

CPE 4040: Data Collection and Analysis, Spring 2024

# **Laboratory Report #2**

## **MQTT PUB/SUB on Raspberry Pi**

Team Members: Anindita Deb and Damisi Kayode

Electrical and Computer Engineering

Kennesaw State University

Faculty: Dr. Jeffrey L Yiin

Date of Lab Session: January 29, 2024

## I. Objective

1. Learn to create MQTT Broker on Raspberry Pi
2. Understand basic PUB/SUB messaging using Mosquitto MQTT package
3. Understand how to use MQTT messaging options (Topics) with Mosquitto

## II. Material List

### Software:

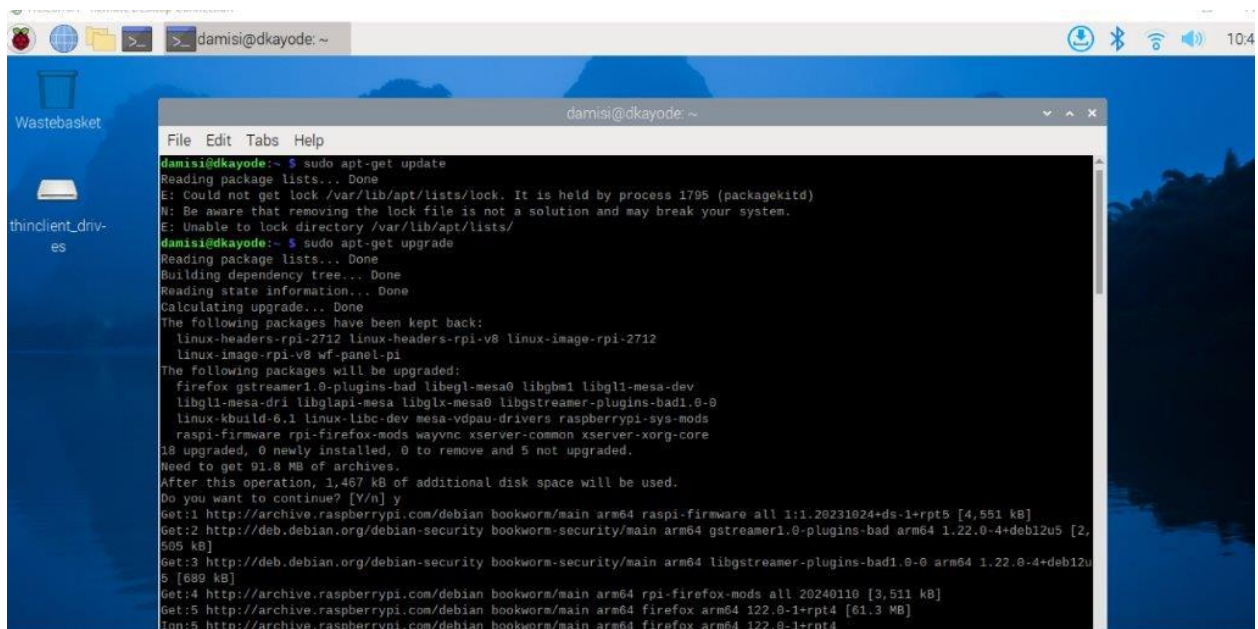
- MQTT
- PuTTY
- VNC Viewer

### Hardware:

- Raspberry Pi 4
- Power cord
- PC

## III. Lab Procedures and Results

1. Power up Pi and open Remote Desktop Connection on your laptop and connect to the raspberry Pi.
2. After login, we open the terminal window and update and upgrade the Linux packages.

