場域三：AI 智慧教練

WIRE

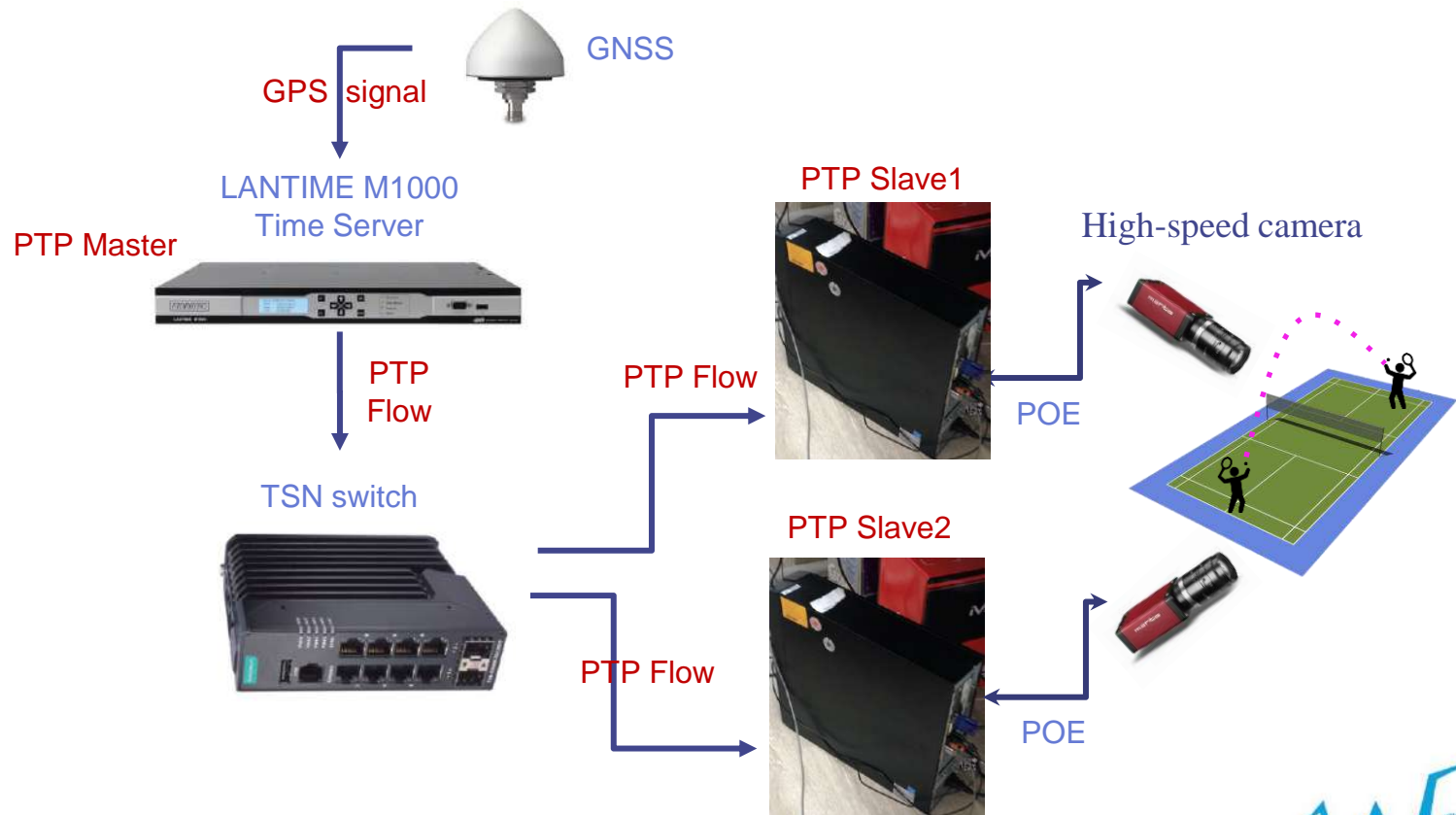Wireless Internet Research and Engineering Laboratory

Outline
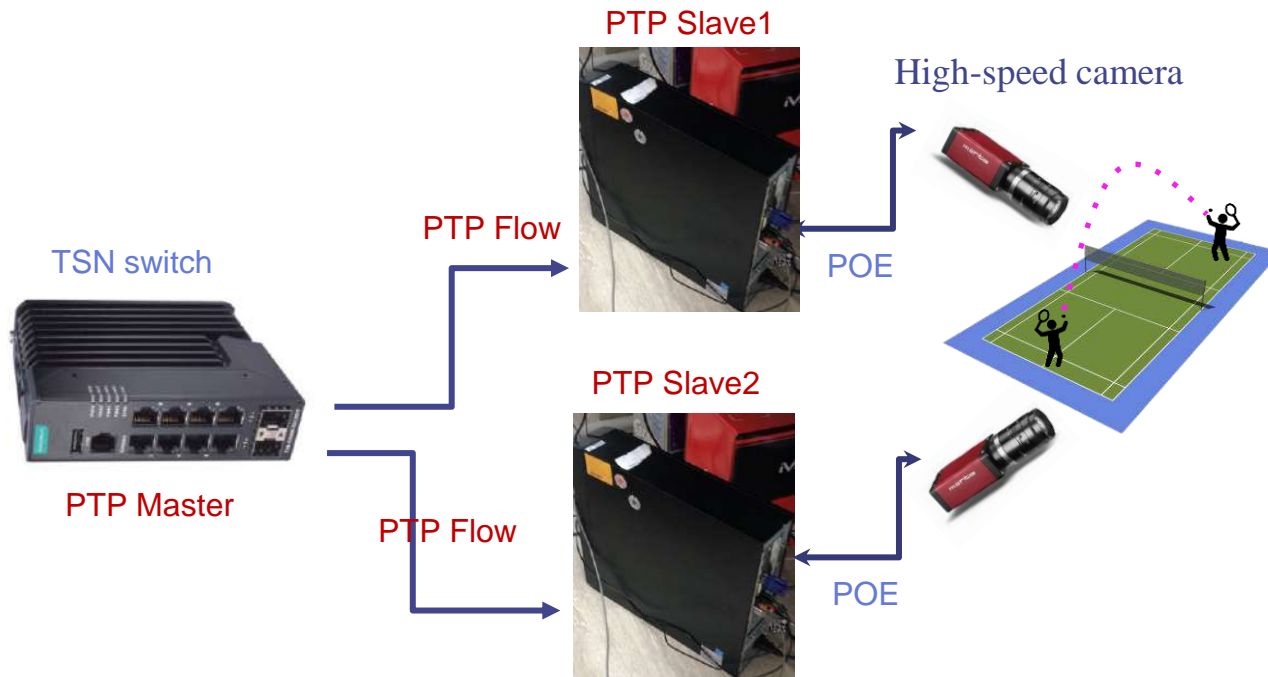
- 精確影像時間同步介紹與實作
    - 影像時間同步線路圖
    - PTP時間同步實作手冊
- AI智慧教練介紹與實作
    - 同步影像5G傳輸線路圖
    - 整體5G架構線路圖
    - 連接5G網路設定
    - AI智慧教練操作手冊

精確影像時間同步介紹與實作

影像時間同步線路圖-Option1

GNSS

GPS signal

LANTIME M1000
Time Server

PTP Master

PTP Slave1

High-speed camera

PTP
Flow

PTP Flow

POE

TSN switch

PTP Slave2

PTP Flow

POE

影像時間同步線路圖-Option2

PTP Slave1

High-speed camera

TSN switch

PTP Flow

POE

PTP Master

PTP Slave2

PTP Flow

POE

PTP時間同步實作手冊

Outline

- 設備規格
- Allied vision Vimba 套件安裝
- Allied vision g235c 設定
- Time Server 設定
- TSN Switch 設定
- PTP Slave PC同步設定
- 結果呈現

設備規格-1

設備	數量	規格	照片
High-speed Camera	2	Allied vision Manta G-235C	
TSN switch	1	MOXA TSN-g5004	
PC	2	Ubuntu 20.04 LTS Python 3.8.10 Vimba 5.1	
Time Server	1	LANTIME M1000	

設備規格-2

設備	數量	規格	照片
5G USB 無線網卡	2	APAL	
5G SIM卡	2	free5GC	
POE Injector	2	EdiMAX GP-101IT	
支援TSN 網路介面卡	2	Intel i210 NIC	

Allied vision Vimba 套件安裝

- 下載 VimbaViewer 至使用者自定義位置，並解壓縮
- wget https://downloads.alliedvision.com/Vimba_v5.0_Linux.tgz
- tar xvf Vimba_v5.0_Linux.tgz

```
faker@faker:~/research_student/coachAI/Reader$ wget https://downloads.alliedvision.com/Vimba_v5.0_Linux.tgz
--2021-11-23 15:28:21--  https://downloads.alliedvision.com/Vimba_v5.0_Linux.tgz
Resolving downloads.alliedvision.com (downloads.alliedvision.com)... 13.35.30.45, 13.35.30.118, 13.35.30.34, ...
Connecting to downloads.alliedvision.com (downloads.alliedvision.com)|13.35.30.45|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 55020351 (52M) [application/octet-stream]
Saving to: 'Vimba_v5.0_Linux.tgz'

Vimba_v5.0_Linux.tgz           100%[=================================================================>]  52.47M   110MB/s    in 0.5s

2021-11-23 15:28:21 (110 MB/s) - 'Vimba_v5.0_Linux.tgz' saved [55020351/55020351]

faker@faker:~/research_student/coachAI/Reader$ ls
Allied_Vision  CSVReader  example  FileReader  Image_Source  Vimba_5_0  Vimba_v5.0_Linux.tgz
faker@faker:~/research_student/coachAI/Reader$ tar xvf Vimba_v5.0_Linux.tgz
Vimba_5_0/
Vimba_5_0/VimbaUSBTL/
Vimba_5_0/VimbaUSBTL/SetGenTLPath.sh
Vimba_5_0/VimbaUSBTL/Documentation/
```

