Raspberry Pi IoT 無線傳輸技術
- Bluetooth

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Nov 15, 2016/Raspberry Pi #16

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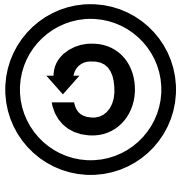
姓名標示 — 非商業性 — 相同方式分享

姓名標示 — 你必須給予 適當表彰、提供指向本授權條款的連結，以及 指出（本作品的原始版本）是否已被變更。你可以任何合理方式為前述表彰，但不得以任何方式暗示授權人為你或你的使用方式背書。

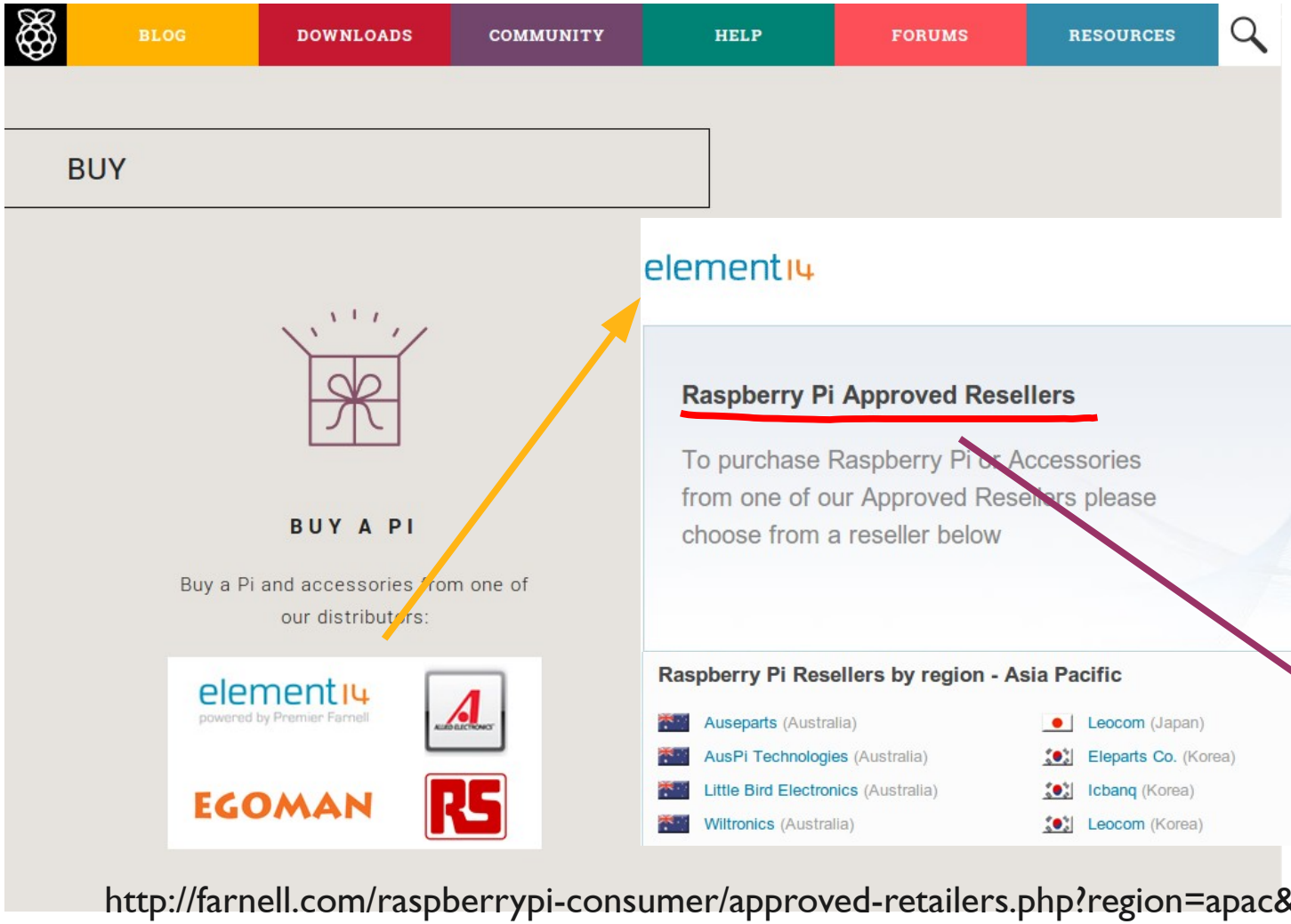
非商業性 — 你不得將本素材進行商業目的之使用。



相同方式分享 — 若你重混、轉換本素材，或依本素材建立新素材，你必須依本素材的授權條款來散布你的貢獻物。

about 台灣樹莓派

- element14 指定台灣地區 Raspberry Pi 個人用戶經銷商



http://farnell.com/raspberrypi-consumer/approved-retailers.php?region=apac&MER=MER-LM-OB-RPICC-76315

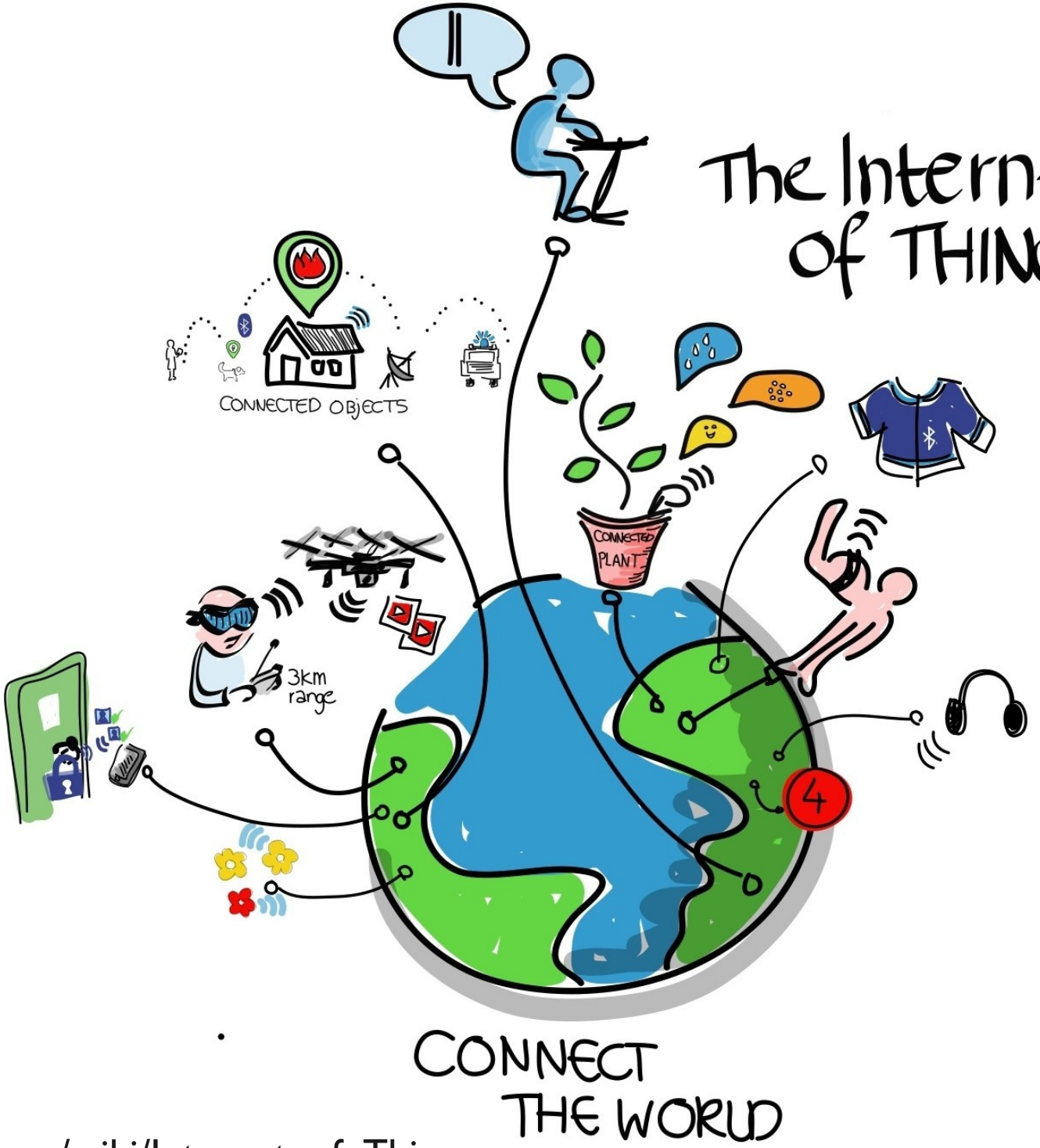
about 台灣樹莓派

- 專注於 Raspberry Pi 應用與推廣
- 舉辦社群聚會 / 工作坊 / 讀書會 / 黑客松
- Website ：
  - https://www.raspberrypi.com.tw/

- Facebook ：
  - 搜尋 RaspberryPi.Taiwan
  - https://www.facebook.com/RaspberryPi.Taiwan

分享 x 社群

- COSCUP, MakerConf, PyCon 講者
- 投影片
  - http://www.slideshare.net/raspberrypi-tw/presentations
- 程式碼
  - https://github.com/raspberrypi-tw



http://en.wikipedia.org/wiki/Internet_of_Things

物聯網技術重點之一在”無線傳輸”

無線技術比較

Bluetooth®

Name	Bluetooth Classic	Bluetooth 4.0 Low Energy (BLE)	ZigBee	WiFi
IEEE Standard	802.15.1	802.15.1	802.15.4	802.11 (a, b, g, n)
Frequency (GHz)	2.4	2.4	0.868, 0.915, 2.4	2.4 and 5
Maximum raw bit rate (Mbps)	1-3	1	0.250	11 (b), 54 (g), 600 (n)
Typical data throughput (Mbps)	0.7-2.1	0.27	0.2	7 (b), 25 (g), 150 (n)
Maximum (Outdoor) Range (Meters)	10 (class 2), 100 (class 1)	50	10-100	100-250
Relative Power Consumption	Medium	Very low	Very low	High
Example Battery Life	Days	Months to years	Months to years	Hours
Network Size	7	Undefined	64,000+	255

還有 LoRA 、 NFC 、 UWB 、 IR 等等 ...

藍牙起源

- 目的
  - 為了解決電腦與電器設備之間的傳輸問題
- 歷史
  - 十世紀丹麥挪威和國王的名字 (Harald Blåtand)
  - 由 Ericsson 在 1994 年創製， 現由 SIG 維護標準
- 特色
  - 短距離無線技術 (10 - 100m)
  - 使用 2.4 至 2.485 GHz 的 ISM 頻段

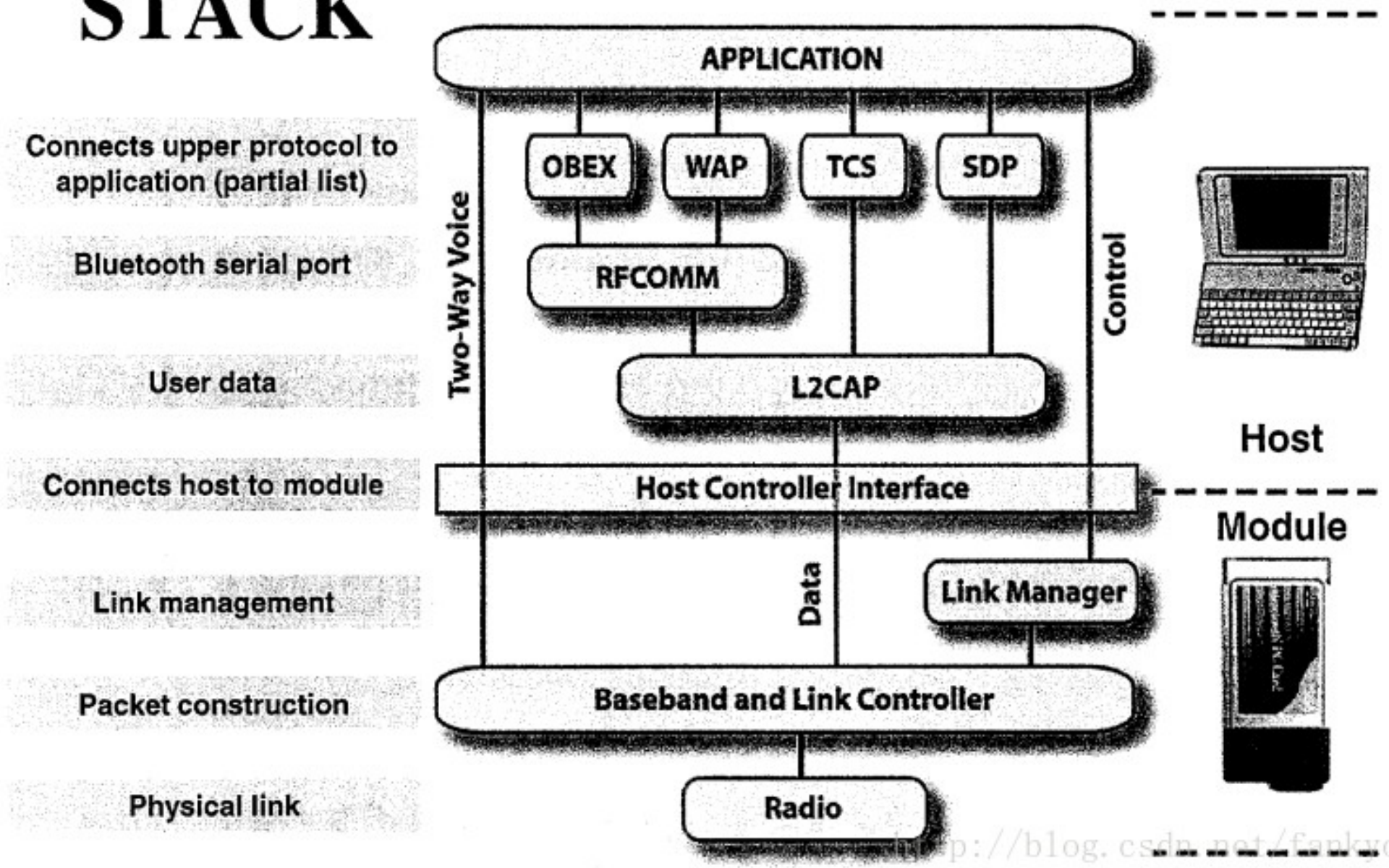
https://zh.wikipedia.org/zh-tw/%E8%97%8D%E7%89%99

