CIS 3990

Mobile and IoT Computing

https://penn-waves-lab.github.io/cis3990-24spring

Lecture 11: Batteryless Connectivity

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TA: Haowen Lai (hwlai@cis.upenn.edu)

Some material adapted from Omid Abari (UCLA)

Objectives of This Module

Learn the fundamentals, applications, and implications of Network technologies for Mobile and IoT Systems

1. What are the various classes of network technologies?
2. How do we choose the right technology for a given application?
3. What are the different routing architectures?
4. How does energy impact the system design?
5. How does batteryless connection work?

Focus of this lecture

Last Lecture

Bluetooth®
Low Energy

Bluetooth®
Classic

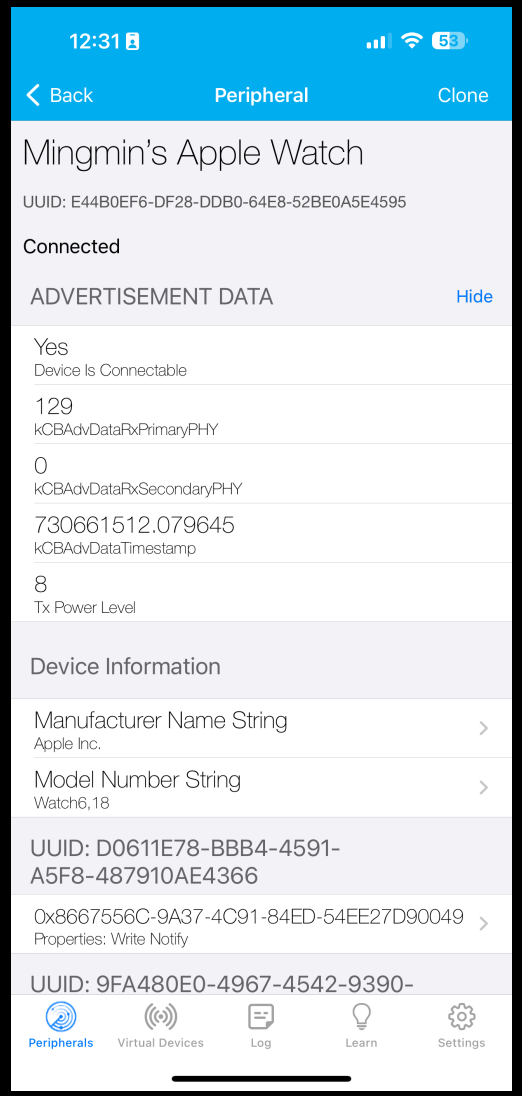
Bluetooth Classic and Bluetooth Low Energy (BLE)

How does BLE work?

Two parts:

1. Advertisements (aka beaconing) for device discovery
2. Connection phase for data exchange

BLE Advertisements are periodic

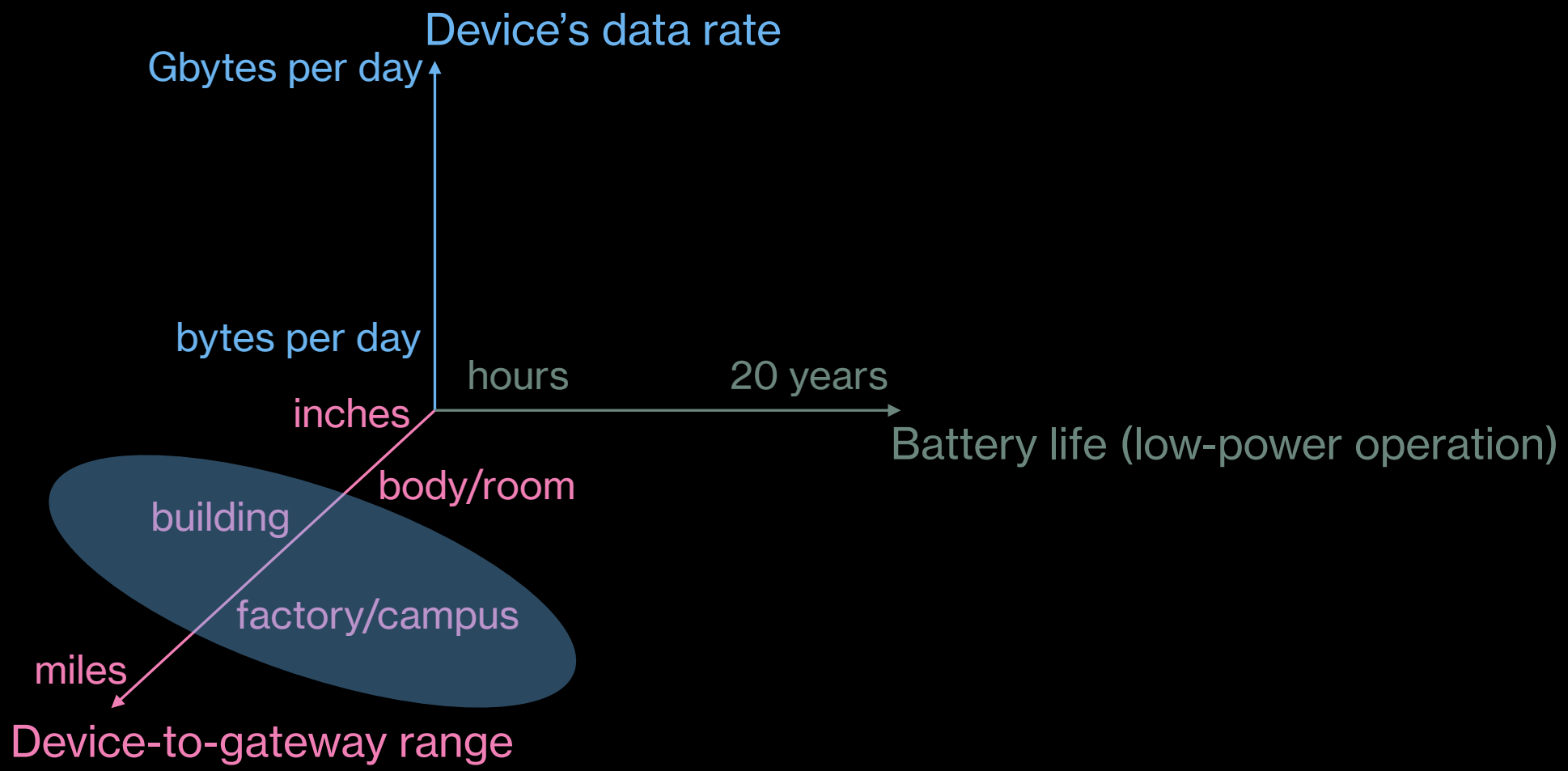


- Typical period: 100 ms
- Less frequent is fine
- Triggered advertisement are often a good idea

- Trade-off between energy consumption and discovery latency

Extending communication range

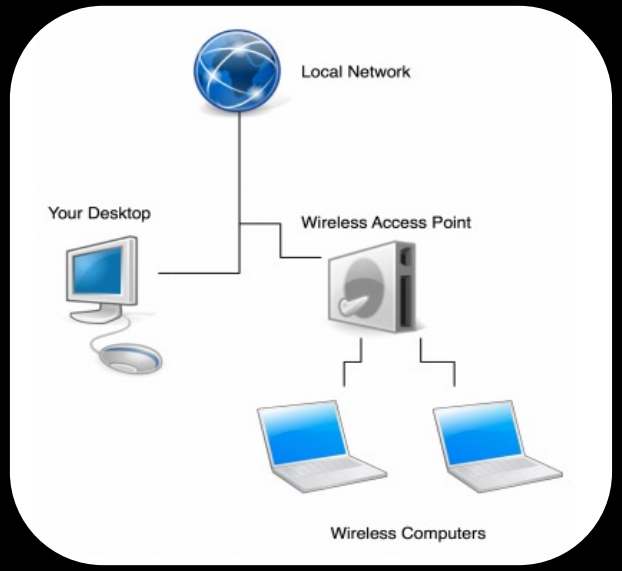
What are the metrics that we care about?



Wireless Network Architectures

There are 3 kinds of wireless network architectures

Access Network

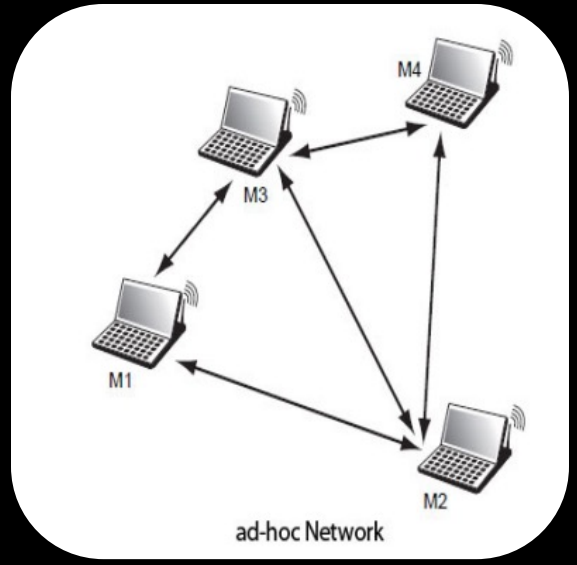


e.g., WiFi, cellular

Device-to-device

e.g., Bluetooth

Ad Hoc Network



e.g., leverage P2P to reach internet (crises)

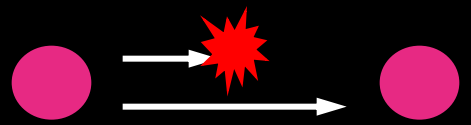
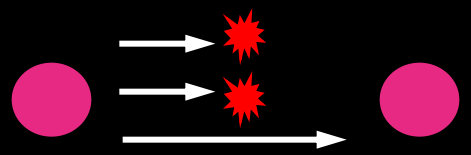
One-hop

