Intro to MQTT

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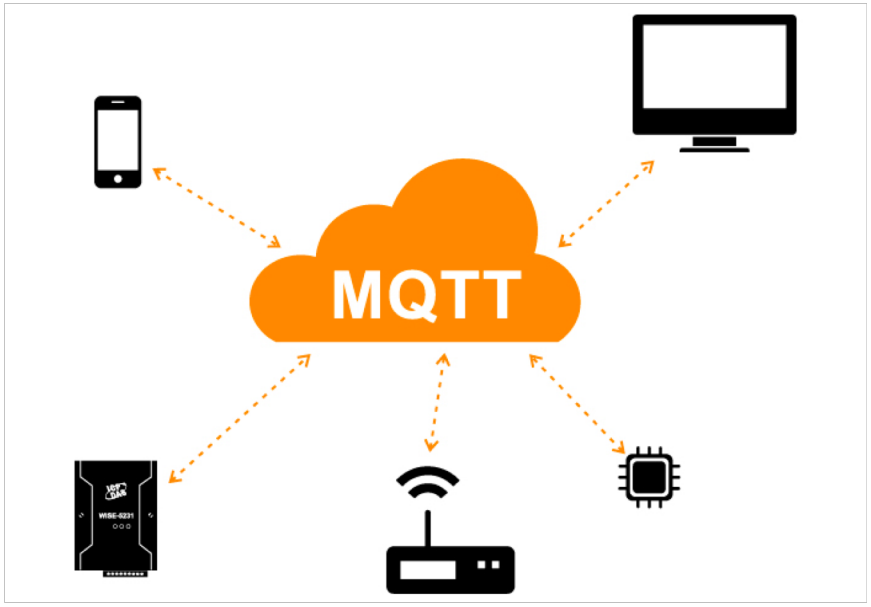


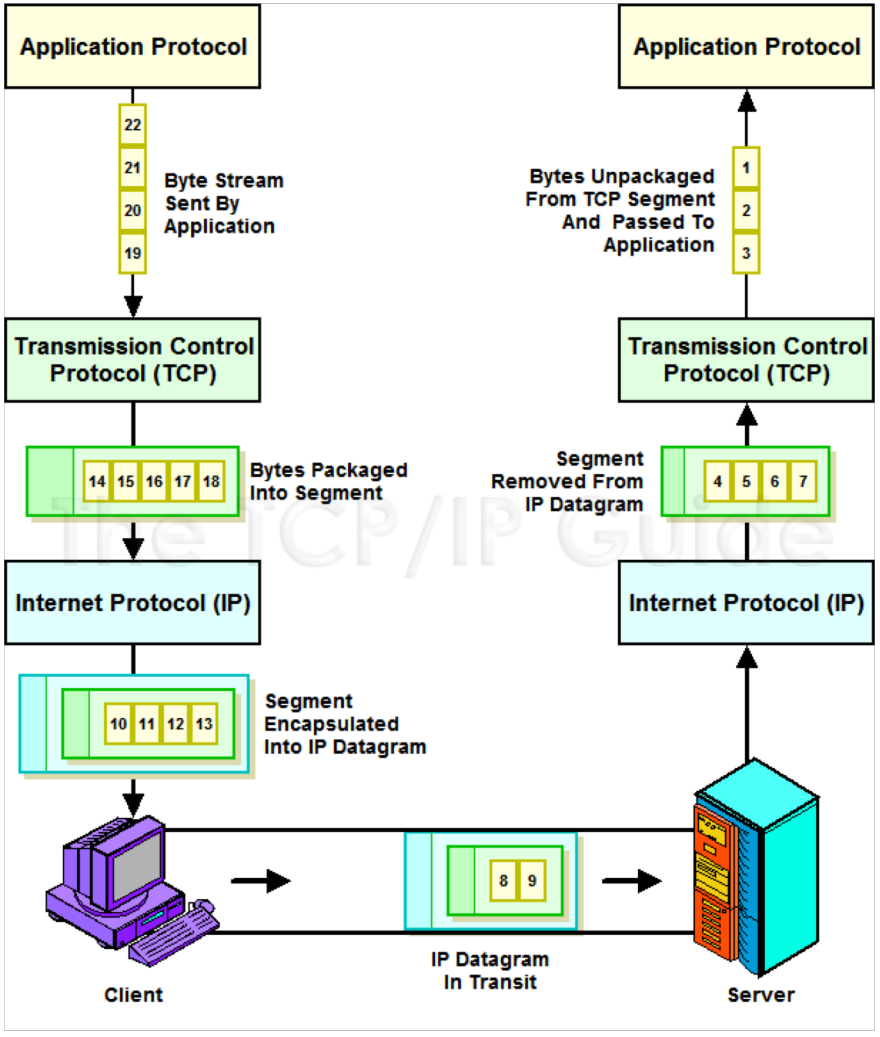
http://bit.ly/ictp2019-mqtt

Universitat Politècnica de València

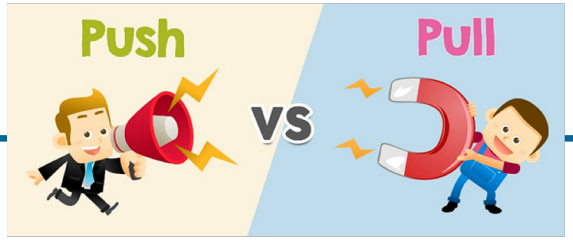
- The *Universitat Politècnica de València* (UPV) is a Spanish public educational institution founded in 1968.
- Its academic community comprises 36.823 students, almost 2.661 lecturers and researchers, and 1.422 administration and services professionals.
- The Vera Campus covers around 840.000 m² and is almost 2 km long. It is a pedestrian campus with over 123.000 m² of green areas.
- UPV is composed of 10 schools, 3 faculties and 2 higher polytechnic schools.

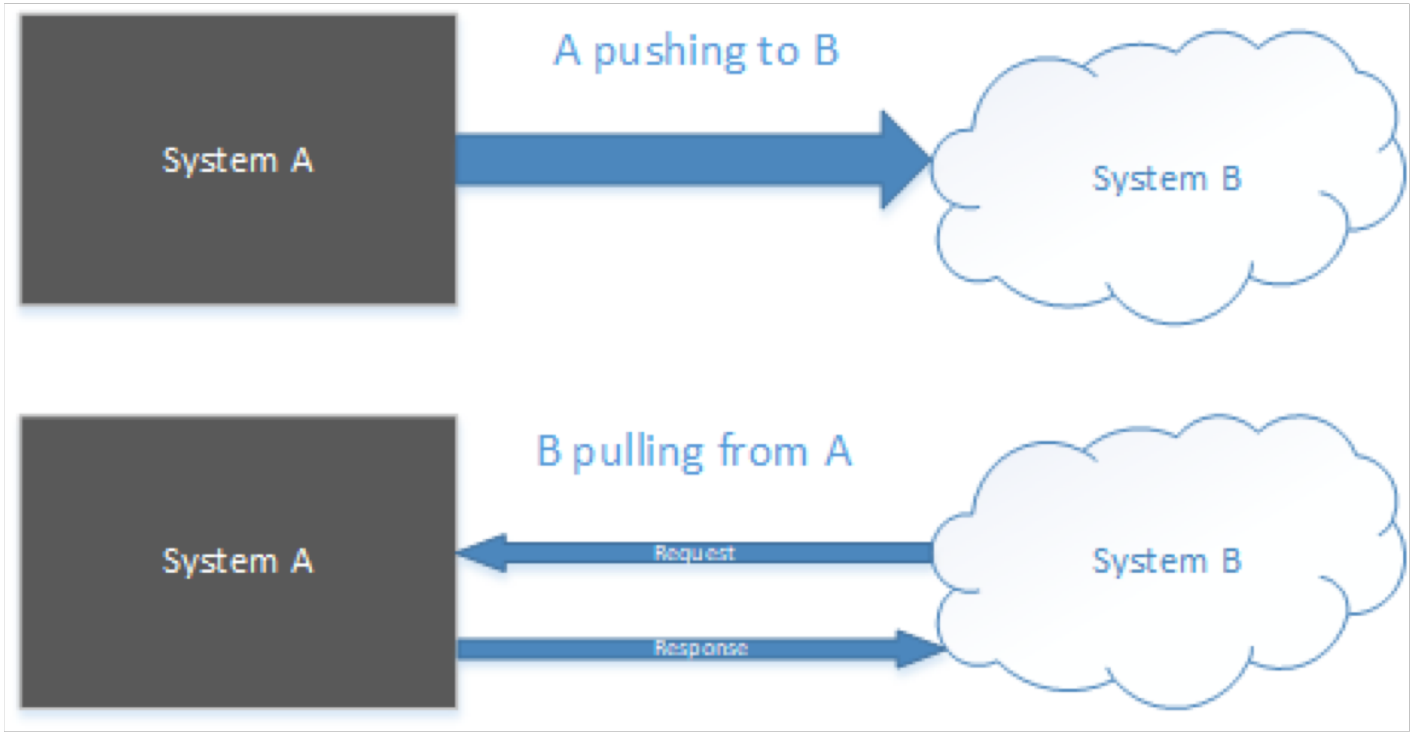
From "byte streams" to "messages"

- The "old" vision of data communication was based on **reliable byte streams**, i.e., TCP
- Nowadays **messages interchange** is becoming more common
  - E.g., Twitter, Whatsapp, Instagram, Snapchat, Facebook,…
- Actually is not that new…
  - emails: SMTP+MIME,
  - FTP,



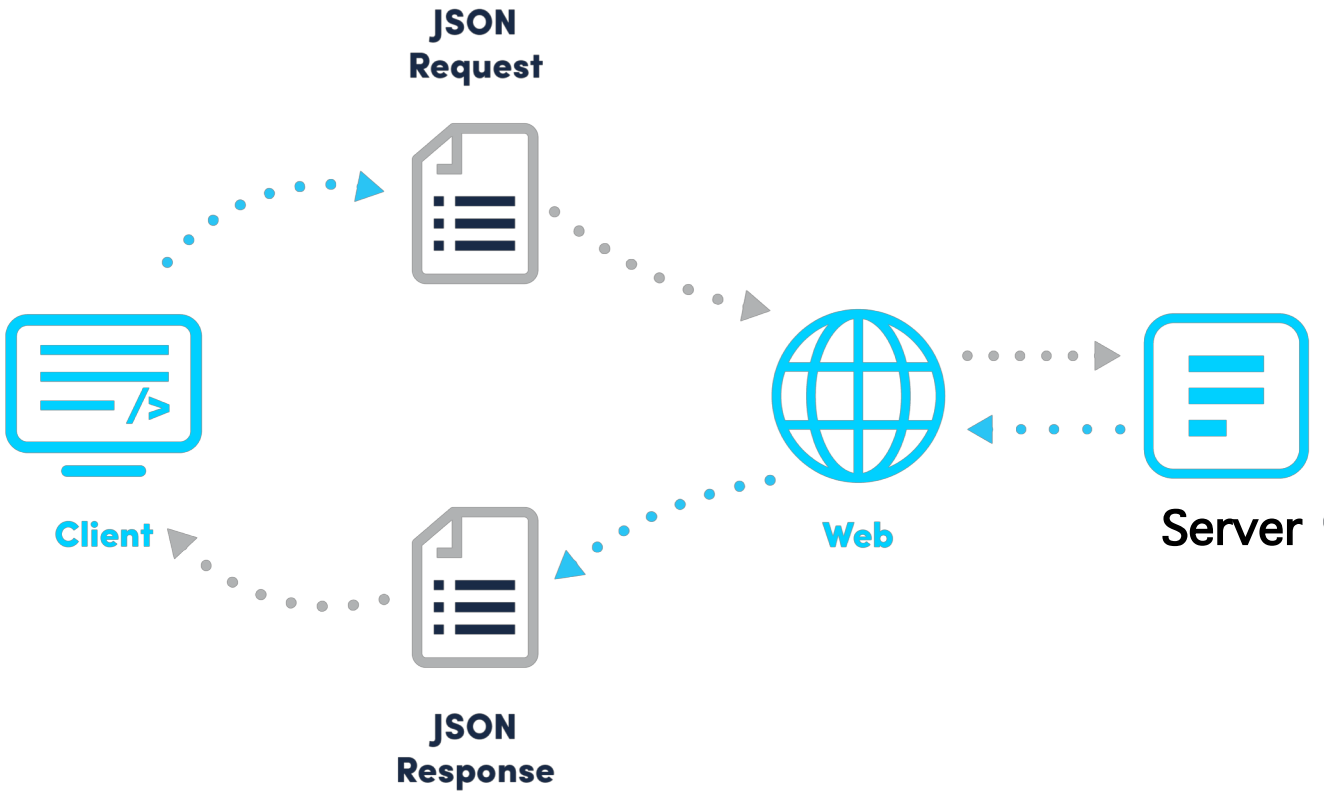
Ways to interchange "messages"