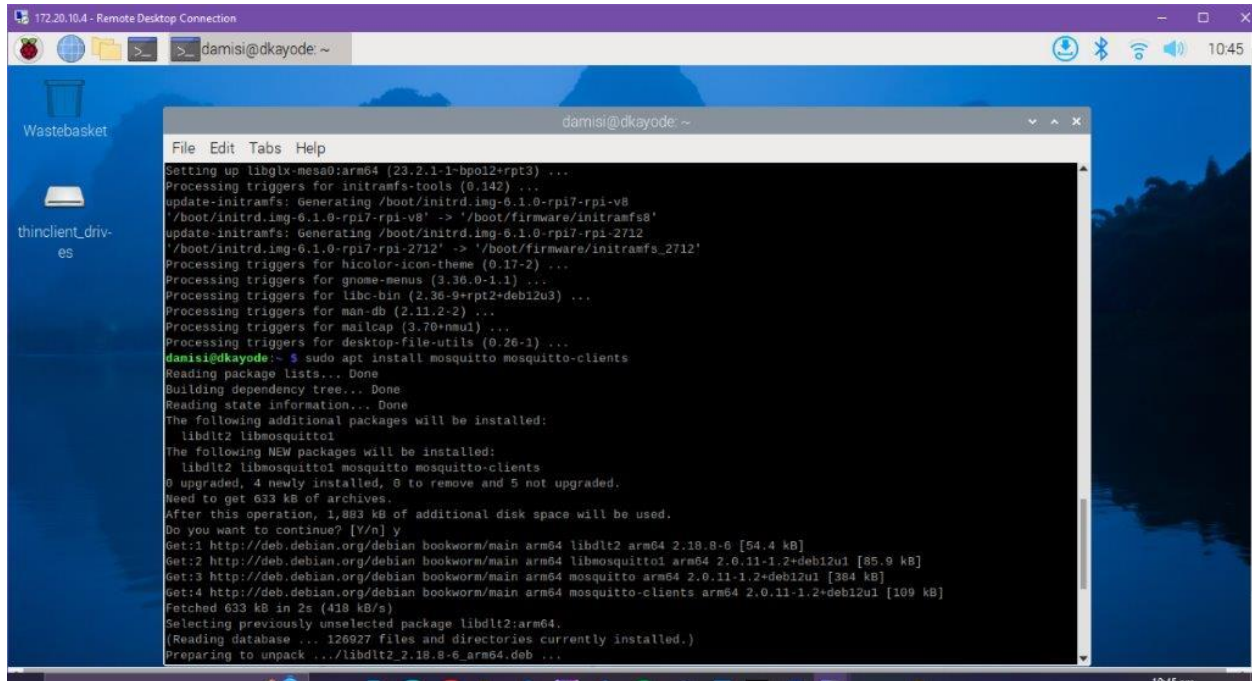


The screenshot shows a Raspberry Pi desktop with a blue background. A terminal window is open, displaying the following commands and output:

```
damisi@dkayode: ~  
File Edit Tabs Help  
damisi@dkayode:~$ sudo apt-get update  
Reading package lists... Done  
E: Could not get lock /var/lib/apt/lists/lock. It is held by process 1795 (packagekitd)  
N: Be aware that removing the lock file is not a solution and may break your system.  
E: Unable to lock directory /var/lib/apt/lists/  
damisi@dkayode:~$ sudo apt-get upgrade  
Reading package lists... Done  
Building dependency tree... Done  
Reading state information... Done  
Calculating upgrade... Done  
The following packages have been kept back:  
  linux-headers-rpi-2712 linux-headers-rpi-v8 linux-image-rpi-2712  
  linux-image-rpi-v8 wf-panel-pi  
The following packages will be upgraded:  
  firefox gstreamer1.0-plugins-bad libegl-mesa0 libgbm1 libgl1-mesa-dev  
  libgl1-mesa-dri libglapi-mesa libglx-mesa0 libgstreamer-plugins-bad1.0-0  
  linux-kbuild-6.1 linux-libc-dev mesa-vdpau-drivers raspberrypi-sys-modes  
  raspi-firmware rpi-firefox-mods wayvnc xserver-common xserver-xorg-core  
18 upgraded, 0 newly installed, 0 to remove and 5 not upgraded.  
Need to get 91.8 MB of archives.  
After this operation, 1,467 kB of additional disk space will be used.  
Do you want to continue? [Y/n] y  
Get:1 http://archive.raspberrypi.com/debian bookworm/main arm64 raspi-firmware all 1:1.20231024+ds-1+rrpt5 [4,551 kB]  
Get:2 http://deb.debian.org/debian-security bookworm-security/main arm64 gstreamer1.0-plugins-bad arm64 1.22.0-4+deb12u5 [2,505 kB]  
Get:3 http://deb.debian.org/debian-security bookworm-security/main arm64 libgstreamer-plugins-bad1.0-0 arm64 1.22.0-4+deb12u5 [689 kB]  
Get:4 http://archive.raspberrypi.com/debian bookworm/main arm64 rpi-firefox-mods all 20240110 [3,511 kB]  
Get:5 http://archive.raspberrypi.com/debian bookworm/main arm64 firefox arm64 122.0-1+rrpt4 [61.3 MB]  
Ign:5 http://archive.raspberrypi.com/debian bookworm/main arm64 firefox arm64 122.0-1+rrpt4
```

3. We need to create a MQTT Client/Broker (Publisher-subscriber) architecture with one broker and one publisher and 2 subscribers on the same Raspberry Pi.

a) “sudo apt install mosquito-clients”



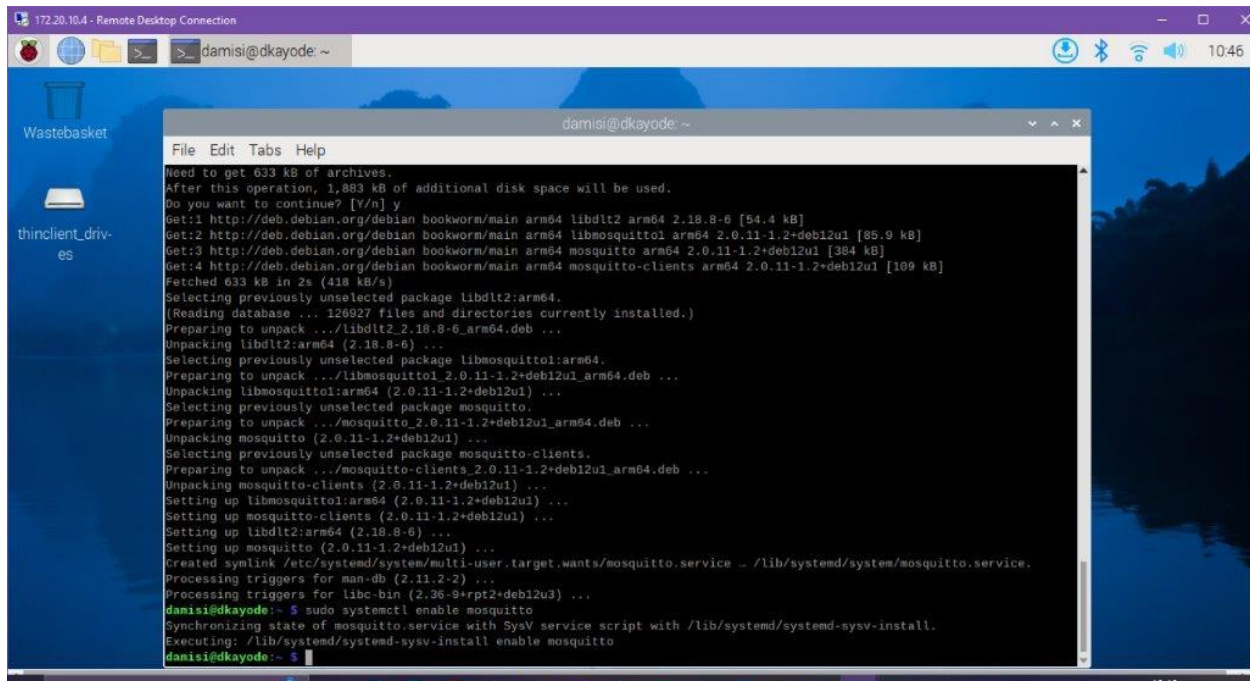
The screenshot shows a terminal window titled "damisi@dkayode: ~" with a file manager in the background. The terminal output shows the installation of mosquito-clients. The command "sudo apt install mosquito-clients" is entered, and the system shows the progress of installing the package, including downloading and unpacking files. The output is as follows:

```
Setting up libglx-mesa0:arm64 (23.2.1-1-bpo12+rpt3) ...
Processing triggers for initramfs-tools (0.142) ...
update-initramfs: Generating /boot/initrd.img-6.1.0-rpi7-rpi-v8
'/boot/initrd.img-6.1.0-rpi7-rpi-v8' -> '/boot/firmware/initramfs8'
update-initramfs: Generating /boot/initrd.img-6.1.0-rpi7-rpi-2712
'/boot/initrd.img-6.1.0-rpi7-rpi-2712' -> '/boot/firmware/initramfs_2712'
Processing triggers for hicolor-icon-theme (0.17-2) ...
Processing triggers for gnome-menus (3.30.0-1.1) ...
Processing triggers for libc-bin (2.36-9+rpt2+deb12u3) ...
Processing triggers for man-db (2.11.2-2) ...
Processing triggers for mailcap (3.70+nmul) ...
Processing triggers for desktop-file-utils (0.26-1) ...
damisi@dkayode:~$ sudo apt install mosquito-clients
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following additional packages will be installed:
  libdlt2 libmosquitto1
The following NEW packages will be installed:
  libdlt2 libmosquitto1 mosquito mosquitto-clients
0 upgraded, 4 newly installed, 0 to remove and 5 not upgraded.
Need to get 633 kB of archives.
After this operation, 1,883 kB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://deb.debian.org/debian bookworm/main arm64 libdlt2 arm64 2.18.8-6 [54.4 kB]
Get:2 http://deb.debian.org/debian bookworm/main arm64 libmosquitto1 arm64 2.0.11-1.2+deb12u1 [85.9 kB]
Get:3 http://deb.debian.org/debian bookworm/main arm64 mosquito arm64 2.0.11-1.2+deb12u1 [384 kB]
Get:4 http://deb.debian.org/debian bookworm/main arm64 mosquitto-clients arm64 2.0.11-1.2+deb12u1 [109 kB]
Fetched 633 kB in 2s (418 kB/s)
Selecting previously unselected package libdlt2:arm64.
(Reading database ... 126927 files and directories currently installed.)
Preparing to unpack .../libdlt2_2.18.8-6_arm64.deb ...
```

- b) Enable the broker and allow it to auto-start after reboot (Question: What does “systemctl” do? The systemctl is used for managing system services.