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Allied vision Vimba 套件安裝

- 進入 Vimba_x_x/VimbaGigETL

```
faker@faker:~/research_student/coachAI/Reader$ tree Vimba_5_0/VimbaGigETL/
Vimba_5_0/VimbaGigETL/
├── CTI
│   └── x86_64bit
│       ├── VimbaGigETL.cti
│       └── VimbaGigETL.xml
├── Documentation
│   ├── ReleaseNotes.txt
│   └── VimbaGigETLFeaturesManual.pdf
├── Install.sh
├── SetGenTLPath.sh
└── Uninstall.sh
```

- 安裝及更新環境變數
  - sudo ./Install.sh ./SetGenTLPath.sh

Allied vision Vimba 套件安裝

- 進入 Vimba_x_x/VimbaPython

```
faker@faker:~/research_student/coachAI/Reader/Vimba_5_0/VimbaPython$ tree
.
├── Documentation
│   └── Vimba Python Manual.pdf
├── Examples
│   ├── action_commands.py
│   ├── asynchronous_grab_opencv.py
│   ├── asynchronous_grab.py
│   ├── create_trace_log.py
│   ├── event_handling.py
│   ├── list_ancillary_data.py
│   ├── list_cameras.py
│   ├── list_features.py
│   ├── load_save_settings.py
│   ├── multithreading_opencv.py
│   ├── synchronous_grab.py
│   └── user_set.py
├── Install.sh
```

- 安裝 vimba python module
  - sudo ./Install.sh

- 重新開機
  - sudo shutdown –r now

Allied vision g235c 設定
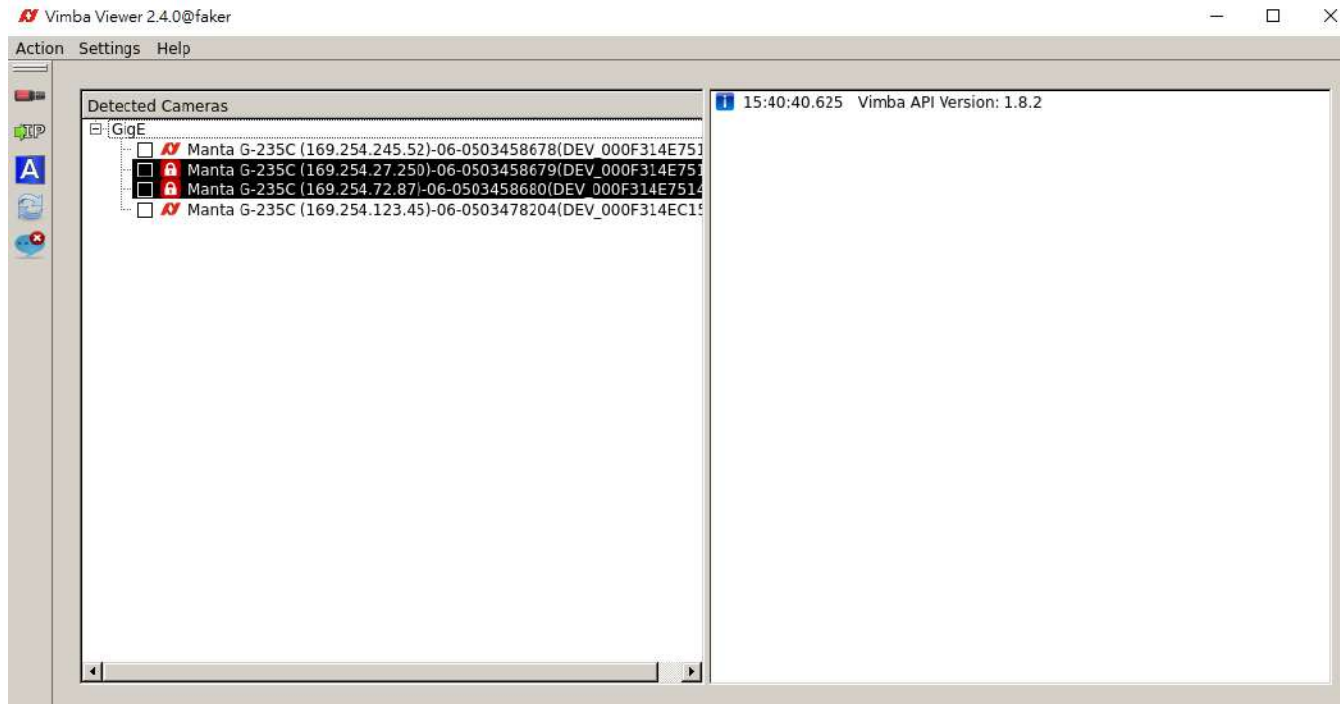
- 設定接上 camera 之電腦網卡介面資訊

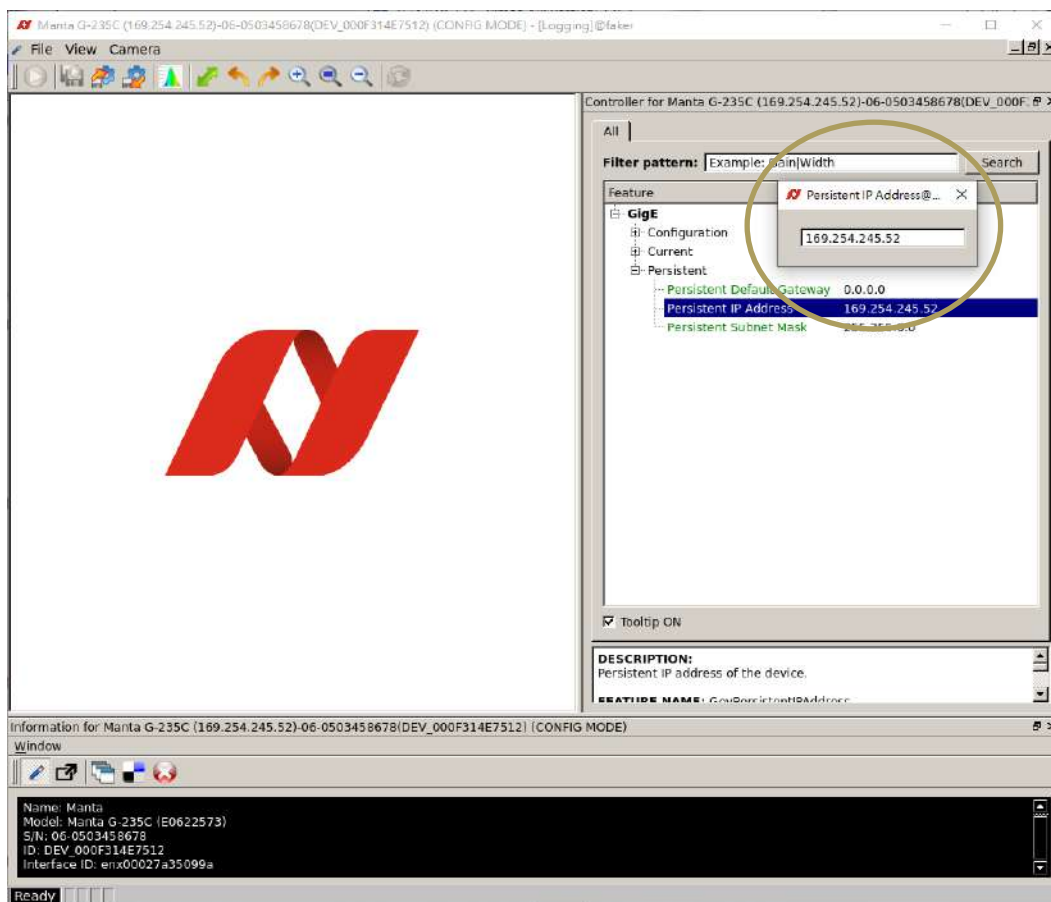| VIMBA: LLL	Obtain an IP address automatically
PvAPI: Auto IP	(169.254.xxx.xxx)