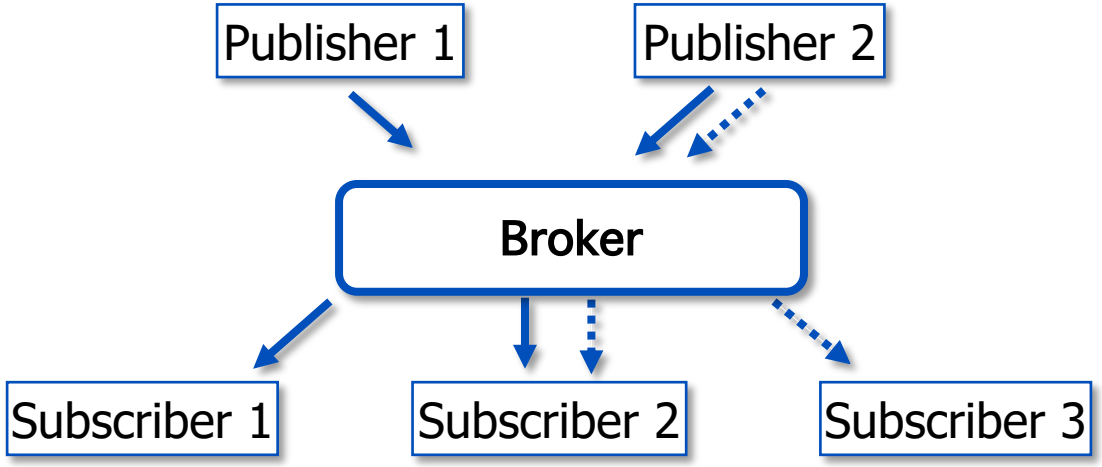
Request/response approach

- **REST**: Representational State Transfer
- Widely used; based on HTTP
- *Lighter version: **CoAP** (Constrained Application Protocol)*



Pub/sub approach

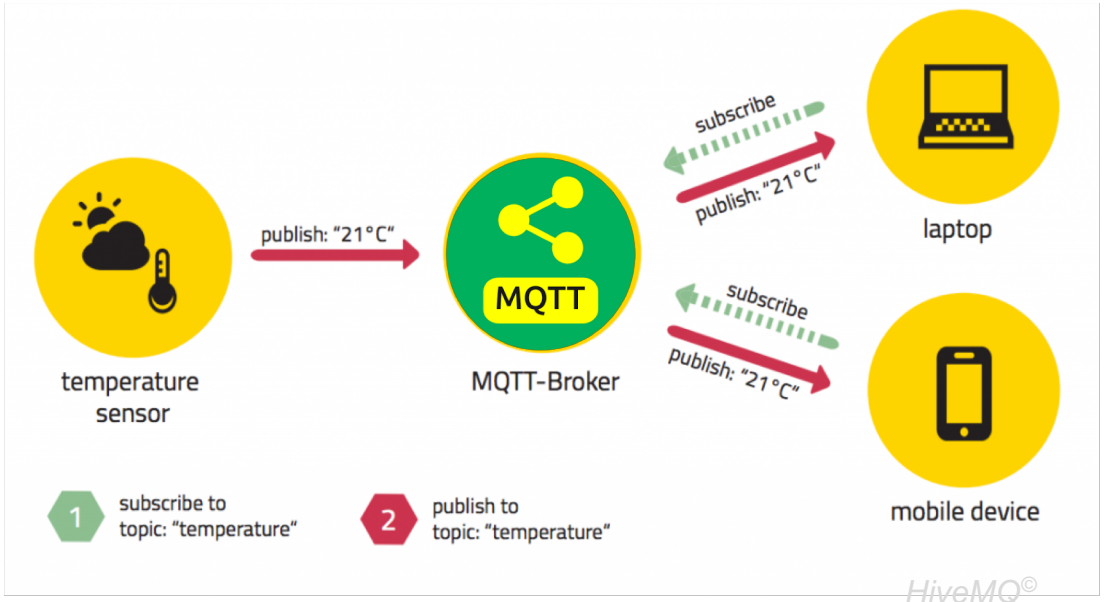
- Publish/Subscriber
  - aka: producer/consumer



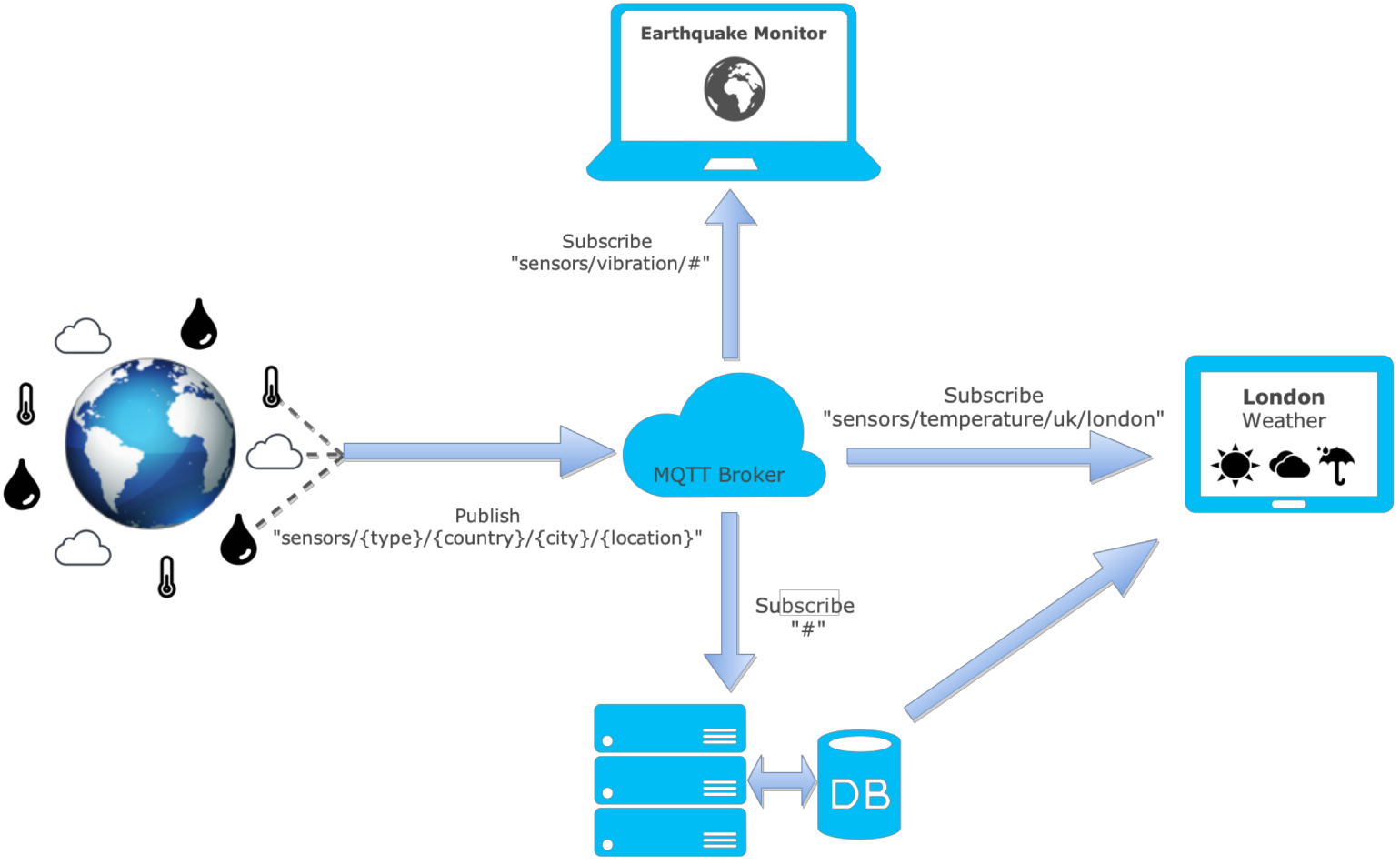
- Various protocols:
  - **MQTT**, AMQP, XMPP (was Jabber)
- Growing technique
  - E.g., https://cloud.google.com/iot/docs/how-tos/mqtt-bridge

Pub/sub approach

- Pub/Sub separate a client, who is sending a message about a specific **topic**, called publisher, from another client (or more clients), who is receiving the message, called subscriber.
- There is a third component, called broker, which is known by both the publisher and subscriber, which filters all incoming messages and distributes them accordingly.



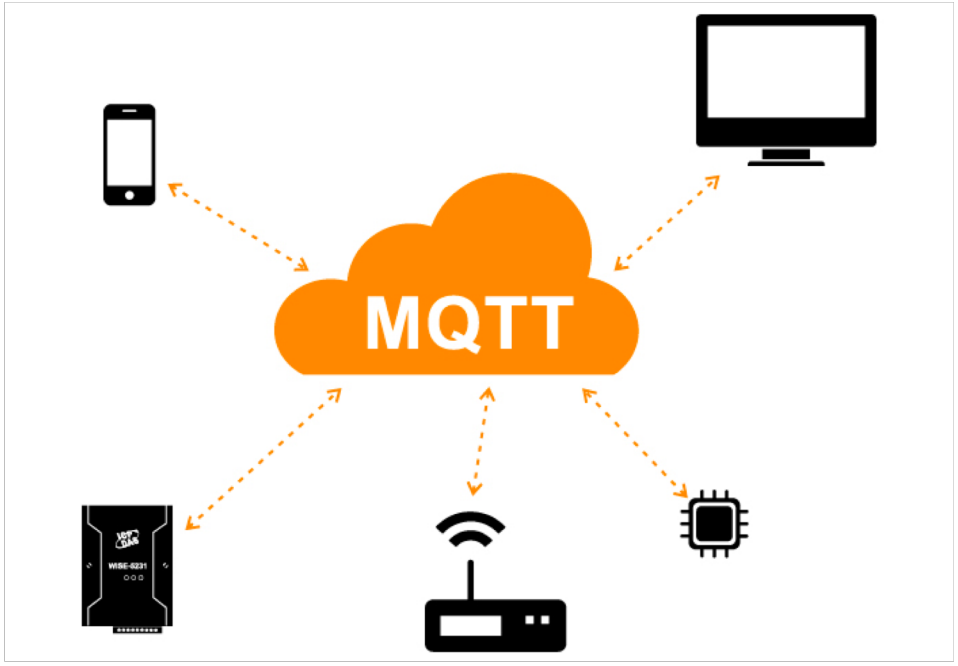
An example



Source: https://zoetrope.io/tech-blog/brief-practical-introduction-mqtt-protocol-and-its-application-iot

Intro to MQTT

- Fundamental concepts



Message Queuing Telemetry Transport

- A lightweight publish-subscribe protocol that can run on embedded devices and mobile platforms ➔ http://mqtt.org/
  - Low power usage.
  - Binary compressed headers
  - Maximum message size of 256MB
    - not really designed for sending large amounts of data
    - better at a high volume of low size messages.
- Documentation sources:
  - The MQTT community wiki:
    - `https://github.com/mqtt/mqtt.github.io/wiki`
  - A very good tutorial:
    - `http://www.hivemq.com/mqtt-essentials/`

Some details about versions

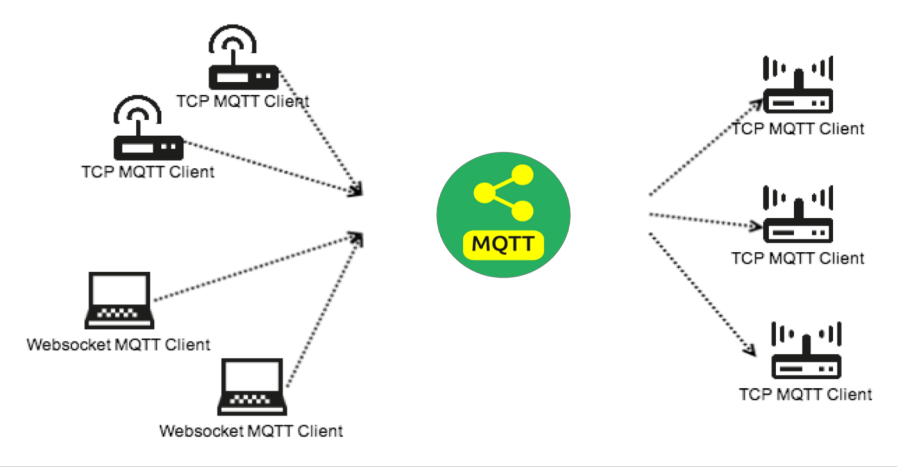
- **MQTT 3.1.1 is the current version of the protocol.**
  - Standard document here:
    - http://docs.oasis-open.org/mqtt/mqtt/v3.1.1/mqtt-v3.1.1.html
  - October 29th 2014: MQTT was officially approved as OASIS Standard.
    - https://www.oasis-open.org/committees/tc_home.php?wg_abbrev=mqtt

