KV6006 practical session - 3 - MQTT

The core of many Internet of Things systems is the message-passing protocol MQTT. The letters used to stand for something like ‘Message Queue Telemetry Transport’ but there was never really a ‘queue’. Officially it’s no longer even pretending to be an acronym.

Topics and Payloads

An MQTT message originates from a data source, which *publishes* to a *broker* – server – which in turn retransmits the message to anything that’s *subscribed* to listen to it. Messages are sent on specific *topics*, which are named like:

> */Northumbria/City_Campus/Ellison_Building/E_Block/305*

The topic doesn’t need to already exist before a client publishes or subscribes to it. Subscribers can specify wildcards:

> */Northumbria/City_Campus/+/E_Block/+*

The + is a single-level wildcard, so this would receive messages about any building on City Campus that has an ‘E_Block’, and for any room in that building.

> */Northumbria/City_Campus/#*

matches any number of levels, so this would match *everything* on City Campus. On a busy MQTT broker, */#* might involve quite a lot of messages.

Subscribing to MQTT messages

We’re going to use the Paho MQTT client library in Python, and we’ve a little bit of setup to do. In a fresh Thonny document:

```
# examples/mqtt_subscribe/mqtt_subscribe.py
import paho.mqtt.client as mqtt
import config
import json

def on_connect(client, userdata, flags, rc):
    """Callback for when mqtt client connects."""
    print("Connected with result code: " + str(rc))
    # For now, subscribe to the firehose
```

```
    client.subscribe("/KV6006/#")

def on_message(client, userdata, msg):
    """Callback for when mqtt client receives a message."""
    topic = msg.topic
    # Decode the payload: convert it from bytes to a string
    payload = str(msg.payload.decode("utf-8"))
    # For now, output the message
    print(topic + " " + payload)

def on_log(mqttc, obj, level, string):
    print(string)

# Now we have our callback functions for connection and message receipt,
# we can go ahead and make a connection.
client = mqtt.Client()
client.on_connect = on_connect
client.on_message = on_message
client.username_pw_set(config.mqtt_username, config.mqtt_password)

try:
    client.connect("connect.nustem.uk", 1883, 60)
    print("MQTT connection successful.")
    client.loop_forever()
except:
    print("MQTT connection failed.")
    exit(1)
```

You'll notice the import from `config.py`: this file should already be in your `student_work` directory. It contains the username and password for the MQTT broker we're using.

If all goes well, the `client.loop_forever()` line will keep the program running. When a message is received, `on_message()` is called to handle it - you should see messages being output. This approach of 'register a callback function to be triggered when an event occurs; now loop waiting for events' approach is very common for these sorts of programs. It's a little surprising the first time you see it.

If the connection drops the program will likely crash; in a real-world situation you'd want to be a bit more robust in your error handling. That said, I've had very similar code to the above running on a server for almost a year without issue.

Parsing data received over MQTT

You'll notice a steady stream of data on the `/KV6006/Sensors` topic. This is coming from a device at the front of the room: a Raspberry Pi Pico W microcontroller connected to a bunch of different sensors. A MicroPython script on the Pico polls data from the sensors, packages it as JSON, and broadcasts it over MQTT every second.

The Pico is connected to a WiFi network from a 4G mobile router. The MQTT broker is physically in London.

Since the sensors data feed is formatted as JSON, you can expand your `on_message()` function to do something like:

```
# [...]
payload = msg.payload.decode("utf-8")
# Parse  the string as JSON
data = json.loads(payload)

# Now we can iterate over the sensor data:
for sensor in data['sensors']:
    print("Sensor: " + sensor['name'])
    print("Value: " + str(sensor['value']))
```

The sensor `value` is of type `float` or `int`: here, we're explicitly casting it to a string with `str()`.

Running this file will turn very wide output into… very tall output. Which doesn't feel like an improvement as such.

> *NOTE: the Paho MQTT library we're using suppresses error messages in the `on_message()` callback. Which makes debugging infuriatingly difficult. You can work around this by adding `client.on_log = on_log` to the configuration after the `client.on_connect` and `client.on_message` lines. You will, however, see a lot of diagnostics.*

Getting just some of the data

Suppose you wanted just the dial sensor data. Unfortunately, there isn't a useful key you can access: something like `data['sensors']['dial']` won't work. It's possible my Python-fu just isn't strong enough, but I think you have to do something like:

```
for sensor in data['sensors']:
    if sensor['name'] == 'dial':
        print("Dial value is: " + str(sensor['value']))
```

Try that out. You'll need to comment out the previous output lines. You'll also need to walk over to the sensor package and twiddle the little dial input to see if the value changes.