Multi-hop

Approach #4: Wireless routing metric: ETX

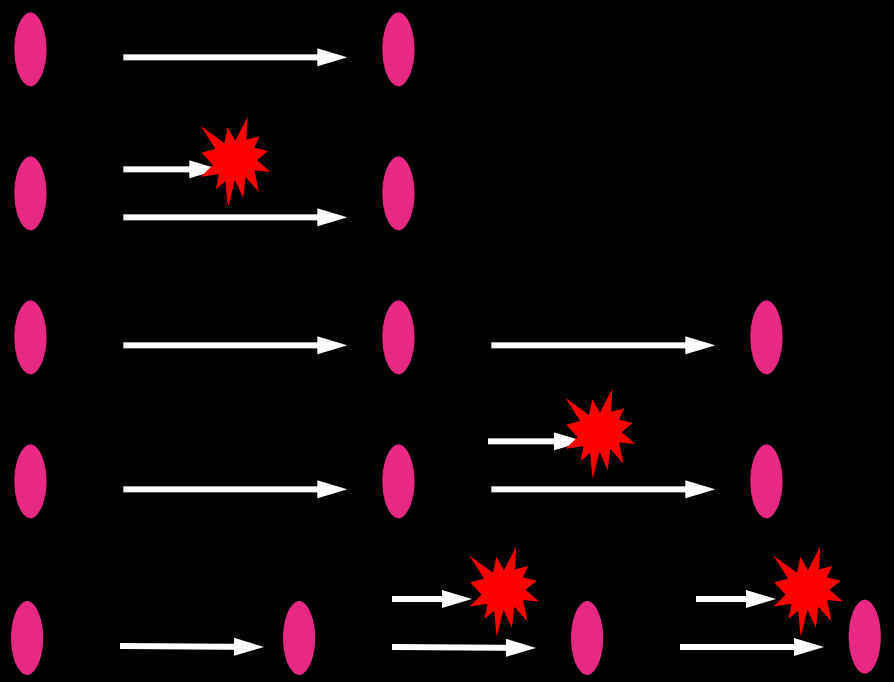
Minimize total transmissions per packet
(ETX, 'Expected Transmission Count')

Link throughput ≈ 1/ Link ETX

Delivery Ratio		Link ETX	Throughput
100%		1	100%
50%		2	50%
33%		3	33%

Route ETX

Route ETX = Sum of link ETXs

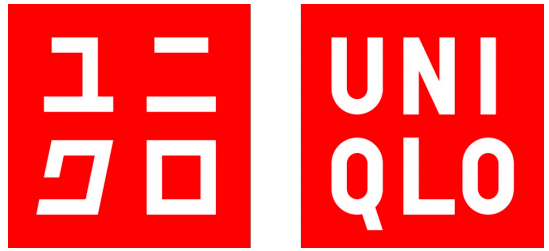


Route ETX	Throughput
1	100%
2	50%
2	50%
3	33%
5	20%

Today’s Topic:
RFID and Batteryless Connection


NIKE

macy's


ユニクロ
UNI
QLO


lululemon


H&M


ZARA


RALPH LAUREN


BURBERRY
LONDON


(01)03608439746888(21) 0000 0056 4751
RFID
(01)03608439746888(21)
0000 0056 4751
Serial Number
ITEM : 1738390
TIGHT FORCLAZ 50 NAVY
S:S - CC:00102229


25-27cm
0102956326


E 3S T PNT TRIC
DU0452
XLT
E 3S TT TRIC
DU0445
XL


Restart
Scan Item
1. Ultra stretch jeans
Add Alteration
2. Fleece jacket
3. Sweat hoodie
4. K's HEATTECH cap
202••••••1127
5 Items
BACK
£39.90
£29.90
£34.90
£9.90
Total £144.50
NEXT
PLEASE PLACE
ITEMS ON BASKET HERE
£5 welcome coupon

Forbes

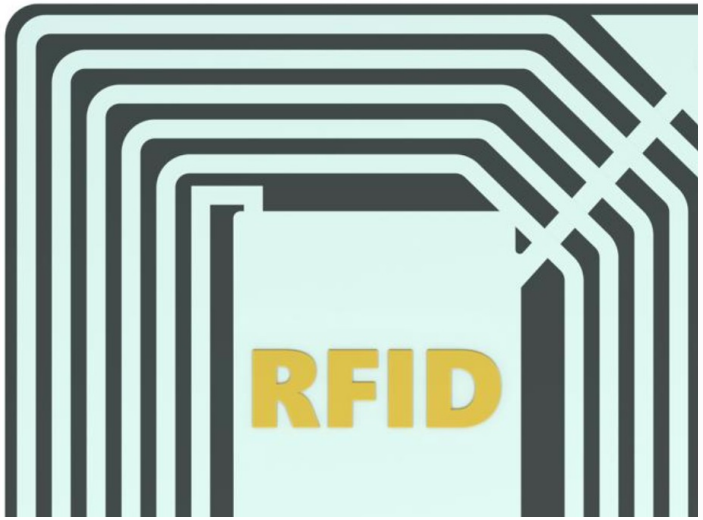
Mar 8, 2021, 07:10am EST | 374 views

How RFID Helps Retail Companies Save Money

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

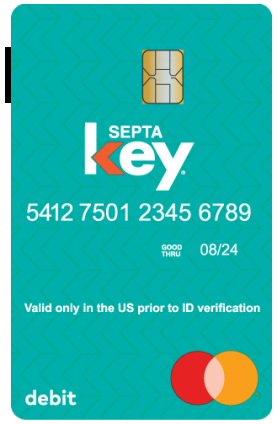
Akiko Katayama Contributor ⓘ

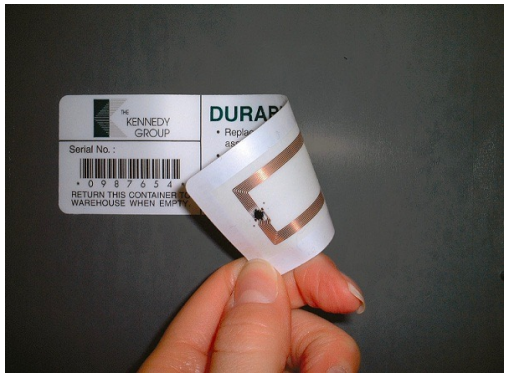
Food & Drink

This article is more than 2 years old.

RFID (Radio Frequency IDentification)

Access Control





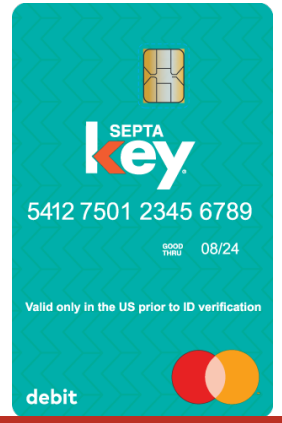
Inventory control

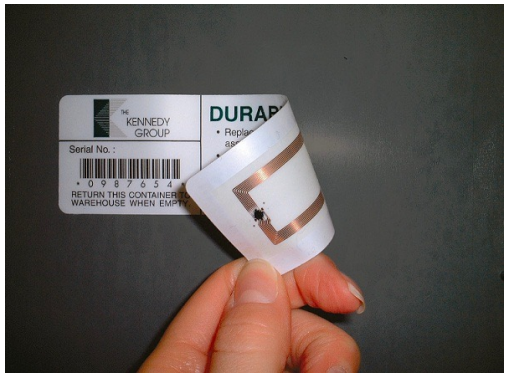
Security Sensitive Applications

Tracking & Localization

Long-Range Payment Systems

RFID (Radio Frequency IDentification)





> 100 Billion in the world

EDITION: US

ZDNet | VIDEOS | WINDOWS 10 | 5G | BEST VPNS | CLOUD | SECURITY | AI | MORE | NEWSLETTERS | ALL W

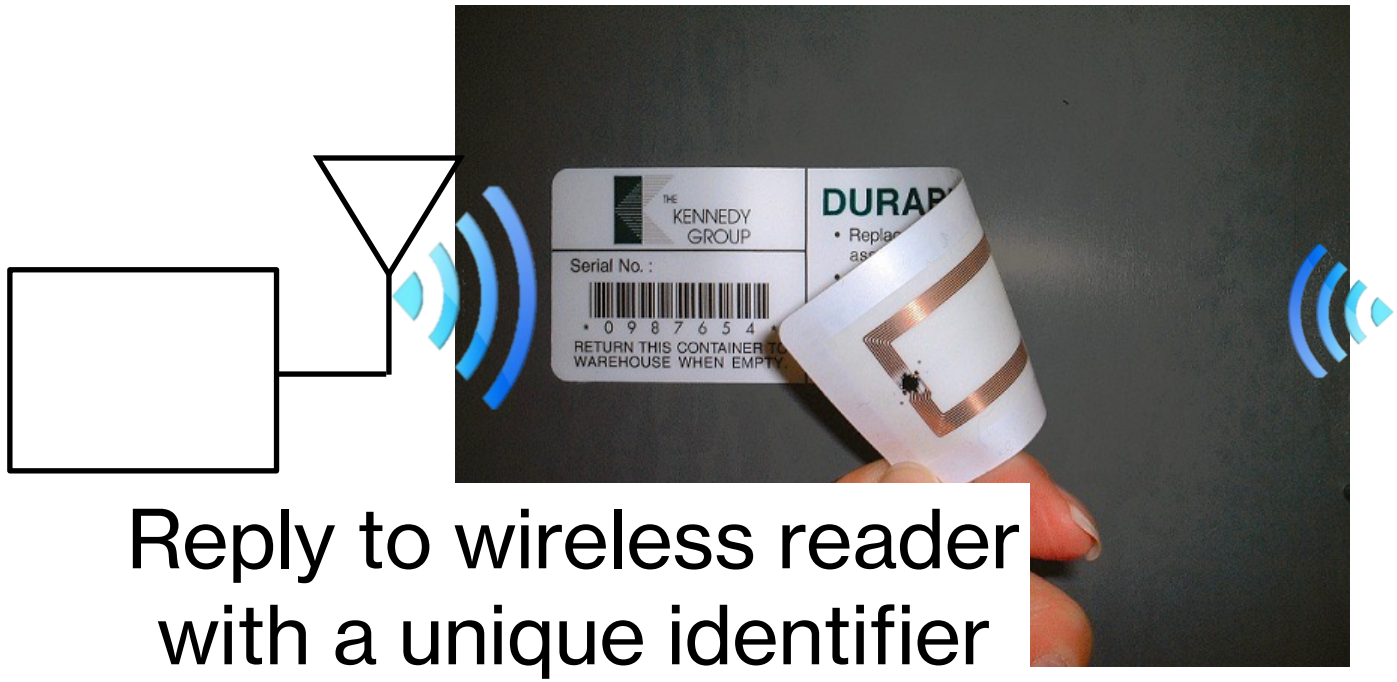
MUST READ: Everything you need to know about the Microsoft Exchange Server hack

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.

