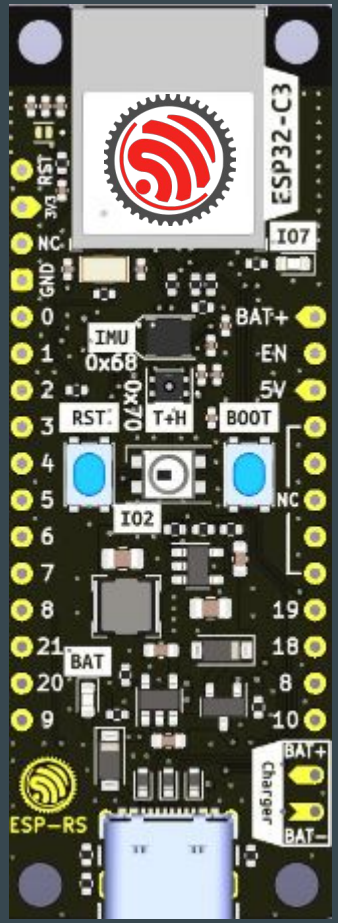
Development with ESP32 and Matter



2023-04-25
FEKT VUT - Brno

Juraj Michálek - Espressif Systems

Espressif System

Espressif Systems (688018.SH) is a public multinational, fabless semiconductor company established in 2008, with offices in China, the Czech Republic, India, Singapore and Brazil.

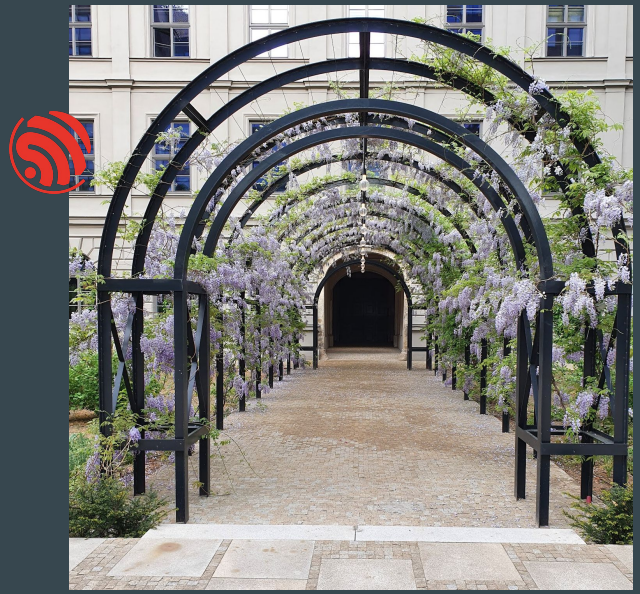
ESP8266 - WiFi

ESP32 - dual-core

ESP32-S, ESP32-C and ESP32-H series

Open source: https://github.com/espressif

Espressif in Brno



Near Main train station

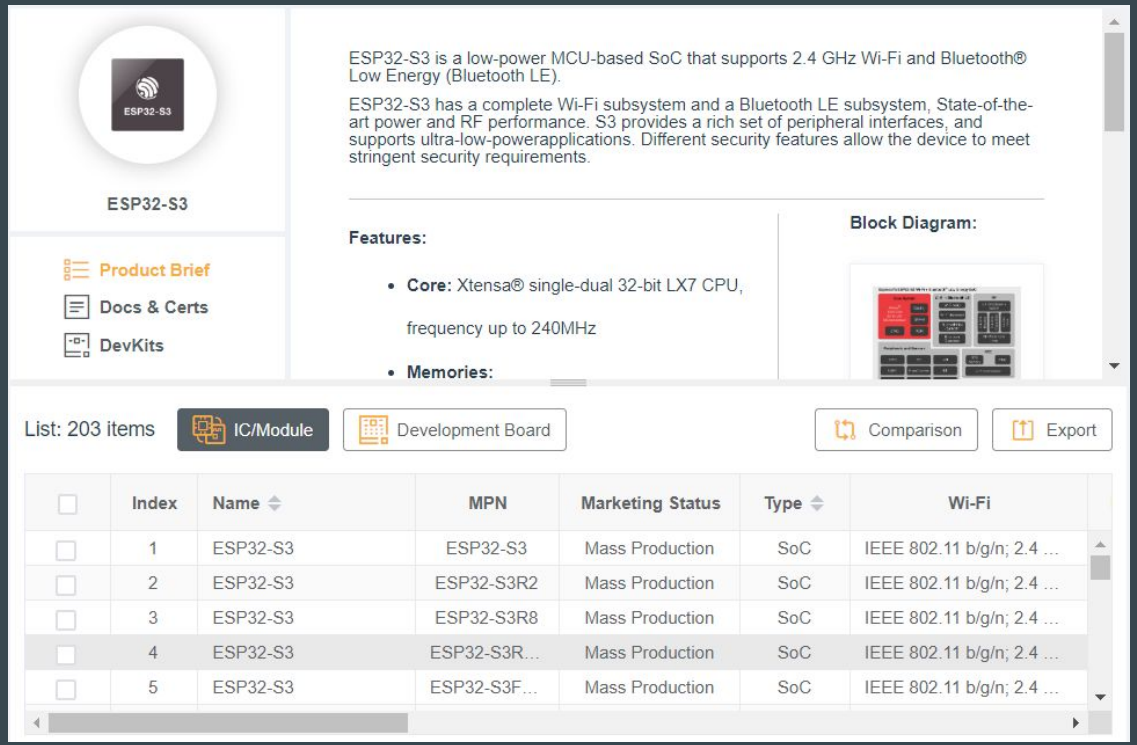
Espressif Systems (Czech) s.r.o.

Přízova 3, 602 00 Brno

Czechia, Europe

Many chips, many boards - quick help

https://products.espressif.com/



OSes and integration

ESP-IDF (OS based on FreeRTOS) - https://github.com/espressif/esp-idf

no_std a.k.a. bare metal with Rust - https://github.com/esp-rs/esp-hal (minimalistic)

Zephyr - https://zephyrproject.org/

- EDC22 Day 1 Talk 10: Applications of Asymmetric Multiprocessing with ESP32 Devices - including Rust on one core - https://youtu.be/oble9ObAqxM

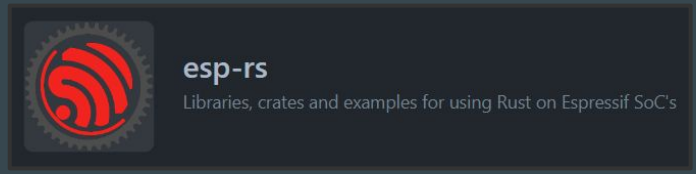
NuttX - https://nuttx.apache.org/ (as app, Linux-like OS)

SVD files: https://github.com/espressif/svd

Programming languages

Active support by Espressif teams

- C/C++
  - most common choice - https://github.com/espressif/esp-idf
- Rust
  - recommended for new design evaluation - https://github.com/esp-rs
  - security and memory guaranties of Rust
  - multi-target Xtensa, RISC-V, plus WASM, desktops or mobile
- Arduino - Maker choice
  - Arduino IDE 2.x
  - note: check the license for production



Languages and frameworks

New and noteworthy:

- Ada/Spark - from AdaCore
- Embedded Wizard - DSL and C
- Zig

VM based:

- CircuitPython and MicroPython - Python-like language
- Toit
- Nanoframework - C# language
- Mongoose OS
- Lua
- downside: bigger VM
- upside: more robust, comes with OTA and monitoring

IDE

Supported by Espressif:

- VS Code with Espressif Extension - https://docs.espressif.com/projects/esp-idf/en/stable/esp32/get-started/vscode-setup.html
- Espressif IDE - https://dl.espressif.com/dl/esp-idf/

Supported by JetBrains:

