



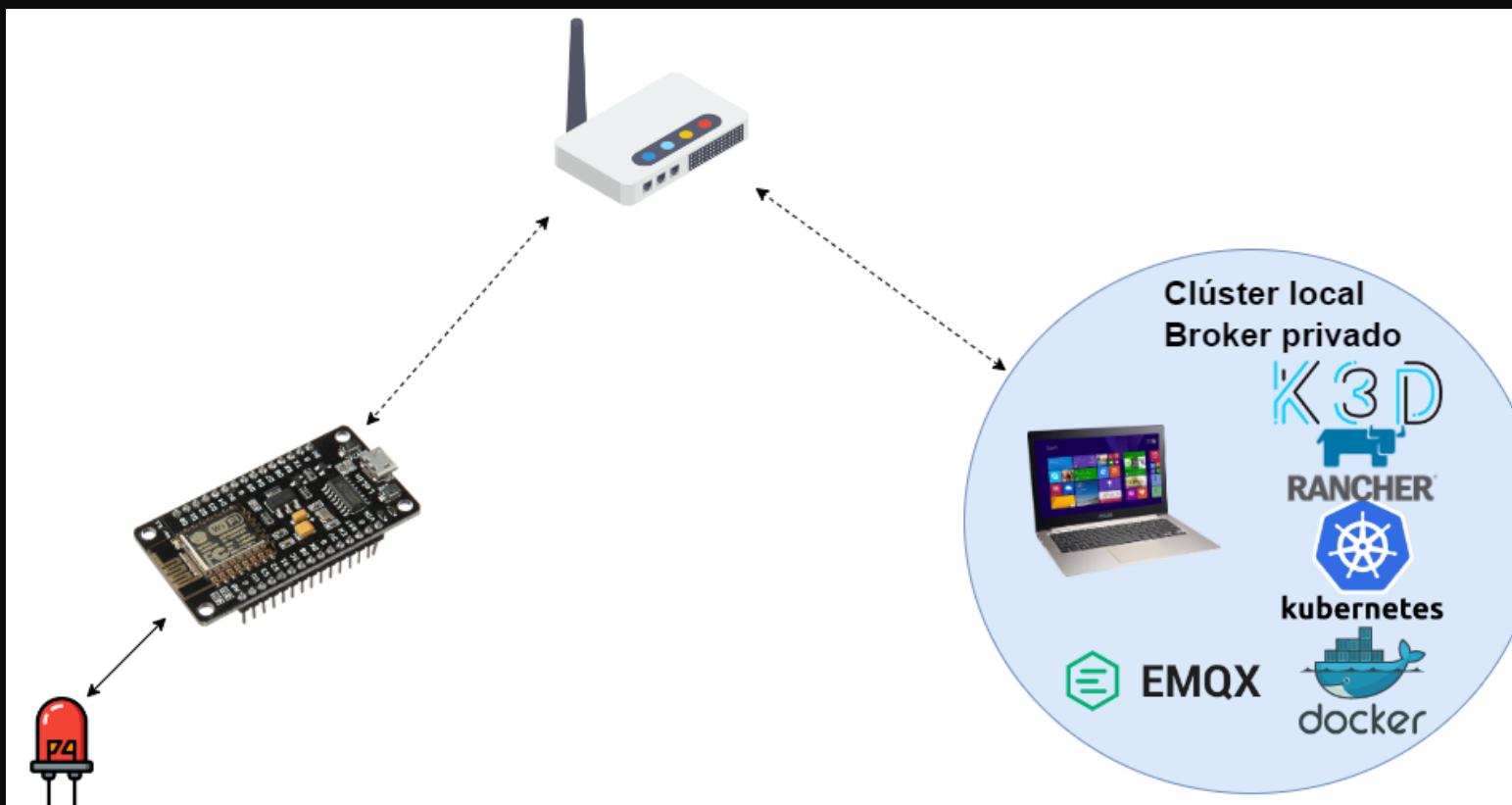
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COMPUTACIÓN TOLERANTE A FALLAS  
CALENDARIO 2022A  
DR. MICHEL EMMANUEL LÓPEZ FRANCO

# PROYECTO - IoT

# INTRODUCCIÓN

## COMPUTACIÓN TOLERANTE



Conexión de una placa NodeMCU8266 a un clúster de Kubernetes para dar una primera etapa a un sistema IoT.

# Introducción

04

## TECNOLOGÍAS UTILIZADAS

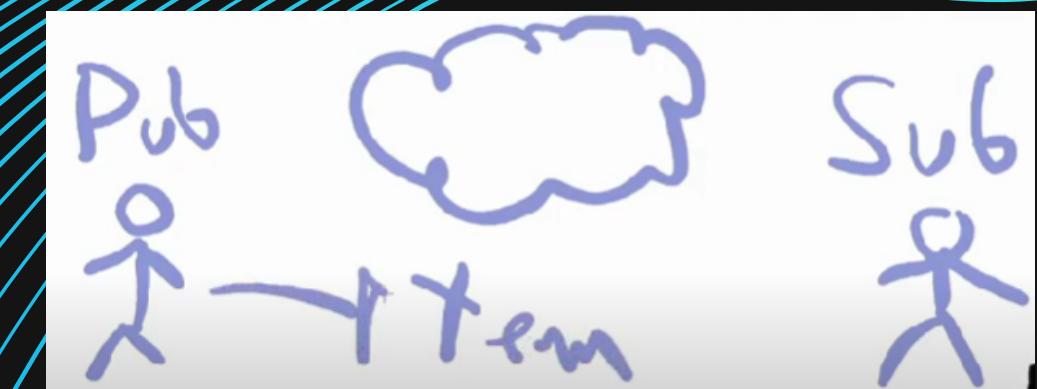
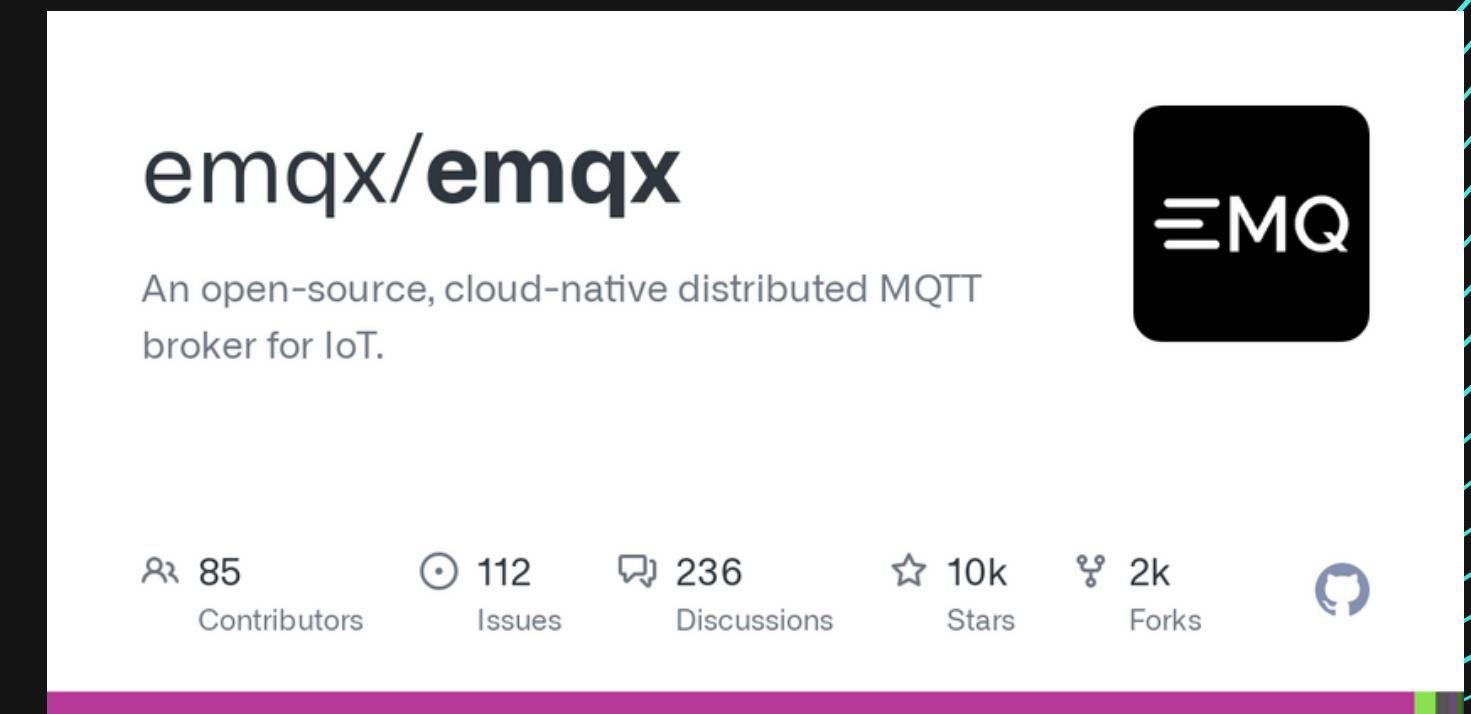
Se expondrán las tecnologías que fueron necesarias para realizar el proyecto.

## CONEXIÓN NODEMCU8266

Conexión de una placa NodeMCU8266 a un clúster de Kubernetes para dar una primera etapa a un sistema IoT.

