Welcome!

6.1820/MAS.453: Mobile and Sensor Computing

aka IoT Systems

https://6mobile.github.io/

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IoT in the News

techradar pro THE BUSINESS TECHNOLOGY EXPERTS US Edition

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Pro

Say hello to HaLow: Wi-Fi routers that can send 250Mbps across 10 miles (yes, 10 miles) have been demoed at CES 2025 and I'm very excited

News By Efosa Udinmwen published January 11, 2025

From 18Mbps to 250Mbps, HaLow routers have significantly improved since 2016

STATESCOOP

EMERGING TECH

AI cameras, sensors, and sometimes drones aiding fight against L.A. wildfires

New technologies are aiding the battle against the blazes in Southern California, but high winds limit the use of drones, said one fire official.

BY SOPHIA FOX-SOWELL - JANUARY 14, 2025

What do you think about when you hear IoT?

Internet of Things

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

- *Acquire* (*sense*) data from the environment
- *Pre-process* data locally (on-device / “edge”)
- *Deliver* data to servers (“cloud”)
- *Draw inferences* and *provide insights* about the world from the data:
  - Sensor fusion, data integration
  - Signal processing
  - Machine learning
- *Control* actions in the environment

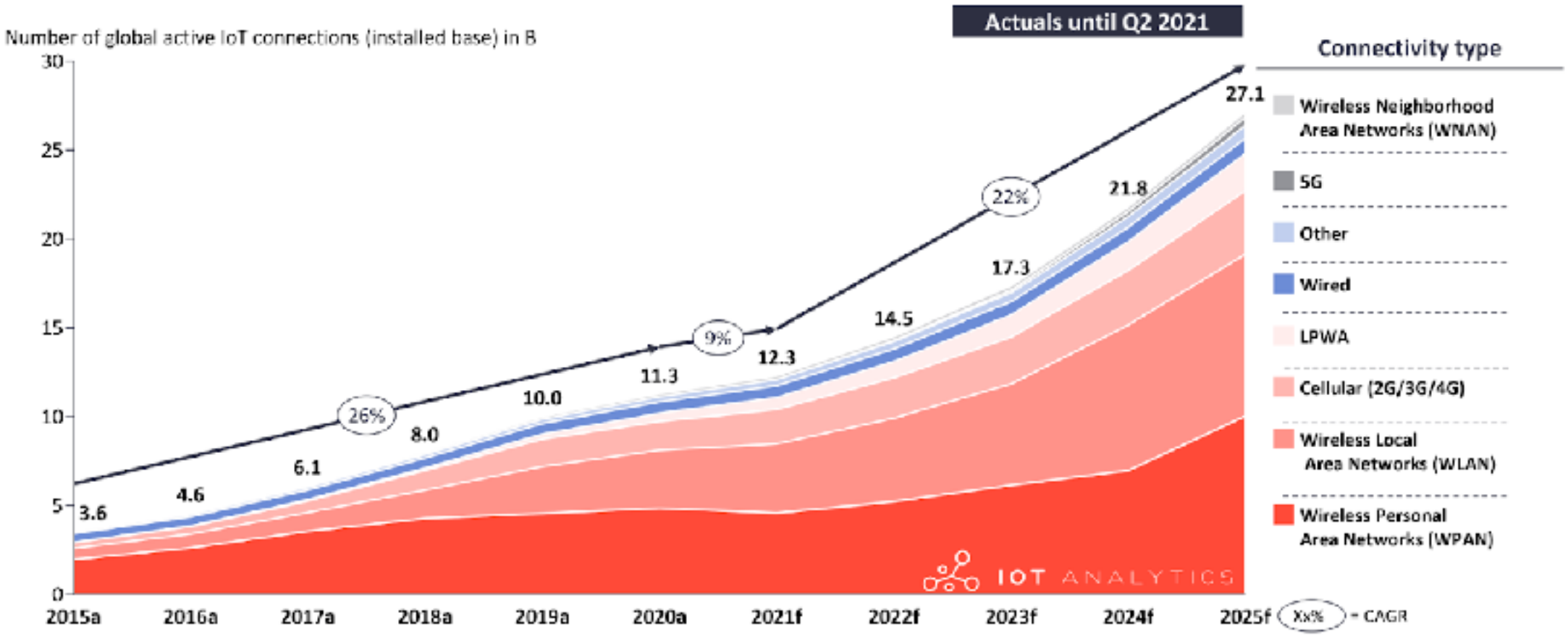
Focus of 6.1820: fundamentals, applications, and future of IoT

IOT ANALYTICS

September 2021

Your Global IoT Market Research Partner

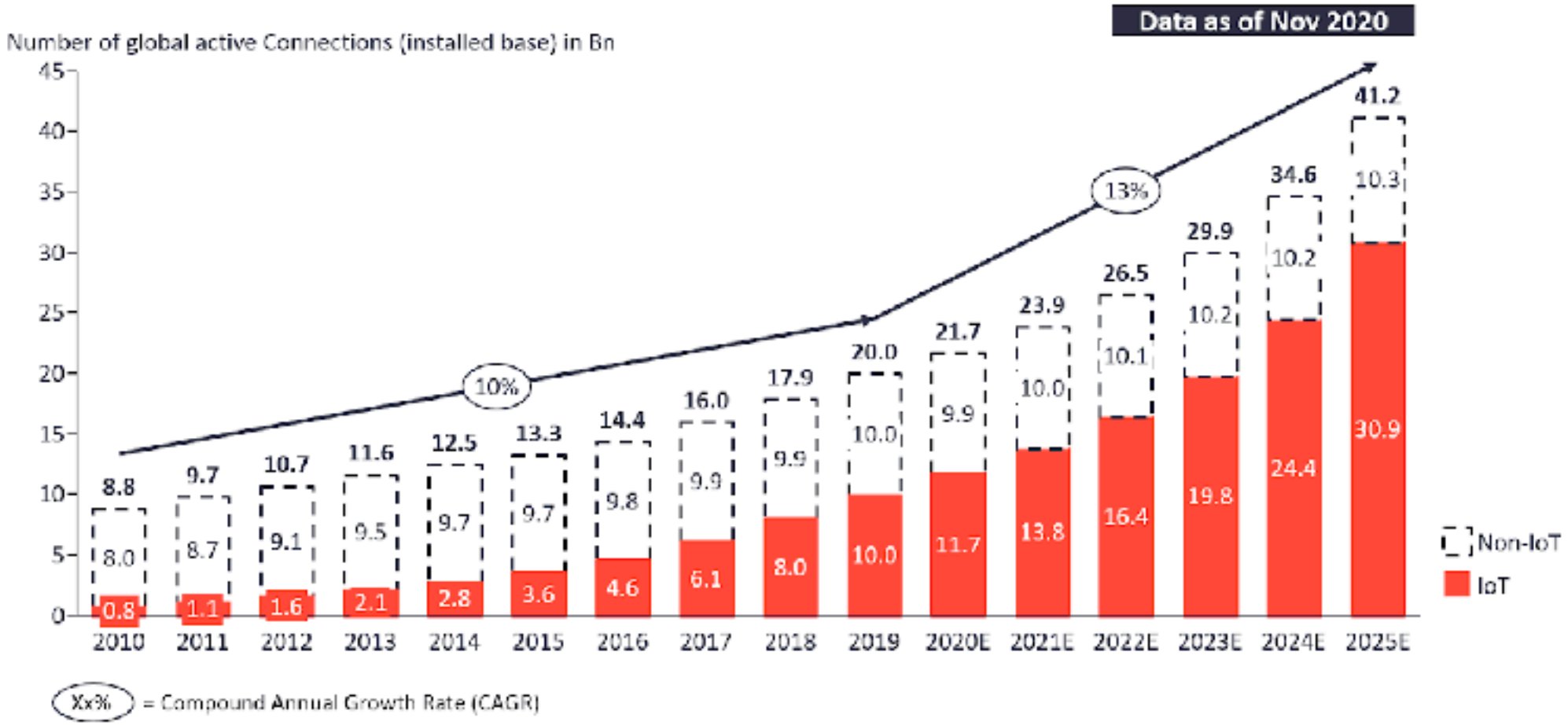
Global IoT market forecast (in billion connected IoT devices)



Note: IoT Connections do not include any computers, laptops, fixed phones, cellphones or tablets. Counted are active nodes/devices or gateways that concentrate the end-sensors, not every sensor/actuator. Simple one-directional communications technology not considered (e.g., RFID, NFC). Wired includes ethernet and fieldbuses (e.g., connected industrial PLCs or I/O modules). Cellular includes 2G, 3G, and 4G. LPWAN includes unlicensed and licensed low-power networks. WPAN includes Bluetooth, Zigbee, Z-Wave, or similar. WLAN includes Wi-Fi and related protocols. WNAN includes non-short range mesh, such as Wi-SUN. Other includes satellite and unclassified proprietary networks with any range.

Total number of device connections (incl. Non-IoT)

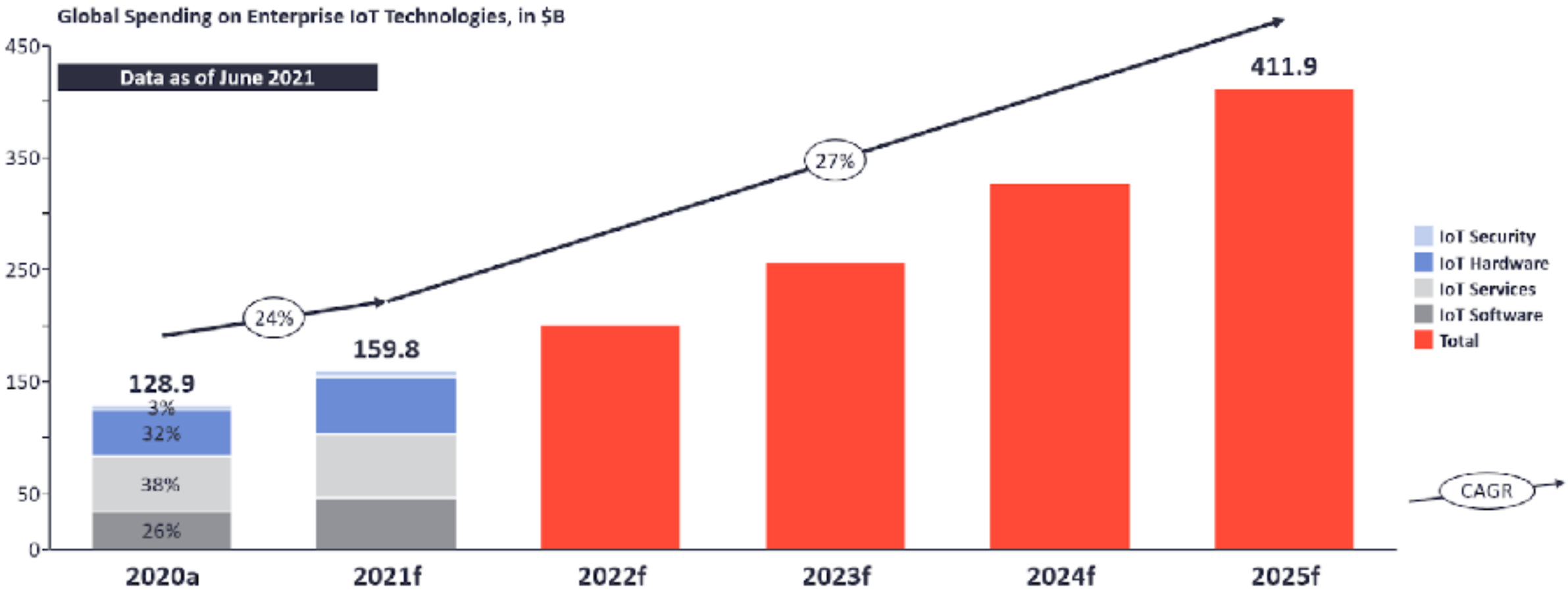
20.0Bn in 2019– expected to grow 13% to 41.2Bn in 2025



