嵌入式系統總整與實作

曾煜棋、吳昆儒

National Yang Ming Chiao Tung University

嵌入式系統總整與實作

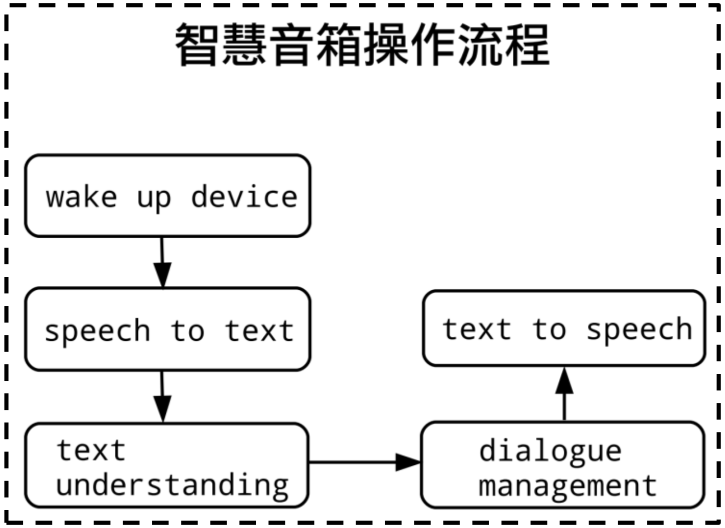
期中考周
(4/7-4/13)

期末考周
(5/27-6/2)

日期	主題
2/17	0. 課程介紹
2/24	梅竹賽!!
3/3	1. 嵌入式開發板 - 樹莓派介紹與設定 (headless)
3/10	2. 連接感測器 (GPIO, I2C) + 2 topic sharing
3/17	3. 處理感測資訊 (valuable data) + 2 topic sharing
3/24	4. 網路攝影機 IP cam+ 2 topic sharing
3/31	5. 語音互動
4/7	6.嵌入式 + AI模型: 邊緣裝置影像辨識
4/14	期中考Midterm, Project分組
4/21	專案檢索分享 (分組報告)
4/28	Final Project – Proposal (分組報告)
5/5	7. 嵌入式 + AI模型: 語音模型 (台灣樹莓派)
5/12	8. 網路應用: 推播廣告
5/19	9. 樹莓派核心編譯 (Cross compile, Kernel)
5/26	Final Project checkpoint, Q&A, 補demo
6/2	Final Project demonstration (學期考試周)
6/9, 16	彈性補充周

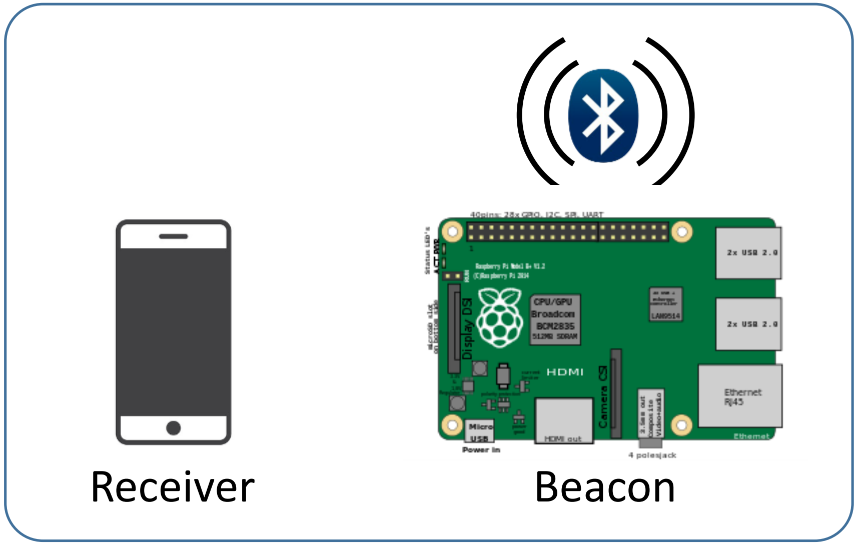
Last week

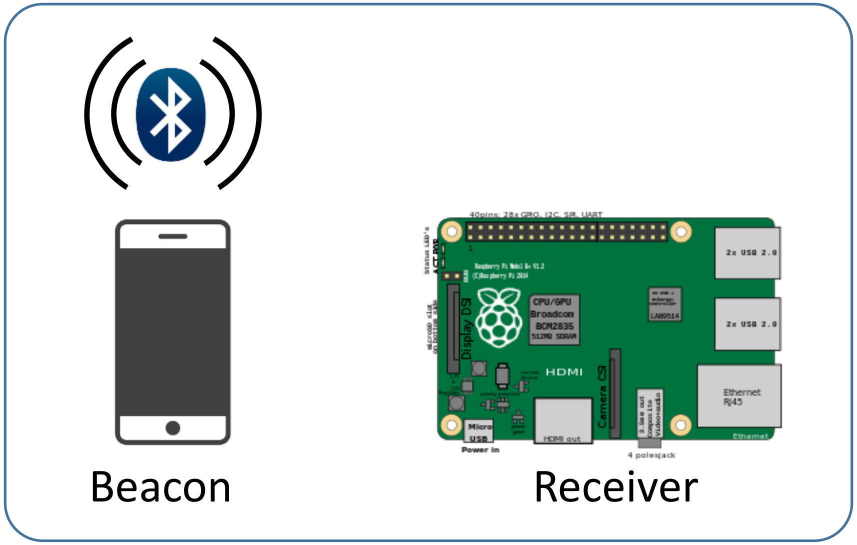
- 嵌入式應用: 語音助理 by 台灣數莓派
  - Linux ALSA 介紹
  - Hack Audio 語音應用
  - Echo cancellation 和系統整合服務



This week

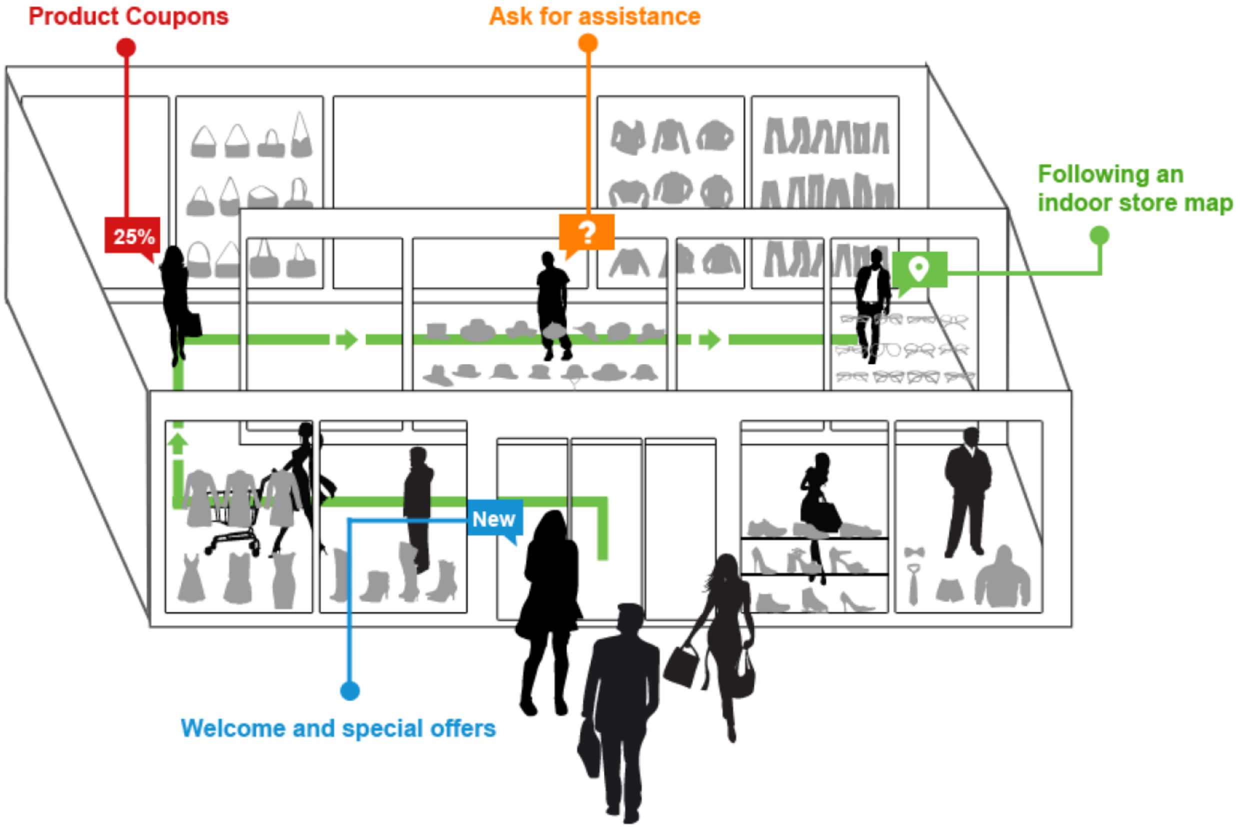
- 嵌入式應用: BLE beacon
  - Beacon applications
  - Eddystone, iBeacon protocol





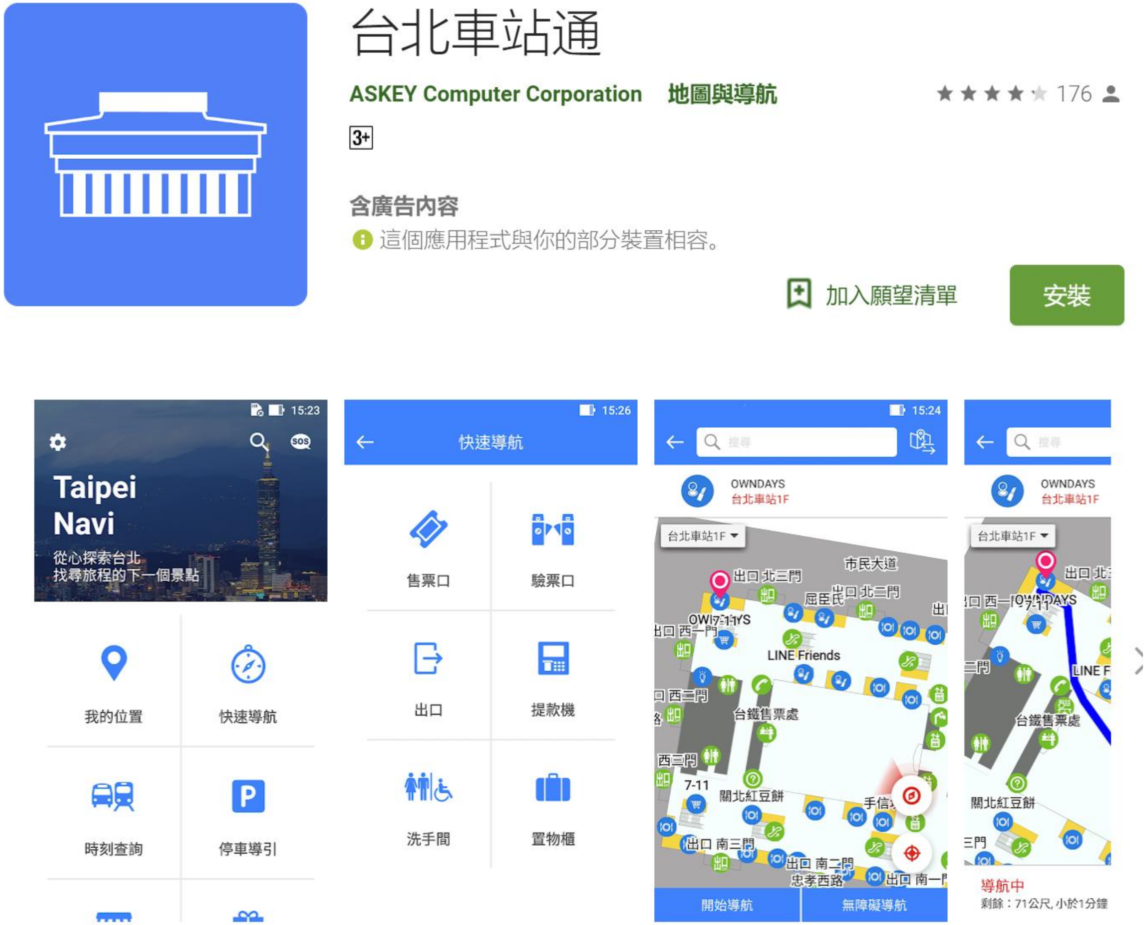
BLE 的應用

- 微型定位服務
- 推播訊息



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

Beacon x 台北車站



台北車站通

ASKEY Computer Corporation 地圖與導航

★★★★☆ 176

3+

含廣告內容

這個應用程式與你的部分裝置相容。

加入願望清單

安裝

https://tw.linebiz.com/download/line-beacon

2021 LINE Beacon
台北捷運專案-Sales Kit

LINE Beacon 是什麼？

串連媒介

LINE Beacon

以藍牙訊號與手機連線的無線設備

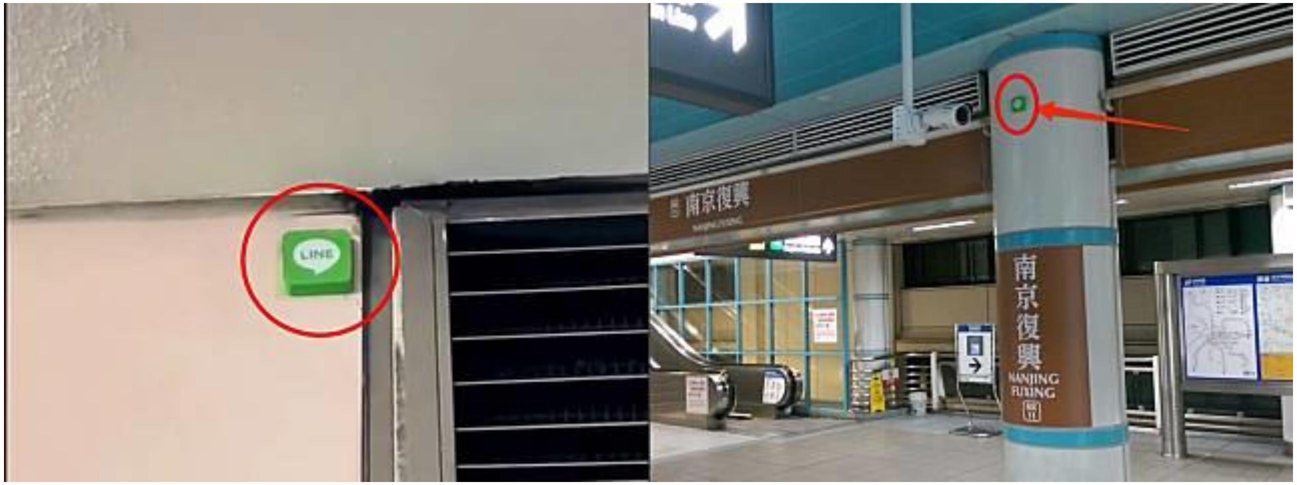
用戶進入Beacon發送範圍，即可收到OA推播訊息

半徑50公尺
南京復興
NANJING FUXING
!