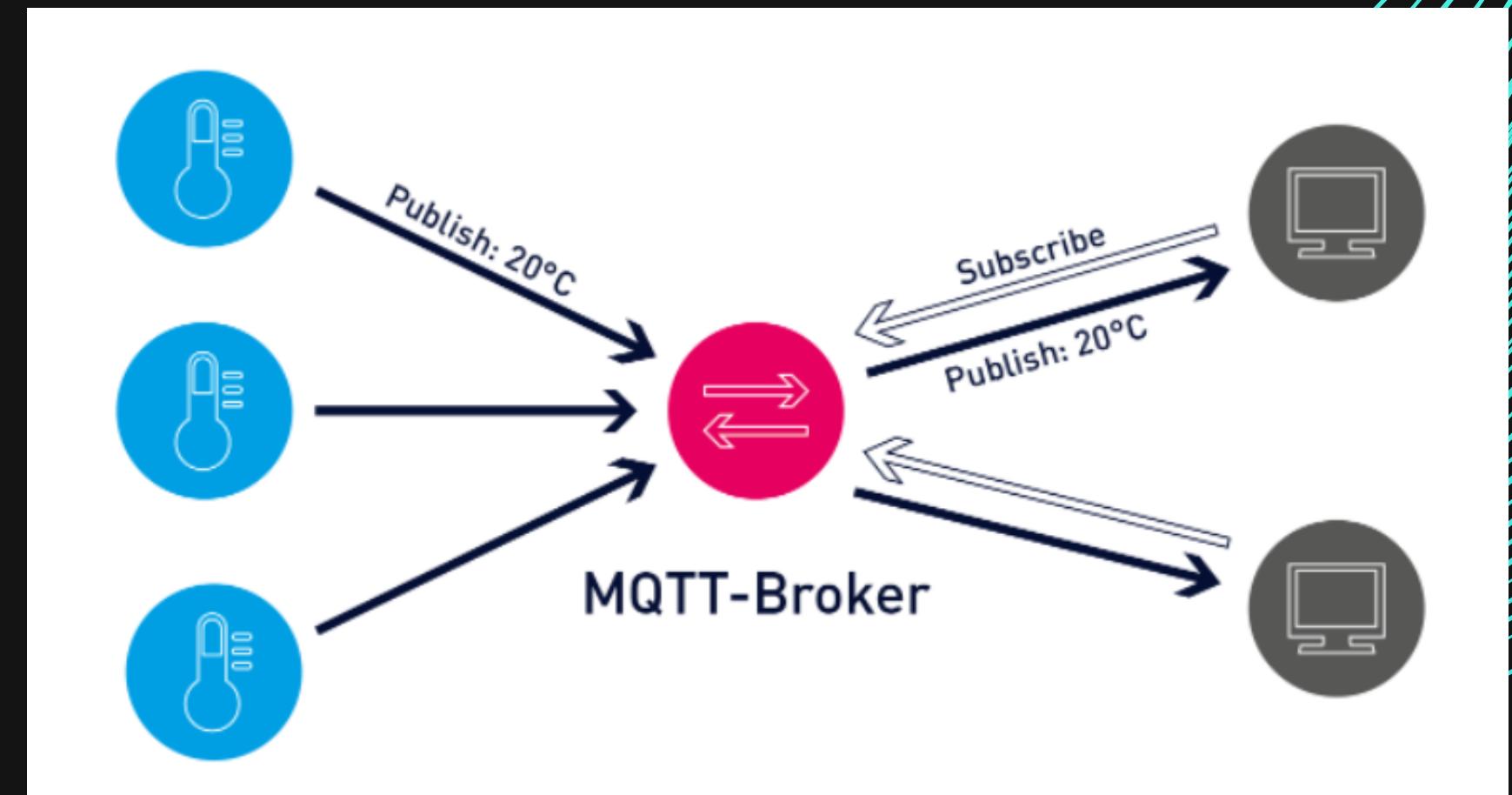
# EMQX

Es un proyecto open-source, apoyado por Cloud Native, el cuál funge como broker MQTT para IoT.



# MQTT

MQTT (Message Queuing Telemetry Transport) es un protocolo de comunicación maquina a maquina para redes de bajos recursos.

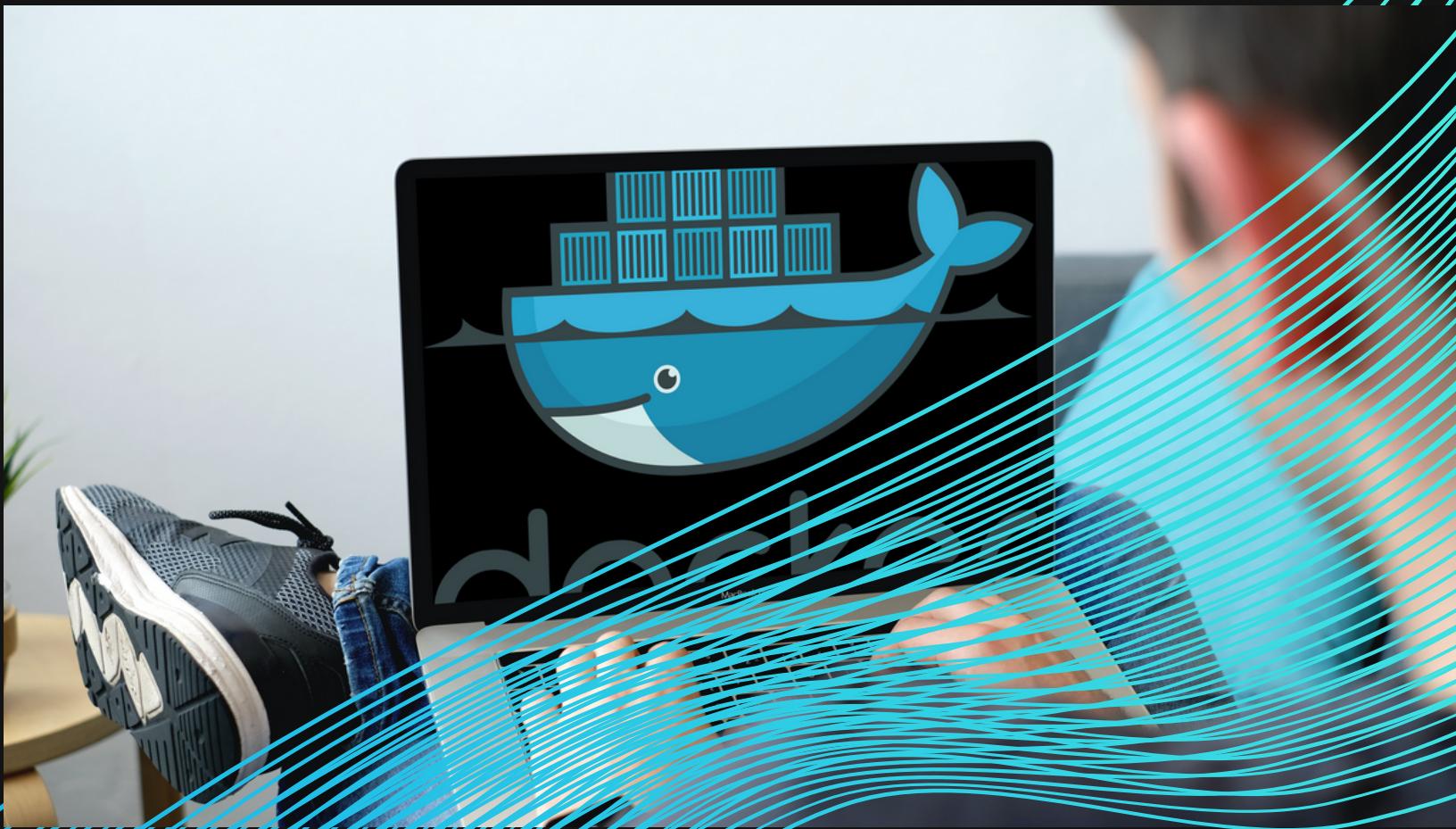


# Docker

Se hará uso de la imagen "emqx/emqx", con el cuál será posible desplegarlo en Kubernetes.

**DOCKER PULL EMQX/EMQX:4.4.3**

```
DOCKER RUN -D --NAME EMQX -P  
1883:1883 -P 8081:8081 -P 8083:8083 -P  
8084:8084 -P 8883:8883 -P 18083:18083  
EMQX/EMQX:4.4.3
```



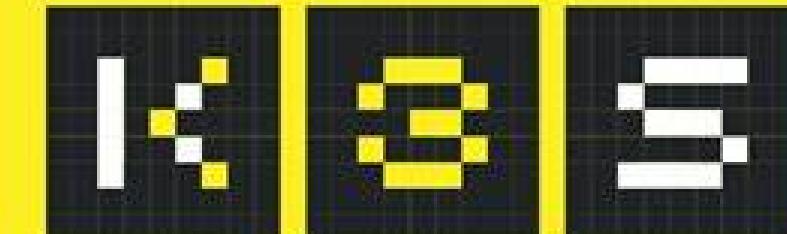
# Kubernetes



Se creó un Deployment  
y Service para este  
clúster.

# K3S

K3S es una versión ligera de Kubernetes, el cuál trabaja con Rancher (K3D).



