

- 1) lot in the news**
- 2) Hardware we will use to build our own**
- 3) Demo of a small DIY IOT**

IOT Freshman Seminar

Thur Oct 19, 2023

Robert Cudmore

rhcudmore@ucdavis.edu

Delaying “lab” classes a bit

2) 10/26

3) 10/31

1) 10/24

4	7	10/19	Thur	- Demo: Introduction to wiring an Arduino with sensors and actuators.
5	8	10/24	Tue	Lab: Connecting sensors/actuators to an Arduino and communicating with a local cloud dashboard.
5	9	10/26	Thur	Lab: Connecting an Arduino to an internet cloud dashboard.
6	10	10/31	Tue	<ul style="list-style-type: none">- Personal bio-metric data and the IOT.- IOT in health care and biology research.- Citizen science and the IOT.

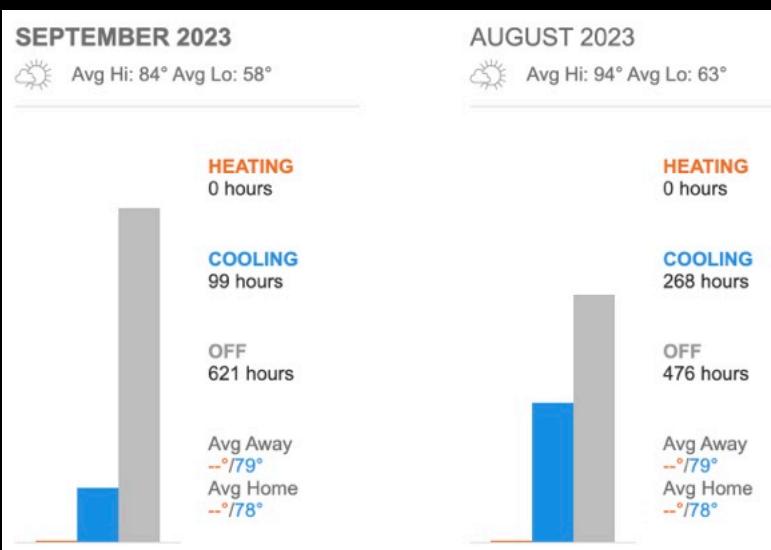


Smart Home - iot fail

Alexa asked me

“Would you like to finish your day
with a calm thought by listening
to a sports recap?”

Smart Thermostat (Honeywell)



Be an Energy Hero!

The Energy Hero Rewards program optimizes your thermostat to help prevent blackouts, by saving energy when it matters most. You may receive a \$75 e-gift card and a chance to win an e-bike! (sweepstakes administered by Leap)

[Learn More](#)

IOT system

- Monitors home energy usage
- Provides summary reports on usage
- Opt in to be an energy hero, have my heating/cooling remotely controlled

This IOT system **automates** and **optimizes** a whole process.

As an energy hero, the company's cloud computer will control my heating/cooling based on energy network data to reduce/prevent brownouts and blackouts

Shake Alert Wed Oct 8, 2023

Shake Alert Wed Oct 8, 2023

Managed by USGS (US Geological Survey)

Designed to detect earthquakes of 4.8 magnitude or greater

Ground movement sensors placed 6-12 miles apart

Transmit to a local shakealert center

Then to the cloud

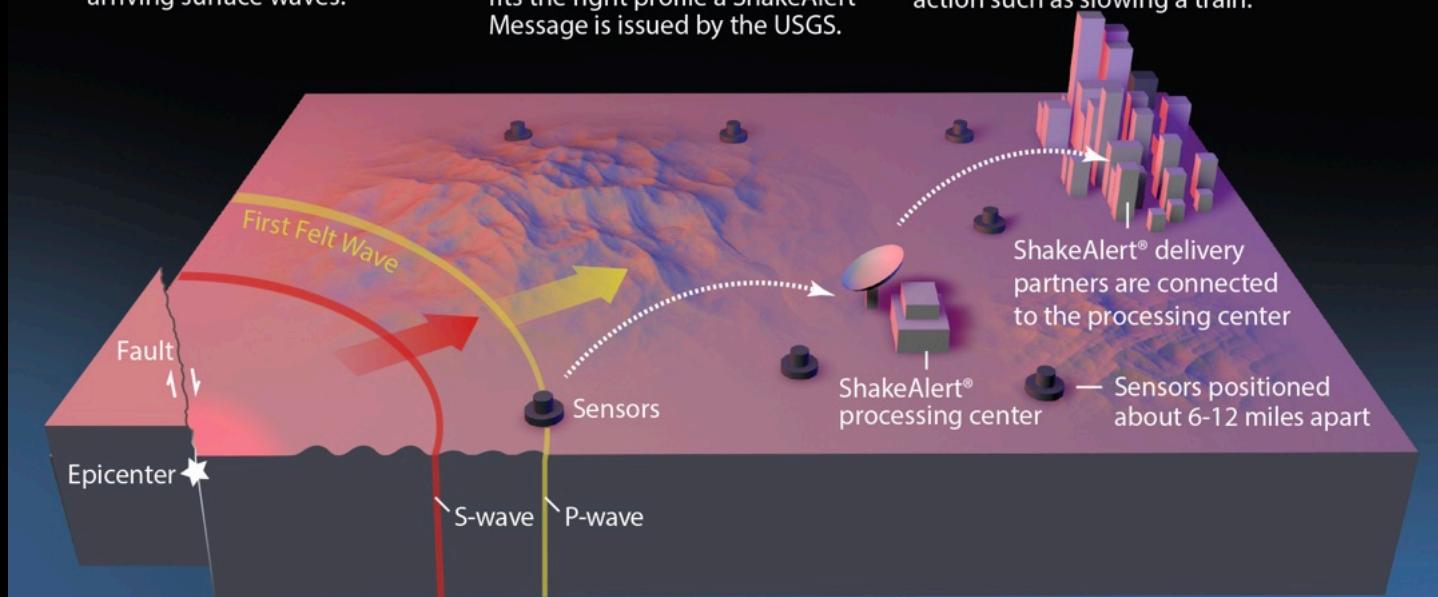
Then to your phone for an alert

All within 10 minutes of an earthquake

This IOT system **automates** and **optimizes** a whole process.

ShakeAlert® Earthquake Early Warning Basics

- 1 During an earthquake, a rupturing fault sends out different types of waves. The fast-moving P-wave is first to arrive, followed by the slower S-wave and later-arriving surface waves.
- 2 Sensors detect the P-wave and immediately transmit data to a ShakeAlert® processing center where the location, size, and estimated shaking of the quake are determined. If the earthquake fits the right profile a ShakeAlert® Message is issued by the USGS.
- 3 The ShakeAlert® Message is then picked up by delivery partners (such as a transportation agency) that could be used to produce an alert to notify people to take a protective action such as Drop, Cover, and Hold On and/or trigger an automated action such as slowing a train.



