

BU-EC444

Fall 2024
Prof. Little

Smart and Connected Systems: Course Overview

Content areas and course objectives

The course is meant to be a hands-on, giving students the opportunity to learn topics in cyber-physical and IoT systems, and then put those concepts to practice by developing and debugging small scale connected microcontroller systems. The course goals are to introduce students to

1. **Microcontrollers as single units**
2. *Sensors and actuators*
3. *Multiple connected microcontrollers and networking (and wireless)*
4. *Cyberphysical systems (safety critical)*
5. *N-tier and distributed applications*

Microcontrollers



\$22.00

Arduino Uno Rev3



\$38.50

Arduino Mega 2560 Rev3

Low-cost DIY
platform
(integrated)

From Arduino.cc

Microcontrollers

Single chip
microcontroller
(un-integrated)

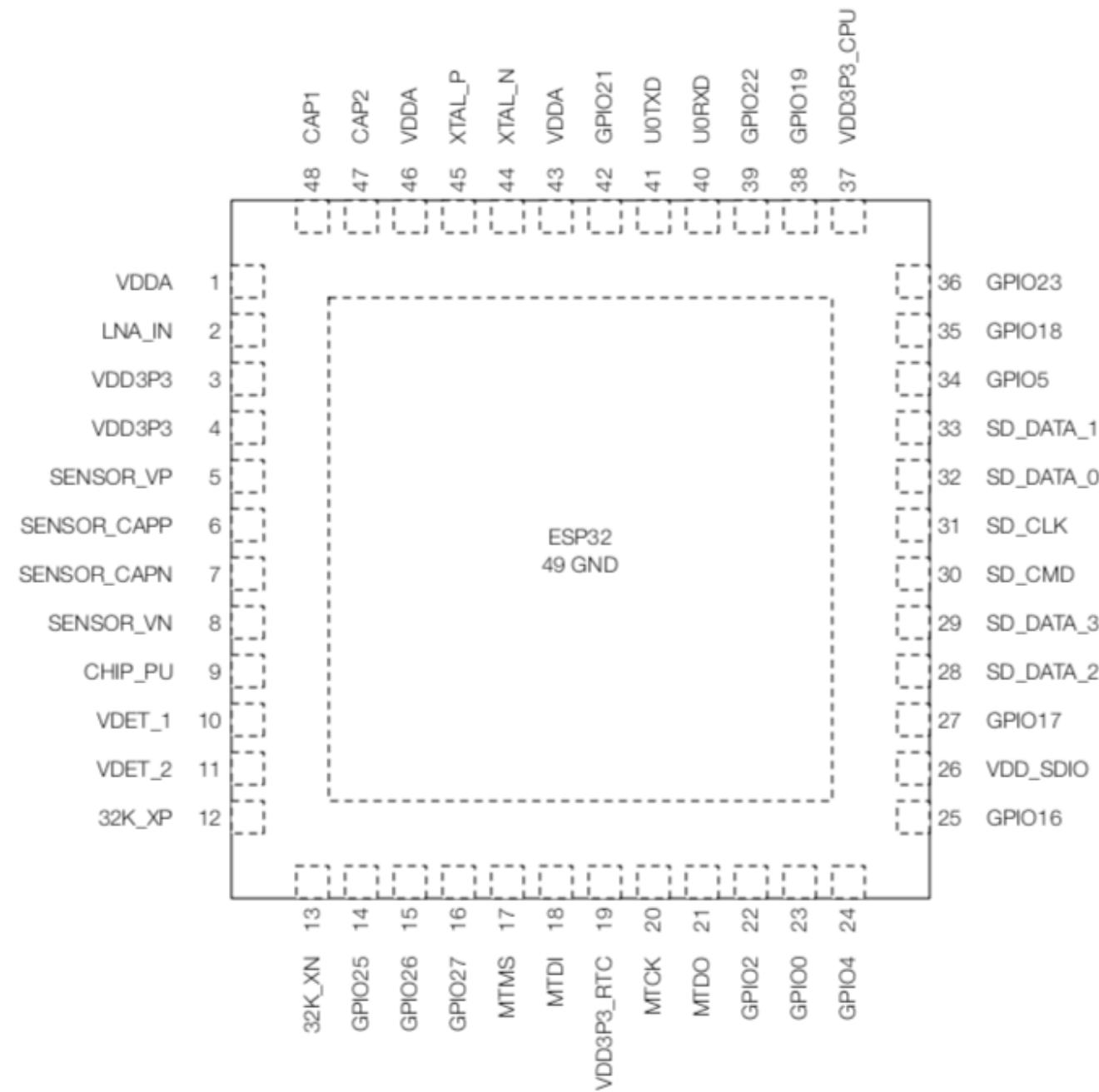


Figure 2: ESP32 Pin Layout (QFN 6*6, Top View)