藍牙版本演進

版本	發布年份	特色與功能
1.0	2000 年	HCI 、 L2CAP 、 RFCOMM 、 SPP 等
1.1	2001 年	IEEE 802.15.1
1.2	2003 年	列入 IEEE 802.15.1.1a
2.0 + EDR	2004 年	EDR 速度達 2-3Mbps
2.1 + EDR	2007 年	簡易安全配對 (SSP)
3.0 + HS	2009 年	交替射頻技術 (Alternative MAC/PHY)
4.0 + LE	2010 年	低功耗藍牙 / 傳統藍牙 / 高速藍牙
4.1	2013 年	共存性，智慧連線，改進資料傳輸
4.2	2014 年	可和 Internet 連接，增強隱私權、速度
5.0	2016 年	IoT(更遠、更快、無連線狀態)

https://en.wikipedia.org/wiki/Bluetooth

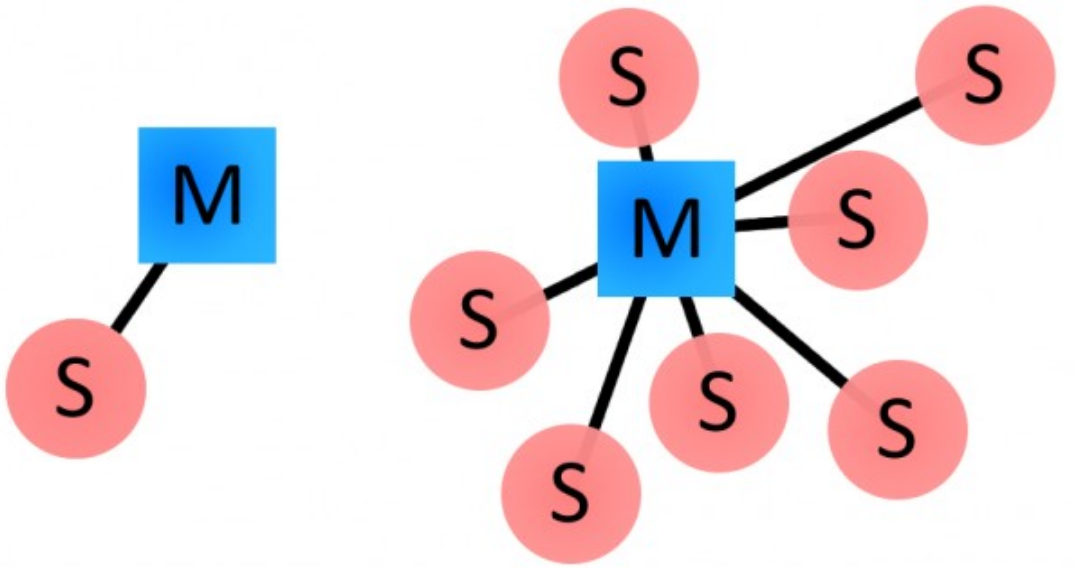
BLUETOOTH PROTOCOL STACK



http://blog.csdn.net/fankyo/article/details/9459289

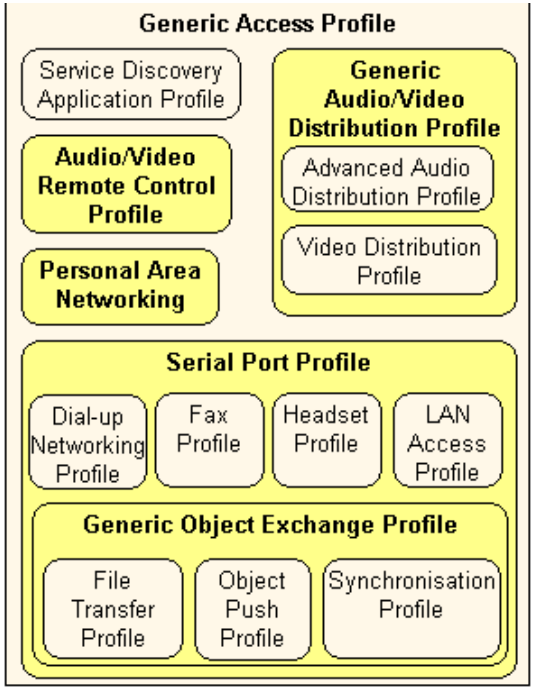
藍牙網路

- 主 / 從式架構
  - 藍牙主控端 (Master) 發出探索訊號 (inquiry)
  - 藍牙從端 (Slave) 回應名稱和位址
  - 配對 (pairing) 後使用網路傳輸



https://learn.sparkfun.com/tutorials/bluetooth-basics/how-bluetooth-works

藍牙規範 (Profile)

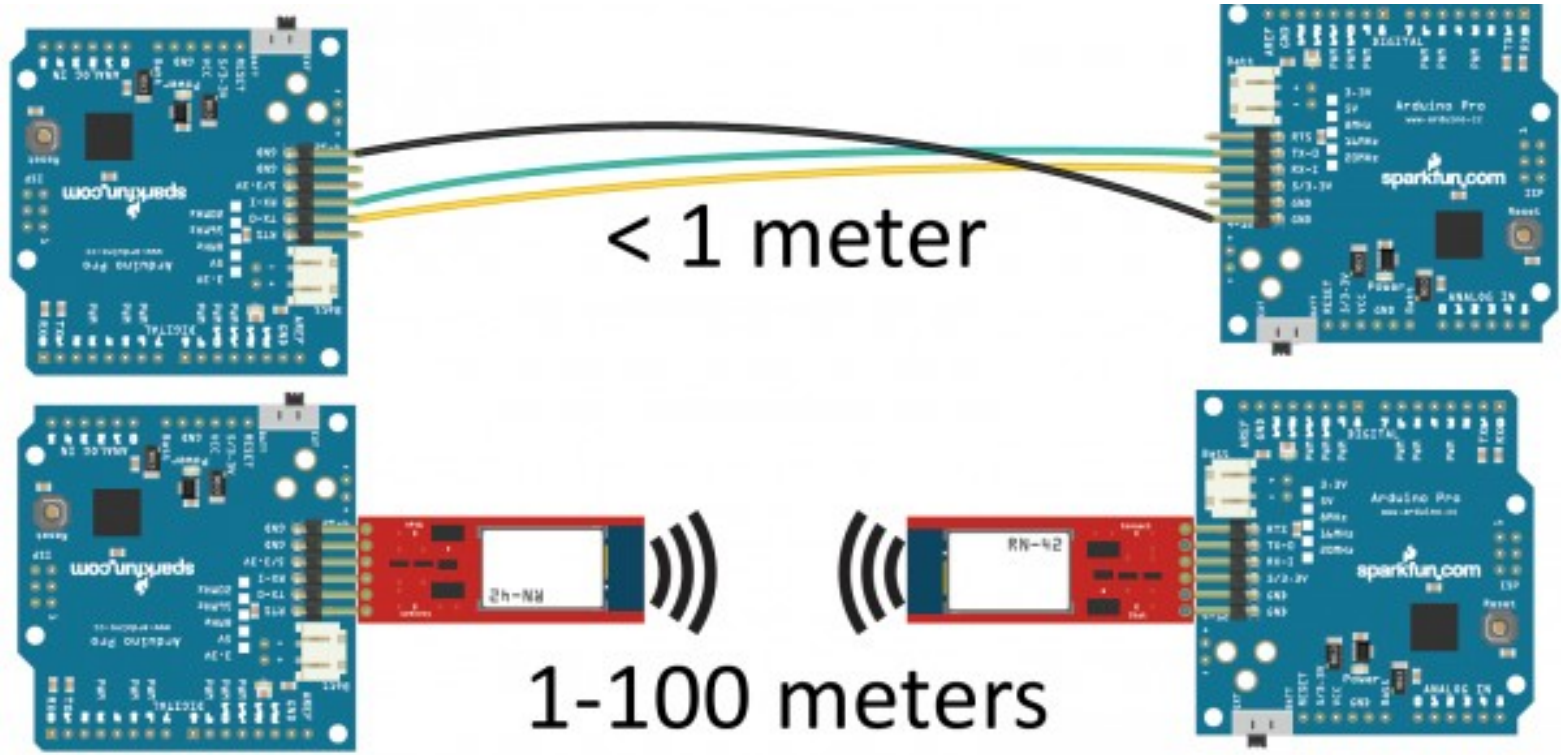


- 確保藍牙設備間的互通性
- 基本規範
  - GAP(Generic Access Profile)
  - Serial Port Profile (SPP)
  - General Object Exchange Profile(GOEP)
  - SDAP(Service Discovery Application Profile)
- 應用規範
  - A2DP(Advance Audio Distribution Profile)
  - HSP(Headset Profile)
  - ...

http://allenluadvance.blogspot.tw/2009/02/blog-post.html

Serial Port Profile (SPP)

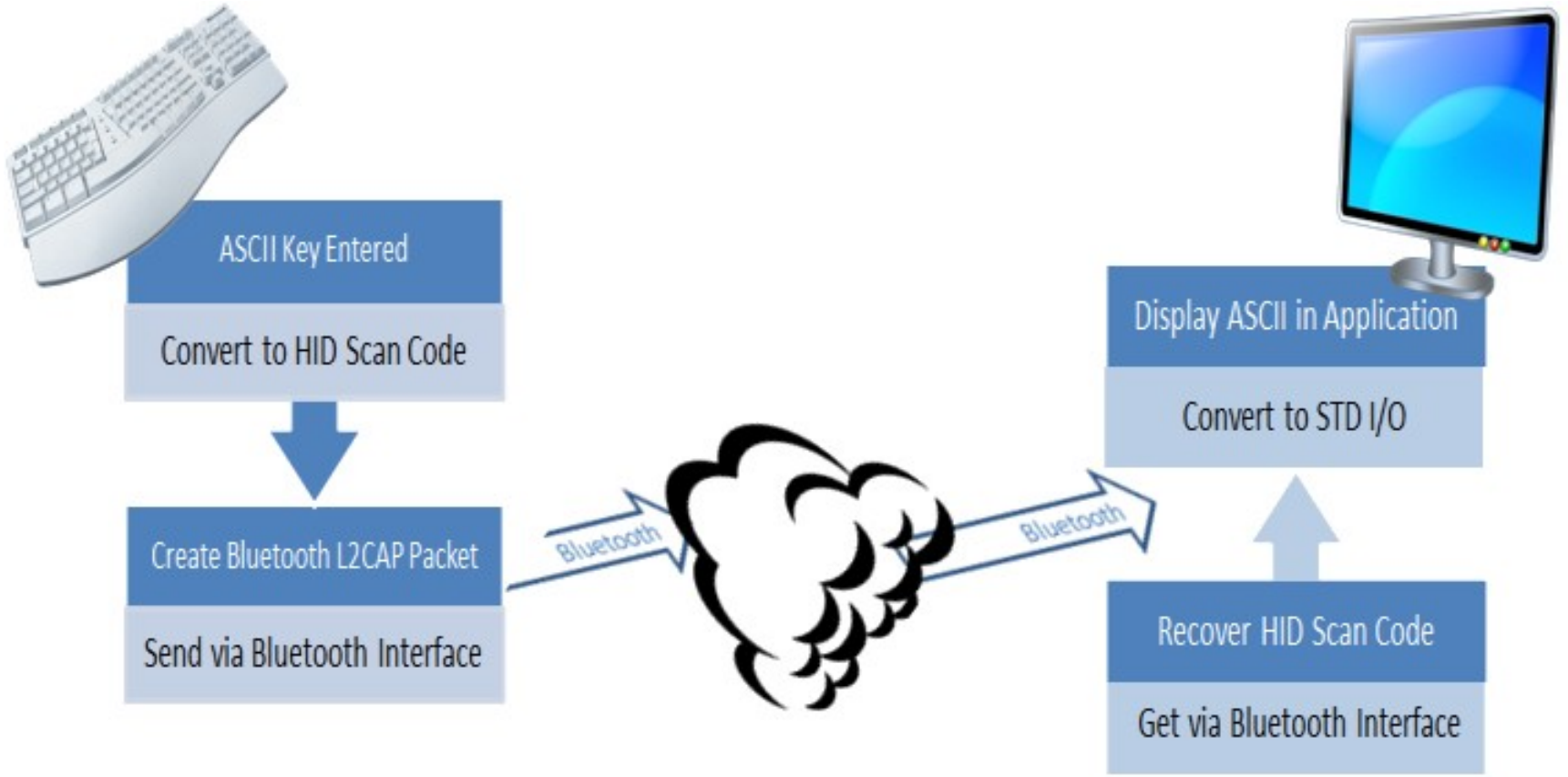
- 使用 `serial communication interface` 通訊，例如 UART



https://learn.sparkfun.com/tutorials/bluetooth-basics

Human Interface Device (HID)