https://today.line.me/tw/v2/article/WBkWEwa

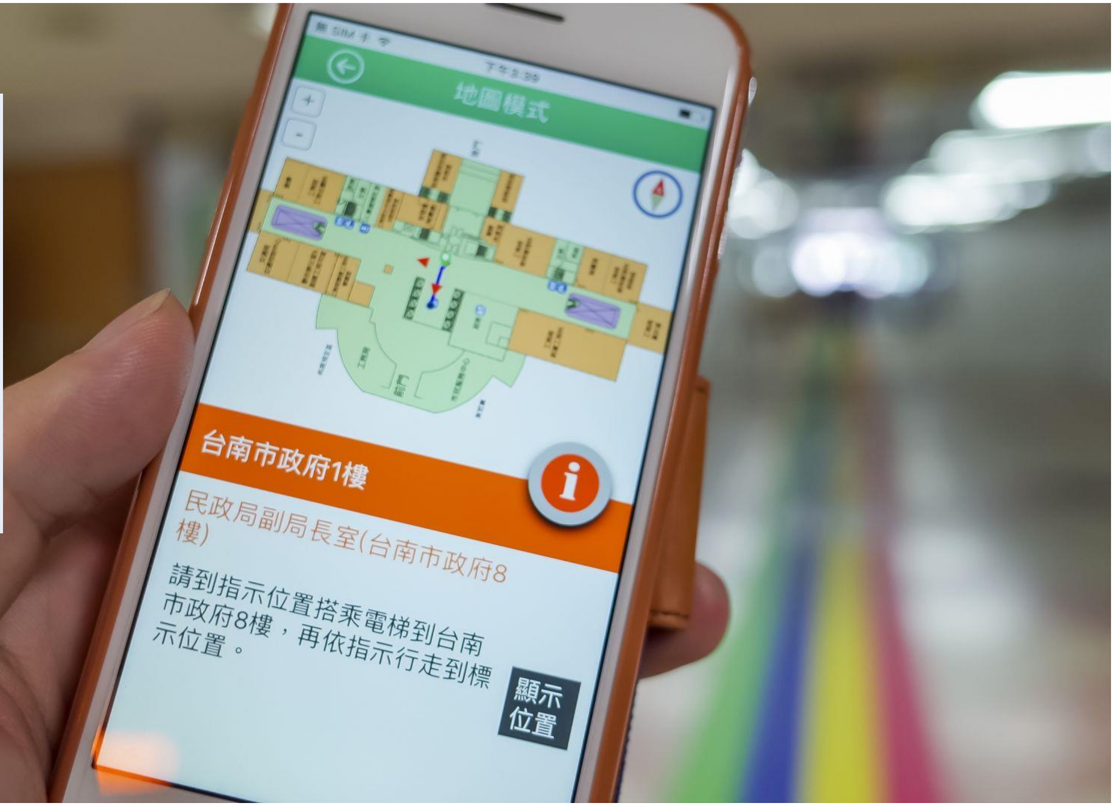
LINE Beacon簡介

- 「LINE Beacon」是LINE 2017年11月所推出的一個藍牙發射裝置，可以將優惠、特價資訊，或是特別情報發送到用戶手機中。只要走到LINE Beacon的發送範圍(約50公尺)，並且開啟手機藍牙，就可以收到LINE Beacon發出訊號！
- 成功啟用LINE Beacon的話，當用戶走進有設置LINE Beacon的店家購物時，手機的LINE應用程式，就有可能收到像是可在店內使用的優惠券、眼前商品的貼心介紹，隨著停留地點不同，還有可能接收到不同的驚喜訊息。



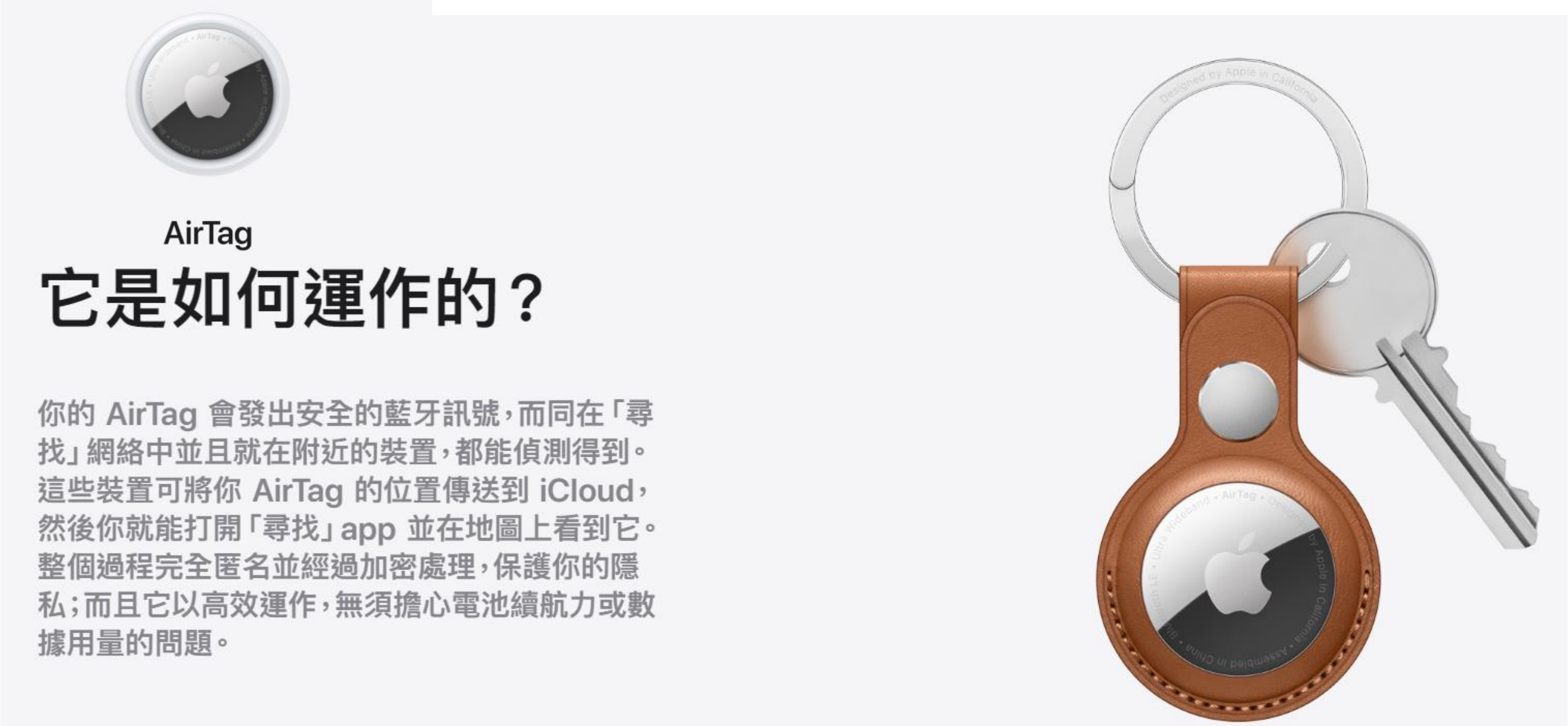
https://www.ithome.com.tw/news/116008

Beacon x 台南市政府


地圖模式
台南市政府1樓
民政局副局長室(台南市政府8樓)
請到指示位置搭乘電梯到台南市政府8樓，再依指示行走到標示位置。
顯示位置

要到臺南市政府永華行政中心洽公的市民，現在透過洽公智慧導航系統的幫助，如要向市府申請補助，可以先下載「臺南洽公小幫手」的App，就可以搜尋衛生醫療、補助資訊、教育與求職相關的便民服務，這裡提供了洽辦單位的聯絡電話，並顯示了在行政大樓內的位置，還能透過室內導航，引導民眾直接前往。

AirTag

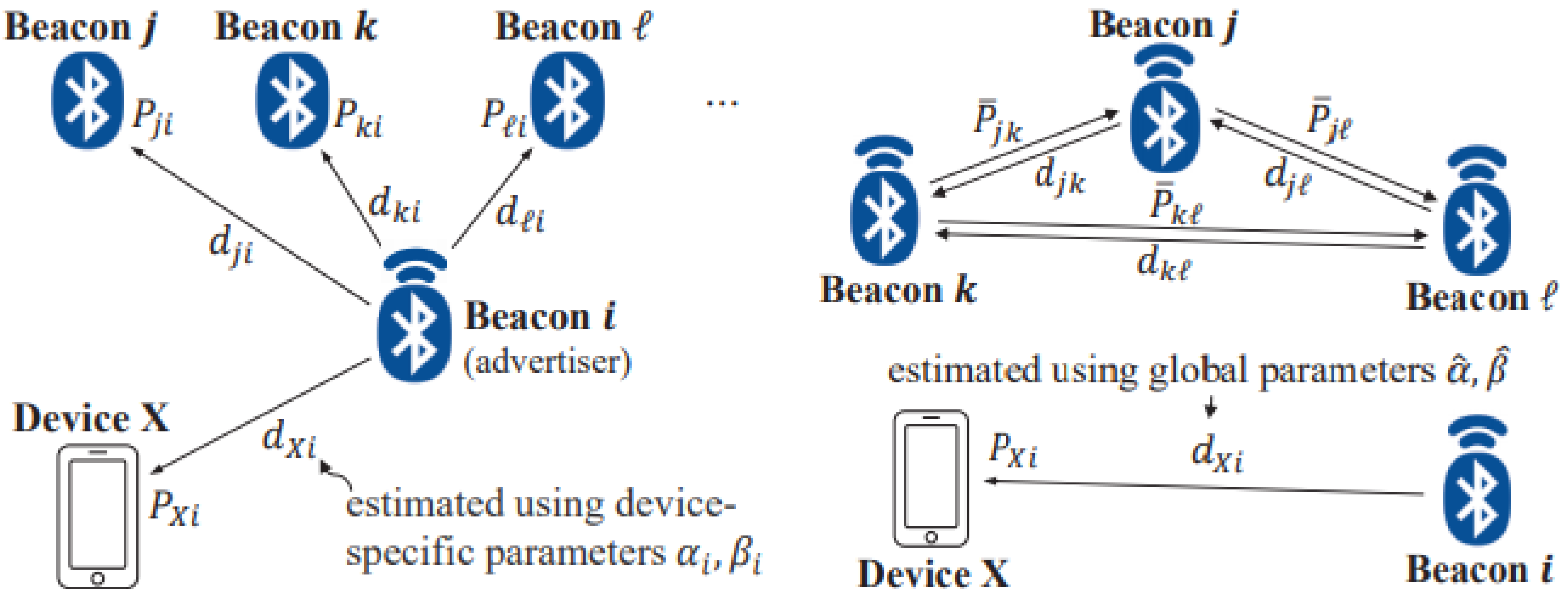


AirTag

它是如何運作的？

你的 AirTag 會發出安全的藍牙訊號，而同在「尋找」網絡中並且就在附近的裝置，都能偵測得到。這些裝置可將你 AirTag 的位置傳送到 iCloud，然後你就能打開「尋找」app 並在地圖上看到它。整個過程完全匿名並經過加密處理，保護你的隱私；而且它以高效運作，無須擔心電池續航力或數據用量的問題。

Research paper



(a) Device-specific parameters.

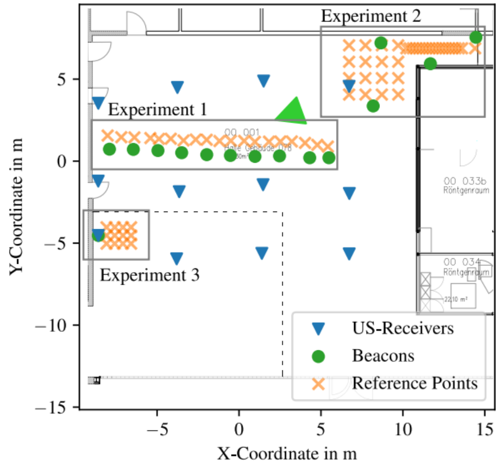
(b) Global parameters.

