

# 通訊網路實驗

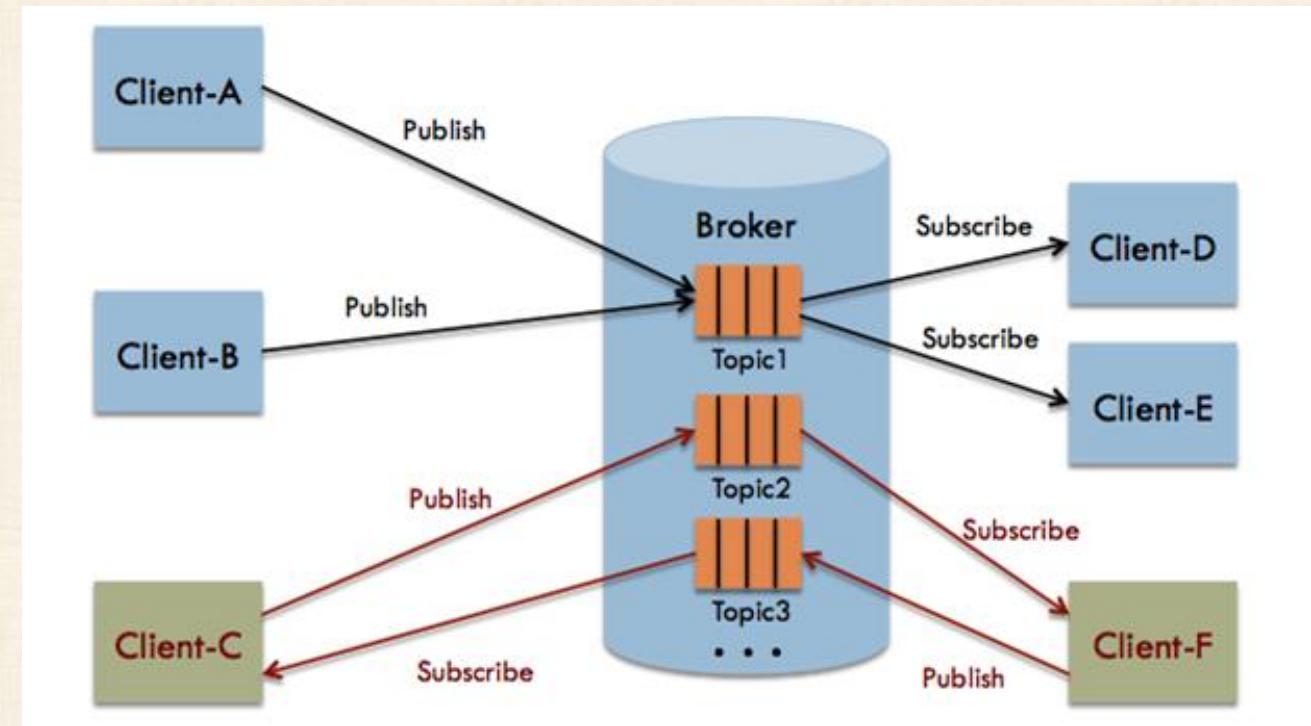
## MQTT

Dept. of Electrical and Computer Engineering (ECE)  
**National Yang Ming Chiao Tung University**

# 課程大綱

## □ 1. 認識 MQTT 及其應用

- Publisher
- Subscriber
- Broker

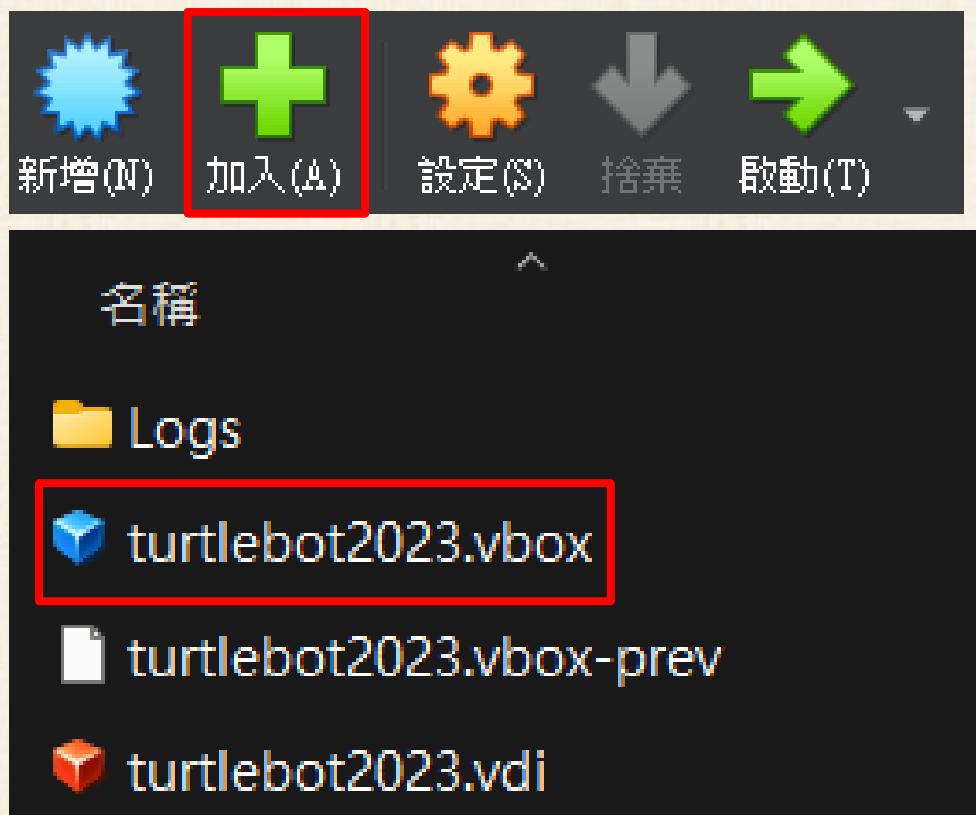


# 結報題目

- 本次Lab不用Demo
- Q1、Q2：基本應用 - publish / subscribe
- Q3 : 排除匿名使用者
- Q4 : Bridge應用
  
- 本次lab有指定結報格式 & 問題回答，請在E3上下載
- 至雲端硬碟中下載映像檔
  - [Google drive](#)
  - [OneDrive](#)

