

通訊網路實驗

Topic 2

Bluetooth

112學年度 第一學期

Dept. of Electrical and Computer Engineering (ECE)

National Yang Ming Chiao Tung University

藍牙 Bluetooth

- 目的
 - 為了解決電腦與電器設備之間的傳輸問題
- Bluetooth Classic: 802.15
- Bluetooth 4.0 Low Energy (BLE): 802.15.1
- Bluetooth 5.0: Faster, Further, for IoT



<https://zh.wikipedia.org/zh-tw/%E8%97%8D%E7%89%99>

Bluetooth 5.0

- 目前藍芽技術的最新版本
- 出現目的: IoT (針對物聯網進行多種底層最佳化)
- 室內導航、安全、抗干擾 (New Algorithm)

	4.2	5.0
Data Rate	1 Mbps	2 Mbps
Range	1x	4x
Bandwidth	1x	8x



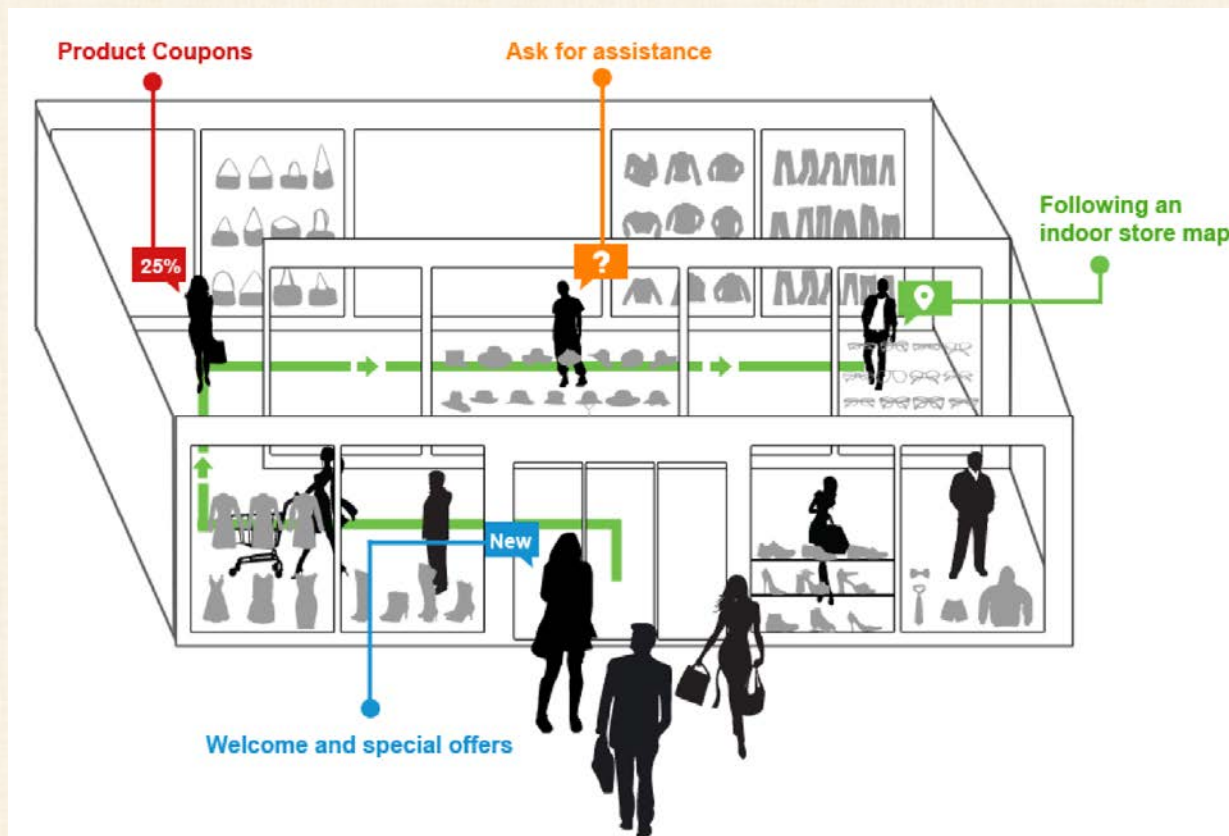
Bluetooth Low Energy (BLE)

- 一種無線個人區域網路(WirelessPAN)的技術
- 出現目的:低成本, 低耗電(CR2032電池可用1年)
- 多用在穿戴式設備上, 如: 小米手環、Apple Watch 等等
- Bluetooth 分成 Classic(BR/EDR), High Speed(HS), Low Energy 三種模式

	Classic	BLE
Throughput	2 ~ 3 Mbps	0.2 Mbps
Range	50 ~ 300 m	10 ~ 30 m
Power consumption	1 W	0.01 ~ 0.5 W
Connection time	5 s	0.1 s

BLE 的應用

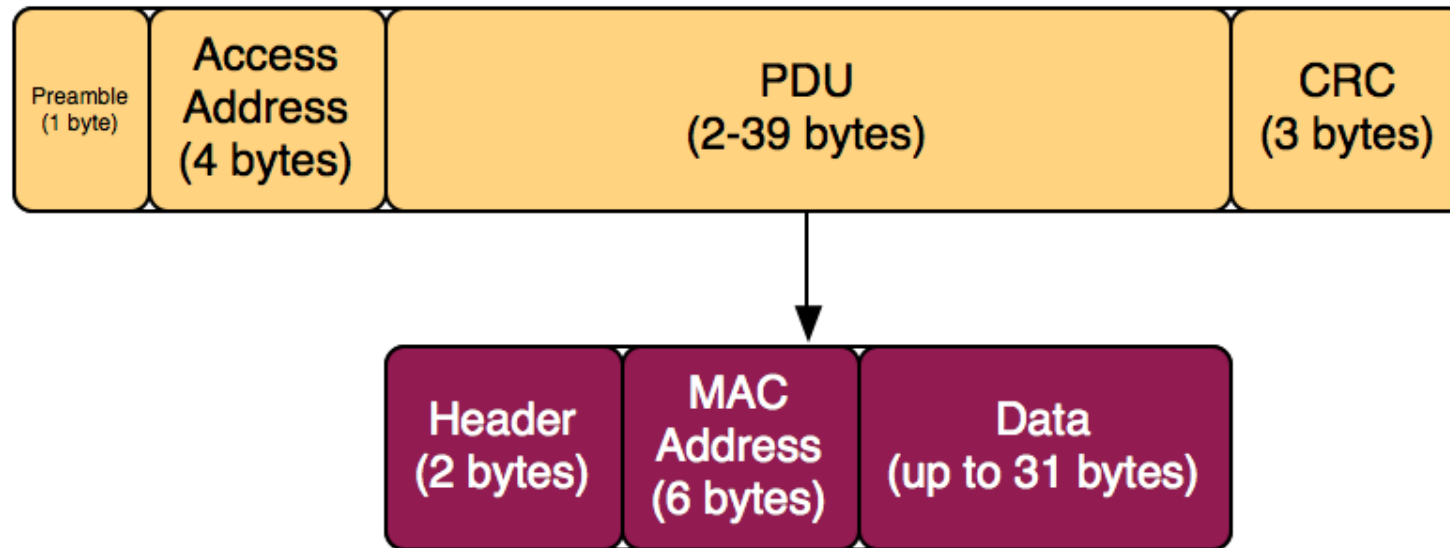
- 微型定位服務
- 推播訊息
- 收集數據



<https://learn.adafruit.com/pibeacon-ibeacon-with-a-raspberry-pi/overview>

BLE frame format

- 1 byte preamble
- 4 byte access address
- 2-39 bytes advertising channel PDU
- 3 bytes CRC