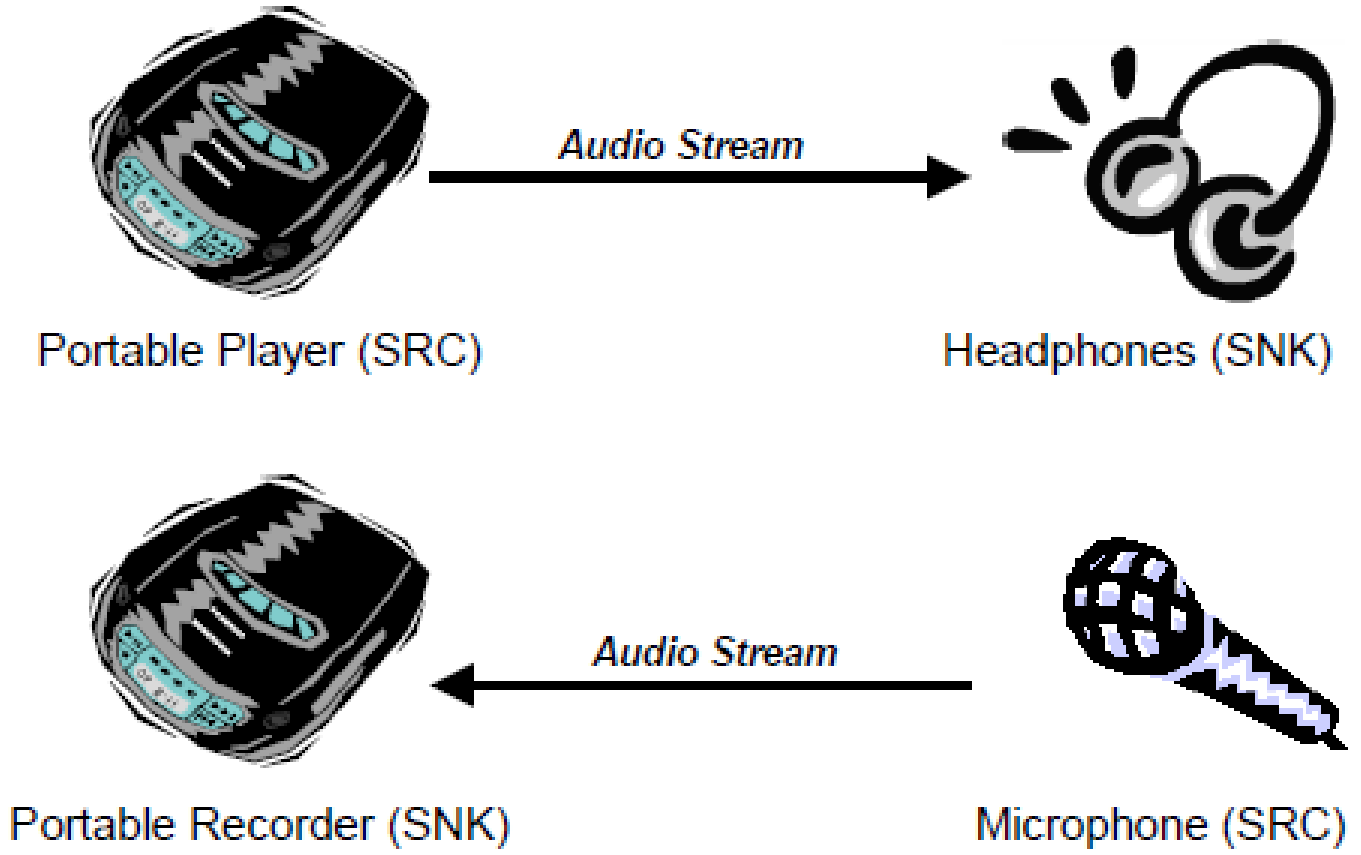
- 使用 `user-input devices` 裝置，例如鍵盤、滑鼠、搖桿



https://learn.sparkfun.com/tutorials/bluetooth-basics

Advanced Audio Distribution Profile (A2DP)

- 傳輸音訊(audio)，例如耳機、喇叭、麥克風



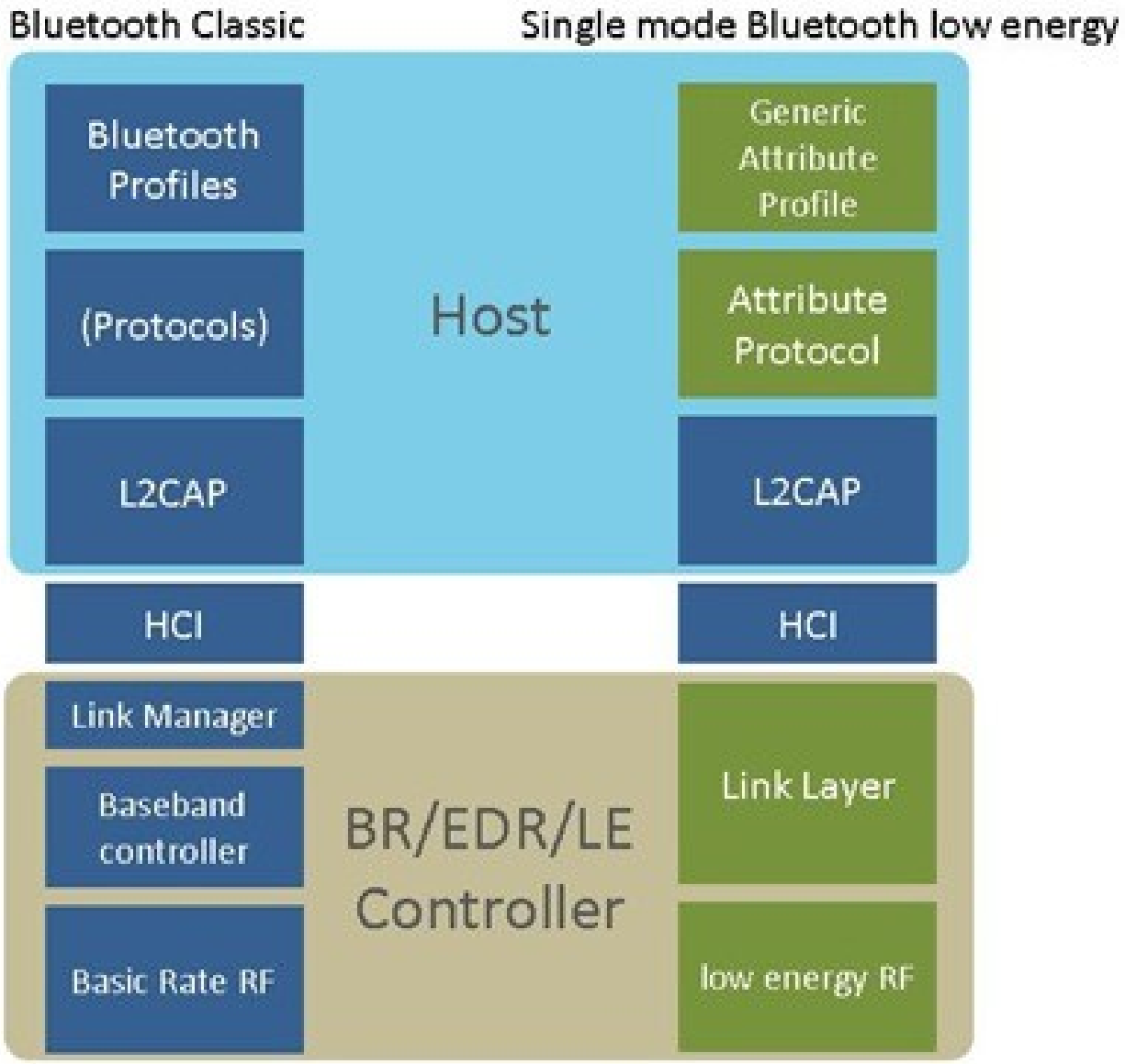
https://learn.sparkfun.com/tutorials/bluetooth-basics

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

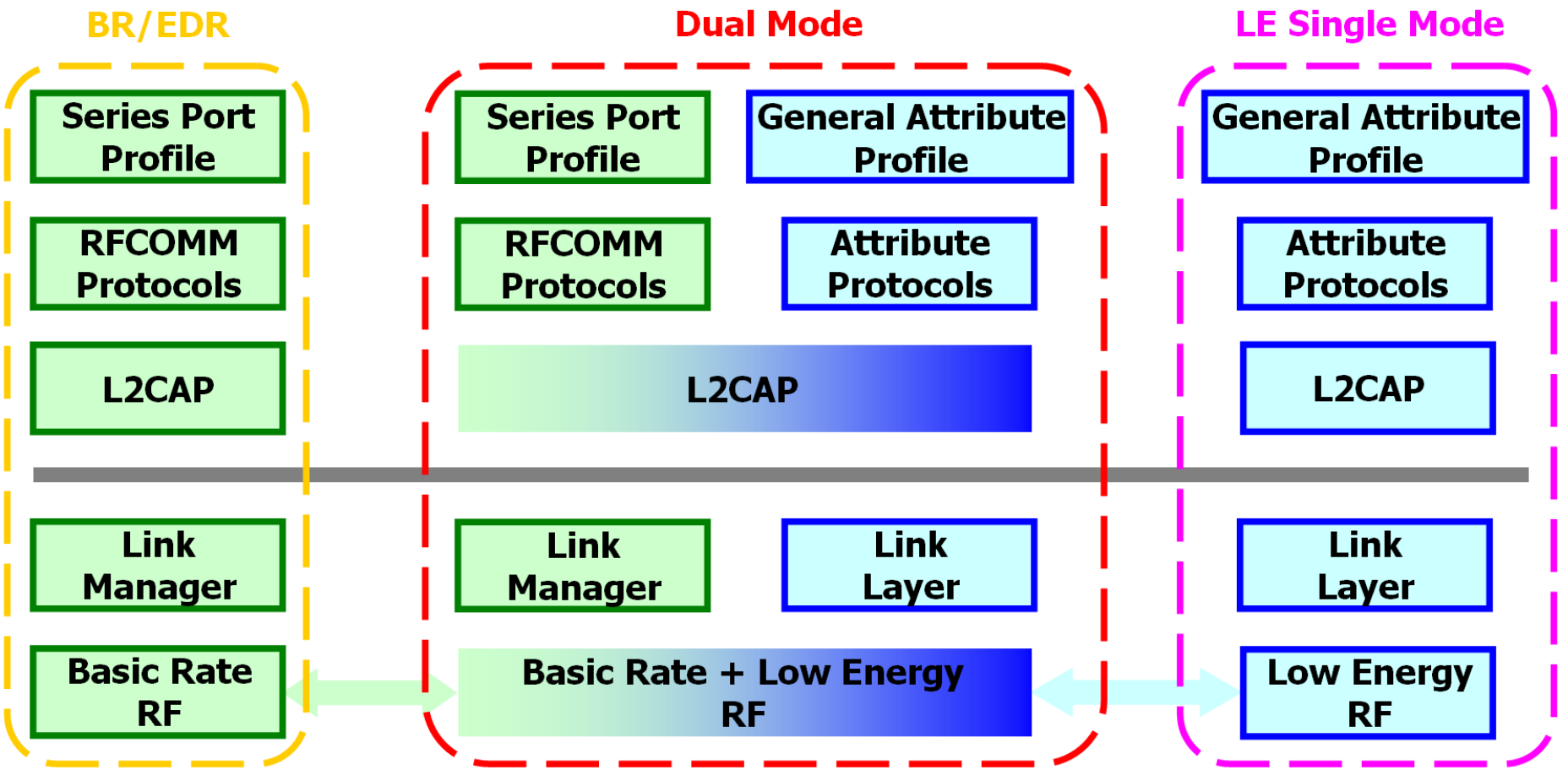
	Classic	BLE
throughput	2-3Mbps	0.2Mbps
range	50-300m	10-30m
power consumption	1W	0.01 ~ 0.5W
Connection time	5s	0.1s
cost	$7	$2

Bluetooth Classic vs. BLE



http://wjungle.blogspot.tw/2012/01/btble.html

Bluetooth 4.0 Single/Dual-Mode:



