

教育部 5G 行動寬頻人才培育跨校教學聯盟計畫
5G 行動網路協定與核網技術聯盟中心示範課程

4G/5G 行動寬頻協同網路

實驗三 SBA 建置與協定分析

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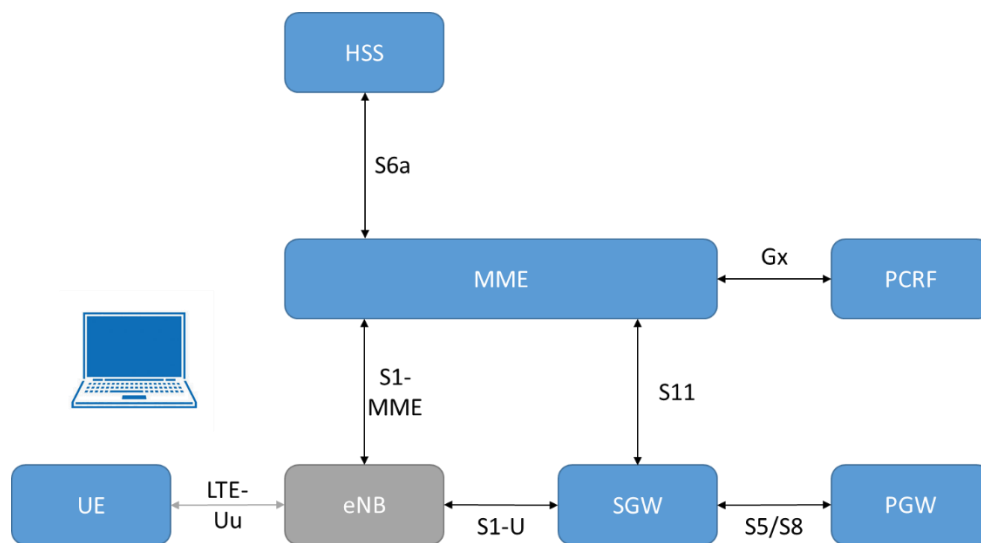
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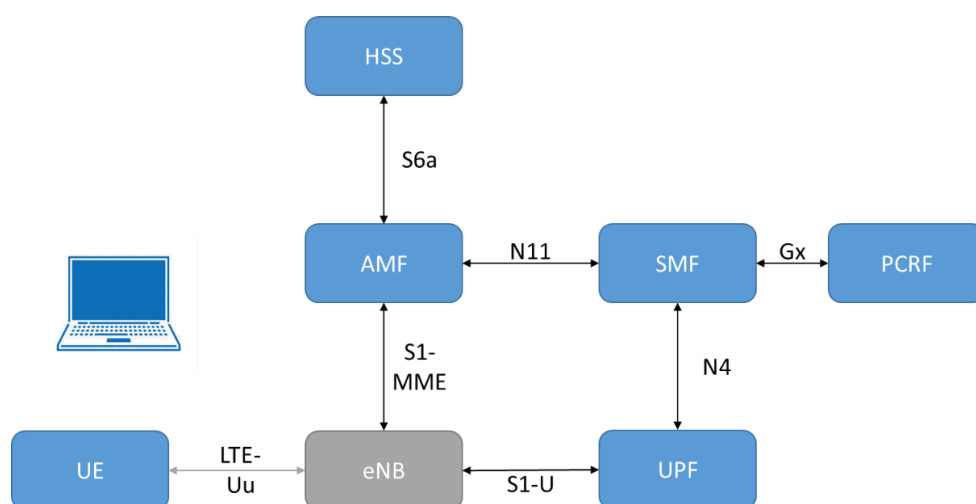
一、實驗架構

本實驗架構如下圖所示，共分成兩個部分，第一部分由 5GC 和 eNB 組成，透過程式指定 ip 位址由電腦開啟，而另一部分為 UE，使用手機進行訊號傳遞，形成 5G 基本網路架構。

1. LTE 實驗架構



2. Free5GC 實驗架構



二、軟硬體需求

1. 軟體

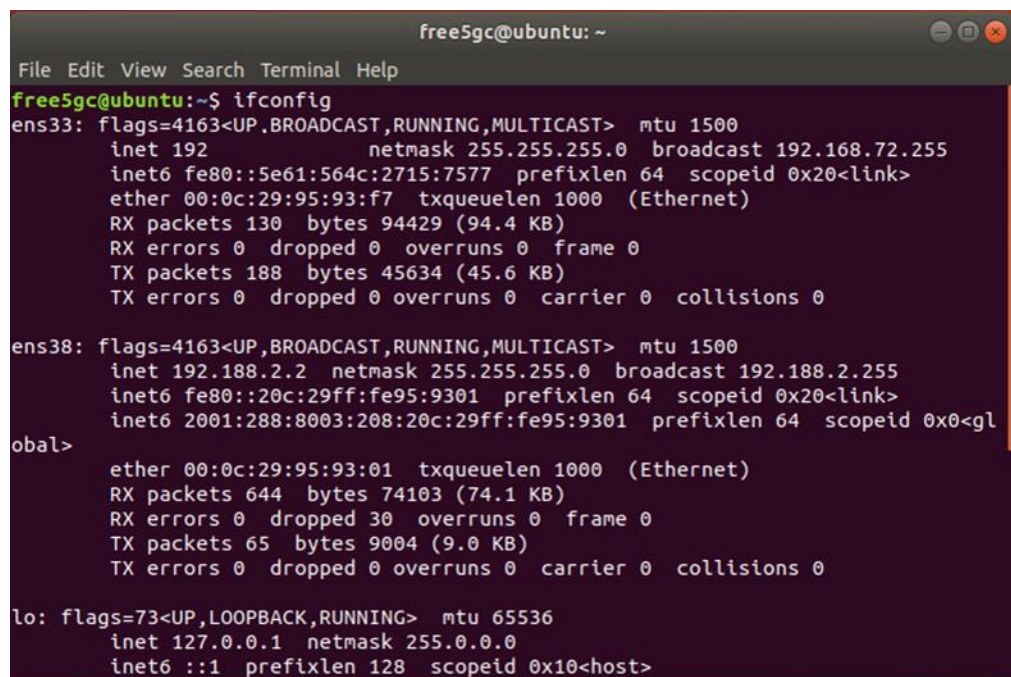
名稱	軟體	版本	目的
Free5GC	OS :	Ubuntu 18.04	啟動 HSS、 AMF、 SMF、 PCRF 和 UPF 功能
	Ubuntu	4.15.0-43-generic	
	Free5GC 的軟體	https://bitbucket.org/nctu_5g/free5gc.git	
	第三方擴充 套件: Gcc GO MongoDB		

2. 硬體

名稱	規格	數量	目的
5GC+eNB	桌上型電腦	2	啟動 HSS、 AMF、 SMF、 PCRF 和 UPF 功能
	USRP B210	1	
UE	ASUS_Z016D	1	

VM NIC Cards :

- NIC for connecting to the Internet :
- Network source: Virtual network - NAT
- Interface name in VM: ens33
- NIC for connecting to eNB :
- Network source: Host device <Host Interface Name>
- Interface name in VM: ens3



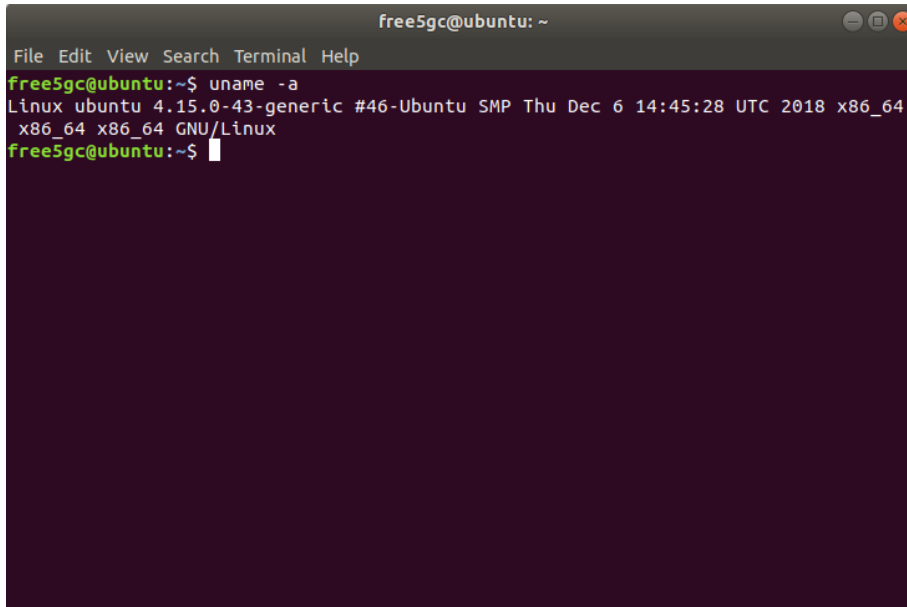
```
free5gc@ubuntu: ~  
File Edit View Search Terminal Help  
free5gc@ubuntu:~$ ifconfig  
ens33: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500  
    inet 192.168.72.255 netmask 255.255.255.0 broadcast 192.168.72.255  
    inet6 fe80::5e61:564c:2715:7577 prefixlen 64 scopeid 0x20<link>  
    ether 00:0c:29:95:93:f7 txqueuelen 1000 (Ethernet)  
    RX packets 130 bytes 94429 (94.4 KB)  
    RX errors 0 dropped 0 overruns 0 frame 0  
    TX packets 188 bytes 45634 (45.6 KB)  
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0  
  
ens38: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500  
    inet 192.188.2.2 netmask 255.255.255.0 broadcast 192.188.2.255  
    inet6 fe80::20c:29ff:fe95:9301 prefixlen 64 scopeid 0x20<link>  
    inet6 2001:288:8003:208:20c:29ff:fe95:9301 prefixlen 64 scopeid 0x0<global>  
    ether 00:0c:29:95:93:01 txqueuelen 1000 (Ethernet)  
    RX packets 644 bytes 74103 (74.1 KB)  
    RX errors 0 dropped 30 overruns 0 frame 0  
    TX packets 65 bytes 9004 (9.0 KB)  
    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>
```

