Integrarea sistemelor informatice

Suport curs practic nr. 4

Integrare hard-soft. IoT.

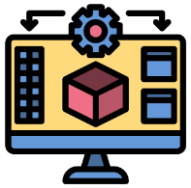
2024-2025

Obiective

- Înțelegerea arhitecturii sistemelor IoT
- Înțelegerea metodelor de conectare a dispozitivelor IoT
- Identificarea funcționalităților comune în sistemele IoT
- Înțelegerea modului de realizare a unei aplicații IoT

Cuprins

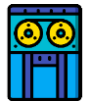
- Introducere în IoT
- Clasificarea sistemelor IoT
- Arhitectura sistemelor IoT
  - Arhitectura generală
  - Dispozitive IoT
  - Conectivitate
  - Platforme IoT



- Aplicație practică
  - Dezvoltarea aplicațiilor IoT cu ESP32
  - Integrarea cu Firebase
  - Platforme IoT

IoT – Scurt istoric

1969 ARPANET este lansat ca un precursor al internetului modern



1982 Cercetătorii de la Carnegie-Mellon conectează un automat pentru băuturi la internet

1993 Prima cameră web este instalată pentru a monitoriza un automat de cafea

1995 Sistemul GPS devine complet operațional

1999 Termenul de “Internet of Things” este folosit pentru prima dată de Kevin Ashton de la MIT

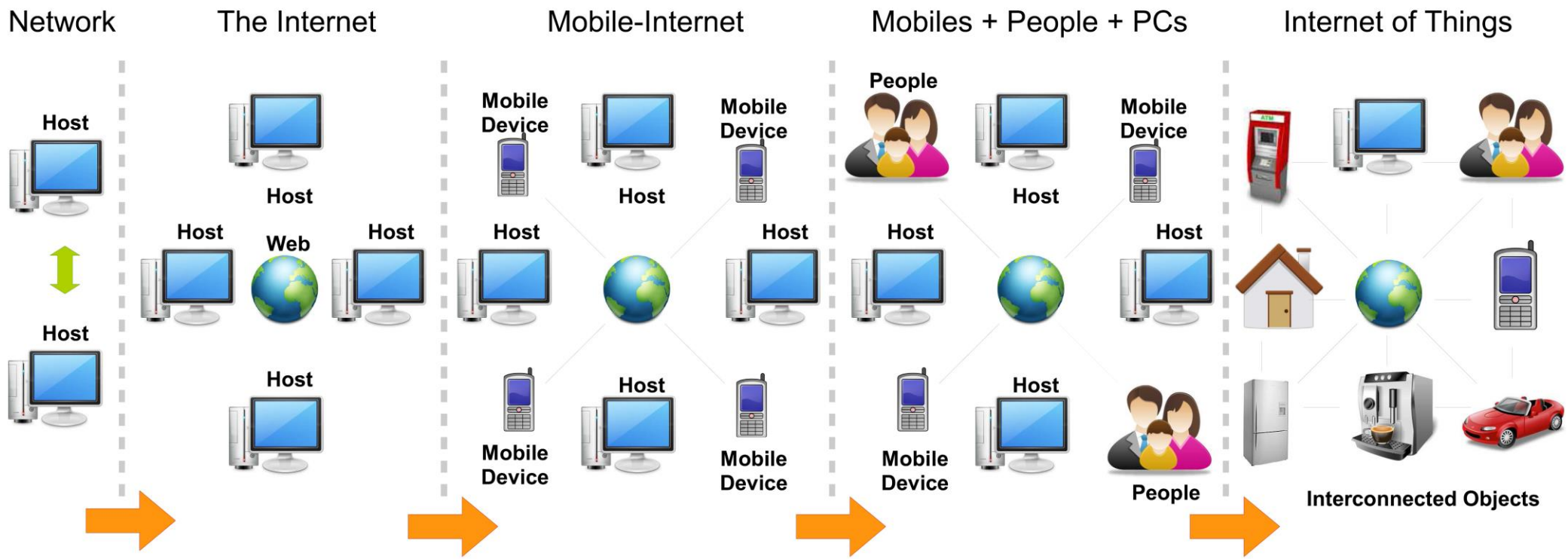
2008 Prima conferință internațională de IoT / numărul de dispozitive IoT depășește pe cel al oamenilor

2009 Google inițiază programul mașinilor autonome

2014 Amazon Echo pornește trendul dispozitivelor de tip Smart Home

2017 Dezvoltarea sistemelor IoT și a multiplelor integrări: AI, blockchain, edge computing

Evoluția sistemelor IoT



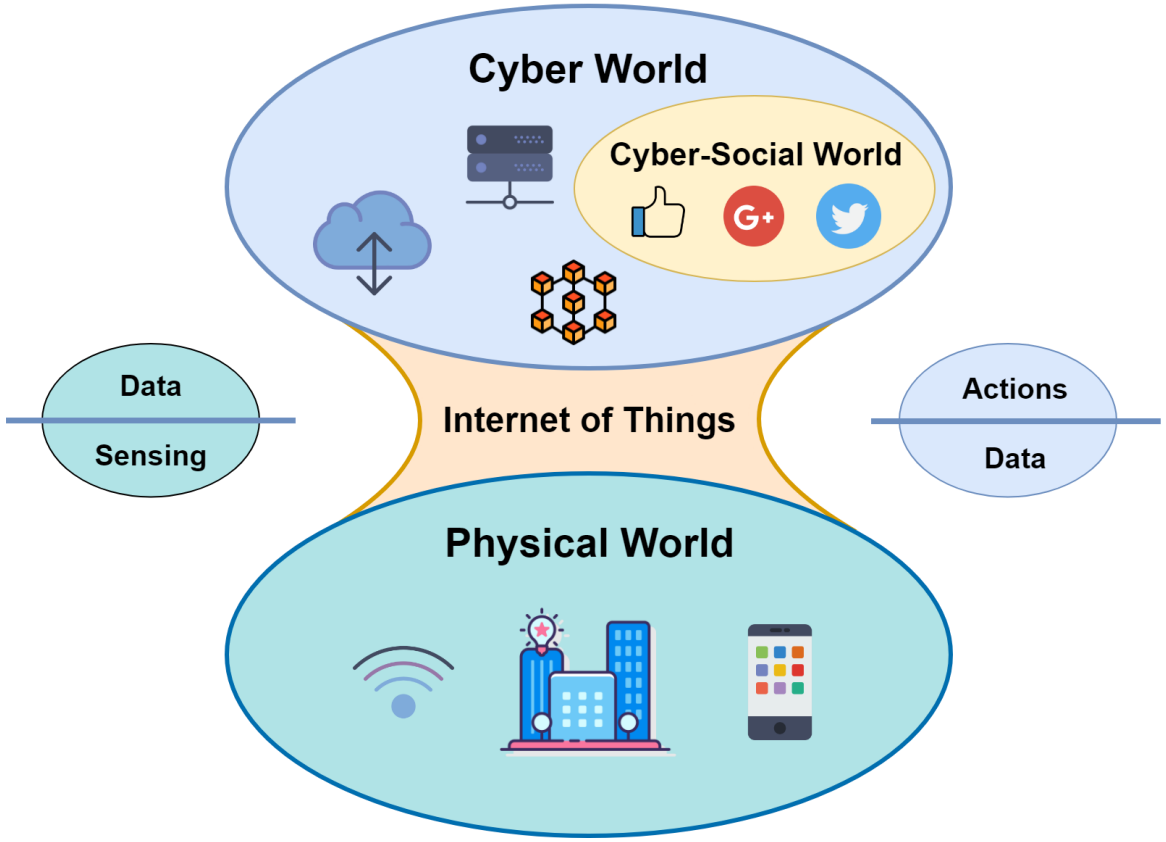
C. Perera *et al.* A Survey on Internet of Things From Industrial Market Perspective

Rolul IoT în sistemele hard-soft

IoT – Internet of Things reprezintă tehnologia prin care se conectează dispozitivele fizice la internet

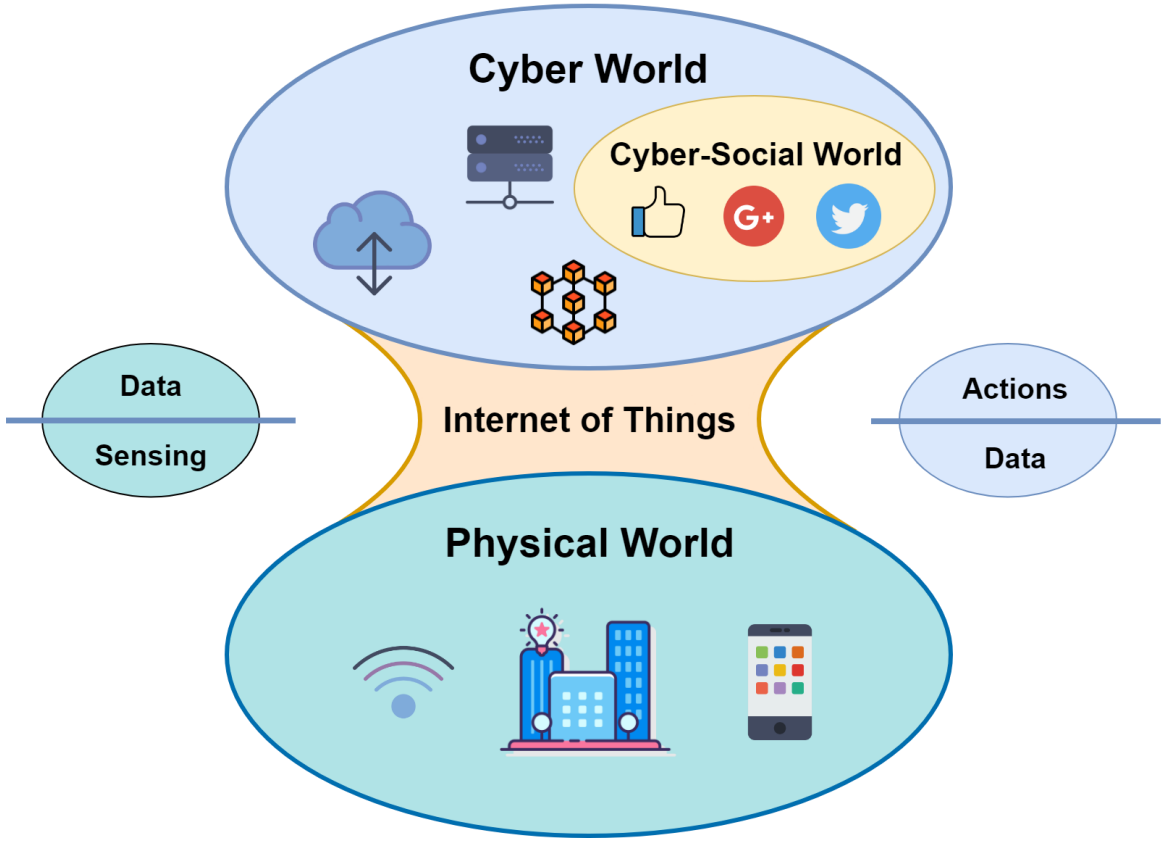
CPS – Cyber Physical System este un sistem integrat de monitorizare și control a proceselor fizice

CPSS – Cyber Physical Social System implică interacțiunea factorului uman în procesele de monitorizare și control



Rolul IoT în sistemele hard-soft

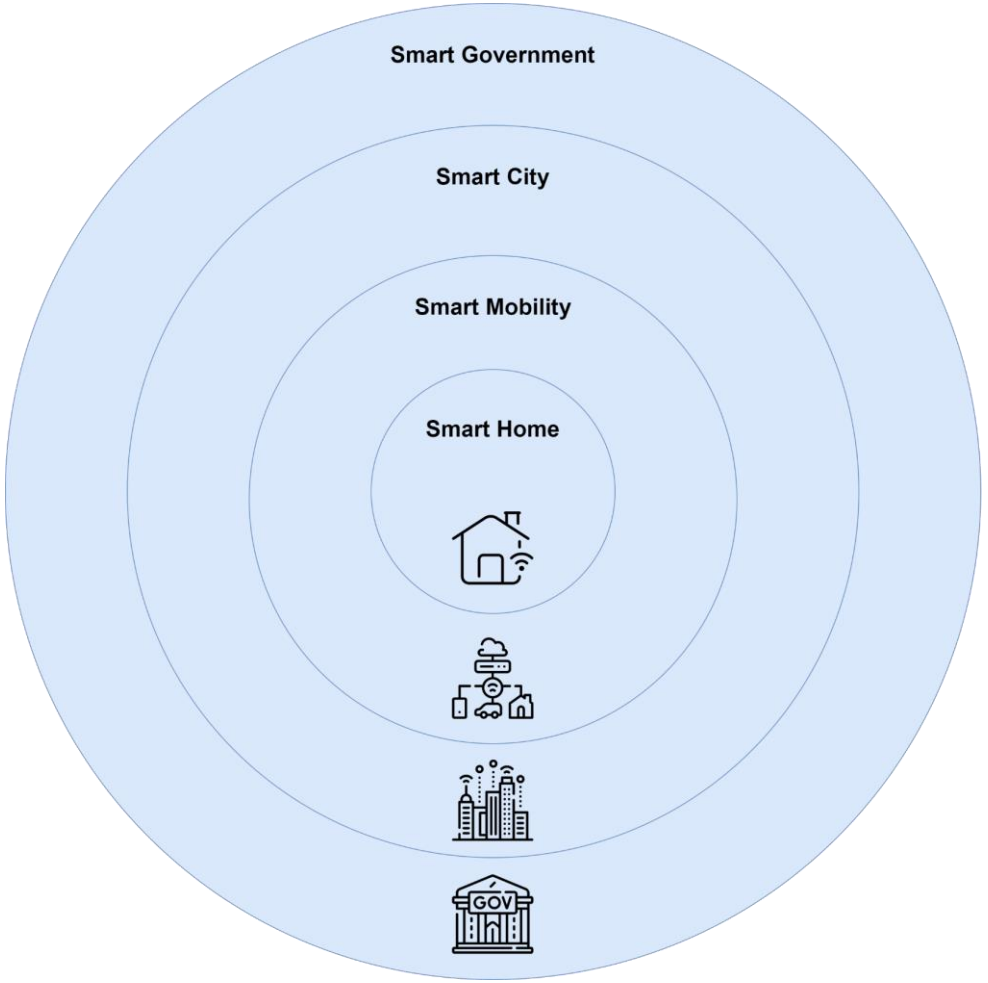
- Machine to Machine (M2M) Communication
- Device to Device (D2D) Communication
- Wireless Sensor Networks (Distributed Sensor Nodes)
- Remote Ubiquitous Computing and Monitoring Systems