- CLion - https://www.jetbrains.com/clion/

Supported by SysProgs

- Visual Studio with VisualGDB - https://visualgdb.com/

Supported by TARA Systems

- Embedded Wizard - https://www.embedded-wizard.de/

SysProgs

Embedded Wizard

GUI Solutions by TARA Systems

Quick prototyping

Free for students

Supports ESP32, WASM or Desktop

wokwi.com/rust

Contribute: https://github.com/wokwi

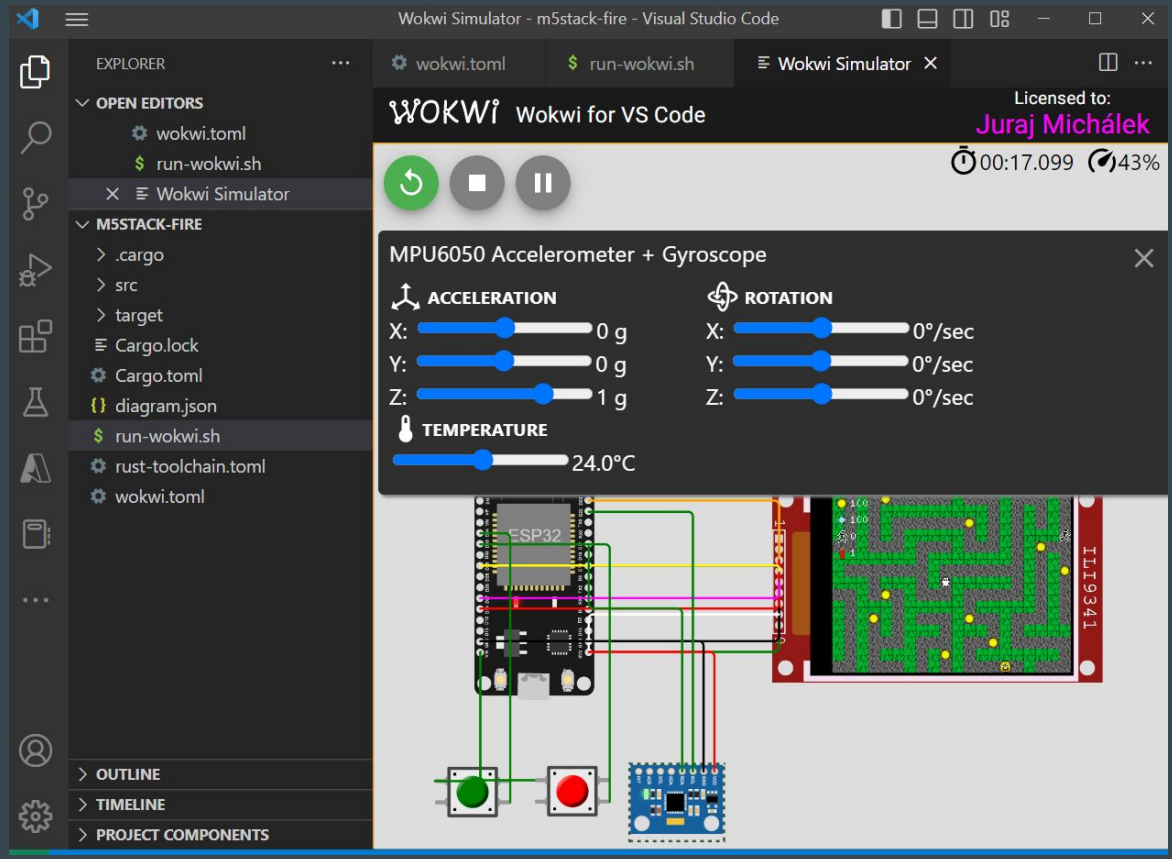
EDC22 Day 1 Talk 9: Your browser is ESP32 - Wokwi - https://youtu.be/TKe4MgD6O8o

Wokwi - VS Code Plugin

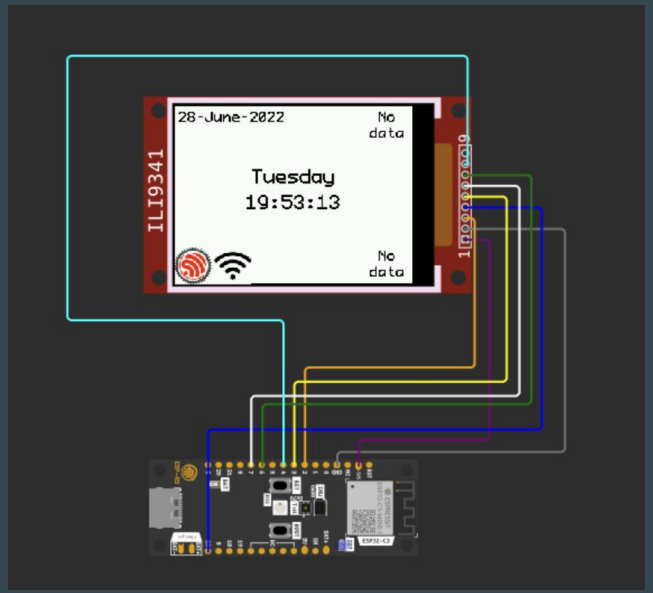
Add wokwi.toml and diagram.json

to your project

CTRL+Shift+P - Wokwi: Start Simulator



Development containers and Wokwi



https://github.com/playfulFence/esp-clock#dev-containers

GUI

- LVGL - with SquareLine Studio
- Embedded Wizard
- QT for MCU
- Slint
- Rust bare metal with Embedded Graphics

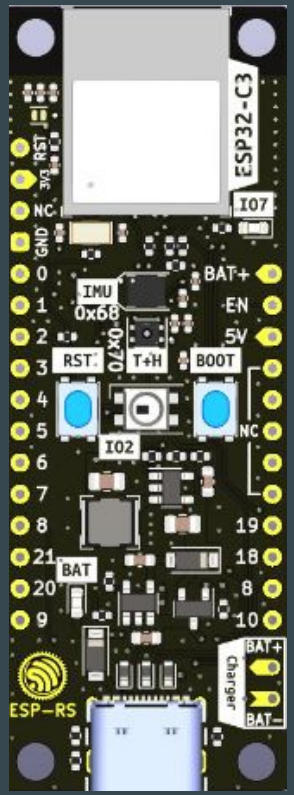
Designing Open Hardware - esp-rust-board

KiCad templates

https://github.com/esp-rs/esp-rust-board

ESP32-C3-DevKit-RUST-1 (available at Mouser, AliExpress)

https://www.espressif.com/en/products/devkits



Some examples of ESP32 based projects

CTAG-TBD

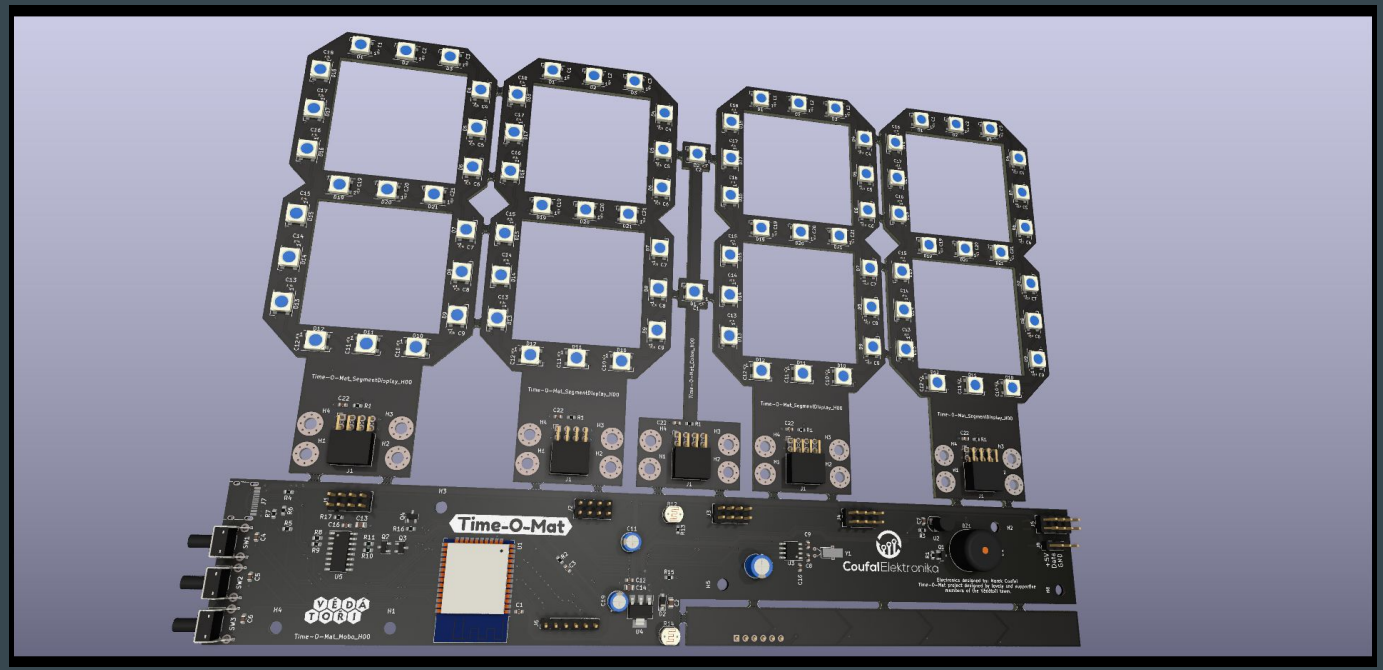
CTAG TBD >>to be determined<< an extendible