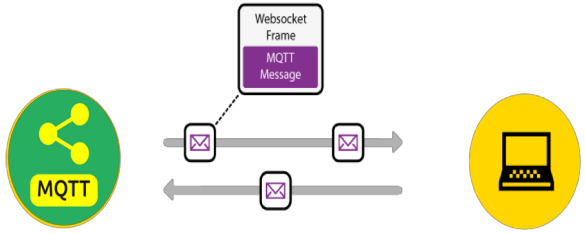
- MQTT v5.0 is the successor of MQTT 3.1.1
  - Current status: Committee Specification 02 (15 May 2018)
    - http://docs.oasis-open.org/mqtt/mqtt/v5.0/cs02/mqtt-v5.0-cs02.html
  - **Not backward compatible**; too many new things are introduced so existing implementations have to be revisited, for example:
    - **Enhancements for scalability** and large scale systems in respect to setups with 1000s and millions of devices.
    - **Improved error reporting** (Reason Code & Reason String)
    - Performance improvements and improved support for small clients
  - https://www.youtube.com/watch?time_continue=3&v=YIpesv_bJgU

MQTT works on top of…

- mainly of TCP
  - There is also the closely related MQTT for Sensor Networks (MQTT-SN) where TCP is replaced by UDP → TCP stack is too complex for WSN

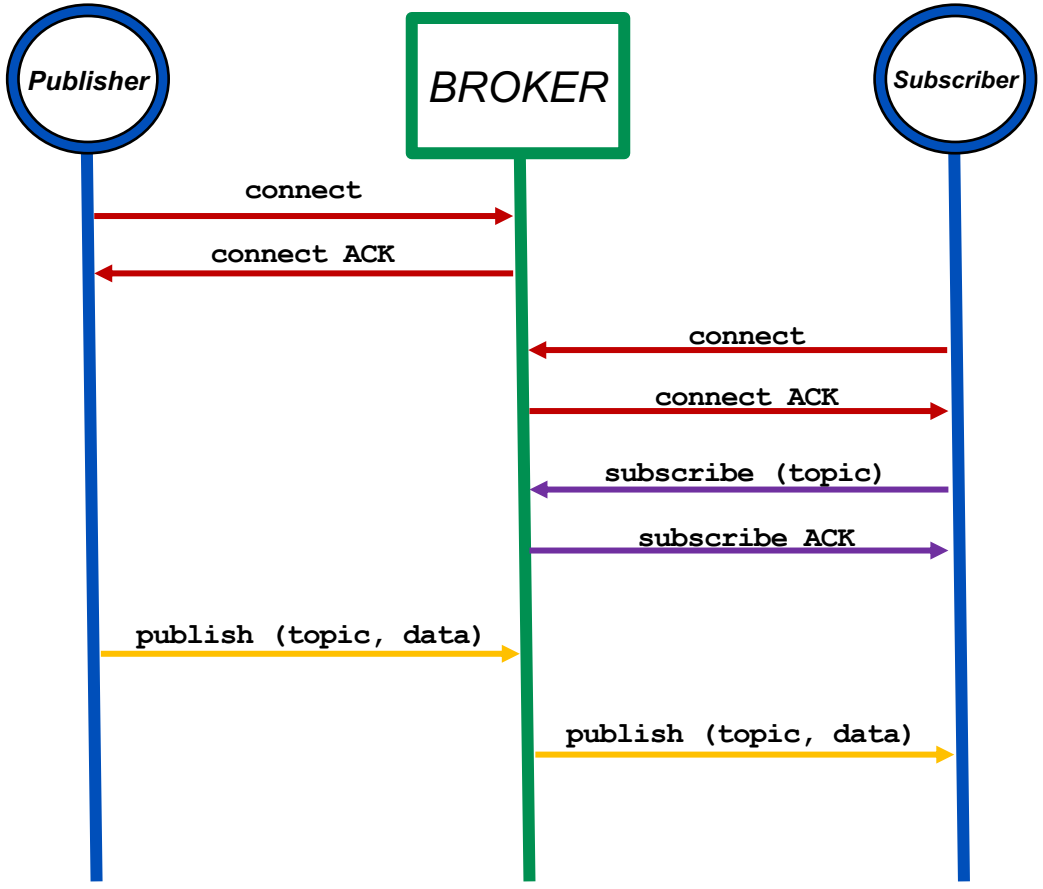
- websockets can be used, too!
  - Websockets allows you to receive MQTT data directly into a web browser.





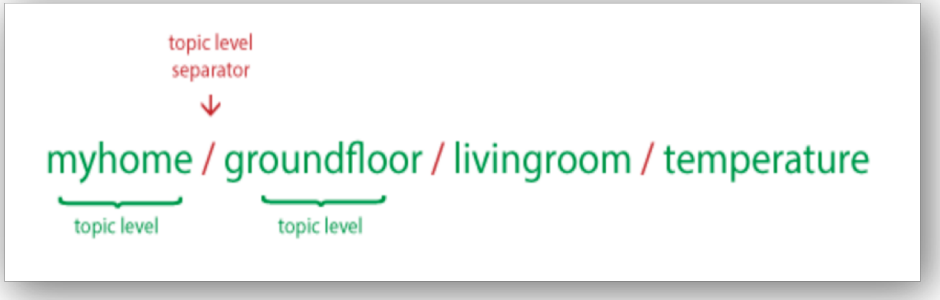
- Both, TCP & websockets can work on top of "Transport Layer Security (TLS)" (and its predecessor, Secure Sockets Layer (SSL))

Publish/subscribe interactions sequence



Topics

- MQTT Topics are structured in a hierarchy similar to folders and files in a file system using the forward slash (/) as a delimiter.
- Allow to create a user friendly and self descriptive **naming structures**



- Topic names are:
  - Case sensitive
  - use UTF-8 strings.
  - Must consist of at least one character to be valid.
- Except for the $SYS topic **there is no default or standard topic structure.**

Special $SYS/ topics

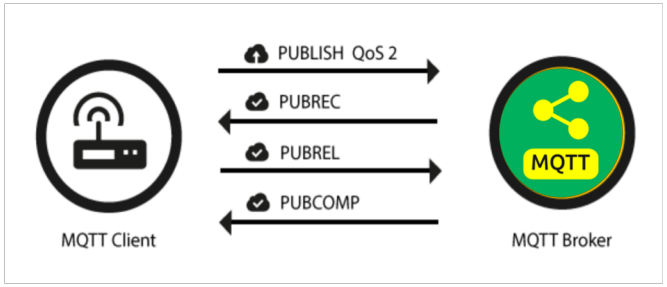
$SYS/broker/clients/connected
$SYS/broker/clients/disconnected
$SYS/broker/clients/total
$SYS/broker/messages/sent
$SYS/broker/uptime

Topics wildcards

- Topic subscriptions can have wildcards. These enable nodes to subscribe to groups of topics that don't exist yet, allowing greater flexibility in the network's messaging structure.
  - '+' matches anything at a given tree level
  - '#' matches a whole sub-tree
- Examples:
  - Subscribing to topic `house/#` covers:
    - ✓ house/room1/main-light
    - ✓ house/room1/alarm
    - ✓ house/garage/main-light
    - ✓ house/main-door
  - Subscribing to topic `house/+/main-light` covers:
    - ✓ house/room1/main-light
    - ✓ house/room2/main-light
    - ✓ house/garage/main-light
  - but doesn't cover
    - ✓ house/room1/side-light
    - ✓ house/room2/side-light

Quality of Service (QoS)

- Messages are published with a Quality of Service (QoS) level, which specifies delivery requirements.
- A QoS 0 ("at most once") message is fire-and-forget.
  - For example, a notification from a doorbell may only matter when immediately delivered.
- With QoS 1 ("at least once"), the broker stores messages on disk and retries until clients have acknowledged their delivery.
  - (Possibly with duplicates.) It's usually worth ensuring error messages are delivered, even with a delay.
- QoS 2 ("exactly once") messages have a second acknowledgement round-trip, to ensure that non-idempotent messages can be delivered exactly once.



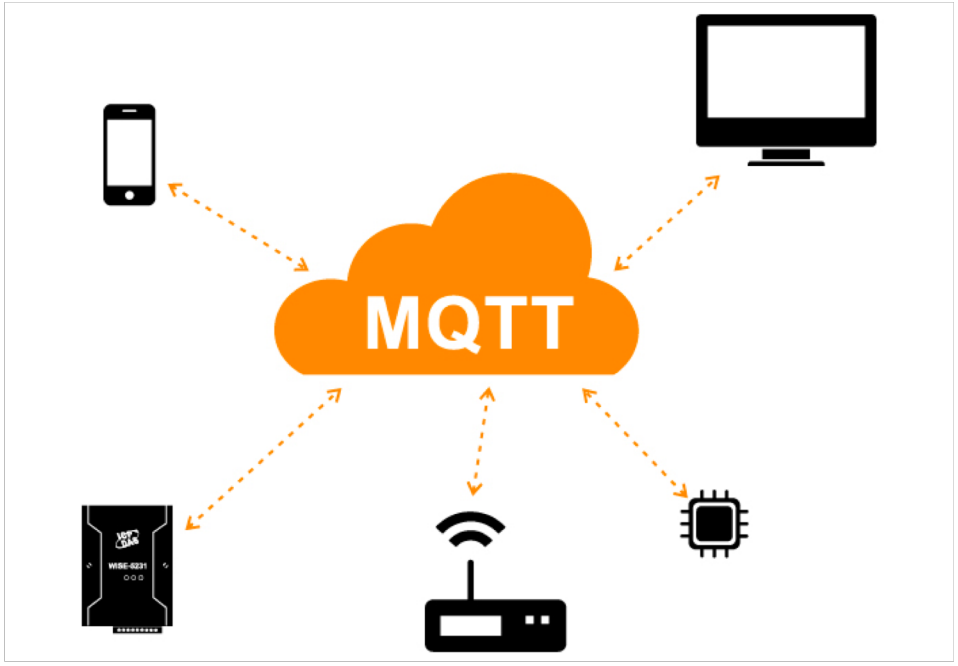
Retained Messages!!!

- A retained message is a normal MQTT message with the **retained flag set to true**. The broker will store the last retained message and the corresponding QoS for that topic
  - Each client that subscribes to a topic pattern, which matches the topic of the retained message, will receive the message immediately after subscribing.
  - For each topic **only one retained message** will be stored by the broker.

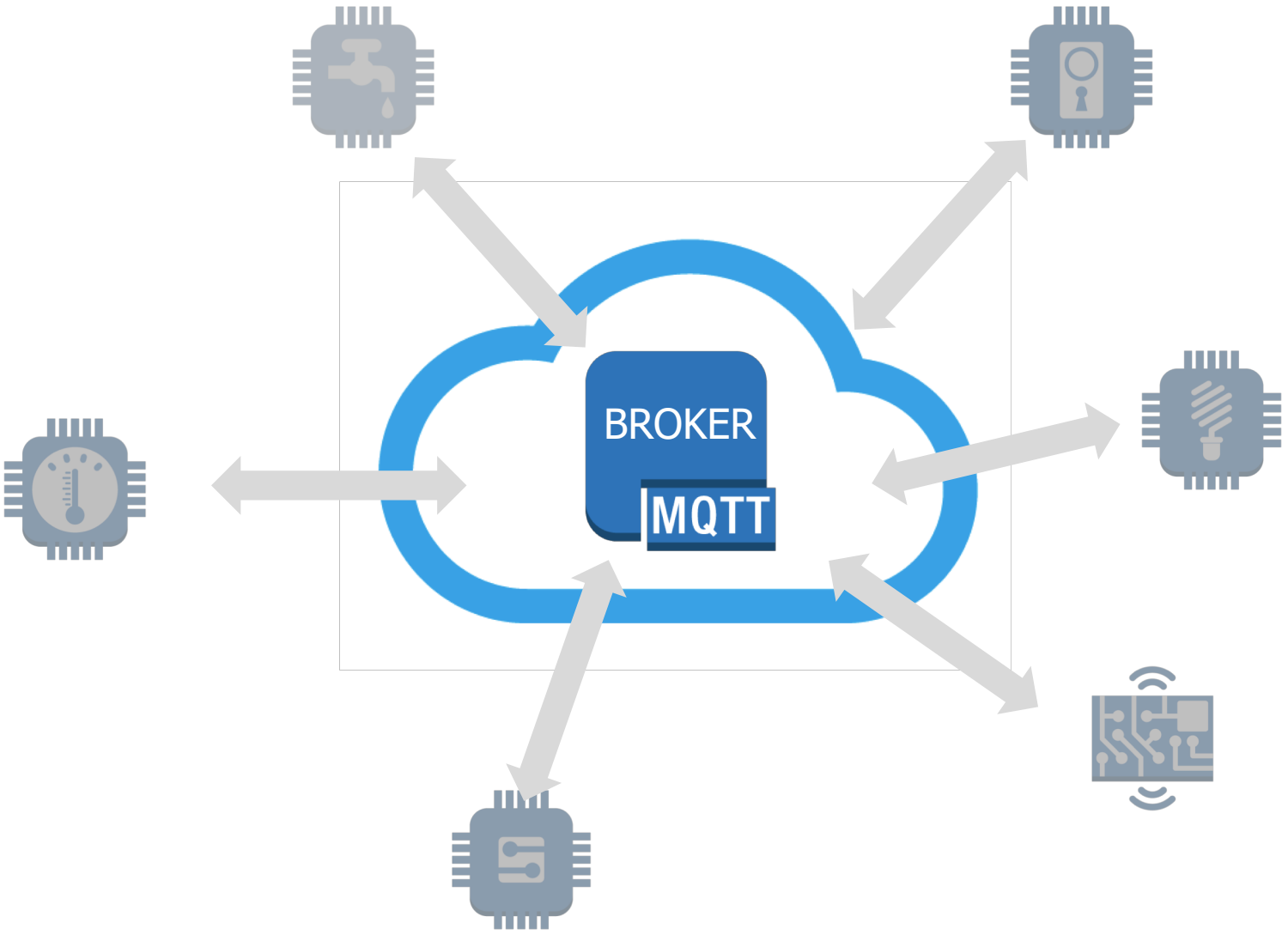
- Retained messages can help newly subscribed clients to get a status update immediately after subscribing to a topic and don't have to wait until a publishing clients send the next update.
  - In other words a retained message on a topic is the last known good value, because it doesn't have to be the last value, but it certainly is the last message with the retained flag set to true.