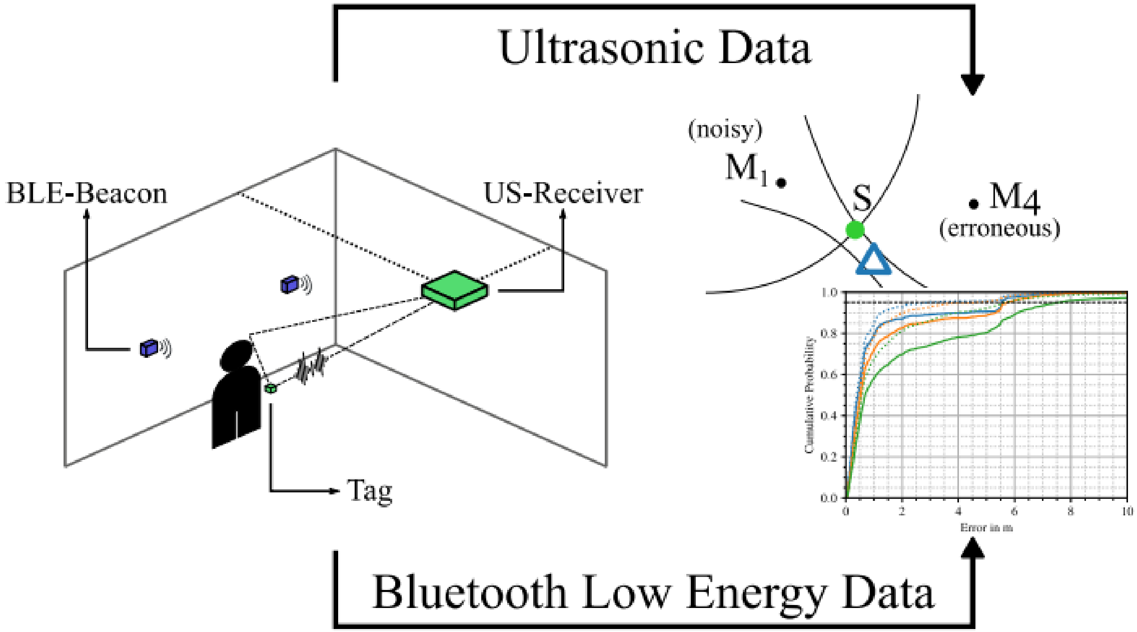
Fig. 2. Two types of regression parameters for adaptive ranging.

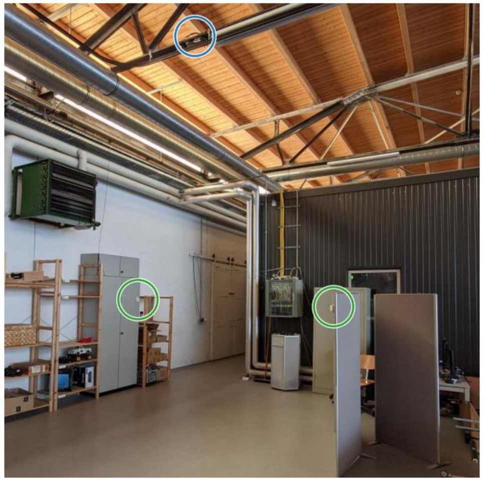
J.-W. Qiu, C.-P. Lin, and Y.-C. Tseng, “BLE-based Collaborative Indoor Localization with Adaptive Multi-lateration and Mobile Encountering”, in Proc. IEEE Wireless Communications and Networking Conference (WCNC), 2016.

https://ieeexplore.ieee.org/abstract/document/9701307

Research paper







G. Fischer *et al.*, "Multimodal Indoor Localization: Fusion Possibilities of Ultrasonic and Bluetooth Low-Energy Data," *IEEE Sensors Journal*, vol. 22, no. 6, pp. 5857-5868, 2022.

Bluetooth (藍牙)

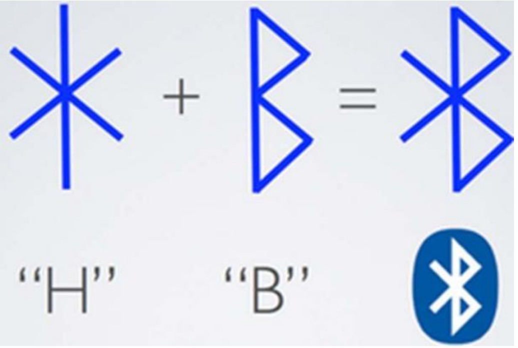
- 目的
  - 為了解決電腦與電器設備之間的傳輸問題
- 特色
  - 短距離無線技術 (10 - 100m)
  - 使用 2.4 至 2.485 GHz 的 ISM 頻段
- Bluetooth Classic: 802.15
- Bluetooth 4.0 Low Energy (BLE): 802.15.1

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

藍牙起源

- 歷史
  - 十世紀國王的名字 (Harald Blåtand)
    - 統一了因宗教戰爭和領土爭議而分裂的挪威與丹麥而聞名於世
    - 喜歡吃藍莓，因此牙齒都變成藍色 (Blue tooth)
    - 另一說，他的牙齒很差，看起來像藍色(blue, dark, black)
    - 他喜歡穿藍色的服飾，當時的藍色有昂貴、尊爵、不凡的意思
  - 由 Ericsson 在 1994 年創製 ,希望為裝置間的通訊創造一組統一規則（標準化協定），以解決用戶間互不相容的移動電子裝置

不要寫成藍**芽**喔!



https://zh.wikipedia.org/zh-tw/%E8%97%8D%E7%89%99
https://en.wikipedia.org/wiki/Harald_Bluetooth

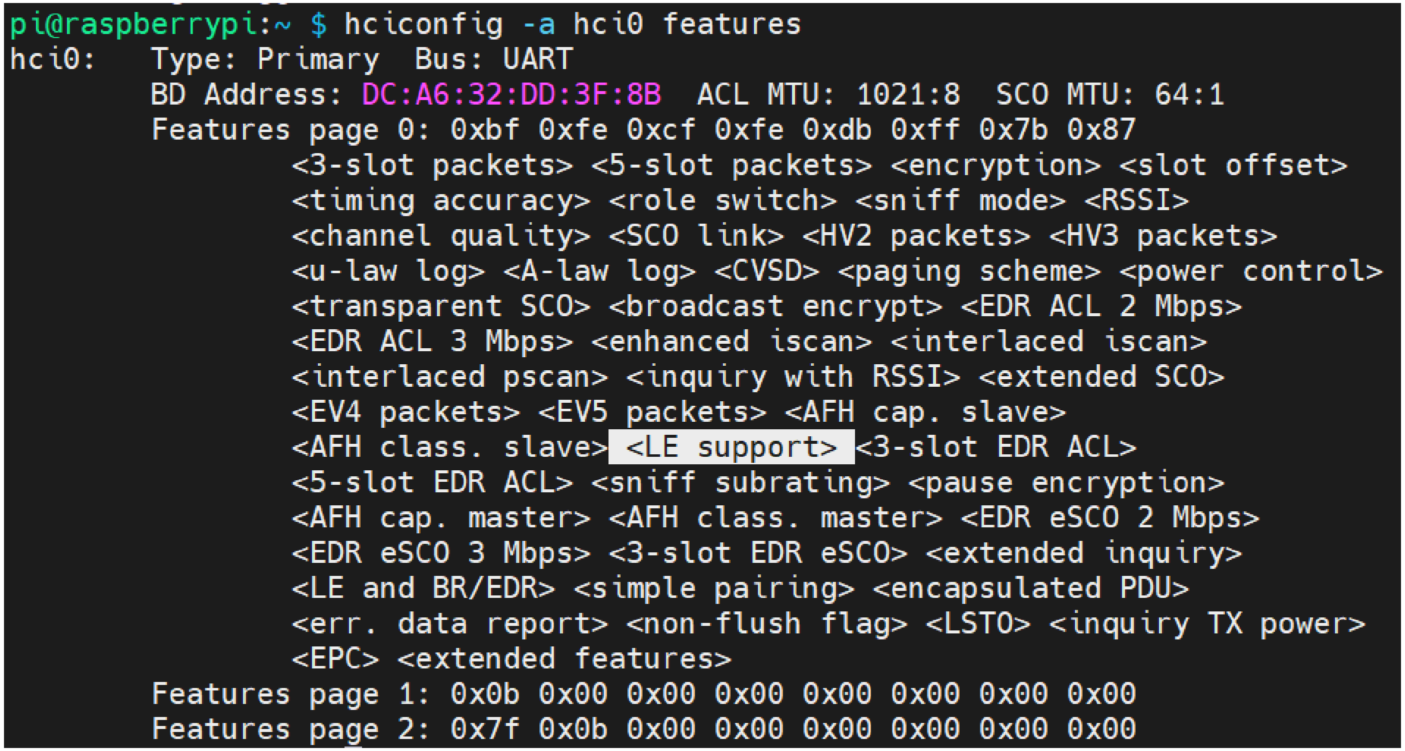
Bluetooth Low Energy (BLE)

- 一種無線個人區域網路 (Wireless PAN) 的技術
- 出現目的 : 低成本 , 低耗電 (CR2032 電池可用 1 年)
- BT4 分 Classic(BR/EDR), High Speed(HS), Low Energy

	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

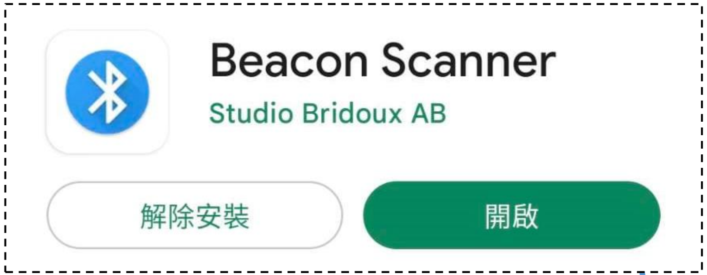
Bluetooth on PI

- Does your BT device support BLE?
  - hciconfig -a hci0 features (“**LE support**”)



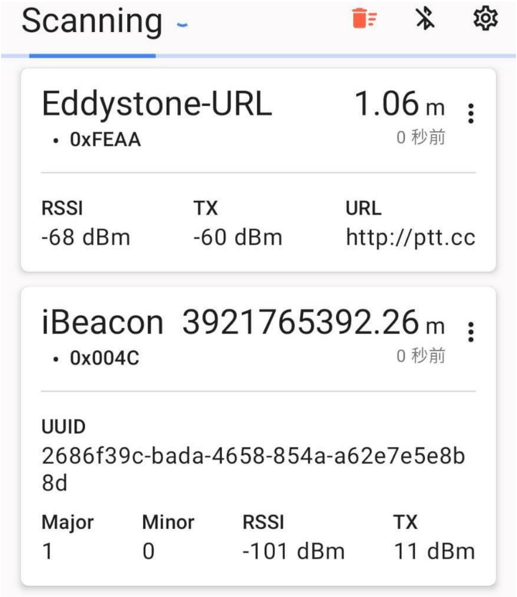
```
pi@raspberrypi:~ $ hciconfig -a hci0 features
hci0:   Type: Primary  Bus: UART
        BD Address: DC:A6:32:DD:3F:8B  ACL MTU: 1021:8  SCO MTU: 64:1
        Features page 0: 0xbf 0xfe 0xcf 0xfe 0xdb 0xff 0x7b 0x87
                <3-slot packets> <5-slot packets> <encryption> <slot offset>
                <timing accuracy> <role switch> <sniff mode> <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>
                <err. data report> <non-flush flag> <LSTO> <inquiry TX power>
                <EPC> <extended features>
        Features page 1: 0x0b 0x00 0x00 0x00 0x00 0x00 0x00 0x00
        Features page 2: 0x7f 0x0b 0x00 0x00 0x00 0x00 0x00 0x00
```