open source Eurorack sound module

https://github.com/ctag-fh-kiel/ctag-tbd

Time-O-Mat - built at summer camp

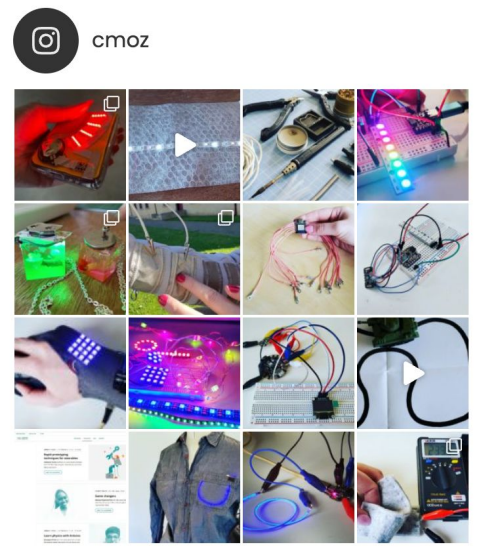
https://github.com/vedatori/Time-O-Mat



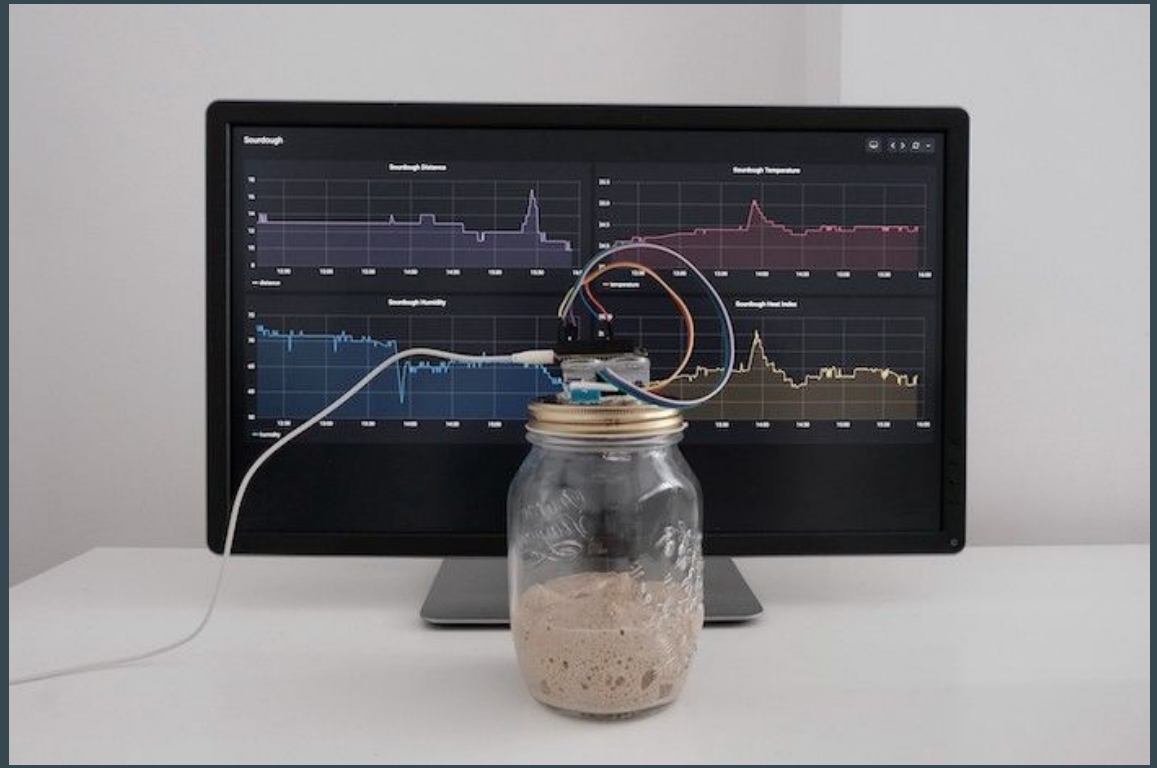
Wearables

The Ultimate Guide to Informed Wearable Technology

- book: https://packt.link/01VBv



Grafana



https://grafana.com/blog/2020/06/17/how-to-monitor-a-sourdough-starter-with-grafana/

https://github.com/grafana/diy-iot - Arduino now. We're not Rust yet :)


matter

Many Problems of Home Automation and IoT

Silos

Fragmentation

Security

UX

Development

Certification

...

Matter 1.0

Repo: https://github.com/project-chip/connectedhomeip

Specs: https://csa-iot.org/developer-resource/specifications-download-request/

Matter for end user

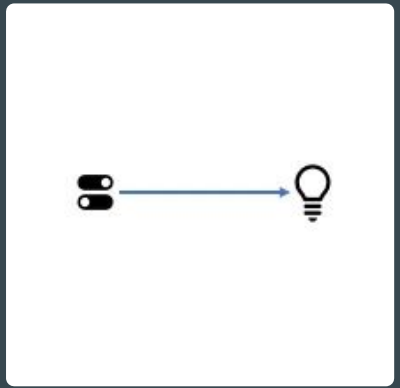
No more silos

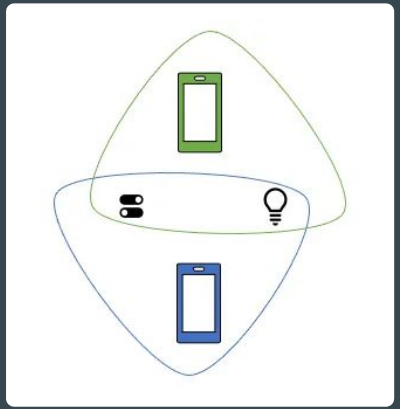
More automation - device-to-device communication

No more transport silos

More ecosystems

Better security





https://blog.espressif.com/what-does-matter-mean-to-you-fa3bb53a7793

Matter for device makers

Ease of development

Power of open

Device-to-device automation

Matter ecosystems

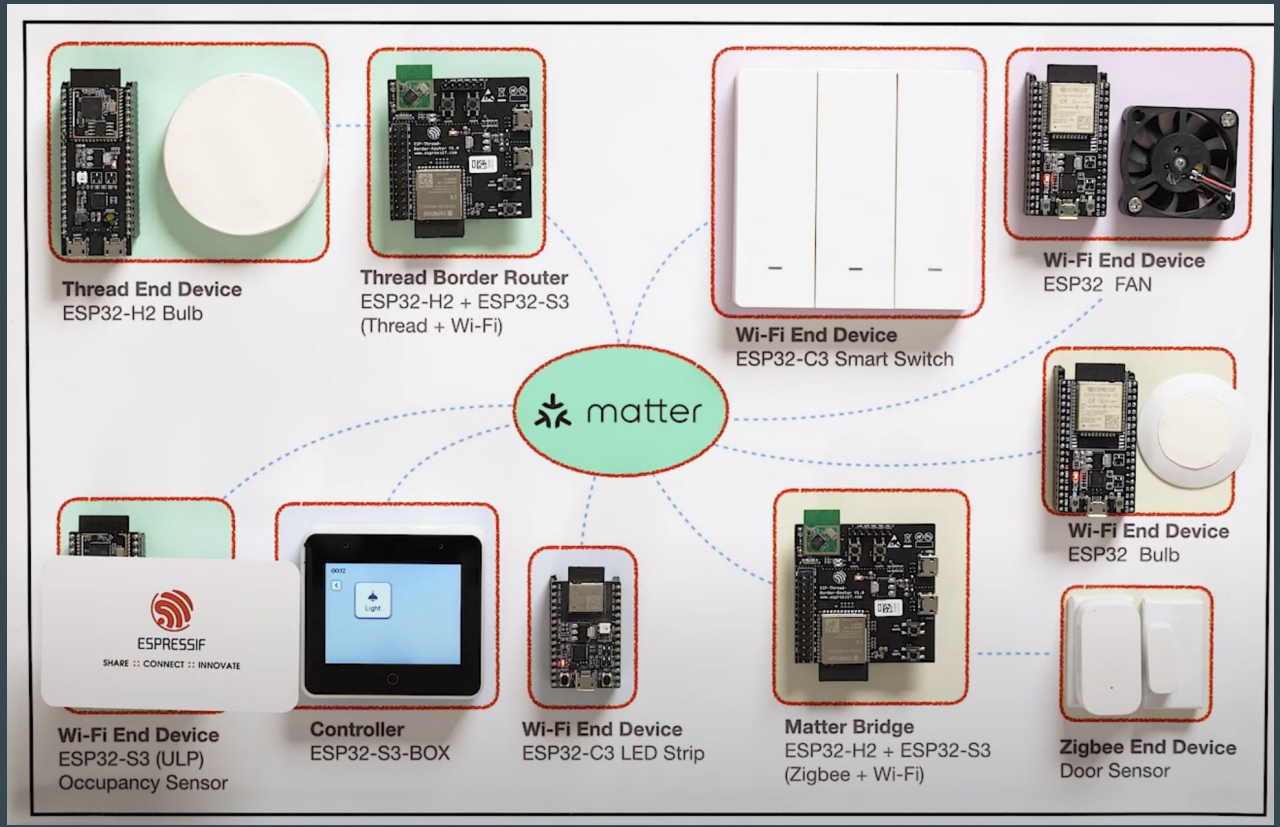
Manufacturer-specific innovations

Espressif and Matter

Support for ESP32 is upstream
https://github.com/project-chip/connectedhomeip/tree/master/examples/all-clusters-app/esp32