Clasificarea sistemelor IoT

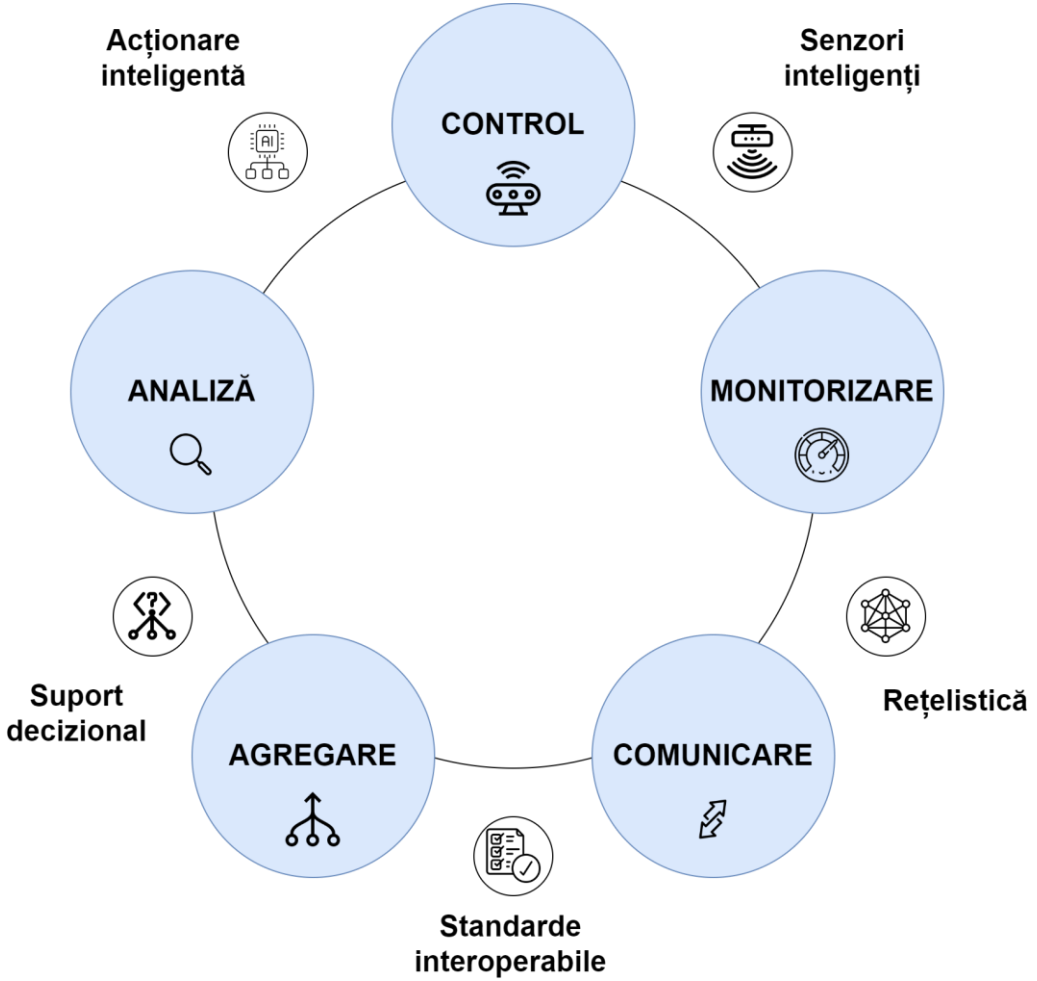
Domeniile de aplicabilitate ale sistemelor IoT

- Smart Home: integrarea sistemelor de monitorizare inteligentă și control la nivel de locuințe / clădiri
- Smart Mobility: creșterea mobilității prin interconectarea dispozitivelor mobile
- Smart City: gestionarea infrastructurii inteligente la nivel de oraș
- Smart Government: Digitalizarea proceselor în diferite domenii cheie



Funcțiile sistemelor IoT

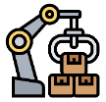
- MONITORIZARE: Utilizarea senzorilor inteligenți pentru colectarea informațiilor despre un proces fizic
- COMUNICARE: Transmiterea informațiilor
- AGREGARE: Integrarea diferitelor informații colectate la momente sau din surse diferite
- ANALIZĂ: Identificarea modelelor sau a relațiilor dintre fenomene pentru definirea acțiunilor necesare
- CONTROL: Menținerea sau modificarea parametrilor proceselor fizice



Clasificarea sistemelor IoT

- The Internet of Health Things (IoHT)
- The Internet of Medical Things (IoMedT)
- The Medical Internet of Things (m-IoT)
- The Internet of Bio-Nano things

- The Internet of Nano Things (IoNT)



- The Industrial Internet of Things (IIoT)

- The Internet of Vehicles (IoV)
- The Internet of Vehicle Things (IoVT)

- The Internet of Robotic Things (IoRT)

- The Internet of Home Things (IHoT)

- The Internet of Multimedia Things (IoMulT)
- The Internet of Multimedia Nano-Things (IoMNT)
- The Internet of Audio Things (IoAuT)
- The Internet of Musical Things (IoMusT)
- The Internet of Sound (IoS)
- The Internet of Video Things (IoViT)
- The Visual Internet of Things (VIoT)

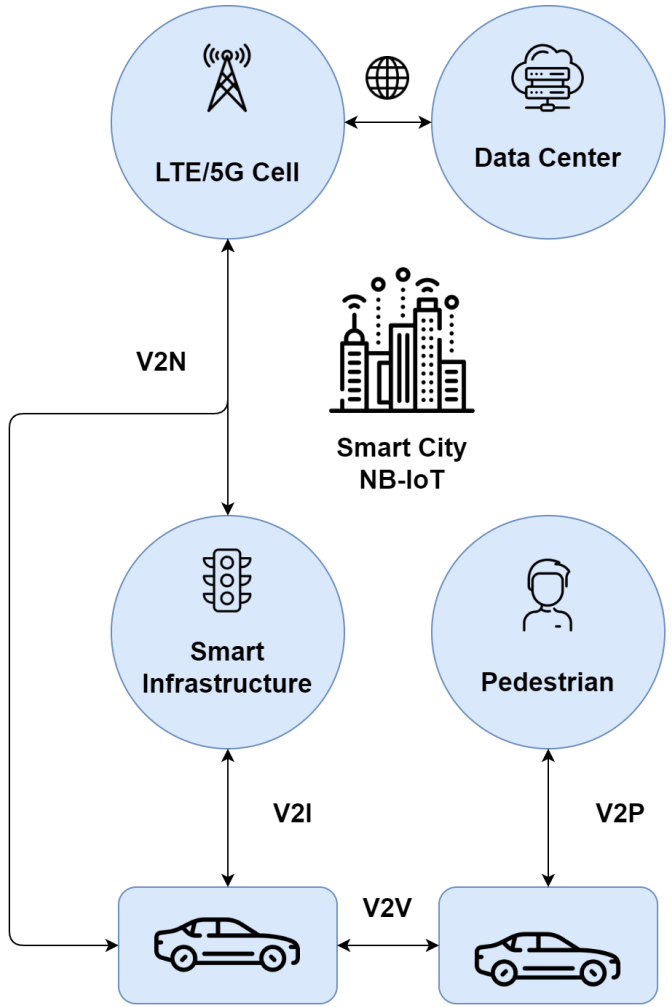
- The Internet of Surveillance Things (IoSurT)
- The Surveillance of Things (SoT)
- The Internet of Secure Things (IoSecT)

- The Environmental Internet of Things (EIoT)
- The Internet of Environmental Things (IoET)

- The Internet of Smart Things (IoSmaT)

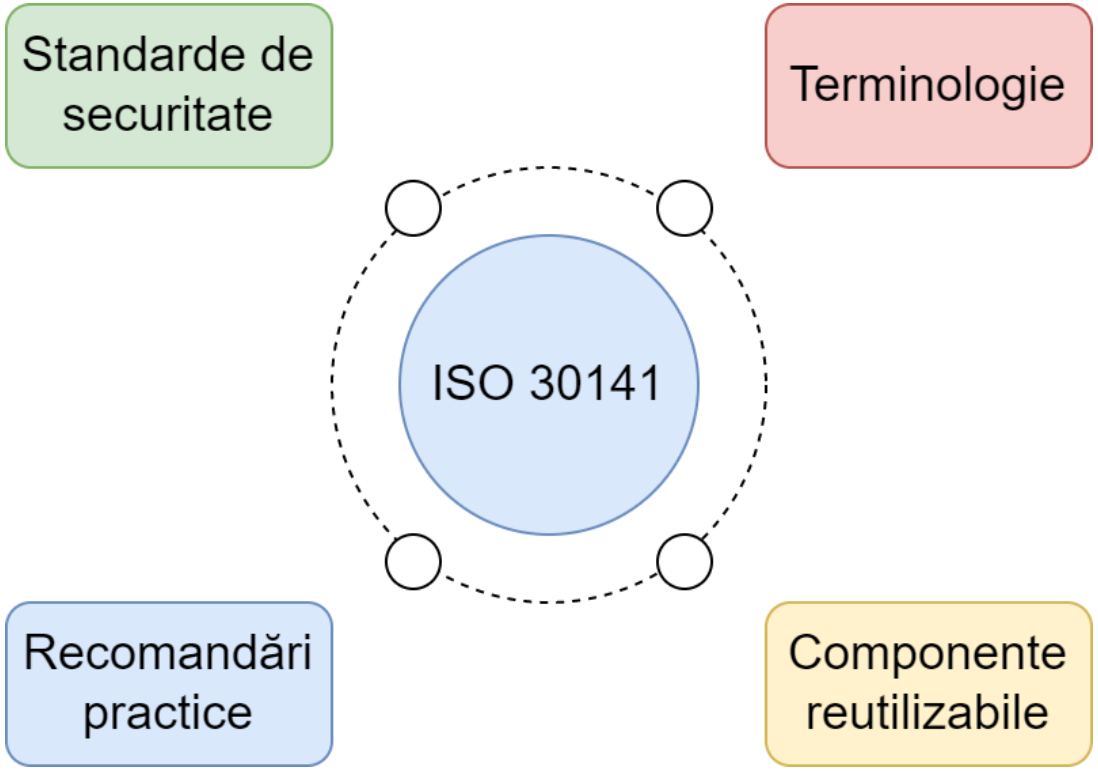
Studiu de caz
Sistem IoT de localizare a vehiculelor

- Tehnologii
  - RFID (Radio-frequency identification)
  - GPS (Global Positioning System)
  - OBD-II (On-board diagnostics)
- IoT pentru vehicule
  - V2V (Vehicle-to-Vehicle)
  - V2I (Vehicle-to-Infrastructure)
  - V2P (Vehicle-to-Pedestrian)
  - V2N (Vehicle-to-Network)