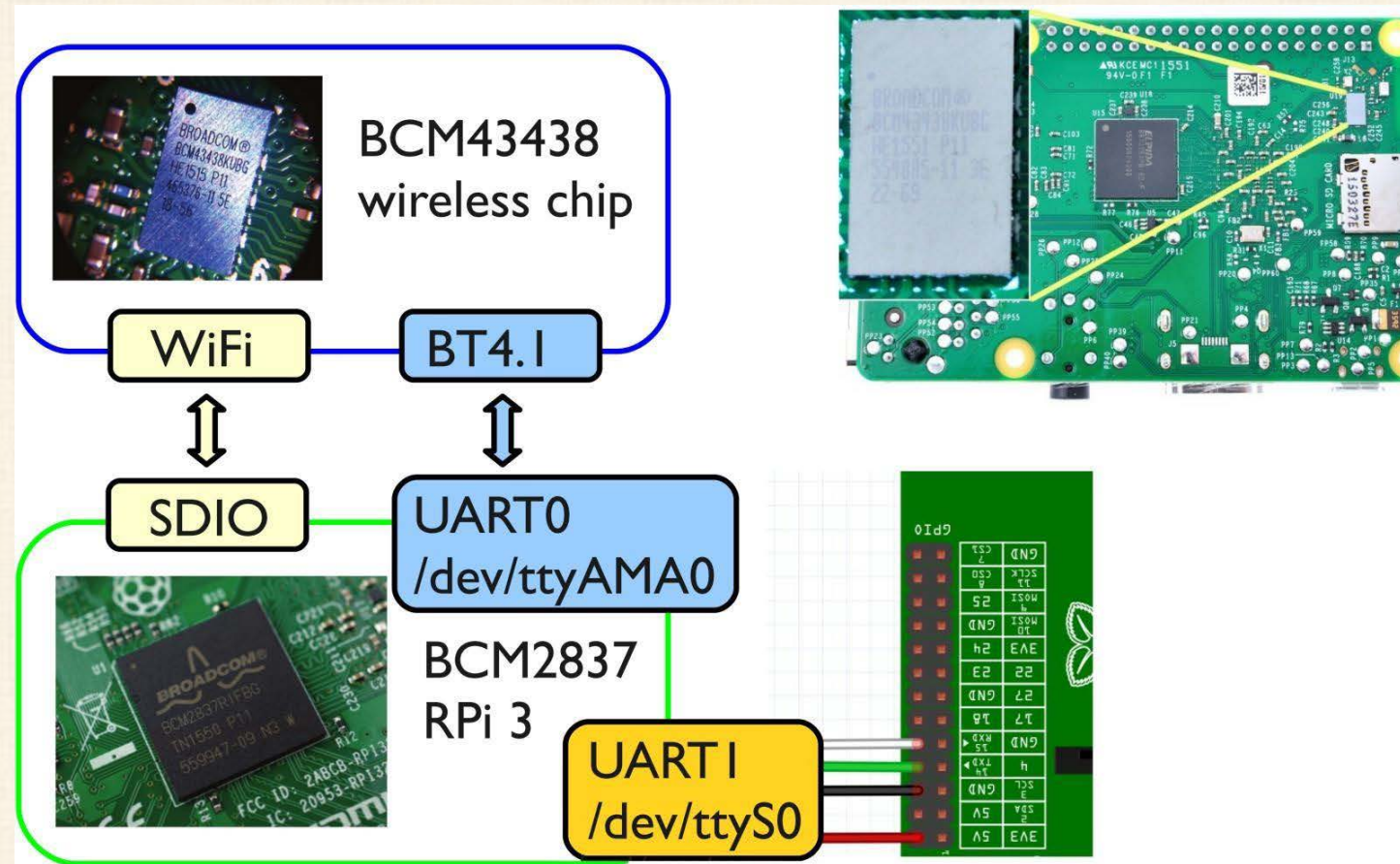


Eddystone

- 為 Google BLE Beacon 技術所使用的通訊協定
- 提供多種 BLE 廣播的格式
- 本次實驗使用的是 EddyStone-URL 格式

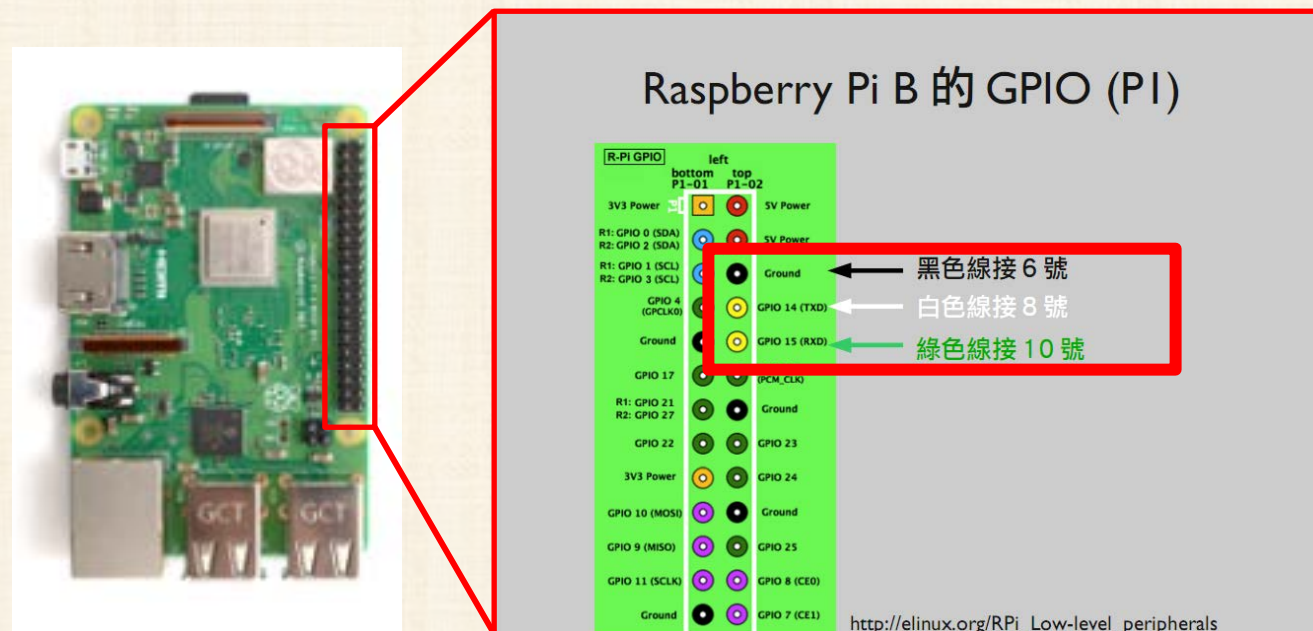


Hardware Architecture of Pi3



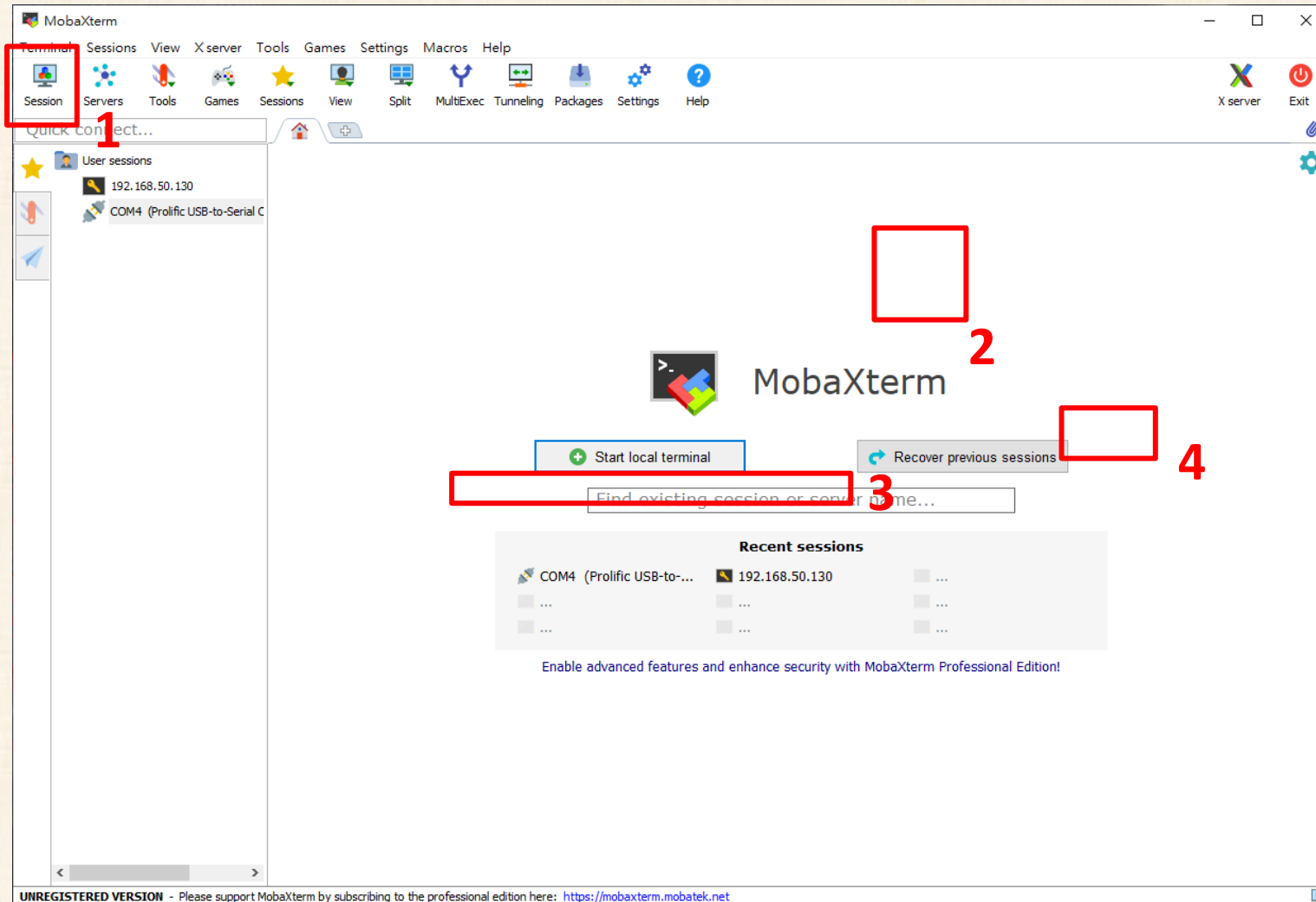
TTL序列連接

- 將 SD 卡插入 Rpi 並且接上電源線(務必先插SD卡再接電源，不然SD卡會燒壞)
- 透過 USB 轉 TTL 序列傳輸線，就可以在不需螢幕和鍵盤滑鼠的情況下登入 Raspberry Pi
- Pi板預設登入帳號密碼
 - 帳號: **pi**
 - 密碼: **raspberry**