From ESP32 data sheet

Microcontrollers

Functional View

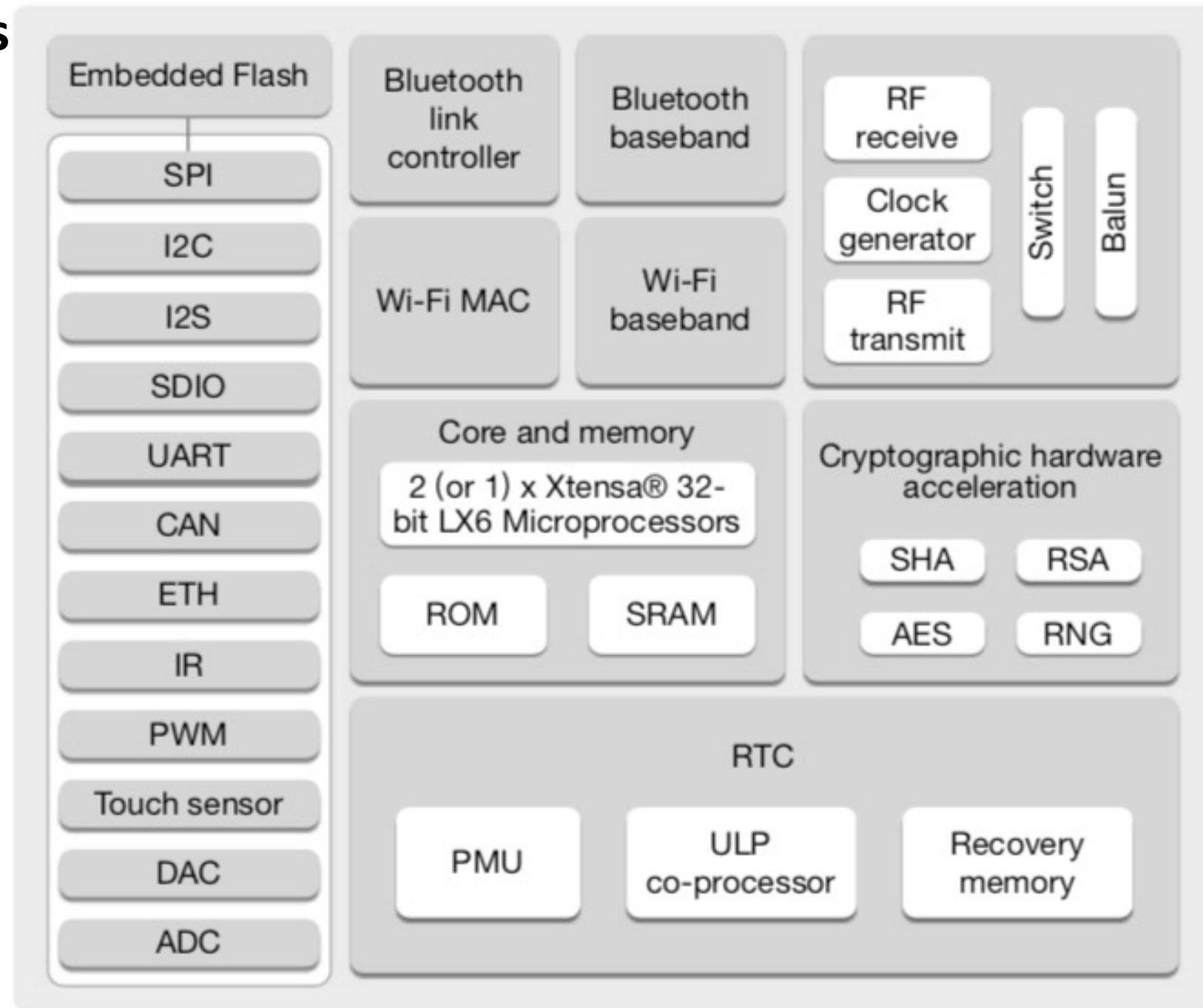


Figure 1: Functional Block Diagram

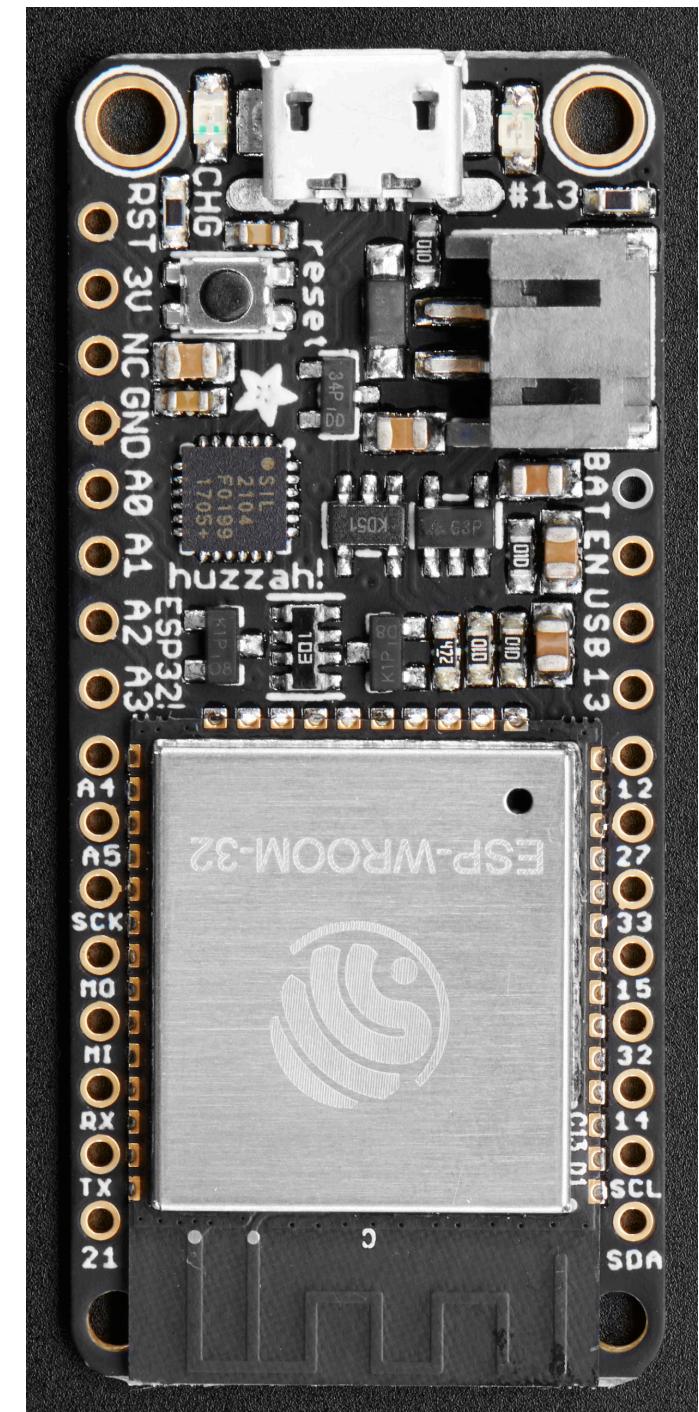
From ESP32 data sheet

Microcontrollers



Single chip
microcontroller
(integrated)

Support
interfaces and
connectors



Content areas

1. *Microcontrollers as single units*
2. **Sensors and actuators**
3. *Multiple connected microcontrollers and networking*
4. *Cyberphysical systems*
5. *N-tier and distributed applications*

Sensors and Actuators



AquaGenie: The World's Smartest Water Bottle

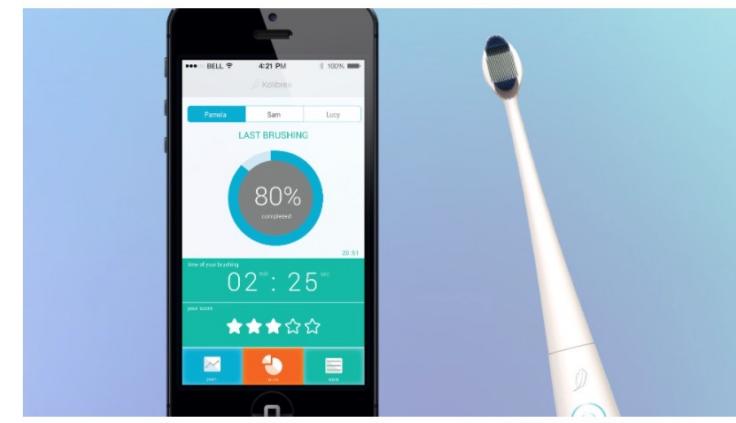


A smart water bottle to help you stay hydrated that tracks your water intake & gives glowing reminders when it's time to drink.

CNN BUSINESS LIVE TV ≡

habits

By Brandon Griggs, CNN
Updated 12:06 PM ET, Sun February 23, 2014



This connected toothbrush from Kolibree will track your brushing habits and send them to your phone.