Source by: EE Times

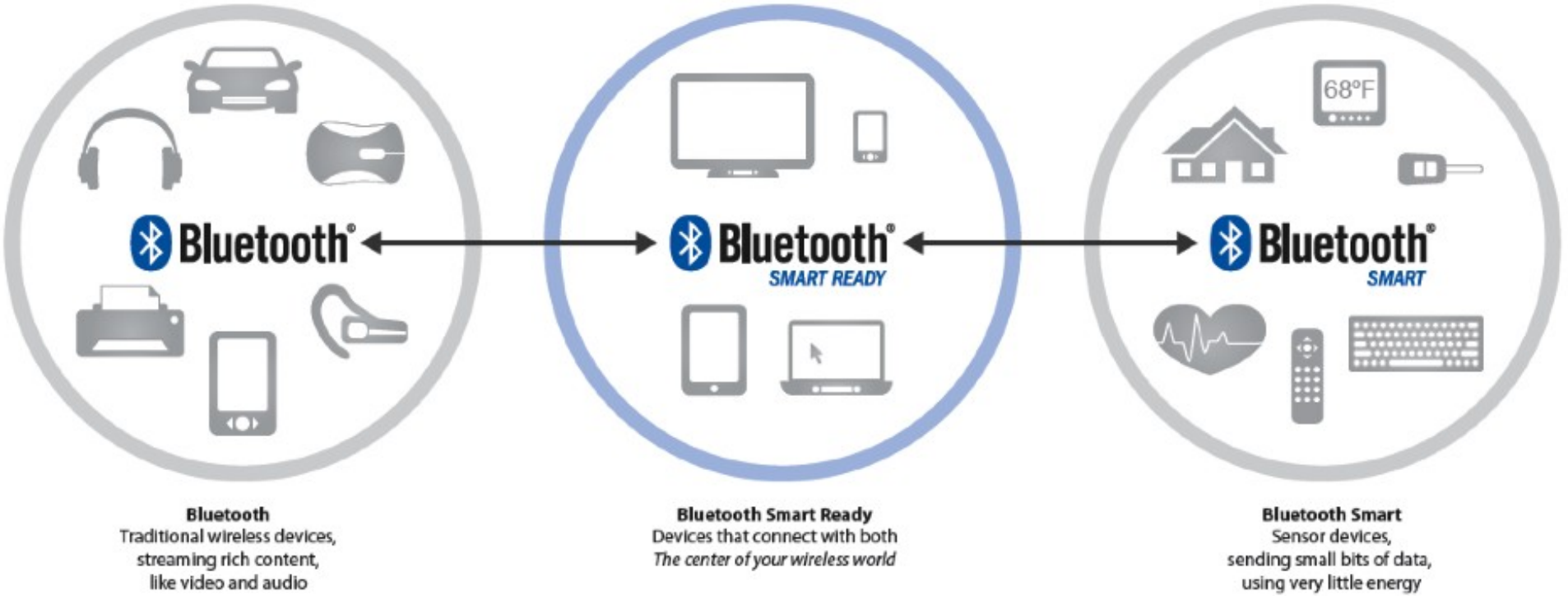
Bluetooth®

Bluetooth® SMART READY

Bluetooth® SMART

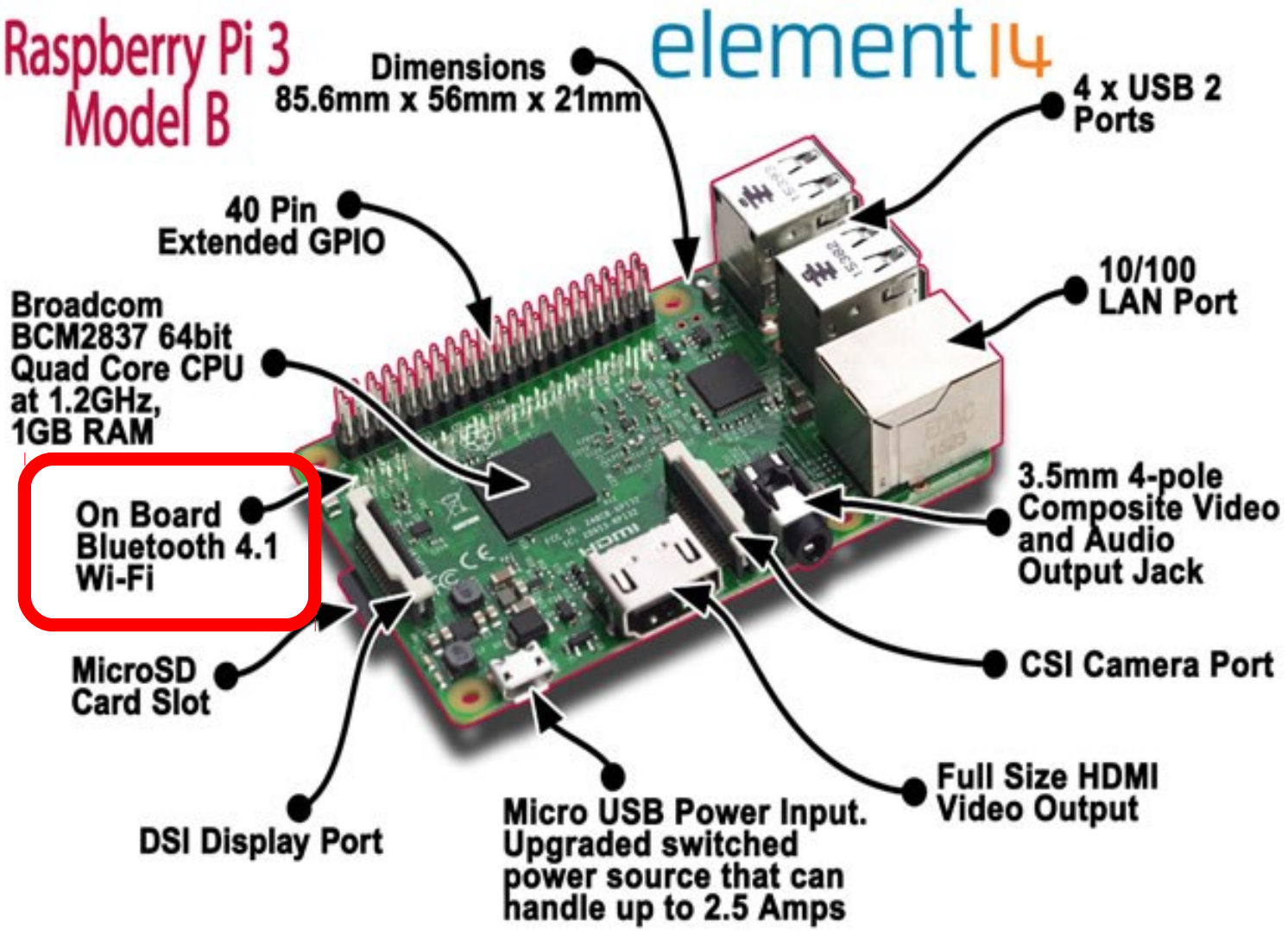
http://amiccom.blogspot.tw/2014/11/bt-40-dual-mode-single-mode-bluetooth.html

IoT 藍牙裝置與功能



https://learn.sparkfun.com/tutorials/connectivity-of-the-internet-of-things/bluetooth

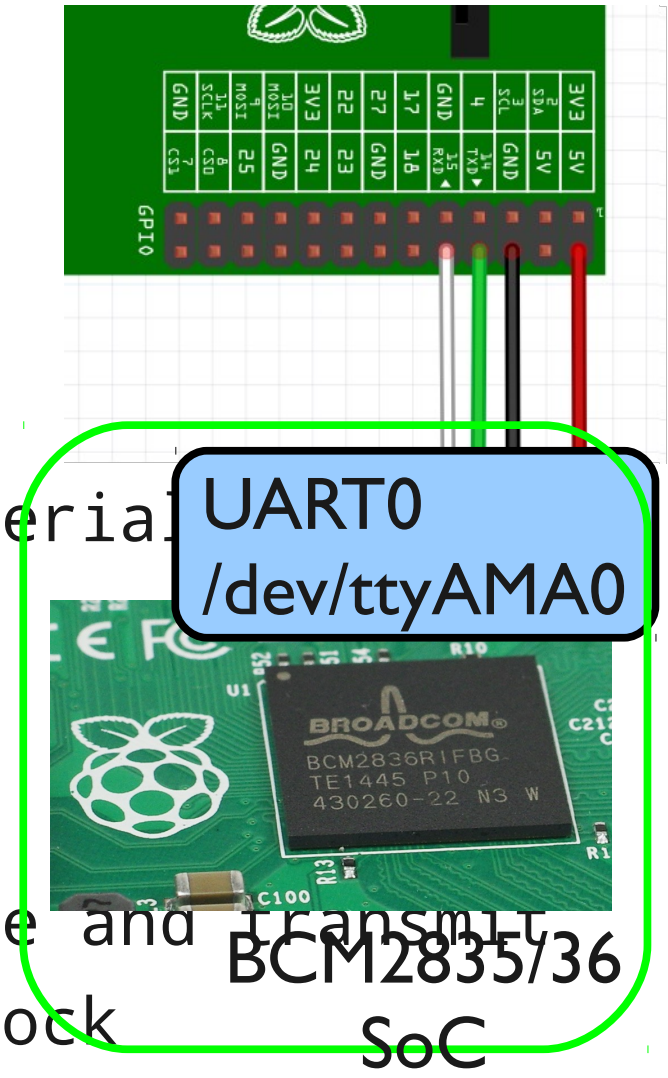
Raspberry Pi 3



https://appdevelopermagazine.com/3688/2016/2/29/Raspberry-Pi-3-Model-B-Offers-Built-in-Wireless-LAN-and-Bluetooth/

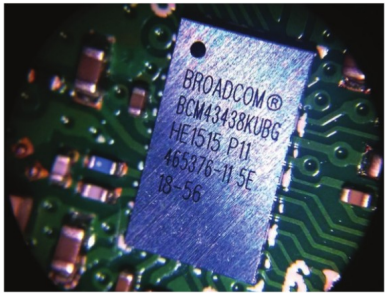
BCM283x 有兩個 UARTs

- UART0: Full UART (/dev/ttyAMA0)
  - Based on ARM Primecell PL011
  - Larger FIFO buffers
  - 16x8 transmit, 16x12 receive
  - High performance full feature serial
- UART1: “mini UART” (/dev/ttyS0)
  - A secondary low throughput UART
  - 8 symbols deep FIFOs for receive and transmit
  - Baudrate derived from system clock

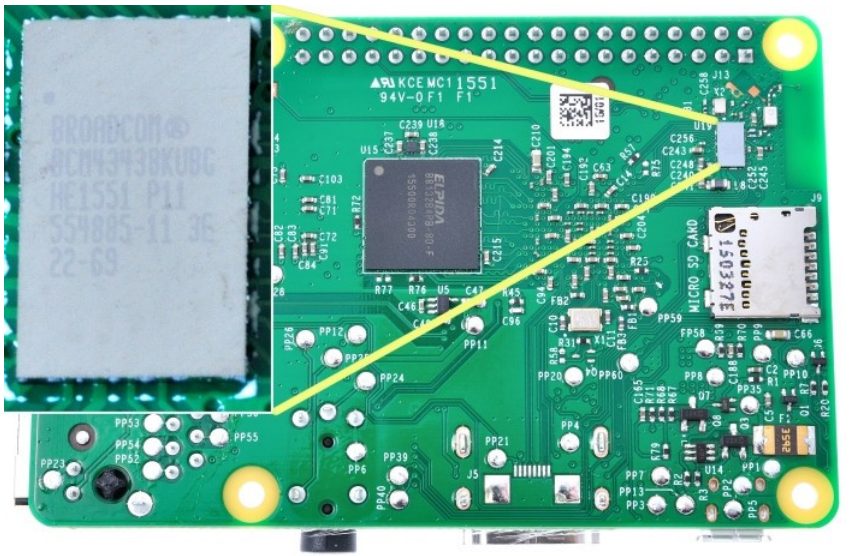


www.slideshare.net/yeokm1/raspberry-pi-3-uartbluetooth-issues

Hardware Architecture of Pi 3



BCM43438
wireless chip

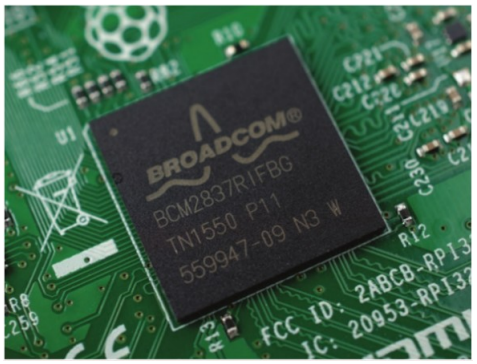


WiFi

BT4.1

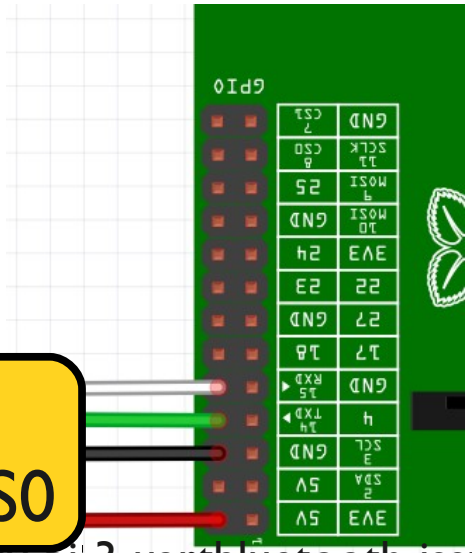
SDIO

UART0
/dev/ttyAMA0



BCM2837
RPi 3

UART1
/dev/ttyS0



www.slideshare.net/yeokm1/raspberry-pi-3-uartbluetooth-issues

UART1 有什麼問題嗎？

2.2 Mini UART

The mini UART is a secondary low throughput[4] UART intended to be used as a console. It needs to be enabled before it can be used. It is also recommended that the correct GPIO function mode is selected before enabling the mini Uart.

The mini Uart has the following features:

- 7 or 8 bit operation.
- 1 start and 1 stop bit.
- No parities.
- Break generation.
- 8 symbols deep FIFOs for receive and transmit.
- SW controlled RTS, SW readable CTS.
- Auto flow control with programmable FIFO level.
- 16550 *like* registers.
- Baudrate derived from system clock.

The mini UART uses 8-times oversampling. The Baudrate can be calculated from:

$$baudrate = \frac{system\_clock\_freq}{8*(baudrate\_reg+1)}$$

If the system clock is 250 MHz and the baud register is zero the baudrate is 31.25 Mega baud. (25 Mbits/sec or 3.125 Mbytes/sec). The lowest baudrate with a 250 MHz system clock is 476 Baud.

- Baudrate 從 system clock 取得
- UART 預設 115200
- Frequency 會動態改變

誰會受影響？

- 有使用 TX/RX 腳位
  - Serial debug console
  - RS232 模組 ,GSM 模組 ,GPS 模組
  - 裝置之間透過 UART 通訊
  - 藍牙裝置

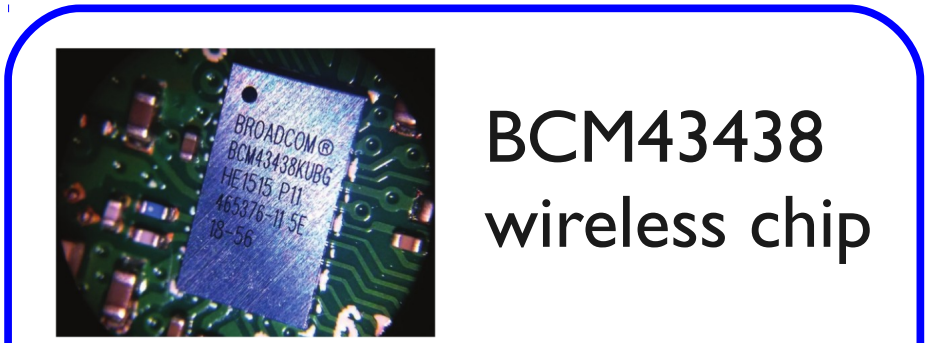
解決方法 I

- 需求：
  - Serial Console 和 normal Bluetooth
- 想法：
  - 固定 core_freq
- 作法：
  - 修改 /boot/config.txt, 新增以下兩行
  - enable_uart=1
  - force_turbo=1 或是 core_freq=250

解決方法 2

- 需求：
  - Full UART 和 Slow Bluetooth 或是 BLE
- 想法：
  - 使用 Device Tree Overlay(DTO) 重新映射腳位
- 作法：
  - 修改 /boot/config.txt, 新增以下兩行
  - dtoverlay=pi3-miniuart-bt
  - force_turbo=1 或是 core_freq=250