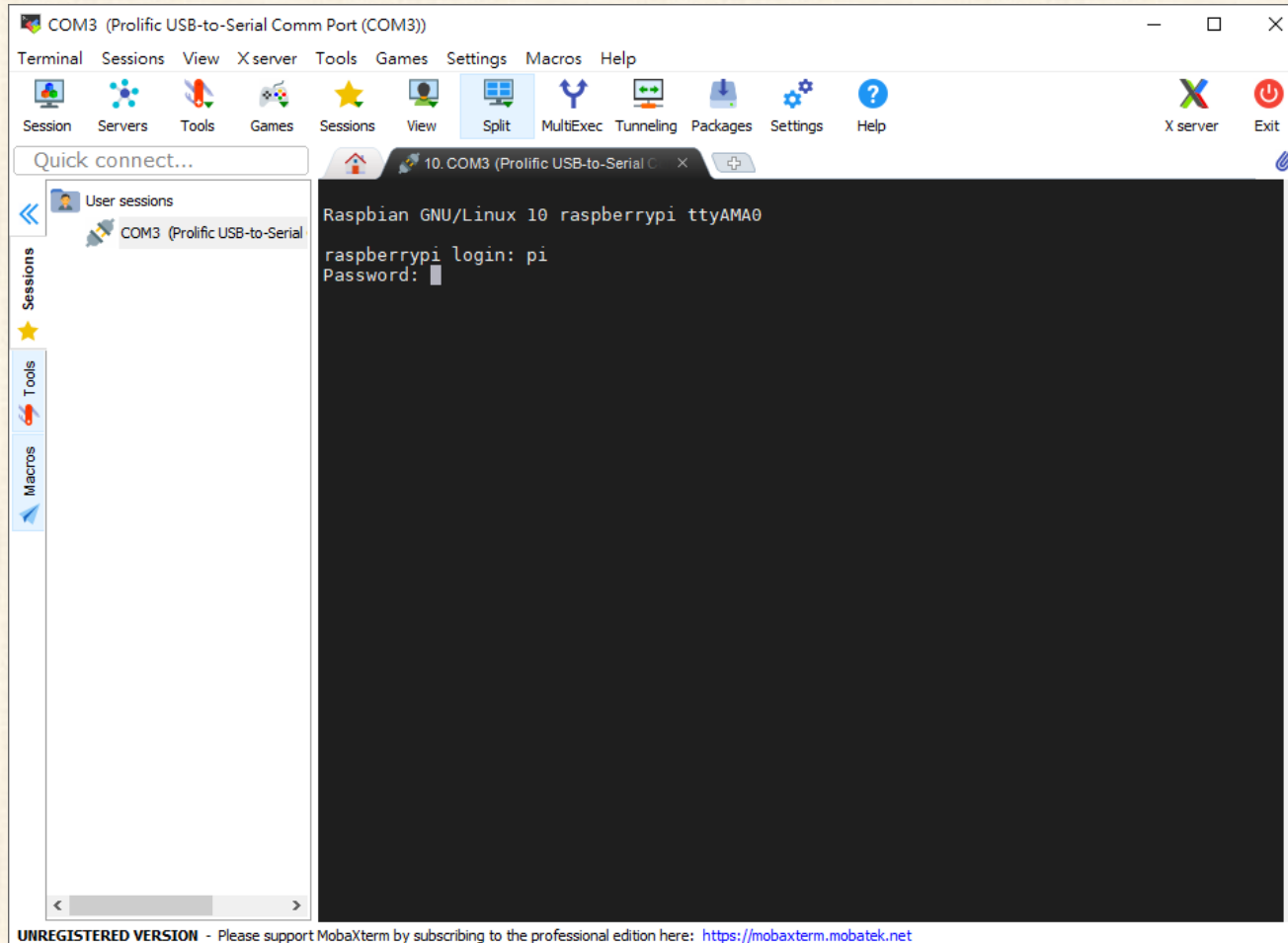


<https://www.raspberrypi.com.tw/tag/usb-to-ttl/>

MobaXterm



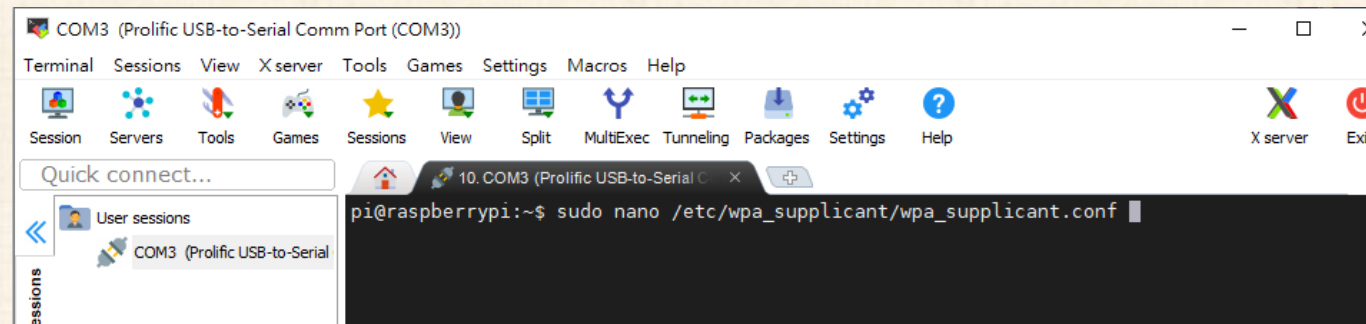
MobaXterm



- ❑ Pi板預設登入帳號密碼
 - ❑ 帳號: pi
 - ❑ 密碼: raspberry

RPi Wi-Fi 設定

- 1. 輸入 `sudo nano /etc/wpa_supplicant/wpa_supplicant.conf` (編輯設定檔)



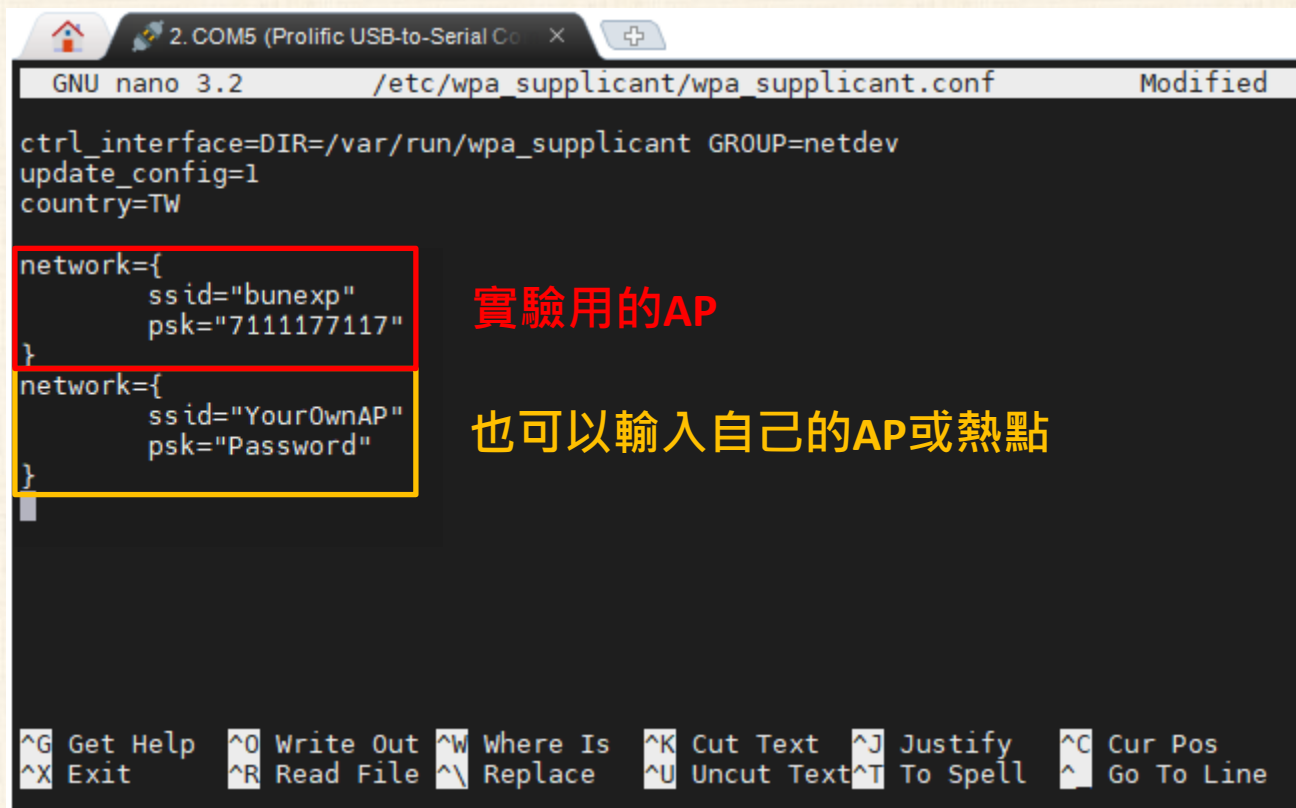
- 2. 填寫SSID與密碼 (新增下面欄位) 請改成自己的AP 或熱點 ssid 和密碼

```
network={  
    ssid="bunexp"  
    psk="711177117"  
}
```

RPi Wi-Fi 設定

□ 文字編輯器 nano

- 編輯結束按 **ctrl + x** 離開
- 若有變動, 會問你是否存檔, 輸入 **Y** 按enter即可退出編輯器



```
GNU nano 3.2 /etc/wpa_supplicant/wpa_supplicant.conf Modified

ctrl_interface=DIR=/var/run/wpa_supplicant GROUP=netdev
update_config=1
country=TW

network={
    ssid="bunexp"
    psk="7111177117"
}

network={
    ssid="YourOwnAP"
    psk="Password"
}

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

實驗用的AP

也可以輸入自己的AP或熱點

RPi Wi-Fi 設定

- 3. 輸入 **sudo reboot** 將 RPi 重新開機
- 4. 使用 **ifconfig** 與 **iwconfig** 指令檢查連線狀態 (請記住自己的IP)

```
pi@raspberrypi:~$ ifconfig
eth0: flags=4099<UP,BROADCAST,MULTICAST> mtu 1500
    ether b8:27:eb:d6:af:d1 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 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

wlan0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 192.168.50.130 netmask 255.255.255.0 broadcast 192.168.50.255
    inet6 fe80::200e:c37e:c9e9:77d5 prefixlen 64 scopeid 0x20<link>
    ether b8:27:eb:83:fa:84 txqueuelen 1000 (Ethernet)
    RX packets 325 bytes 50925 (49.7 KiB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 122 bytes 16959 (16.5 KiB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

記住自己的IP

```
pi@raspberrypi:~$ iwconfig
lo      no wireless extensions.

eth0    no wireless extensions.

wlan0   IEEE 802.11 ESSID:"BUNLAB"
        Mode:Managed Frequency:2.427 GHz Access Point: 0C:9D:92:4B:7A:88
        Bit Rate=65 Mb/s Tx-Power=31 dBm
        Retry short limit:7 RTS thr:off Fragment thr:off
        Power Management:on
        Link Quality=70/70 Signal level=-37 dBm
        Rx invalid nwid:0 Rx invalid crypt:0 Rx invalid frag:0
        Tx excessive retries:1 Invalid misc:0 Missed beacon:0
```