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

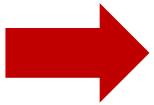
- 1980s: development of E-Toll transponders

- 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 circuitr

Types of RFIDs

UHF (~900MHz)

HF (13.56MHz)

LF (120-150kHz)

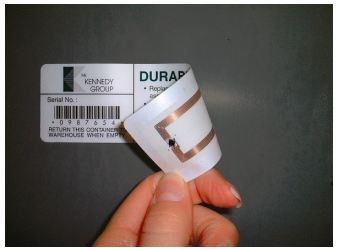
long range (few m)

short range (few cm)

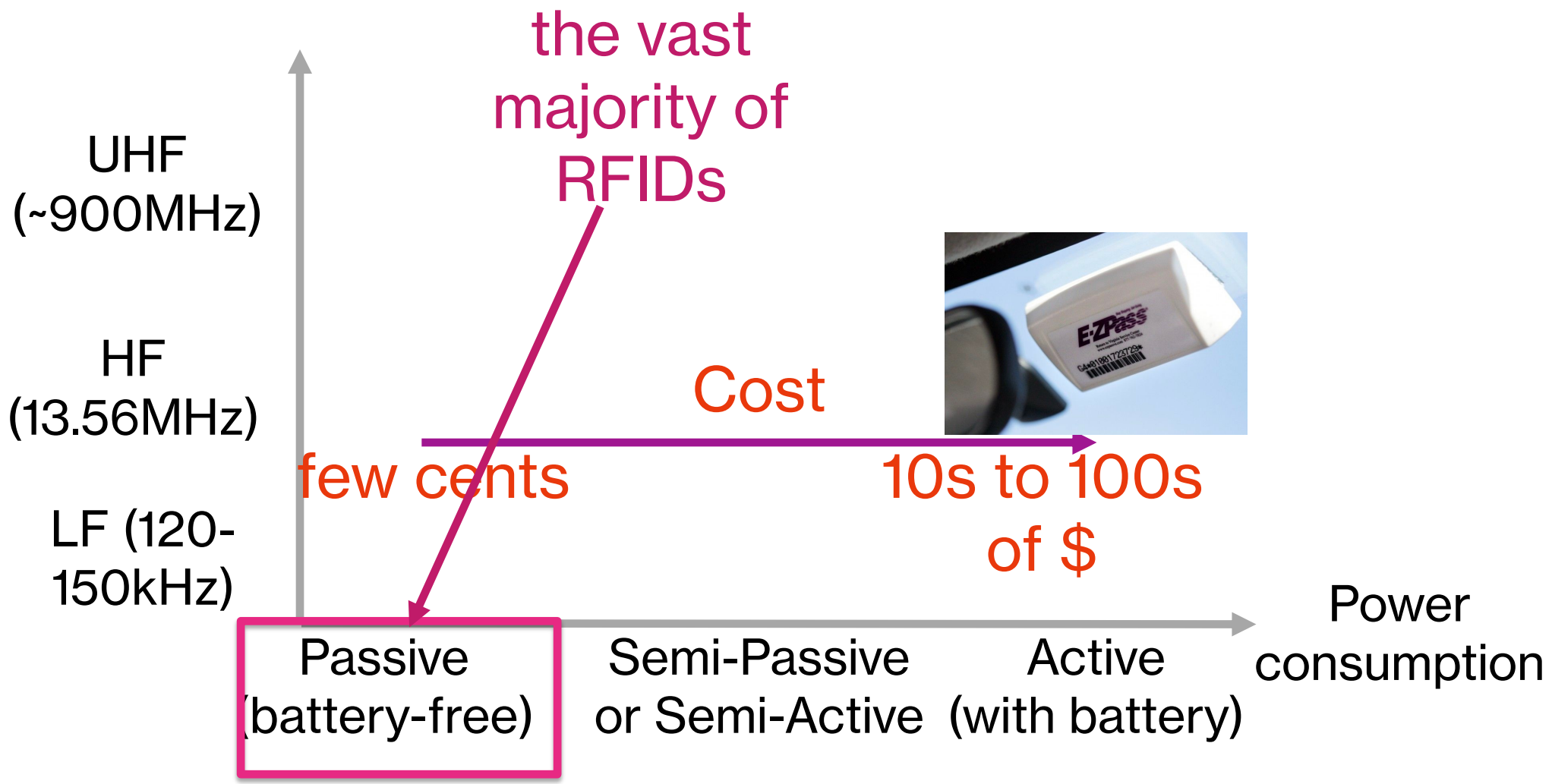
Range of Operation

"need to tap"

Where do these fall?



Types of RFIDs

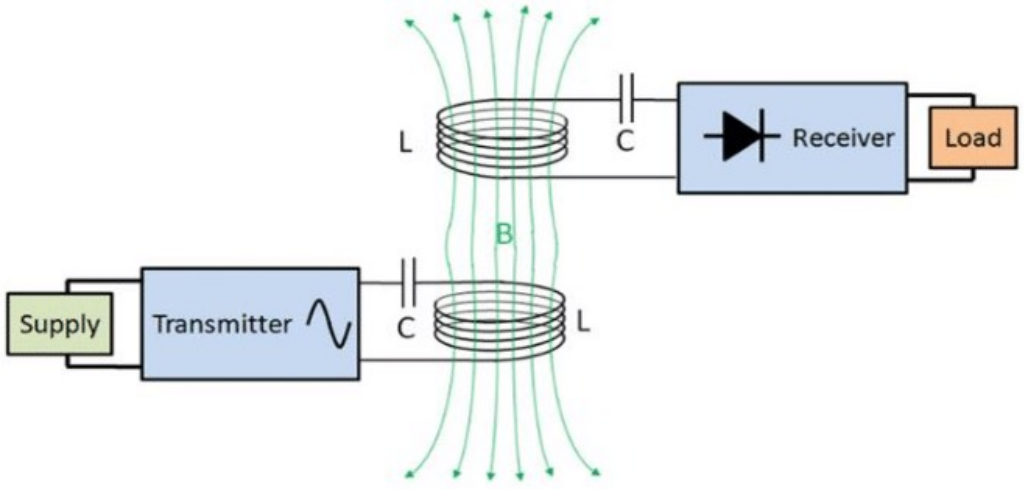


How does an RFID power up?

Harvests Energy from Reader's Signal

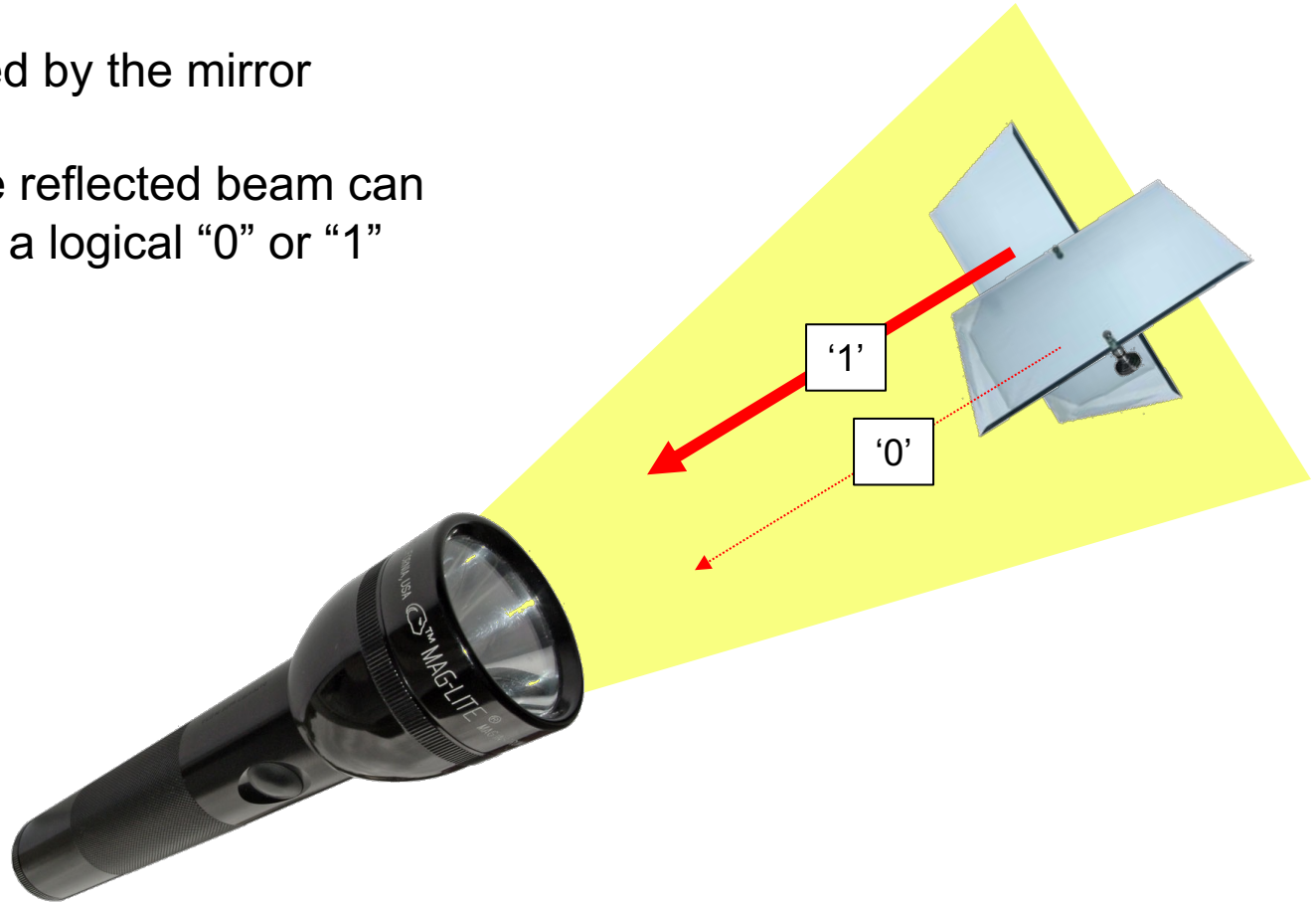
Inductive Coupling		Radiative
LF (120-150kHz)	HF (13.56MHz)	UHF (~900MHz)
Magnetic (Near Field)		Electromagnetic (Far Field)
Coil		Antenna

