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

Mobile Edge Computing: 行動邊緣計算

實驗單元-02：
邊緣計算實作環境建置—雲端伺服器及邊緣計算伺服器

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國立高雄科技大學 電腦與通訊工程系

Outline

- 實驗目的及實驗內容
- 實驗環境
- 平台架設需求
- Cloud Server 平台安裝
- Edge Server 平台安裝
- UE 安裝

實驗目的

- 在 Linux 平台架設雲端伺服器 (Cloud Server) 與邊緣伺服器(Edge Server)。
- UE 連接 Cloud Server 與 Edge Server 的基本觀察與量測。

實驗內容

- 使用 Linux 平台架設 Edge Server (邊緣伺服器, 含 OAI-LTE)
- 使用 Linux 平台架設 Cloud Server (雲端伺服器)
- 使用UE 以 USRP 連接 Edge Server 與 Cloud Server 進行基本觀察與量測

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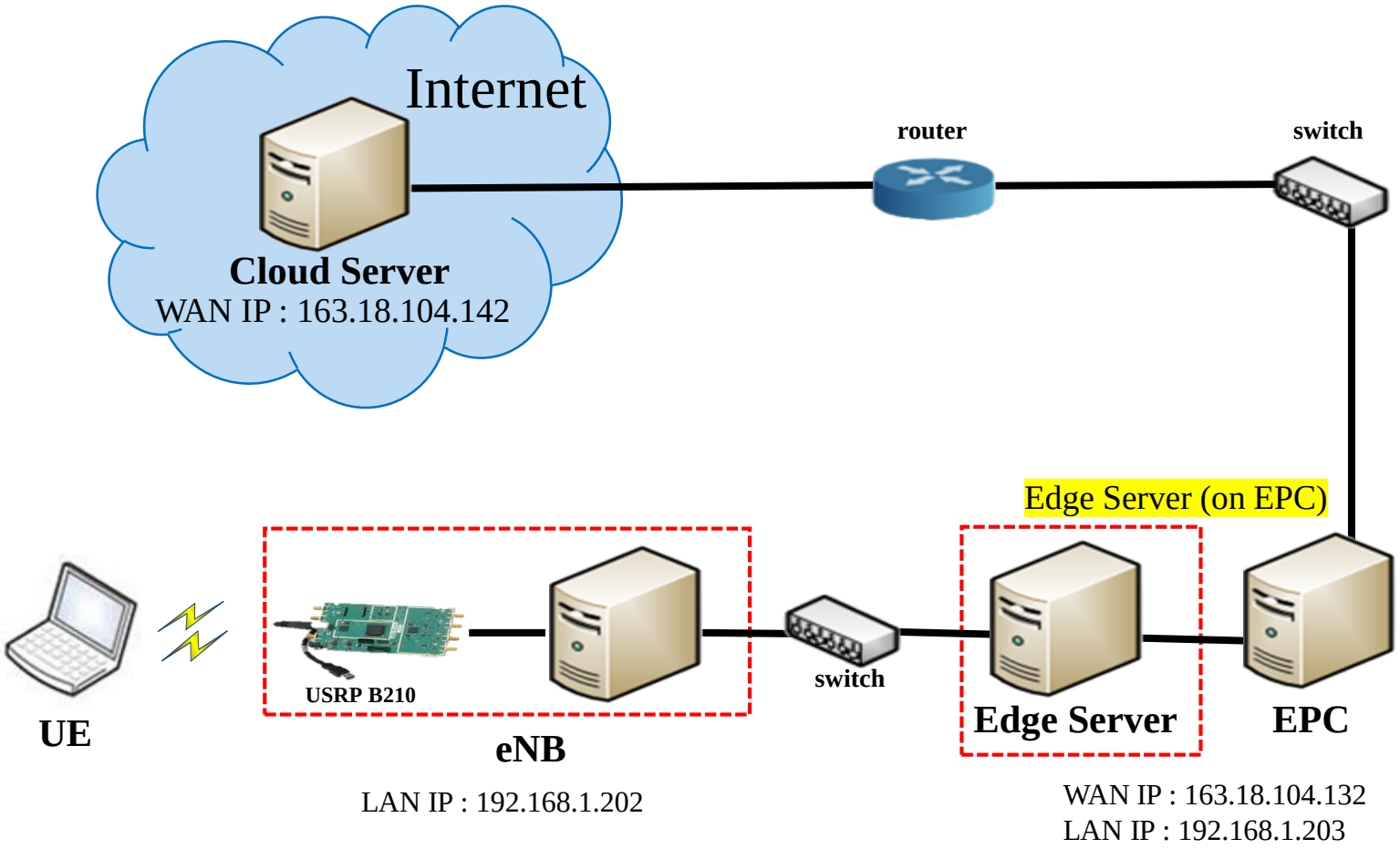
實驗架構


Internet
Cloud Server
WAN IP : 163.18.104.142
router
switch
Edge Server (on EPC)
USRP B210
UE
eNB
LAN IP : 192.168.1.202
switch
Edge Server
EPC
WAN IP : 163.18.104.132
LAN IP : 192.168.1.203

實驗設備-硬體(1/2)

名稱	硬體	數量	目的
Cloud Server	CPU: i7-6500U RAM: 8 GB HDD: 1 TB	1台	當雲端伺服器
	Ethernet Network PCIE Card	1個	連接WAN (for Internet)
Edge Server	CPU: i7-8559U RAM: 32 GB SSD: 1 TB	1台	當邊緣伺服器(on EPC)
	Ethernet Network PCIE Card	1個	連接WAN (for Internet)
	RJ45外接網卡 (USB)	1個	連接LAN (for eNB)
eNB	CPU: i7-8559U RAM: 32 GB SSD: 1 TB	1台	eNodeB基地台
	Ethernet Network PCIE Card (embedded)	1個	連接EPC的LAN
	USRP B210	1片	接收 eNB 封包資料 LTE訊號收發
	VERT2450 Antenna	2支	收發 LTE Band 7 (2600 MHz) 訊號
	USB 3.0 cable	1條	連接 eNB 與 USRP B210

實驗設備-硬體(2/2)

名稱	硬體	數量	目的
UE	CPU: i5-6200U RAM: 4 GB HDD: 500 GB	1台	連接eNB，瀏覽影片
	4G Dongle	1個	提供電腦使用行動網路
	LTE SIM卡	1張	提供UE使用，註冊EPC
Switch	4-port switch (legacy)	1台	LAN互相連接
RJ45雙絞線	RJ45雙邊接頭的CAT 5e網路線	5條	Edge*2條、eNB*1條 Cloud*1條、Web Server*1條

實驗設備-軟體

名稱	軟體	版本
Cloud Server	OS：Ubuntu	16.04 LTS
	Nginx	1.5.0
	C Language	5.4.0
	OpenCV	4.1.0
Edge Server	OS：Ubuntu	16.04 LTS
	OAI-EPC	https://gitlab.eurecom.fr/oai/openair-cn.git (發布日期:2017/3/31)
	Nginx	1.5.0
	C Language	5.4.0
	OpenCV	4.1.0
eNB	OS：Ubuntu	16.04 LTS
	OAI-eNB	https://gitlab.eurecom.fr/oai/openairinterface5g/tree/17b9a9e917ce2a3a8c7004c7b9a221c350ddfe17 (發布日期:2015/8/8)
UE	OS：Ubuntu	16.04 LTS
	FFmpeg	2.8.17

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- Edge Server 平台安裝
- UE 安裝

Cloud Server 安裝需求

Cloud Server的安裝需求(ubuntu 16.04)

1. Video Streaming Server 安裝
   – Nginx 軟體

2. TCP/UDP Socket 安裝
   – C Language 軟體

3. Digital Image Processing 安裝
   – OpenCV 軟體

Edge Server 安裝需求

Edge Server的安裝需求(ubuntu 16.04)

1. Video Streaming Server 安裝
   – Nginx 軟體

2. TCP/UDP Socket 安裝
   – C Language 軟體

3. Digital Image Processing 安裝
   – OpenCV 軟體

4. Radio Access Network 安裝
   – OAI-EPC 軟體，請參考實驗單元-01

其他安裝需求

UE的安裝需求(ubuntu 16.04)

1. 影片瀏覽
   - FFmpeg

eNodeB安裝需求(ubuntu 16.04)

1. Radio Access Network 安裝
   - OAI-eNB 軟體，請參考實驗單元-01

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Cloud Server 安裝

Edge Server的安裝需求(ubuntu 16.04)

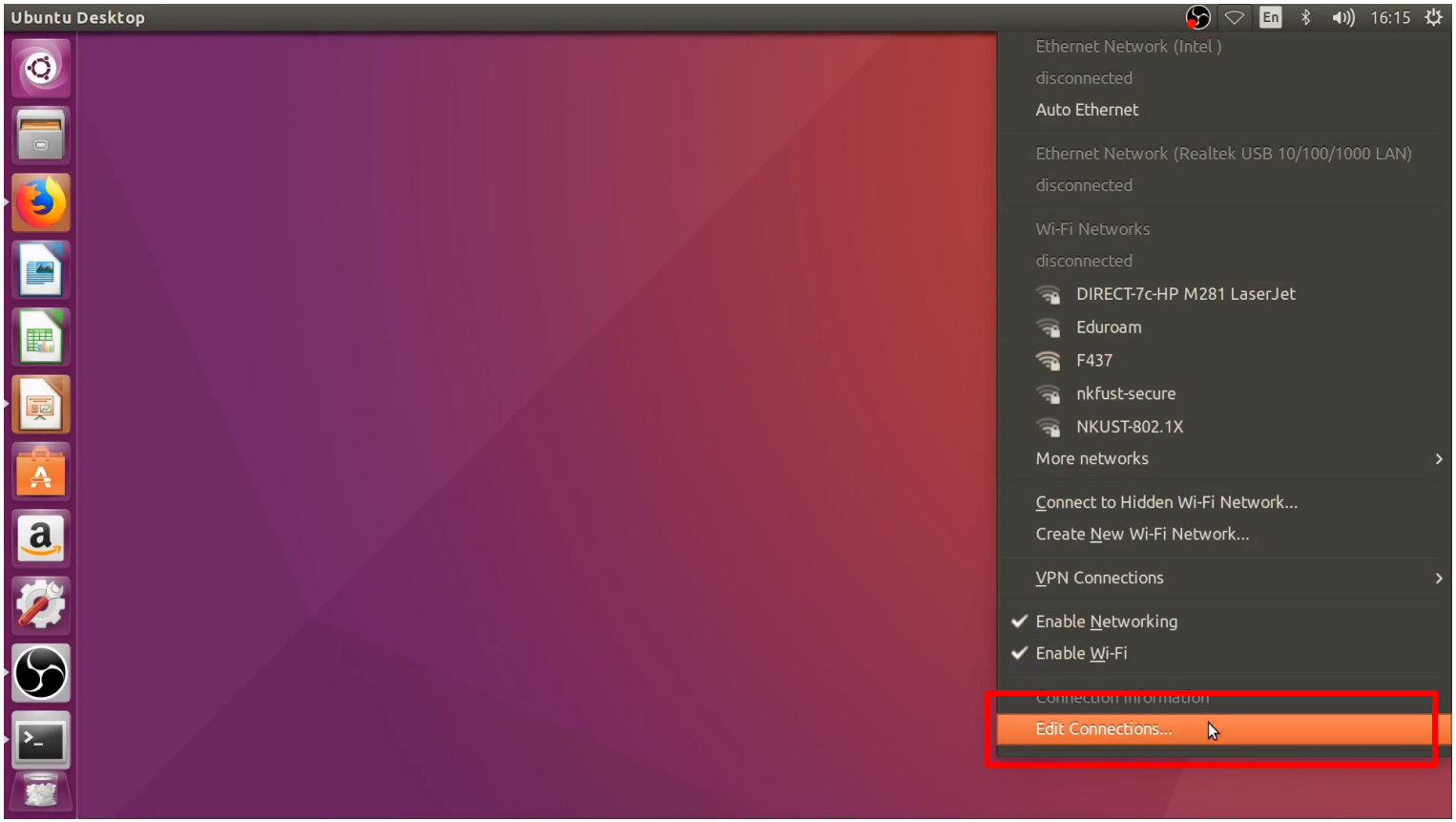
1. Video Streaming Server 安裝
   – Nginx 軟體

2. TCP/UDP Socket 安裝
   – C Language 軟體

3. Digital Image Processing 安裝
   – OpenCV 軟體

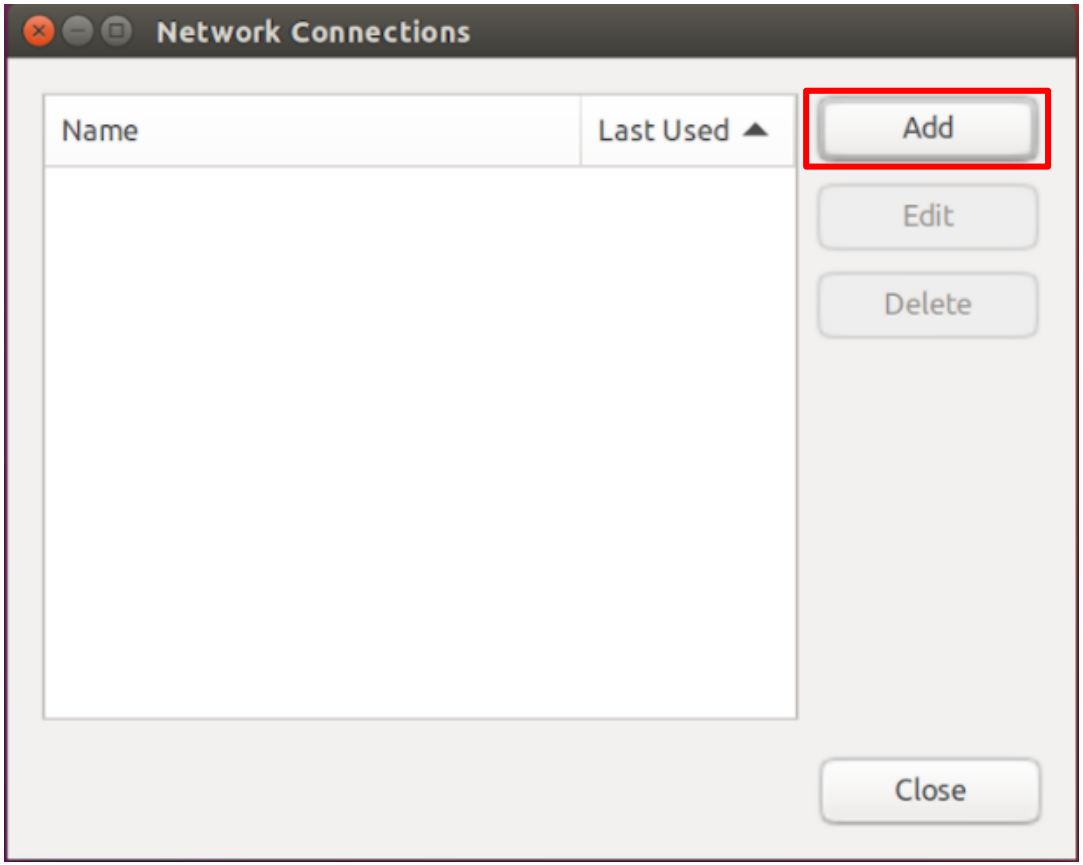
Nginx安裝(新增外網-1)

點選右上角Edit Connections



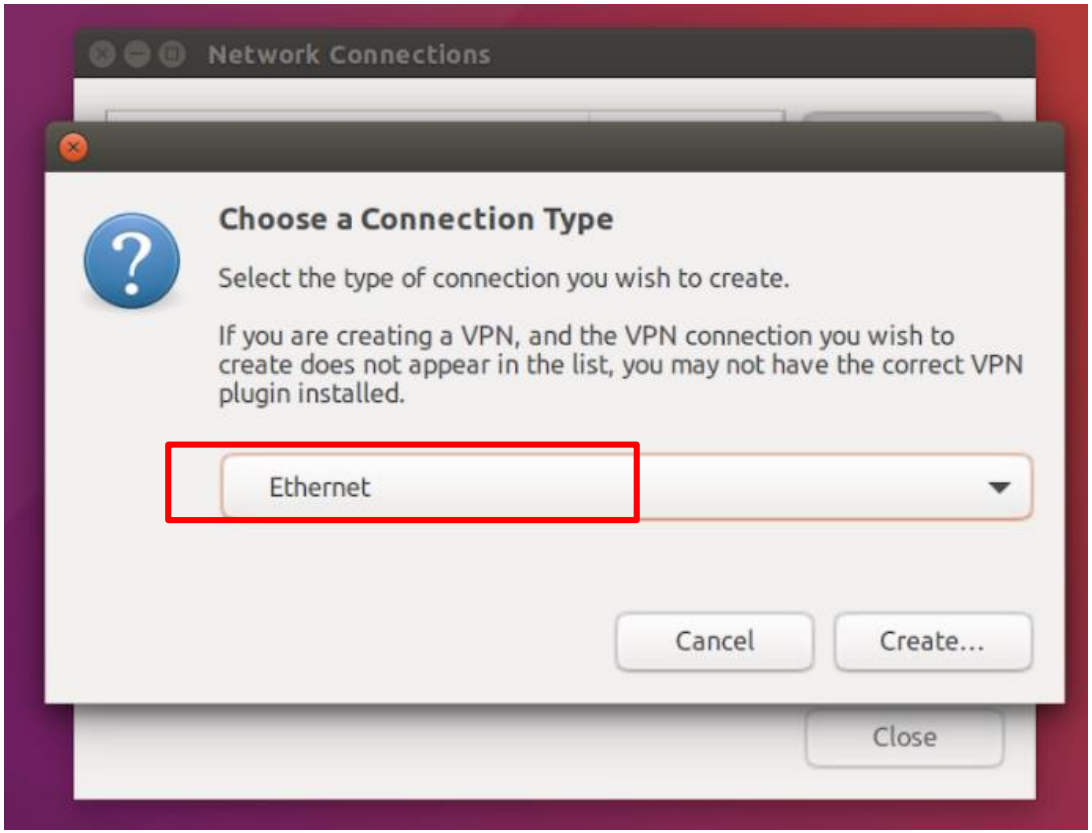
Nginx安裝(新增外網-2)