三、 Free5GC 網路實驗平台建置

檢查

確認 Kernel 版本

- `uname -a`



```
free5gc@ubuntu: ~  
File Edit View Search Terminal Help  
free5gc@ubuntu:~$ uname -a  
Linux ubuntu 4.15.0-43-generic #46-Ubuntu SMP Thu Dec 6 14:45:28 UTC 2018 x86_64  
x86_64 x86_64 GNU/Linux  
free5gc@ubuntu:~$
```

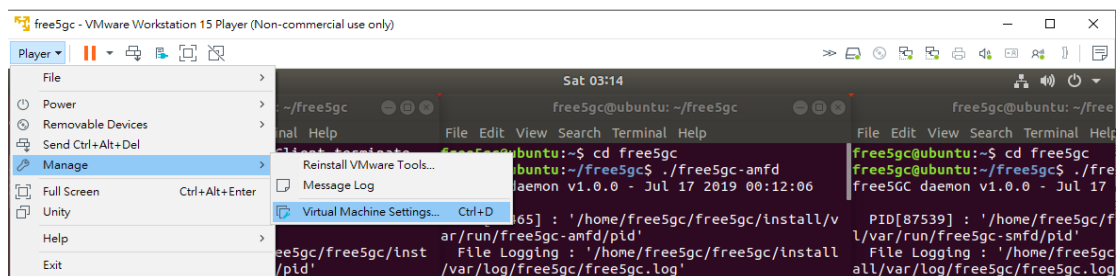
0. 新增額外橋接 NIC(First)

VM NIC Cards :

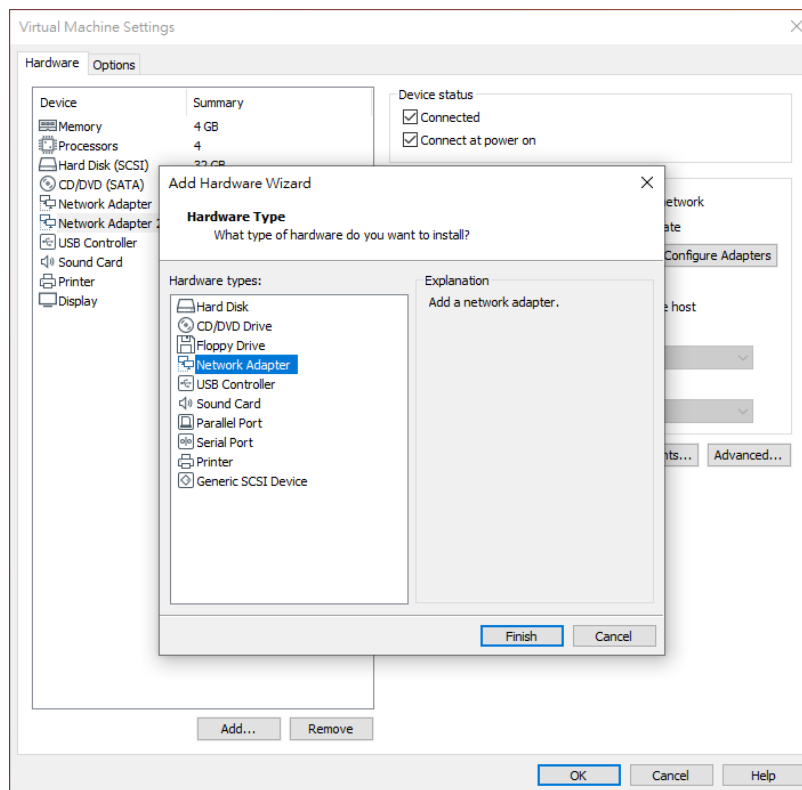
- 用於連接 Internet 的 NIC :
 - 網路來源 : Virtual network - NAT
 - 介面名稱 in VM : ens33
- 用於連接 eNB 的 NIC :
 - 網路來源 : Host device <Host Interface Name>
 - 介面名稱 in VM: ens38

添加另一個具有橋接模式的網路以連接到您的 eNodeB

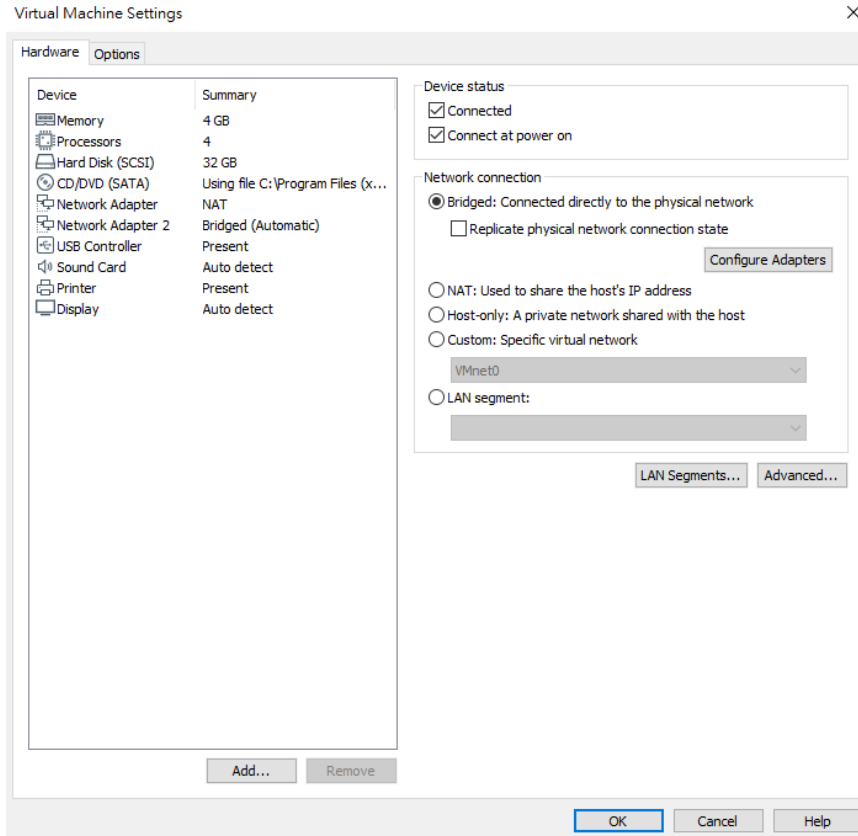
- 點選 Player -> Manage -> Virtual Machine Setting



- 選擇下方 Add 去選擇所需要的 Hardware Type
- 這邊我們選擇 Network Adapter



- 在 Network connection 選擇所需要的設定：Bridged
- 點選 Configure Adapters 確認連接網卡
- 確認完畢後即可點選 OK



1. MongoDB Golang Setup

安裝 MongoDB 3.6.3, Golang 1.11.4.

開啟一個終端機(Terminal)，並且依序輸入

- `sudo apt-get update`
- `sudo apt-get -y install mongodb wget git`
- `sudo systemctl start mongodb` (如果 `/usr/bin/mongod` 沒有運行)

```

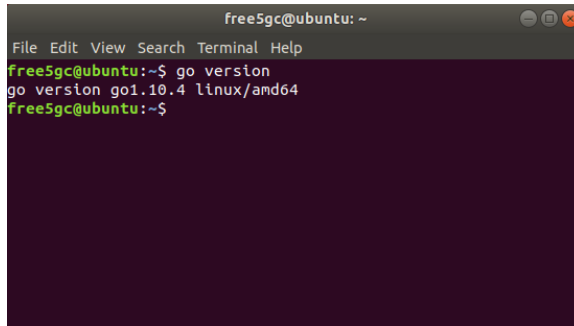
free5gc@ubuntu:~$ sudo apt-get update
Get:1 http://security.ubuntu.com/ubuntu bionic-security InRelease [88.7 kB]
Hit:2 http://us.archive.ubuntu.com/ubuntu bionic InRelease
Hit:3 http://ppa.launchpad.net/wfreshark-dev/stable/ubuntu bionic InRelease
Get:4 http://us.archive.ubuntu.com/ubuntu bionic-updates InRelease [88.7 kB]
Get:5 http://security.ubuntu.com/ubuntu bionic-security/main amd64 Packages [451 kB]
Get:6 http://us.archive.ubuntu.com/ubuntu bionic-backports InRelease [74.6 kB]
Get:7 http://us.archive.ubuntu.com/ubuntu bionic-updates/main i386 Packages [559 kB]
Get:8 http://security.ubuntu.com/ubuntu bionic-security/main i386 Packages [340 kB]
Get:9 http://us.archive.ubuntu.com/ubuntu bionic-updates/main amd64 Packages [682 kB]
Get:10 http://security.ubuntu.com/ubuntu bionic-security/main amd64 DEP-11 Metadata [24.2 kB]
Get:11 http://security.ubuntu.com/ubuntu bionic-security/main DEP-11 48x48 Icons [10.4 kB]
Get:12 http://security.ubuntu.com/ubuntu bionic-security/main DEP-11 64x64 Icons [31.7 kB]
Get:13 http://us.archive.ubuntu.com/ubuntu bionic-updates/main amd64 Packages [682 kB]
Get:14 http://us.archive.ubuntu.com/ubuntu bionic-updates/main amd64 DEP-11 Metadata [283 kB]
Get:15 http://us.archive.ubuntu.com/ubuntu bionic-updates/main DEP-11 48x48 Icons [66.7 kB]
Get:16 http://security.ubuntu.com/ubuntu bionic-security/universe i386 Packages [565 kB]
Get:17 http://us.archive.ubuntu.com/ubuntu bionic-updates/main DEP-11 64x64 Icons [138 kB]
Get:18 http://us.archive.ubuntu.com/ubuntu bionic-updates/universe amd64 Packages [972 kB]
Get:19 http://security.ubuntu.com/ubuntu bionic-security/universe amd64 DEP-11 Metadata [41.3 kB]
Get:20 http://security.ubuntu.com/ubuntu bionic-security/universe DEP-11 48x48 Icons [16.4 kB]
Get:21 http://security.ubuntu.com/ubuntu bionic-security/universe DEP-11 64x64 Icons [111 kB]
Get:22 http://security.ubuntu.com/ubuntu bionic-security/multiverse amd64 DEP-11 Metadata [2,464 B]
Get:23 http://us.archive.ubuntu.com/ubuntu bionic-updates/universe i386 Packages [955 kB]
Get:24 http://us.archive.ubuntu.com/ubuntu bionic-updates/universe Translation-en [294 kB]
Get:25 http://us.archive.ubuntu.com/ubuntu bionic-updates/universe amd64 DEP-11 Metadata [249 kB]
Get:26 http://us.archive.ubuntu.com/ubuntu bionic-updates/universe DEP-11 48x48 Icons [195 kB]
Get:27 http://us.archive.ubuntu.com/ubuntu bionic-updates/universe DEP-11 64x64 Icons [419 kB]
Get:28 http://us.archive.ubuntu.com/ubuntu bionic-updates/multiverse amd64 DEP-11 Metadata [2,468 B]
Get:29 http://us.archive.ubuntu.com/ubuntu bionic-backports/universe amd64 DEP-11 Metadata [7,224 B]
Fetched 7,240 kB in 14s (513 kB/s)
Reading package lists... Done
free5gc@ubuntu:~$ sudo apt-get -y install mongodb wget git
Reading package lists... Done
Building dependency tree
Reading state information... Done
git is already the newest version (1:2.17.1-1ubuntu0.4).
wget is already the newest version (1.19.4-1ubuntu2.2).
mongodb is already the newest version (3.6.3-0ubuntu1.1).
The following packages were automatically installed and are no longer required:
  amd64-microcode intel-microcode lucode-tool libmongoc-1.0-0 libsnappy-dev
  thermald
Use 'sudo apt autoremove' to remove them.
0 upgraded, 0 newly installed, 0 to remove and 51 not upgraded.
free5gc@ubuntu:~$ sudo systemctl start mongodb

