

CSCI 4907

Introduction to IoT and Edge Computing Applications

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Week 11 [04/11/2024]

- MQTT using ThingSpeak
- Using SenseHat with MQTT
- In-class Raspberry Pi Lab – ThingSpeak MQTT

```
git clone git@github.com:gwu-csci3907/Spring2024.git
```

```
git clone https://github.com/gwu-csci3907/Spring2024.git
```



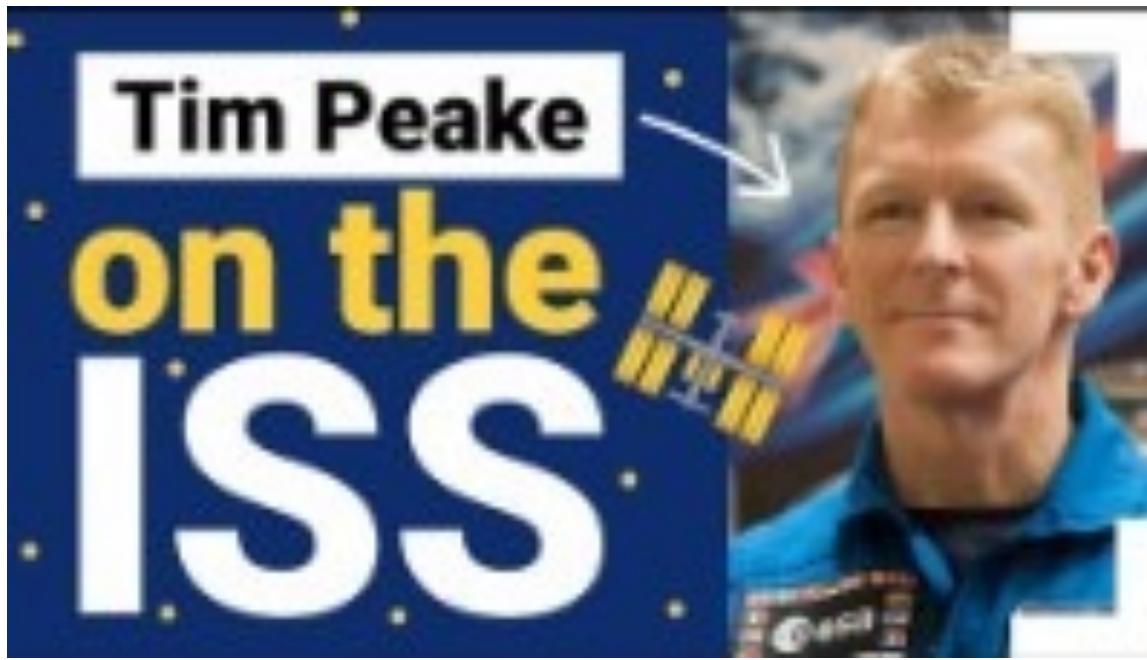
School of Engineering
& Applied Science

Explore SenseHat

(The RPi companion sensor in the
International Space Station)

Example of who is using the sense HAT and where

- Astro Pi



Source: https://youtu.be/kk_7KNuRLrk

What we will do today

- Co-work
 - Observe, ask and try in groups
- Write small program using Python
- Think about
 - Challenges, Opportunities, Gaps and Surprises

What we will learn today

- Communicate with the Sense HAT using Python
- Access the outputs of the Sense HAT
- Use the Sense HAT library to display messages and images
- Use loops to repeat certain code blocks

Step-1: “Put on the Sense HAT”

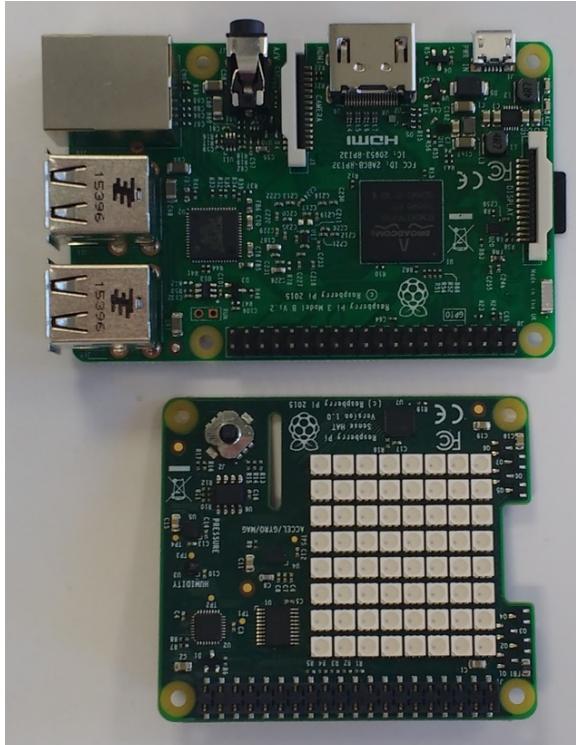


Image and animation source: <https://projects.raspberrypi.org/en/projects/getting-started-with-the-sense-hat/2>

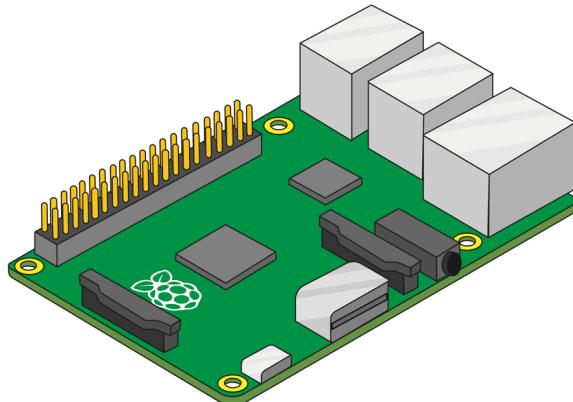


Image source: <https://reference.wolfram.com/language/ref/device/SenseHAT.html>



Source: <https://youtu.be/8NwWNOMqai4>

“and take a closer look” ...