預設 Bluetooth 與 UART 設定



WiFi

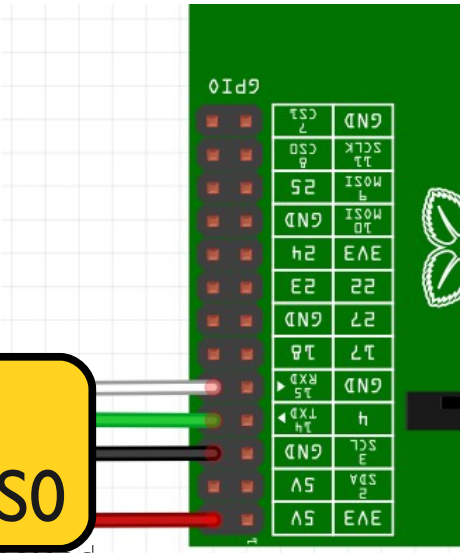
BT4.1

SDIO

UART0
/dev/ttyAMA0

BCM2837
RPi 3

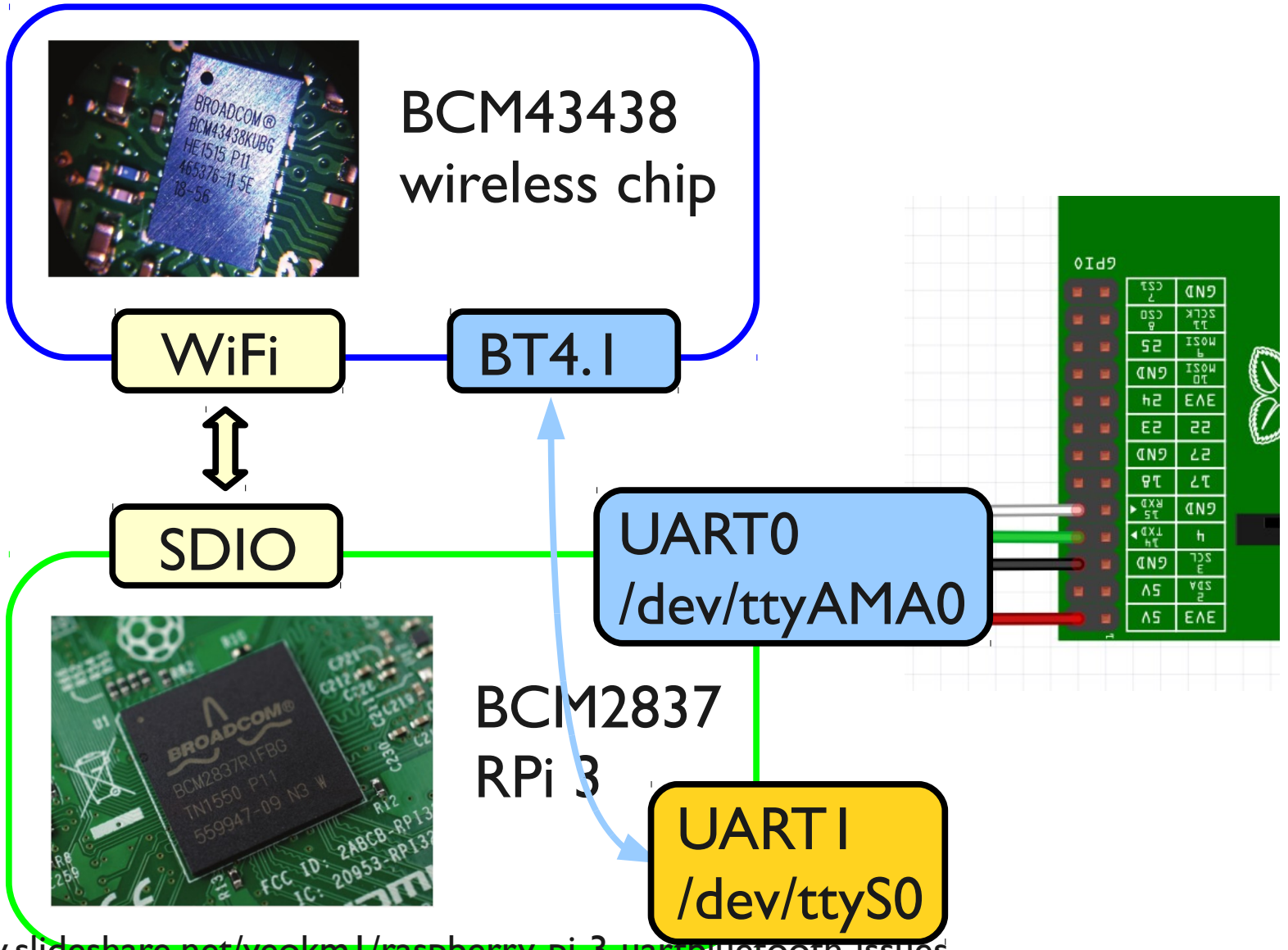
UART1
/dev/ttyS0



www.slideshare.net/yeokm1/raspberry-pi-3-uartbluetooth-issues

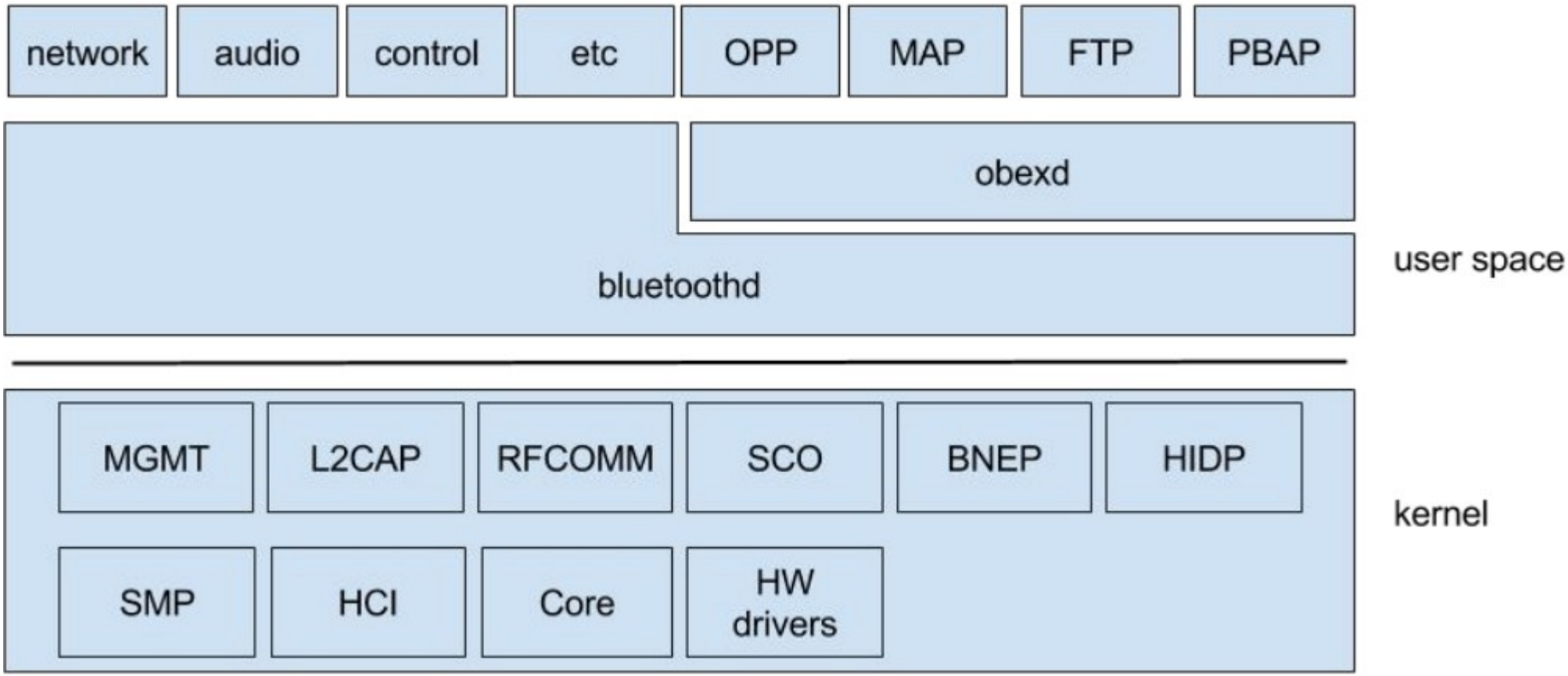
使用 DTO 重新映射腳位

- dtoverlay=pi3-miniuart-bt



www.slideshare.net/yeokm1/raspberry-pi-3-uartbluetooth-issues

Linux Bluetooth Stack Architecture(BlueZ)



http://events.linuxfoundation.org/sites/events/files/slides/Bluetooth%20on%20Modern%20Linux_0.pdf

Bluetooth 常用工具

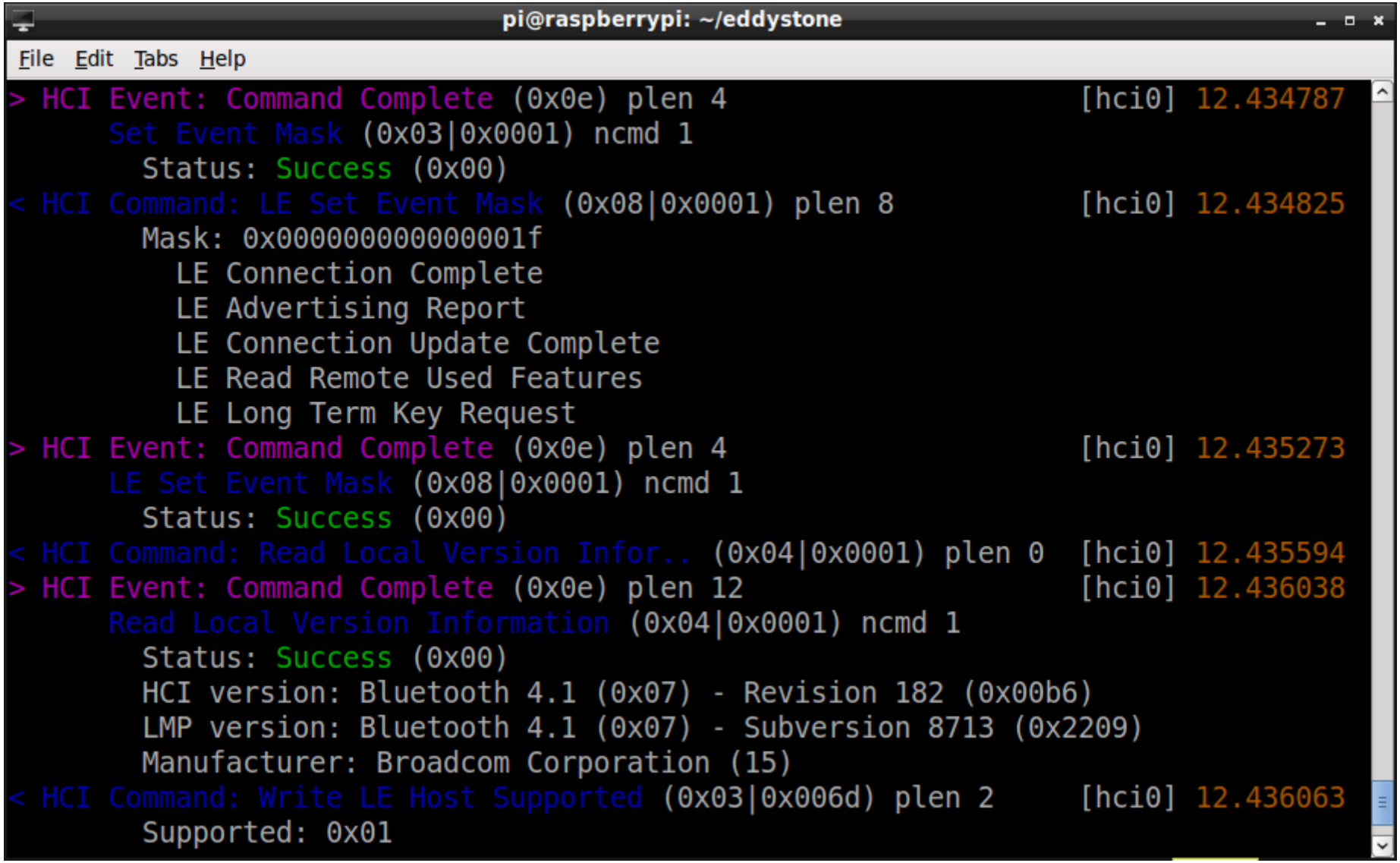
- bluetoothctl - bluetooth control tool
- hciconfig - configure Bluetooth devices
- hcitool - configure Bluetooth connections
- l2ping - Send L2CAP echo request and receive answer
- btmon - Bluetooth monitor
- gatttool - GATT tool

用 bluetoothctl 進行配對

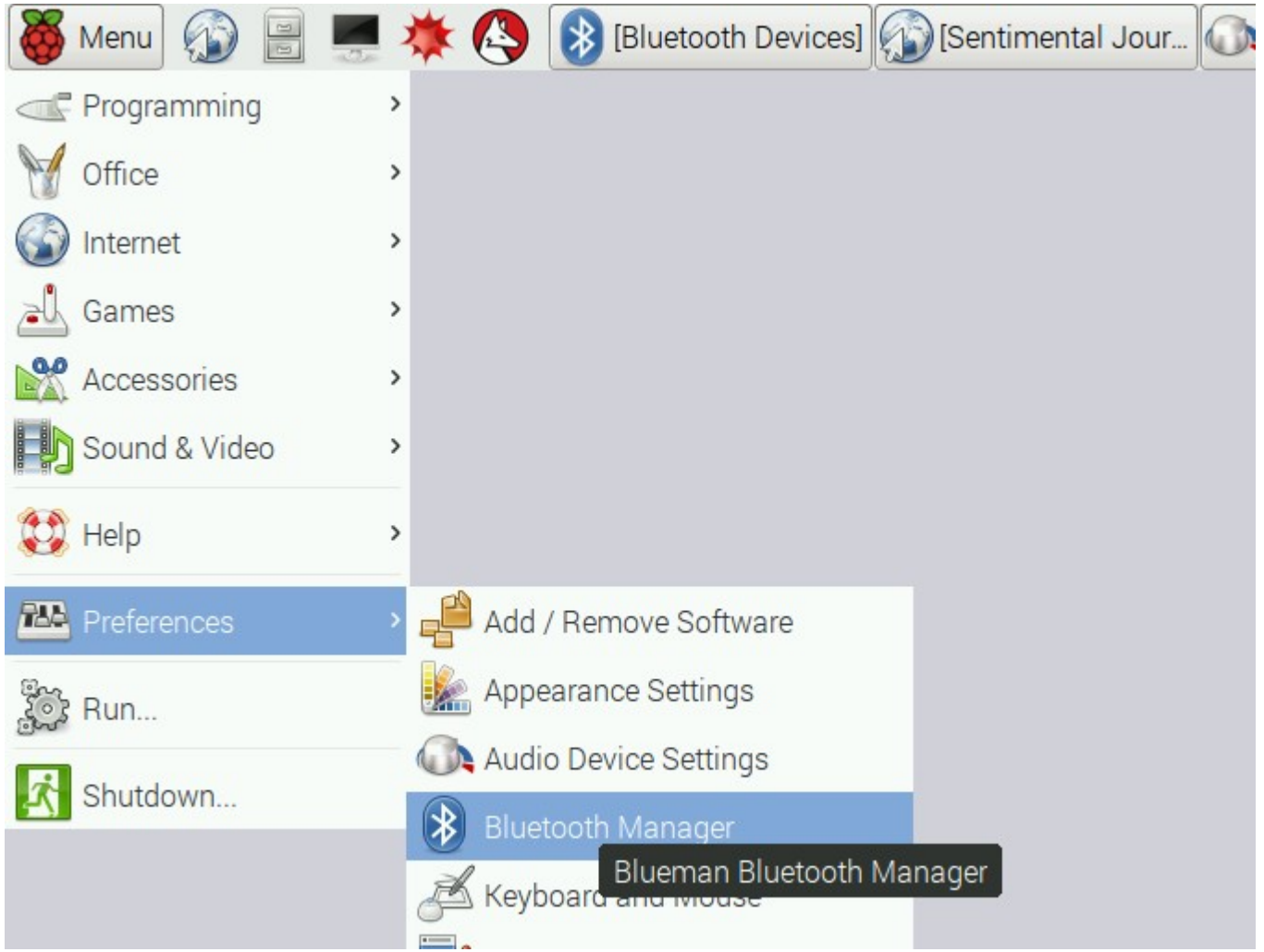
- `$ bluetoothctl  # 進入 bluetoothctl 互動模式`

```
[bluetoothctl] power on
[bluetoothctl] agent on
[bluetoothctl] scan on
[bluetoothctl] pair MAC_ADDRESS
[bluetoothctl] connect MAC_ADDRESS
[bluetoothctl] disconnect MAC_ADDRESS
[bluetoothctl] remove MAC_ADDRESS
```