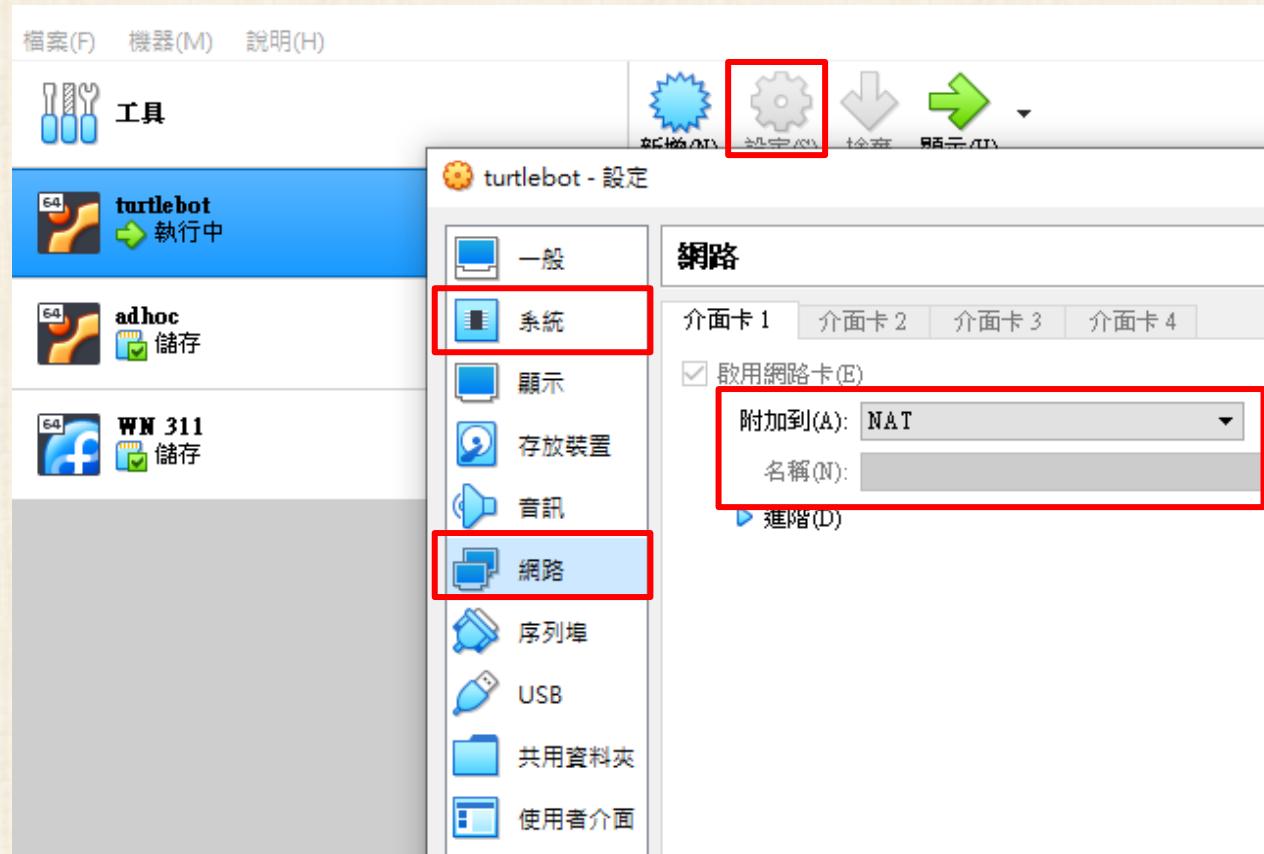
# 啟用虛擬機

- 安裝Oracle VM VirtualBox
- 如果PC上已有虛擬機，則不用再安裝一次
  
- 下載turtlebot2023，並解壓縮
- 開啟VM，點擊加入
- 選擇turtlebot2023.vbox，開啟



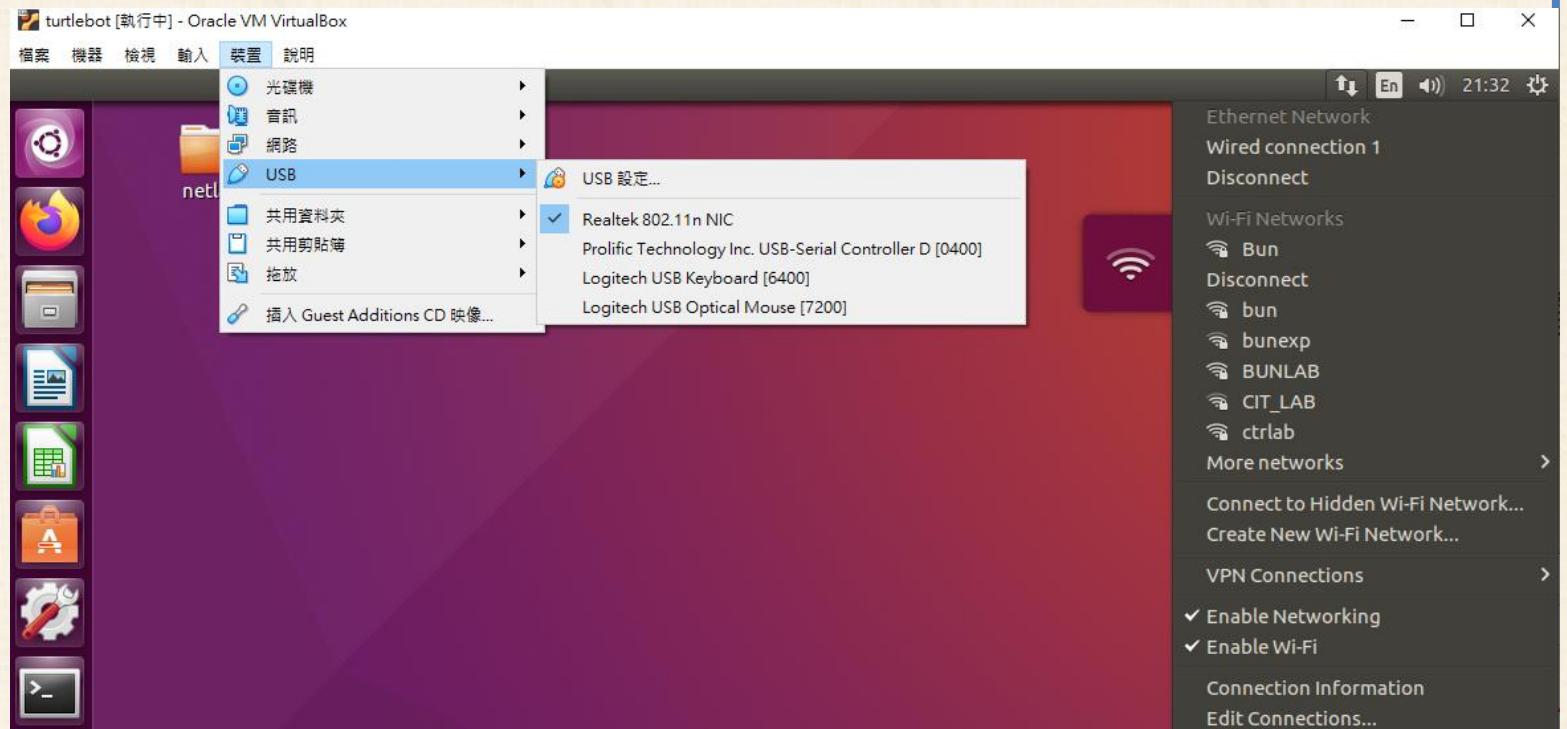
# 設定Oracle VM

- 選取turtlebot2023 > 設定 > 系統 > 處理器>  
調整處理器(CPU)至綠色範圍
- 網路 > 介面卡設
  - 學校電腦 : NAT
  - 自己電腦 : 橋接介面卡
- 儲存並啟動
- 密碼 : turtlebot