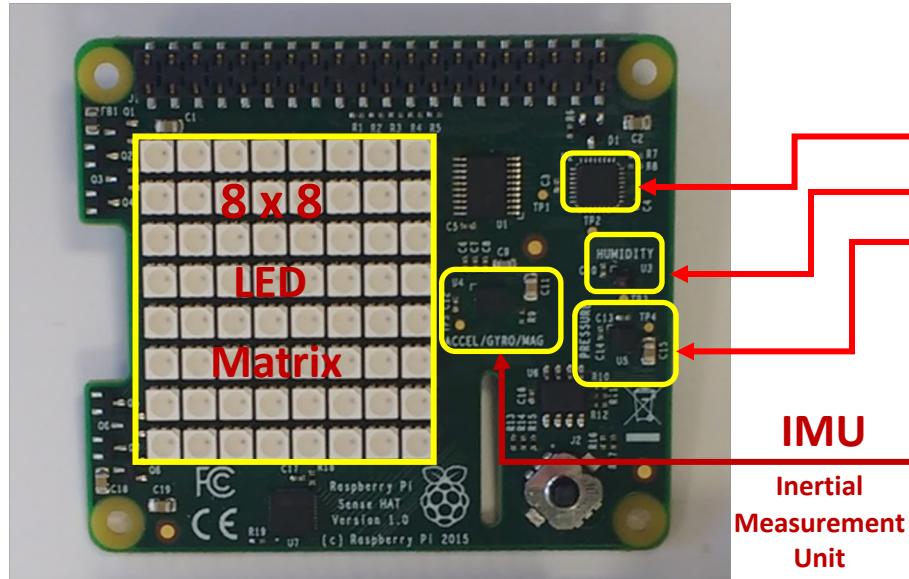
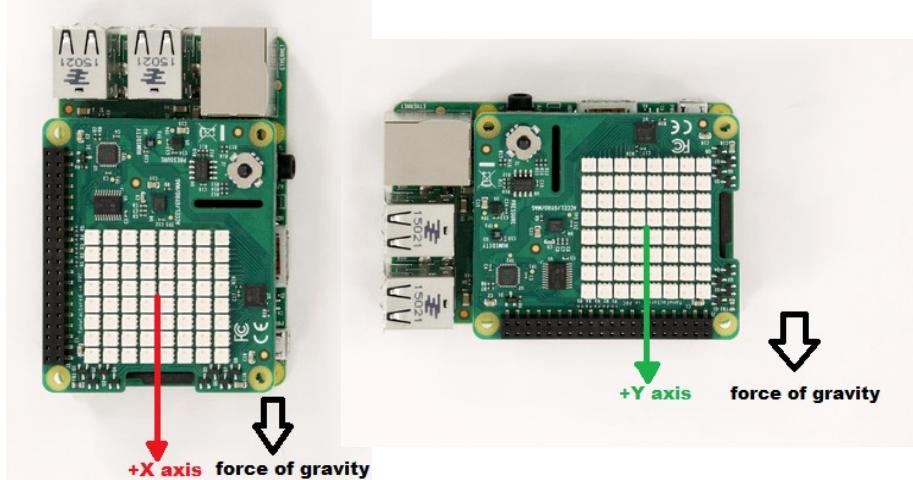


Image source: <https://projects.raspberrypi.org/en/projects/getting-started-with-the-sense-hat/2>

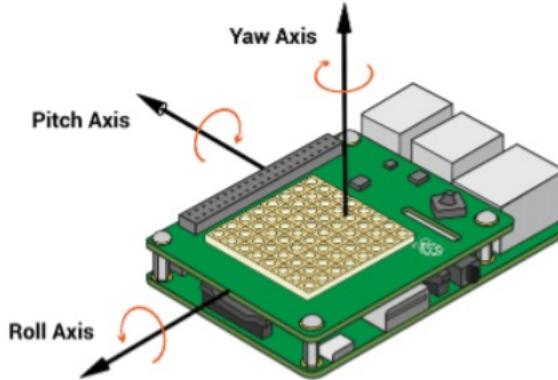


Source: <https://www.mathworks.com/help/supportpkg/raspberrypi/examples/auto-rotate-an-image-displayed-on-sense-hat-led-matrix.html>

- The Sense HAT has a variety of sensors that can be read from:

"Temperature"	reads temperature in degrees Celsius
"Humidity"	reads humidity in % RH
"Pressure"	reads atmospheric pressure in millibars
"Rotation"	reads gyroscopic motion in revolutions per second
"Acceleration"	reads acceleration in terms of standard accelerations due to gravity on Earth's surface
"Orientation"	reads orientation relative to magnetic north in degrees
"Magnetic Field"	reads strength and direction of a magnetic field around the sensor in microteslas

- The gyroscope, accelerometer, and magnetometer sensors return a list of three values that corresponds to $\{roll, pitch, yaw\}$, as oriented according to the following image:



Starting point for further exploration:
[Link for “Getting started with the Sense HAT”](https://reference.wolfram.com/language/ref/device/SenseHAT.html)

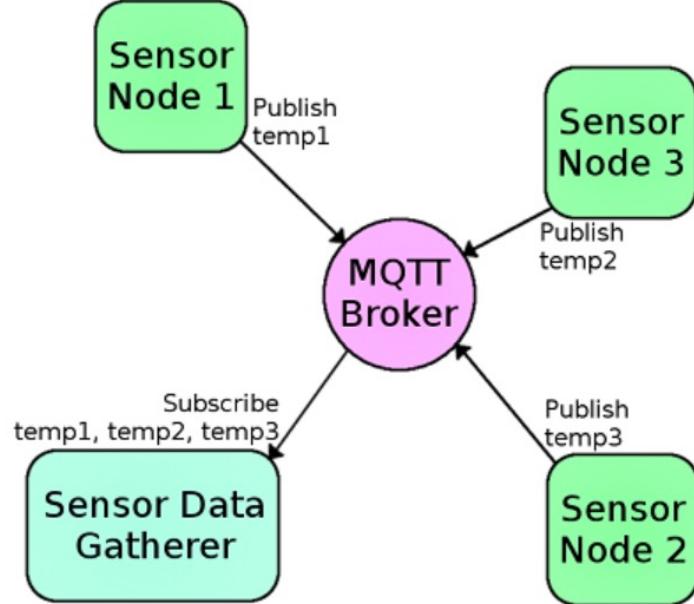
Source: <https://reference.wolfram.com/language/ref/device/SenseHAT.html>

Explore MQTT Basics

Message Queuing Telemetry Transport

Goal: To understand how publishing and subscribing works practically

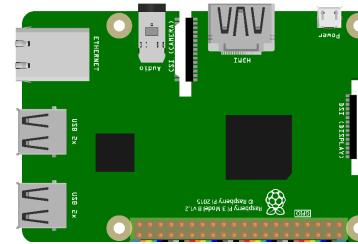
MQTT paradigm



Hardware

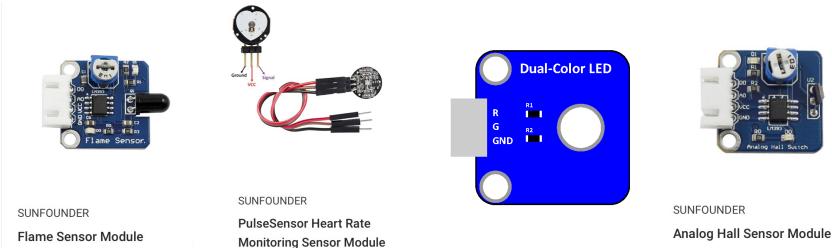
Broker

- The broker is the server
- It distributes the information to the interested devices connected to the server.



Client

- The device that connects to broker to send or receive information.



Messaging

Topic

- The name that the message is about.
- Clients publish, subscribe, or do both to a topic.

Publish

- Clients that send information to the broker to distribute to interested clients based on the topic name.