點選Add新增外網



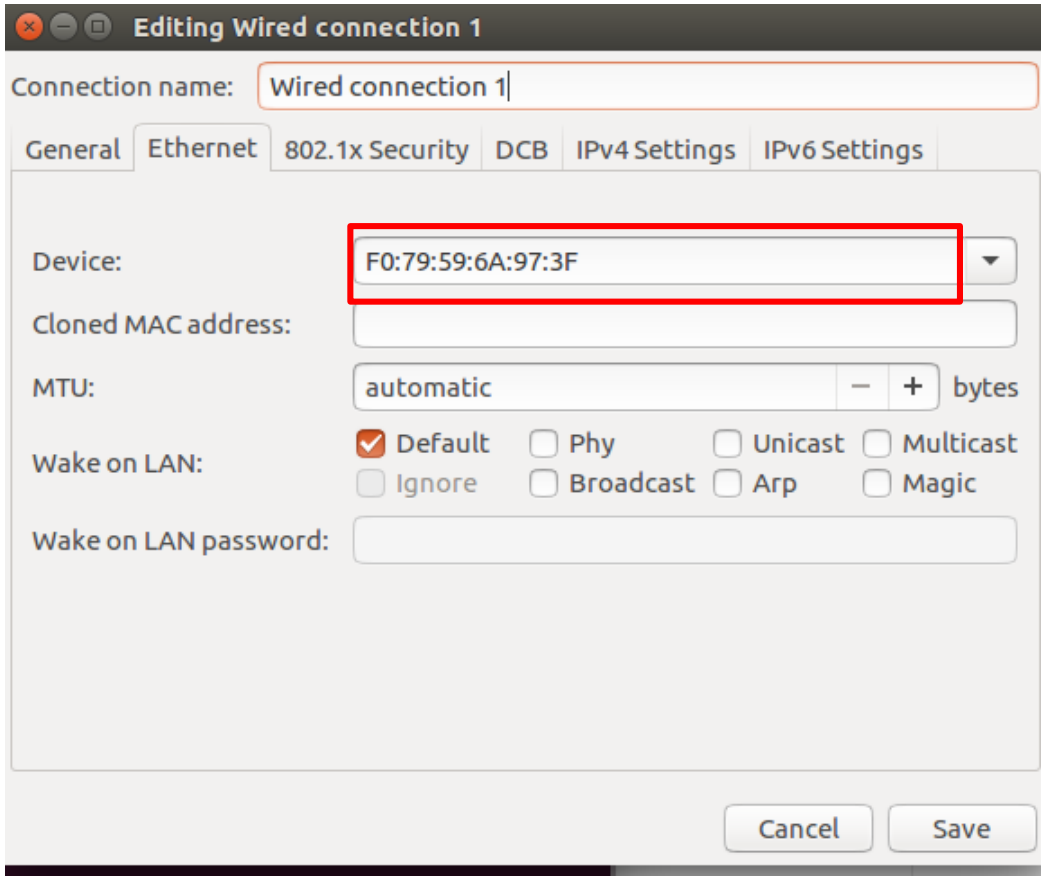
Nginx安裝(新增外網-3)

模式選擇Ethernet



Nginx安裝(新增外網-4)

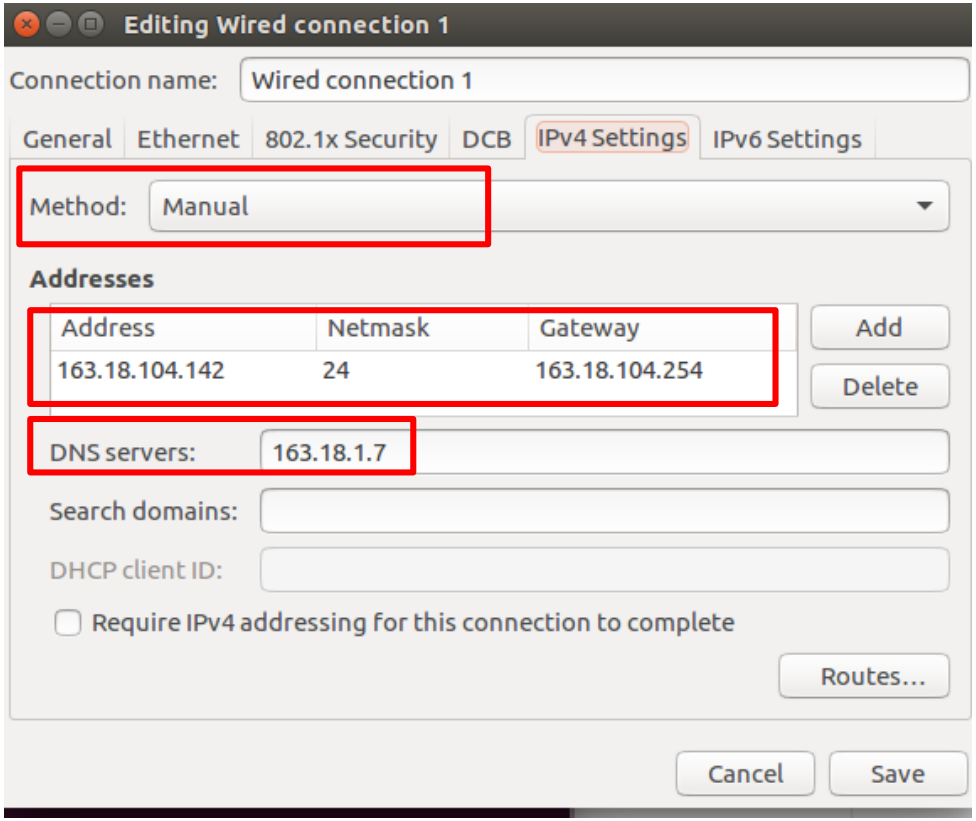
點選Ethernet -> device 選擇對應網卡



Nginx安裝(新增外網-5)

點選IPv4 Settings -> Method 選擇 Manual

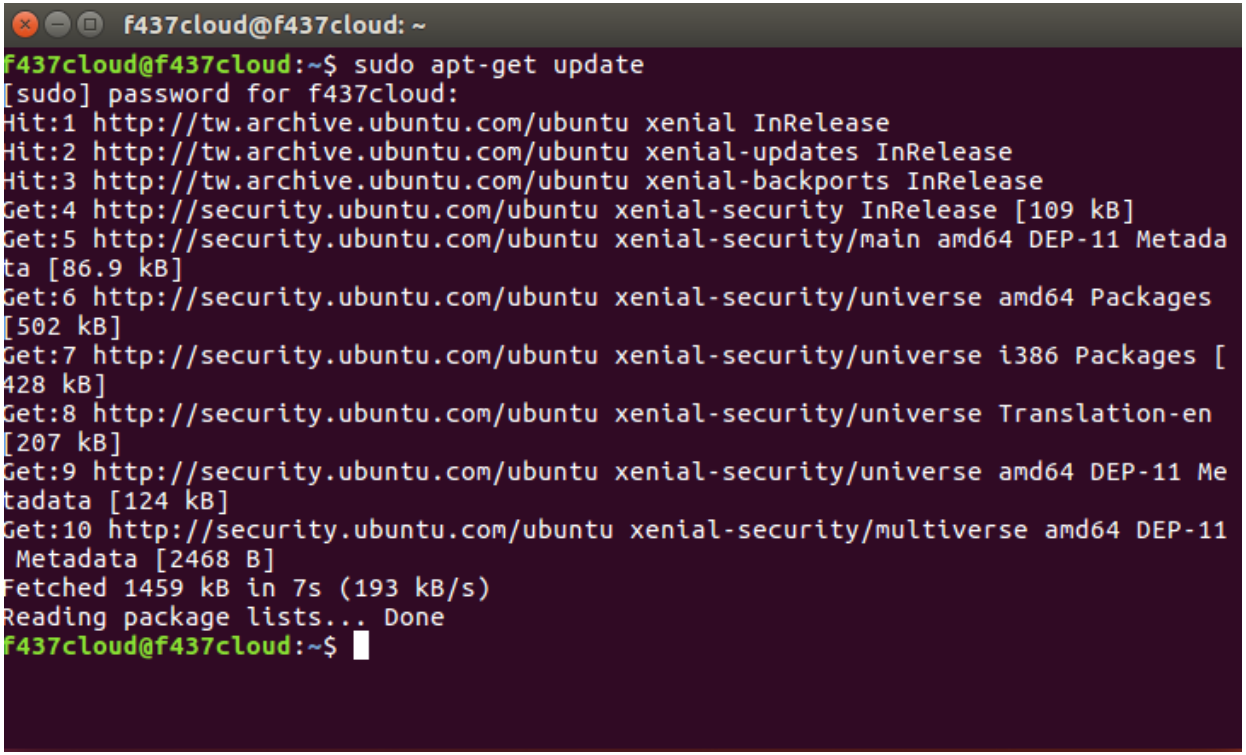
新增 Addresses (參照自己的IP設定)



Nginx安裝(更新ubuntu-1)

在終端機輸入

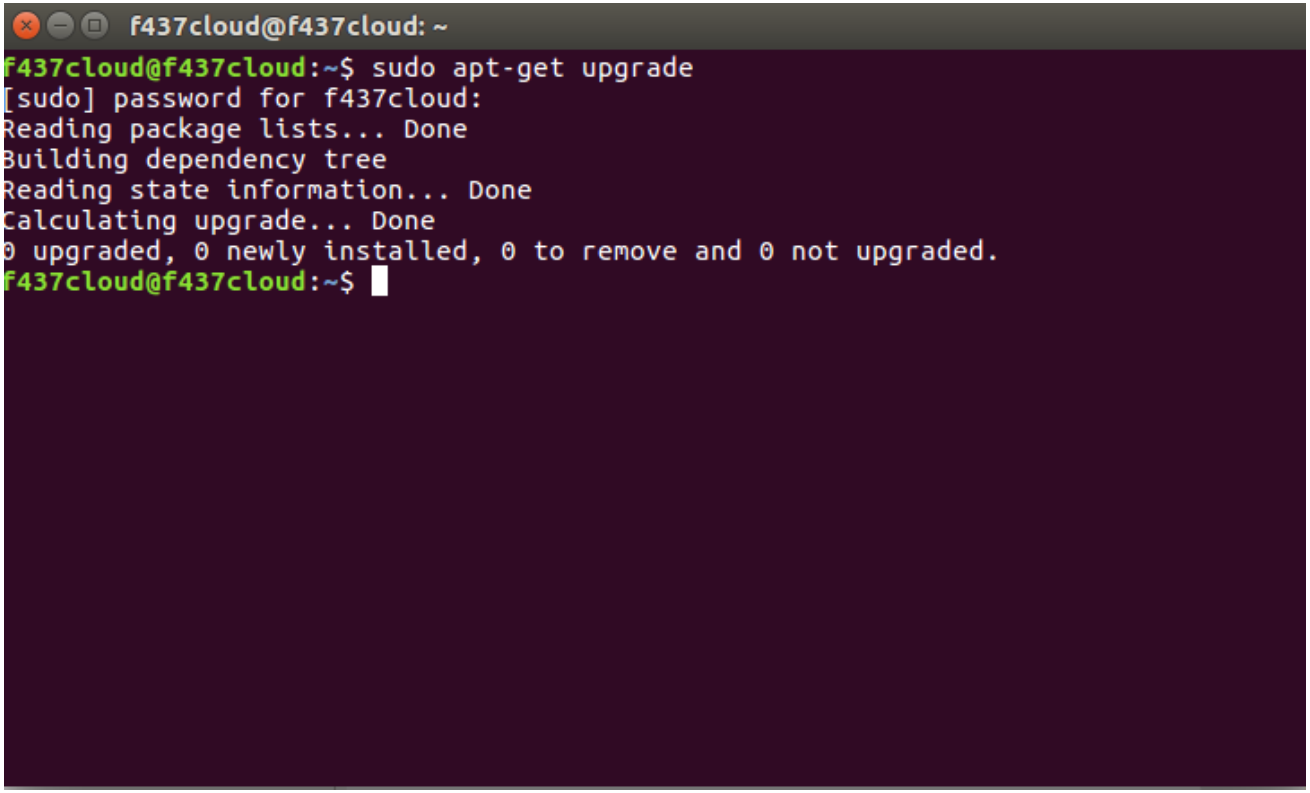
- $ sudo apt-get update



Nginx安裝(更新ubuntu-2)

在終端機輸入

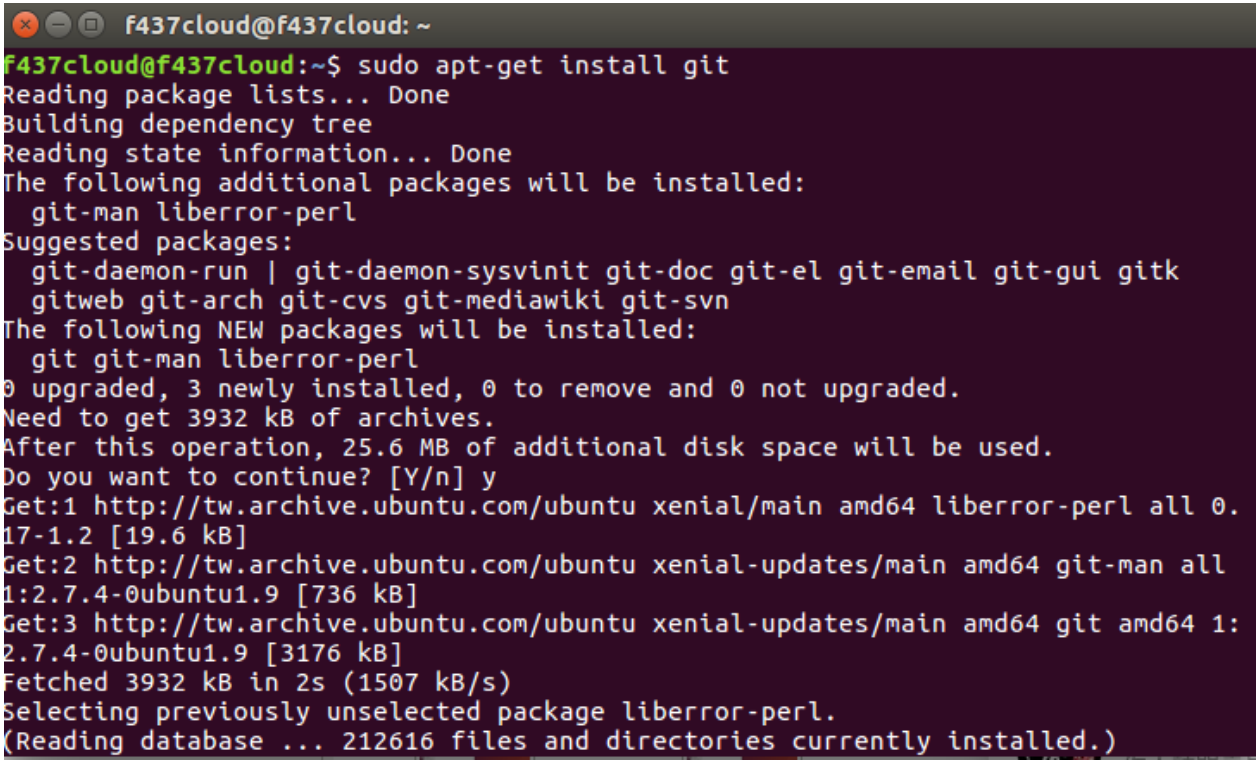
- $ sudo apt-get upgrade



Nginx安裝(安裝git)

在終端機輸入

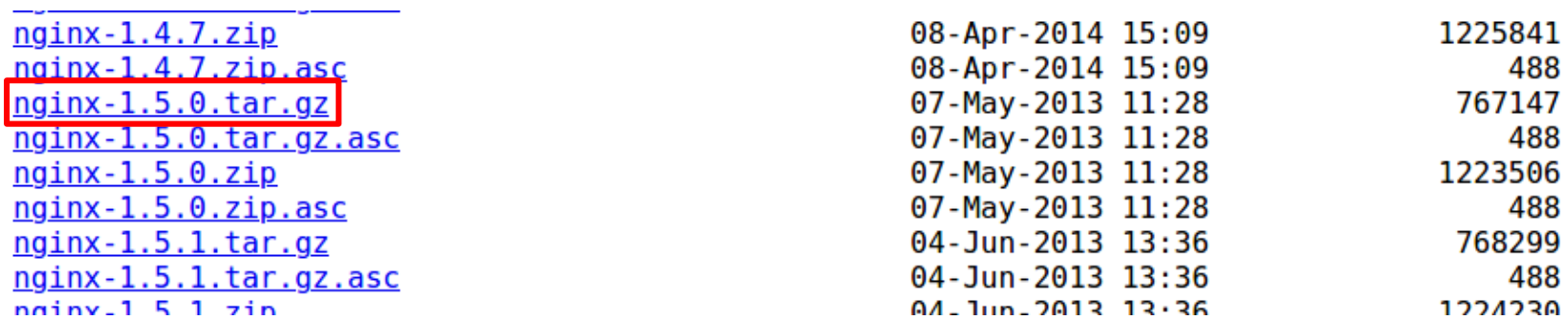
- $ sudo apt-get install git



Nginx安裝(下載nginx-1.5.0)

網址：http://nginx.org/download/

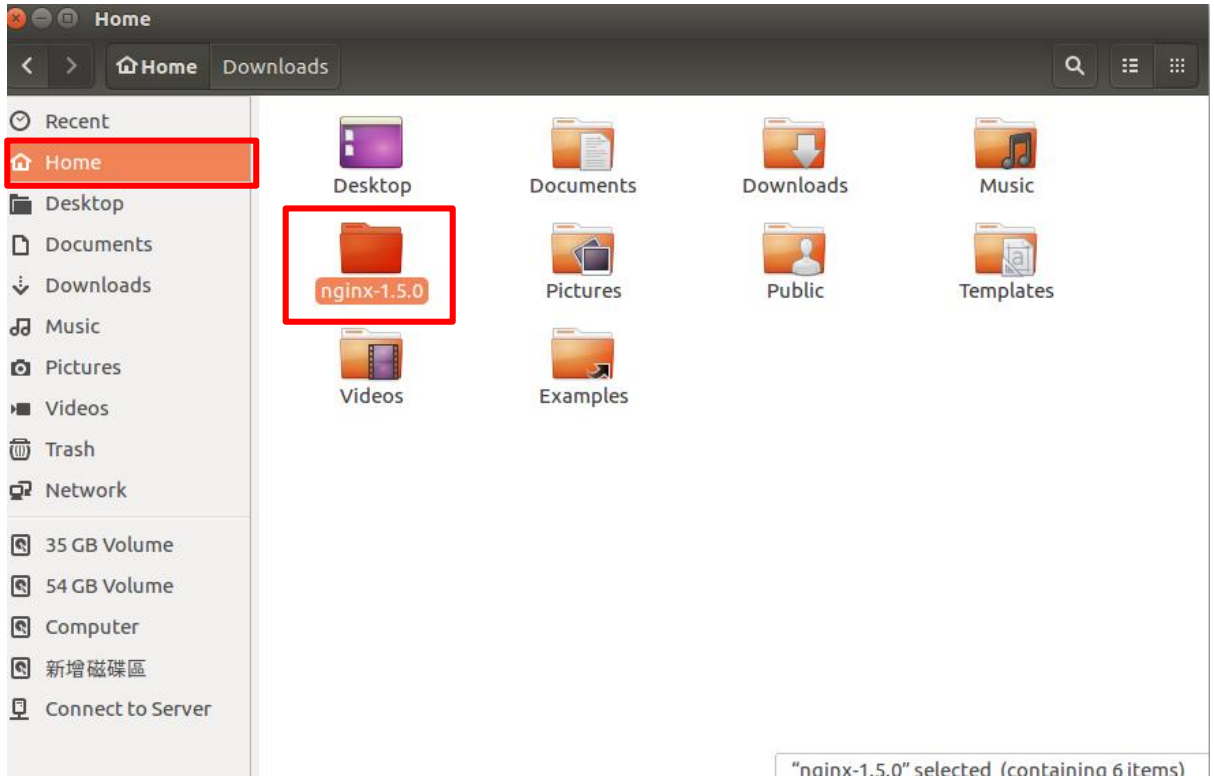
- 下載nginx-1.5.0.tar.gz



nginx-1.4.7.zip	08-Apr-2014 15:09	1225841
nginx-1.4.7.zip.asc	08-Apr-2014 15:09	488
nginx-1.5.0.tar.gz	07-May-2013 11:28	767147
nginx-1.5.0.tar.gz.asc	07-May-2013 11:28	488
nginx-1.5.0.zip	07-May-2013 11:28	1223506
nginx-1.5.0.zip.asc	07-May-2013 11:28	488
nginx-1.5.1.tar.gz	04-Jun-2013 13:36	768299
nginx-1.5.1.tar.gz.asc	04-Jun-2013 13:36	488