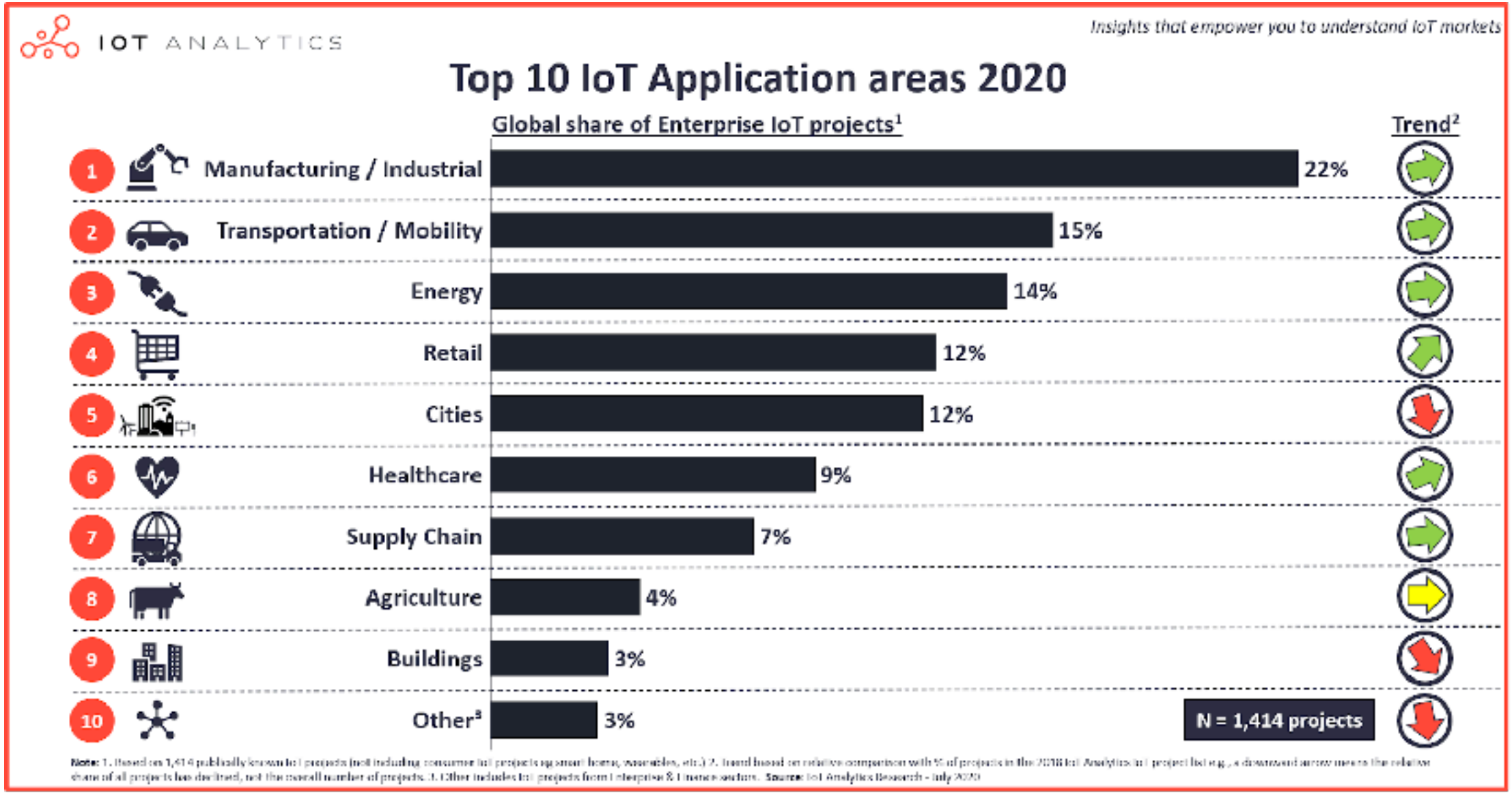
Note: Non-IoT includes all mobile phones, tablets, PCs, laptops, and fixed line phones. IoT includes all consumer and B2B devices connected – see IoT break down for further details

Source(s): IoT Analytics - Cellular IoT & LPWA Connectivity Market Tracker 2010-25

IoT Enterprise Spending 2020 – 2025



Note: IoT Analytics defines IoT as a network of internet-enabled physical objects. Objects that become internet-enabled (IoT devices) typically interact via embedded systems, some form of network communication, or a combination of edge and cloud computing. The data from IoT-connected devices is often used to create novel end-user applications. Connected personal computers, tablets, and smartphones are not considered IoT, although these may be part of the solution setup. Devices connected via extremely simple connectivity methods, such as radio frequency identification or quick response codes, are not considered IoT devices. . a: Actuals, f: Forecast
Source: IoT Analytics Research 2021

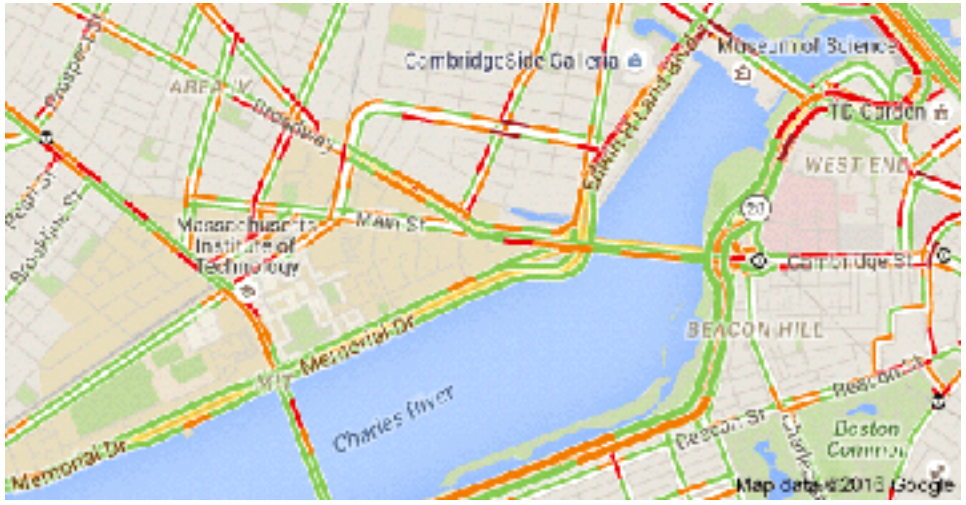


Connected solutions bring increased vehicle uptime for our customers, better safety for drivers, operators and other road users and of course – less emissions of carbon dioxide.