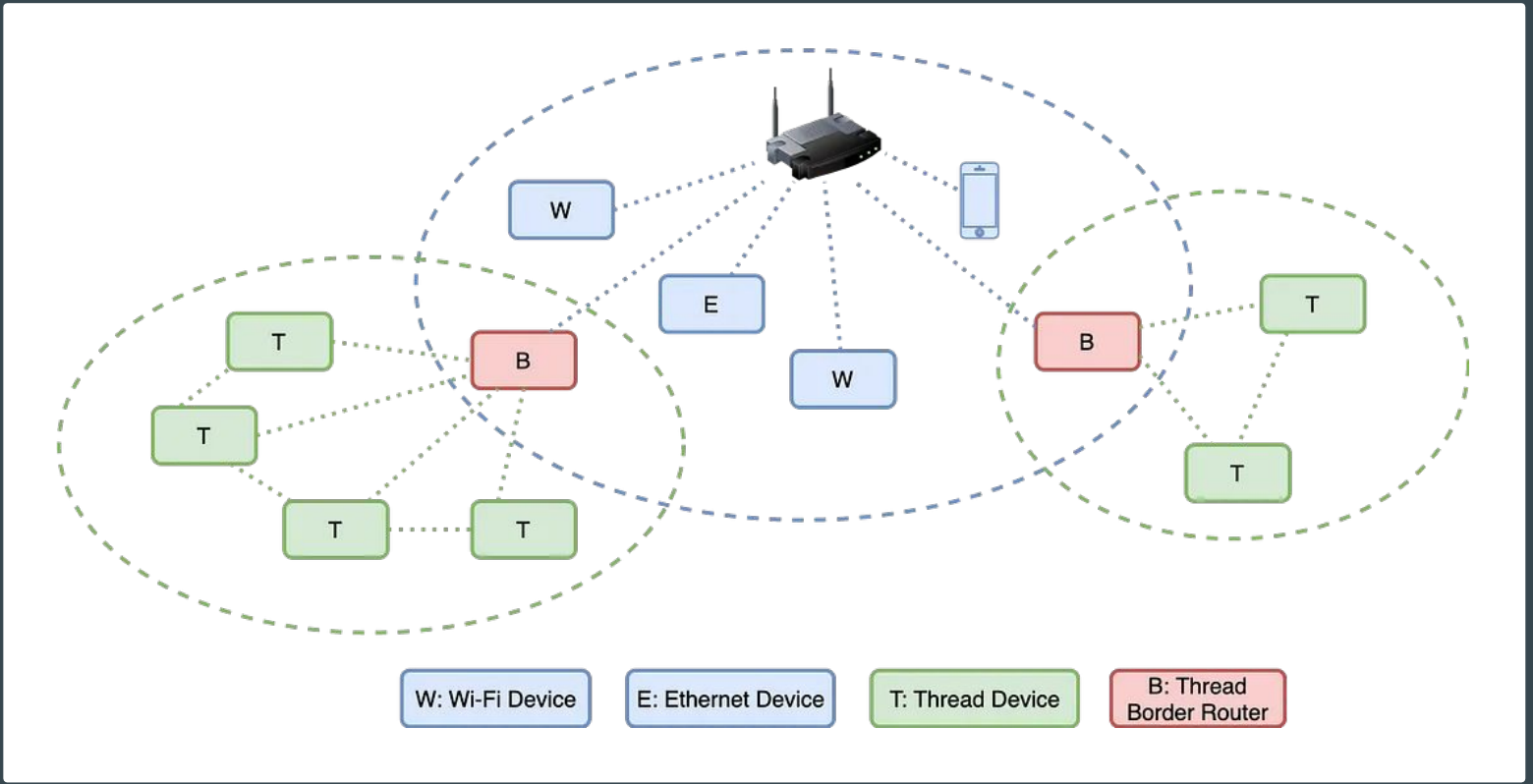
esp-matter project - https://github.com/espressif/esp-matter

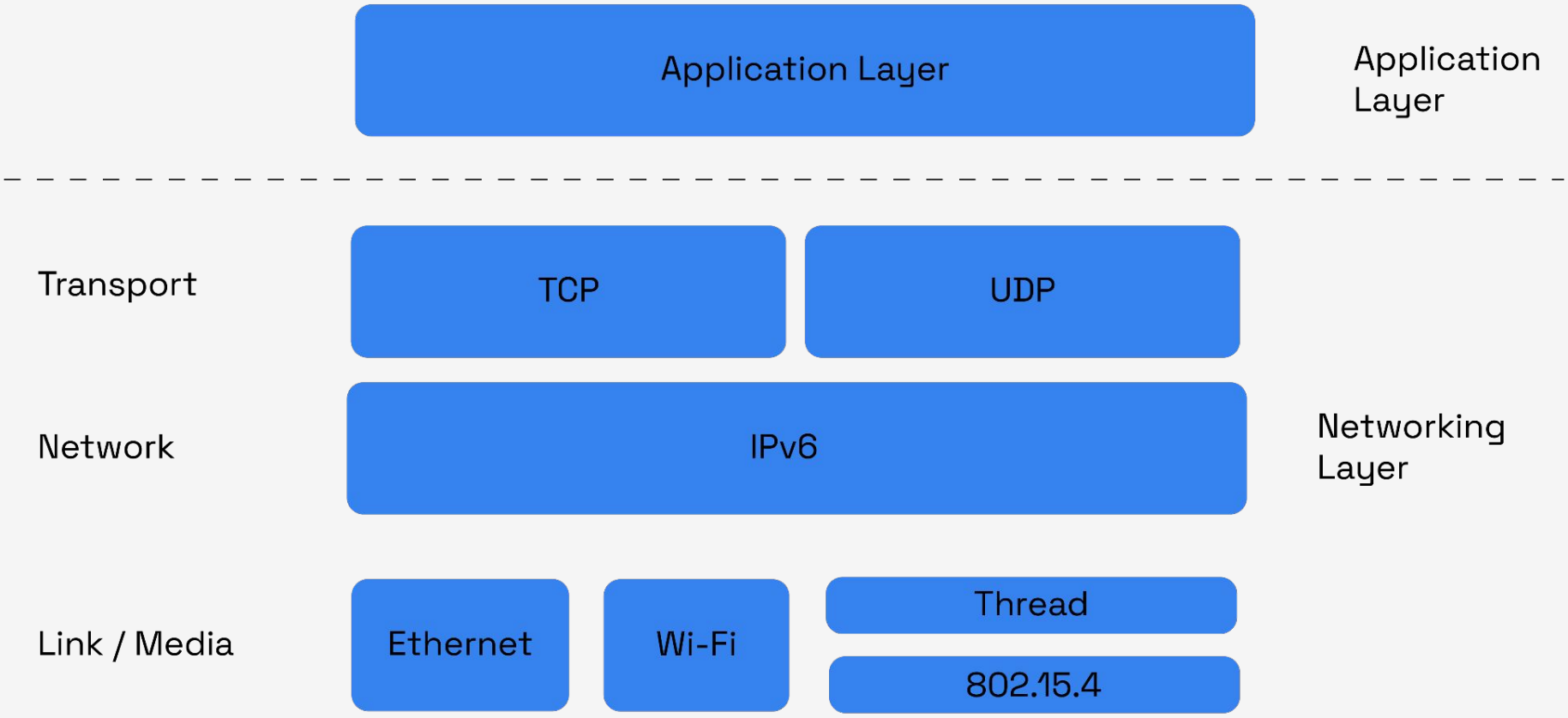
matter-rs - Rust - https://github.com/project-chip/matter-rs



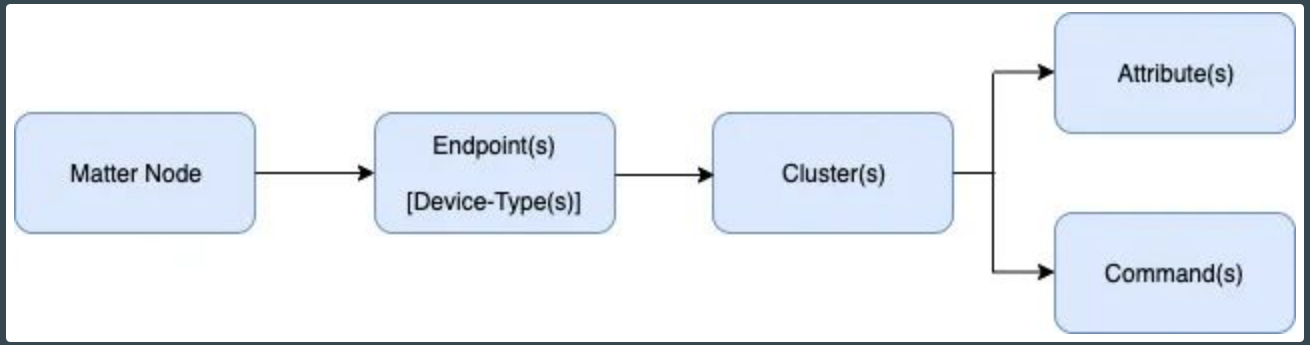
Espressif's Matter Demo - https://youtu.be/Jr4Lut_NggA