“sudo systemctl enable mosquito”

## CPE4040 Lab Report

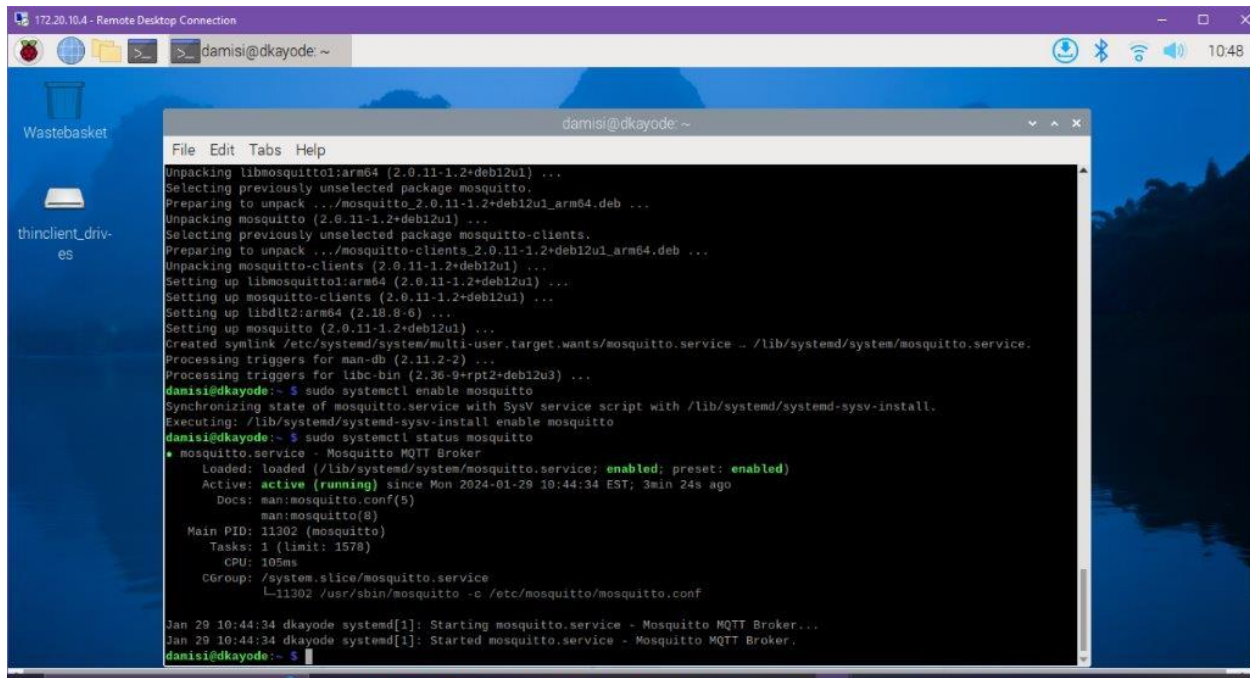


```
172.20.10.4 - Remote Desktop Connection
damisi@dkayode: ~

File Edit Tabs Help

Need to get 633 kB of archives.
After this operation, 1,883 kB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://deb.debian.org/debian bookworm/main arm64 libdlt2 arm64 2.18.8-6 [54.4 kB]
Get:2 http://deb.debian.org/debian bookworm/main arm64 libmosquitto1 arm64 2.0.11-1.2+deb12u1 [85.9 kB]
Get:3 http://deb.debian.org/debian bookworm/main arm64 mosquitto arm64 2.0.11-1.2+deb12u1 [384 kB]
Get:4 http://deb.debian.org/debian bookworm/main arm64 mosquitto-clients arm64 2.0.11-1.2+deb12u1 [109 kB]
Fetched 633 kB in 2s (418 kB/s)
Selecting previously unselected package libdlt2:arm64.
(Reading database ... 126927 files and directories currently installed.)
Preparing to unpack .../libdlt2_2.18.8-6_arm64.deb ...
Unpacking libdlt2:arm64 (2.18.8-6) ...
Selecting previously unselected package libmosquitto1:arm64.
Preparing to unpack .../libmosquitto1_2.0.11-1.2+deb12u1_arm64.deb ...
Unpacking libmosquitto1:arm64 (2.0.11-1.2+deb12u1) ...
Selecting previously unselected package mosquitto.
Preparing to unpack .../mosquitto_2.0.11-1.2+deb12u1_arm64.deb ...
Unpacking mosquitto (2.0.11-1.2+deb12u1) ...
Selecting previously unselected package mosquitto-clients.
Preparing to unpack .../mosquitto-clients_2.0.11-1.2+deb12u1_arm64.deb ...
Unpacking mosquitto-clients (2.0.11-1.2+deb12u1) ...
Setting up libmosquitto1:arm64 (2.0.11-1.2+deb12u1) ...
Setting up mosquitto-clients (2.0.11-1.2+deb12u1) ...
Setting up libdlt2:arm64 (2.18.8-6) ...
Setting up mosquitto (2.0.11-1.2+deb12u1) ...
Created symlink /etc/systemd/system/multi-user.target.wants/mosquitto.service → /lib/systemd/system/mosquitto.service.
Processing triggers for man-db (2.11.2-2) ...
Processing triggers for libc-bin (2.36-9+rpt2+deb12u3) ...
damisi@dkayode:~$ sudo systemctl enable mosquitto
Synchronizing state of mosquitto.service with SysV service script with /lib/systemd/systemd-sysv-install.
Executing: /lib/systemd/systemd-sysv-install enable mosquitto
damisi@dkayode:~$
```

c) The broker should be running. You can confirm by entering “sudo systemctl status mosquitto”.



```
172.20.10.4 - Remote Desktop Connection
damisi@dkayode: ~

File Edit Tabs Help

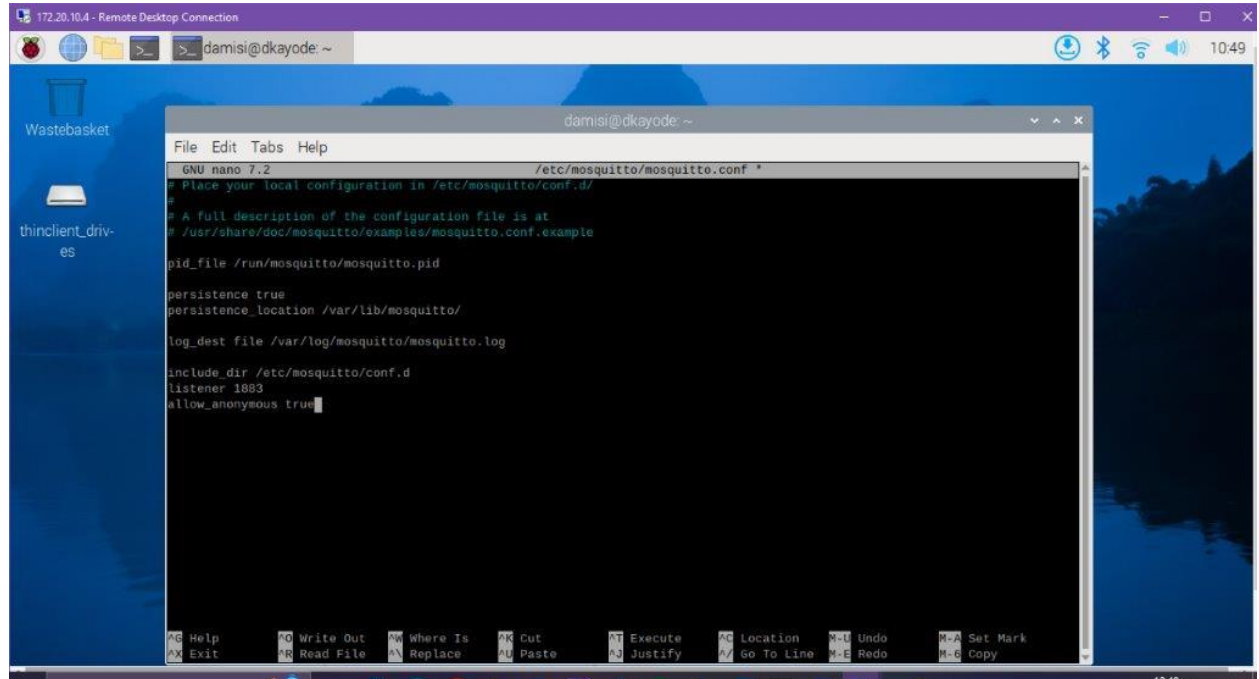
Unpacking libmosquitto1:arm64 (2.0.11-1.2+deb12u1) ...
Selecting previously unselected package mosquitto.
Preparing to unpack .../mosquitto_2.0.11-1.2+deb12u1_arm64.deb ...
Unpacking mosquitto (2.0.11-1.2+deb12u1) ...
Selecting previously unselected package mosquitto-clients.
Preparing to unpack .../mosquitto-clients_2.0.11-1.2+deb12u1_arm64.deb ...
Unpacking mosquitto-clients (2.0.11-1.2+deb12u1) ...
Setting up libmosquitto1:arm64 (2.0.11-1.2+deb12u1) ...
Setting up mosquitto-clients (2.0.11-1.2+deb12u1) ...
Setting up libdlt2:arm64 (2.18.8-6) ...
Setting up mosquitto (2.0.11-1.2+deb12u1) ...
Created symlink /etc/systemd/system/multi-user.target.wants/mosquitto.service → /lib/systemd/system/mosquitto.service.
Processing triggers for man-db (2.11.2-2) ...
Processing triggers for libc-bin (2.36-9+rpt2+deb12u3) ...
damisi@dkayode:~$ sudo systemctl enable mosquitto
Synchronizing state of mosquitto.service with SysV service script with /lib/systemd/systemd-sysv-install.
Executing: /lib/systemd/systemd-sysv-install enable mosquitto
damisi@dkayode:~$ sudo systemctl status mosquitto
● mosquitto.service - Mosquitto MQTT Broker
   Loaded: loaded (/lib/systemd/system/mosquitto.service; enabled; preset: enabled)
   Active: active (running) since Mon 2024-01-29 10:44:34 EST; 3min 24s ago
     Docs: man:mosquitto.conf(5)
           man:mosquitto(8)
    Main PID: 11302 (mosquitto)
      Tasks: 1 (limit: 1578)
        CPU: 105ms
    CGroup: /system.slice/mosquitto.service
            └─11302 /usr/sbin/mosquitto -c /etc/mosquitto/mosquitto.conf

Jan 29 10:44:34 dkayode systemd[1]: Starting mosquitto.service - Mosquitto MQTT Broker...
Jan 29 10:44:34 dkayode systemd[1]: Started mosquitto.service - Mosquitto MQTT Broker.
damisi@dkayode:~$
```