Subscribe

- Clients tell the broker which topic(s) they're interested in.

QoS

- Quality of Service to the broker
- Integer value ranging from. 0-2.



Practical view of MQTT in IoT applications

Node-RED

dweet.io

Broker

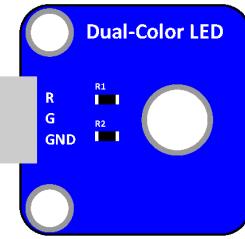
Clients



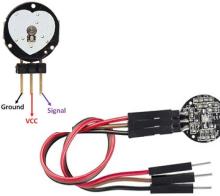
SUNFOUNDER
Analog Hall Sensor Module



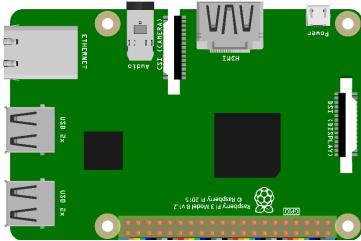
SUNFOUNDER
Flame Sensor Module



Clients



SUNFOUNDER
PulseSensor Heart Rate
Monitoring Sensor Module



MQTT to control data output



MQTT to read and publish data



Eclipse Mosquitto - An open source MQTT broker



Eclipse Mosquitto provides a lightweight server implementation of the MQTT protocol that is suitable for all situations from full power machines to embedded and low power machines.

Sensors and actuators, which are often the sources and destinations of MQTT messages, can be very small and lacking in power. This also applies to the embedded machines to which they are connected, which is where Mosquitto could be run.

Step-1: Eclipse Mosquitto - An open source MQTT broker

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

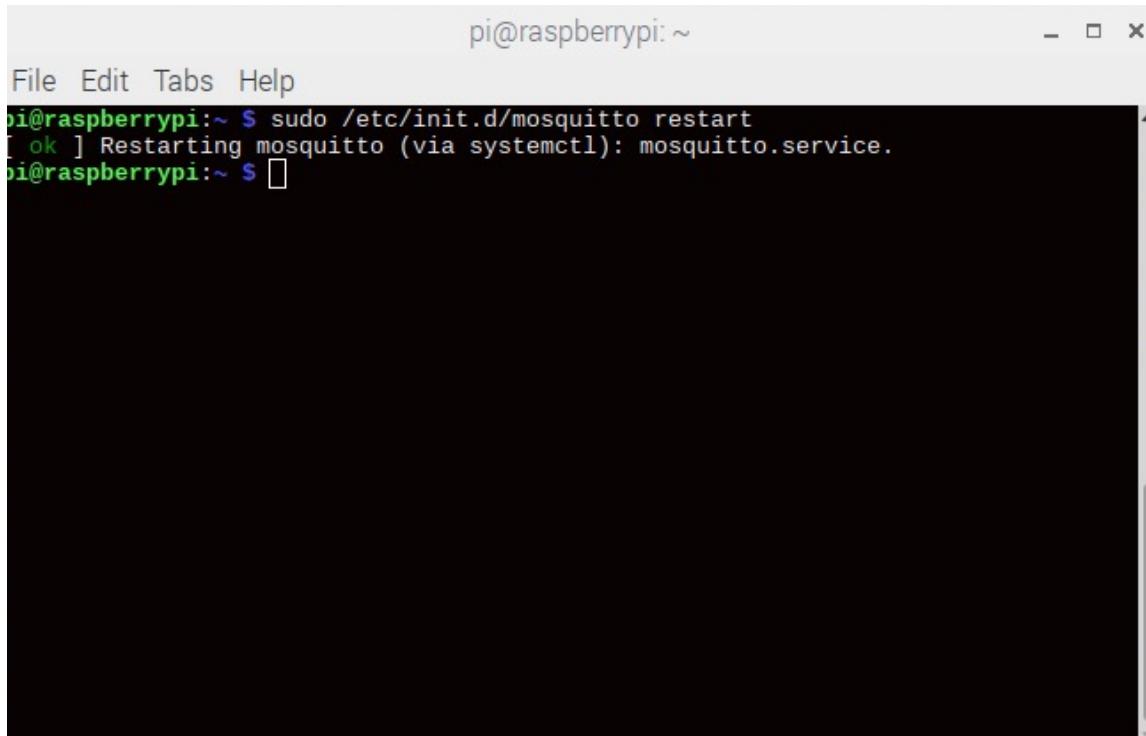
```
pi@raspberrypi: ~
File Edit Tabs Help
pi@raspberrypi: ~ $ sudo apt install mosquitto
```

```
pi@raspberrypi: ~ $ sudo apt install mosquitto
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following additional packages will be installed:
  libev4 libwebsockets8
Suggested packages:
  apparmor
The following NEW packages will be installed:
  libev4 libwebsockets8 mosquitto
0 upgraded, 3 newly installed, 0 to remove and 0 not upgraded.
Need to get 241 kB of archives.
After this operation, 543 kB of additional disk space will be used.
Do you want to continue? [Y/n] y
```

```
File Edit Tabs Help
0 upgraded, 3 newly installed, 0 to remove and 0 not upgraded.
Need to get 241 kB of archives.
After this operation, 543 kB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://mirror.pi.terawhite.com/raspbian/raspbian stretch/main armhf libbe
/v4 armhf 1:4.22-1 [34.0 kB]
Get:2 http://mirror.us.leaseweb.net/raspbian/raspbian stretch/main armhf mosquit
to armhf 1:4.10-3+deb9u5 [122 kB]
Get:3 http://archive.raspberrypi.org/debian stretch/main armhf libwebsockets8 ar
mhf 2.0.3-2+b1-rpt1 [85.2 kB]
Fetched 241 kB in 5 s (44.1 kB/s)
Selecting previously unselected package libev4.
(Reading database ... 97725 files and directories currently installed.)
Unpacking libev4 (1:4.22-1) ...
Selecting previously unselected package libwebsockets8:armhf.
Unpacking libwebsockets8:armhf (2.0.3-2+b1-rpt1) ...
Selecting previously unselected package mosquitto.
Unpacking mosquitto (1:4.10-3+deb9u5) ...##.
Setting up libev4 (1:4.22-1) ...#####
Processing triggers for libc-bin (2.24-11+deb9u4) ...#####
Setting up mosquitto (1:4.10-3+deb9u5) ...
Processing triggers for systemd (232-25+deb9u14) ...#####
```