Allied vision g235c 設定

- 開啟 VimbaViewer
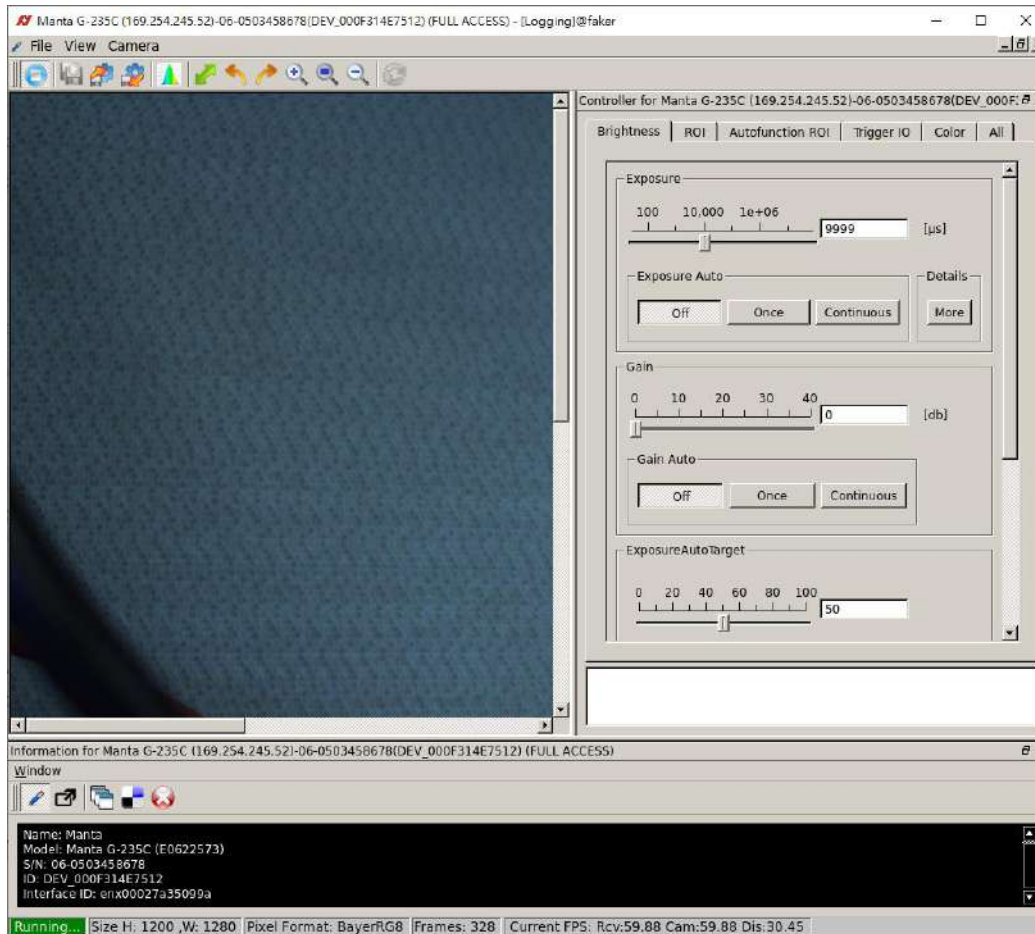 - ./Vimba_x_x/Tools/Viewer/Bin/x86_64bit/VimbaViewer

Allied vision g235c 設定

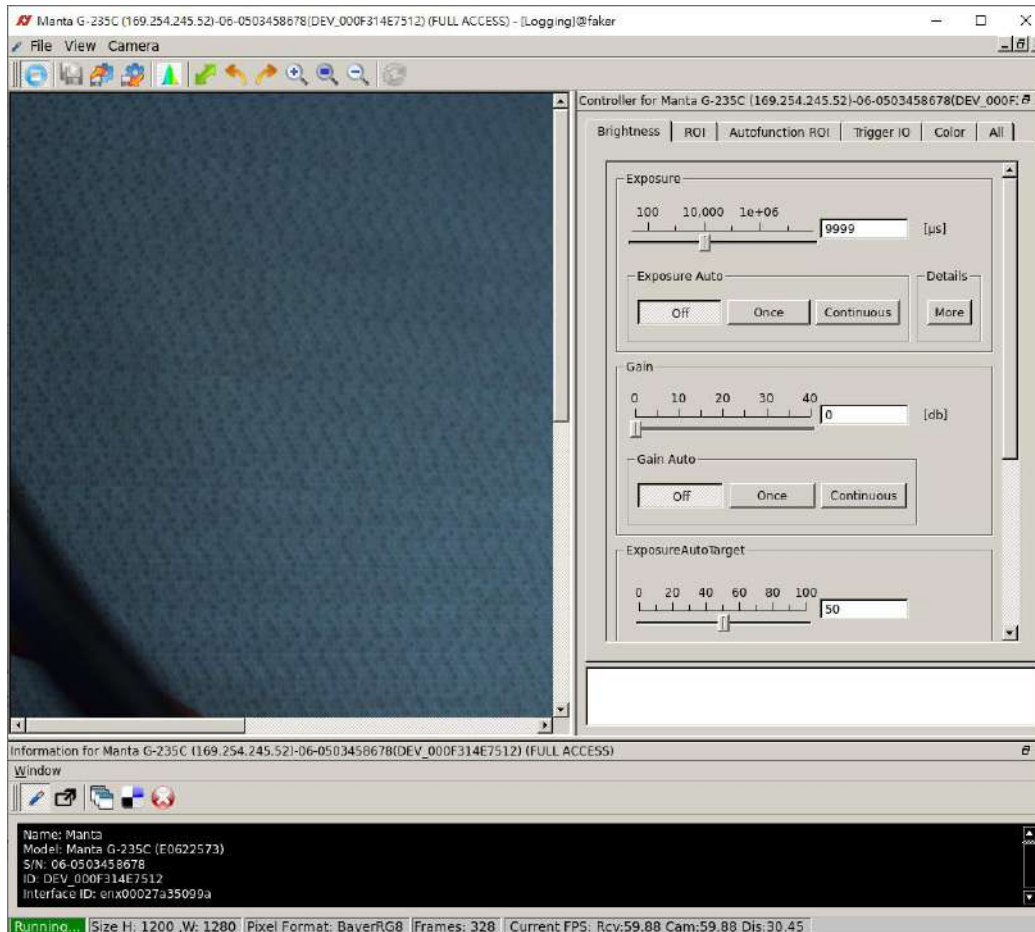- 依使用者自定義相機之 IP，同時也要將連接之網卡 IP 改至自定義 IP

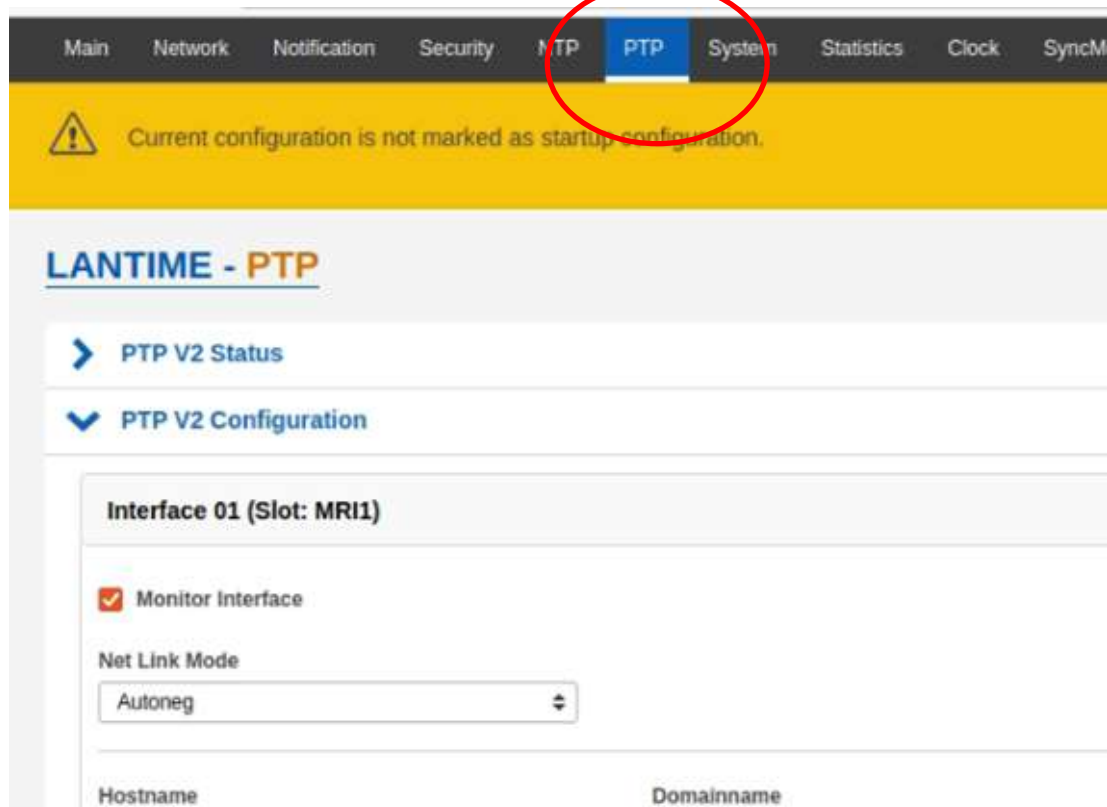# Allied vision g235c 設定

- VimbaViewer 測試，確認相機可以接收拍攝畫面

Allied vision g235c 設定

- VimbaViewer 測試，確認相機可以接收拍攝畫面

Time Server 設定

- 進入 Time Server 設定頁面，並選擇設定 PTP

Time Server 設定

- 在PTP V2 Configuration 中設定 Network config，主要需更改TCP/IP Address

Time Server 設定

- 在PTP V2 Configuration 中設定 Global config，選擇 Profile，並更改 Intervals 與 Receipt Timeout 值

