MAS.S61: Emerging Wireless & Mobile Technologies aka The “Extreme IoT” Class

Lecturers

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Reza Ghaffarivardavagh (rezagh@mit.edu)

Website

http://www.mit.edu/~fadel/courses/MAS.S61/index.html

Sign up on Piazza for announcements

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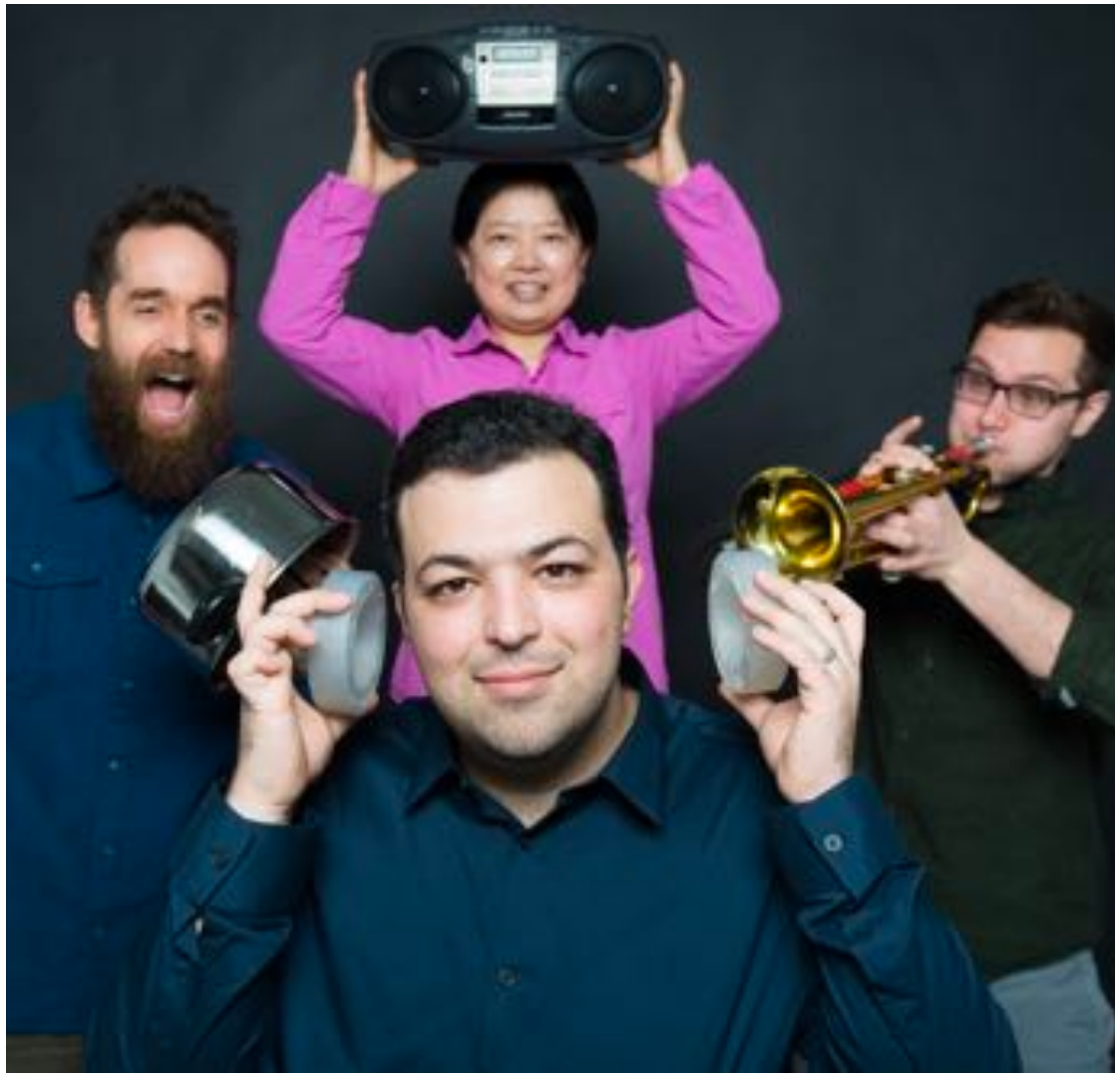
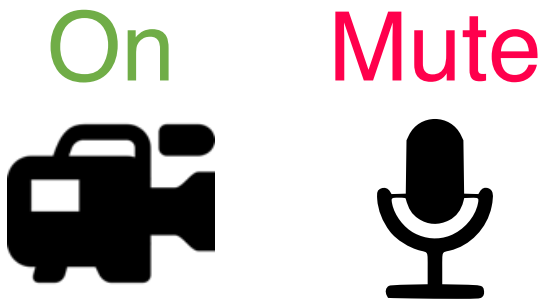


Logistics & Norm Settings

- What to do now?
  1. Turn on your video (if your connection allows it)
  2. Mute your mic (unless you are the active speaker)
  3. Open the “Participant” List
     - Make sure your full name is shown



- If you have a question:
  - Use the chat feature to either write the question or to indicate your interest in asking the question
  - We will be monitoring the chat
  - Unmute -> ask question -> mute again
  - Once done asking/answering, please state “Done” to clearly mark it (helps translation/moderation)
  - Same procedure for answering questions

- This lecture will be recorded. It will only be accessible to people in the class

9:50

General Software Upda

iOS 13.7

Apple Inc.

Downlo

iOS 13.7 lets you

TC

England's long-delayed COVID-19 contacts-tra app to launch on September 24

The Intercept_

THE INVENTORS OF BLUETOOTH SAY

WIRED BACKCHANNEL BUSINESS CULTURE GEAR IDEAS SCIENCE MORE SIGN IN SUBSCRIBE

GREGORY BARBER WILL KNIGHT BUSINESS 09.08.2020 07:00 AM

Why Contact-Tracing Apps Haven't Slowed Covid-19 in the US

Lack of coordination, test shortages, and mistrust of technology have hobbled what looked like a promising innovation.

The New York Times

I Live in California. How Do I Know It's Safe to Go Outside?

A high-tech sensor network brought me closer to the natural cycles of my environment.

By Annalee Newitz
Contributing Opinion Writer

CNBC MARKETS BUSINESS INVESTING TECH POLITICS CNBC TV

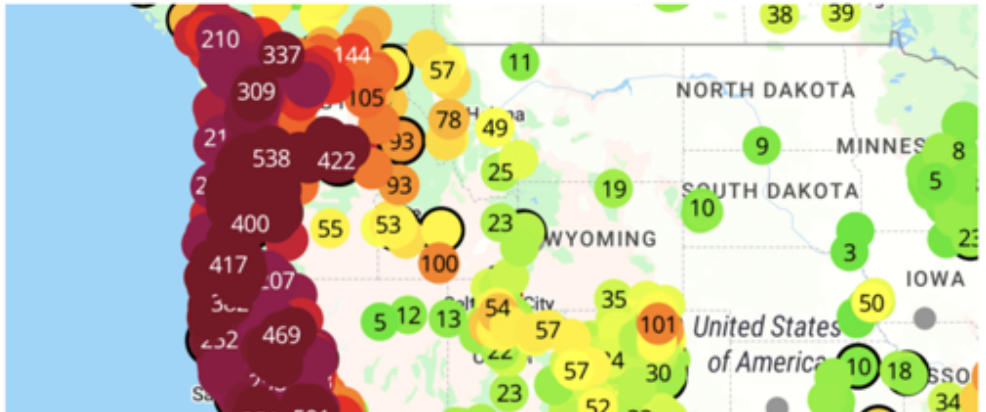
TECH

The West Coast is suffering from some of the worst air in the world — these apps show how bad it is