Sensors and Actuators

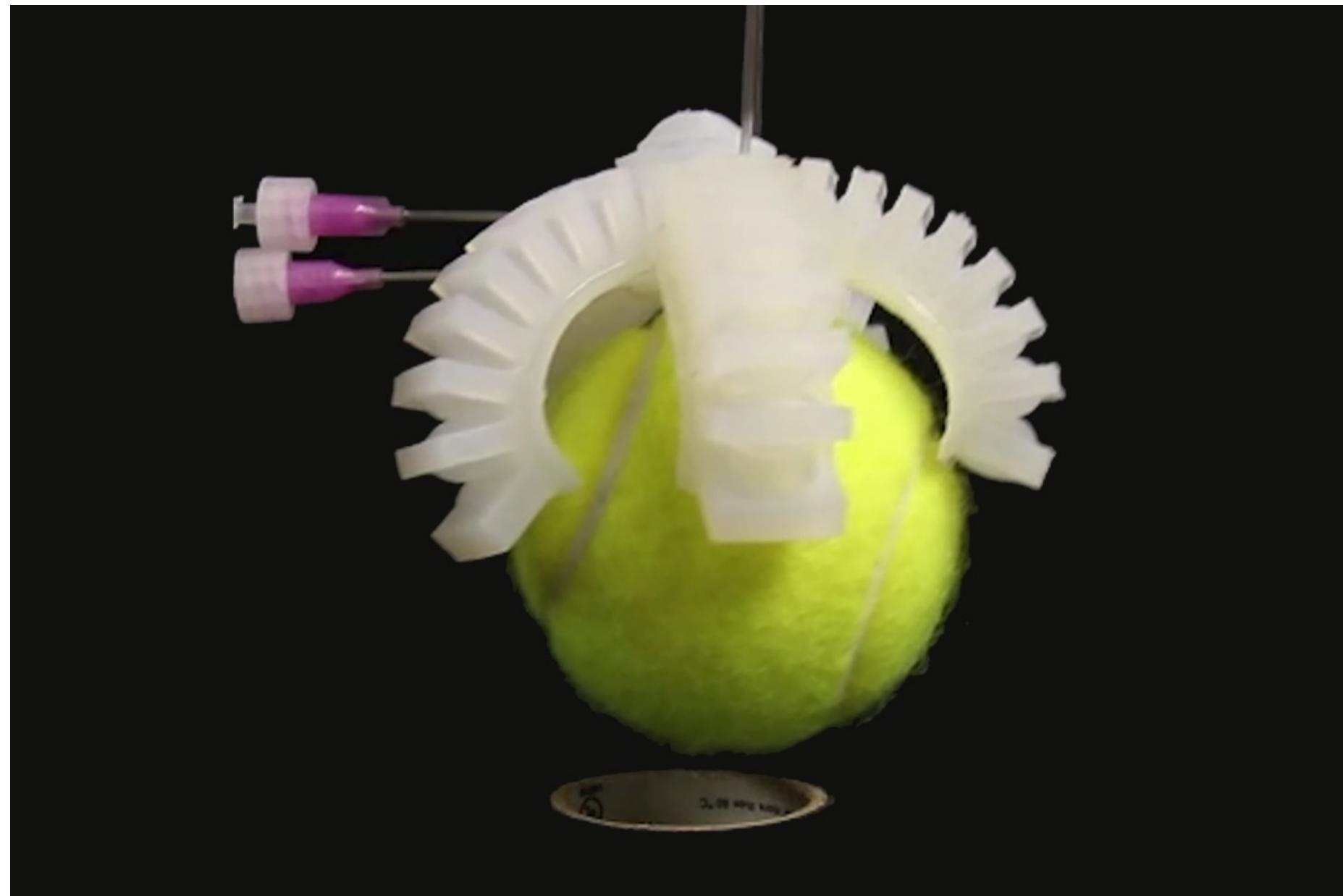
GENX™

high bypass
turbofan
engines



From geaviation.com

Sensors and Actuators



Sensors and Actuators



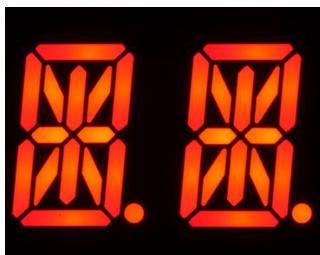
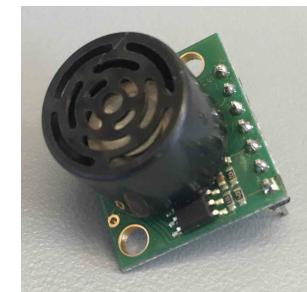
Devin Coldewey @techcrunch 5:14 pm EDT • August 15, 2019

Comment



From techcrunch.com

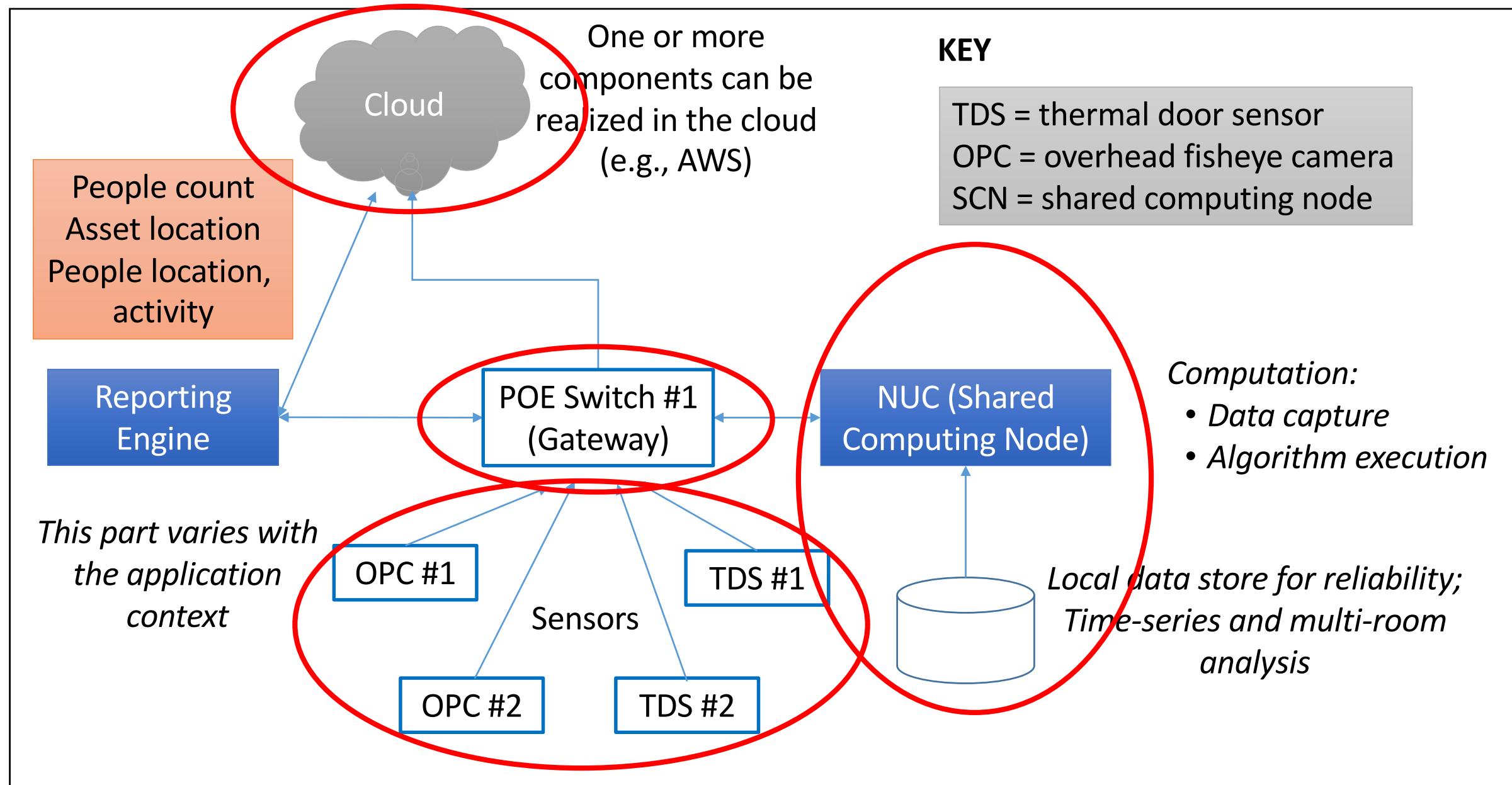
Sensors and Actuators



Content areas

1. *Microcontrollers as single units*
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5. *N-tier and distributed applications*

