4ID3 - IoT Devices and Networks

Communicating Sensor Data over WiFi using MQTT

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Sponsored by *Future Skills Center, Canada* and *McMaster W Booth SEPT*

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Submission Date:

W BOOTH SCHOOL OF ENGINEERING PRACTICE AND TECHNOLOGY

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Objective

In this lab, we will be constructing a basic IoT network with a single node that collects data from connected sensors and communicates that data to a remote MQTT broker using a local WiFi connection.

Contents

Feedback

Q1 - What would you rate the difficulty of this lab?

(1 = easy, 5 = difficult)

1 **2** **3** **4** **5**

Comments about the difficulty of the lab:

Q2 - Did you have enough time to complete the lab within the designated lab time?

YES **NO**

Q3 - How easy were the lab instructions to understand?

(1 = easy, 5 = unclear)

1 **2** **3** **4** **5**

List any unclear steps:

Q4 - Could you see yourself using the skills learned in this lab to tackle future engineering challenges?

(1 = no, 5 = yes)

1 **2** **3** **4** **5**

Additional Resources

Mosquitto MQTT Broker Tutorial (https://youtu.be/DH-VSAACtBk)

NodeRED Fundamentals Tutorial (https://youtu.be/3AR432bguOY)

ESP8266 Overview (https://youtu.be/dGrJi-ebZgI)

Lab GitHub Repo (https://github.com/sokacza/4ID3_Labs)

Pre-Lab Questions

Q1 - In your own words, describe the **publish-subscribe messaging pattern**. What role does the broker play? What role do the clients play?

(Suggested: 2 sentences)

Q2 - In your own words, what does **QoS** mean for MQTT transmissions? What **levels** of QoS exist?

(Suggested: 3 sentences)

Q3 – In your own words, what is the role of each of the **fields below**, when connecting to an MQTT broker?

Host IP Address	
Topic Name	
Protocol (tcp/ws/wss/tls)	

Post-Lab Questions

Q1 – Using software like **PowerPoint** or **Draw.IO**, create a diagram to represent the nodes in this IoT network and **label the data** being exchanged between each node.

(Suggested: Diagram, 5 points)

Q2 - Explain your **observations** of the Node-Red user interface as you interact with the sensors. Is the change instantaneous? What changes?

(Suggested: 2 sentences, 2 points)

Q3 – If the microcontroller loses battery, will the **NodeRED dashboard** still be connected to the MQTT server? Explain your answer.

(Suggested: 3 sentences, 2 points)

Q3 – Draw a diagram or in a detailed paragraph, explain the differences in connecting an **analog, IIC,** and **SPI** sensor to an ESP-based development board. The submission must include **pin connections** on the development board and where they correspond to on each sensor.

(Suggested: Sketch, 5 points)

Q4 – Using the official Paho-MQTT examples, write a short **Python script** that subscribes to the same topic and MQTT broker used in this lab, and **prints** the published payload to the terminal window.

https://github.com/eclipse/paho.mqtt.python/tree/master/examples

(Suggested: Python script, 5 points)

Q5 – Using a remote MQTT broker on the cloud allows client Node-RED dashboards to visualize sensor data without needing to be in the same **geographical location** as the network. Explain **2 security** vulnerabilities with the network established in this lab and **2 ways** these issues could be **mitigated**.

(Suggested: 4 sentences, 2 points)

Q6 - Below, write a **LinkedIn post** about **4 key learning takeaways** from this lab.

(Suggested: Paragraph or screenshot, 2 points)

Pulling from GitHub

View the status of your local repository to verify that there aren't any uncommitted changes.

git status

```
PS C:\Users\adama\OneDrive\Documents\Repositories\4ID3> git status
On branch main
nothing to commit, working tree clean
PS C:\Users\adama\OneDrive\Documents\Repositories\4ID3>
```

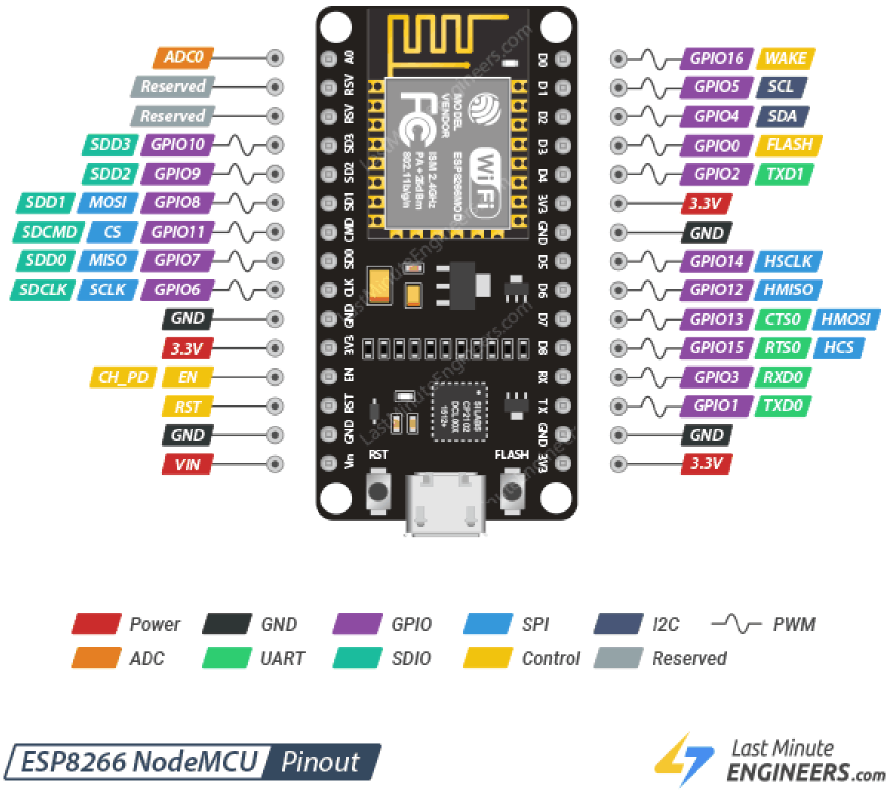
Pull changes from GitHub to ensure that your local repository is up-to-date.

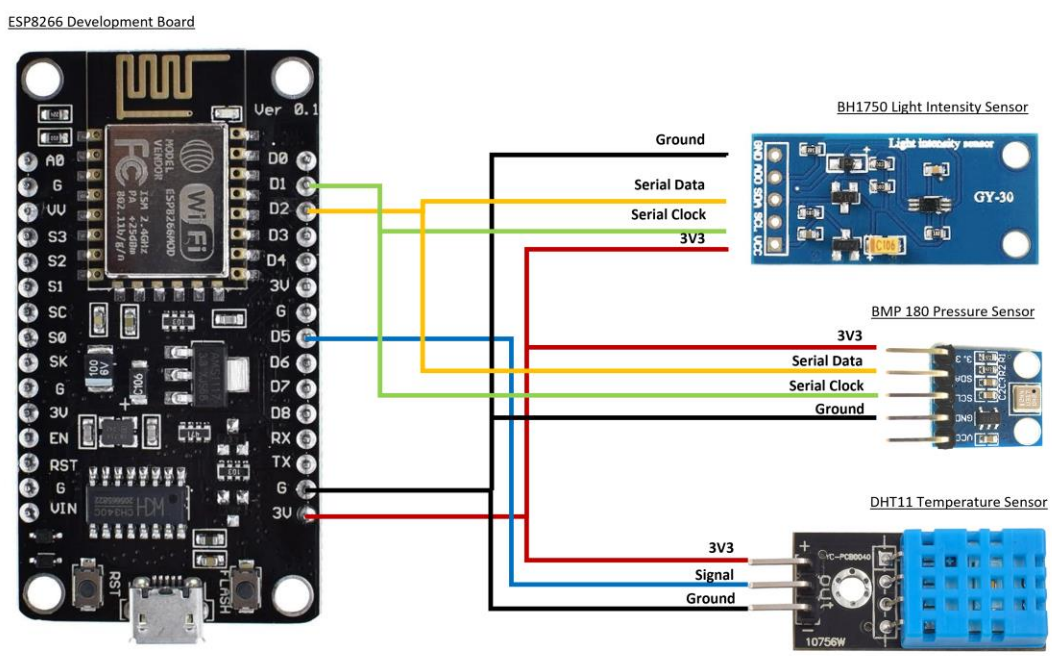
git pull origin main

```
PS C:\Users\adama\OneDrive\Documents\Repositories\4ID3> git pull origin main
From github.com:sokacza/4ID3_Labs
 * branch            main       -> FETCH_HEAD
Already up to date.
PS C:\Users\adama\OneDrive\Documents\Repositories\4ID3>
```

Wiring Diagram

ESP8266 Development Board Pinout:

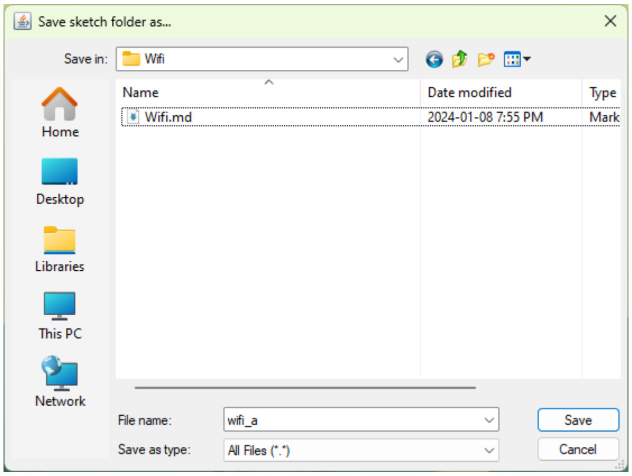


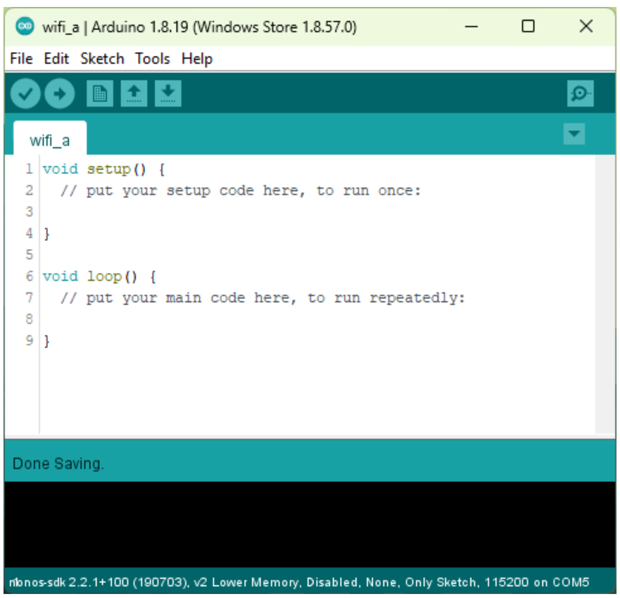


Reading Sensor Data

The goal of this section of the lab is to read data from 3 sensors and print them to the serial monitor, before we communicate to a server.

Launch the Arduino IDE and **Save as** into your lab 1 folder.



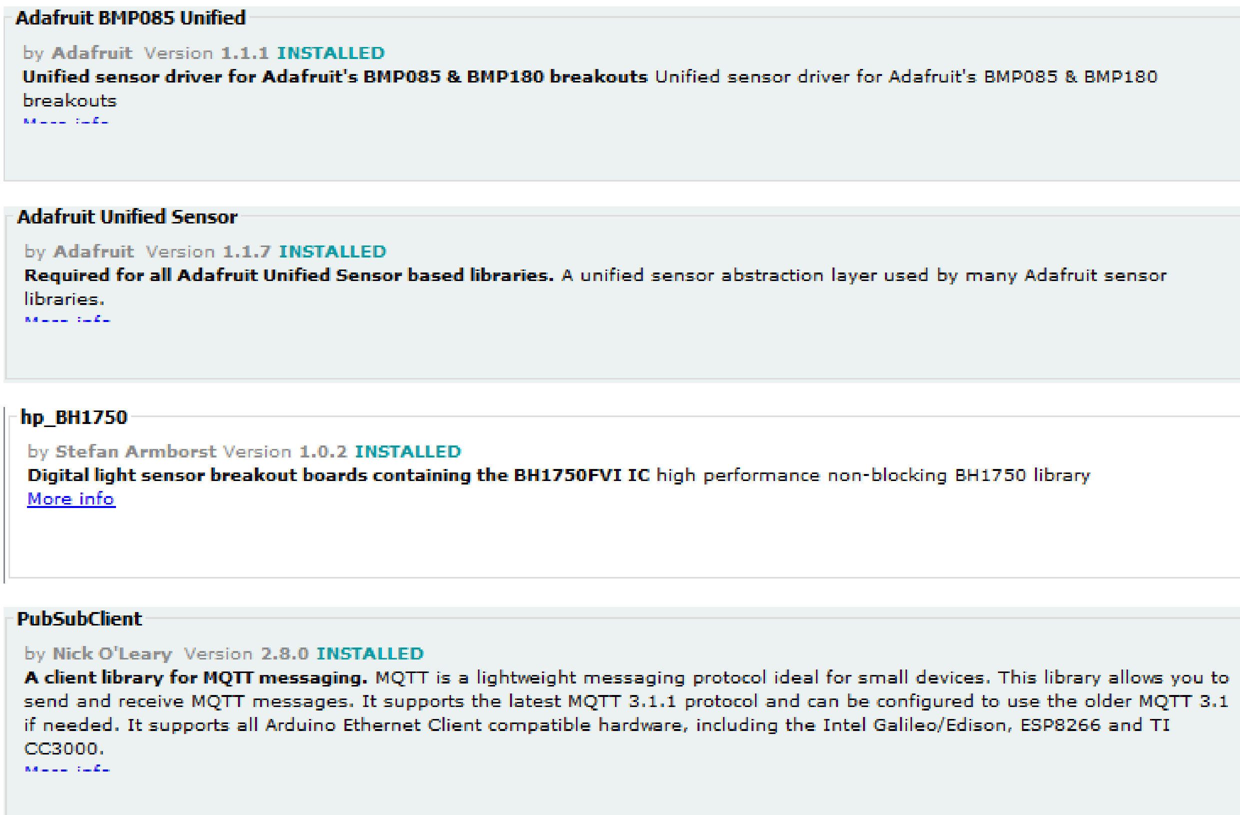


The 3 sensors we will be using are as follows:

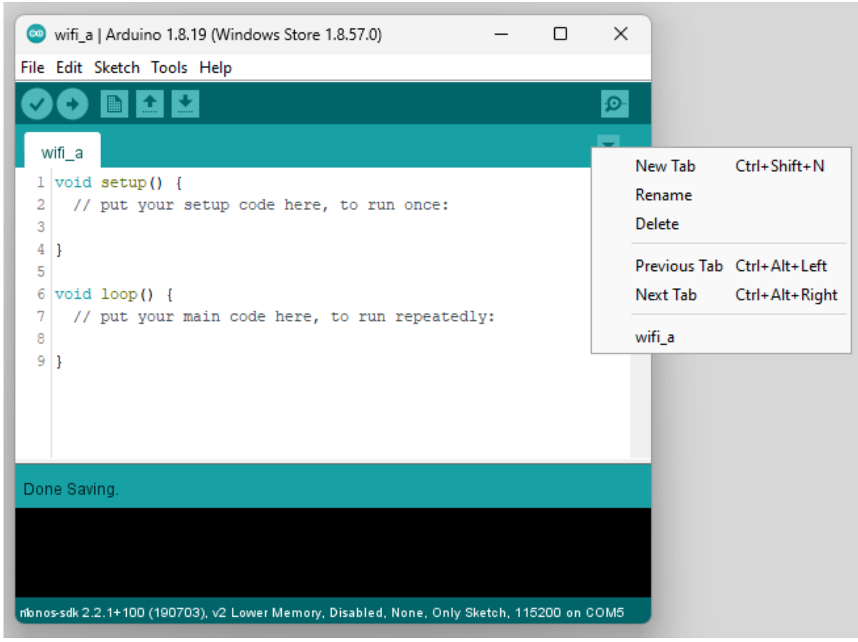
- DHT11 for Temperature and Humidity
- BMP180 for Pressure
- BH1750 for Light Intensity