順利連線則會顯示剛剛設定的SSID

SSH

- 由於使用序列線要上傳或下載檔案比較麻煩，因此我們這邊會希望使用 SSH 來控制 Rpi
 - 請先輸入 **sudo raspi-config**
 - 先選取 **5 Interfacing Options**
 - 再選取 **P2 SSH**，將它開啟，完成之後再輸入 **sudo reboot** 將 RPi重新開機

```
Raspberry Pi Software Configuration Tool (raspi-config)

1 Change User Password Change password for the current user
2 Network Options       Configure network settings
3 Boot Options          Configure options for start-up
4 Localisation Options  Set up language and regional settings to match your location
5 Interfacing Options   Configure connections to peripherals
6 Overclock             Configure overclocking for your Pi
7 Advanced Options      Configure advanced settings
8 Update                Update this tool to the latest version
9 About raspi-config    Information about this configuration tool

<Select>                <Finish>
```

```
Raspberry Pi Software Configuration Tool (raspi-config)

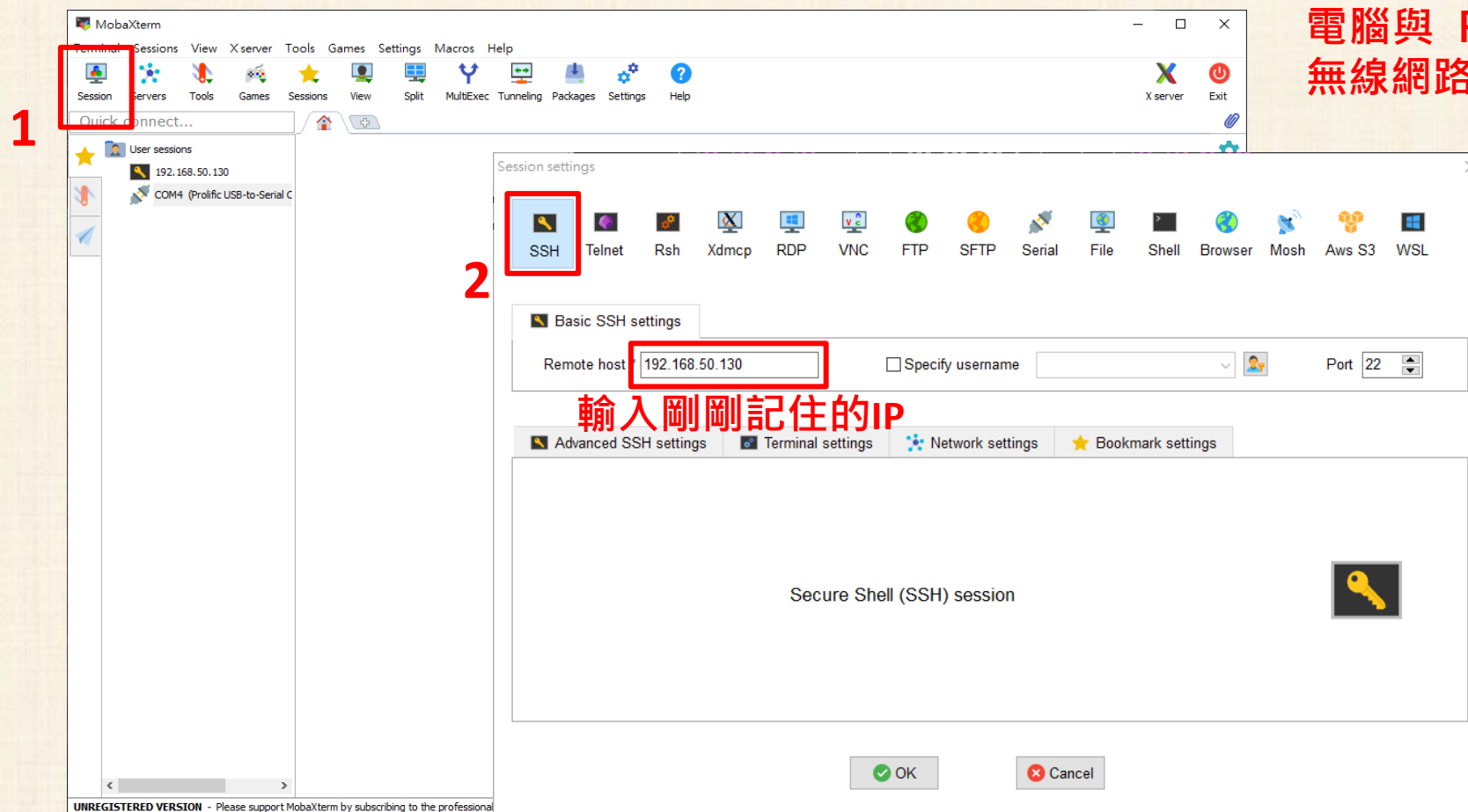
P1 Camera              Enable/Disable connection to the Raspberry Pi Camera
P2 SSH                 Enable/Disable remote command line access to your Pi using
P3 VNC                 Enable/Disable graphical remote access to your Pi using RealVNC
P4 SPI                 Enable/Disable automatic loading of SPI kernel module
P5 I2C                 Enable/Disable automatic loading of I2C kernel module
P6 Serial              Enable/Disable shell and kernel messages on the serial conn
P7 1-Wire              Enable/Disable one-wire interface
P8 Remote GPIO         Enable/Disable remote access to GPIO pins

<Select>                <Back>
```