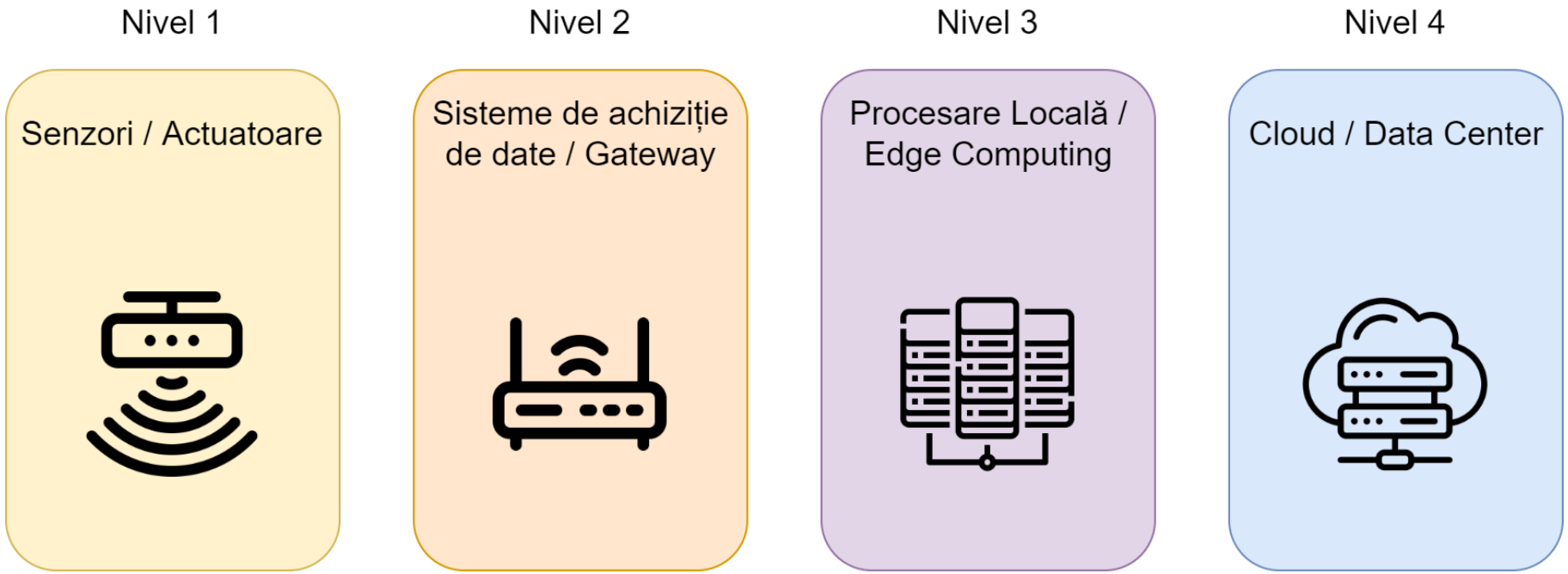
Arhitectura sistemelor IoT

Arhitectura sistemelor IoT



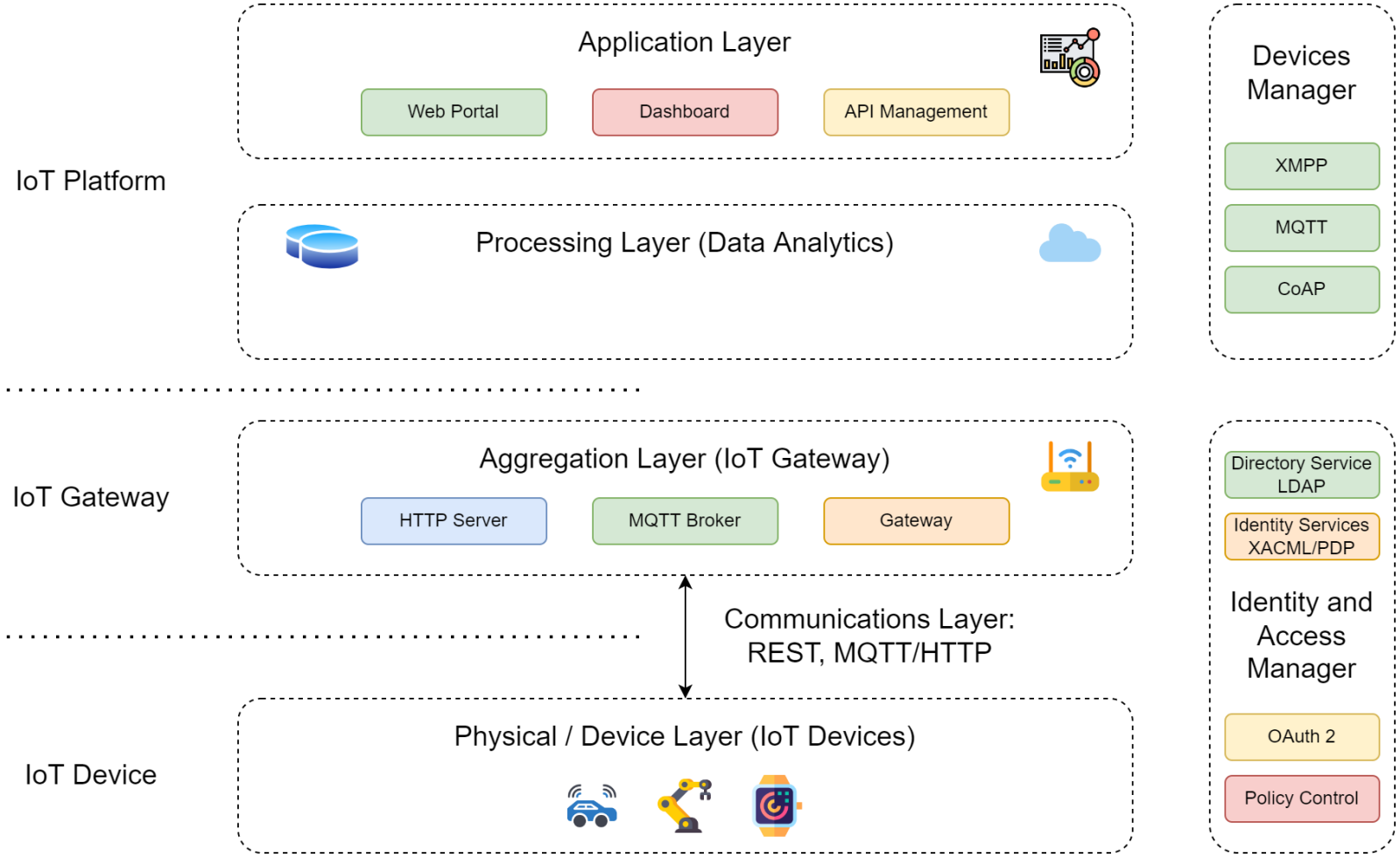
ISO/IEC 30141:2018 Internet of Things (IoT) — Reference Architecture

Arhitectura sistemelor IoT



Niveluri de dezvoltare

Arhitectura sistemelor IoT

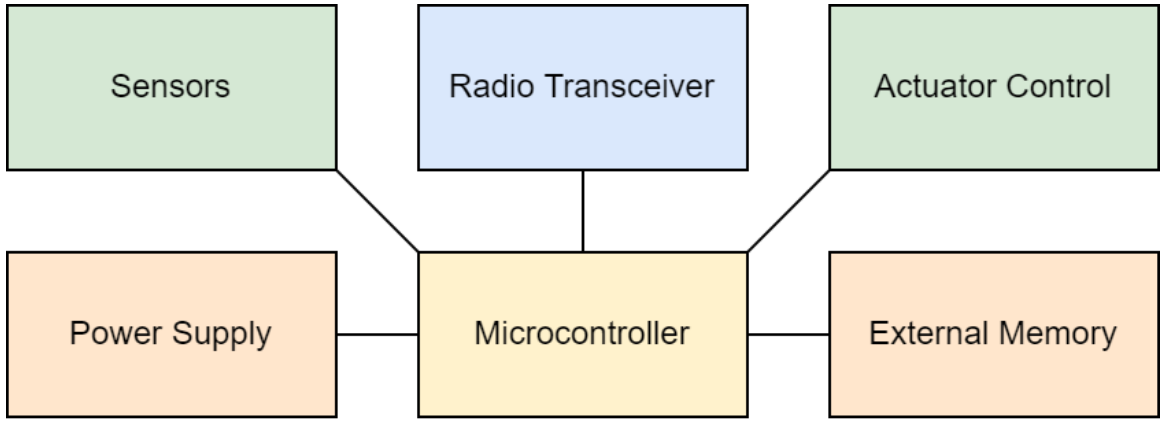


IoT Architecture | Internet Of Things Architecture For Beginners | IoT Tutorial | Simplilearn

Dispozitive IoT

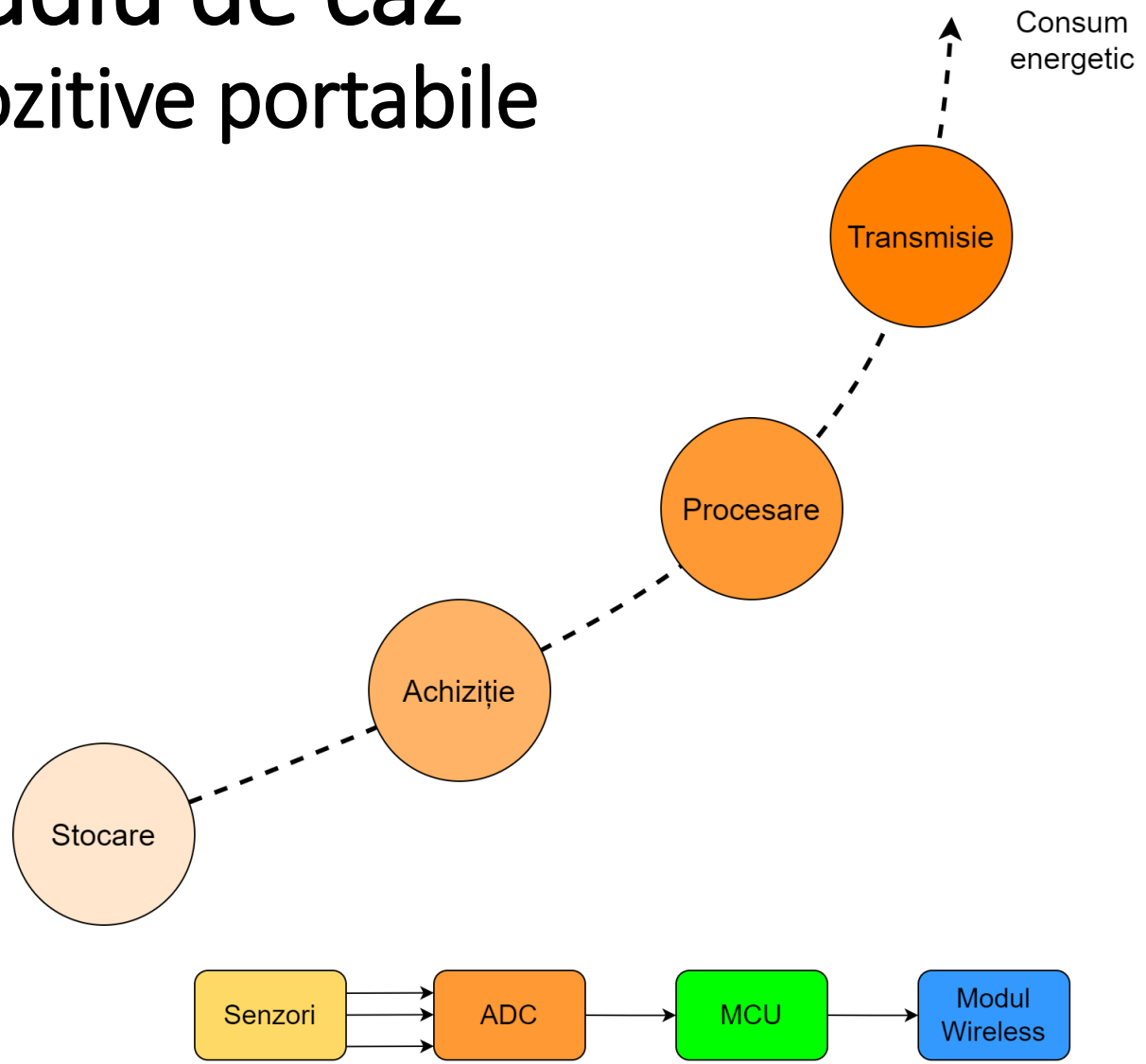
Dispozitive IoT. Structură generală

- Procesoare low-power
  - Resurse computaționale limitate
- Memorie
  - Capacitate redusă
- Modul comunicație wireless
  - Low-power
  - Viteză de transfer redusă
  - Distanță limitată
- Senzori
  - Scalari: temperatură, lumină, etc.
  - Multimedia: imagine, sunet, etc.
- Sursă de alimentare
  - Eficiență energetică



Studiu de caz
Dispozitive portabile

- Achiziția datelor
  - Amplificatoare
  - Filtre analogice
  - ADC
- Procesarea datelor
  - Reducerea zgomotelor
  - Extragerea parametrilor
  - Compresia datelor
  - Securitatea datelor
- Transmisia datelor
  - Transmisie wireless
- Stocarea datelor
  - Scrierea/citirea datelor
  - La nivel de dispozitiv



Studiu de caz

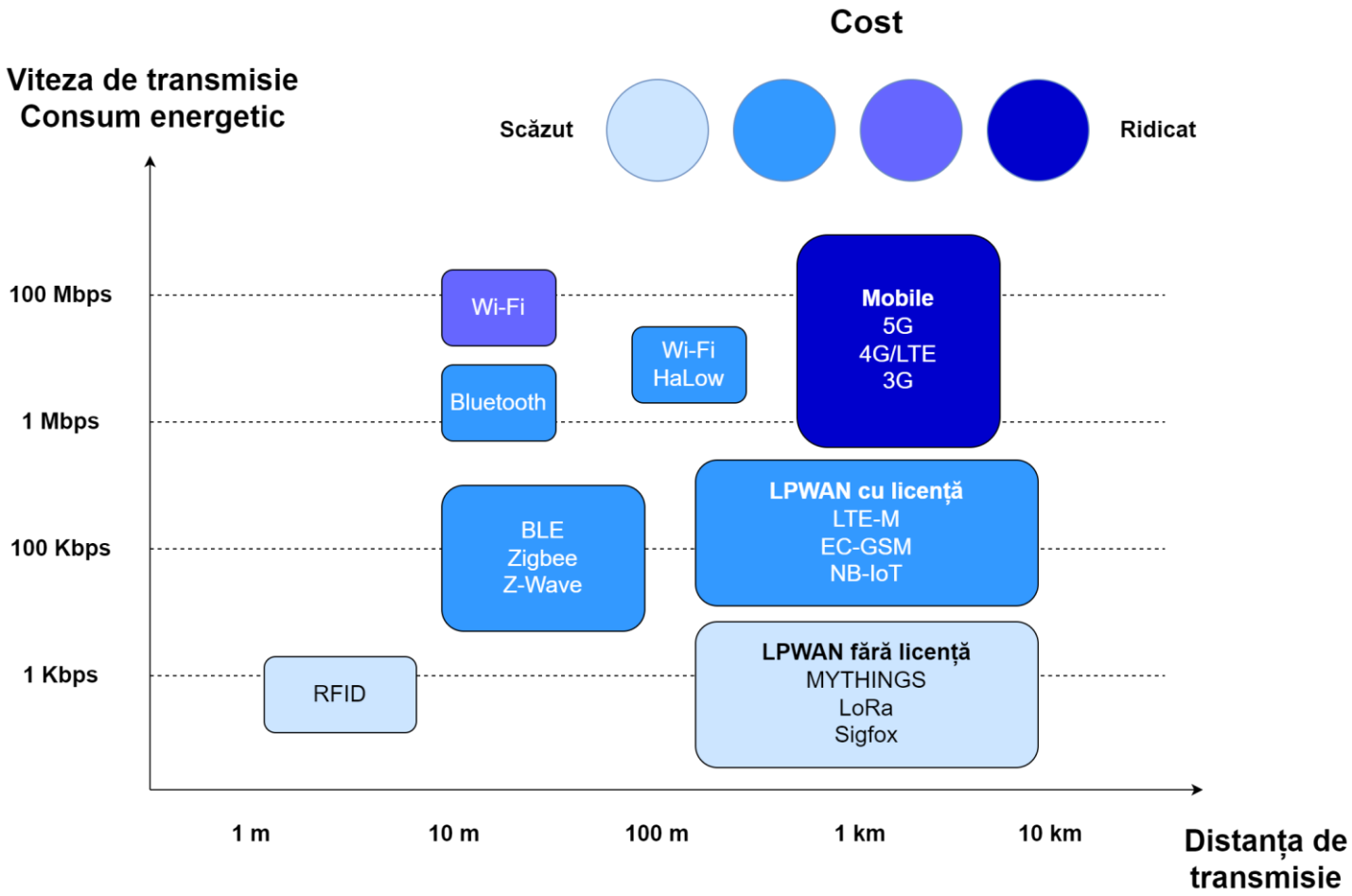
Dispozitive portabile

Device	Voltage	Power Consumption	Ref.
Accelerometers			
Analog, 300 mV/g, ADXL337	3.0 V	900 µW	[16]
Digital, 3.9 mg/LSB, ADXL345	2.5 V	350 µW	[16]
KX022 tri-axis (*—low power mode)	1.8–3.6 V	522 (36*) µW	[17]
Temperature sensors			
BD1020HFV −30 °C to +100 °C	2.4–5.5 V	38.5 µW	[17]
MAX30208 0 °C to +70 °C	1.7–3.6 V	241 µW	[18]
MCP9700 −40 °C to +150 °C	2.3–5.5 V	82 µW	[19]
Heart rate monitors			
Samsung Galaxy Gear Neo 2 component	-	~50 mW	[20]
MAX30102 pulse oximetry/heart-rate monitor	1.8–3.3 V	<1 mW	[18]
BH1790GLC optical heart rate sensor	1.7–3.6 V	720 µW	[17]
A/D converters			
AD7684 16-bit SAR 100 kS/s	2.7–5.0 V	15 µW	[16]
ADS1114 16-bit sigma-delta 0.860 kS/s	2.0–5.5 V	368 µW	[16]
DS1251 24-bit sigma-delta 20 kS/s	3.3–5.0 V	1.95 mW	[18]
Signal processors			
MC56F8006 Audio DSP, 16-bit 56800E	1.8–3.6 V	4282 µW/MHz	[16]
STM32L151C8 High-perf. MCU, 32-bit ARM Cortex-M3	1.7–3.6 V	540 µW/MHz	[16]
nRF52832 Bluetooth SoC, 32-bit ARM Cortex-M4	1.7–3.6 V	100 µW/MHz	[16]
Wireless communication devices			
RFID 13.56 MHz 860–960 MHz (range: 0–3 m)	5.0 V	200 mW	[29]
Bluetooth 2.4–2.5 GHz (range: 1–100 m)	-	2.5–100 mW	[29]
MICS 402–405 MHz (range: 0–2 m)	-	25 µW	[29]