PUBLISHED SAT, SEP 12 2020·10:55 AM EDT | UPDATED SUN, SEP 13 2020·2:02 PM EDT

Lora Kolodny
@LORAKOLODNY

SHARE



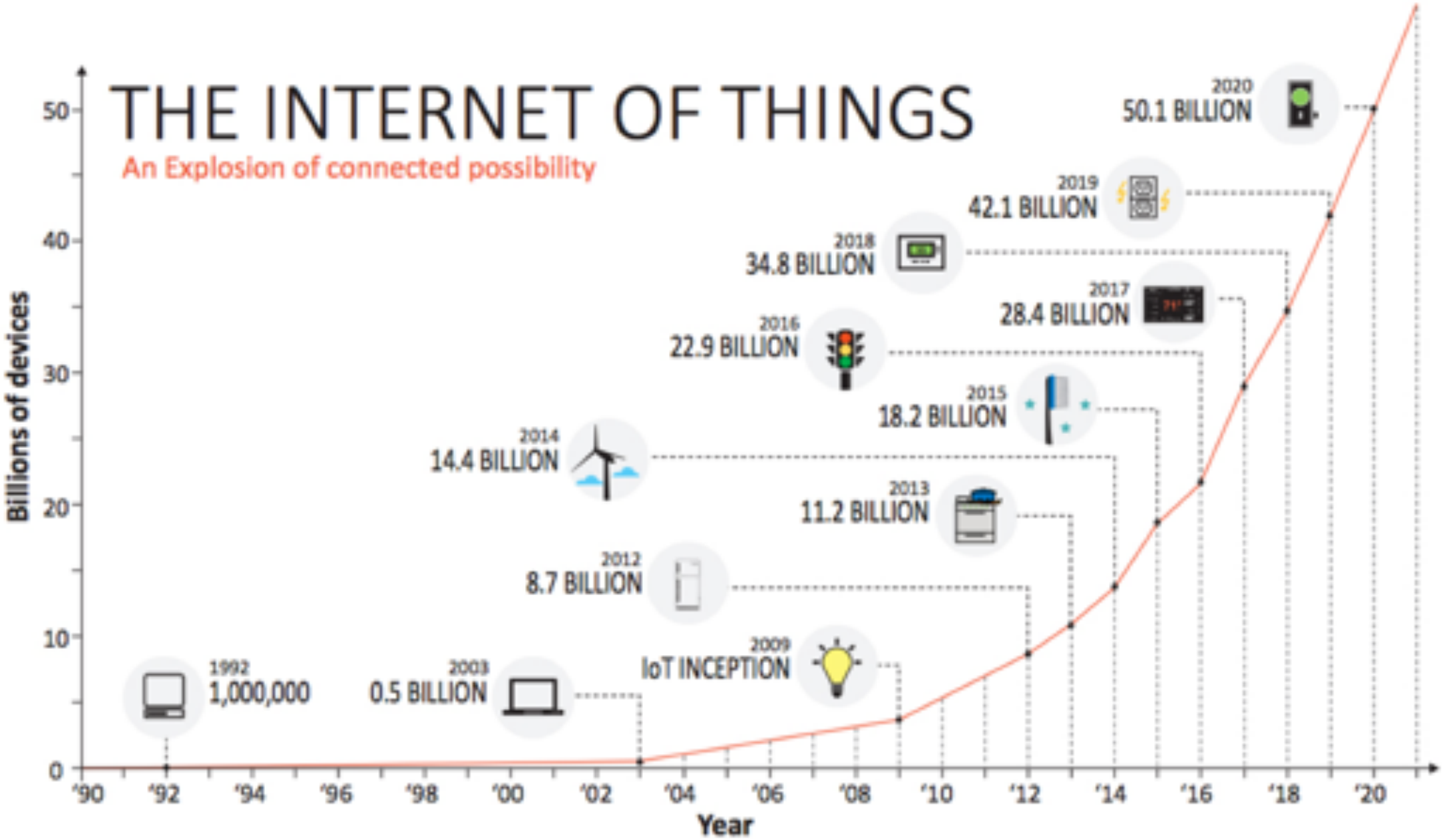
Internet-of-Things

Convergence of micro-sensing, computation, and communication that allows us to:

- *Acquire* (*sense*) data from the environment
- *Pre-process* data locally
- *Deliver* data to servers
- *Draw inferences* and *provide insights* about the world from the data using computational techniques
  - Sensor fusion, data integration
  - Signal processing
  - Machine learning
- *Control* actions in the environment

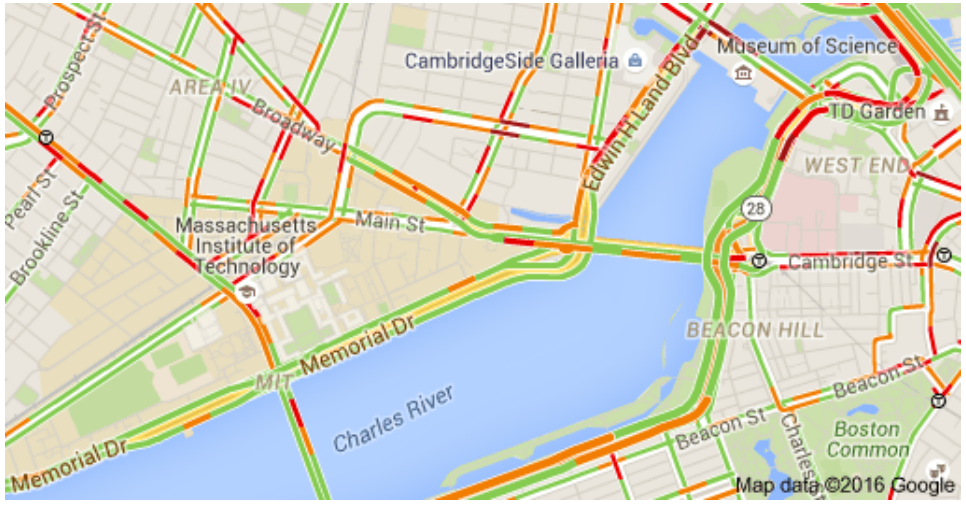
Example: GPS

Focus of class: Foundational knowledge + emerging technologies (wireless+mobile)


THE INTERNET OF THINGS
An Explosion of connected possibility
Billions of devices
Year
0
10
20
30
40
50
'90
'92
'94
'96
'98
'00
'02
'04
'06
'08
'10
'12
'14
'16
'18
'20
1992
1,000,000
2003
0.5 BILLION
2009
IoT INCEPTION
2012
8.7 BILLION
2013
11.2 BILLION
2014
14.4 BILLION
2015
18.2 BILLION
2016
22.9 BILLION
2017
28.4 BILLION
2018
34.8 BILLION
2019
42.1 BILLION
2020
50.1 BILLION

IoT is Transforming Industries

Transportation & Smart Cities



Medicine

Smart Homes

Health & Wellness

Connected vehicles

Precision Agriculture

Main Components of IoT Systems

Axis #1:
Power/Energy

Axis #3:
High-level Task
(Sensing, Actuation)

Axis #2:
Connectivity

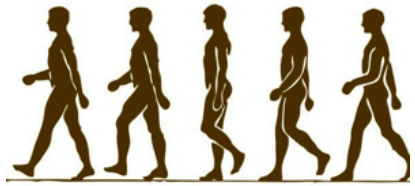
Axis #3: High-Level Task (Sensing, Actuation)

WHAT?