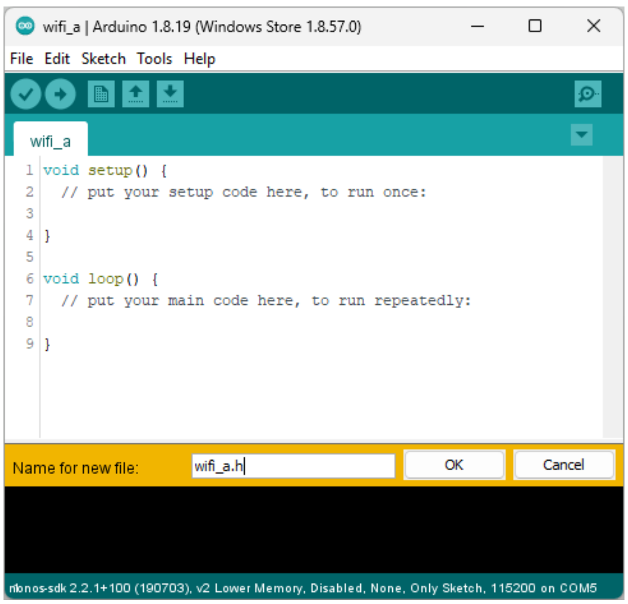
Ensure that the following libraries are installed from the **Arduino Library Manager**:

- Adafruit Unified Sensor by Adafruit
- Adafruit BMP085 Unified by Adafruit
- Hp_BH1750 by Stefan Armborst
- PubSubClient by Nick O'Leary
- The ESP8266 driver as described in the pre-lab



Create a new header file. Name this file **wifi_a.h**.





In this file, we will keep our dependencies, preprocessor macros, global variables, and global objects.

Include the libraries for each sensor.

File: wifi_a.h

```
//DHT11 Libraries
#include <Adafruit_Sensor.h>
#include <DHT.h>
#include <DHT_U.h>

//BMP180 Libraries
#include <Wire.h>
#include <Adafruit_Sensor.h>
#include <Adafruit_BMP085_U.h>

//HP_BH1750 Libraries
#include <hp_BH1750.h>
```

Below, include any macros that you need. Macros act as a find-and-replace. The C++ preprocessor will copy ‘14’ everywhere in the code where ‘DHTPIN’ is found at compile time.

File: wifi_a.h

```
//HP_BH1750 Libraries
#include <hp_BH1750.h>

//Macros
#define DHTPIN 14
#define DHTTYPE DHT11
#define DELAY_BETWEEN_SAMPLES_MS 5000
```

Lastly, lets instantiate some global objects for classes that we will be using throughout the code.

File: wifi_a.h

```
#define DELAY_BETWEEN_SAMPLES_MS 5000

//Instantiate Sensor Objects
DHT_Unified dht(DHTPIN, DHTTYPE);
Adafruit_BMP085_Unified bmp = Adafruit_BMP085_Unified(10085);
hp_BH1750 BH1750;
```

This concludes the header file. Let's move back to the implementation file.

Firstly, include our header file.

File: wifi_a.ino

```
#include "wifi_a.h"

void setup(){

}

void loop(){

}
```

Next, set up the void setup() function.

File: wifi_a.ino

```
void setup() {
  //Start the serial monitor at 115200 baud
  Serial.begin(115200);

  //Create a sensor object that is passed into the getSensor method of the dht class
  //Only the dht sensor requires this
  sensor_t sensor;
  dht.temperature().getSensor(&sensor);
  dht.humidity().getSensor(&sensor);

  //Run the begin()method on each sensor to start communication
  dht.begin();
  bmp.begin();
  BH1750.begin(BH1750_TO_GROUND);

}
```

Moving onto the void loop() function, it should be noticed that both the DHT sensor and BMP sensor are part of the same Adafruit unified library, so they will be polled differently than the BH sensor.

File: wifi_a.ino

```
void loop() {

   //Polling the DHT and BMP sensor using events
   sensors_event_t dhtTempEvent, dhtHumEvent, bmpEvent;
   dht.temperature().getEvent(&dhtTempEvent);
   dht.humidity().getEvent(&dhtHumEvent);
   bmp.getEvent(&bmpEvent);

   //Polling the BH sensor
   BH1750.start();
   float lux=BH1750.getLux();
}
```

Next, we want to print the sensor readings to the serial monitor.

File: wifi_a.ino

```
void loop() {

   […]

   //Printing sensor readings to serial monitor
   Serial.println("\n-");

   if(!isnan(dhtTempEvent.temperature)){
       Serial.println("Temperature: " + String(dhtTempEvent.temperature) + " degC");
   }
   else{
       Serial.println("Temperature Sensor Disconnected");
   }
   if(!isnan(dhtHumEvent.relative_humidity)){
       Serial.println("Humidity: " + String(dhtHumEvent.relative_humidity) + " %");
   }
   else{
       Serial.println("Humidity Sensor Disconnected");
   }
   if(!isnan(bmpEvent.pressure)){
       Serial.println("Pressure: " + String(bmpEvent.pressure) + " hPa");
   }
   else{
       Serial.println("Pressure Sensor Disconnected");
   }
   if(!isnan(lux)){
       Serial.println("Light Intensity: " + String(lux) + " lux");
   }
   else{
       Serial.println("Lux Sensor Disconnected");
   }

   delay(DELAY_BETWEEN_SAMPLES_MS);

}
```

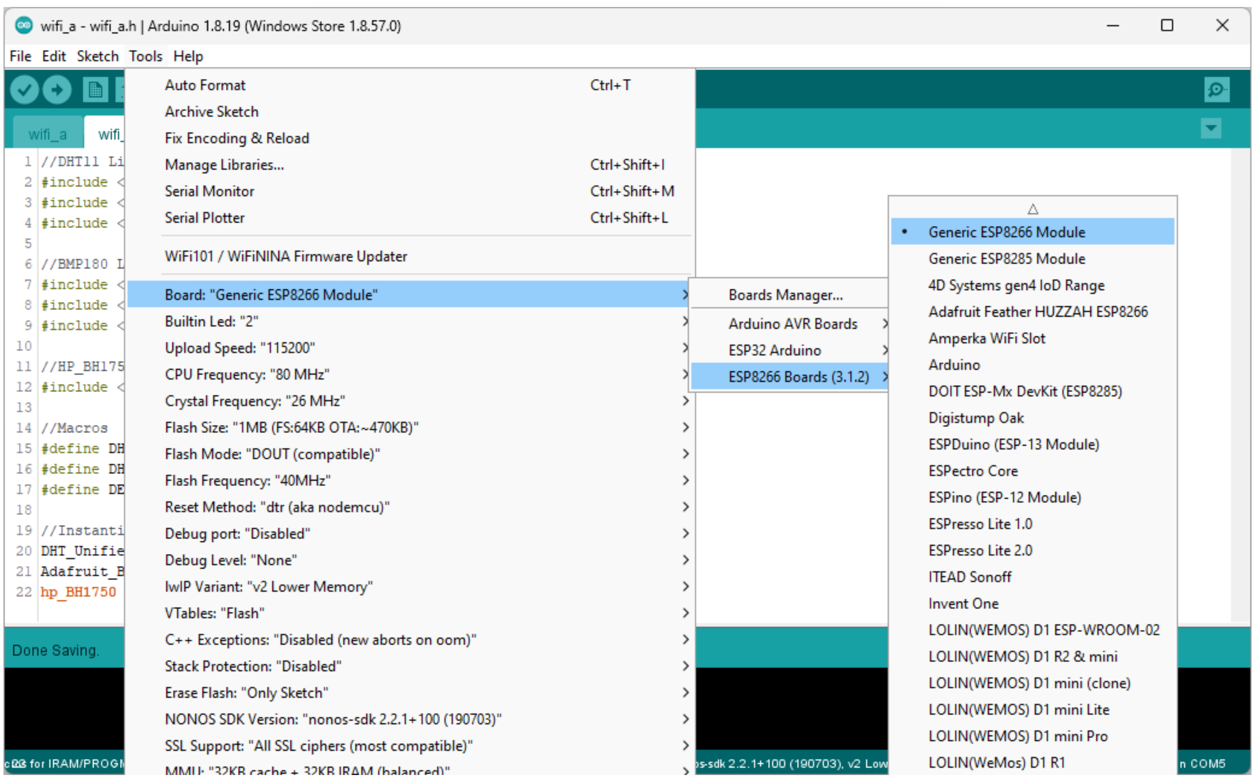
To concatenate different datatypes into a print statement, we must **cast them to strings** and **concatenate them** together. An easy way to do this is to use **String**(float value) to cast and **+** operator to concatenate two strings together.

Thirdly, when printing to the serial monitor, the **print()** command does not include a newline character. In order to print on a new line, we could add it in **print(string + '\n')** or use the **println()** function.

Lastly, we want to let time pass between polls. This can be done simply by adding a delay in the loop.

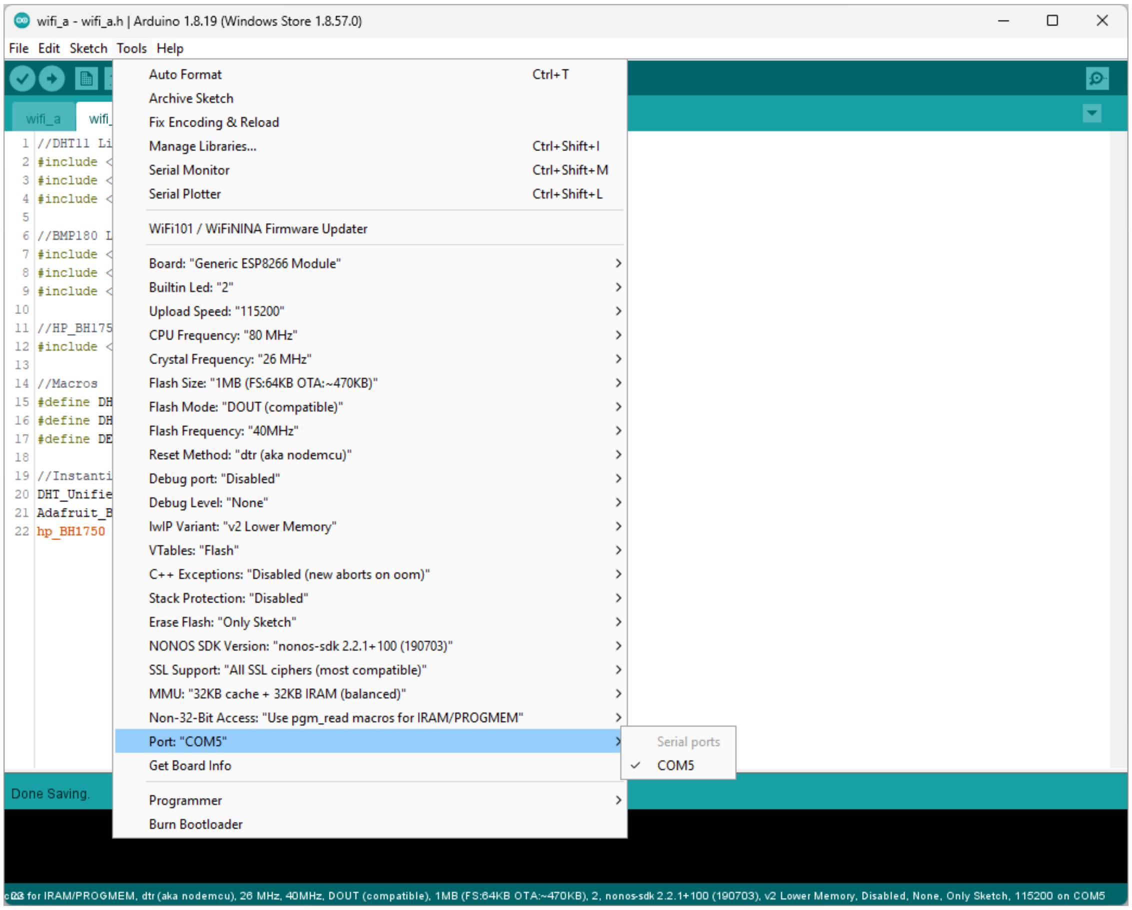
To upload to the board, change the board to Generic ESP8266 Module.

Tools > Board > ESP8266 Boards > Generic ESP8266 Module



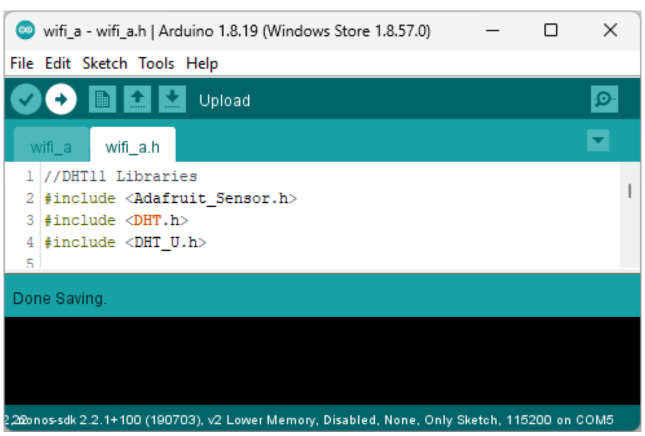
Leave the default communication settings the same, with the exception of the COM port. Select the COM port that your microcontroller is connected to.

Tools > Port > COM<#>



Press the **upload** button to compile and upload the code. Keep an eye on the terminal window for any errors that arise.