Intro to MQTT

- Brokers and clients



Creating a broker



Available MQTT brokers

- The most widely used are:
  - http://mosquitto.org/
    - man page: https://mosquitto.org/man/mosquitto-8.html
  - http://www.hivemq.com/
    - The standard trial version only supports 25 connections.
- And also:
  - https://www.rabbitmq.com/mqtt.html
  - http://activemq.apache.org/mqtt.html
- A quite complete list can be found here:
  - https://github.com/mqtt/mqtt.github.io/wiki/servers

Installing Mosquitto on a Raspberry Pi

- It takes only a few seconds to install a Mosquitto broker on a Raspberry. You need to execute the following steps:

```
sudo apt-get update
sudo apt-get install mosquitto mosquitto-clients
```

- Installation guidelines with websockets

```
https://gist.github.com/smoofit/dafa493aec8d41ea057370dbfde3f3fc
```

- Managing the broker:
  - To start and stop its execution use:

    ```
    sudo /etc/init.d/mosquitto start/stop
    ```

  - Verbose mode:

    ```
    sudo mosquitto –v
    ```

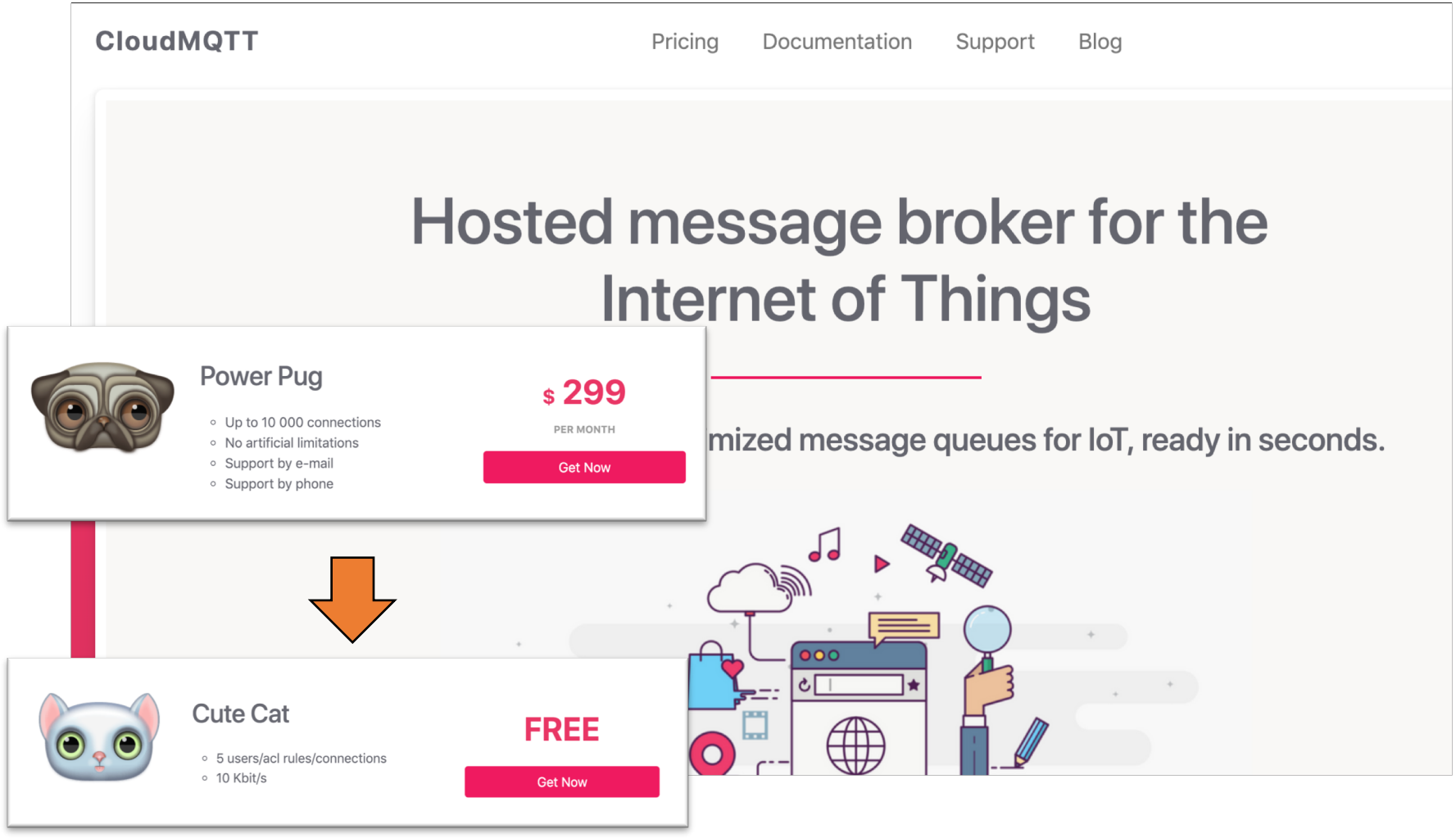
  - To check if the broker is running you can use the command:

    ```
    sudo netstat -tanlp | grep 1883
    ```

    - *note: "-tanlp" stands for: tcp, all, numeric, listening, program*

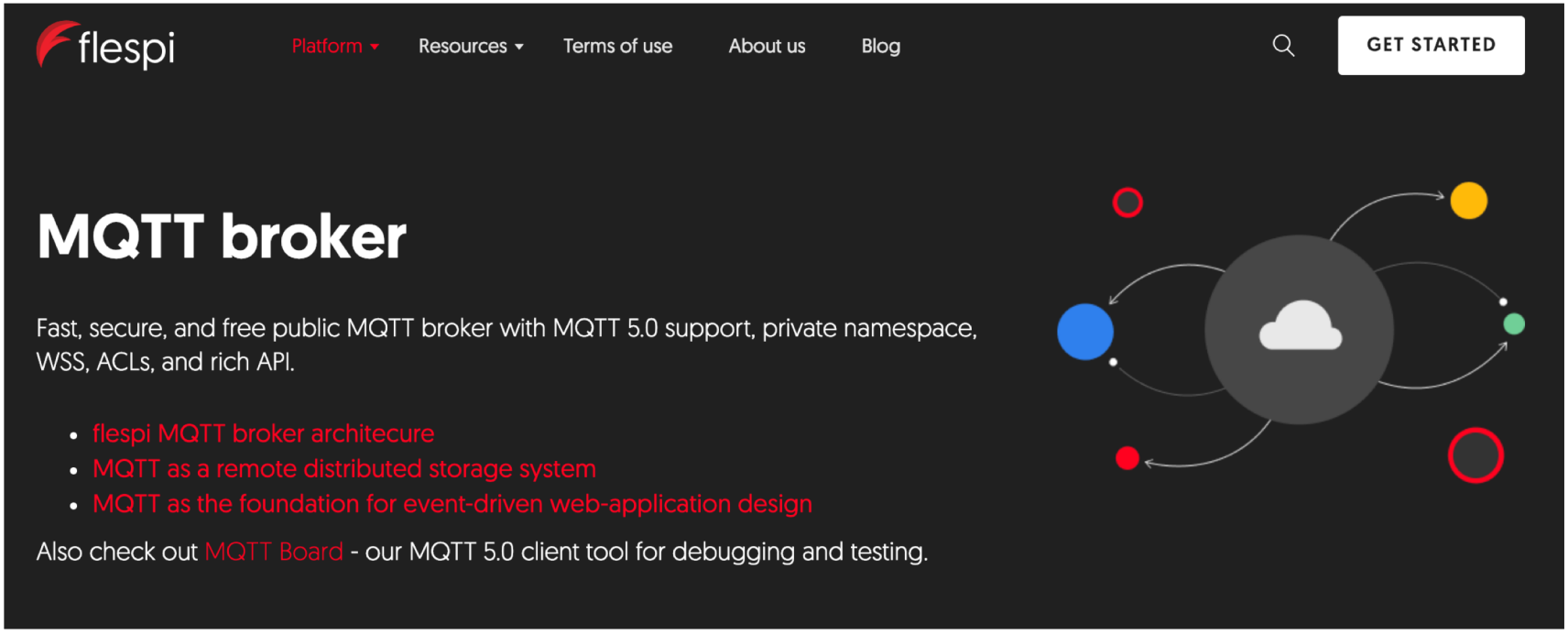
Cloud based MQTT brokers: CloudMQTT

https://www.cloudmqtt.com/ ➔ based on Mosquitto



Cloud based brokers: flespi

https://flespi.com/mqtt-broker



Cloud based brokers: flespi

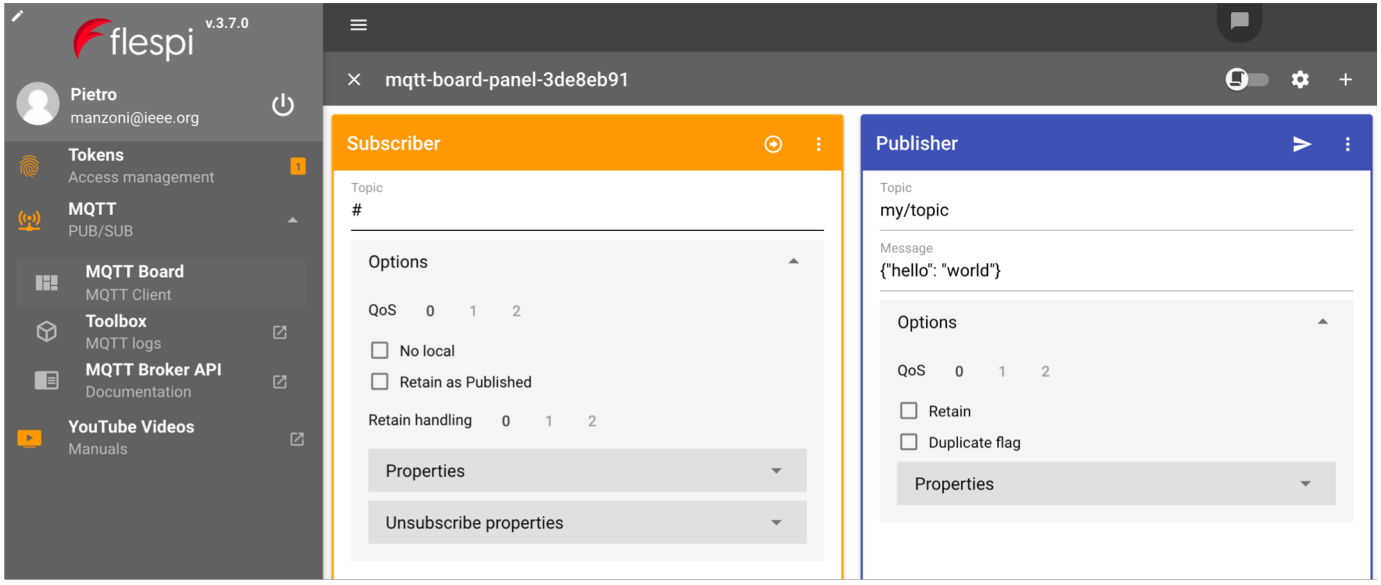
Terms of use

Free $0/mo

MQTT

100 active MQTT sessions

https://flespi.io/#/panel/mqttboard



https://flespi.com/mqtt-api

flespi MQTT broker connection details

- **Host** — **mqtt.flespi.io**.
  Port — **8883 (SSL)** or **1883 (non-SSL)**; for MQTT over WebSockets: **443 (SSL)** or **80 (non-SSL)**.
- **Authorization** — use a flespi platform token as MQTT session username; no password.
- **Client ID** — use any unique identifier within your flespi user session.
- **Topic** — you can publish messages to any topic except **flespi/**.
- **ACL** — both **flespi/** and **MQTT pub/sub** restrictions determined by the token.

```
I1RKMMIUJppLdlQoSgAQ8MvJPyNV9R2HIJgijO1S1gt5rajaeIOaiaKWwlHt2z1z
```