– *Martin Lundstedt, CEO of the Volvo Group, Oct 2019*

IoT is Transforming Industries

Transportation & Smart Cities



Medicine

Smart Homes

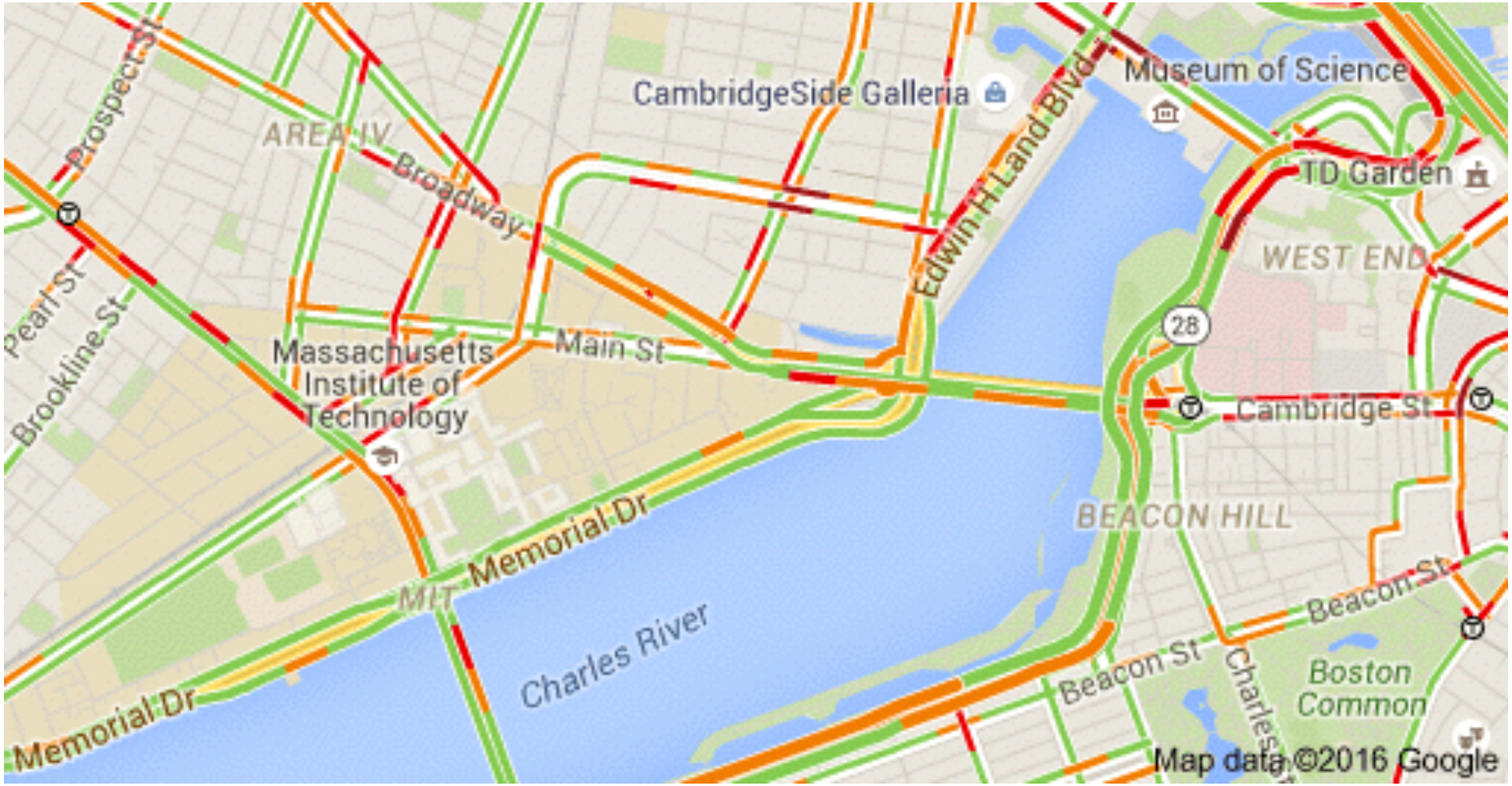
Health & Wellness

Connected Vehicles

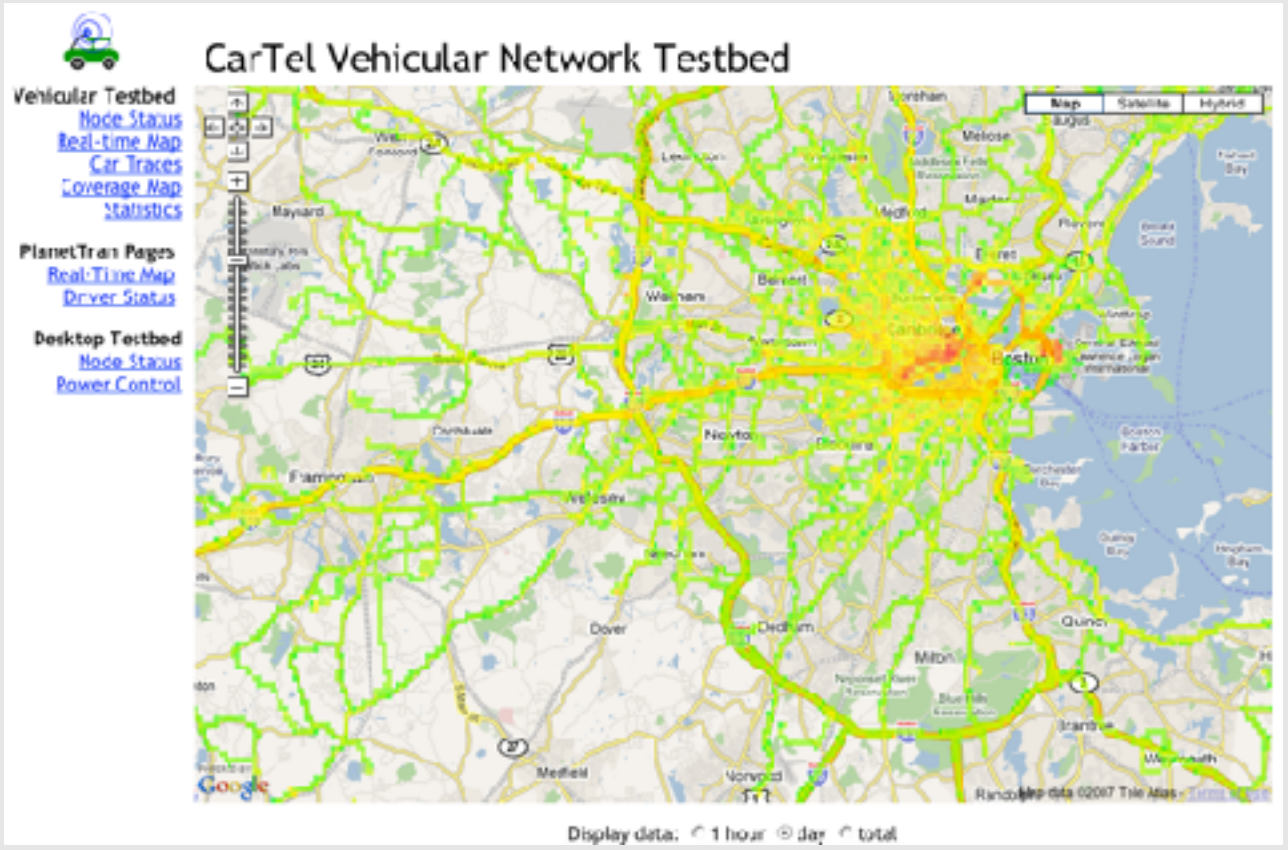
Precision Agriculture

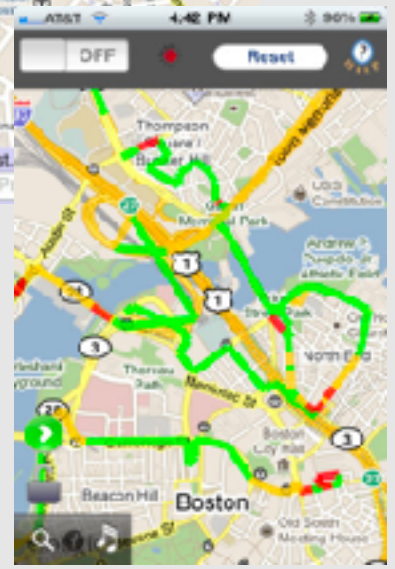
Example systems we will cover

Transportation & Smart Cities

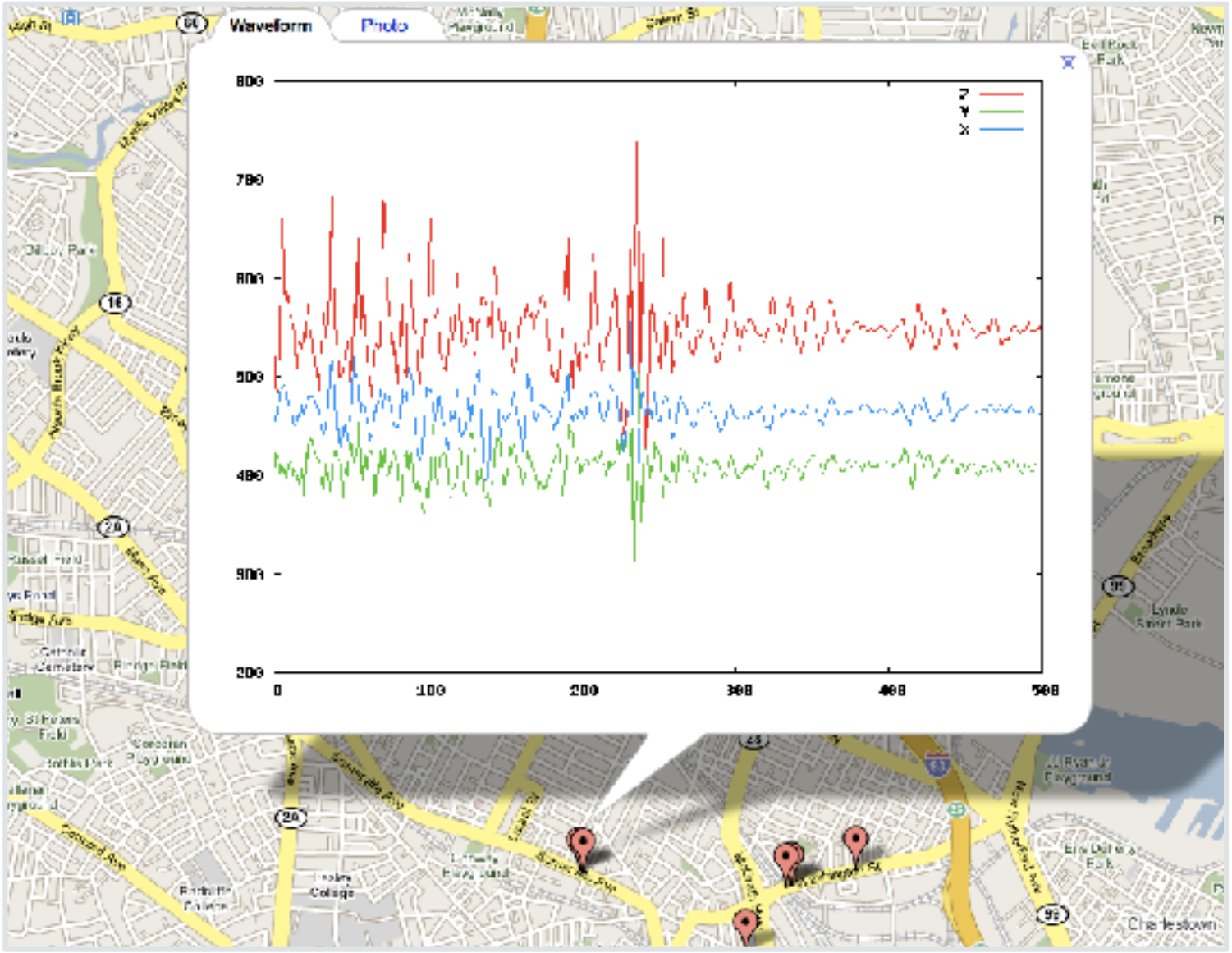


CarTel Project at MIT (2005-2011)





Pothole Patrol



Insurance Telematics Market Size to Reach USD 18.7 Billion by 2032 | Growing Demand for Personalized Insurance Solutions Fuels Market Growth | Research by SNS Insider

The insurance telematics market is experiencing significant growth, driven by the increasing demand for personalized insurance products and the increasing use of telematics to promote safer driving practices.

October 22, 2024 09:00 ET | Source: SNS Insider pvt ltd

Fully Autonomous Driving
(Self-driving cars)