# 選取USB網卡

- 若有外接USB網卡
- 登入後，裝置 > USB > 勾選擬入的網卡型號
- 就可以選取Wi-Fi連線





# 確認是否橋接設定成功

- 開啟 Terminal > \$ ifconfig，確認已在區域網路內

```
turtlebot@turtlebot-VirtualBox:~$ ifconfig
enp0s3      Link encap:Ethernet HWaddr 08:00:27:ce:bb:72
              inet addr:192.168.50.156 Bcast:192.168.50.255 Mask:255.255.255.0
              inet6 addr: fe80::e771:4a2:4825:6aef/64 Scope:Link
                      UP BROADCAST RUNNING MULTICAST MTU:1500 Metric:1
                      RX packets:85 errors:0 dropped:0 overruns:0 frame:0
                      TX packets:222 errors:0 dropped:0 overruns:0 carrier:0
                      collisions:0 txqueuelen:1000
                      RX bytes:13197 (13.1 KB) TX bytes:29660 (29.6 KB)

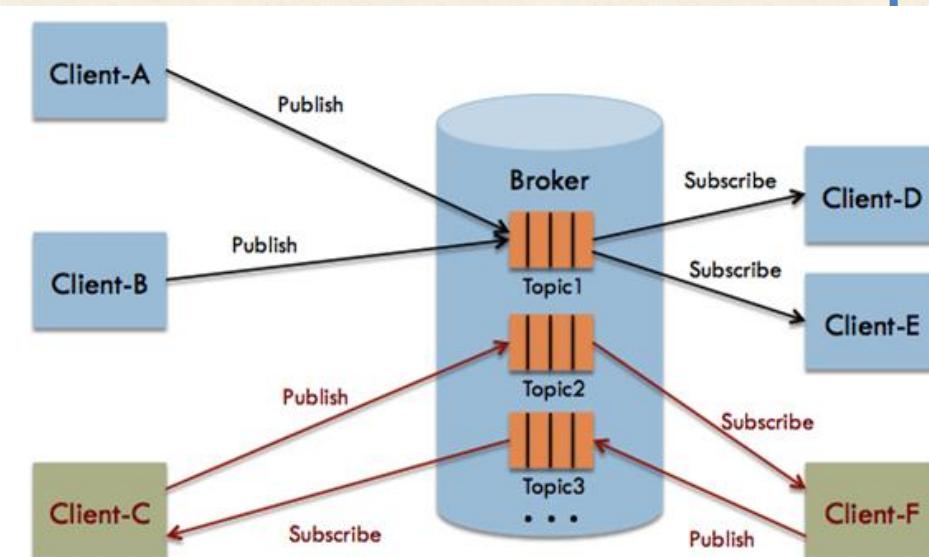
lo          Link encap:Local Loopback
              inet addr:127.0.0.1 Mask:255.0.0.0
              inet6 addr: ::1/128 Scope:Host
                      UP LOOPBACK RUNNING MTU:65536 Metric:1
                      RX packets:138 errors:0 dropped:0 overruns:0 frame:0
                      TX packets:138 errors:0 dropped:0 overruns:0 carrier:0
                      collisions:0 txqueuelen:1000
                      RX bytes:10820 (10.8 KB) TX bytes:10820 (10.8 KB)
```

# MQTT簡介

- MQTT 是一種發佈/訂閱機制的訊息傳輸協定，  
非常適用用於M2M、IoT應用
  - 訊息內容精簡
  - 所需頻寬較少
  - 適用於硬體設備較低階或網路狀況不佳的情形

# Publisher, Subscriber & Broker

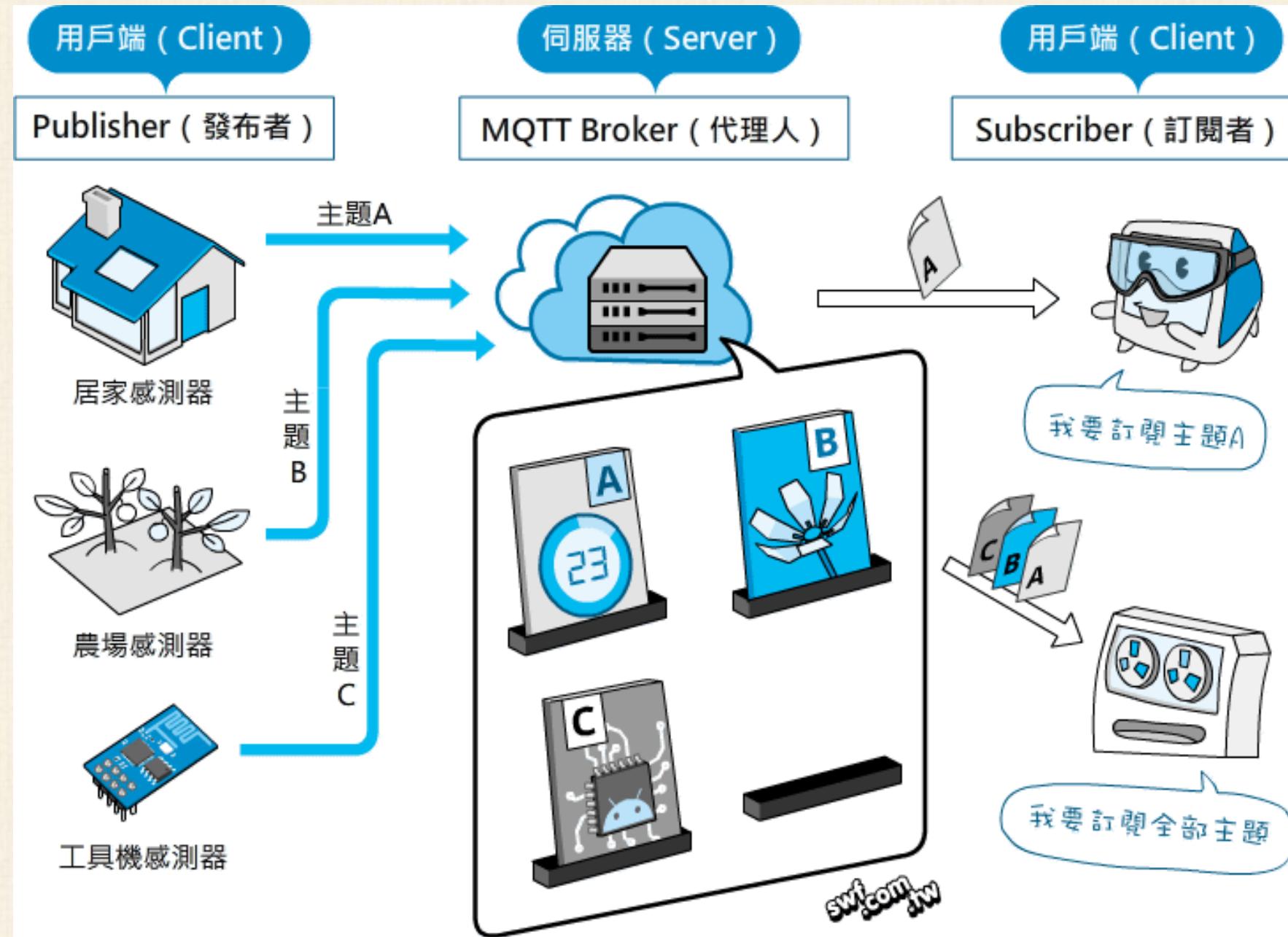
- 在訊息傳遞的過程中，Publisher 、Subscriber 不需要互相知道彼此的 IP ，只需要知道 Broker (代理)的IP就可以進行訊息傳遞 。
- Client 透過訂閱/發佈一個主題(Topic)來溝通
- MQTT 的 Topic 主題帶有階層式設計  
，用 / 來分開  
Ex : a/b/c/d