The first waves to arrive at a station are the lower amplitude P waves that travel at 5-6 km/s, on average.

The large amplitude (**more damaging**) S waves travel at ~3 km/s

Shake Alert Wed Oct 8, 2023

\$42.3 million to build
\$30.7 per year to maintain

Can we predict when an earthquake is going to happen?

With Warning



Without



In a serious earthquake, getting a cell phone warning a few seconds before the quake hits you can be a lifesaver

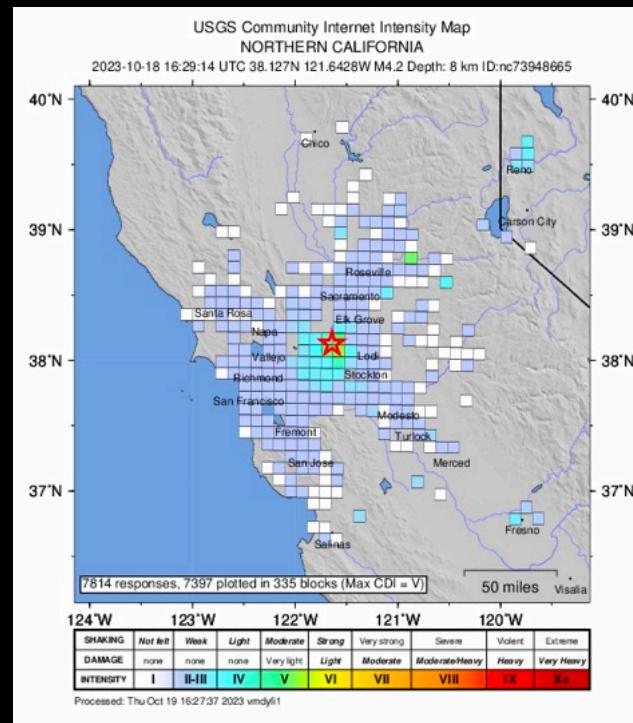
All starts with a distributed system of remote sensors transmitting real-time data

Shake Alert Wed Oct 8, 2023

Automatically generated maps



Citizen Science with “Did you feel it”



<https://earthquake.usgs.gov/earthquakes/eventpage/nc73948665/executive>

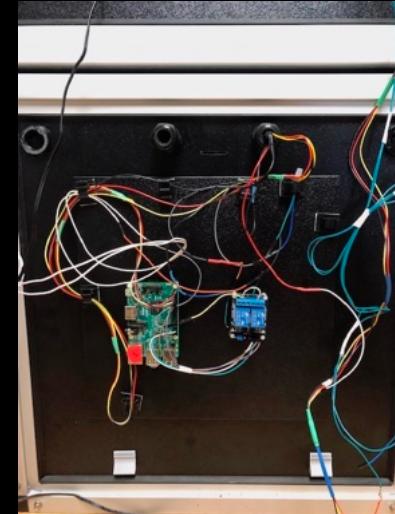
Open-Source Hardware in the lab

Open-Source Hardware in the lab

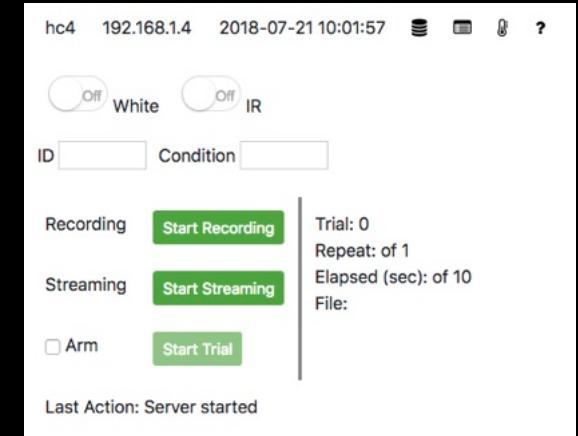
Behavior boxes
for mice to live in



Each has a
Raspberry Pi computer



Web interface to
monitor and
control the boxes



hc4 192.168.1.4 2018-07-21 10:01:57

Off White Off IR

ID: Condition:

Recording: Start Recording

Streaming: Start Streaming

Trial: 0
Repeat: 1
Elapsed (sec): 10
File:

Arm: Start Trial

Last Action: Server started

<https://cudmore.github.io/pie-doc/images/>

Open-Source Hardware in the lab

A

PiE Web Interface
Remote Control and Monitoring

The screenshot shows a web interface for a single Raspberry Pi unit (pi15). It displays a status bar with IP address (192.168.1.15), date (2019-01-01 17:45:02), and battery level. Below this is a control panel for a light source, with buttons for 'White' and 'IR'. A dropdown menu shows 'ID: a100 Condition: c1'. Underneath are buttons for 'Recording' (red) and 'Streaming' (green). A status message indicates 'Recording' and 'Trial: 1 of 5'. At the bottom, it says 'Status: Start trial 3 repeat 1 at 17:44:53'.

Raspberry Pi
Web and File Server
Video Recording/Streaming
Environmental Control

A diagram showing a Raspberry Pi board connected to a cloud icon labeled 'Internet'. Below the board is a double-headed arrow pointing to a photograph of a 'Behavior Box'. The Behavior Box is a clear acrylic enclosure containing a small animal (likely a mouse) and several mirrors. Wires from the box are connected to the Raspberry Pi board.