BLE beacon tools



Beacon Scanner

Studio Bridoux AB



Scanning

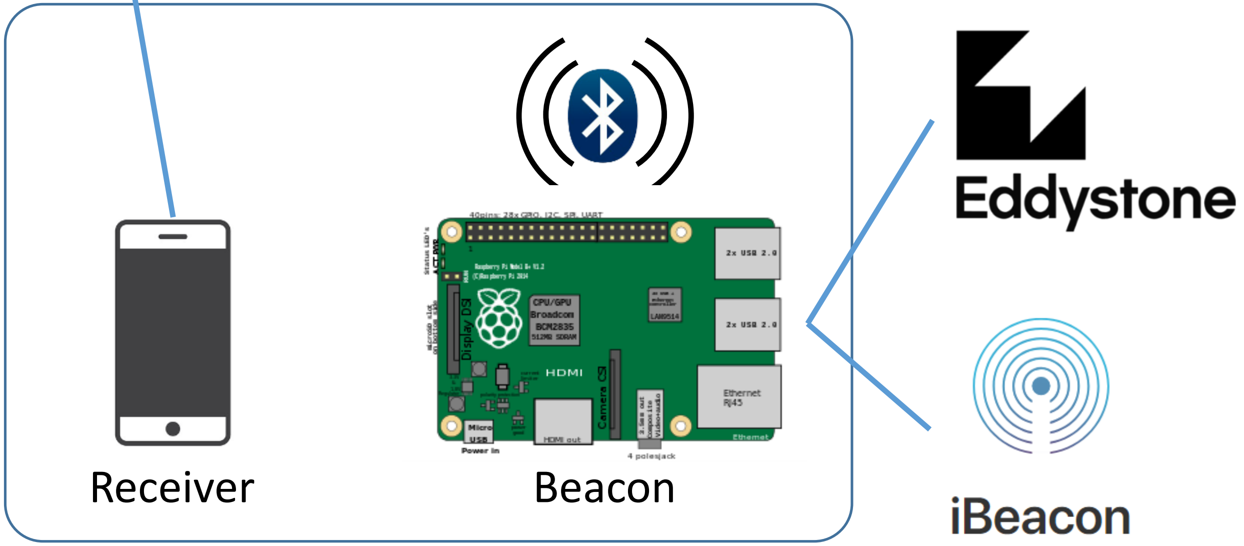
Eddystone-URL 1.06 m
• 0xFEAA 0 秒前

RSSI	TX	URL
-68 dBm	-60 dBm	http://ptt.cc

iBeacon 3921765392.26 m
• 0x004C 0 秒前

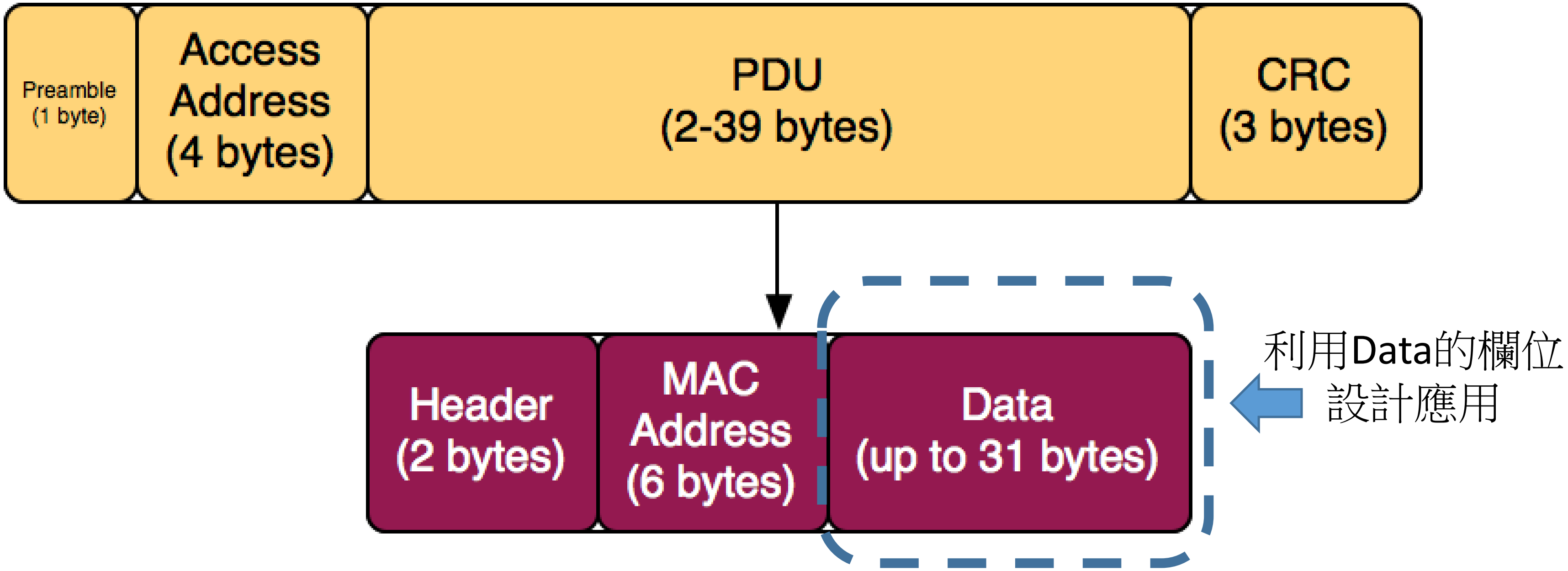
UUID
2686f39c-bada-4658-854a-a62e7e5e8b8d

Major	Minor	RSSI	TX
1	0	-101 dBm	11 dBm



BLE frame format

- The length of BLE packet is 47 bytes maximum
  - 1 byte preamble
  - 4 byte access address
  - 2-39 bytes advertising channel PDU
  - 3 bytes CRC



http://www.warski.org/blog/2014/01/how-ibeacons-work/

A. Eddystone

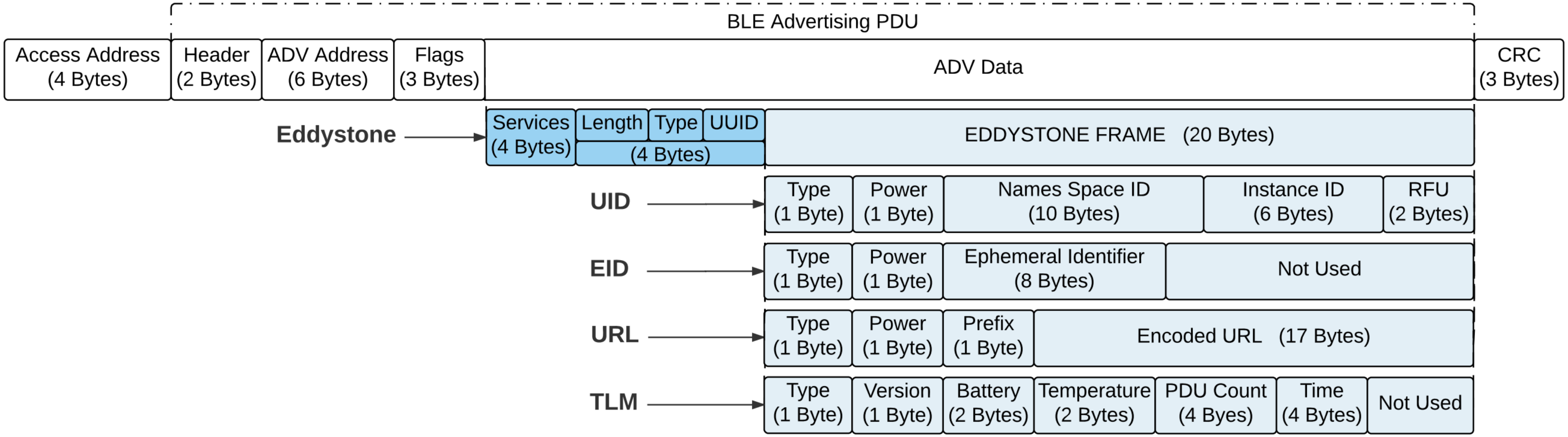
- Eddystone is a protocol specification that defines a Bluetooth low energy (BLE) message format for proximity beacon messages.

- Design Goals
  - Works well with Android and iOS Bluetooth developer APIs
  - Straightforward implementation on a wide range of existing BLE devices
  - Flexible architecture permitting development of new frame types
  - Fully compliant with the Bluetooth Core Specification

https://github.com/google/eddystone

Fig source: https://www.mdpi.com/1424-8220/18/1/57

A. Eddystone Frame format



BLE Advertising PDU

Access Address (4 Bytes) | Header (2 Bytes) | ADV Address (6 Bytes) | Flags (3 Bytes) | ADV Data | CRC (3 Bytes)

Eddystone → Services (4 Bytes) | Length Type UUID (4 Bytes) | EDDYSTONE FRAME (20 Bytes)

UID → Type (1 Byte) | Power (1 Byte) | Names Space ID (10 Bytes) | Instance ID (6 Bytes) | RFU (2 Bytes)

EID → Type (1 Byte) | Power (1 Byte) | Ephemeral Identifier (8 Bytes) | Not Used

URL → Type (1 Byte) | Power (1 Byte) | Prefix (1 Byte) | Encoded URL (17 Bytes)

TLM → Type (1 Byte) | Version (1 Byte) | Battery (2 Bytes) | Temperature (2 Bytes) | PDU Count (4 Byes) | Time (4 Bytes) | Not Used

Frame Type	High-Order 4 bits	Byte Value
UID	0000	0x00
URL	0001	0x10
TLM	0010	0x20
EID	0011	0x30
RESERVED	0100	0x40

The Eddystone-URL frame forms the backbone of the Physical Web, an effort to enable frictionless discovery of web content relating to one’s surroundings.

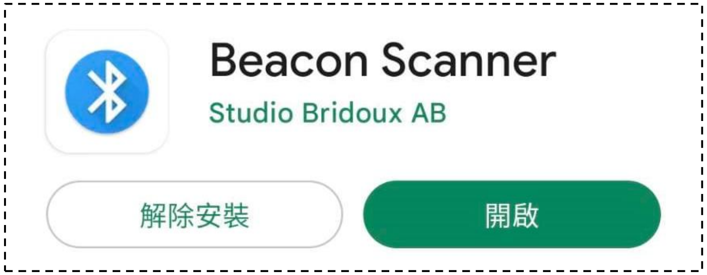
https://github.com/google/eddystone/blob/master/protocol-specification.md

A. Eddystone by Python

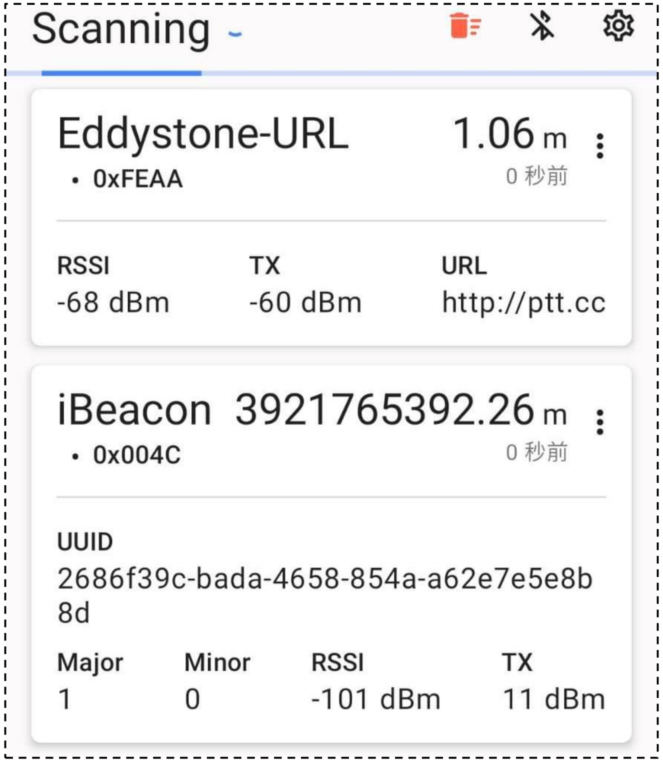
- Source: https://github.com/google/eddystone
- Download tool
  - wget https://raw.githubusercontent.com/google/eddystone/master/eddystone-url/implementations/linux/advertise-url
  - chmod +x advertise-url
  - sudo ./advertise-url -u http://ptt.cc // adversity URL
  - sudo ./advertise-url -s // stop

A. Eddystone

- 手機端可安裝app查看Eddystone訊息


Beacon Scanner
Studio Bridoux AB

```
{
  "beacon_type": "eddystone_url",
  "distance": 0.8818019258442197,
  "eddystone_url_data": {
    "url": "http://ptt.cc"
  },
  "hashcode": -1844177626,
  "isBlocked": false,
  "last_seen": 1683515926080,
  "manufacturer": 65194,
  "rssi": -58,
  "tx_power": -60
}
```



Eddystone-URL 1.06 m
- 0xFEAA

0 秒前

RSSI	TX	URL
-68 dBm	-60 dBm	http://ptt.cc

iBeacon 3921765392.26 m
- 0x004C

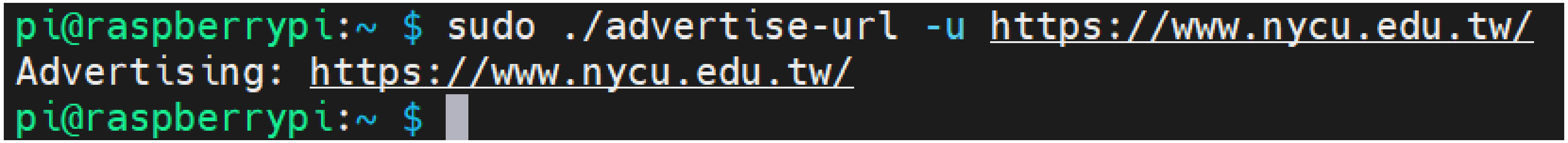
0 秒前

UUID
2686f39c-bada-4658-854a-a62e7e5e8b8d

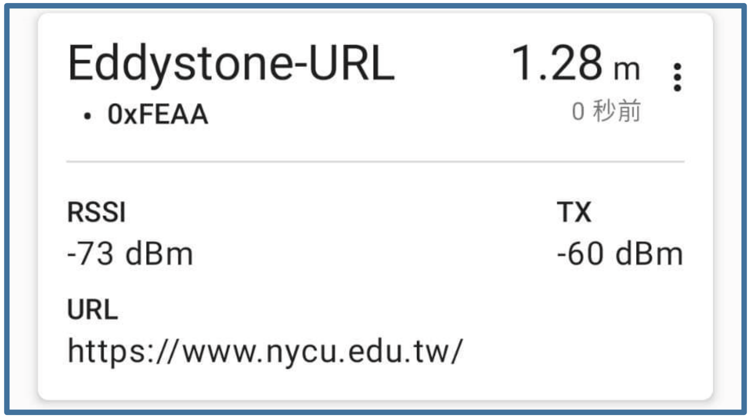
Major	Minor	RSSI	TX
1	0	-101 dBm	11 dBm

A. Eddystone by Python

- sudo ./advertise-url -u http://hk.3345678



```
pi@raspberrypi:~ $ sudo ./advertise-url -u https://www.nycu.edu.tw/
Advertising: https://www.nycu.edu.tw/
pi@raspberrypi:~ $
```



Eddystone-URL 1.28 m

- 0xFEAA

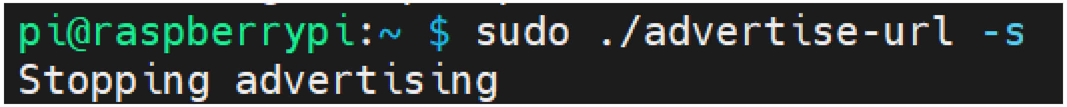
0 秒前

RSSI
-73 dBm

TX
-60 dBm

URL
https://www.nycu.edu.tw/

- sudo ./advertise-url -s



```
pi@raspberrypi:~ $ sudo ./advertise-url -s
Stopping advertising
```

A. Eddystone

- Translate URL to Eddystone message
  - Ex: http://ptt.cc
  - ACSII table https://zh.wikipedia.org/wiki/ASCII