Gljušćić P, Zelenika S, Blažević D, Kamenar E. Kinetic Energy Harvesting for Wearable Medical Sensors. *Sensors (Basel)*. 2019;19(22):4922.

Dispozitive IoT. Tehnologii wireless

- Alegerea tehnologiei wireless pentru o aplicație IoT
  - Viteza de transmisie
  - QoS – calitatea transmisiei
  - Securitate
  - Consum energetic
  - Cost dispozitive hardware



6 Leading Types of IoT Wireless Technologies | BehrTech Blog

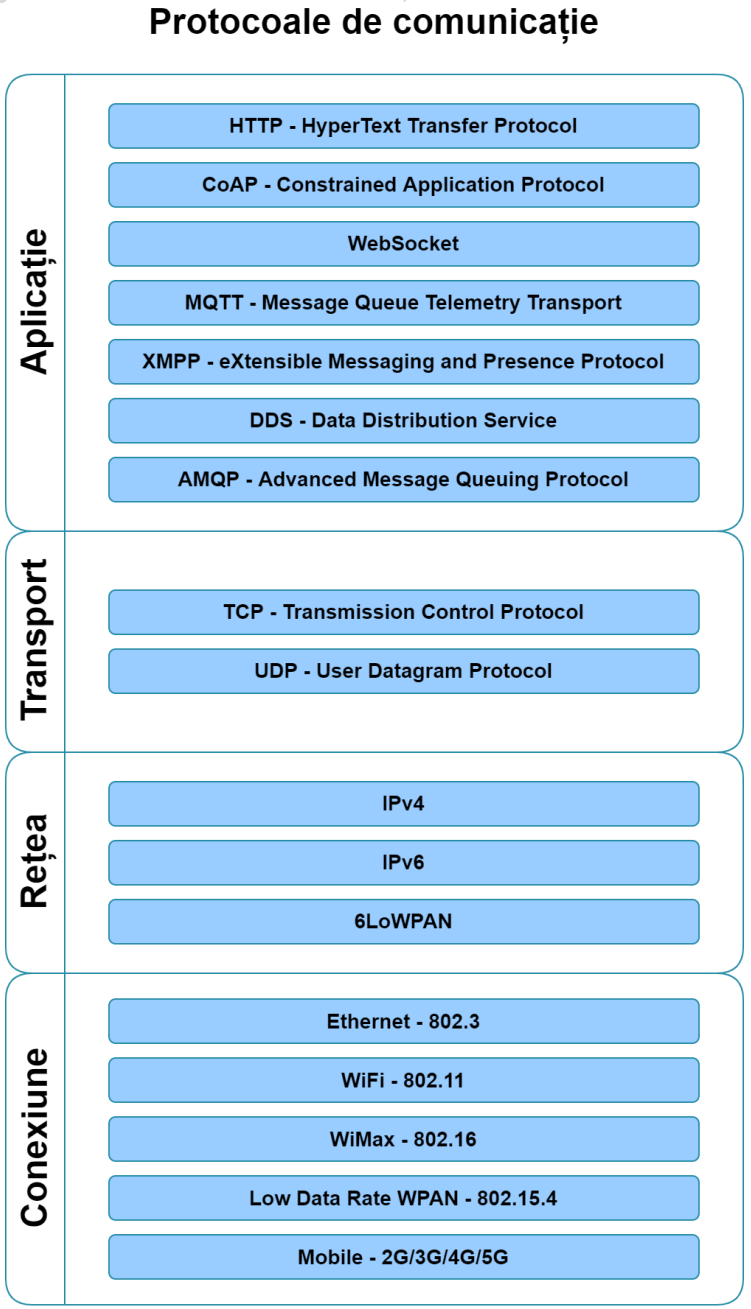
Dispozitive IoT. Tehnologii wireless

Caracteristici	Bluetooth	LR-WPAN	WiFi	Mobile	WiMAX	LoRa
Standard	IEEE 802.15.1	IEEE 802.15.4 (ZigBee) Low-Rate Wireless Personal Area Network	IEEE 802.11 a/c/b/d/g/n	2G (GSM) CDMA 3G (UMTS) CDMA2000 4G LTE	IEEE 802.16	LoRaWAN R1.0
Consum	Mediu / Foarte scăzut (BLE)	Scăzut	Ridicat	Mediu	Mediu	Foarte scăzut
Frecvență	2.4 GHZ	868/915 MHz, 2.4 GHz	5 – 60 GHz	865 MHz – 2 GHz	2 – 66 GHz	868/900 MHz
Viteză	1 – 24 Mb/s	40 – 250 Kb/s	1 Mb/s – 6.75 Gb/s	200 Kb/s – 1 Gb/s	1 Mb/s – 1 Gb/s (fix) 50 – 100 Mb/s (mobil)	0.3 – 50 Kb/s
Distanță	8 – 10 m	10 – 20 m	20 – 100 m	Arie acoperire	<50 Km	<30 Km
Cost	$	$	$$	$$$	$$$	$$$

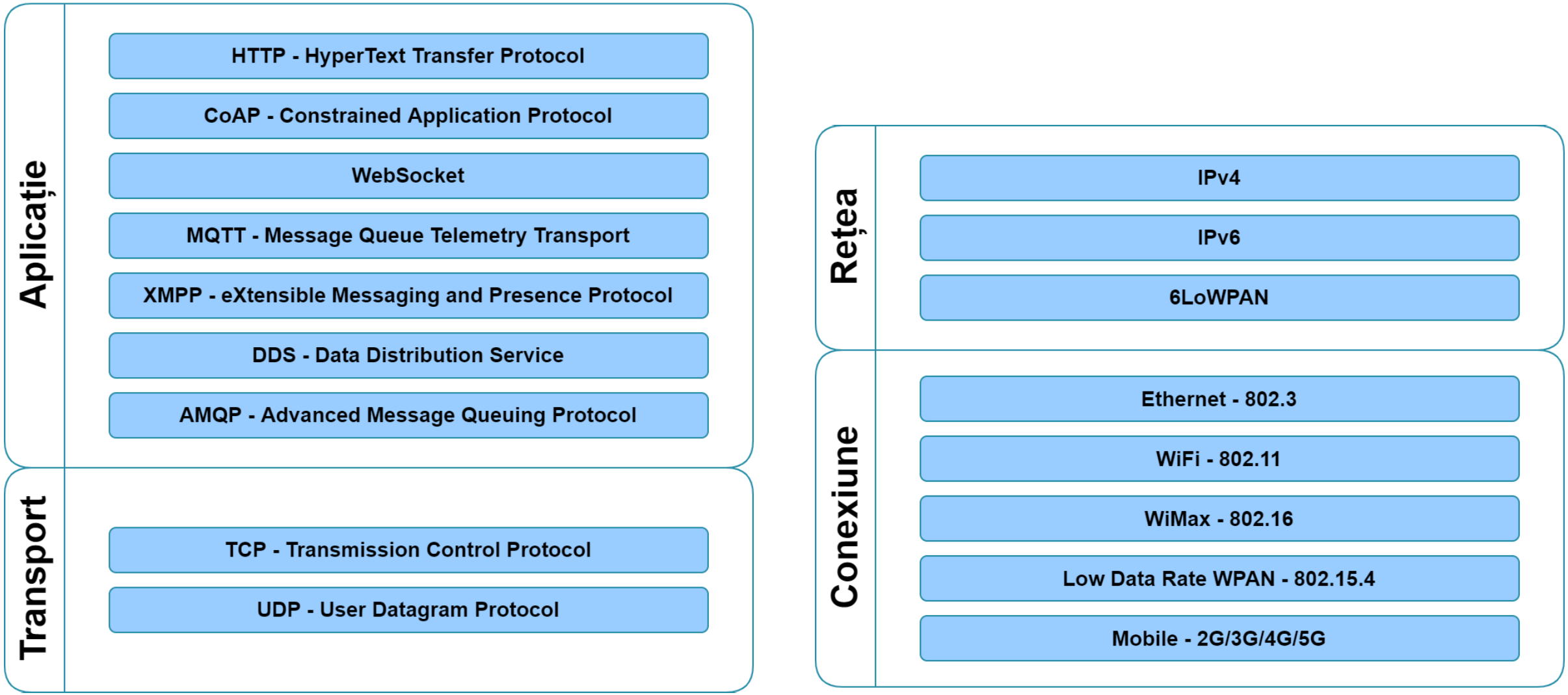
Conectivitate

Conectivitate

- Protocoale de comunicație
- La nivel de
  - Conexiune (Link Layer)
  - Rețea (Network Layer)
  - Transport (Transport Layer)
  - Aplicație (Application Layer)

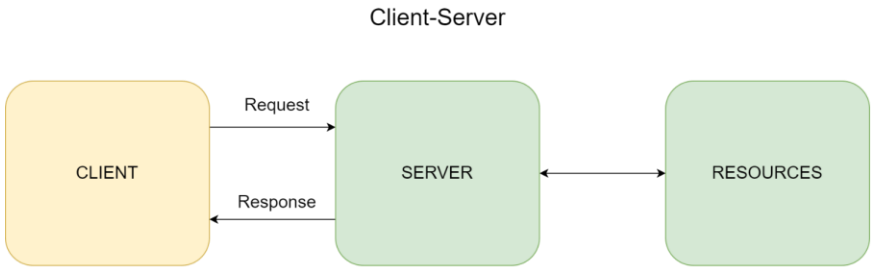


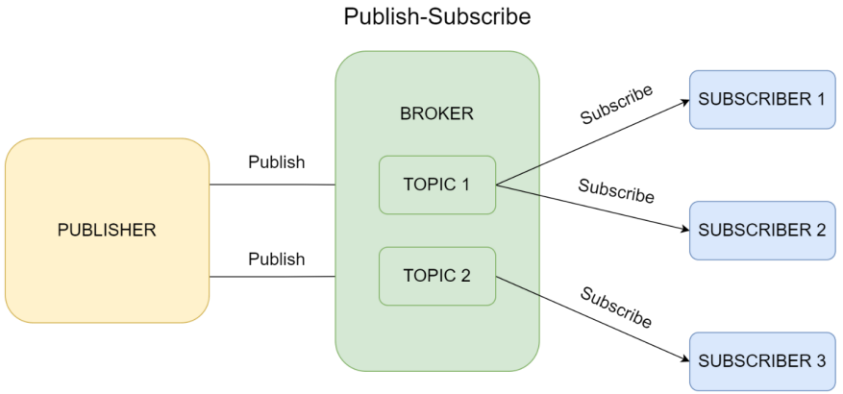
Conectivitate – protocoale de comunicație

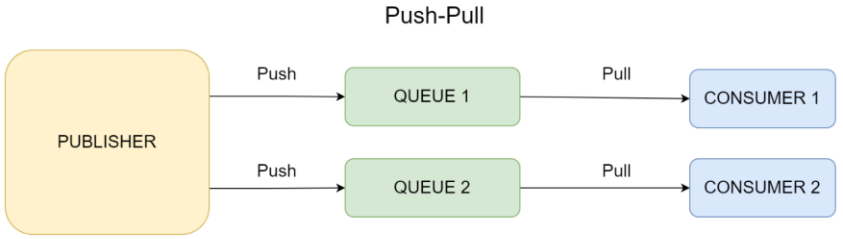


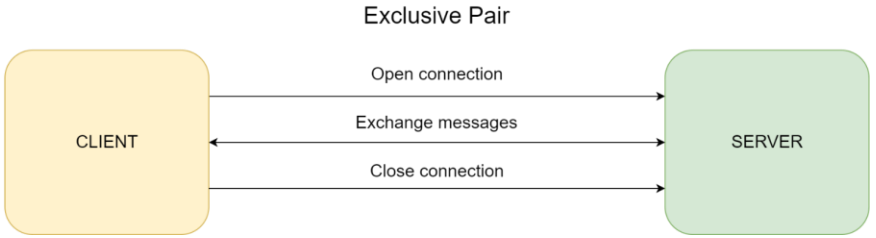
Conectivitate

- Protocoale de comunicație
  - Nivel aplicație
- Arhitecturi
  - Client – Server
  - Publish – Subscribe
  - Push – Pull
  - Exclusive Pair