BUN LAB

Broadband Ubiquitous Networking Lab



# Topic

- 主題名稱建議使用英文，可依據裝置名稱、位置、IP or MAC address命名
  - 不可包含以下字元：#、+、-、\*
  - 勿用\$開頭
  - 名稱最好不要加入空格(全形半形有差)
  - 英文大小寫有區別
  - 階層名稱可以空自

## 不需要在開

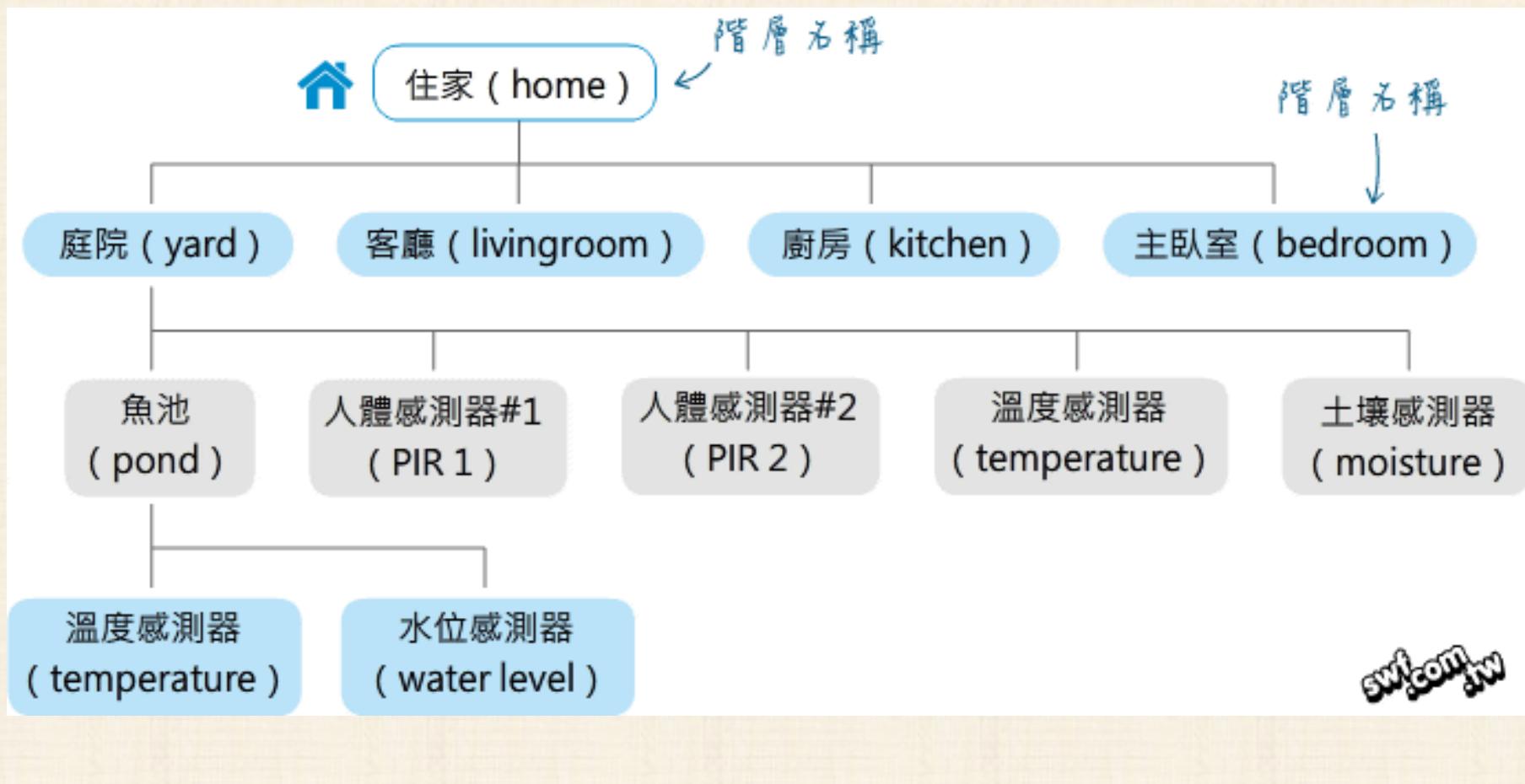
頭加上斜線 → /home/yard/PIR\_1

home/yard/PIR 1

名稱可包含座格和議減號，但不建議。

Home/yard/pir\_1 ← 大小鳥有區別

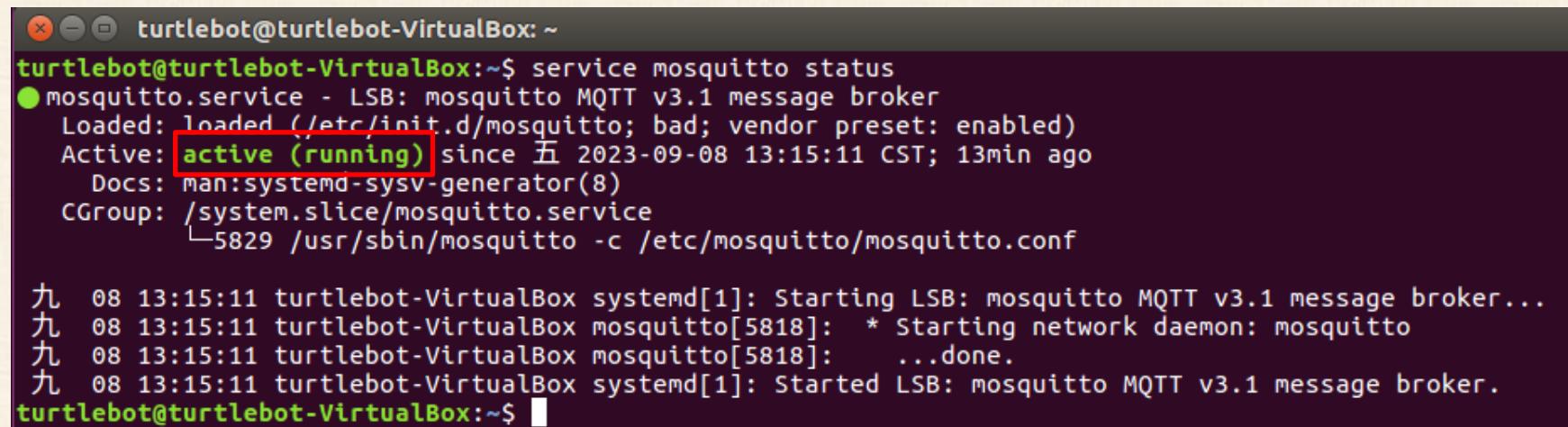
# 階層結構範例



# 安裝

- 安裝mosquitto
  - \$ sudo apt update
  - \$ sudo apt-get update
  - \$ sudo apt-get install mosquitto
  - \$ sudo apt-get install mosquitto-clients
- 輸入\$ service mosquitto status 查看mosquitto狀態

- Ctrl+c退出



```
turtlebot@turtlebot-VirtualBox:~$ service mosquitto status
● mosquitto.service - LSB: mosquitto MQTT v3.1 message broker
  Loaded: loaded (/etc/init.d/mosquitto; bad; vendor preset: enabled)
  Active: active (running) since 五 2023-09-08 13:15:11 CST; 13min ago
    Docs: man:systemd-sysv-generator(8)
   CGroup: /system.slice/mosquitto.service
           └─5829 /usr/sbin/mosquitto -c /etc/mosquitto/mosquitto.conf

九 08 13:15:11 turtlebot-VirtualBox systemd[1]: Starting LSB: mosquitto MQTT v3.1 message broker...
九 08 13:15:11 turtlebot-VirtualBox mosquitto[5818]: * Starting network daemon: mosquitto
九 08 13:15:11 turtlebot-VirtualBox mosquitto[5818]: ...done.
九 08 13:15:11 turtlebot-VirtualBox systemd[1]: Started LSB: mosquitto MQTT v3.1 message broker.

turtlebot@turtlebot-VirtualBox:~$
```

# Publish & Subscribe

## □ Subscribe

- 為開啟一個持續訂閱topic\_name主題的視窗，一旦跳出SUB就不會print出任何東西

□ \$ mosquitto\_sub -v -t topic

顯示訊息  
turtlebot@turtlebot-VirtualBox:~\$ mosquitto\_sub -v -t a/topic  
a/topic message1  
a/topic message2

## □ Publish

□ \$ mosquitto\_pub -m message -t topic

turtlebot@turtlebot-VirtualBox:~\$ mosquitto\_pub -m message1 -t a/topic  
turtlebot@turtlebot-VirtualBox:~\$ mosquitto\_pub -m message2 -t a/topic

# 基本應用 範例

- 先開啟一個終端機，用來訂閱主題 (不要關掉or跳出)

\$ mosquitto\_sub -v -t apple

訂閱特定主題

或 \$ mosquitto\_sub -v -t '#'

訂閱所有主題

- 開啟第二個終端機，用來發布訊息

\$ mosquitto\_pub -t apple -m testmsg

- 一組subscribe & publish 測試完成

# Subscribe multiple topic

- ‘+’ 可對應到任意名稱，但能對應至固定單一階層
  - 如 a/b/+/d、a/b/c/+、+/b/c/d
  
- ‘#’ 只可用於尾端，可對應到之後的任何多個階層
  - 如 a/b/c/#、a/b/#、a/#

# Subscribe multiple topic

- 對不同的topic，發送訊息