Sketch > Upload

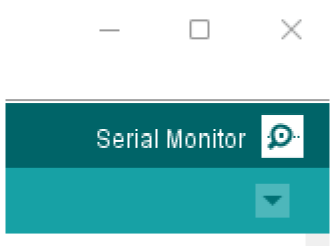


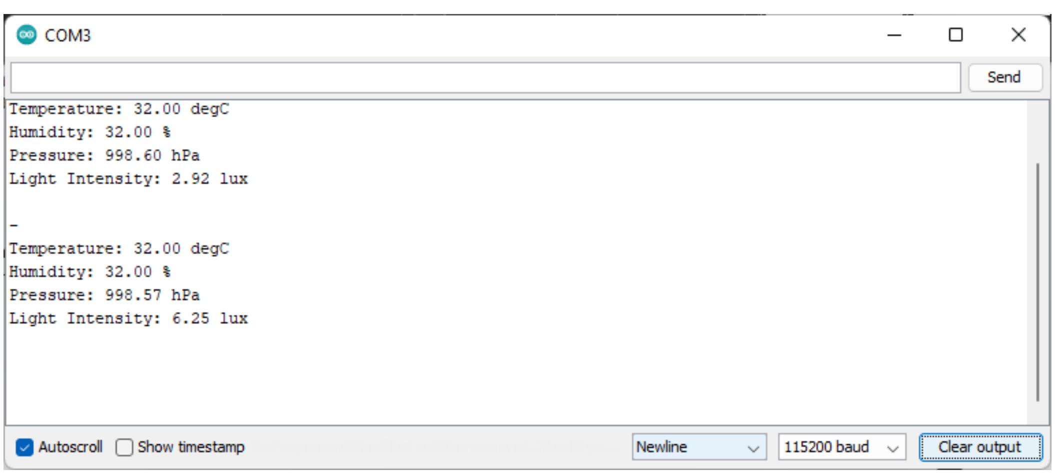
A successful upload should look like this:

```
Crystal is 26MHz
MAC: 48:3f:da:aa:57:09
Uploading stub...
Running stub...
Stub running...
Configuring flash size...
Auto-detected Flash size: 4MB
Flash params set to 0x0340
Compressed 280256 bytes to 205447...
Writing at 0x00000000... (7 %)
Writing at 0x00004000... (15 %)
Writing at 0x00008000... (23 %)
Writing at 0x0000c000... (30 %)
Writing at 0x00010000... (38 %)
Writing at 0x00014000... (46 %)
Writing at 0x00018000... (53 %)
Writing at 0x0001c000... (61 %)
Writing at 0x00020000... (69 %)
Writing at 0x00024000... (76 %)
Writing at 0x00028000... (84 %)
Writing at 0x0002c000... (92 %)
Writing at 0x00030000... (100 %)
Wrote 280256 bytes (205447 compressed) at 0x00000000 in 18.2 seconds (effective 122.9 kbit/s)...
Hash of data verified.

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

After the upload is complete (NOT DURING), launch the **Serial monitor** to view the microcontroller output.

Tools > Serial Monitor

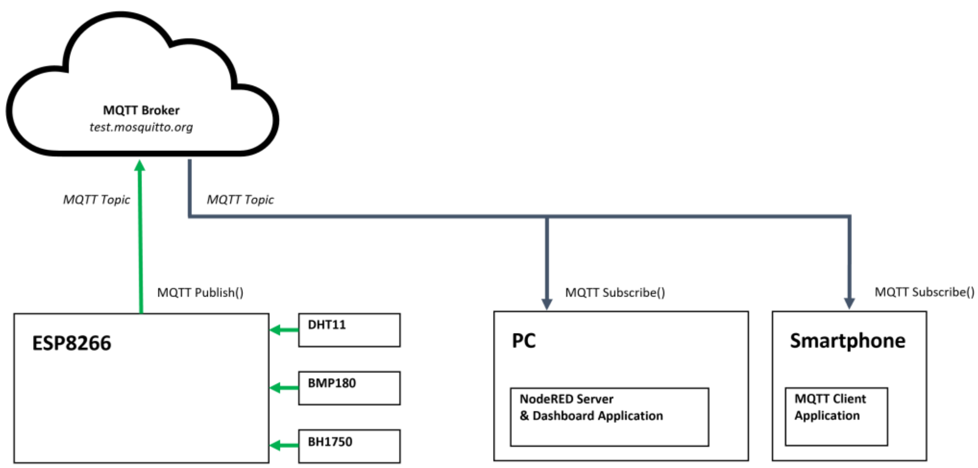




Publishing to an MQTT Broker

The ESP8266 has a built-in WiFi transceiver, which allows it to connect to the internet easily. We will be using the PubSubClient library to:

a) Connect to a local WiFi network
b) Connect to an MQTT broker
c) Connect to a NodeRED interface



Modify your header file to include some **global variables** for the WiFi driver, the **MQTT libraries**, and instantiate **the MQTT Client** object. Also change the delay to 20 seconds (20,000 ms).

When adding the broker ip address, you have two options:

a) Use an online public broker
b) Use a local broker on the same network

Public Broker

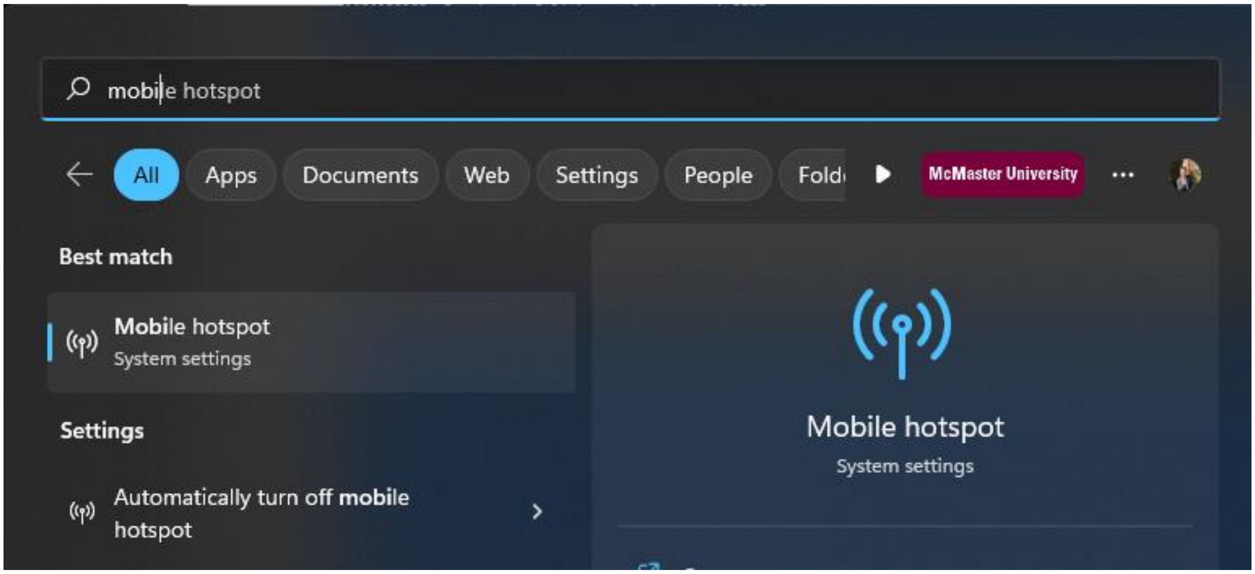
Use the IP address of a known public broker such as Mosquitto's test broker:

test.mosquitto.org

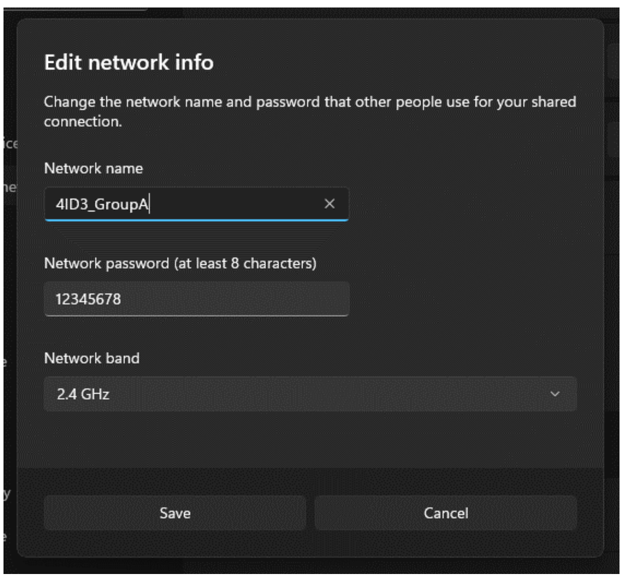
Port is 1883

Hotspotting your Microcontroller

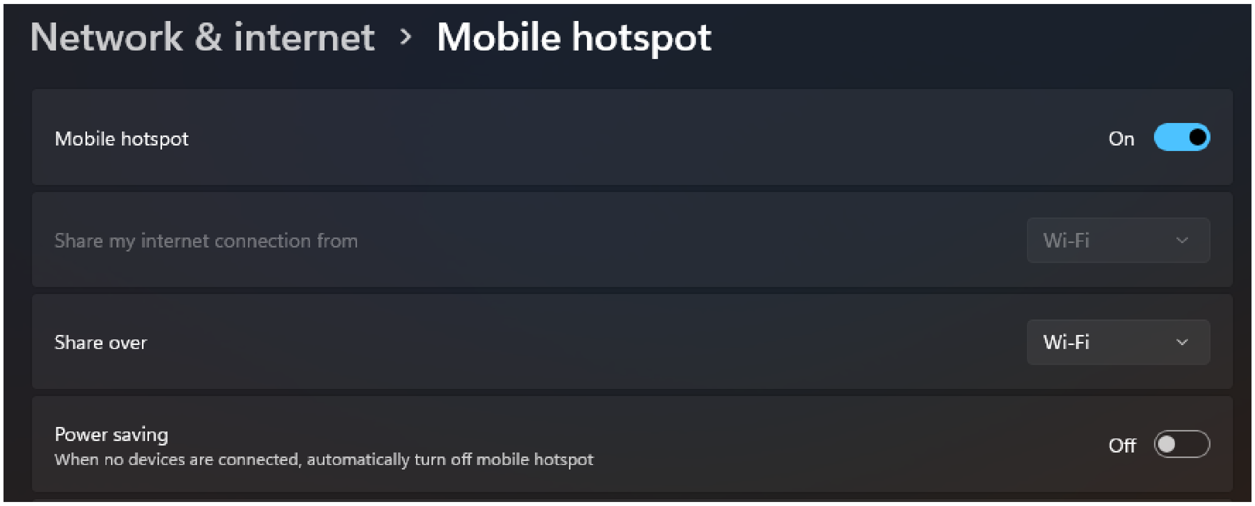
Open **Windows Mobile Hotspot**.



Set your login credentials.

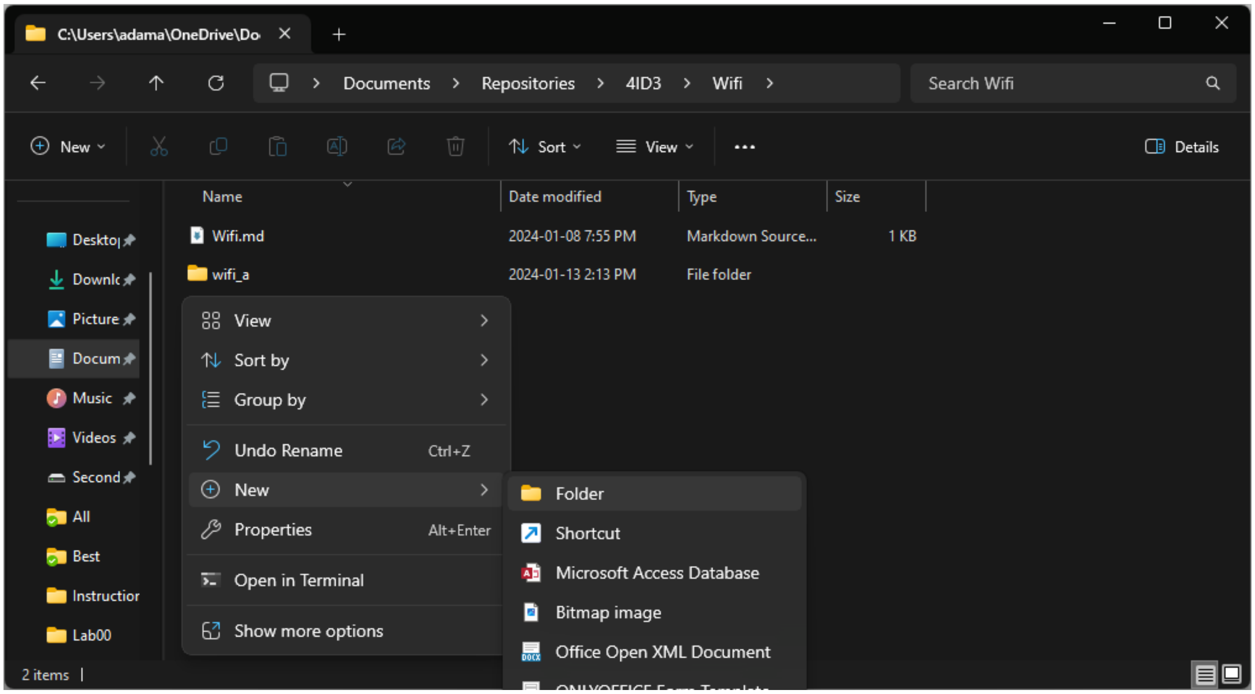


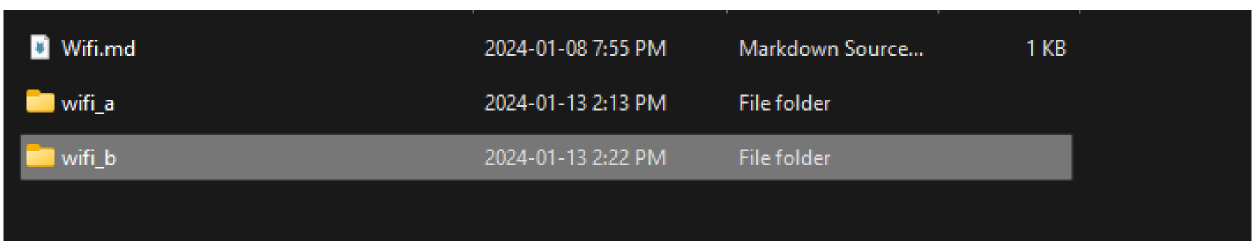
Toggle it **on** and **disable power saving**.


Network & internet > Mobile hotspot
Mobile hotspot
On
Share my internet connection from
Wi-Fi
Share over
Wi-Fi
Power saving
When no devices are connected, automatically turn off mobile hotspot
Off

Code Changes

Create a new folder in the lab folder in your course repository called **wifi_b/** .

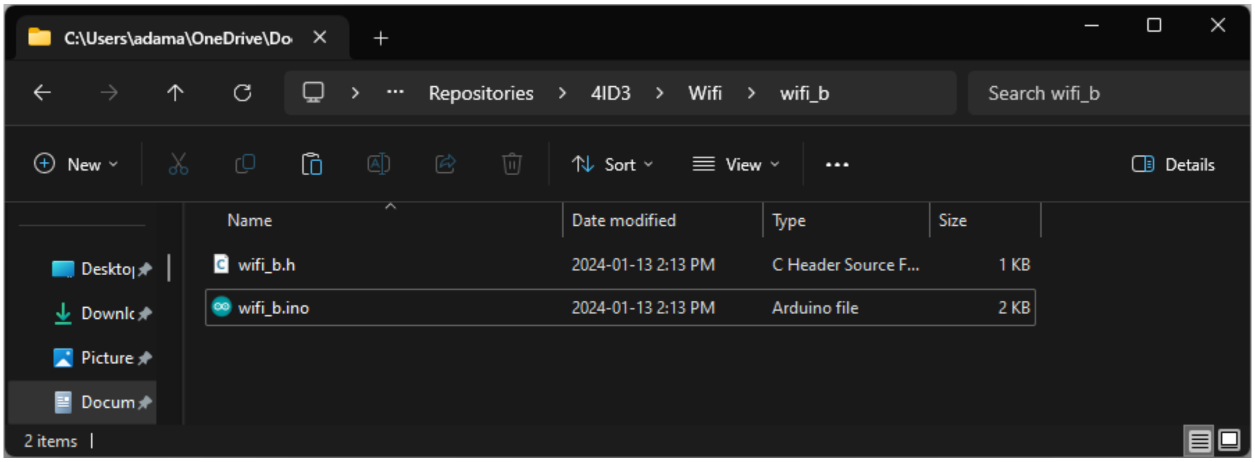




SaveAs (copy) the existing project as **wifi_b.**

wifi_a.h -> (SaveAs) -> wifi_b.h

wifi_a.ino -> (SaveAs) -> wifi_b.ino



Open the files in a new Arduino IDE tab.

Select the header file tab.

Above the existing code, include the following communication libraries:

File: wifi_b.h

```
//MQTT Libraries
#include <ESP8266WiFi.h>
#include <PubSubClient.h>
```

Below the existing code, include the following global variables:

File: wifi_b.h

```
//Instantiate Sensor Objects
DHT_Unified dht(DHTPIN, DHTTYPE);
Adafruit_BMP085_Unified bmp = Adafruit_BMP085_Unified(10085);
hp_BH1750 BH1750;

//Global Variables
char* ssid = "GroupA";
char* pass = "12345678";
const char* brokerAddress = "test.mosquitto.org";
uint16_t addressPort = 1883;
```

Next, instantiate the WifiClient object and PubSubClient object below.

File: wifi_b.h

```
//Instantiate MQTT Client
WiFiClient espClient;
PubSubClient client(espClient);
```

In the implementation file, modify the include statement to include the correct header file.

File: wifi_b.ino

```
#include "wifi_b.h"
```

Modify the **setup()** function, to initialize the WiFi driver and MQTT client.

File: wifi_b.ino

```
#include "wifi_b.h"

void setup() {

  [...]