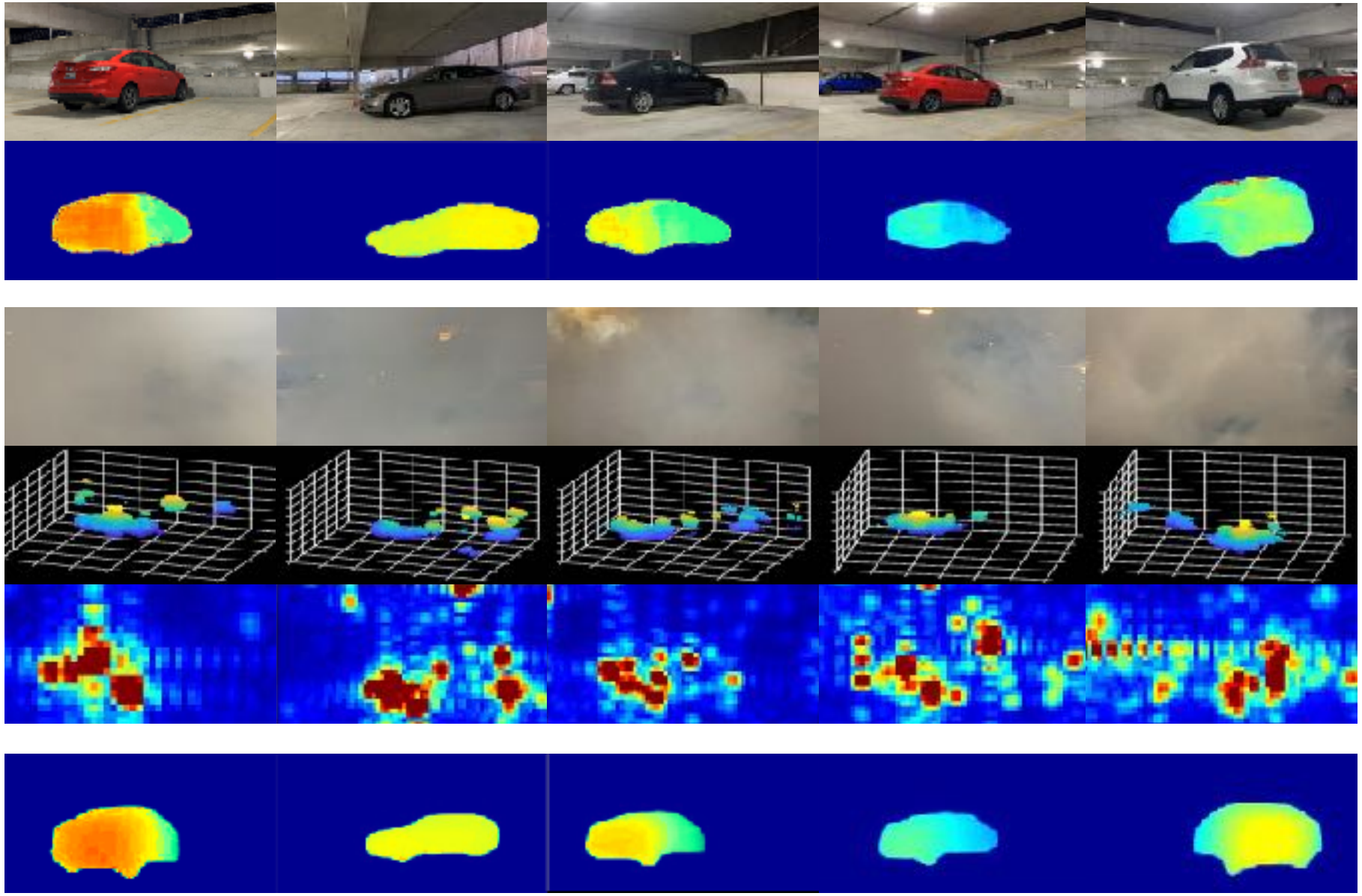

Tesla in Clear Conditions


Tesla in Fog
38
38

Tesla in Fog

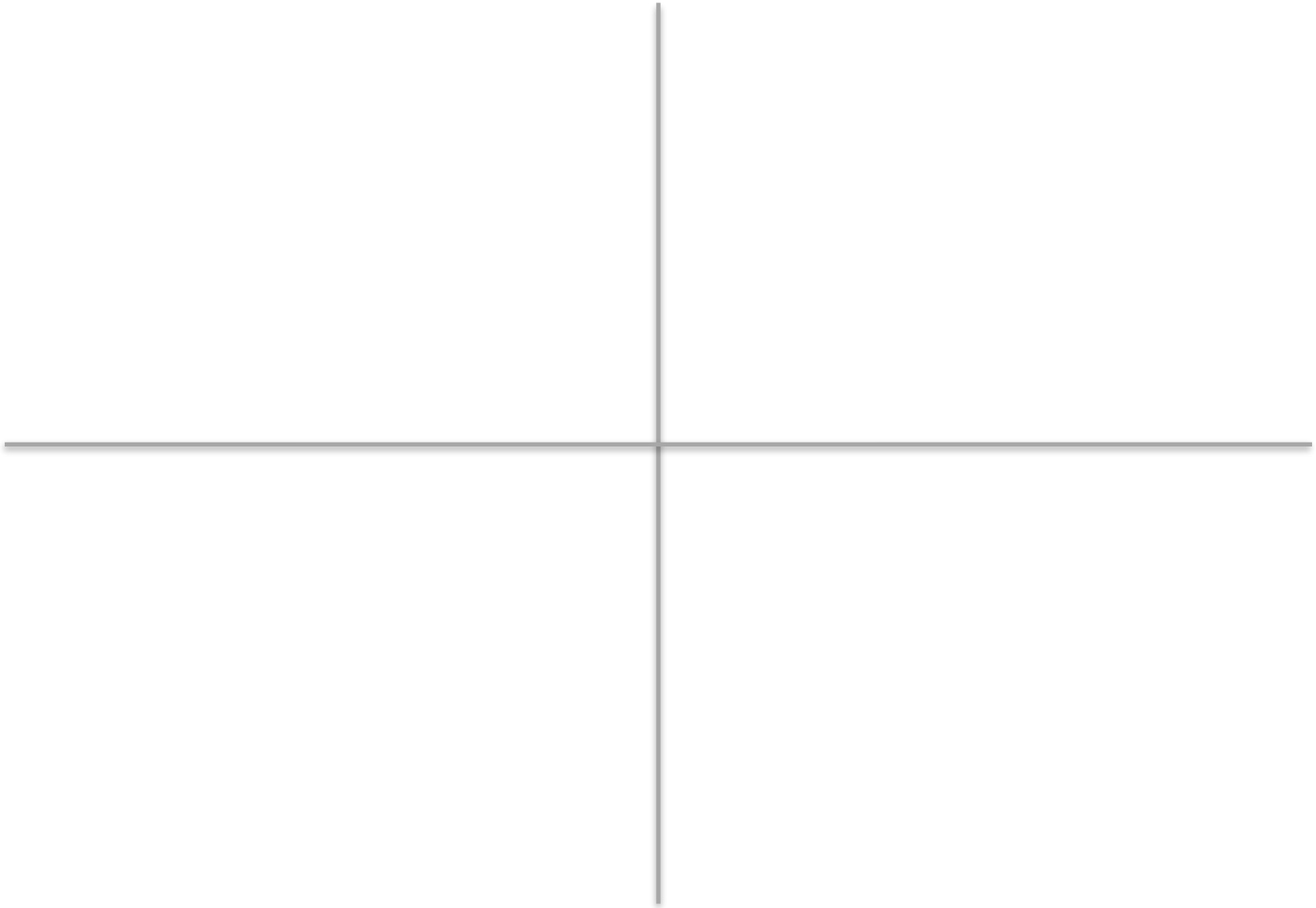
Why does it fail in adverse conditions?

Using AI-powered radars to see through fog



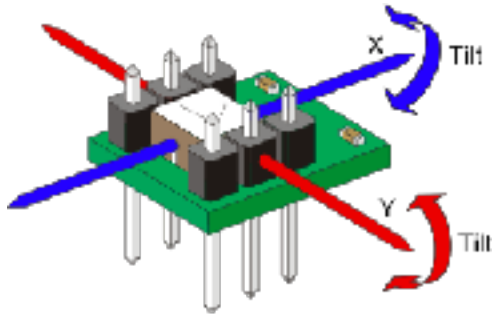
Hawkeye [CVPR'22]

IoT Systems are designed along 4 quadrants



IoT Systems are designed along 4 quadrants

Sensing Tasks & Modalities



Computation

Power/Energy

Connectivity

Sensing Tasks and Modalities

Sensing = bridge between the physical and digital worlds

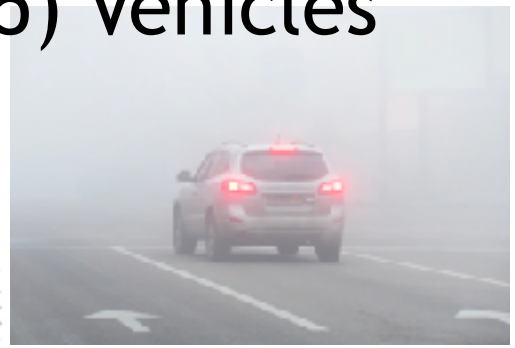
WHAT?

(1) Locations

(2) Health

(3) Activity

(5) Vehicles



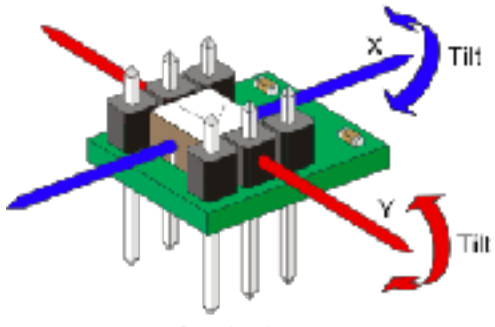
(4) Environment

HOW?

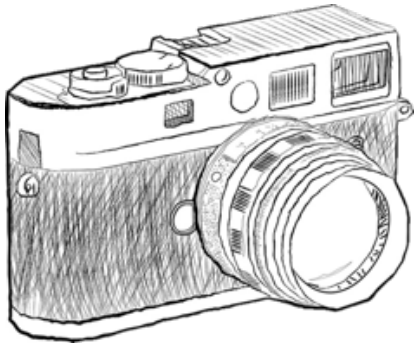
(1) Radio

(2) Acoustic/ Ultrasonic

(3) Inertial



(4) Visual



Computation

HOW can we use the sensing modalities to achieve the sensing task?