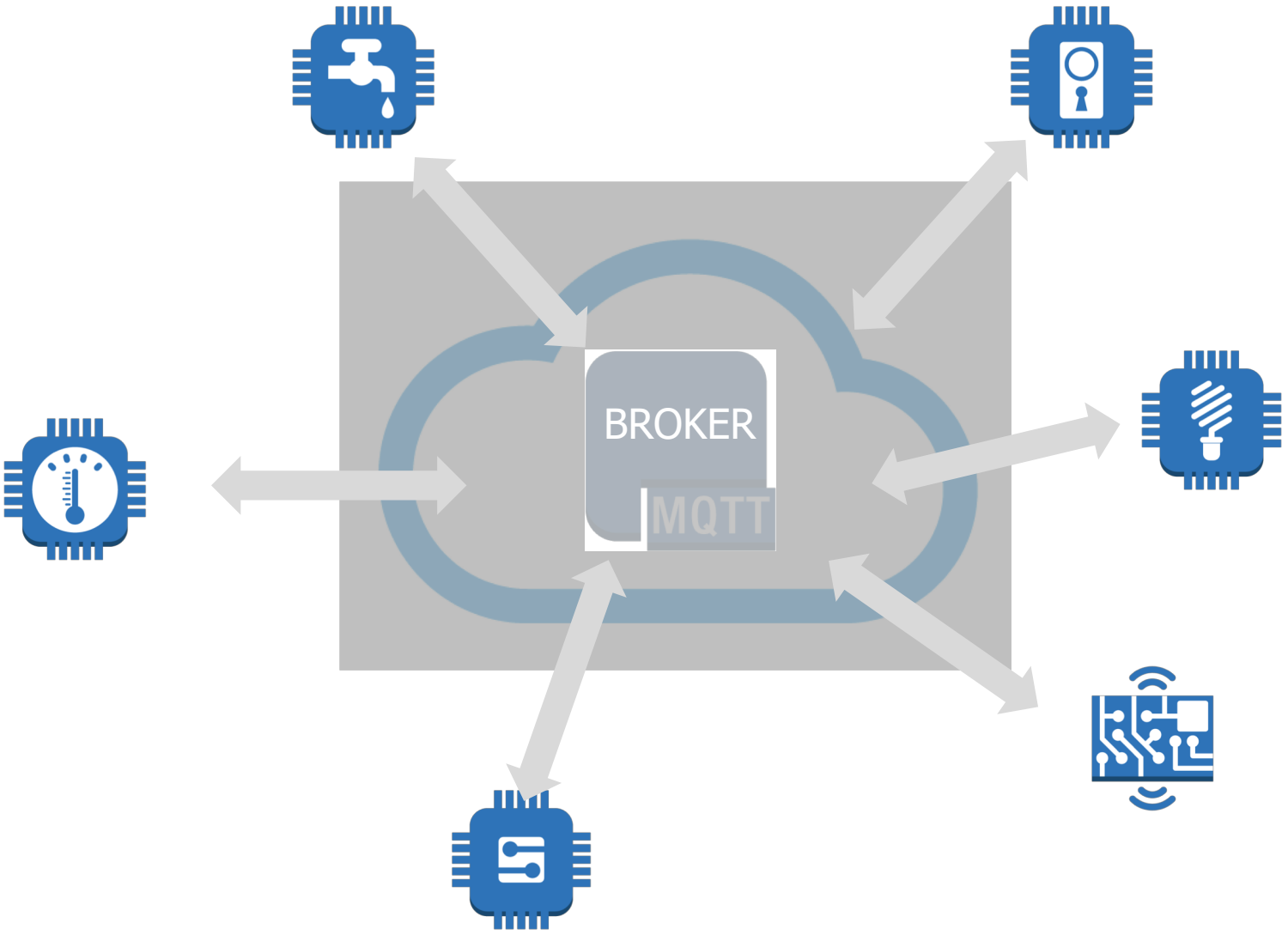
Open brokers ("Sandboxes")

- TCP based:
  - https://iot.eclipse.org/getting-started/#sandboxes
    - Hostname: **iot.eclipse.org**
  - http://test.mosquitto.org/
    - Hostname: **test.mosquitto.org**
  - https://www.hivemq.com/mqtt-demo/
    - Hostname: **broker.hivemq.com**
    - http://www.mqtt-dashboard.com/
  - Ports:
    - standard: 1883
    - encrypted: 8883 *(TLS v1.2, v1.1 or v1.0 with x509 certificates)*

- Websockets based:
  - broker.mqttdashboard.com port: 8000
  - test.mosquitto.org port: 8080
  - broker.hivemq.com port: 8000

- https://github.com/mqtt/mqtt.github.io/wiki/public_brokers

Creating clients



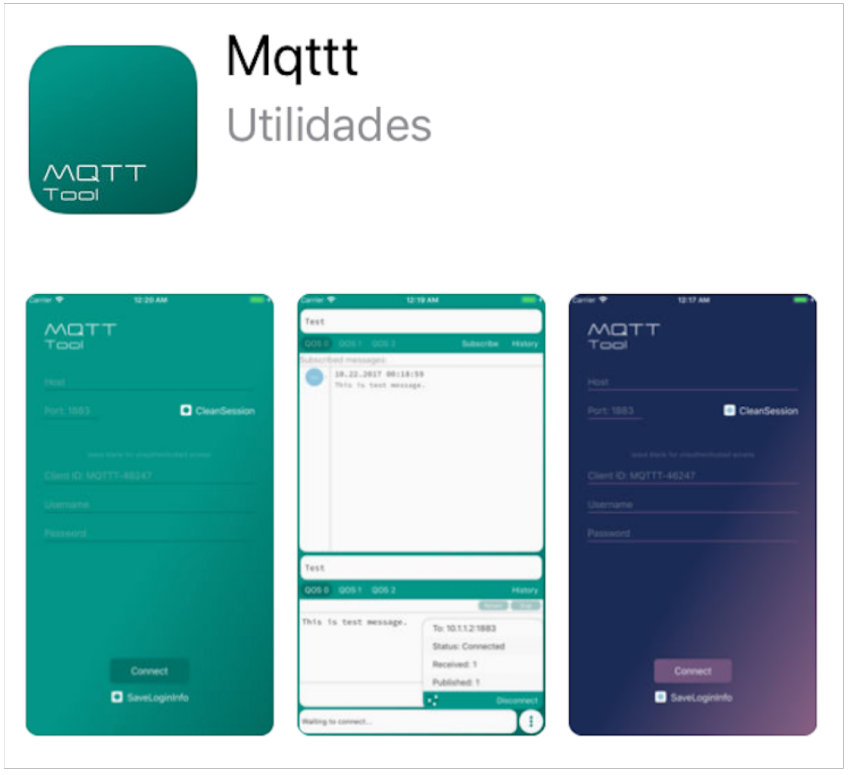
Clients for testing

- The Mosquitto broker comes with a couple of useful commands to quickly publish and subscribe to some topic.

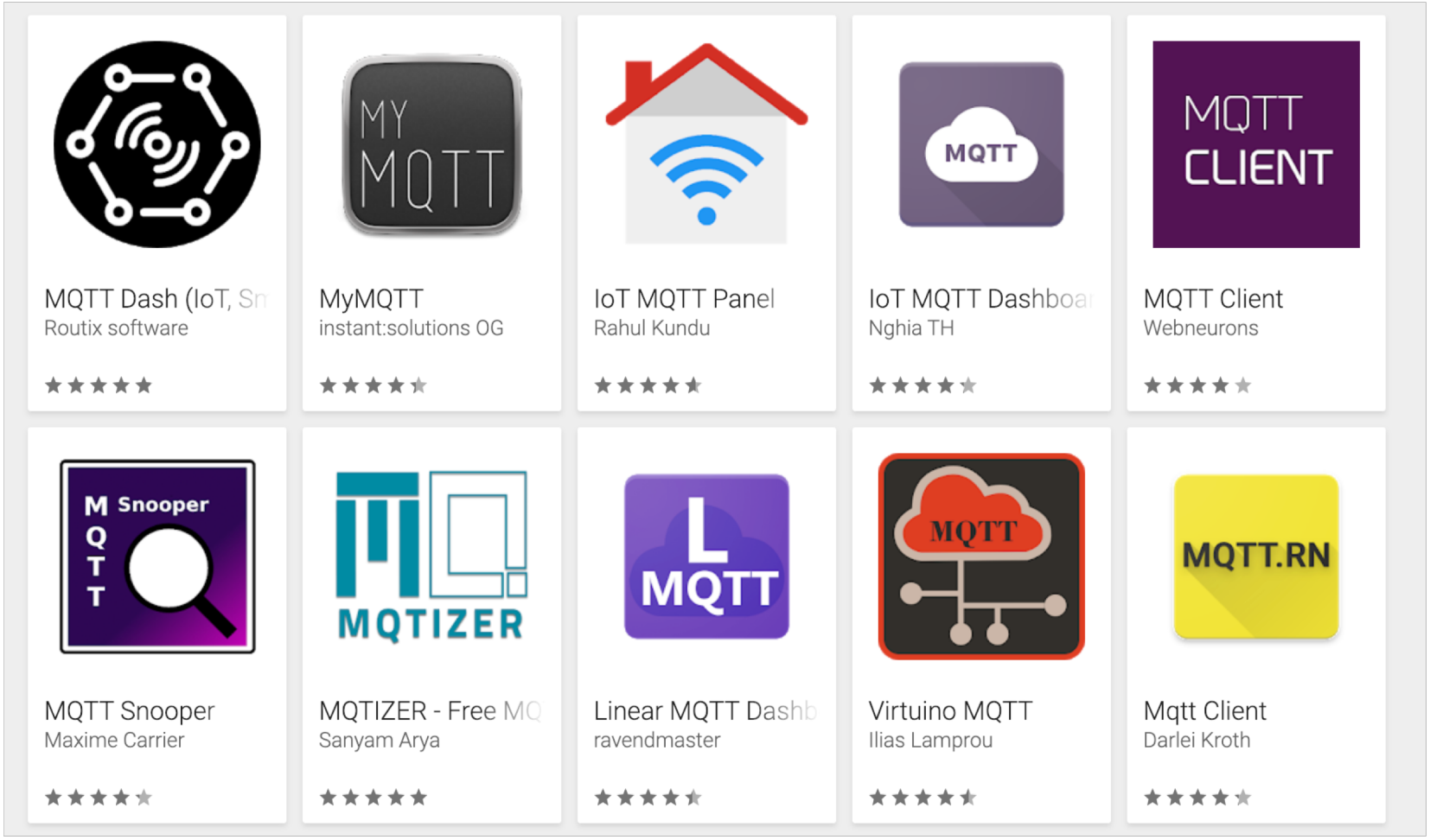
- Their basic syntax is the following.
  - `mosquitto_sub -h HOSTNAME -t TOPIC`
  - `mosquitto_pub -h HOSTNAME -t TOPIC -m MSG`

- More information can be found:
  - https://mosquitto.org/man/mosquitto_sub-1.html
  - https://mosquitto.org/man/mosquitto_pub-1.html