  //Start the WiFi driver and tell it to connect to your local network
  //WiFi.mode(WIFI_STA);
  WiFi.begin(ssid, pass);

  //While it is connecting, print a '.' to the serial monitor every 500 ms
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }

  //Once connected, print the local IP address
  Serial.println("");
  Serial.println("WiFi connected");
  Serial.println("IP address: ");
  Serial.println(WiFi.localIP());

  //Set the MQTT client to connect to the desired broker
  client.setServer(brokerAddress, addressPort);

}
```

If the microcontroller loses connection to the MQTT server, we want to have a callback function that would attempt to reconnect.

Below the setup() function, create a reconnect function. This function will be called from void loop().

File: wifi_b.ino

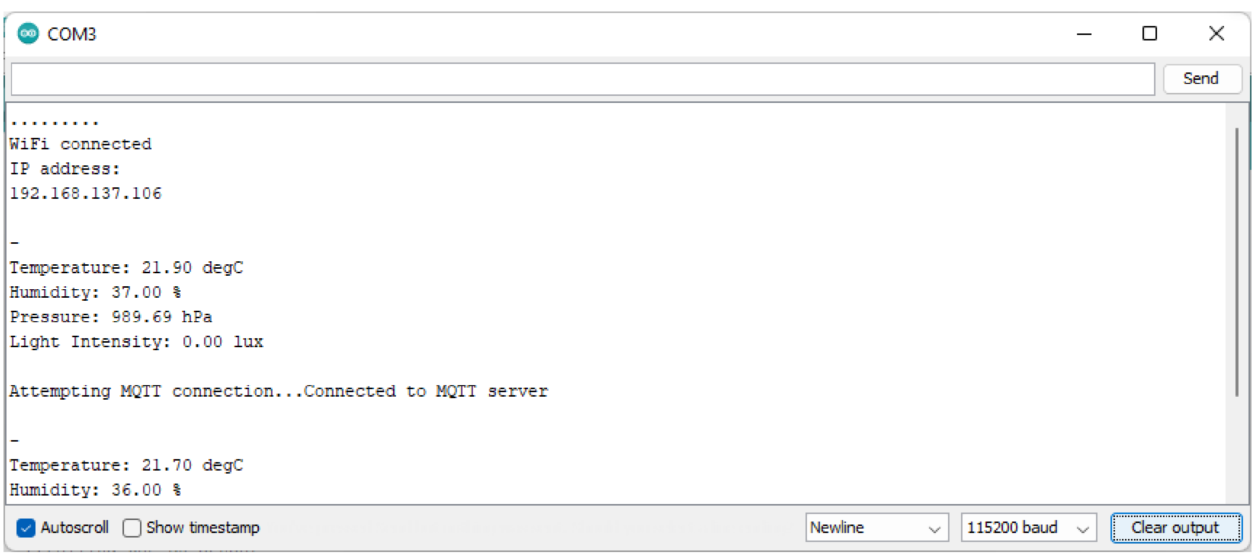
```
void reconnect() {

  //While the client remains unconnected from the MQTT broker, attempt to reconnect every 2 seconds
  //Also, print diagnostic information
  while (!client.connected()) {
    Serial.print("\nAttempting MQTT connection...");

    if (client.connect("ESP8266Client")) {
      Serial.println("Connected to MQTT server");
      client.subscribe("testTopic");
    } else {
      Serial.print("\nFailed to connect to MQTT server, rc = ");
      Serial.print(client.state());
      delay(2000);
    }
  }
}
```

In void loop(), if connection is lost then call the reconnect function. Once you are connected, publish each sensor data to its associated topic.

File: wifi_b.ino

```
void loop() {

  [...]

 if(!client.loop())
   client.connect("ESP8266Client");

 //Publish the sensor data to the associated topics
 client.publish("4ID3_GroupA/temperature", String(dhtTempEvent.temperature).c_str());
 delay(100);
 client.publish("4ID3_GroupA/humidity", String(dhtHumEvent.relative_humidity).c_str());
 delay(100);
 client.publish("4ID3_GroupA/pressure", String(bmpEvent.pressure).c_str());
 delay(100);
 client.publish("4ID3_GroupA/light", String(lux).c_str());
 Serial.println("Published data.");