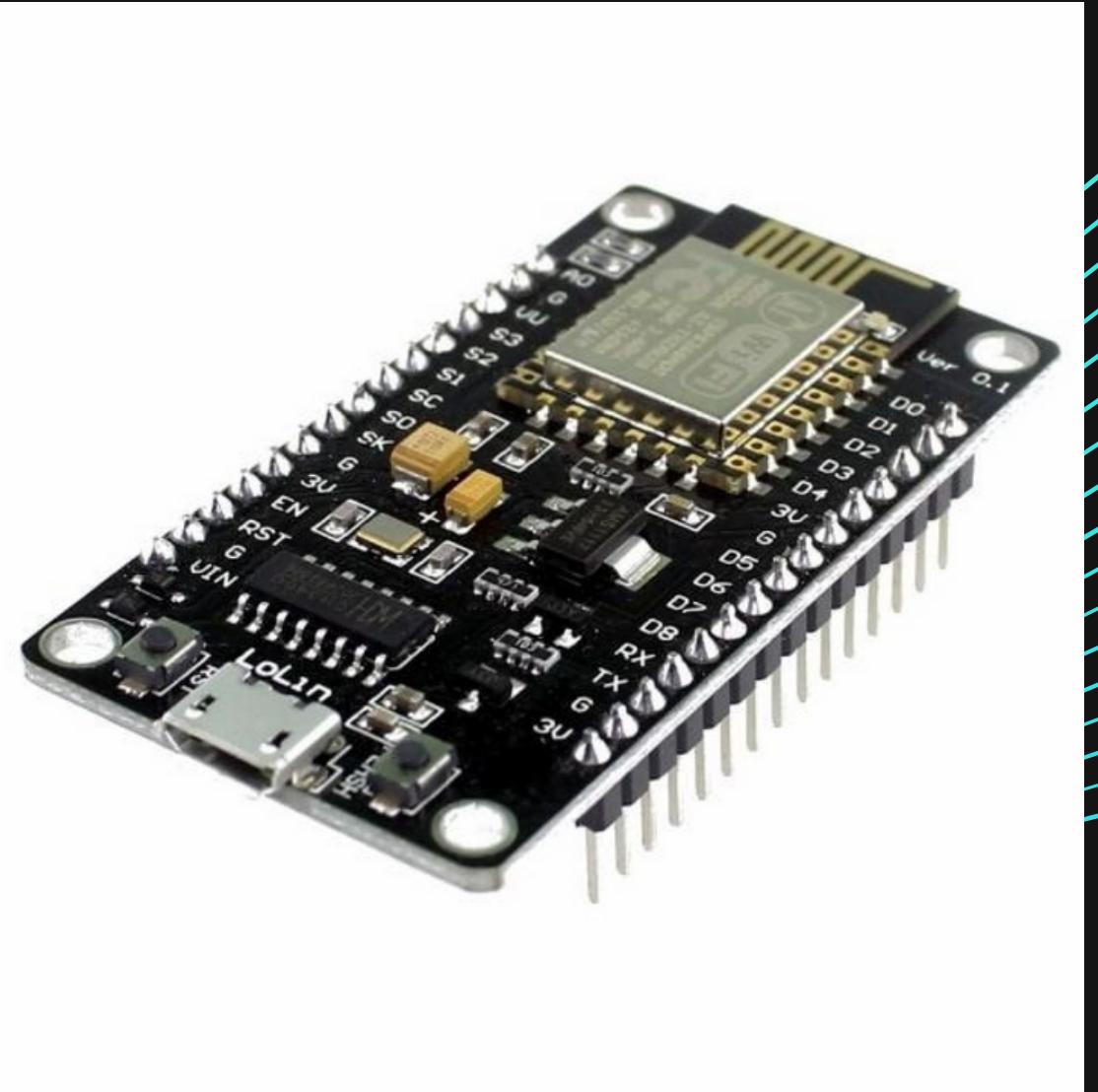
# Rancher

Rancher como gestor  
del clúster.



# NodeMCU8266

Placa de desarrollo que cuenta con el módulo ESP8266, el cuál contiene un dispositivo Wifi de 2.4Ghz.



# Instalación

Es fundamental tener instalado Docker, y para facilitar los procesos de instalación se instaló un Packet Manager llamado "Chocolatey" para instalar los programas faltantes.



```
CHOCO INSTALL K3D -Y  
>> CHOCO INSTALL JQ -Y  
>> CHOCO INSTALL YQ -Y  
>> CHOCO INSTALL KUBERNETES-HELM -Y
```

# Configuración de K3D

Se creó un cluster "IoT" en K3D,  
con su respectivo comando,  
declarando los puertos que  
serán expuestos:

```
K3D CLUSTER CREATE --API-PORT 6448 -P  
"18083:18083" -P "1883:1883" -P "8883:8883" -P  
"8081:8081" -P "8083:8083" -P "8084:8084" IOT
```

Por otro lado, es importante configurar la  
variable de entorno dentro del sistema, en este  
caso es Windows 10 con WSL:

```
K3D KUBECONFIG GET ${ENV:CLUSTER_NAME}  
> $ENV:KUBECONFIG_FILE
```

```
$ENV:KUBECONFIG=($ENV:KUBECONFIG_FILE)
```



# Configuración de K3D



```
Administrator: Windows PowerShell
PS C:\WINDOWS\system32> docker container list
CONTAINER ID   IMAGE                               COMMAND                  CREATED             STATUS              PORTS
 NAMES
4c4e545bd08d   ghcr.io/k3d-io/k3d-tools:5.4.1    "/app/k3d-tools noop"   3 hours ago        Up 2 hours
k3d-IoT-tools
329705bddb85   ghcr.io/k3d-io/k3d-proxy:5.4.1    "/bin/sh -c nginx-pr..."  3 hours ago        Up 2 hours   0.0.0.0:1883->188
3/tcp, 0.0.0.0:8081->8081/tcp, 0.0.0.0:8083-8084->8083-8084/tcp, 0.0.0.0:8883->8883/tcp, 80/tcp, 0.0.0.0:18083->18083
/tcp, 0.0.0.0:6448->6443/tcp   k3d-IoT-serverlb
ee5596fc08fe   rancher/k3s:v1.22.7-k3s1         "/bin/k3s server --t..."  3 hours ago        Up 2 hours
k3d-IoT-server-0
PS C:\WINDOWS\system32>
```

# Configuración de Deployment y Service

Se hará un Deployment y Servicio dentro de K3S que use la imagen "emqx/emqx", asignando los puertos correspondientes a cada uno de los servicios internos, todo esto lo lograremos con un archivo YAML generado.

**K3S KUBECTL APPLY -F EMQX.YAML**

```
! EMQX.yaml
 1 apiVersion: apps/v1
 2 kind: Deployment
 3   metadata:
 4     name: emqx-deployment
 5   labels:
 6     app: emqx
 7   spec:
 8     replicas: 1
 9     selector:
10       matchLabels:
11         app: emqx
12     template:
13       metadata:
14         labels:
15           app: emqx
16     spec:
17       containers:
18         - name: emqx
19           image: emqx/emqx:v4.1-rc.1
20           ports:
21             - name: mqtt
22               containerPort: 1883
23             - name: mqttssl
24               containerPort: 8883
25             - name: mgmt
26               containerPort: 8081
```

# Configuración de Deployment y Service



```
Administrator: Windows PowerShell
PS C:\WINDOWS\system32> kubectl get deployments
NAME           READY   UP-TO-DATE   AVAILABLE   AGE
emqx-deployment 1/1     1           1           163m
PS C:\WINDOWS\system32> kubectl get svc
NAME        TYPE      CLUSTER-IP    EXTERNAL-IP   PORT(S)
AGE
kubernetes  ClusterIP  10.43.0.1    <none>       443/TCP
166m
emqx-service  ClusterIP  10.43.234.76  <none>       1883/TCP,8883/TCP,8081/TCP,8083/TCP,8084/TCP,18083/TCP
163m
```

# Creando servicios

Se crearan servicios para cada servicio interno del despliegue, para lo cuál se usaran de tipo NodePort para poderlos exponer al exterior, a continuación, ejemplos:

```
KUBECTL EXPOSE DEPLOYMENT EMQX-  
DEPLOYMENT --NAME EMQX-DASHBOARD --PORT  
18083 --TARGET-PORT=18083 --TYPE NODEPORT
```

```
KUBECTL EXPOSE DEPLOYMENT EMQX-  
DEPLOYMENT --NAME EMQX-SOCKET --PORT 1883  
--TARGET-PORT=1883 --TYPE NODEPORT
```

```
! EMOX.yaml  
1 apiVersion: apps/v1  
2 kind: Deployment  
3   metadata:  
4     name: emqx-deployment  
5     labels:  
6       app: emqx  
7   spec:  
8     replicas: 1  
9     selector:  
10    matchLabels:  
11      app: emqx  
12    template:  
13      metadata:  
14        labels:  
15          app: emqx  
16    spec:  
17      containers:  
18        - name: emqx  
19          image: emqx/emqx:v4.1-rc.1  
20        ports:  
21          - name: mqtt  
22            containerPort: 1883  
23          - name: mqttssl  
24            containerPort: 8883  
25          - name: mgmt  
26            containerPort: 8081
```

# Creando servicios

```
Administrator: Windows PowerShell
PS C:\WINDOWS\system32> kubectl get deployments
NAME        READY   UP-TO-DATE   AVAILABLE   AGE
emqx-deployment   1/1      1          1          163m
PS C:\WINDOWS\system32> kubectl get svc
NAME           TYPE      CLUSTER-IP    EXTERNAL-IP   PORT(S)
AGE
kubernetes     ClusterIP  10.43.0.1    <none>       443/TCP
166m
emqx-service   ClusterIP  10.43.234.76  <none>       1883/TCP,8883/TCP,8081/TCP,8083/TCP,8084/TCP,18083/TCP
163m
emqx-dashboard NodePort   10.43.243.100  <none>       18083:30535/TCP
163m
emqx-socket    NodePort   10.43.40.41   <none>       1883:30250/TCP
162m
emqx-2         NodePort   10.43.175.255  <none>       8883:31212/TCP
161m
emqx-3         NodePort   10.43.241.101  <none>       8081:30708/TCP
161m
emqx-4         NodePort   10.43.163.136  <none>       8083:32425/TCP
161m
emqx-5         NodePort   10.43.13.213   <none>       8084:32594/TCP
161m
PS C:\WINDOWS\system32>
```

