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

「5G行動寬頻協同網路」課程模組

實驗二
DC效能量測與分析

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國立高雄大學 資訊工程學系

Outline

- 實驗目的及實驗內容
- srsLTE-nukxDC實驗環境
  - 軟硬體環境
  - srsLTE 架構
- srsLTE 網路實驗平台建置
  - 一. 環境設定及安裝必要軟體
  - 二. 編譯及安裝srsLTE
  - 三. 設定srsLTE設定檔
  - 四. srsLTE測試
- nukxDC(LWA)網路實驗平台建置
  - 一. nukxDC設定及流量測試-傳輸比例
  - 二. nukxDC設定及流量測試-封包排序
  - 三. nukxDC設定及流量測試-自動調整傳輸比例
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實驗目的

- 了解如何修改srsLTE平台以支援DC，讓學生熟悉srsLTE軟體結構及3GPP網路架構。
- 調整srsLTE的設定及控制DC的傳輸比例，讓學生深入了解DC的運作原理及效能議題。
- 讓學生嘗試調試nukxDC(LWA)的傳輸比例、封包重組等機制，來量測及分析其對DC效能的影響。

實驗內容

- 在兩台主機上測試srsLTE EPC、eNB和UE
  - 初步認識srsLTE的架構
  - 設置srsLTE的環境
  - 設置srsLTE EPC、eNB和UE
  - 執行srsLTE EPC、eNB和UE
  - 觀察 eNB和UE在傳送資料時，底層對信道的測量值
  - 調試訊號強度來觀察吞吐量的變化
  - 測試nukxDC(LWA)對傳送資料時的流量影響和變化

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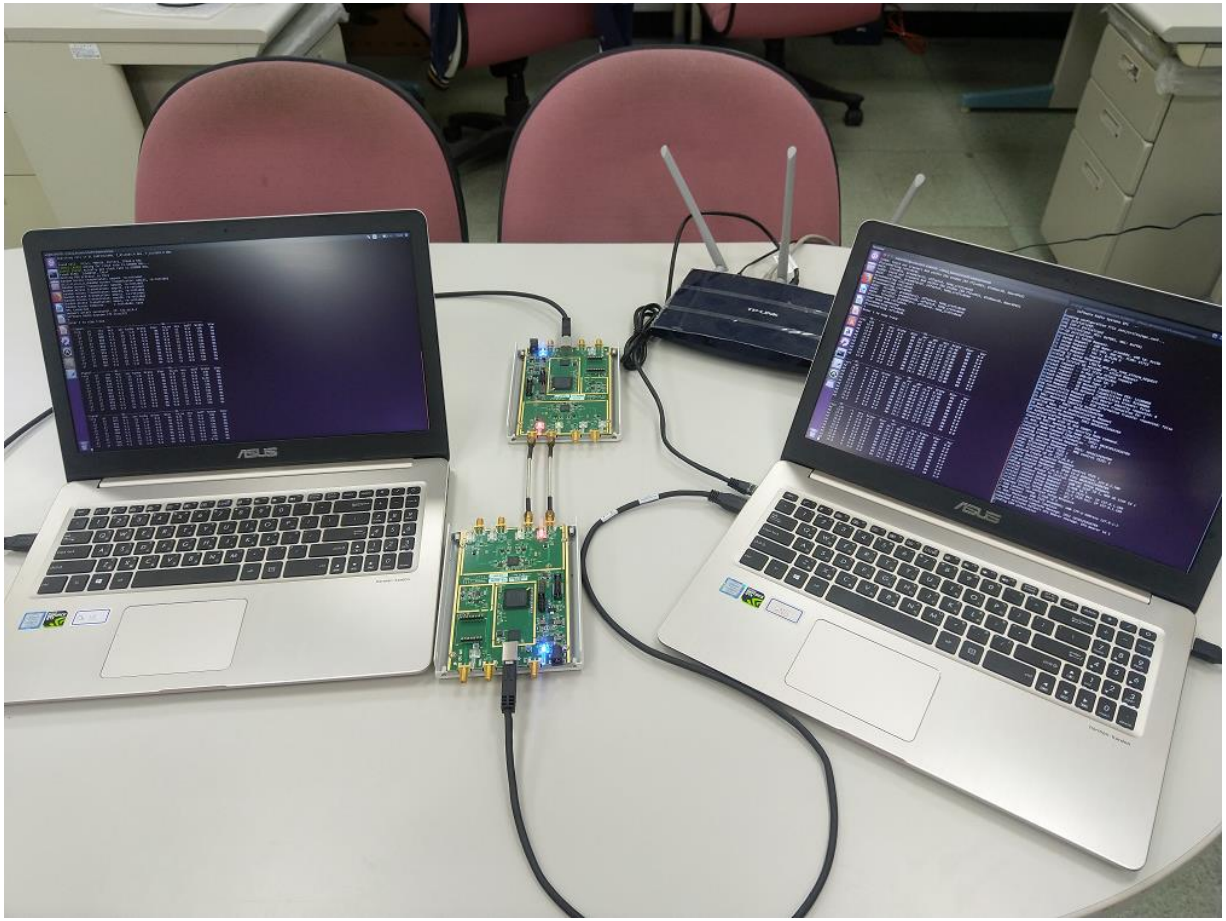
實驗環境



軟硬體環境 - 軟體

名稱	軟體	版本	目的
EPC	OS： Ubuntu	Ubuntu 16.04 linux-image-4.13.16-041316-lowlatency	啟動EPC功能
	srsLTE的EPC軟體 srsLTE	採用18.6.1版本 470953bf9c5875646e4d5049c8f213d202fa84fd https://github.com/srsLTE/srsLTE	
	第三方擴充套件 PolarSSL/mbedTLS	採用2.6.0版本 https://tls.mbed.org/	
eNB	OS： Ubuntu	Ubuntu 16.04 Kernel linux-image-4.13.16-041316-lowlatency	啟動eNB功能
	srsLTE的eNB軟體 srsLTE	採用18.6.1版本 470953bf9c5875646e4d5049c8f213d202fa84fd https://github.com/srsLTE/srsLTE	
	第三方驅動程式 USRP Hardware Driver	採用3.13.1.0版本 http://files.ettus.com/binaries/uhd_stable/	

軟硬體環境 - 軟體

名稱	軟體	版本	目的
UE	OS： Ubuntu	Ubuntu 16.04 linux-image-4.13.16-041316-lowlatency	啟動UE功能
	srsLTE的UE軟體 srsLTE	採用18.6.1版本 470953bf9c5875646e4d5049c8f213d202fa84fd https://github.com/srsLTE/srsLTE	
	第三方擴充套件 PolarSSL/mbedTLS	採用2.6.0版本 https://tls.mbed.org/	
	第三方驅動程式 USRP Hardware Driver	採用3.13.1.0版本 http://files.ettus.com/binaries/uhd_stable/	

軟硬體環境 - 硬體

名稱	規格	數量	目的
EPC eNB	電腦型號：ASUS M580V	1	啟動srsLTE EPC、srsLTE eNB功能
	USRP B210	1	對UE接收及發送訊號
	Ethernet Network Cards	1	連接無線分享器
	無線分享器型號：TP-LINK TL-WR1043ND	1	連接外部網路及實現無線分享器功能
UE	電腦型號：ASUS M580V	1	啟動srsLTE UE功能
	USRP B210	1	對eNB接收及發送訊號
	Wireless Network Card	1	UE用來連接eNB WLAN

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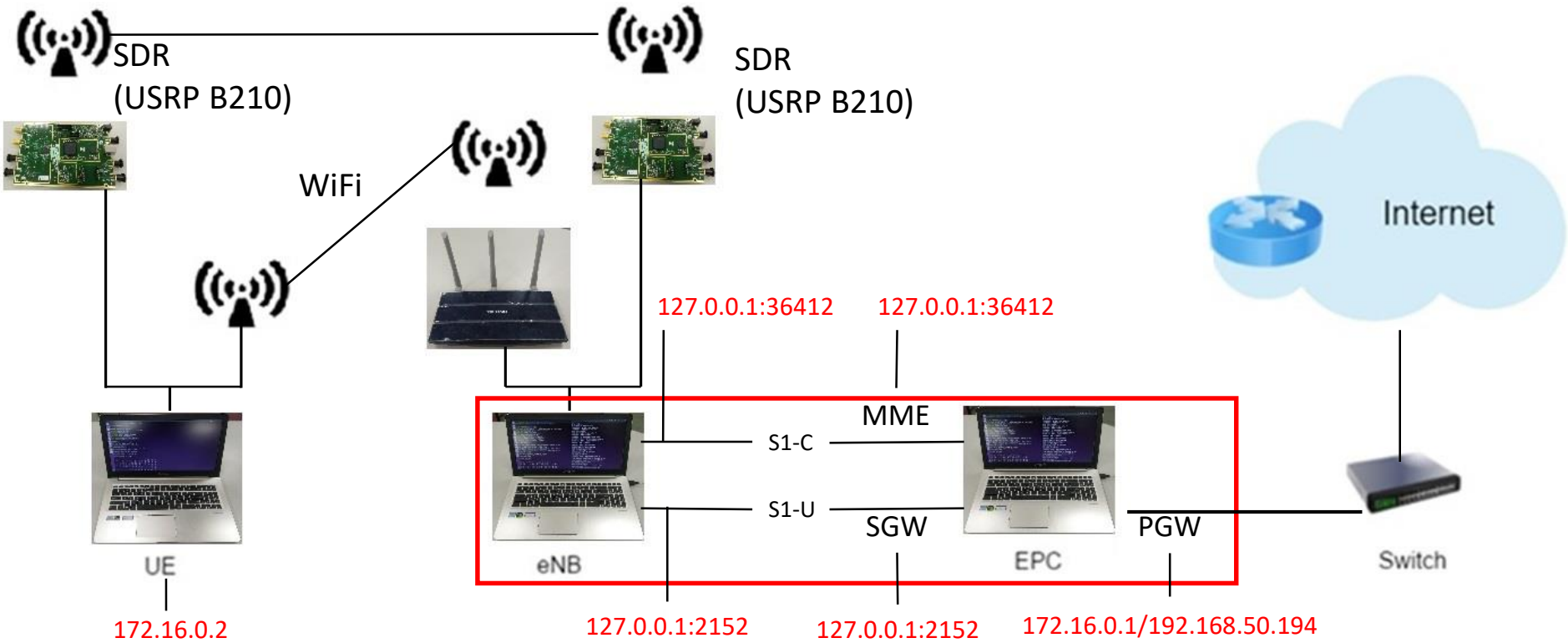
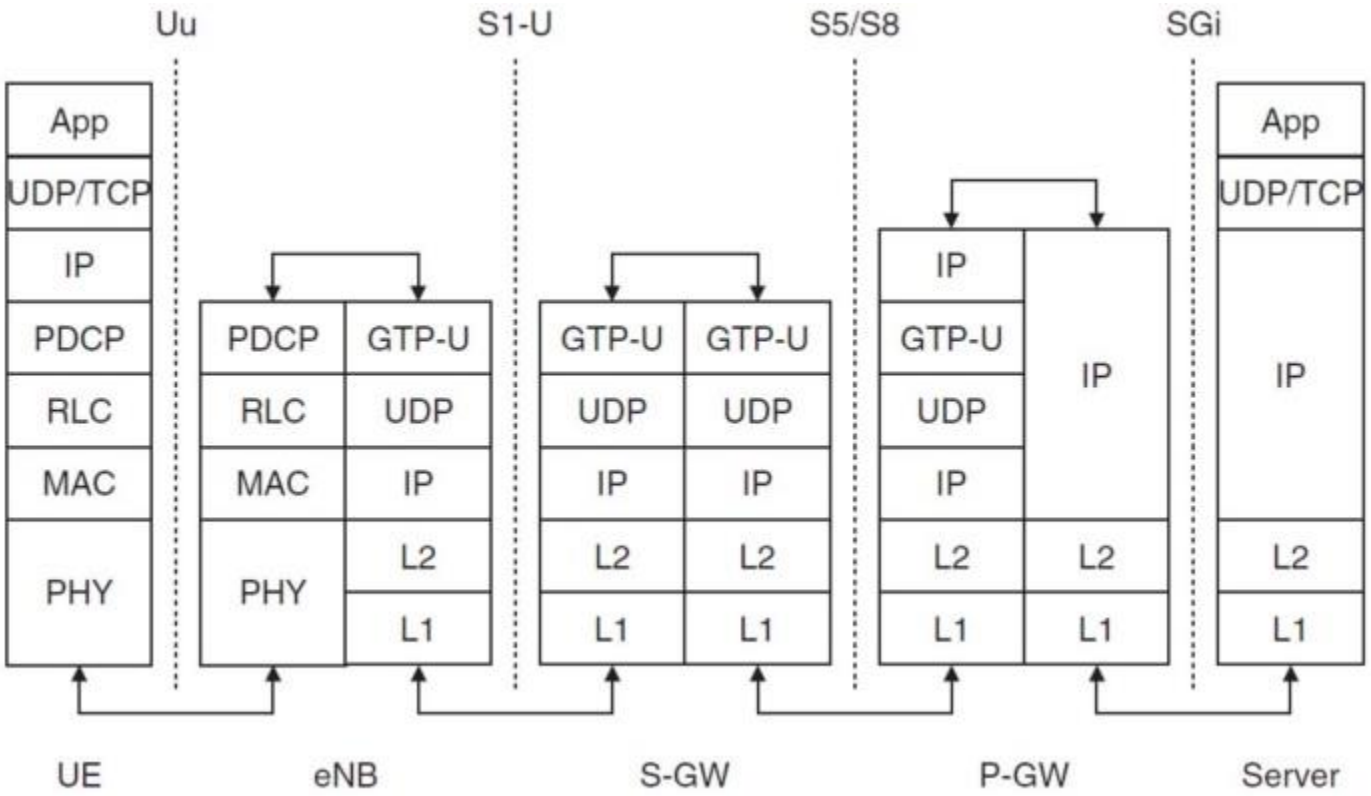
srsLTE 實驗架構


SDR
(USRP B210)
SDR
(USRP B210)
WiFi
Internet
127.0.0.1:36412
127.0.0.1:36412
MME
S1-C
S1-U
SGW
PGW
UE
eNB
EPC
Switch
172.16.0.2
127.0.0.1:2152
127.0.0.1:2152
172.16.0.1/192.168.50.194

LTE Data Flow



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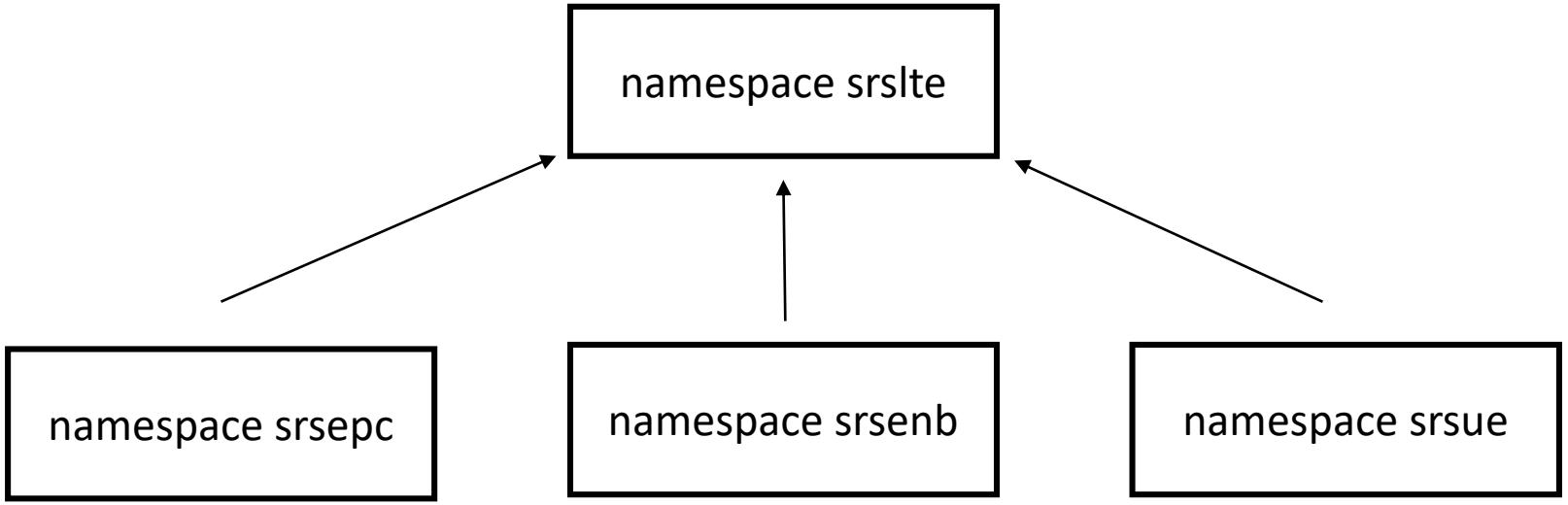
srsLTE 結構