  delay(DELAY_BETWEEN_SAMPLES_MS);
}
```

Ensure the code compiles and reupload the modified code to the microcontroller.



Verifying Connection

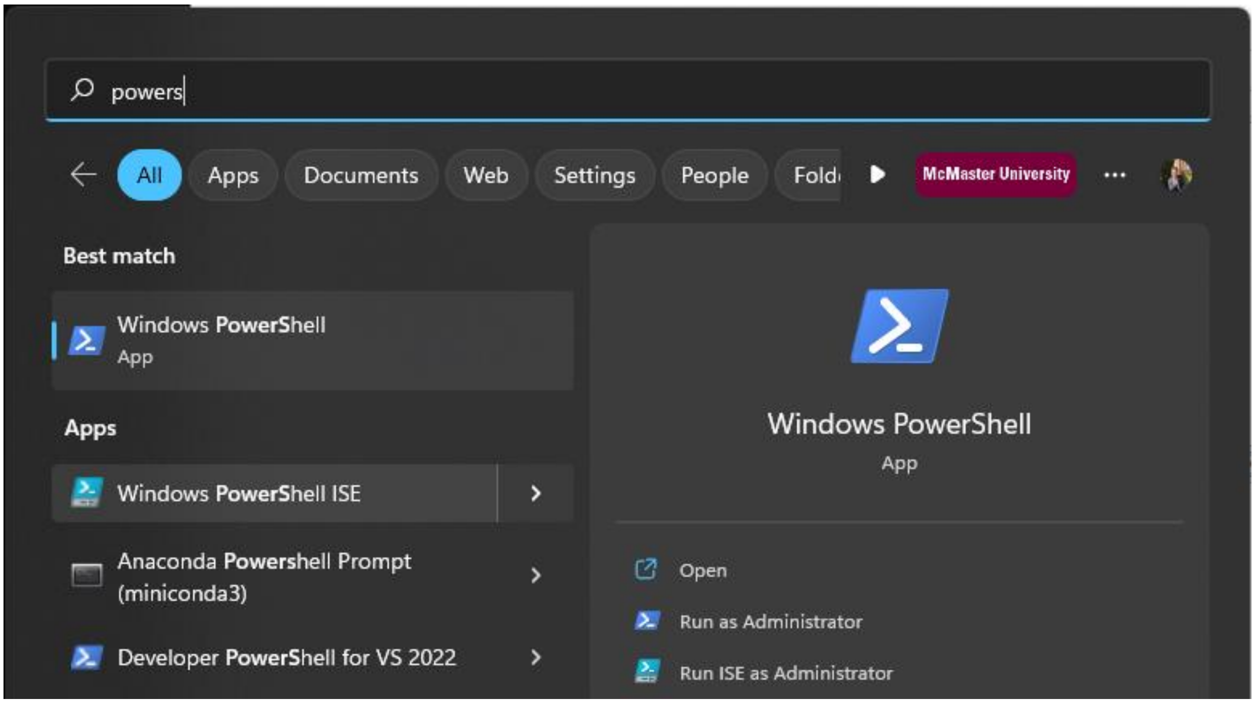
To verify and demonstrate the communication of sensor data over the internet, we will be connecting to the public mqtt broker from a variety of client applications.

Please try each method on a different device.

Using a Desktop Terminal Application

Open a Powershell terminal.

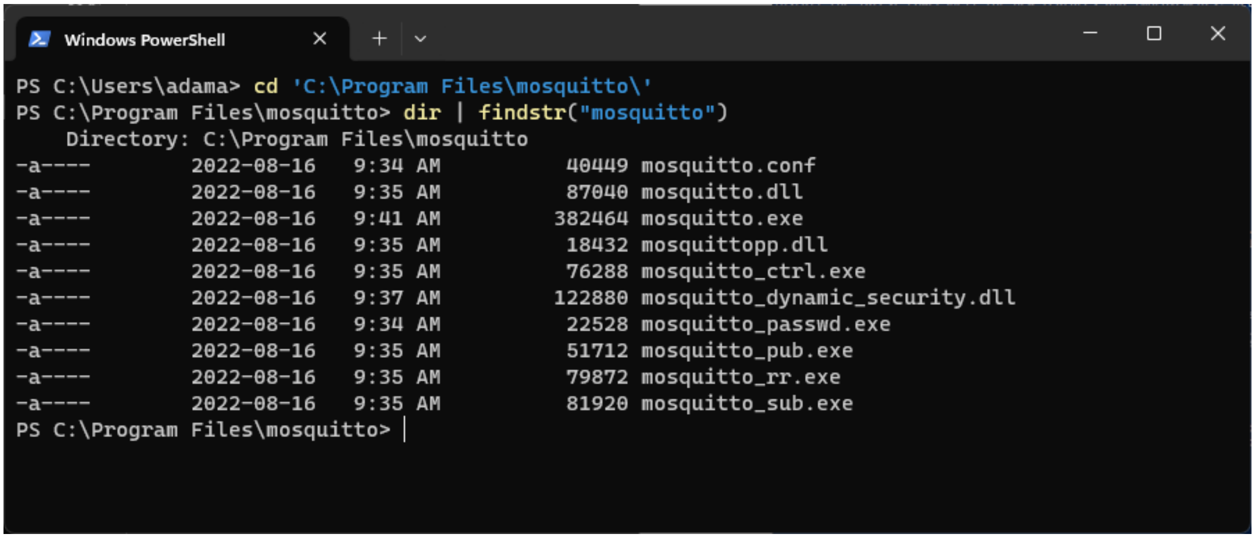
Windows Terminal > Powershell or Windows Powershell



Navigate to the installation directory of the mosquitto mqtt client.

cd 'C:\Program Files\mosquitto\"

dir | findstr("mosquitto")



Launch the subscribe applications with the following flags:

.\mosquitto_sub.exe -h test.mosquitto.org -t "4ID3_GroupA/humidity"

-h - MQTT broker IP address

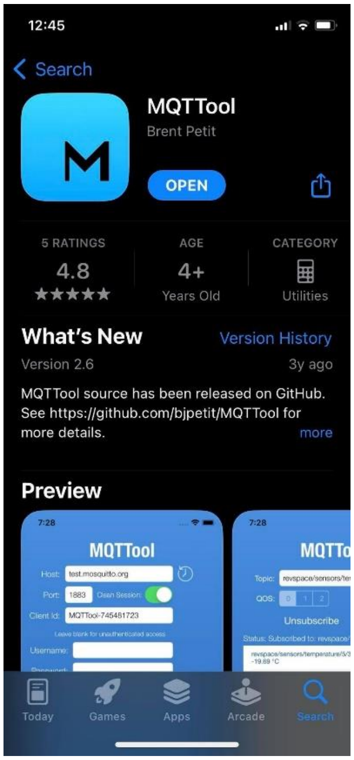
-t - the topic that your wish to connect to

After waiting a period of time, you should see the values being printed to the terminal window every 20 seconds.

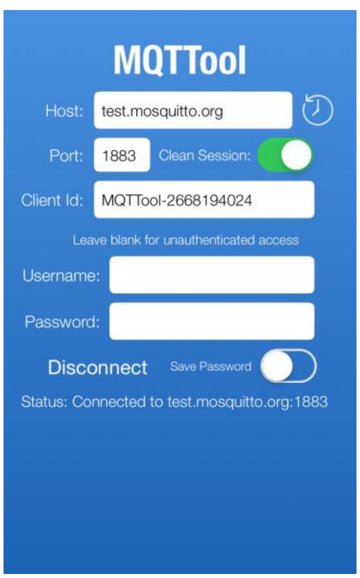
Using a Mobile Client Application

The phone application will likely be delayed from when the terminal application receives the message. If you are using iOS, install the following app:

https://apps.apple.com/ca/app/mqttool/id1085976398



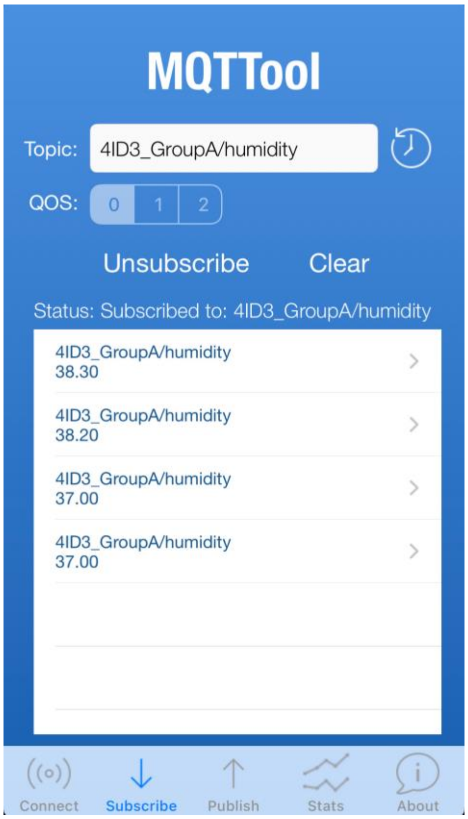
Next, connect to the public mosquito broker:

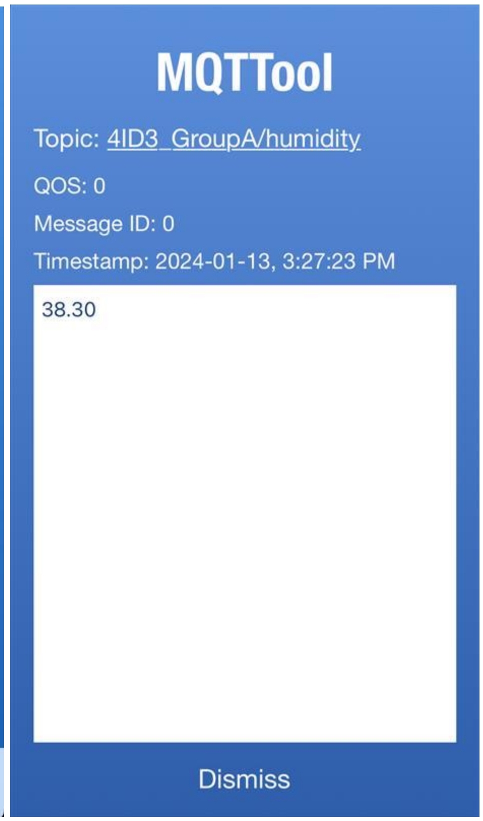


Next, subscribe to the topic of choice.

Lastly, wait for values to populate.

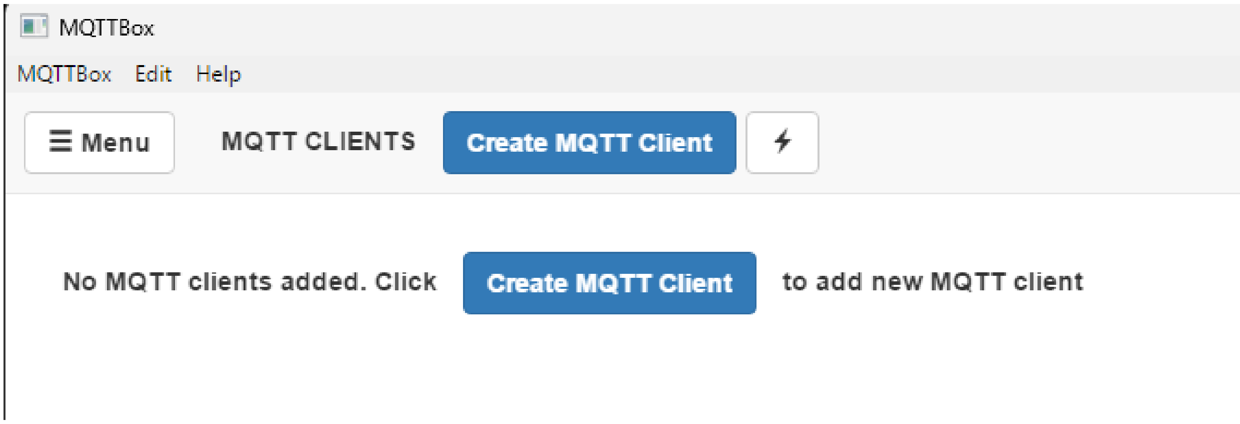
You can also try it with other sensor readings to ensure all of them are working correctly.



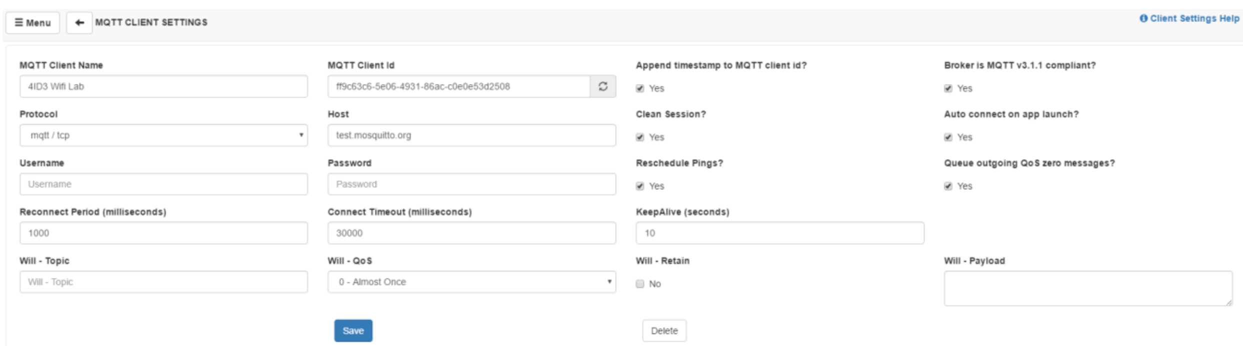


Using a Desktop Client Application

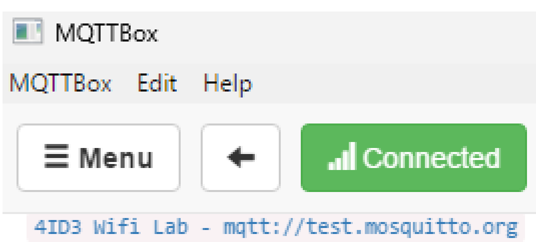
Open **MQTTBox** and select **Create New MQTT Client**.



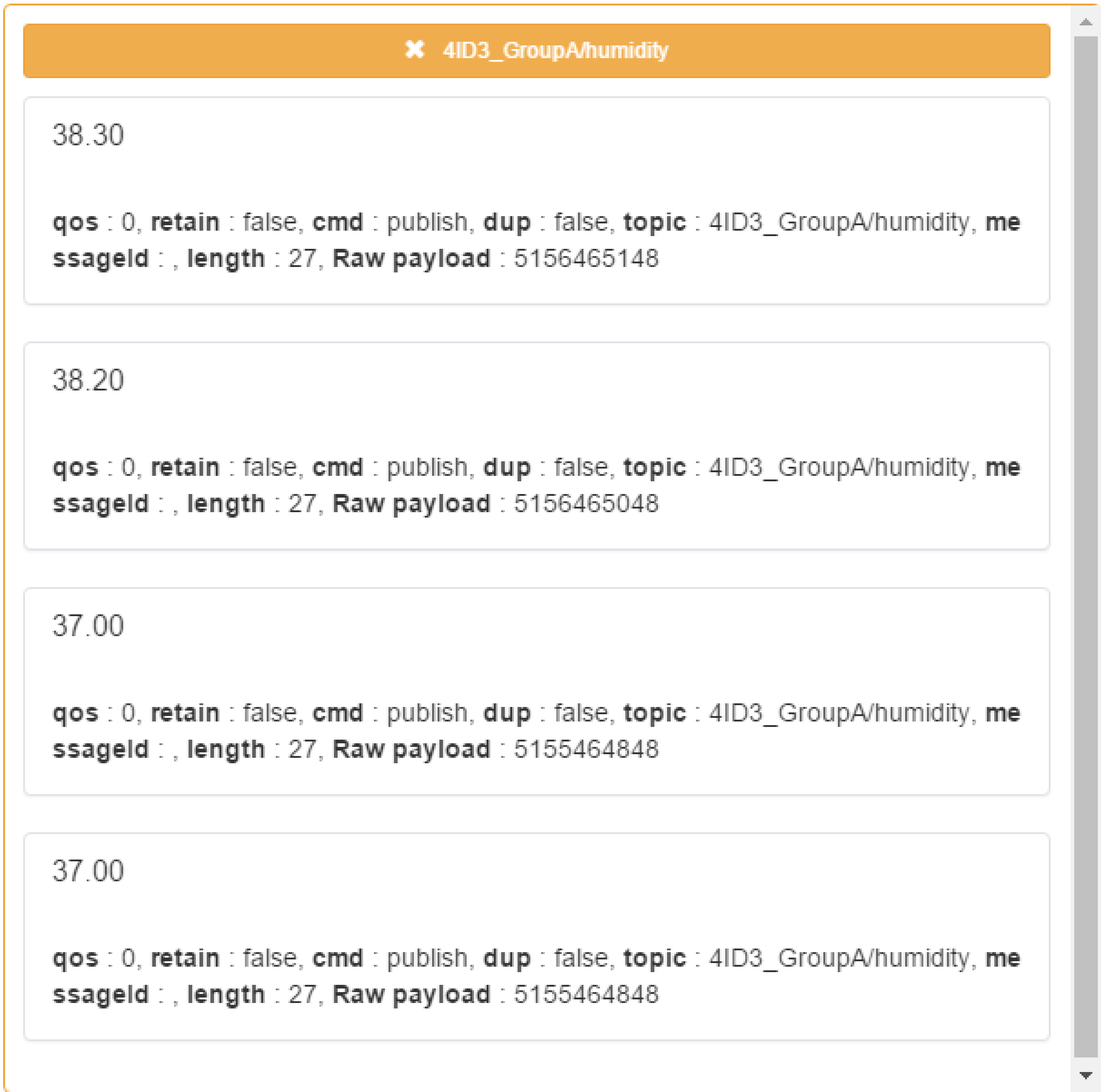
Configure the following connection details:



Press **Save** and ensure that the toolbar says **Connected**.



Subscribe to your desired topic and watch as messages populate.

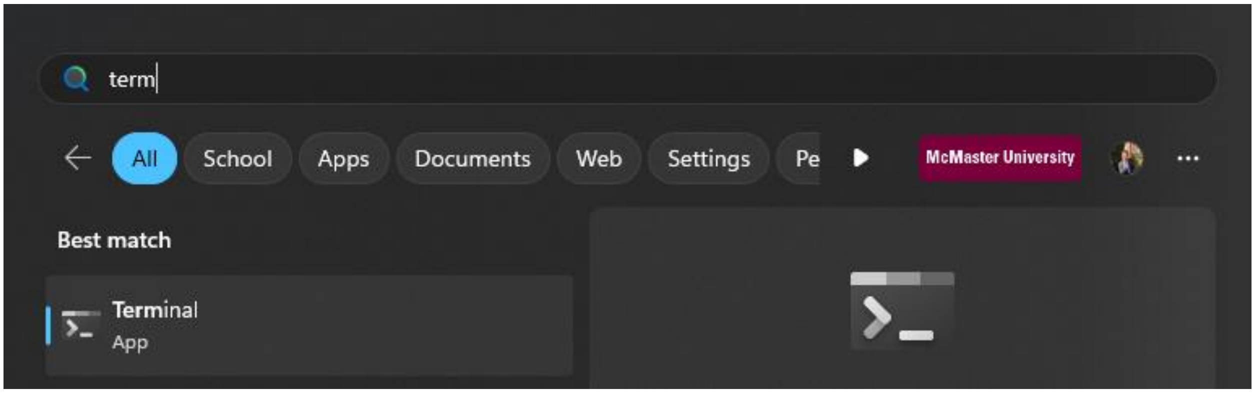

4ID3_GroupA/humidity
38.30
qos : 0, retain : false, cmd : publish, dup : false, topic : 4ID3_GroupA/humidity, messageId : , length : 27, Raw payload : 5156465148
38.20
qos : 0, retain : false, cmd : publish, dup : false, topic : 4ID3_GroupA/humidity, messageId : , length : 27, Raw payload : 5156465048
37.00
qos : 0, retain : false, cmd : publish, dup : false, topic : 4ID3_GroupA/humidity, messageId : , length : 27, Raw payload : 5155464848
37.00
qos : 0, retain : false, cmd : publish, dup : false, topic : 4ID3_GroupA/humidity, messageId : , length : 27, Raw payload : 5155464848

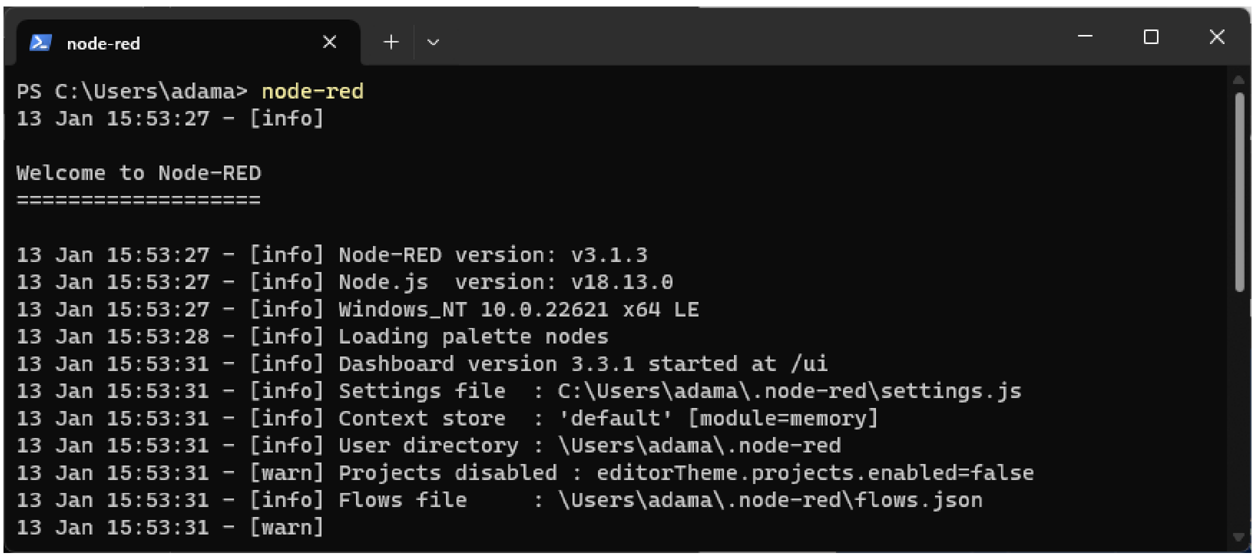
NodeRED Dashboard

Please follow the pre-lab instructions to install NodeRED.

To start NodeRED, open Windows Terminal > Powershell and type the command:

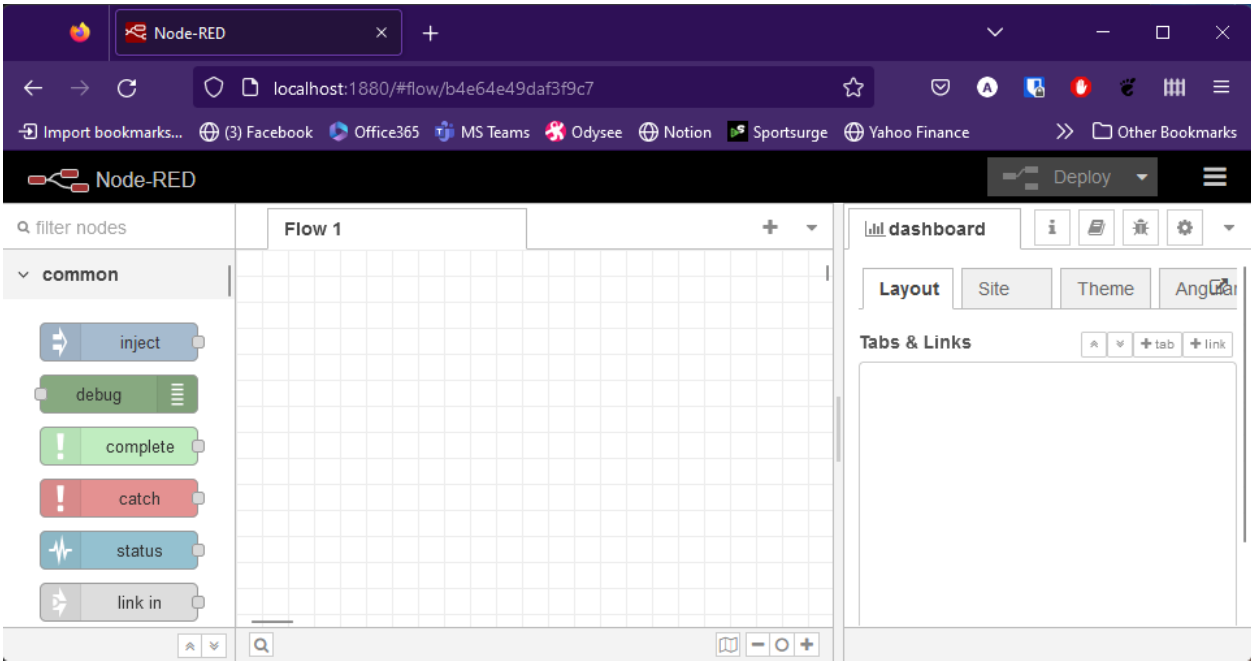
node-red



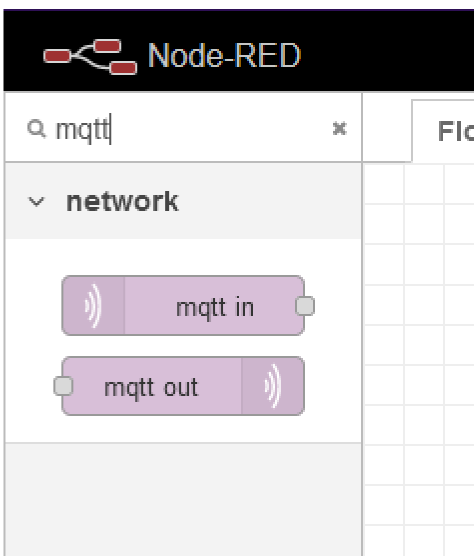


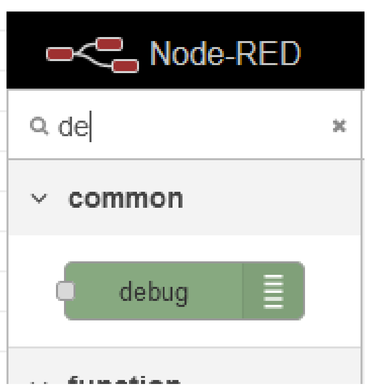
Navigate to the URL presented, in a web browser:

Web Browser > *127.0.0.1:1880*

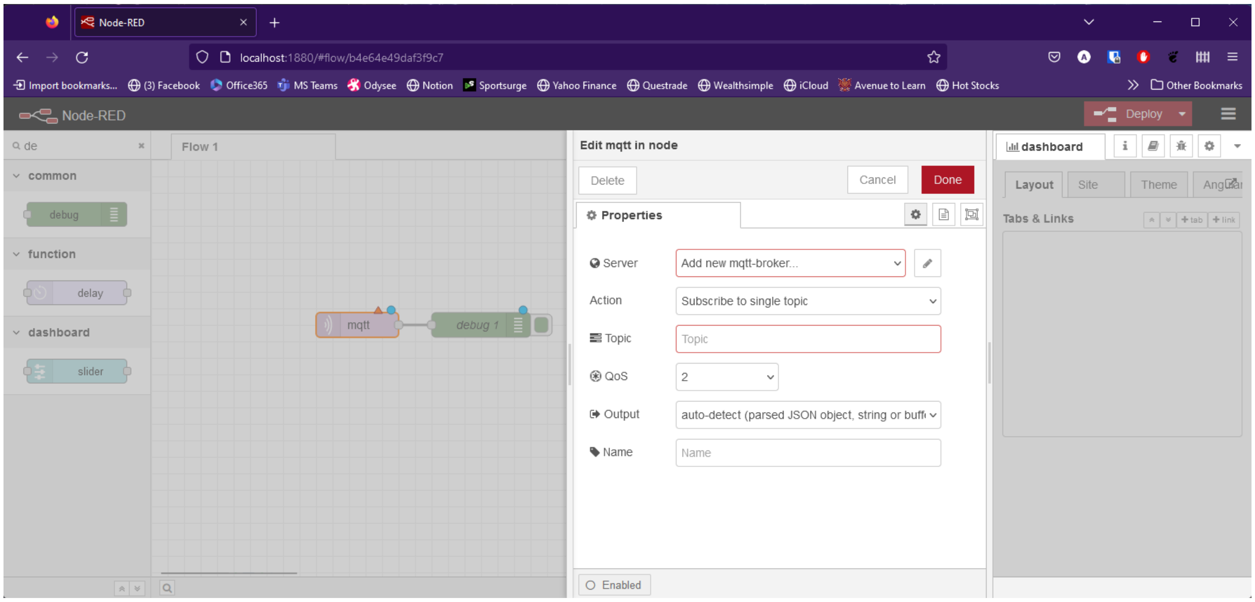


Filter nodes to find the **mqtt in** node and the **debug** node. Drag them into your flow diagram.

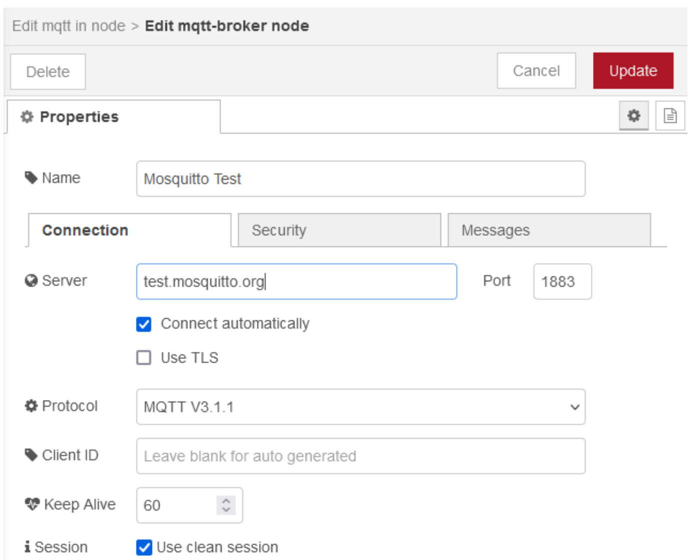




Click on the **mqtt in** node to begin editing its configuration.

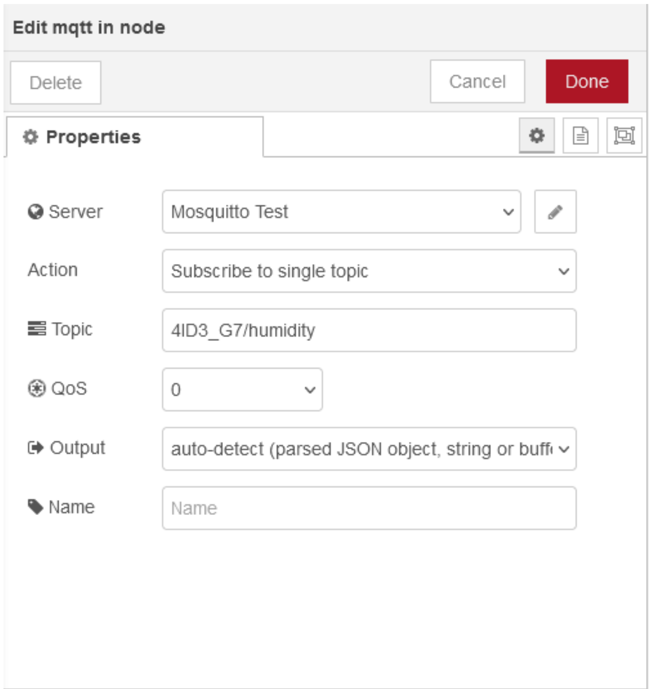


Fill in the information for the public broker.