Behavior Box
Home Cage
Orthogonal Mirrors
Video Camera
White/IR Lights
Environmental Sensors/Actuators

B

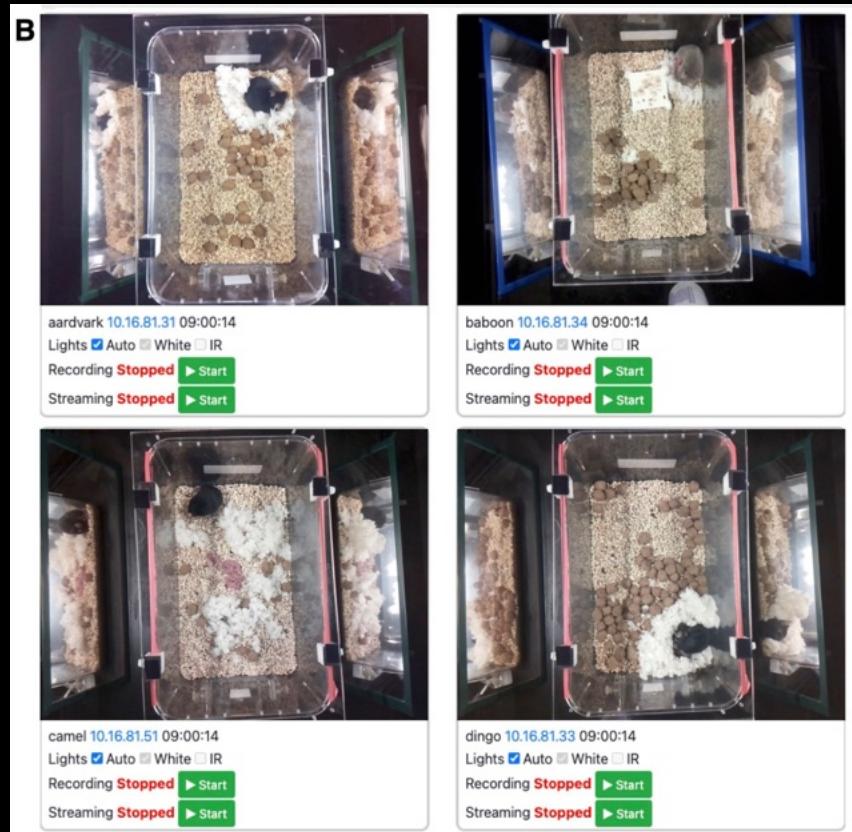
Swarm Web Interface
Remote Control and Monitoring

The screenshot shows a web interface titled 'Swarm Web Interface' for a 'Server Swarm'. It displays a table with columns for State, Record, Auto lights, White, IR, ID, Condition, Repeat Forever, Number of Repeats, Report Duration (sec), Elapsed (sec), Trial, Repeat, and File. The table lists three units: pi3, pi4, and pi15, all in a 'recording' state. The 'pi15' row has a dropdown menu set to '5'. The table also includes a timestamp (2019-01-01 17:55:26).

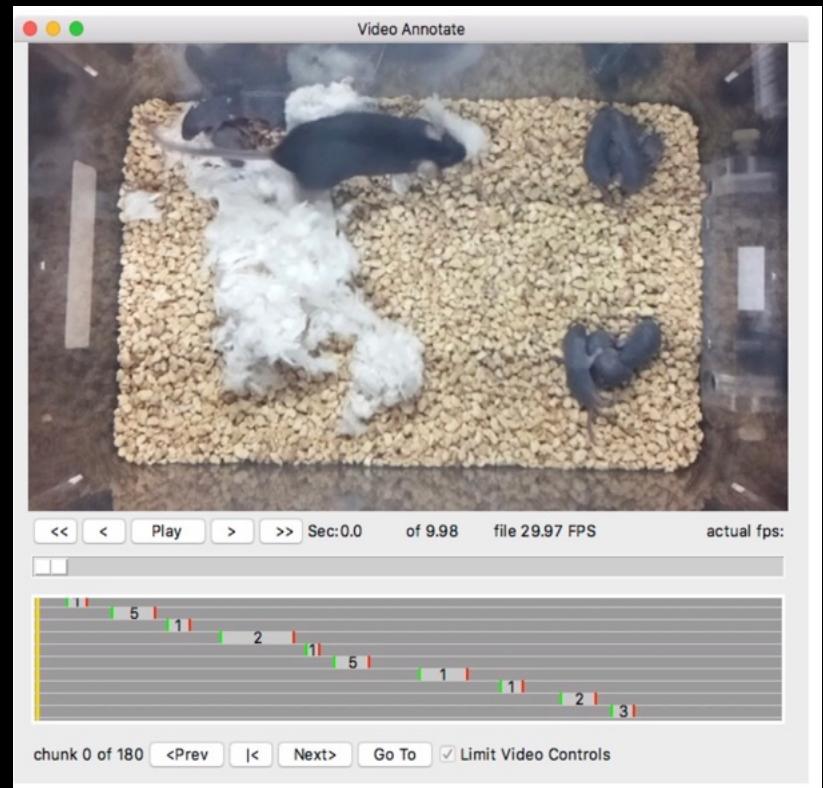
A diagram showing four Raspberry Pi boards connected to a central cloud icon labeled 'Internet'. Each Pi is connected to a separate photograph of a 'Behavior Box'. The boxes are arranged horizontally, with ellipses indicating more units in the swarm.

Open-Source Hardware in the lab

Video Monitor/Record (Web)



Video Annotate



Do we use machine learning?

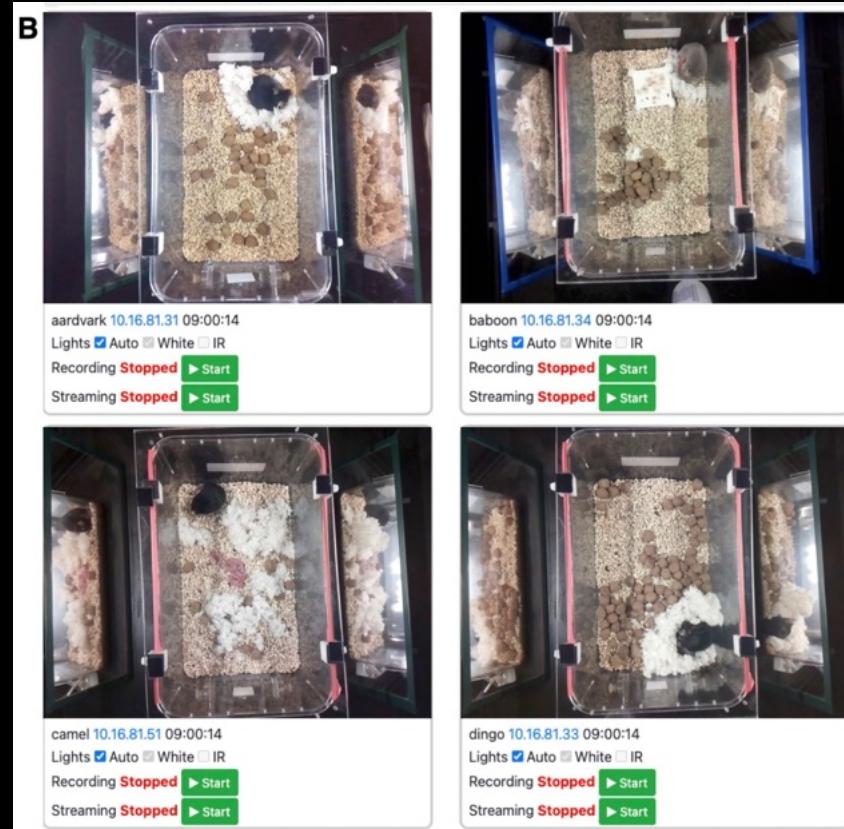
Open-Source Hardware in the lab

Why is this important?