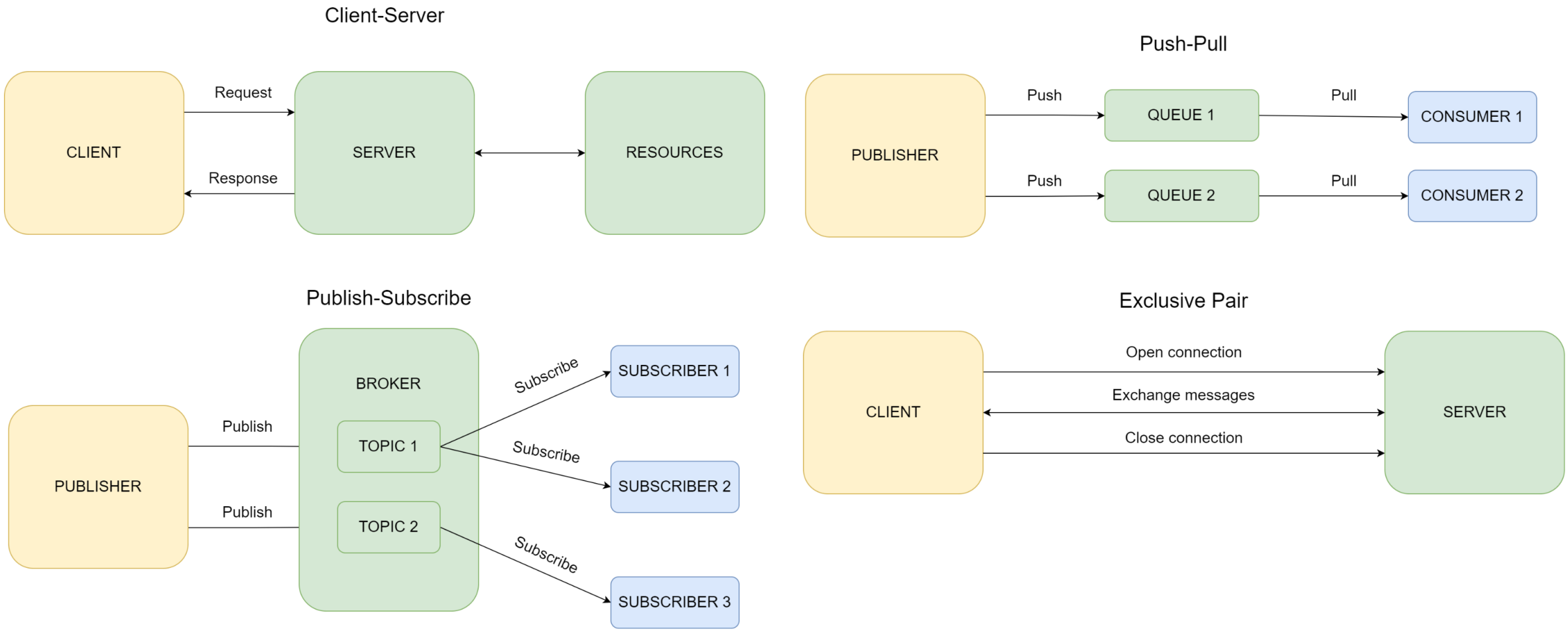






[Communication Models in IoT]

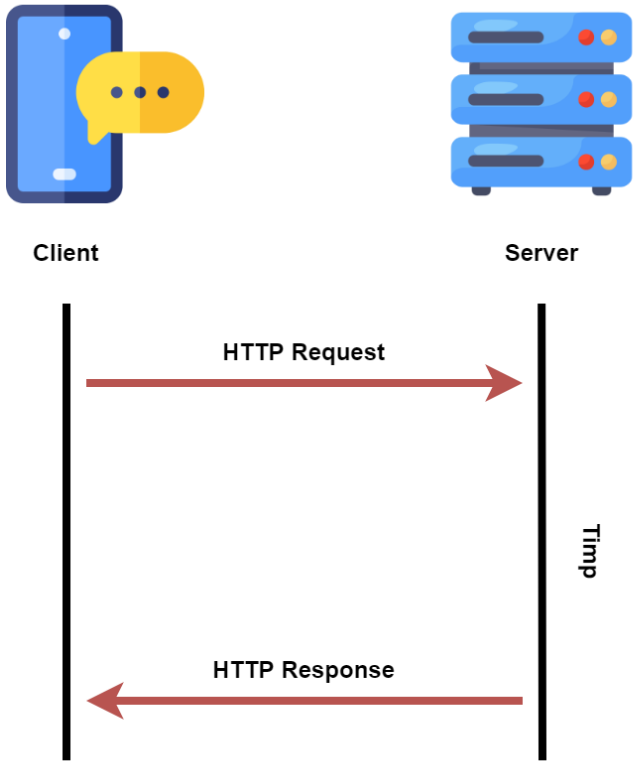
Conectivitate – arhitecturi nivel aplicație



Communication Models in IoT

Conectivitate. HTTP

- Arhitectură REST – REpresentational State Transfer
  - Reprezentare unificată (REST API)
  - Arhitectură decuplată
  - Client – Server
  - Stateless – întreg contextul este conținut în mesajul curent
- HTTP Request
- HTTP Response



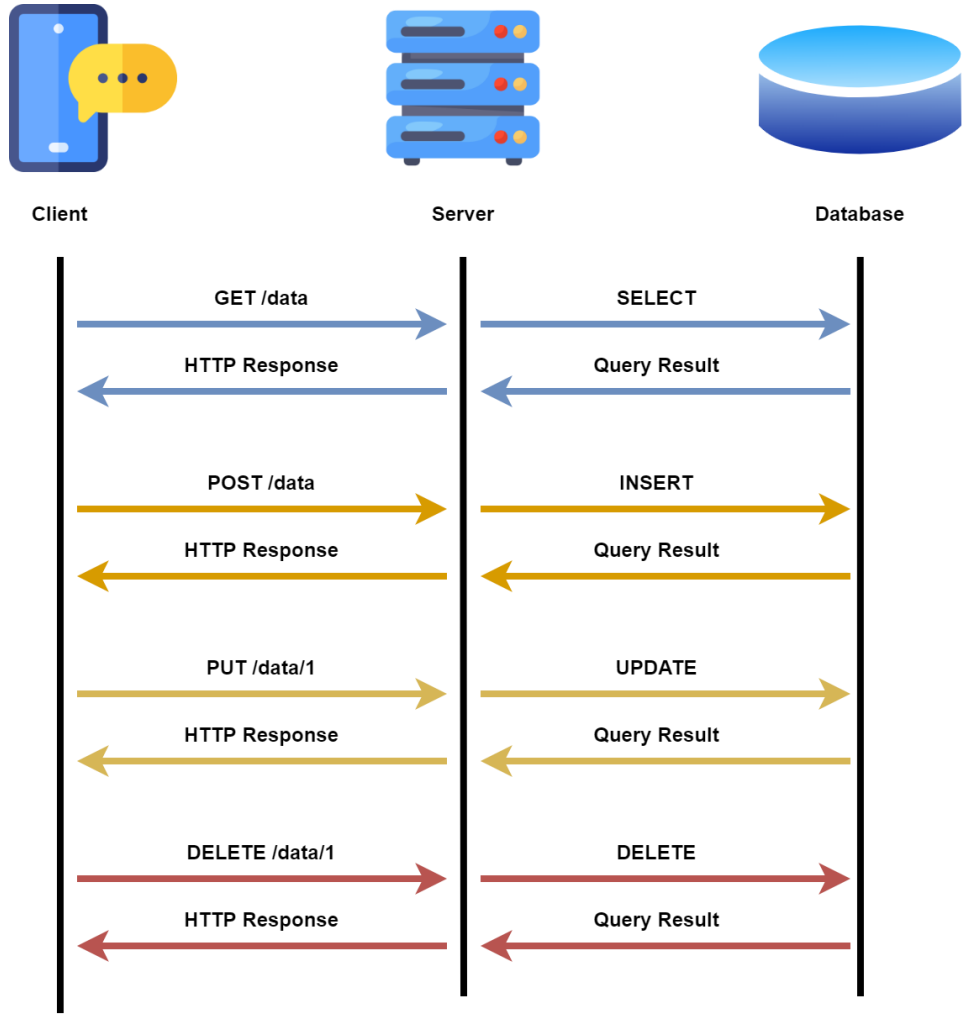

```
GET / HTTP/1.1
Host: developer.mozilla.org
Accept-Language: en
```

```
HTTP/1.1 200 OK
Content-Type: text/html; charset=utf-8
Content-Length: 55743
Connection: keep-alive
Cache-Control: s-maxage=300, public, max-age=0
Content-Language: en-US
Date: Thu, 06 Dec 2018 17:37:18 GMT
ETag: "2e77ad1dc6ab0b53a2996dfd4653c1c3"
Server: meinheld/0.6.1
Strict-Transport-Security: max-age=63072000
X-Content-Type-Options: nosniff
X-Frame-Options: DENY
X-XSS-Protection: 1; mode=block
Vary: Accept-Encoding,Cookie
Age: 7

<!DOCTYPE html>
<html lang="en">
<head>
  <meta charset="utf-8">
  <title>A simple webpage</title>
</head>
<body>
  <h1>Simple HTML webpage</h1>
  <p>Hello, world!</p>
</body>
</html>
```

[An overview of HTTP | developer.mozilla.org]

Conectivitate. HTTP

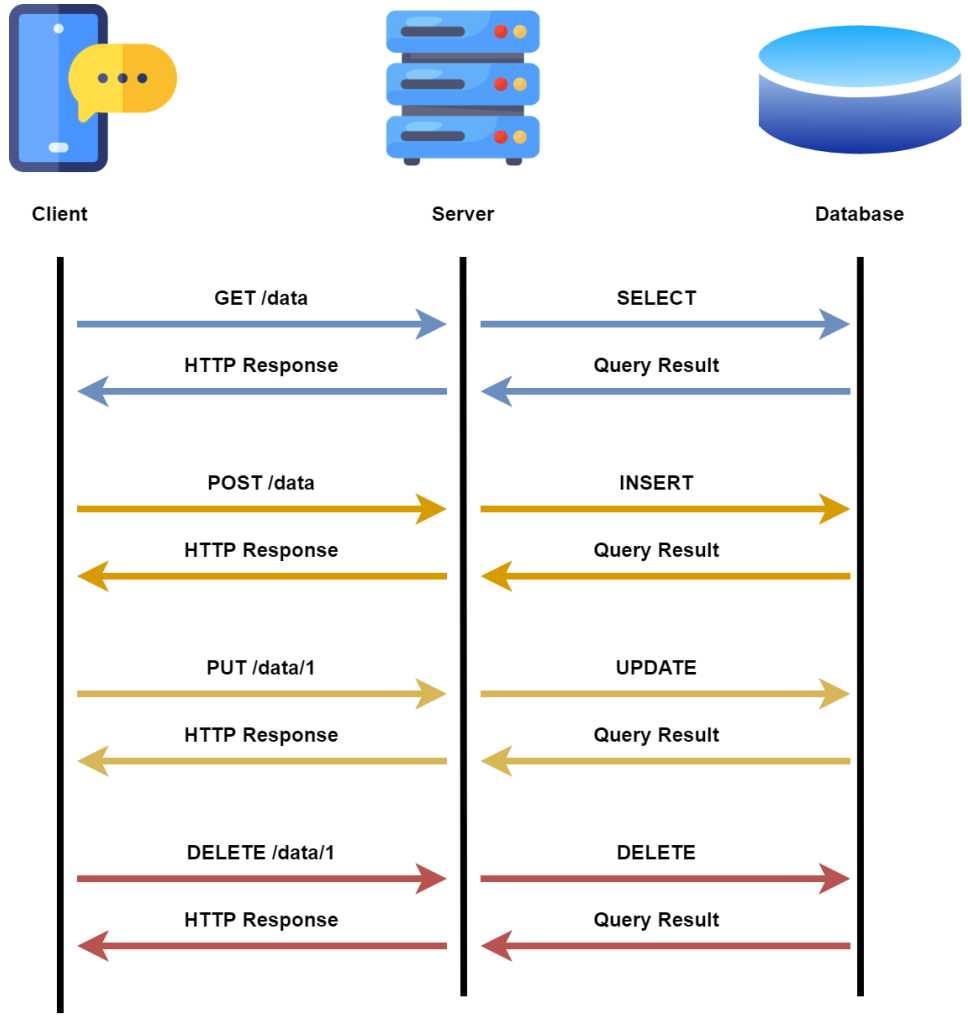
- HTTP Request – Metode
  - **GET**
  - **POST**
  - PUT
  - DELETE
- URL Endpoint
- HTTP Headers
  - General: Via
  - Context: User-Agent, Accept
  - Reprezentare: Content-Type
- Date (Body)
  - Simplu (single-resource)
  - Multiplu (multipart)



An overview of HTTP | developer.mozilla.org

Conectivitate. HTTP

- HTTP Response – Status
  - 1XX (informational)
  - 2XX (successful)
  - 3XX (redirection)
  - 4XX (client error)
  - 5XX (server error)