數值 (16進位)	網址
02	http://
70	p
74	t
74	t
2e	.
63	c
63	c

Decimal	Hex	Expansion
0	0x00	http://www.
1	0x01	https://www.
2	0x02	http://
3	0x03	https://

A. Eddystone by hcitool

- 使用bluetooth工具傳送網址廣播

```
sudo hciconfig hci0 leadv 3       // 啟用藍牙的低耗能廣告(LE advertising)模式
sudo hciconfig hci0 noscan        // 並關閉掃描功能

sudo hcitool -i hci0 cmd 0x08 0x0008 14 02 01 1a 03 03 aa fe 0c 16 aa fe 10 ed
02 70 74 74 2e 63 63 00 00 00 00 00 00 00 00 00 00 00   //傳送Eddystone frame
```

↑ http://ptt.cc

```
sudo hciconfig hci0 noleadv          //停止廣告
```

數值 (16進位)	網址
02	http://
70	p
74	t
74	t
2e	.
63	c
63	c

A. Eddystone by hcitool

sudo hcitool -i hci0 cmd 0x08 0x0008 14 02 01 1a 03 03 aa fe 0c 16 aa fe 10 ed **02 70 74 74 2e 63 63** 00 00 00 00 00 00 00 00 00 00 00

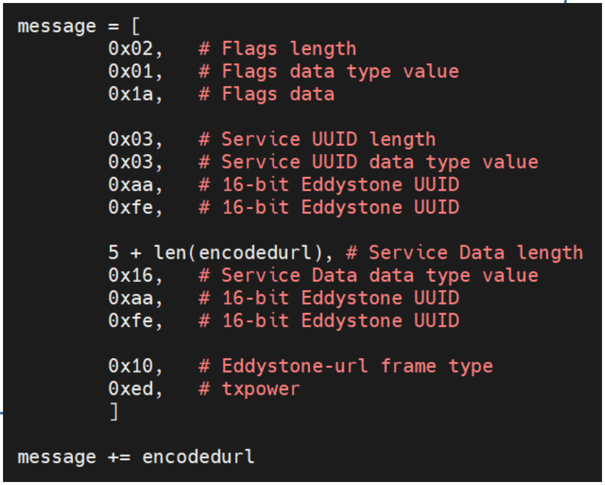
- 0x08 0x0008: set the ad package
  - #OGF = Operation Group Field = Bluetooth Command Group = 0x08
  - #OCF = Operation Command Field = HCI_LE_Set_Advertising_Data = 0x0008
- 14: the ENTIRE following data packet in bytes (16進位的14 = 20 byte)

20 byte

- 02 01 1a: Eddystone Adv Flags
  - 0x06 - The device is BLE only. The full Bluetooth stack is not supported.
  - 0x1A - The device can be used as BLE as well as full Bluetooth Controller/Host simultaneously.
- 03 03 aa fe: Eddystone service adv
- 0c: length (0c = 12 byte)
- 16: type (data)
- aa fe: Eddystone UUID
- 10: URL frame type (here is URL)
- ed: TX power
- **02 70 74 74 2e 63 63**: http://ptt.cc,共 7 byte

12 byte

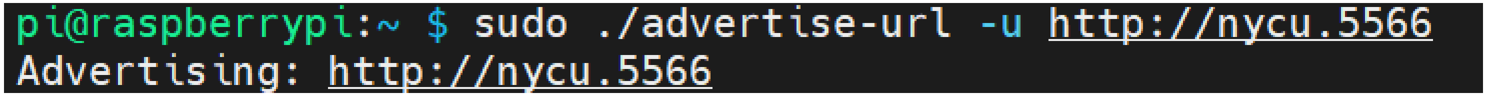
- 00 00 00 00 00 00 00 00 00 00 00: 共 10 byte



```
message = [
        0x02,   # Flags length
        0x01,   # Flags data type value
        0x1a,   # Flags data

        0x03,   # Service UUID length
        0x03,   # Service UUID data type value
        0xaa,   # 16-bit Eddystone UUID
        0xfe,   # 16-bit Eddystone UUID

        5 + len(encodedurl), # Service Data length
        0x16,   # Service Data data type value
        0xaa,   # 16-bit Eddystone UUID
        0xfe,   # 16-bit Eddystone UUID

        0x10,   # Eddystone-url frame type
        0xed,   # txpower
        ]

message += encodedurl
```

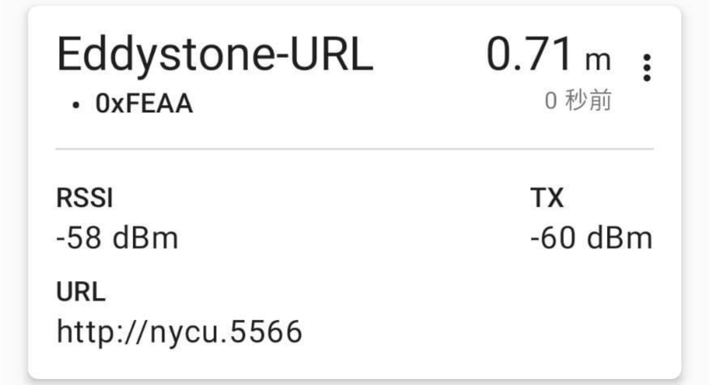
Discussion 1

- Advertise an your own URL
  - Ex: nycu.5566



```
pi@raspberrypi:~ $ sudo ./advertise-url -u http://nycu.5566
Advertising: http://nycu.5566
```

- Show/Capture your scanning result



Eddystone-URL 0.71 m

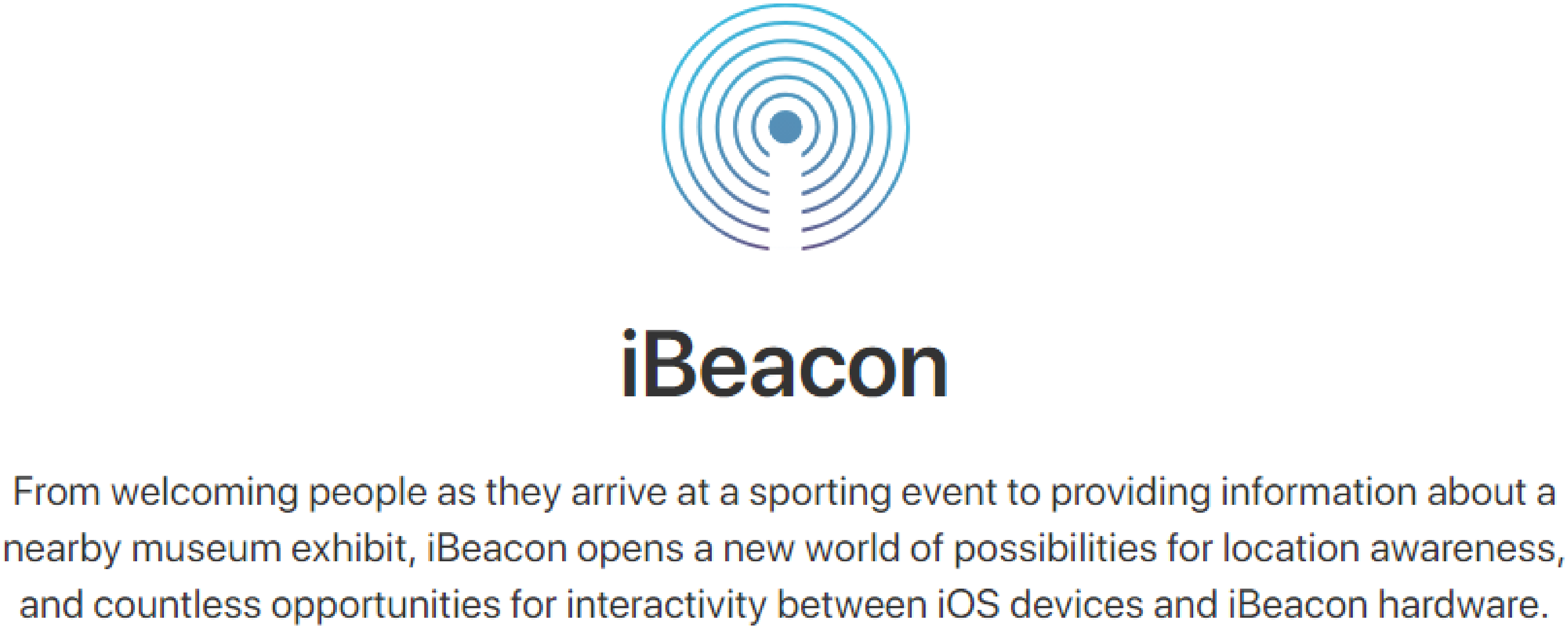
- 0xFEAA

0 秒前

RSSI
-58 dBm

TX
-60 dBm

URL
http://nycu.5566



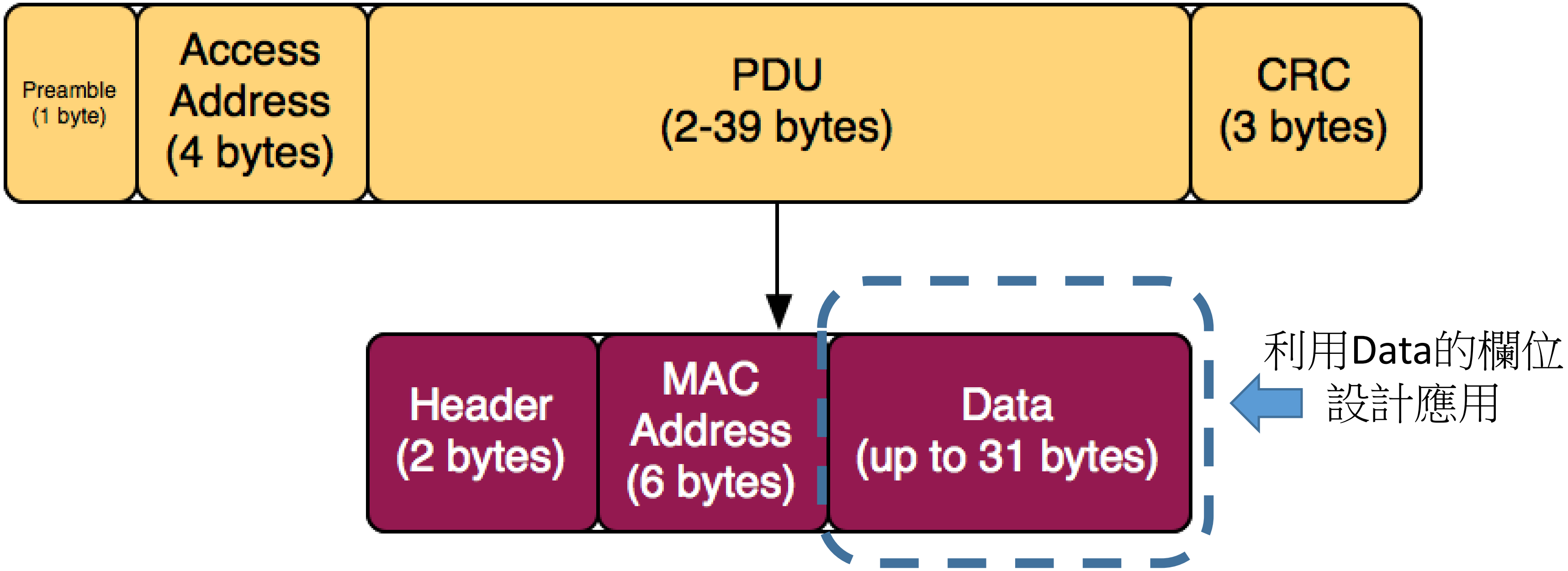
iBeacon

From welcoming people as they arrive at a sporting event to providing information about a nearby museum exhibit, iBeacon opens a new world of possibilities for location awareness, and countless opportunities for interactivity between iOS devices and iBeacon hardware.

https://developer.apple.com/ibeacon/

Recall BLE frame format

- The length of BLE packet is 47 bytes maximum
  - 1 byte preamble
  - 4 byte access address
  - 2-39 bytes advertising channel PDU
  - 3 bytes CRC