Time Server 設定

- 在PTP V2 Configuration 中設定 Misc config，啟用 PTP One Step 選項
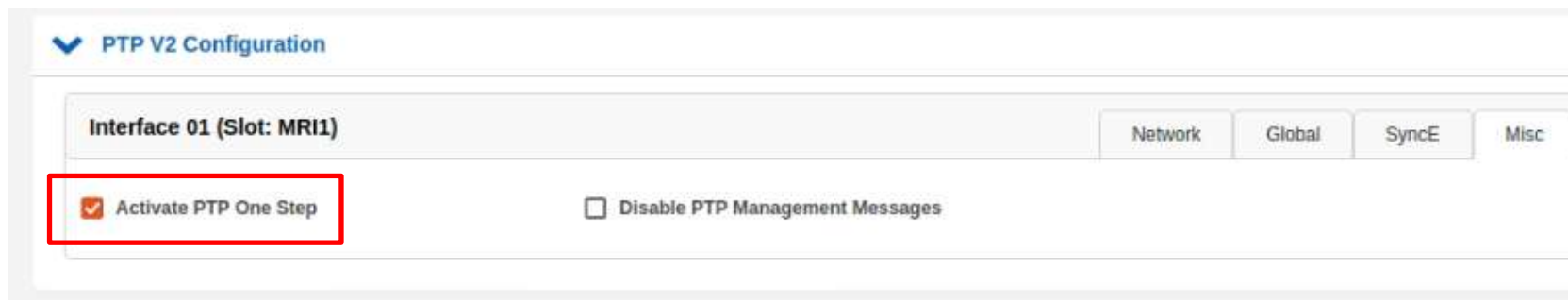
TSN Switch 設定

- 將對接的網路介面IP設定為192.168.127.253/24
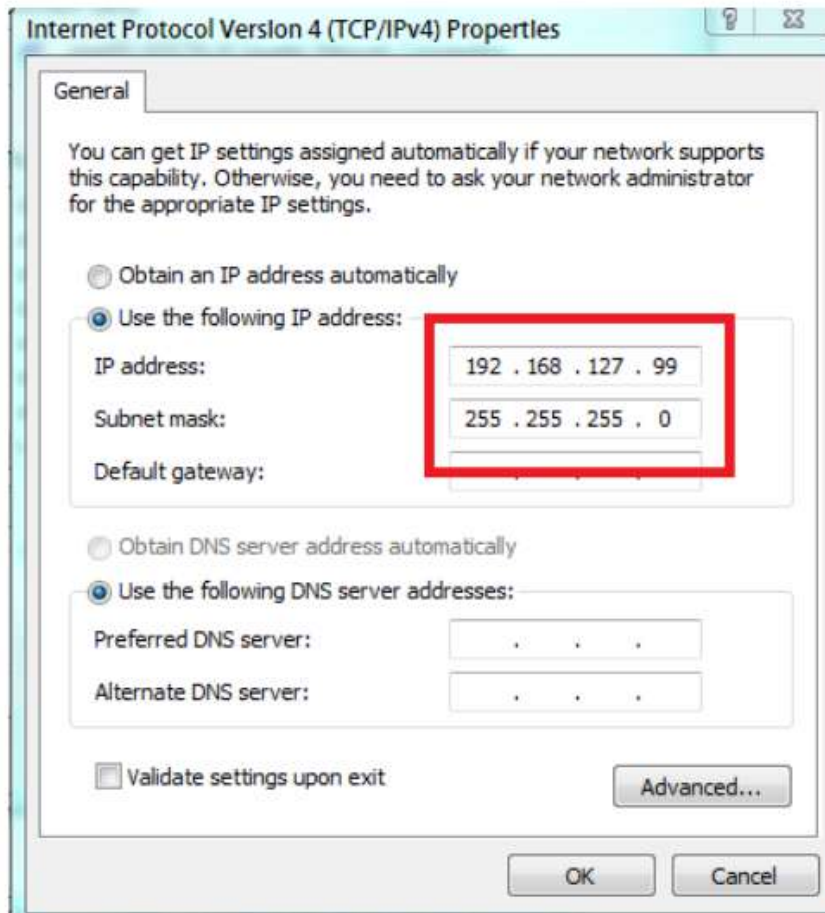
TSN Switch 設定

- 進入 http://192.168.127.253 為 switch 的 web console
- account：admin
- password：moxa

TSN Switch 設定

- 觀看系統資訊
- 設定系統時鐘

PTP Slave PC 同步設定 (1/6)

- 在 Ubuntu 環境中安裝 ethtool，並確認完成安裝

```
user@user-VirtualBox:~$ sudo apt-get install ethtool
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following NEW packages will be installed:
  ethtool
0 upgraded, 1 newly installed, 0 to remove and 41 not upgraded.
Need to get 0 B/97.5 kB of archives.
After this operation, 318 kB of additional disk space will be used.
Selecting previously unselected package ethtool.
(Reading database ... 223753 files and directories currently installed.)
Preparing to unpack .../ethtool_1%3a4.5-1_amd64.deb ...
Unpacking ethtool (1:4.5-1) ...
Processing triggers for man-db (2.7.5-1) ...
Setting up ethtool (1:4.5-1) ...
user@user-VirtualBox:~$ ethtool --version
ethtool version 4.5
user@user-VirtualBox:~$ 
```

PTP Slave PC 同步設定 (2/6)

- 確認網卡是否支援 PTP，且有能力收送 time-stamping 封包
- Ethtool –T 網卡名稱

```
~]# ethtool -T eth3
Time stamping parameters for eth3:
Capabilities:
        hardware-transmit      (SOF_TIMESTAMPING_TX_HARDWARE)
        software-transmit      (SOF_TIMESTAMPING_TX_SOFTWARE)
        hardware-receive       (SOF_TIMESTAMPING_RX_HARDWARE)
        software-receive       (SOF_TIMESTAMPING_RX_SOFTWARE)
        software-system-clock  (SOF_TIMESTAMPING_SOFTWARE)
        hardware-raw-clock     (SOF_TIMESTAMPING_RAW_HARDWARE)
PTP Hardware Clock: 0
Hardware Transmit Timestamp Modes:
        off                    (HWTSTAMP_TX_OFF)
        on                     (HWTSTAMP_TX_ON)
Hardware Receive Filter Modes:
        none                   (HWTSTAMP_FILTER_NONE)
        all                    (HWTSTAMP_FILTER_ALL)
```

支援 Software time stamping

支援 Hardware time stamping

PTP Slave PC 同步設定 (3/6)

- 安裝 linuxptp 套件

```
user@user-VirtualBox:~$ sudo apt-get install linuxptp
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following NEW packages will be installed:
  linuxptp
0 upgraded, 1 newly installed, 0 to remove and 41 not upgraded.
Need to get 0 B/109 kB of archives.
After this operation, 414 kB of additional disk space will be used.
Selecting previously unselected package linuxptp.
(Reading database ... 223741 files and directories currently installed.)
Preparing to unpack .../linuxptp_1.6-1_amd64.deb ...
Unpacking linuxptp (1.6-1) ...
Processing triggers for man-db (2.7.5-1) ...
Setting up linuxptp (1.6-1) ...
```

- 確認 ptp4l 與 phc2sys 成功安裝

```
user@user-VirtualBox:~$ ptp4l -v
1.6
user@user-VirtualBox:~$ phc2sys -v
1.6
```

PTP Slave PC 同步設定 (4/6)

- 若網卡有支援 Hardware time stamping，加入 -H 開啟 ptp4l
  - 已連接 foreign mater time server，ID 為 Time server 的UUID
  - 狀態 s0、s1、s2代表 clock 的不同階段，在 s2 時為穩定狀態，offset 值不會有大改動，並真正成為 PTP Slave

UUID

EC:46:70:FF:FE:0A:A6:CD

```
^Cfree5gc@free5gc:~/linuxptp$ sudo ptp4l -i eno1 -mHs
ptp4l[1385.375]: selected /dev/ptp0 as PTP clock
ptp4l[1385.375]: port 1 (eno1): INITIALIZING to LISTENING on INIT_COMPLETE
ptp4l[1385.375]: port 0 (/var/run/ptp4l): INITIALIZING to LISTENING on INIT_COMPLETE
ptp4l[1385.375]: port 0 (/var/run/ptp4lro): INITIALIZING to LISTENING on INIT_COMPLETE
ptp4l[1385.386]: port 1 (eno1): new foreign master ec4670.fffe.0aa6cd-1
ptp4l[1389.386]: selected best master clock ec4670.fffe.0aa6cd
ptp4l[1389.386]: port 1 (eno1): LISTENING to UNCALIBRATED on RS_SLAVE
ptp4l[1391.386]: master offset       292862 s0 freq  +18669 path delay      11230
ptp4l[1392.386]: master offset       294625 s1 freq  +20432 path delay      11230
ptp4l[1393.386]: master offset        -2466 s2 freq  +17966 path delay      11230
ptp4l[1393.386]: port 1 (eno1): UNCALIBRATED to SLAVE on MASTER_CLOCK_SELECTED
ptp4l[1394.386]: master offset        -1296 s2 freq  +18396 path delay      11230
ptp4l[1395.386]: master offset          703 s2 freq  +20006 path delay      11198
ptp4l[1396.386]: master offset         -851 s2 freq  +18663 path delay      11230
ptp4l[1397.386]: master offset         -436 s2 freq  +18823 path delay      11230
ptp4l[1398.386]: master offset         -167 s2 freq  +18961 path delay      11183
ptp4l[1399.386]: master offset         -761 s2 freq  +18317 path delay      11141
ptp4l[1400.386]: master offset         -352 s2 freq  +18498 path delay      11141
ptp4l[1401.386]: master offset           52 s2 freq  +18796 path delay      11114
ptp4l[1402.386]: master offset         1918 s2 freq  +20678 path delay      11013
ptp4l[1403.386]: master offset         -772 s2 freq  +18563 path delay      11013
```

PTP Slave PC 同步設定 (5/6)