Multiple connected microcontrollers and networking – a system



Multiple connected microcontrollers and networking – a system

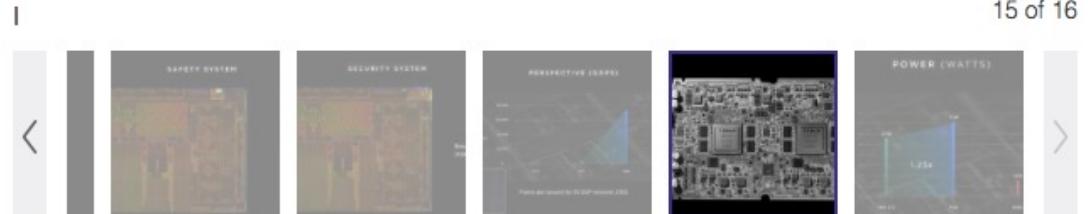
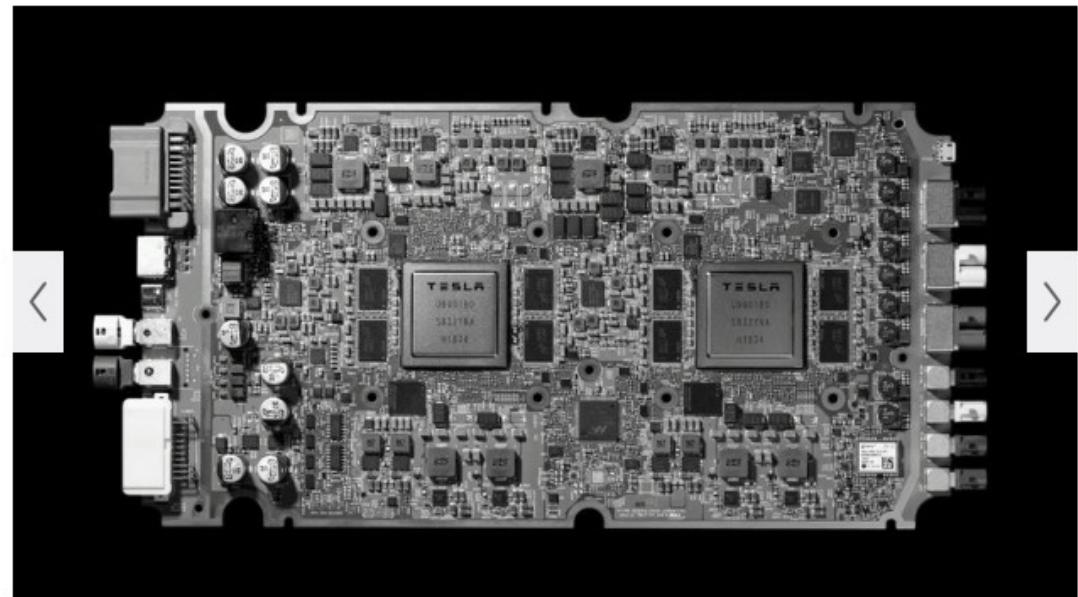
- 50–100 microcontrollers in modern car
- Safety-critical



Tesla.com

THE VERGE [TWITTER](#) [FACEBOOK](#)

[GRID VIEW](#)



There's an awful lot of specs associated with this new Tesla-designed, Samsung-manufactured silicon — you can peruse them at your leisure in our gallery above — but the overall message Tesla's trying to send today is that this hardware is purpose-built to handle all of the data from the car's sensors far faster and more efficiently than the AI chips it could buy off the shelf. There

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Cyberphysical Systems



Nest.com



IoT Plug



Provisioning
without
keyboard



Tesla.com

Safety Critical

Data Collection
and Privacy



Elektra/GE Precision
Radiation Therapy

Safety Critical

Trust

TECH \ CYBERSECURITY \ GADGETS \

Security researchers find that DSLR cameras are vulnerable to ransomware attack

Canon has issued a security advisory and firmware patch for the vulnerability

By [Andrew Liptak](#) | [@AndrewLiptak](#) | Aug 11, 2019, 2:33pm EDT

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SAMSUNG

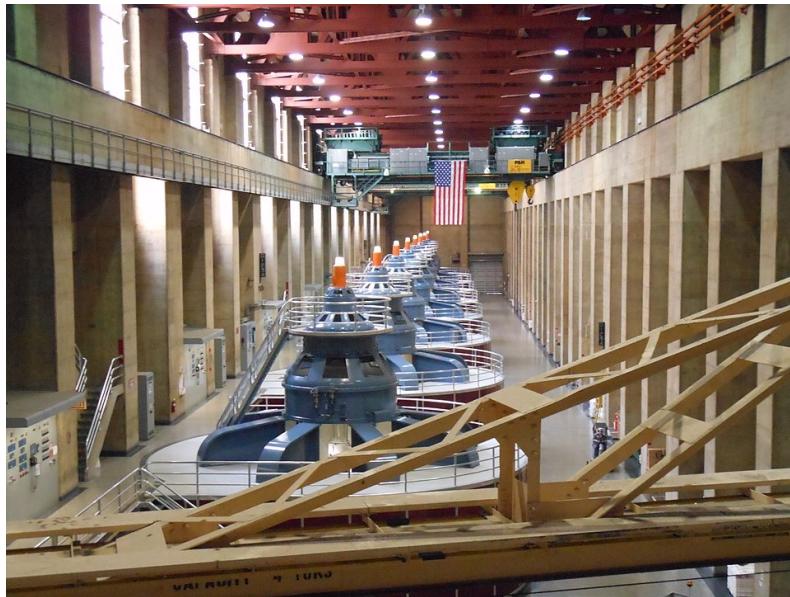
Galaxy Note10 | 10+

Screen images simulated.