Nginx安裝(解壓nginx-1.5.0)

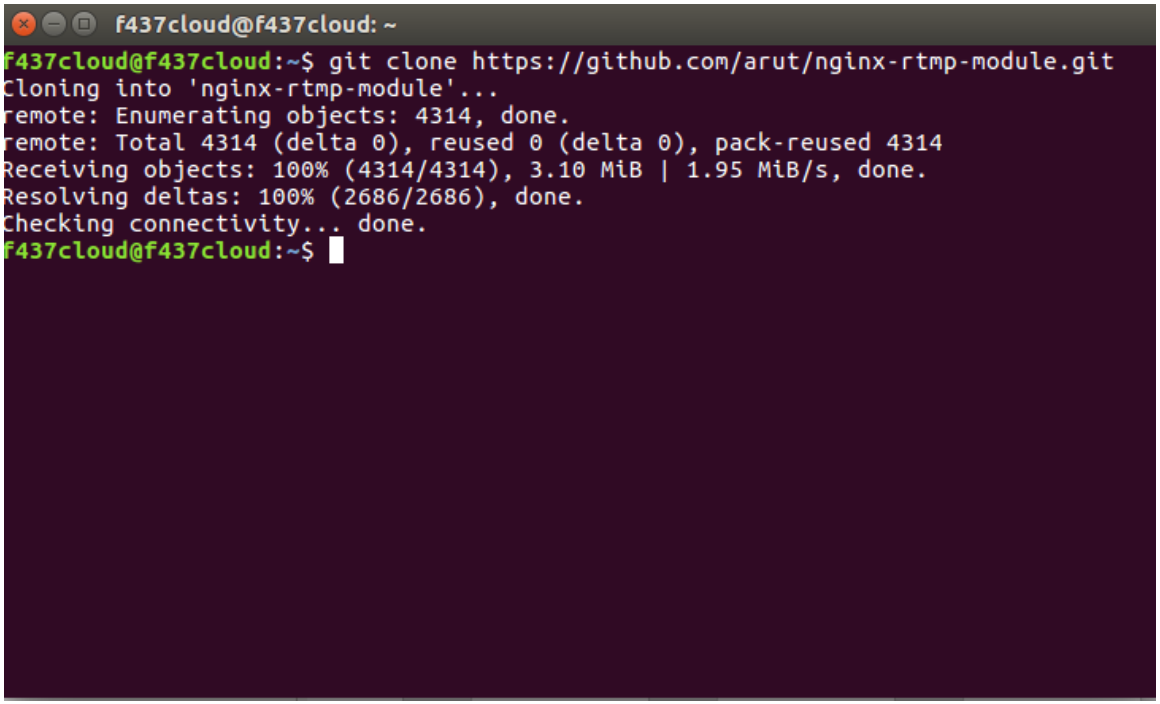
將nginx-1.5.0.tar.gz解壓縮到home下



Nginx安裝(安裝module)

在終端機輸入

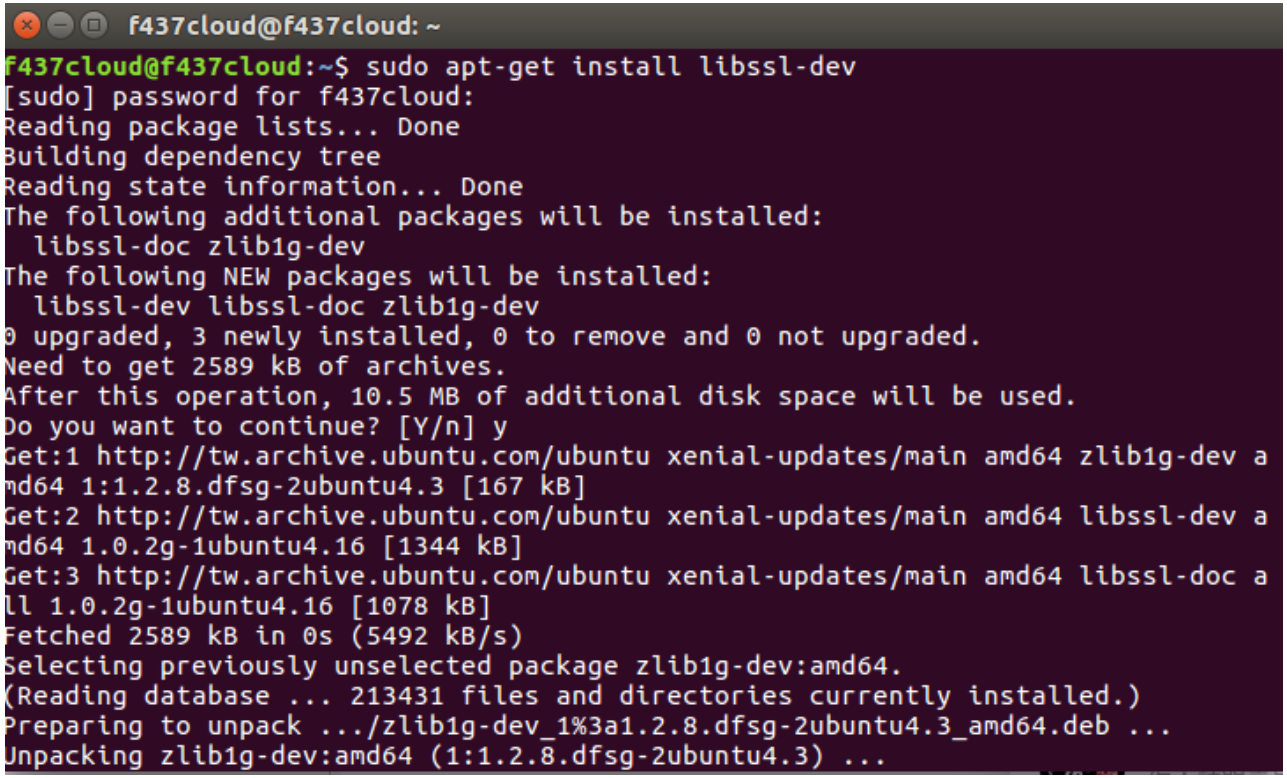
- $ git clone https://github.com/arut/nginx-rtmp-module.git



Nginx安裝(安裝套件)

在終端機輸入

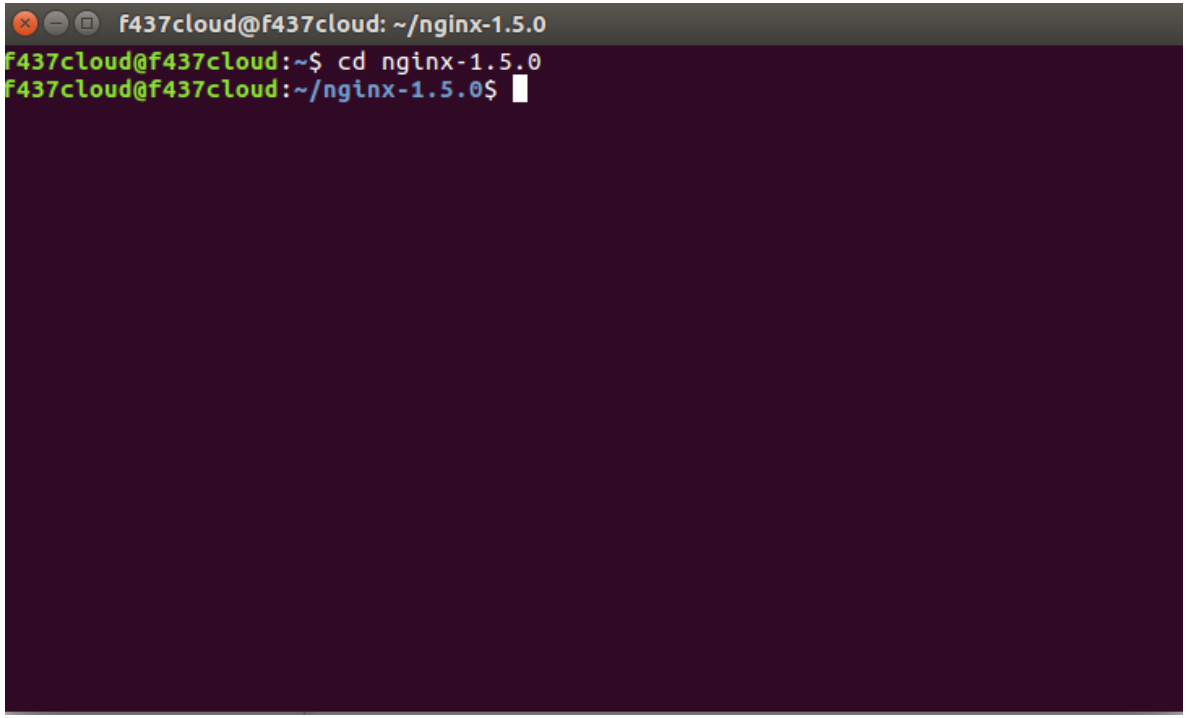
- $ sudo apt-get install libssl-dev



Nginx安裝(安裝nginx-1)

在終端機輸入

- $ cd nginx-1.5.0

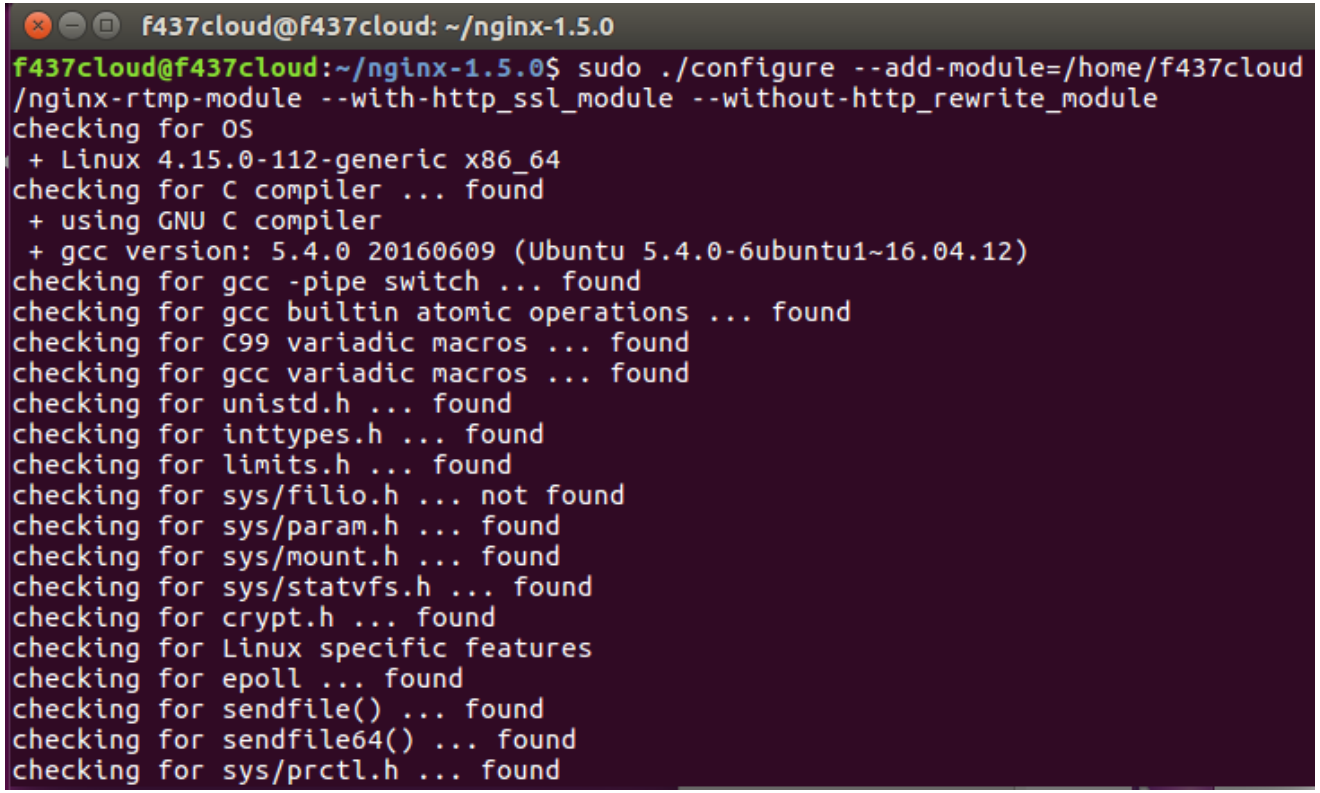


Nginx安裝(安裝nginx-2)

在終端機輸入

主機名稱

- $ sudo ./configure --add-module=/home/f437cloud/nginx-rtmp-module --with-http_ssl_module --without-http_rewrite_module



Nginx安裝(安裝nginx-3)

在終端機輸入

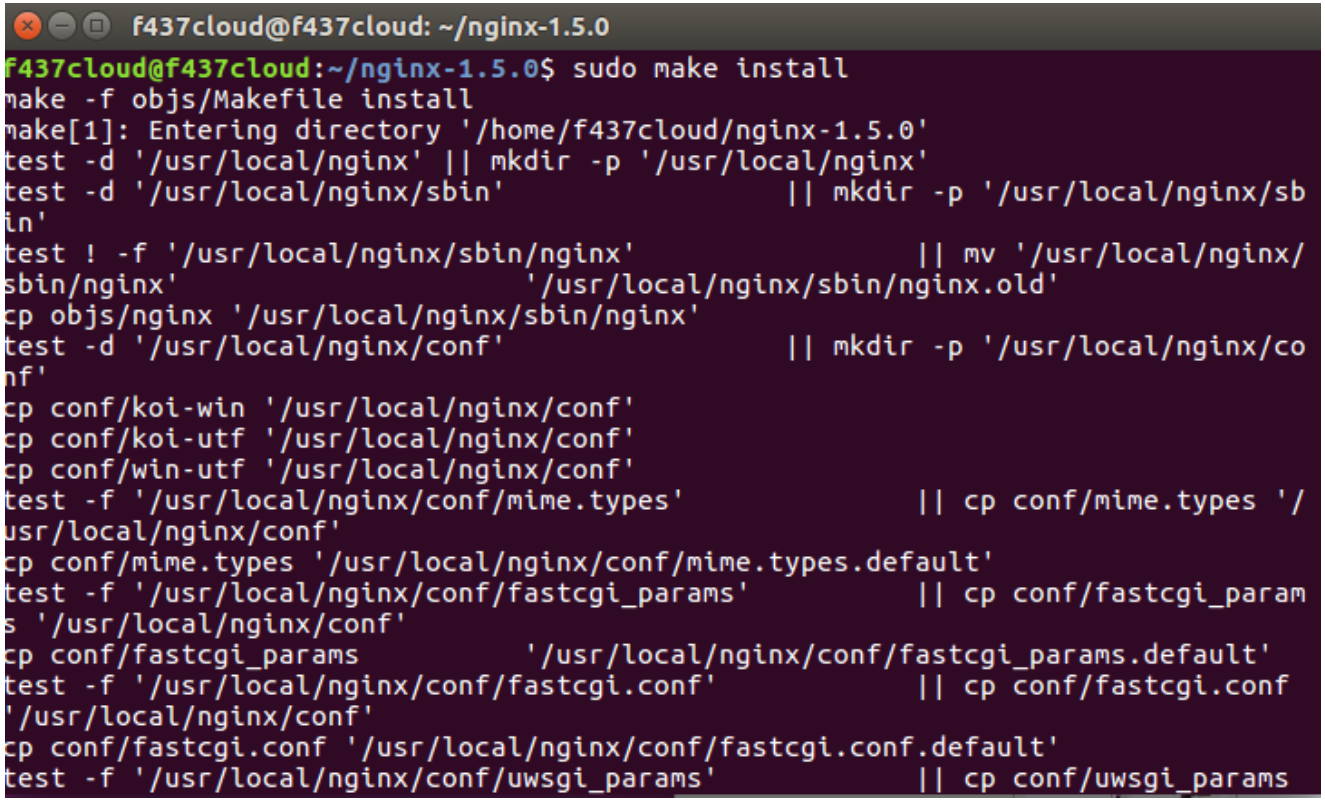
- $ sudo make

```
f437cloud@f437cloud:~/nginx-1.5.0$ sudo make
make -f objs/Makefile
make[1]: Entering directory '/home/f437cloud/nginx-1.5.0'
make[1]: 'objs/nginx' is up to date.
make[1]: Leaving directory '/home/f437cloud/nginx-1.5.0'
make -f objs/Makefile manpage
make[1]: Entering directory '/home/f437cloud/nginx-1.5.0'
make[1]: Nothing to be done for 'manpage'.
make[1]: Leaving directory '/home/f437cloud/nginx-1.5.0'
f437cloud@f437cloud:~/nginx-1.5.0$
```

Nginx安裝(安裝nginx-4)

在終端機輸入

- $ sudo make install



Nginx安裝(修改nginx)

在終端機輸入

- $ sudo gedit /usr/local/nginx/conf/nginx.conf
- 以下程式取代原本內容

```
worker_processes 2;
events {
    worker_connections 1024;
}
rtmp {
    server {          Server Port Number
        listen 1935;
        chunk_size 4000;

        application myapp {
                live on;   URL直播路徑
        }
        application vod {URL影片路徑
                play /home/f437cloud/Videos;
        }                          主機名稱
    }
}
```