```

檢查是否 golang 已經安裝

開啟終端機(Terminal)輸入以下指令

- go version

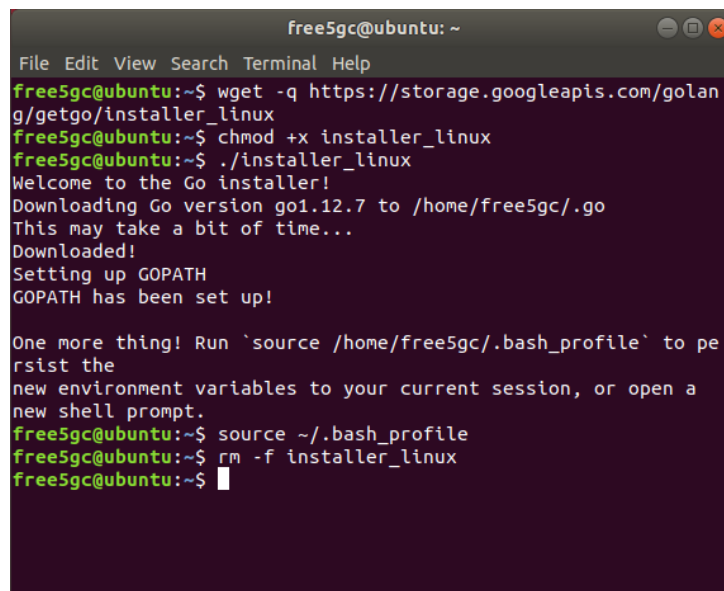


```
free5gc@ubuntu: ~  
File Edit View Search Terminal Help  
free5gc@ubuntu:~$ go version  
go version go1.10.4 linux/amd64  
free5gc@ubuntu:~$
```

如果沒有安裝，執行以下指令

開啟終端機(Terminal)輸入以下指令

- wget -q
https://storage.googleapis.com/golang/getgo/installer_
linux
- chmod +x installer_linux
- ./installer_linux
- source ~/.bash_profile
- rm -f installer_linux



```
free5gc@ubuntu: ~  
File Edit View Search Terminal Help  
free5gc@ubuntu:~$ wget -q https://storage.googleapis.com/golang/getgo/installer_linux  
free5gc@ubuntu:~$ chmod +x installer_linux  
free5gc@ubuntu:~$ ./installer_linux  
Welcome to the Go installer!  
Downloading Go version go1.12.7 to /home/free5gc/.go  
This may take a bit of time...  
Downloaded!  
Setting up GOPATH  
GOPATH has been set up!  
  
One more thing! Run `source /home/free5gc/.bash_profile` to persist the  
new environment variables to your current session, or open a  
new shell prompt.  
free5gc@ubuntu:~$ source ~/.bash_profile  
free5gc@ubuntu:~$ rm -f installer_linux  
free5gc@ubuntu:~$
```

- go get -u -v "github.com/gorilla/mux"
- go get -u -v "golang.org/x/net/http2"
- go get -u -v "golang.org/x/sys/unix"

```
free5gc@ubuntu: ~  
File Edit View Search Terminal Help  
free5gc@ubuntu:~$ wget -q https://storage.googleapis.com/golang/getgo/installer_linux  
free5gc@ubuntu:~$ chmod +x installer_linux  
free5gc@ubuntu:~$ ./installer_linux  
Welcome to the Go installer!  
Downloading Go version go1.12.7 to /home/free5gc/.go  
This may take a bit of time...  
Downloaded!  
Setting up GOPATH  
GOPATH has been set up!  
  
One more thing! Run `source /home/free5gc/.bash_profile` to persist the  
new environment variables to your current session, or open a  
new shell prompt.  
free5gc@ubuntu:~$ source ~/.bash_profile  
free5gc@ubuntu:~$ rm -f installer_linux  
free5gc@ubuntu:~$ go get -u -v "github.com/gorilla/mux"  
github.com/gorilla/mux (download)  
free5gc@ubuntu:~$ go get -u -v "golang.org/x/net/http2"  
Fetching https://golang.org/x/net/http2?go-get=1  
Parsing meta tags from https://golang.org/x/net/http2?go-get=1  
(status code 200)
```

將配置文件寫入 TUN device。

開啟終端機(Terminal)輸入以下指令

- `sudo sh -c "cat << EOF > /etc/systemd/network/99-free5gc.netdev`
- `[NetDev]`
- `Name=uptun`
- `Kind=tun`
- `EOF"`
- `sudo systemctl enable systemd-networkd`
- `sudo systemctl restart systemd-networkd`

```
free5gc@ubuntu: ~  
File Edit View Search Terminal Help  
free5gc@ubuntu:~$ sudo sh -c "cat << EOF > /etc/systemd/network/99-free5gc.netdev  
> [NetDev]  
> Name=uptun  
> Kind=tun  
> EOF"  
[sudo] password for free5gc:  
free5gc@ubuntu:~$ sudo systemctl enable systemd-networkd  
free5gc@ubuntu:~$ sudo systemctl restart systemd-networkd  
free5gc@ubuntu:~$
```

如果 TUN device 禁用 IPv6，請從下面刪除 `Address = cafe :: 1/64`。

- `sudo sh -c "cat << EOF > /etc/systemd/network/99-free5gc.network`
- `[Match]`
- `Name=uptun`

- [Network]
- Address=45.45.0.1/16
- Address=cafe::1/64
- EOF"
- sudo systemctl enable systemd-networkd
- sudo systemctl restart systemd-networkd

```

free5gc@ubuntu: ~
File Edit View Search Terminal Help
free5gc@ubuntu:~$ sudo sh -c "cat << EOF > /etc/systemd/network/99-free5gc.network
> [Match]
> Name=uptun
> [Network]
> Address=45.45.0.1/16
> Address=cafe::1/64
> EOF"
[sudo] password for free5gc:
free5gc@ubuntu:~$ sudo systemctl enable systemd-networkd
free5gc@ubuntu:~$ sudo systemctl restart systemd-networkd

```

檢查 Uptun 是否已啟動

- sudo apt-get install net-tools

```

free5gc@ubuntu: ~
File Edit View Search Terminal Help
free5gc@ubuntu:~$ sudo apt-get install net-tools
[sudo] password for free5gc:
Reading package lists... Done
Building dependency tree
Reading state information... Done
net-tools is already the newest version (1.60+git20161116.90da8a0-1ubuntu1).
The following packages were automatically installed and are no longer required:
  amd64-microcode intel-microcode iucode-tool libmongoc-1.0-0 libsnappy-dev
  thermald
Use 'sudo apt autoremove' to remove them.
0 upgraded, 0 newly installed, 0 to remove and 51 not upgraded.
free5gc@ubuntu:~$

```

安裝用於 source 的依賴項目

- sudo apt-get -y install autoconf libtool gcc pkg-config git flex bison libsctp-dev libgnutls28-dev libgcrypt-dev libssl-dev libidn11-dev libmongoc-dev libbson-dev libyaml-dev

```

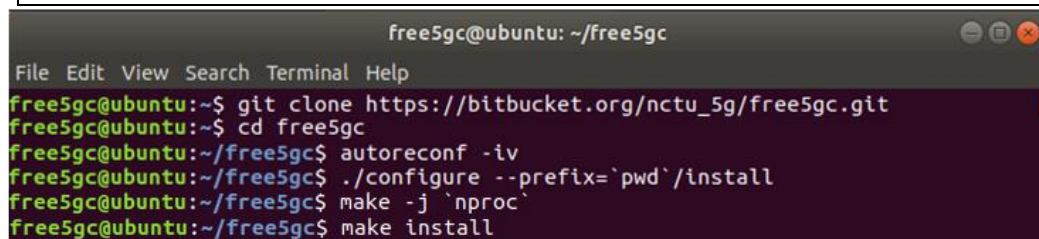
free5gc@ubuntu: ~
File Edit View Search Terminal Help
free5gc@ubuntu:~$ sudo apt-get -y install autoconf libtool gcc pkg-config git fl
ex bison libsctp-dev libgnutls28-dev libgcrypt-dev libssl-dev libidn11-dev libmo
ngoc-dev libbson-dev libyaml-dev