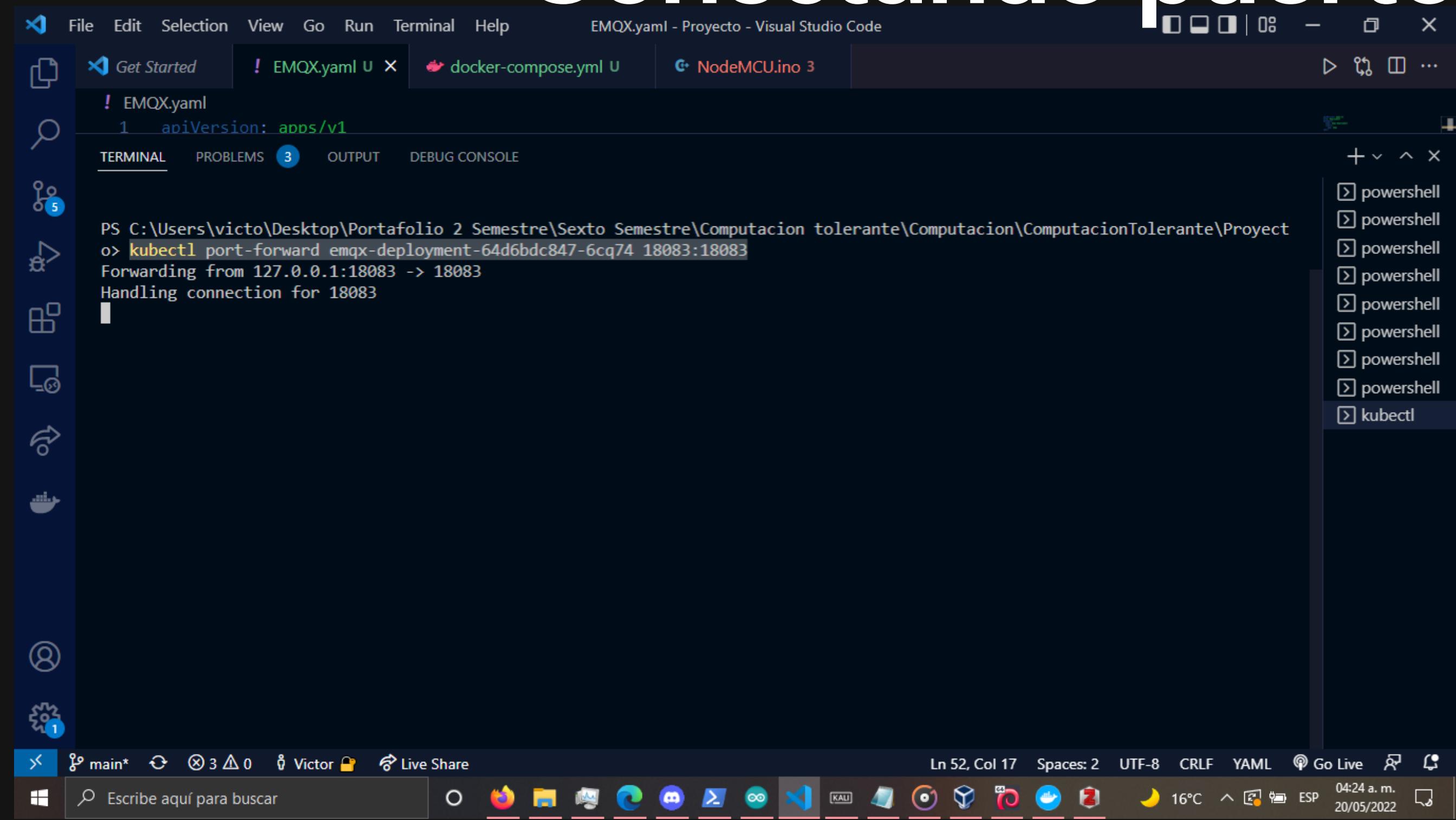
# Conectando puertos

Y por ultimo los servicios los enlazamos con los puertos del servidor, a continuación, ejemplos de lo que se implementará:

KUBECTL PORT-FORWARD EMQX-DASHBOARD  
18083:18083

```
! EMOX.yaml
 1 apiVersion: apps/v1
 2 kind: Deployment
 3   metadata:
 4     name: emqx-deployment
 5     labels:
 6       app: emqx
 7   spec:
 8     replicas: 1
 9     selector:
10       matchLabels:
11         app: emqx
12     template:
13       metadata:
14         labels:
15           app: emqx
16     spec:
17       containers:
18         - name: emqx
19           image: emqx/emqx:v4.1-rc.1
20         ports:
21           - name: mqtt
22             containerPort: 1883
23           - name: mqttssl
24             containerPort: 8883
25           - name: mgmt
26             containerPort: 8081
```

# Conectando puertos



The screenshot shows a Visual Studio Code interface with a dark theme. The title bar reads "EMQX.yaml - Proyecto - Visual Studio Code". The left sidebar has icons for file operations, search, and other development tools. The main area has tabs for "Get Started", "EMQX.yaml", "docker-compose.yml", and "NodeMCU.ino". The "TERMINAL" tab is active, displaying the following command and its output:

```
PS C:\Users\Victor\Desktop\Portafolio 2 Semestre\Sexto Semestre\Computacion tolerante\ComputacionTolerante\Proyecto> kubectl port-forward emqx-deployment-64d6bdc847-6cq74 18083:18083
Forwarding from 127.0.0.1:18083 -> 18083
Handling connection for 18083
```

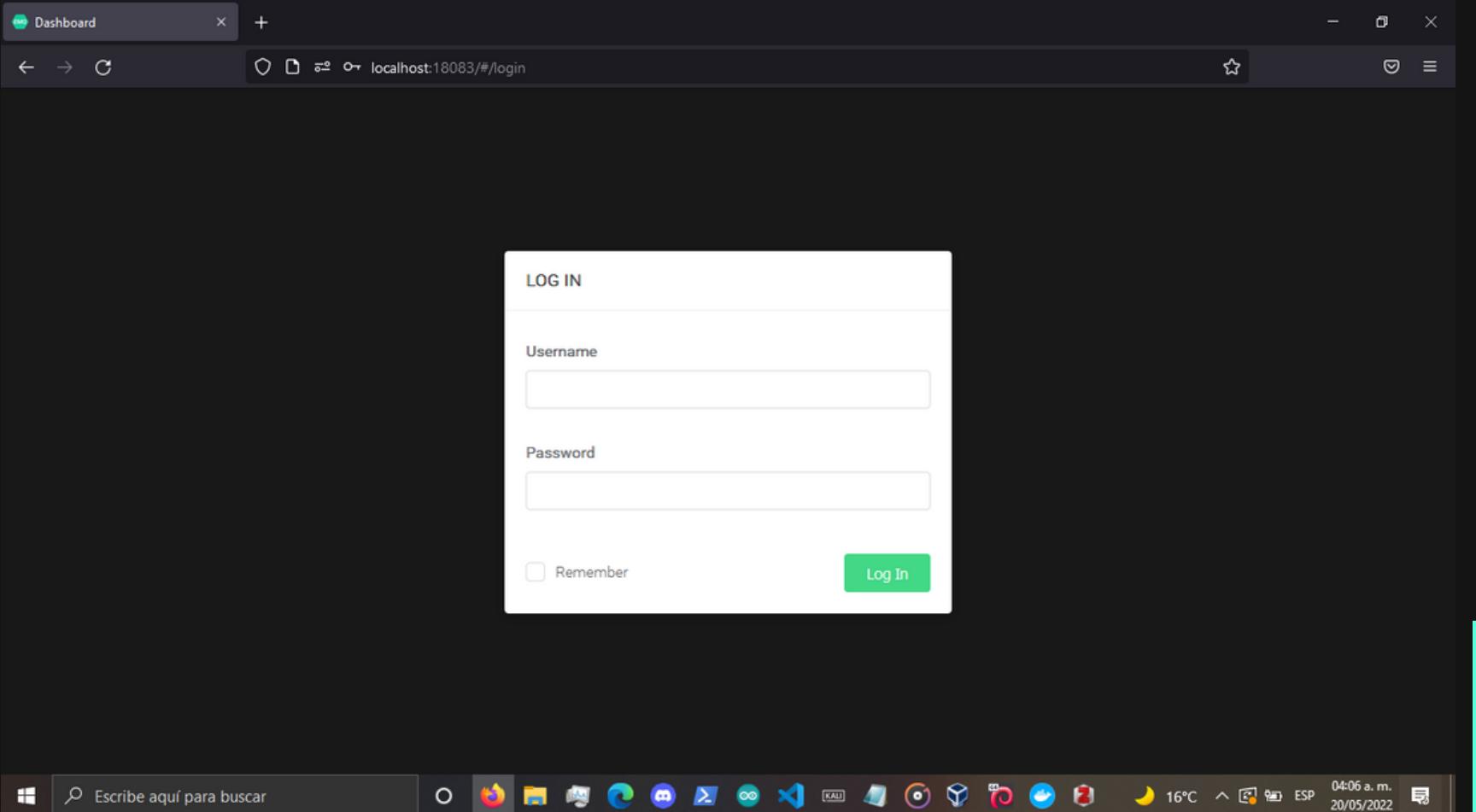
The terminal also shows a list of open PowerShell sessions on the right side.

# Dashboard

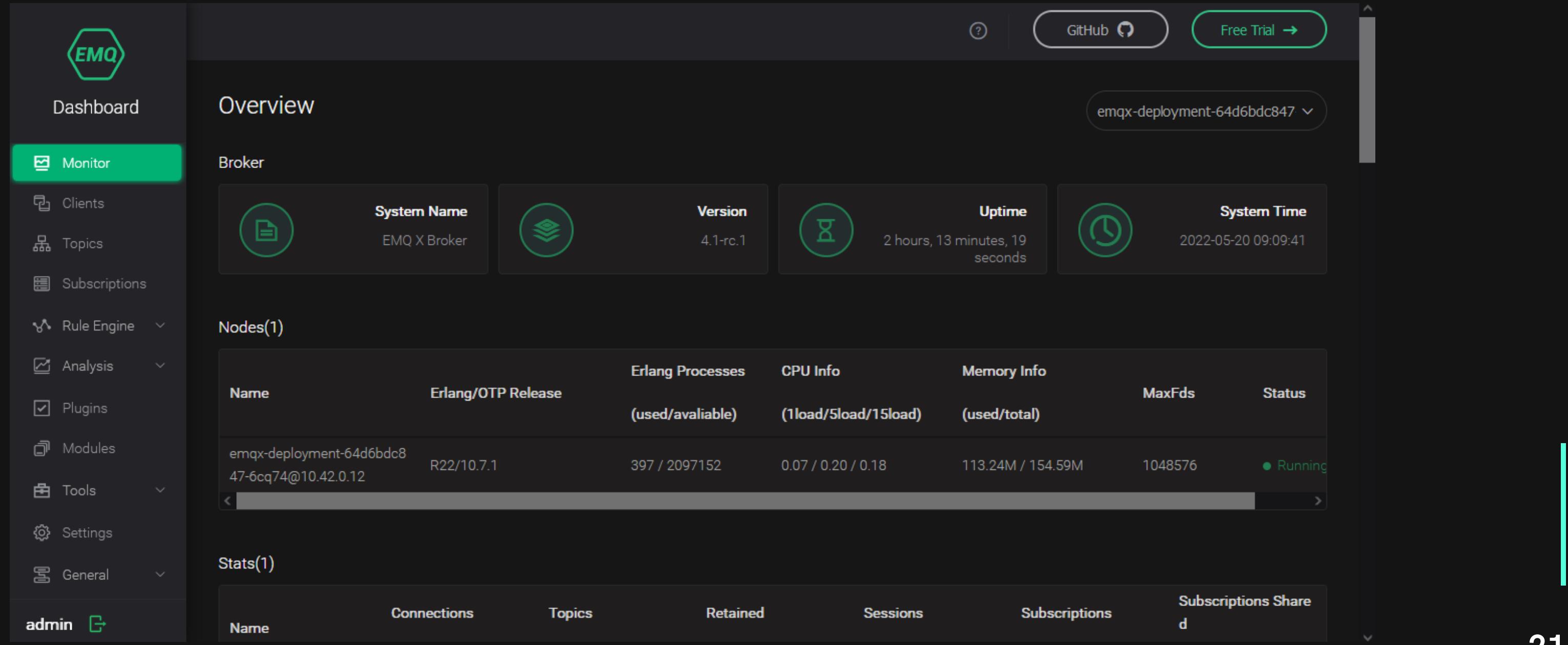
Al haber sincronizado los puertos, nos metemos al Dashboard, con puerto **18083**, en el cuál tendremos que logearnos por primera vez, usaremos el usuario default.