用 btmon 查看藍牙封包除錯

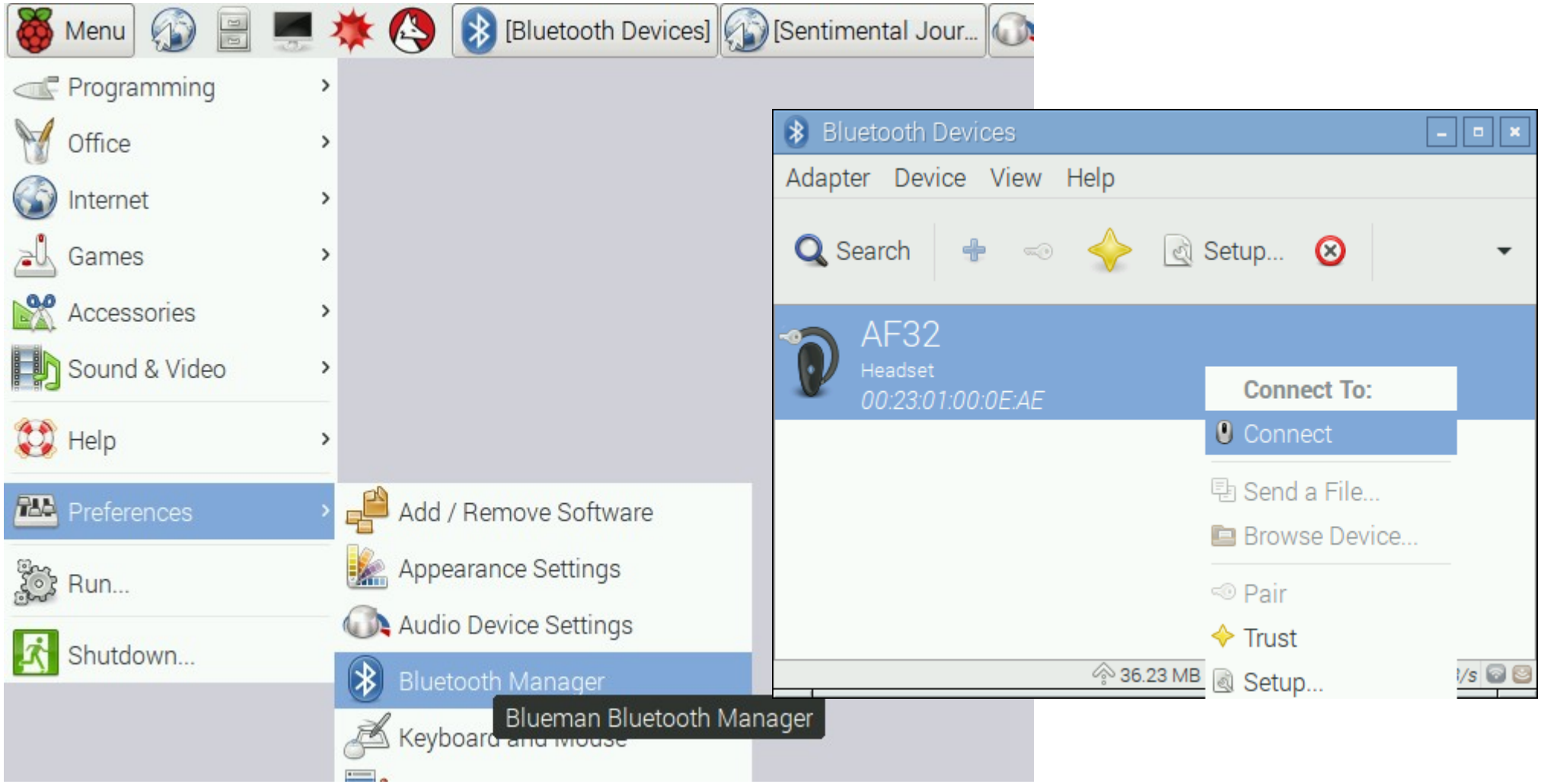


Bluetooth GUI 工具



http://plugable.com/2016/03/14/listening-to-bluetooth-audio-on-your-raspberry-pi-3-pi-2-or-pi-zero/

Bluetooth GUI 工具



http://plugable.com/2016/03/14/listening-to-bluetooth-audio-on-your-raspberry-pi-3-pi-2-or-pi-zero/

使用 python 寫 bluetooth 程式

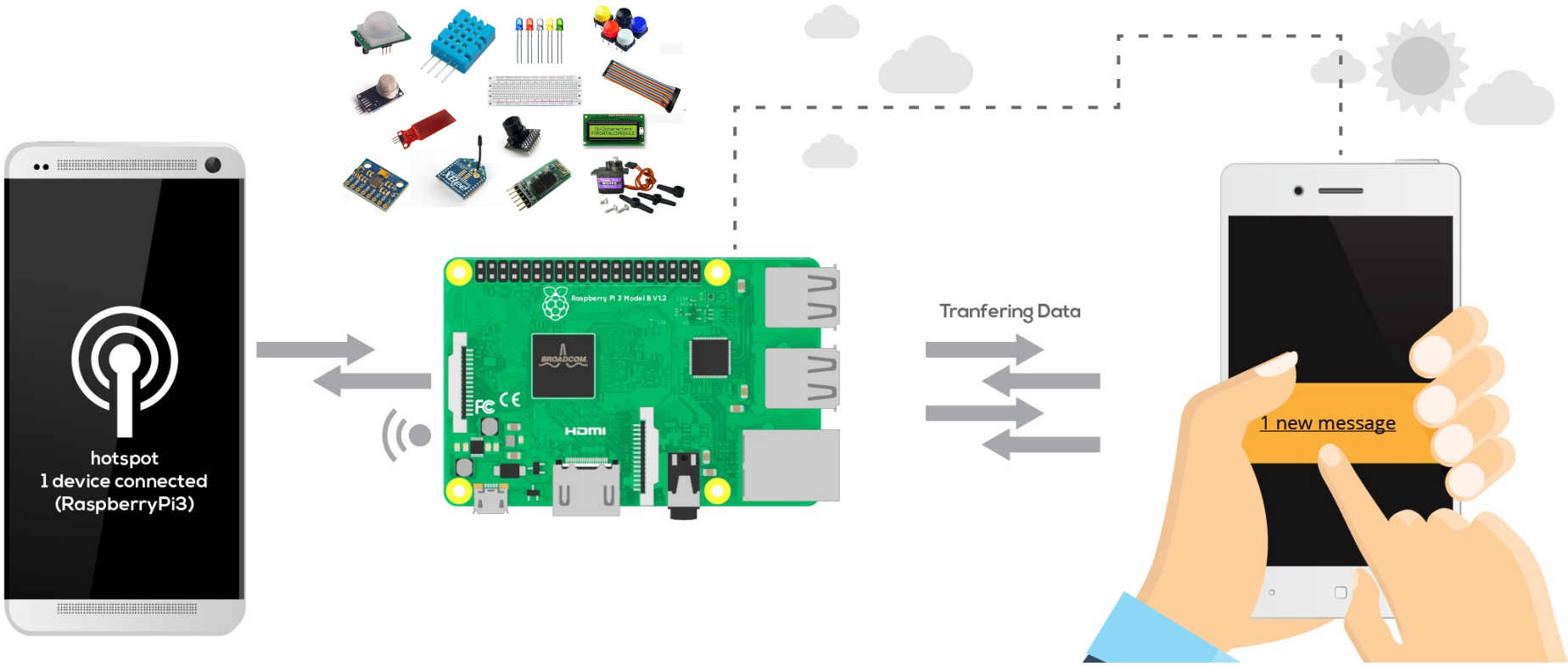
- Bluetooth classic
  - 透過 RFCOMM 或 L2CAP 通訊 (socket)
  - $ sudo apt-get install bluetooth pi-bluetooth python-bluez

- BLE
  - 基於 BlueZ 的 python 套件
  - $ sudo pip install bluepy

http://ianharvey.github.io/bluepy-doc/
https://people.csail.mit.edu/albert/bluez-intro/

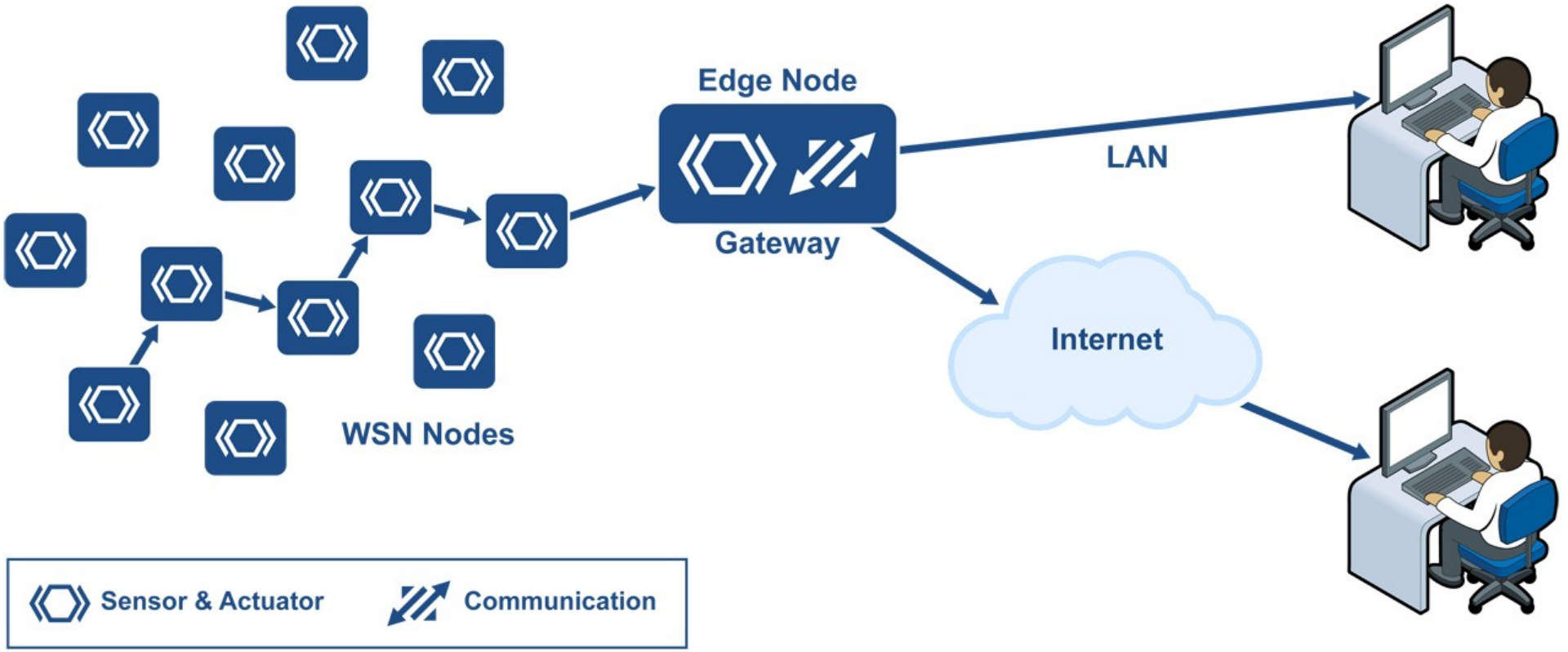
常見 IoT 架構

Raspberry Pi + Smart Phone



www.slideshare.net/yeokm1/raspberry-pi-3-uartbluetooth-issues

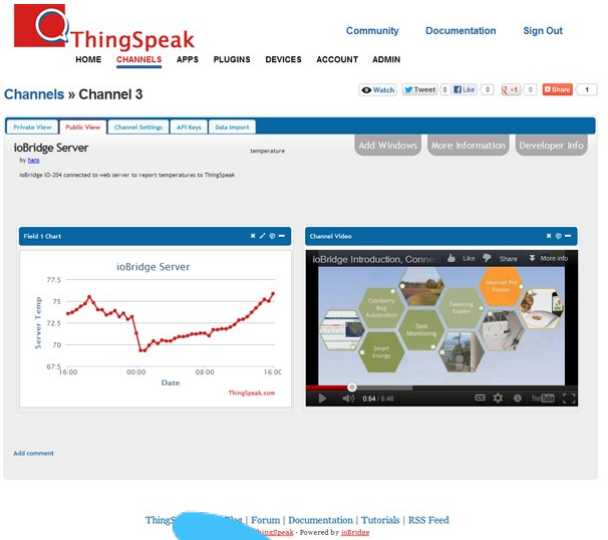
Sensor Node + Internet Gateway



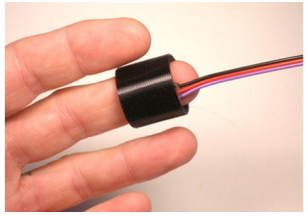
http://micrium.com/iot/devices/

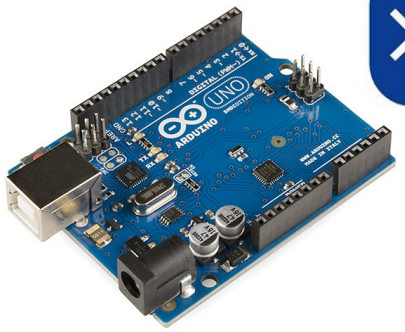
生理監控上雲端

Cloud



Sensor Node





MQTT.ORG

Internet Gateway

3G

OpenAPI

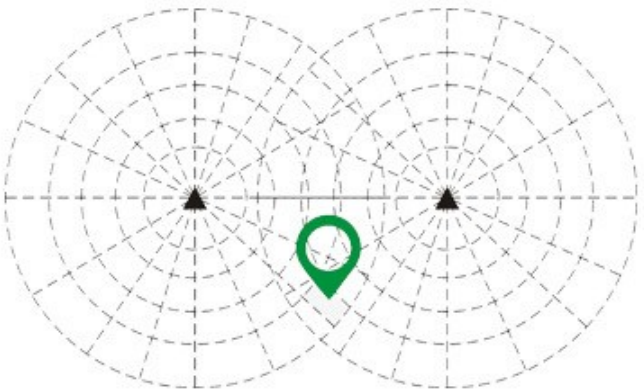
和 Sensor Node 用 SP Profile 連線

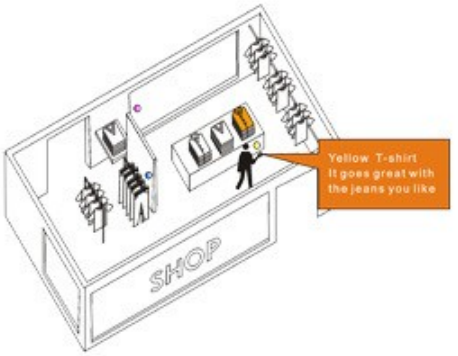
- 如果用App Inventor 2寫Android程式要和Pi 3通訊
- 或是使用Arduino + HC-05要和Pi 3通訊
  - 需要用SDP tool新增SP服務與compat指令介面
    - 修改藍牙的systemd設定檔(bluetooth.service)
      路徑:/lib/systemd/system/bluetooth.service
    - 新增與修改兩行
      ExecStart=/usr/lib/bluetooth/bluetoothd -C
      ExecStartPost=/usr/bin/sdptool add SP

https://www.raspberrypi.org/forums/viewtopic.php?f=28&t=125922

Beacon + Smart Phone

- Beacon 是一種基於 BLE 的技術
- 單向廣播封包 (advertise specific data one-way)