Nginx安裝(執行nginx)

在終端機輸入

- $ cd /usr/local/nginx/sbin
- $ sudo ./nginx -c /usr/local/nginx/conf/nginx.conf

```
f437cloud@f437cloud: /usr/local/nginx/sbin
f437cloud@f437cloud:~$ cd /usr/local/nginx/sbin
f437cloud@f437cloud:/usr/local/nginx/sbin$ sudo ./nginx -c /usr/local/nginx/conf
/nginx.conf
f437cloud@f437cloud:/usr/local/nginx/sbin$
```

※如果發生下圖時，代表port 1935正在被使用，使用以下指令來刪除

- $ sudo lsof -i:1935

```
nginx: [emerg] bind() to 0.0.0.0:1935 failed (98: Address already in use)
nginx: [emerg] bind() to 0.0.0.0:1935 failed (98: Address already in use)
nginx: [emerg] bind() to 0.0.0.0:1935 failed (98: Address already in use)
nginx: [emerg] bind() to 0.0.0.0:1935 failed (98: Address already in use)
nginx: [emerg] bind() to 0.0.0.0:1935 failed (98: Address already in use)
nginx: [emerg] still could not bind()
```

- $ sudo kill “PID”　(ex:sudo kill 2140)

```
COMMAND  PID   USER   FD   TYPE DEVICE SIZE/OFF NODE NAME
nginx   2140   root    6u  IPv4  29207      0t0  TCP *:1935 (LISTEN)
nginx   2141 nobody    6u  IPv4  29207      0t0  TCP *:1935 (LISTEN)
nginx   2142 nobody    6u  IPv4  29207      0t0  TCP *:1935 (LISTEN)
```

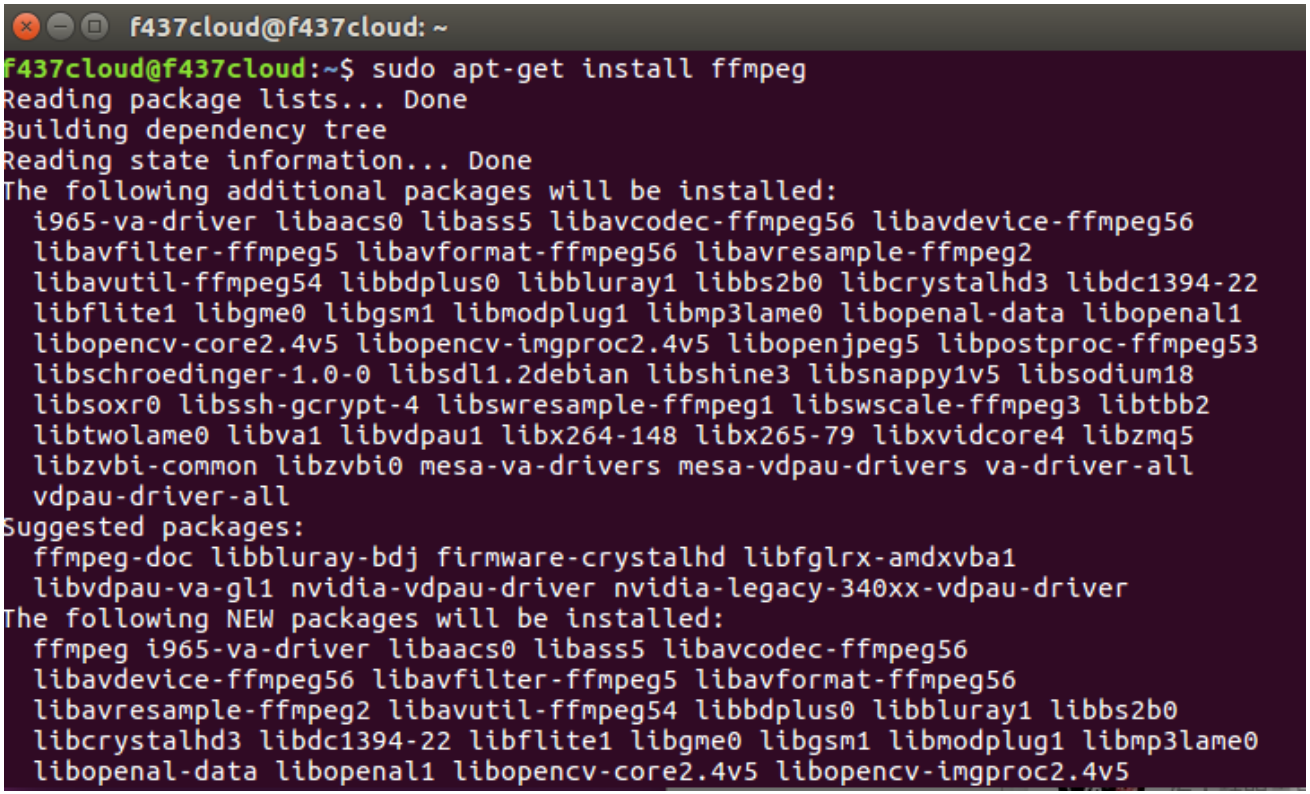
重新執行

- $ sudo ./nginx -c /usr/local/nginx/conf/nginx.conf

Nginx直播測試-1

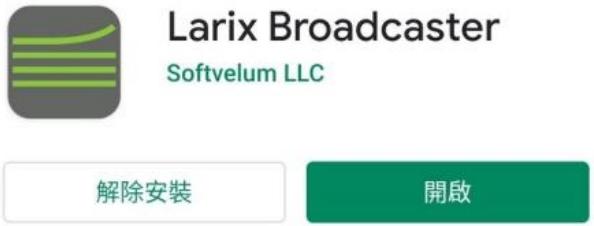
在終端機輸入

- $ sudo apt-get install ffmpeg



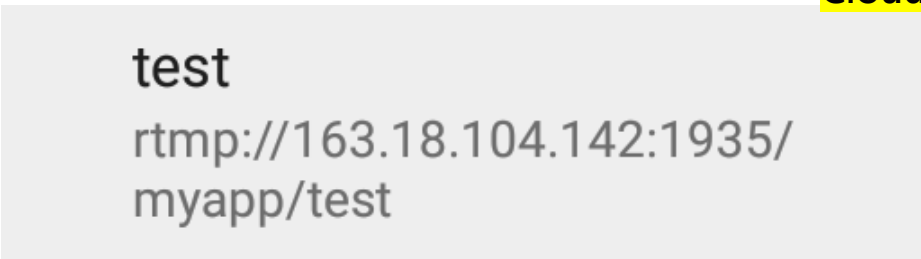
Nginx直播測試-2

任一台手機安裝Larix Broadcaster



Larix Broadcaster的Connections新增New connection，
新增 Name：test、URL：rtmp://163.18.104.142:1935/myapp/test

Cloud Server外網IP

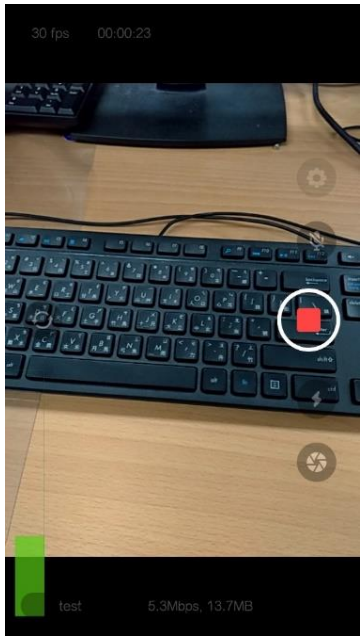


Nginx直播測試-3

- Larix Broadcaster參數設定

  Video size：1280x720、Bitrate：5000Kbps

- 手機按下紅色鍵，開始上傳影片到Cloud Server

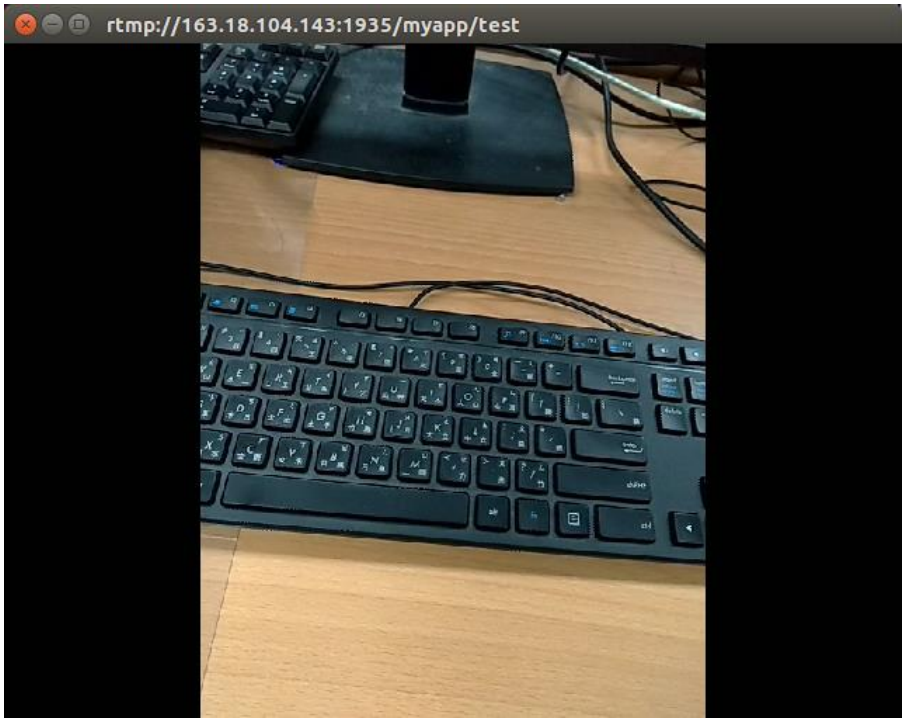


Nginx直播測試-4

- 在ubuntu上觀看手機拍攝上傳的影片

  $ ffplay rtmp://163.18.104.142:1935/myapp/test

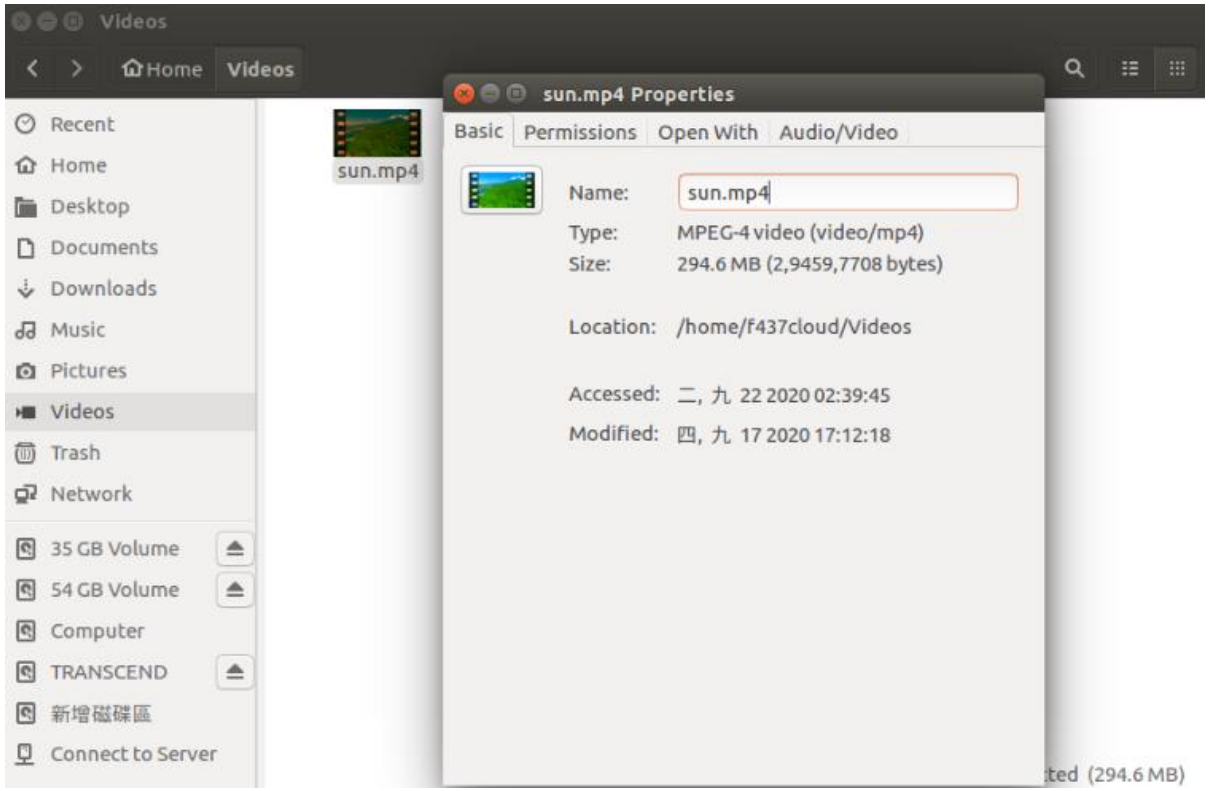
  Cloud Server外網IP



Nginx影片瀏覽測試-1

把影片放入到/home/f437cloud/Videos目錄下

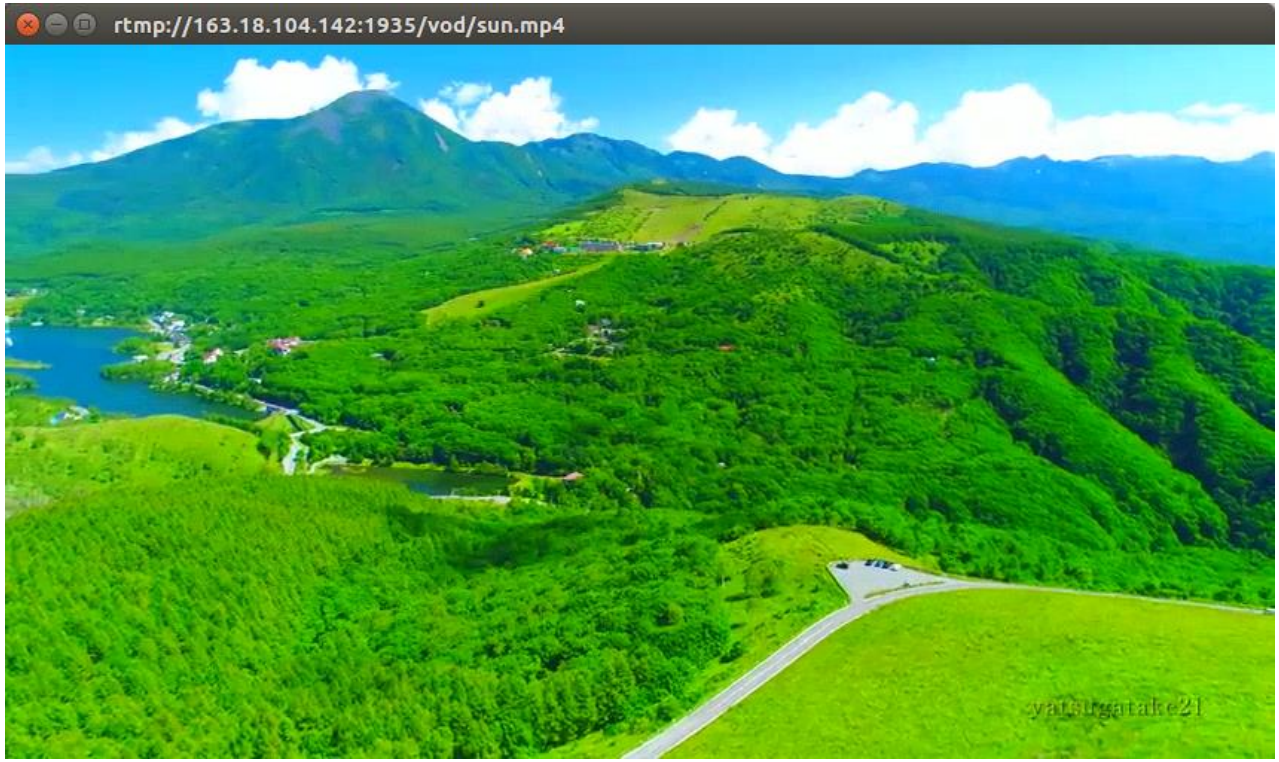
主機名稱



Nginx影片瀏覽測試-2

在終端機輸入

- $ ffplay rtmp://163.18.104.142:1935/vod/sun.mp4



Cloud Server 安裝

Edge Server的安裝需求(ubuntu 16.04)

1. Video Streaming Server 安裝
   – Nginx 軟體

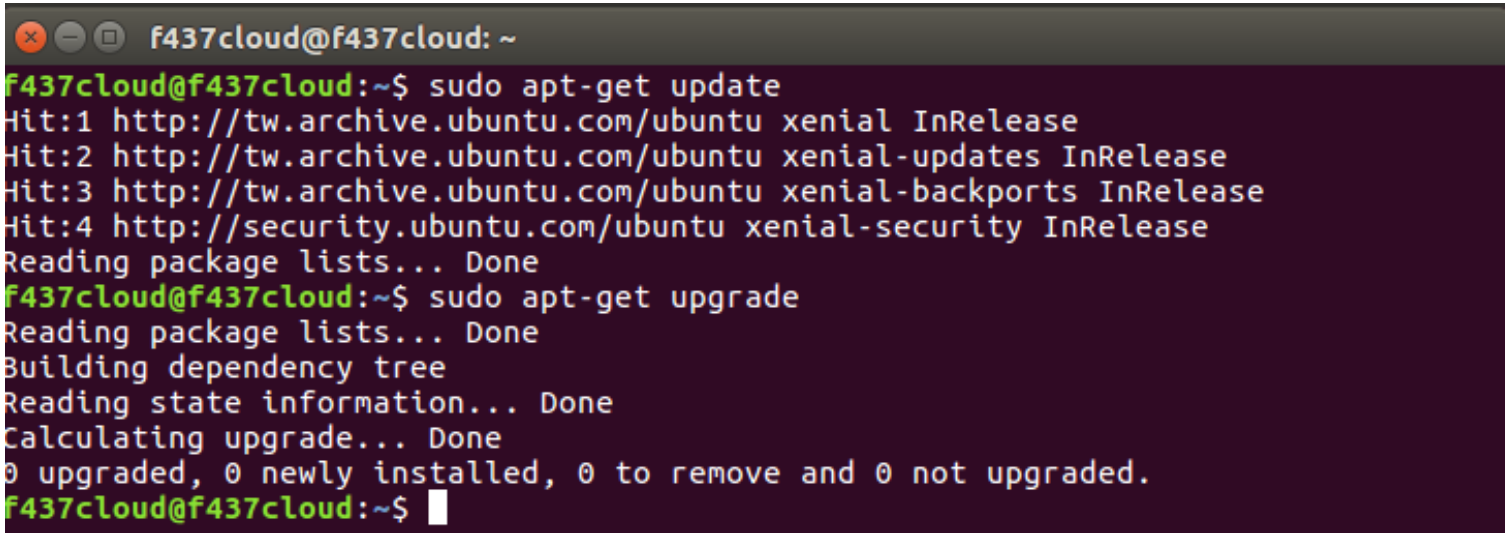
2. TCP/UDP Socket 安裝
   – C Language 軟體

3. Digital Image Processing 安裝
   – OpenCV 軟體

C Language(更新ubuntu)