srsepc、srsenb、srsue有一些程式碼是共用的，共用的程式碼會寫在namespace srslte，當有需要使用的時候會呼叫srslte裏面的程式碼

namespace srslte

namespace srslte

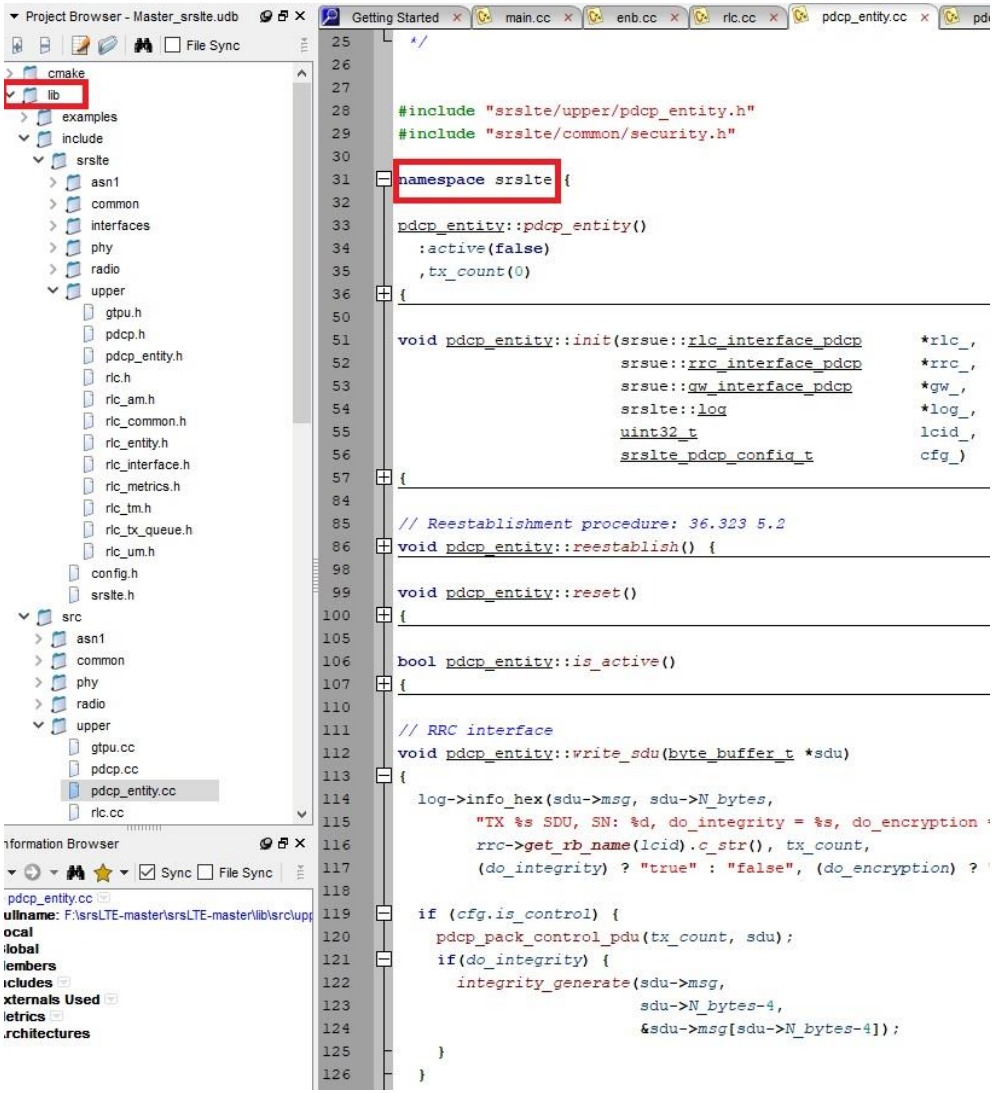
{

// pdcp all function

class pdcp{…};

}

//eNB及UE共用pdcp的功能，因此寫在srslte



eNB_interface.h

namespace srsenb

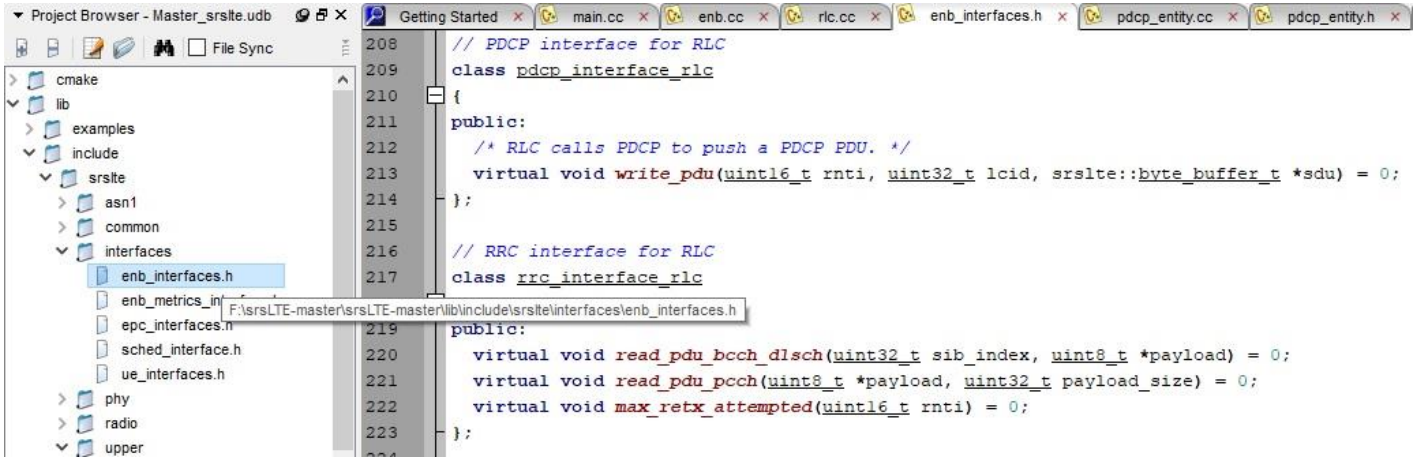
{

class pdcp_interface_rlc{…}; // pdcp function for rlc

class rlc_interface_pdcp{…}; // rlc function for pdcp

}

//eNB所有界面會寫在enb_interfaces.h



pdcp init

srsenb\src\upper\pdcp.cc

```
void pdcp::init(rlc_interface_pdcp* rlc_, …, srslte::log* pdcp_log_)
{
        rlc   = rlc_;
        rrc   = rrc_;
        gtpu  = gtpu_;
        log_h = pdcp_log_;
        pool = srslte::byte_buffer_pool::get_instance();
        pthread_rwlock_init(&rwlock, NULL);
}
```

//srsenb界面的運作部份會寫在srsenb\src\，同時如果srsenb的界面有需要使用其他層的function，它在初始化的時候會取得其他層的界面，有需要時再呼叫其他層的界面來使用其他層的function。

srsenb\src\enb.cc

```
namespace srsenb
{
        bool enb::init(all_args_t *args_)
        {
                pdcp_log.init("PDCP ", logger);
                pdcp_log.set_level(level(args->log.pdcp_level));
                pdcp_log.set_hex_limit(args->log.pdcp_hex_limit);
                pdcp.init(&rlc, &rrc, &gtpu, &pdcp_log);
        }
}
```

//srsenb所有程式的界面初始化會在srsenb\src\enb.cc開始

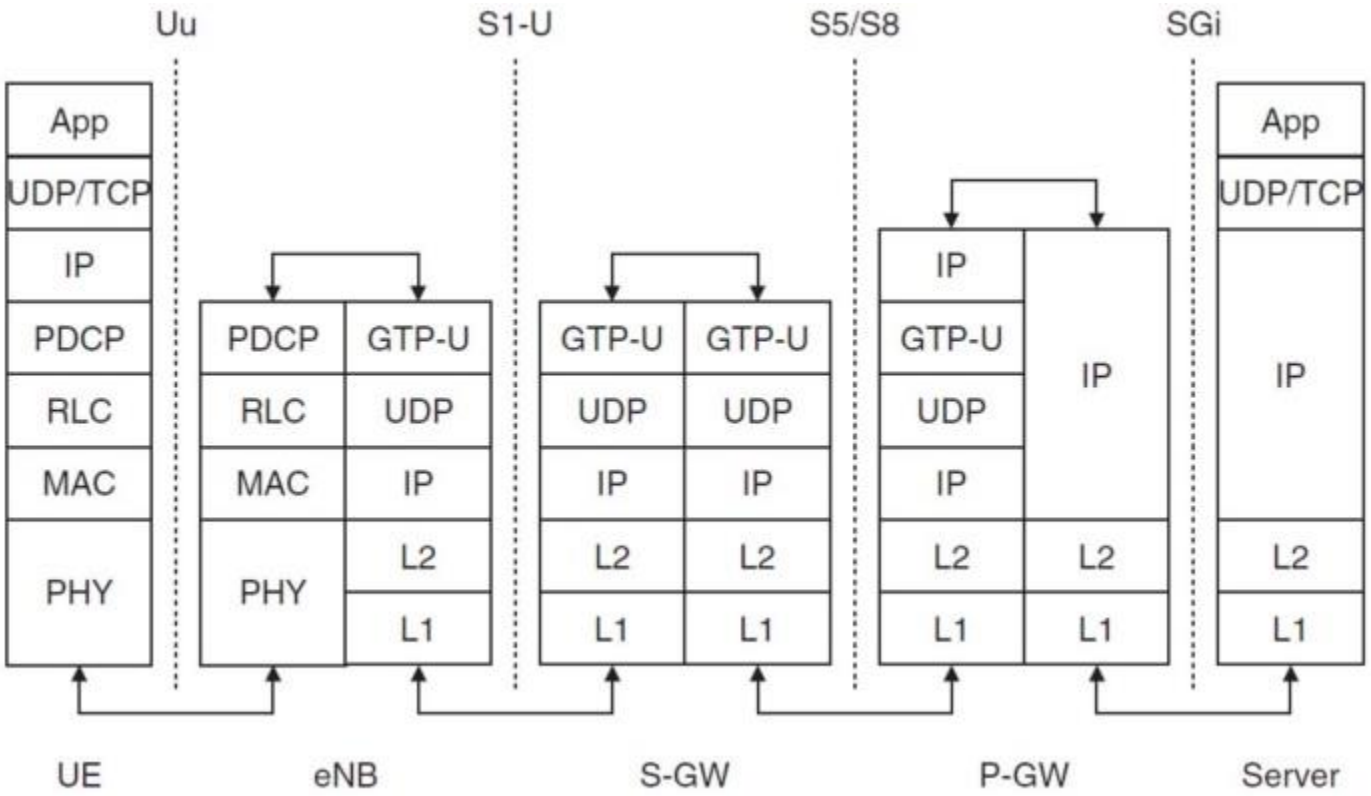
pdcp init

srsenb\src\upper\pdcp.cc

```
void pdcp::init(rlc_interface_pdcp* rlc_, …, srslte::log* pdcp_log_)
{
        rlc   = rlc_;
        rrc   = rrc_;
        gtpu  = gtpu_;
        log_h = pdcp_log_;
        pool = srslte::byte_buffer_pool::get_instance();
        pthread_rwlock_init(&rwlock, NULL);
}
```

//上一頁的pdcp.init會呼叫srsenb\src\upper\pdcp.cc裏面的init()

LTE Data Flow



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eNB封包流程

```
UE -> eNB -> EPC                          //eNB收到從UE收到封包，rlc層收到封包
srsenb::pdcp::write_pdu()                 //rlc呼叫pdcp的界面把封包送到pdcp層
|-> srslte::pdcp::write_pdu()             //enb的pdcp界面呼叫srslte的pdcp界面
    |-> srslte::pdcp_entity::write_pdu()      // srslte的pdcp界面再呼叫運作程式
        |-> srsenb::gtpu::write_pdu()         //pdcp再呼叫gtpu界面

UE <- eNB <- EPC                          //eNB收到從EPC收到封包，gtpu層收到封包
srsenb::gtpu::run_thread(){  recv();  }   //gtpu層收到EPC送來的封包
|-> srsenb::pdcp::write_sdu()             //gtpu層呼叫pdcp的界面把封包送到pdcp層
    |-> srslte::pdcp::write_sdu()         //enb的pdcp界面呼叫srslte的pdcp界面
        |-> srslte::pdcp_entity::write_sdu()    //srslte的pdcp界面再呼叫運作程式
            |-> srsenb::rlc::write_sdu()       //pdcp再呼叫rlc界面
                |->…
```

ue_interface.h

namespace srsue

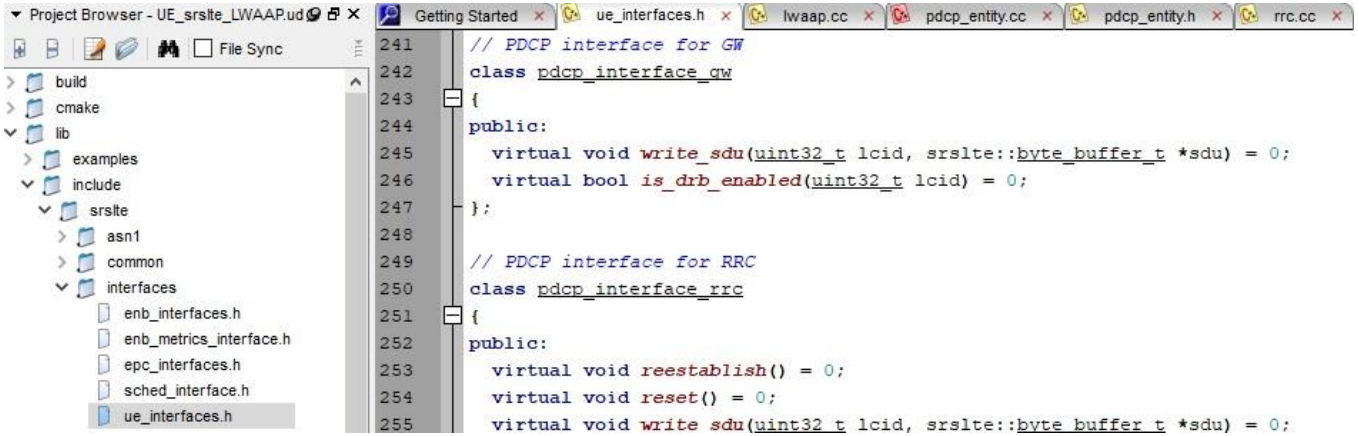
{

class pdcp_interface_rrc{…}; // pdcp function for rrc

class rlc_interface_pdcp{…}; // rlc function for pdcp

}

//UE所有的界面會寫在ue_interfaces.h

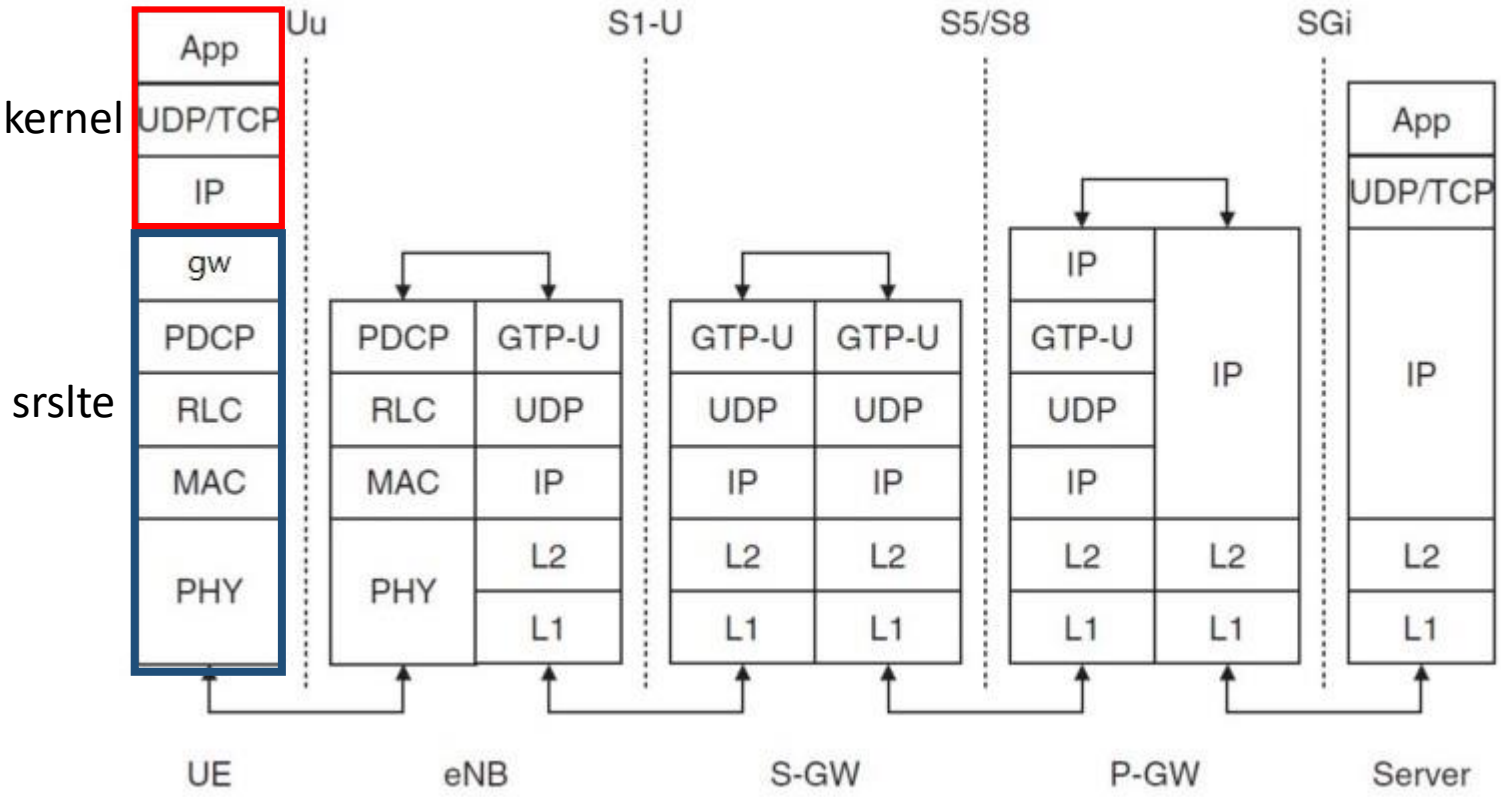


srsue\src\ue.cc

```
namespace srsue
{
        bool ue::init(all_args_t *args_)
        {
                pdcp_log.init("PDCP ", logger);
                pdcp_log.set_level(level(args->log.pdcp_level));
                pdcp_log.set_hex_limit(args->log.pdcp_hex_limit);
                pdcp.init(&rlc, &rrc, &gw, &pdcp_log, …);
        }
}
```