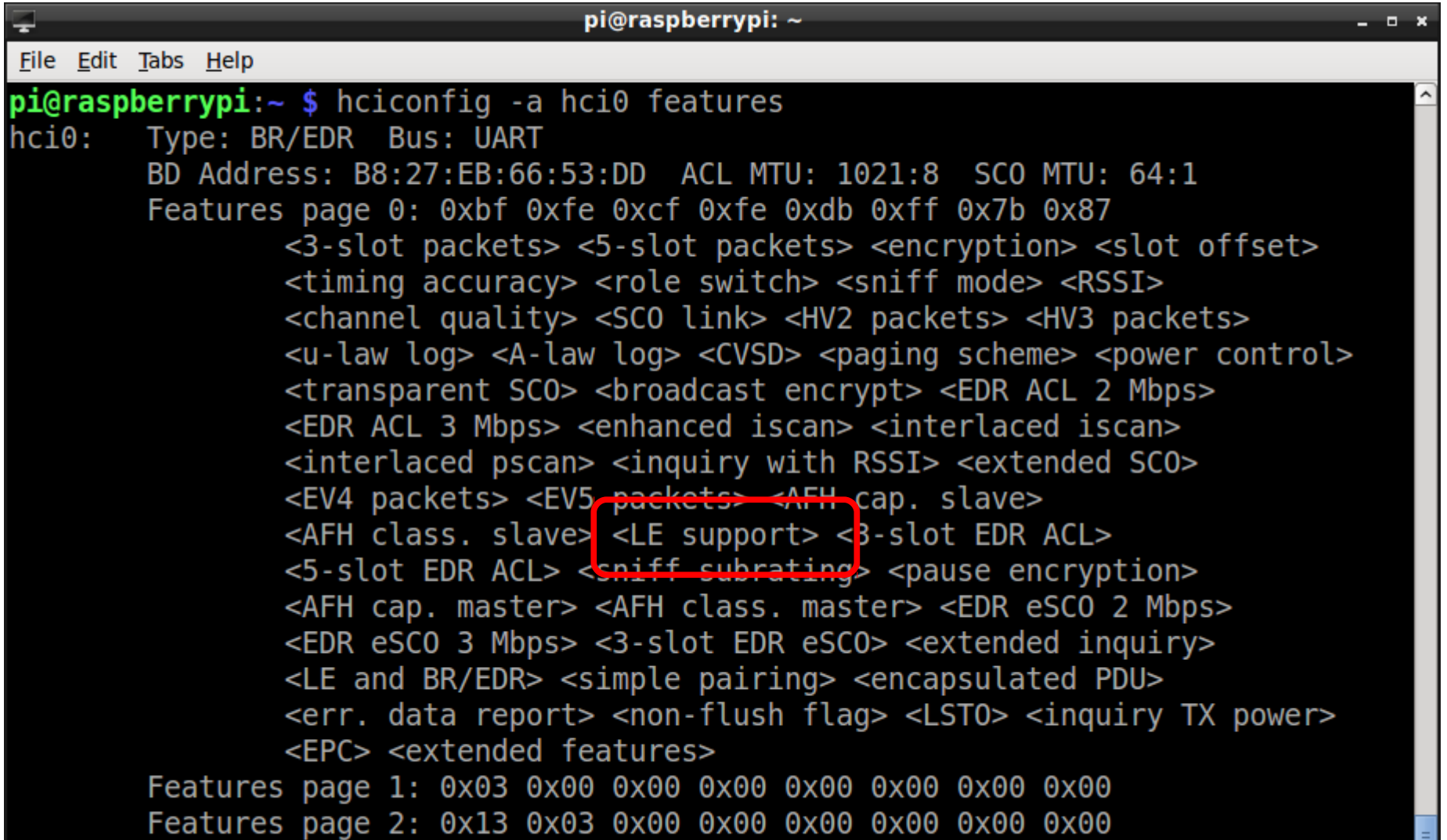
- 為 app 或 server 端的應用 (例如室內定位或推播)

支援 BLE 的平台

- iOS5+ (iOS7+ preferred)
- Android 4.3+ (numerous bug fixes in 4.4+)
- Apple OS X 10.6+
- Windows 8 (XP, Vista and 7 only support Bluetooth 2.1)
- GNU/Linux Vanilla BlueZ 4.93+

檢查 BCM43438 是否有支援 BLE ？

- `$ hciconfig -a hci0 features`



實做 Beacon

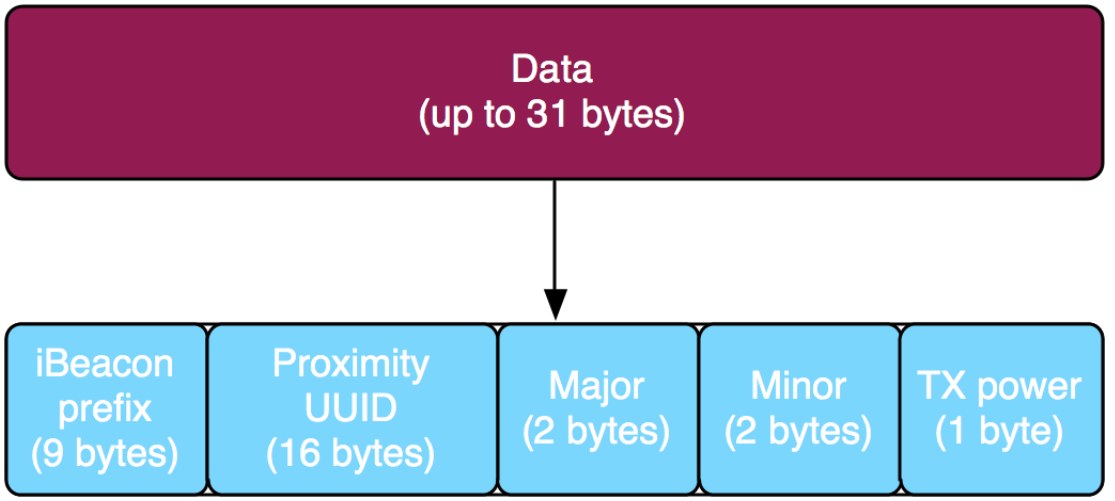
- $ sudo hciconfig hci0 noscan
- $ sudo hciconfig hci0 leadv 3
- $ sudo hcitool -i hci0 cmd 0x08 0x0008 1E 02 01 1A 1A FF 4C 00 02 15 BD 2F 21 F0 B3 CA 4B 67 A1 2C 1F 3C D4 F5 29 11 00 00 00 00 C8 00

```
pi@raspberrypi:~ $ sudo hcitool -i hci0 cmd 0x08 0x0008 1E 02 01 1A 1A FF 4C 00 0
2 15 BD 2F 21 F0 B3 CA 4B 67 A1 2C 1F 3C D4 F5 29 11 00 00 00 00 C8 00
< HCI Command: ogf 0x08, ocf 0x0008, plen 32
  1E 02 01 1A 1A FF 4C 00 02 15 BD 2F 21 F0 B3 CA 4B 67 A1 2C
  1F 3C D4 F5 29 11 00 00 00 00 C8 00
> HCI Event: 0x0e plen 4
  01 08 20 00
```

- $ sudo hciconfig hci0 noleadv # 停止廣播

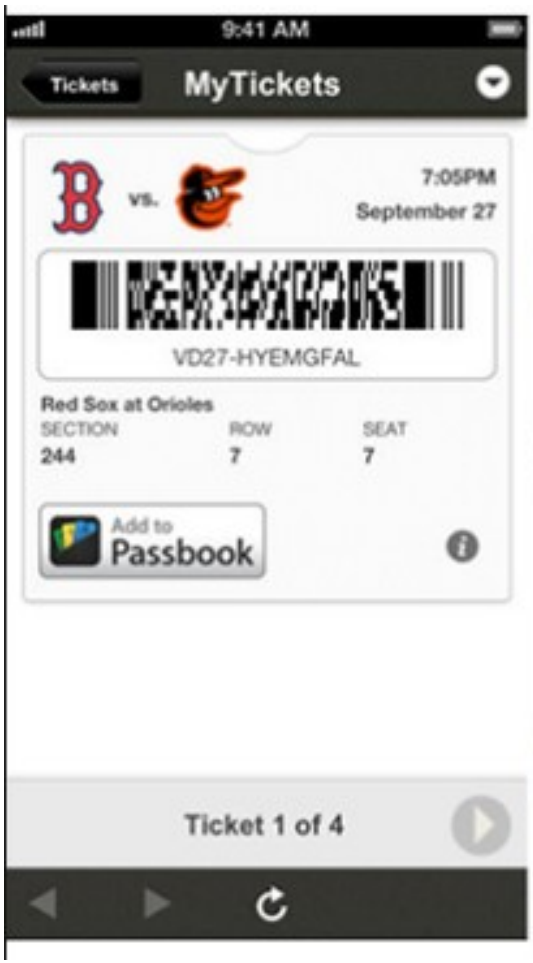
Beacon 資料封包

- BLE Device
  - 藍牙接收器的編號
- UUID
  - 唯一識別碼 (自訂)
- Major
  - 大分類編號 (自訂，由 0000 到 FFFF)
- Minor
  - 小分類編號 (自訂，由 0000 到 FFFF)
- Measured Power
  - 發射端與接收端相距一公尺時的訊號強度