```
turtlebot@turtlebot-VirtualBox: ~$ mosquitto_pub -m test_1 -t a/b/c/d
turtlebot@turtlebot-VirtualBox: ~$ mosquitto_pub -m test_2 -t a/b/x/d
turtlebot@turtlebot-VirtualBox: ~$ mosquitto_pub -m test_3 -t a/b/x/y
turtlebot@turtlebot-VirtualBox: ~$ mosquitto_pub -m test_4 -t a/b/x/d/e
```

- 透過訂閱不同主題，可以過濾、篩選想要收的特定訊息

```
turtlebot@turtlebot-VirtualBox: ~$ mosquitto_sub -v -t a/b/+/d
a/b/c/d test_1
a/b/x/d test_2
```

```
turtlebot@turtlebot-VirtualBox: ~$ mosquitto_sub -v -t a/b/#
a/b/c/d test_1
a/b/x/d test_2
a/b/x/y test_3
a/b/x/d/e test_4
```

# Q1

- 當訂閱的topic為 **/a/test** 時，能不能接收到topic為a/test的訊息? why or why not?
  
- \$ mosquitto\_sub -t /a/test -v  
\$ mosquitto\_pub -t a/test -m test\_q1

## Q2

□ Msg format : Place/Floor/Sensor Type/Time/ 共36種

- Place : house1 、 house2
- Floor : firstfloor 、 secondfloor 、 roof
- Sensor Type : temp 、 humid 、 brightness
- Time : day 、 night

□ 若只想收到以下內容，那麼subscriber的topic分別要定為什麼？

- 所有roof在day的brightness
- house1 firstfloor的所有內容
- house2在night的所有內容
- 所有roof的所有內容

# 建立使用者-帳號

- \$ sudo mosquitto\_passwd -c /etc/mosquitto/passwd **name** 自取

```
turtlebot@turtlebot-VirtualBox:~$ sudo mosquitto_passwd -c /etc/mosquitto/passwd user
[sudo] password for turtlebot:
Password:
Reenter password:
```

- 建立後可看到, /etc/mosquitto中多了一個 passwd

```
turtlebot@turtlebot-VirtualBox:~$ cd /etc/mosquitto
turtlebot@turtlebot-VirtualBox:/etc/mosquitto$ ls
```

Before

```
ca_certificates certs conf.d mosquitto.conf
```

After

```
ca_certificates certs conf.d mosquitto.conf passwd
```

# passwd

- \$ nano /etc/mosquitto/passwd

```
GNU nano 2.5.3                                         File: passwd
user:$6$4JSoodTHLIX1En3A$rzxH2560Sz8pmK0S8XAvS3k3mWg+8YTk3WWrk08/b...
```

- 密碼有經過hash  
文件內格式為 name:password

# 設定broker

- 修改MQTT broker的設定檔

- \$ sudo nano /etc/mosquitto/mosquitto.conf
- 加入 password\_file /etc/mosquitto/passwd  
allow\_anonymous false

```
# 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 /var/run/mosquitto.pid

persistence true
persistence_location /var/lib/mosquitto/

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

include_dir /etc/mosquitto/conf.d

password_file /etc/mosquitto/passwd
allow_anonymous false
```