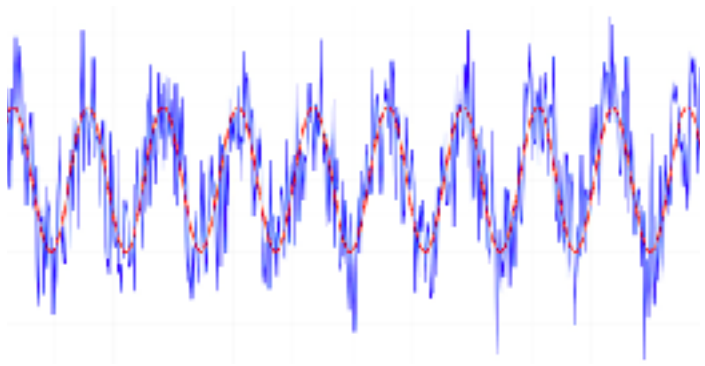
(1) Programming model

- Embedded
- Mobile
- Edge/Cloud

(2) Data Management

- Storage
- Queries

(3) Signal Processing & Machine Learning

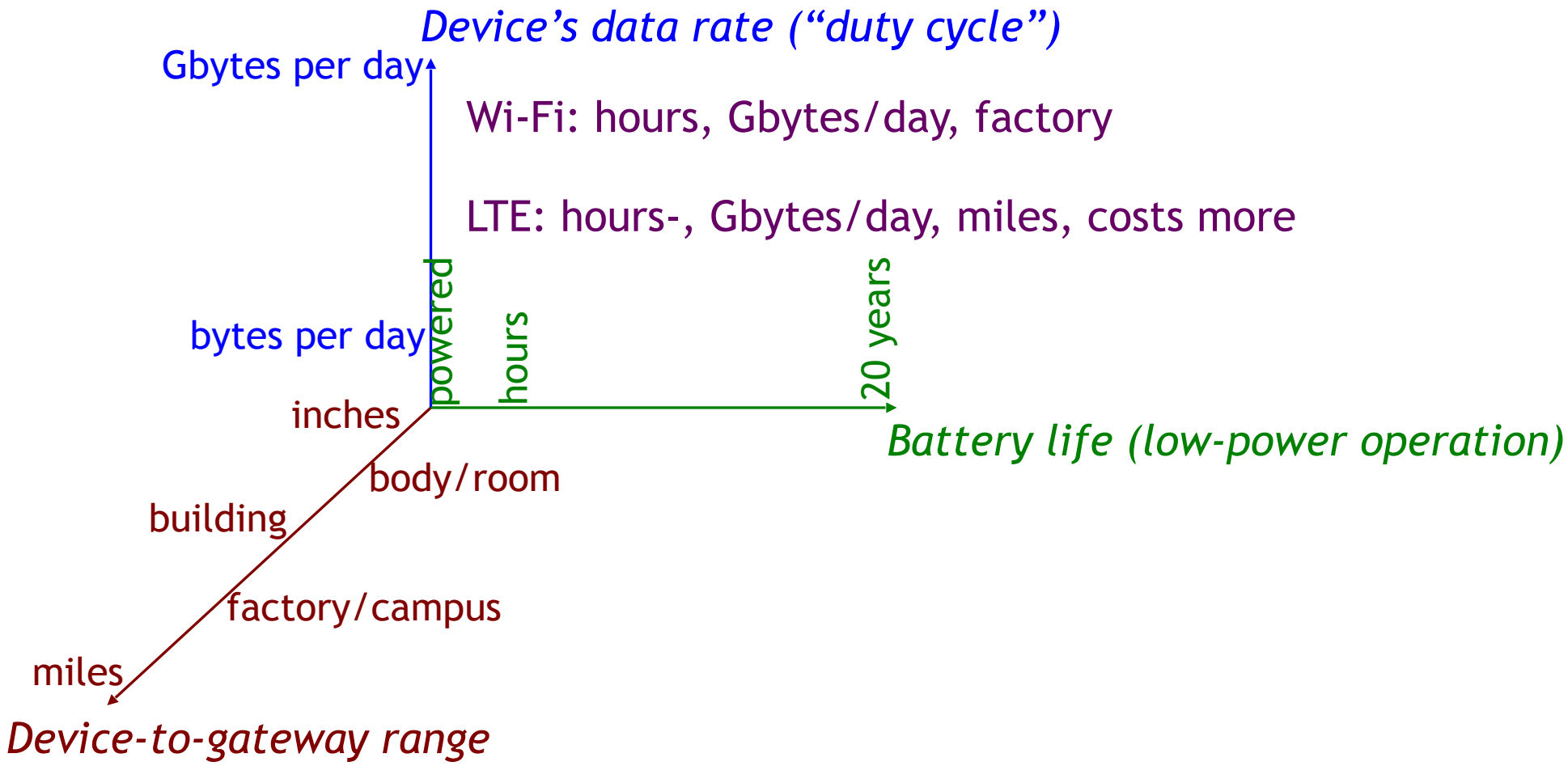


- Digitization
- Inference & Machine Learning

(4) Security

- Digital, Analog
- Trust, Privacy

Connectivity



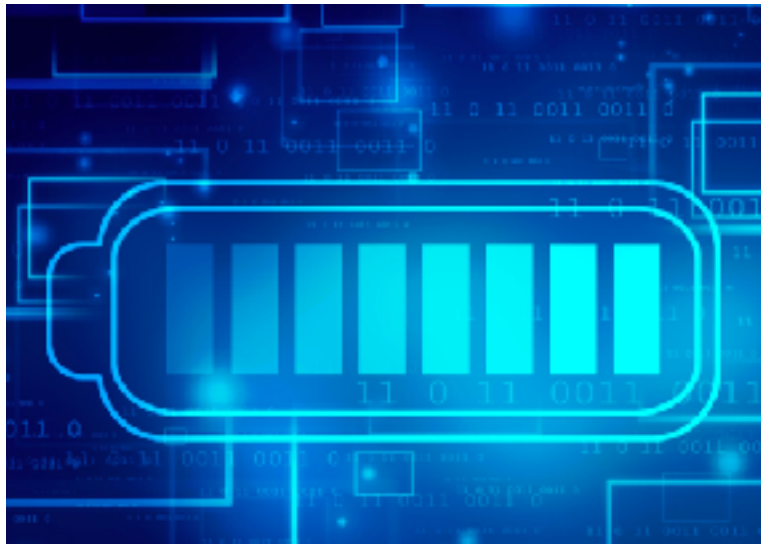
Power/Energy

HOW will we power the nodes? And what are the energy constraints?

(1) Infrastructure

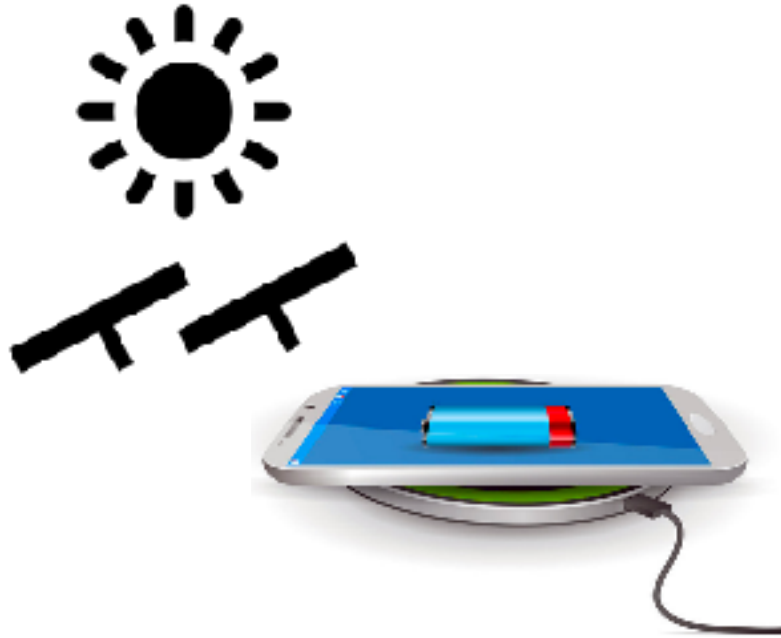
- Electricity, Network

(2) Battery



- Rechargeable/Non

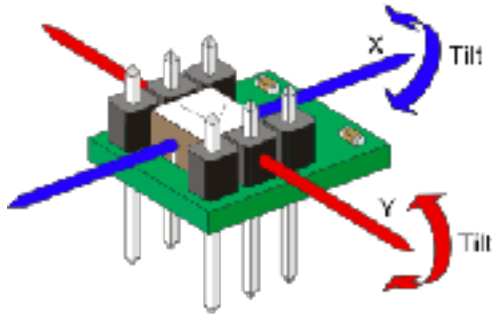
(3) Energy Harvesting



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

IoT Systems are designed along 4 quadrants

Sensing Tasks & Modalities



Computation

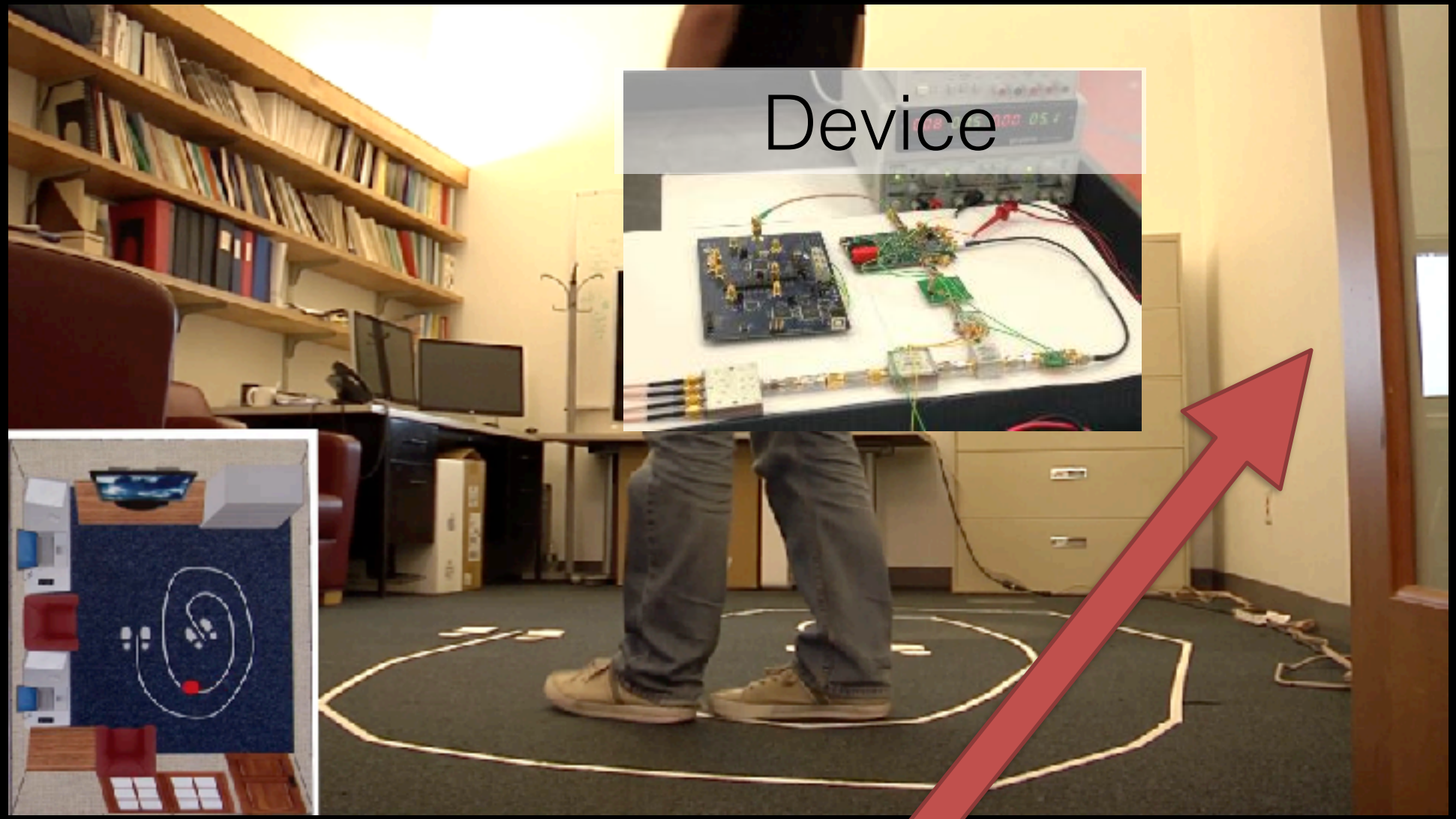
Power/Energy

Connectivity

Indoor Positioning (Cricket, 2001)