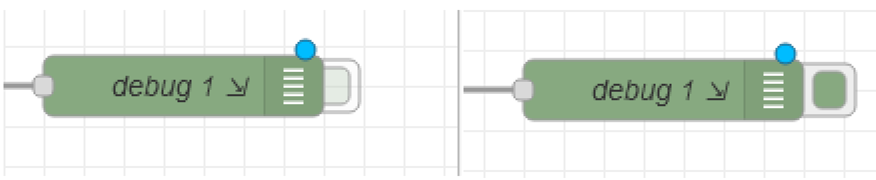


Press **Update**.

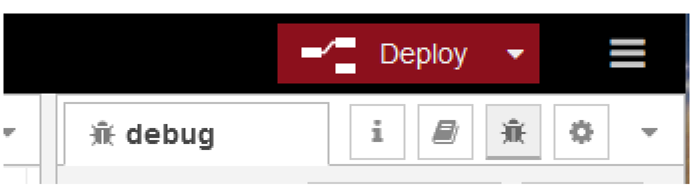
Under **Properties** fill in the **Topic** field.

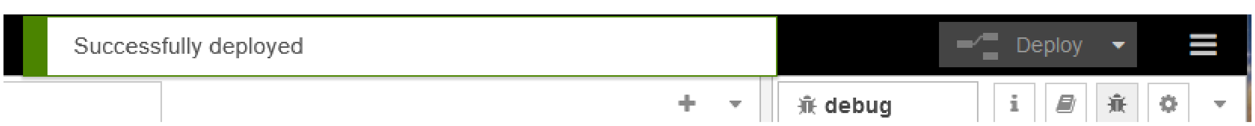


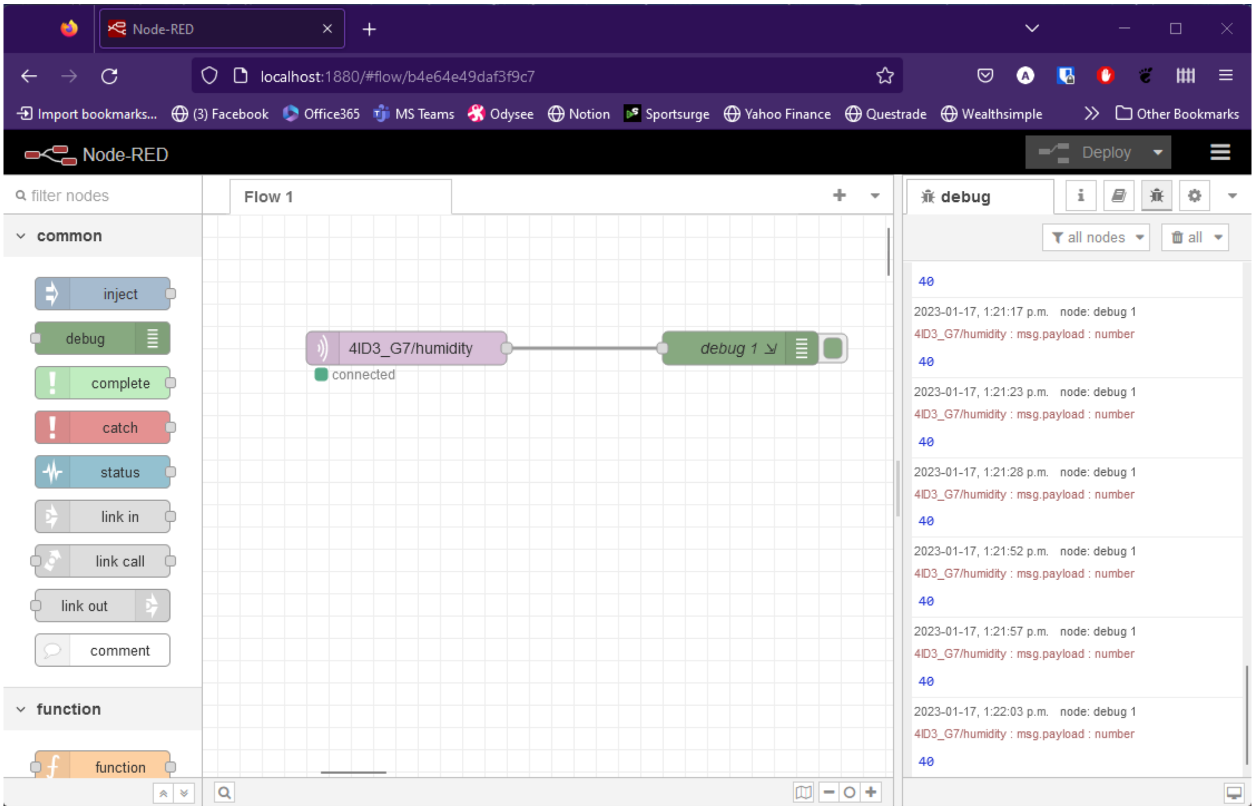
Enable the **debug** node by pressing the **green box**.



Lastly, press **Deploy** and watch the **Debug Panel** populate with sensor values.





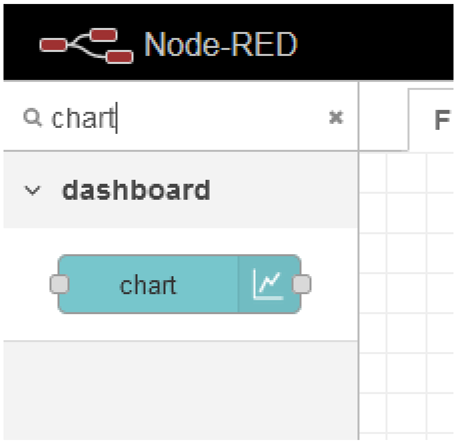


Node-RED
localhost:1880/#flow/b4e64e49daf3f9c7
Deploy
filter nodes
common
inject
debug
complete
catch
status
link in
link call
link out
comment
function
function
Flow 1
4ID3_G7/humidity
connected
debug 1
debug
all nodes
all
40
2023-01-17, 1:21:17 p.m. node: debug 1
4ID3_G7/humidity : msg.payload : number
40
2023-01-17, 1:21:23 p.m. node: debug 1
4ID3_G7/humidity : msg.payload : number
40
2023-01-17, 1:21:28 p.m. node: debug 1
4ID3_G7/humidity : msg.payload : number
40
2023-01-17, 1:21:52 p.m. node: debug 1
4ID3_G7/humidity : msg.payload : number
40
2023-01-17, 1:21:57 p.m. node: debug 1
4ID3_G7/humidity : msg.payload : number
40
2023-01-17, 1:22:03 p.m. node: debug 1
4ID3_G7/humidity : msg.payload : number
40

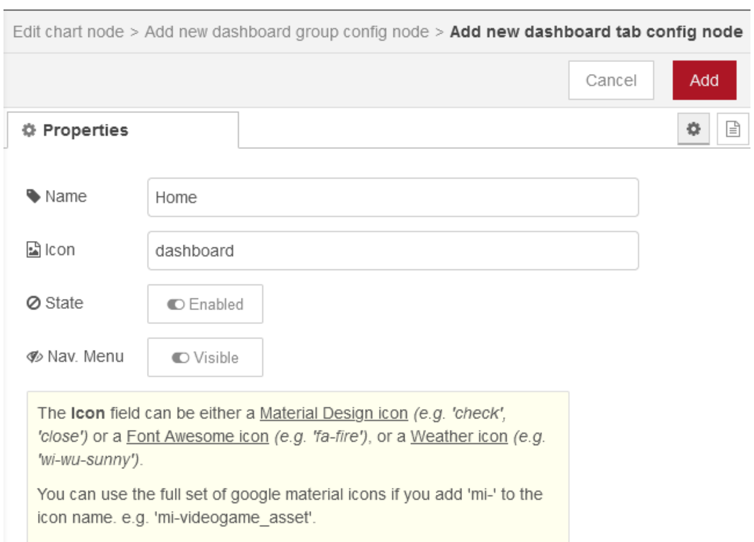
Visualizing NodeRED Data

In the pre-lab, the node-red-dashboard add-on was installed which enables us to create a dashboard of graphs, charts, and toggles to visualize and control data.

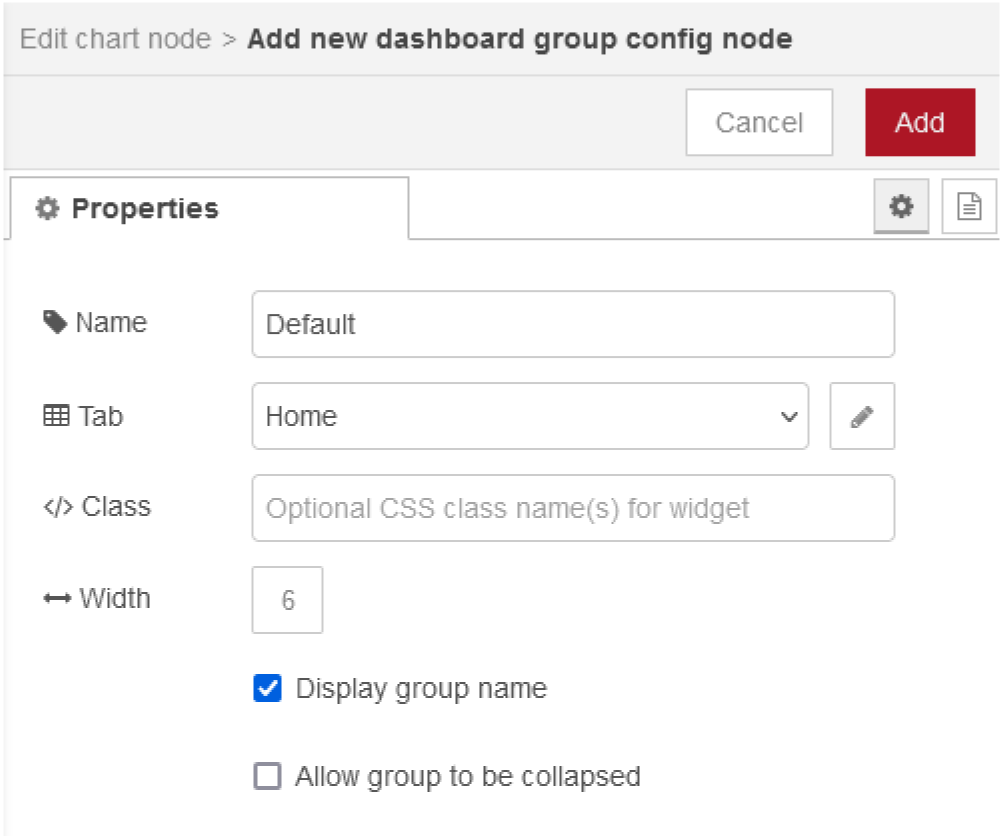
In the **filter nodes** field, search for **chart** and drag it into your flow diagram.



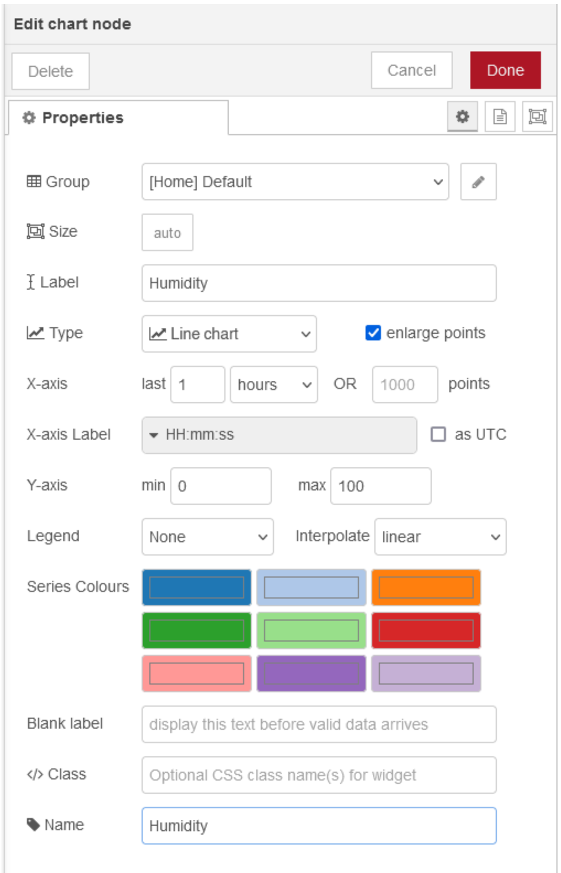
When you click on the node, you will need to create a new **Dashboard Tab**. Use the default name and press **Add**.



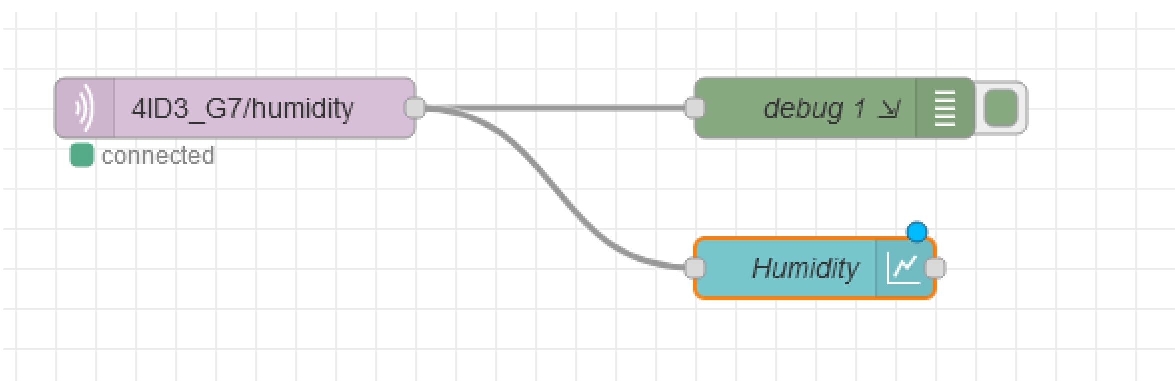
Add the dashboard group to that new dashboard by pressing **Add**.



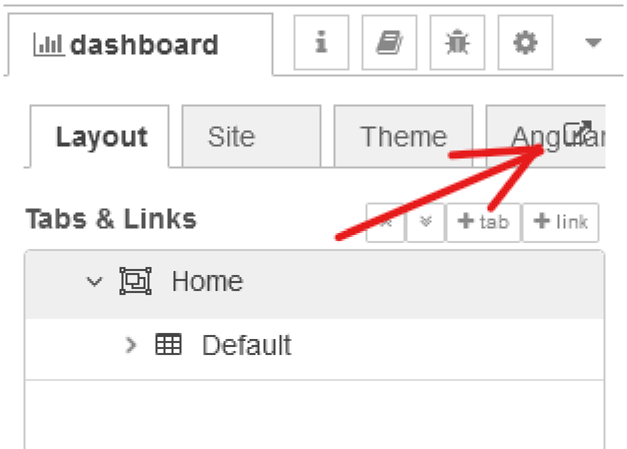
Lastly, edit the chart node to visualize your data nicely. Press **Done** when complete.



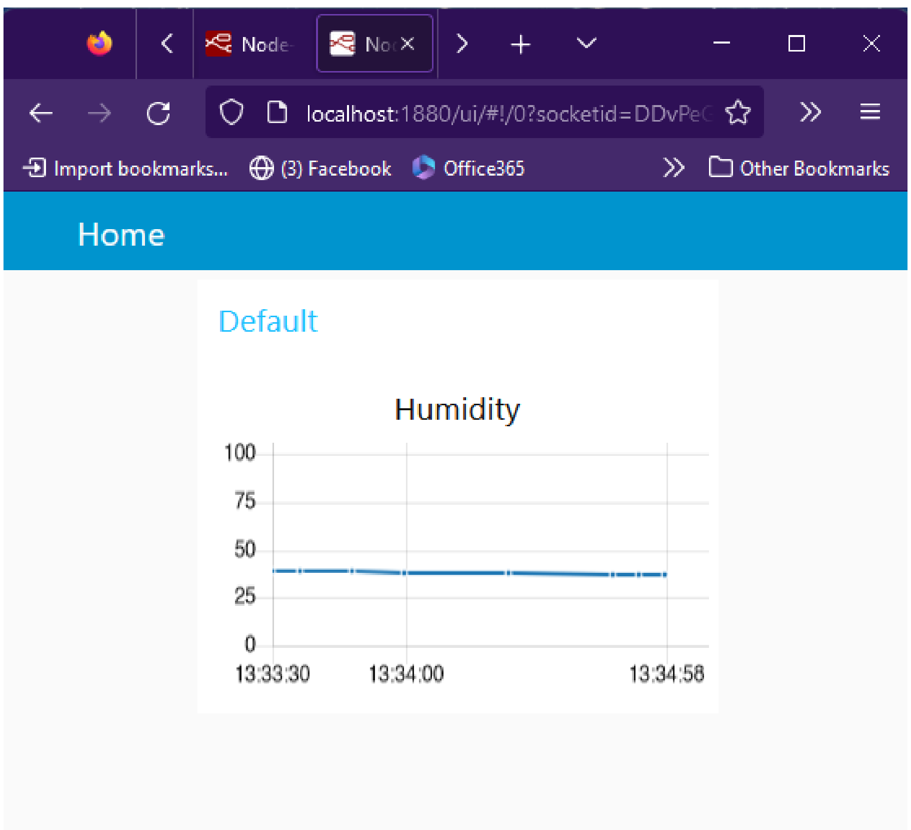
Connect your **mqtt in** node to the input of your **chart** node. Press **Deploy** to save changes.



To view the dashboard, either append **ui/** to your url (http://localhost:1880/ui) or press the **open dashboard** icon in the top right corner of the dashboard panel.

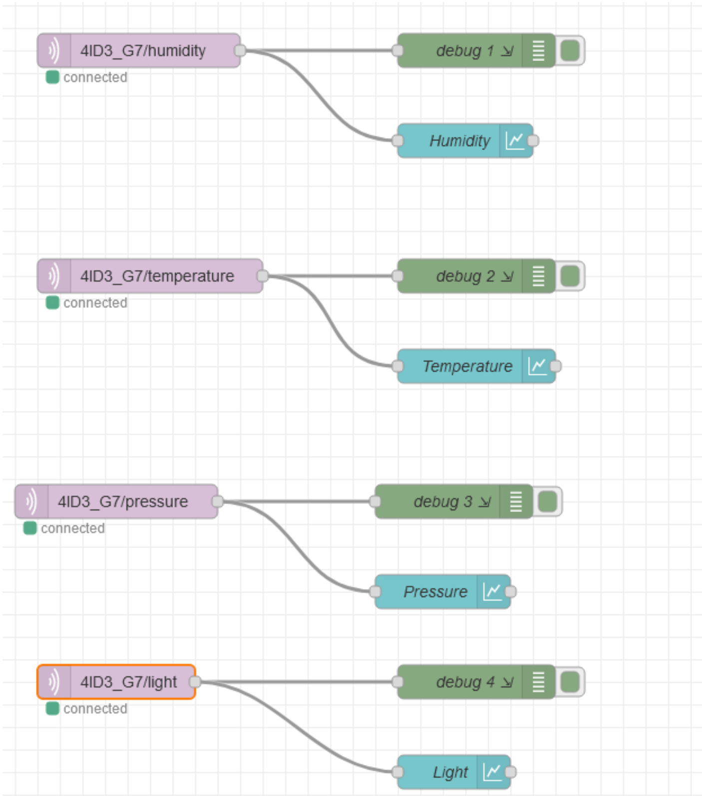


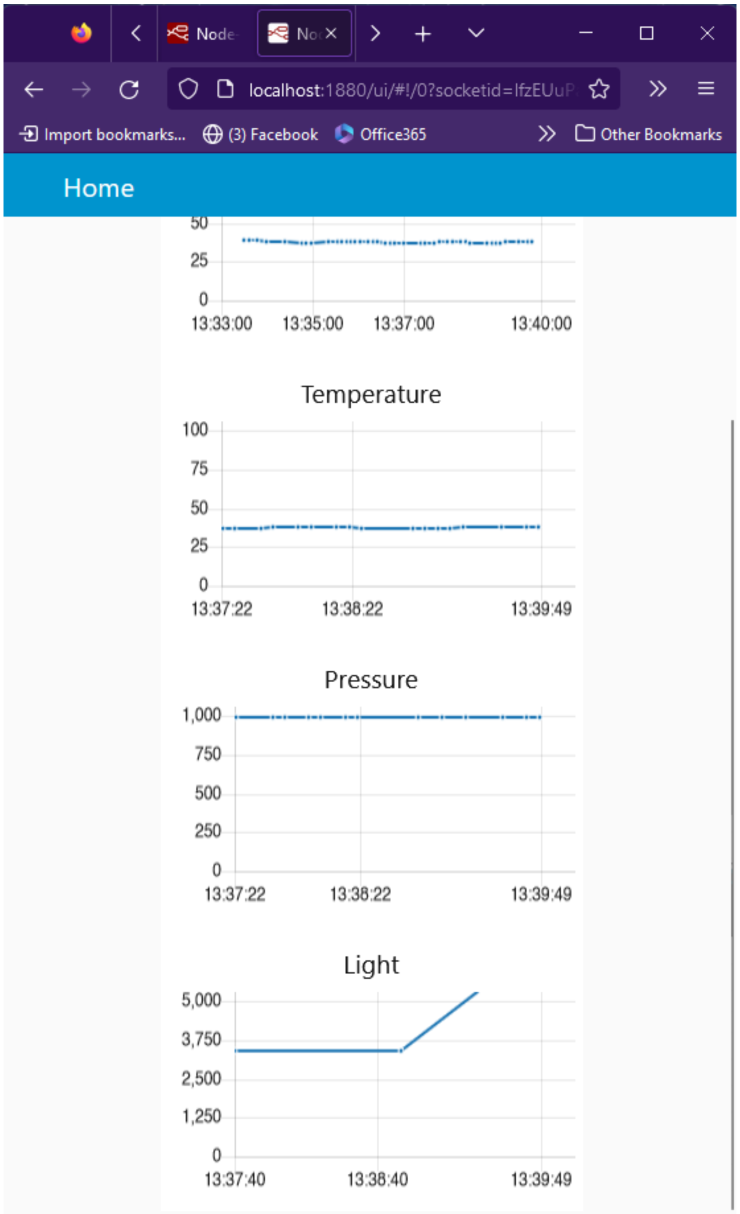
Wait for data to populate.



Now that you have seen how to visualize one topic, attempt to visualize the rest.

The resultant flow should look like this:


4ID3_G7/humidity
connected
debug 1
Humidity
4ID3_G7/temperature
connected
debug 2
Temperature
4ID3_G7/pressure
connected
debug 3
Pressure
4ID3_G7/light
connected
debug 4
Light



If values are not showing up, ensure that your y-axis scale is correct.

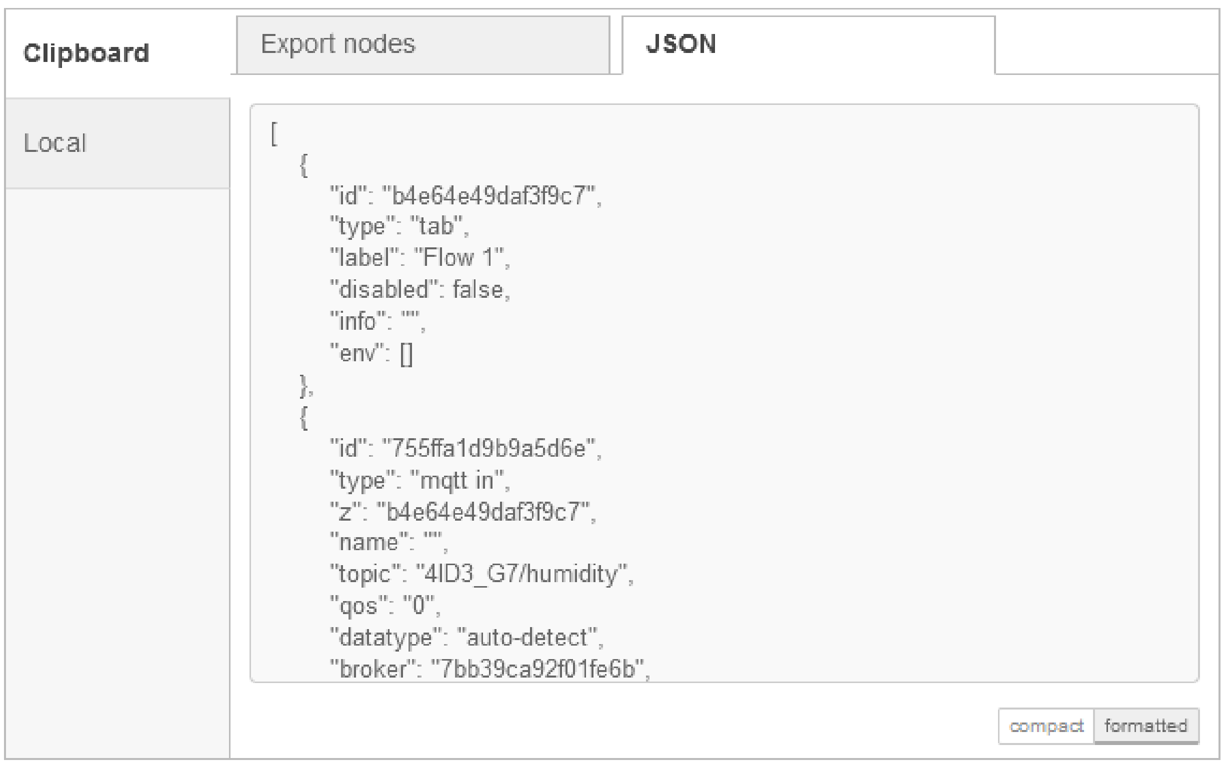
Saving and Pushing Your Project

Exporting a NodeRED Flow as JSON

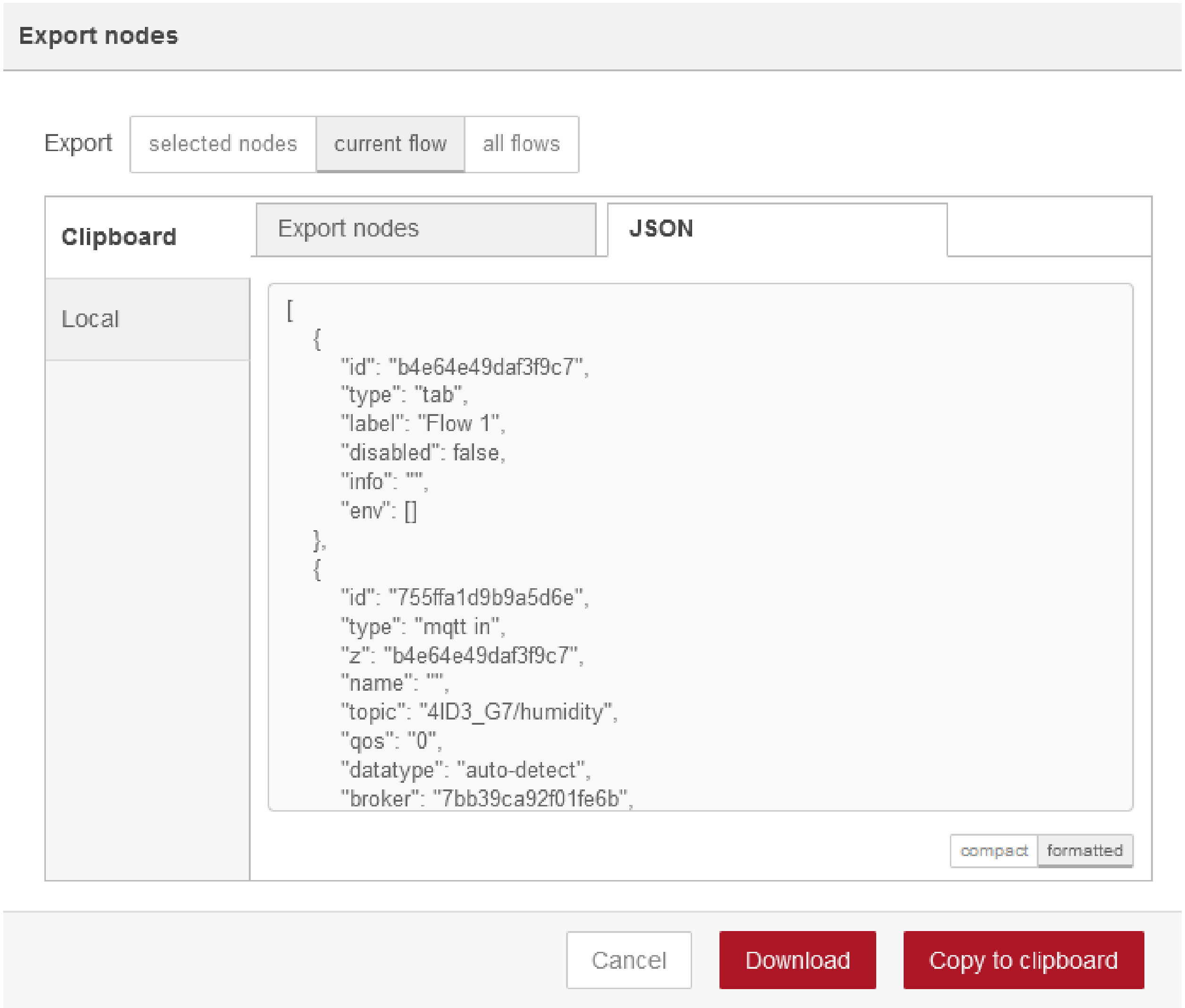
Click on the **hamburger menu** and select **export**.

Select **current flow**.

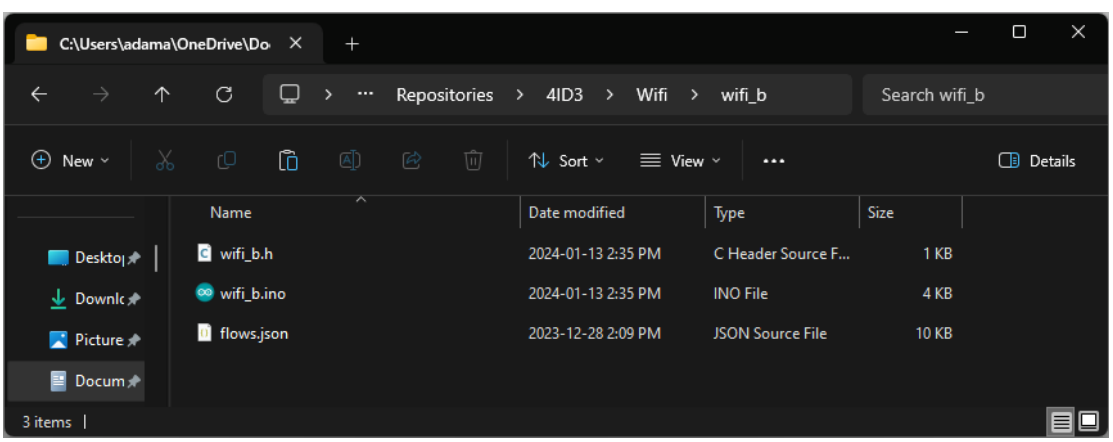
Select **JSON**.



Press **Download**.

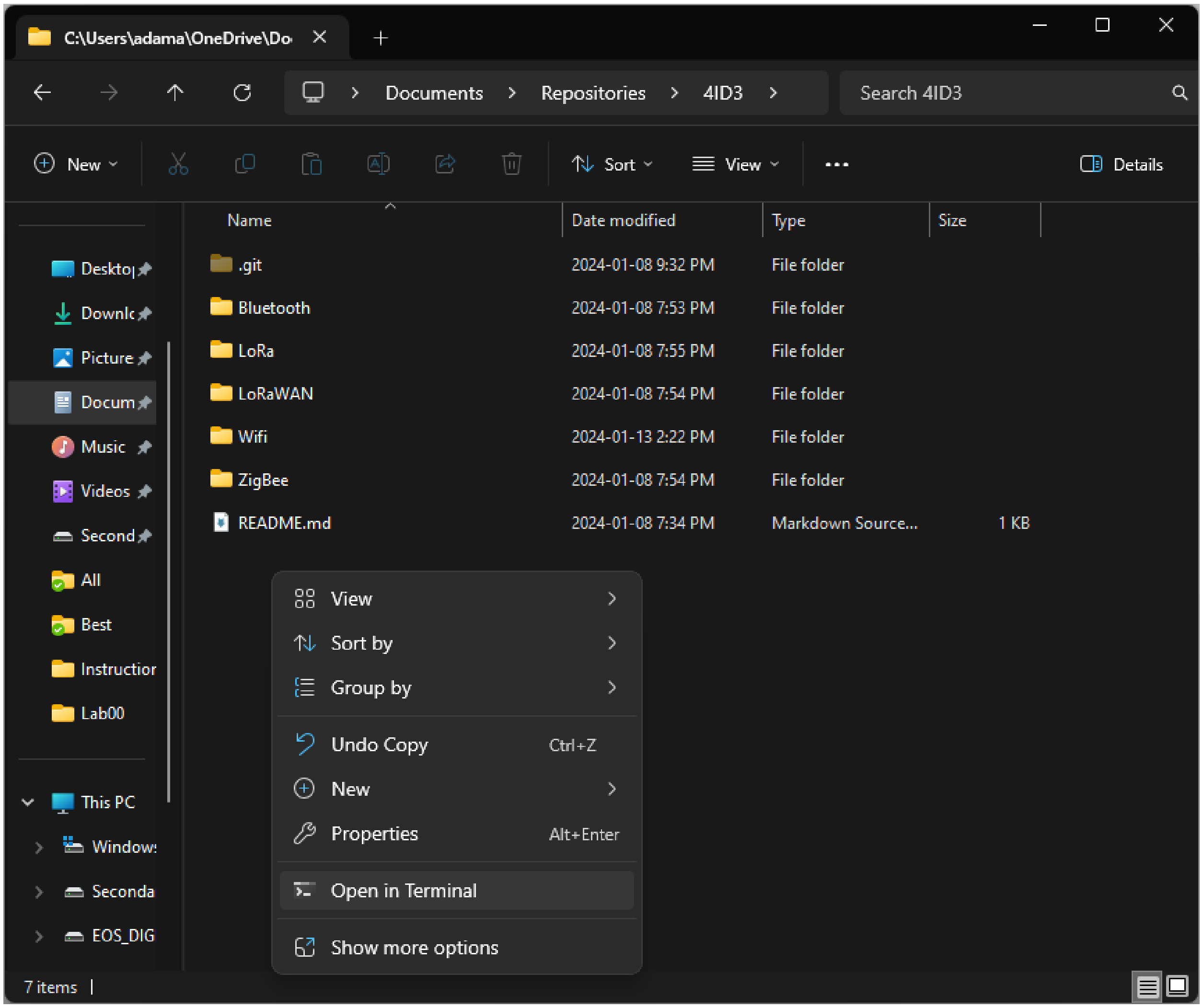


Cut and paste the **flows.json** file from your **Downloads/** folder to the **Wifi/** folder in the **local repo.**



Pushing Changes to GitHub

Right click on the root directory, *Repositories/4ID3/*, of your lab repository and select **Open with Terminal** from the context menu.



Use the diff command to compare the changes in your repo to the last commit in your **main** branch.

git diff main

:q