MQTT clients: iOS

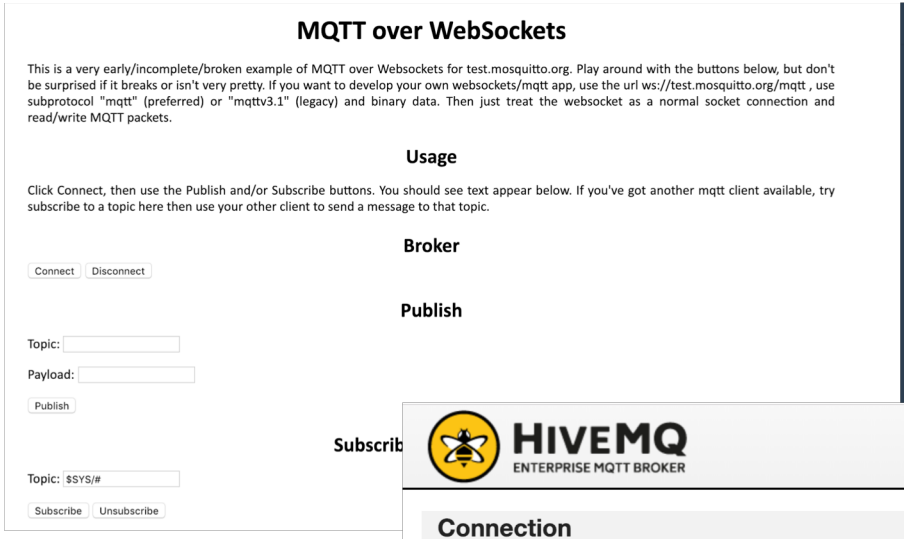


MQTT clients: Android

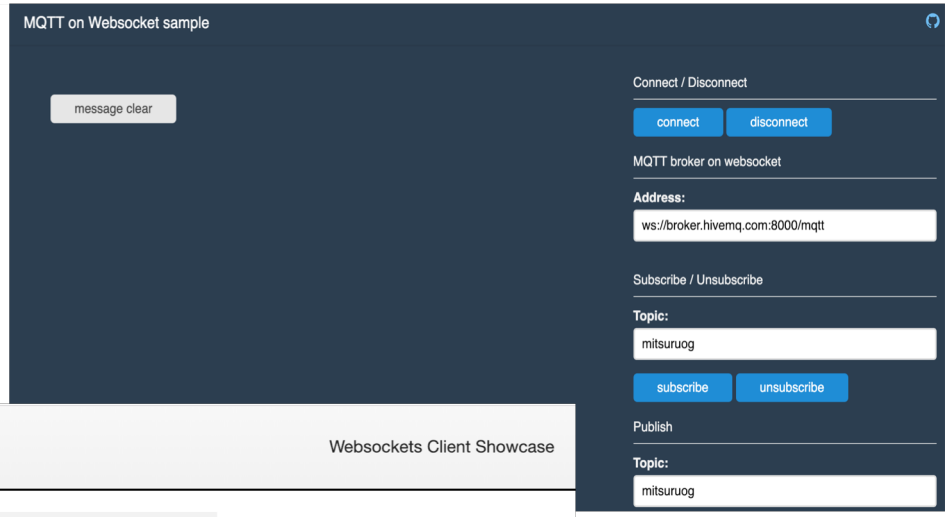


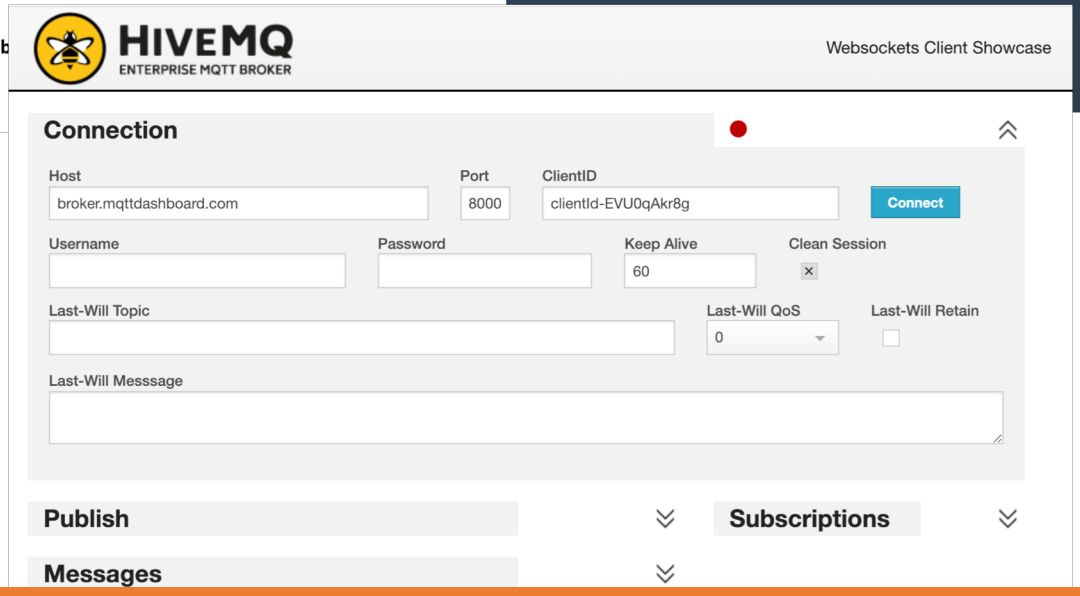
MQTT websocket clients

http://test.mosquitto.org/ws.html



http://mitsuruog.github.io/what-mqtt/





http://www.hivemq.com/demos/websocket-client/

Intro to MQTT

- Time for some exercise: Lab 0

https://bit.ly/ictp2019-lab0

Intro to MQTT

- More time for some demo/exercise: Lab 0.1

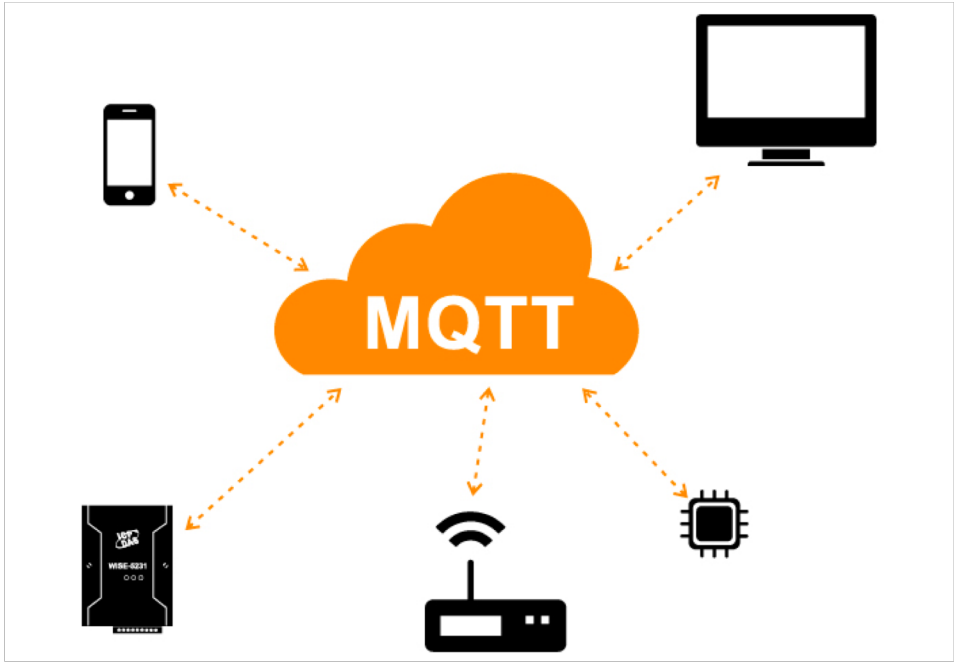
Broker address:

192.168.XX.XX
port: 9001

https://www.raspberrypi.org/products/sense-hat/

Intro to MQTT

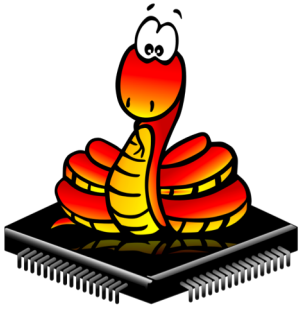
- Clients in Python



MQTT clients: Python vs Micropython

- The MQTT available versions for Python and MicroPython are slightly different.
- MicroPython is intended for constrained environments, in particular, microcontrollers, which have orders of magnitude less performance and memory than "desktop" systems on which Python3
- Basically remember that, when using the LoPy you have to use the MicroPython version of MQTT
- In the following we will see information about both cases.

vs.



Eclipse Paho Python

- Eclipse Paho Python (originally the mosquitto Python client)
  - http://www.eclipse.org/paho/
- Documentation: https://pypi.org/project/paho-mqtt/
  - or: http://www.eclipse.org/paho/clients/python/docs/
- Source: https://github.com/eclipse/paho.mqtt.python

Client	MQTT 3.1	MQTT 3.1.1	MQTT 5.0	LWT	SSL / TLS	Automatic Reconnect	Offline Buffering	Message Persistence	WebSocket Support	Standard MQTT Support	Blocking API	Non-Blocking API	High Availability
Java	✔	✔	✖	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Python	✔	✔	✖	✔	✔	✔	✔	✖	✔	✔	✔	✔	✖
JavaScript	✔	✔	✖	✔	✔	✔	✔	✔	✔	✖	✖	✔	✔
GoLang	✔	✔	✖	✔	✔	✔	✔	✔	✔	✔	✖	✔	✔
C	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
C++	✔	✔	✖	✔	✔	✔	✔	✔	✖	✔	✔	✔	✔
Rust	✔	✔	✖	✔	✔	✔	✔	✔	✖	✔	✔	✔	✔
.Net (C#)	✔	✔	✖	✔	✔	✖	✖	✖	✖	✔	✖	✔	✖
Android Service	✔	✔	✖	✔	✔	✔	✔	✔	✔	✔	✖	✔	✔
Embedded C/C++	✔	✔	✖	✔	✔	✖	✖	✖	✖	✔	✔	✔	✖

Paho MQTT Python client: general usage flow

The general usage flow is as follows:

- Create a client instance
- Connect to a broker using one of the connect*() functions
- Call one of the loop*() functions to maintain network traffic flow with the broker
- Use subscribe() to subscribe to a topic and receive messages
- Use publish() to publish messages to the broker
- Use disconnect() to disconnect from the broker

Example 1: a simple subscriber

```
# File: sisub.py

import paho.mqtt.client as mqtt

THE_BROKER = "iot.eclipse.org"
THE_TOPIC = "$SYS/#"
CLIENT_ID = ""

# The callback for when the client receives a CONNACK response from the server.
def on_connect(client, userdata, flags, rc):
    print("Connected to ", client._host, "port: ", client._port)
    print("Flags: ", flags, "returned code: ", rc)
    client.subscribe(THE_TOPIC, qos=0)

# The callback for when a message is received from the server.
def on_message(client, userdata, msg):
    print("sisub: msg received with topic: {} and payload: {}".format(msg.topic, str(msg.payload)))

client = mqtt.Client(client_id=CLIENT_ID,
                     clean_session=True,
                     userdata=None,
                     protocol=mqtt.MQTTv311,
                     transport="tcp")

client.on_connect = on_connect
client.on_message = on_message

client.username_pw_set(None, password=None)
client.connect(THE_BROKER, port=1883, keepalive=60)

# Blocking call that processes network traffic, dispatches callbacks and handles reconnecting.
client.loop_forever()
```

More on this later

Example 1: output

```
Connected to  iot.eclipse.org port:  1883
Flags:  {'session present': 0} returned code:  0
sisub: msg received with topic: $SYS/broker/version and payload: b'mosquitto version 1.4.15'
sisub: msg received with topic: $SYS/broker/timestamp and payload: b'2018-04-11 '
sisub: msg received with topic: $SYS/broker/clients/total and payload: b'162523'
sisub: msg received with topic: $SYS/broker/clients/active and payload: b'4103'
sisub: msg received with topic: $SYS/broker/clients/inactive and payload: b'158420'
sisub: msg received with topic: $SYS/broker/clients/maximum and payload: b'162524'
sisub: msg received with topic: $SYS/broker/clients/disconnected and payload: b'158420'
sisub: msg received with topic: $SYS/broker/clients/connected and payload: b'4103'
sisub: msg received with topic: $SYS/broker/clients/expired and payload: b'0'
sisub: msg received with topic: $SYS/broker/messages/received and payload: b'1171291305'
sisub: msg received with topic: $SYS/broker/messages/sent and payload: b'6271921352'
sisub: msg received with topic: $SYS/broker/messages/stored and payload: b'1380714' …

...
```

Paho MQTT Python client: connect

- connect(host, port=1883, keepalive=60, bind_address="")

- The broker acknowledgement will generate a callback (on_connect).
- Return Codes:
  - 0: Connection successful
  - 1: Connection refused – incorrect protocol version
  - 2: Connection refused – invalid client identifier
  - 3: Connection refused – server unavailable
  - 4: Connection refused – bad username or password
  - 5: Connection refused – not authorised
  - 6-255: Currently unused.