SSH

- 使用MobaXterm 裡面的SSH功能連接上 RPi

※實驗時若要使用 SSH 來連線的話，
電腦與 RPi 板子需要連結到同一個
無線網路分享器或熱點



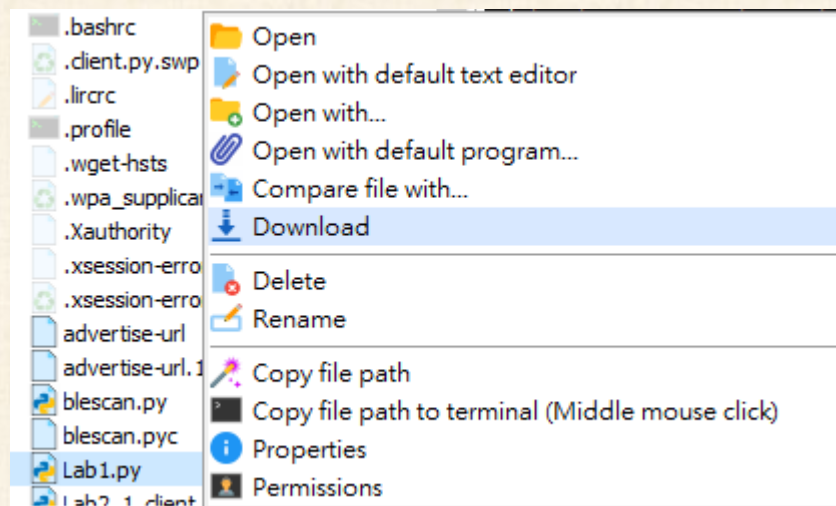
SSH

□ 輸入預設帳號密碼

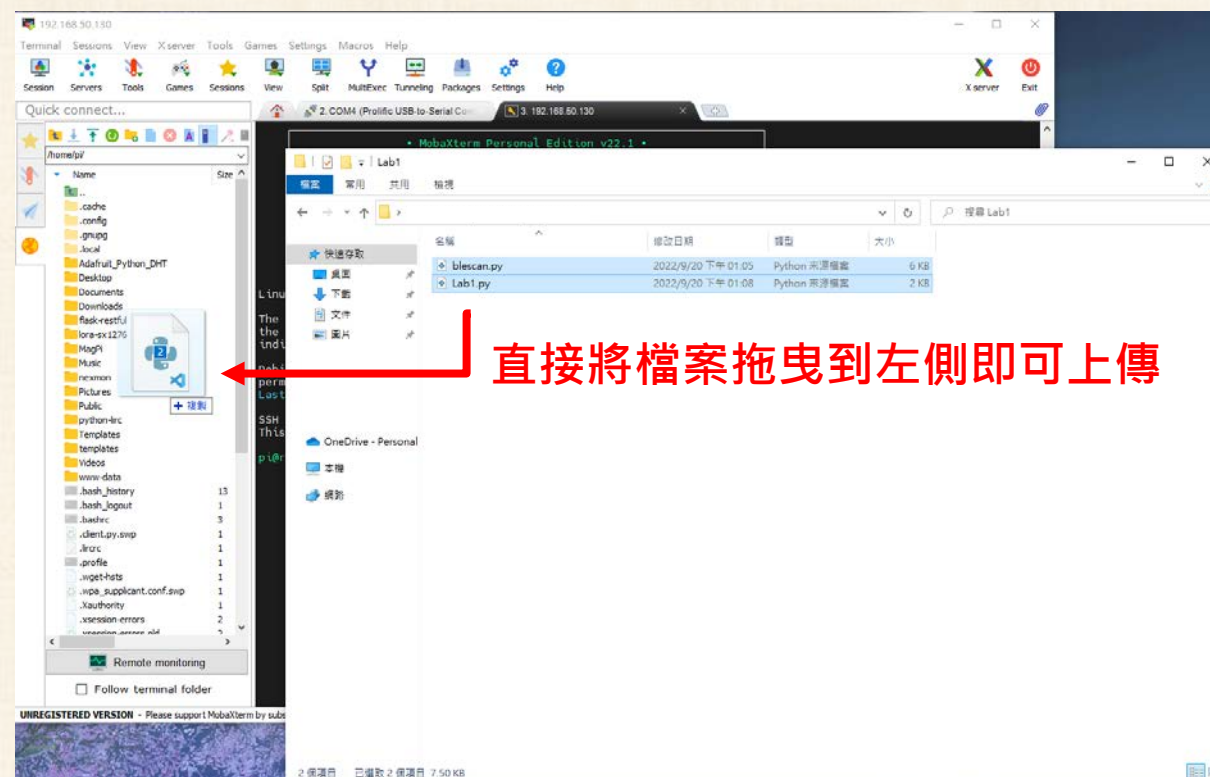


- 帳號: **pi**
- 密碼: **raspberry**

□ 登入後即可輕鬆上傳/下載檔案



對檔案按右鍵並選擇**Download**即可下載



Raspberry Pi 指令

- `sudo raspi-config`
 - 設定 ssh, wifi ...等功能
- `sudo shutdown -h now`
 - 關機指令
- `sudo reboot`
 - 重新開機
- `ifconfig / iwconfig`
 - 確認網路連線
- `cd <folder name>`
 - 進入資料夾
- `cd ..`
 - 返回前一路徑
- `ls`
 - 列出當前路徑的所有檔案
- `pwd`
 - 查看當前路徑

Bluetooth on RPi

- 如何查看Pi是否支援 BLE ?
 - `hciconfig -a hci0 features` => 尋找 <LE support>

```
pi@raspberrypi:~ $ hciconfig -a hci0 features
hci0:  Type: Primary  Bus: USB
       BD Address: 00:1A:7D:DA:71:13  ACL MTU: 310:10  SCO MTU: 64:8
       Features page 0: 0xff 0xff 0x8f 0xfe 0xdb 0xff 0x5b 0x87
               <3-slot packets> <5-slot packets> <encryption> <slot offset>
               <timing accuracy> <role switch> <hold mode> <sniff mode>
               <park state> <RSSI> <channel quality> <SCO link> <HV2 packets>
               <HV3 packets> <u-law log> <A-law log> <CVSD> <paging scheme>
               <power control> <transparent SCO> <broadcast encrypt>
               <EDR ACL 2 Mbps> <EDR ACL 3 Mbps> <enhanced iscan>
               <interlaced iscan> <interlaced pscan> <inquiry with RSSI>
               <extended SCO> <EV4 packets> <EV5 packets> <AFH cap. slave>
               <AFH class. slave> <LE support> <3-slot EDR ACL>
               <5-slot EDR ACL> <sniff subrating> <pause encryption>
               <AFH cap. master> <AFH class. master> <EDR eSCO 2 Mbps>
               <EDR eSCO 3 Mbps> <3-slot EDR eSCO> <extended inquiry>
               <LE and BR/EDR> <simple pairing> <encapsulated PDU>
               <non-flush flag> <LSTO> <inquiry TX power> <EPC>
               <extended features>
       Features page 1: 0x03 0x00 0x00 0x00 0x00 0x00 0x00 0x00
```

如何使用 RPi 上的藍芽模組

- RPi 做為 Beacon，並利用手機接收信號
- 使用 **advertise-url** 指令來傳送網址廣播
 - `wget https://raw.githubusercontent.com/google/eddystone/master/eddystone-url/implementations/linux/advertise-url`
 - 下載後
 - `chmod +x advertise-url` 新增執行權限
 - `sudo ./advertise-url -u http://ptt.cc` 開始廣播
 - `sudo ./advertise-url -s` 停止廣播

如何使用 RPi 上的藍芽模組

- 若需利用 RPi 來掃描特定 UUID 並接收訊息:
 - `sudo python Lab1.py`
 - 下面例子的 UUID 設定為 00000000111111110000000000556601
- 可以得到 TX_power 和 RSSI，如下圖

```
('raw_uuid', '00000000111111110000000000556601')  
('uuid:', '00000000-1111-1111-0000-000000556601')  
('major:', '0', ', minor:', '0', ', txpower:', '-59')  
('rssi', '-37')
```

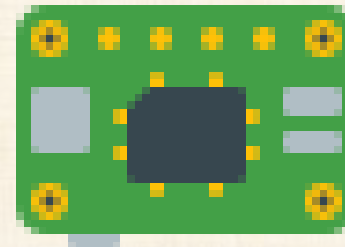
如何使用 RPi 上的藍芽模組

- 如何計算距離？
 - RSSI (Receive signal strength indication) & TX power
 - Propagation model (path loss)
 - Free Space, Two-ray ground-reflection ... etc
 - $\text{Path loss} = \text{TX_power(dBm)} - \text{RX_power(dBm)}$

Beacon



Receiver



計算傳輸距離

- Ratio = RSSI / TX power
- 當 Ratio < 1 時:

$$distance = \left(\frac{RSSI}{TX\ power} \right)^{10}$$

- 當 Ratio >= 1 時:

$$distance = \alpha \left(\frac{RSSI}{TX\ power} \right)^{\beta} + \gamma$$

計算傳輸距離

□ 該如何選擇 α, β, γ ?