Usuario: **admin**

Password: **public**



# Dashboard



The screenshot shows the EMQ X Broker dashboard interface. The top navigation bar includes the EMQ logo, a help icon, GitHub integration, and a free trial button. A dropdown menu shows the current deployment name: emqx-deployment-64d6bdc847.

The main content area is divided into sections:

- Overview**: Displays broker information: System Name (EMQ X Broker), Version (4.1-rc.1), Uptime (2 hours, 13 minutes, 19 seconds), and System Time (2022-05-20 09:09:41).
- Broker**: Monitored metrics for the node: Erlang Processes (397 / 2097152), CPU Info (0.07 / 0.20 / 0.18), Memory Info (113.24M / 154.59M), MaxFds (1048576), and Status (Running).
- Nodes(1)**: Shows the node details: emqx-deployment-64d6bdc847-47-6cq74@10.42.0.12, Erlang/OTP Release (R22/10.7.1), and a list of modules.
- Stats(1)**: Summary statistics for connections, topics, retained messages, sessions, subscriptions, and shared subscriptions.

The left sidebar contains a navigation menu with the following items:

- Dashboard
- Monitor** (selected)
- Clients
- Topics
- Subscriptions
- Rule Engine
- Analysis
- Plugins
- Modules
- Tools
- Settings
- General

The bottom left corner shows the user is logged in as **admin**.

# Dashboard

The screenshot shows the EMQ Dashboard interface. The left sidebar has a dark theme with white icons and text. The 'Clients' option is highlighted with a green background. The main content area is titled 'Clients' and displays a table with columns: Client ID, Username, IP Address, Keepalive (s), Expiry Interval(s), Subscriptions Count, Connect Status, Create, and Operation. A message 'No Data' is shown in the table body. At the bottom of the screen, there is a taskbar with various application icons and system status indicators.

Dashboard

Clients

Client ID

Username

Search

Reset

Expand

Client ID	Username	IP Address	Keepalive (s)	Expiry Interval(s)	Subscriptions Count	Connect Status	Create	Operation
No Data								

admin

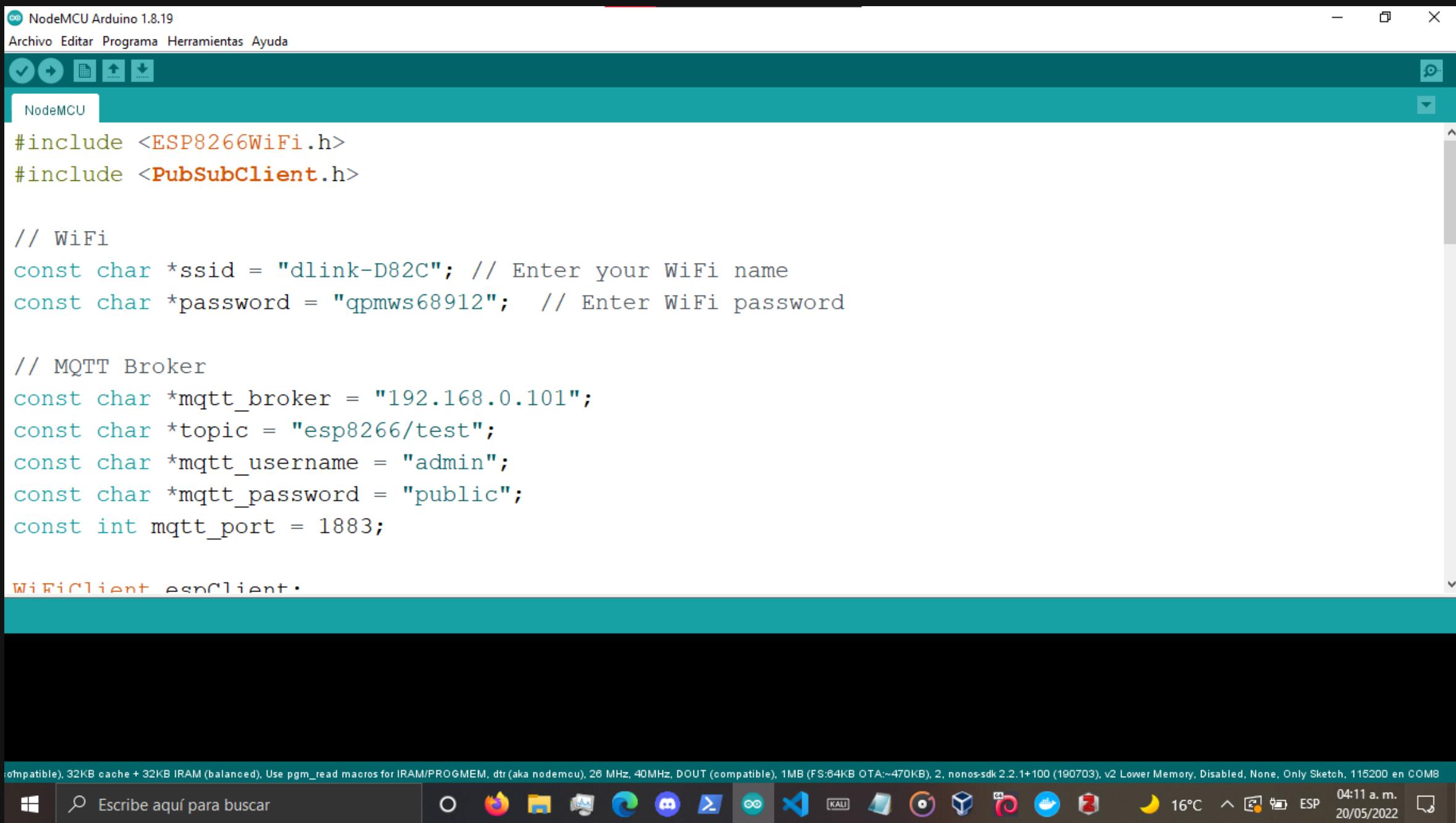
Escribe aquí para buscar

22

# Dashboard

The screenshot shows the EMQ Dashboard interface. On the left, a sidebar menu includes options like Topics, Subscriptions, Rule Engine, Analysis, Plugins, Modules, Tools (selected), Websocket (highlighted in green), HTTP API, Settings, and General. The main area has a large "Subscribe" button. Below it, a "Messages" section allows sending messages to a topic. A message is currently being typed into the "Messages" input field: `{ "msg": "Hello, World!" }`. The "Topic" dropdown is set to "testtopic". The "QoS" dropdown is set to "0". A "Retained" checkbox is unchecked. A "send" button is visible. At the bottom, there are sections for "Messages already sent" and "Messages received", both currently showing "No Data". The status bar at the bottom of the browser window displays various icons and information, including the date and time.

# NodeMCU8266



The screenshot shows the NodeMCU Arduino IDE interface. The title bar reads "NodeMCU Arduino 1.8.19". The menu bar includes "Archivo", "Editar", "Programa", "Herramientas", and "Ayuda". The toolbar has icons for file operations like new, open, save, and upload. The main window displays a sketch titled "NodeMCU" containing C++ code for an ESP8266. The code includes #includes for WiFi and PubSubClient, defines WiFi credentials, sets up an MQTT broker connection, and initializes a WiFi client. The status bar at the bottom provides system information: "Windows", "Escribe aquí para buscar", "O", "16°C", "16:11 a.m.", "ESP", "04/11 a.m.", "20/05/2022", and a battery icon.

```
#include <ESP8266WiFi.h>
#include <PubSubClient.h>

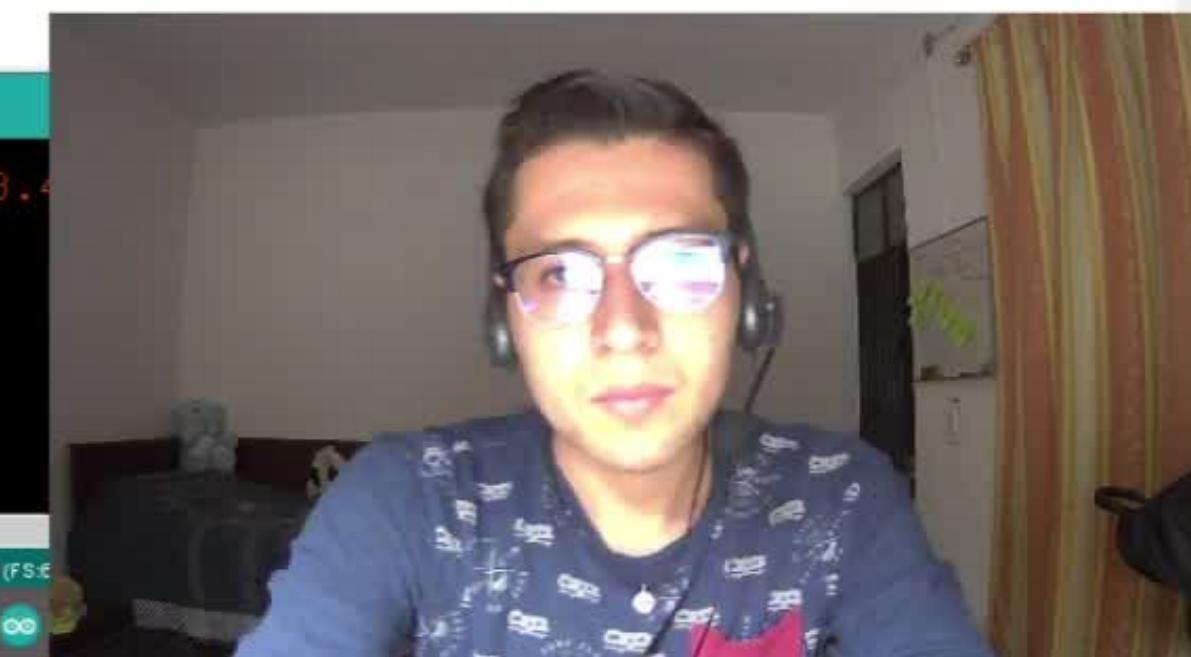
// WiFi
const char *ssid = "dlink-D82C"; // Enter your WiFi name
const char *password = "qpmws68912"; // Enter WiFi password

// MQTT Broker
const char *mqtt_broker = "192.168.0.101";
const char *topic = "esp8266/test";
const char *mqtt_username = "admin";
const char *mqtt_password = "public";
const int mqtt_port = 1883;

WiFiClient espClient;
```