Inductive Coupling



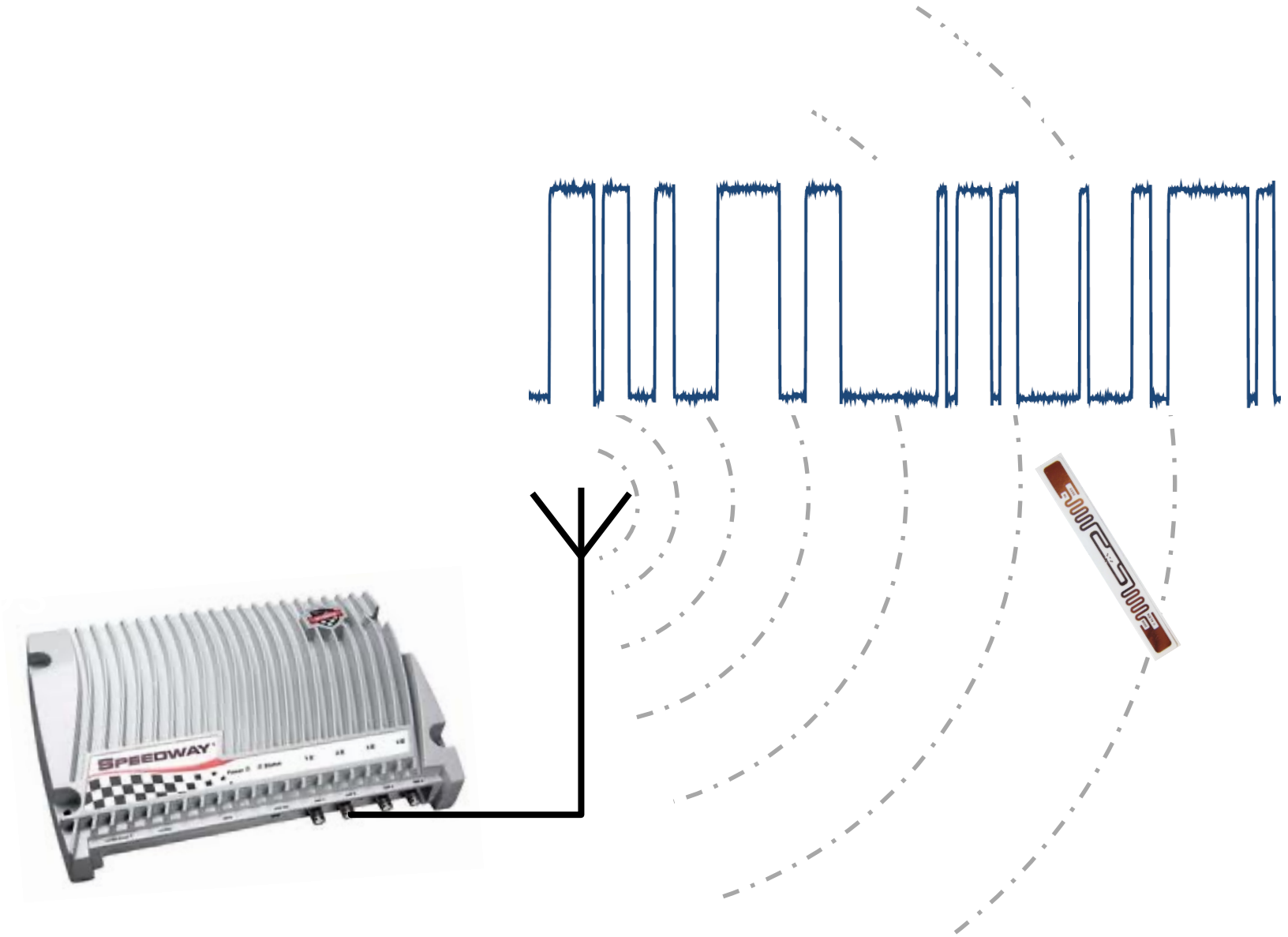
UHF Backscatter Communication

- 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”