- 以 ptp4l 之時間實際調整系統時間
- phc2sys -s 網卡名稱 -O 0，狀態 s0、s1、s2代表 clock 的不同階段，在 s2 時為穩定狀態，offset 值不會有大改動

```
free5gc@free5gc:~/linuxptp$ sudo phc2sys -s eno1 -m -O 0
phc2sys[2103.165]: CLOCK_REALTIME phc offset -25771248258 s0 freq -100000000 delay   1008
phc2sys[2104.165]: CLOCK_REALTIME phc offset -25680278214 s1 freq  +19349 delay   1003
phc2sys[2105.166]: CLOCK_REALTIME phc offset       10429 s2 freq  +29778 delay    945
phc2sys[2106.166]: CLOCK_REALTIME phc offset        -290 s2 freq  +22188 delay    882
phc2sys[2107.166]: CLOCK_REALTIME phc offset       -3993 s2 freq  +18398 delay    896
phc2sys[2108.166]: CLOCK_REALTIME phc offset       -3399 s2 freq  +17794 delay    882
phc2sys[2109.167]: CLOCK_REALTIME phc offset       -1753 s2 freq  +18420 delay    869
phc2sys[2110.167]: CLOCK_REALTIME phc offset        -828 s2 freq  +18819 delay    898
phc2sys[2111.167]: CLOCK_REALTIME phc offset        -364 s2 freq  +19035 delay    882
phc2sys[2112.167]: CLOCK_REALTIME phc offset        -446 s2 freq  +18844 delay    865
phc2sys[2113.167]: CLOCK_REALTIME phc offset         352 s2 freq  +19508 delay    902
phc2sys[2114.168]: CLOCK_REALTIME phc offset        -140 s2 freq  +19121 delay    882
phc2sys[2115.168]: CLOCK_REALTIME phc offset        -423 s2 freq  +18796 delay    867
phc2sys[2116.168]: CLOCK_REALTIME phc offset          47 s2 freq  +19139 delay    866
phc2sys[2117.168]: CLOCK_REALTIME phc offset         617 s2 freq  +19724 delay    862
phc2sys[2118.168]: CLOCK_REALTIME phc offset         744 s2 freq  +20036 delay    852
phc2sys[2119.169]: CLOCK_REALTIME phc offset        -534 s2 freq  +18981 delay    849
phc2sys[2120.169]: CLOCK_REALTIME phc offset        -413 s2 freq  +18942 delay    913
phc2sys[2121.169]: CLOCK_REALTIME phc offset          54 s2 freq  +19285 delay    899
phc2sys[2122.169]: CLOCK_REALTIME phc offset        -133 s2 freq  +19114 delay    882
phc2sys[2123.169]: CLOCK_REALTIME phc offset         523 s2 freq  +19730 delay    902
^Cphc2sys[2123.983]: CLOCK_REALTIME phc offset         633 s2 freq  +19997 delay    911
```

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PTP Slave PC 同步設定 (6/6)

- 利用 pmc 取得時間同步之詳細資訊
 - sudo pmc -u -b 0 'GET TIME_STATUS_NP'

```
free5gc@free5gc:~/linuxptp$ sudo pmc -u -b 0 'GET TIME_STATUS_NP'
[sudo] password for free5gc:
sending: GET TIME_STATUS_NP
        e03f49.fffe.e87037-0 seq 0 RESPONSE MANAGEMENT TIME_STATUS_NP
                master_offset             834
                ingress_time              1637902746601475375
                cumulativeScaledRateOffset +0.000000000
                scaledLastGmPhaseChange   0
                gmTimeBaseIndicator       0
                lastGmPhaseChange         0x0000'0000000000000000.0000
                gmPresent                 true
                gmIdentity                ec4670.fffe.0aa6cd
```

  - sudo pmc -u -b 0 'GET CURRENT_DATA_SET'

```
free5gc@free5gc:~/linuxptp$ sudo pmc -u -b 0 'GET CURRENT_DATA_SET'
sending: GET CURRENT_DATA_SET
        e03f49.fffe.e87037-0 seq 0 RESPONSE MANAGEMENT CURRENT_DATA_SET
                stepsRemoved      1
                offsetFromMaster -627.0
                meanPathDelay     16979.0
```

結果呈現

- 使用 Network Time Protocol (NTP) 與 Precision Time Protocol (PTP) 之系統時鐘差異值差別
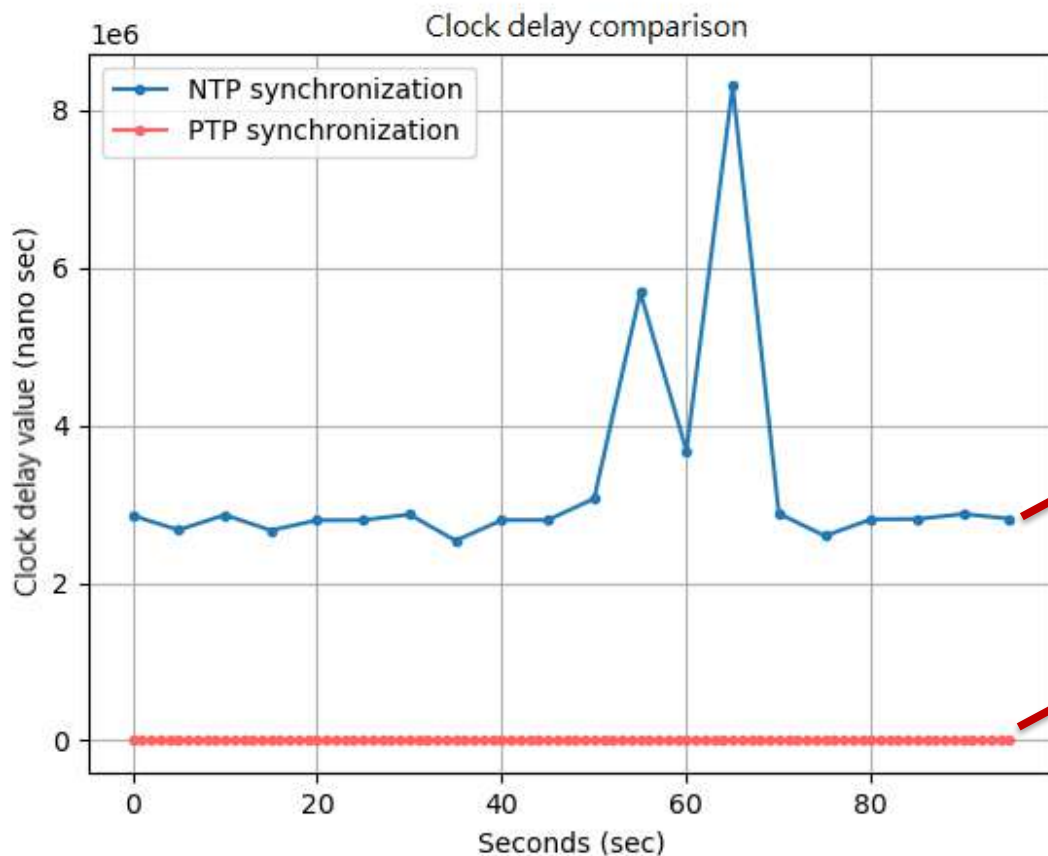
Avg：3,258,450 ns

Avg：757 ns

結果呈現

- 使用 TSN Switch 與使用非 TSN Switch 進行時間同步，其封包轉送至目標電腦的時間差異
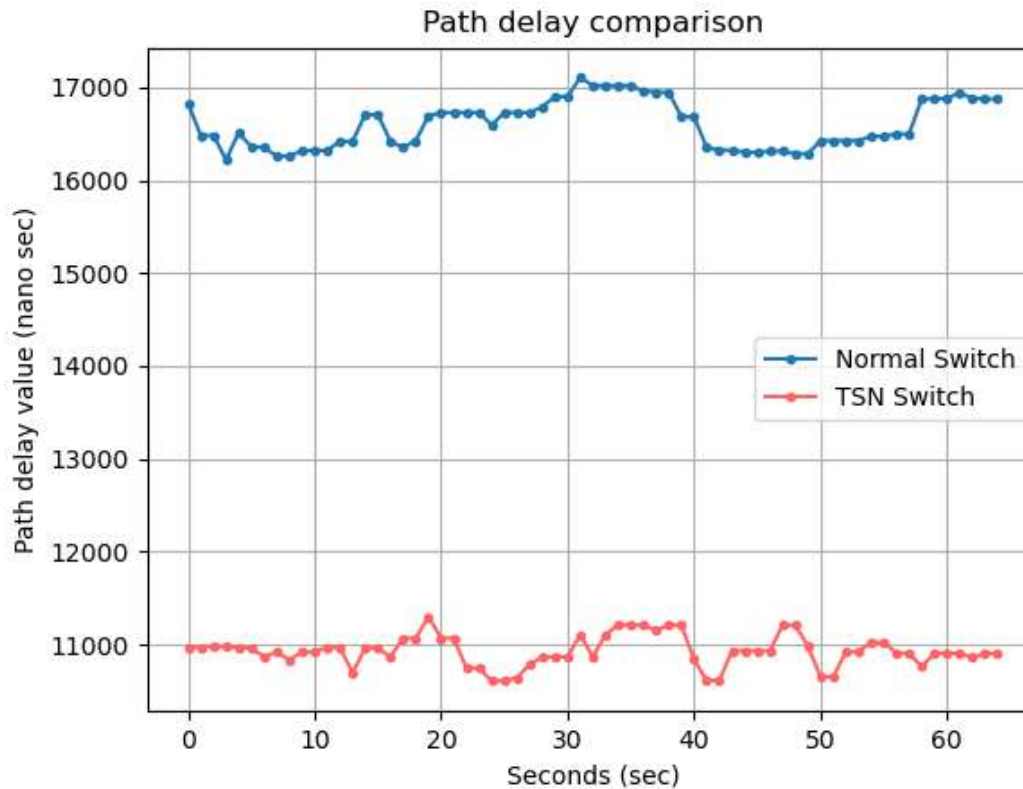
結果呈現