Beacon 應用

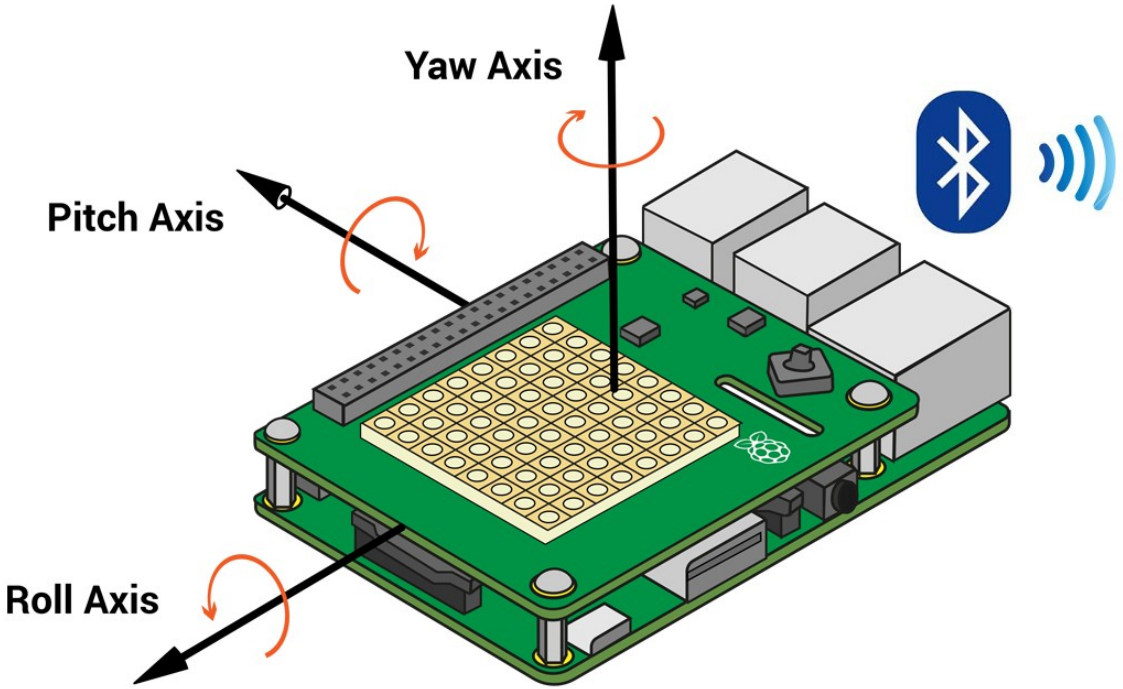
- 微型定位服務 + 推播訊息



http://www.bnext.com.tw/article/32652/BN-ARTICLE-32652

藍牙應用展示

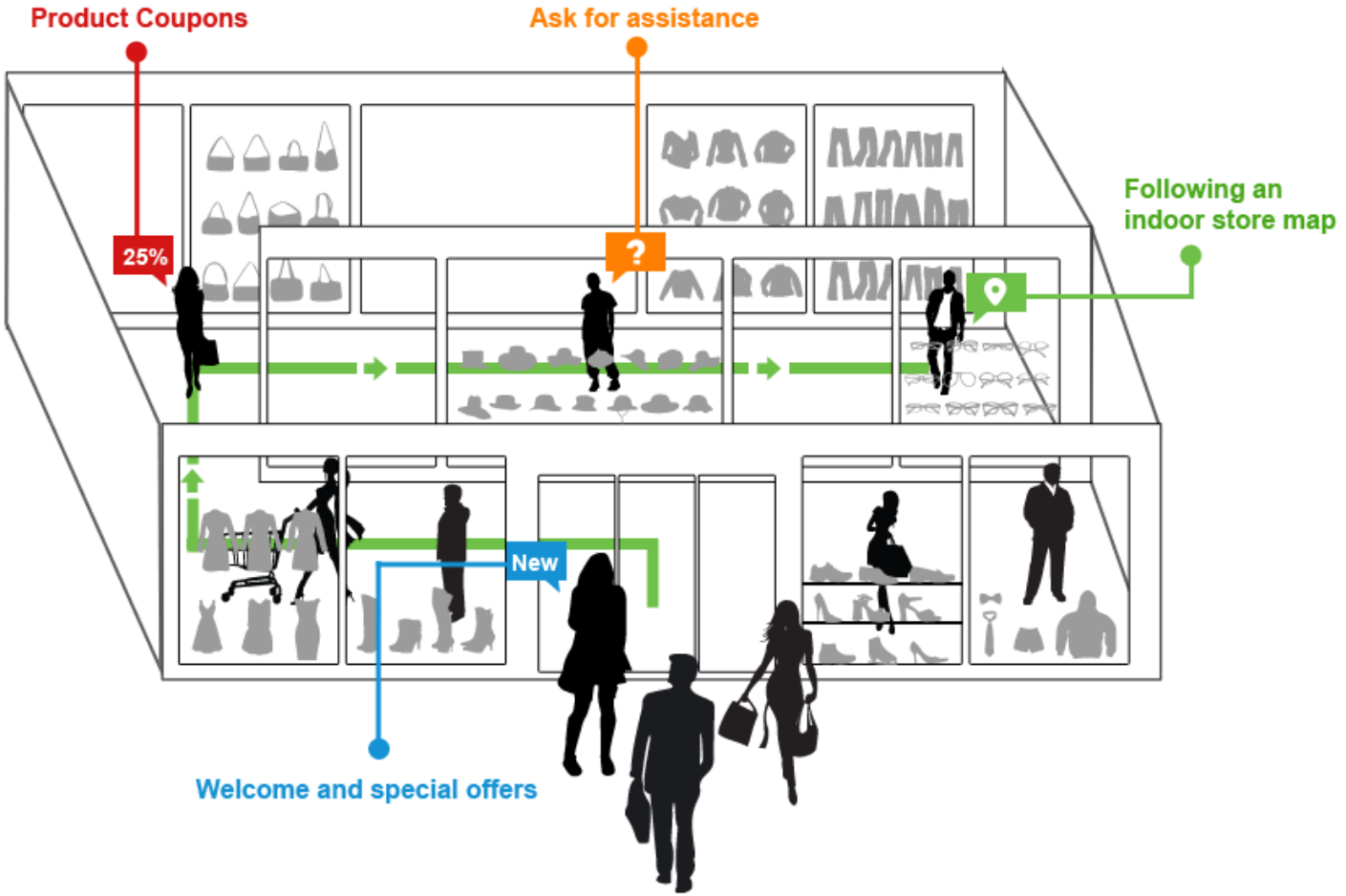
Transfer Gyro data to Mobile Phone



http://danceswithcode.net/engineeringnotes/rotations_in_3d/demo3D/rotations_in_3d_tool.html

PiBEACON

- 微定位
- 微推播



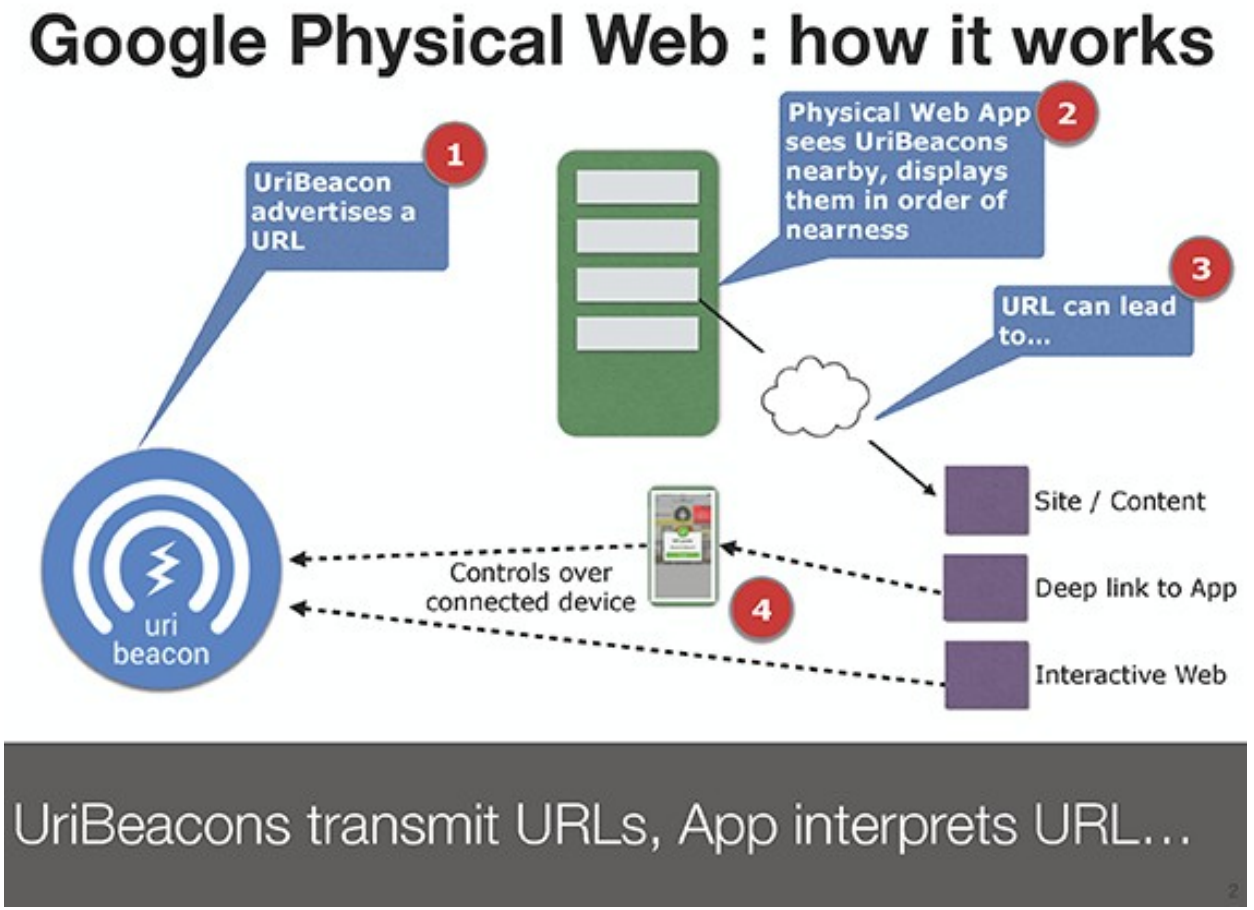
https://learn.adafruit.com/pibeacon-ibeacon-with-a-raspberry-pi/overview

Physical Web

- `Eddystone-URL`

http://www.loadthegame.com/2014/10/03/google-developing-physical-web/

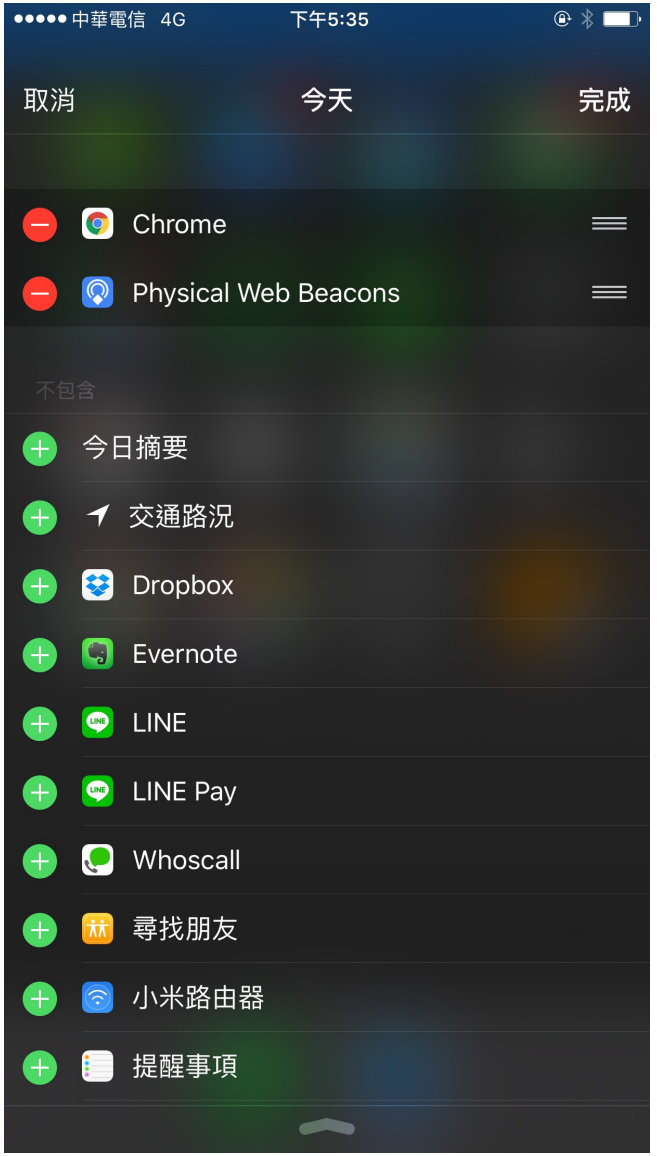
Physical Web How It Works

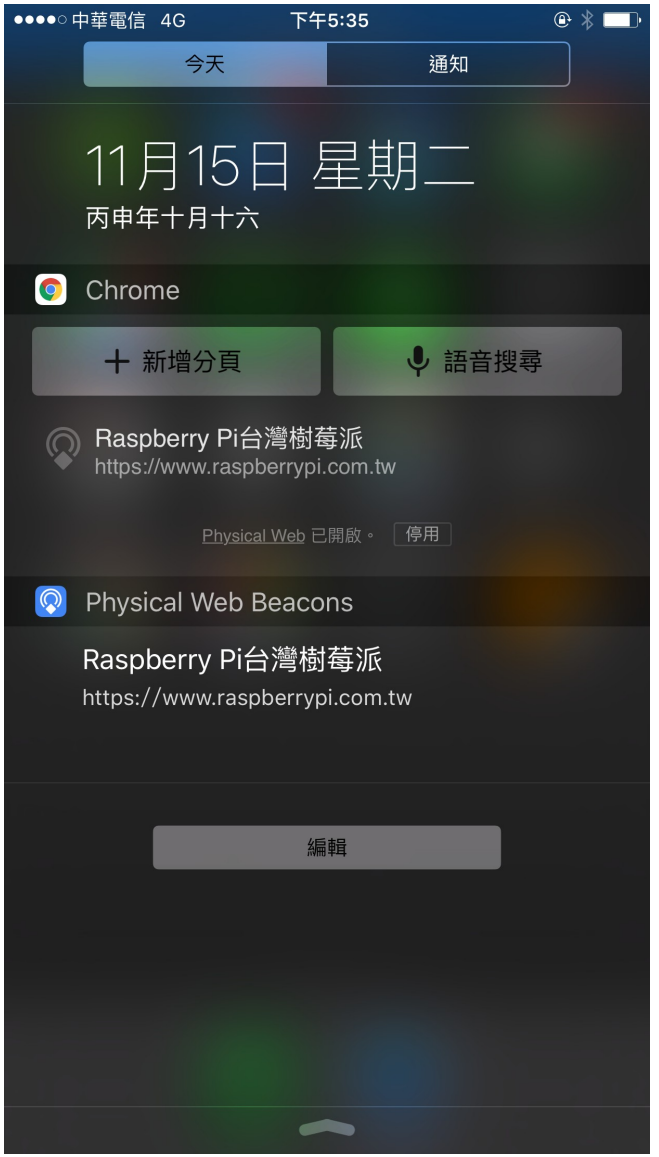


http://radar.oreilly.com/2015/04/googles-physical-web-vs-apples-ibeacon.html

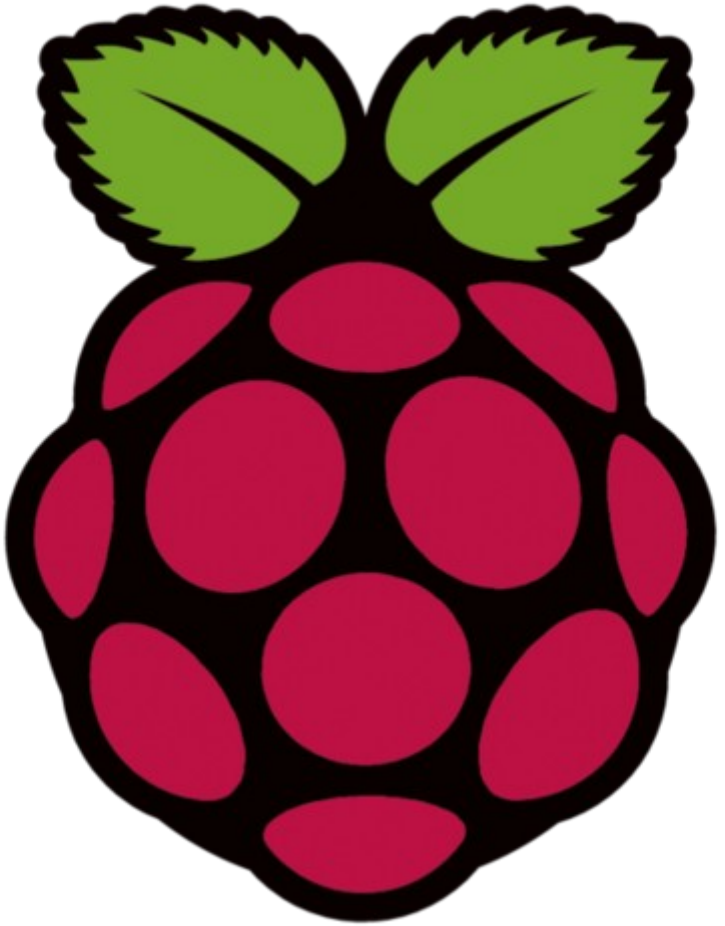
DEMO

Physical Web + iPhone





Raspberry Pi Rocks the World



Thanks