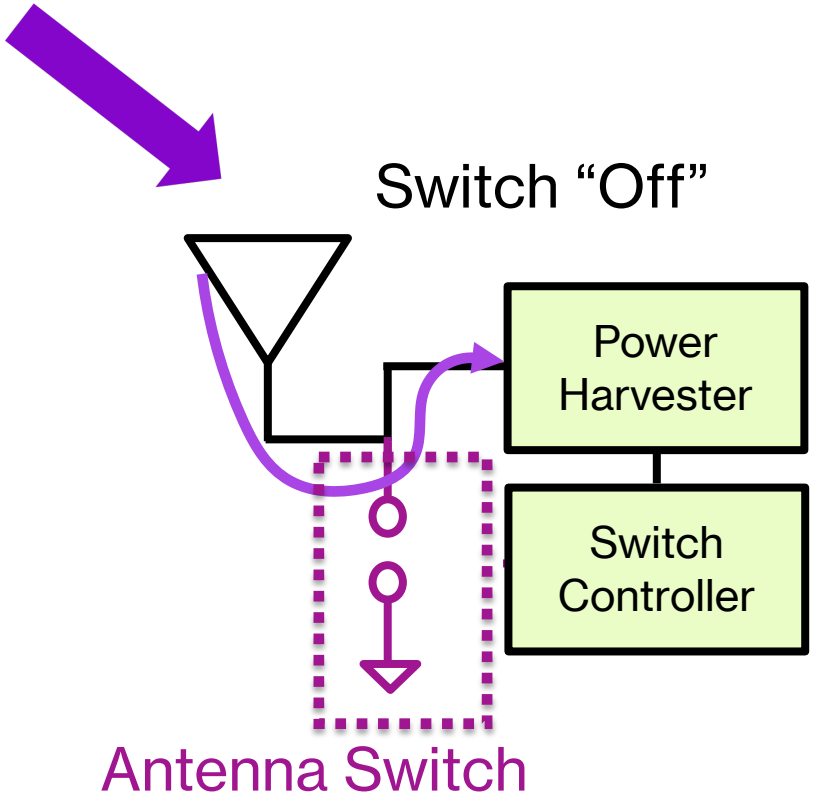


Backscatter Communication

Backscatter Communication

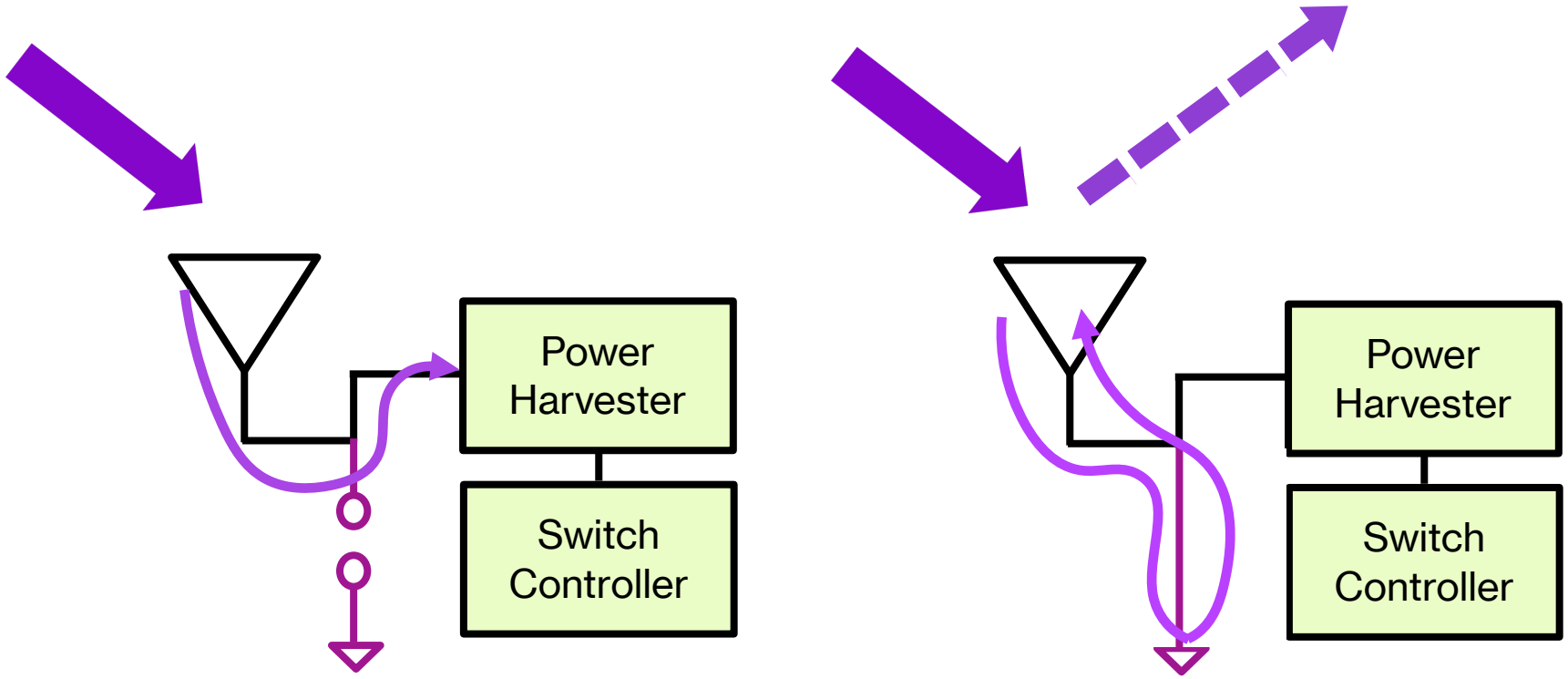


Uplink Communication

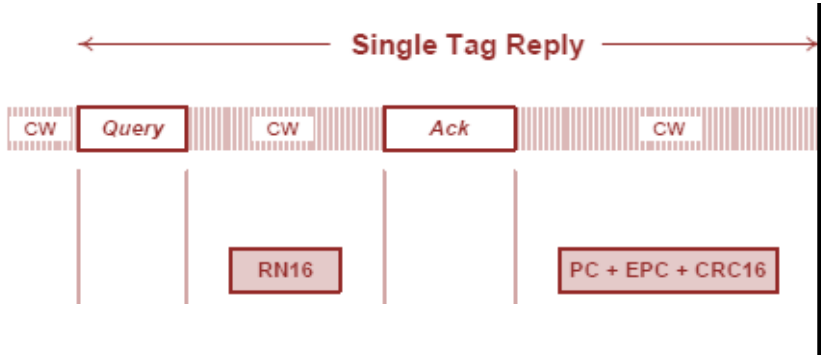


Simplified RFID schematic

Uplink Communication



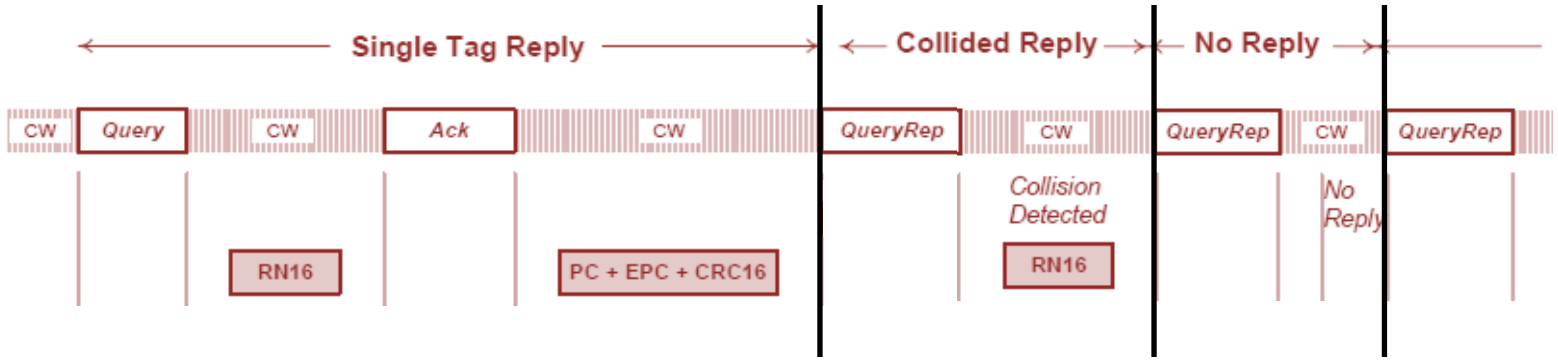
EPC Gen2 Standard – MAC



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

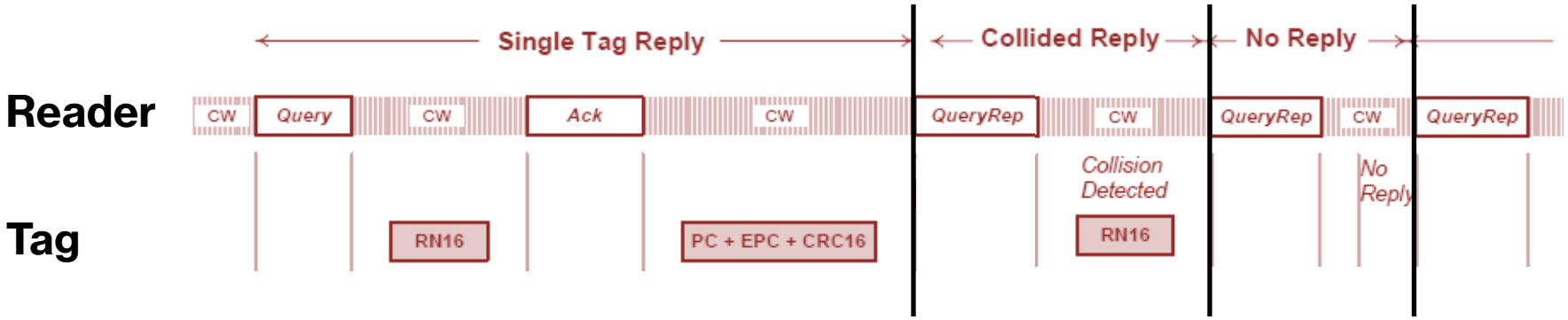


Let's consider an example with Q=4, no tag; and Q=4, 1 tag

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

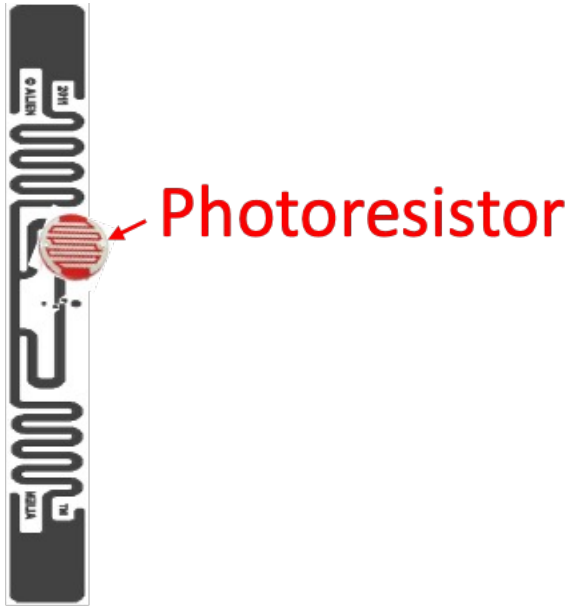
Ju Wang, Omid Abari and Srinivasan Keshav

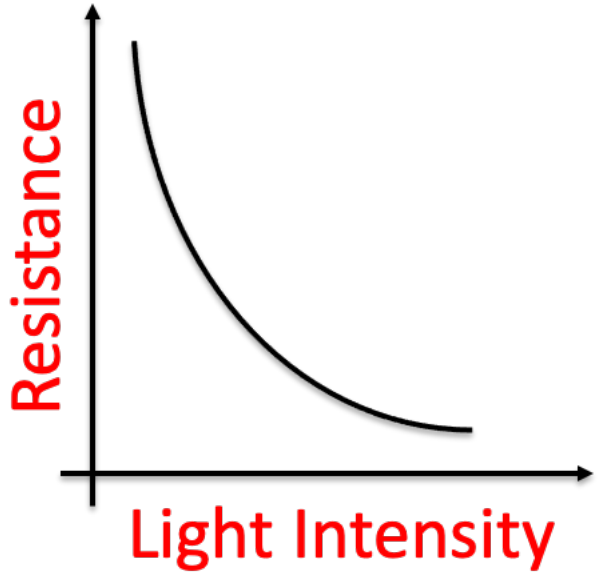
{ju.wang,omid.abari,keshav}@uwaterloo.ca

UNIVERSITY OF WATERLOO

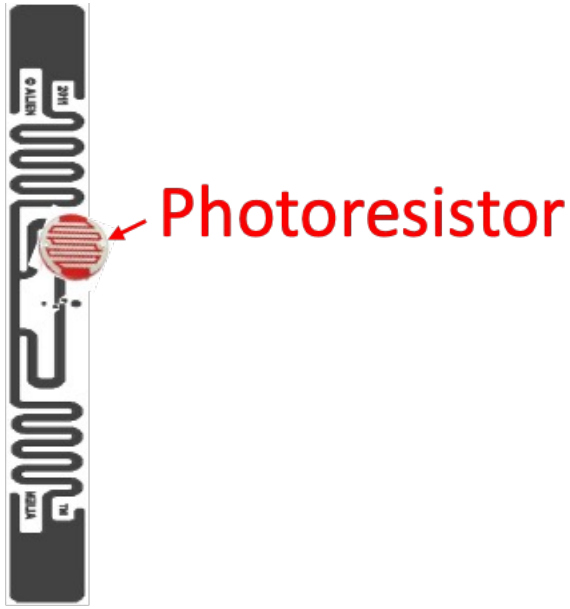
ICONLAB.ca

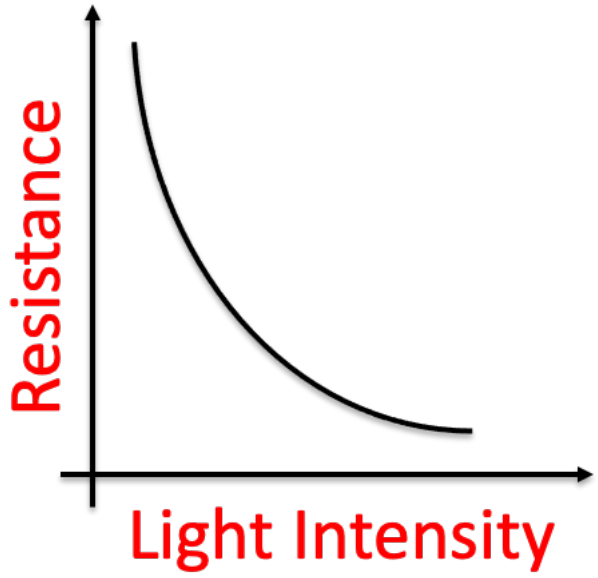
What's the basic approach?