Ctrl + X 離開, 並存檔

## □ 重啟 mosquitto

□ \$ sudo service mosquitto restart

## □ 匿名使用者已被阻擋

```
turtlebot@turtlebot-VirtualBox:/etc/mosquitto$ mosquitto_sub -t '#' -v
Connection Refused: not authorised.
Connection Refused: not authorised.
```

## □ 加上剛剛設定的 name-password 組合(sub 及 pub 都要)

\$ mosquitto\_sub -v -t topic -u name -P password

```
turtlebot@turtlebot-VirtualBox:/etc/mosquitto$ mosquitto_sub -t '#' -v -u user -P user
topic test
```

# 注意

- 如目標資料夾中沒有passwd file，  
但是config檔中有設定passwd\_file /etc/mosquitto/passwd，  
mosquitto會無法啟動

# 新增/刪除 使用者

□ 新增

```
$sudo mosquitto_passwd /etc/mosquitto/passwd new
```

自取

```
User:$6$4JSoodTHLlx1En3A$rZxH2560Sz8pmK0S8XAvS3k3mWg+8YTk3WWrl  
→ new:$6$QYaGhAFw+8ks1eBh$/mJzlAoMCncKEWZNHntk3IAlUEfVRk0qG1M4w.
```

□ 刪除

```
$sudo mosquitto_passwd -D /etc/mosquitto/passwd user
```

GNU nano 2.5.3

File: passwd

```
new:$6$QYaGhAFw+8ks1eBh$/mJzlAoMCncKEWZNHntk3IAlUEfVRk0qG1M4waTQN7y
```

□ 新增完要restart才會讀到更改過的 passwd file

```
$sudo service mosquitto restart
```

# Q3

- 根據上述步驟，建立一個需要name-password才能發佈/訂閱的MQTT broker。
- 並附上操作截圖(範例如下)

```
turtlebot@turtlebot-VirtualBox:/etc/mosquitto$ mosquitto_sub -t '#' -v  
Connection Refused: not authorised.  
Connection Refused: not authorised.
```

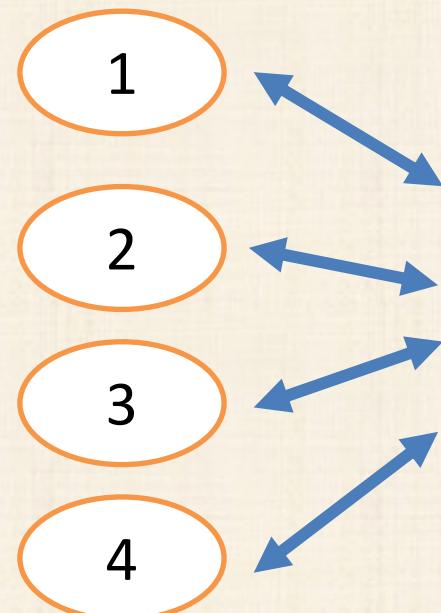
```
turtlebot@turtlebot-VirtualBox:/etc/mosquitto$ mosquitto_sub -t '#' -v -u user -P user  
topic test
```

```
GNU nano 3.2 passwd
```

```
new:$6$/kcS2zt50hDceh5l$q+n4NA niwz3bQ6x60evoQVDrYB3ccTL/eNtGteegCfAbhI9M1qLxagn$
```

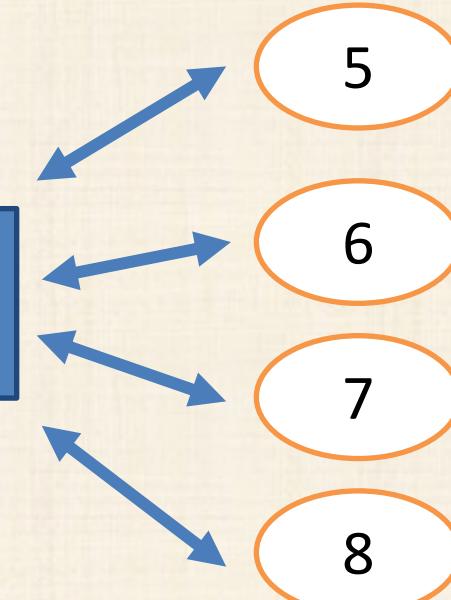
# Bridge

A's Clients



Bridge  
Share topic

B's Clients



Broker 1

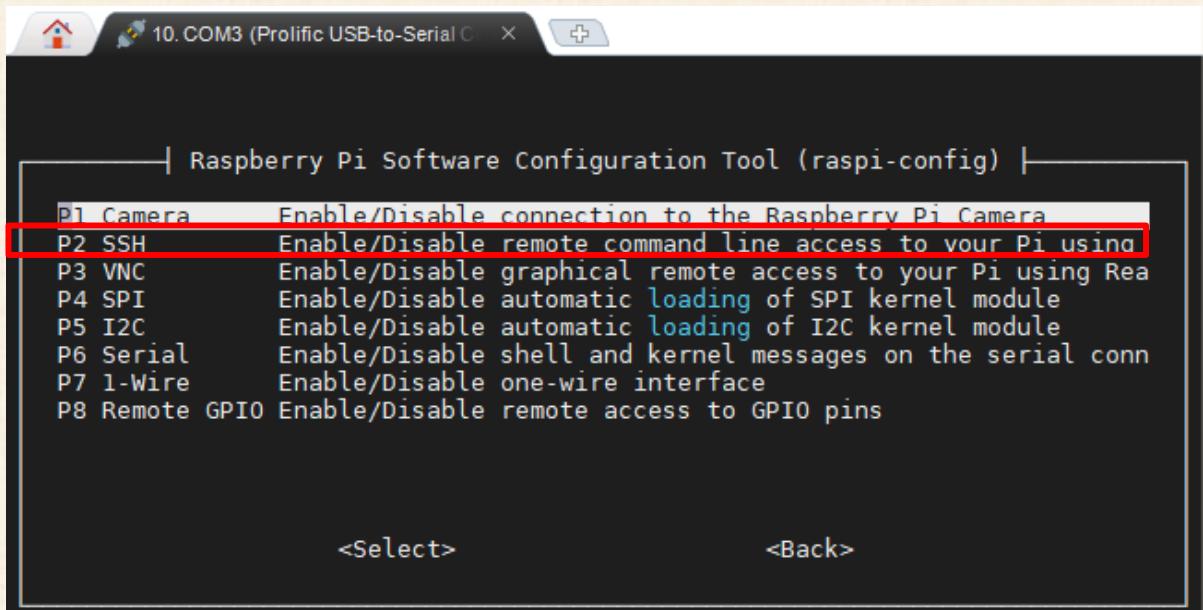
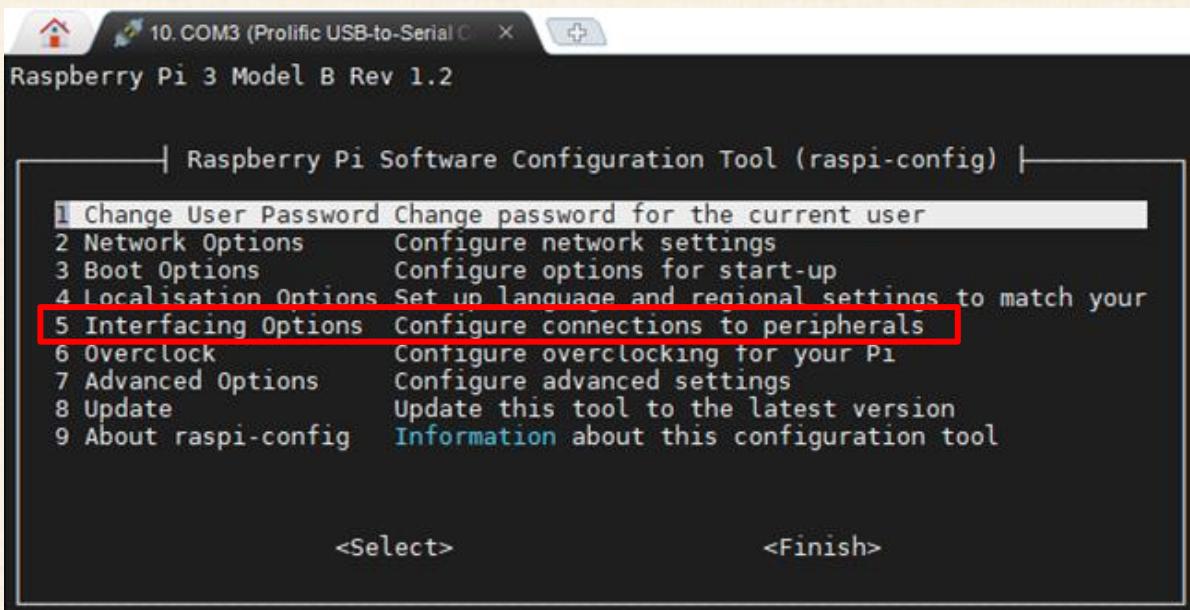
Broker 2