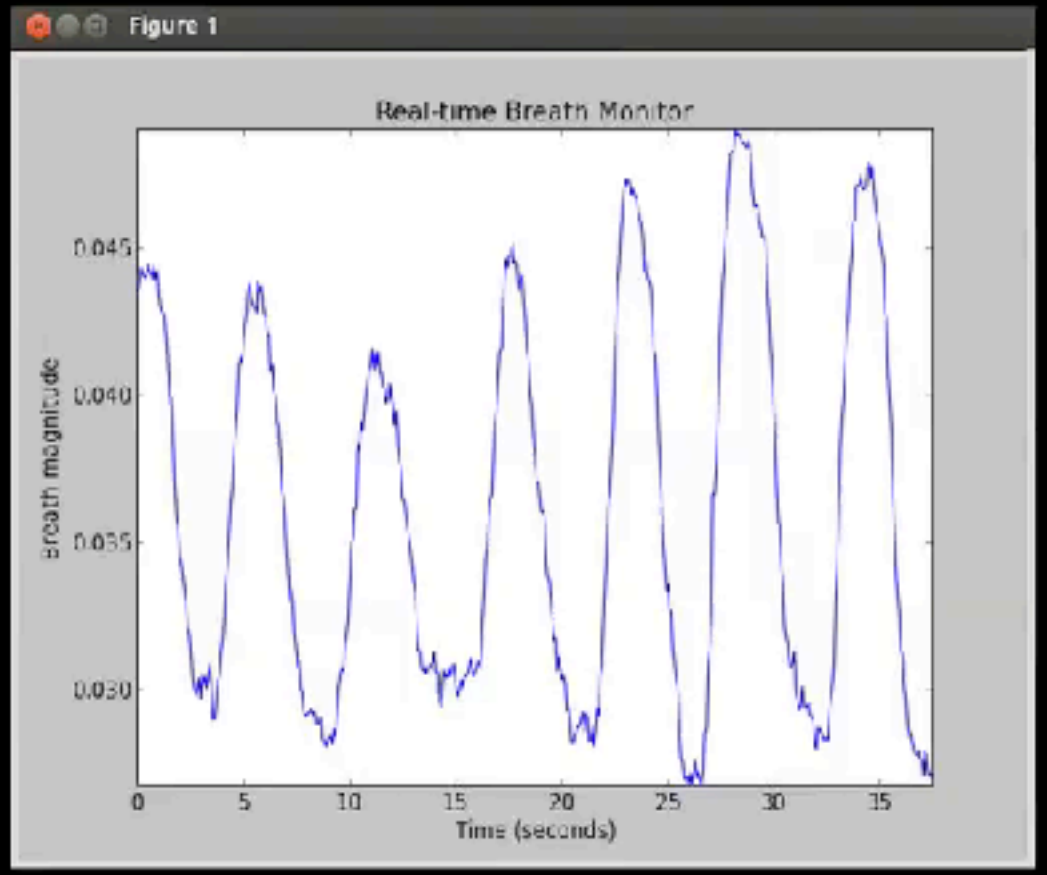
Accurate Localization (Cricket, 2003)

Device-Free Localization (WiTrack, 2014)

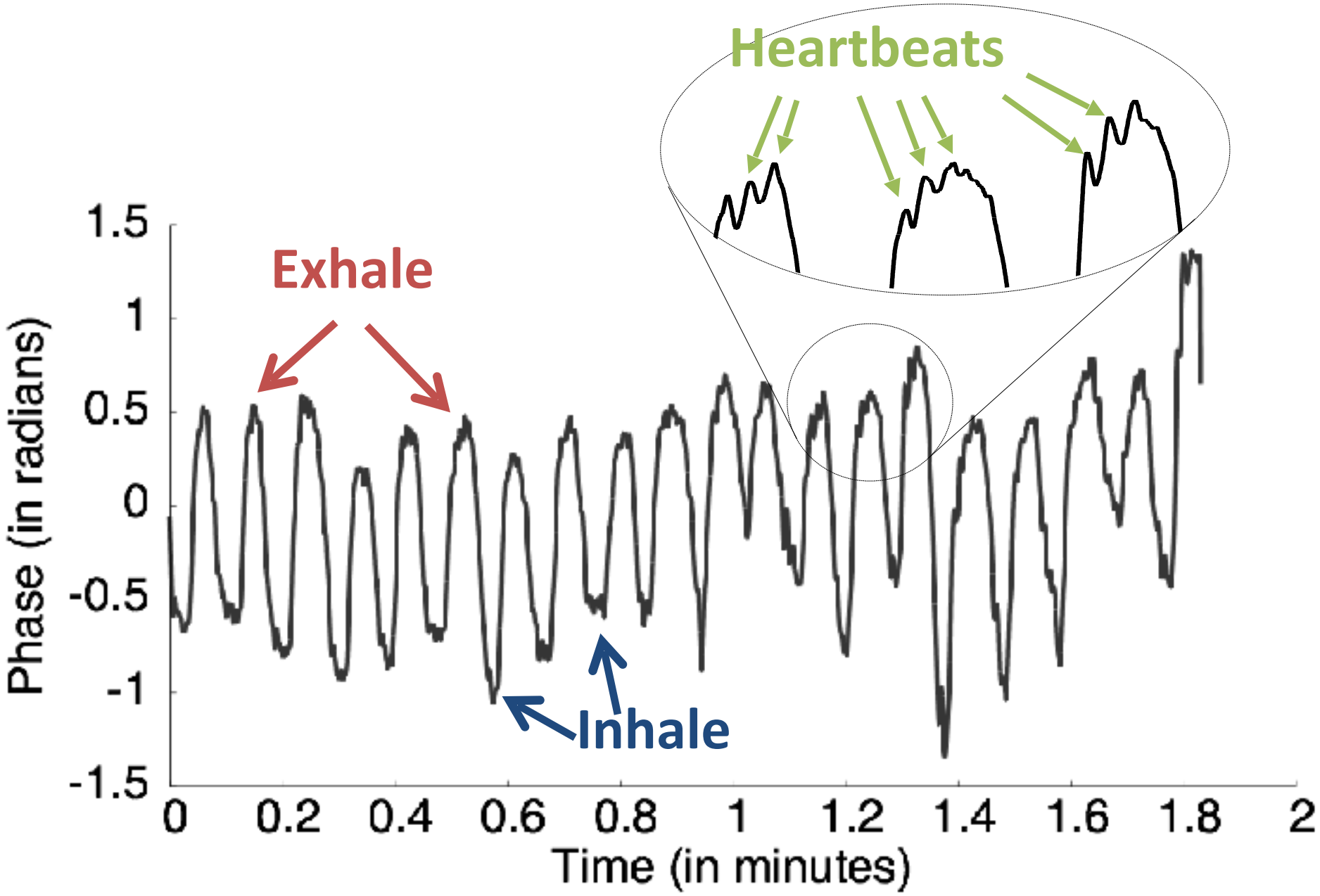


Seeing Through Walls (RF-Capture, 2015)

Breath Monitoring using Wireless (Vital-Radio, 2015)