```
PS C:\Users\adama\OneDrive\Documents\Repositories\4ID3> git diff main
diff --git a/Wifi/wifi_a/wifi_a.h b/Wifi/wifi_a/wifi_a.h
deleted file mode 100644
index 2f31b31..0000000
--- a/Wifi/wifi_a/wifi_a.h
+++ /dev/null
@@ -1,22 +0,0 @@
-//DHT11 Libraries
-#include <Adafruit_Sensor.h>
-#include <DHT.h>
-#include <DHT_U.h>
-
-//BMP180 Libraries
-#include <Wire.h>
-#include <Adafruit_Sensor.h>
-#include <Adafruit_BMP085_U.h>
-
-//HP_BH1750 Libraries
-#include <hp_BH1750.h>
-
-//Macros
-#define DHTPIN 14
-#define DHTTYPE DHT11
-#define DELAY_BETWEEN_SAMPLES_MS 5000
-
-//Instantiate Sensor Objects
-DHT_Unified dht(DHTPIN, DHTTYPE);
-Adafruit_BMP085_Unified bmp = Adafruit_BMP085_Unified(10085);
-hp_BH1750 BH1750;
diff --git a/Wifi/wifi_a/wifi_a.ino b/Wifi/wifi_a/wifi_a.ino
```

Add your changes to the staging area.

git add .