Step-2: restart Mosquitto

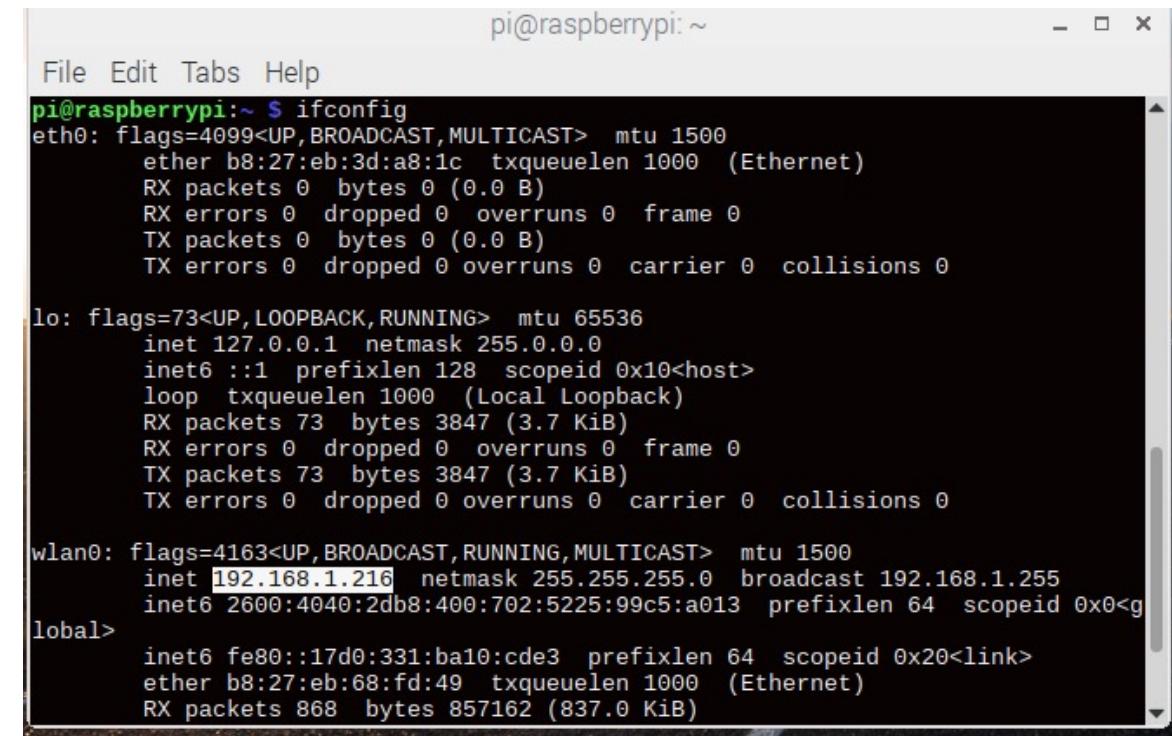
```
sudo /etc/init.d/mosquitto restart
```



```
pi@raspberrypi: ~
File Edit Tabs Help
pi@raspberrypi:~ $ sudo /etc/init.d/mosquitto restart
[ ok ] Restarting mosquitto (via systemctl): mosquitto.service.
pi@raspberrypi:~ $
```

Step-3: Get your IP address

```
ifconfig
```



```
pi@raspberrypi: ~
File Edit Tabs Help
pi@raspberrypi:~ $ ifconfig
eth0: flags=4099<UP,BROADCAST,MULTICAST> mtu 1500
      ether b8:27:eb:3d:a8:1c txqueuelen 1000  (Ethernet)
      RX packets 0 bytes 0 (0.0 B)
      RX errors 0 dropped 0 overruns 0 frame 0
      TX packets 0 bytes 0 (0.0 B)
      TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

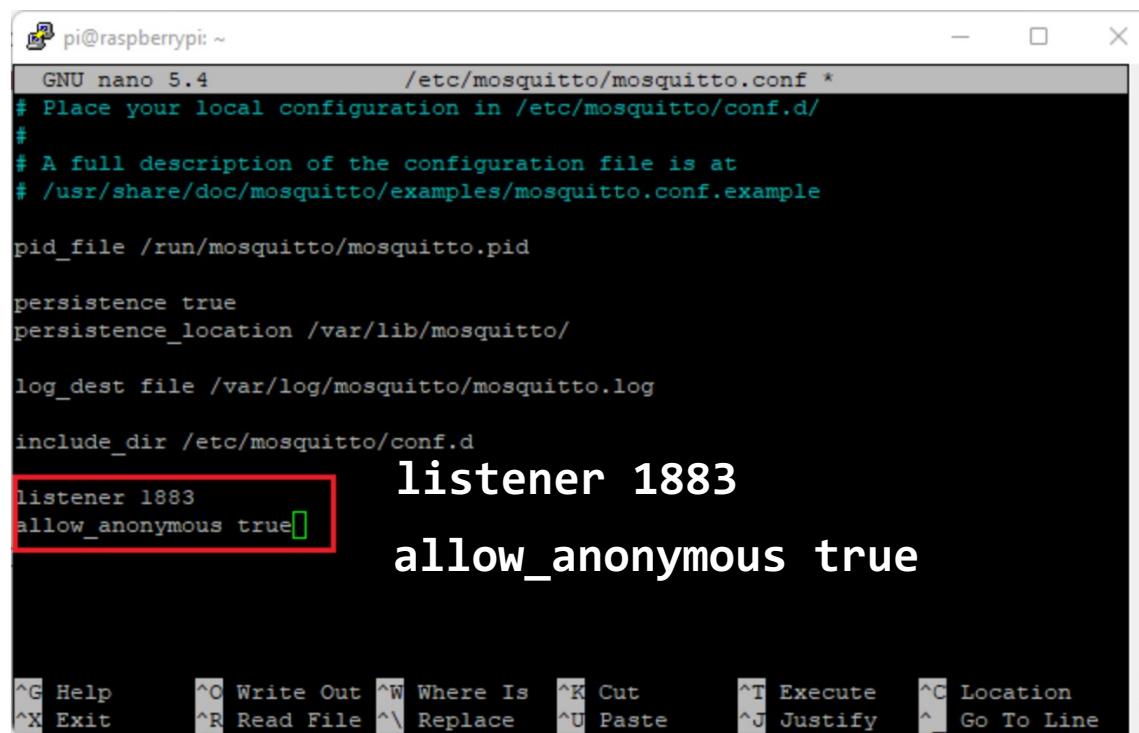
lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
      inet 127.0.0.1 netmask 255.0.0.0
      inet6 ::1 prefixlen 128 scopeid 0x10<host>
      loop txqueuelen 1000  (Local Loopback)
      RX packets 73 bytes 3847 (3.7 KiB)
      RX errors 0 dropped 0 overruns 0 frame 0
      TX packets 73 bytes 3847 (3.7 KiB)
      TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

wlan0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
      inet 192.168.1.216 netmask 255.255.255.0 broadcast 192.168.1.255
      inet6 2600:4040:2db8:400:702:5225:99c5:a013 prefixlen 64 scopeid 0x0<global>
      inet6 fe80::17d0:331:ba10:cde3 prefixlen 64 scopeid 0x20<link>
      ether b8:27:eb:68:fd:49 txqueuelen 1000  (Ethernet)
      RX packets 868 bytes 857162 (837.0 KiB)
      TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

```
hostname -I # this is also OK to use
```

Step-4: Enable Remote Access to Mosquitto Broker (No Authentication)

sudo nano /etc/mosquitto/mosquitto.conf