d) Before publishing and sending messages to the broker, a few settings need to be configured. “sudo nano /etc/mosquitto/mosquitto.conf”

- e) Once in the file, navigate to the bottom of the file. Add the following two lines of code at the bottom:

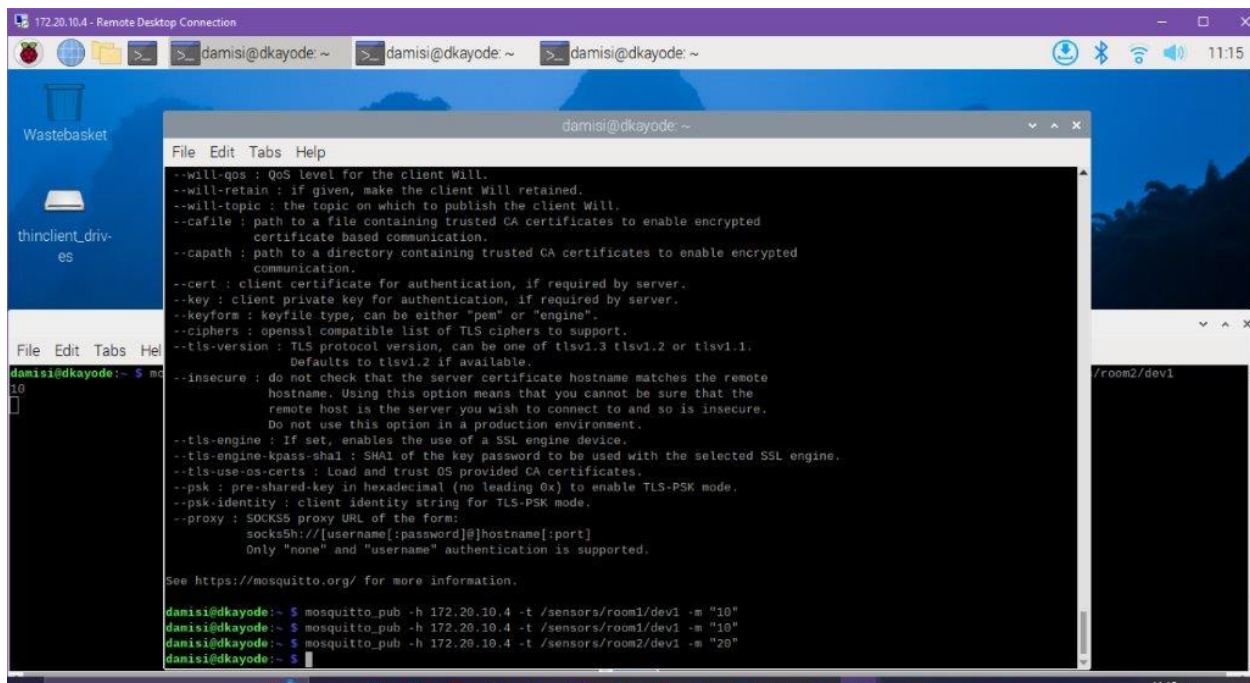
```
"listener 1883"
"allow_anonymous true"
```



- f) Save and execute the following line `"sudo systemctl restart mosquitto"`
4. Open two additional Terminal windows. Now you should have three open terminals. Make a note that one of them is for "Publisher" and the other two are for "Subscriber 1" and "Subscriber 2", respectively.
  5. We set up subscriber 1 in terminal 1 to a "topic": `mosquitto_sub -h -t /sensors/room1/dev1`
  6. We repeat the steps from 5 to terminal 2 for subscriber 2 now: `mosquitto_sub -h -t /sensors/room2/dev1`
  7. In the Publisher Terminal we start to publish messages to the newly created topics