Mouse behavior is critically dependent on the environment they live in

Behavior, especially maternal behavior can be disrupted if there are noises like people entering, leaving, opening and closing doors, talking, cleaning the room, etc ...

Thus we can fully remotely control everything



Open-Source hardware designers and distributors

Open-Source hardware designers and distributors



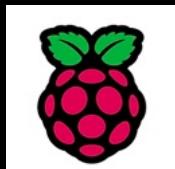
Arduino
<https://www.arduino.cc/>



Adafruit
<https://www.adafruit.com/>



Sparkfun
<https://www.sparkfun.com/>



Raspberry Pi
<https://www.raspberrypi.com/>



Digi-Key
<https://www.digikey.com/>

All these companies

- Design and build open-source hardware
- Sell their products

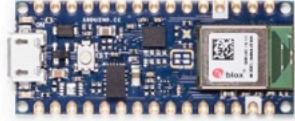
*** Provide extensive documentation, tutorials, and learning resources

Microcontrollers

Arduino

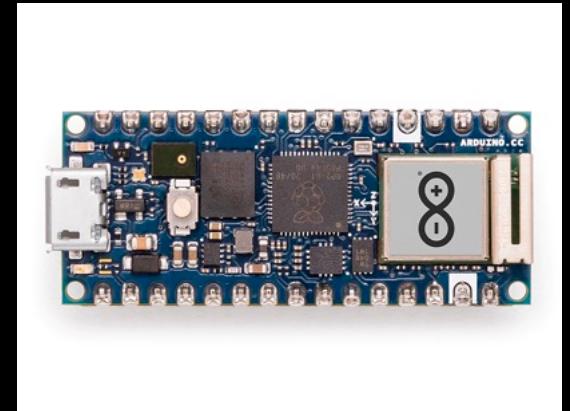
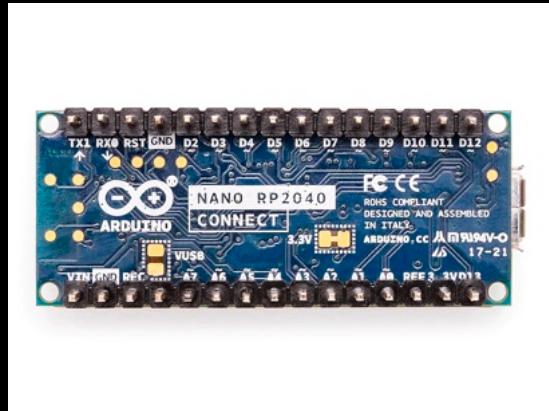
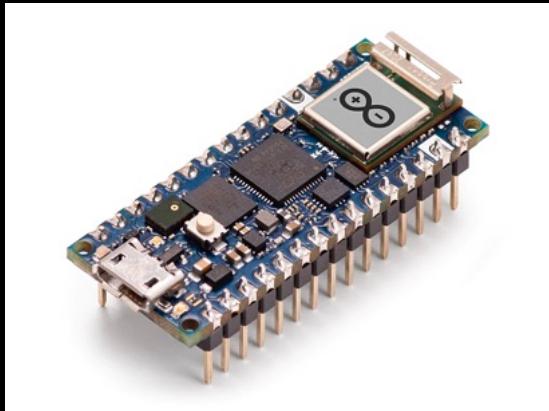
How are
“microcontrollers”
different from
“computers” like
laptop and cellphone?

<https://www.arduino.cc/>

			
Arduino Nano 33 IoT	Arduino Nano RP2040 Connect	Arduino Nano ESP32	Arduino Nano 33 BLE Sense
			
Arduino Nano 33 BLE	Arduino Nano Every	Arduino Nano	Arduino Nano Motor Carrier

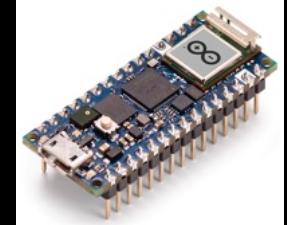
Microcontrollers

Arduino - “Nano RP2040 Connect”



CPU is designed and manufactured by Raspberry Pi Foundation
Nano board is designed, manufactured and sold by Arduino
Adafruit and Sparkfun have done the same

Arduino - “Nano RP2040 Connect”



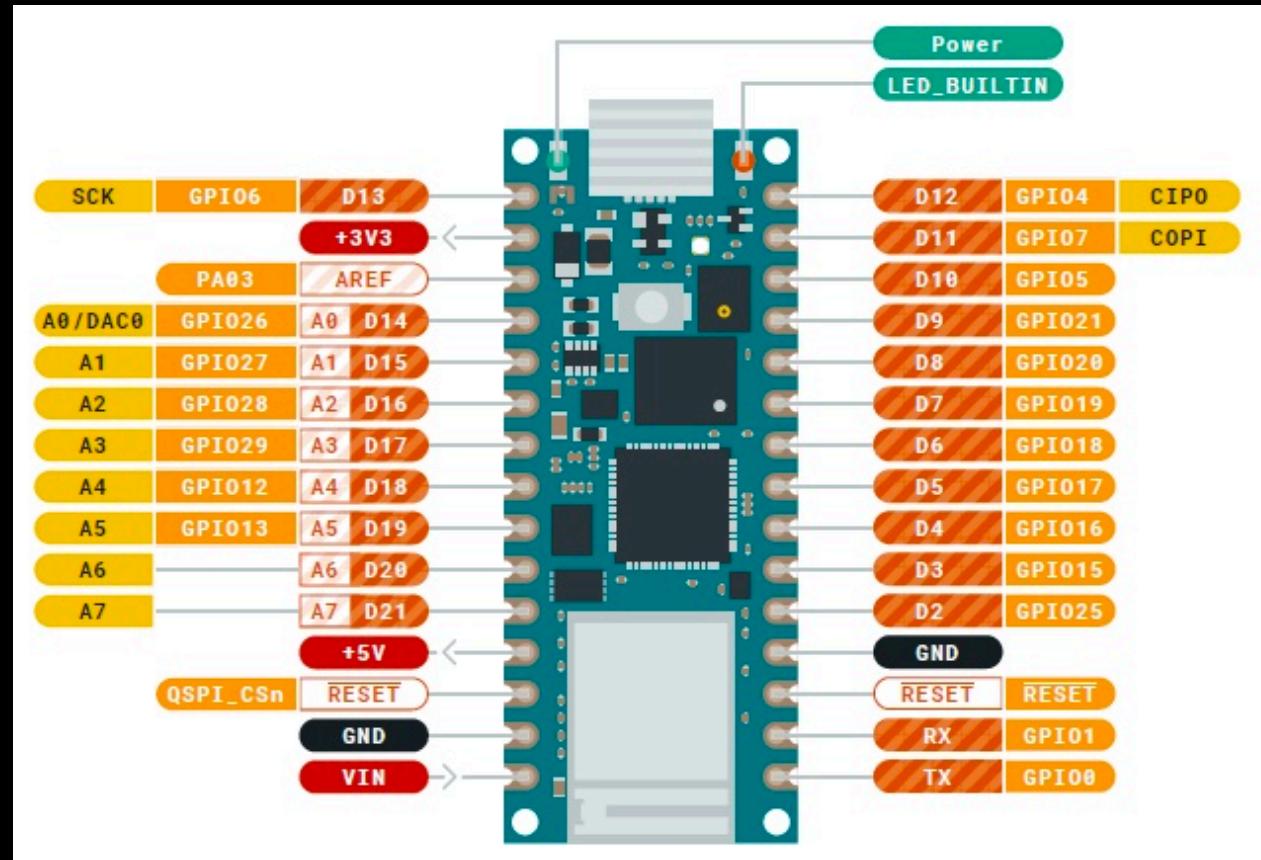
What is included?