- 使用現實世界之電風扇，比較NTP與PTP差異

NTP

PTP

AI智慧教練介紹與實作

同步影像5G傳輸線路圖

PTP Slave1

POE

5G dongle

free5GC

5G SA System

PTP Slave2

POE

5G dongle

publish

High-speed camera

CoachAI Server
MQTT Broker

WiRE
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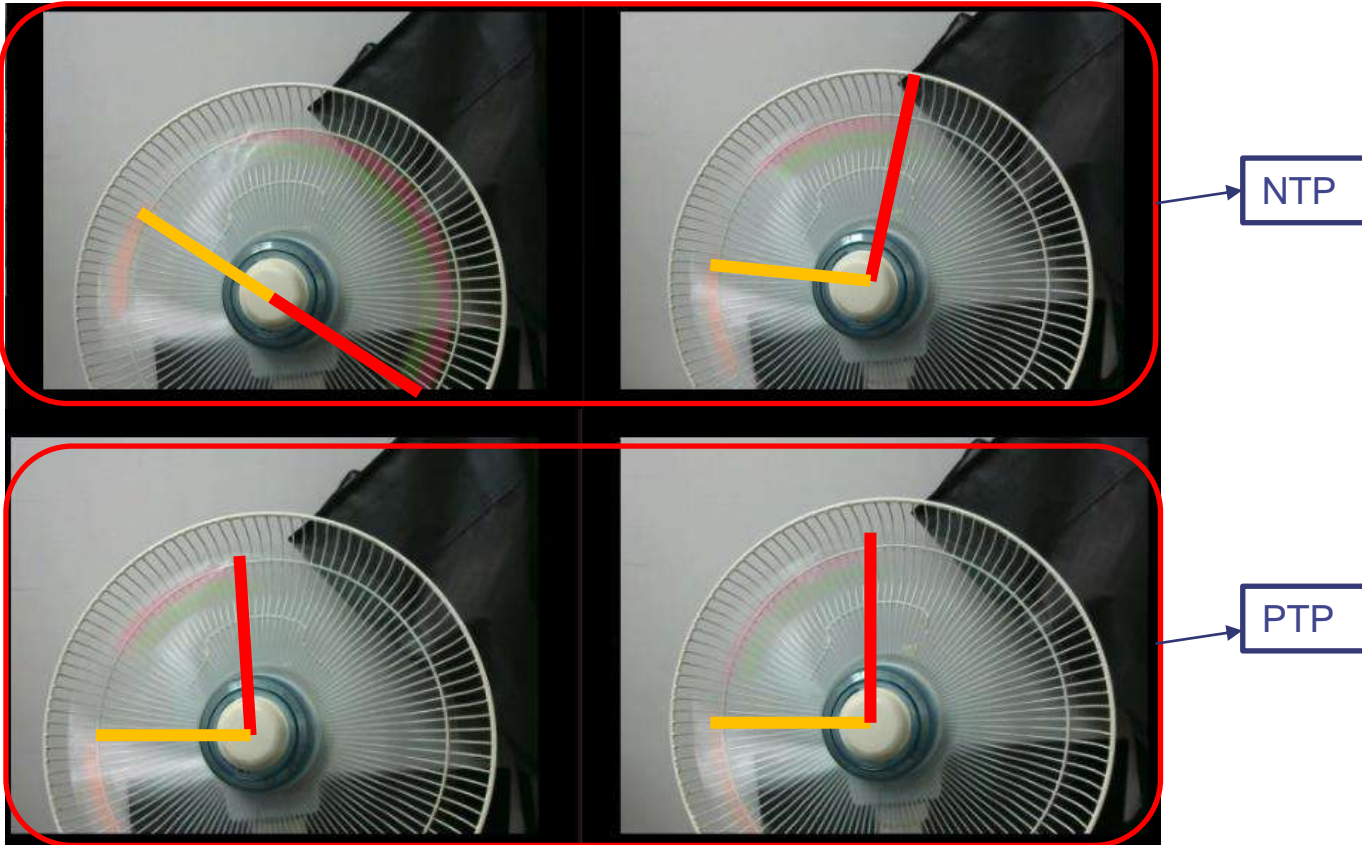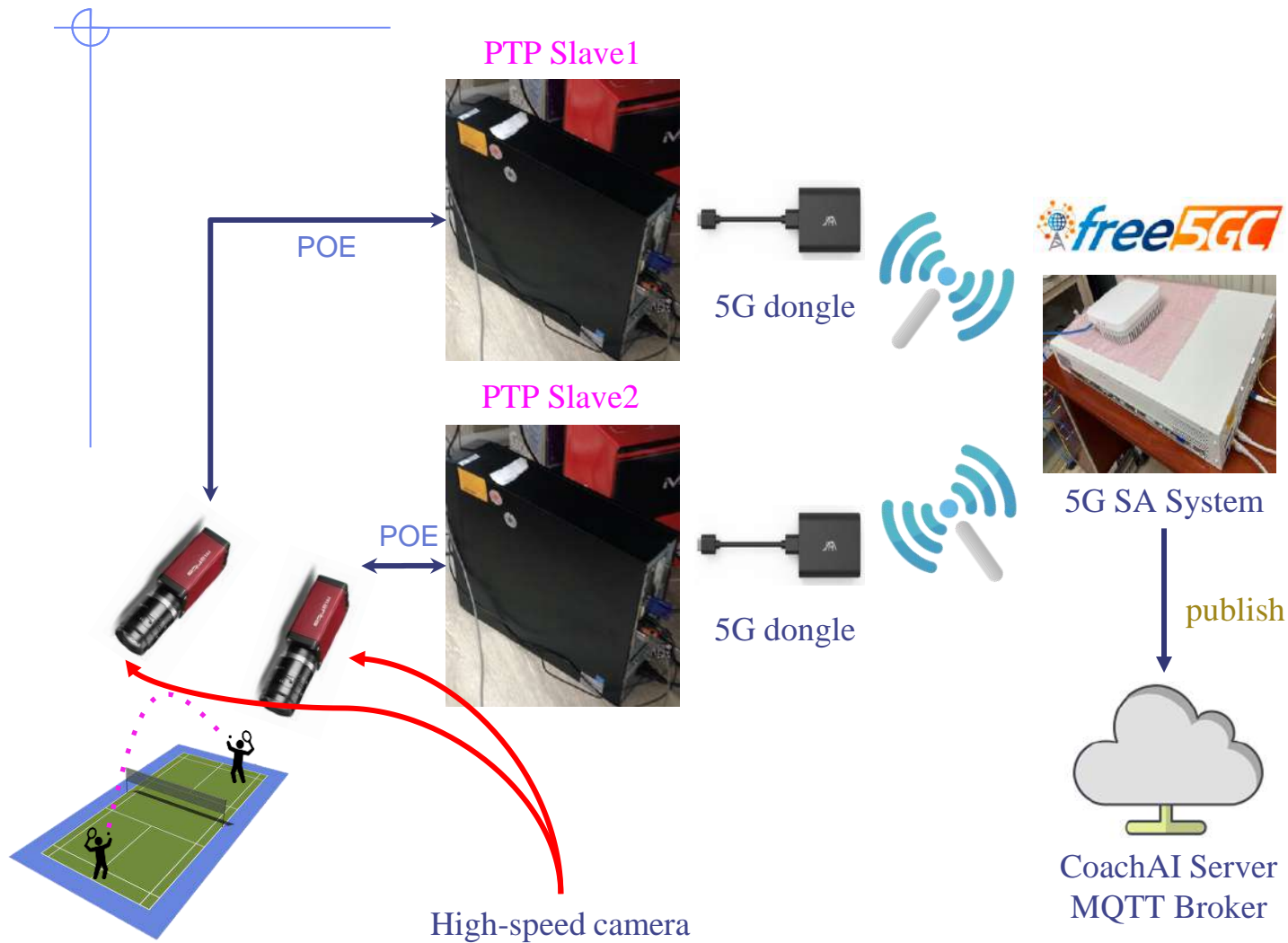
整體5G架構線路圖

連接5G網路設定

Step 1

1) 在桌上型電腦安裝好free5gc，並切換至free5gc資料夾內
2) 先輸入 ./force_kill.sh
3) 再輸入 ./run.sh，啟動free5gc

Step 2

1) 插入5G SA基地台的電源
2) 並按下啟動鍵

Step 3

1) 切換至~/gnbfs/system/bin資料夾
2) 輸入sudo ./bringup_cudu_phy.sh init
3) 輸入sudo ./bringup_cudu_phy.sh start
4) 等待畫面出現如右圖所示最後一行

    waiting first slot…

Step 4

1) 將POE網路線插入OUT孔
2) 並等待畫面呈現如右下角所示
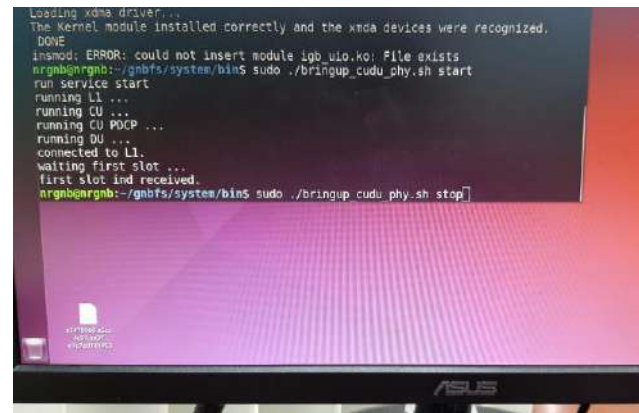
Step 5