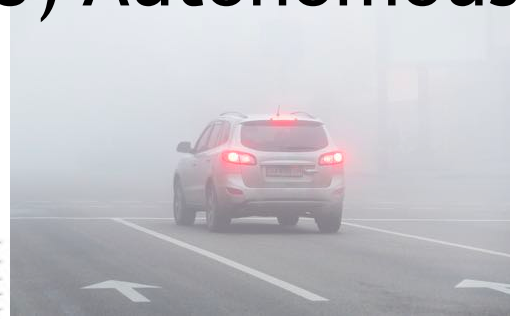
(1) Locations

(2) Health

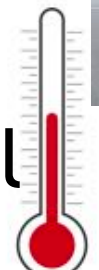
(3) Activity



(5) Autonomous



(4) Environmental

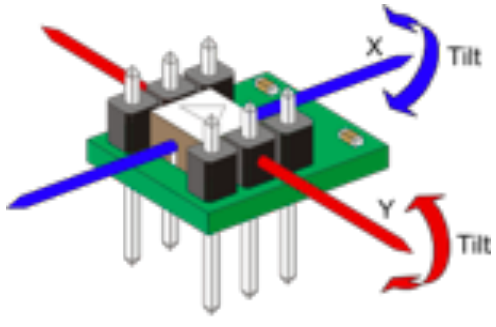


HOW?

(1) Radio

(2) Acoustic/ Ultrasonic

(3) Inertial



(4) Visual

Axis #2: Computation & Connectivity

HOW do we obtain and process information?

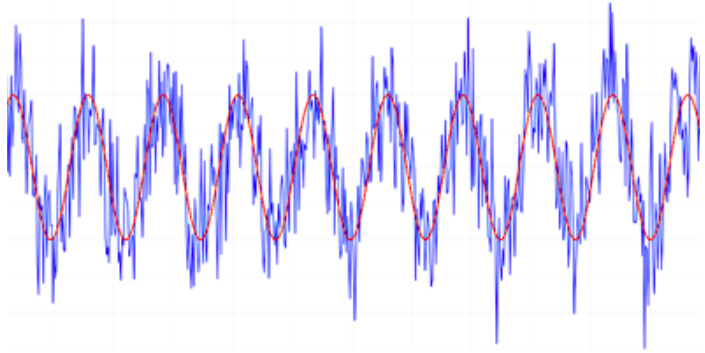
(1) Networking

- Connectivity
- Communication

(2) Data Management

- Storage
- Queries

(3) Signal Processing & Inference



- Digitization
- Inference & Machine Learning

(4) Security

- Digital, Analog
- Trust, Privacy

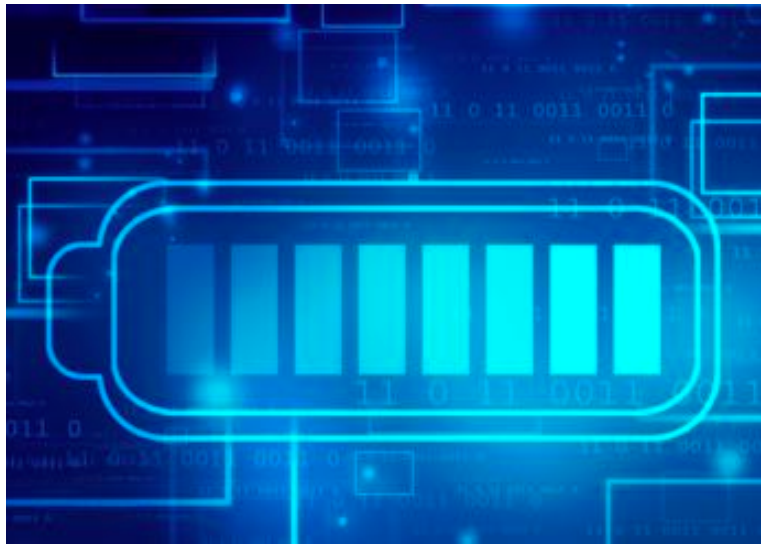
Axis #1: Power/Energy

HOW will we power up the nodes?

(1) Infrastructure

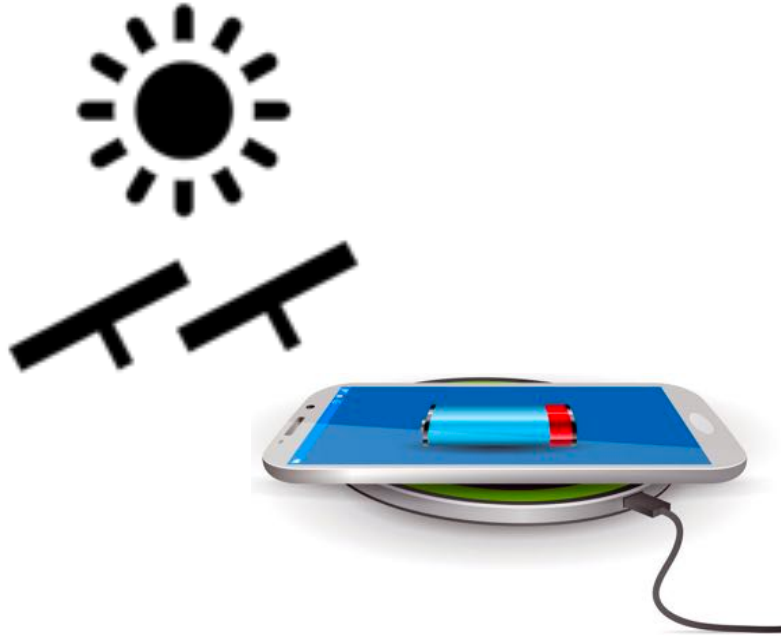
- Electricity, Network

(2) Battery



- Rechargeable/Non

(3) Energy Harvesting



- Ambient, Wireless power
- Solar, Waves, Human Activity, RF

IoT System Architecture

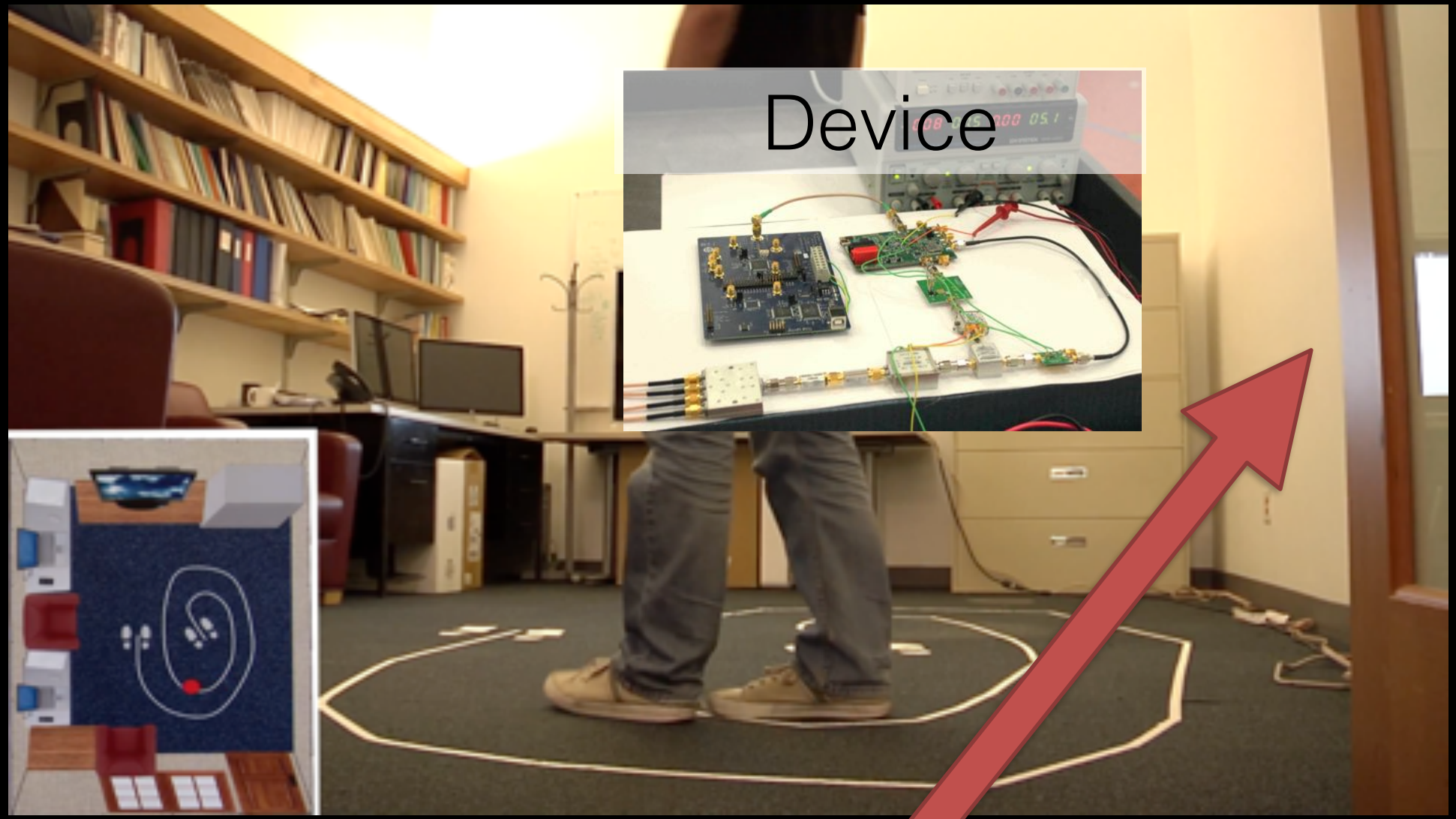
Axis #3: High-Level Tasks	**What**		**How**	
	Location, Dynamics, Properties		Radio, Sound, Inertial, Visual	
Axis #3: Computation & Connectivity	(1) Networking	(2) Data Management	(3) Signal Processing & Inference	(4) Security
Axis #1: Power/ Energy	(1) Infrastructure	(2) Battery	(3) Energy Harvesting	