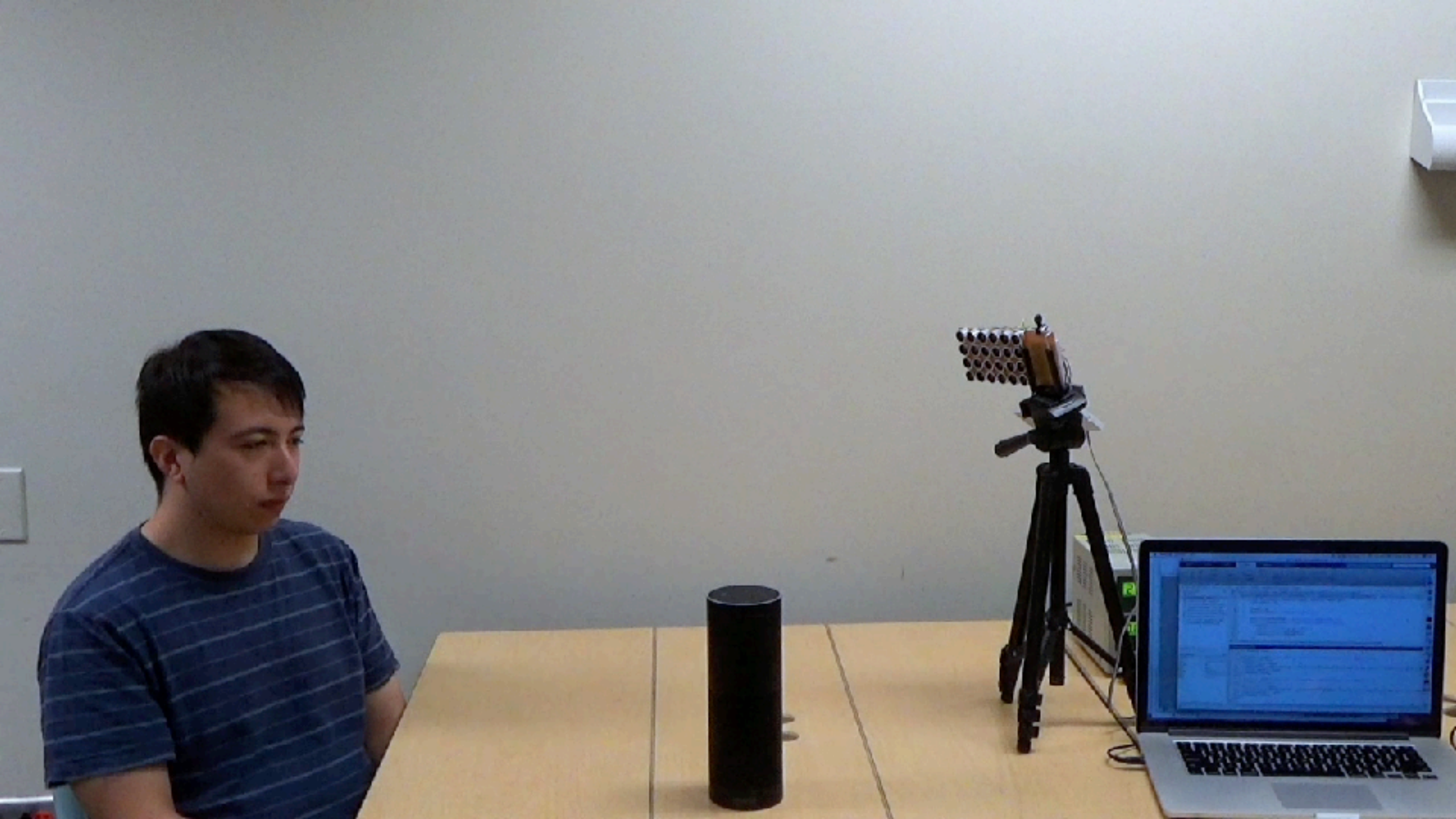
Let’s zoom in on respiration signals


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

Mobile Security
Case Study: Inaudible Voice Commands

Can hack Android/Alexa using inaudible voice commands



Mixed Reality + LLMs

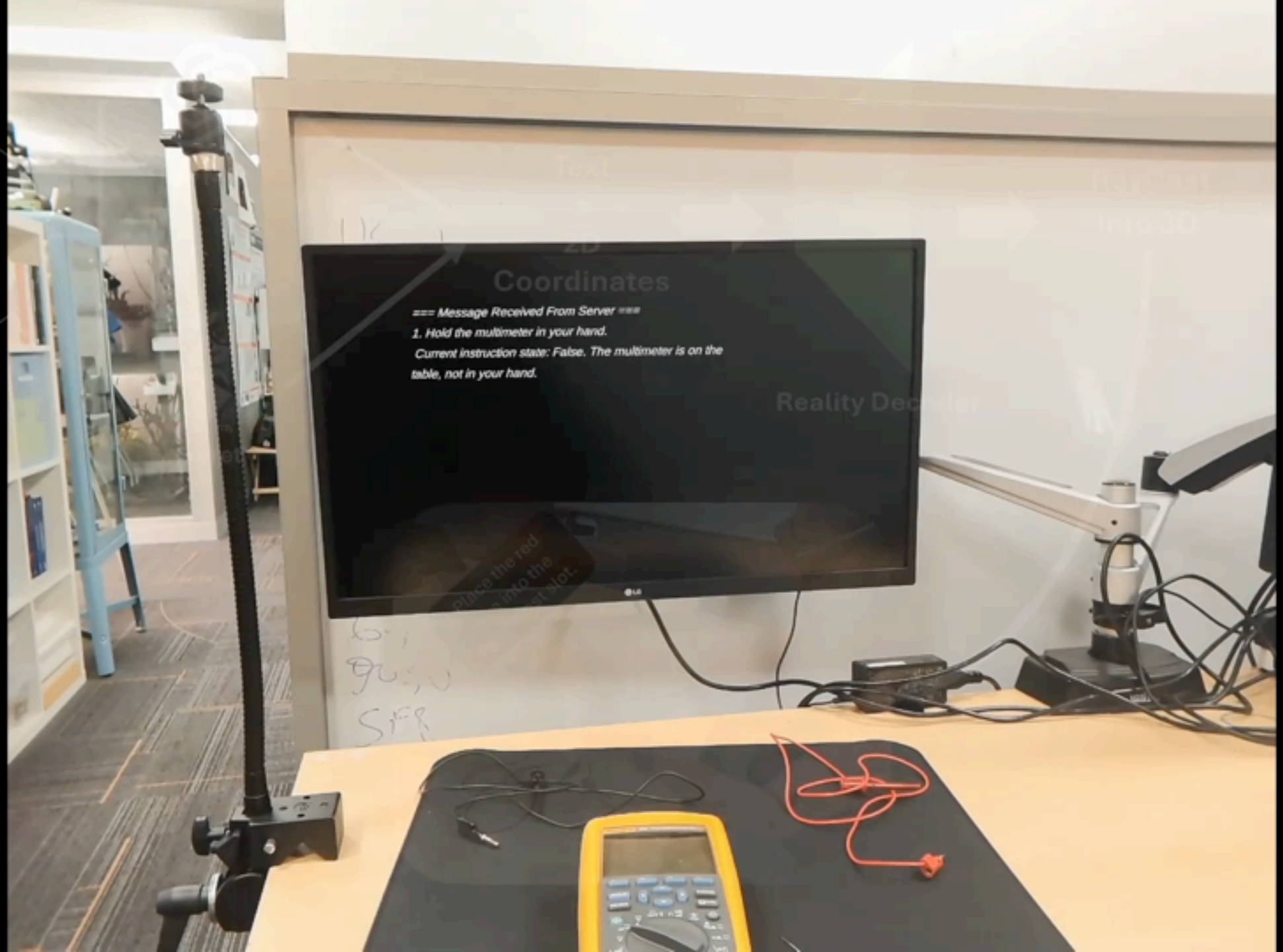
IEEE ISMAR 2024

GREATER SEATTLE AREA

XaiR

An XR Platform that Integrates Large Language Models with the Physical World

Sruti Srinidhi, Edward Lu, Anthony Rowe

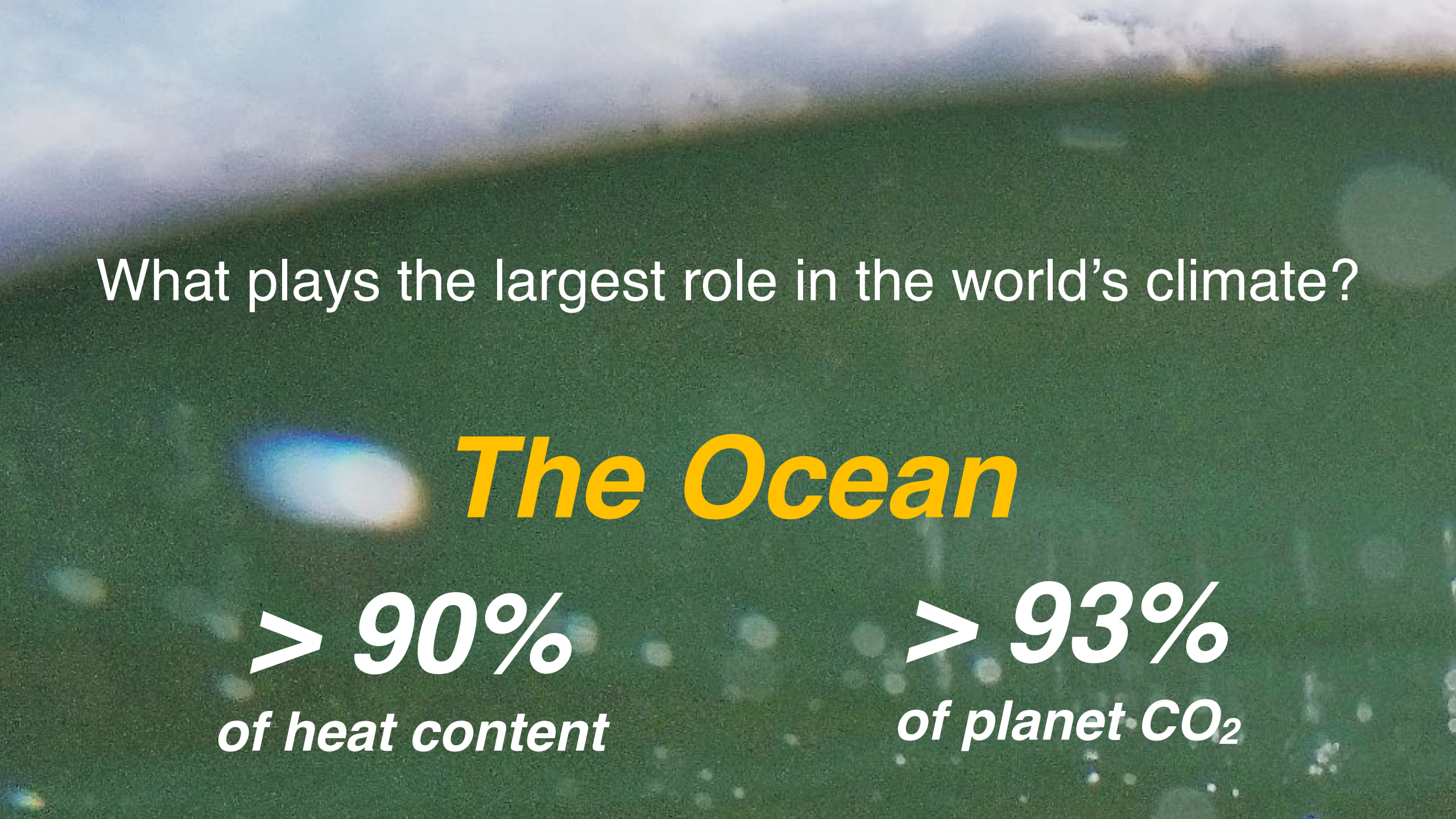

Prompt
Coordinates
=== Message Received From Server
1. Hold the multimeter in your hand.
Current instruction state: False. The multimeter is on the table, not in your hand.

End-to-end IoT System

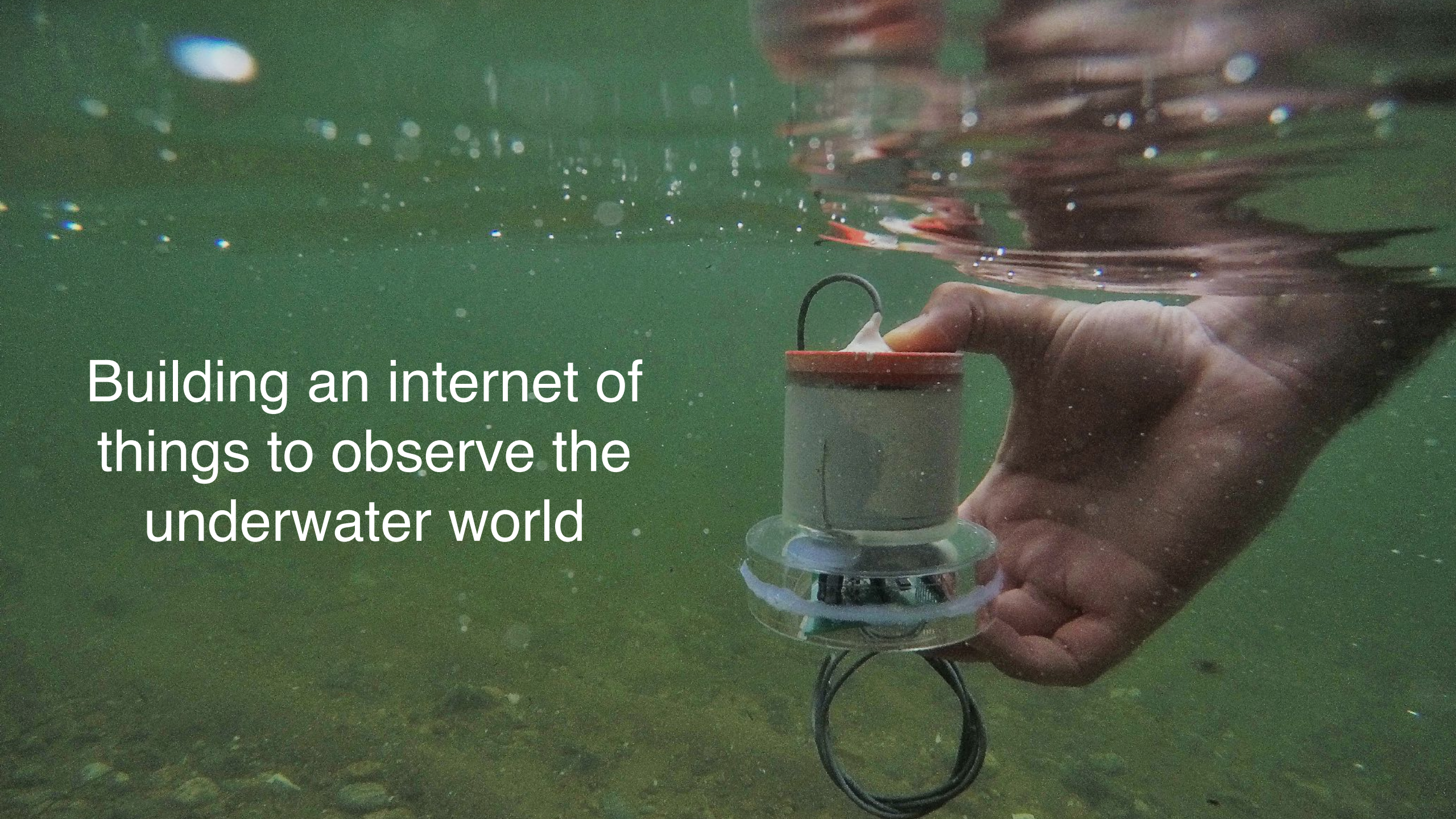
Case Study: Precision Agriculture

What plays the largest role in the world’s climate?