```
pi@raspberrypi: ~
GNU nano 5.4          /etc/mosquitto/mosquitto.conf *
# Place your local configuration in /etc/mosquitto/conf.d/
#
# A full description of the configuration file is at
# /usr/share/doc/mosquitto/examples/mosquitto.conf.example

pid_file /run/mosquitto/mosquitto.pid

persistence true
persistence_location /var/lib/mosquitto/

log_dest file /var/log/mosquitto/mosquitto.log

include_dir /etc/mosquitto/conf.d

listener 1883
allow_anonymous true

^G Help      ^O Write Out  ^W Where Is  ^K Cut      ^T Execute  ^C Location
^X Exit      ^R Read File  ^\ Replace   ^U Paste    ^J Justify  ^
^_ Go To Line
```

sudo systemctl restart mosquitto

sudo systemctl status mosquitto

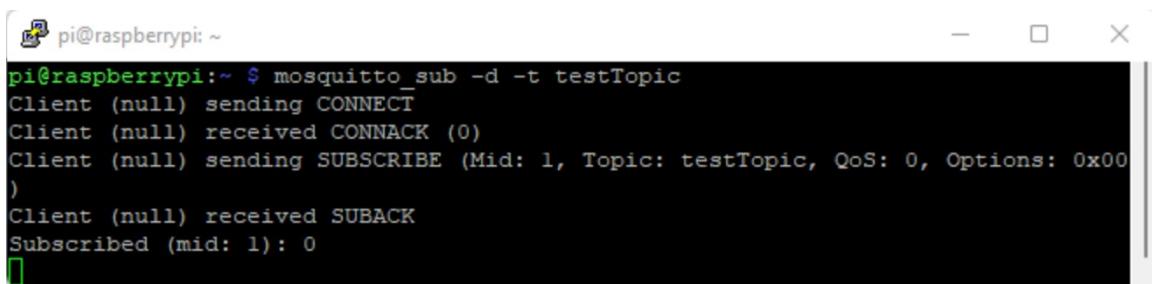
Step-4: Publishing “Hello World!” Message to *testTopic* Topic

Install mosquitto-clients

```
sudo apt install -y mosquitto mosquitto-clients
```

Open a terminal window and type the following:

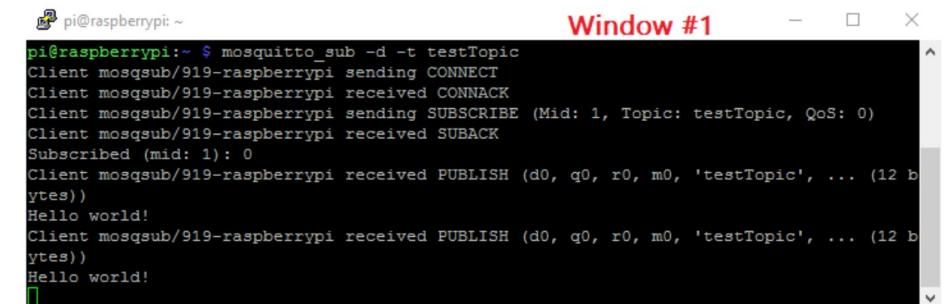
```
mosquitto_sub -d -t testTopic
```



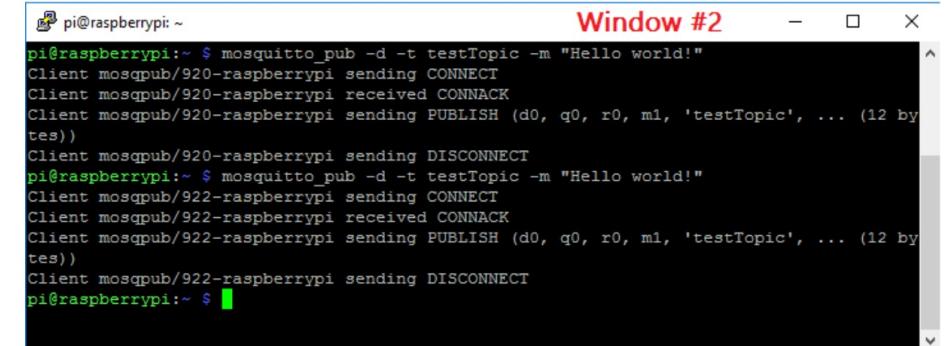
```
pi@raspberrypi:~ $ mosquitto_sub -d -t testTopic
Client (null) sending CONNECT
Client (null) received CONNACK (0)
Client (null) sending SUBSCRIBE (Mid: 1, Topic: testTopic, QoS: 0, Options: 0x00)
Client (null) received SUBACK
Subscribed (mid: 1): 0
```

```
mosquitto_sub -v -t '#' -h 192.168.1.248
```

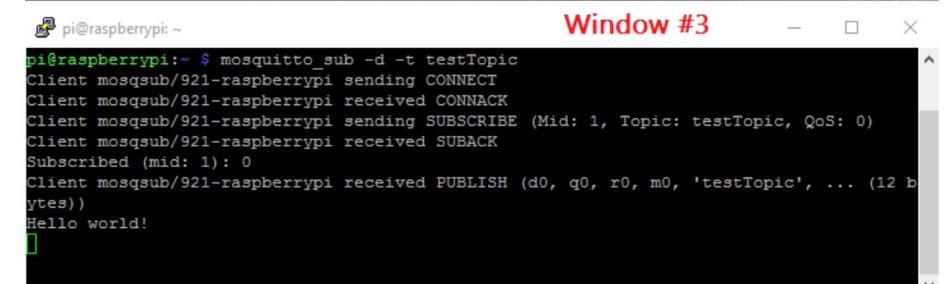
```
mosquitto_pub -d -t testTopic -m "Hello world!"
```



```
pi@raspberrypi:~ $ mosquitto_sub -d -t testTopic
Client mosqsub/919-raspberrypi sending CONNECT
Client mosqsub/919-raspberrypi received CONNACK
Client mosqsub/919-raspberrypi sending SUBSCRIBE (Mid: 1, Topic: testTopic, QoS: 0)
Client mosqsub/919-raspberrypi received SUBACK
Subscribed (mid: 1): 0
Client mosqsub/919-raspberrypi received PUBLISH (d0, q0, r0, m0, 'testTopic', ... (12 bytes))
Hello world!
Client mosqsub/919-raspberrypi received PUBLISH (d0, q0, r0, m0, 'testTopic', ... (12 bytes))
Hello world!
```



```
pi@raspberrypi:~ $ mosquitto_pub -d -t testTopic -m "Hello world!"
Client mosqpub/920-raspberrypi sending CONNECT
Client mosqpub/920-raspberrypi received CONNACK
Client mosqpub/920-raspberrypi sending PUBLISH (d0, q0, r0, m1, 'testTopic', ... (12 bytes))
Client mosqpub/920-raspberrypi sending DISCONNECT
pi@raspberrypi:~ $ mosquitto_pub -d -t testTopic -m "Hello world!"
Client mosqpub/922-raspberrypi sending CONNECT
Client mosqpub/922-raspberrypi received CONNACK
Client mosqpub/922-raspberrypi sending PUBLISH (d0, q0, r0, m1, 'testTopic', ... (12 bytes))
Client mosqpub/922-raspberrypi sending DISCONNECT
pi@raspberrypi:~ $
```