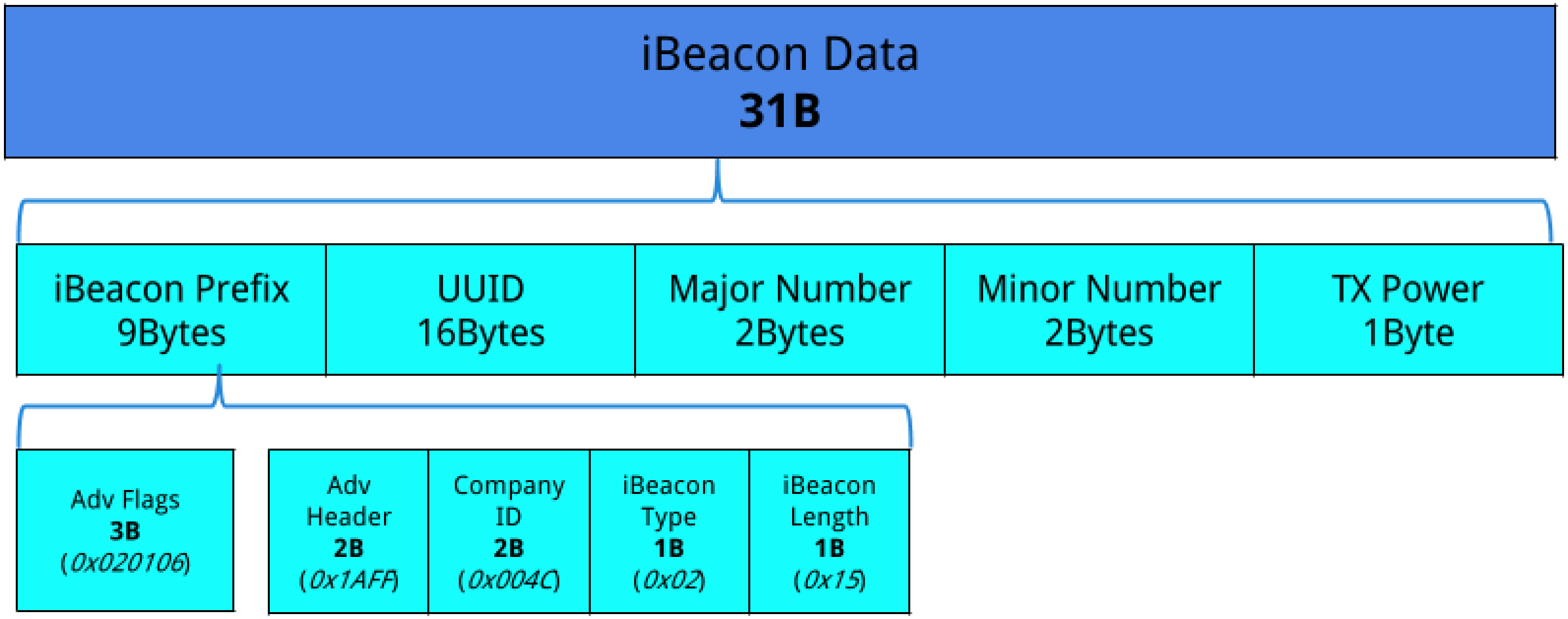
利用Data的欄位設計應用

http://www.warski.org/blog/2014/01/how-ibeacons-work/

https://os.mbed.com/blog/entry/BLE-Beacons-URIBeacon-AltBeacons-iBeacon/

B. iBeacon format

iBeacon



iBeacon Data
31B

iBeacon Prefix
9Bytes

UUID
16Bytes

Major Number
2Bytes

Minor Number
2Bytes

TX Power
1Byte

Adv Flags
3B
(*0x020106*)

Adv Header
2B
(*0x1AFF*)

Company ID
2B
(*0x004C*)

iBeacon Type
1B
(*0x02*)

iBeacon Length
1B
(*0x15*)

https://github.com/dburr/linux-ibeacon

B. iBeacon tool

- Dependecies
  - sudo apt-get install bluetooth blueman libbluetooth-dev
  - sudo pip3 install pybluez

- git clone https://github.com/coldwufish/linux-ibeacon
- cd linux-ibeacon/
- chmod +x ibeacon_python3
- sudo ./ibeacon_python3 -u your_uuid -M your_majorID -m your_minorID
- sudo ./ibeacon_python3 -z   // stop ibeacon

https://support.kontakt.io/hc/en-gb/articles/201620741-iBeacon-Parameters-UUID-Major-and-Minor

B. iBeacon tool

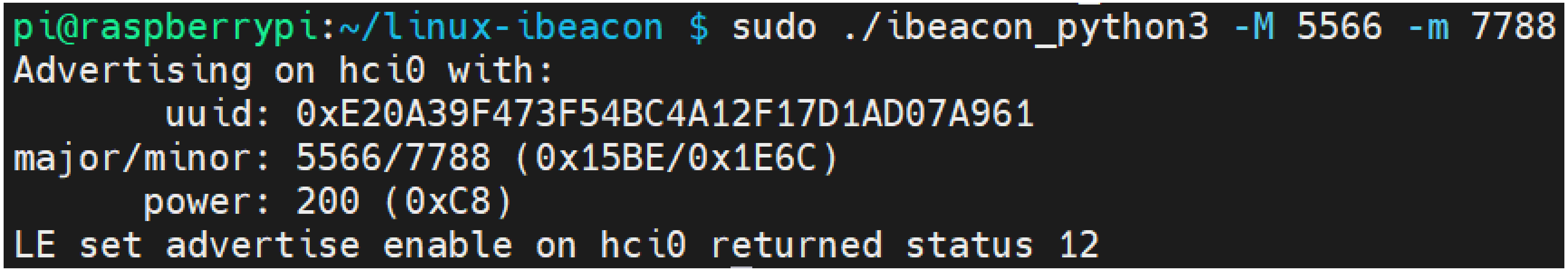
- What is UUID?
  - UUID stands for Universally Unique Identifier.
  - It contains 32 hexadecimal digits, split into 5 groups, separated by hyphens and should look something like this:

    f7826da6-4fa2-4e98-8024-bc5b71e0893e

- Each of the 5 groups must contain the following number of characters per section:
  - First section: 8
  - Second section: 4
  - Third section: 4
  - Fourth section: 4
  - Fifth section: 12

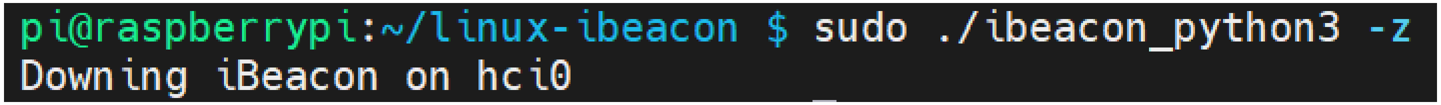
B. Start advertising

- sudo ./ibeacon_python3 -M 5566 -m 7788
  - Major ID = 5566; Minor ID = 7788



```
pi@raspberrypi:~/linux-ibeacon $ sudo ./ibeacon_python3 -M 5566 -m 7788
Advertising on hci0 with:
       uuid: 0xE20A39F473F54BC4A12F17D1AD07A961
major/minor: 5566/7788 (0x15BE/0x1E6C)
      power: 200 (0xC8)
LE set advertise enable on hci0 returned status 12
```

- Stop: sudo ./ibeacon_python3 -z

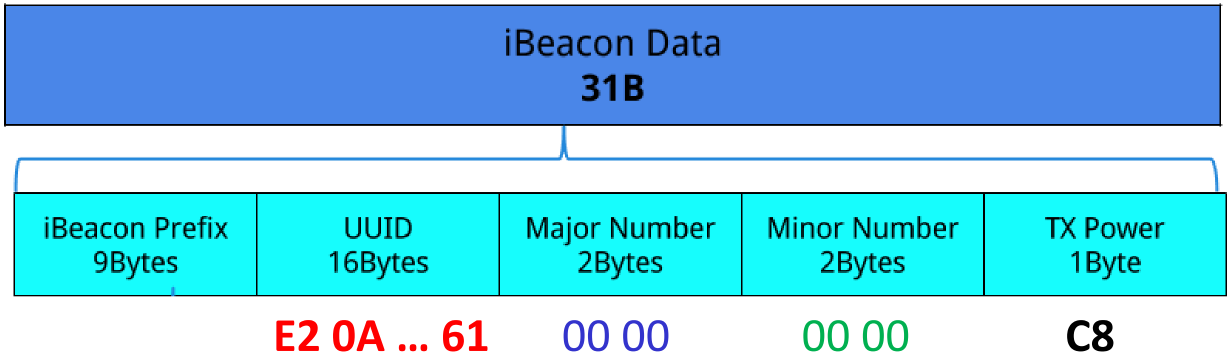


```
pi@raspberrypi:~/linux-ibeacon $ sudo ./ibeacon_python3 -z
Downing iBeacon on hci0
```

https://blog.gtwang.org/iot/raspberry-pi/diy-build-raspberry-pi-ibeacon-transmitter-tutorial/

B. Advertising by hciconfig

- sudo hciconfig hci0 up
- sudo hciconfig hci0 leadv 3
- sudo hciconfig hci0 noscan
- sudo hcitool -i hci0 cmd 0x08 0x0008 1E 02 01 06 1A FF 00 4C 02 15 **E2 0A 39 F4 73 F5 4B C4 A1 2F 17 D1 AD 07 A9 61** 00 00 00 00 **C8** 00



iBeacon Data
31B

iBeacon Prefix 9Bytes	UUID 16Bytes	Major Number 2Bytes	Minor Number 2Bytes	TX Power 1Byte
	E2 0A … 61	00 00	00 00	**C8**

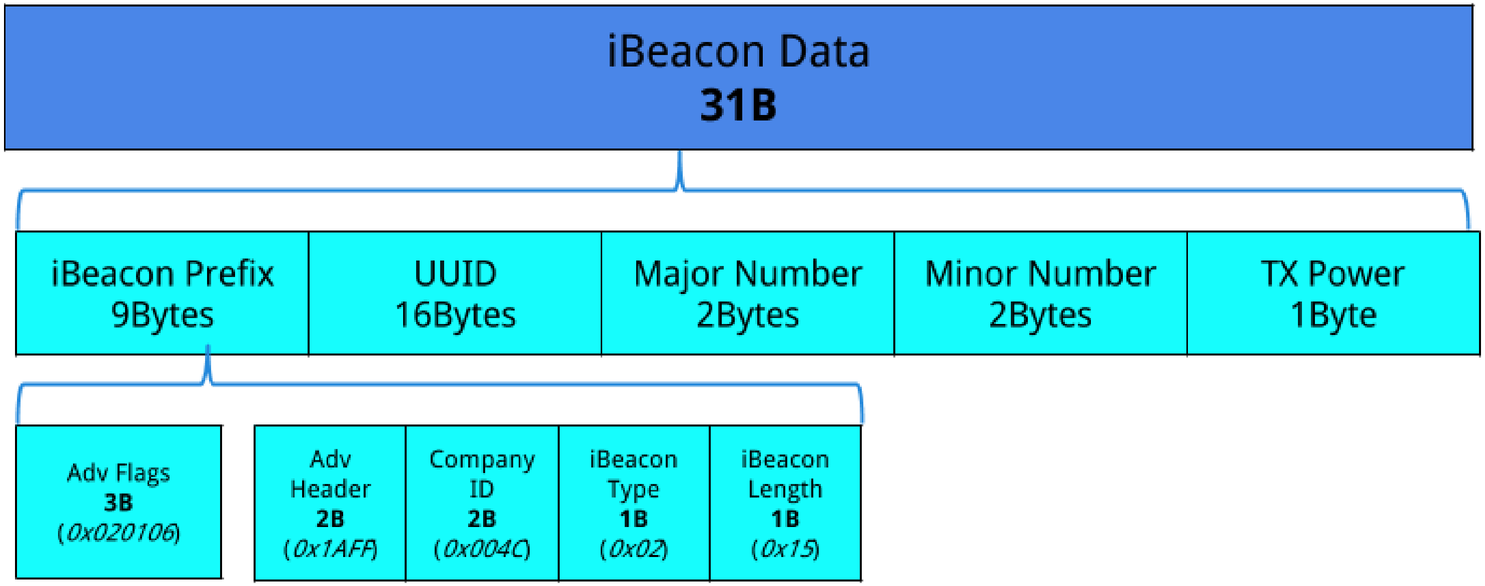
https://www.exploringbinary.com/twos-complement-converter/

B. iBeacon by hcitool

- sudo hcitool -i hci0 cmd 0x08 0x0008 1E 02 01 06 1A FF 00 4C 02 15 **E2 0A 39 F4 73 F5 4B C4 A1 2F 17 D1 AD 07 A9 61** 00 00 00 00 **C8**
- 0x08 0x0008: set the ad package
  - #OGF = Operation Group Field = Bluetooth Command Group = 0x08
  - #OCF = Operation Command Field = HCI_LE_Set_Advertising_Data = 0x0008
- **1E** // the ENTIRE following data packet in bytes (31 byte)
- **02 01 06** // set the flags for General Discoverable and BR/EDR not supported
- **1A FF** // the length of the Manufacturer specific data field will be 26 bytes
- **00 4C** // Company ID
- **02** // iBeacon type, ID
- **15** // length of remaining data in bytes
  (16B UUID+ 2B major, 2B minor, 1B Txpower)
- **E2 0A 39 F4 73 F5 4B C4 A1 2F 17 D1 AD 07 A9 61 // UUID**
- **00 00 // Major ID**
- **00 00 // Minor ID**
- **C8 // Tx power**. C8 = 11001000 --(2's)--> -56dBm

Discussion 2

- What is the maximum value of major and minor ID? How to calculate this value?
  - You can refer to iBeacon data format



iBeacon Data
31B

iBeacon Prefix
9Bytes

UUID
16Bytes

Major Number
2Bytes

Minor Number
2Bytes

TX Power
1Byte

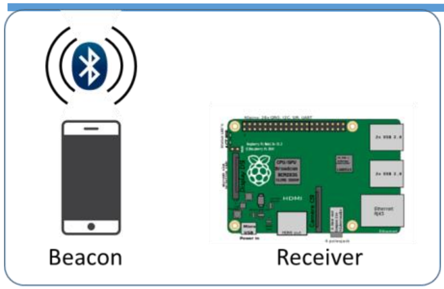
Adv Flags
3B
(*0x020106*)

Adv Header
2B
(*0x1AFF*)

Company ID
2B
(*0x004C*)

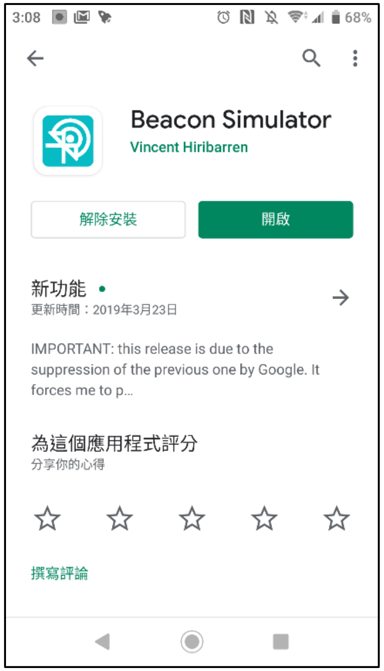
iBeacon Type
1B
(*0x02*)

iBeacon Length
1B
(*0x15*)



Scan a nearby beacon

- Prepare iBeacon generator app
  - Android: Beacon Simulator
  - **iOS: Locate Beacon**


3:08 68%

Beacon Simulator
Vincent Hiribarren

解除安裝 開啟

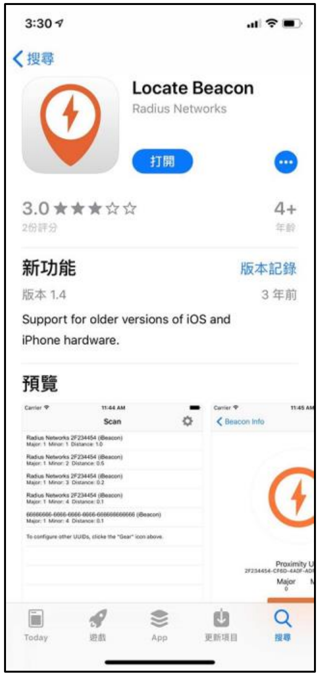
新功能 •
更新時間：2019年3月23日

IMPORTANT: this release is due to the suppression of the previous one by Google. It forces me to p...