```

2. Free5gc Git clone 及編譯

開啟終端機(Terminal)輸入以下指令

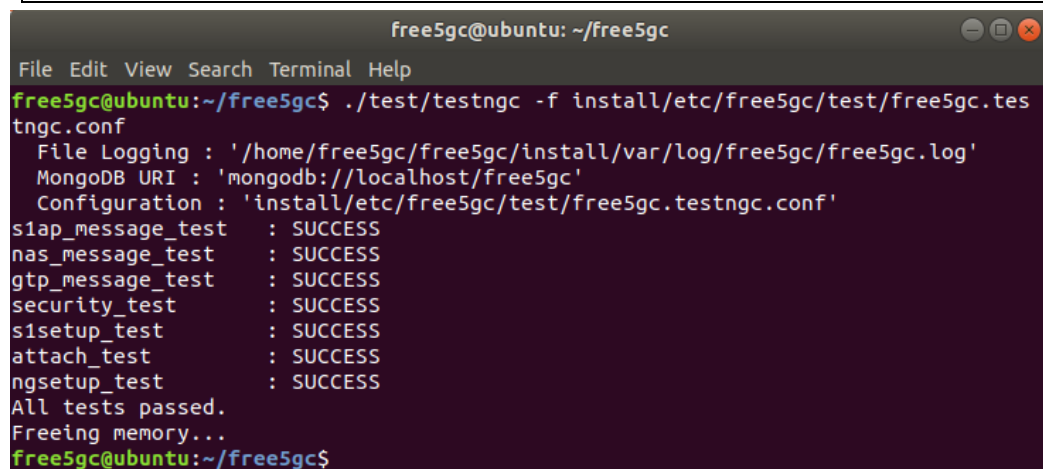
- `git clone https://bitbucket.org/nctu_5g/free5gc.git`
- `cd free5gc`
- `autoreconf -iv`
- `./configure --prefix='pwd' /install`
- `make -j 'nproc'`
- `make install`



```
free5gc@ubuntu: ~/free5gc
File Edit View Search Terminal Help
free5gc@ubuntu:~$ git clone https://bitbucket.org/nctu_5g/free5gc.git
free5gc@ubuntu:~$ cd free5gc
free5gc@ubuntu:~/free5gc$ autoreconf -iv
free5gc@ubuntu:~/free5gc$ ./configure --prefix='pwd' /install
free5gc@ubuntu:~/free5gc$ make -j 'nproc'
free5gc@ubuntu:~/free5gc$ make install
```

確認安裝

- `./test/testngc -f install/etc/free5gc/test/free5gc.testngc.conf`



```
free5gc@ubuntu: ~/free5gc
File Edit View Search Terminal Help
free5gc@ubuntu:~/free5gc$ ./test/testngc -f install/etc/free5gc/test/free5gc.testngc.conf
File Logging : '/home/free5gc/free5gc/install/var/log/free5gc/free5gc.log'
MongoDB URI : 'mongodb://localhost/free5gc'
Configuration : 'install/etc/free5gc/test/free5gc.testngc.conf'
s1ap_message_test : SUCCESS
nas_message_test : SUCCESS
gtp_message_test : SUCCESS
security_test : SUCCESS
s1setup_test : SUCCESS
attach_test : SUCCESS
ngsetup_test : SUCCESS
All tests passed.
Freeing memory...
free5gc@ubuntu:~/free5gc$
```

(發生問題&解決方法)

※請先確認是否連接網路正常。

※查詢前面 MongoDB, Golang 是否有成功啟動/安裝。

3. 配置核心網絡並添加用戶信息

檢查 NIC 的環境

#用於連接 Internet 的 NIC :

- ens33

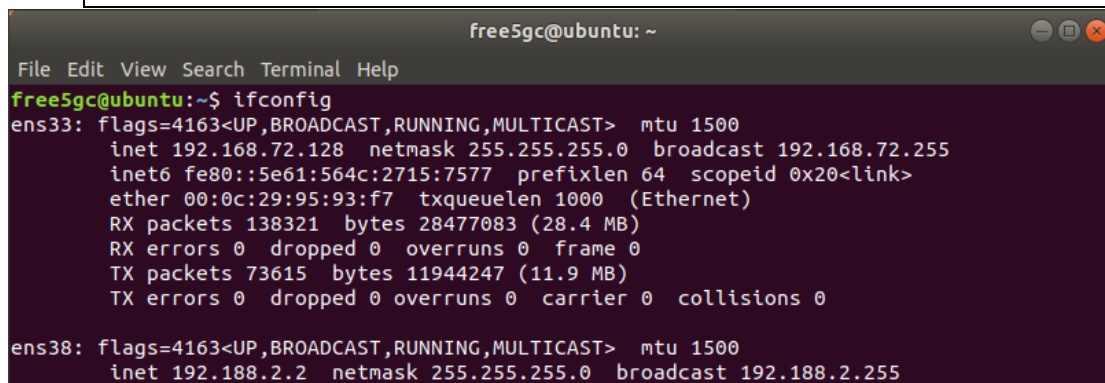
#用於連接 eNB 的 NIC :

- ens38

使用指令確認對內網卡及對外網卡

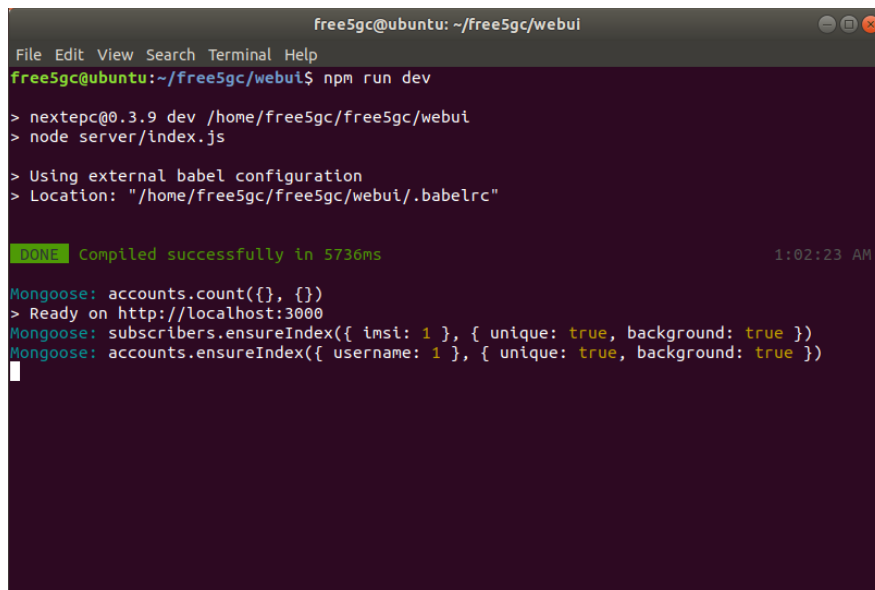
開啟終端機(Terminal)輸入以下指令

- ifconfig



```
free5gc@ubuntu: ~  
File Edit View Search Terminal Help  
free5gc@ubuntu:~$ ifconfig  
ens33: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500  
    inet 192.168.72.128 netmask 255.255.255.0 broadcast 192.168.72.255  
    inet6 fe80::5e61:564c:2715:7577 prefixlen 64 scopeid 0x20<link>  
    ether 00:0c:29:95:93:f7 txqueuelen 1000 (Ethernet)  
    RX packets 138321 bytes 28477083 (28.4 MB)  
    RX errors 0 dropped 0 overruns 0 frame 0  
    TX packets 73615 bytes 11944247 (11.9 MB)  
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0  
  
ens38: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500  
    inet 192.188.2.2 netmask 255.255.255.0 broadcast 192.188.2.255
```

- sudo ifconfig ens38 192.188.2.2
- cd free5gc/webui/
- sudo apt install npm
- npm install
- npm run dev



```
free5gc@ubuntu: ~/free5gc/webui  
File Edit View Search Terminal Help  
free5gc@ubuntu:~/free5gc/webui$ npm run dev  
  
> nextepc@0.3.9 dev /home/free5gc/free5gc/webui  
> node server/index.js  
  
> Using external babel configuration  
> Location: "/home/free5gc/free5gc/webui/.babelrc"  
  
[DONE] Compiled successfully in 5736ms 11:02:23 AM  
  
Mongoose: accounts.count({}, {})  
> Ready on http://localhost:3000  
Mongoose: subscribers.ensureIndex({ imsi: 1 }, { unique: true, background: true })  
Mongoose: accounts.ensureIndex({ username: 1 }, { unique: true, background: true })
```

新增用戶信息

- 在網頁上輸入網址 <http://localhost:3000>
- 點選右下 ⊕ 進行新增動作
- 輸入使用者帳號密碼
 - Username : admin
 - Password : 1423
- 新增用戶資訊的 IMSI, K, OPc

■ USIM 資訊 (在這個例子)

```
- IMSI 208930000000003
- K 8baf473f2f8fd09487cccbd7097c6862
- OPc 8e27b6af0e692e750f32667a3b14605d
```