# 裝置需求

- 需要一台Pi板 + 虛擬機(皆需接wifi)
- Pi板同前述步驟安裝mosquitto
- mosquitto資料夾路徑為 /etc/mosquitto
- 把Q3的 **allow\_anonymous** 改回 true，並且重開mosquitto

# SSH無線連線

- 輸入 sudo raspi-config
- 選擇 Interfacing Options > SSH > Yes > Ok > Finish
- 設定好後 sudo reboot



# SSH無線連線

- Pi板及電腦接上相同Wi-Fi
- 透過ifconfig查看Pi板IP
- 可用 MobaXterm 或 Terminal

? MobaXterm:

- Session > SSH > Remote host 輸入Pi板IP

? Terminal:

- ssh pi@**Pi板IP**

帳號:pi

密碼:raspberry

```
wlan0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
        inet 192.168.50.145 netmask 255.255.255.0 broadcast 192.168.50.255
        inet6 fe80::defd:c0a9:e294:d673 prefixlen 64 scopeid 0x20<link>
          ether b8:27:eb:30:4f:58 txqueuelen 1000 (Ethernet)
            RX packets 26 bytes 2893 (2.8 KiB)
            RX errors 0 dropped 0 overruns 0 frame 0
            TX packets 32 bytes 4954 (4.8 KiB)
```