Emerging Sensing Technologies

Indoor Positioning (Cricket, 2001)

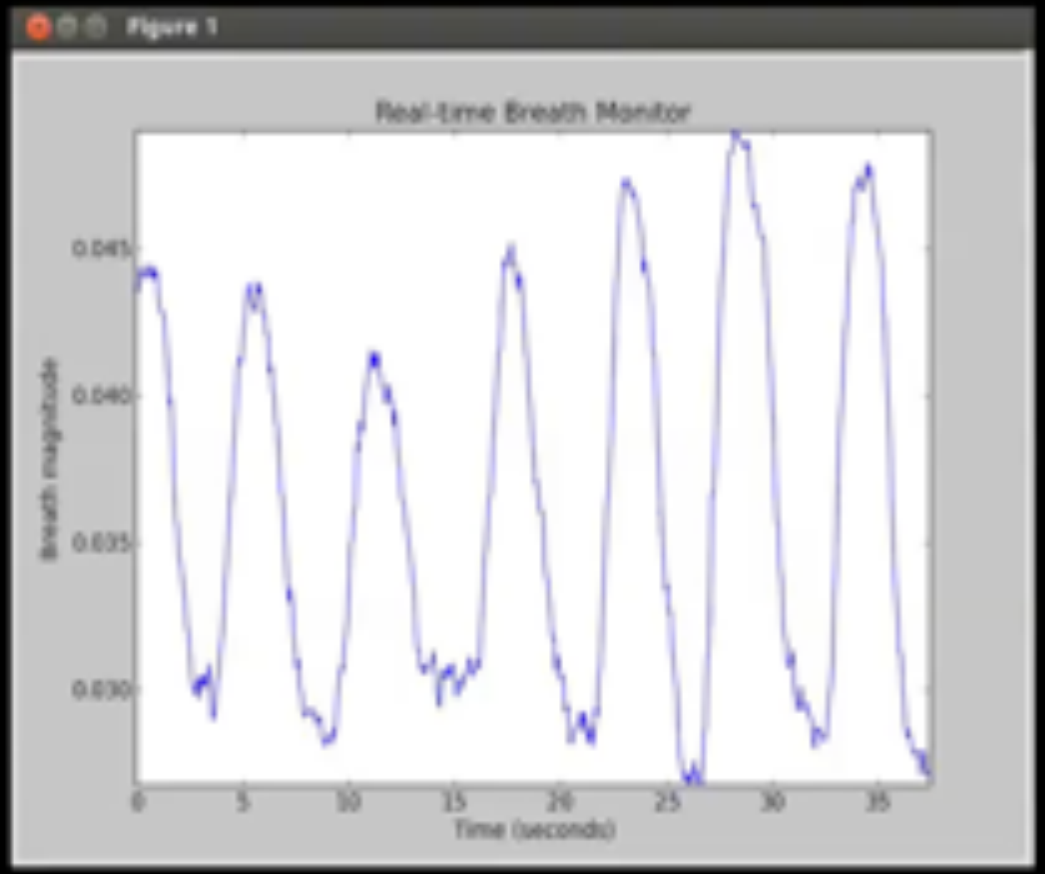
Accurate Localization (Cricket, 2003)

Device-Free Localization (WiTrack, 2014)

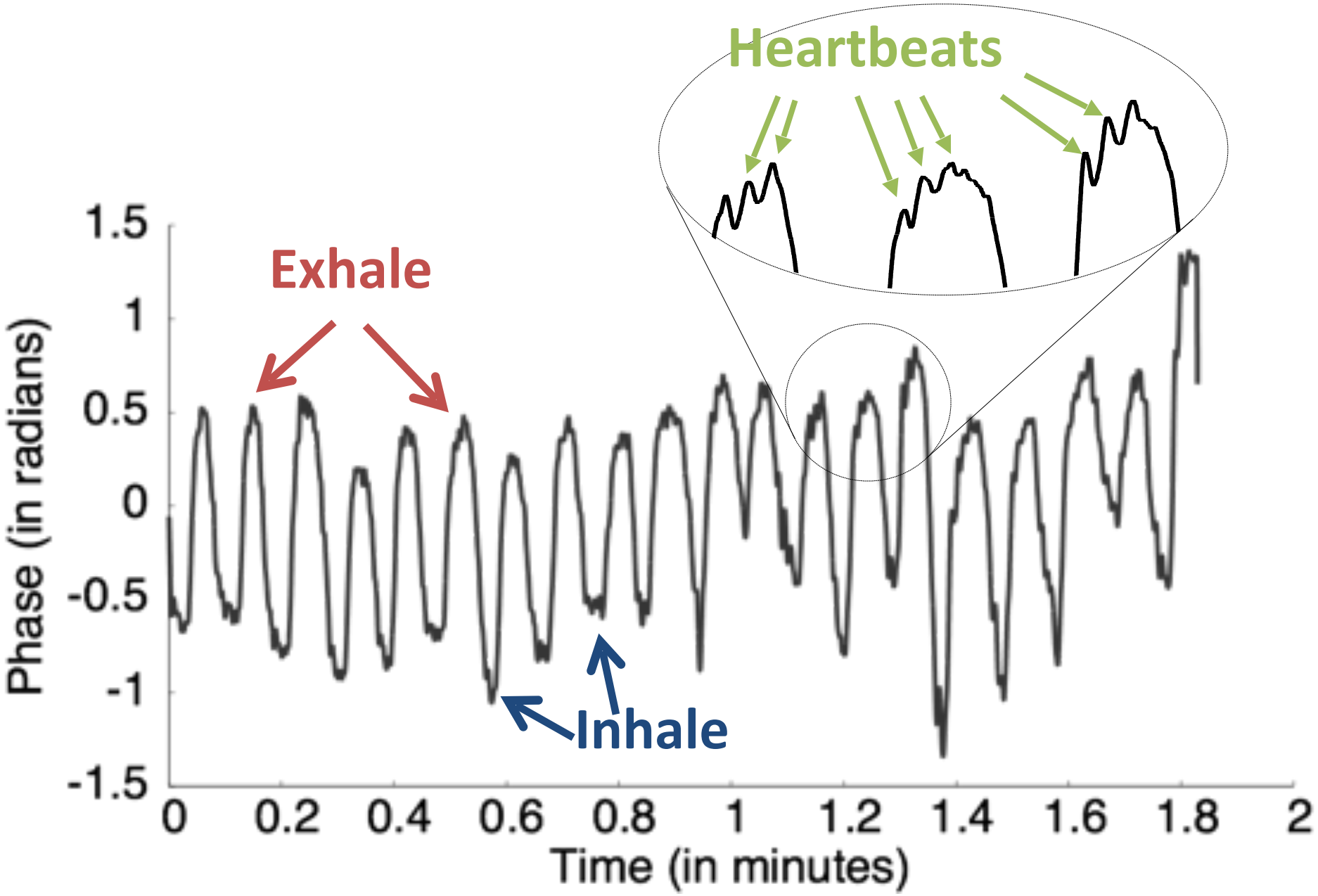


Seeing Through Walls (RF-Capture, 2015)