HTTP response status codes | developer.mozilla.org

Conectivitate. HTTP

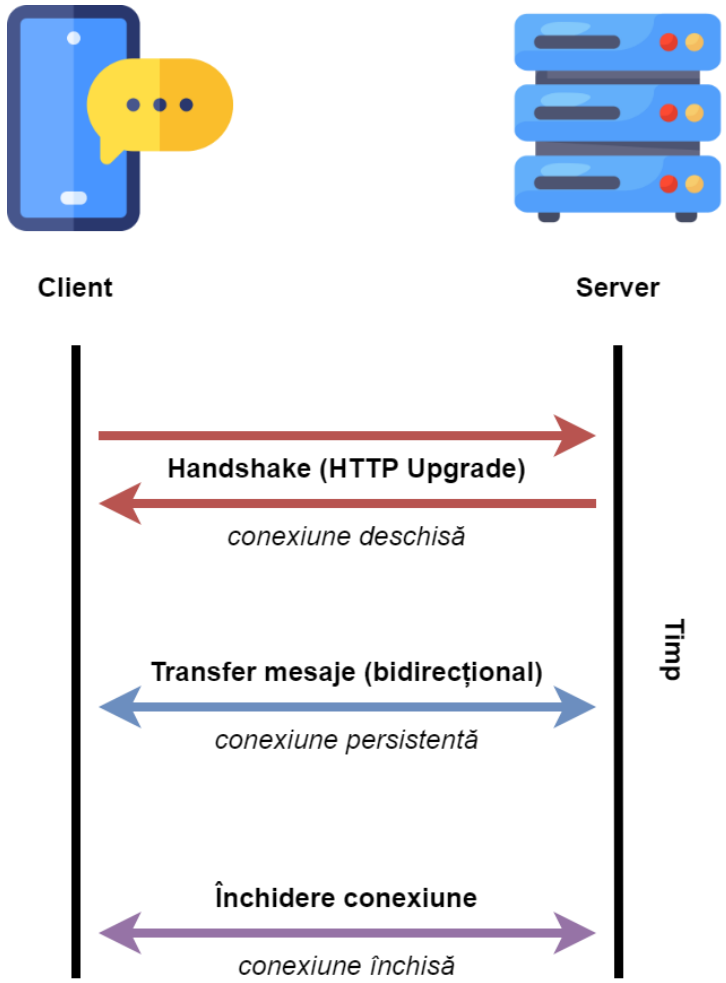
- HTTP Response – MIME Type
- Multipurpose Internet Mail Extensions – type/subtype
  - Text
    - application/octet-stream
    - text/plain
    - text/html
  - Imagini
    - image/jpeg
  - Audio/Video
    - audio/wav
    - video/webm
  - Multipart
    - multipart/form-data

Content-Type | developer.mozilla.org

```
HTTP/1.1 200 OK
Date: Mon, 23 May 2005 22:38:34 GMT
Content-Type: text/html; charset=UTF-8
Content-Length: 155
Last-Modified: Wed, 08 Jan 2003 23:11:55 GMT
Server: Apache/1.3.3.7 (Unix) (Red-Hat/Linux)
ETag: "3f80f-1b6-3e1cb03b"
Accept-Ranges: bytes
Connection: close

<html>
 <head>
  <title>An Example Page</title>
 </head>
 <body>
  <p>Hello World, this is a very simple HTML document.</p>
 </body>
</html>
```

Conectivitate. WebSockets

- Comunicație full duplex pentru schimb de mesaje bidirecțional între client și server
- Are la bază protocolul TCP
- Client: browser, dispozitiv IoT, aplicație mobilă, etc.



RFC 6455: The WebSocket Protocol

Conectivitate. WebSockets

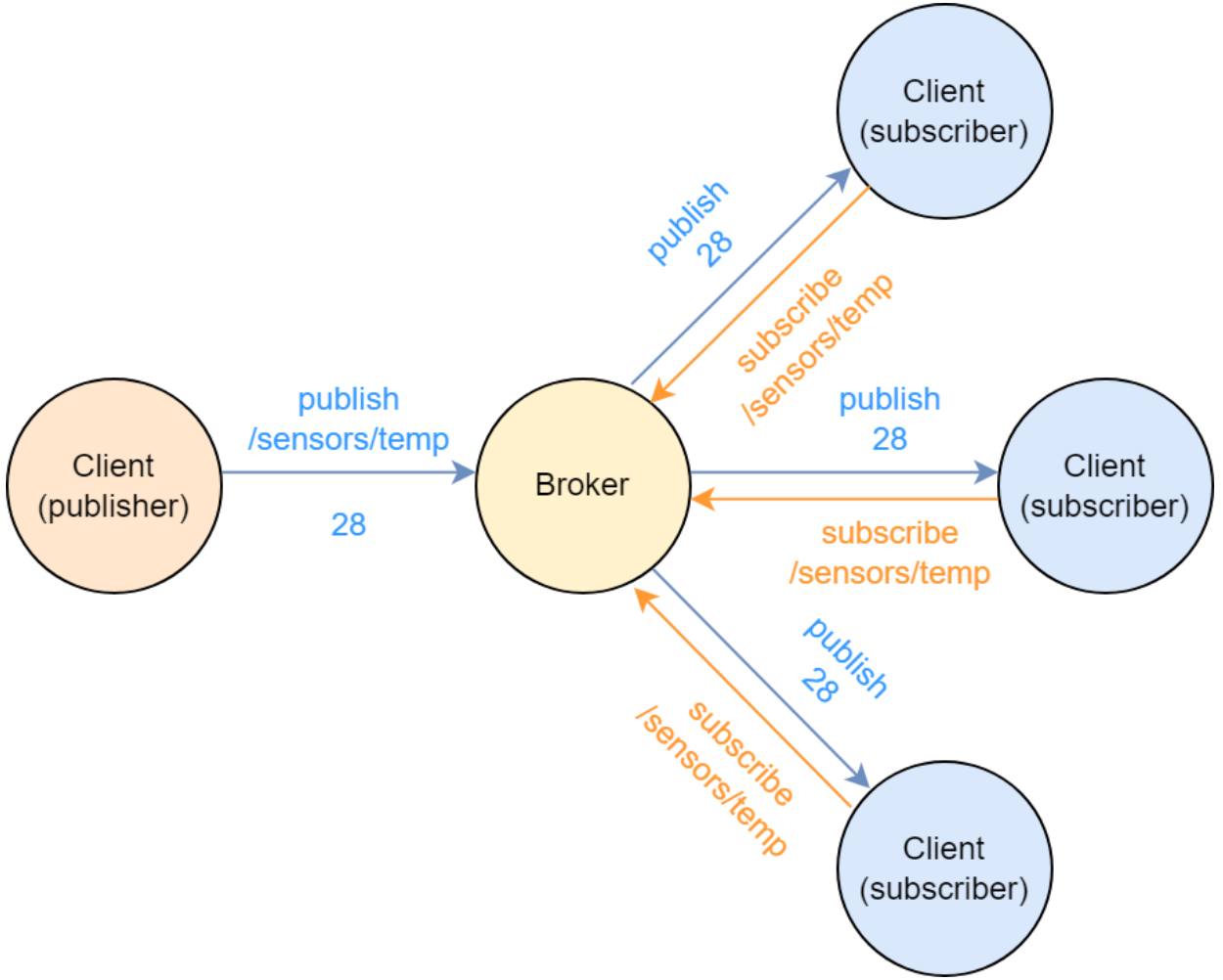
- API standardizat la nivel de browser
- Event – based
- Exemplu în CodePen
  - Utilizează Postman WebSocket Echo Service

```
var socket = new WebSocket('wss://ws.postman-echo.com/raw');

socket.onerror = function(error) {
  console.log('WebSocket Error: ' + error);
};

socket.onopen = function(event) {
  console.log("Connected to: " + event.currentTarget.url);
};

socket.onmessage = function(event) {
  console.log("Received message: " + event.data);
};

socket.onclose = function(event) {
  console.log("Disconnected from WebSocket");
};
```

RFC 6455: The WebSocket Protocol

Conectivitate. MQTT

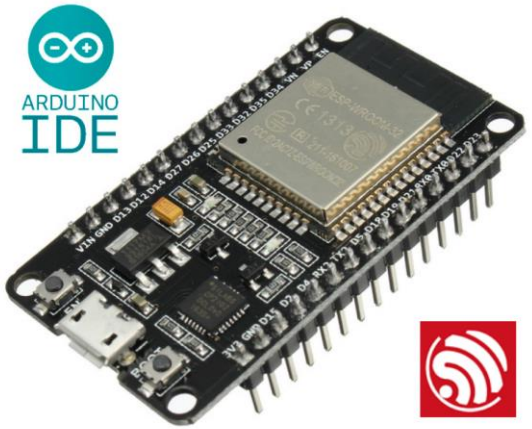
- Arhitectură Publish – Subscribe
  - Broker mesaje
  - Subiecte (topics)
- Acțiuni
  - Publish
  - Subscribe
  - Ping
  - Disconnect
- QoS: cum ajunge mesajul
  - 0 – cel mult o dată (best effort)
  - 1 – cel puțin o dată (retry)
  - 2 – o singură dată (ack)



ISO/IEC 20922 / MQTT Version 5.0

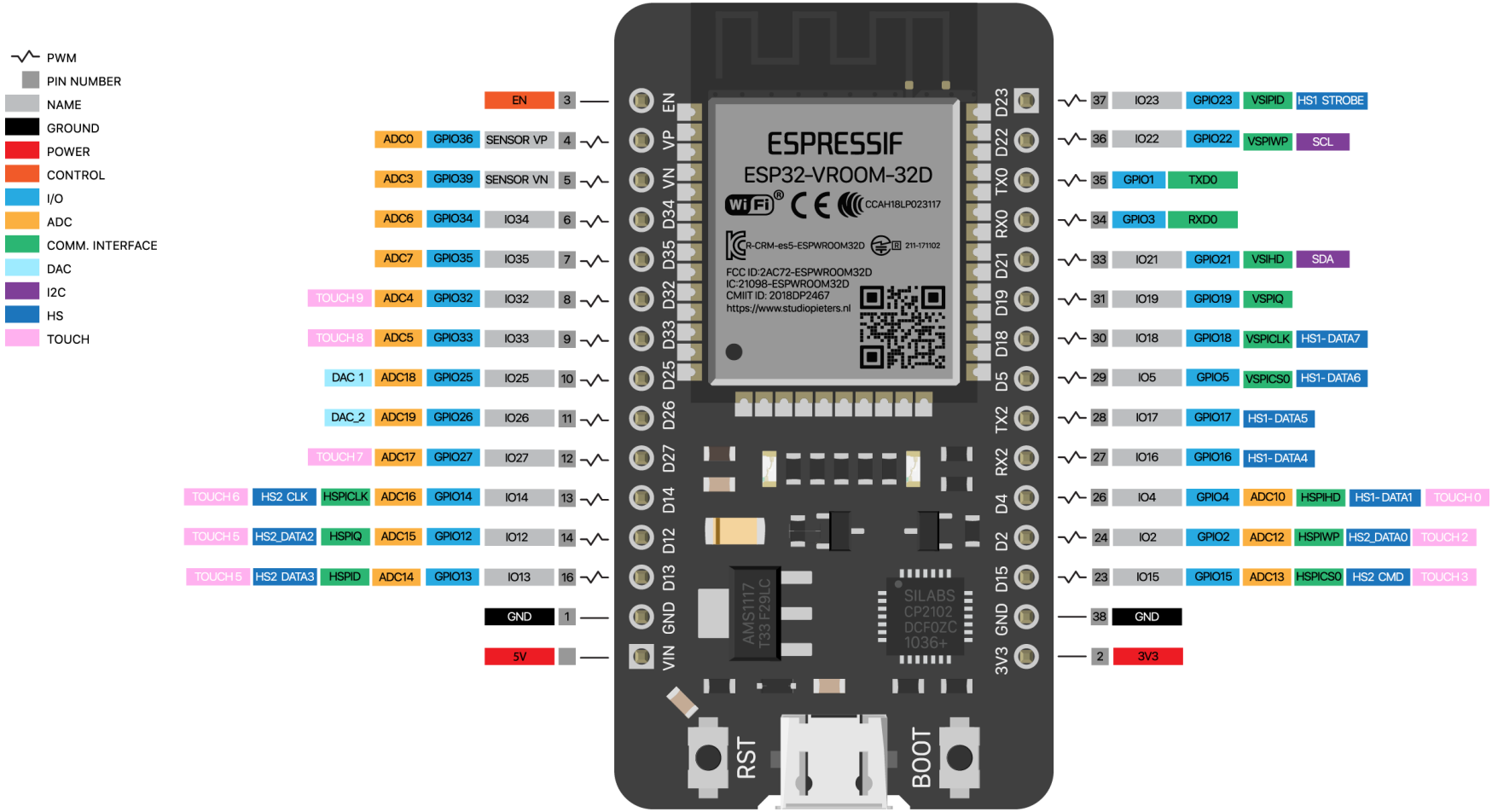
Aplicație IoT cu ESP32

Aplicație IoT cu ESP32



- Platformă IoT programabilă în Arduino IDE
- Capabilități
  - Wi-Fi
  - Bluetooth / BLE
  - Dual-core 32 bit 160 / 240 MHz
  - ROM: 448 KB, SRAM: 520 KB, Flash: 0-4 MB
  - Varietate mare de periferice: ADC (18x12 bit), DAC (2x8 bit), UART, CAN, SPI, I2C (2x), PWM (16x), GPIO + senzori touch capacitivi (10x) + RTC
- Software
  - FreeRTOS (sistem de operare în timp real pentru microcontrolere)
- Cost ~10 EUR

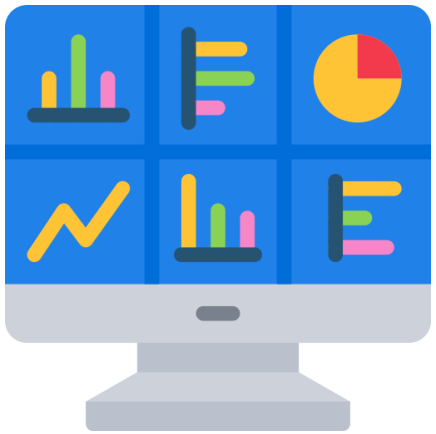
Aplicație IoT cu ESP32



[ESP32 - PinOut]

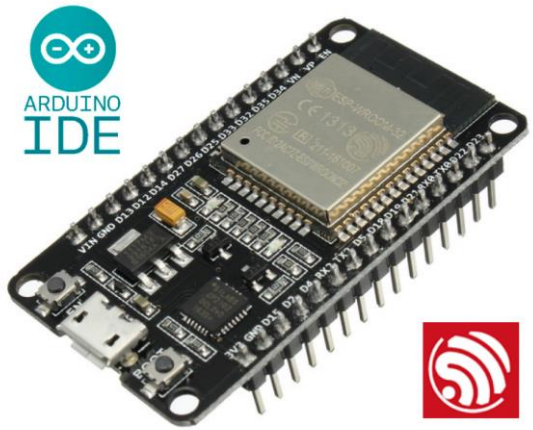
Aplicație IoT cu ESP32

- Arduino IDE
- Instalare driver USB CP210x
- Instalare definiții Arduino IDE
  - https://raw.githubusercontent.com/espressif/arduino-esp32/gh-pages/package_esp32_index.json
  - http://arduino.esp8266.com/stable/package_esp8266com_index.json
- Biblioteci
  - https://github.com/adafruit/Adafruit_HTU21DF_Library
  - https://github.com/me-no-dev/AsyncTCP