# 補充-固定IP

## □ 修改/etc/dhcpcd.conf

- \$ sudo nano /etc/dhcpcd.conf
- 加入以下內容

```
interface wlan0
```

#無線網路

```
static ip_address=192.168.X.X
```

#想改成的IP地址，可自訂

```
static routers=192.168.Y.Y
```

#無線基地台地址

```
static domain_name_servers=192.168.Y.Y
```

#無線基地台地址

- Ctrl+O 存檔，Ctrl+X 跳出 nano

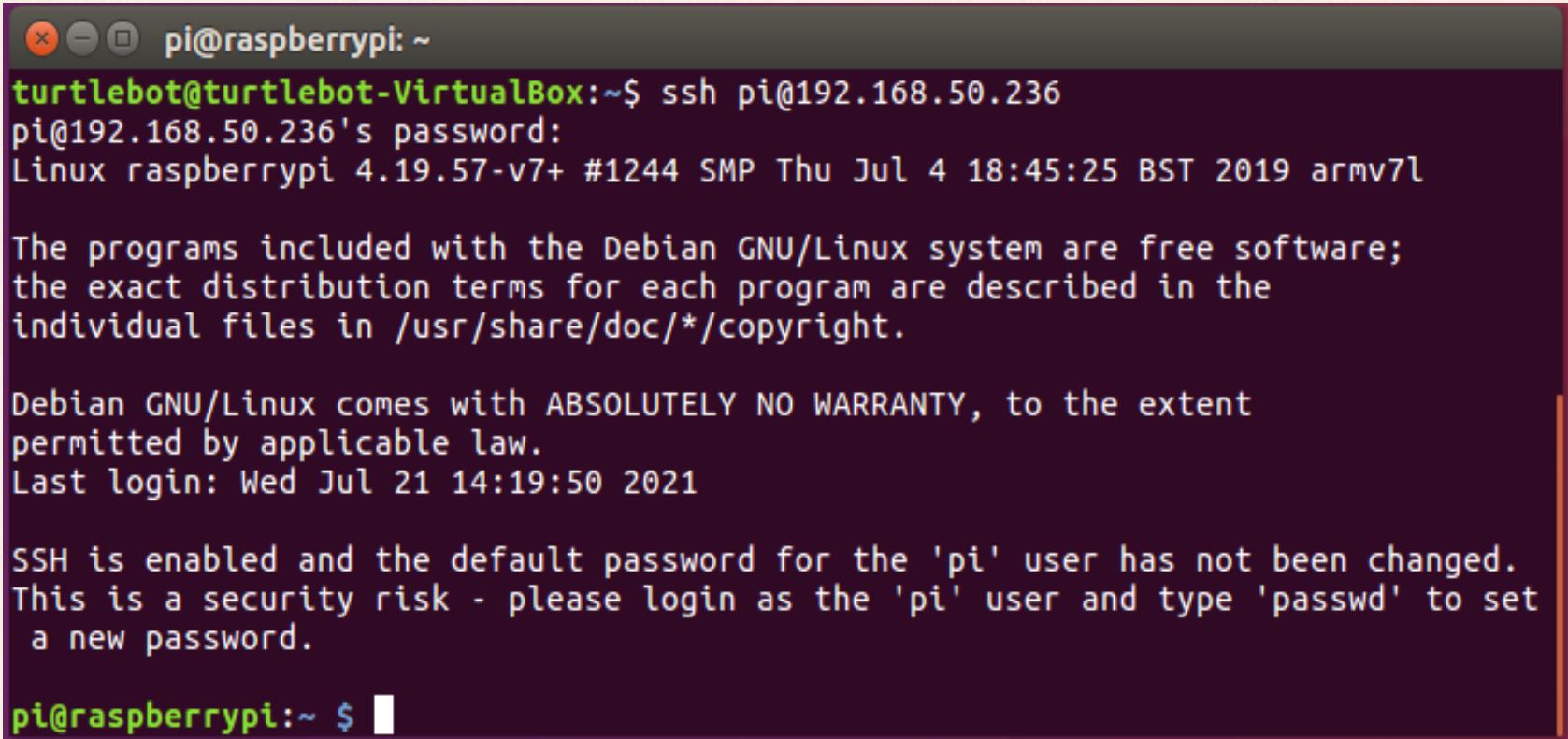
## □ 重開機

- \$ sudo reboot

HINT:  
ifconfig  
查看目前IP位址

# VM SSH

- 確認 PI板 與 VM 在相同網域 (ex: 兩者IP皆為192.168.50.xxx)
- 在VM開啟 Terminal > 輸入\$ ssh pi@ip address(pi板)



```
pi@raspberrypi:~  
turtlebot@turtlebot-VirtualBox:~$ ssh pi@192.168.50.236  
pi@192.168.50.236's password:  
Linux raspberrypi 4.19.57-v7+ #1244 SMP Thu Jul 4 18:45:25 BST 2019 armv7l  
  
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: Wed Jul 21 14:19:50 2021  
  
SSH is enabled and the default password for the 'pi' user has not been changed.  
This is a security risk - please login as the 'pi' user and type 'passwd' to set  
a new password.  
pi@raspberrypi:~ $
```



BUN LAB

Broadband Ubiquitous Networking Lab

# 在VM中設定 Bridge - 範例

- 在mosquitto.conf中新增以下設定，

只要有一方設Bridge即可！  
增加完設定要restart

- connection name

address PI板ip

```
topic # out 1
topic # in 1
```

```
turtlebot@turtlebot-VirtualBox: ~
GNU nano 2.5.3      File: /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 /var/run/mosquitto.pid

persistence true
persistence_location /var/lib/mosquitto/

connection PI
address Your PI板ip
topic # out 1
topic # in 1

^G Get Help ^O Write Out ^W Where Is ^K Cut Text ^J Justify
^X Exit      ^R Read File  ^\ Replace   ^U Uncut Text ^T To Spell
```



設bridge時，先設out再設in

# Bridge-configuration

## □ topic topic\_name direction qos local-prefix remote-prefix

- topic\_name : topic name
- direction : in ` out ` both
- qos-level : 0 ` 1 ` 2
- local-prefix : topic remapping 設定
- remote-prefix: 同上

```
connection PI
address Your PI板ip
topic # out 1
topic # in 1
```

## □ Bridge all topics without remapping

# Bridge 範例

## □ Broker A (VM中)

subscribe 視窗

```
turtlebot@turtlebot-VirtualBox:~$ mosquitto_sub -v -t '#'  
topic_VM sned_from_VM  
topic_PI send_from_PI
```

publish 視窗 (指令)

```
turtlebot@turtlebot-VirtualBox:~$ mosquitto_pub -t topic_VM -m sned_from_VM  
turtlebot@turtlebot-VirtualBox:~$
```

## □ Broker B (PI板)

subscribe 視窗

```
pi@raspberrypi:~ $ mosquitto_sub -v -t '#'  
topic_VM sned_from_VM  
topic_PI send_from_PI
```

publish 視窗 (指令)

```
pi@raspberrypi:~$ mosquitto_pub -t topic_PI -m send_from_PI  
pi@raspberrypi:~$
```

# Topic remapping (1)

- topic # in 1 recv/ b/ \* 稱有設Bridge的一方為A、另一方為B

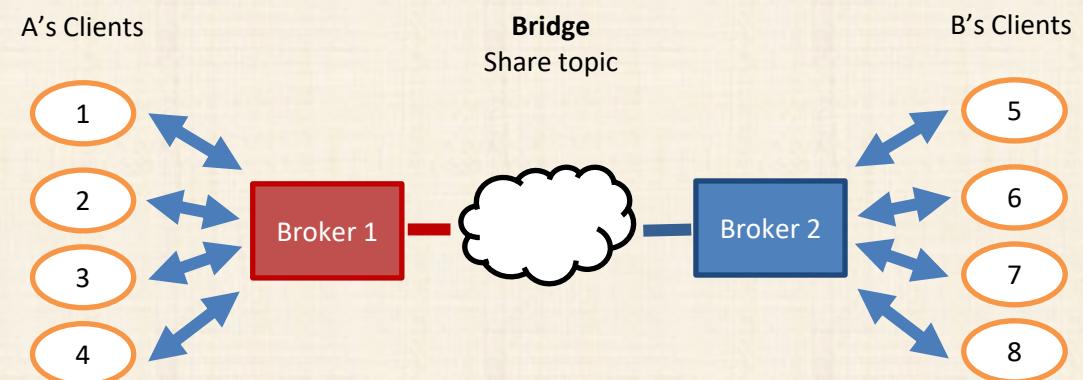
- 外來訊息 (BrokerA以外的訊息)

topic 的第一層是 ‘b/’，才會被Broker A接收

並將topic的第一層‘b/’轉成 ‘recv/’ 顯示在 A 的subscribe介面

- 在B的subscribe介面正常顯示

- e.g. b/topic1 >> recv/topic1



# Topic remapping (2)

- topic # **out** 1 a/ send/

\* 稱有設Bridge的一方為A、另一方為B

- 輸出訊息(從BrokerA傳出去的訊息)

topic 的第一層是 'a/'，則會同時publish至 Broker B

並將topic的第一層'**a/**'轉成 '**send/**' 顯示在 B 的subscribe介面

- 在A的subscribe介面正常顯示

- e.g. a/topic2 >> send/topic2

## Q4

- 選定一個broker設bridge (A) , 建議設定在VM中 , topic依照以下紅框設定，兩邊的Client皆訂閱所有topic，自行測試並完成表格，填表過程中不用更改bridge 設定。

topic # out 1 out/ fromA/

topic # in 1 fromB/

記得重開mosquitto!!

```
connection VM
address Your PI板ip
cleansession true
clientid 123
start_type automatic
topic # out 1 out/ fromA/
topic # in 1 fromB/
```

# Q4 表格

Broker : topic 、 msg	Broker 1 (A) sub 顯示(topic 、 msg)	Broker 2 (B) sub 顯示(topic 、 msg)
A : in 、 msg1		
A : out 、 msg2		
A : out/msg 、 msg3		
A : /out 、 msg4		
B : out 、 msg5		
B : fromB 、 msg6		