//srsue所有程式的界面初始化會在srsue\src\ue.cc開始

srsLTE UE Data flow



TS 23.401

UE封包流程

UE -> eNB //UE把封包送到eNB

srsue::gw::run_thread() //UE取得封包

|-> srslte::pdcp::write_sdu() //gw層呼叫pdcp界面並把封包送到pdcp層

|-> srslte::pdcp_entity::write_sdu()

|->…

UE <- eNB //UE底層收到eNB的封包

|->...

|-> srslte::pdcp::write_pdu() //底層呼叫pdcp界面並把封包送到pdcp層

|-> srslte::pdcp_entity::write_pdu()//pdcp界面呼叫pdcp運作程式

|-> srsue::gw::write_pdu() { write(); }//pdcp呼叫gw層的界面

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下載及安裝Kernel

在EPC上開啟一個新的終端機，並且輸入

- wget -P ~/Downloads/kernel http://kernel.ubuntu.com/~kernel-ppa/mainline/v4.13.16/linux-headers-4.13.16-041316_4.13.16-041316.201711240901_all.deb
- wget -P ~/Downloads/kernel http://kernel.ubuntu.com/~kernel-ppa/mainline/v4.13.16/linux-headers-4.13.16-041316-lowlatency_4.13.16-041316.201711240901_amd64.deb
- wget -P ~/Downloads/kernel http://kernel.ubuntu.com/~kernel-ppa/mainline/v4.13.16/linux-image-4.13.16-041316-lowlatency_4.13.16-041316.201711240901_amd64.deb
- sudo dpkg -i ~/Downloads/kernel/*.deb

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=0"

更新剛才的設定

在終端機輸入以下指令

- sudo update-grub2

然後終端機輸入以下指令，重啟電腦

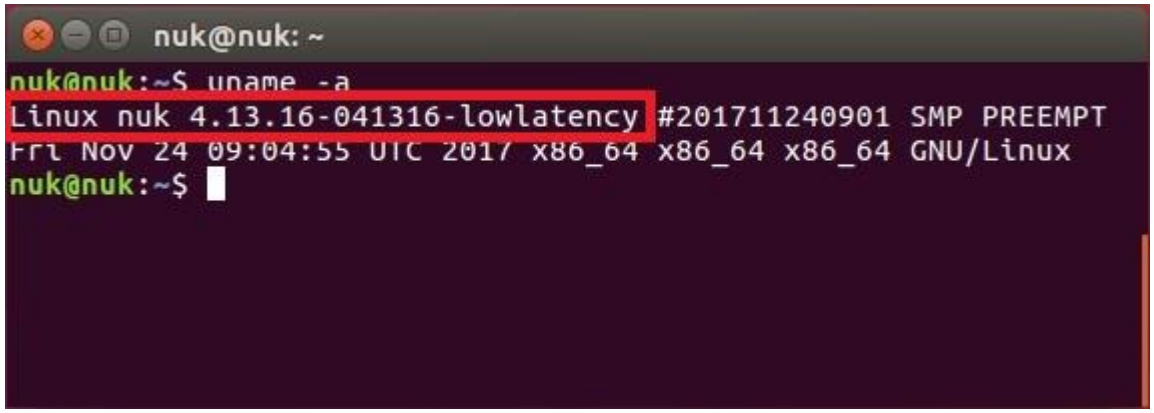
- sudo reboot

然後在開機選單選剛才安裝的lowlatency kernel

檢查CPU的效能設定

重新開機後在終端機輸入，確認Kernel版本

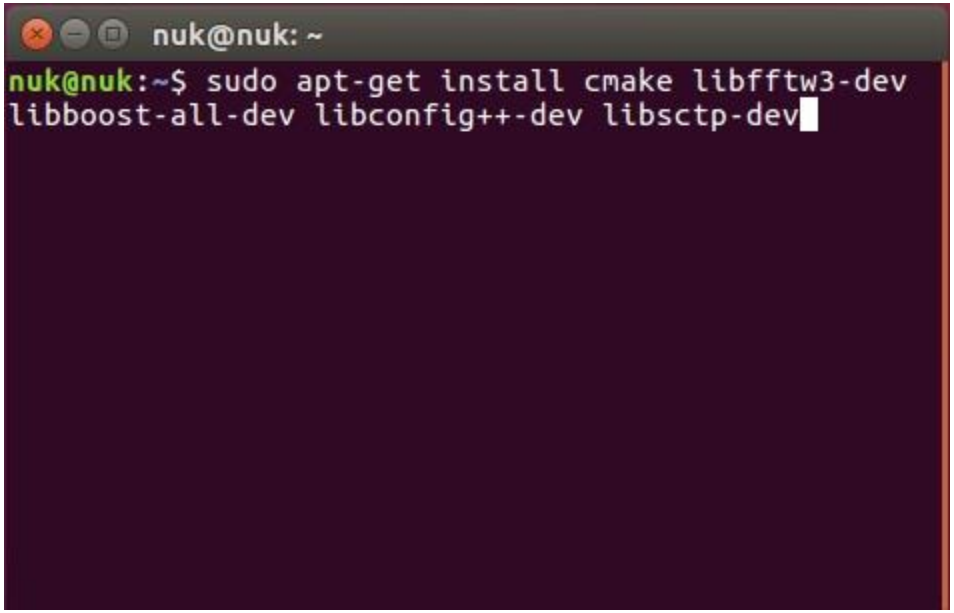
- uname -a



安裝必要套件

在EPC、eNB及UE上開啟一個新的終端機，並且輸入

- sudo apt-get install cmake libfftw3-dev libboost-all-dev libconfig++-dev libsctp-dev



下載mbedTLS

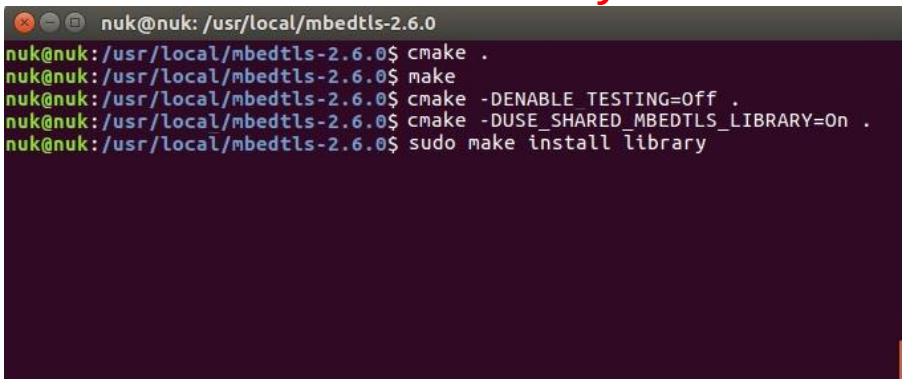
在EPC、eNB及UE的終端機輸入以下指令

- wget -P ~/Downloads https://tls.mbed.org/download/mbedtls-2.6.0-apache.tgz
- tar zxvf ~/Downloads/mbedtls-2.6.0-apache.tgz
- sudo mv ~/mbedtls-2.6.0 /usr/local
- cd /usr/local/mbedtls-2.6.0

安裝mbedTLS

然後在EPC、eNB及UE的終端機輸入以下指令安裝驅動程式

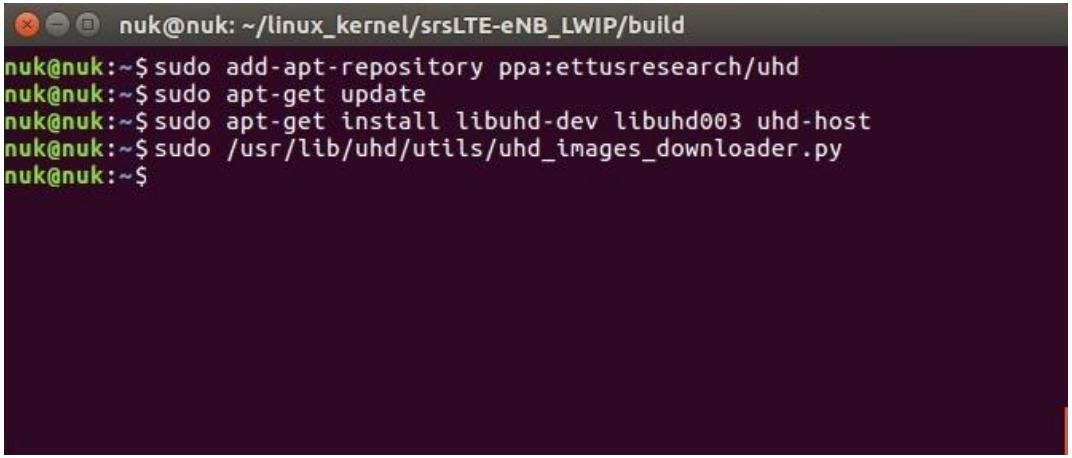
- cmake .
- make
- cmake -DENABLE_TESTING=Off .
- cmake -DUSE_SHARED_MBEDTLS_LIBRARY=On .
- sudo make install library



安裝驅動程式

然後在EPC、eNB及UE的終端機輸入以下指令

- sudo add-apt-repository ppa:ettusresearch/uhd
- sudo apt-get update
- sudo apt-get install libuhd-dev libuhd003 uhd-host
- sudo /usr/lib/uhd/utils/uhd_images_downloader.py



Download and Build srsLTE

- git clone https://github.com/nukcsie2066/nukxDC.git
- cd srsLTE
- mkdir build
- cd build
- cmake ../
- make
- make test
- sudo make install

