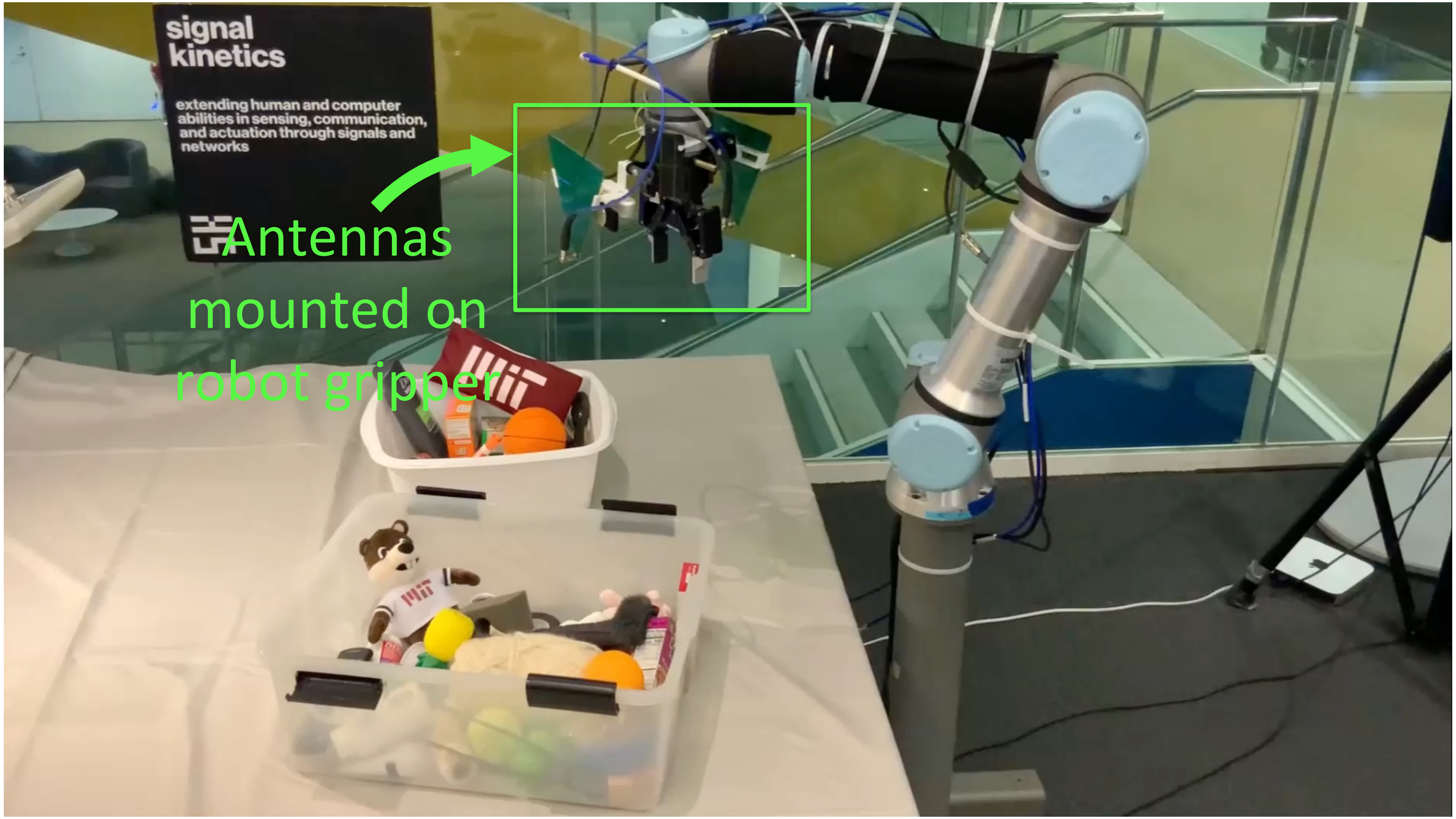
One infrastructure for many smart services



Caraoke

- A system for delivering smart services using existing e-toll transponders
- Can count, localize and decode transponders in the presence of interference
- Built into a small PCB

Application of Batteryless RFID Localization to Robotic Picking


signal
kinetics
extending human and computer abilities in sensing, communication, and actuation through signals and networks
Antennas
mounted on
robot gripper

Summary of Lecture

- RFID background, history, and applications
- Types of RFIDs (LF, HF, UHF. Passive, Active)
- Principles of operation: energy harvesting & backscatter communication
- Etoll transponders for smart cities
- Dealing with interference
- RFID Localization

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Next class

- Wed Sep 27
- Introduction to Inertial Sensing & Activity Recognition
- Reading: Inertial Navigation System (INS)