為這個應用程式評分
分享你的心得

☆ ☆ ☆ ☆ ☆

撰寫評論


3:30

搜尋

Locate Beacon
Radius Networks

打開

3.0 ★★★☆☆ 4+
2份評分 年齡

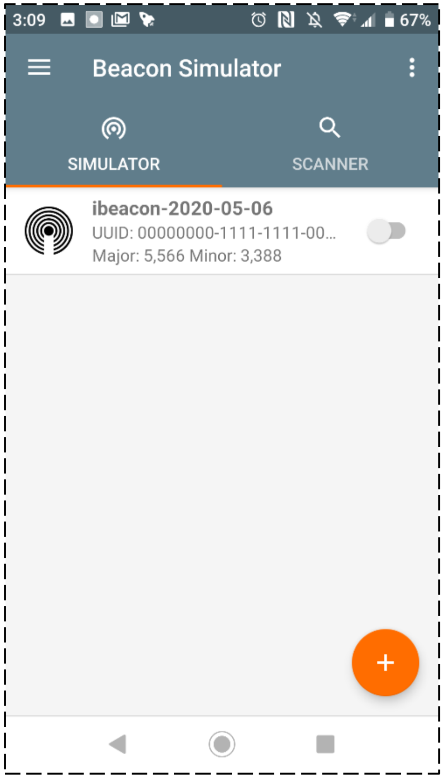
新功能 版本記錄
版本 1.4 3 年前
Support for older versions of iOS and iPhone hardware.

預覽

Carrier 11:44 AM
Scan
Radius Networks 2F234454 (iBeacon)
Major: 1 Minor: 1 Distance: 1.0
Radius Networks 2F234454 (iBeacon)
Major: 1 Minor: 2 Distance: 0.5
Radius Networks 2F234454 (iBeacon)
Major: 1 Minor: 3 Distance: 0.2
Radius Networks 2F234454 (iBeacon)
Major: 1 Minor: 4 Distance: 0.1
66666666-6666-6666-6666-666666666666 (iBeacon)
Major: 1 Minor: 4 Distance: 0.1
To configure other UUIDs, clicke the "Gear" icon above.

Carrier 11:45 AM
Beacon Info
Proximity U
2F234454-CF6D-4A0F-AD
Major
0

Today 遊戲 App 更新項目 搜尋

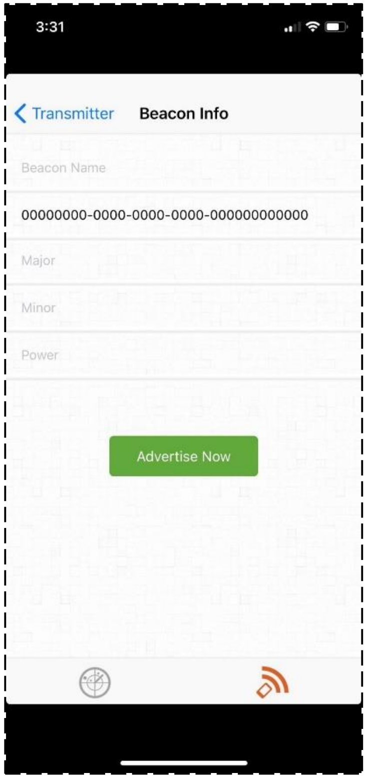

3:09 67%

Beacon Simulator

SIMULATOR SCANNER

ibeacon-2020-05-06
UUID: 00000000-1111-1111-00...
Major: 5,566 Minor: 3,388

+


3:31

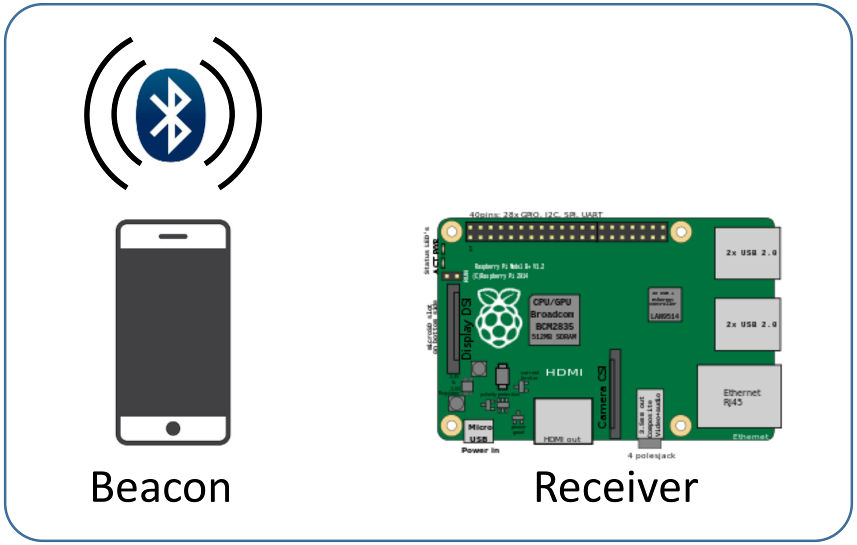
Transmitter Beacon Info

Beacon Name
00000000-0000-0000-0000-000000000000
Major
Minor
Power

Advertise Now

Scan a nearby beacon

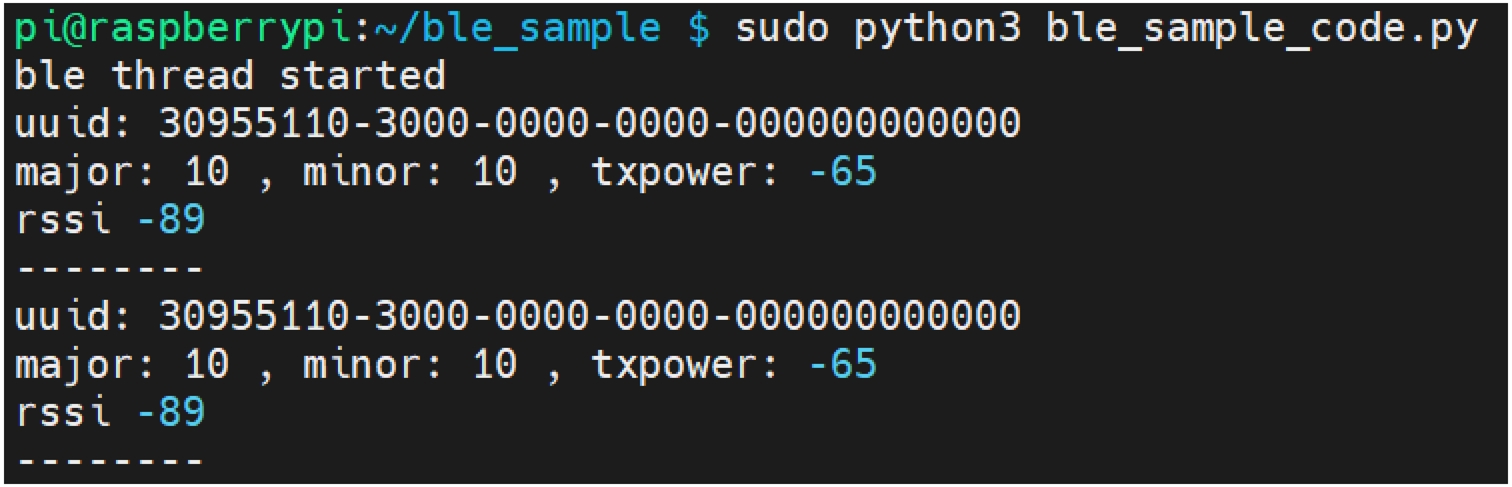
- How to calculate distance?
  - Based on **RSSI** (Received signal strength indication) and **TX power** in BLE frame
  - Use **propagation model (path loss)** to calculate
    - Ex: Free Space, Two-ray ground-reflection, Friis Transmission … etc



Path Loss = TX_power(dBm) – RX_power(dBm)

Scan a nearby beacon

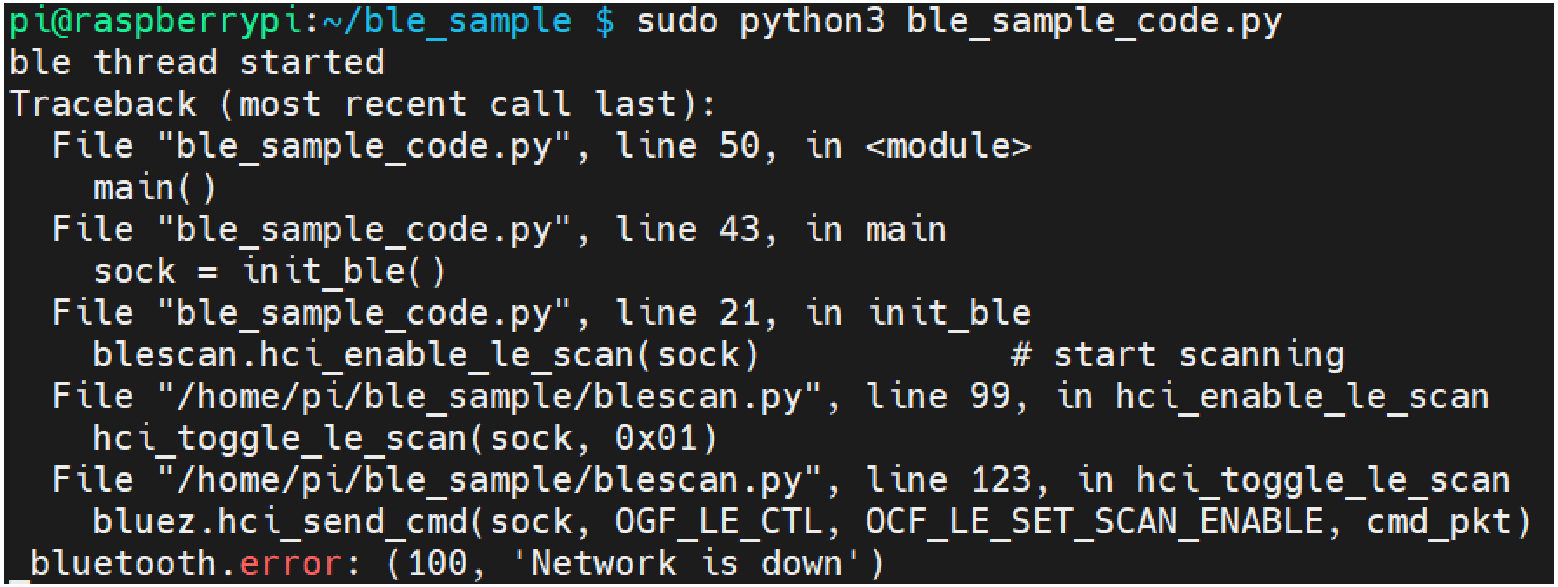
- Scan a specific ibeacon uuid:
  - Download and unzip sample code
  - Run: sudo python3 ble_sample_code.py
    - Ex: uuid= 30955110-3000-0000-0000-000000000000



```
pi@raspberrypi:~/ble_sample $ sudo python3 ble_sample_code.py
ble thread started
uuid: 30955110-3000-0000-0000-000000000000
major: 10 , minor: 10 , txpower: -65
rssi -89
--------
uuid: 30955110-3000-0000-0000-000000000000
major: 10 , minor: 10 , txpower: -65
rssi -89
--------
```

Error message?