## CPE4040 Lab Report



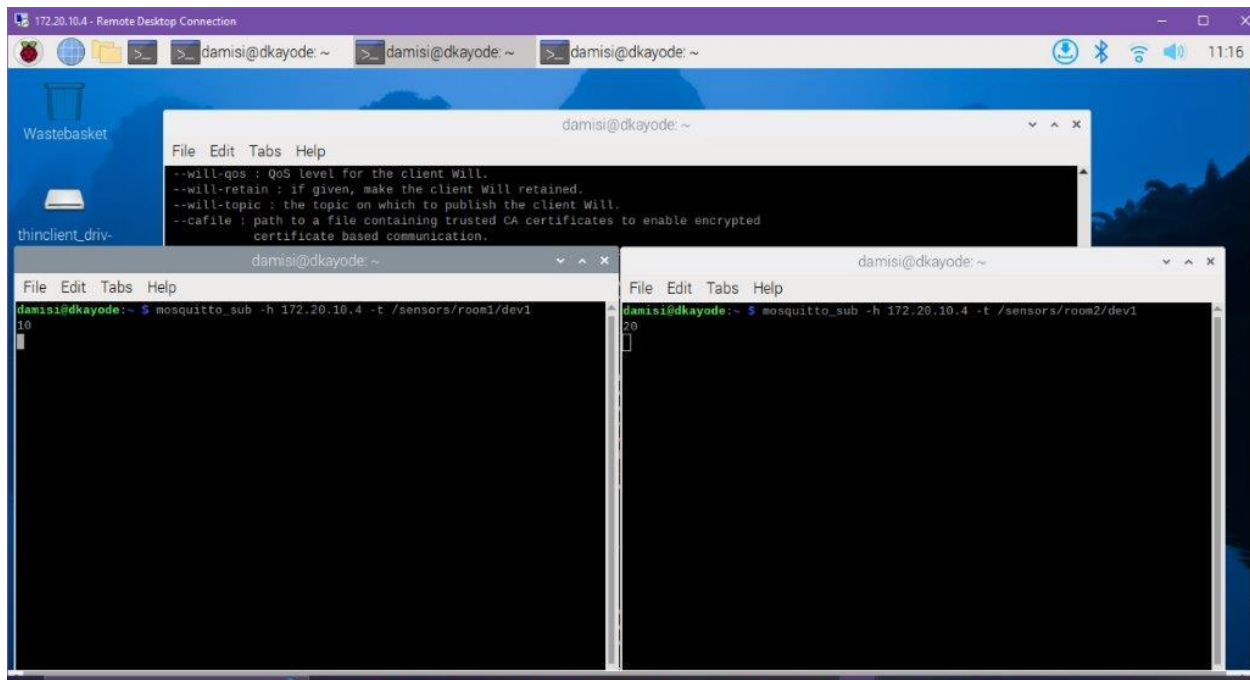
```
172.20.10.4 - Remote Desktop Connection
damisi@dkayode: ~
damisi@dkayode: ~
damisi@dkayode: ~
11:15

File Edit Tabs Help
--will-qos : QoS level for the client Will.
--will-retain : If given, make the client Will retained.
--will-topic : the topic on which to publish the client Will.
--cafile : path to a file containing trusted CA certificates to enable encrypted
certificate based communication.
--capath : path to a directory containing trusted CA certificates to enable encrypted
communication.
--cert : client certificate for authentication, if required by server.
--key : client private key for authentication, if required by server.
--keyform : keyfile type, can be either "pem" or "engine".
--ciphers : openssl compatible list of TLS ciphers to support.
--tls-version : TLS protocol version, can be one of tlsv1.3 tlsv1.2 or tlsv1.1.
Defaults to tlsv1.2 if available.
--insecure : do not check that the server certificate hostname matches the remote
hostname. Using this option means that you cannot be sure that the
remote host is the server you wish to connect to and so is insecure.
Do not use this option in a production environment.
--tls-engine : If set, enables the use of a SSL engine device.
--tls-engine-kpass-sha1 : SHA1 of the key password to be used with the selected SSL engine.
--tls-use-os-certs : Load and trust OS provided CA certificates.
--psk : pre-shared-key in hexadecimal (no leading 0x) to enable TLS-PSK mode.
--psk-identity : client identity string for TLS-PSK mode.
--proxy : SOCKS5 proxy URL of the form:
socks5h://[username[:password]@]hostname[:port]
Only "none" and "username" authentication is supported.

See https://mosquitto.org/ for more information.

damisi@dkayode:~ $ mosquitto_pub -h 172.20.10.4 -t /sensors/room1/dev1 -m "10"
damisi@dkayode:~ $ mosquitto_pub -h 172.20.10.4 -t /sensors/room1/dev1 -m "10"
damisi@dkayode:~ $ mosquitto_pub -h 172.20.10.4 -t /sensors/room2/dev1 -m "20"
damisi@dkayode:~ $
```

8. We view if the messages were received by terminals for subscriber 1 and subscriber 2.



```
172.20.10.4 - Remote Desktop Connection
damisi@dkayode: ~
damisi@dkayode: ~
damisi@dkayode: ~
11:16

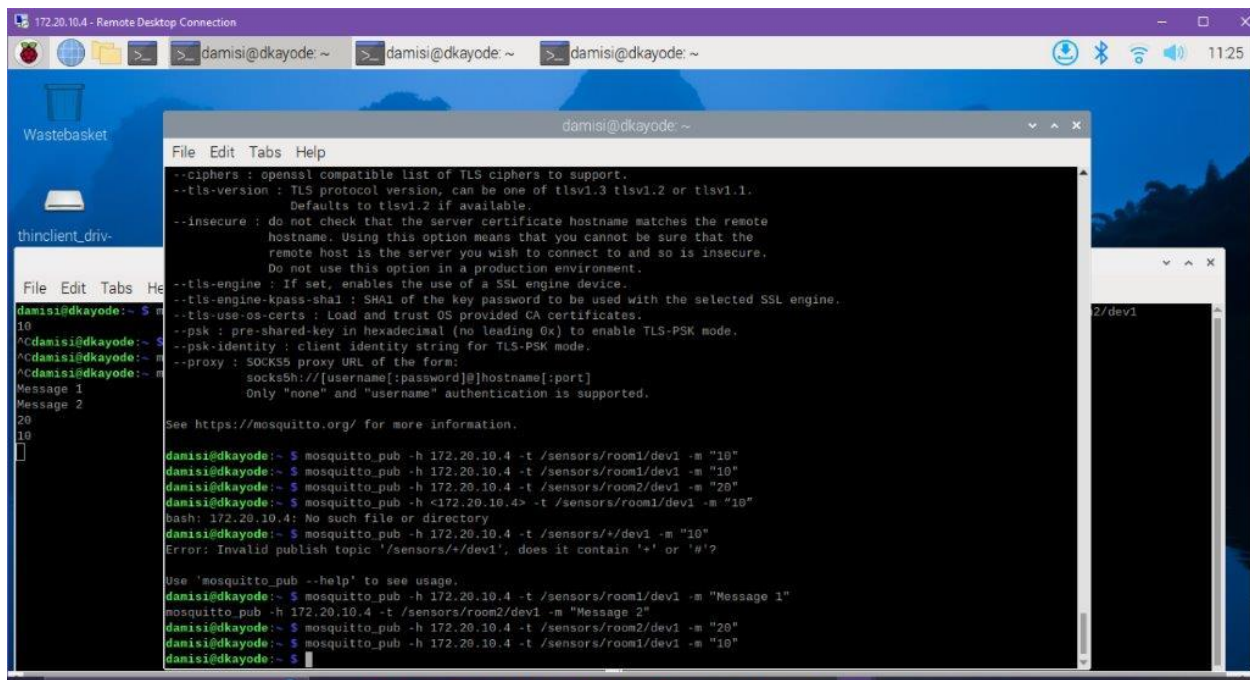
File Edit Tabs Help
--will-qos : QoS level for the client Will.
--will-retain : If given, make the client Will retained.
--will-topic : the topic on which to publish the client Will.
--cafile : path to a file containing trusted CA certificates to enable encrypted
certificate based communication.

damisi@dkayode:~ $ mosquitto_sub -h 172.20.10.4 -t /sensors/room1/dev1
10

damisi@dkayode:~ $ mosquitto_sub -h 172.20.10.4 -t /sensors/room2/dev1
20
```

9. Topic Wildcard: We go back to subscriber 1 and change topic to `"/sensors/+/dev1"`. Subscriber 1 should receive both messages while Subscriber 2 only receives the second message.