在終端機輸入

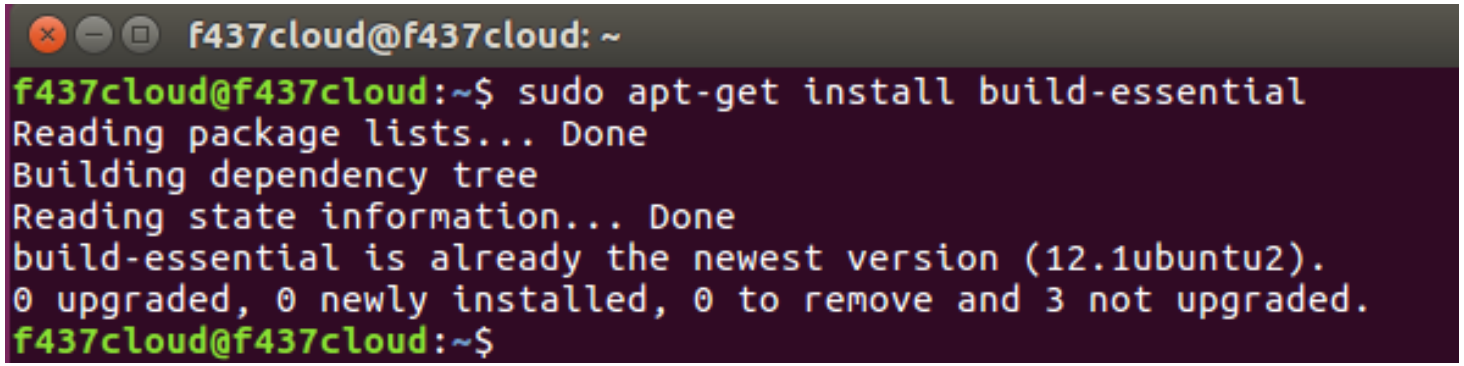
- $ sudo apt-get update
- $ sudo apt-get upgrade



C Language 安裝(安裝套件-1)

在終端機輸入

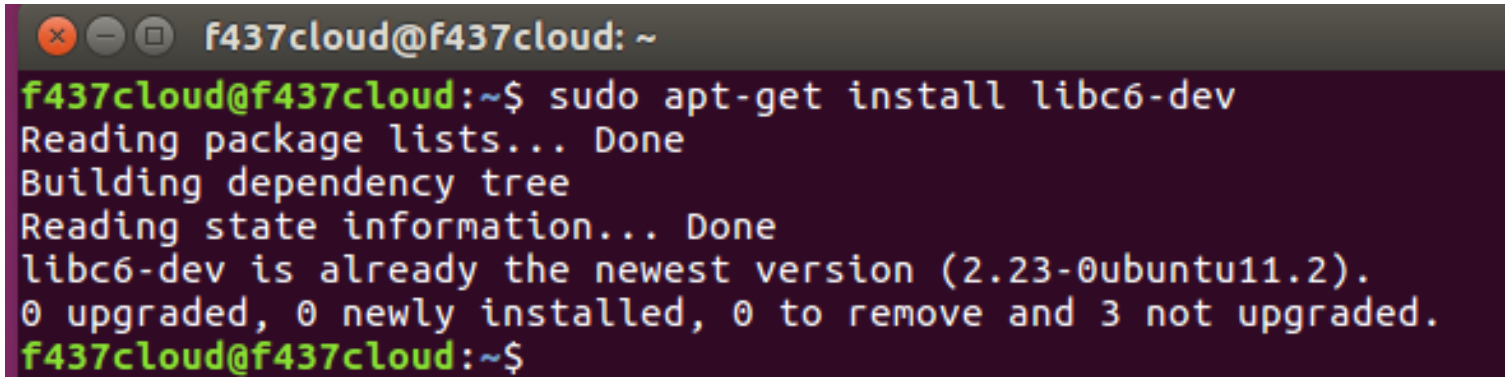
- $ sudo apt-get install build-essential



C Language 安裝(安裝套件-2)

在終端機輸入

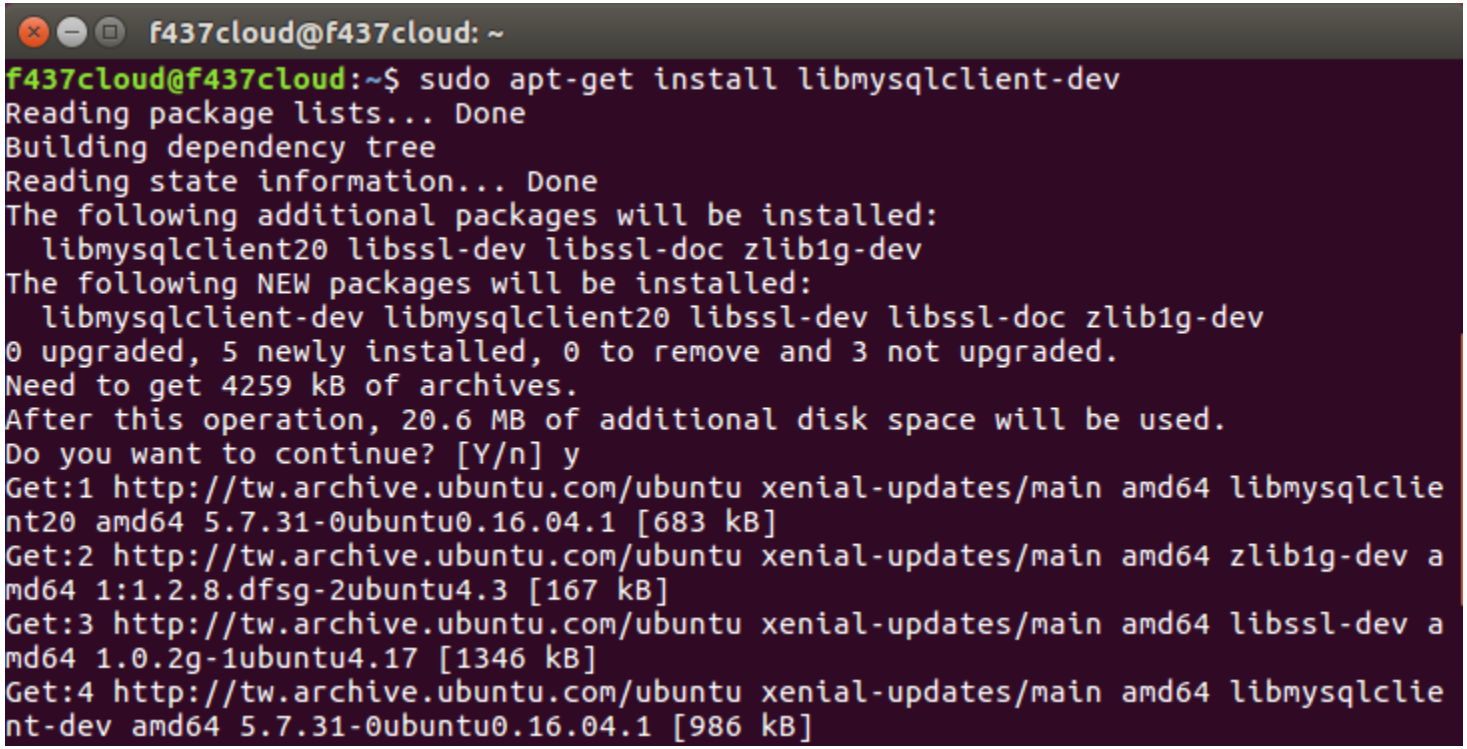
- $ sudo apt-get install libc6-dev



C Language 安裝(安裝套件-3)

在終端機輸入

- $ sudo apt-get install libmysqlclient-dev



C Language 安裝(測試-1)

在home目錄下新增以下程式

- $ gedit test.c

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <unistd.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>
#include <arpa/inet.h>
#include<mysql/mysql.h>