```
PS C:\Users\adama\OneDrive\Documents\Repositories\4ID3> git add .
PS C:\Users\adama\OneDrive\Documents\Repositories\4ID3>
```

Commit these changes.

git commit -m "wifi lab complete"

```
PS C:\Users\adama\OneDrive\Documents\Repositories\4ID3> git commit -m "wifi lab complete"
[main 8019f43] wifi lab complete
 5 files changed, 613 insertions(+)
 create mode 100644 Wifi/wifi_a/wifi_a.h
 create mode 100644 Wifi/wifi_a/wifi_a.ino
 create mode 100644 Wifi/wifi_b/flows.json
 create mode 100644 Wifi/wifi_b/wifi_b.h
 create mode 100644 Wifi/wifi_b/wifi_b.ino
PS C:\Users\adama\OneDrive\Documents\Repositories\4ID3>
```

Verify that all your changes have been committed.

git status

```
PS C:\Users\adama\OneDrive\Documents\Repositories\4ID3> git status
On branch main
nothing to commit, working tree clean
PS C:\Users\adama\OneDrive\Documents\Repositories\4ID3>
```

View a list of all your commits.

git log

:q

```
PS C:\Users\adama\OneDrive\Documents\Repositories\4ID3> git log
commit a8020847e399a97478b9dd45e133b6ea3221a709 (HEAD -> main, origin/main)
Merge: 8019f43 adc1cda
Author: Adam <sokacza@mcmaster.ca>
Date:   Sat Jan 13 16:11:33 2024 -0500

    wifi lab complete
:...skipping...
commit a8020847e399a97478b9dd45e133b6ea3221a709 (HEAD -> main, origin/main)
Merge: 8019f43 adc1cda
Author: Adam <sokacza@mcmaster.ca>
Date:   Sat Jan 13 16:11:33 2024 -0500

    wifi lab complete

:...skipping...
commit a8020847e399a97478b9dd45e133b6ea3221a709 (HEAD -> main, origin/main)
Merge: 8019f43 adc1cda
Author: Adam <sokacza@mcmaster.ca>
Date:   Sat Jan 13 16:11:33 2024 -0500

    wifi lab complete

commit 8019f4383bc4e8fa8961fcc523ee136bf99402cc
:...skipping...
```

Push your changes to GitHub.

git push origin main

```
Windows PowerShell
PS C:\Users\adama\OneDrive\Documents\Repositories\4ID3> git push origin main
Enumerating objects: 29, done.
Counting objects: 100% (29/29), done.
Delta compression using up to 12 threads
Compressing objects: 100% (19/19), done.
Writing objects: 100% (26/26), 4.54 KiB | 1.13 MiB/s, done.
Total 26 (delta 5), reused 0 (delta 0), pack-reused 0
remote: Resolving deltas: 100% (5/5), completed with 1 local object.
To github.com:sokacza/4ID3_Labs.git
   adc1cda..a802084  main -> main
PS C:\Users\adama\OneDrive\Documents\Repositories\4ID3>
```

Use a web browser to confirm that GitHub reflects these changes.

END