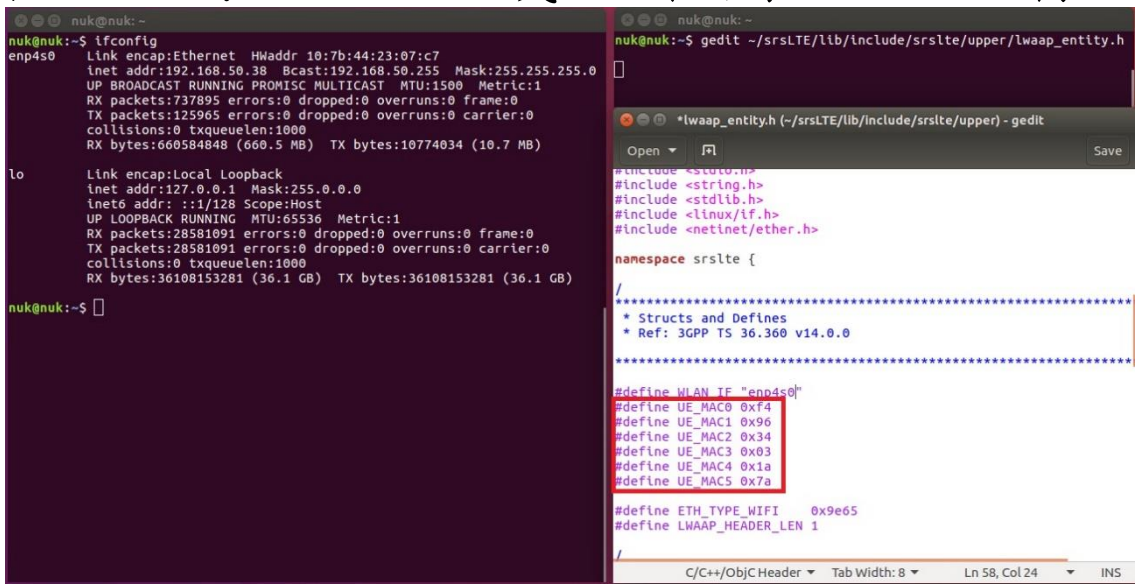
設定UE MAC

在eNB的終端機輸入以下指令

- gedit /path/to/srsLTE/lib/include/srslte/upper/lwaap_entity.h

如下圖，在eNB主機上設定LWA的DST MAC

把UE的MAC設成如下圖header樣式



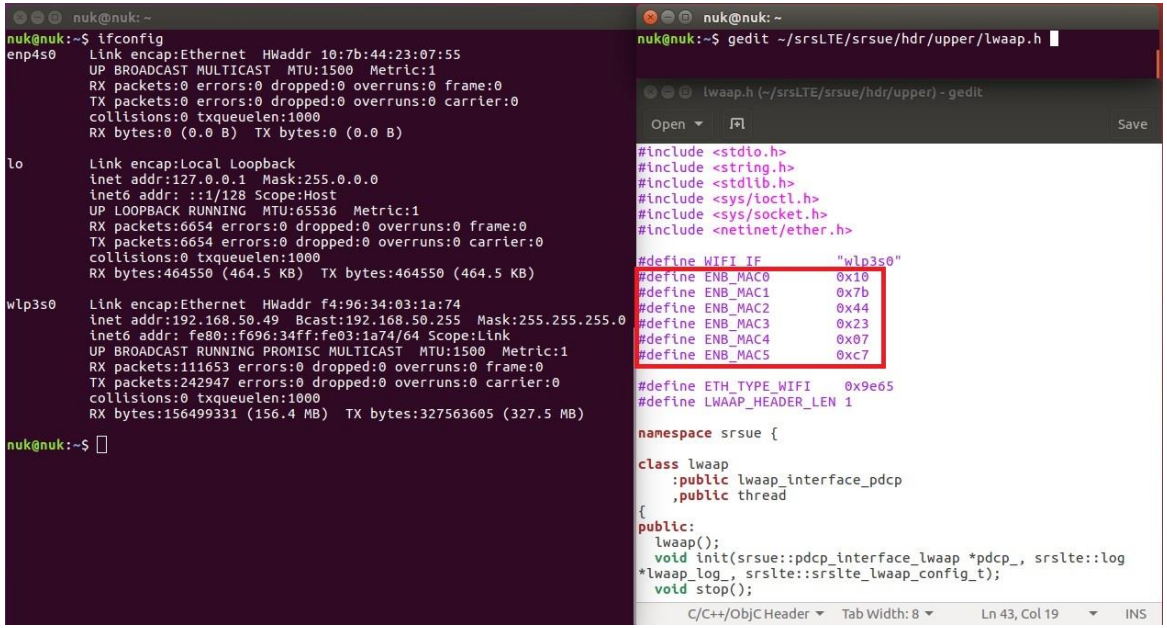
設定eNB MAC

在UE的終端機輸入以下指令

- gedit /path/to/srsLTE/srsue/hdr/upper/lwaap.h

如下圖，在UE主機上設定LWA的DST MAC

把eNB的MAC設成如下圖header樣式

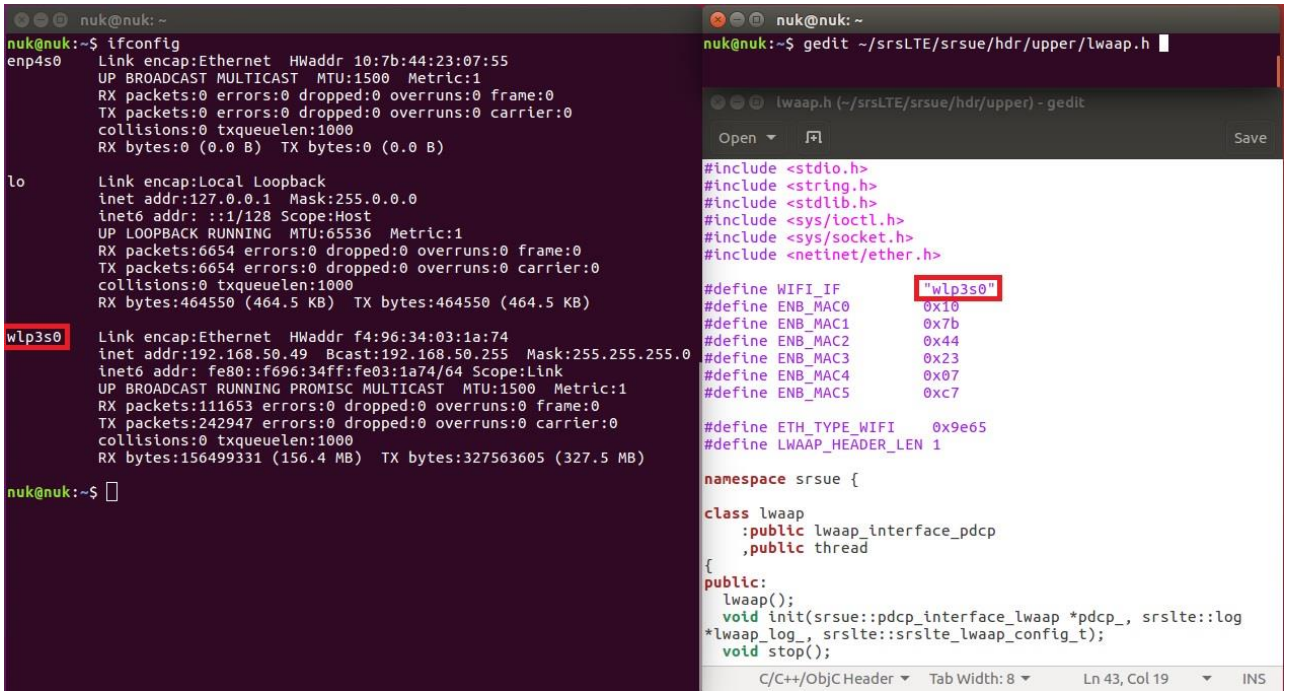


設定UE NIC Name

在UE的終端機輸入以下指令

- gedit /path/to/srsLTE/srsue/hdr/upper/lwaap.h

如下圖，在UE設定LWA的網卡名稱

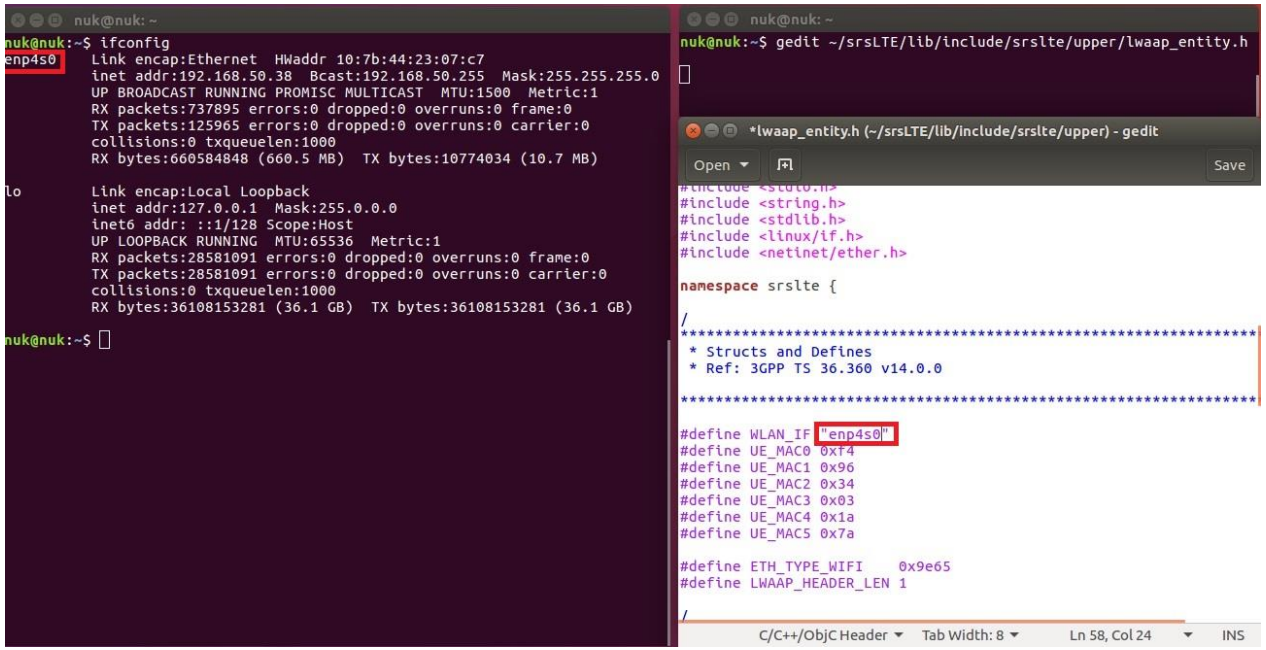


設定eNB NIC Name

在eNB的終端機輸入以下指令

- gedit /path/to/srsLTE/lib/include/srslte/upper/lwaap_entity.h

如下圖，在eNB設定LWA的網卡名稱



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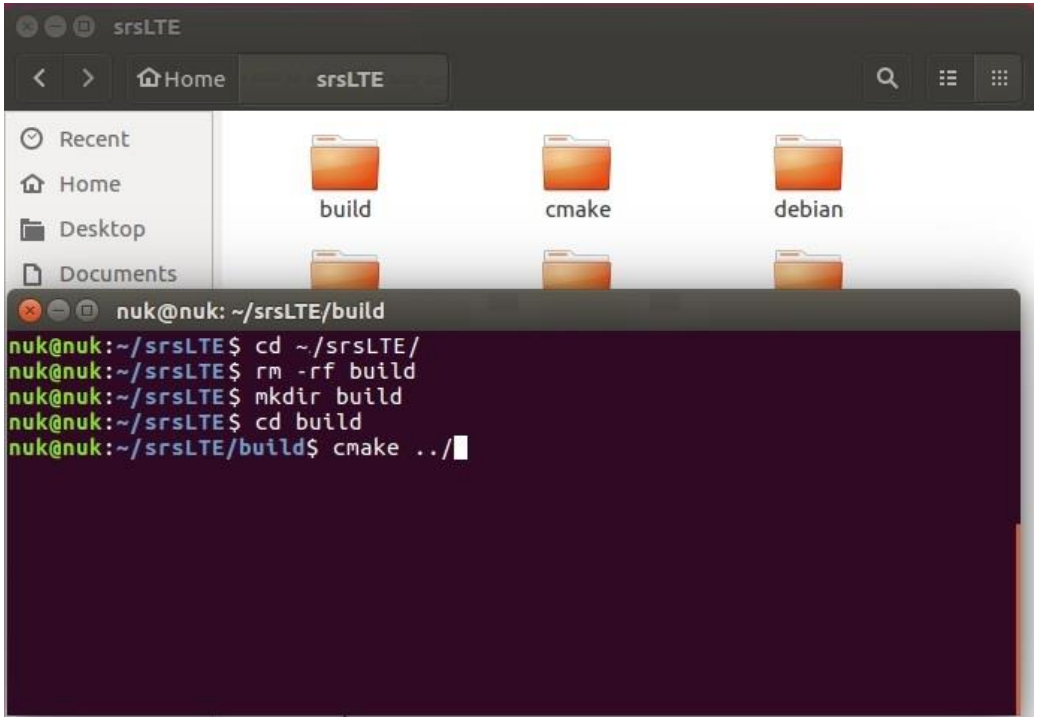
  - 軟硬體環境
  - srsLTE 架構
- srsLTE 網路實驗平台建置
  - 一. 環境設定及安裝必要軟體
  - 二. 編譯及安裝srsLTE
  - 三. 設定srsLTE設定檔
  - 四. srsLTE測試
- nukxDC(LWA)網路實驗平台建置
  - 一. nukxDC設定及流量測試-傳輸比例
  - 二. nukxDC設定及流量測試-封包排序
  - 三. nukxDC設定及流量測試-自動調整傳輸比例
- Summary
- Questions

編譯及安裝srsLTE

在EPC、eNB及UE的終端機輸入

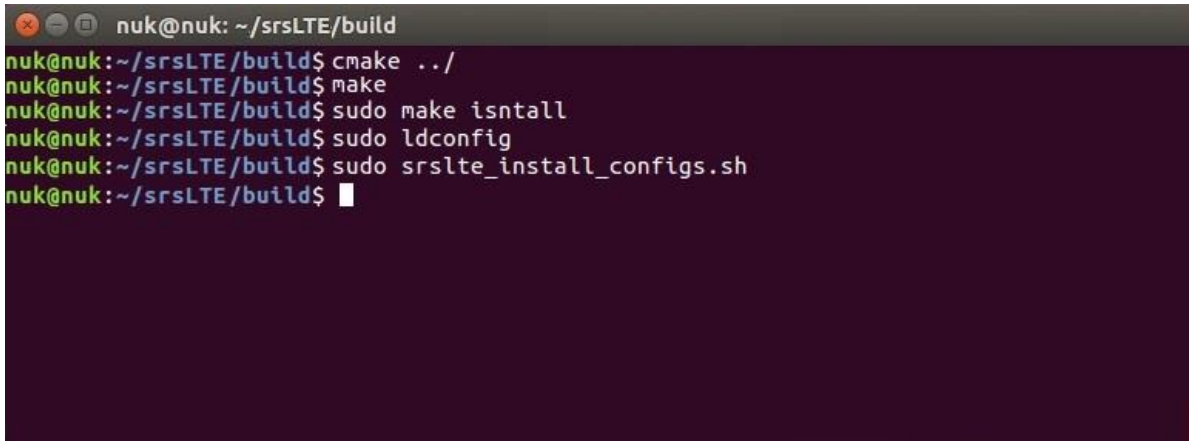
- cd ~/srsLTE
- rm -rf build
- mkdir build
- cd build



編譯及安裝srsLTE(Cont.)

在EPC、eNB及UE的終端機輸入

- cmake ../
- make
- sudo make install
- sudo ldconfig
- sudo srslte_install_configs.sh



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- 實驗目的及實驗內容
- srsLTE-nukxDC實驗環境
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- Summary
- Questions

修改 srsEPC 設定檔 (1/3)

- cd /path/to/srsLTE/srsepc
- gedit epc.conf

```
1 ##########################################################################
2 #                    srsEPC configuration file
3 ##########################################################################
4
5 ##########################################################################
6 # MME configuration
7 #
8 # mme_code:          8-bit MME code identifies the MME within a group.
9 # mme_group:         16-bit MME group identifier.
10 # tac:               16-bit Tracking Area Code.
11 # mcc:               Mobile Country Code
12 # mnc:               Mobile Network Code
13 # apn:                     Set Access Point Name (APN)
14 # mme_bind_addr:     IP bind addr to listen for eNB S1-MME connnection
15 # dns_addr:          DNS server address for the UEs
16 #
17 ##########################################################################
18 [mme]
19 mme_code = 0x1a
20 mme_group = 0x0001
21 tac = 0x0007
22 mcc = 001
23 mnc = 01
24 mme_bind_addr = 192.168.10.12
25 apn = srsapn
26 dns_addr = 8.8.8.8
```

需與eNB設定相同

修改 srsEPC 設定檔(2/3)

```
1 ##########################################################################
2 #                      srsEPC configuration file
3 ##########################################################################
4
5 ##########################################################################
6 # MME configuration
7 #
8 # mme_code:          8-bit MME code identifies the MME within a group.
9 # mme_group:         16-bit MME group identifier.
10 # tac:               16-bit Tracking Area Code.
11 # mcc:               Mobile Country Code
12 # mnc:               Mobile Network Code
13 # apn:                     Set Access Point Name (APN)
14 # mme_bind_addr:     IP bind addr to listen for eNB S1-MME connnection
15 # dns_addr:          DNS server address for the UEs
16 #
17 ##########################################################################
18 [mme]
19 mme_code = 0x1a
20 mme_group = 0x0001
21 tac = 0x0007
22 mcc = 001
23 mnc = 01
24 mme_bind_addr = 192.168.10.12
25 apn = srsapn
26 dns_addr = 8.8.8.8
27
28 ##########################################################################
29 # HSS configuration
30 #
31 # algo:             Authentication algorithm (xor/milenage)
32 # db_file:          Location of .csv file that stores UEs information.
33 #
34 ##########################################################################
35 [hss]
36 auth_algo = xor
37 db_file = user_db.csv
```

與eNB連接的IP和DNS

資料庫與認證演算法

修改 srsEPC 設定檔(3/3)

```
40 ##########################################################################
41 # SP-GW configuration
42 #
43 # gtpu_bind_addr:   GTP-U bind adress.
44 #
45 ##########################################################################
46
47 [spgw]
48 gtpu_bind_addr=192.168.50.194          EPC對外連接IP
49 sgi_if_addr=172.16.0.1
```

修改 srsEPC 資料庫

- cd /path/to/srsLTE/srsepc
- gedit user_db.csv

```
# .csv to store UE's information in HSS
# Kept in the following format: "Name,IMSI,Key,OP_Type,OP,AMF,SQN,QCI"
#
# Name:    Human readable name to help distinguish UE's. Ignored by the HSS
# IMSI:    UE's IMSI value
# Key:     UE's key, where other keys are derived from. Stored in hexadecimal
# OP_Type: Operator's code type, either OP or OPc
# OP/OPc:  Operator Code/Cyphered Operator Code, stored in hexadecimal
# AMF:     Authentication management field, stored in hexadecimal
# SQN:     UE's Sequence number for freshness of the authentication
# QCI:     QoS Class Identifier for the UE's default bearer.
#
# Note: Lines starting by '#' are ignored and will be overwritten
ue2,001010123456780,00112233445566778899aabbccddeeff,opc,63bfa50ee6523365ff14c1f45f88737d,8000,000000001234,7
ue1,001010123456789,00112233445566778899aabbccddeeff,opc,63bfa50ee6523365ff14c1f45f88737d,9001,00000000148b,7
```

7 RLC UM
9 RLC AM

UE預設SIM卡資訊

修改 srsENB 設定檔 (1/3)

- cd /path/to/srsLTE/srsenb
- gedit enb.conf

```
1  ##########################################################################
2  #                      srsENB configuration file
3  ##########################################################################
4
5  ##########################################################################
6  # eNB configuration
7  #
8  # enb_id:           20-bit eNB identifier.
9  # cell_id:          8-bit cell identifier.
10 # tac:              16-bit Tracking Area Code.
11 # mcc:              Mobile Country Code
12 # mnc:              Mobile Network Code
13 # mme_addr:         IP address of MME for S1 connnection
14 # gtp_bind_addr:    Local IP address to bind for GTP connection
15 # n_prb:            Number of Physical Resource Blocks (6,15,25,50,75,100)
16 #
17 ##########################################################################
18 [enb]
19 enb_id = 0x19B
20 cell_id = 0x01
21 phy_cell_id = 1
22 tac = 0x0001
23 mcc = 001
24 mnc = 01
25 mme_addr = 192.168.10.254
26 gtp_bind_addr = 192.168.10.12
27 n_prb = 25
28
```

需與EPC設定相同

修改 srsENB 設定檔 (2/3)

```
1  ##########################################################################
2  #                      srsENB configuration file
3  ##########################################################################
4
5  ##########################################################################
6  # eNB configuration
7  #
8  # enb_id:          20-bit eNB identifier.
9  # cell_id:         8-bit cell identifier.
10 # tac:             16-bit Tracking Area Code.
11 # mcc:             Mobile Country Code
12 # mnc:             Mobile Network Code
13 # mme_addr:        IP address of MME for S1 connnection
14 # gtp_bind_addr:   Local IP address to bind for GTP connection
15 # n_prb:           Number of Physical Resource Blocks (6,15,25,50,75,100)
16 #
17 ##########################################################################
18 [enb]
19 enb_id = 0x19B
20 cell_id = 0x01
21 phy_cell_id = 1
22 tac = 0x0001
23 mcc = 001
24 mnc = 01
25 mme_addr = 192.168.10.254
26 gtp_bind_addr = 192.168.10.12
27 n_prb = 25
```

mme_addr MME的IP位址
gtp_bind_addr eNB與EPC連接的IP位址

修改 srsENB 設定檔 (3/3)

- cd /path/to/srsLTE/srsenb
- gedit sib.conf.example
- gedit rr.conf.example
- gedit drb.conf.example

資料庫預設QCI 7 (RLC UM)

```
// All times are in ms. Use -1 for infinity, where available

qci_config = (

{
  qci=7;
  pdcp_config = {
    discard_timer = 100;
    pdcp_sn_size = 12;
  }
  rlc_config = {
    ul_um = {
      sn_field_length = 10;
    };
    dl_um = {
      sn_field_length = 10;
      t_reordering    = 40;
    };
  };
  logical_channel_config = {
    priority = 13;
    prioritized_bit_rate   = -1;
    bucket_size_duration  = 100;
    log_chan_group = 2;
  };
},
```

SRB (RLC AM)

```
{
  qci=9;
  pdcp_config = {
    discard_timer = -1;
    status_report_required = true;
  }
  rlc_config = {
    ul_am = {
      t_poll_retx = 120;
      poll_pdu = 64;
      poll_byte = 750;
      max_retx_thresh = 16;
    };
    dl_am = {
      t_reordering = 50;
      t_status_prohibit = 50;
    };
  };
  logical_channel_config = {
    priority = 11;
    prioritized_bit_rate   = -1;
    bucket_size_duration  = 100;
    log_chan_group = 3;
  };
}
```

修改 srsUE 設定檔 (1/2)

- cd /path/to/srsLTE/srsue
- gedit ue.conf

```
[rf]
dl_earfcn = 500
freq_offset = 0
tx_gain = 60
rx_gain = 40

#nof_rx_ant = 1
#device_name = auto
#device_args = auto
#time_adv_nsamples = auto
#burst_preamble_us = auto
#continuous_tx     = auto
```

設定頻段(請參考下列網址)

調整收送功率(請參考之後投影片)

Band	Name	Downlink (MHz)			Bandwidth DL/UL (MHz)	Uplink (MHz)			Duplex spacing (MHz)	Geographical area	3GPP release
		Low	Middle	High		Low	Middle	High			
		Earfcn				Earfcn					
1	2100	2110	**2140**	2170	60	1920	**1950**	1980	190	Global	8
		0	300	599		18000	18300	18599			

資料來源：http://niviuk.free.fr/lte_band.php

修改 srsUE 設定檔 (2/2)

```
88 ######################################################################
89 # USIM configuration
90 #
91 # mode: USIM mode (soft/pcsc)
92 # algo: Authentication algorithm (xor/milenage)
93 # op:   128-bit Operator Variant Algorithm Configuration Field (hex)
94 # k:    128-bit subscriber key (hex)
95 # imsi: 15 digit International Mobile Subscriber Identity
96 # imei: 15 digit International Mobile Station Equipment Identity
97 # pin:  PIN in case real SIM card is used
98 # reader: Specify card reader by it's name as listed by 'pcsc_scan'. If empty, try all available readers.
99 ######################################################################
100 [usim]
101 mode = soft
102 algo = xor
103 opc  = 63BFA50EE6523365FF14C1F45F88737D
104 k    = 00112233445566778899aabbccddeeff
105 imsi = 001010123456789
106 imei = 353490069873319
107 #reader =
108 #pin  = 1234
```