int main(int arge , char *argv[])
{
    printf("test\n");
    return 0;
}
```

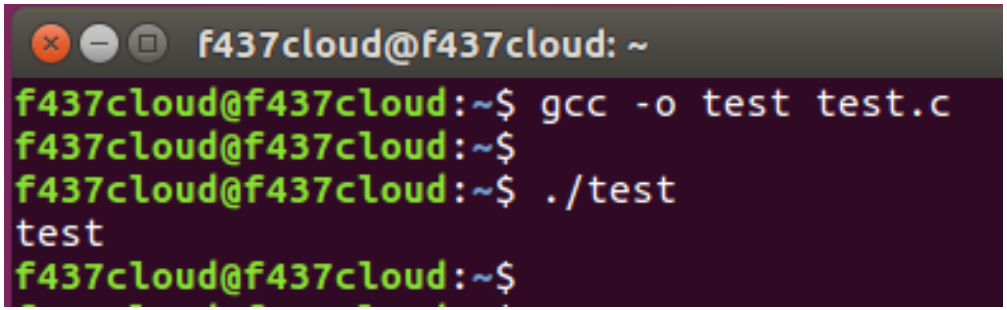
C Language 安裝(測試-2)

在終端機下輸入

- $ gcc -o test test.c
- 編譯test.c

在終端機下輸入

- $ ./test



Cloud Server 安裝

Edge Server的安裝需求(ubuntu 16.04)

1. Video Streaming Server 安裝
   – Nginx 軟體

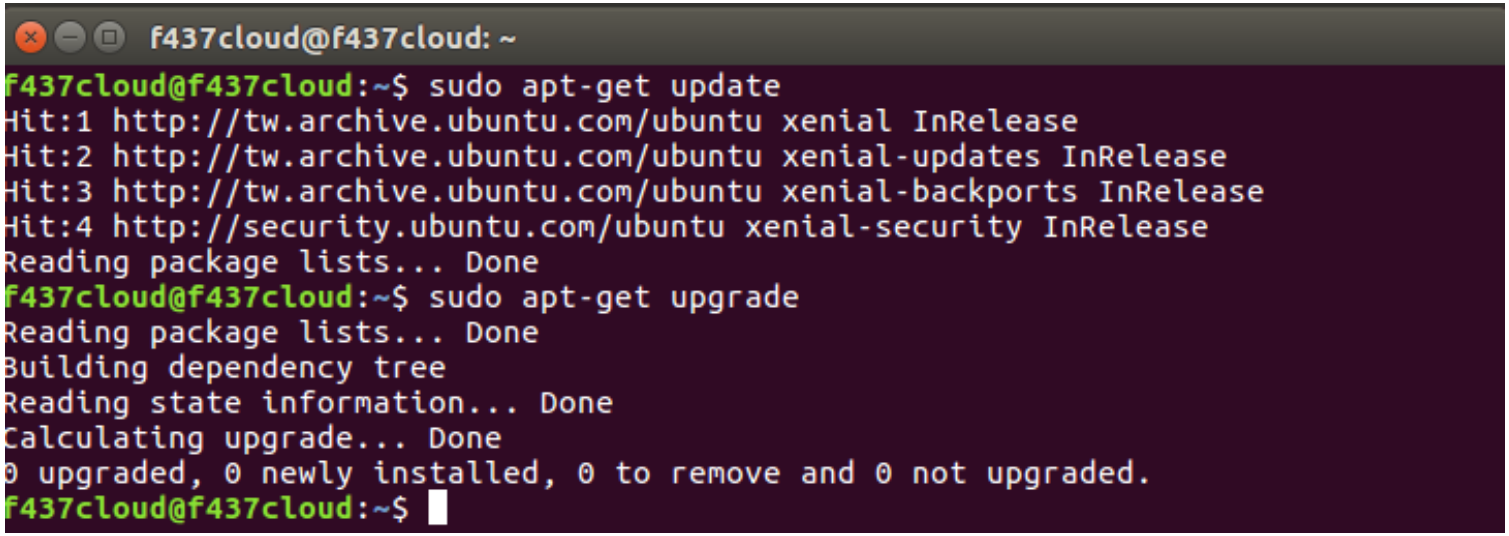
2. TCP/UDP Socket 安裝
   – C Language 軟體

3. Digital Image Processing 安裝
   – OpenCV 軟體

OpenCV安裝(更新ubuntu)

在終端機輸入

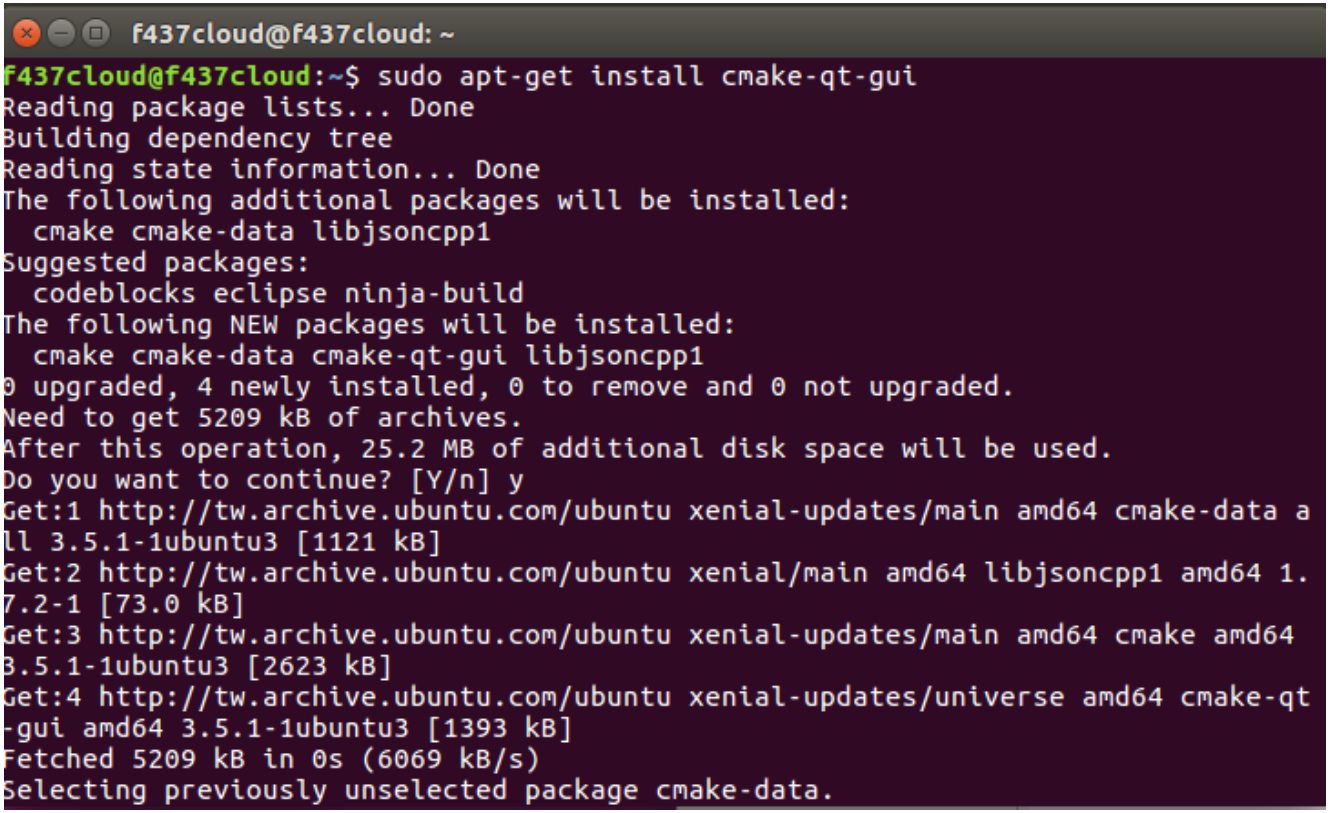
- $ sudo apt-get update
- $ sudo apt-get upgrade



OpenCV安裝(安裝cmake-gui)

在終端機輸入

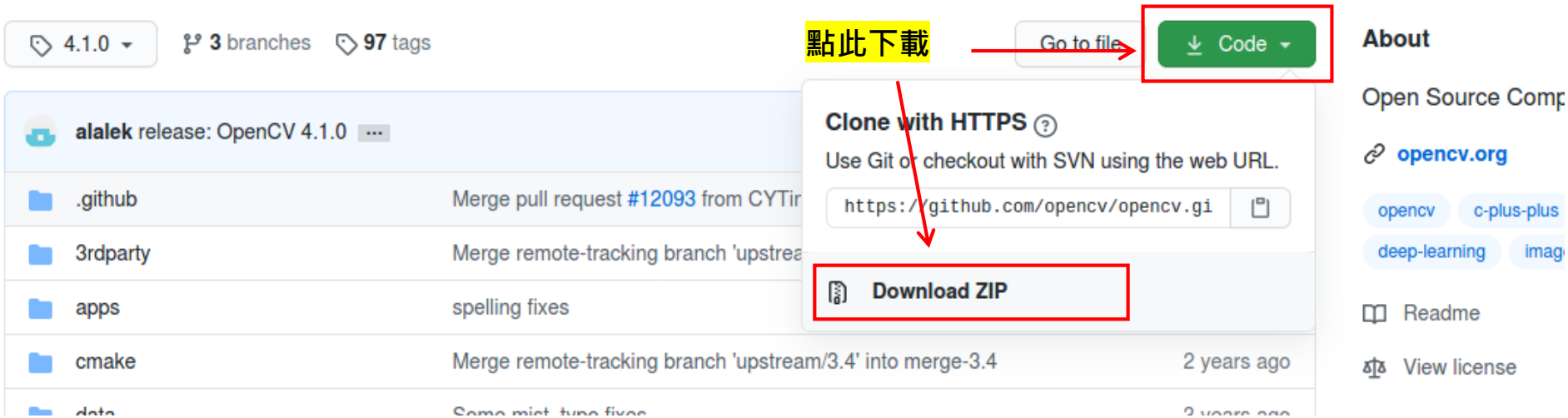
- $ sudo apt-get install cmake-qt-gui



OpenCV安裝(下載OpenCV)

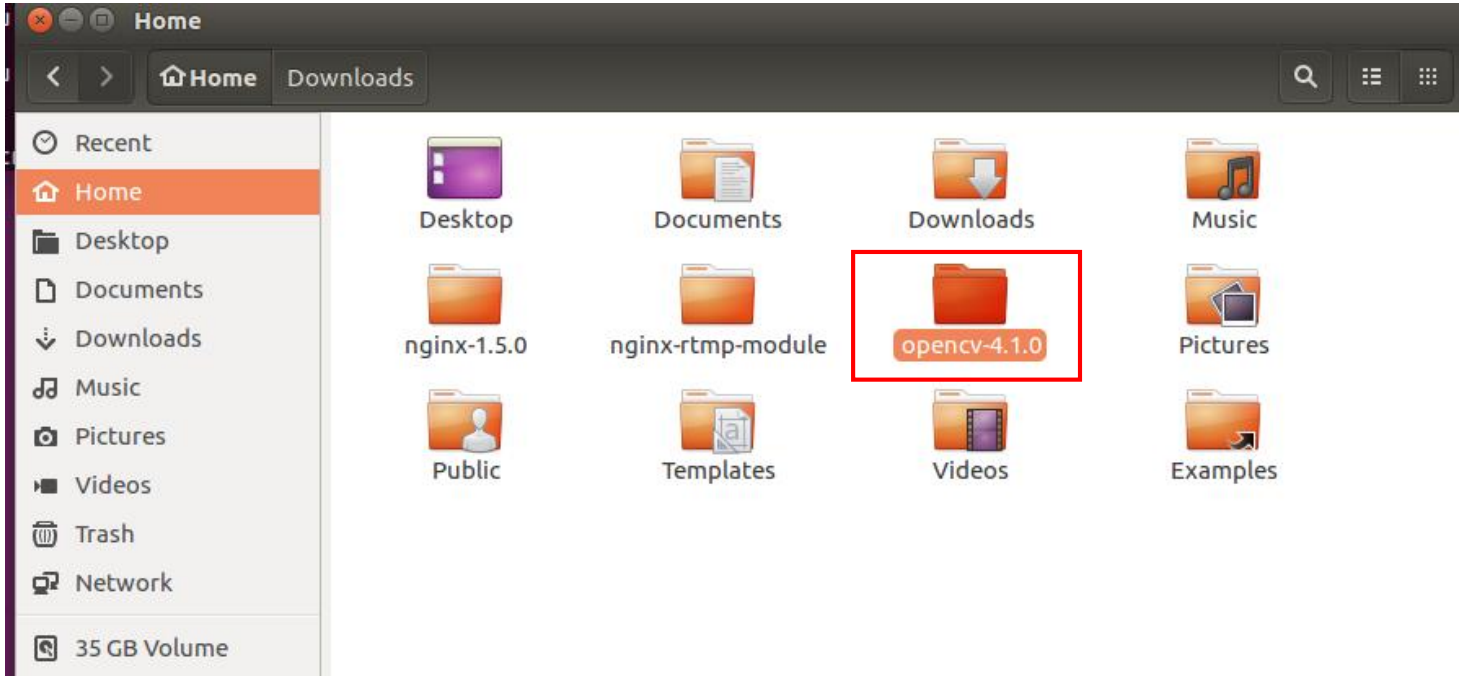
下載OpenCV 4.1.0

網址：https://github.com/opencv/opencv/tree/4.1.0



OpenCV安裝(解壓OpenCV)

將OpenCV 4.1.0解壓縮到home下



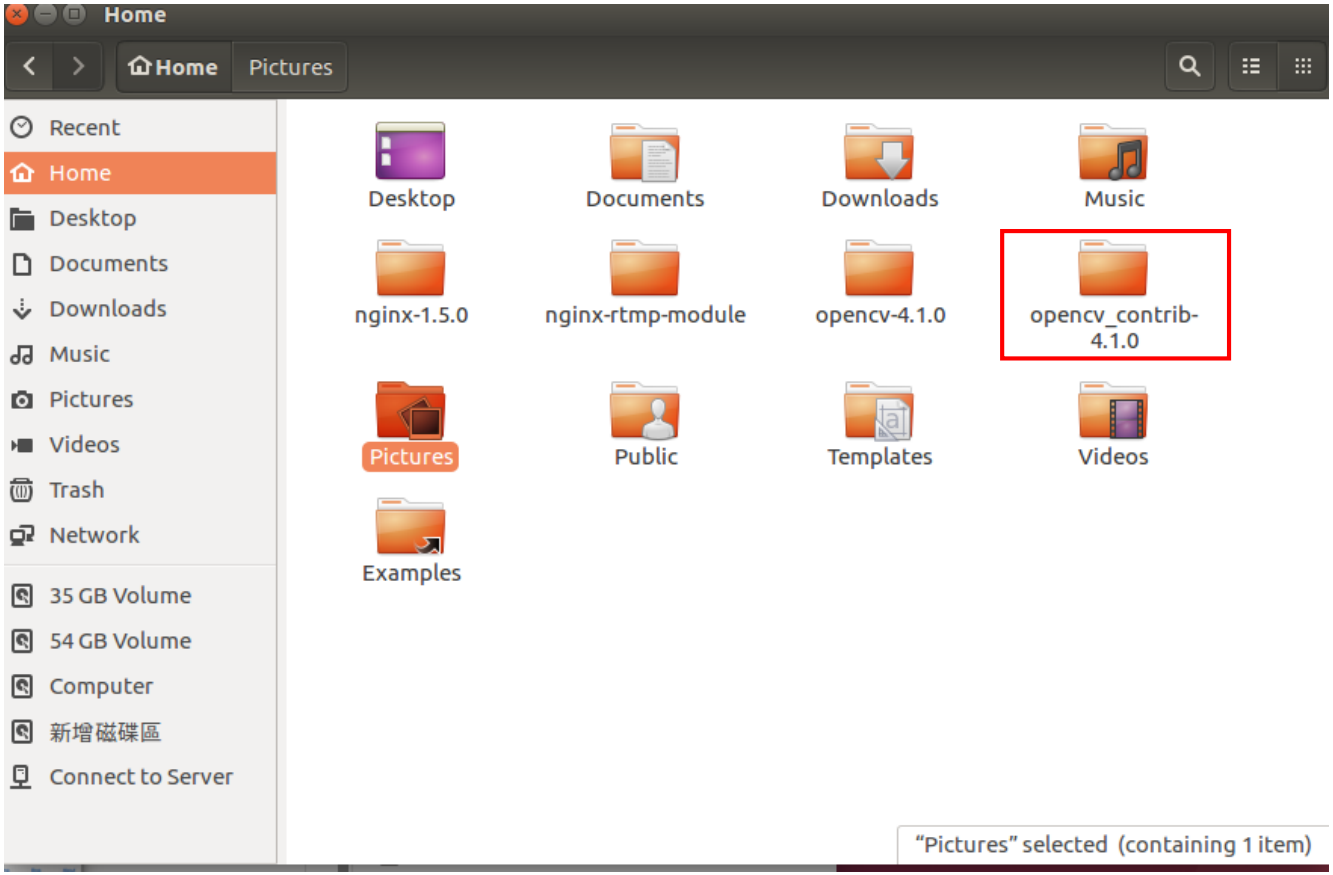
OpenCV安裝(下載contrib)

下載OpenCV_contrib 4.1.0

網址：https://github.com/opencv/opencv_contrib/tags

OpenCV安裝(解壓contrib)

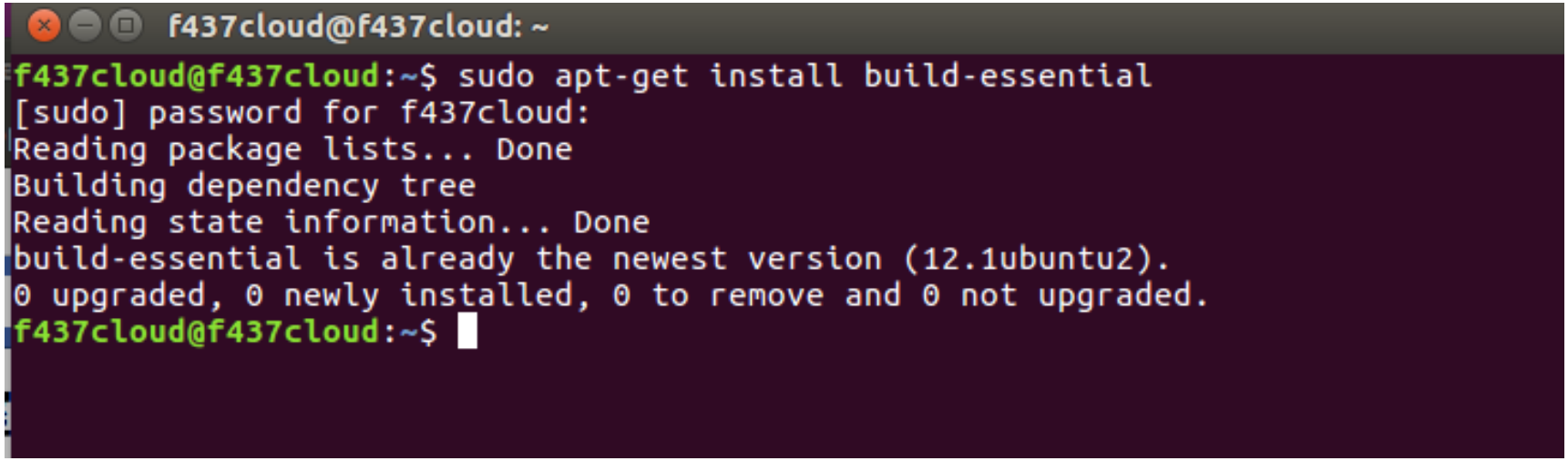
將OpenCV_contrib 4.1.0解壓縮到home下



OpenCV安裝(安裝依賴庫-1)

在終端機輸入

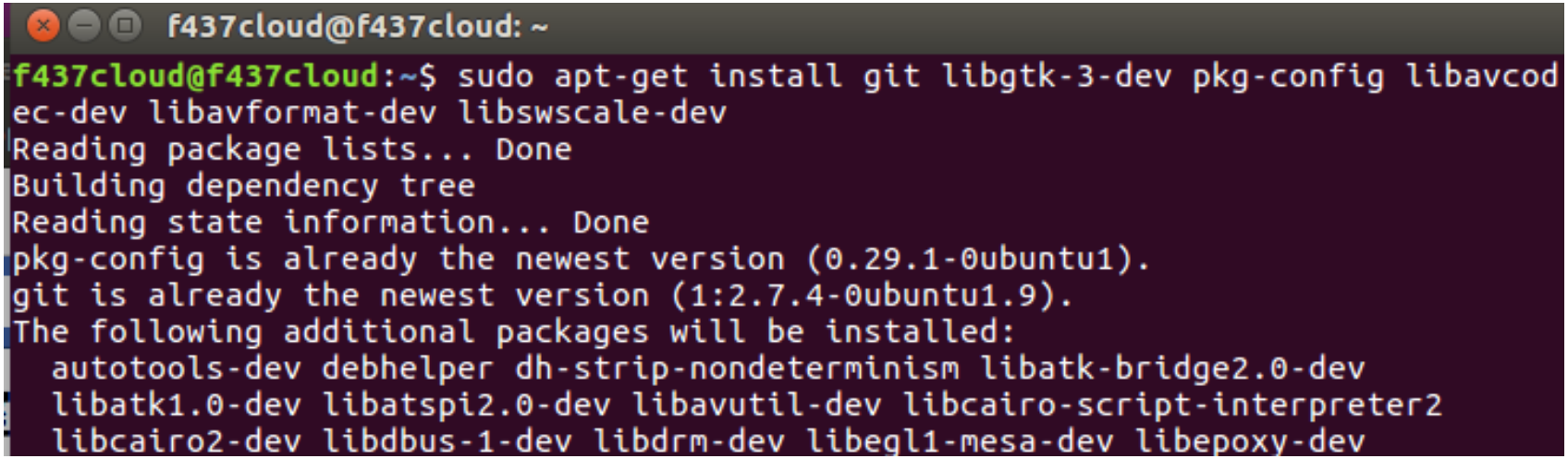
- $ sudo apt-get install cmake-qt-gui



OpenCV安裝(安裝依賴庫-2)

在終端機輸入

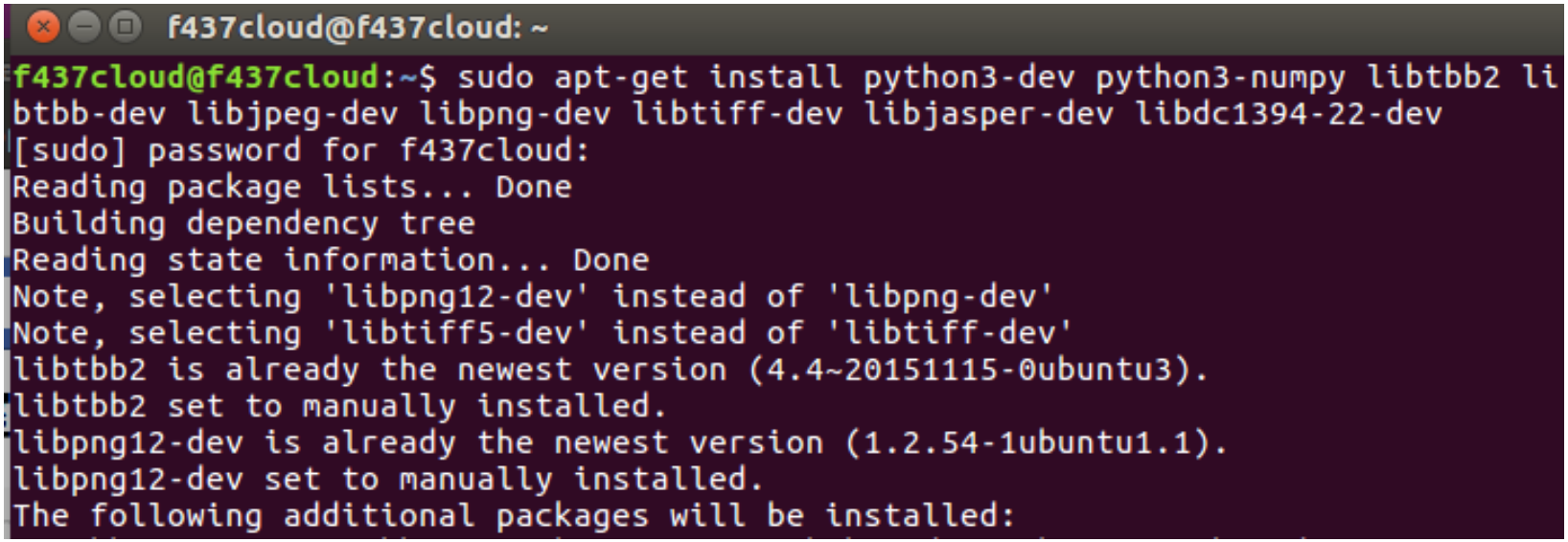
- $ sudo apt-get install git libgtk-3-dev pkg-config libavcodec-dev libavformat-dev libswscale-dev



OpenCV安裝(安裝依賴庫-3)

在終端機輸入

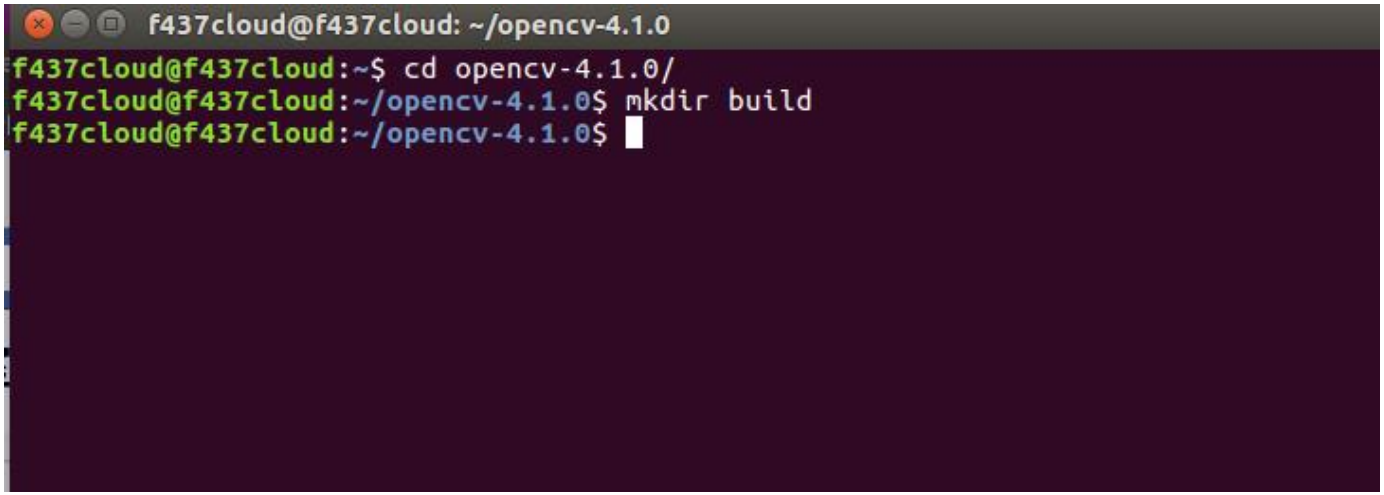
- $ sudo apt-get install python3-dev python3-numpy libtbb2 libtbb-dev libjpeg-dev libpng-dev libtiff-dev libjasper-dev libdc1394-22-dev



OpenCV安裝(建立build目錄)

在終端機輸入

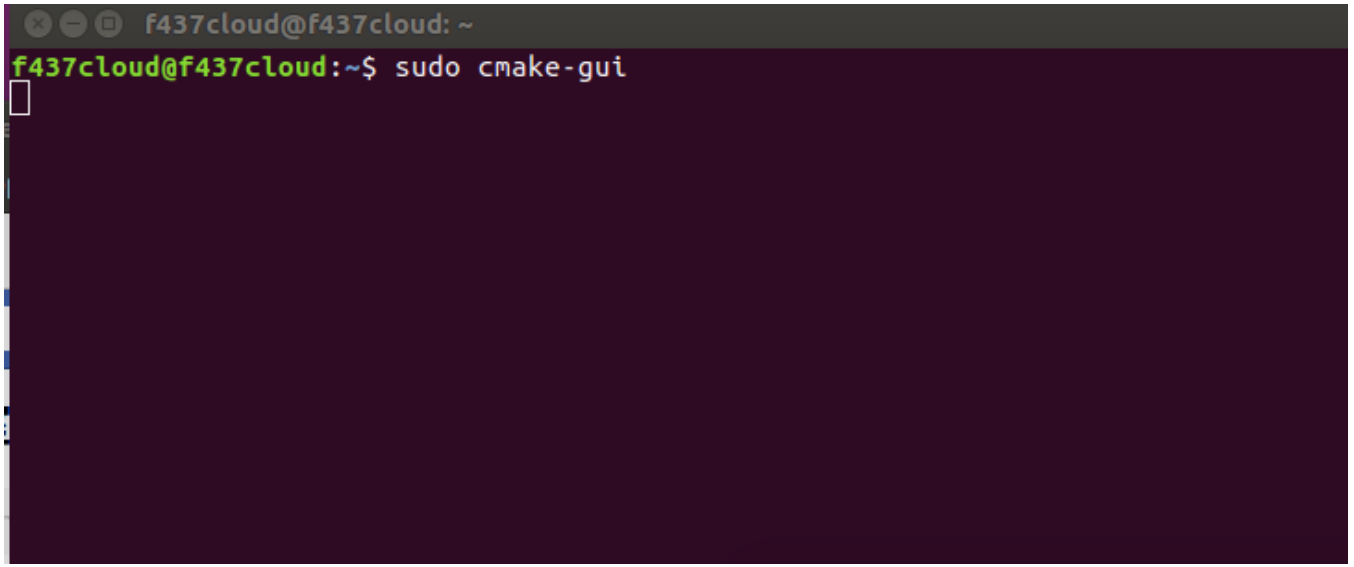
- $ cd opencv-4.1.0/
- $ mkdir build



OpenCV安裝(生成Makefile-1)

在終端機輸入

- $ sudo cmake-gui

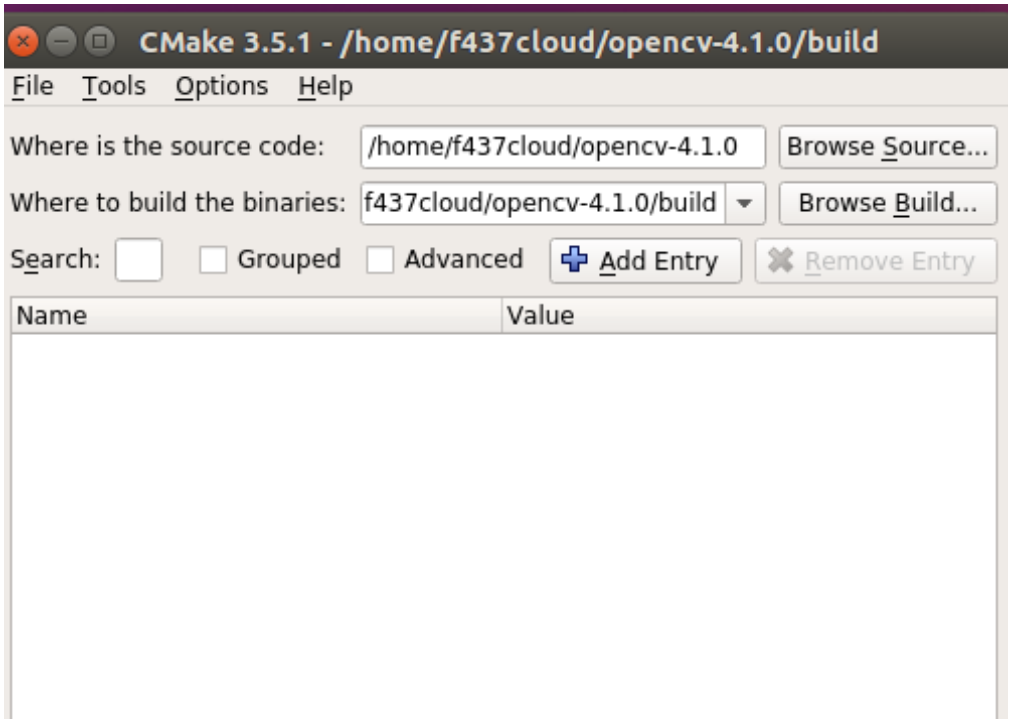


OpenCV安裝(生成Makefile-2)

你的目錄名稱

source code目錄為/home/your-name/opencv-4.1.0

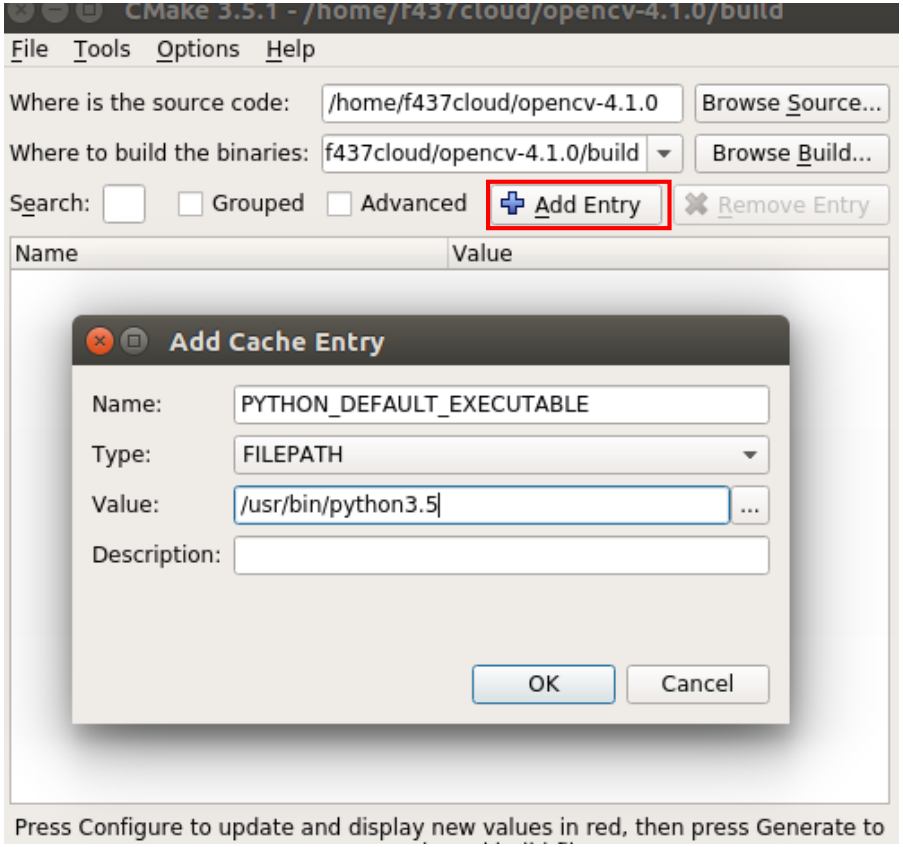
binarires目錄為/home/your-name/opencv-4.1.0/build



OpenCV安裝(生成Makefile-3)

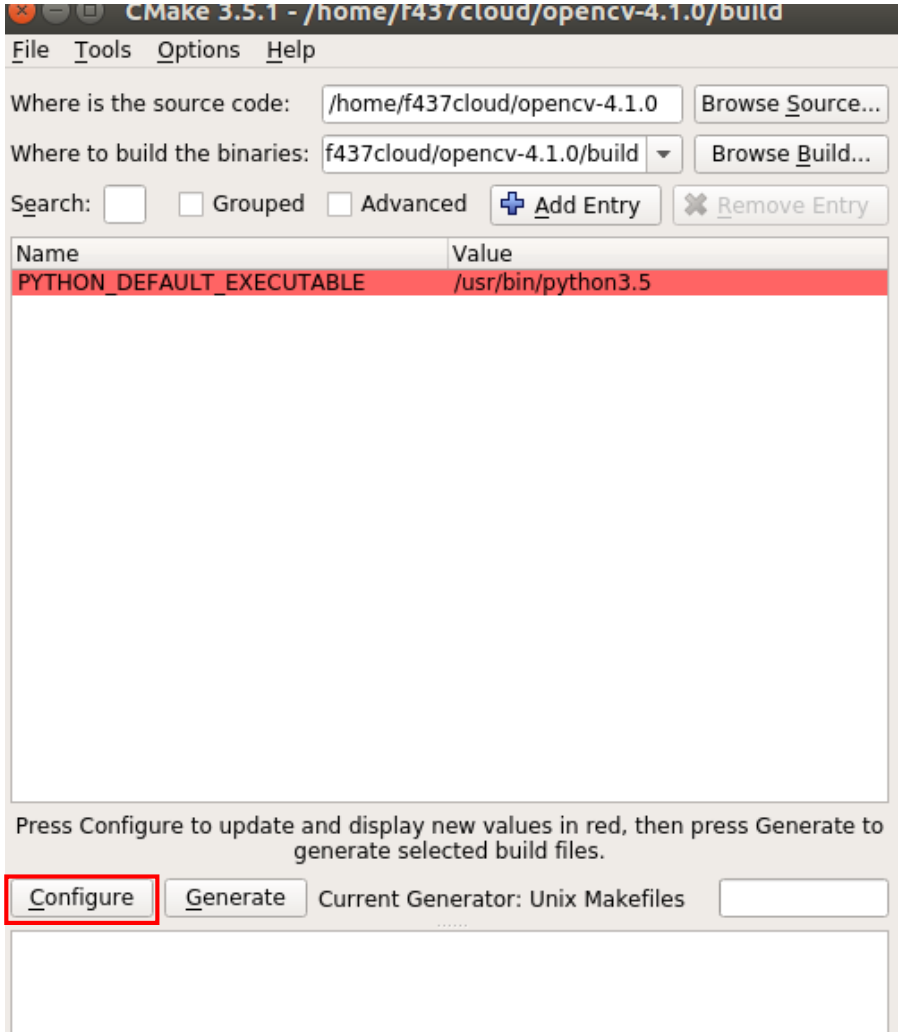
點選Add Entry

- Name設定PYTHON_DEFAULT_EXECUTABLE
- Type設定FILEPATH
- Value設定/usr/bin/python3.5



OpenCV安裝(生成Makefile-4)

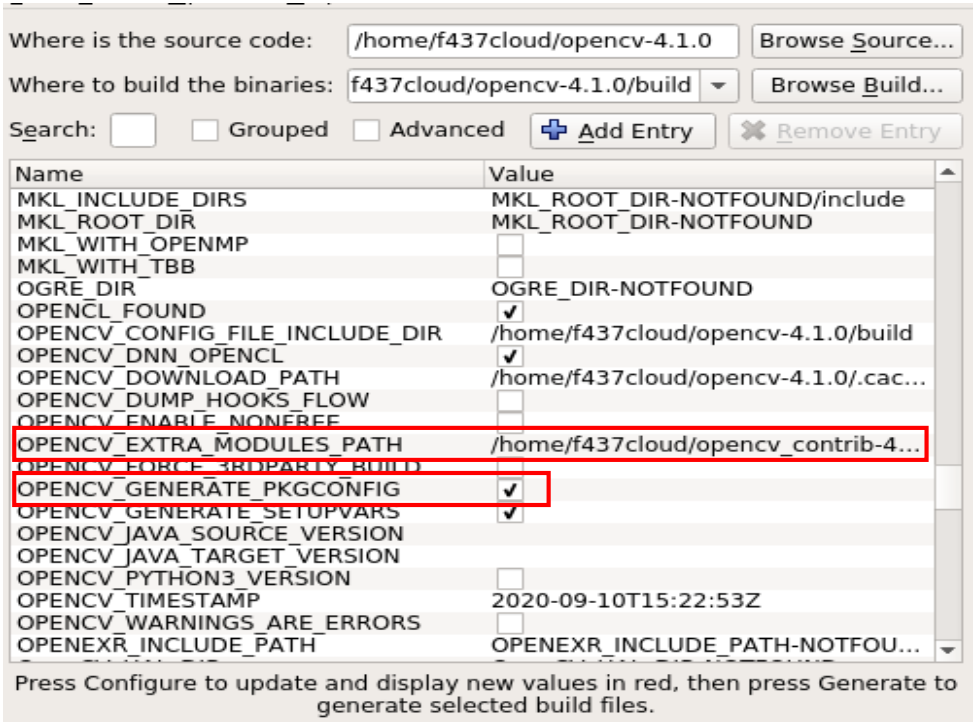
點選Congifure



OpenCV安裝(生成Makefile-5)