- Save

free5GC

Edit Subscriber

Subscriber Configuration

IMSI*
208930000000003

Subscriber Key (K)*
8baf473f2f8fd09487cccbd7097c6862

Authentication Management Field (AMF)*
8000

USIM Type
OPc

Operator Key (OPc/OP)*
8e27b6af0e692e750f32667a3b14605d

UE-AMBR Downlink (Kbps)*
1024000

UE-AMBR Uplink (Kbps)*
1024000

APN Configurations

Access Point Name (APN)*

CANCEL SAVE

(發生問題&解決方法)

查詢 npm install 是否安裝正確，npm 套件可能在安裝中打結。

4. 重建 Project

- (Control-C kill free5gc-ngcd)
- make maintainer-clean
- rm -rf ./install
- git pull
- autoreconf -iv
- ./configure --prefix='pwd' /install
- make -j 'nproc'
- make install
- ./free5gc-ngcd

5. 安裝並設定 OAI 的 eNB 軟體

安裝 Ubuntu 14.04(ubuntu-14.04.4-desktop-amd64)

- 安裝時選擇英文。

開啟終端機輸入以下指令將更新所有已安裝套件。

- `sudo apt-get update`
- `sudo apt-get upgrade`

在 eNB 上開啟一個新的終端機，並且輸入

- `sudo apt-get install linux-image-3.19.0-61-lowlatency linux-headers-3.19.0-61-lowlatency`
- `sudo apt-get install cpufrequtils`
- `sudo apt-get install i7z`

修改開機選單和設定

在終端機輸入以下指令

- `sudo gedit /etc/default/grub`

"GRUB_HIDDEN_TIMEOUT=0" 改成 "#GRUB_HIDDEN_TIMEOUT=60"

然後把

`GRUB_CMDLINE_LINUX_DEFAULT = ""`

改成

`GRUB_CMDLINE_LINUX_DEFAULT="quiet intel_pstate=distable
processor.max_cstate=1 intel_idle.max_cstate=0 idle=poll"`

在終端機輸入以下指令

- `sudo gedit /etc/default/cpufrequtils`

新增以下這行指令

`GOVERNOR="performance"`

然後儲存並關閉

在終端機輸入以下指令

- `sudo update-grub2`
- `sudo update-rc.d ondemand disable`

然後終端機輸入以下指令，重啟電腦

- `sudo reboot`

下載 git 套件並取得認證

開啟一個新的終端機，並且輸入

- `sudo apt-get install subversion git`
- `git config --global user.name "輸入你的名稱"`
- `git config --global user.email "輸入你的電子信箱"`
- `sudo su`
- `echo -n | openssl s_client -showcerts -connect gitlab.eurecom.fr:443
2>/dev/null | sed -ne '/-BEGIN CERTIFICATE-/,/-END CERTIFICATE-
/p' >> /etc/ssl/certs/ca-certificates.crt`
- `exit`

請先前往 Gitlab 註冊

如果這一頁的指令執行正確，終端機是不會有任何訊息產生

下載源始碼並安裝 OAI eNB 軟體所需的套件

在終端機輸入

- `git clone https://gitlab.eurecom.fr/oai/openairinterface5g.git`

在終端機輸入以下指令來下載並安裝 OAI eNB 軟體所需的套件

- `cd ~/openairinterface5g`
- `source oaienv`
- `cd cmake_targets`
- `./build_oai -l --eNB -x --install-system-files -w USRP --install-optional-packages`

修改 eNB 的設定檔

在終端機輸入

- `gedit ~/openairinterface5g/targets/PROJECTS/GENERIC-LTE-EPC/CONF/enb.band39.tm1.usrpb210.conf`

或

- `gedit ~/openairinterface5g/targets/PROJECTS/GENERIC-LTE-EPC/CONF/enb.band7.tm1.usrpb210.conf`

在 “~/openairinterface5g/targets/PROJECTS/GENERIC-LTE-EPC/CONF/” 目錄下有很多種 eNB 的設定檔，當 eNB 啟動時會載入這些設定檔，有需要的話可以修改訊號頻率，這裡是使用 Band 39 和 Band 7

修改以下設定

- tracking_area_code = "1";
- mobile_country_code = "208";
- mobile_network_code = "93";

設定 mobile_country_code、mobile_network_code、tracking_area_code 這三個部分，須確定跟 EPC 的資料庫及 SIM 卡中的 MCC、MNC、TAC 這三部分對應

設定 eNB 所連接的 5GC 的 IP 位址

```
140
141
142 // MME parameters:
143 mme_ip_address = ( { ipv4 = "192.188.2.2";
144                       ipv6 = "192:168:16::17";
145                       active = "yes";
146                       preference = "ipv4";
147                     } );
148
149 NETWORK_INTERFACES :
150 {
151   ENB_INTERFACE_NAME_FOR_S1_MME = "enb0s31f6";
152   ENB_IPV4_ADDRESS_FOR_S1_MME = "192.188.2.253/24";
153
154   ENB_INTERFACE_NAME_FOR_S1U = "enb0s31f6";
155   ENB_IPV4_ADDRESS_FOR_S1U = "192.188.2.253/24";
156   ENB_PORT_FOR_S1U = 2152; # Spec 2152
157 };
```

解釋：

設定 eNB 所連接的 EPC 的 IP 位址

ipv4 = "EPC 對內網卡的 IP"

ENB_INTERFACE_NAME_FOR_S1_MME = "eNB 的網卡名稱"

ENB_IPV4_ADDRESS_FOR_S1_MME = "eNB 的網卡 IP"

ENB_INTERFACE_NAME_FOR_S1U = "eNB 的網卡名稱"

ENB_IPV4_ADDRESS_FOR_S1U = "eNB 的網卡 IP"

重新編譯 eNB

在終端機輸入

- cd ~/openairinterface5g
- source oaienv
- ./cmake_targets/build_oai -w USRP -x -c -eNB
- cd cmake_targets/lte_build_oai/build

(發生問題&解決方法)

- 檢查 CPU 的效能設定
 - (在終端機輸入)
 - sudo i7z (確認 CPU 頻率)
 - cpufreq-info

(CPU Frequency Scaling 從 Powersave 模式變為 Performance 模式)

- 確認 Kernel 版本
 - `uname -a`

```
enb@enb:~  
Cpu speed from cpufreq 3591.00MHz  
cpufreq might be wrong if cpufreq is enabled. To guess correctly try estimating  
Linux's inbuilt cpu_khz code emulated now  
True Frequency (without accounting Turbo) 3591 MHz  
CPU Multiplier 36x || Bus clock frequency (BLCK) 99.75 MHz  
  
Socket [0] - [physical cores=4, logical cores=8, max online cores ever=4]  
TURBO ENABLED on 4 Cores, Hyper Threading ON  
Max Frequency without considering Turbo 3690.75 MHz (99.75 x [37])  
Max TURBO Multiplier (if Enabled) with 1/2/3/4 Cores is 40x/40x/39x/38x  
Real Current Frequency 3790.40 MHz [99.75 x 38.00] (Max of below)  
Core [core-id] :Actual Freq (Mult.) C0% Halt(C1)% C3 % C6 %  
Core 1 [0]: 3790.40 (38.00x) 100 0 0 0  
Core 2 [1]: 3790.40 (38.00x) 100 0 0 0  
Core 3 [2]: 3790.40 (38.00x) 100 0 0 0  
Core 4 [3]: 3790.40 (38.00x) 100 0 0 0  
  
C0 = Processor running without halting  
C1 = Processor running with halts (States >C0 are power saver)  
C3 = Cores running with PLL turned off and core cache turned off  
C6 = Everything in C3 + core state saved to last level cache  
Above values in table are in percentage over the last 1 sec
```

```
enb@enb:~$ cpufreq-info  
cpufrequtils 008: cpufreq-info (C) Dominik Brodowski 2004-2009  
Report errors and bugs to cpufreq@vger.kernel.org, please.  
analyzing CPU 0:  
driver: intel_pstate  
CPUs which run at the same hardware frequency: 0  
CPUs which need to have their frequency coordinated by software: 0  
maximum transition latency: 0.97 ms.  
hardware limits: 800 MHz - 4.00 GHz  
available cpufreq governors: performance, powersave  
current policy: frequency should be within 800 MHz and 4.00 GHz.  
The governor "performance" may decide which speed to use  
within this range.  
current CPU frequency is 3.80 GHz.
```

```
enb@enb:~$ uname -a  
Linux enb 3.19.0-61-lowlatency #69~14.04.1-Ubuntu SMP  
enb@enb:~$
```

6. 啟動 Free5GC

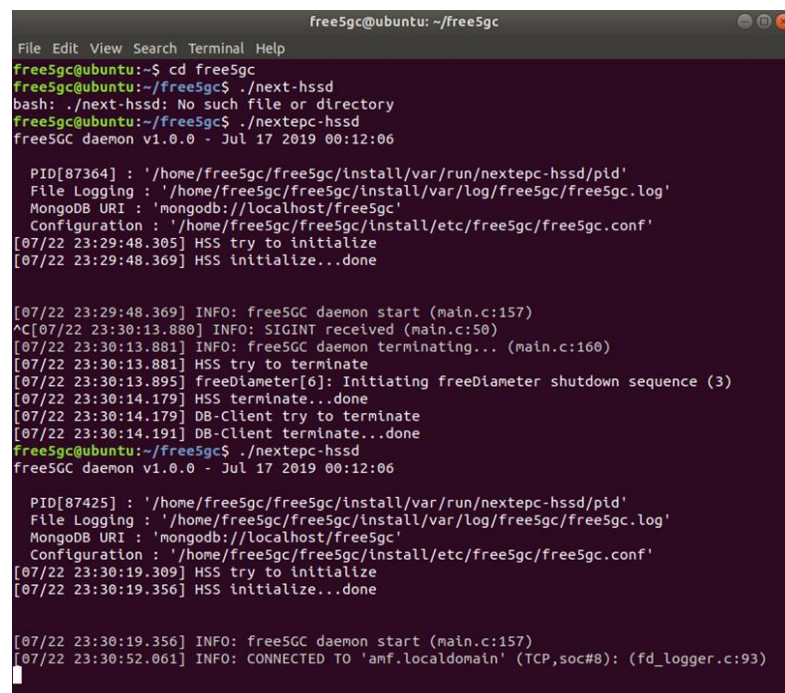
srsLTE 執行順序為 5GC->eNB->UE，USRP-B210 需用 USB 3.0 接口，若是使用 USB 2.0 可能會導致無法讀取。