需與資料庫設置相同

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執行 srsEPC

在EPC開一個新的終端機輸入

- cd ~/path/to/srsLTE/srsepc
- ./srsepc_if_masq.sh enp4s0　#enp4s0是本例使用的對外網卡名稱
- sudo srsepc epc.conf

```
asus-medium@asusmedium-UN65H: ~/Desktop/lwa_enb/srsepc
asus-medium@asusmedium-UN65H:~$ cd ~/Desktop/lwa_enb/srsepc/
asus-medium@asusmedium-UN65H:~/Desktop/lwa_enb/srsepc$ ./srsepc_if_masq.sh wlp3s0
[sudo] password for asus-medium:
Masquerading Interface wlp3s0
asus-medium@asusmedium-UN65H:~/Desktop/lwa_enb/srsepc$ sudo srsepc epc.conf

---  Software Radio Systems EPC  ---

Reading configuration file epc.conf...
HSS Initialized.
MME GTP-C Initialized
MME Initialized.
SP-GW Initialized.
```

執行 srsENB

在eNB再開一個新的終端機輸入

- cd ~/path/to/srsLTE/srsenb
- sudo srsenb enb.conf

```
asus-medium@asusmedium-UN65H: ~/Desktop/lwa_enb/srsenb
asus-medium@asusmedium-UN65H:~$ cd ~/Desktop/lwa_enb/srsenb/
asus-medium@asusmedium-UN65H:~/Desktop/lwa_enb/srsenb$ sudo srsenb enb.conf
[sudo] password for asus-medium:
---  Software Radio Systems LTE eNodeB  ---

Reading configuration file enb.conf...
[INFO] [UHD] linux; GNU C++ version 5.4.0 20160609; Boost_105800; UHD_3.14.
0.0-release
Opening USRP with args: type=b200,master_clock_rate=30.72e6
[INFO] [B200] Detected Device: B210
[INFO] [B200] Operating over USB 3.
[INFO] [B200] Initialize CODEC control...
[INFO] [B200] Initialize Radio control...
[INFO] [B200] Performing register loopback test...
[INFO] [B200] Register loopback test passed
[INFO] [B200] Performing register loopback test...
[INFO] [B200] Register loopback test passed
[INFO] [B200] Asking for clock rate 30.720000 MHz...
[INFO] [B200] Actually got clock rate 30.720000 MHz.
Setting frequency: DL=2160.0 Mhz, UL=1970.0 MHz
[INFO] [B200] Asking for clock rate 23.040000 MHz...
[INFO] [B200] Actually got clock rate 23.040000 MHz.
Setting Sampling frequency 5.76 MHz

==== eNodeB started ===
Type <t> to view trace
```

執行 srsUE

在UE開一個新的終端機輸入

- cd ~/path/to/srsLTE/srsue
- sudo srsue ue.conf

```
ue@ue-X580VD: ~/Desktop/lwaap_ue/srsue
ue@ue-X580VD:~$ cd ~/Desktop/lwaap_ue/srsue/
ue@ue-X580VD:~/Desktop/lwaap_ue/srsue$ sudo srsue ue.conf
[sudo] password for ue:
Reading configuration file ue.conf...

Built in Release mode using commit 0a69e56 on branch develop_ue.

Buffer capacity 10240
Buffer capacity 40960
---  Software Radio Systems LTE UE  ---

Opening RF device with 1 RX antennas...
[INFO] [UHD] linux; GNU C++ version 5.4.0 20160609; Boost_105800; UHD_3.14.0.0-r
elease
Opening USRP with args: type=b200,master_clock_rate=30.72e6
[INFO] [B200] Detected Device: B210
[INFO] [B200] Operating over USB 3.
[INFO] [B200] Initialize CODEC control...
[INFO] [B200] Initialize Radio control...
[INFO] [B200] Performing register loopback test...
[INFO] [B200] Register loopback test passed
[INFO] [B200] Performing register loopback test...
[INFO] [B200] Register loopback test passed
[INFO] [B200] Asking for clock rate 30.720000 MHz...
[INFO] [B200] Actually got clock rate 30.720000 MHz.
LWAAP MAC f4:96:34:3:6a:a6
LWAAP IP packet receiver thread run_enable
Waiting PHY to initialize...
...
Attaching UE...
Searching cell in DL EARFCN=500, f_dl=2160.0 MHz, f_ul=1970.0 MHz
.
Found Cell:  PCI=1, PRB=25, Ports=1, CFO=0.5 KHz
[INFO] [B200] Asking for clock rate 23.040000 MHz...
[INFO] [B200] Actually got clock rate 23.040000 MHz.
Found PLMN:  Id=00101, TAC=7
Random Access Transmission: seq=9, ra-rnti=0x2
Random Access Transmission: seq=42, ra-rnti=0x2
Random Access Transmission: seq=9, ra-rnti=0x2
RRC Connected
Random Access Complete.     c-rnti=0x48, ta=0
Network attach successful. IP: 172.16.0.2
Software Radio Systems LTE (srsLTE)
```

UE Attach 成功

```
root@NUK: /home/enb/srsLTE-eNB_LWIP/srsepc
SPGW Allocated IP 172.16.0.2 to ISMI 001010123456789
Adding attach accept to Initial Context Setup Request
Initial Context Setup Request -- eNB UE S1AP Id 1, MME UE S1AP Id 1
Initial Context Setup Request -- E-RAB id 5
Initial Context Setup Request -- S1-U TEID 0x1. IP 192.168.50.194
Initial Context Setup Request -- S1-U TEID 0x1. IP 192.168.50.194
Initial Context Setup Request -- QCI 9
Received Initial Context Setup Response
E-RAB Context Setup. E-RAB id 5
E-RAB Context -- eNB TEID 0x460003; eNB GTP-U Address 127.0.0.1
Integrity Protected UL NAS: Received Attach Complete
Unpacked Attached Complete Message. IMSI 1010123456789
Unpacked Activate Default EPS Bearer message. EPS Bearer id 5
Packing EMM Information
Sending EMM Information, bytes 67
DL NAS: Sent Downlink NAS Message. DL NAS Count=2, UL NAS count=1
DL NAS: MME UE S1AP id 1
SCTP Association Shutdown. Association: 128
Deleting eNB context. eNB Id: 0x19b
Releasing UEs context
Releasing UE ECM context. UE-MME S1AP Id: 1
```

EPC

```
nuk@nuk: ~/srsLTE-eNB_LWIP/srsue
[INFO] [B200] Register loopback test passed
[INFO] [B200] Asking for clock rate 30.720000 MHz...
[INFO] [B200] Actually got clock rate 30.720000 MHz.

lwipep lib init rnti = 0x0
lwipep MAC f4:96:34:3:1a:74
Waiting PHY to initialize...
...
Attaching UE...
Searching cell in DL EARFCN=500, f_dl=2160.0 MHz, f_ul=1970.0 MHz
.
Found Cell:  PCI=1, PRB=50, Ports=1, CFO=-0.8 KHz
[INFO] [B200] Asking for clock rate 11.520000 MHz...
[INFO] [B200] Actually got clock rate 11.520000 MHz.
Found PLMN:  Id=00101, TAC=1
Random Access Transmission: seq=5, ra-rnti=0x2
RRC Connected
Random Access Complete.     c-rnti=0x46, ta=18
lwipep rnti = 0x46
Network attach successful. IP: 172.16.0.2
Software Radio Systems LTE (srsLTE)
```

UE

UE Attach 失敗

```
nuk_lab@lab: ~/srsLTE/srsue
[INFO] [CORES] Performing timer loopback test...
[INFO] [CORES] Timer loopback test passed
[INFO] [CORES] Performing timer loopback test...
[INFO] [CORES] Timer loopback test passed
LWAAP MAC f4:96:34:3:66:5a
Waiting PHY to initialize...
...
Attaching UE...
Searching cell in DL EARFCN=500, f_dl=2160.0 MHz, f_ul=1970.0 MHz
.
Found Cell:  PCI=1, PRB=25, Ports=1, CFO=-1.7 KHz
[INFO] [B200] Asking for clock rate 23.040000 MHz...
[INFO] [B200] Actually got clock rate 23.040000 MHz.
[INFO] [CORES] Performing timer loopback test...
[INFO] [CORES] Timer loopback test passed
[INFO] [CORES] Performing timer loopback test...
[INFO] [CORES] Timer loopback test passed
Found PLMN:  Id=00101, TAC=1
Random Access Transmission: seq=9, ra-rnti=0x2
RRC Connected
Random Access Complete.     c-rnti=0x46, ta=0
Network attach successful. IP: 172.16.0.2
Software Radio Systems LTE (srsLTE)
```

PLMN不同：沒有找到eNB

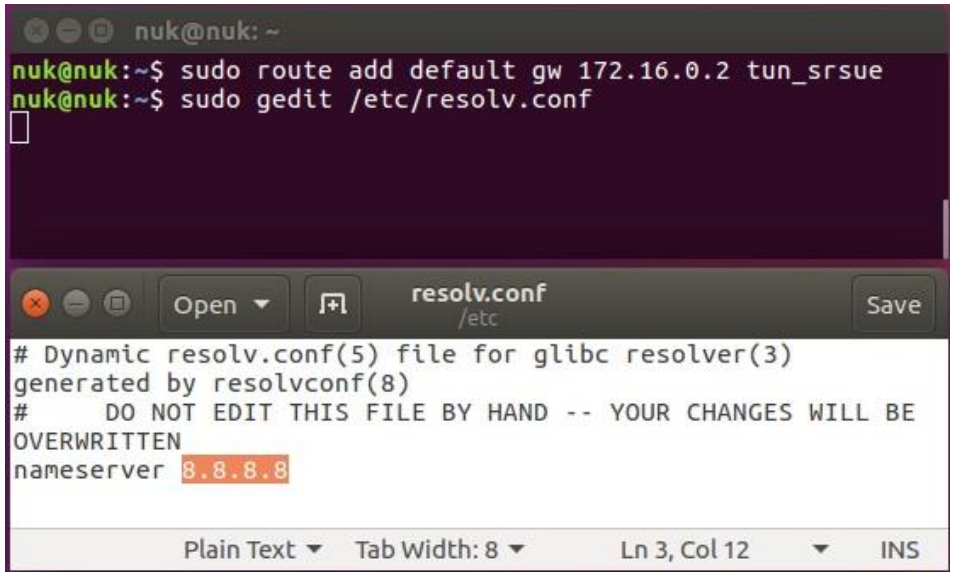
沒有RRC Connected：與eNB連接失敗

沒有IP：與EPC連接失敗

UE 設定

在UE開一個新的終端機輸入

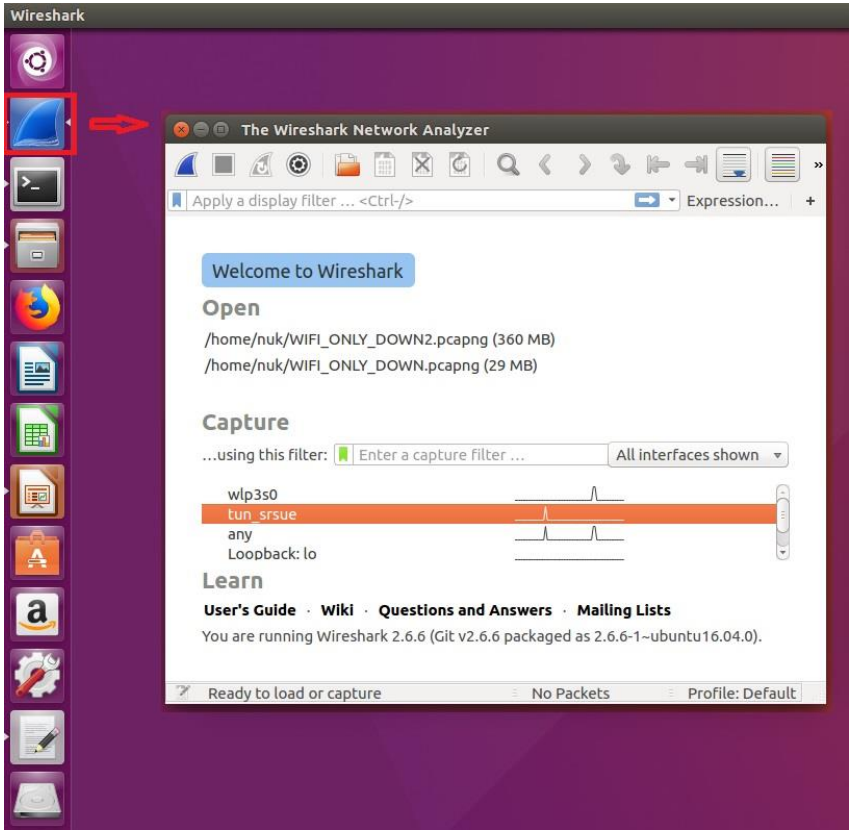
- sudo route add default gw 172.16.0.2 tun_srsue
- sudo gedit /etc/resolv.conf
- 彈出新的視窗resolv.conf，如下圖所示來修改，然後關閉它



Wireshark

在UE開啓wireshark

- 看到新增了一個網路界面
- 打開瀏覽器或iperf測試，可以看到封包會從tun_srsue 進出



流量測試

在EPC開一個新的終端機輸入

- iperf3 -s -B 172.16.0.1

```
nuk@nuk: ~/iperf
nuk@nuk:~/iperf$ iperf3 -s -B 172.16.0.1
-----------------------------------------------------------
Server listening on 5201
-----------------------------------------------------------
Accepted connection from 172.16.0.2, port 44411
[  5] local 172.16.0.1 port 5201 connected to 172.16.0.2 port 38249
[ ID] Interval           Transfer     Bitrate         Total Datagrams
[  5]   0.00-1.00   sec  11.9 MBytes  99.9 Mbits/sec  8759
[  5]   1.00-2.00   sec  11.9 MBytes   100 Mbits/sec  8765
[  5]   2.00-3.00   sec  11.9 MBytes   100 Mbits/sec  8766
[  5]   3.00-4.00   sec  11.9 MBytes   100 Mbits/sec  8766
[  5]   4.00-5.00   sec  11.9 MBytes   100 Mbits/sec  8766
[  5]   5.00-6.00   sec  11.9 MBytes   100 Mbits/sec  8765
[  5]   6.00-7.00   sec  11.9 MBytes   100 Mbits/sec  8766
```

在UE開一個新的終端機輸入

- iperf3 -c 172.16.0.1 -B 172.16.0.2 -u -l 1426b -t 120 -b 100m -R

```
nuk@nuk: ~

nuk@nuk:~$ iperf3 -c 172.16.0.1 -B 172.16.0.2 -l 1426b -t 120 -u -b 100m -R
Connecting to host 172.16.0.1, port 5201
Reverse mode, remote host 172.16.0.1 is sending
[  5] local 172.16.0.2 port 52864 connected to 172.16.0.1 port 5201
[ ID] Interval           Transfer     Bitrate         Jitter    Lost/Total Datagrams
[  5]   0.00-1.00   sec  1.82 MBytes  15.3 Mbits/sec  0.456 ms  7042/8382 (84%)
[  5]   1.00-2.00   sec  1.73 MBytes  14.5 Mbits/sec  0.435 ms  7488/8757 (86%)
[  5]   2.00-3.00   sec  1.73 MBytes  14.5 Mbits/sec  0.484 ms  7497/8767 (86%)
[  5]   3.00-4.00   sec  1.73 MBytes  14.5 Mbits/sec  0.434 ms  7504/8774 (86%)
[  5]   4.00-5.00   sec  1.73 MBytes  14.5 Mbits/sec  0.458 ms  7488/8757 (86%)
```

UE & eNB TX/RX調校

- 在UE/eNB的Console視窗內輸入t後按Enter

```
enb@NUK: ~/srsLTE/srsenb
LWAAP add user rnti=0x46
User 0x46 connected
t
Enter t to stop trace.

------DL------------------------------------------------UL------------------------------------------------
rnti   cqi     ri    mcs   tbits   brate    bler    snr    phr    mcs   rbits   brate    bler     bsr
46    15.0      0    0.0     0.0     0.0      0%   29.8   40.0   15.0   12.8k   12.8k      0%     0.0
46    15.0      0    0.0     0.0     0.0      0%   29.8   40.0   15.0   12.8k   12.8k      0%     0.0
46    15.0      0    0.0     0.0     0.0      0%   29.8   40.0   15.0   12.8k   12.8k      0%     0.0
46    15.0      0    0.0     0.0     0.0      0%   29.4   40.0   15.0   12.8k   12.8k      0%     0.0
46    15.0      0    0.0     0.0     0.0      0%   29.2   40.0   15.0   12.8k   12.8k      0%     0.0
46    15.0      0    0.0     0.0     0.0      0%   29.4   40.0   15.0   12.8k   12.8k      0%     0.0
46    15.0      0    0.0     0.0     0.0      0%   29.6   40.0   15.0   12.8k   12.8k      0%     0.0
46    15.0      0    0.0     0.0     0.0      0%   29.8   40.0   15.0   12.8k   12.8k      0%     0.0
46    15.0      0    0.0     0.0     0.0      0%   29.8   40.0   15.0   12.8k   12.8k      0%     0.0
46    15.0      0    0.0     0.0     0.0      0%   29.7   40.0   15.0   12.8k   12.8k      0%     0.0
46    15.0      0    0.0     0.0     0.0      0%   30.0   40.0   15.0   12.8k   12.8k      0%     0.0

------DL------------------------------------------------UL------------------------------------------------
rnti   cqi     ri    mcs   tbits   brate    bler    snr    phr    mcs   rbits   brate    bler     bsr
46    15.0      0    0.0     0.0     0.0      0%   30.0   40.0   15.0   12.8k   12.8k      0%     0.0
46    15.0      0    0.0     0.0     0.0      0%   30.0   40.0   15.0   12.8k   12.8k      0%     0.0
```