See `examples/mqtt_subscribe/mqtt_subscribe-parse.py` if you can't get this working.

Having to iterate over the entire JSON tree to extract a single piece of data probably illustrates that I should have thought more carefully about the data structure. It's fine for this number of sensors, but what if you had hundreds or even thousands of data elements? Think about (and discuss) how

the sensor data could be better structured. Perhaps I should have broken the individual sensors out into different MQTT topics? How might you allow selectors like `data['sensors']['dial']`?

Sending MQTT messages

All this time, there's been a little blue board with a little blue light sitting on your table, patiently waiting for you to tell it to do something. Its time has come.

The controller is an even simpler device than the Pico – an ESP8266, which is about as cheap as WiFi-enabled boards get. It's sitting on a chunk of breadboard (the white slab with holes in it), wired up to two output devices:

- An RGB LED, which can display a range of colours at variable brightness.
- A servo motor, which can turn its white plastic 'horn' through about 180 degrees.

Each device listens for commands via its own MQTT topic, `/KV6006/output/[device_code]`. The device code is printed on a sticker on the device.

Sending MQTT messages is just as straightforward as subscribing to them. Which is to say: it depends on your definition of 'straightforward.'

```
# examples/mqtt_send/basic_send.py
import json
import paho.mqtt.client as mqtt
import config

# TODO: Change the client name here, it has to be unique.
client = mqtt.Client("Control_D55")
client.username_pw_set(config.mqtt_username, config.mqtt_password)
client.connect(config.mqtt_server, config.mqtt_port, 60)

# TODO: Change the target device here. It's written on a label stuck to the control b
topic = "/KV6006/output/D55"

payload = {"command": "LEDhue", "value": 120}
client.publish(topic, json.dumps(payload))

payload = {"command": "servoAngle", "value": 30}
client.publish(topic, json.dumps(payload))
```

Note that you'll need to change the `D55` parts to whatever's stuck on your controller board. You'll also need to change the values each time you run the code, or you'll be commanding the LED or servo motor to change to the thing they're already at.

Ideally, you'd wrap the `publish` calls in a `try/except` structure, but for our purposes today it's not terribly important. The `json.dump()` method handles converting the Python dictionary `payload` into JSON format for us.

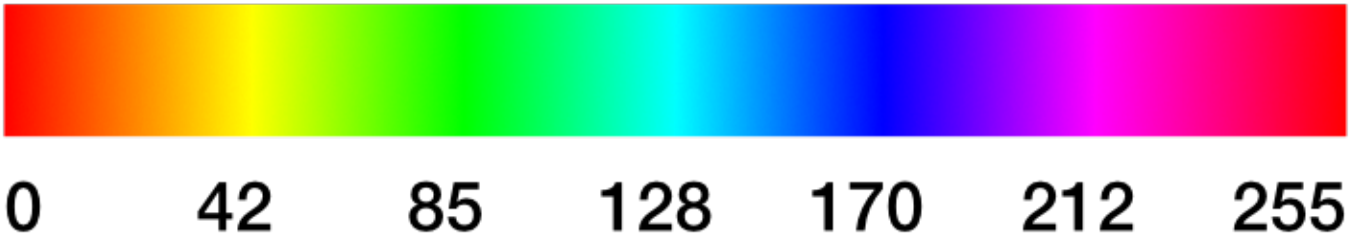
You might like to run `examples/mqtt_subscribe/mqtt_subscribe_all.py` and watch your messages scroll past.

A note about colour

Colour representation is one of *those* subjects. You'd think it would be easy, but… no. I've just deleted 300 words from the worksheet here. A lucky escape. The important bits:

The ESP8266 devices use an HSV colour model. You pass them a 'hue angle' to describe a colour, rather than trying to mix the colour you want by varying red, green and blue components. That conversion is handled by the device. Only, 'hue angle' in this case is an 8-bit value, so we're mapping `0..360` degrees into a `0..255` numeric range.

Upshot: pick a colour from the scale below, take a broad guess at the number associated with it, and try that.



Things to discuss at this point

- `LEDhue` and `servoAngle` aren't great names for commands. More common would be `setLEDhue` and `setServoAngle`. Why?
- The code the ESP8266s are running was written years ago, for an installation art project. For obscure reasons they got called 'Skutters,' and the code is… mmm, *not good*. If you need a laugh (or to recoil in horror), take a look in `output_devices/skutter`. However, the code still works after all these years, so I don't feel too terrible about it. Skutters have a much more extensive API than covered above, and can in theory handle looping animation between two different states.
- If you find the command to change the LED brightness, be warned that full brightness is eye-searingly horrid. Don't say I didn't warn you.