在本實驗中 5GC 跟 eNB 是使用同一台電腦執行，UE 則是使用手機。

6.1 HSS

開啟終端機(Terminal)輸入以下指令

- `cd free5gc`
- `./nextepc-hssd`



```
free5gc@ubuntu: ~/free5gc
File Edit View Search Terminal Help
free5gc@ubuntu:~$ cd free5gc
free5gc@ubuntu:~/free5gc$ ./next-hssd
bash: ./next-hssd: No such file or directory
free5gc@ubuntu:~/free5gc$ ./nextepc-hssd
free5GC daemon v1.0.0 - Jul 17 2019 00:12:06

PID[87364] : '/home/free5gc/free5gc/install/var/run/nextepc-hssd/pid'
File Logging : '/home/free5gc/free5gc/install/var/log/free5gc/free5gc.log'
MongoDB URI : 'mongodb://localhost/free5gc'
Configuration : '/home/free5gc/free5gc/install/etc/free5gc/free5gc.conf'
[07/22 23:29:48.305] HSS try to initialize
[07/22 23:29:48.369] HSS initialize...done

[07/22 23:29:48.369] INFO: free5GC daemon start (main.c:157)
^C[07/22 23:30:13.880] INFO: SIGINT received (main.c:50)
[07/22 23:30:13.881] INFO: free5GC daemon terminating... (main.c:160)
[07/22 23:30:13.881] HSS try to terminate
[07/22 23:30:13.895] freeDiameter[6]: Initiating freeDiameter shutdown sequence (3)
[07/22 23:30:14.179] HSS terminate...done
[07/22 23:30:14.179] DB-Client try to terminate
[07/22 23:30:14.191] DB-Client terminate...done
free5gc@ubuntu:~/free5gc$ ./nextepc-hssd
free5GC daemon v1.0.0 - Jul 17 2019 00:12:06

PID[87425] : '/home/free5gc/free5gc/install/var/run/nextepc-hssd/pid'
File Logging : '/home/free5gc/free5gc/install/var/log/free5gc/free5gc.log'
MongoDB URI : 'mongodb://localhost/free5gc'
Configuration : '/home/free5gc/free5gc/install/etc/free5gc/free5gc.conf'
[07/22 23:30:19.309] HSS try to initialize
[07/22 23:30:19.356] HSS initialize...done

[07/22 23:30:19.356] INFO: free5GC daemon start (main.c:157)
[07/22 23:30:52.061] INFO: CONNECTED TO 'amf.localdomain' (TCP,soc#8): (fd_logger.c:93)
```

6.2 AMF

開啟終端機(Terminal)輸入以下指令

- `cd free5gc`
- `./free5gc-amfd`

```
free5gc@ubuntu: ~/free5gc
File Edit View Search Terminal Help
free5gc@ubuntu:~$ cd free5gc
free5gc@ubuntu:~/free5gc$ ./free5gc-amfd
free5GC daemon v1.0.0 - Jul 17 2019 00:12:06

PID[87465] : '/home/free5gc/free5gc/install/var/run/free5gc-amfd/pid'
File Logging : '/home/free5gc/free5gc/install/var/log/free5gc/free5gc.log'
MongoDB URI : 'mongodb://localhost/free5gc'
Configuration : '/home/free5gc/free5gc/install/etc/free5gc/free5gc.conf'
[07/22 23:30:50.126] AMF try to initialize
[07/22 23:30:52.002] AMF initialize...done

[07/22 23:30:52.002] INFO: free5GC daemon start (main.c:157)
[07/22 23:30:52.008] sip_server() [192.188.2.2]:36412
[07/22 23:30:52.080] INFO: CONNECTED TO 'hss.localdomain' (TCP,soc#10): (fd_logger.c:93)
[07/23 06:35:56.001] AM4G overload_start (load_avg/n_cores=2.34, threshold=0.80)
[07/23 06:35:44.900] AMF4G overload_stop (load_avg/n_cores=0.76, threshold=0.80)
[07/23 07:02:40.429] AM4G overload_start (load_avg/n_cores=1.12, threshold=0.80)
[07/23 07:05:13.082] AMF4G overload_stop (load_avg/n_cores=0.73, threshold=0.80)
[07/23 18:29:50.165] AM4G overload_start (load_avg/n_cores=1.05, threshold=0.80)
[07/23 18:31:12.941] AMF4G overload_stop (load_avg/n_cores=0.68, threshold=0.80)
[07/24 05:26:14.151] AM4G overload_start (load_avg/n_cores=2.48, threshold=0.80)
[07/24 05:30:33.873] AMF4G overload_stop (load_avg/n_cores=0.80, threshold=0.80)
[07/24 05:57:31.262] AM4G overload_start (load_avg/n_cores=1.45, threshold=0.80)
[07/24 05:58:43.459] AMF4G overload_stop (load_avg/n_cores=0.74, threshold=0.80)
[07/24 06:28:20.411] AM4G overload_start (load_avg/n_cores=1.64, threshold=0.80)
[07/24 06:30:21.532] AMF4G overload_stop (load_avg/n_cores=0.79, threshold=0.80)
[07/24 07:30:37.785] AM4G overload_start (load_avg/n_cores=0.90, threshold=0.80)
[07/24 07:31:27.969] AMF4G overload_stop (load_avg/n_cores=0.77, threshold=0.80)
[07/24 08:01:11.528] AM4G overload_start (load_avg/n_cores=0.99, threshold=0.80)
[07/24 08:01:41.589] AMF4G overload_stop (load_avg/n_cores=0.73, threshold=0.80)
[07/24 08:31:48.005] AM4G overload_start (load_avg/n_cores=0.81, threshold=0.80)
[07/24 08:32:52.316] AMF4G overload_stop (load_avg/n_cores=0.68, threshold=0.80)
[07/24 09:03:00.526] AM4G overload_start (load_avg/n_cores=0.87, threshold=0.80)
[07/24 09:04:14.193] AMF4G overload_stop (load_avg/n_cores=0.76, threshold=0.80)
[07/24 09:34:22.002] AM4G overload_start (load_avg/n_cores=1.14, threshold=0.80)
[07/24 09:34:52.100] AMF4G overload_stop (load_avg/n_cores=0.69, threshold=0.80)
[07/24 10:04:45.318] AM4G overload_start (load_avg/n_cores=1.13, threshold=0.80)
[07/24 10:05:25.824] AMF4G overload_stop (load_avg/n_cores=0.68, threshold=0.80)
```

6.3 SMF

開啟終端機(Terminal)輸入以下指令

- `cd free5gc`
- `./free5gc-smfd`

```
free5gc@ubuntu: ~/free5gc
File Edit View Search Terminal Help
free5gc@ubuntu:~$ cd free5gc
free5gc@ubuntu:~/free5gc$ ./free5gc-smfd
free5GC daemon v1.0.0 - Jul 17 2019 00:12:06

PID[87539] : '/home/free5gc/free5gc/install/var/run/free5gc-smfd/pid'
File Logging : '/home/free5gc/free5gc/install/var/log/free5gc/free5gc.log'
MongoDB URI : 'mongodb://localhost/free5gc'
Configuration : '/home/free5gc/free5gc/install/etc/free5gc/free5gc.conf'
[07/22 23:31:20.703] SMF try to initialize
[07/22 23:31:21.080] pfcf_server() [127.0.0.2]:8805
[07/22 23:31:21.080] pfcf_connect() [192.188.2.2]:8805
[07/22 23:31:21.080] pfcf_xact_local_create 1 not freed in pfcf_xact_pool[64] of PFCF
Transaction
[07/22 23:31:21.080] SMF initialize...done

[07/22 23:31:21.081] INFO: free5GC daemon start (main.c:157)
[07/22 23:31:21.083] ERROR: corek_rcvfrom(len:8192) failed(111:Connection refused) (un
ix/socket.c:635)
[07/22 23:31:21.083] WARN: corek_rcv failed(111:Connection refused) (pfcf_path.c:208)
[07/22 23:31:24.086] ERROR: corek_rcvfrom(len:8192) failed(111:Connection refused) (un
ix/socket.c:635)
[07/22 23:31:24.087] WARN: corek_rcv failed(111:Connection refused) (pfcf_path.c:208)
[07/22 23:31:27.097] ERROR: corek_rcvfrom(len:8192) failed(111:Connection refused) (un
ix/socket.c:635)
[07/22 23:31:27.098] WARN: corek_rcv failed(111:Connection refused) (pfcf_path.c:208)
[07/22 23:31:30.104] WARN: [1] LOCAL No Reponse. Give up! for step 1 type 5 peer [192
.188.2.2]:8805 (pfcf_xact.c:671)
[07/22 23:31:57.911] INFO: CONNECTED TO 'pcrf.localdomain' (TCP,soc#9): (fd_logger.c:9
3)
[07/24 05:27:32.382] ERROR: DROPPED 'Answer received with no corresponding sent request
(54: init request)'
```