數值越大傳越快(搭配iPerf測試)

```
nuk_lab@lab: ~/srsLTE/srsue
   -55     55   -1.8k    7.0     42    1.0     0.0     0.0     0%     15     0.0     13k     13k      0%
   -55     55   -1.8k    7.0     42    1.0     0.0     0.0     0%     15     0.0     13k     13k      0%
   -55     55   -1.8k    7.0     41    1.0     0.0     0.0     0%     15     0.0     13k     13k      0%
   -55     55   -1.6k    7.0     41    1.0     0.0     0.0     0%     15     0.0     13k     13k      0%
   -55     55   -1.8k    7.0     40    1.0     0.0     0.0     0%     15     0.0     13k     13k      0%

--Signal-------------- DL-------------------------------UL------------------------------------------
  rsrp     pl     cfo    mcs    snr  turbo    bits   brate    bler    mcs    buff   bits    brate    bler
   -55     55   -1.8k    7.0     41    1.0     0.0     0.0     0%     15     0.0    8.5k    8.5k      0%
   -55     55   -1.8k    7.0     41    1.0     0.0     0.0     0%     15     0.0     13k     13k      0%
   -55     55   -1.9k    7.0     42    1.0     0.0     0.0     0%     15     0.0     13k     13k      0%
   -55     55   -1.8k    7.0     41    1.0     0.0     0.0     0%     15     0.0     13k     13k      0%
   -55     55   -1.9k    7.0     41    1.0     0.0     0.0     0%     15     0.0     13k     13k      0%
   -55     55   -1.9k    7.0     41    1.0     0.0     0.0     0%     15     0.0     13k     13k      0%
   -55     55   -1.9k    7.0     41    1.0     0.0     0.0     0%     15     0.0     13k     13k      0%
   -55     55   -1.9k    7.0     41    1.0     0.0     0.0     0%     15     0.0     13k     13k      0%
   -55     55   -1.9k    7.0     42    1.0     0.0     0.0     0%     15     0.0     13k     13k      0%
   -55     55   -1.8k    7.0     41    1.0     0.0     0.0     0%     15     0.0     13k     13k      0%
   -55     55   -1.6k    7.0     41    1.0     0.0     0.0     0%     15     0.0     13k     13k      0%

--Signal-------------- DL-------------------------------UL------------------------------------------
  rsrp     pl     cfo    mcs    snr  turbo    bits   brate    bler    mcs    buff   bits    brate    bler
   -55     55   -1.6k    7.0     40    1.0     0.0     0.0     0%     15     0.0     13k     13k      0%
```

數值盡量相近

MCS

- UE 測量 PRB (Physical Resource Block)
  - 接收功率和干擾得到 SINR 值, 在 BLER 值不超過 10%
  - 將測量值轉換成 CQI
  - eNodeB 會根據 CQI 值選擇最合適的 MCS

- LTE傳輸效能通過MCS（Modulation and Coding Scheme，調製與編碼策略）速率表來決定

DL MCS Table & TBS Table

< 36.213 Table 7.1.7.1-1 >

MCS Index I_{MCS}	Modulation Order Q_m	TBS Index I_{TBS}
0	2	0
1	2	1
2	2	2
3	2	3
4	2	4
5	2	5
6	2	6
7	2	7
8	2	8
9	2	9
10	4	9
11	4	10
12	4	11
13	4	12
14	4	13
15	4	14
16	4	15
17	6	15
18	6	16
19	6	17
20	6	18
21	6	19
22	6	20
23	6	21
24	6	22
25	6	23
26	6	24
27	6	25
28	6	26
29	2	reserved
30	4	
31	6	

Table 7.1.7.2.1-1: Transport block size table (dimension 27×110)

I_{TBS}	N_{PRB}									
	1	2	3	4	5	6	7	8	9	10
0	16	32	56	88	120	152	176	208	224	256
1	24	56	88	144	176	208	224	256	328	344
2	32	72	144	176	208	256	296	328	376	424
3	40	104	176	208	256	328	392	440	504	568
4	56	120	208	256	328	408	488	552	632	696
5	72	144	224	328	424	504	600	680	776	872
6	328	176	256	392	504	600	712	808	936	1032
7	104	224	328	472	584	712	840	968	1096	1224
8	120	256	392	536	680	808	968	1096	1256	1384
9	136	296	456	616	776	936	1096	1256	1416	1544
10	144	328	504	680	872	1032	1224	1384	1544	1736
11	176	376	584	776	1000	1192	1384	1608	1800	2024
12	208	440	680	904	1128	1352	1608	1800	2024	2280
13	224	488	744	1000	1256	1544	1800	2024	2280	2536
14	256	552	840	1128	1416	1736	1992	2280	2600	2856
15	280	600	904	1224	1544	1800	2152	2472	2728	3112
16	328	632	968	1288	1608	1928	2280	2600	2984	3240
17	336	696	1064	1416	1800	2152	2536	2856	3240	3624
18	376	776	1160	1544	1992	2344	2792	3112	3624	4008
19	408	840	1288	1736	2152	2600	2984	3496	3880	4264
20	440	904	1384	1864	2344	2792	3240	3752	4136	4584
21	488	1000	1480	1992	2472	2984	3496	4008	4584	4968
22	520	1064	1608	2152	2664	3240	3752	4264	4776	5352
23	552	1128	1736	2280	2856	3496	4008	4584	5160	5736
24	584	1192	1800	2408	2984	3624	4264	4968	5544	5992
25	616	1256	1864	2536	3112	3752	4392	5160	5736	6200
26	712	1480	2216	2984	3752	4392	5160	5992	6712	7480

UL MCS Table & TBS Table

< 36.213 Table 8.6.1-1 >

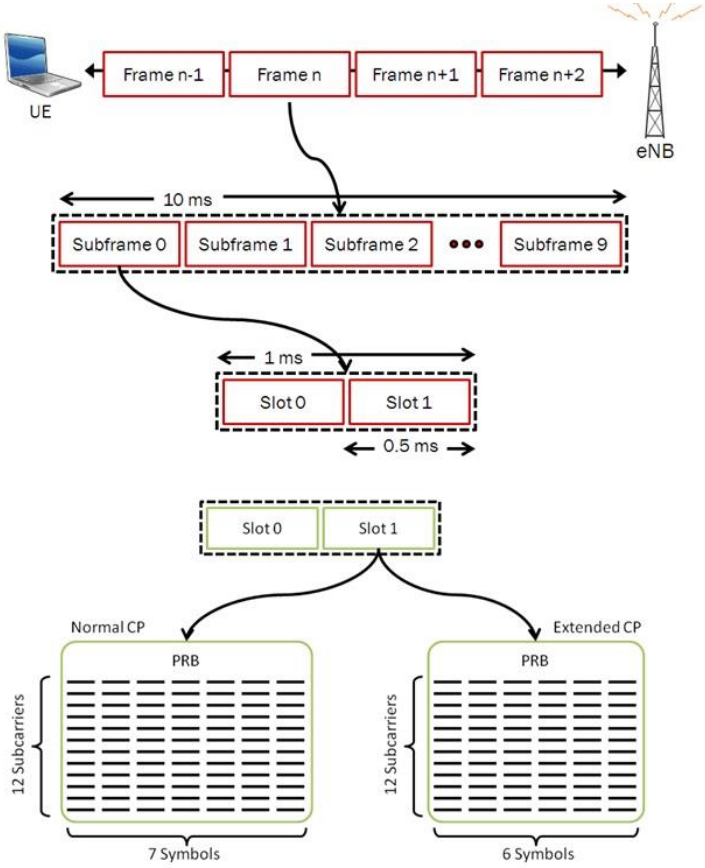
MCS Index I_{MCS}	Modulation Order Q'_m	TBS Index I_{TBS}	Redundancy Version rv_{idx}
0	2	0	0
1	2	1	0
2	2	2	0
3	2	3	0
4	2	4	0
5	2	5	0
6	2	6	0
7	2	7	0
8	2	8	0
9	2	9	0
10	2	10	0
11	4	10	0
12	4	11	0
13	4	12	0
14	4	13	0
15	4	14	0
16	4	15	0
17	4	16	0
18	4	17	0
19	4	18	0
20	4	19	0
21	6	19	0
22	6	20	0
23	6	21	0
24	6	22	0
25	6	23	0
26	6	24	0
27	6	25	0
28	6	26	0
29	reserved		1
30			2
31			3

Table 7.1.7.2.1-1: Transport block size table (dimension 27×110)

I_{TBS}	N_{PRB}									
	1	2	3	4	5	6	7	8	9	10
0	16	32	56	88	120	152	176	208	224	256
1	24	56	88	144	176	208	224	256	328	344
2	32	72	144	176	208	256	296	328	376	424
3	40	104	176	208	256	328	392	440	504	568
4	56	120	208	256	328	408	488	552	632	696
5	72	144	224	328	424	504	600	680	776	872
6	328	176	256	392	504	600	712	808	936	1032
7	104	224	328	472	584	712	840	968	1096	1224
8	120	256	392	536	680	808	968	1096	1256	1384
9	136	296	456	616	776	936	1096	1256	1416	1544
10	144	328	504	680	872	1032	1224	1384	1544	1736
11	176	376	584	776	1000	1192	1384	1608	1800	2024
12	208	440	680	904	1128	1352	1608	1800	2024	2280
13	224	488	744	1000	1256	1544	1800	2024	2280	2536
14	256	552	840	1128	1416	1736	1992	2280	2600	2856
15	280	600	904	1224	1544	1800	2152	2472	2728	3112
16	328	632	968	1288	1608	1928	2280	2600	2984	3240
17	336	696	1064	1416	1800	2152	2536	2856	3240	3624
18	376	776	1160	1544	1992	2344	2792	3112	3624	4008
19	408	840	1288	1736	2152	2600	2984	3496	3880	4264
20	440	904	1384	1864	2344	2792	3240	3752	4136	4584
21	488	1000	1480	1992	2472	2984	3496	4008	4584	4968
22	520	1064	1608	2152	2664	3240	3752	4264	4776	5352
23	552	1128	1736	2280	2856	3496	4008	4584	5160	5736
24	584	1192	1800	2408	2984	3624	4264	4968	5544	5992
25	616	1256	1864	2536	3112	3752	4392	5160	5736	6200
26	712	1480	2216	2984	3752	4392	5160	5992	6712	7480

計算LTE FDD吞吐量

- RE = Symbols * (PRB * Subcarries)



計算LTE FDD吞吐量

- RE = Symbol * (PRB * Subcarries)

- CR = (TBS * CRC) / (RE * Bits per RE)
  - TBS 查3gpp
  - CRC = Cyclic Redundancy Check
  - Bits per RE = Modulation scheme
- Throughput = TBS * CR

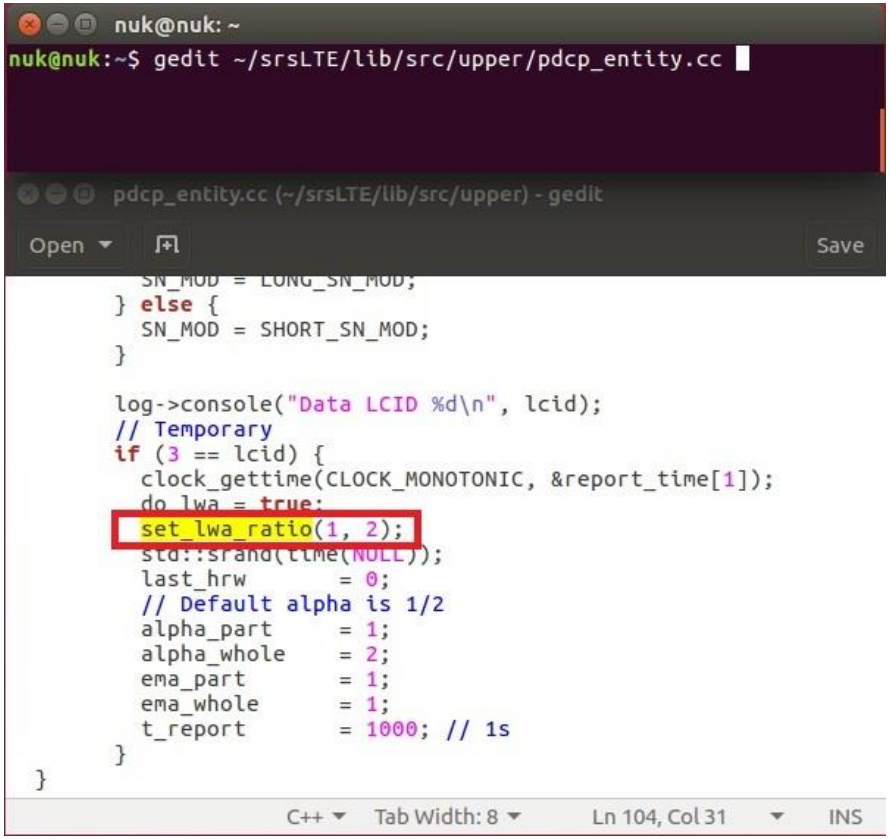
Outline

- 實驗目的及實驗內容
- srsLTE-nukxDC實驗環境
  - 軟硬體環境
  - srsLTE 架構
- srsLTE 網路實驗平台建置
  - 一. 環境設定及安裝必要軟體
  - 二. 編譯及安裝srsLTE
  - 三. 設定srsLTE設定檔
  - 四. srsLTE測試
- nukxDC(LWA)網路實驗平台建置
  - 一. nukxDC設定及流量測試-傳輸比例
  - 二. nukxDC設定及流量測試-封包排序
  - 三. nukxDC設定及流量測試-自動調整傳輸比例
- Summary
- Questions

設定LTE WLAN 比例

在eNB的終端機輸入

- gedit /path/to/srsLTE/lib/src/upper/pdcp_entity.cc

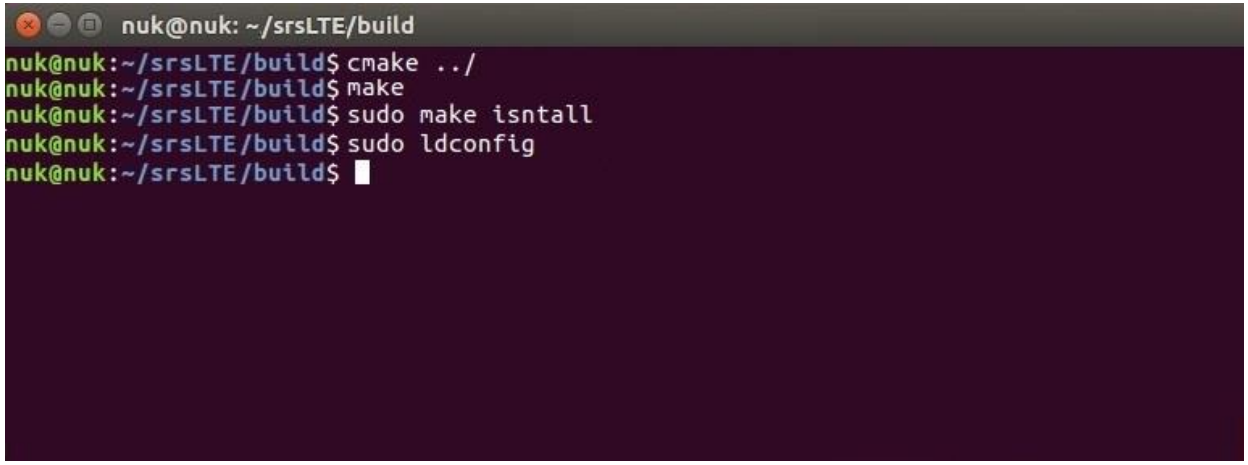


- set_lwa_ratio(x, y)
  - LTE:WLAN = x:y

重新編譯及安裝srsLTE

在eNB的終端機輸入

- cmake ../
- make
- sudo make install
- sudo ldconfig



執行 srsEPC

在EPC開一個新的終端機輸入

- cd ~/path/to/srsLTE/srsepc
- ./srsepc_if_masq.sh enp4s0　#enp4s0是本例使用的對外網卡名稱
- sudo srsepc epc.conf

```
asus-medium@asusmedium-UN65H: ~/Desktop/lwa_enb/srsepc
asus-medium@asusmedium-UN65H:~$ cd ~/Desktop/lwa_enb/srsepc/
asus-medium@asusmedium-UN65H:~/Desktop/lwa_enb/srsepc$ ./srsepc_if_masq.sh wlp3s0
[sudo] password for asus-medium:
Masquerading Interface wlp3s0
asus-medium@asusmedium-UN65H:~/Desktop/lwa_enb/srsepc$ sudo srsepc epc.conf

---  Software Radio Systems EPC  ---

Reading configuration file epc.conf...
HSS Initialized.
MME GTP-C Initialized
MME Initialized.
SP-GW Initialized.
```

執行 srsENB

在eNB再開一個新的終端機輸入

- cd ~/path/to/srsLTE/srsenb
- sudo srsenb enb.conf

```
asus-medium@asusmedium-UN65H: ~/Desktop/lwa_enb/srsenb
asus-medium@asusmedium-UN65H:~$ cd ~/Desktop/lwa_enb/srsenb/
asus-medium@asusmedium-UN65H:~/Desktop/lwa_enb/srsenb$ sudo srsenb enb.conf
[sudo] password for asus-medium:
---  Software Radio Systems LTE eNodeB  ---

Reading configuration file enb.conf...
[INFO] [UHD] linux; GNU C++ version 5.4.0 20160609; Boost_105800; UHD_3.14.
0.0-release
Opening USRP with args: type=b200,master_clock_rate=30.72e6
[INFO] [B200] Detected Device: B210
[INFO] [B200] Operating over USB 3.
[INFO] [B200] Initialize CODEC control...
[INFO] [B200] Initialize Radio control...
[INFO] [B200] Performing register loopback test...
[INFO] [B200] Register loopback test passed
[INFO] [B200] Performing register loopback test...
[INFO] [B200] Register loopback test passed
[INFO] [B200] Asking for clock rate 30.720000 MHz...
[INFO] [B200] Actually got clock rate 30.720000 MHz.
Setting frequency: DL=2160.0 Mhz, UL=1970.0 MHz
[INFO] [B200] Asking for clock rate 23.040000 MHz...
[INFO] [B200] Actually got clock rate 23.040000 MHz.
Setting Sampling frequency 5.76 MHz

==== eNodeB started ===
Type <t> to view trace
```