Link de Drive:

[https://drive.google.com/file/d/1v7-\\_ClrggtQCW6O1r4HuX6lM3AB7Bfwz/view?  
usp=sharing](https://drive.google.com/file/d/1v7-_ClrggtQCW6O1r4HuX6lM3AB7Bfwz/view?usp=sharing)



The image shows a screenshot of a NodeMCU Arduino IDE window. The code in the editor is as follows:

```
#include <ESP8266WiFi.h>
#include <PubSubClient.h>
int var;
String results;
// WiFi
const char *ssid = "dlink-D82C"; // Enter your WiFi name
const char *password = "qpmws68912"; // Enter WiFi password

// MQTT Broker
const char *mqtt_broker = "192.168.0.101";
const char *topic = "esp8266/test";
const char *mqtt_username = "admin";

Subido
Wrote 283776 bytes (207814 compressed) at 0x00000000 in 18.4
Hash of data verified.

Leaving...
Hard resetting via RTS pin...
```

The terminal window below the code shows the output of the upload process, indicating 283776 bytes written and a hard reset via RTS pin.

# Failure Injection

Se hará uso de la herramienta de Chaos Engineering, [Litmus](#), es open-source, proyecto encubado de la [CNCF \(Cloud Native Cloud Foundation\)](#), con este haremos pruebas de "pod-delete".



# Failure Injection

SE INSTALA LITMUS EN EL CLÚSTER:

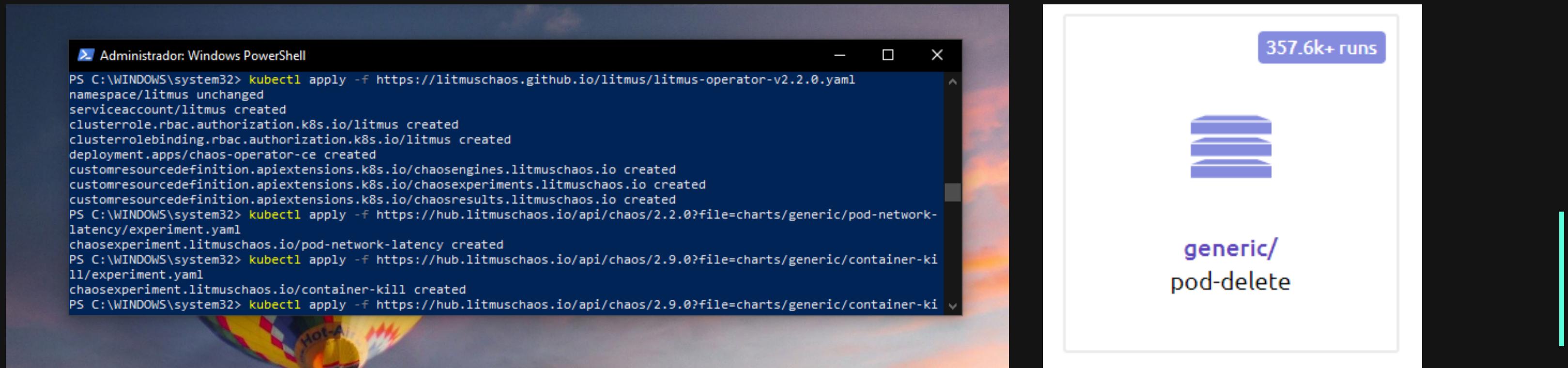
`KUBECTL APPLY -F HTTPS://LITMUSCHAOS.GITHUB.IO/LITMUS/LITMUS-OPERATOR-V2.2.0.YAML`

SE INSTALA EL CHAOS EXPERIMENT "POD-DELETE":

`KUBECTL APPLY -F HTTPS://HUB.LITMUSCHAOS.IO/API/CHAOS/2.9.0?FILE=CHARTS/GENERIC/POD-  
DELETE/EXPERIMENT.YAML`

SE CONCEDEN PERMISOS(RBAC) PARA QUE EL EXPERIMENTO TRABAJE:

`KUBECTL APPLY -F HTTPS://HUB.LITMUSCHAOS.IO/API/CHAOS/2.9.0?FILE=CHARTS/GENERIC/POD-  
DELETE/RBAC.YAML`



Después, descargaremos el archivo YAML que incluye el sitio web del "pod-deletion", para ajustar la configuración y después implementarla en el clúster.

Podemos apreciar que el pod ha sido eliminado, y se ha replicado exitosamente, por lo tanto es tolerante a "pod-deletion"

The screenshot shows a Visual Studio Code interface. In the top left, there's a file icon with a red exclamation mark, indicating a problem with the file. The file name is "generic-container-kill-engine.yaml". The code content is:

```
! generic-container-kill-engine.yaml
apiVersion: litmuschaos.io/v1alpha1
kind: ChaosEngine
metadata:
  name: emqx-deployment-chaos
  namespace: default
spec:
  # It can be active/stop
```

Below the editor are four tabs: TERMINAL, PROBLEMS, OUTPUT, and DEBUG CONSOLE. The TERMINAL tab is selected, showing two sets of command-line output from "11-Failure injection".

The first set of commands is:

```
\11-Failure injection> kubectl get pods
NAME                      READY   STATUS    RESTARTS   AGE
container-kill-gxfzeo--1-9j5cf   0/1    Completed   0          17m
emqx-deployment-chaos-runner   0/1    Completed   0          17m
pod-delete-4eui8j--1-whckg     0/1    Completed   0          11m
emqx-pod-chaos-runner         0/1    Completed   0          11m
emqx-deployment-64d6bdc847-6cq74 1/1    Terminating 2 (70m ago) 13h
emqx-deployment-64d6bdc847-m6hlx 1/1    Running    0          29s
```

The second set of commands is:

```
PS C:\Users\victo\Desktop\Portafolio 2 Semestre\Sexto Semestre\Computacion tolerante\Computacion\ComputacionTolerante\11-Failure injection>
kubectl get pods
NAME                      READY   STATUS    RESTARTS   AGE
container-kill-gxfzeo--1-9j5cf   0/1    Completed   0          17m
emqx-deployment-chaos-runner   0/1    Completed   0          17m
pod-delete-4eui8j--1-whckg     0/1    Completed   0          11m
emqx-pod-chaos-runner         0/1    Completed   0          11m
emqx-deployment-64d6bdc847-m6hlx 1/1    Running    0          33s
```

At the bottom, there's a search bar with placeholder text "Escribe aquí para buscar" and a toolbar with various icons.

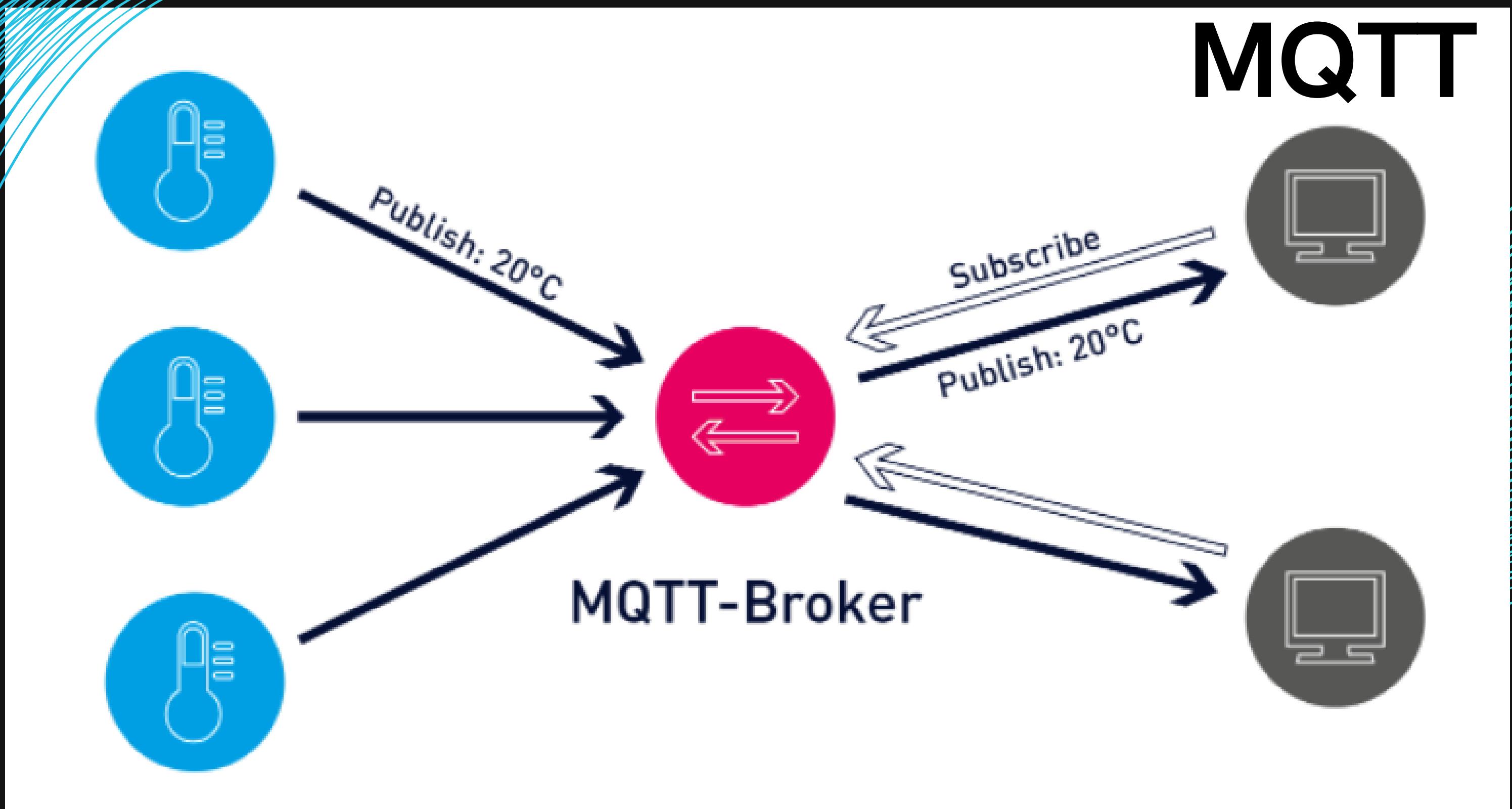
# Reto

Se ha propuesto el reto de conectar más de una placa de desarrollo con las cuales:

- Se prenderán sus focos con un solo mensaje.
- Uso de sensores para enviar mensaje.