Wifi
Bluetooth

Red LED
RGB LED
Microphone
Gyroscope
Accelerometer

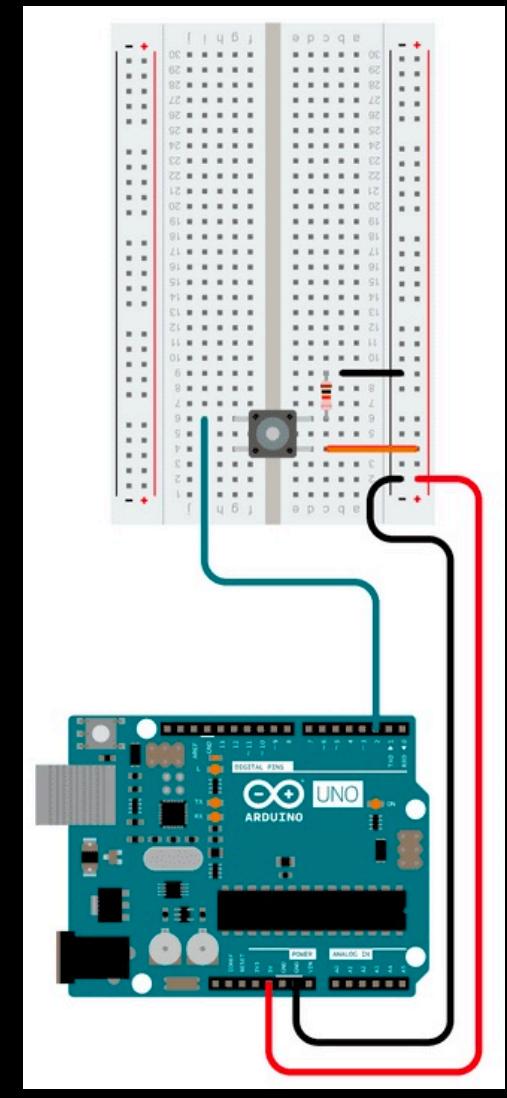
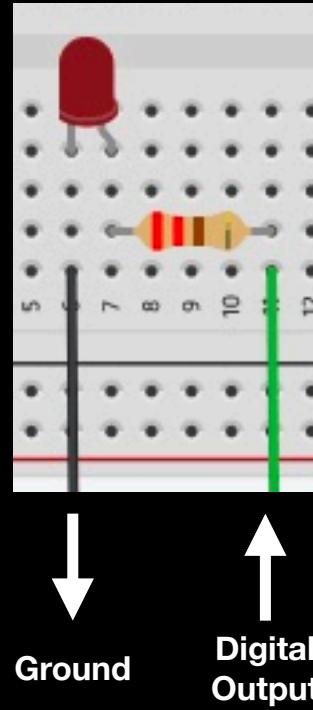
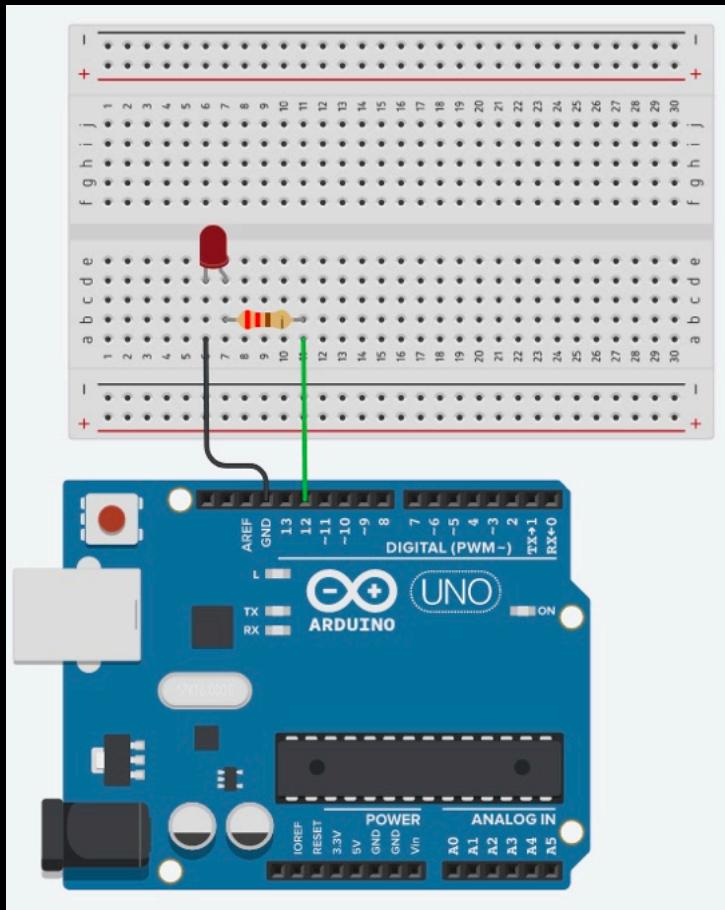
Pins Provide