## CPE4040 Lab Report



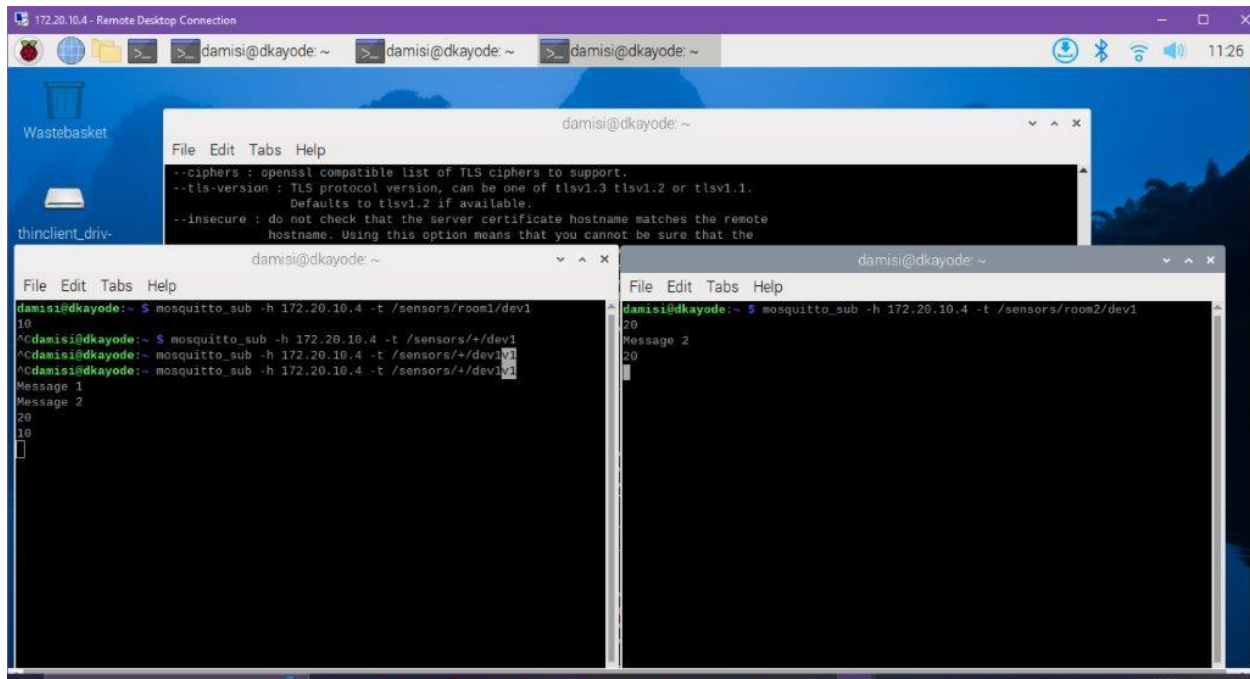
```
172.20.10.4 - Remote Desktop Connection
damisi@dkayode: ~
damisi@dkayode: ~
damisi@dkayode: ~

File Edit Tabs Help
--ciphers : openssl compatible list of TLS ciphers to support.
--tls-version : TLS protocol version, can be one of tlsv1.3 tlsv1.2 or tlsv1.1.
Defaults to tlsv1.2 if available.
--insecure : do not check that the server certificate hostname matches the remote
hostname. Using this option means that you cannot be sure that the
remote host is the server you wish to connect to and so is insecure.
Do not use this option in a production environment.
--tls-engine : If set, enables the use of a SSL engine device.
--tls-engine-kpass-sha1 : SHA1 of the key password to be used with the selected SSL engine.
--tls-use-os-certs : Load and trust OS provided CA certificates.
--psk : pre-shared-key in hexadecimal (no leading 0x) to enable TLS-PSK mode.
--psk-identity : client identity string for TLS-PSK mode.
--proxy : SOCKS proxy URL of the form:
socksSh://[username[:password]@]hostname[:port]
Only "none" and "username" authentication is supported.

See https://mosquitto.org/ for more information.

damisi@dkayode:~ $ mosquitto_pub -h 172.20.10.4 -t /sensors/room1/dev1 -m "10"
damisi@dkayode:~ $ mosquitto_pub -h 172.20.10.4 -t /sensors/room1/dev1 -m "10"
damisi@dkayode:~ $ mosquitto_pub -h 172.20.10.4 -t /sensors/room2/dev1 -m "20"
damisi@dkayode:~ $ mosquitto_pub -h <172.20.10.4> -t /sensors/room1/dev1 -m "10"
bash: 172.20.10.4: No such file or directory
damisi@dkayode:~ $ mosquitto_pub -h 172.20.10.4 -t /sensors/+/dev1 -m "10"
Error: Invalid publish topic '/sensors/+/dev1', does it contain '+' or '#'?

Use 'mosquitto_pub --help' to see usage.
damisi@dkayode:~ $ mosquitto_pub -h 172.20.10.4 -t /sensors/room1/dev1 -m "Message 1"
mosquitto_pub -h 172.20.10.4 -t /sensors/room2/dev1 -m "Message 2"
damisi@dkayode:~ $ mosquitto_pub -h 172.20.10.4 -t /sensors/room2/dev1 -m "20"
damisi@dkayode:~ $ mosquitto_pub -h 172.20.10.4 -t /sensors/room1/dev1 -m "10"
damisi@dkayode:~ $
```



```
172.20.10.4 - Remote Desktop Connection
damisi@dkayode: ~
damisi@dkayode: ~
damisi@dkayode: ~

File Edit Tabs Help
--ciphers : openssl compatible list of TLS ciphers to support.
--tls-version : TLS protocol version, can be one of tlsv1.3 tlsv1.2 or tlsv1.1.
Defaults to tlsv1.2 if available.
--insecure : do not check that the server certificate hostname matches the remote
hostname. Using this option means that you cannot be sure that the

damisi@dkayode:~
damisi@dkayode:~

File Edit Tabs Help
damisi@dkayode:~ $ mosquitto_sub -h 172.20.10.4 -t /sensors/room1/dev1
10
^Cdamisi@dkayode:~ $ mosquitto_sub -h 172.20.10.4 -t /sensors/+/dev1
^Cdamisi@dkayode:~ $ mosquitto_sub -h 172.20.10.4 -t /sensors/+/dev1
^Cdamisi@dkayode:~ $ mosquitto_sub -h 172.20.10.4 -t /sensors/+/dev1
Message 1
Message 2
20
10
[]

File Edit Tabs Help
damisi@dkayode:~ $ mosquitto_sub -h 172.20.10.4 -t /sensors/room2/dev1
20
Message 2
20
[]
```