GOOD DEALS

From The Verge

Cyberphysical Systems

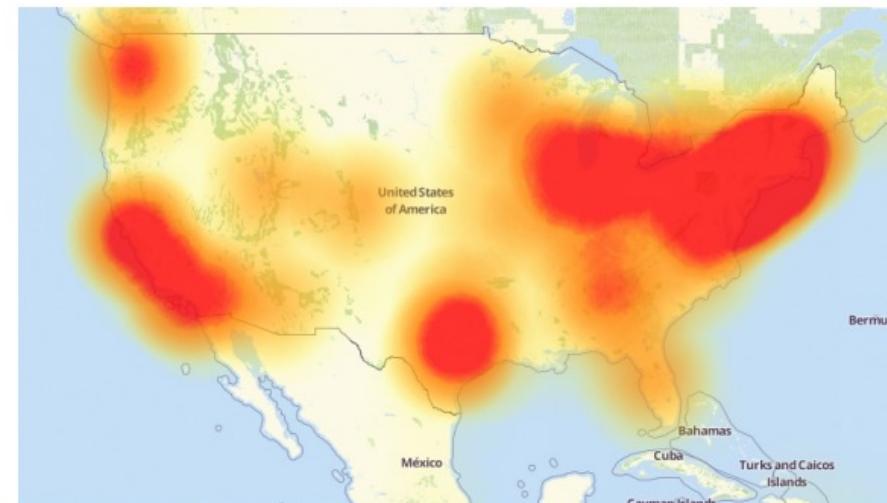


Hoover Dam Hydroelectric Generators (Wiki)

21 Hacked Cameras, DVRs Powered Today's Massive Internet Outage

OCT 16 A massive and sustained Internet attack that has caused outages and network congestion today for a large number of Web sites was launched with the help of hacked "Internet of Things" (IoT) devices, such as CCTV video cameras and digital video recorders, new data suggests.

Earlier today cyber criminals began training their attack cannons on **Dyn**, an Internet infrastructure company that provides critical technology services to some of the Internet's top destinations. The attack began creating problems for Internet users reaching an array of sites, including Twitter, Amazon, Tumblr, Reddit, Spotify and Netflix.



A depiction of the outages caused by today's attacks on Dyn, an Internet infrastructure company. Source: Downdetector.com.

From KrebsOnSecurity, 10/2016

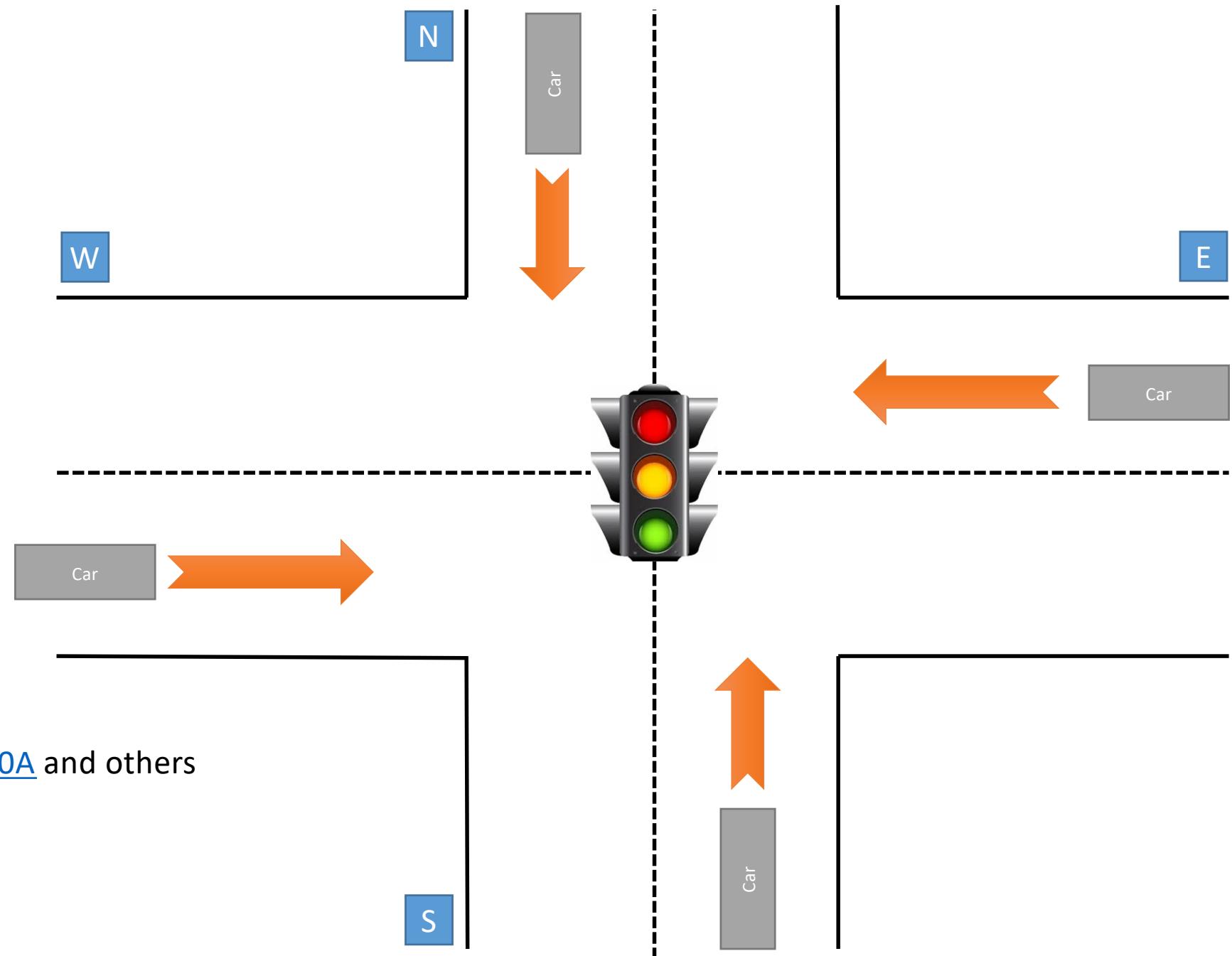
Cyberphysical Systems

More recent news

- Unpatched AVTECH cameras proliferating Corona Mirai botnet (2024)
- FCC Proposes measure to combat (domestic) abuse through connected cars (
- Wyze security camera patch allows users to see video from other users (2024)
- Pandoraspear botnet hijacks android-based smart TVs and boxes (2024)

Cyberphysical systems

Can we
guarantee that
no two cars will
occupy the same
space at the
same time?