- Network is down



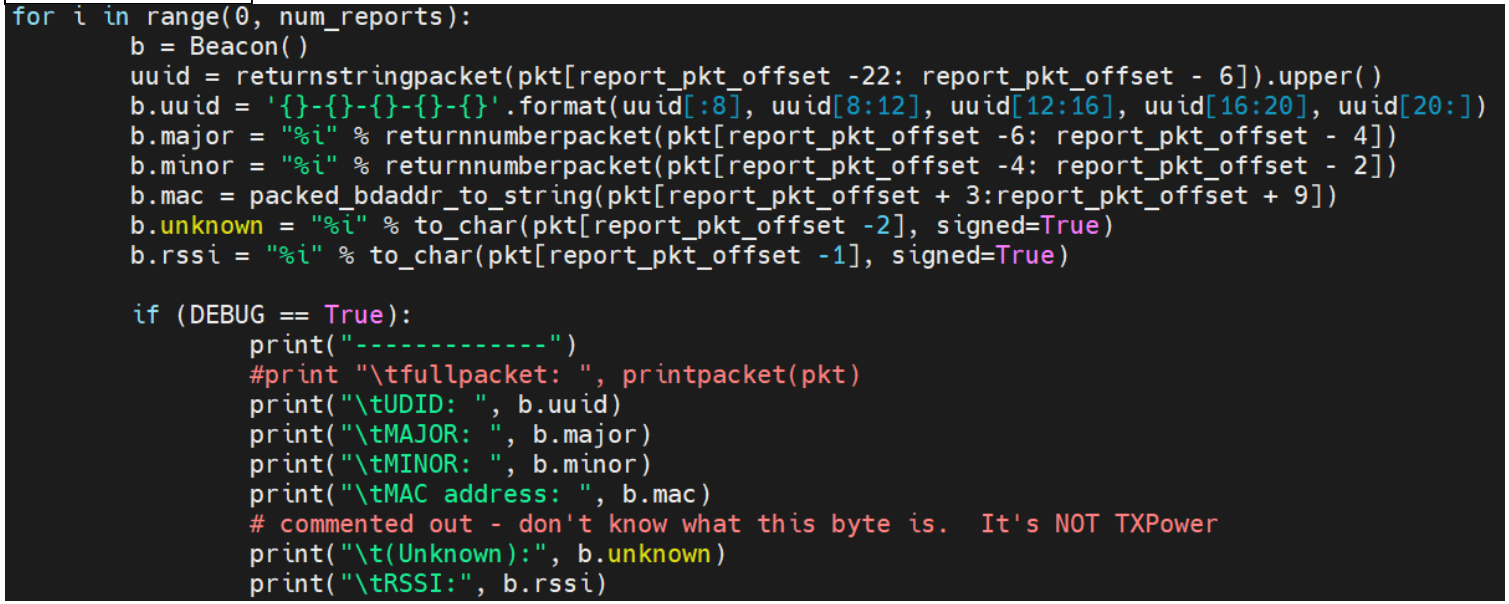
```
pi@raspberrypi:~/ble_sample $ sudo python3 ble_sample_code.py
ble thread started
Traceback (most recent call last):
  File "ble_sample_code.py", line 50, in <module>
    main()
  File "ble_sample_code.py", line 43, in main
    sock = init_ble()
  File "ble_sample_code.py", line 21, in init_ble
    blescan.hci_enable_le_scan(sock)                # start scanning
  File "/home/pi/ble_sample/blescan.py", line 99, in hci_enable_le_scan
    hci_toggle_le_scan(sock, 0x01)
  File "/home/pi/ble_sample/blescan.py", line 123, in hci_toggle_le_scan
    bluez.hci_send_cmd(sock, OGF_LE_CTL, OCF_LE_SET_SCAN_ENABLE, cmd_pkt)
_bluetooth.error: (100, 'Network is down')
```

- Sol: sudo hciconfig hci0 up

Scan result

```
ble thread started
uuid: 30955110-3000-0000-0000-000000000000
major: 10 , minor: 10 , txpower: -65
rssi -89
--------
……
```

blescan.py



```python
for i in range(0, num_reports):
        b = Beacon()
        uuid = returnstringpacket(pkt[report_pkt_offset -22: report_pkt_offset - 6]).upper()
        b.uuid = '{}-{}-{}-{}-{}'.format(uuid[:8], uuid[8:12], uuid[12:16], uuid[16:20], uuid[20:])
        b.major = "%i" % returnnumberpacket(pkt[report_pkt_offset -6: report_pkt_offset - 4])
        b.minor = "%i" % returnnumberpacket(pkt[report_pkt_offset -4: report_pkt_offset - 2])
        b.mac = packed_bdaddr_to_string(pkt[report_pkt_offset + 3:report_pkt_offset + 9])
        b.unknown = "%i" % to_char(pkt[report_pkt_offset -2], signed=True)
        b.rssi = "%i" % to_char(pkt[report_pkt_offset -1], signed=True)

        if (DEBUG == True):
                print("-------------")
                #print "\tfullpacket: ", printpacket(pkt)
                print("\tUDID: ", b.uuid)
                print("\tMAJOR: ", b.major)
                print("\tMINOR: ", b.minor)
                print("\tMAC address: ", b.mac)
                # commented out - don't know what this byte is.  It's NOT TXPower
                print("\t(Unknown):", b.unknown)
                print("\tRSSI:", b.rssi)
```

Distance solution by AltBeacon

- AltBeacon: The Open and Interoperable Proximity Beacon specification

[CurveFittedDistanceCalculator.java]

```
public double calculateDistance(int txPower, double rssi) {
    if (rssi == 0) {
        return -1.0; // if we cannot determine accuracy, return -1.
    }
    LogManager.d(TAG, "calculating distance based on mRssi of %s and txPower of %s", rssi, txPower);

    double ratio = rssi*1.0/txPower;
    double distance;
    if (ratio < 1.0) {
        distance =  Math.pow(ratio,10);
    }
    else {
        distance =  (mCoefficient1)*Math.pow(ratio,mCoefficient2) + mCoefficient3;
    }
    LogManager.d(TAG, "avg mRssi: %s distance: %s", rssi, distance);
    return distance;
  }
```

Source code: https://github.com/AltBeacon/android-beacon-library/blob/b9876b45acd6c72c84b8d0325062259020eb89ba/lib/src/main/java/org/altbeacon/beacon/distance/CurveFittedDistanceCalculator.java

Calculate distance by AltBeacon

$$dist = \left(\frac{RSSI}{TXpower}\right)^{10}$$

$$dist = \alpha\left(\frac{RSSI}{TXpower}\right)^{\beta} + \gamma$$

```
ratio = rssi*1.0/txPower;
if (ratio < 1.0) {
    distance =  Math.pow(ratio,10);
}
else {
    distance =  (Coefficient1)*Math.pow(ratio,Coefficient2) + Coefficient3;
}
return distance;
```

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

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

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

https://altbeacon.github.io/android-beacon-library/distance-calculations.html

Distance estimates

- **How accurate are the estimates?**
- At close proximity of about 1 meter, you can expect to see distance estimates between 0.5-2 meters. At further distances you will see more variation. At 20 meters or actual distance, the estimate provided by the library may vary from 10-40 meters. The variation is caused by noise on the signal measurement, along with signal reflections and obstructions.

- **Formula**
- Despite formulas suggested by signal theory, the most accurate predictor of distance based on signal strength (RSSI) can be obtained by doing a power regression against a known table of distance/RSSI values for a specific device. This uses the formula d=A*(r/t)^B+C, where d is the distance in meters, r is the RSSI measured by the device and t is the reference RSSI at 1 meter. A, B, and C are constants.

https://altbeacon.github.io/android-beacon-library/distance-calculations2.html

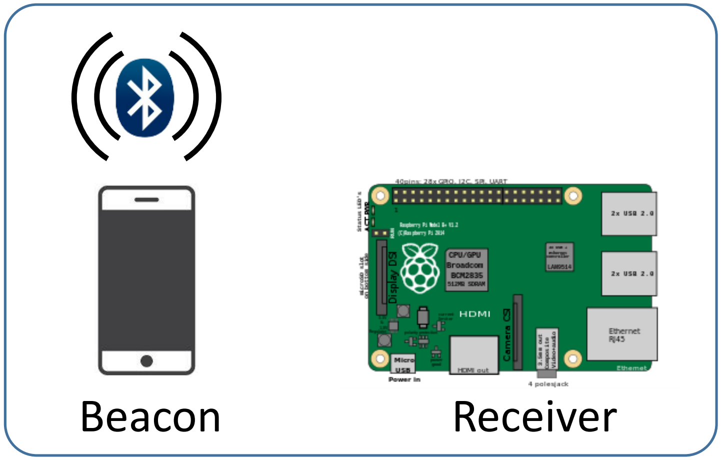
Calculating Formula Constants

- After taking distance measurements for a specific Android device, the next step is to run a power regression to get the A, B and C constants used in the y=A*x^B+C formula.

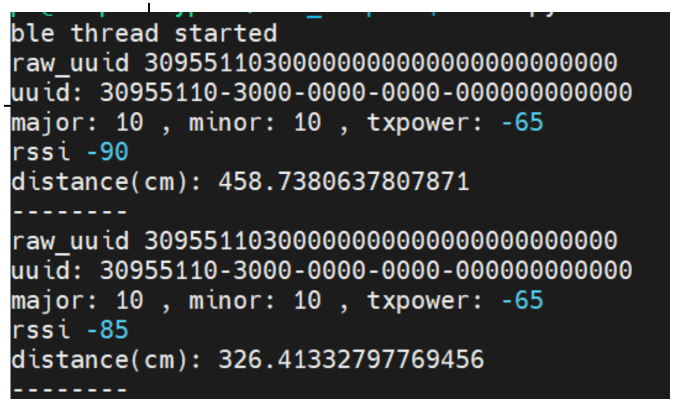
- Step 1: Calculate Ratio
- Step 2: Format Data for Regression
- Step 3: Run the Regression
- Step 4: Test the Prediction
- Step 4. Calculate C
- Step 5. Test the Prediction again
- Step 6. Validate Results
- Step 7. Submit a Pull Request
  - The model database is paltry. I was hoping to get a number of submissions from the community for a wide variety of models. Unfortunately, submissions have been very meagre.
  - https://stackoverflow.com/questions/47104375/model-specific-distance

Discussion 3

- Based on ble_sample_code.py, after receiving txpower and rssi, **calculate the distance**
  - Req: Set your smartphone as an iBeacon. Put your uuid in python
- Refer to the formula by AltBeacon (use Nexus 4’s coefficient)



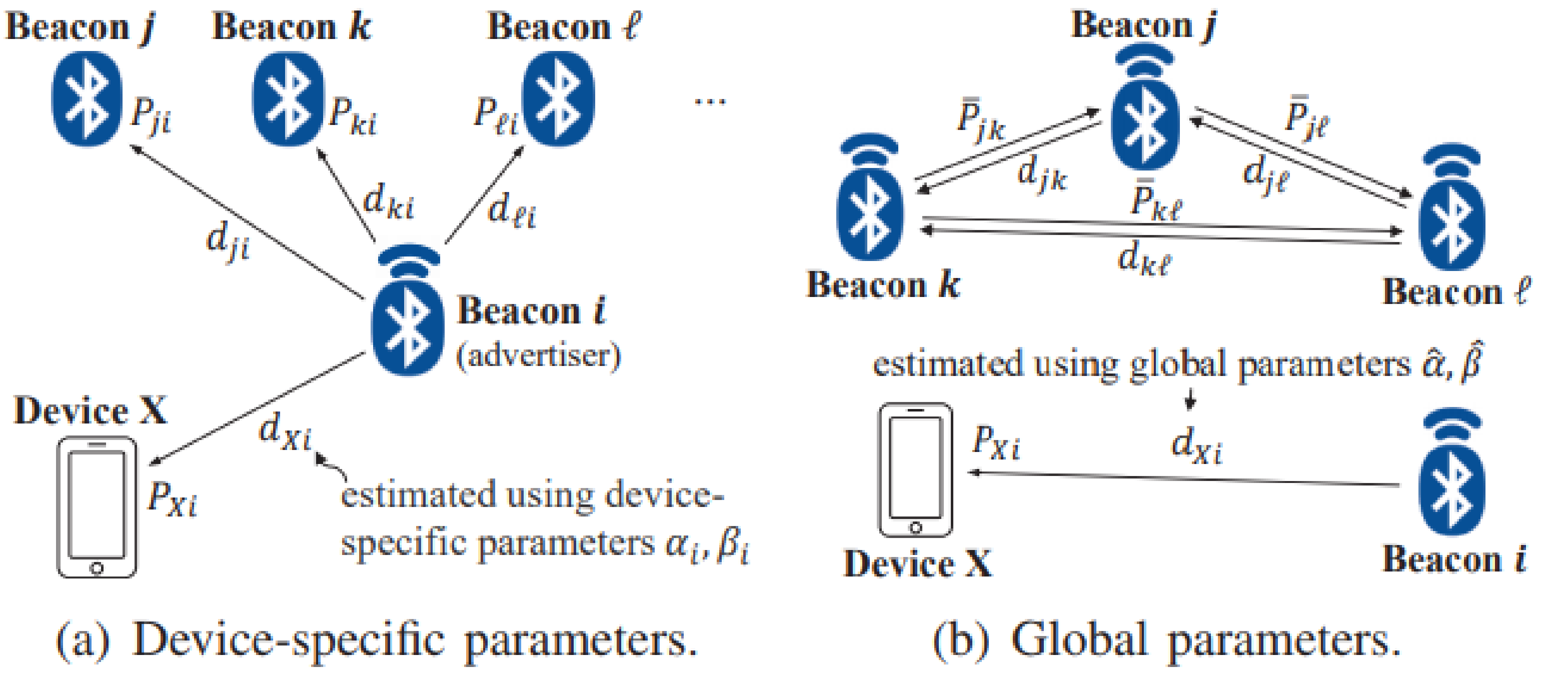
```
{
    "coefficient1": 0.42093,
    "coefficient2": 6.9476,
    "coefficient3": 0.54992,
    "version":"4.4.2",
    "build_number":"KOT49H",
    "model":"Nexus 4",
    "manufacturer":"LGE"
  },
```



```
ble thread started
raw_uuid 30955110300000000000000000000000
uuid: 30955110-3000-0000-0000-000000000000
major: 10 , minor: 10 , txpower: -65
rssi -90
distance(cm): 458.7380637807871
--------
raw_uuid 30955110300000000000000000000000
uuid: 30955110-3000-0000-0000-000000000000
major: 10 , minor: 10 , txpower: -65
rssi -85
distance(cm): 326.41332797769456
--------
```

Discussion 4

- BLE beacon can be used for indoor localization.
- If we put a lot of beacons, can we get a more precise result?



(a) Device-specific parameters.

(b) Global parameters.

Fig. 2. Two types of regression parameters for adaptive ranging.

Summary

- Practice Lab (BLE)

- Write down the answer for discussion 1-4
  - Discussion 1: Advertise an your own URL
  - Discussion 2: What is the maximum value of major and minor ID?
  - Discussion 3: Based on ble_sample_code.py, after receiving txpower and rssi, calculate the distance
  - Discussion 4: More beacon, more precise result?
- Deadline: Before 13:10, **4/19**