```
pi@raspberrypi:~ $ mosquitto_sub -d -t testTopic
Client mosqsub/921-raspberrypi sending CONNECT
Client mosqsub/921-raspberrypi received CONNACK
Client mosqsub/921-raspberrypi sending SUBSCRIBE (Mid: 1, Topic: testTopic, QoS: 0)
Client mosqsub/921-raspberrypi received SUBACK
Subscribed (mid: 1): 0
Client mosqsub/921-raspberrypi received PUBLISH (d0, q0, r0, m0, 'testTopic', ... (12 bytes))
Hello world!
```

Eclipse paho - Another open source MQTT broker



Paho is an



project



Eclipse-paho provides a client class which enable applications to connect to an [MQTT](#) broker to publish messages, and to subscribe to topics and receive published messages.

It also provides some helper functions to make publishing one off messages to an MQTT server very straightforward.

Source:

Step-2: Install paho-mqtt & psutil libraries

sudo apt-get update && sudo apt-get upgrade

```
pi@raspberrypi:~
```

File Edit Tabs Help

```
pi@raspberrypi:~ $ sudo apt-get update && sudo apt-get upgrade
Get:1 http://raspbian.raspberrypi.org/raspbian stretch InRelease [15.0 kB]
Hit:2 http://archive.raspberrypi.org/debian stretch InRelease
Fetched 15.0 kB in 5s (2,647 B/s)
Reading package lists... Done
Reading package lists... Done
Building dependency tree
Reading state information... Done
Calculating upgrade... Done
0 upgraded, 0 newly installed, 0 to remove and 0 not upgraded.
pi@raspberrypi:~ $
```

sudo pip –upgrade install psutil

sudo pip install paho-mqtt

```
pi@raspberrypi:~
```

File Edit Tabs Help

```
pi@raspberrypi:~ $ sudo pip3 install paho-mqtt
/usr/lib/python3/dist-packages/secretstorage/dhcrypto.py:15: CryptographyDeprecationWarning: Python 3.5 support will be dropped in the next release of cryptography. Please upgrade your Python.
  from cryptography.utils import int_from_bytes
DEPRECATION: Python 3.5 reached the end of its life on September 13th, 2020. Please upgrade your Python as Python 3.5 is no longer maintained. pip 21.0 will drop support for Python 3.5 in January 2021. pip 21.0 will remove support for this functionality.
Looking in indexes: https://pypi.org/simple, https://www.piwheels.org/simple
Requirement already satisfied: paho-mqtt in /usr/local/lib/python3.5/dist-packages (1.6.1)
pi@raspberrypi:~ $
```

paho-mqtt 2.0.0

[pip install paho-mqtt](#)

sudo pip install psutil