**7 Analog input
12 Digital output**



Sensors and Actuators

Wiring a sensor and actuator

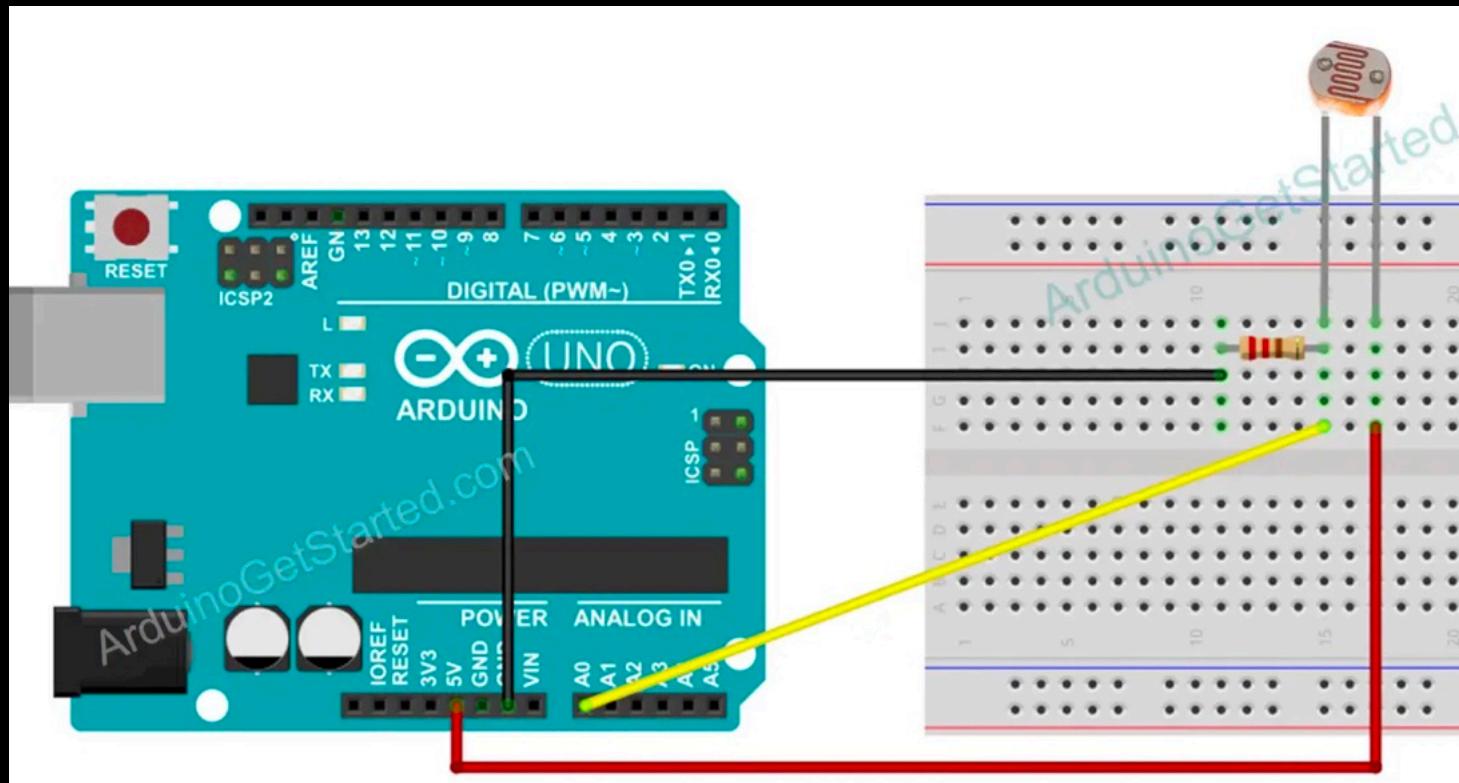


Wiring a sensor and actuator

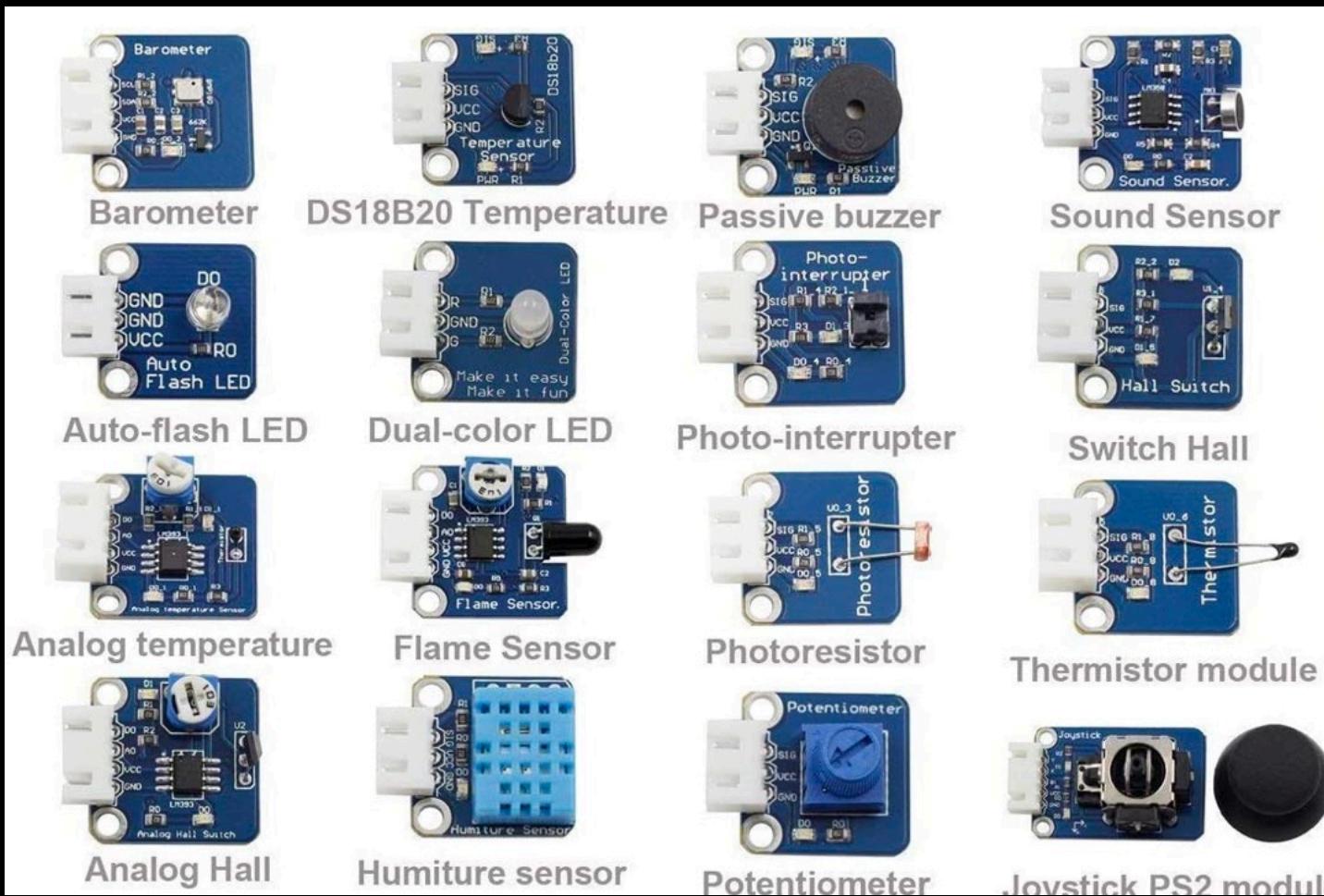
Light Sensor



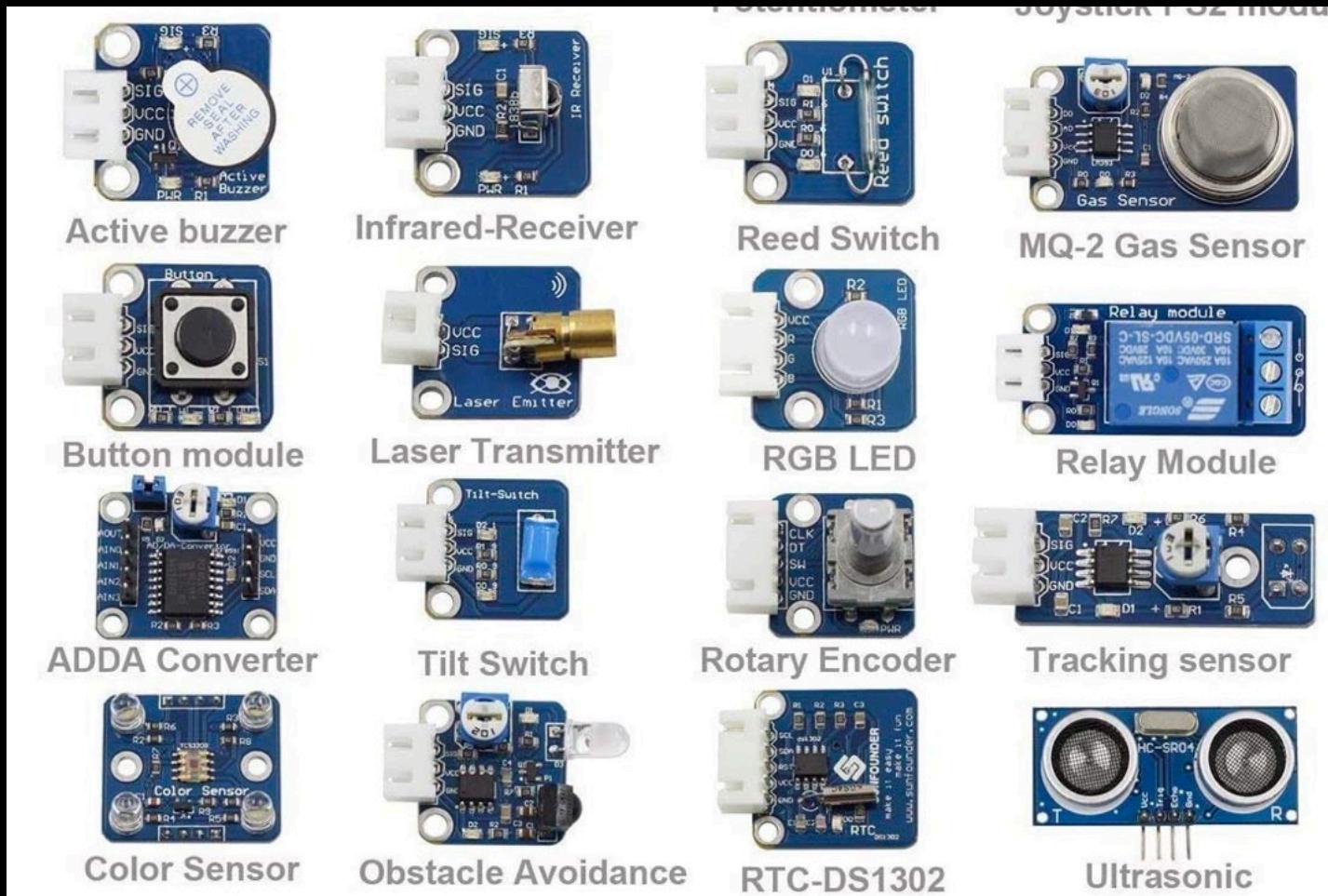
A variable resistor that changes when there is more or less light



Sensors and Actuators



Sensors and Actuators



Sensors and Actuators

- Soil humidity/moisture
- PIR motion sensor
- Motors
- Capacitive touch (triggers when touched, like your smart phone screen)
- Pressure sensor (analog signal representing pressure)