□ AltBeacon 有提供參數 ([點此進入連結](#))

```
{  
  "coefficient1": 0.42093,  
  "coefficient2": 6.9476,  
  "coefficient3": 0.54992,  
  "version": "4.4.2",  
  "build_number": "KOT49H",  
  "model": "Nexus 4",  
  "manufacturer": "LGE"  
},
```

```
"coefficient1": 0.42093,  
"coefficient2": 6.9476,  
"coefficient3": 0.54992,  
"version": "4.4.2",  
"build_number": "LPV79",  
"model": "Nexus 5",  
"manufacturer": "LGE",  
"default": true
```

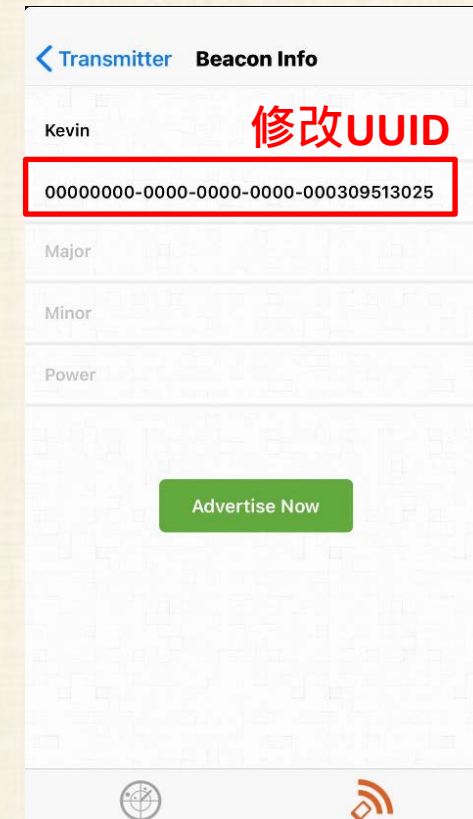
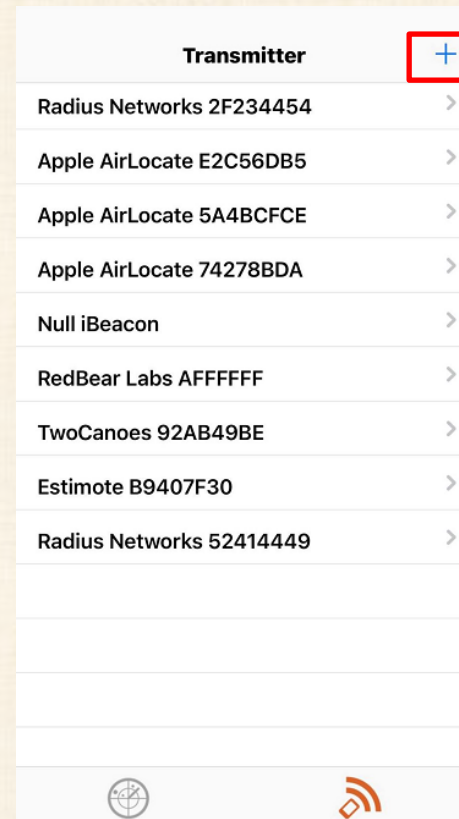
```
"coefficient1": 0.9401940951,  
"coefficient2": 6.170094565,  
"coefficient3": 0.0,  
"version": "5.0.2",  
"build_number": "LXG22.67-7.1",  
"model": "Moto X Pro",  
"manufacturer": "XT1115",  
"default": false
```

```
"coefficient1": 0.1862616782,  
"coefficient2": 8.235367435,  
"coefficient3": -0.45324519,  
"version": "6.0",  
"build_number": "MPE24.49-18",  
"model": "XT1092",  
"manufacturer": "Motorola",  
"default": false
```

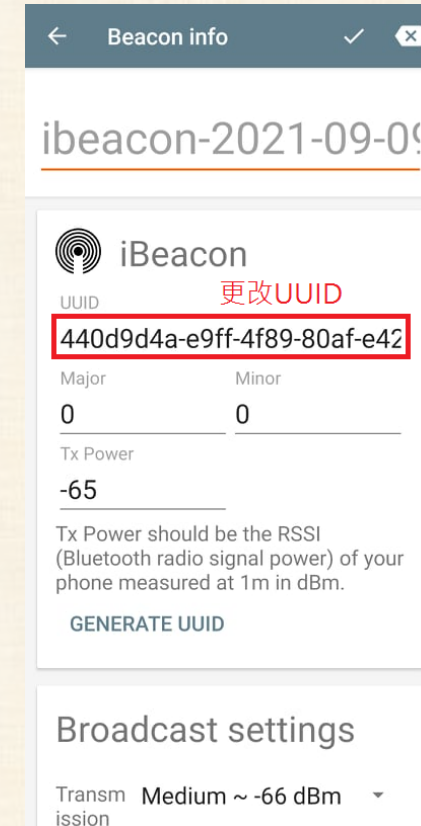
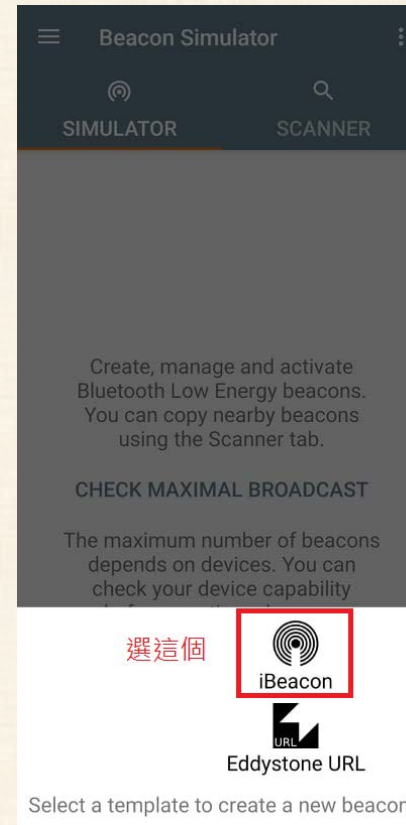
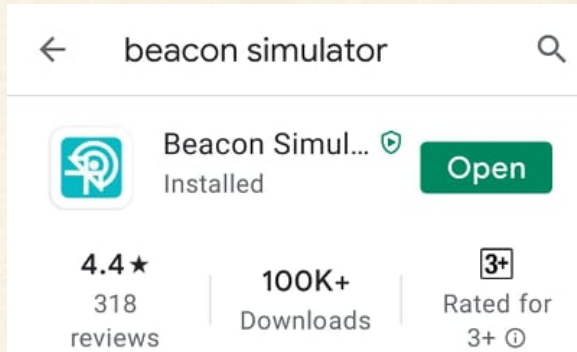
<https://github.com/AltBeacon/android-beacon-library/blob/b9876b45acd6c72c84b8d0325062259020eb89ba/lib/src/main/resources/model-distance-calculations.json>

iBeacon generator app(iOS)

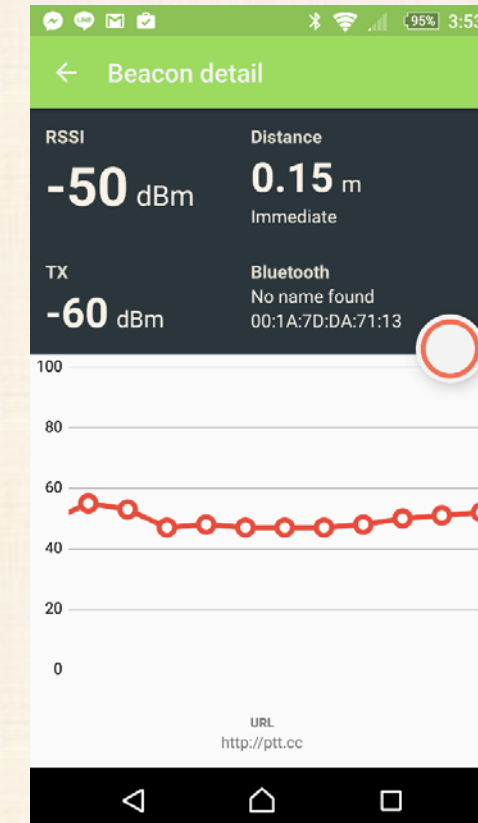
- 手機端可安裝 app 查看 Eddystone 訊息或當作 Beacon 發送 Eddystone 訊息



iBeacon generator app(Android)



iBeacon generator app(Android)



下載本次實驗函式庫

- ❑ `sudo apt-get install bluetooth`
- ❑ `sudo apt-get install bluez`
- ❑ `sudo apt-get install python-bluez`
- ❑ 程式碼已放在E3教材區