執行 srsUE

在UE開一個新的終端機輸入

- cd ~/path/to/srsLTE/srsue
- sudo srsue ue.conf

```
ue@ue-X580VD: ~/Desktop/lwaap_ue/srsue
ue@ue-X580VD:~$ cd ~/Desktop/lwaap_ue/srsue/
ue@ue-X580VD:~/Desktop/lwaap_ue/srsue$ sudo srsue ue.conf
[sudo] password for ue:
Reading configuration file ue.conf...

Built in Release mode using commit 0a69e56 on branch develop_ue.

Buffer capacity 10240
Buffer capacity 40960
---  Software Radio Systems LTE UE  ---

Opening RF device with 1 RX antennas...
[INFO] [UHD] linux; GNU C++ version 5.4.0 20160609; Boost_105800; UHD_3.14.0.0-r
elease
Opening USRP with args: type=b200,master_clock_rate=30.72e6
[INFO] [B200] Detected Device: B210
[INFO] [B200] Operating over USB 3.
[INFO] [B200] Initialize CODEC control...
[INFO] [B200] Initialize Radio control...
[INFO] [B200] Performing register loopback test...
[INFO] [B200] Register loopback test passed
[INFO] [B200] Performing register loopback test...
[INFO] [B200] Register loopback test passed
[INFO] [B200] Asking for clock rate 30.720000 MHz...
[INFO] [B200] Actually got clock rate 30.720000 MHz.
LWAAP MAC f4:96:34:3:6a:a6
LWAAP IP packet receiver thread run_enable
Waiting PHY to initialize...
...
Attaching UE...
Searching cell in DL EARFCN=500, f_dl=2160.0 MHz, f_ul=1970.0 MHz
.
Found Cell:  PCI=1, PRB=25, Ports=1, CFO=0.5 KHz
[INFO] [B200] Asking for clock rate 23.040000 MHz...
[INFO] [B200] Actually got clock rate 23.040000 MHz.
Found PLMN:  Id=00101, TAC=7
Random Access Transmission: seq=9, ra-rnti=0x2
Random Access Transmission: seq=42, ra-rnti=0x2
Random Access Transmission: seq=9, ra-rnti=0x2
RRC Connected
Random Access Complete.     c-rnti=0x48, ta=0
Network attach successful. IP: 172.16.0.2
Software Radio Systems LTE (srsLTE)
```

流量測試

在EPC開一個新的終端機輸入

- iperf3 -s -B 172.16.0.1

```
nuk@nuk: ~/iperf
nuk@nuk:~/iperf$ iperf3 -s -B 172.16.0.1
-----------------------------------------------------------
Server listening on 5201
-----------------------------------------------------------
Accepted connection from 172.16.0.2, port 44411
[  5] local 172.16.0.1 port 5201 connected to 172.16.0.2 port 38249
[ ID] Interval           Transfer     Bitrate         Total Datagrams
[  5]   0.00-1.00   sec  11.9 MBytes  99.9 Mbits/sec  8759
[  5]   1.00-2.00   sec  11.9 MBytes   100 Mbits/sec  8765
[  5]   2.00-3.00   sec  11.9 MBytes   100 Mbits/sec  8766
[  5]   3.00-4.00   sec  11.9 MBytes   100 Mbits/sec  8766
[  5]   4.00-5.00   sec  11.9 MBytes   100 Mbits/sec  8766
[  5]   5.00-6.00   sec  11.9 MBytes   100 Mbits/sec  8765
[  5]   6.00-7.00   sec  11.9 MBytes   100 Mbits/sec  8766
```

在UE開一個新的終端機輸入

- iperf3 -c 172.16.0.1 -B 172.16.0.2 -u -l 1426b -t 120 -b 100m -R

```
nuk@nuk: ~
nuk@nuk:~$ iperf3 -c 172.16.0.1 -B 172.16.0.2 -l 1426b -t 120 -u -b 100m -R
Connecting to host 172.16.0.1, port 5201
Reverse mode, remote host 172.16.0.1 is sending
[  5] local 172.16.0.2 port 59703 connected to 172.16.0.1 port 5201
[ ID] Interval           Transfer     Bitrate         Jitter    Lost/Total Datagrams
[  5]   0.00-1.00   sec  10.1 MBytes  85.1 Mbits/sec  29.219 ms  1743/9206 (19%)
[  5]   1.00-2.00   sec  9.67 MBytes  81.1 Mbits/sec  29.333 ms  1652/8765 (19%)
[  5]   2.00-3.00   sec  9.67 MBytes  81.1 Mbits/sec  31.073 ms  1653/8766 (19%)
[  5]   3.00-4.00   sec  9.67 MBytes  81.2 Mbits/sec  29.649 ms  1652/8766 (19%)
[  5]   4.00-5.00   sec  9.67 MBytes  81.1 Mbits/sec  25.812 ms  1654/8766 (19%)
[  5]   5.00-6.00   sec  9.67 MBytes  81.1 Mbits/sec  25.955 ms  1651/8764 (19%)
```

Outline

- 實驗目的及實驗內容
- srsLTE-nukxDC實驗環境
  - 軟硬體環境
  - srsLTE 架構
- srsLTE 網路實驗平台建置
  - 一. 環境設定及安裝必要軟體
  - 二. 編譯及安裝srsLTE
  - 三. 設定srsLTE設定檔
  - 四. srsLTE測試
- nukxDC(LWA)網路實驗平台建置
  - 一. nukxDC設定及流量測試-傳輸比例
  - 二. nukxDC設定及流量測試-封包排序
  - 三. nukxDC設定及流量測試-自動調整傳輸比例
- Summary
- Questions

設定LTE WLAN 排序功能

在UE的終端機輸入

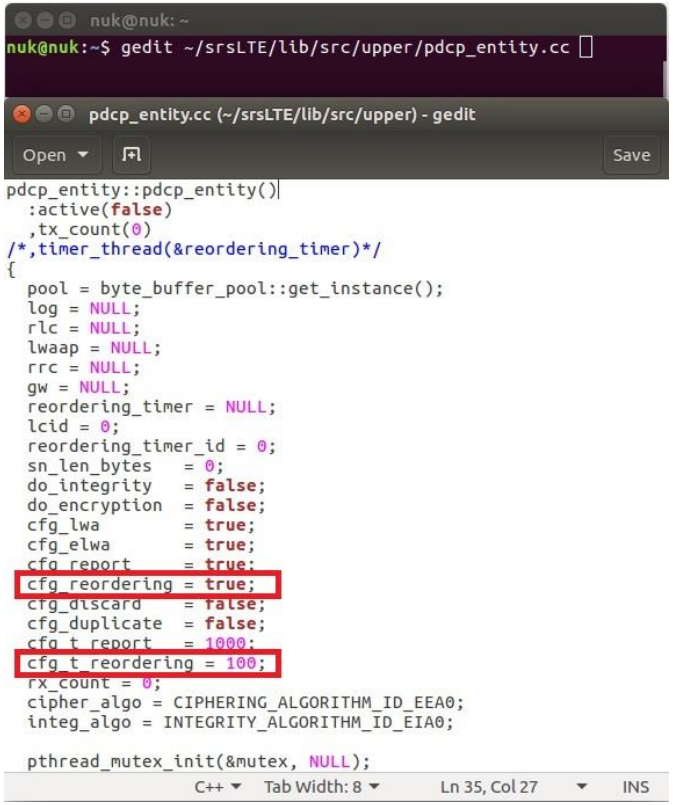
- gedit /path/to/srsLTE/lib/src/upper/pdcp_entity.cc

cfg_reordering = true

啓動LWA 的重新排序功能

cfg_t_reordering = 100

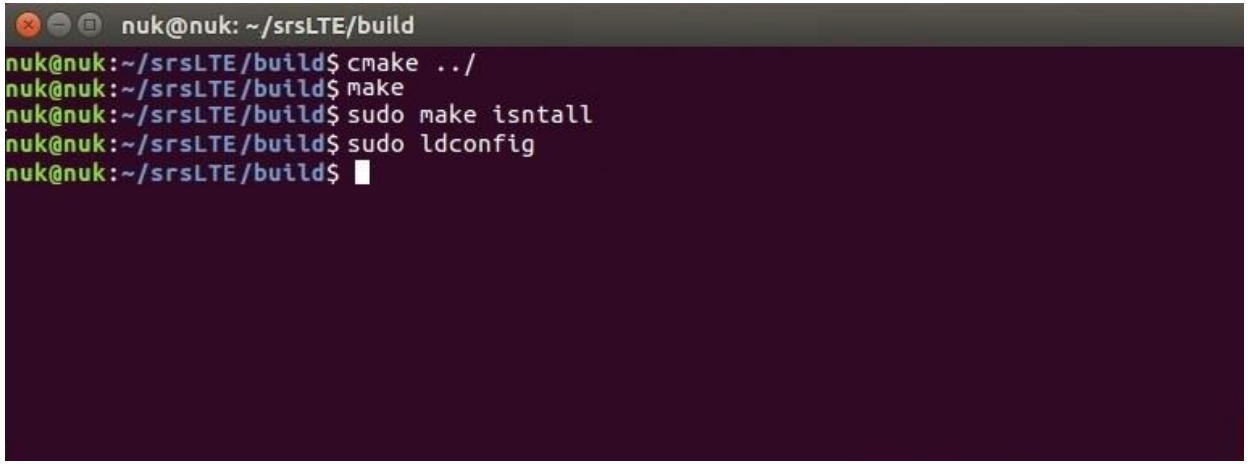
啓動LWA重新排序的等待時間



重新編譯及安裝srsLTE

在EPC、eNB及UE的終端機輸入

- cmake ../
- make
- sudo make install
- sudo ldconfig



執行 srsEPC

在EPC開一個新的終端機輸入

- cd ~/path/to/srsLTE/srsepc
- ./srsepc_if_masq.sh enp4s0　#enp4s0是本例使用的對外網卡名稱
- sudo srsepc epc.conf

```
asus-medium@asusmedium-UN65H: ~/Desktop/lwa_enb/srsepc
asus-medium@asusmedium-UN65H:~$ cd ~/Desktop/lwa_enb/srsepc/
asus-medium@asusmedium-UN65H:~/Desktop/lwa_enb/srsepc$ ./srsepc_if_masq.sh wlp3s0
[sudo] password for asus-medium:
Masquerading Interface wlp3s0
asus-medium@asusmedium-UN65H:~/Desktop/lwa_enb/srsepc$ sudo srsepc epc.conf

---  Software Radio Systems EPC  ---

Reading configuration file epc.conf...
HSS Initialized.
MME GTP-C Initialized
MME Initialized.
SP-GW Initialized.
```

執行 srsENB

在eNB再開一個新的終端機輸入

- cd ~/path/to/srsLTE/srsenb
- sudo srsenb enb.conf

```
asus-medium@asusmedium-UN65H: ~/Desktop/lwa_enb/srsenb
asus-medium@asusmedium-UN65H:~$ cd ~/Desktop/lwa_enb/srsenb/
asus-medium@asusmedium-UN65H:~/Desktop/lwa_enb/srsenb$ sudo srsenb enb.conf
[sudo] password for asus-medium:
---  Software Radio Systems LTE eNodeB  ---

Reading configuration file enb.conf...
[INFO] [UHD] linux; GNU C++ version 5.4.0 20160609; Boost_105800; UHD_3.14.
0.0-release
Opening USRP with args: type=b200,master_clock_rate=30.72e6
[INFO] [B200] Detected Device: B210
[INFO] [B200] Operating over USB 3.
[INFO] [B200] Initialize CODEC control...
[INFO] [B200] Initialize Radio control...
[INFO] [B200] Performing register loopback test...
[INFO] [B200] Register loopback test passed
[INFO] [B200] Performing register loopback test...
[INFO] [B200] Register loopback test passed
[INFO] [B200] Asking for clock rate 30.720000 MHz...
[INFO] [B200] Actually got clock rate 30.720000 MHz.
Setting frequency: DL=2160.0 Mhz, UL=1970.0 MHz
[INFO] [B200] Asking for clock rate 23.040000 MHz...
[INFO] [B200] Actually got clock rate 23.040000 MHz.
Setting Sampling frequency 5.76 MHz

==== eNodeB started ===
Type <t> to view trace
```

執行 srsUE

在UE開一個新的終端機輸入

- cd ~/path/to/srsLTE/srsue
- sudo srsue ue.conf

```
ue@ue-X580VD: ~/Desktop/lwaap_ue/srsue
ue@ue-X580VD:~$ cd ~/Desktop/lwaap_ue/srsue/
ue@ue-X580VD:~/Desktop/lwaap_ue/srsue$ sudo srsue ue.conf
[sudo] password for ue:
Reading configuration file ue.conf...

Built in Release mode using commit 0a69e56 on branch develop_ue.

Buffer capacity 10240
Buffer capacity 40960
---  Software Radio Systems LTE UE  ---

Opening RF device with 1 RX antennas...
[INFO] [UHD] linux; GNU C++ version 5.4.0 20160609; Boost_105800; UHD_3.14.0.0-r
elease
Opening USRP with args: type=b200,master_clock_rate=30.72e6
[INFO] [B200] Detected Device: B210
[INFO] [B200] Operating over USB 3.
[INFO] [B200] Initialize CODEC control...
[INFO] [B200] Initialize Radio control...
[INFO] [B200] Performing register loopback test...
[INFO] [B200] Register loopback test passed
[INFO] [B200] Performing register loopback test...
[INFO] [B200] Register loopback test passed
[INFO] [B200] Asking for clock rate 30.720000 MHz...
[INFO] [B200] Actually got clock rate 30.720000 MHz.
LWAAP MAC f4:96:34:3:6a:a6
LWAAP IP packet receiver thread run_enable
Waiting PHY to initialize...
...
Attaching UE...
Searching cell in DL EARFCN=500, f_dl=2160.0 MHz, f_ul=1970.0 MHz
.
Found Cell:  PCI=1, PRB=25, Ports=1, CFO=0.5 KHz
[INFO] [B200] Asking for clock rate 23.040000 MHz...
[INFO] [B200] Actually got clock rate 23.040000 MHz.
Found PLMN:  Id=00101, TAC=7
Random Access Transmission: seq=9, ra-rnti=0x2
Random Access Transmission: seq=42, ra-rnti=0x2
Random Access Transmission: seq=9, ra-rnti=0x2
RRC Connected
Random Access Complete.     c-rnti=0x48, ta=0
Network attach successful. IP: 172.16.0.2
Software Radio Systems LTE (srsLTE)
```

流量測試

在EPC開一個新的終端機輸入

- iperf3 -s -B 172.16.0.1

```
nuk@nuk: ~/iperf
nuk@nuk:~/iperf$ iperf3 -s -B 172.16.0.1
-----------------------------------------------------------
Server listening on 5201
-----------------------------------------------------------
Accepted connection from 172.16.0.2, port 44411
[  5] local 172.16.0.1 port 5201 connected to 172.16.0.2 port 38249
[ ID] Interval           Transfer     Bitrate         Total Datagrams
[  5]   0.00-1.00   sec  11.9 MBytes  99.9 Mbits/sec  8759
[  5]   1.00-2.00   sec  11.9 MBytes   100 Mbits/sec  8765
[  5]   2.00-3.00   sec  11.9 MBytes   100 Mbits/sec  8766
[  5]   3.00-4.00   sec  11.9 MBytes   100 Mbits/sec  8766
[  5]   4.00-5.00   sec  11.9 MBytes   100 Mbits/sec  8766
[  5]   5.00-6.00   sec  11.9 MBytes   100 Mbits/sec  8765
[  5]   6.00-7.00   sec  11.9 MBytes   100 Mbits/sec  8766
```

在UE開一個新的終端機輸入

- iperf3 -c 172.16.0.1 -B 172.16.0.2 -u -l 1426b -t 120 -b 100m -R

```
nuk@nuk: ~
nuk@nuk:~$ iperf3 -c 172.16.0.1 -B 172.16.0.2 -l 1426b -t 120 -u -b 100m -R
Connecting to host 172.16.0.1, port 5201
Reverse mode, remote host 172.16.0.1 is sending
[  5] local 172.16.0.2 port 40566 connected to 172.16.0.1 port 5201
[ ID] Interval           Transfer     Bitrate         Jitter    Lost/Total Datagrams
[  5]   0.00-1.00   sec  8.85 MBytes  74.3 Mbits/sec  0.440 ms  1370/7880 (17%)
[  5]   1.00-2.00   sec  9.67 MBytes  81.1 Mbits/sec  0.568 ms  1653/8766 (19%)
[  5]   2.00-3.00   sec  9.68 MBytes  81.2 Mbits/sec  0.946 ms  1653/8772 (19%)
[  5]   3.00-4.00   sec  9.66 MBytes  81.0 Mbits/sec  0.502 ms  1665/8769 (19%)
[  5]   4.00-5.00   sec  9.66 MBytes  81.0 Mbits/sec  0.495 ms  1666/8766 (19%)
```