See: <https://youtu.be/4pbAI40dKOA> and others

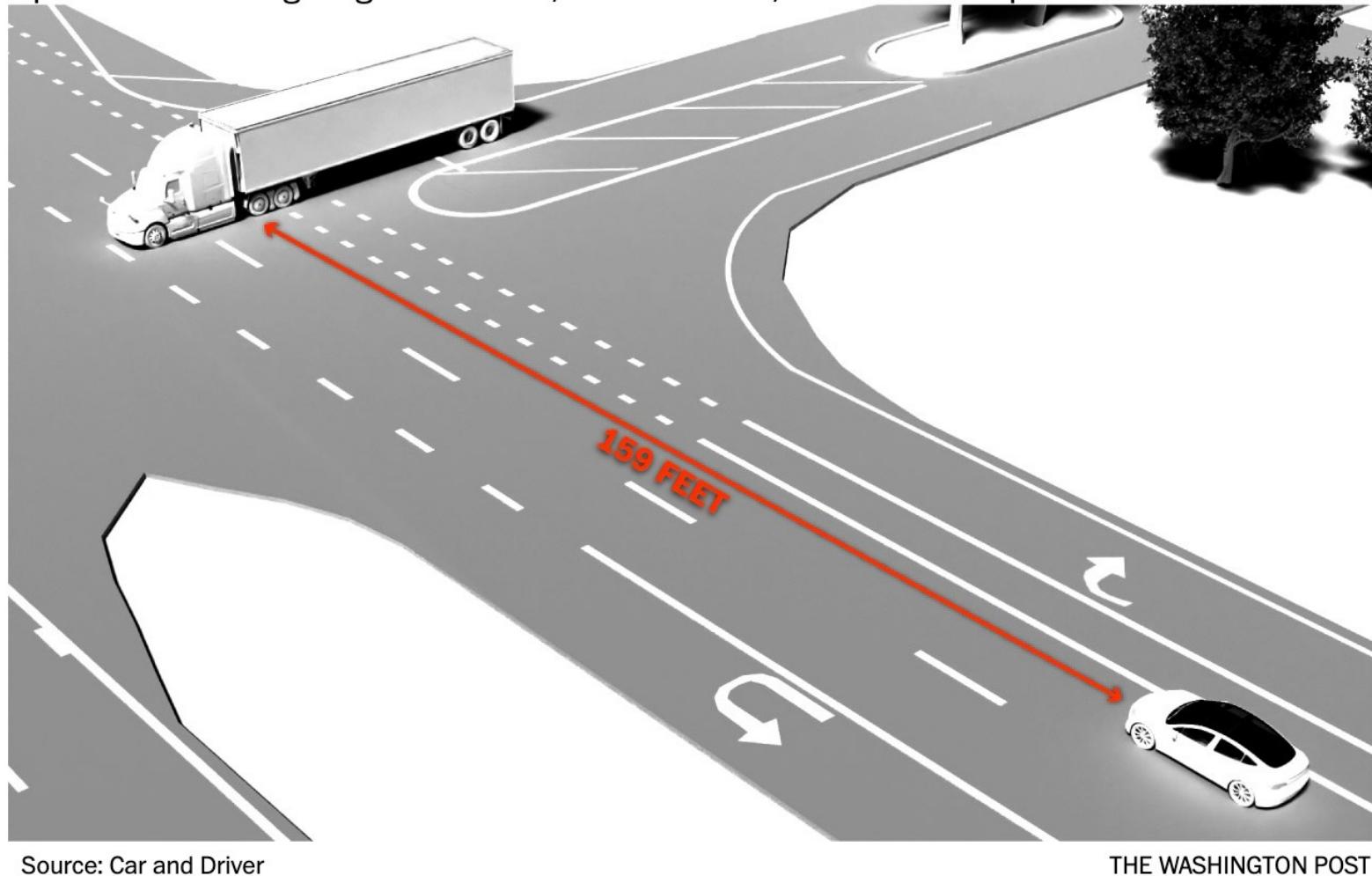
Cyberphysical Systems

Tesla crash

inattention and the truck driver's failure to fully yield to oncoming traffic were probable causes of the crash. However, the NTSB also cited Banner's "overreliance on automation," saying Tesla's design "permitted disengagement by the driver" and contributed to the crash

2019 Tesla Model 3 braking distance 70-0 mph

Specifications: Long-range dual motor, all-wheel drive, Michelin Pilot Sport 4 tires



From Washington Post

<https://www.washingtonpost.com/technology/interactive/2023/tesla-autopilot-crash-analysis/#>

Content areas

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5. **N-tier and distributed applications**

N-Tier and distributed systems



From Volvo

Prerequisites

- Basic computer organization
- Programming in C
- Design of a software solution for a “system” problem
- Working with basic electronics

We will program in C.
If you are not prepared to do this, then you should
reconsider taking the course

6 Quests in the course...

Quest 1: SmartPill Ingestible Sensor Due 9/20

This quest involves implementing periodic sensing using multiple modalities and time cycles, and reporting alarm conditions.

Skill cluster:

- 07 - [Battery](#)
- 08 - [Thermistor](#)
- 09 - [Photocell](#)
- 10 - [Console IO](#)
- 11 - [RTOS -- Multiple Tasks](#)
- 12 - [Hardware Interrupts](#)

Quest 2: CatTrack Due 10/4

In this quest you will create a wearable that will track activity of a cat using as a collar. It will show the cat's name, activity, and time in activity on the collar and will deliver data to a graphical display in real time.

Skill cluster:

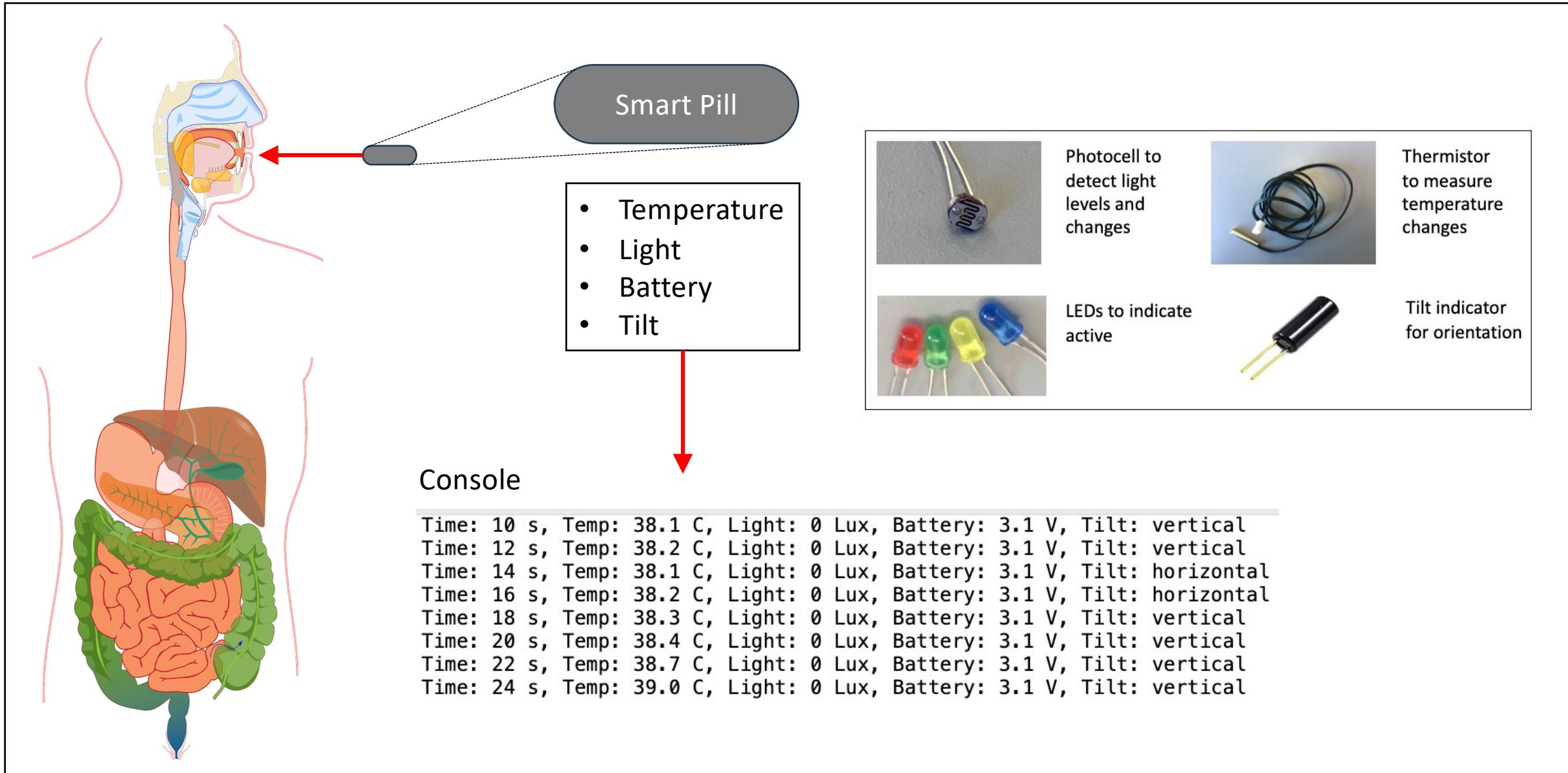
- 13 - [Alphanumeric Display I2C](#)
- 14 - [Timer](#)
- 15 - [Accelerometer I2C](#)
- 16 - [Node.js](#)
- 17 - [CanvasJS](#)