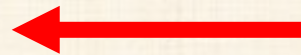
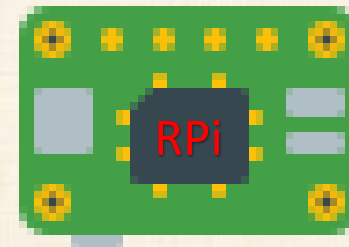
本次實驗 Demo

- Q1: 用 advertise-url 指令產生 Eddystone 的廣告訊息(請參考 PPT 第 19 頁)
 - 廣告訊息格式為 <http://www.nycu.edu.tw/xx>
 - xx = 自己的學號後兩碼
 - 再利用手機 App 抓取 Eddystone 廣告訊息並截圖附在結報內

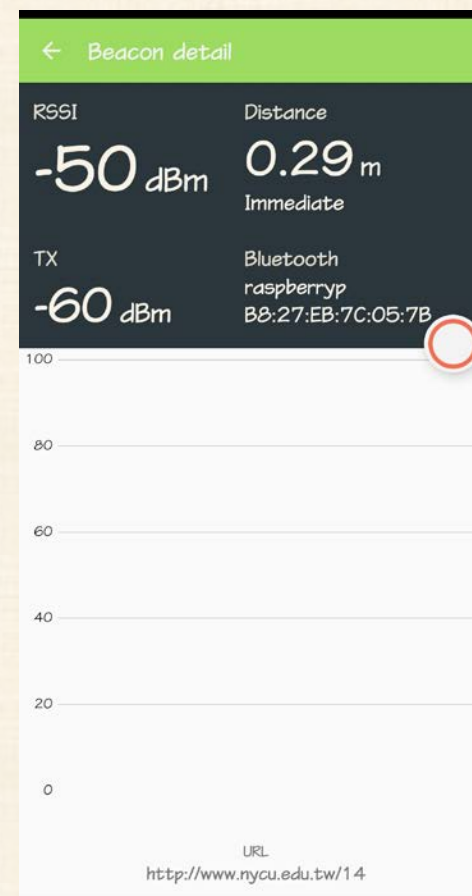
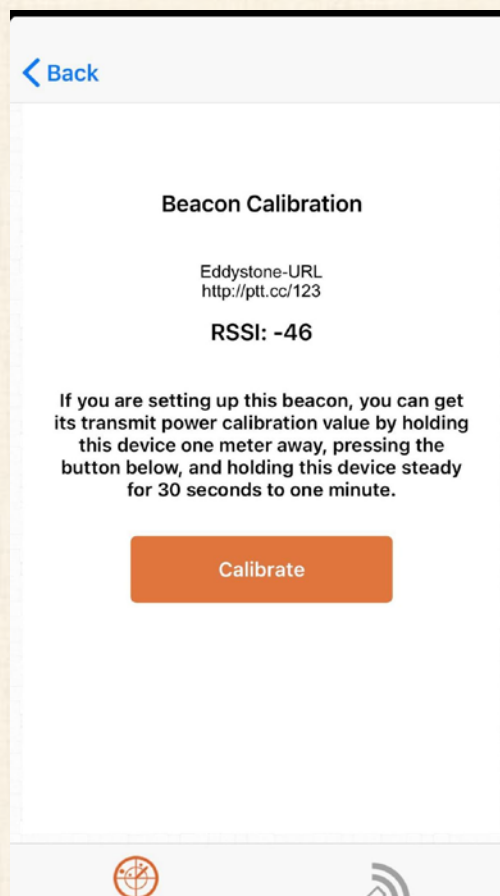
Receiver



Beacon



- 結報中請附上截圖(須包含距離、RSSI、要求傳送的 URL)



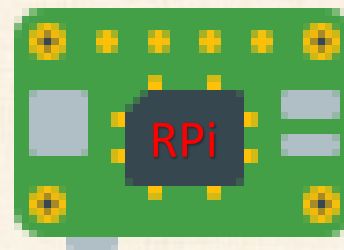
本次實驗 Demo

- Q2: 由手機擔任 Beacon，RPI 利用接收到的 RSSI、TX power 計算出傳輸距離
 - 根據助教提供的 **Lab1.py**，並自行完成
 - 接收到 RSSI 跟 TX power 後計算出距離，並按照公式輸出距離在 terminal (PPT 第 22 頁)
 - UUID = 00000000000000000000000000000000**xxxxxxxxxx**
 - 請將 **xxxxxxxxxx** 部分改成自己學號，UUID 共有 **32** 碼
 - 使用 AltBeacon 中 Nexus 4 model 的參數 (PPT 第 23 頁)

Beacon



Receiver



※請用 **sudo python Lab1.py** 來執行 Q2 程式，提供權限讓 python 能使用藍芽模組

本次實驗 Demo

```
ble thread started
-----
('raw_uuid', '00000000000000000000000000000000309513137')
('uuid:', '00000000-0000-0000-0000-0000309513137')
('major:', '0', ' ', 'minor:', '0', ' ', 'txpower:', '-59')
('rssi', '-45')
('distance (m)', 0.06662006028197409)
-----
('raw_uuid', '00000000000000000000000000000000309513137')
('uuid:', '00000000-0000-0000-0000-0000309513137')
('major:', '0', ' ', 'minor:', '0', ' ', 'txpower:', '-59')
('rssi', '-41')
('distance (m)', 0.026261434835529902)
-----
('raw_uuid', '00000000000000000000000000000000309513137')
('uuid:', '00000000-0000-0000-0000-0000309513137')
('major:', '0', ' ', 'minor:', '0', ' ', 'txpower:', '-59')
('rssi', '-42')
('distance (m)', 0.03341741003670675)
-----
('raw_uuid', '00000000000000000000000000000000309513137')
('uuid:', '00000000-0000-0000-0000-0000309513137')
('major:', '0', ' ', 'minor:', '0', ' ', 'txpower:', '-59')
('rssi', '-43')
('distance (m)', 0.04228286819738083)
-----
('raw_uuid', '00000000000000000000000000000000309513137')
('uuid:', '00000000-0000-0000-0000-0000309513137')
('major:', '0', ' ', 'minor:', '0', ' ', 'txpower:', '-59')
('rssi', '-56')
('distance (m)', 0.593417232241864)
-----
('raw_uuid', '00000000000000000000000000000000309513137')
('uuid:', '00000000-0000-0000-0000-0000309513137')
('major:', '0', ' ', 'minor:', '0', ' ', 'txpower:', '-59')
('rssi', '-43')
```


本次結報內容

- 1. 請比對 Q1 和 Q2 所量測(接收)到距離的準確度(請附上兩題截圖對照)，Q1 的方式較準確還是 Q2？或者是沒有差別呢？為什麼？
- 2. -59 dBm 是多少瓦特 (W)？請列出計算過程。
- 3. 試想 BLE 如 Eddystone 等可以應用在哪些領域？
(愈詳細且創新分數越高)

本次結報內容

- 4. 請提出Q1和Q2實驗過程中，可降低周圍裝置干擾的可行方法
(愈詳細且創新分數越高)
- 5. 本次實驗心得，你學到了什麼東西?

評分標準 & 注意事項

- 出席 30 %
- Demo 30 %
- 結報 40 %
- 請繳交 .pdf 檔，檔名為 學號_姓名_Labx.pdf
- 交錯週次者，該次結報成績扣20%

Reference

- [Raspberry Pi IoT 無線傳輸技術介紹 Bluetooth](#)
- [Eddystone](#)
- [Eddystone URL Beacon Implementations](#)
- [AltBeacon: Android-beacon-library](#)