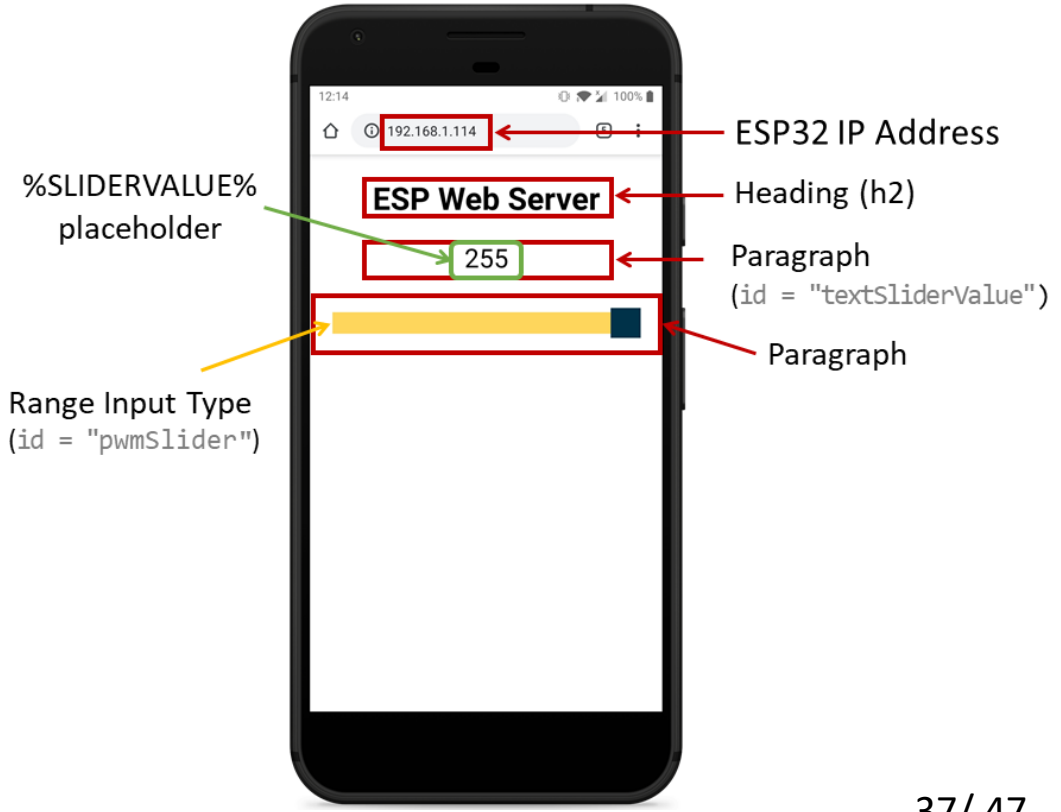


Installing the ESP32 Board in Arduino IDE (Windows, Mac OS X, Linux)

Aplicație IoT cu ESP32 (1)

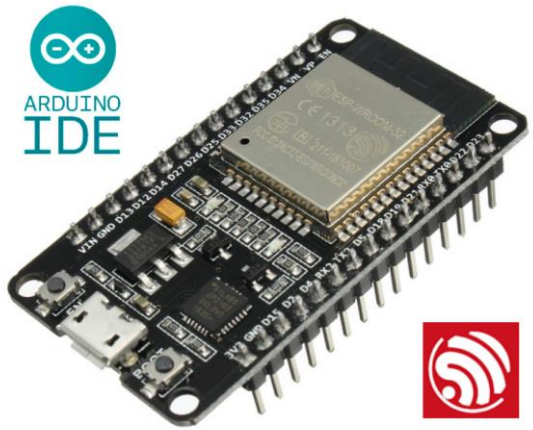


- Biblioteci
  - https://github.com/adafruit/Adafruit_HTU21DF_Library
  - https://github.com/me-no-dev/AsyncTCP
  - https://github.com/me-no-dev/ESPAsyncWebServer
- Webserver
  - Pagină web interactivă hostată pe ESP32
  - HTTP server configurat asincron
  - Încărcarea paginilor web în memoria Flash (compatibil Ardino IDE 1.x)

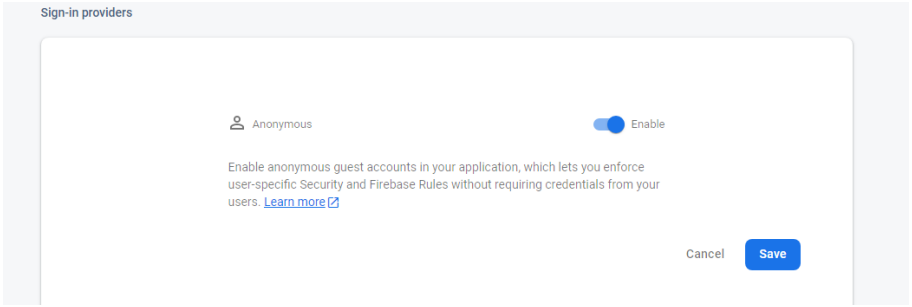


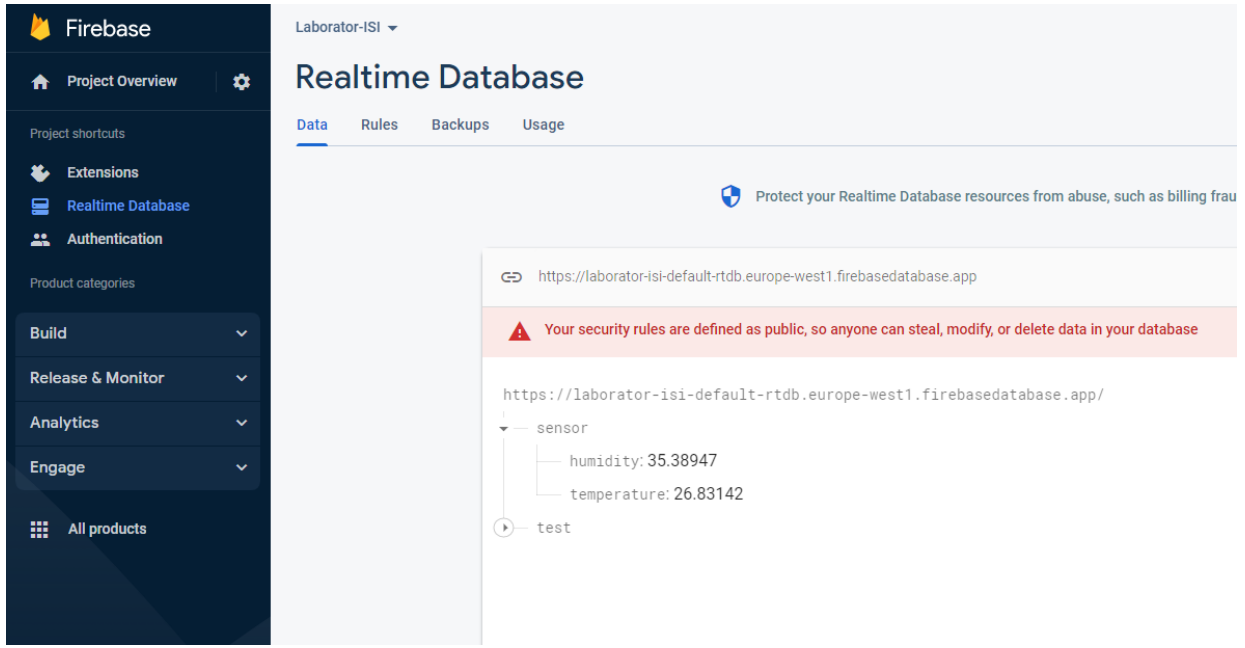
ESP32 Web Server with Slider: Control LED Brightness (PWM)

Aplicație IoT cu ESP32 (2)



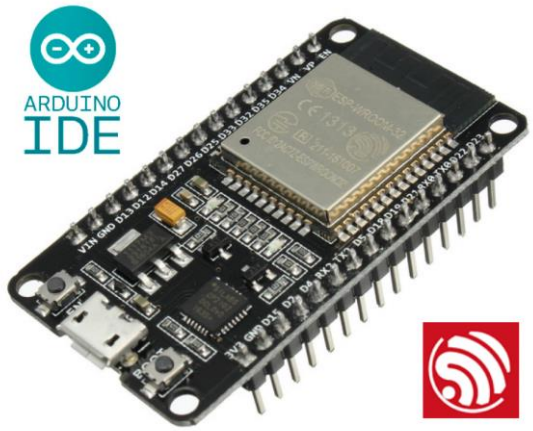
- Biblioteci
  - https://github.com/adafruit/Adafruit_HTU21DF_Library
  - https://github.com/me-no-dev/AsyncTCP
  - https://github.com/mobizt/Firebase-ESP-Client
- Firebase
  - Conectarea la Firebase
    - Activare mod conectare anonimă din Firebase Console





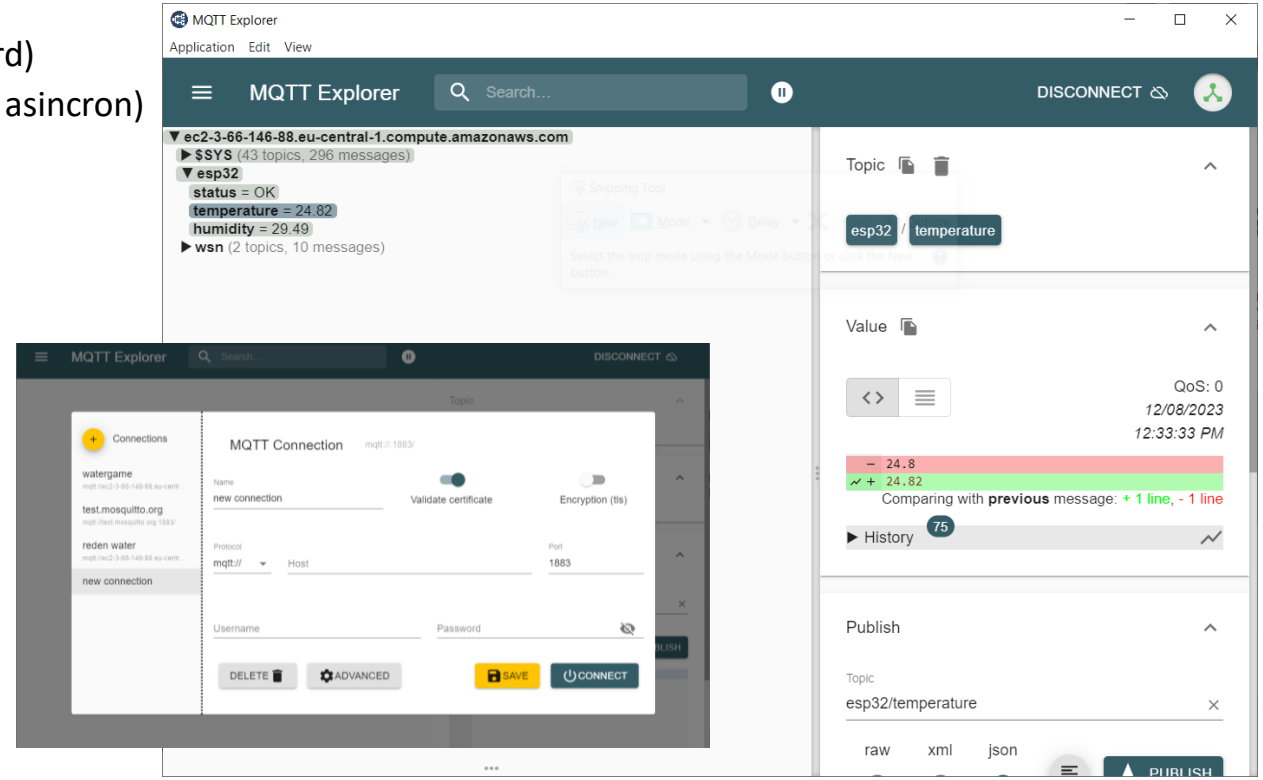
ESP32: Getting Started with Firebase (Realtime Database)

Aplicație IoT cu ESP32 (3)



- Biblioteci
  - https://github.com/adafruit/Adafruit_HTU21DF_Library
  - https://github.com/me-no-dev/AsyncTCP
  - https://github.com/knolleary/pubsubclient (MQTT - standard)
  - https://github.com/marvinroger/async-mqtt-client (MQTT - asincron)
- MQTT
  - Conectarea la un broker MQTT
  - Mosquitto (broker MQTT)
    - Instalare
    - Configurare

      listener 1883
      allow_anonymous true
    - MQTT Explorer (client MQTT)