Quest 3: FitCat Due 10/24

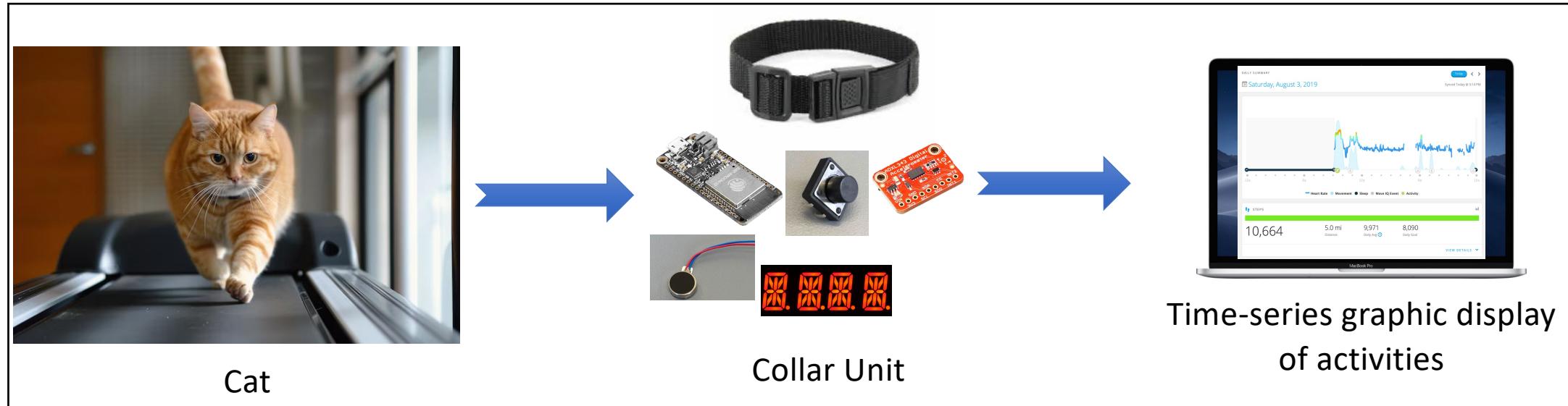
In this quest you will harness the data produced from cat fitness trackers to create a leaderboard for a feline social network. We'll also add video from a pi camera. Data will be sent from one camera plus multiple devices via WiFi to a server for web display.

- 18 - [Router Config \(team skill\)](#)
- 19 - [DDNS on Router \(team skill\)](#)
- 20 - [WiFi-ESP-Station](#)

Q1: Ingestible “Smart Pill”



Quest 2: Cat Collar Wearable



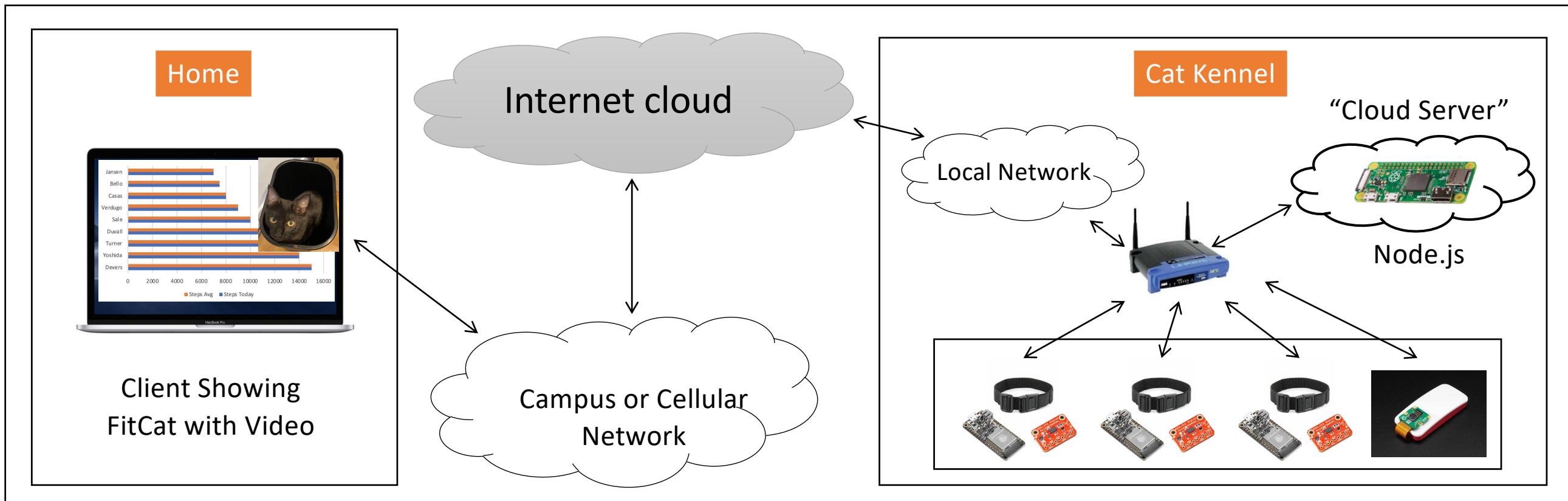
Functions

- Tracks active and inactive times
- Reports on activities vs time
- Button press displays cat name and current activity and time in activity

Key takeaways:

- I2C interfacing
- Alphanumeric display
- Using node
- Reporting and displaying results