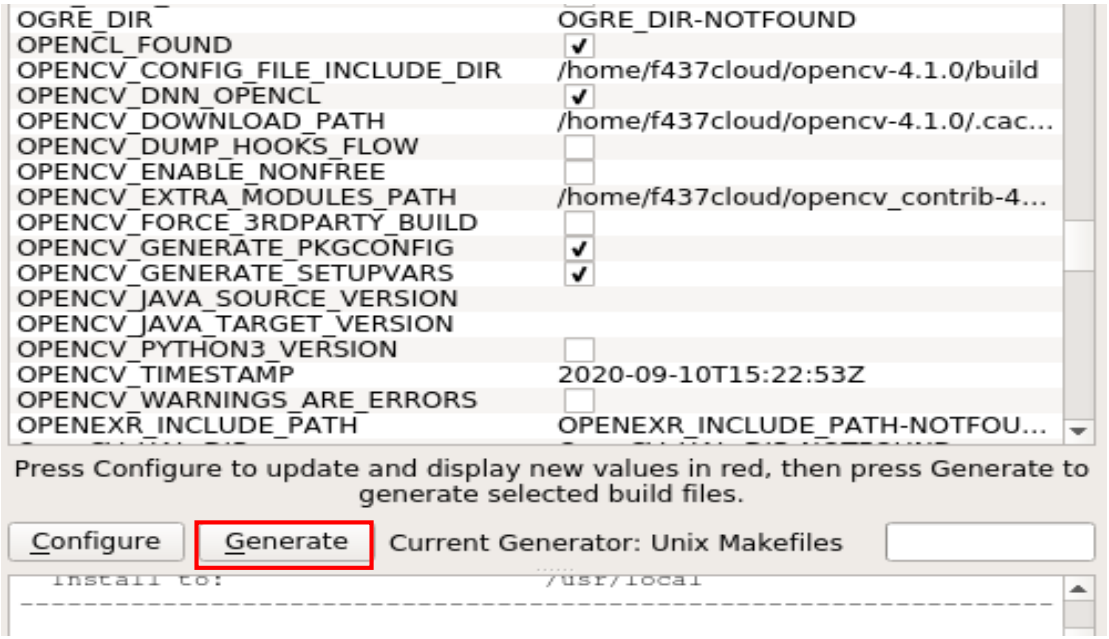
- 勾選OPENCV_GENERATE_PKGCONFIG
- 在OPENCV_EXTRA_MODULES_PATH，填入 /home/your-name/opencv_contrib-4.1.0/modules/

你的目錄名稱



OpenCV安裝(生成Makefile-6)

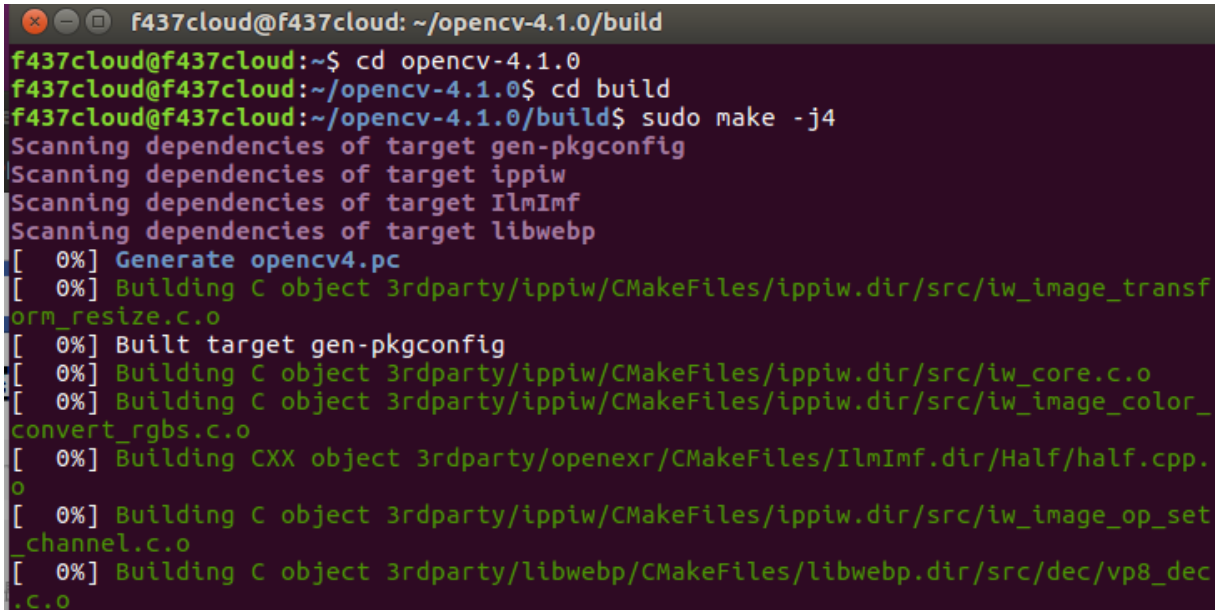
點選Generate，生成Makefile



OpenCV安裝(編譯OpenCV)

在終端機輸入

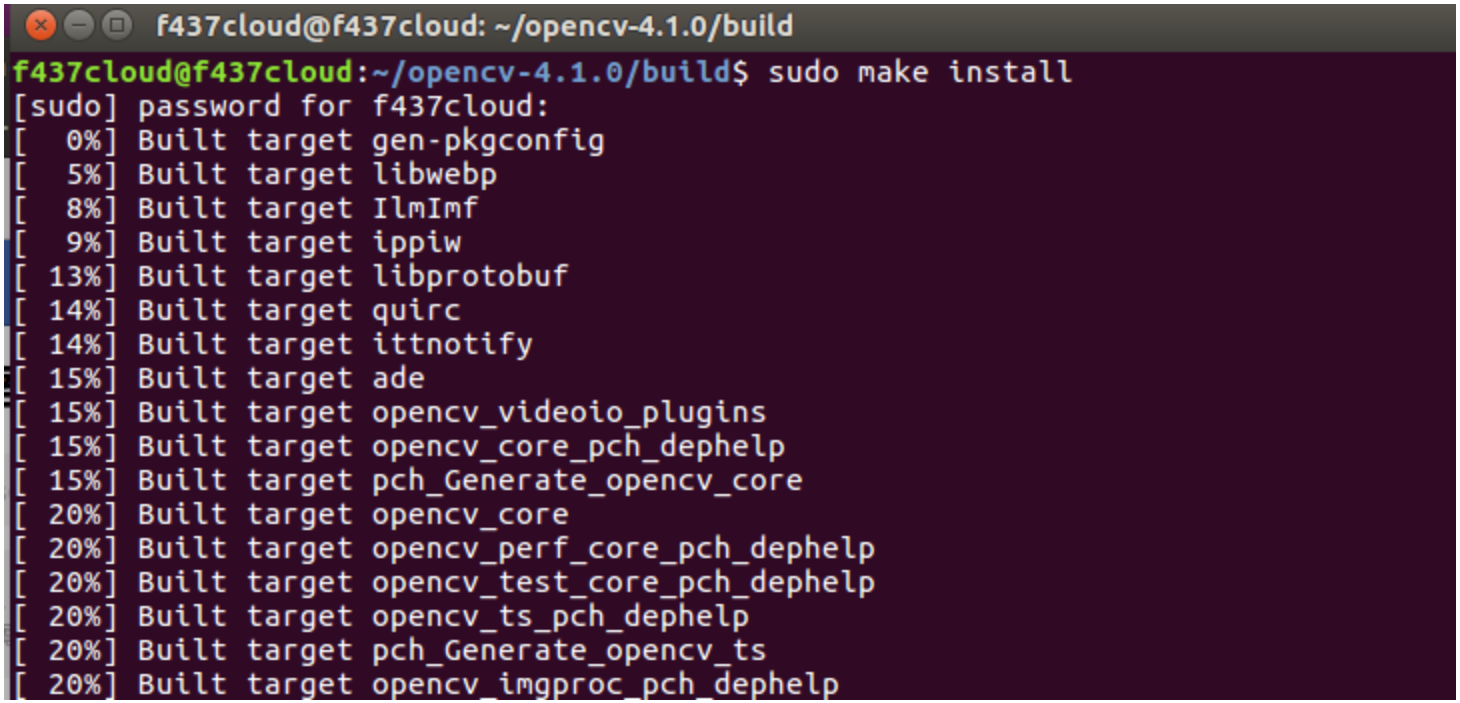
- $ cd opencv-4.1.0/build
- $ sudo make -j4



OpenCV安裝(安裝OpenCV-1)

在終端機輸入

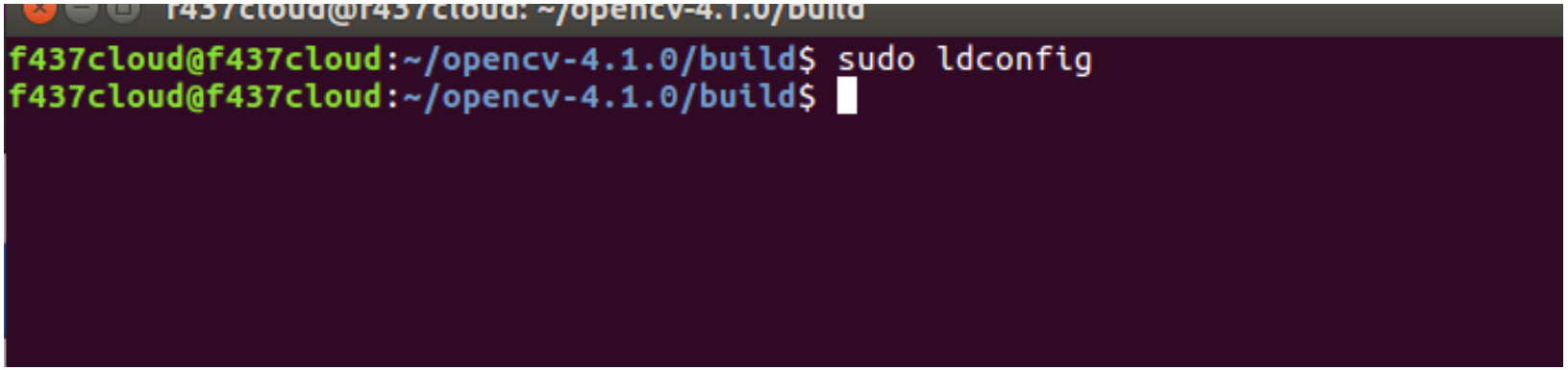
- $ sudo make install



OpenCV安裝(安裝OpenCV-2)

在終端機輸入

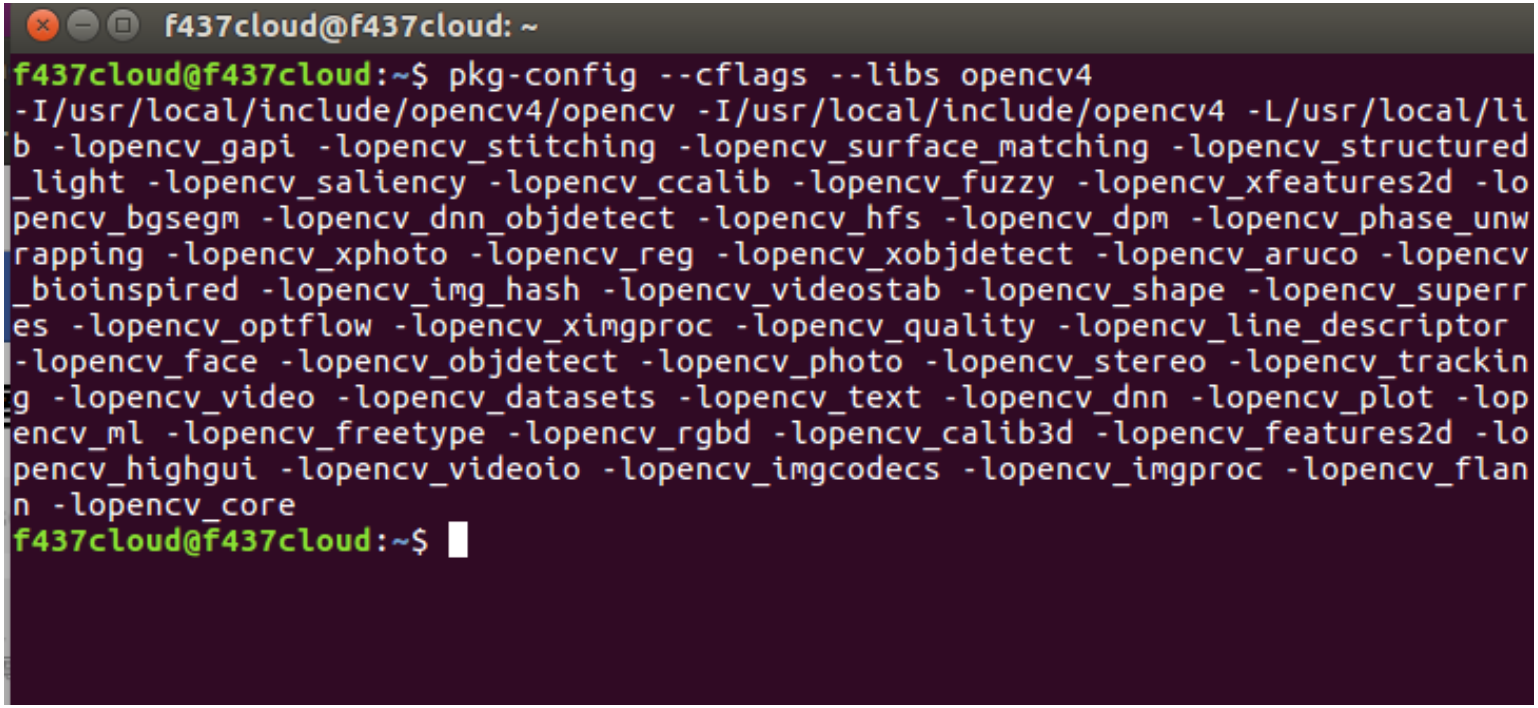
- $ sudo ldconfig



OpenCV安裝(驗證pkg功能)

在終端機輸入

- $ pkg-config --cflags --libs opencv4



OpenCV測試-1

新增OpenCV程式

- $ gedit test.cpp

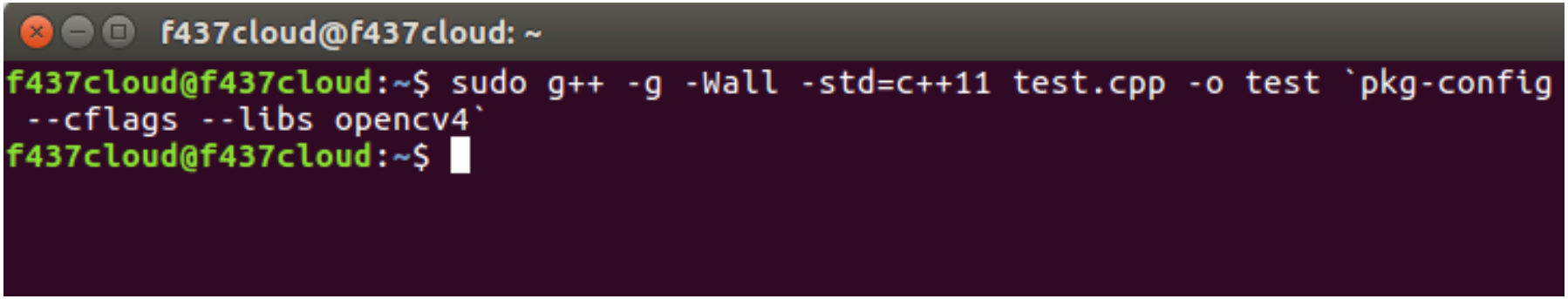
```
#include <opencv2/core.hpp>
#include <opencv2/videoio.hpp>
#include <opencv2/highgui.hpp>
using namespace cv;
using namespace std;
int main (int argc, char** argv) {
  Mat frame;
  VideoCapture cap;
  //cap.open(0); // 表示畫面來源由電腦的相機鏡頭拍攝
  //cap.open("~/test.mp4"); // 表示檔案的路徑與名稱
  cap.open("rtmp://163.18.104.142:1935/myapp/test"); // 表示適用於
影音串流的網路協定。 URL格式=(協定:IP:port/路徑與檔案名稱)
  while (1) {
        if(!cap.read(frame))  {// 讀取畫面
        waitKey();
        return -1;
        }
        imshow("My Video", frame); // 顯示畫面
        if (waitKey(1) >= 0)
           break;
  }
}
```

video streaming server的IP

OpenCV測試-2

編譯OpenCV程式

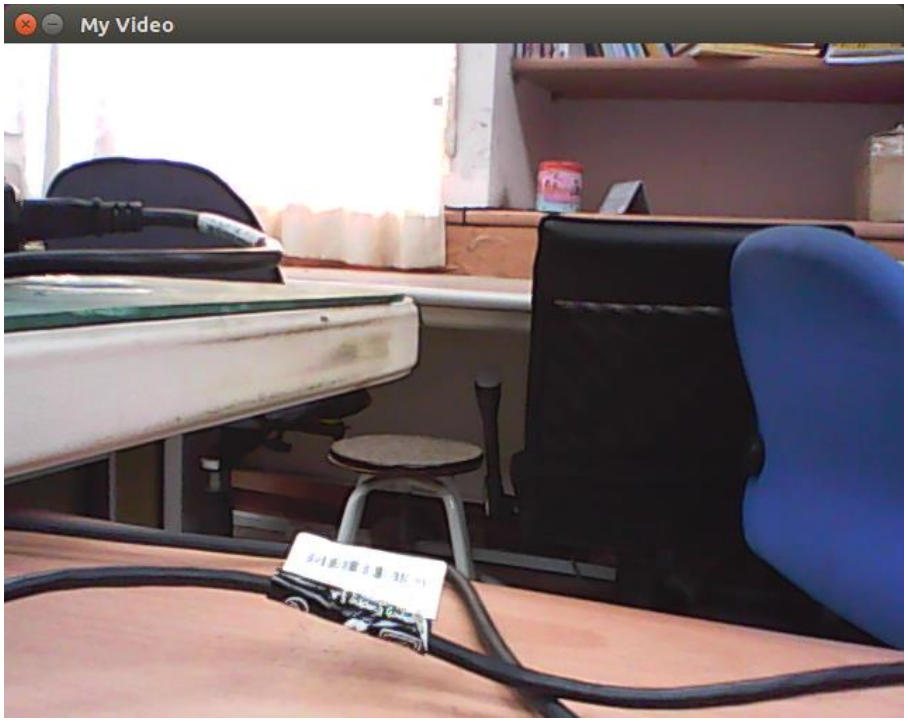
- $ sudo g++ -g -Wall -std=c++11 test.cpp -o test `pkg-config --cflags --libs opencv4`



OpenCV測試-3

執行OpenCV程式

- $ ./test



Outline

- 實驗目的及實驗內容
- 實驗環境
- 平台架設需求
- Cloud Server 平台安裝
- Edge Server 平台安裝
- UE 安裝

Edge Server 安裝需求

Edge Server的安裝需求(ubuntu 16.04)

1. Video Streaming Server 安裝
   – Nginx 軟體，請參考Cloud Server安裝

2. TCP/UDP Socket 安裝
   – C Language 軟體，請參考Cloud Server安裝

3. Digital Image Processing 安裝
   – OpenCV 軟體，請參考Cloud Server安裝

4. Radio Access Network 安裝
   – OAI-EPC 軟體，請參考實驗單元-01

Outline

- 實驗目的及實驗內容
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- UE 安裝

UE安裝

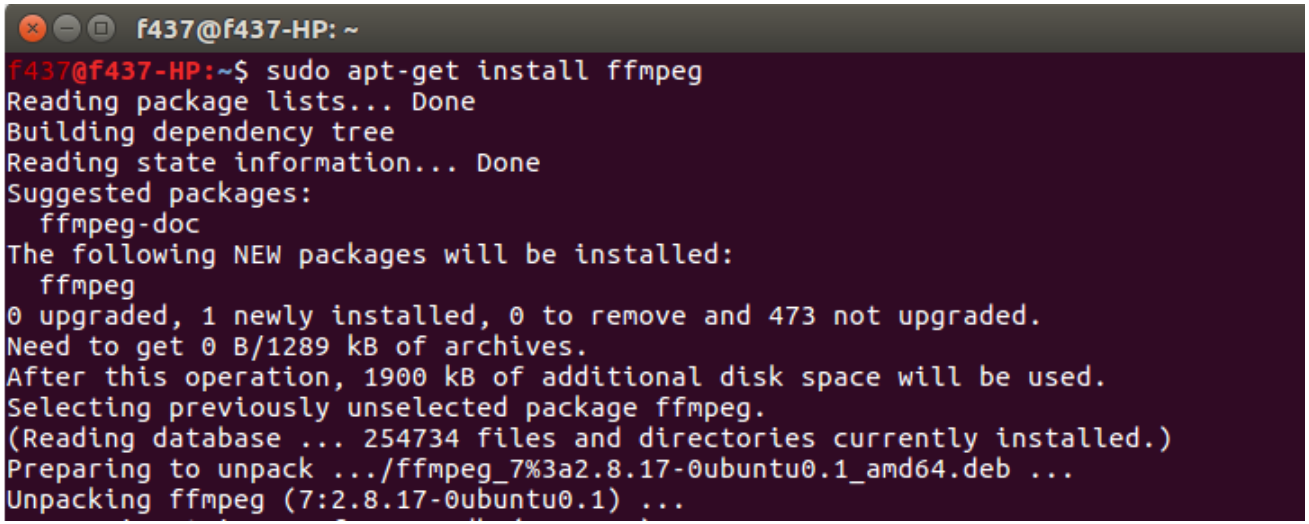
UE的安裝需求(ubuntu 16.04)

1. 影片瀏覽

– FFmpeg

在終端機輸入

- $ sudo apt-get install ffmpeg



UE上傳影片測試-1

開啟Cloud Server影音串流服務

在終端機輸入

- $ cd /usr/local/nginx/sbin
- $ sudo ./nginx -c /usr/local/nginx/conf/nginx.conf