1) 將5G SIM卡插入5G USB無線網卡
2) 並透過連接線將5G USB無線網卡接上筆記型電腦

Step 6

1) 進入電腦Setting
2) 切換至Network介面
3) 等待Connecting成功
4) 點擊紅框內的圖標
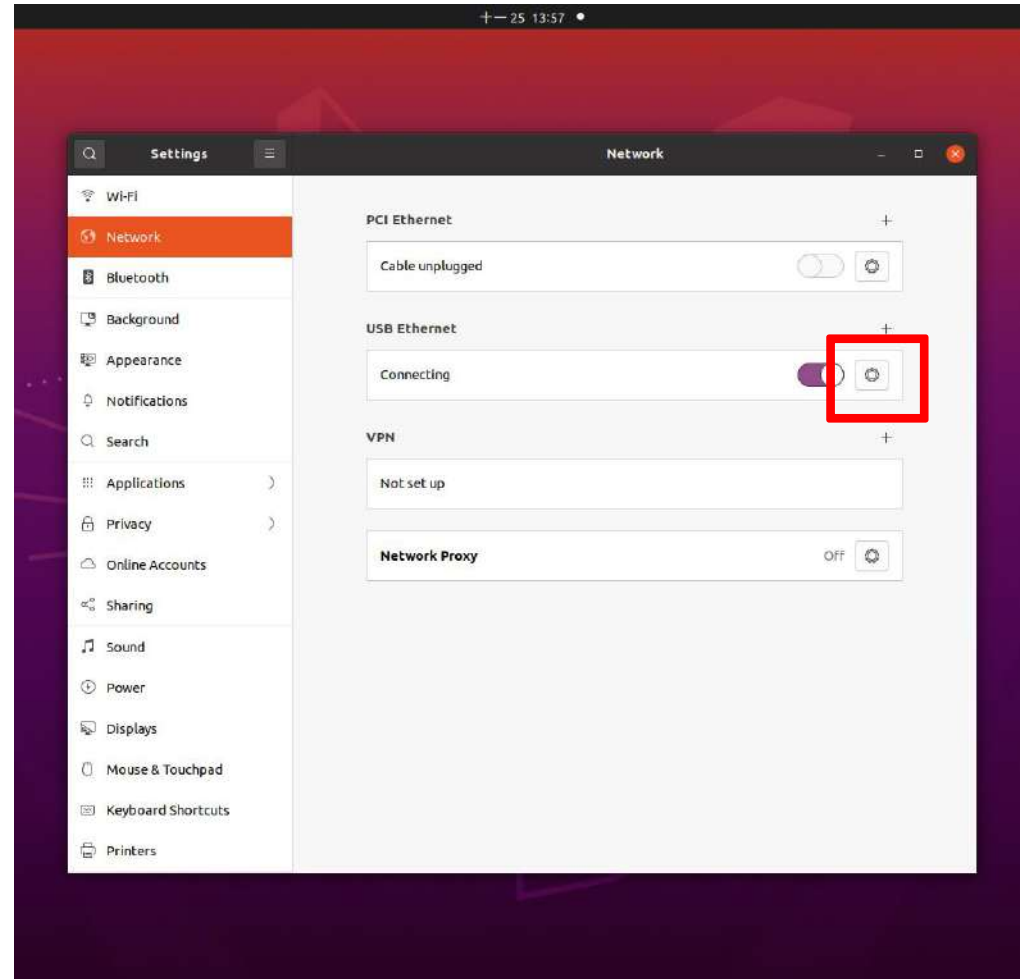
Step 7

1) 確認畫面有出現紅框內的**IP**後

2) 開啟瀏覽器，並輸入192.168.255.1
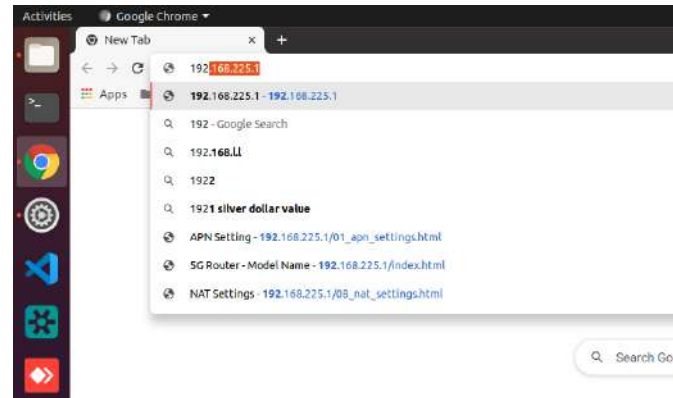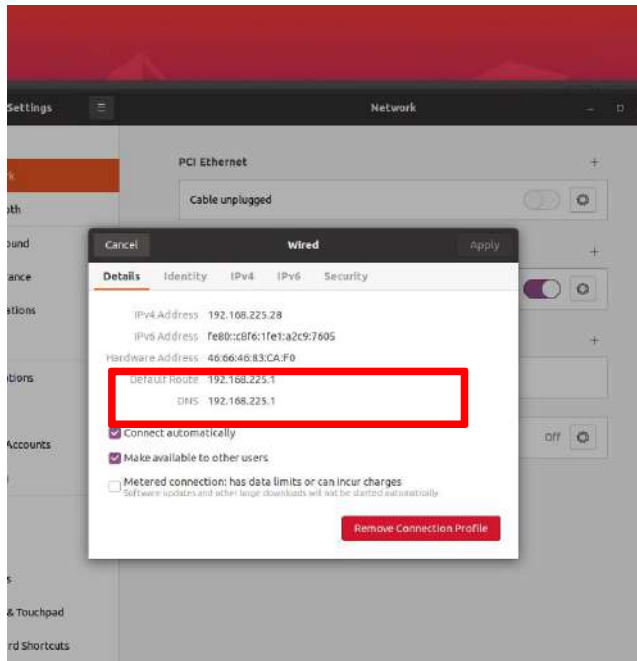
Step 8