Paho MQTT Python client: pub/sub

subscribe(topic, qos=0)

- e.g., subscribe("my/topic", 2)
- E.g., subscribe([("my/topic", 0), ("another/topic", 2)])

- on_message(client, userdata, message) Called when a message has been received on a topic that the client subscribes to.

publish(topic, payload=None, qos=0, retain=False)

Paho MQTT Python client: Network loop

```
client.username_pw_set(None, password=None)
client.connect(THE_BROKER, port=1883, keepalive=60)

# Blocking call that processes network traffic, dispatches callbacks and handles reconnecting.
client.loop_forever()
```

More on this later

What are network loops for?

Paho MQTT Python client: Network loop

loop_forever()

- This is a blocking form of the network loop and will not return until the client calls disconnect(). It automatically handles reconnecting.

loop_start() / loop_stop()

- These functions implement a threaded interface to the network loop.
  - Calling loop_start() once, before or after connect(), runs a thread in the background to call loop() automatically. This frees up the main thread for other work that may be blocking.
  - Call loop_stop() to stop the background thread.

loop(timeout=1.0)

- Call regularly to process network events.
  - This call waits in select() until the network socket is available for reading or writing, if appropriate, then handles the incoming/outgoing data.
  - This function blocks for up to timeout seconds.

Example 2: subscriber with `loop_start/loop_stop`

```
import sys
import time

import paho.mqtt.client as mqtt

THE_BROKER = "test.mosquitto.org"
THE_TOPIC = "$SYS/broker/load/bytes/#"

def on_connect(mqttc, obj, flags, rc):
    print("Connected to ", mqttc._host, "port: ", mqttc._port)
    mqttc.subscribe(THE_TOPIC, 0)

def on_message(mqttc, obj, msg):
    global msg_counter
    print(msg.topic+" "+str(msg.qos)+" "+str(msg.payload))
    msg_counter+=1

def on_subscribe(mqttc, obj, mid, granted_qos):
    print("Subscribed: ", mid, "granted QoS: ", granted_qos)

mqttc = mqtt.Client()
mqttc.on_message = on_message
mqttc.on_connect = on_connect
mqttc.on_subscribe = on_subscribe

mqttc.connect(THE_BROKER, keepalive=60)

msg_counter = 0
mqttc.loop_start()
while msg_counter < 10:
    time.sleep(0.1)
mqttc.loop_stop()
print msg_counter
```

```
paho-code:pietro$ python example3.py
('Connected to ', 'test.mosquitto.org', 'port: ', 1883)
('Subscribed: ', 1, 'granted QoS: ', (0,))
$SYS/broker/load/bytes/received/1min 0 489527.05
$SYS/broker/load/bytes/received/5min 0 491792.65
$SYS/broker/load/bytes/received/15min 0 495387.48
$SYS/broker/load/bytes/sent/1min 0 4133472.81
$SYS/broker/load/bytes/sent/5min 0 3515397.37
$SYS/broker/load/bytes/sent/15min 0 2885966.59
$SYS/broker/load/bytes/received/1min 0 483622.23
$SYS/broker/load/bytes/sent/1min 0 3766302.58
$SYS/broker/load/bytes/received/5min 0 490441.96
$SYS/broker/load/bytes/sent/5min 0 3458734.24
$SYS/broker/load/bytes/received/15min 0 494888.07
$SYS/broker/load/bytes/sent/15min 0 2874493.79
12
```

Example 3: very basic periodic producer

```
import random
import time

import paho.mqtt.client as mqtt

THE_BROKER = "test.mosquitto.org"
THE_TOPIC = "PMtest/rndvalue"
CLIENT_ID = ""

# The callback for when the client receives a CONNACK response
from the server.
def on_connect(client, userdata, flags, rc):
    print("Connected to ", client._host, "port: ", client._port)
    print("Flags: ", flags, "returned code: ", rc)

# The callback for when a message is published.
def on_publish(client, userdata, mid):
    print("sipub: msg published (mid={})".format(mid))
```

```
client = mqtt.Client(client_id=CLIENT_ID,
                     clean_session=True,
                     userdata=None,
                     protocol=mqtt.MQTTv311,
                     transport="tcp")

client.on_connect = on_connect
client.on_publish = on_publish

client.username_pw_set(None, password=None)
client.connect(THE_BROKER, port=1883, keepalive=60)

client.loop_start()

while True:

    msg_to_be_sent = random.randint(0, 100)
    client.publish(THE_TOPIC,
                   payload=msg_to_be_sent,
                   qos=0,
                   retain=False)

    time.sleep(5)

client.loop_stop()
```

Generates a new data every 5 secs

Example 3: output

```
Python 3.6.1 (default, Dec 2015, 13:05:11)
[GCC 4.8.2] on linux
sipub: msg published (mid=1)
Connected to  test.mosquitto.org port:  1883
Flags:  {'session present': 0} returned code:  0
sipub: msg published (mid=2)
sipub: msg published (mid=3)
sipub: msg published (mid=4)
sipub: msg published (mid=5)
sipub: msg published (mid=6)
sipub: msg published (mid=7)
```

Producer output

Output obtained with a modified version of Example1. **Which parts of that code had to be modified?**

```
Python 3.6.1 (default, Dec 2015, 13:05:11)
[GCC 4.8.2] on linux
Connected to  test.mosquitto.org port:  1883
Flags:  {'session present': 0} returned code:  0
sisub: msg received with topic: PMtest/rndvalue and payload: b'11'
sisub: msg received with topic: PMtest/rndvalue and payload: b'14'
sisub: msg received with topic: PMtest/rndvalue and payload: b'31'
sisub: msg received with topic: PMtest/rndvalue and payload: b'27'
sisub: msg received with topic: PMtest/rndvalue and payload: b'60'
sisub: msg received with topic: PMtest/rndvalue and payload: b'70'
sisub: msg received with topic: PMtest/rndvalue and payload: b'60'
sisub: msg received with topic: PMtest/rndvalue and payload: b'66'
sisub: msg received with topic: PMtest/rndvalue and payload: b'45'
sisub: msg received with topic: PMtest/rndvalue and payload: b'56'
sisub: msg received with topic: PMtest/rndvalue and payload: b'37'
…
```

Example 4: Pub/Sub with JSON

Producer

```
…

mqttc.loop_start()

while True:
    # Getting the data
    the_time = time.strftime("%H:%M:%S")
    the_value = random.randint(1,100)
    the_msg={'Sensor': 1, 'C_F': 'C',
             'Value': the_value, 'Time': the_time}

    the_msg_str = json.dumps(the_msg)

    mqttc.publish(THE_TOPIC, the_msg_str)
    time.sleep(5)

mqttc.loop_stop()
```

Consumer

```
…

# The callback for when a PUBLISH message is received
from the server.
def on_message(client, userdata, msg):
    print(msg.topic+" "+str(msg.payload))

    themsg = json.loads(str(msg.payload))

    print("Sensor "+str(themsg['Sensor'])+" got value "+
          str(themsg['Value'])+" "+themsg['C_F']+
          " at time "+str(themsg['Time']))

…
```

```
paho-code:pietro$ python example4-cons.py
Connected with result code 0
PMtest/jsonvalue {"Time": "12:19:30", "Sensor": 1, "Value": 33, "C_F": "C"}
Sensor 1 got value 33 C at time 12:19:30
PMtest/jsonvalue {"Time": "12:19:35", "Sensor": 1, "Value": 11, "C_F": "C"}
Sensor 1 got value 11 C at time 12:19:35
```

- Import the library

```
from mqtt import MQTTClient
```

- Creating a client:

```
MQTTclient(client_id, server, port=0, user=None, password=None,
           keepalive=0,  ssl=False, ssl_params={})
e.g., client = MQTTClient("dev_id", "10.1.1.101", 1883)
```

- The various calls:
  - `connect(clean_session=True):`
  - `publish(topic, msg, retain=False, qos=0):`
  - `subscribe(topic, qos=0):`
  - `set_callback(self, f):`

- `wait_msg():`
  - Wait for a single incoming MQTT message and process it. Subscribed messages are delivered to a callback previously set by .set_callback() method. Other (internal) MQTT messages processed internally.
- `check_msg():`
  - Checks whether a pending message from server is available. If not, returns immediately with None. Otherwise, does the same processing as wait_msg.

MicroPython: a simple publisher

```
# file: mp_sipub.py

from mqtt import MQTTClient
import pycom
import sys
import time

import ufun

wifi_ssid = 'THE_NAME_OF_THE_AP'
wifi_passwd = ''

THE_BROKER = "iot.eclipse.org"
THE_TOPIC = "test/SRM2018"
CLIENT_ID = ""

def settimeout(duration):
   pass

def get_data_from_sensor(sensor_id="RAND"):
    if sensor_id == "RAND":
        return ufun.random_in_range()
```

```
### if __name__ == "__main__":

ufun.connect_to_wifi(wifi_ssid, wifi_passwd)

client = MQTTClient(CLIENT_ID, THE_BROKER, 1883)

print ("Connecting to broker: " + THE_BROKER)
try:
    client.connect()
except OSError:
    print ("Cannot connect to broker: " + THE_BROKER)
    sys.exit()
print ("Connected to broker: " + THE_BROKER)

print('Sending messages...')
while True:
    # creating the data
    the_data = get_data_from_sensor()
    # publishing the data
    client.publish(THE_TOPIC, str(the_data))
    print("Published message with value: {}".format(the_data))
    time.sleep(1)
```

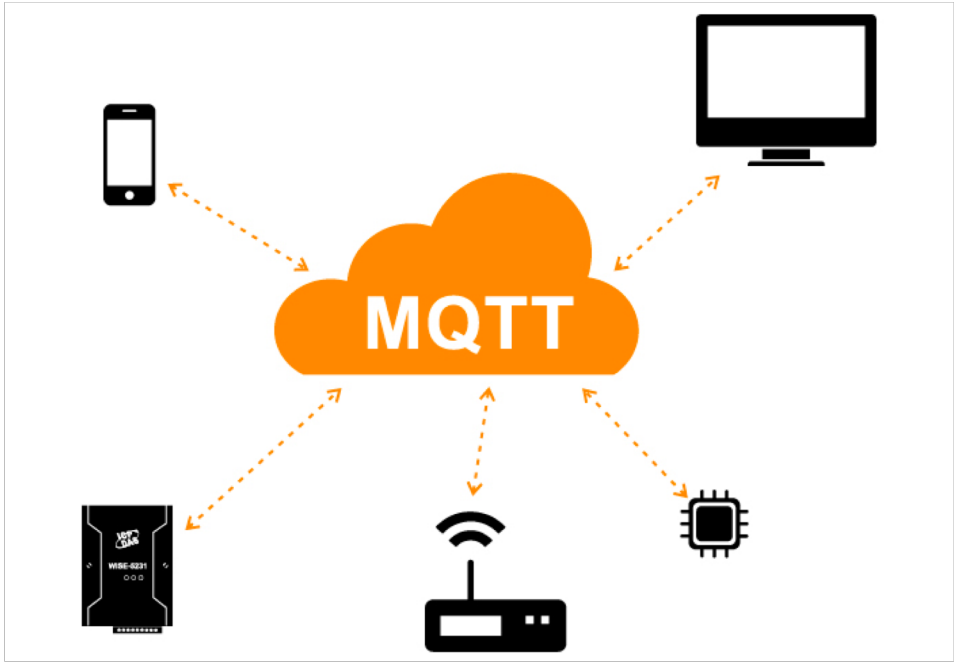
MicroPython: a simple subscriber

```
# file: mp_sisub.py

from mqtt import MQTTClient
import pycom
import sys
import time

import ufun

wifi_ssid = 'THE_NAME_OF_THE_AP'
wifi_passwd = ''

THE_BROKER = "iot.eclipse.org"
THE_TOPIC = "test/SRM2018"
CLIENT_ID = ""

def settimeout(duration):
   pass

def on_message(topic, msg):
    print("Received msg: ", str(msg),
          "with topic: ", str(topic))
```

```
### if __name__ == "__main__":

ufun.connect_to_wifi(wifi_ssid, wifi_passwd)

client = MQTTClient(CLIENT_ID, THE_BROKER, 1883)
client.set_callback(on_message)

print ("Connecting to broker: " + THE_BROKER)
try:
    client.connect()
except OSError:
    print ("Cannot connect to broker: " + THE_BROKER)
    sys.exit()
print ("Connected to broker: " + THE_BROKER)

client.subscribe(THE_TOPIC)

print('Waiting messages...')
while 1:
    client.check_msg()
```

Intro to MQTT

- Some final details

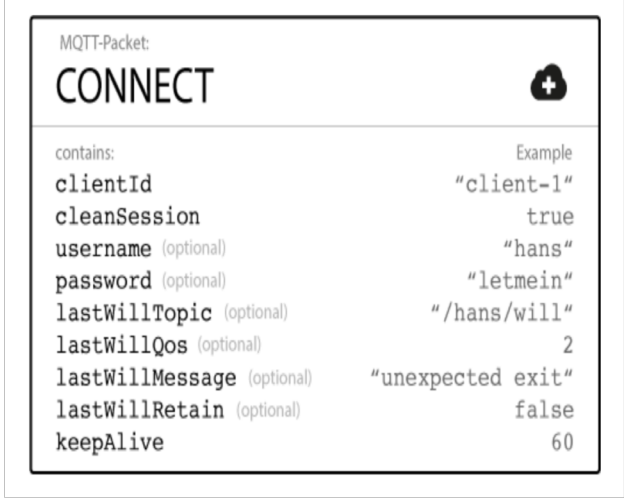


MQTT Keep alive

- The keep alive functionality assures that the connection is still open and both broker and client are connected to one another.
- The client specifies a time interval in seconds and communicates it to the broker during the establishment of the connection.
  - The interval is the longest possible period of time which broker and client can endure without sending a message.
  - If the broker doesn't receive a PINGREQ or any other packet from a particular client, it will close the connection and send out the last will and testament message (if the client had specified one).
- Good to Know
  - The MQTT client is responsible of setting the right keep alive value.
  - The maximum keep alive is 18h 12min 15 sec.
  - If the keep alive interval is set to **0**, the keep alive mechanism is deactivated.