Breath Monitoring using Wireless (Vital-Radio, 2015)



Let’s zoom in on these signals


Heartbeats
Exhale
Inhale
Phase (in radians)
1.5
1
0.5
0
-0.5
-1
-1.5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (in minutes)

Baby Monitoring

BroadbandCommunities
BUILDING A FIBER-CONNECTED WORLD MAGAZINE

Wi-Fi Becomes Sound Backbone for Motion Sensing and Smart-Home Monitoring

Share

November/December 2019 •

By Oleksiy Kravets | Cognitive Systems

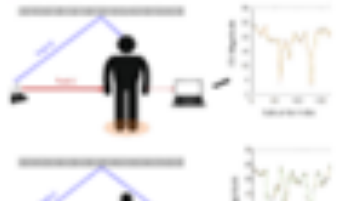
Service providers should look to thei emerging motion-sensing and smart

Network World

Cisco moves WiFi roaming technology to wireless broadband consortium

Synced

Samsung AI Uses WiFi Signals to Generate Consistent In-Home User Localization Data



Gizmodo

Motion Sensing Wifi Is a Limited But Fascinating Peek at the Future of the Smart Home

Non-contact Respiration Monitoring

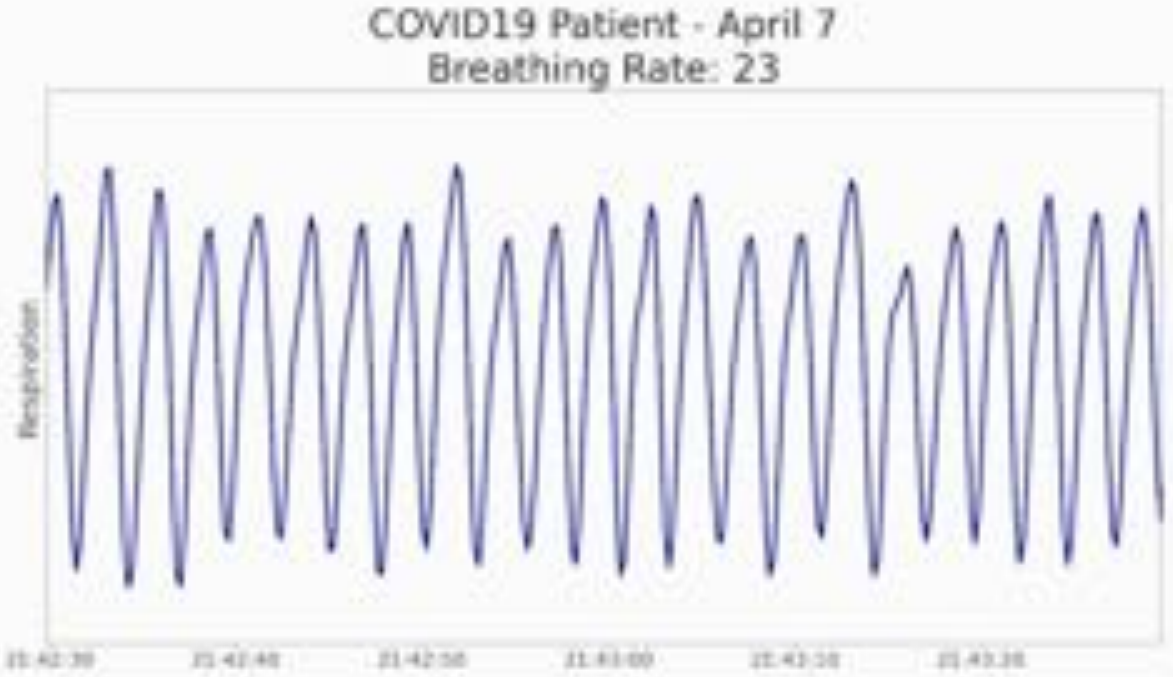
EMERALD

HERITAGE AT FRAMINGHAM

McLean HARVARD MEDICAL SCHOOL AFFILIATE

- Technology has been used in monitoring a COVID-19 Patient
- Deployed in ***Heritage Assisted Living*** in Boston suburb
- Medical doctors from Harvard Medical School analyzed remotely

Monitoring COVID-19 Patient



The patient's breathing decreased as it went back to normal

The patient's movements also demonstrate a marked improvement.

Through Fog High Resolution Imaging Using Millimeter Wave Radar

Junfeng Guan, Sohrab Madani, Suraj Jog,
Saurabh Gupta, Haitham Hassanieh
University of Illinois at Urbana-Champaign

Emerging Networking Technologies

ars TECHNICA

5GEE WHIZ —

5G in rural areas bridges a gap that 4G doesn't, especially low- and mid-band

The mmWave revolution isn't here yet, but the other parts of 5G are more important.

JIM SALTER - 9/14/2020, 9:00 AM

Aurich Lawson / Getty Images

Enlarge / This might be the best listing image Aurich has ever created. The duck just kills me. Look

The Telegraph port Business Money Opinion Tech Life Style Travel Culture

Gadgets Innovation Big tech Start-ups Politics of tech Gaming

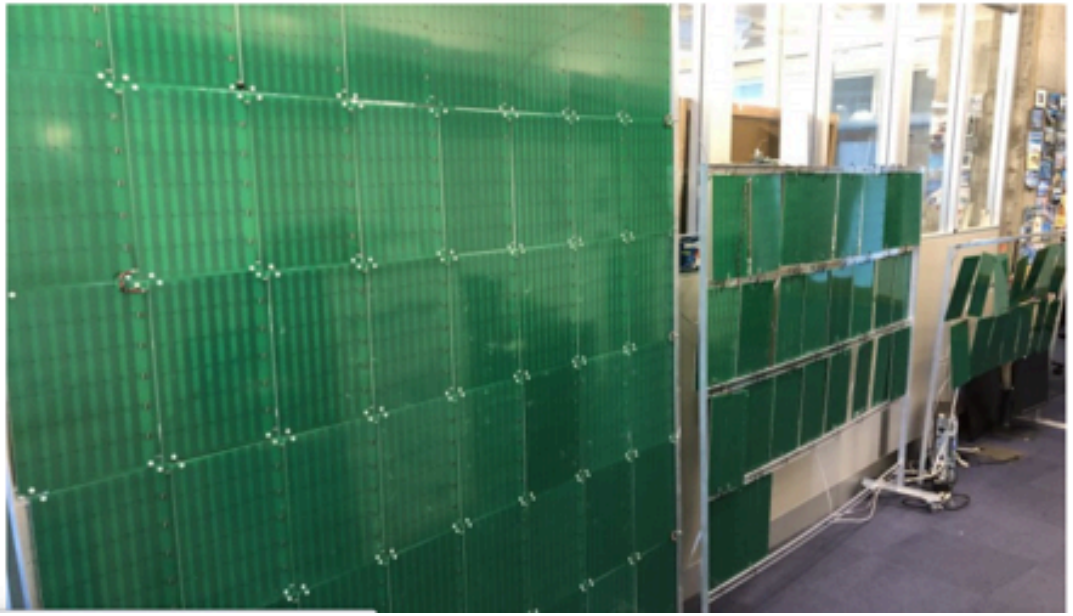
The 'smart wallpaper' that can boost Wi-Fi signals tenfold