```
pi@raspberrypi:~
```

File Edit Tabs Help

```
pi@raspberrypi:~ $ sudo pip3 install psutil
/usr/lib/python3/dist-packages/secretstorage/dhcrypto.py:15: CryptographyDeprecationWarning: Python 3.5 support will be dropped in the next release of cryptography. Please upgrade your Python.
  from cryptography.utils import int_from_bytes
DEPRECATION: Python 3.5 reached the end of its life on September 13th, 2020. Please upgrade your Python as Python 3.5 is no longer maintained. pip 21.0 will drop support for Python 3.5 in January 2021. pip 21.0 will remove support for this functionality.
Looking in indexes: https://pypi.org/simple, https://www.piwheels.org/simple
Requirement already satisfied: psutil in /usr/local/lib/python3.5/dist-packages (5.9.4)
pi@raspberrypi:~ $
```

psutil 5.9.8

[pip install psutil](#)

psutil (process and system utilities) is a cross-platform library for retrieving information on **running processes** and **system utilization** (CPU, memory, disks, network, sensors) in Python

Explore MQTT with ThingSpeak IoT Analytics [Graded lab assignment]

Thingspeak – An IoT analytics platform



ThingSpeak is an IoT analytics platform service that allows you to aggregate, visualize, and analyze live data streams in the cloud.

You can send data to ThingSpeak from your devices, create instant visualization of live data, and send alerts.



Collect
Send sensor data privately to the cloud.



Analyze
Analyze and visualize your data with MATLAB.



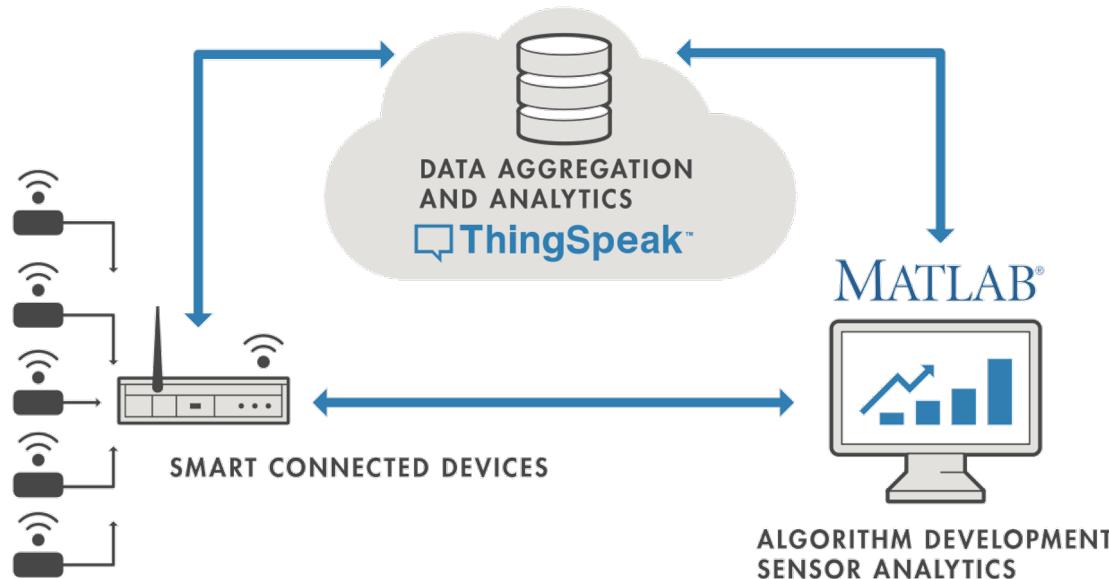
Act
Trigger a reaction.

Create a Thingspeak account:

<https://thingspeak.com/login?skipSSOCheck=true>

To use ThingSpeak, you must sign in with your existing MathWorks account or create a new one.

Non-commercial users may use ThingSpeak for free.



Email

kartik.bulusu@gmail.com



No account? [Create one!](#)

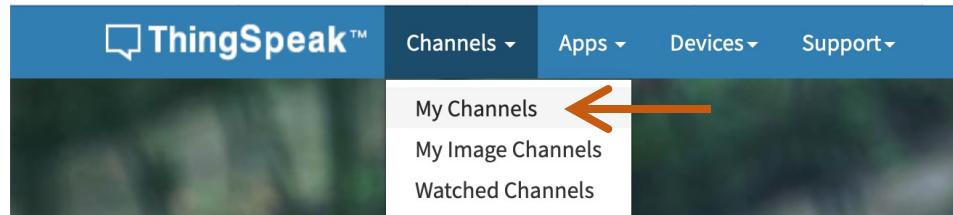
By signing in, you agree to our [privacy policy](#).

Next

Source:

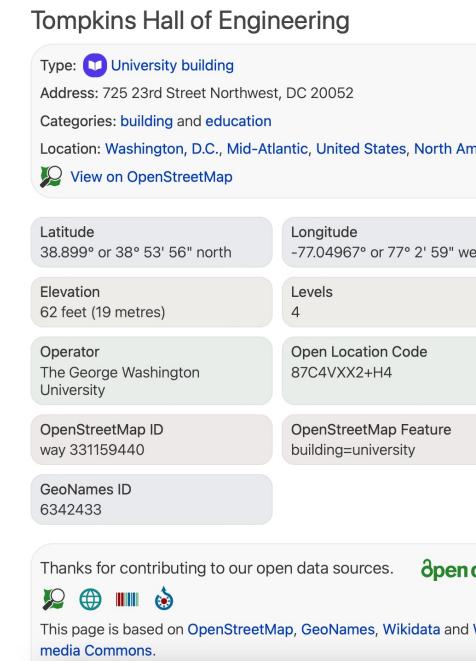
<https://towardsdatascience.com/iot-made-easy-esp-micropython-mqtt-thingspeak-ce05eea27814>
<https://nothans.com/thingspeak-tutorials/update-a-thingspeak-channel-using-mqtt-on-a-raspberry-pi>
<https://www.mathworks.com/help/thingspeak/collect-data-in-a-new-channel.html>
<https://mapcarta.com/25030544>

Step-3: Build the ThingSpeak channels



New Channel

Name	IoT_CPU_RAM_demo	←
Description	Demo channel for CS3907-Spring 2023	←
Field 1	CPU (%)	←
Field 2	RAM (%)	←
Field 3		←
Field 4		←
Field 5		←
Field 6		←
Field 7		←
Field 8		←



My Channels

New Channel

Search by tag

Tags	(Tags are comma separated)
Link to External Site	http://
Link to GitHub	https://github.com/
Elevation	
Show Channel Location	<input checked="" type="checkbox"/> ←
Latitude	38.899 ←
Longitude	-77.04962 ←
Show Video	<input type="checkbox"/>
YouTube	<input type="checkbox"/>
Vimeo	<input type="checkbox"/>
Video URL	http://
Show Status	<input type="checkbox"/>
Save Channel	←

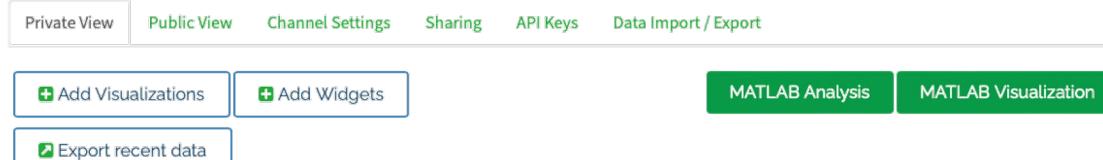


IoT_CPU_RAM_demo

Channel ID: 2097727

Author: kartikbulusu

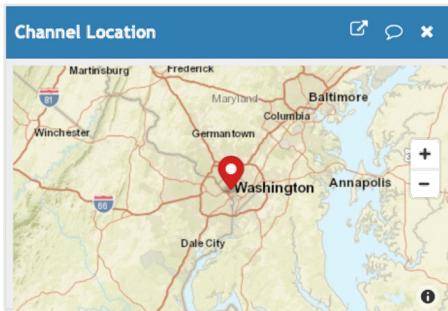
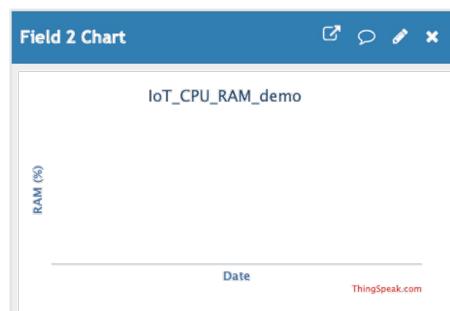
Access: Private



Channel Stats

Created: about a minute ago

Entries: 0



- Familiarize yourself with the panel
- Note down the Channel ID



IoT_CPU_RAM_demo