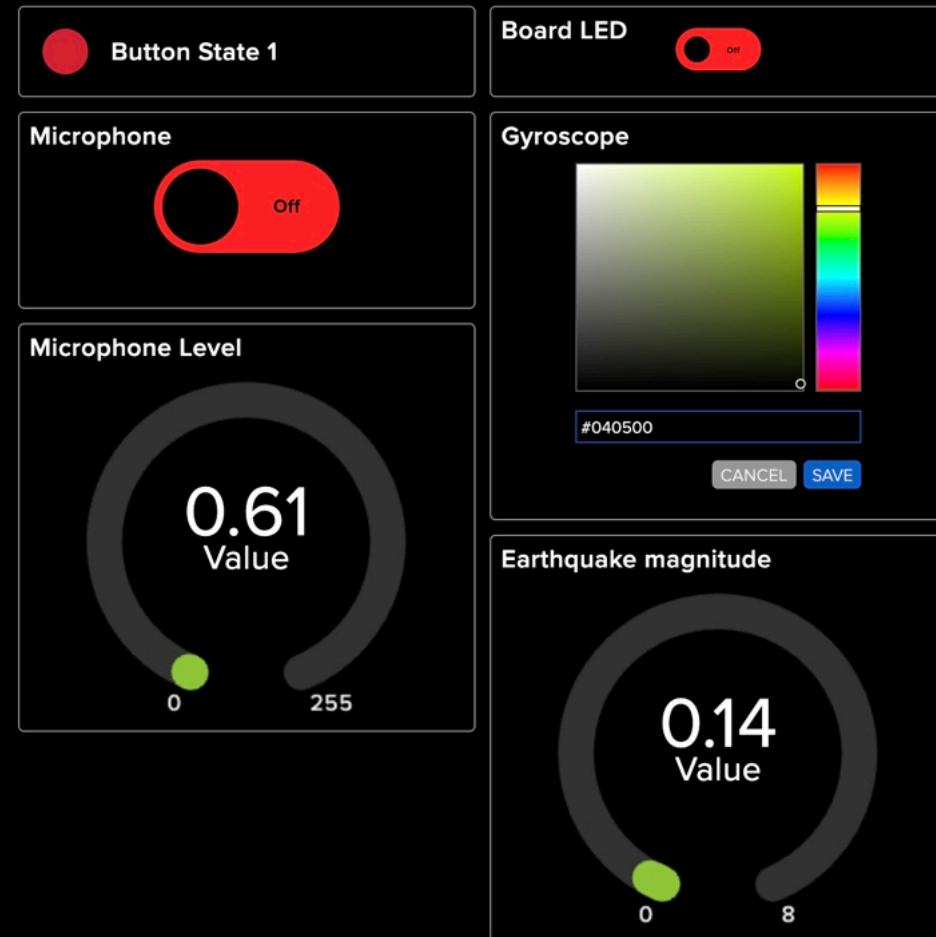
Adafruit-IO



Cloud computing with dashboard

- Dashboard is updated by thing
- Thing can update dashboard

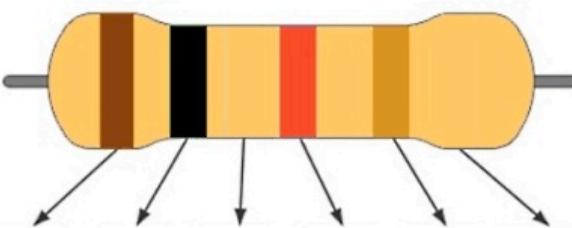
rhcudmore / Dashboards / iot-2023-dashboard



<https://io.adafruit.com/rhcudmore/dashboards/iot-2023-dashboard>

Resistor Color Calculator:

Resistance: 10K Ω 5%



1st	2nd	3rd	Mul.	Tol.	TCR.
-	-	NOT USED	-	-	NOT USED
0	0	0	1	1%	-
1	1	1	10	2%	100
2	2	2	100	-	50
3	3	3	1k	-	15
4	4	4	10k	-	25
5	5	5	100k	0.5%	-
6	6	6	1M	0.25%	10
7	7	7	10M	0.1%	5
8	8	8	100M	0.05%	-
9	9	9	1G	-	-
-	-	-	0.1	5%	-
-	-	-	0.01	10%	-

Network Protocols

MQTT

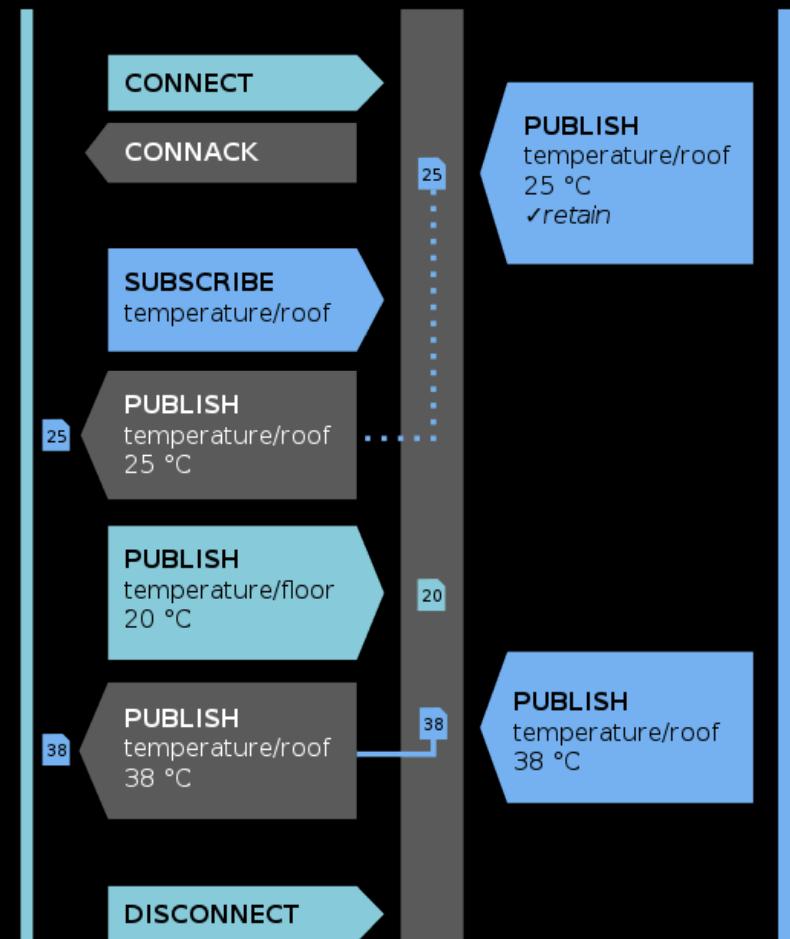
Network Protocols

MQTT

- MQTT: MQ Telemetry Transport. The MQ part is no longer an acronym, referred to some internal software when this was being designed at IBM.
- Designed as an extremely lightweight publish/subscribe messaging transport
- Ideal for connecting remote devices with a small code footprint, limited resources, and minimal network bandwidth.
- MQTT today is used in a wide variety of industries, such as automotive, manufacturing, telecommunications, oil and gas, etc.
- The protocol is an open OASIS standard and an ISO recommendation (ISO/IEC 20922).

MQTT

- Requires a server call an “MQTT Broker”
- Devices with sensors and actuators can either “subscribe” or “publish” to a “topic”
- A topic is uniquely identified using a string, usually of the form:
 - huzzah1/led1
 - huzzah2/temperature1
- The broker is very light-weight and just sits and waits for other devices to either “subscribe” or to “publish”
- When broker receives “publish” data it sends it to all who have “subscribed”
- Important: Publishers don’t need to know who has subscribed or the number of subscribers



MQTT

MQTT software is available most everywhere

- Because MQTT is an open standard, a number of client and broker software are available
- Can be installed on anything:

macOS, Windows, Linux

microcontroller (Arduino)

Raspberry Pi computer (Linux)

Smart Phone