```
f437cloud@f437cloud: /usr/local/nginx/sbin
f437cloud@f437cloud:~$ cd /usr/local/nginx/sbin
f437cloud@f437cloud:/usr/local/nginx/sbin$ sudo ./nginx -c /usr/local/nginx/conf
/nginx.conf
f437cloud@f437cloud:/usr/local/nginx/sbin$
```

※如果發生下圖時，代表port 1935正在被使用，使用以下指令來刪除

- $ sudo lsof -i:1935

```
nginx: [emerg] bind() to 0.0.0.0:1935 failed (98: Address already in use)
nginx: [emerg] bind() to 0.0.0.0:1935 failed (98: Address already in use)
nginx: [emerg] bind() to 0.0.0.0:1935 failed (98: Address already in use)
nginx: [emerg] bind() to 0.0.0.0:1935 failed (98: Address already in use)
nginx: [emerg] bind() to 0.0.0.0:1935 failed (98: Address already in use)
nginx: [emerg] still could not bind()
```

- $ sudo kill “PID” (ex:sudo kill 2140)

```
COMMAND  PID   USER   FD   TYPE DEVICE SIZE/OFF NODE NAME
nginx   2140   root    6u  IPv4  29207      0t0  TCP *:1935 (LISTEN)
nginx   2141 nobody    6u  IPv4  29207      0t0  TCP *:1935 (LISTEN)
nginx   2142 nobody    6u  IPv4  29207      0t0  TCP *:1935 (LISTEN)
```

重新執行

- $ sudo ./nginx -c /usr/local/nginx/conf/nginx.conf

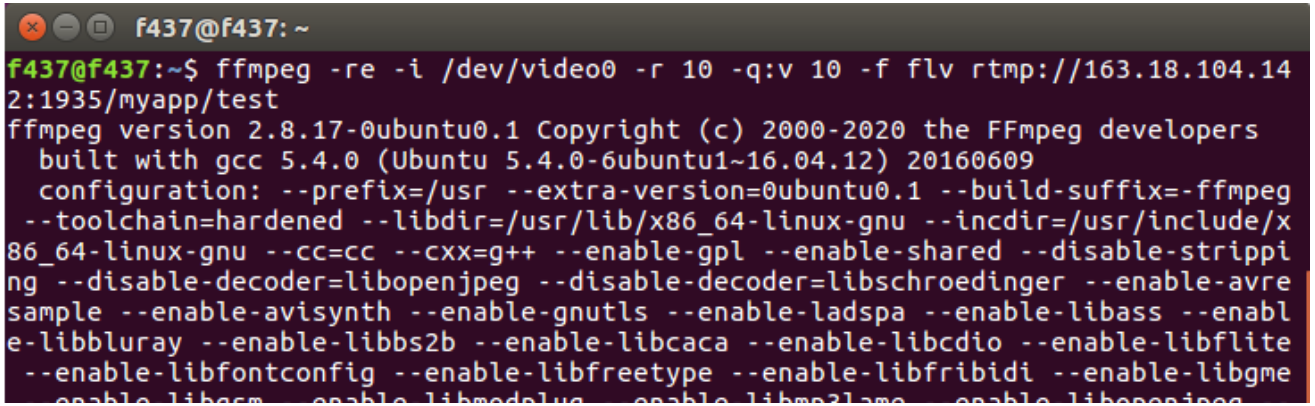
UE上傳影片測試-2

UE上傳影片至Cloud Server

Cloud Server的IP

- $ ffmpeg -re -i /dev/video0 -r 10 -q:v 15 -f flv rtmp://163.18.104.142:1935/myapp/test

1. 設定FPS：-r 30 (FPS=30)
2. 設定畫質：-q:v 1 (1表示最好，30最差)
3. 設定格式：-f flv
4. 設定輸出位置：rtmp://163.18.104.132:1935/myapp/test



UE上傳影片測試-3

- 在UE或Cloud Server上輸入下列指令，就可觀看UE串流影片
- $ ffplay rtmp://163.18.104.142:1935/myapp/test

Cloud Server的IP