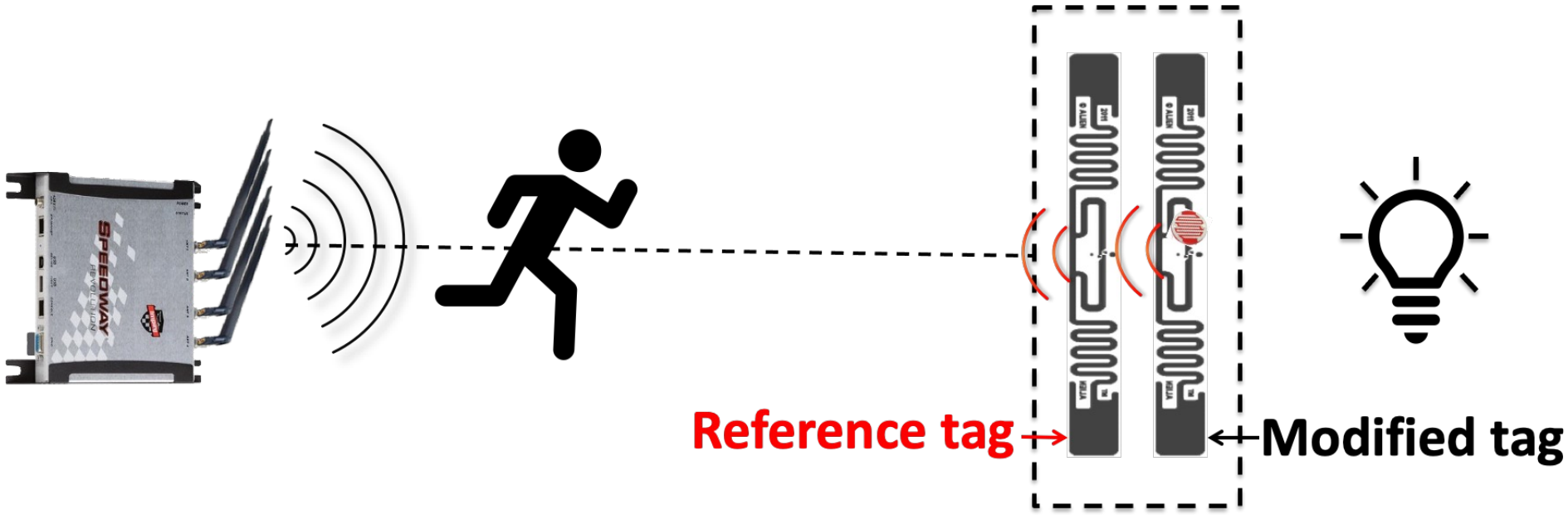
What's the basic approach?





- How do they isolate the impact of the environment vs the photoresists on RSS?

Solution: Differential Sensing to deal with environmental variations

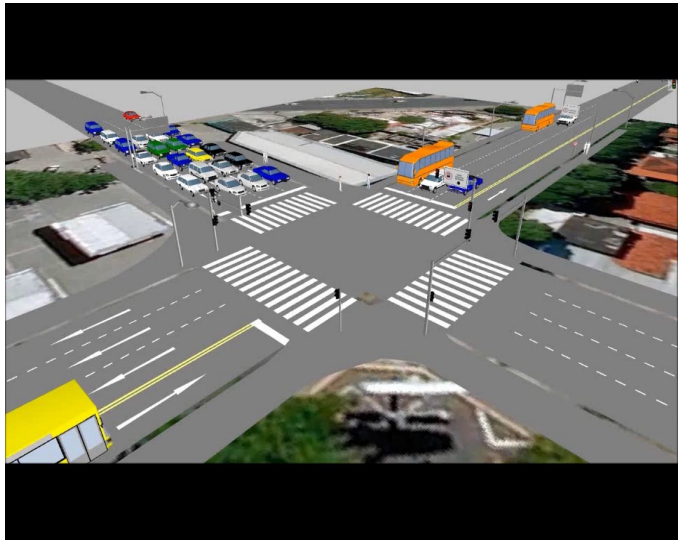


- **Reference tag**: RSS1 ∝ Environment
- **Modified tag**: RSS2 ∝ Light + Environment
- **Differential: (RSS2 – RSS1) ∝ Light**

An E-Toll Transponder Network for Smart Cities

Smart City Services

Traffic Management

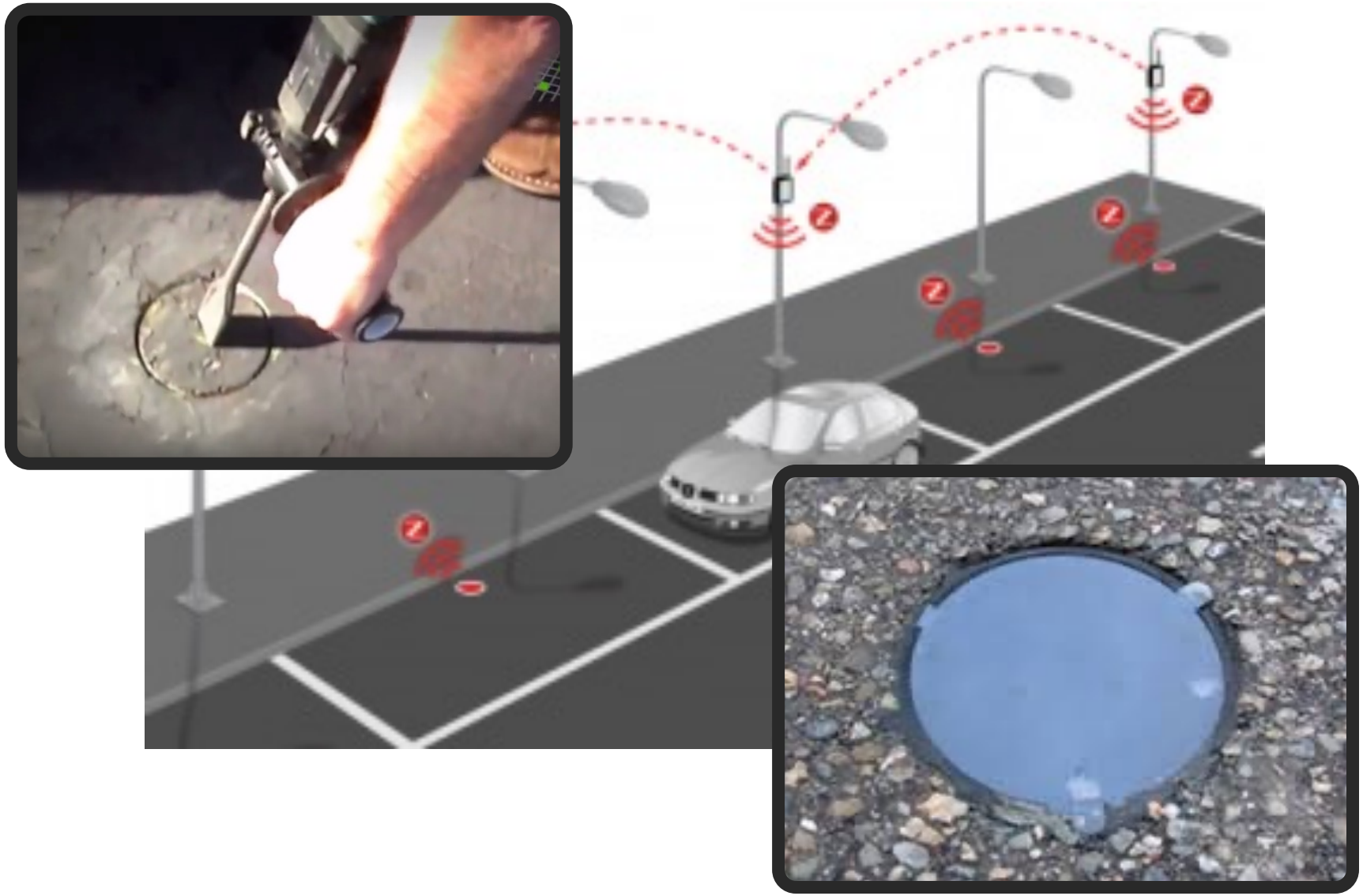


Detect Red-Light Runner

Smart Parking

Key Problem: each service needs a new infrastructure

Smart Parking



Traffic Management

Ideally...