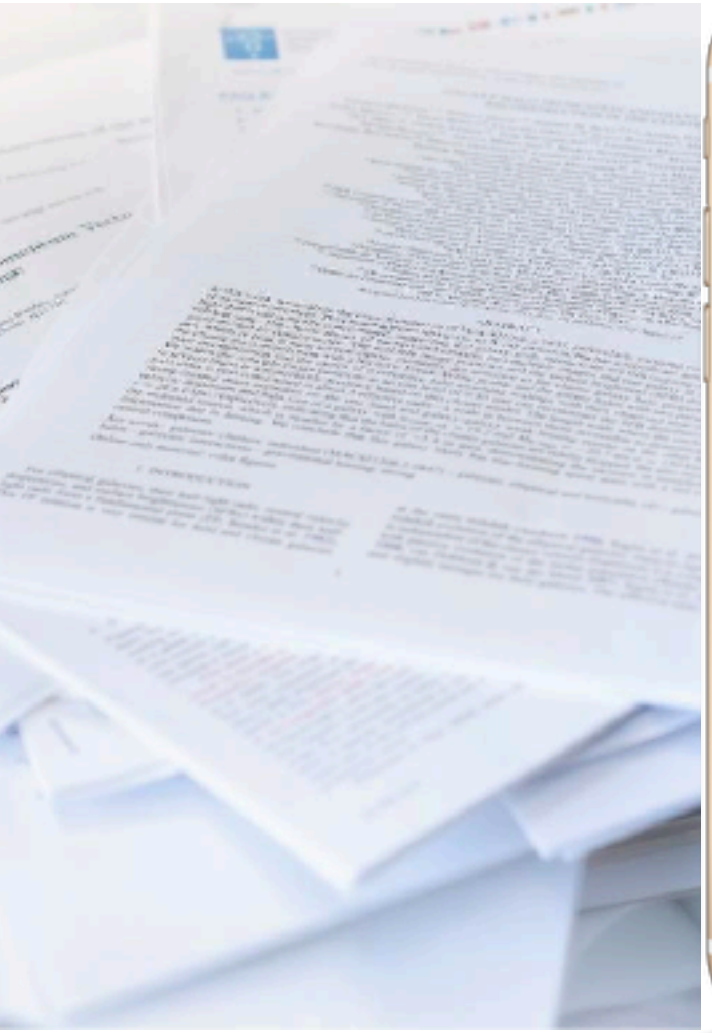

What plays the largest role in the world’s climate?
The Ocean


What plays the largest role in the world's climate?
The Ocean
> 90%
of heat content
> 93%
of planet CO_2


What percent of the ocean has never been observed?
> 95%


Building an internet of things to observe the underwater world

Course Organization



Reading & Reviewing Papers

Mobile (iOS) Labs

Class Project

Logistics

Grading:

- 1 Course Project (40%)
- 4+1 Labs (25%)
- 1 Quiz: April 17, during lecture (15%)
- 2 PSets (10%)
- Participation (10%)
  - Includes answering questions before every lecture
  - May skip one review without affecting grade
  - Attendance is mandatory

Website: https://6mobile.github.io/

Slack: 

Attendance is mandatory
Zoom may be fall-back for medical reasons

Counts toward: AUS2, DLAB2, II requirements

Upcoming: iOS Tutorial (Fri 10-11AM, TBD location, not mandatory, but need to check off)

Policies

Late Policy

Late +Pset lab policy: 72 hours

AI Policy

Permitted uses:

- Debugging, refactoring, optimizing code
- Concept explanation
- Brainstorming with AI

Prohibited Use:

- Writing Reviews & Answering Questions about papers

Disclosure Requirement:

- If you use it AI in any capacity, you must disclose it, and explain how it's used (examples on website)

More details on the course website

iOS Labs (Need iPhone/iPad and Mac)

iPad loaner:

- request via this form: https://ist.mit.edu/loaner-equipment/ipad-terms
- We also have some iPhones to loan if IS&T run out

Mac loaner (first-come first-serve):

- ~~request via this form~~ ~~http://kb.mit.edu/confluence/x/GQdS~~
- We will get loaners for those who need them this year (and fill in the form that was sent in Slack)

Please request them asap, will send the links in Slack

Projects

Students have most fun & learn most from the projects

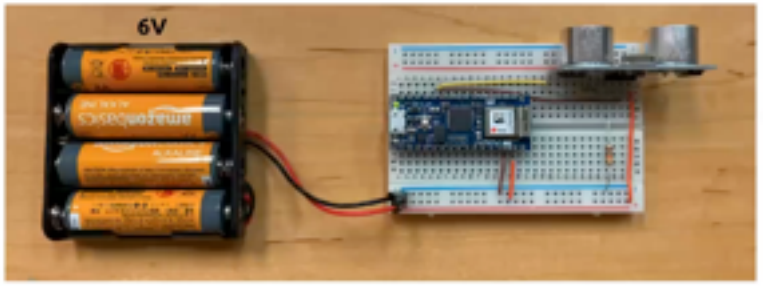
- All projects involve system implementation
- Ideal group size: 3
- Will suggest project ideas; students can choose their own projects

Timeline:

- Proposal (1-2 pages): April 1
  - We meet on April 8 & 10 (during class time) to give feedback
- Project Final Components Due: April 15
- Project titles & abstracts: May 6
- Project demos & presentations: May 13

Sample 6.1820 Projects (past years)

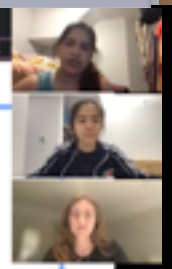
Arduino Schematic

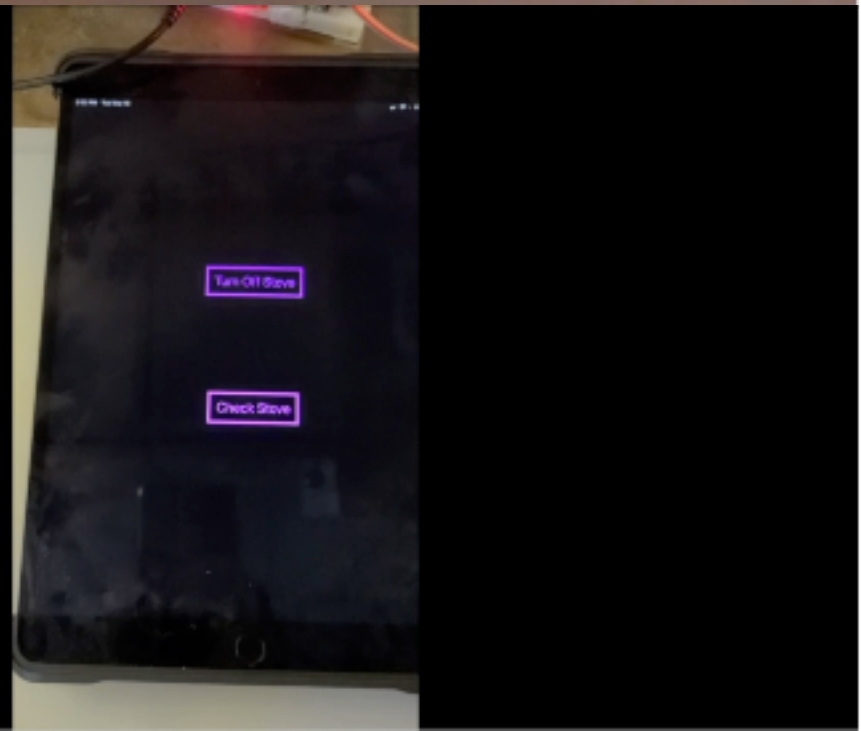


Arduino Nano 33 IoT: 57 mA (with BLE)
Ultrasonic Sensor: 15 mA
Total: 72 mA

Battery: 8000 mAh

Duration: 8000/72 ≈ 111 hours





Monday	Tuesday	Wednesday	Thursday	Friday
	Feb 4 *Last day of classes* **LEC 1:** Introduction and Key Ideas **Assigned:** Lab 0		Feb 6 **LEC 2:** Fundamentals of IoT Localization **Preparation:** Read Location-based Services, Wikipedia: GPS (Questions)	Feb 7 *ICS Tutorial 10am-11am, Room TBD.*
	Feb 11		Feb 13 **LEC 4:** Seeing through Walls & Device-Free Localization **Preparation:** Read WiTrack	
Feb 17 *Presidents' Day*			Feb 20 **LEC 5:** Network Connectivity (BLE, Low-power WAN, Wi-Fi, cellular, 5G) **Preparation:** Read gps surveillance **DUE:** Lab 1	
			Feb 27 **LEC 7:** Batteryless Connectivity & Smart Cities **Preparation:** Read Hacking RFIDs **Assigned:** Lab 2	
	Preparation: Read Developments of Inertial Sensing		Mar 5 **LEC 9:** Pothole detection **Preparation:** Read Pothole Patrol **DUE:** Post 1	
			Mar 13	
Mar 24 *Spring Break*				Mar 28 *Spring Break*
	DUE: Project Proposals			
	Apr 8 **Project meetings** (No lecture; meet with staff during class time) **DUE:** Lab 4			
	Apr 15 Quiz review session during class **DUE:** Final Project Components List			
Apr 21 *Patriots' Day*	Apr 22 **Project meetings** (No lecture; meet with staff during class time) *Drop Date*			
	Apr 29 **Project meetings** (No lecture; meet with staff during class time)			
	May 6 **Project meetings** (No lecture; meet with staff during class time) **DUE:** Project Titles and Abstracts			
	May 13 **Final Presentations** **DUE:** Presentations and Demos *Last Day of Classes*			May 16 Finals begin

New Topics:

- Earables
- Mixed reality with LLMs
- Self-driving cars

If the exam deadline conflicts with any religious observance, please let us know asap

Note:

For cross-registered students, please make sure you are available for all classes and there's no conflict on exams/etc.

Will collect feedback within 2-3 weeks of the beginning of the semester