The wallpaper, designed by engineers at the Massachusetts Institute of Technology, could solve the problem of "not-spots" in the home

By Matthew Field

3 February 2020 • 2:40pm

14

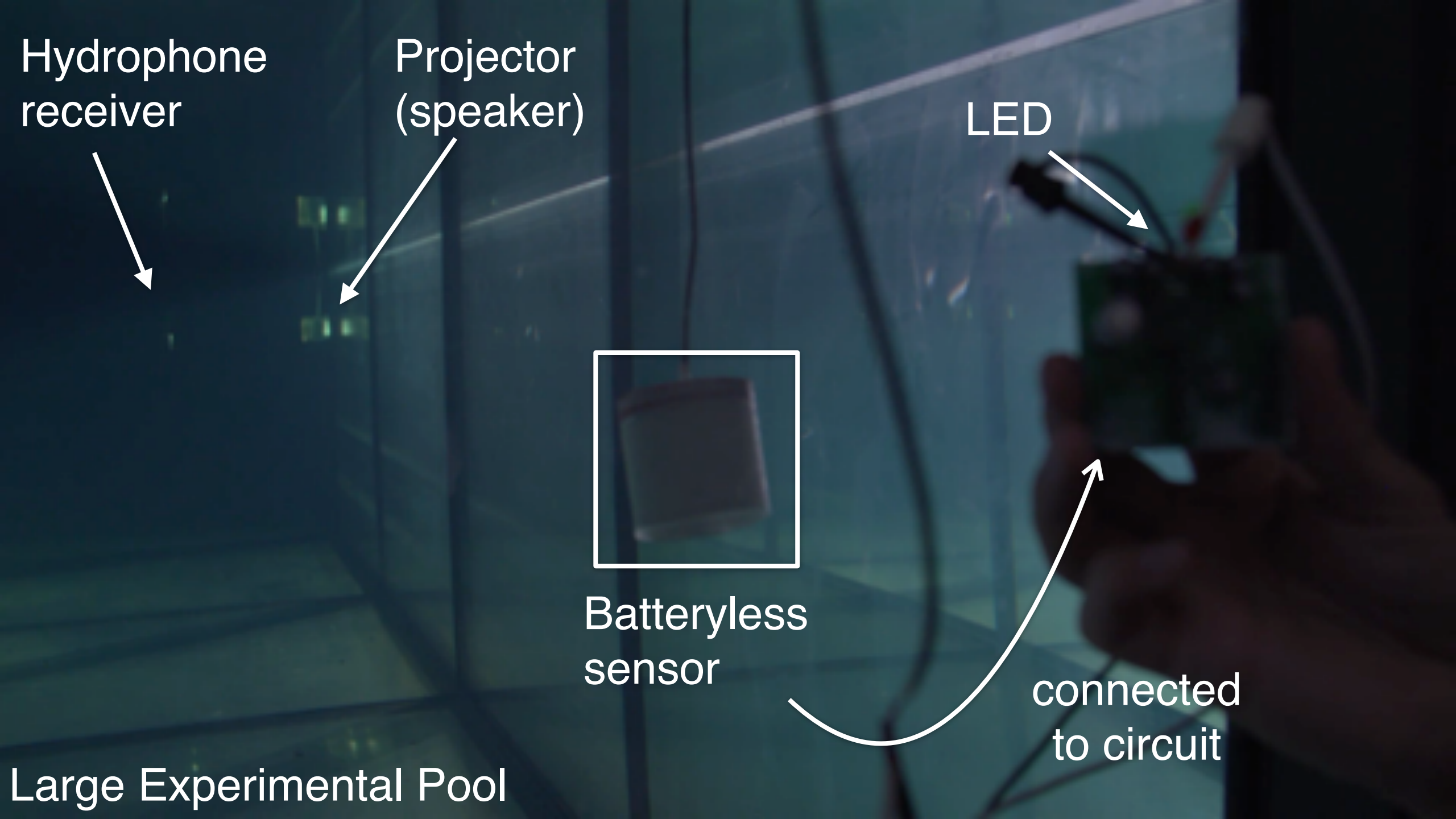


Continuous & Long-Term Drug Delivery

In-body Sensing
and Diagnosis

Subsea IoT

Case Study: Batteryless Sensor for the Ocean


Hydrophone receiver
Projector (speaker)
LED
Batteryless sensor
connected to circuit
Large Experimental Pool

IoT Security

WIRED BACKCHANNEL BUSINESS CULTURE GEAR IDEAS SCIENCE MORE SIGN IN SUBSCRIBE

An Alexa Bug Could Have Exposed Your Voice History to Hackers

Amazon has patched the flaw, but its discovery underscores the importa
your voice assistant interactions.

BBC Sign in Home News Sport Reel Worklife Travel Future C

NEWS

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Tech

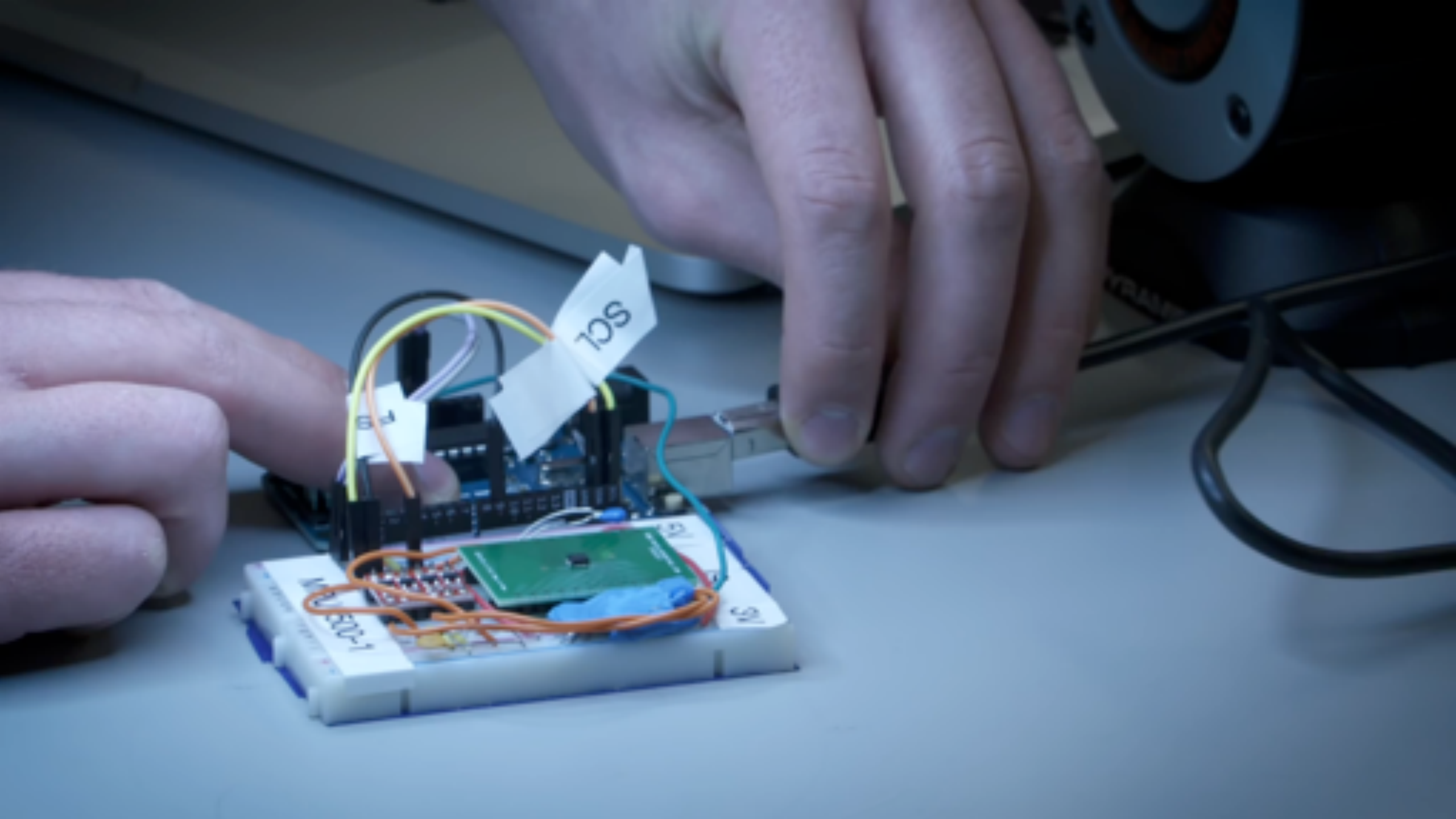
'Smart' home devices used as weapons in website attack