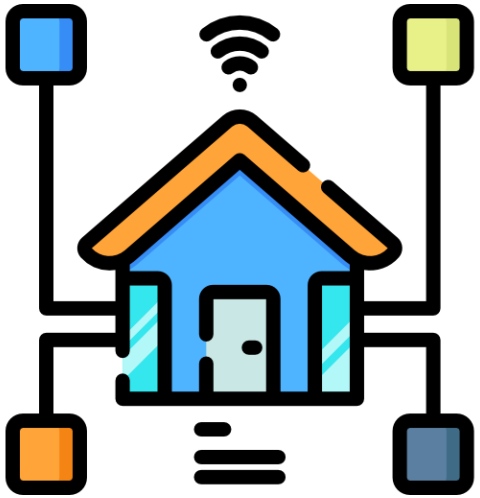


ESP32 MQTT – Publish and Subscribe with Arduino IDE

Platforme IoT

Platforme IoT

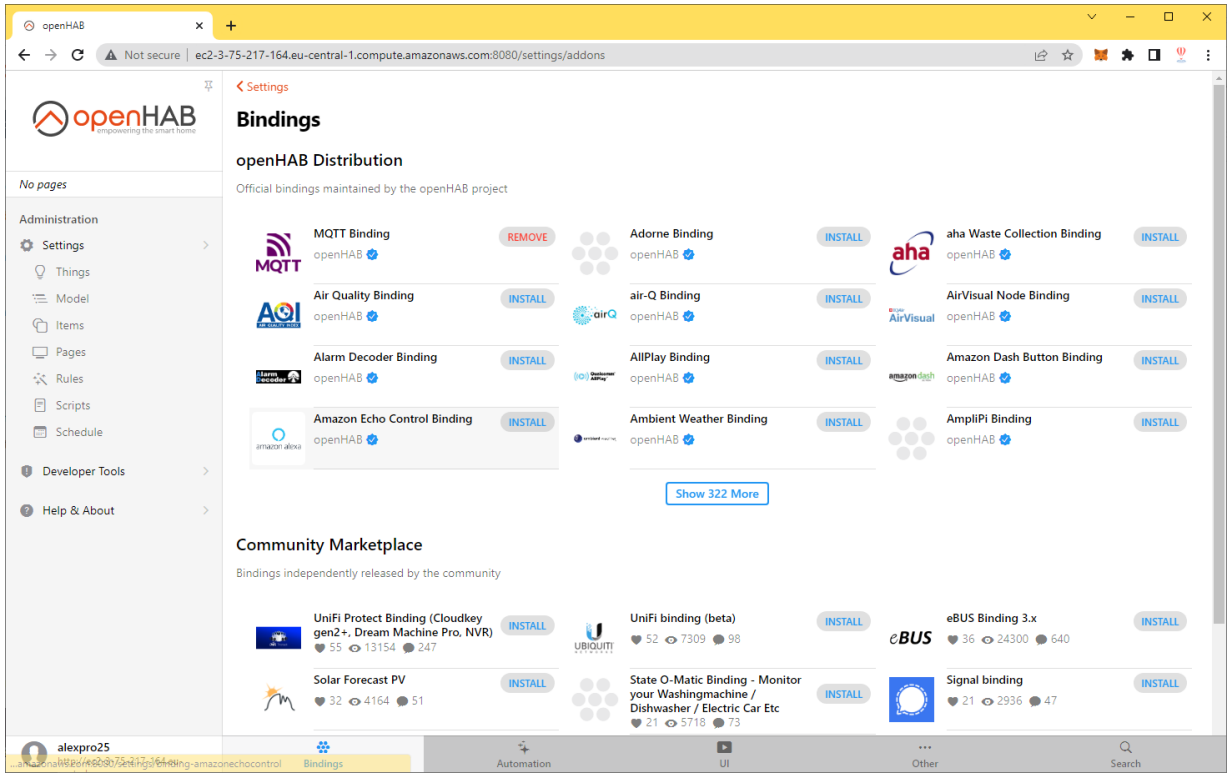
- Funcționalități
  - Vizualizare date
  - Acționare dispozitive
  - Colectare și agregare date
  - Stocare date
  - Fluxuri de automatizare
- Studiu de caz
  - Smart Home – platforme de automatizare a locuinței
  - Platforme generice pentru aplicații IoT



[9 Home Automation Open-Source Platforms for Your projects]

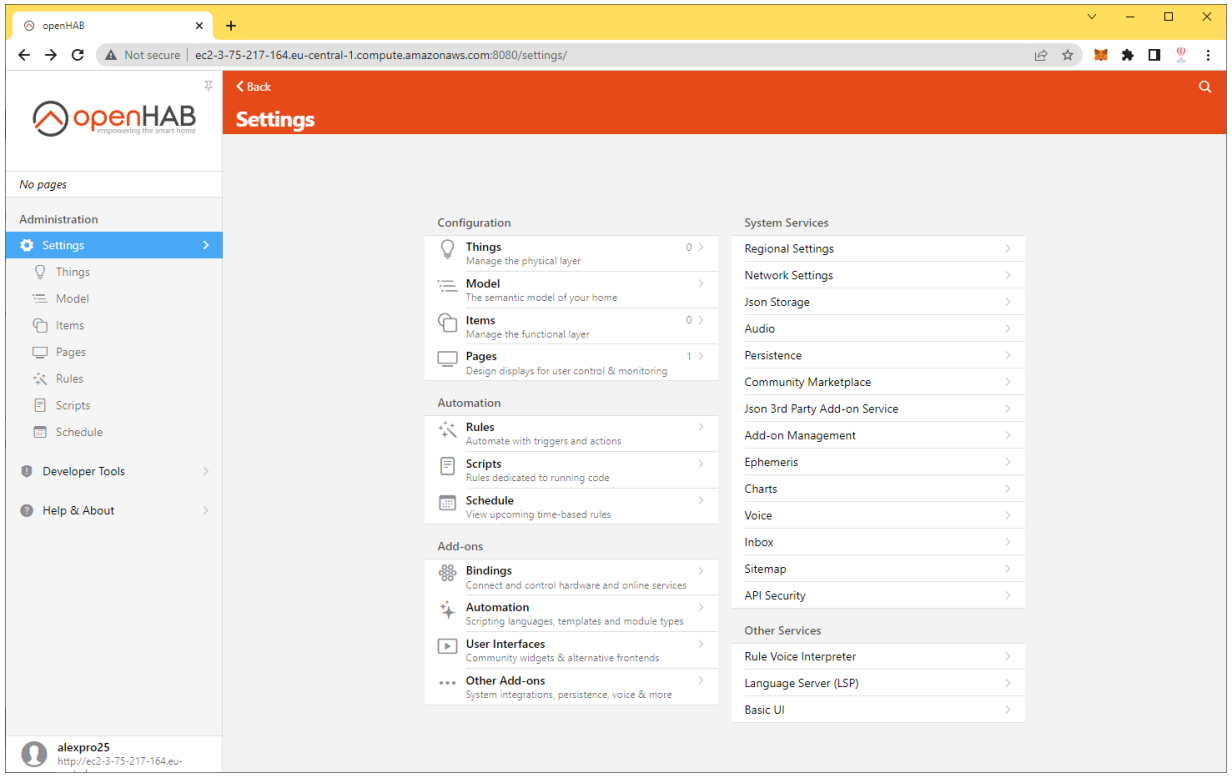
Studiu de caz. OpenHAB

- Platformă IoT Open-Source cu aplicabilitate în domeniul Smart Home
- Integrarea dispozitivelor IoT în scheme de automatizare a locuinței
- Instalare
  - Instalare Java 11
  - Instalare OpenHAB
  - Instalare legături (bindings)
    - MQTT Binding



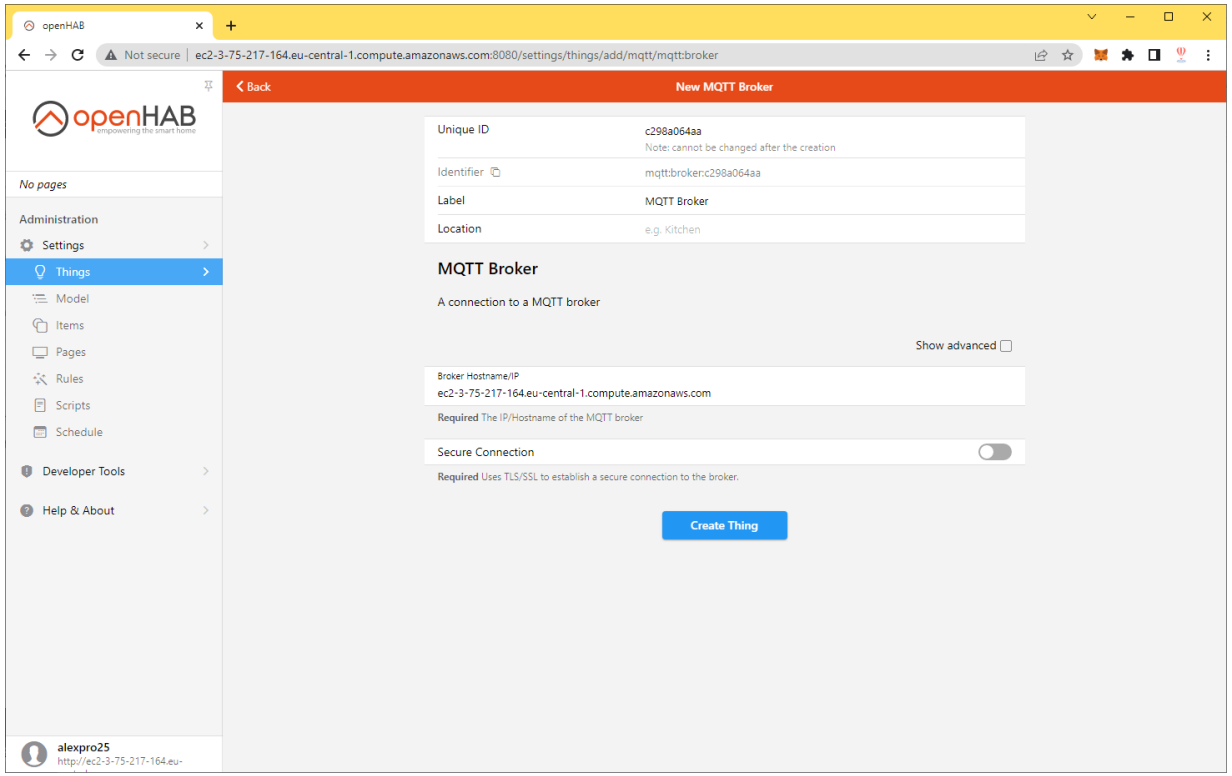
Studiu de caz. OpenHAB

- Platformă IoT Open-Source cu aplicabilitate în domeniul Smart Home
- Integrarea dispozitivelor IoT în scheme de automatizare a locuinței
- Configurare
  - Things (devices)
  - Channels (sensors)
  - Items (UI)
  - Pages (dashboard)
  - Rules (automation)
  - …



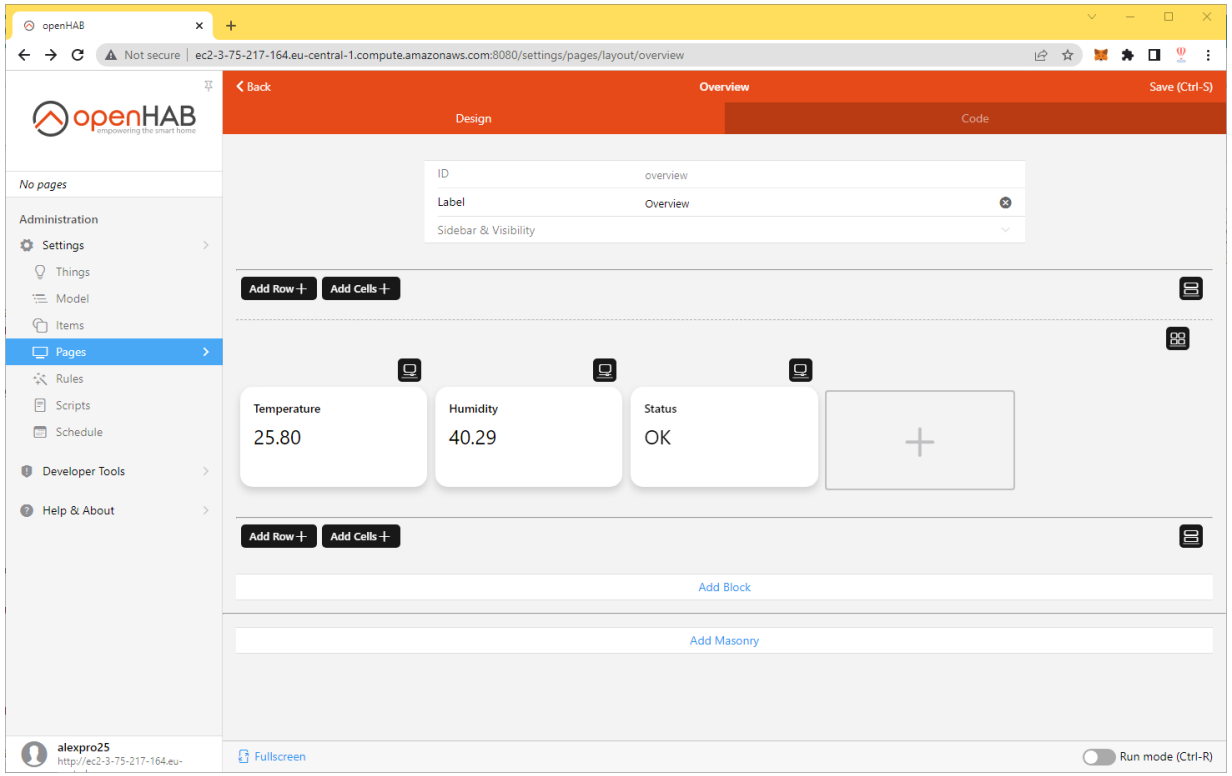
Studiu de caz. OpenHAB

- Platformă IoT Open-Source cu aplicabilitate în domeniul Smart Home
- Integrarea dispozitivelor IoT în scheme de automatizare a locuinței
- Configurare: Things
  - MQTT Thing
  - MQTT Broker (conectare)
  - Generic MQTT Thing
  - Channels (via MQTT topic)



Studiu de caz. OpenHAB

- Platformă IoT Open-Source cu aplicabilitate în domeniul Smart Home
- Integrarea dispozitivelor IoT în scheme de automatizare a locuinței
- Configurare: Pages
  - Items (UI)
- Concluzii
  - Platformă user-friendly
  - Configurare din interfață



Întrebări?

Bibliografie

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- Internet of Things (curs și laborator, Conf. Dr. Ing. Dan Tudose – master AAC, Conf. Dr. Ing. Laura Ruse – master SRIC)
- Naito, Katsuhiro. (2017). A Survey on the Internet-of-Things: Standards, Challenges and Future Prospects. Journal of Information Processing. 25. 23-31.
- Song, Yonghua & Lin, Jin & Tang, Ming & Dong, Shufeng. (2017). An Internet of Energy Things Based on Wireless LPWAN. Engineering. 3. 460-466. 10.1016/J.ENG.2017.04.011.
- History of IoT: A Timeline of Development
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- Getting Started with the ESP32 Development Board
- 9 Home Automation Open-Source Platforms for Your projects