"Will" message

- When clients connect, they can specify an optional "will" message, to be delivered if they are unexpectedly disconnected from the network.
  - (In the absence of other activity, a 2-byte ping message is sent to clients at a configurable interval.)
- This "last will and testament" can be used to notify other parts of the system that a node has gone down.



WHEN?

Persistent session

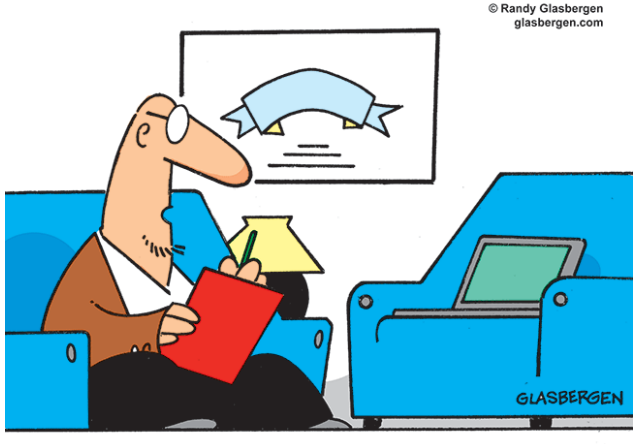
- A persistent session saves all information relevant for the client on the broker. The session is identified by the clientId provided by the client on connection establishment
- So what will be stored in the session?
  - Existence of a session, even if there are no subscriptions
  - All subscriptions
  - All messages in a Quality of Service (QoS) 1 or 2 flow, which are not confirmed by the client
  - All new QoS 1 or 2 messages, which the client missed while it was offline
  - All received QoS 2 messages, which are not yet confirmed to the client
  - That means even if the client is offline all the above will be stored by the broker and are available right after the client reconnects.
- Persistent session on the client side
  - Similar to the broker, each MQTT client must store a persistent session too. So when a client requests the server to hold session data, it also has the responsibility to hold some information by itself:
  - All messages in a QoS 1 or 2 flow, which are not confirmed by the broker
  - All received QoS 2 messages, which are not yet confirmed to the broker

Topics best practices

- First of all:
  - Don't use a leading forward slash
  - Don't use spaces in a topic
  - Use only ASCII characters, avoid non printable characters
- Then, try to..
  - Keep the topic short and concise
  - Use specific topics, instead of general ones
  - Don't forget extensibility
- Finally, be careful and don't subscribe to #

A few words on security

- MQTT has the option for Transport Layer Security (TLS) encryption.
- MQTT also provides username/password authentication with the broker.
  - Note that the password is transmitted in clear text. Thus, be sure to use TLS encryption if you are using authentication.



"It's not just you. We're all insecure in one way or another."

Smart homes can be easily hacked via unsecured MQTT servers

https://www.helpnetsecurity.com/2018/08/20/unsecured-mqtt-servers/

In fact, by using the Shodan IoT search engine, Avast researchers found over 49,000 MQTT servers exposed on the Internet and, of these, nearly 33,000 servers have no password protection, allowing attackers to access them and all the messages flowing through it.

TOTAL RESULTS

49,197

TOP COUNTRIES

China	12,151
United States	8,257
Germany	3,092
Korea, Republic of	2,003
Hong Kong	2,002

TOTAL RESULTS

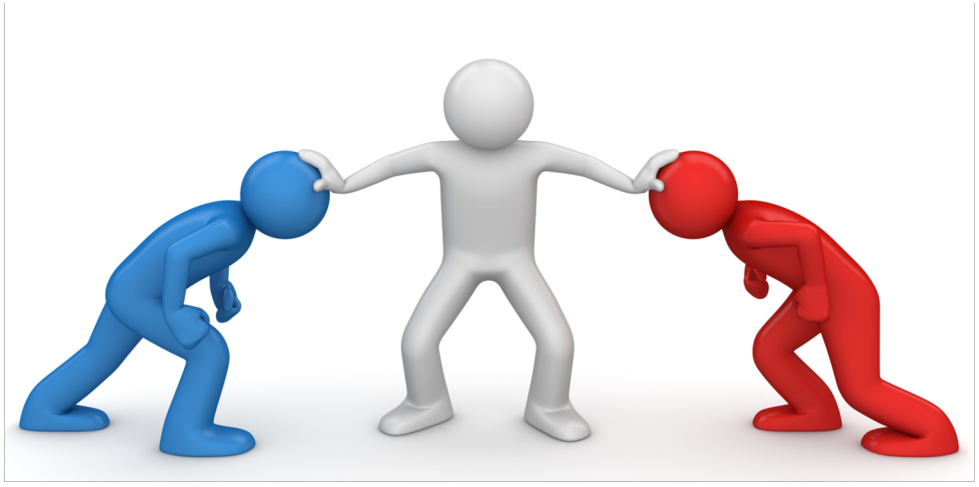
32,888

TOP COUNTRIES

China	8,446
United States	4,733
Germany	1,719
Hong Kong	1,614
Taiwan	1,565

MQTT vs REST

- Can they really be compared?!?!?
  - MQTT was created basically as a lightweight messaging protocol for lightweight communication between devices and computer systems
  - REST stands on the shoulders of the almighty HTTP
- So it's better to understand their weak and strong points and build a system taking the best of both worlds… if required



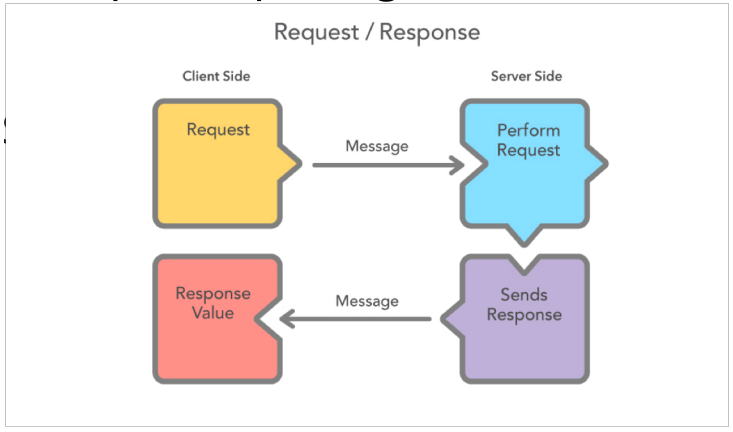
REST advantages

- It is always independent of the type of platform or languages
  - The only thing is that it is indispensable that the responses to the requests should always take place in the language used for the information exchange, normally XML or JSON.

- It is stateless ➔ This allows for scalability, by adding additional server nodes behind a load balancer
  - No state can be stored on servers: "keep the application state on the client."
  - All messages exchanged between client and server have all the context needed to know what to do with the message.

REST disadvantages

- Today's real world embedded devices for IoT usually lacks the ability to handle high-level protocols like HTTP and they may be served better by lightweight binary protocols.
- It is PULL based. This poses a problem when services depend on being up to date with data they don't own and manage.
  - Being up to date requires polling, which quickly add up in a system with enough interconnected services.
  - Pull style can produce heavy unnecessary workloads and bandwidth consumption due to for example a request/response polling-based monitoring & control systems
- It is based on one-to-one interaction



Advantages of MQTT

- **Push based**: no need to continuously look for updates

- It has built-in function useful for reliable behavior in an unreliable or intermittently connected wireless environments.
  1. "last will & testament" so all apps know immediately if a client disconnects ungracefully,
  2. "retained message" so any user re-connecting immediately gets the very latest information, etc.

- Useful for one-to-many, many-to-many applications

- Small memory footprint protocol, with reduced use of battery

Energy usage: some number

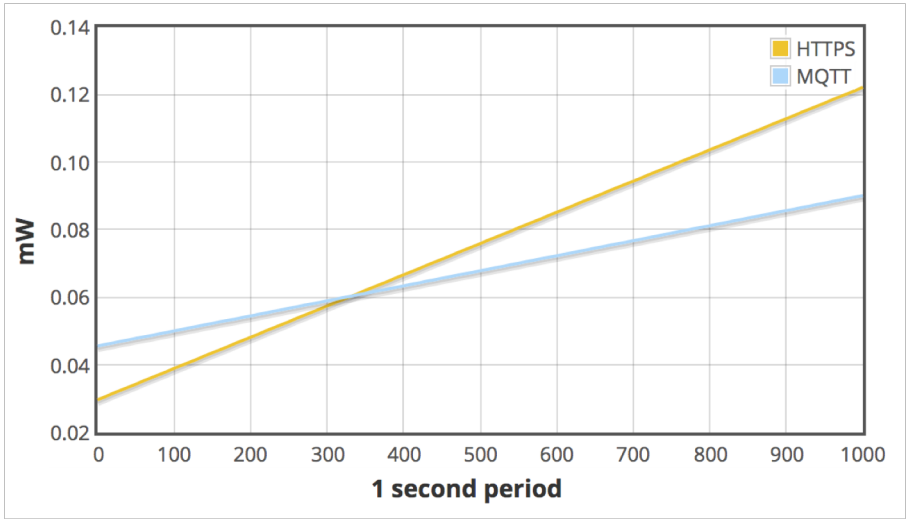
amount of power taken to establish the initial connection to the server:

% Battery Used			
3G		Wifi	
HTTPS	MQTT	HTTPS	MQTT
0.02972	0.04563	**0.00228**	0.00276

cost of 'maintaining' that connection (in % Battery / Hour):

	% Battery / Hour			
	3G		Wifi	
Keep Alive (Seconds)	HTTPS	MQTT	HTTPS	MQTT
60	1.11553	**0.72465**	0.15839	**0.01055**
120	0.48697	**0.32041**	0.08774	**0.00478**
240	0.33277	**0.16027**	0.02897	**0.00230**
480	0.08263	**0.07991**	0.00824	**0.00112**

3G – 240s Keep Alive – % Battery Used Creating and Maintaining a Connection



you'd save ~4.1% battery per day just by using MQTT over HTTPS to maintain an open stable connection.

http://stephendnicholas.com/posts/power-profiling-mqtt-vs-https

MQTT disadvantages

- If the broker fails…
- Does not define a standard client API, so application developers have to select the best fit.
- Does not include many features that are common in Enterprise Messaging Systems like:
  - expiration, timestamp, priority, custom message headers, …
- Does not have a point-to-point (aka queues) messaging pattern
  - Point to Point or One to One means that there can be more than one consumer listening on a queue but only one of them will be get the message
- Maximum message size 256MB


Thank
You
Merci
Gracias
TerimaKasih
Takk
aDank
BarakAllahuFiik
Mèsi
Xièxie
Grazie
Chokrane
Kiitos
Dziakuju
Spacibo
Danke
Arigatô
Hvala
KamSahHamnida
GratiasAgimus
GratiasAgo
Motashakkeram
KopKhunKha
Tak
Dankie
Tanemirt
Tenki
ThintKo
Buznyg
Blagodaram
Rahmat
Matondo
Mercé
Taiku
Dakujem
Gràcies
Faleminderit
Efharisto
NajisTuke
Bayarlalaa
Obrigado
Salamat
Saha
Multumesc
CámOn
Gracie
Sagolun
TapadhLeat
Köszönöm
Murakoze
WaadMahadsantahay
Grazzi
Aabhar
Chnorakaloutioun
TänanVäga
Grandmerci
Nirringrazzjak
Mauruuru
Barkal
Ačiū
Gratzias