Matter topology

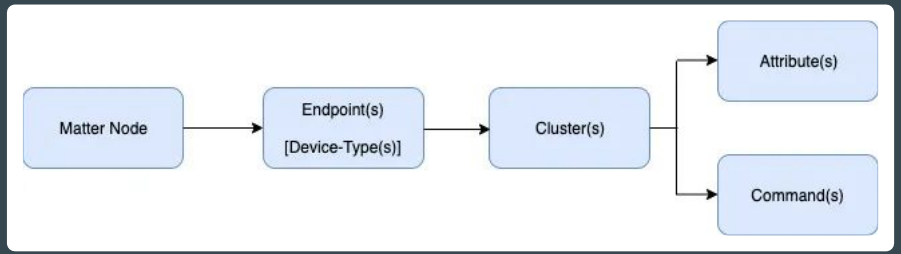


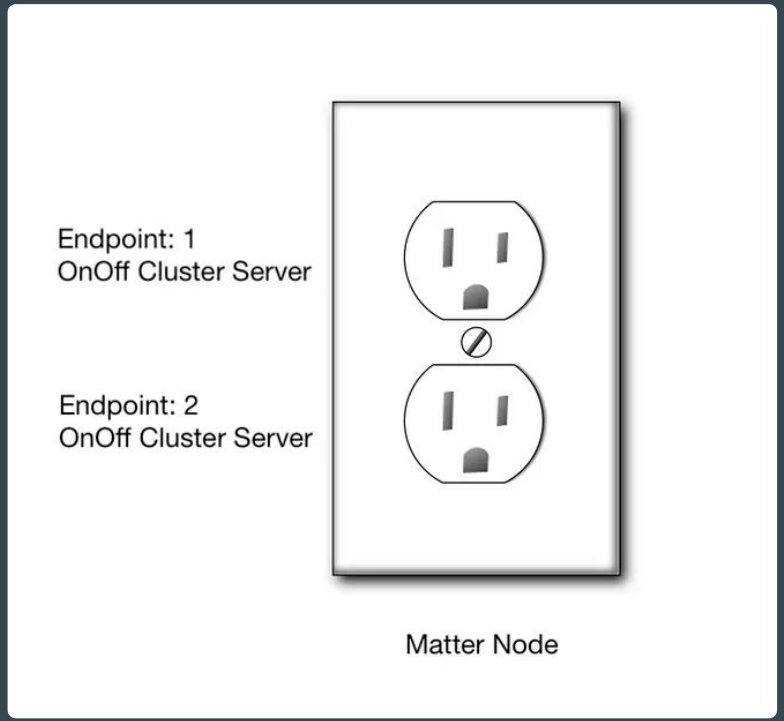

Application Layer
Application Layer
Transport
TCP
UDP
Network
IPv6
Networking Layer
Link / Media
Ethernet
Wi-Fi
Thread
802.15.4

Simplistic Data Model

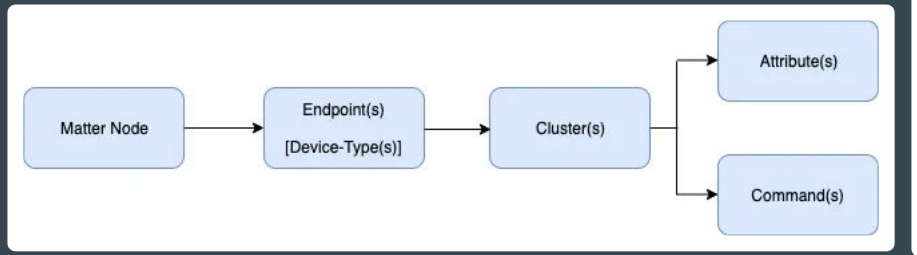


Matter node

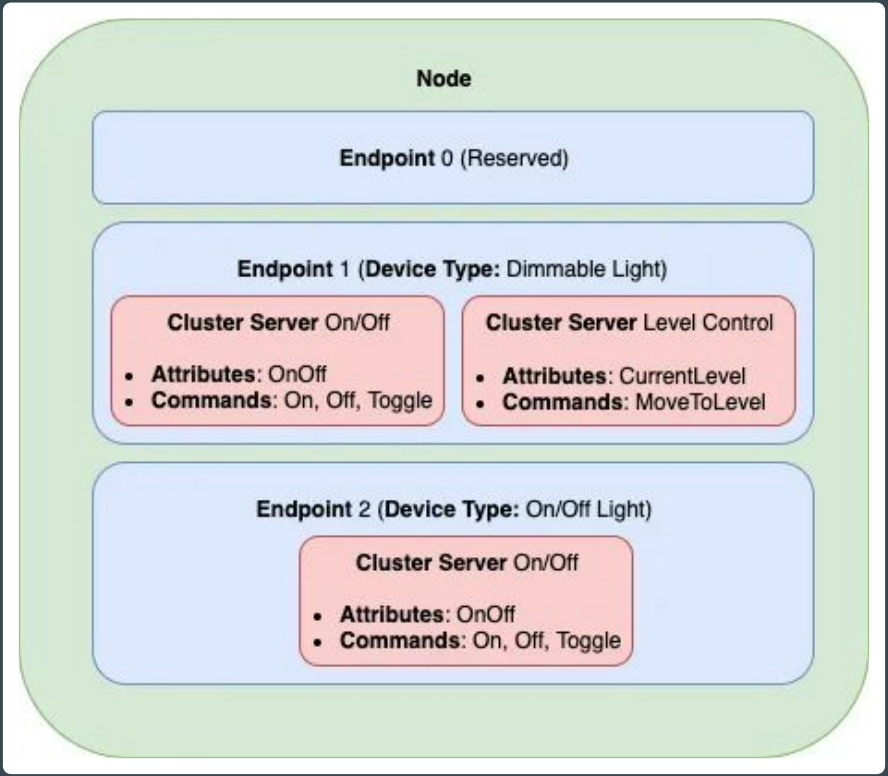

Matter Node
Endpoint(s)
[Device-Type(s)]
Cluster(s)
Attribute(s)
Command(s)


Endpoint: 1
OnOff Cluster Server
Endpoint: 2
OnOff Cluster Server
Matter Node

Matter Node - OnOff Cluster Client - 4 endpoints



Simplistic Representation of a Matter Data Model



https://blog.espressif.com/matter-clusters-attributes-commands-82b8ec1640a0

Endpoint 0 (reserved)

- Basic Information Cluster Server: Provides basic information about the node, like firmware version, manufacturer etc
- ACL Cluster Server: Allows configuration of the Access Control Lists for this node.
- Network Commissioning Cluster Server: Allows configuration of a network (Wi-Fi, Ethernet, Thread) on the node.