Channel ID: 2097727

Author: kartikbulusu

Access: Private



Channel Settings

Percentage complete
50%

Channel ID 2097727

Name IoT_CPU_RAM_demo

Description Demo channel for CS3907-Spring 2023

Field 1 CPU (%)

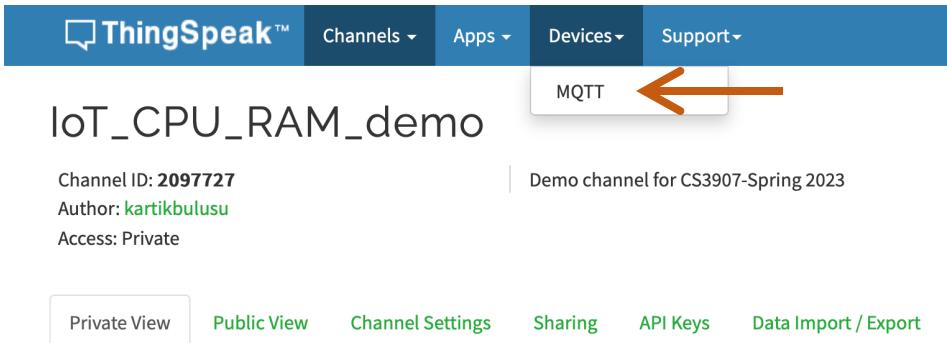
Field 2 RAM (%)



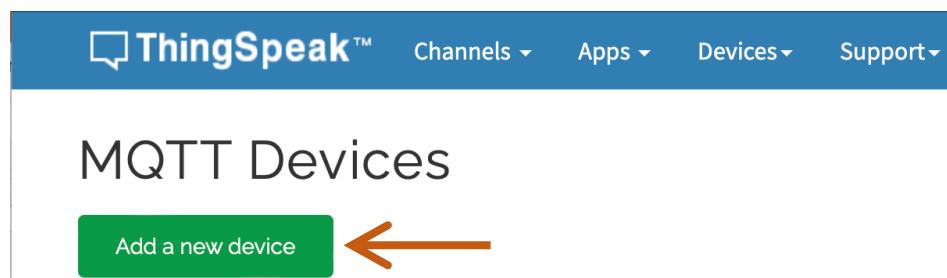
Source:

Step-4: Add MQTT device –Raspberry Pi

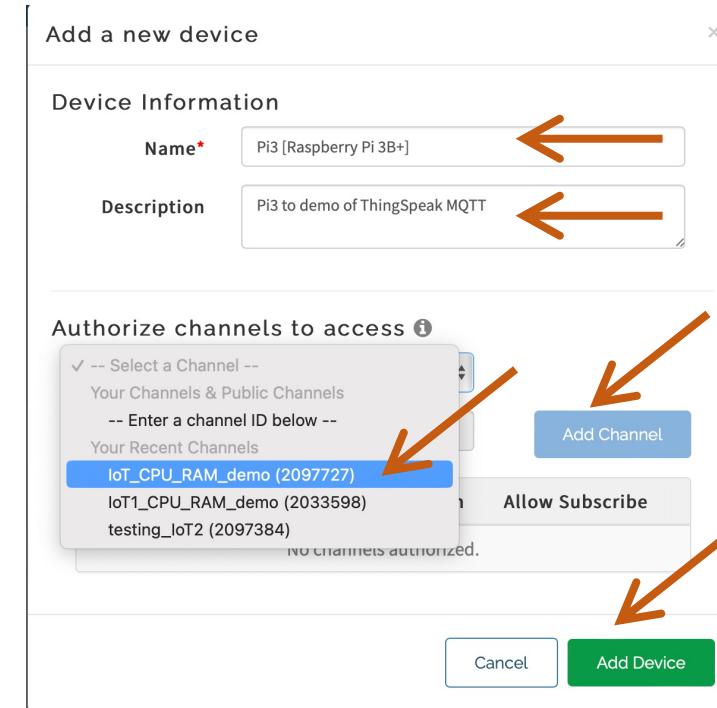
<https://towardsdatascience.com/iot-made-easy-esp-micropython-mqtt-thingspeak-ce05eea27814>
<https://nothans.com/thingspeak-tutorials/update-a-thingspeak-channel-using-mqtt-on-a-raspberry-pi>
<https://www.mathworks.com/help/thingspeak/collect-data-in-a-new-channel.html>
<https://mapcarta.com/25030544>



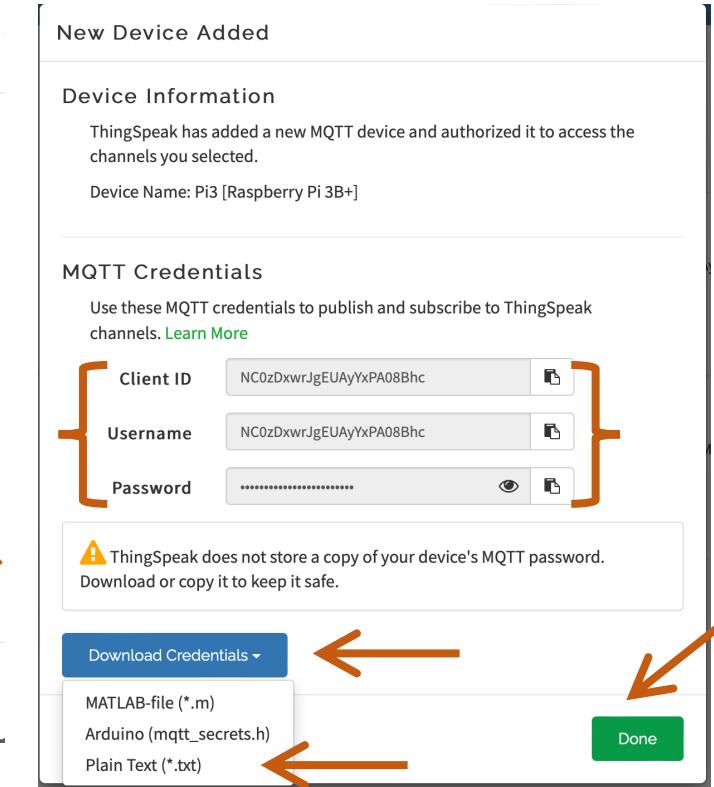
This screenshot shows the ThingSpeak channel interface for 'IoT_CPU_RAM_demo'. The top navigation bar includes 'ThingSpeak™', 'Channels', 'Apps', 'Devices', 'Support', and 'MQTT'. An orange arrow points to the 'MQTT' tab. Below the navigation, the channel name 'IoT_CPU_RAM_demo' is displayed, along with its Channel ID (2097727), Author (kartikbulusu), and Access (Private). The main content area shows a message: 'Demo channel for CS3907-Spring 2023'. At the bottom, there are tabs for 'Private View', 'Public View', 'Channel Settings', 'Sharing', 'API Keys', and 'Data Import / Export'.



This screenshot shows the 'MQTT Devices' section of the ThingSpeak interface. A green button labeled 'Add a new device' is highlighted with an orange arrow. The top navigation bar is identical to the previous screenshot.



This screenshot shows the 'Add a new device' dialog box. It has two sections: 'Device Information' and 'Authorize channels to access'. In 'Device Information', the 'Name*' field is filled with 'Pi3 [Raspberry Pi 3B+]' and the 'Description' field is filled with 'Pi3 to demo of ThingSpeak MQTT'. Both fields have orange arrows pointing to them. In the 'Authorize channels to access' section, a dropdown menu lists 'IoT_CPU_RAM_demo (2097727)', 'IoT1_CPU_RAM_demo (2033598)', and 'testing_IoT2 (2097384)'. The first item is selected and highlighted with an orange arrow. To the right of the dropdown is a 'Allow Subscribe' checkbox and a 'Cancel' button. Below the dropdown is a 'Add Device' button, which also has an orange arrow pointing to it.



This screenshot shows the 'New Device Added' confirmation dialog. It contains three main sections: 'Device Information', 'MQTT Credentials', and a download section. In 'Device Information', it says 'ThingSpeak has added a new MQTT device and authorized it to access the channels you selected.' and 'Device Name: Pi3 [Raspberry Pi 3B+]'. In 'MQTT Credentials', it shows 'Client ID: NC0zDxwrJgEUAYxPA08Bhc', 'Username: NC0zDxwrJgEUAYxPA08Bhc', and 'Password:'. A warning message states: '⚠ ThingSpeak does not store a copy of your device's MQTT password. Download or copy it to keep it safe.' In the download section, there is a 'Download Credentials' dropdown menu with options: 'MATLAB-file (*.m)', 'Arduino (mqtt_secrets.h)', and 'Plain Text (*.txt)'. The 'Plain Text (*.txt)' option is highlighted with an orange arrow. To the right of the dropdown is a 'Done' button, which also has an orange arrow pointing to it.

Graded in-class lab
Download codes from shared-drive and demonstrate
[10 points]