Quest 3: FitCat Social Platform

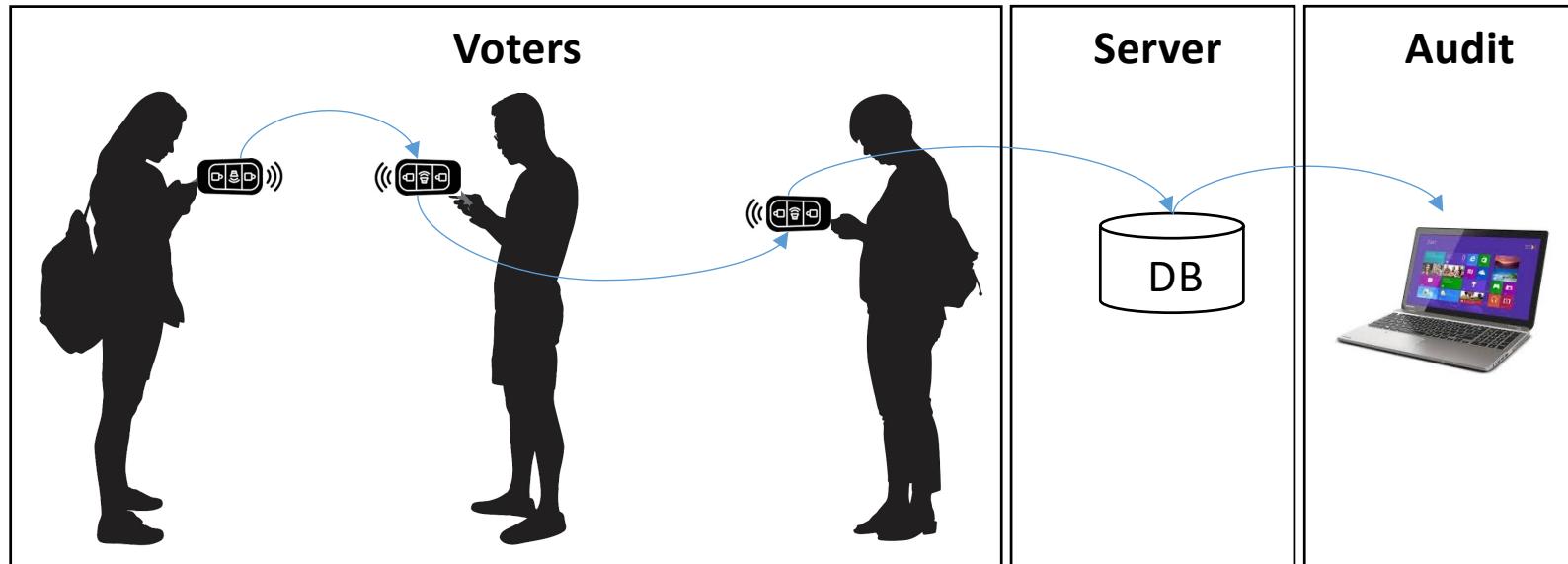


Key takeaways:

- Data aggregation
- Remote IP control
- Wireless embedded systems
- Webcam

- Multiple ESPs
- Nodejs on pi
- Video from pi added
- WiFi
- Hook to future database

Quest 5: Secure Voting



Key Takeaways

- Near Field Communications (NFC)
- Wireless security
- IoT provisioning
- Databases

Quest 5 – Personal Indoor Robot -- context

“Follow me” robots

Bluetooth wrist band, typically





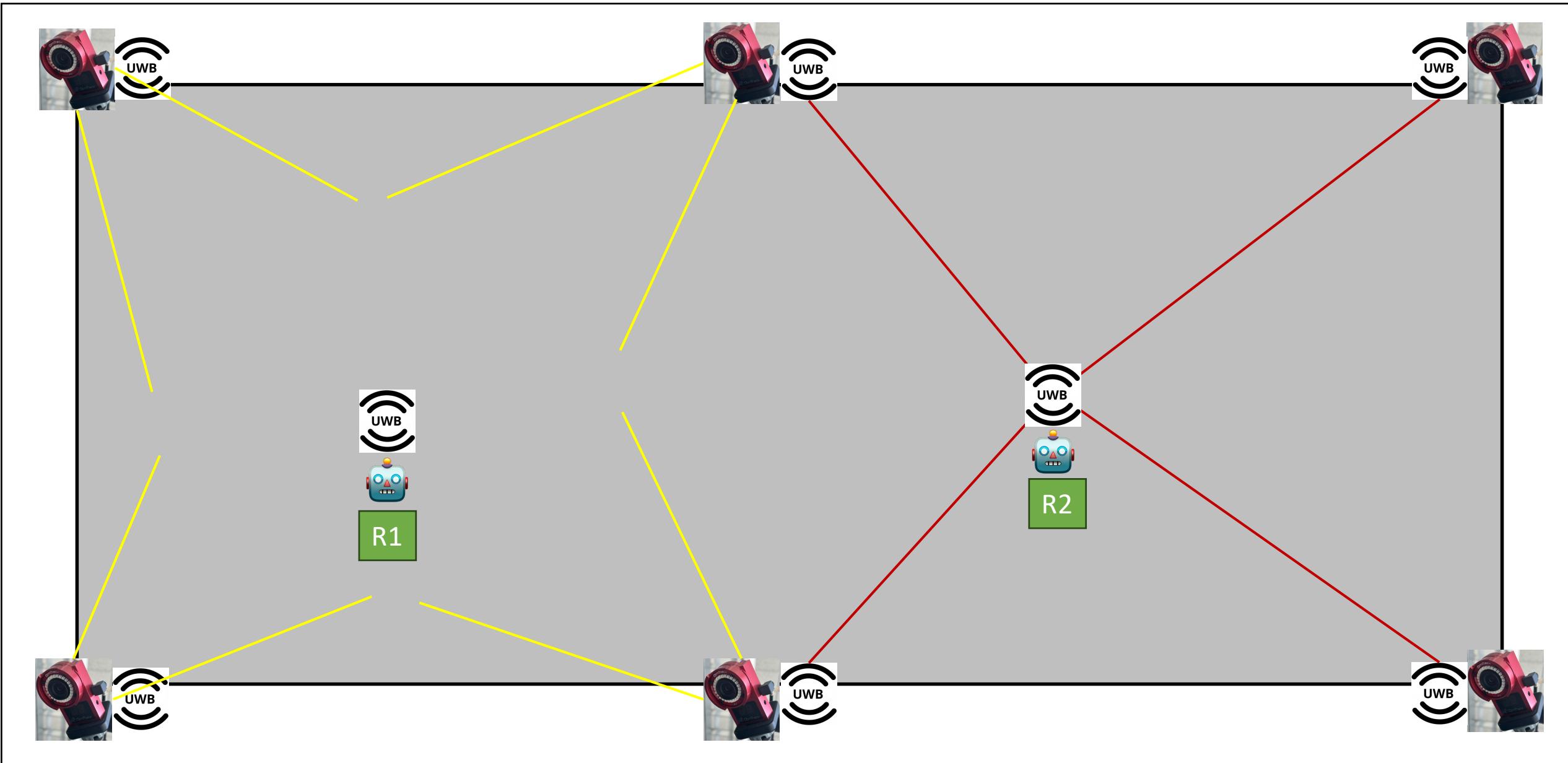
Hospitality robots

Follow map or navigational cues





Quest 5 – Infrastructure



Quest 6: Design your own quest

Must include:

- Car / real-time performance
- Database (tingo or equivalent)
- Remote control / DDNS
- Streaming video with pi cam
- Web client display graphical and/or tabulated data
- State models
- Use of multiple replicated ESP32 units with sensors