6.4 PCRF

開啟終端機(Terminal)輸入以下指令

- `cd free5gc`
- `./nextepc-pcrfd`

```
free5gc@ubuntu: ~/free5gc
File Edit View Search Terminal Help
free5gc@ubuntu:~$ cd free5gc
free5gc@ubuntu:~/free5gc$ ./nextepc-pcrfd
free5GC daemon v1.0.0 - Jul 17 2019 00:12:06

PID[87607] : '/home/free5gc/free5gc/install/var/run/nextepc-pcrfd/pid'
File Logging : '/home/free5gc/free5gc/install/var/log/free5gc/free5gc.log'
MongoDB URI : 'mongodb://localhost/free5gc'
Configuration : '/home/free5gc/free5gc/install/etc/free5gc/free5gc.conf'
[07/22 23:31:57.884] PCRF try to initialize
[07/22 23:31:57.910] PCRF initialize...done

[07/22 23:31:57.910] INFO: free5GC daemon start (main.c:157)
[07/22 23:31:57.912] INFO: CONNECTED TO 'smf.localdomain' (TCP,soc#10): (fd_logger.c:93)
[07/24 05:27:32.451] ERROR: DROPPED 'Answer received with no corresponding sent request.' (fd_
init.c:116)
[07/24 05:27:35.846] ERROR: 'Device-Watchdog-Answer' (fd_init.c:116)
[07/24 05:27:35.846] ERROR: Version: 0x01 (fd_init.c:116)
[07/24 05:27:35.846] ERROR: Length: 88 (fd_init.c:116)
[07/24 05:27:35.846] ERROR: Flags: 0x00 (----) (fd_init.c:116)
[07/24 05:27:35.846] ERROR: Command Code: 280 (fd_init.c:116)
[07/24 05:27:35.846] ERROR: ApplicationId: 0 (fd_init.c:116)
[07/24 05:27:35.846] ERROR: Hop-by-Hop Identifier: 0x1A73F796 (fd_init.c:116)
[07/24 05:27:35.846] ERROR: End-to-End Identifier: 0x90DD28FD (fd_init.c:116)
[07/24 05:27:35.846] ERROR: (internal data): src:smf.localdomain(15) rwb:(nil) rt:0 c
b:(nil),(nil),(nil)) qry:(nil) asso:0 sess:(nil) (fd_init.c:116)
[07/24 05:27:35.846] ERROR: AVP: 'Result-Code'(268) l=12 f=-M val='DIAMETER_SUCCESS'
(2001 (0x7d1)) (fd_init.c:116)
[07/24 05:27:35.846] ERROR: AVP: 'Origin-Host'(264) l=23 f=-M val='smf.localdomain' (
fd_init.c:116)
[07/24 05:27:35.846] ERROR: AVP: 'Origin-Realm'(296) l=19 f=-M val='localdomain' (fd_
init.c:116)
[07/24 05:27:35.846] ERROR: AVP: 'Origin-State-Id'(278) l=12 f=-M val='1563863481 (0x5
d36a9b9)' (fd_init.c:116)
[07/24 05:29:03.004] INFO: CONNECTED TO 'smf.localdomain' (TCP,soc#9): (fd_logger.c:93)
```

6.5 UPF

開啟終端機(Terminal)輸入以下指令

- `cd free5gc`
- `./free5gc-upfd`

```
free5gc@ubuntu: ~/free5gc
File Edit View Search Terminal Help
free5gc@ubuntu:~$ cd free5gc
free5gc@ubuntu:~/free5gc$ ./free5gc-upfd
free5GC daemon v1.0.0 - Jul 17 2019 00:12:06

PID[87676] : '/home/free5gc/free5gc/install/var/run/free5gc-upfd/pid'
File Logging : '/home/free5gc/free5gc/install/var/log/free5gc/free5gc.log'
MongoDB URI : 'mongodb://localhost/free5gc'
Configuration : '/home/free5gc/free5gc/install/etc/free5gc/free5gc.conf'
[07/22 23:32:46.445] UPF try to initialize
[07/22 23:32:47.049] UPF initialize...done

[07/22 23:32:47.050] INFO: free5GC daemon start (main.c:157)
```


7. 啟動 eNB

在另一台電腦的終端機輸入以下其中一個指令，選擇不同的 Band

- `sudo -E ./lte-softmodem -O $OPENAIR_DIR/targets/PROJECTS/GENERIC-LTE-EPC/CONF/enb.band39.tm1.usrpb210.conf -d`

```
enb@D830MT: ~/openairinterfaceSg/cmake_targets/lte_build_oai/build
[LWIP][I] de68 00 12 0 0 0.00 0.00 0.00
Received SIGINT
closing all tasks
^C[UDP][W]Received TERMINATE_MESSAGE
Exiting eNB_single thread
[LWIP][I] de68 00 12 0 0 0.00 0.00 0.00
ready_tasks 0
waiting for XFORMS thread
stopping MODEM threads
Killing eNB 0 processing threads
Exiting eNB thread PRACH
enb@D830MT:~/openairinterfaceSg/cmake_targets/lte_build_oai/build$ sudo -E ./lte-softmodem -O $OPEN
AIR_DIR/targets/PROJECTS/GENERIC-LTE-EPC/CONF/enb.band39.tm1.usrpb210.conf -d
[sudo] password for enb:
# /dev/cpu_dma_latency set to 0us
log init done
Running with XFORMS:
num component carrier 1
WARNING: setting 'gtpu_log_level' not found in configuration file
WARNING: setting 'gtpu_log_verbosity' not found in configuration file
WARNING: setting 'udp_log_level' not found in configuration file
WARNING: setting 'udp_log_verbosity' not found in configuration file
WARNING: setting 'osa_log_level' not found in configuration file
WARNING: setting 'osa_log_verbosity' not found in configuration file

-----
ENB CONFIG FILE CONTENT LOADED (TBC):
-----
ENB CONFIG for instance 0:

eNB name:          eNB_Eurecom_LTEBox:
eNB ID:            3584:
Cell type:         CELL_MACRO_ENB:
TAC:               1:
MCC:               208:
MNC:               93:

node_function for CC 0:  eNodeB_3GPP:
node_timing for CC 0:    synch_to_ext_device:
node_synch_ref for CC 0: 0:
eutra band for CC 0:     39:
downlink freq for CC 0:  1910000000:
uplink freq offset for CC 0: 0:

Cell ID for CC 0:        0:
N_RB_DL for CC 0:        25:
nb_antennas_tx for CC 0: 1:
nb_antennas_rx for CC 0: 1:
rach_numberOFRA_Preambles for CC 0: 15:
rach_preamblesGroupAConfig for CC 0: 0:
rach_powerRampingStep for CC 0: 2:
```


8. 啟動 UE 端

此例的 SIM Card 資料是使用 Free5gc 官方所提供的 SIM Card 資料範例，可跟據自己的情況來燒錄 SIM Card 的資料

- IMSI : 208930000000003
- K : 8baf473f2f8fd09487cccbd7097c6862
- OPc : 8e27b6af0e692e750f32667a3b14605d
- MCC : 208 (FR)
- MNC : 93 (new MNO MNC)

設定 APN

- 名稱設為 eur
- APN 設為 oai.ipv4
- 承載系統為 LTE

編輯存取點	
名稱 eur	未設定
APN oai.ipv4	APN 類型 未設定
Proxy 未設定	APN 通訊協定 IPv4
連接埠 未設定	APN 漫遊通訊協定 IPv4
使用者名稱 未設定	APN 啟用/停用 APN 已啟用
密碼 未設定	承載系統 LTE
伺服器 未設定	MVNO 類型 無
MMSC 未設定	MVNO 值 未設定

注意

- 某些手機可能要關掉 VoLTE 通話
- 某些手機要設定只能使用 LTE
- 以上設置根據不同手機有不同的設置方法



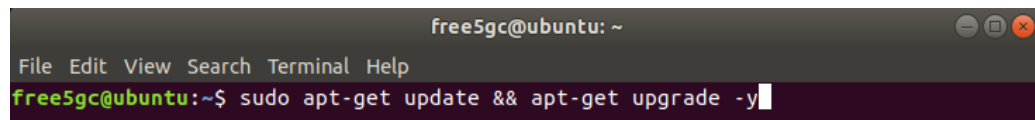
手機主動搜尋基地台



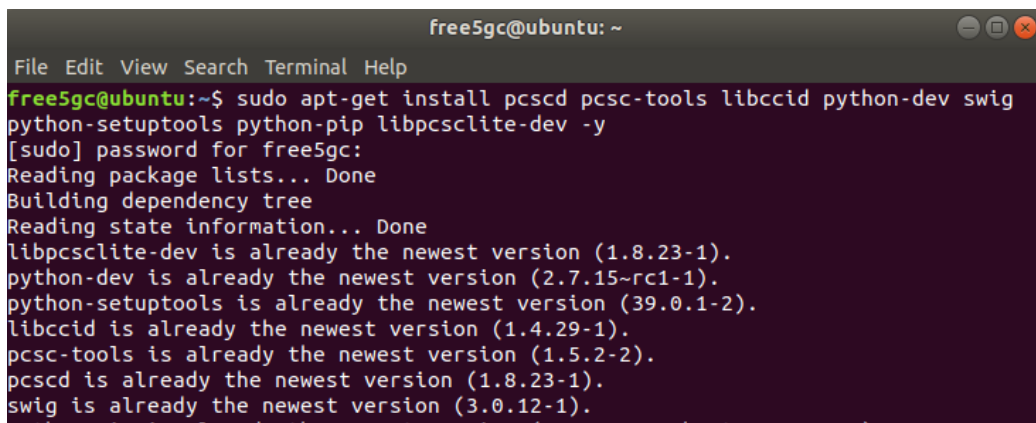
Annex A : P 編程 SIM 卡

開啟終端機(Terminal)輸入以下指令

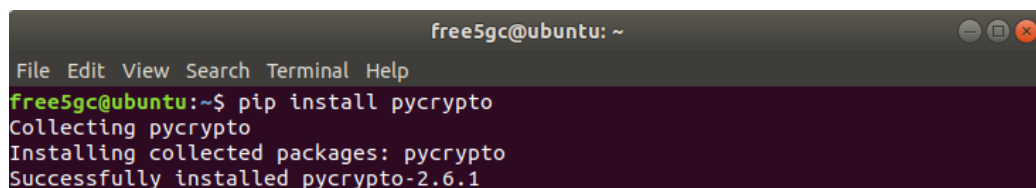
- `sudo apt-get update && sudo apt-get upgrade -y`
- `sudo apt-get install pcscd pcsc-tools libccid python-dev swig python-setuptools python-pip libpcsclite-dev -y`
- `pip install pycrypto`



```
free5gc@ubuntu: ~  
File Edit View Search Terminal Help  
free5gc@ubuntu:~$ sudo apt-get update && apt-get upgrade -y
```



```
free5gc@ubuntu: ~  
File Edit View Search Terminal Help  
free5gc@ubuntu:~$ sudo apt-get install pcscd pcsc-tools libccid python-dev swig  
python-setuptools python-pip libpcsclite-dev -y  
[sudo] password for free5gc:  
Reading package lists... Done  
Building dependency tree  
Reading state information... Done  
libpcsclite-dev is already the newest version (1.8.23-1).  
python-dev is already the newest version (2.7.15-rc1-1).  
python-setuptools is already the newest version (39.0.1-2).  
libccid is already the newest version (1.4.29-1).  
pcsc-tools is already the newest version (1.5.2-2).  
pcscd is already the newest version (1.8.23-1).  
swig is already the newest version (3.0.12-1).
```