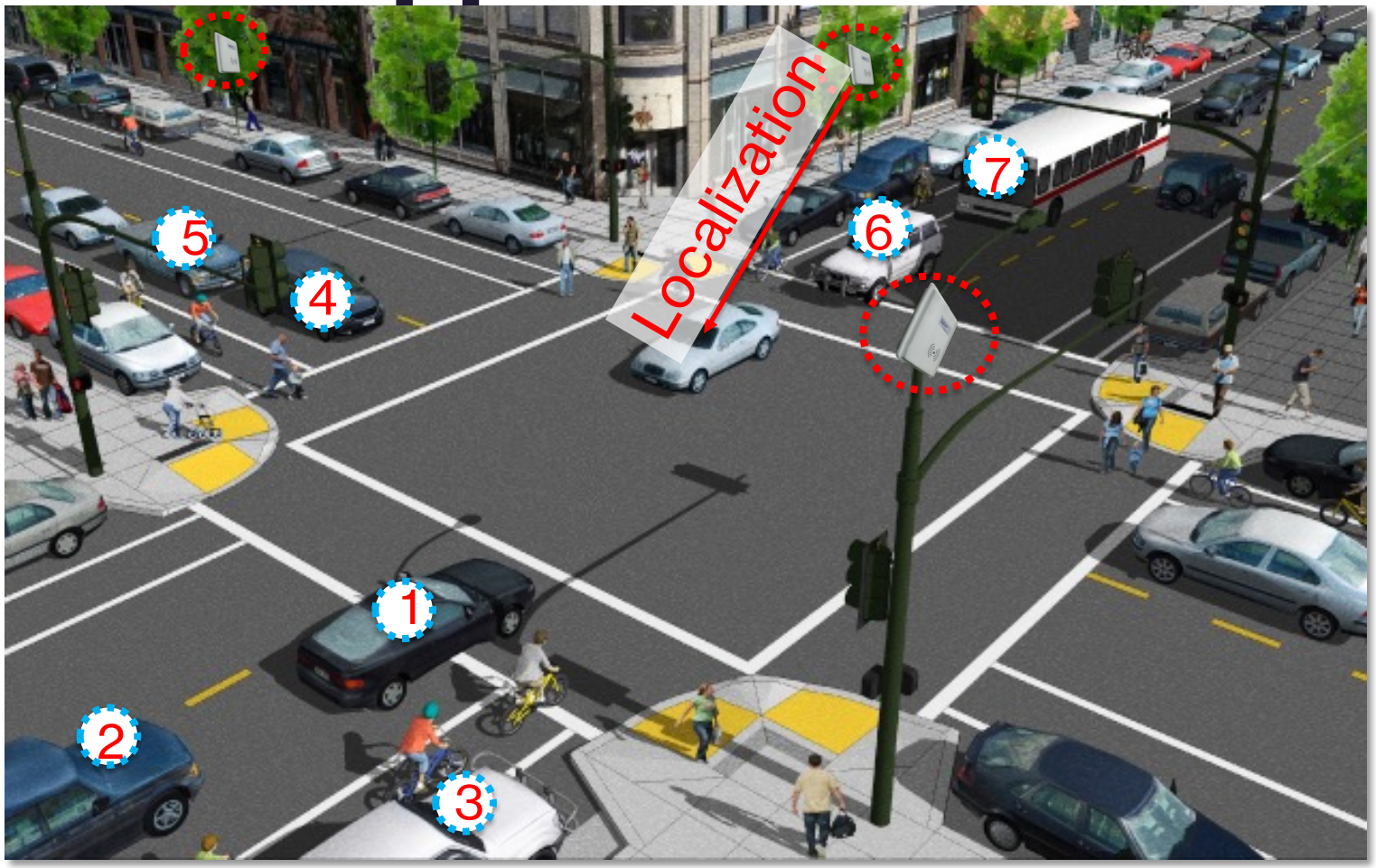
1) ONE Infrastructure

2) Ease of Maintenance

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

Electronic Toll Transponders

Opportunities



One infrastructure for many smart services

Challenge: Interference

Wireless query

One car responds

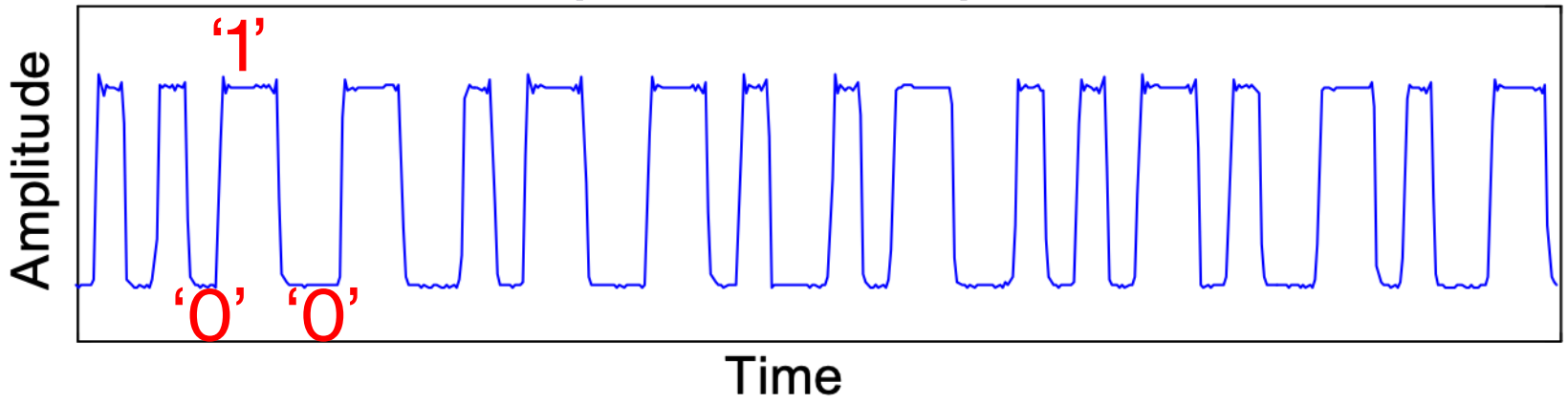
Wireless query

All cars respond

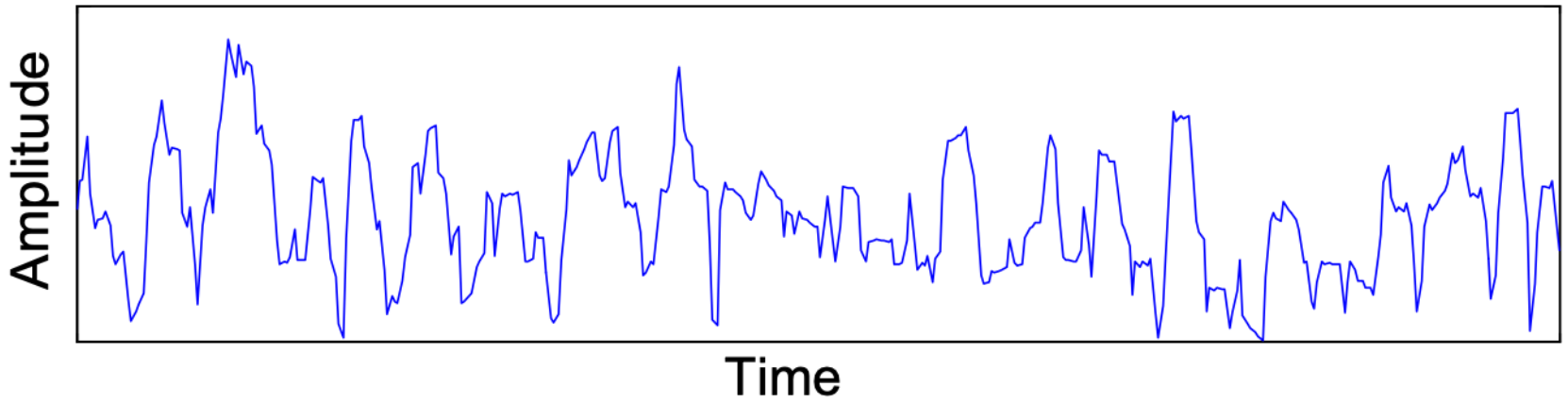
How can we decode transponders
despite Interference?

How can we decode transponders despite Interference?

One Transponder Responds → Decodable



Multiple Transponders Respond

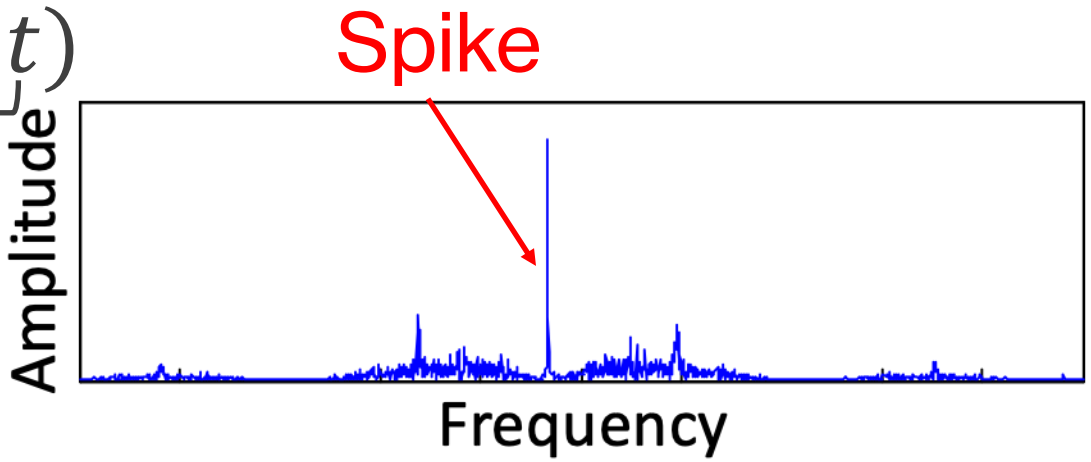


Count cars: How to count despite interference?