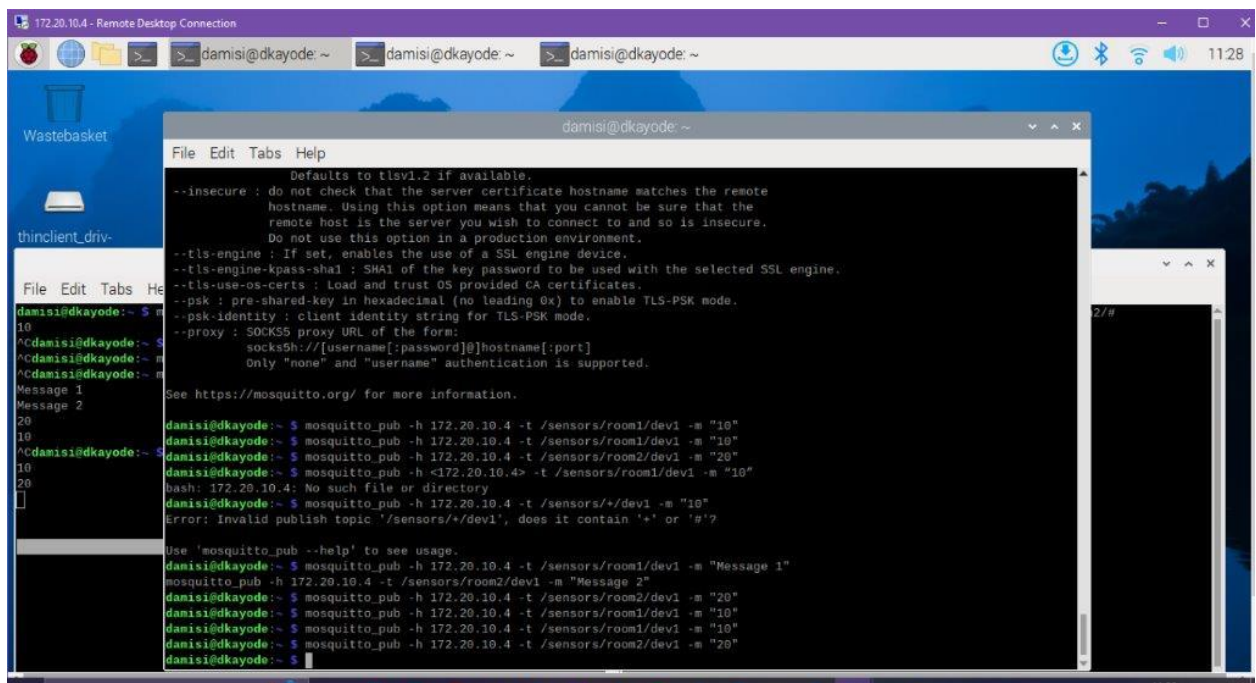
10. Topic Wildcard 2: For Subscriber 1, subscribe to the topic: /sensors/#. Then for Subscriber 2, subscribe to the topic: /sensors/room2/#.

We will send messages similar to those in Step 8, however, using different room numbers and device numbers in each case. Observe and explain the results for both subscribers.

### Explain the Results found in this step.

Subscriber 1 receives the message "10" and "20" because it subscribed to the topic `/sensors/room1/dev1`.

Subscriber 2 will receive the message "20" because it subscribed to the topic `/sensors/room2/dev1`.



The screenshot shows a Remote Desktop Connection to a machine named 172.20.10.4. The desktop environment includes a 'Wastebasket' icon, a 'thinclient\_drive' icon, and a terminal window. The terminal window displays the following commands and output:

```

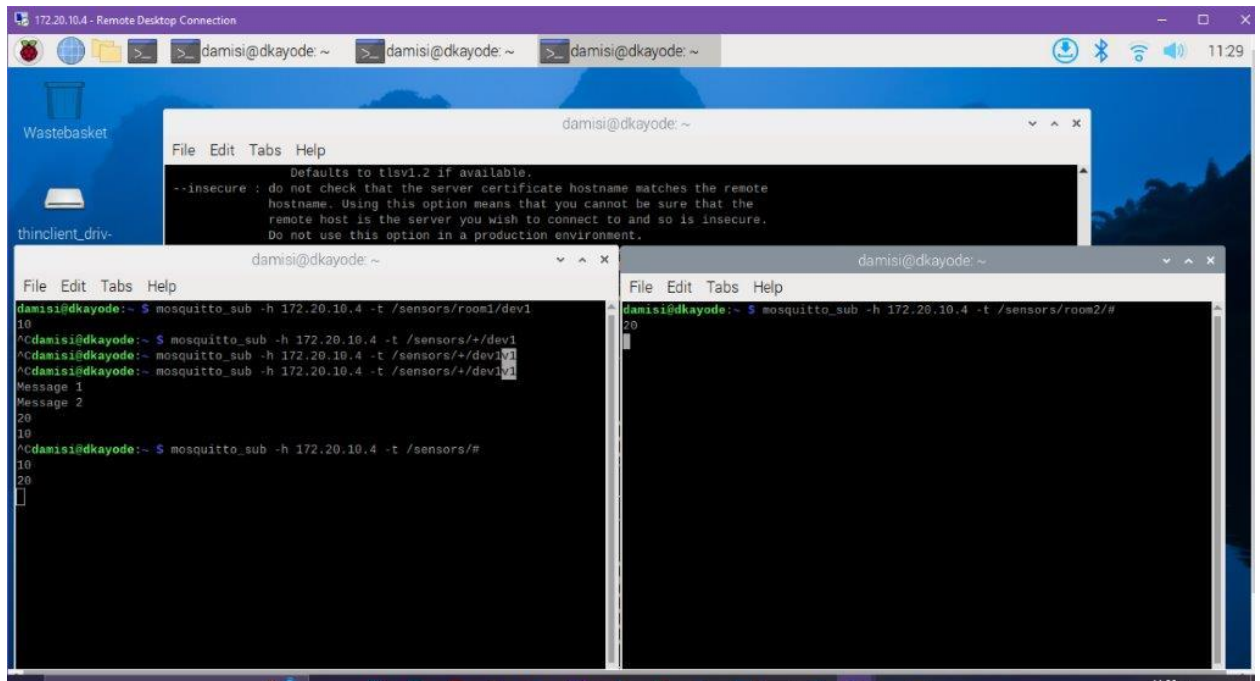
damisi@dkayode:~$ mosquitto_pub -h 172.20.10.4 -t /sensors/room1/dev1 -m "10"
damisi@dkayode:~$ mosquitto_pub -h 172.20.10.4 -t /sensors/room1/dev1 -m "10"
damisi@dkayode:~$ mosquitto_pub -h 172.20.10.4 -t /sensors/room2/dev1 -m "20"
damisi@dkayode:~$ mosquitto_pub -h <172.20.10.4> -t /sensors/room1/dev1 -m "10"
bash: 172.20.10.4: No such file or directory
damisi@dkayode:~$ mosquitto_pub -h 172.20.10.4 -t /sensors/+/dev1 -m "10"
Error: Invalid publish topic '/sensors/+/dev1', does it contain '+' or '#'?

Use 'mosquitto_pub --help' to see usage.
damisi@dkayode:~$ mosquitto_pub -h 172.20.10.4 -t /sensors/room1/dev1 -m "Message 1"
mosquitto_pub -h 172.20.10.4 -t /sensors/room2/dev1 -m "Message 2"
damisi@dkayode:~$ mosquitto_pub -h 172.20.10.4 -t /sensors/room2/dev1 -m "20"
damisi@dkayode:~$ mosquitto_pub -h 172.20.10.4 -t /sensors/room1/dev1 -m "10"
damisi@dkayode:~$ mosquitto_pub -h 172.20.10.4 -t /sensors/room1/dev1 -m "10"
damisi@dkayode:~$ mosquitto_pub -h 172.20.10.4 -t /sensors/room2/dev1 -m "20"

```

A file explorer window is also open, showing the contents of the 'thinclient\_drive'.





11. Handshaking messages and QoS: For Publisher and Subscriber 1, enable debug messages using the option “-d” to observe handshaking messages on both sides. Use option “-q” to change the QoS flags (0, 1, 2) on both Publisher and Subscriber and observe the result.