22 October 2016

ComputerWeekly.com IT Management Industry Sectors Technology Topics Search Computer Weekly

100,000 cheap wireless cameras vulnerable to hacking

TITANIUM BULLET TWEETER
PYRAMID


SCL

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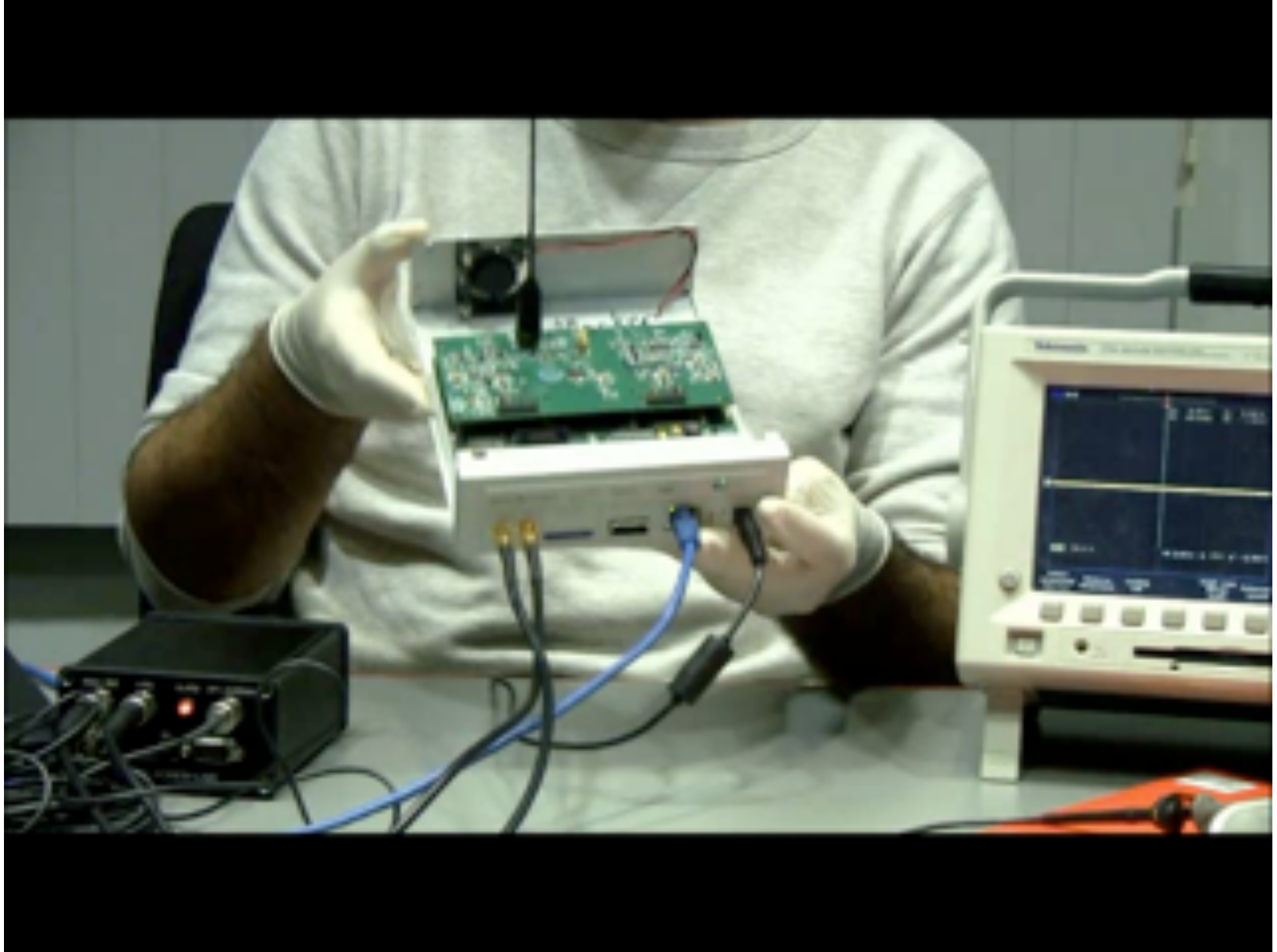
TOKYO

CSE
COMPUTER SCIENCE
AND ENGINEERING
UNIVERSITY OF MICHIGAN

LIGHT COMMANDS

Drone Security
Spoofing GPS Signals

Pacemaker Security
Wireless Control of Pacemaker



Class Format

- **Building the Foundations**
  - Sensing: Localization, Contactless
  - Connectivity: BLE & Communications
  - Power: Energy Harvesting and Backscatter

- **Seminar Series**
  - Acoustic Tracking and its Applications
  - Smart Surfaces for Wireless Networks
  - IoT Security
  - mmWaves: 5G and Self-Driving Cars
  - Underwater Light Communications
  - Mobile Health
  - LoRa City-Scale Wireless Networks

MIT IoT Seminar Series

Prof. Lili Qiu
UT Austin
Acoustic Tracking

Prof. Kyle Jamieson
Princeton University
Smart Wireless Surfaces

Prof. Kevin Fu
University of Michigan
IoT Security

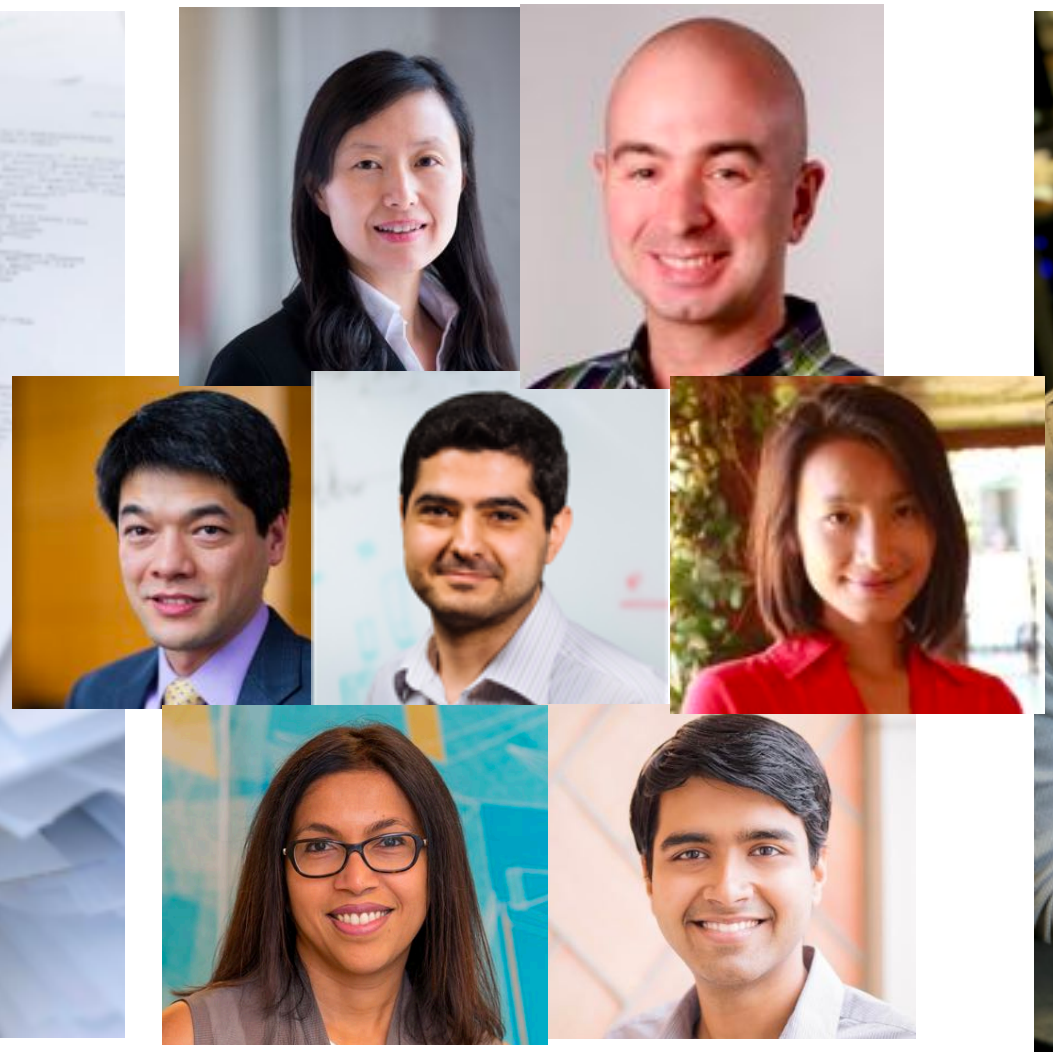
Prof. Haitham Hassanieh
University of Illinoios
mmWaves: 5G & Self-driving