Structure of the Signal

Time-Domain

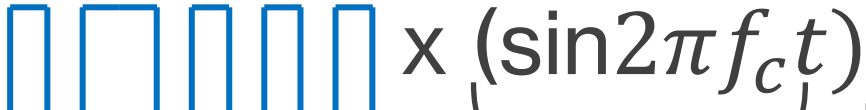
Freq-Domain



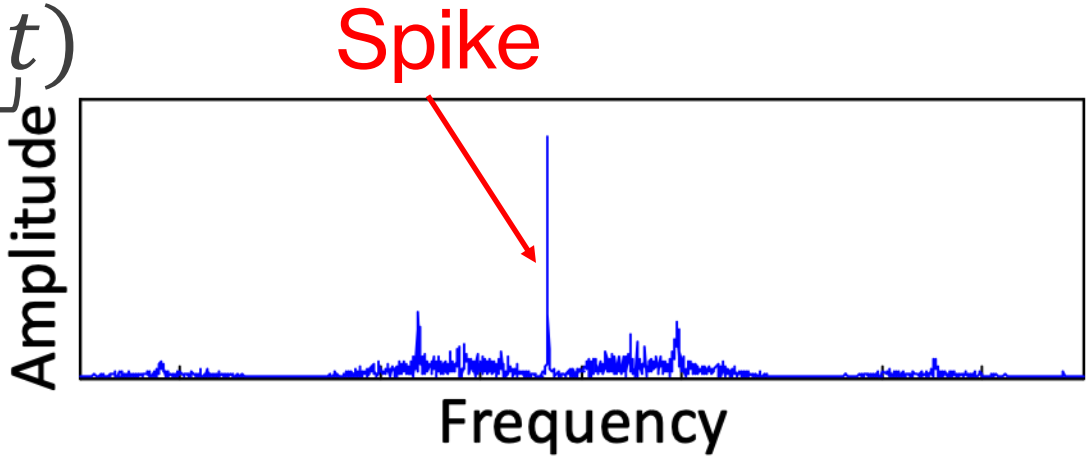
Variability due to manufacturing process

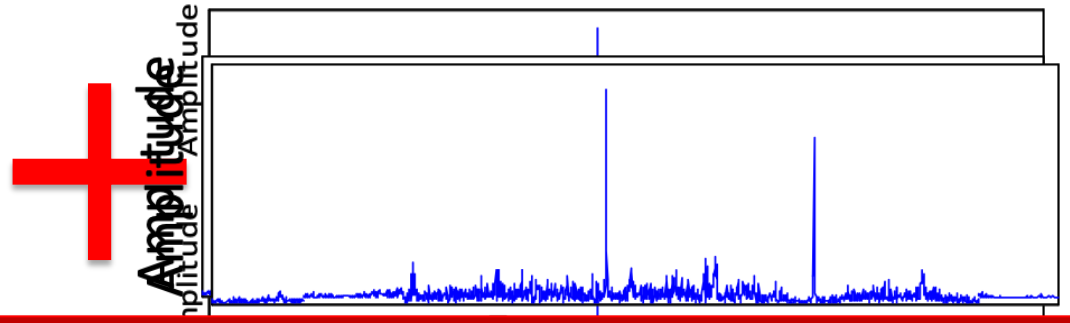
Structure of the Signal

Time-Domain



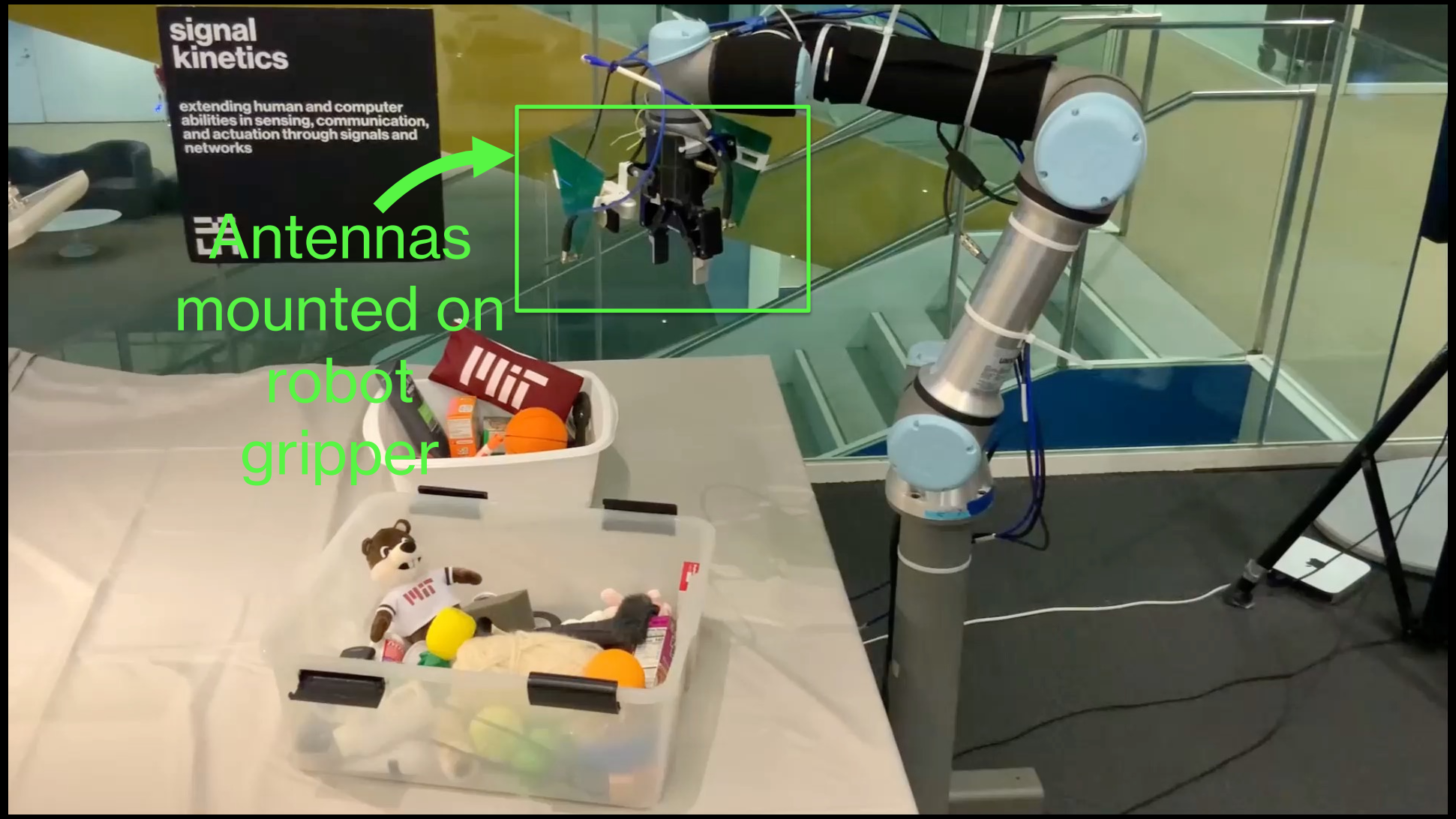
Freq-Domain

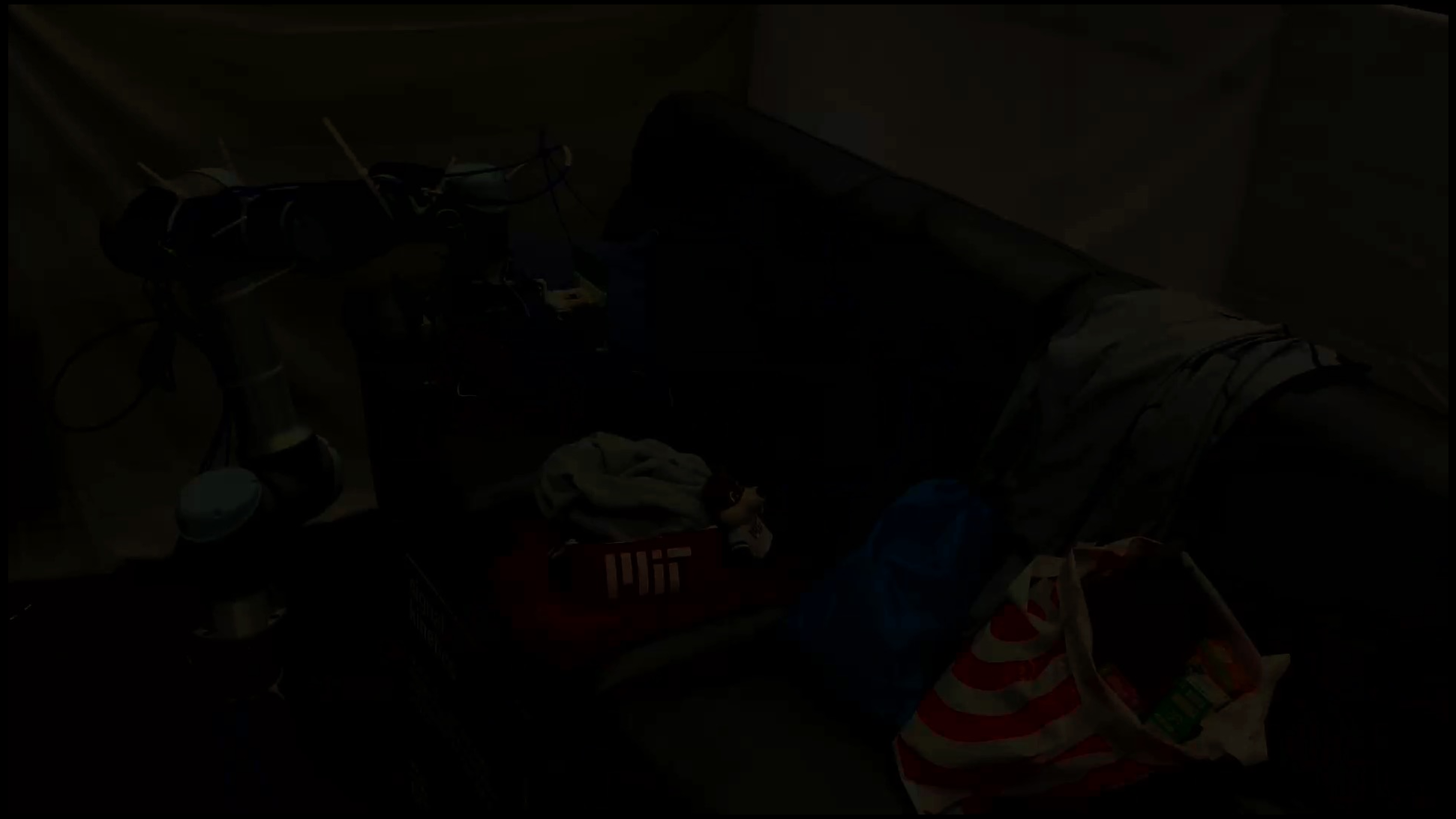




Can count despite interference

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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Learn the fundamentals, applications, and implications of Network technologies for Mobile and IoT Systems

1. What are the various classes of network technologies?
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Module 3 review due: Mar 25th 11:59PM