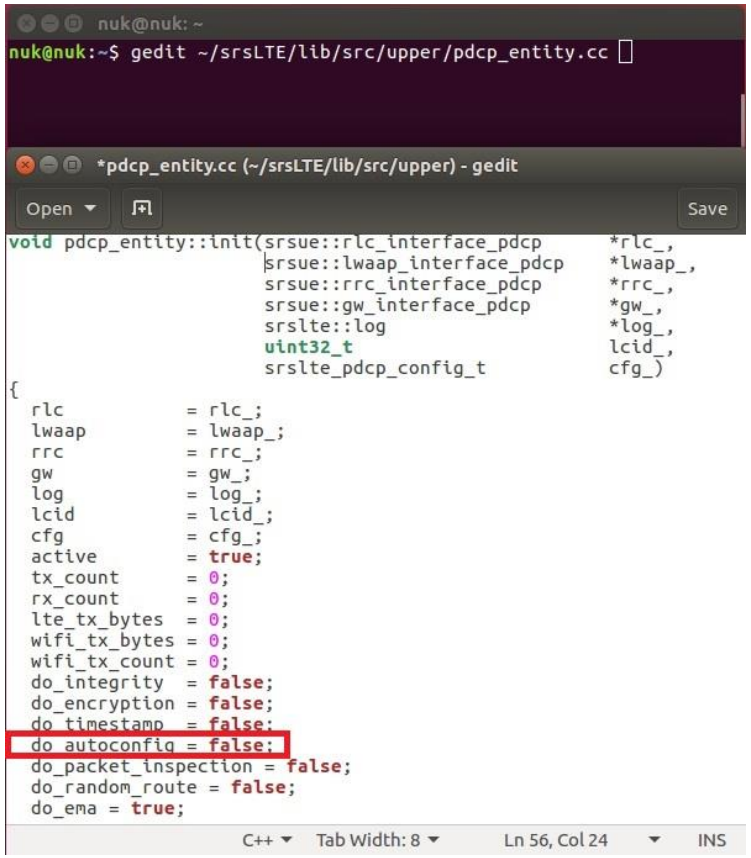
Outline

- 實驗目的及實驗內容
- srsLTE-nukxDC實驗環境
  - 軟硬體環境
  - srsLTE 架構
- srsLTE 網路實驗平台建置
  - 一. 環境設定及安裝必要軟體
  - 二. 編譯及安裝srsLTE
  - 三. 設定srsLTE設定檔
  - 四. srsLTE測試
- nukxDC(LWA)網路實驗平台建置
  - 一. nukxDC設定及流量測試-傳輸比例
  - 二. nukxDC設定及流量測試-封包排序
  - 三. nukxDC設定及流量測試-自動調整傳輸比例
- Summary
- Questions

設定LTE WLAN 自動調配功能

在eNB的終端機輸入

- gedit /path/to/srsLTE/lib/src/upper/pdcp_entity.cc



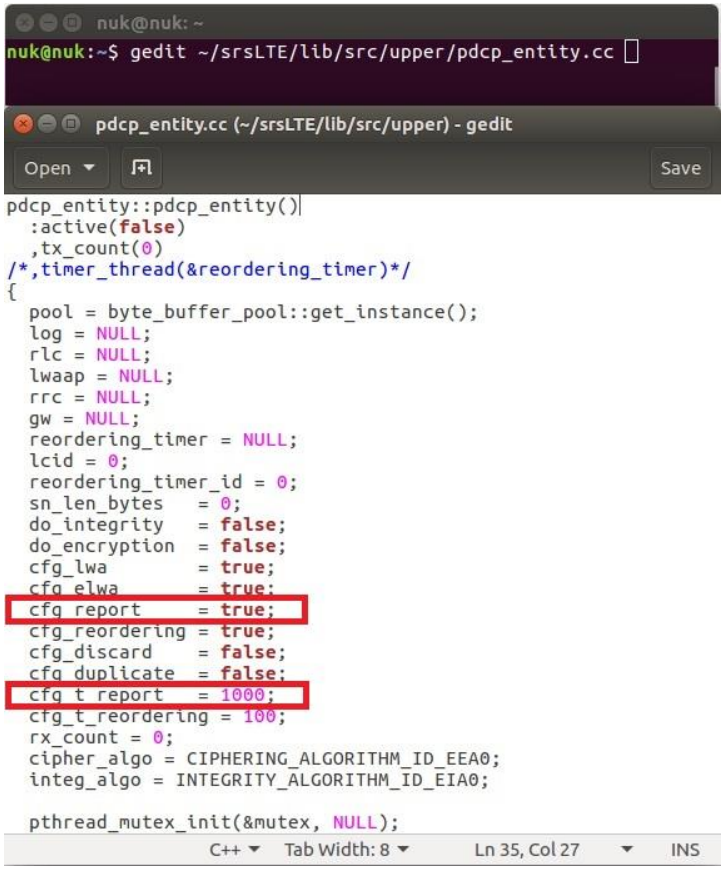
啓動LWA 的自動調配功能

do_autoconfig = true

設定LTE WLAN 自動調配功能

在UE的終端機輸入

- gedit /path/to/srsLTE/lib/src/upper/pdcp_entity.cc



啓動LWA回報網路狀況功能

cfg_report = true

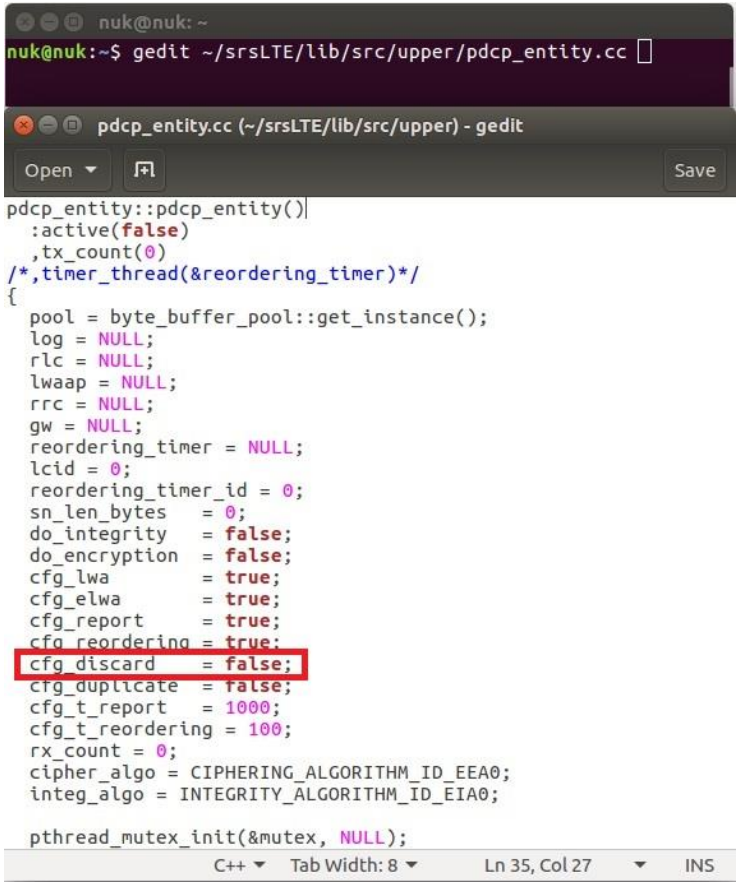
設定LWA回報網路狀況的時間

cfg_t_report = 5000

LTE WLAN丟棄延遲封包功能

在UE的終端機輸入

- gedit /path/to/srsLTE/lib/src/upper/pdcp_entity.cc



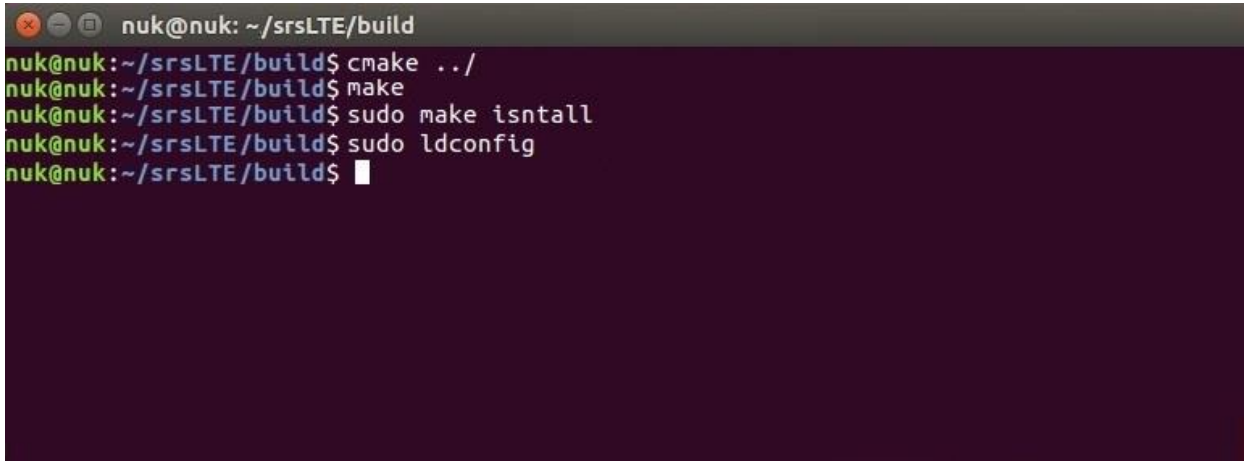
cfg_discard = true

啓動LWA 的丟棄延遲封包功能

重新編譯及安裝srsLTE

在EPC、eNB及UE的終端機輸入

- cmake ../
- make
- sudo make install
- sudo ldconfig



執行 srsEPC

在EPC開一個新的終端機輸入

- cd ~/path/to/srsLTE/srsepc
- ./srsepc_if_masq.sh enp4s0　#enp4s0是本例使用的對外網卡名稱
- sudo srsepc epc.conf

```
asus-medium@asusmedium-UN65H: ~/Desktop/lwa_enb/srsepc
asus-medium@asusmedium-UN65H:~$ cd ~/Desktop/lwa_enb/srsepc/
asus-medium@asusmedium-UN65H:~/Desktop/lwa_enb/srsepc$ ./srsepc_if_masq.sh wlp3s0
[sudo] password for asus-medium:
Masquerading Interface wlp3s0
asus-medium@asusmedium-UN65H:~/Desktop/lwa_enb/srsepc$ sudo srsepc epc.conf

---  Software Radio Systems EPC  ---

Reading configuration file epc.conf...
HSS Initialized.
MME GTP-C Initialized
MME Initialized.
SP-GW Initialized.
```

執行 srsENB

在eNB再開一個新的終端機輸入

- cd ~/path/to/srsLTE/srsenb
- sudo srsenb enb.conf

```
asus-medium@asusmedium-UN65H: ~/Desktop/lwa_enb/srsenb
asus-medium@asusmedium-UN65H:~$ cd ~/Desktop/lwa_enb/srsenb/
asus-medium@asusmedium-UN65H:~/Desktop/lwa_enb/srsenb$ sudo srsenb enb.conf
[sudo] password for asus-medium:
---  Software Radio Systems LTE eNodeB  ---

Reading configuration file enb.conf...
[INFO] [UHD] linux; GNU C++ version 5.4.0 20160609; Boost_105800; UHD_3.14.
0.0-release
Opening USRP with args: type=b200,master_clock_rate=30.72e6
[INFO] [B200] Detected Device: B210
[INFO] [B200] Operating over USB 3.
[INFO] [B200] Initialize CODEC control...
[INFO] [B200] Initialize Radio control...
[INFO] [B200] Performing register loopback test...
[INFO] [B200] Register loopback test passed
[INFO] [B200] Performing register loopback test...
[INFO] [B200] Register loopback test passed
[INFO] [B200] Asking for clock rate 30.720000 MHz...
[INFO] [B200] Actually got clock rate 30.720000 MHz.
Setting frequency: DL=2160.0 Mhz, UL=1970.0 MHz
[INFO] [B200] Asking for clock rate 23.040000 MHz...
[INFO] [B200] Actually got clock rate 23.040000 MHz.
Setting Sampling frequency 5.76 MHz

==== eNodeB started ===
Type <t> to view trace
```

執行 srsUE

在UE開一個新的終端機輸入

- cd ~/path/to/srsLTE/srsue
- sudo srsue ue.conf

```
ue@ue-X580VD: ~/Desktop/lwaap_ue/srsue
ue@ue-X580VD:~$ cd ~/Desktop/lwaap_ue/srsue/
ue@ue-X580VD:~/Desktop/lwaap_ue/srsue$ sudo srsue ue.conf
[sudo] password for ue:
Reading configuration file ue.conf...

Built in Release mode using commit 0a69e56 on branch develop_ue.

Buffer capacity 10240
Buffer capacity 40960
---  Software Radio Systems LTE UE  ---

Opening RF device with 1 RX antennas...
[INFO] [UHD] linux; GNU C++ version 5.4.0 20160609; Boost_105800; UHD_3.14.0.0-r
elease
Opening USRP with args: type=b200,master_clock_rate=30.72e6
[INFO] [B200] Detected Device: B210
[INFO] [B200] Operating over USB 3.
[INFO] [B200] Initialize CODEC control...
[INFO] [B200] Initialize Radio control...
[INFO] [B200] Performing register loopback test...
[INFO] [B200] Register loopback test passed
[INFO] [B200] Performing register loopback test...
[INFO] [B200] Register loopback test passed
[INFO] [B200] Asking for clock rate 30.720000 MHz...
[INFO] [B200] Actually got clock rate 30.720000 MHz.
LWAAP MAC f4:96:34:3:6a:a6
LWAAP IP packet receiver thread run_enable
Waiting PHY to initialize...
...
Attaching UE...
Searching cell in DL EARFCN=500, f_dl=2160.0 MHz, f_ul=1970.0 MHz
.
Found Cell:  PCI=1, PRB=25, Ports=1, CFO=0.5 KHz
[INFO] [B200] Asking for clock rate 23.040000 MHz...
[INFO] [B200] Actually got clock rate 23.040000 MHz.
Found PLMN:  Id=00101, TAC=7
Random Access Transmission: seq=9, ra-rnti=0x2
Random Access Transmission: seq=42, ra-rnti=0x2
Random Access Transmission: seq=9, ra-rnti=0x2
RRC Connected
Random Access Complete.     c-rnti=0x48, ta=0
Network attach successful. IP: 172.16.0.2
Software Radio Systems LTE (srsLTE)
```

流量測試

在EPC開一個新的終端機輸入

- iperf3 -s -B 172.16.0.1

```
nuk@nuk: ~/iperf
nuk@nuk:~/iperf$ iperf3 -s -B 172.16.0.1
-----------------------------------------------------------
Server listening on 5201
-----------------------------------------------------------
Accepted connection from 172.16.0.2, port 44411
[  5] local 172.16.0.1 port 5201 connected to 172.16.0.2 port 38249
[ ID] Interval           Transfer     Bitrate         Total Datagrams
[  5]   0.00-1.00   sec  11.9 MBytes  99.9 Mbits/sec  8759
[  5]   1.00-2.00   sec  11.9 MBytes   100 Mbits/sec  8765
[  5]   2.00-3.00   sec  11.9 MBytes   100 Mbits/sec  8766
[  5]   3.00-4.00   sec  11.9 MBytes   100 Mbits/sec  8766
[  5]   4.00-5.00   sec  11.9 MBytes   100 Mbits/sec  8766
[  5]   5.00-6.00   sec  11.9 MBytes   100 Mbits/sec  8765
[  5]   6.00-7.00   sec  11.9 MBytes   100 Mbits/sec  8766
```

在UE開一個新的終端機輸入

- iperf3 -c 172.16.0.1 -B 172.16.0.2 -u -l 1426b -t 120 -b 100m -R

```
nuk@nuk: ~
nuk@nuk:~$ iperf3 -c 172.16.0.1 -B 172.16.0.2 -l 1426b -t 120 -u -b 100m -R
Connecting to host 172.16.0.1, port 5201
Reverse mode, remote host 172.16.0.1 is sending
[  5] local 172.16.0.2 port 38249 connected to 172.16.0.1 port 5201
[ ID] Interval           Transfer     Bitrate         Jitter    Lost/Total Datagrams
[  5]   0.00-1.00   sec  9.69 MBytes  81.2 Mbits/sec  0.170 ms  1829/8951 (20%)
[  5]   1.00-2.00   sec  9.31 MBytes  78.1 Mbits/sec  0.185 ms  1916/8763 (22%)
[  5]   2.00-3.00   sec  9.33 MBytes  78.3 Mbits/sec  0.153 ms  1916/8776 (22%)
[  5]   3.00-4.00   sec  12.0 MBytes   101 Mbits/sec  0.048 ms  947/9784 (9.7%)
[  5]   4.00-5.00   sec  11.9 MBytes   100 Mbits/sec  0.042 ms  0/8766 (0%)
[  5]   5.00-6.00   sec  11.9 MBytes   100 Mbits/sec  0.060 ms  0/8765 (0%)
```

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- srsLTE-nukxDC實驗環境
  - 軟硬體環境
  - srsLTE 架構
- srsLTE 網路實驗平台建置
  - 一. 環境設定及安裝必要軟體
  - 二. 編譯及安裝srsLTE
  - 三. 設定srsLTE設定檔
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  - 二. nukxDC設定及流量測試-封包排序
  - 三. nukxDC設定及流量測試-自動調整傳輸比例
- Summary
- Questions

Summary

- 了解LTE的運作架構及流程
- 透過建置srsLTE 的環境來學習Ubuntu系統指令之操作
- 在兩台主機上安裝和配置srsLTE nukxDC(LWA)
  - 了解srsLTE 參數之設置
  - 了解srsLTE 之執行過程及狀況
  - 從srsLTE 觀察 UE 和eNB之間的底層訊息的狀況
  - 觀察nukxDC(LWA)對傳輸資料時對流量的影響

Outline

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- Questions

Questions

1. 嘗試調整LTE與WLAN的固定比例，觀察不同比例對流量的影響。

2. 啓動封包重新排序的功能，嘗試調整等待封包的時限，觀察等待時間對流量的影響。

3. 啓動LTE與WLAN自動調整比例的功能，嘗試調整UE回報eNB的時間週期，觀察回報時間週期對流量的影響。