# MQTT



# Arquitectura

## 2 PLACAS NODEMCU8266

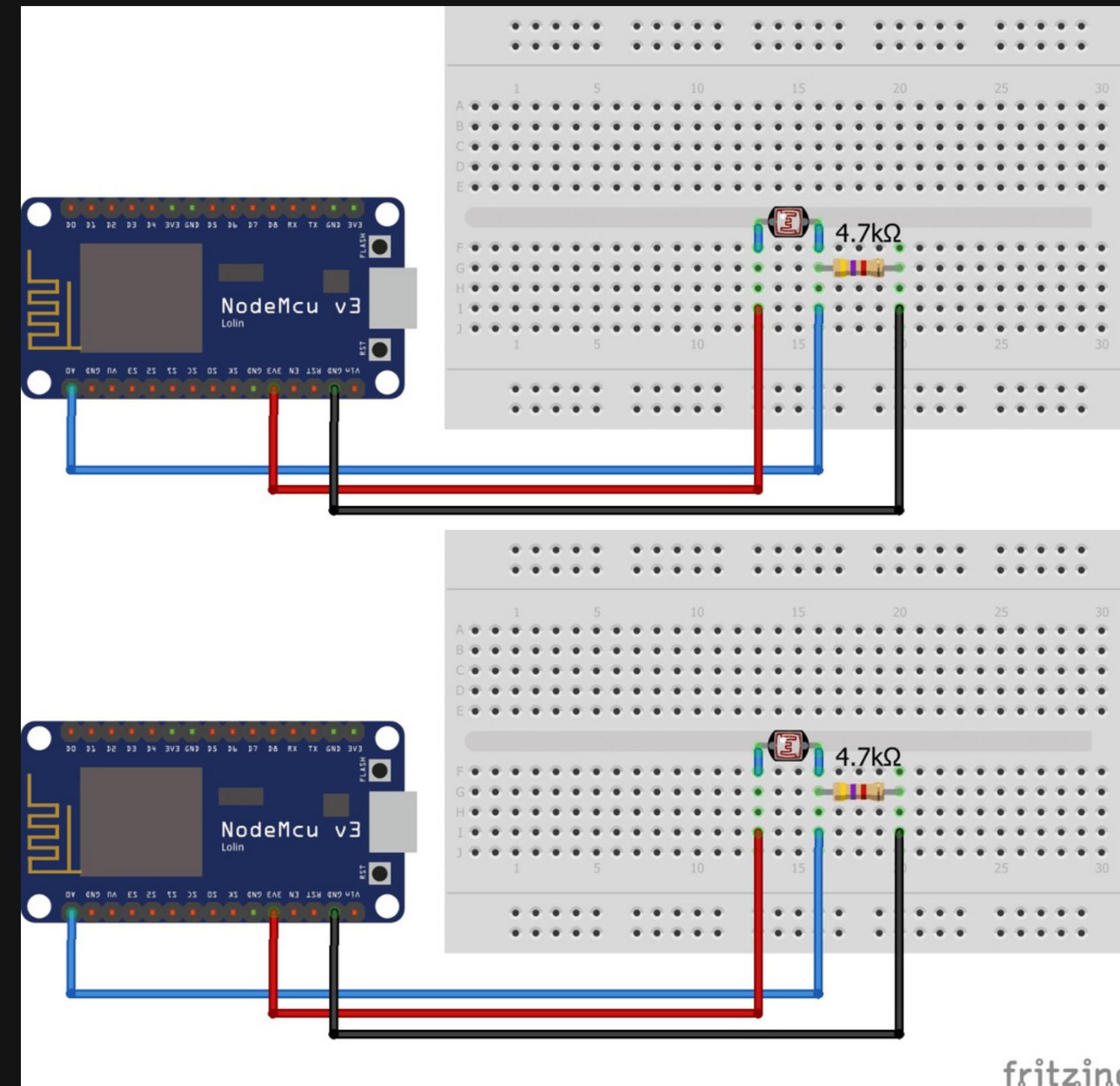
Las cuales se conectan a un PowerRank mediante un cable usb con puerto Micro-B

## 2 SENsoRES DE LUZ

Los cuales a su vez se conectan a la placa mediante un puerto analógico

## 2 LEDs

Controlados por un mismo Topico en el Broker EMQX



fritzing

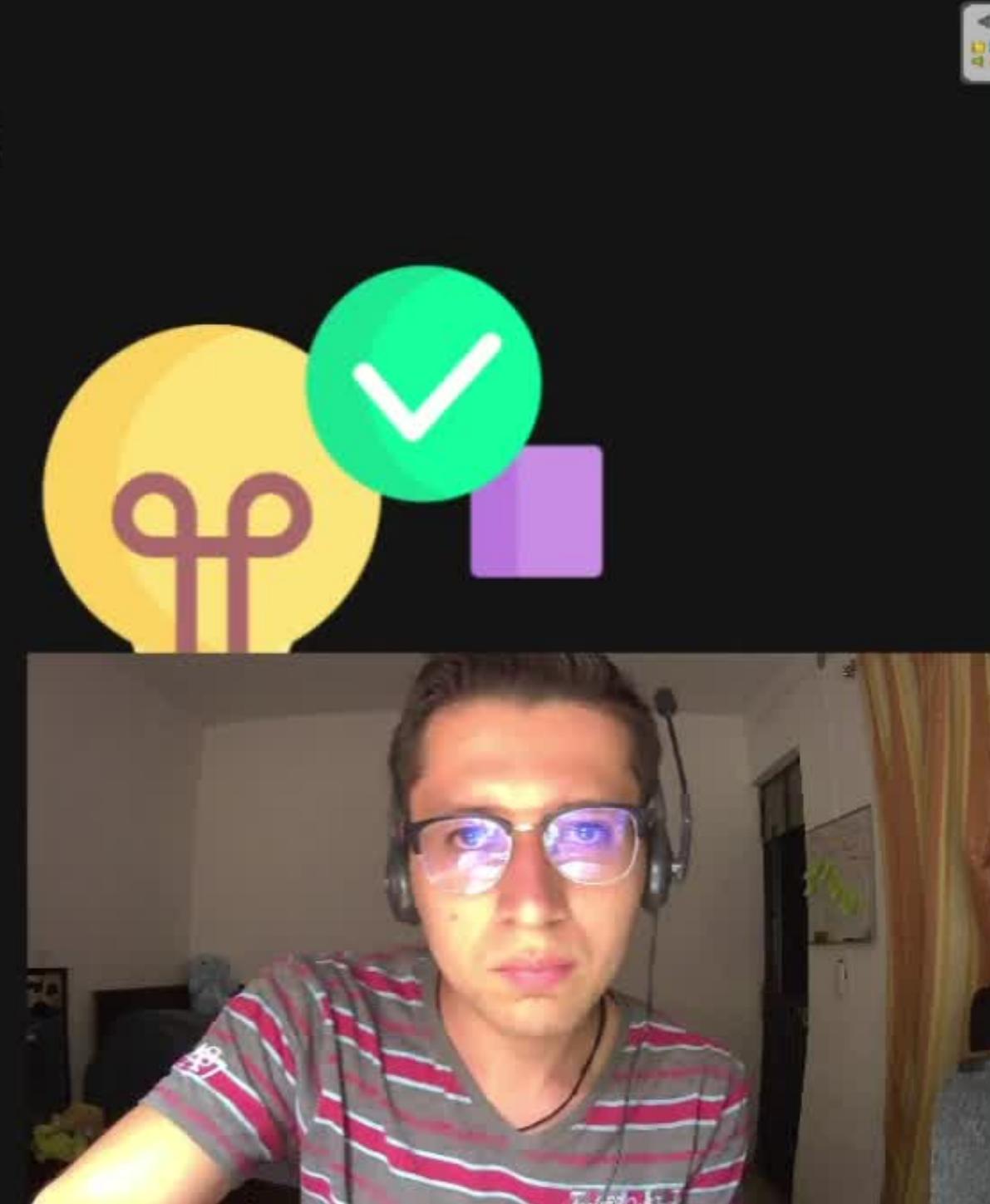
LINK DE DRIVE:  
[HTTPS://DRIVE.GOOGLE.COM/FILE/D/1DDA4RBIDVZXG3WM8QDMOKXUMUQB20X7B/VIEW?USP=SHARING](https://drive.google.com/file/d/1DDA4RBIDVZXG3WM8QDMOKXUMUQB20X7B/view?usp=sharing)