Cluster list

ID; Cluster Name

0x0003 - Identify

0x0004 - Groups

0x0005 - Scenes

0x0006 - On/Off

0x0008 - Level controlling

0x0045 - Boolean state

0x0050 - Mode Select

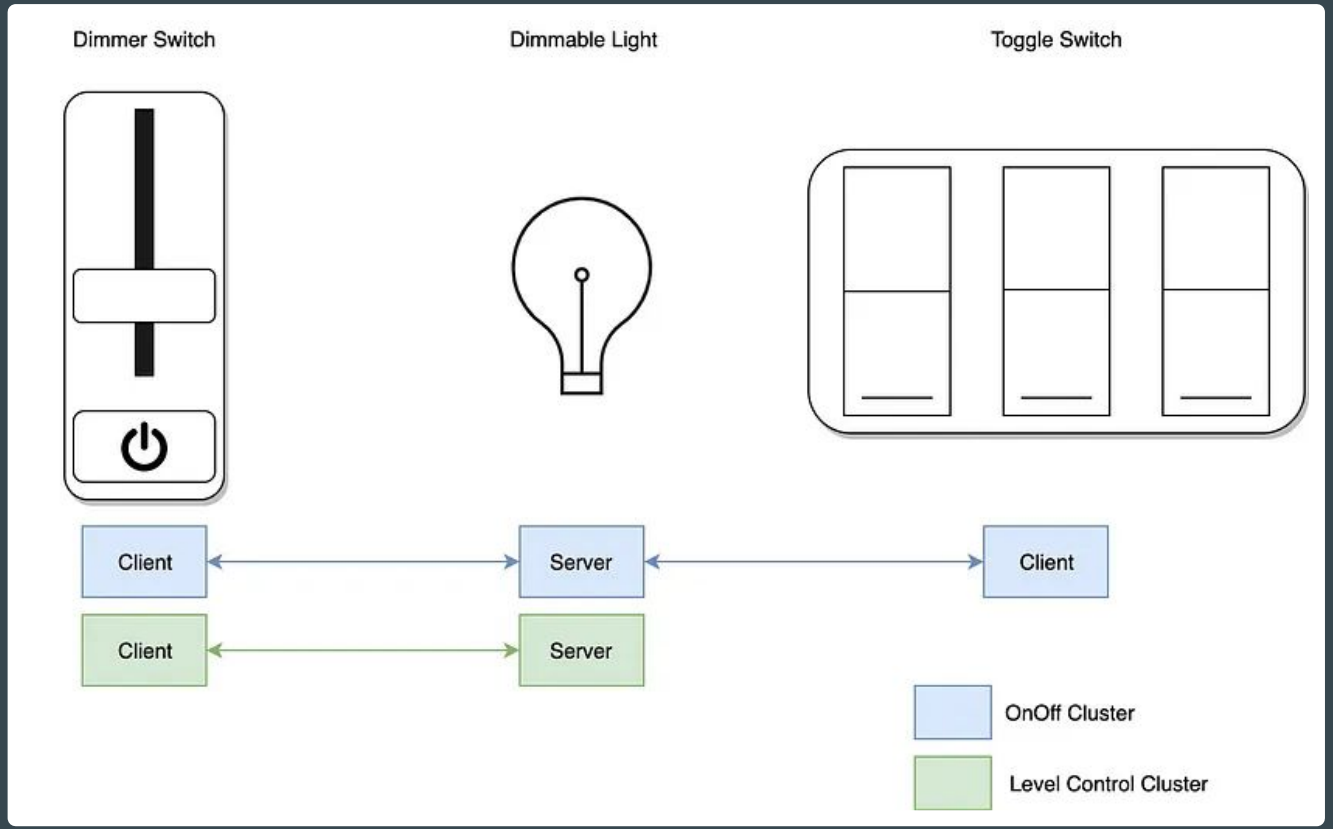
0x0508 - Low Power

0x0503 - Wake On LAN

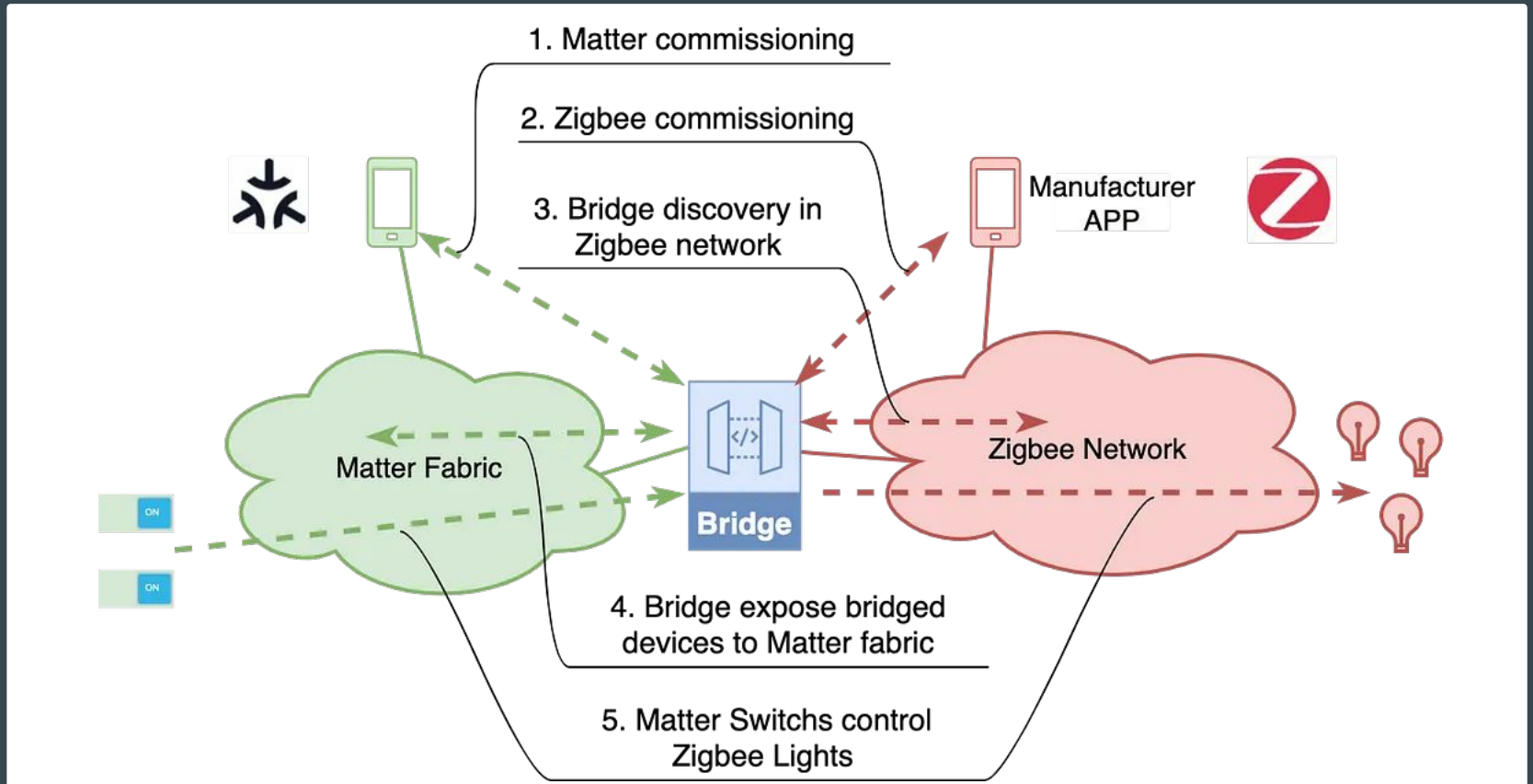
0x003b - Switch

Specification: Matter Application Clusters v1.0

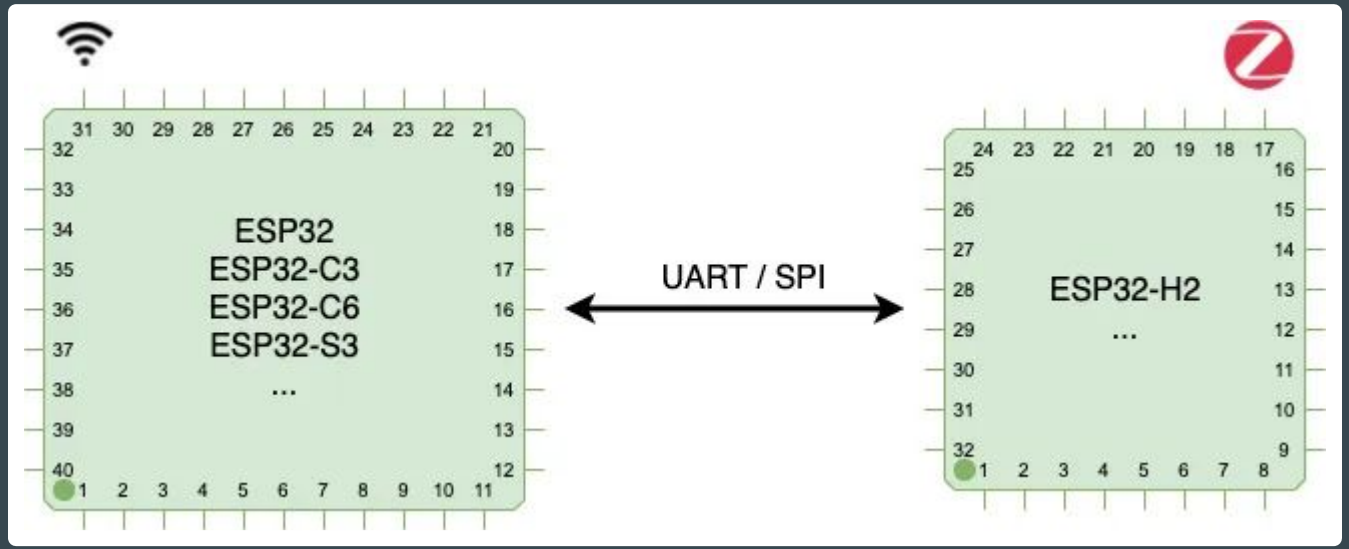
Matter - Client - Server



Matter-Zigbee Bridge Workflow

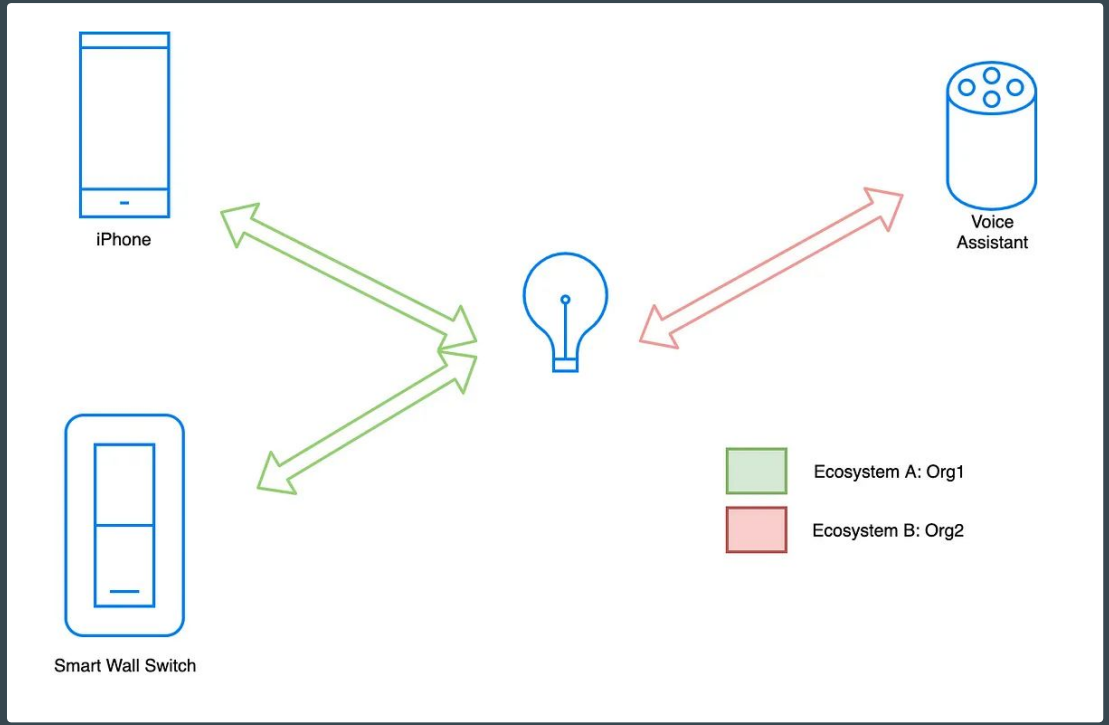


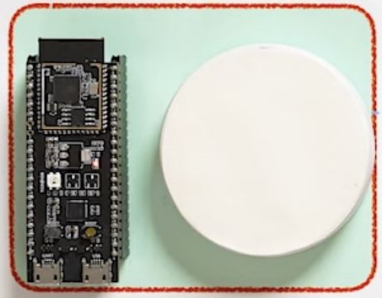
Matter-Zigbee bridge solution



Matter-BLE mesh bridge solution

Multi-Admin

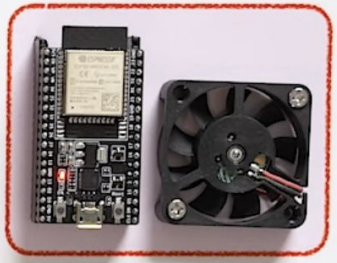

iPhone
Voice Assistant
Smart Wall Switch
Ecosystem A: Org1
Ecosystem B: Org2



Thread End Device
ESP32-H2 Bulb

Thread Border Router
ESP32-H2 + ESP32-S3
(Thread + Wi-Fi)

Wi-Fi End Device
ESP32-C3 Smart Switch



Wi-Fi End Device
ESP32 FAN

matter

Wi-Fi End Device
ESP32 Bulb

Wi-Fi End Device
ESP32-S3 (ULP)
Occupancy Sensor

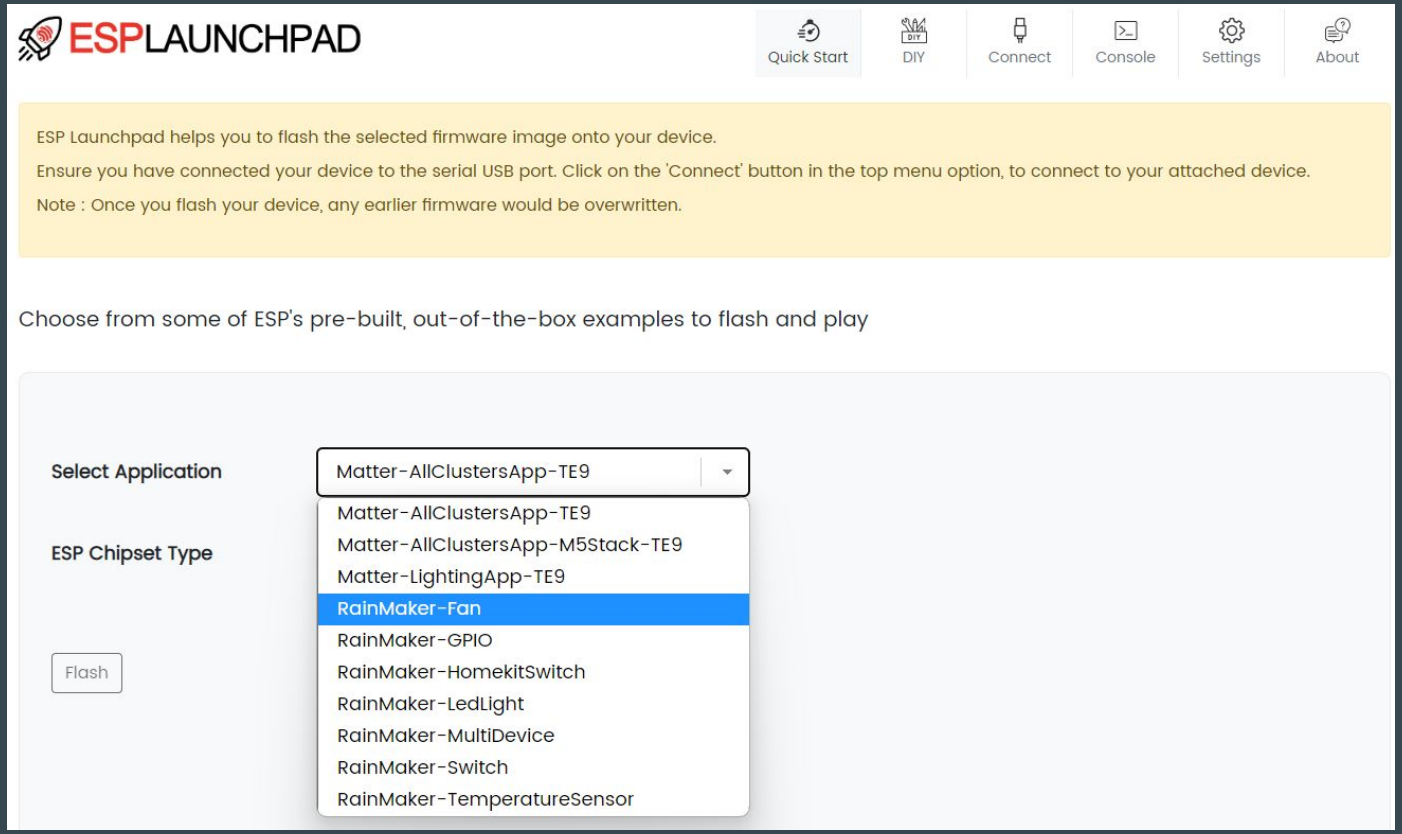
Controller
ESP32-S3-BOX

Wi-Fi End Device
ESP32-C3 LED Strip

Matter Bridge
ESP32-H2 + ESP32-S3
(Zigbee + Wi-Fi)

Zigbee End Device
Door Sensor

ESP Launchpad - https://espressif.github.io/esp-launchpad/



Quick start

esp-matter: https://github.com/espressif/esp-matter

Launchpad for flashing light and light_switch:

- https://espressif.github.io/esp-launchpad/?flashConfigURL=https://espressif.github.io/esp-matter/launchpad.toml

Commissioning

https://docs.espressif.com/projects/esp-matter/en/latest/esp32/developing.html#commissioning

Options: chip-tool, Apple Home or Google Home with proper device in local net

chip-tool interactive start

pairing ble-wifi 0x7283 SSID PASS 20202021 3840

Note: Some older Youtube videos are referring to QR code from

console. The feature was removed. Please, use one from documentation.

Setting up development environment

Please, read programming guide: https://docs.espressif.com/projects/esp-matter/en/latest/esp32/

Warning: Follow steps exactly, small deviation may result into non-working env.