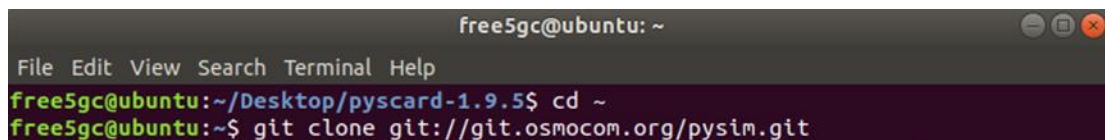
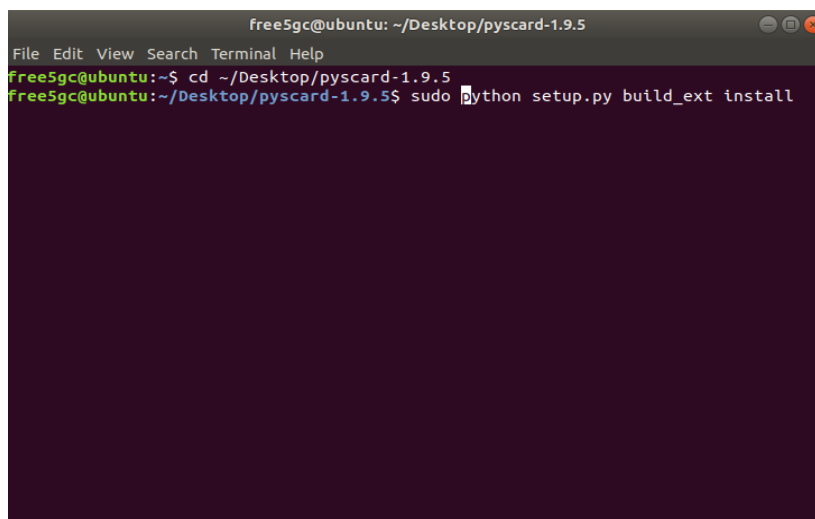
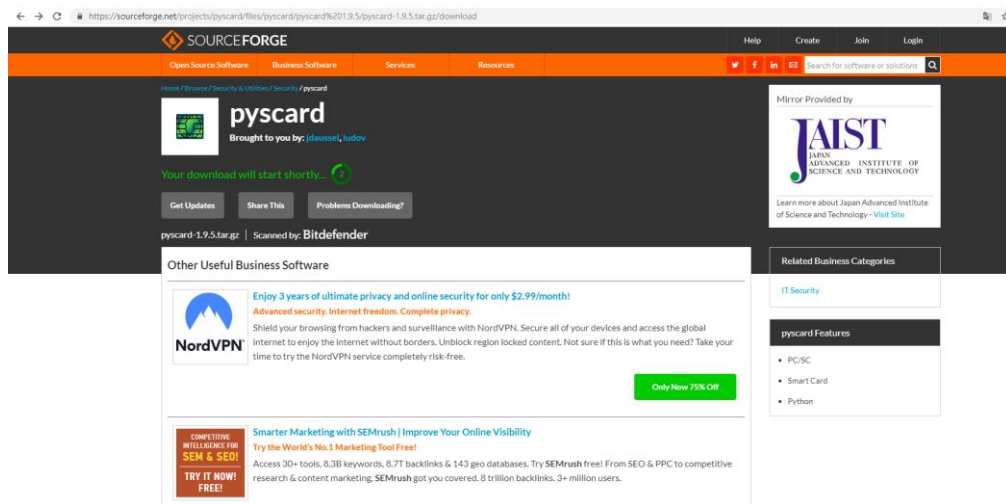
```
free5gc@ubuntu: ~  
File Edit View Search Terminal Help  
free5gc@ubuntu:~$ pip install pycrypto  
Collecting pycrypto  
Installing collected packages: pycrypto  
Successfully installed pycrypto-2.6.1
```

安裝 Pyscard

- 前往下方網址
- <https://sourceforge.net/projects/pyscard/files/pyscard/pyscard%201.9.5/pyscard-1.9.5.tar.gz/download>
- 解壓縮檔案在桌面

開啟終端機(Terminal)輸入以下指令

- `cd ~/Desktop/pyscard-1.9.5`
- `sudo python setup.py build_ext install`
- `cd ~`
- `git clone git://git.osmocom.org/pysim.git`



執行 Pysim 及 連接 SIM Card Reader

- cd pysim/
 - sudo pcsc_scan
- ctrl + C to exit the program
- ./pySim-read.py -p 0
 - ./pySim-prog.py -p 0 -x 208 -y 93 -t sysmoUSIM-SJS1 -i 208930000000003 -- op=8e27b6af0e692e750f32667a3b14605d -k 8baf473f2f8fd09487cccbd7097c6862 -s 8988211000000088313 -a 23605945

```
free5gc@ubuntu: ~/pysim
File Edit View Search Terminal Help
free5gc@ubuntu:~$ cd pysim
free5gc@ubuntu:~/pysim$ sudo pcsc_scan
[sudo] password for free5gc:
PC/SC device scanner
V 1.5.2 (c) 2001-2017, Ludovic Rousseau <ludovic.rousseau@free.fr>
Using reader plug'n play mechanism
Scanning present readers...
Waiting for the first reader... -
```

- 指令解釋：
 - -x = MCC
 - -y = MNC
 - -t = tag
 - -i = IMSI
 - --op = OP
 - -k = KI
 - -s = ICCID
 - -a = ADM1

```

free5gc@ubuntu: ~/pysim
File Edit View Search Terminal Help
free5gc@ubuntu:~/pysim$ sudo pcsc_scan
[sudo] password for free5gc:
PC/SC device scanner
V 1.5.2 (c) 2001-2017, Ludovic Rousseau <ludovic.rousseau@free.fr>
Using reader plug'n play mechanism
Scanning present readers...
Waiting for the first reader...found one
Scanning present readers...
0: VMware Virtual USB CCID 00 00

Thu Jul 25 04:42:45 2019
Reader 0: VMware Virtual USB CCID 00 00
Card state: Card inserted,
ATR: 3B 9F 95 80 1F C3 80 31 E0 73 FE 21 13 57 86 81 02 86 98 44 18 A8

ATR: 3B 9F 95 80 1F C3 80 31 E0 73 FE 21 13 57 86 81 02 86 98 44 18 A8
+ TS = 3B --> Direct Convention
+ T0 = 9F, Y(1): 1001, K: 15 (historical bytes)
TA(1) = 95 --> Fi=512, Di=16, 32 cycles/ETU
125000 bits/s at 4 MHz, fMax for Fi = 5 MHz => 156250 bits/s
TD(1) = 80 --> Y(i+1) = 1000, Protocol T = 0
-----
TD(2) = 1F --> Y(i+1) = 0001, Protocol T = 15 - Global interface bytes followi
ng
-----
TA(3) = C3 --> Clock stop: no preference - Class accepted by the card: (3G) A
5V B 3V
+ Historical bytes: 80 31 E0 73 FE 21 13 57 86 81 02 86 98 44 18
Category indicator byte: 80 (compact TLV data object)
Tag: 3, len: 1 (card service data byte)
Card service data byte: E0
- Application selection: by full DF name
- Application selection: by partial DF name
- BER-TLV data objects available in EF.DIR
- EF.DIR and EF.ATR access services: by GET RECORD(s) command
- Card with MF
Tag: 7, len: 3 (card capabilities)
Selection methods: FE
- DF selection by full DF name
- DF selection by partial DF name
- DF selection by path
- DF selection by file identifier
- Implicit DF selection
- Short EF identifier supported

```

```

free5gc@ubuntu: ~/pysim
File Edit View Search Terminal Help
- DF selection by path
- DF selection by file identifier
- Implicit DF selection
- Short EF identifier supported
- Record number supported
Data coding byte: 21
- Behaviour of write functions: proprietary
- Value 'FF' for the first byte of BER-TLV tag fields: invalid
- Data unit in quartets: 2
Command chaining, length fields and logical channels: 13
- Logical channel number assignment: by the card
- Maximum number of logical channels: 4
Tag: 5, len: 7 (card issuer's data)
Card issuer data: 86 81 02 86 98 44 18
+ TCK = A8 (correct checksum)

Possibly identified card (using /usr/share/pcsc/smartcard_list.txt):
3B 9F 95 80 1F C3 80 31 E0 73 FE 21 13 57 86 81 02 86 98 44 18 A8
GREEN CARD, Grcard (Hong Kong ) Co.,Limited, LTE Usim Card (Telecommunica
tion)
Celcom Postpaid 3G (Telecommunication)
/

```