Prof. Xia Zhou
Dartmouth
Underwater Light Comms

Prof. Tanzeem Choudhury
Cornell University & HealthRythms
Mobile Health

Prof. Swarun Kumar
Carnegie Mellon University
LoRa City-Scale Networks

Course Organization



Reading & Reviewing Papers

Seminar Series + Discussions to Unpacking Tech & Societal Implications

Class Project

Logistics

Grading:

- 1 Course Project (70%)
  - Proposal (10%); Progress Report 1 (10%); Progress Report 2 (10%); Presentation (20%); Final Report (20%)
- Reading Questions & Participation (30%)
  - Includes submitting reviews before every lecture (15%)
  - Participation via Attendance+Interaction (15%)
  - May skip one review without affecting grade

Website: http://www.mit.edu/~fadel/courses/MAS.S61/

Piazza: https://piazza.com/class/kec1m9mhrjy61k

- Ask questions about lectures, labs, etc.

Fadel & Reza office hours will be posted soon (appointment for now)

Readings

We will read 1-3 papers/references per class:

- Everyone is expected to read the papers in advance
- Submit a short review of the required readings by midnight the night before the class
- Say something that is not in the paper

Submit Reviews here:

- http://www.mit.edu/~fadel/courses/MAS.S61/reviews.html

Projects

- All projects involve system implementation
- Work in groups of two (ideally)
- Will suggest project ideas; students can choose their own projects
- Can be (very) related to your research (come talk to me)

Timeline:

- Proposal (1-2 pages): October 7
- Progress Report 1: October 28
- Progress Report 2: November 18
- Final Presentation: December 7
- Final Report (6-8 pages): December 9

We will discuss project updates in class as time permits

Introductions

- Name
- Position (undergrad year, grad year, postdoc, industry)
- Major
- Why are you interested in this class?
- Where are you?

How to Read a Paper

First Pass:

- Title, Abstract
- Figures (illustrations? important results?)
- skim intro & conclusions
- References

Second Pass

- Intro in details
- Overview, related work, or background sections
- Figures in details

Third pass:

- Read in detail
- Mark references for future read

How to Review a System Paper

How to think when reviewing a paper?

How to Review a System Paper

How to think when reviewing a paper?

1) Motivation
Is this an important problem?

- New problem? → Worthwhile or artificial?
- Existing problem? (i.e., have others worked on it) → Does it improve over prior work?

2) Related Work

- Does it really outperform prior work?
- Does it accurately represent prior work?
- Do you know past work? If not, search Google Scholar to get a sense of past work

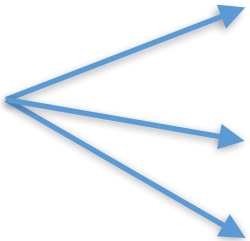
3) Techniques

- Are they novel? intellectually interesting?
- Are they technically sound? Is there a key technical flaw?

How to Review a System Paper

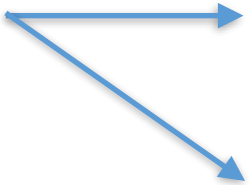
How to think when reviewing a paper?

4) Implementation



- Significant effort?
- Matches the motivation?
- Simulation or real-world prototype?

5) Evaluation



- Comprehensive? Convincing?
- Does the system deliver what it promises?

How to Review a System Paper

How to think when reviewing a paper?

1) Motivation

2) Related Work

3) Techniques

4) Implementation

5) Evaluation

How to Review a System Paper

How to write a review?

1) Summary

2) Strengths & Weaknesses

3) Comments to authors

How to Review a System Paper

How to write a review?

1) Summary

- 5-10 sentences
- If someone hasn't read the paper at all, they should understand what it's about
- Should sound like a "brutally honest and straightforward abstract"

Rough structure:

This paper presents XXX, a system that does YYY. **The goal is to** XXX. The **main challenge** the authors try to address is YYY.

The key idea is to do XXX. The authors do this by introducing/proposing ZZZ

The authors implement (or simulate) their system and **demonstrated** (results) that it outperforms the baseline?

How to Review a System Paper

How to write a review?

1) Summary

- 5-10 sentences
- If someone hasn't read the paper at all, they should understand what it's about
- Should sound like a "brutally honest and straightforward abstracT"

2) Strengths & Weaknesses

- Use your answers to the questions of "How to think when reviewing"
- List 2-4 pros/cons
- Each should be a direct statement about the paper

<u>Rough structure:</u>

Pros:
+ Statement 1
+ Statement 2

Cons:
-
-
-

How to Review a System Paper

How to write a review?

1) Summary

2) Strengths & Weaknesses

3) Comments to authors

- Detailed comments to authors
- Elaborate on your pros/cons, areas for improvement, key concerns
- Ask questions about techniques, figures, results, etc.
- Based on the 5 points from how to think as well as technical details

Examples:

- If you listed a weaknesses small delta over prior work, specify in details why with references
- If experimental details are missing, state exactly what is missing and why it is problematic
- Include typos/grammar mistakes, potential suggestions to correct

How to Review a System Paper

How to write a review?

1) Summary

2) Strengths & Weaknesses

3) Comm… to authors

- Detailed c… …c…
- Elabor… …r pro…
- …s about t…
- …the 5 points…

Examples:

- If you liste… …mall delta o…
- If exper… …ng, state…
- Inclu… …amma… …, potent…

For the sake of this class, we will drop "comments to authors".

Instead, you should add a paragraph on "suggestions for improvement".

- If you could improve this paper, how would you do it?
- How do you envision your proposed technique will improve the work

How to Review a System Paper

How to write a review? (for this class)

1) Summary

2) Strengths & Weaknesses

3) Suggestions for Improvement

Next Class (Localization & Sensing)

1) Required Readings

- **Chapter on Localization -** Covers fundamentals
- **Wireless Sensing** - Sensing from reflections; seeing through walls; deployed

2) Optional Readings

- **Cricket -** More than 100,000 deployed (hospitals); Cited > 5,000 times
- **Radar paper** - Transitioned to real-world products (Microsoft, many startups); Started a new field; Cited > 10,000 times
- **GPS** - how it works