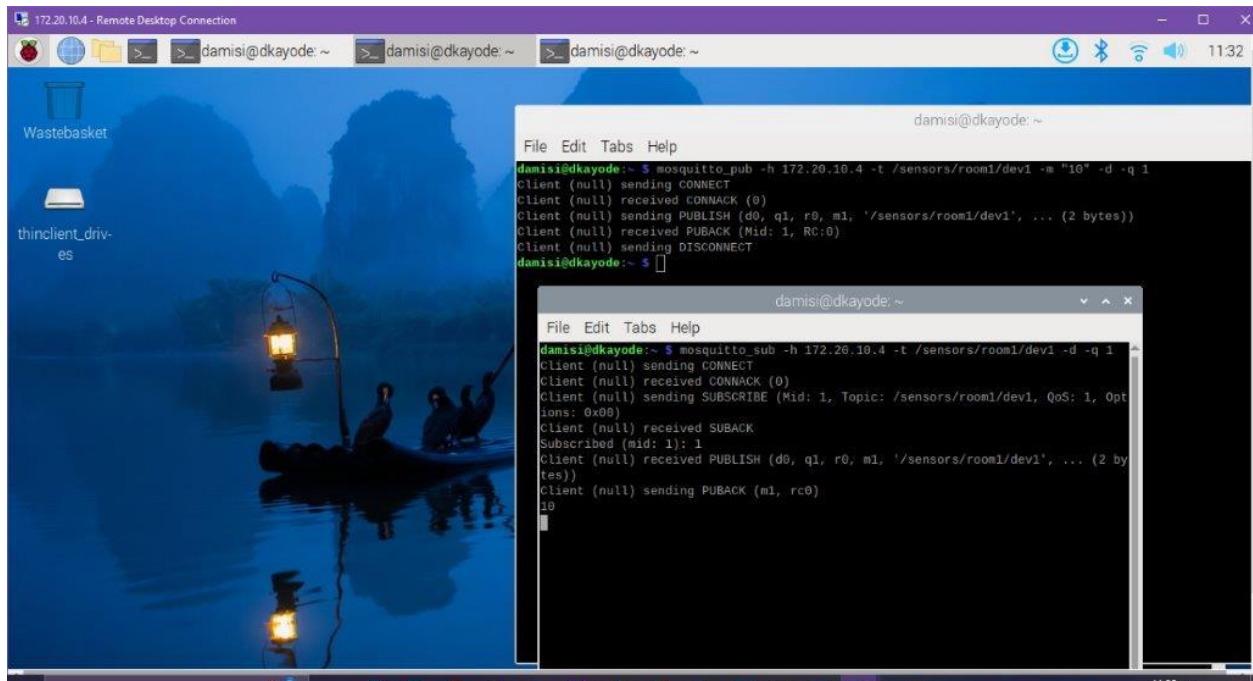
```
mosquitto_sub -h -t /sensors/room1/dev1 -d -q 1
```

```
mosquitto_pub -h -t /sensors/room1/dev1 -m "10" -d -q 1
```

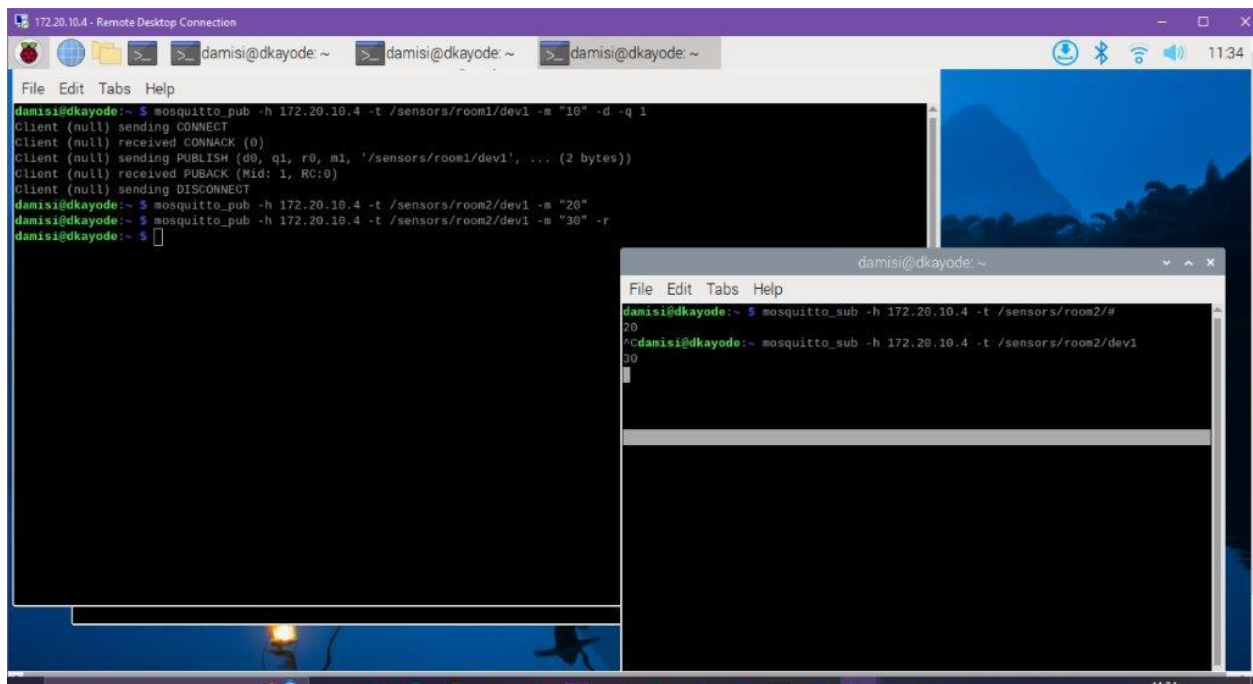
**Explain the differences between the message exchange.**

By choosing QoS level 1 and adding the -d option, you make sure messages are sent more reliably between the subscriber and publisher. QoS 1 ensures messages are delivered at least once, and the -d option helps in understanding the communication process by showing extra details about the message exchange. It is like a safety measure for more dependable communication.

## CPE4040 Lab Report



12. Retained messages: Go back to Subscriber 2 Terminal and stop the client. We will now go to the Publisher and send the same message from previous step with the addition of `-r`.
- ```
mosquitto_pub -h -t /sensors/room2/dev1 -m "30" -r
```



**Post Lab Exercise:**

<https://community.element14.com/members-area/personalblogs/b/blog/posts/get-an-email-from-your-raspberry-pi-with-its-ip-address>



```
PuTTY (inactive)
login as: damisi
damisi@172.20.10.4's password:
Linux dkayode 6.1.0-rpi7-rpi-v8 #1 SMP PREEMPT Debian 1:6.1.63-1+rpt1 (2023-11-2
*) sarch64

The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
Last login: Mon Jan 29 11:38:29 2024
damisi@dkayode:~$ nano ipaddress.py
damisi@dkayode:~$ sudo cron
no cronab for root - using an empty one

Select an editor. To change later, run 'select-editor'.
 1. /bin/nano      <---- easiest
 2. /usr/bin/vim.tiny
 3. /bin/ed

Choose 1-3 [1]: 1
cronab: installing new cronab
damisi@dkayode:~$
damisi@dkayode:~$ sudo reboot

Broadcast message from root@dkayode on pts/2 (Wed 2024-02-07 22:07:22 EST):

The system will reboot now!

damisi@dkayode:~$
```

## IV. Conclusion

The overall lab was not hard to complete step by step. The directions were clear in what we had to document and the various screenshots we needed to show we had achieved the goal. If I had to improve the lab directions, I would make it clear with a marker or indicator when screenshots were required. We paused every step to determine whether it was necessary or not and how many screenshots would be needed to display all information was covered.

We did run into problems with the post lab section. We were not able to send the IP address through email from our Pi. Terminal would open the file on PuTTY but not give us the IP address given the downloaded file contents.