Recommended OS: **macOS**, Ubuntu 22 LTS

apt install git ninja-build clang pkg-config libglib2.0-dev libssl-dev gcc g++ cmake

Install GN https://gn.googlesource.com/gn/+/refs/heads/main/README.md#getting-a-binary

... or use Development Container

Matter development env for Windows - WSL2

winget install usbipd

https://github.com/dorssel/usbipd-win/wiki/WSL-support

sudo apt install linux-tools-virtual hwdata

sudo update-alternatives --install /usr/local/bin/usbip usbip `ls /usr/lib/linux-tools/*/usbip | tail -n1` 20

usbipd wsl attach -b 1-5 -d Ubuntu-22.04

Connect from VM: usbip attach --remote 192.168.32.137 --busid 1-4

Limitations: mDNS, BLE layer

Python Matter Server

Only Ubuntu 20 LTS

https://github.com/home-assistant-libs/python-matter-server

https://nabucasa.github.io/matter-example-apps/

matter.js - NodeJS Matter implementation

https://github.com/project-chip/matter.js

- matter.js: the core Matter implementation in typescript which is JavaScript only and has no native dependencies.
- matter-node.js: a node.js implementation of a Matter Device and Controller

chip-tool

Recommended option

https://docs.espressif.com/projects/esp-matter/en/latest/esp32/developing.html#test-setup-chip-tool

Android app (devel only)

https://github.com/project-chip/connectedhomeip/blob/master/docs/guides/android_building.md

Source code

https://github.com/project-chip/connectedhomeip/tree/master/examples/android

Recommended approach: use chip-tool or Google Home app

Observing Matter network

dns-sd -B _matter._tcp

avahi-browse _matter._tcp -r

_matterc._udp - device waiting to get commissioned

_matter._tcp - lists the commissioned device

Observing Matter network - output

Browsing for _matter._tcp

DATE: ---Mon 17 Apr 2023---

9:28:46.609 ...STARTING...

Timestamp	A/R	Flags	if	Domain	Service Type	Instance Name
9:45:28.368	Add	2	11	local.	_matter._tcp.	494022C0EA7CC12B-000000000001B669
9:45:37.609	Add	2	11	local.	_matter._tcp.	494022C0EA7CC12B-0000000000007283
9:46:42.917	Rmv	0	11	local.	_matter._tcp.	494022C0EA7CC12B-0000000000007283
9:47:29.678	Rmv	0	11	local.	_matter._tcp.	494022C0EA7CC12B-000000000001B669

idf.py monitor

> matter config

VendorId: 65521 (0xFFF1)

ProductId: 32768 (0x8000)

HardwareVersion: 0 (0x0)

PinCode: 20202021

Discriminator: f00

Done

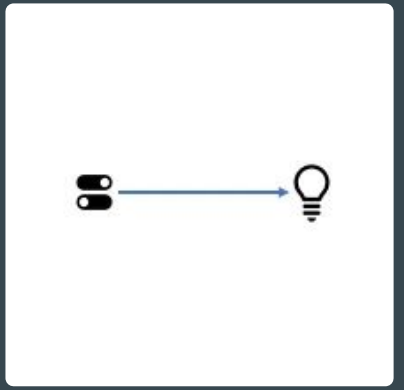
> matter esp attribute get 0x1 0x6 0x0

I (377514) esp_matter_attribute: ********** Endpoint 0x0001's Cluster 0x0006's Attribute 0x0000 is 1 **********

I (377514) esp_matter_attribute: ********** Endpoint 0x0001's Cluster 0x0006's Attribute 0x0000 is 1 **********

Done

Bind light and light_switch



commission light: chip-tool pairing ble-wifi 0x7283 <SSID> <passphrase> setup-pin-code discriminator

commission light_switch: chip-tool pairing ble-wifi 0x7283 <SSID> <passphrase> setup-pin-code discriminator

bind light and switch: https://github.com/espressif/esp-matter/tree/main/examples/light_switch#21-bind-light-to-switch

update ACL of light: accesscontrol write acl '[{"privilege": 5, "authMode": 2, "subjects": [112233, 29315], "targets": null}]' 0x5164 0x0

bind light_switch: binding write binding '[{"node":20836, "endpoint":1, "cluster":6}]' 0x7283 0x1

Working configuration

switch: 0x7283 (29315)

binding write binding '[{"node":20836, "endpoint":1, "cluster":6}]' 0x7283 0x1

light: 0x5164 (20836)

accesscontrol write acl '[{"privilege": 5, "authMode": 2, "subjects": [112233, 29315], "targets": null}]' 0x5164 0x0

onoff toggle 0x5164 1

Working with console

matter esp attribute get <endpoint_id> <cluster_id> <attribute_id>

matter esp attribute get 0x1 0x6 0x0

matter esp attribute set <endpoint_id> <cluster_id> <attribute_id> <attribute value>

matter esp attribute set 0x1 0x6 0x0 1

matter esp controller read-event <node_id> <endpoint_id> <cluster_id> <event_id>

Fade In/Out - using Level Control

levelcontrol step 1 100 10 0 0 0x5164 1

levelcontrol step 0 100 10 0 0 0x5164 1

Developer documentation

Main source: https://csa-iot.org/developer-resource/specifications-download-request/

Simplified documentation:

https://blog.espressif.com/matter-38ccf1d60bcd

https://blog.espressif.com/matter-security-model-37f806d3b0b2

Google - Creating project for testing

https://developers.home.google.com/matter/project/create

Google Nest Hub - supported devices

https://developers.home.google.com/matter/supported-devices#hubs

matter-rs

Early development

https://github.com/project-chip/matter-rs

ESP chips not supported yet

Join Rust ESP32 Community Meeting to see the progress:

https://github.com/esp-rs/rust/discussions

Rust language support

Talk: EDC22 Day 1 Talk 7: Rust on Espressif chips - Scott Mabin - DevConf September 2022

https://youtu.be/qeEmJ_-6fPg

Talk: Embedded Rust on ESP32 - Juraj Michálek - Rust Linz November 2022

https://youtu.be/OPPPdqoDBQs

Multi-target project (PoC) - ESP32 Spooky Maze

Source: https://github.com/georgik/esp32-spooky-maze-game

Idea: sharing business logic in Rust between multiple targets

Demo: https://georgik.rocks/rust-bare-metal-application-for-esp32-desktop-android-and-ios/

Targets: ESP32, ESP32-S2, ESP32-S3, ESP32-C3, M5Stack, Wasm and Desktop

Article: https://georgik.rocks/rust-bare-metal-application-for-esp32-desktop-android-and-ios/

https://github.com/espressif/esp-box

Async with Embassy

Embassy: https://github.com/embassy-rs/embassy

Examples of Embassy on ESP32:

- https://github.com/esp-rs/esp-hal/blob/main/esp32-hal/examples/embassy_hello_world.rs
- https://github.com/esp-rs/esp-hal/blob/main/esp32-hal/examples/embassy_spi.rs
- https://github.com/esp-rs/esp-hal/blob/main/esp32-hal/examples/embassy_wait.rs

Async topic author: Juraj Sadel

Busy Looping (not using async)

- Very inefficient, blocking

```
fn main() {
    let mut button = Button::new();
    let mut led = Led::new();
    loop {
        if button.is_pressed() {
            led.on();
        } else {
            led.off();
        }
    }
}
```

Interrupts (not using async)

- Driven by hardware
- Pretty complex

```
static BUTTON: Mutex<Option<Button>> = Mutex::new(None);
static LED: Mutex<Option<Led>> = Mutex::new(None);
fn main() {
    LED.lock().replace(Led::new());
    BUTTON.lock().replace(Button::new());
    setup_irq(button_event); // Magic
}

fn button_event() {
    if BUTTON.lock().as_mut().unwrap().is_pressed() {
        LED.lock().as_mut().unwrap().on();
    } else {
        LED.lock().as_mut().unwrap().off();
    }
}
```

Using async

- Don’t have to setting and waiting for interrupt resuming the program
- Async executor can do that for us instead
- Power efficient

```
async fn main() {
    let mut button = Button::new();
    let mut led = Led::new();
    loop {
        button.wait_changed().await;
        if button.is_pressed() {
            led.on();
        } else {
            led.off();
        }
    }
}
```

Embassy (EMBedded ASYnc)

- We need an EXECUTOR to be able to use async
- Controlling which task should run

- Embassy consists of multiple crates (Executor, HALs, Networking,...)
- no_std
- Can be (relatively) easily extendable/configurable with other public crates
- https://embassy.dev

Rust Training Embedded for ESP32-C3 by Ferrous Systems

Training: https://ferrous-systems.com/training/#package-espressif-beginner-training

Material: https://esp-rs.github.io/espressif-trainings/

GitHub: https://github.com/esp-rs/espressif-trainings

ferrous systems

Espressif Developer Conference 2022 - recording

https://www.youtube.com/playlist?list=PLOzvoM7_Knrc6o-n25jYuXRB2T8UKk1NU

Developer Conference 2023 - scheduled for 12-13 September - https://devcon.espressif.com/

Embedded World 2024

Meet us in Nuremberg, Germany

Visit us in Brno

Espressif Systems (Czech) s.r.o.

Přízova 3, 602 00 Brno

Czechia, Europe