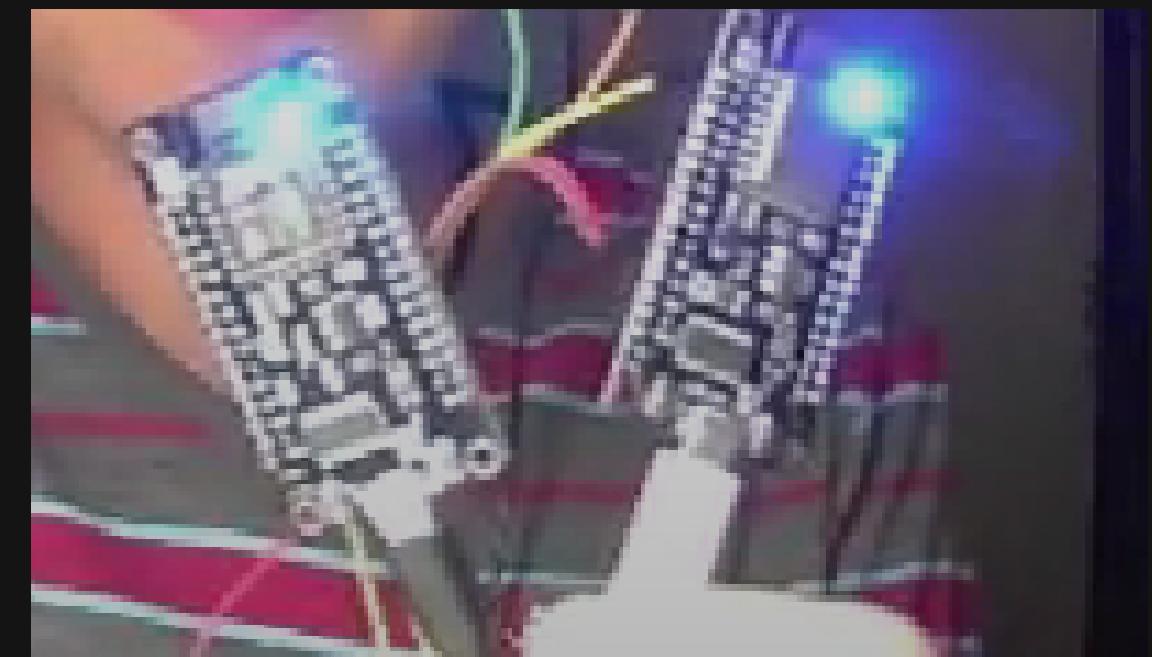
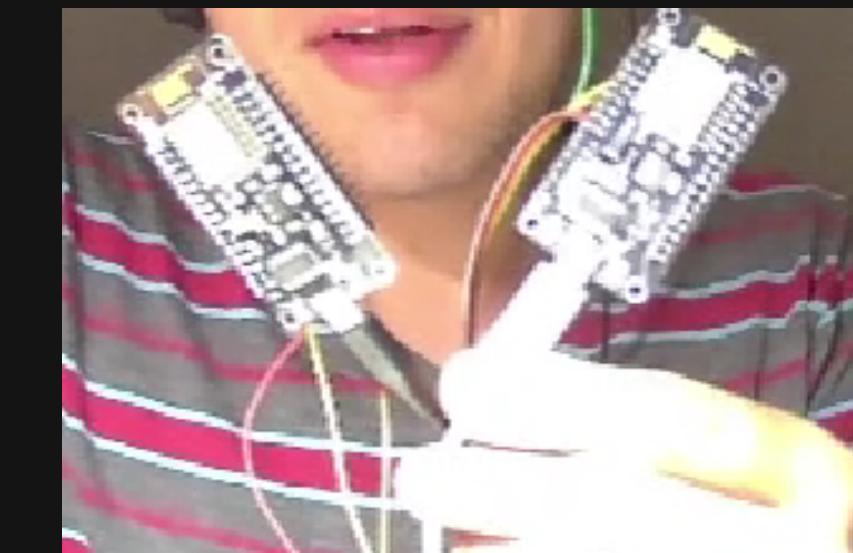
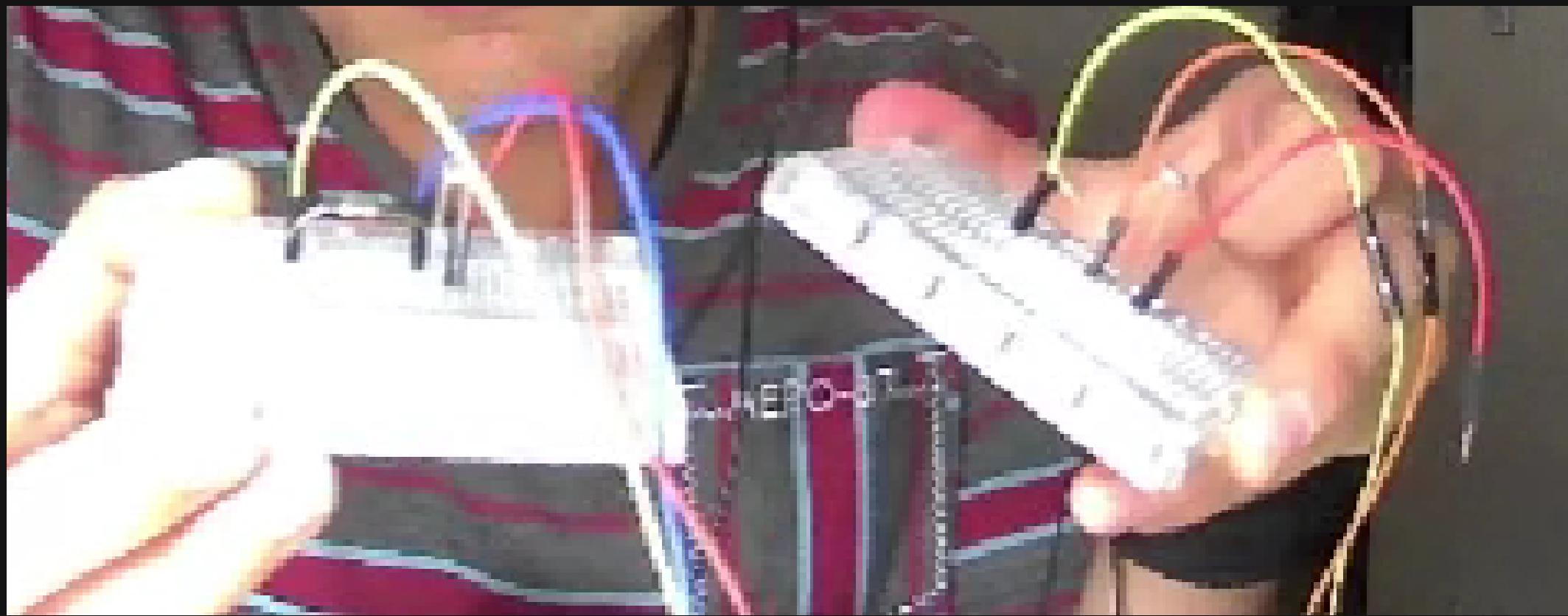
## Reto

Se ha propuesto el reto de conectar más de una placa de desarrollo con las cuales:

- Se prenderán sus focos con un solo mensaje.
- Uso de sensores para enviar mensaje.



# Conexiones en base a la arquitectura



# Funcionamiento en el Broker

localhost:18083/#/websocket

EMQ Dashboard

Messages already sent

Messages	Topic	QoS	Time
0	esp8266/test	0	2022-05-27 01:12:23
1	esp8266/test	0	2022-05-27 01:12:01

Messages received

Messages	Topic	QoS	Time
Valor fotos istencia: 0	esp8266/photo2	0	2022-05-27 01:14:45
Valor fotos istencia: 37	esp8266/photo	0	2022-05-27 01:14:44
Valor fotos istencia: 5	esp8266/photo2	0	2022-05-27 01:14:43
Valor fotos istencia: 37	esp8266/photo	0	2022-05-27 01:14:42
Valor fotos istencia: 5	esp8266/photo2	0	2022-05-27 01:14:41
Valor fotos istencia: 37	esp8266/photo	0	2022-05-27 01:14:40
Valor fotos istencia: 0	esp8266/photo2	0	2022-05-27 01:14:39

Messages received

Messages	Topic	QoS	Time
Valor fotos istencia: 0	esp8266/photo2	0	2022-05-27 01:14:45
Valor fotos istencia: 37	esp8266/photo	0	2022-05-27 01:14:44
Valor fotos istencia: 5	esp8266/photo2	0	2022-05-27 01:14:43
Valor fotos istencia: 37	esp8266/photo	0	2022-05-27 01:14:42
Valor fotos istencia: 5	esp8266/photo2	0	2022-05-27 01:14:41
Valor fotos istencia: 37	esp8266/photo	0	2022-05-27 01:14:40
Valor fotos istencia: 0	esp8266/photo2	0	2022-05-27 01:14:39

Monitor

Clients

Topics

Subscriptions

Rule Engine

Analysis

Plugins

Modules

Tools

Websocket

HTTP API

Alarms

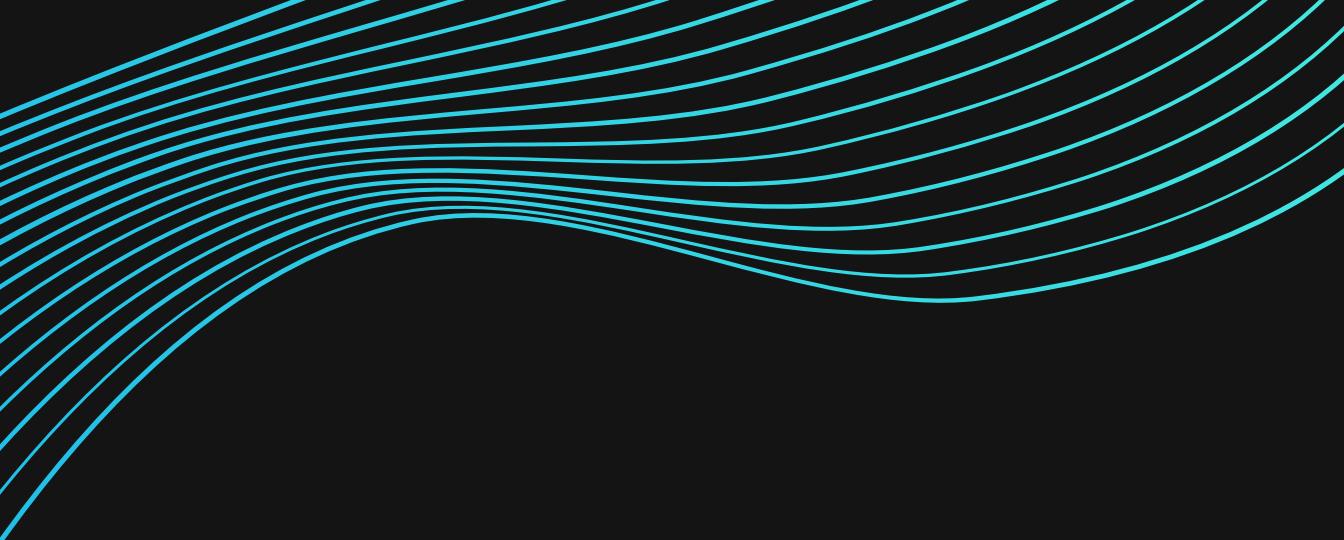
Settings

admin

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# GRACIAS POR SU ATENCIÓN