1) 進入網頁後
2) 輸入帳號及密碼
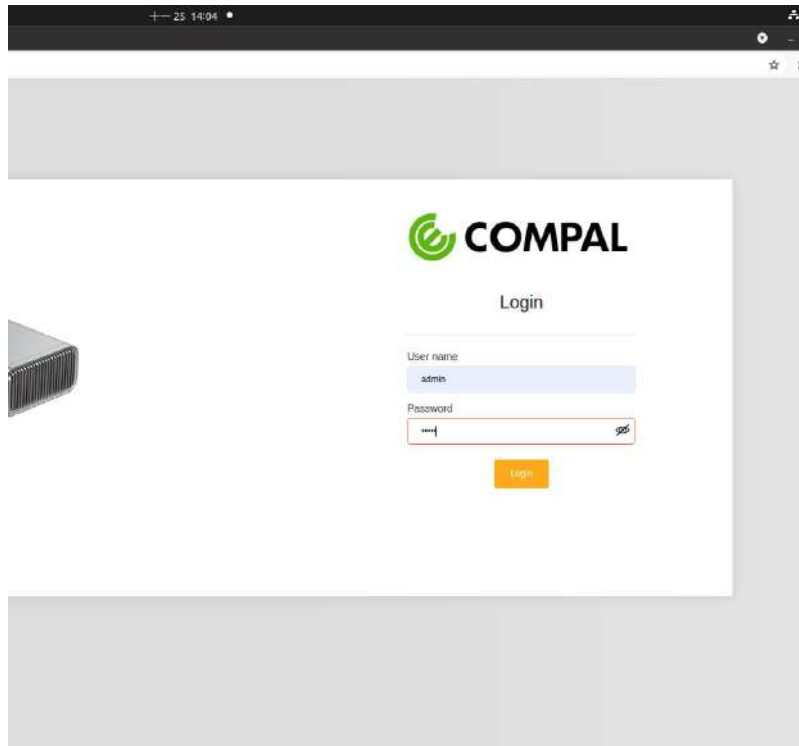
Step 9

1) 至APN Settings頁面
2) 在APN欄位輸入internet
3) 點擊Update按鈕
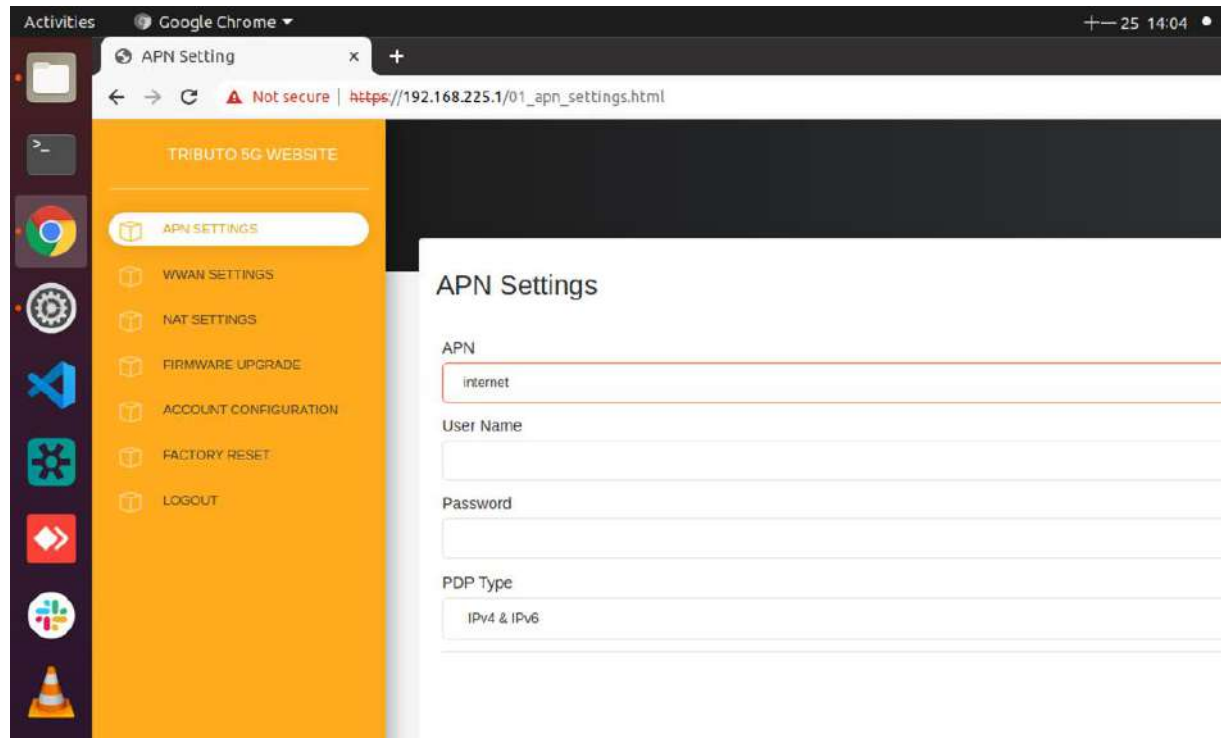
Step 10

1) 至NAT Settings頁面
2) 開啟IP Pass-Through
3) 點擊Update按鈕

Step 11

1) 等待安裝free5gc的桌上型電腦分配PDUAdress

2) 記下分配的PDUAdress
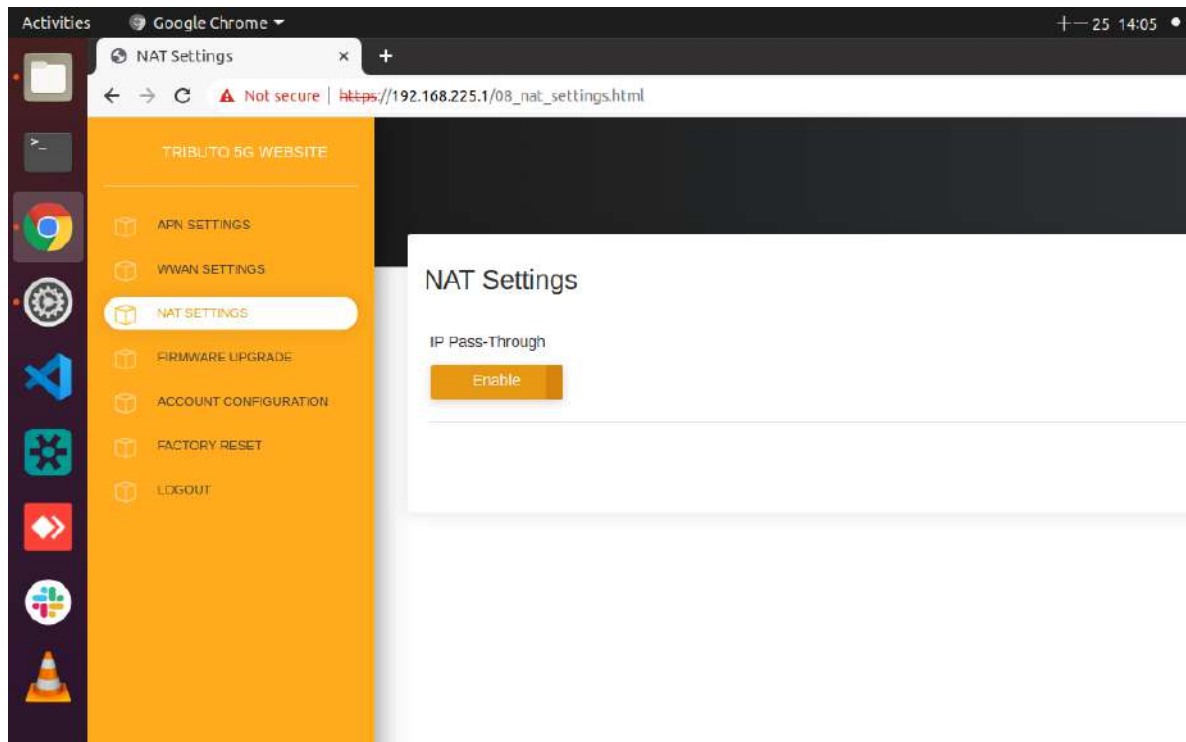
Step 12

1) 重複Step 6
2) 進入IPv4介面
3) 選擇Manual
4) 在Addresses欄位輸入Step 11分配的PDUAddress，以及16，如右下圖
5) 在DNS欄位輸入8.8.8.8
6) 點擊Apply，以儲存變更設定
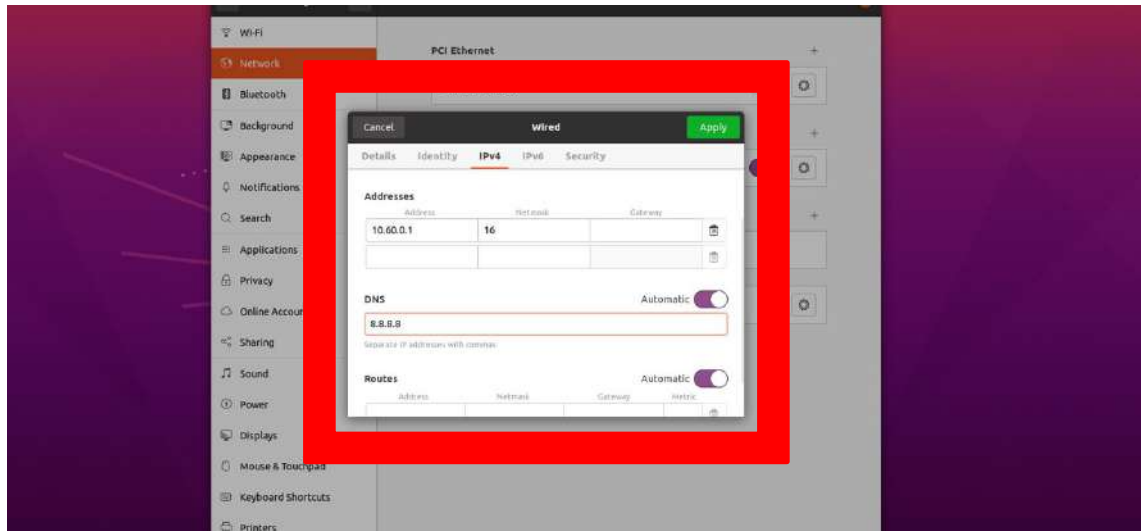
Step 13

1) 等待電腦重新連結，確認Connect的Details介面中IPv4 Address變為剛剛輸入之PDUAddress

2) 到Terminal中輸入ifconfig，複製類似紅框中的字串

Step 14

1) 在Terminal中輸入：sudo ip route add default dev [剛複製的字串]
2) 在Terminal中輸入：ping 8.8.8.8
3) 如果有出現右下角圖示的結果，代表成功連接5G網路了

AI智慧教練操作手冊

更改 CoachAI config 檔案

- vim coachAI/projects/coachbox.cfg
- 更改相機設定至本場域所使用之Allied Vision相機

```
[CameraReaderL]
node_type = Reader
brand = Image_Source
hw_id = 28124278
general_topic = cam_control
output_topic = raw_data_l
monitor_topic = cam_data_l
publish_fps = 0

[CameraReaderR]
node_type = Reader
brand = Image_Source
hw_id = 16124946
general_topic = cam_control
output_topic = raw_data_r
monitor_topic = cam_data_r
publish_fps = 0
```

→

```
[CameraReaderL]
node_type = Reader
brand = Allied_Vision
hw_id = DEV_000F314E65A0
general_topic = cam_control
output_topic = raw_data_l
monitor_topic = cam_data_l
publish_fps = 0

[CameraReaderR]
node_type = Reader
brand = Allied_Vision
hw_id = DEV_000F314EC157
general_topic = cam_control
output_topic = raw_data_r
monitor_topic = cam_data_r
publish_fps = 0
```

更改 CoachAI 時間機制

- 將 frame.get_timestamp() 改為 datetime.now().timestamp()，使夾帶的時間資訊為先前同步過的系統時間。

```
while self.alive:
    if len(self.frame_queue) > 0:
        frame = self.frame_queue.pop(0)
        timestamp = frame.get_timestamp()
        if (timestamp - self.last_send_t) > self.interval and frame != None:
            # publish raw image
            frame.convert_pixel_format(PixelFormat.Bgr8)
            cv_image = frame.as_opencv_image()
            if self.recorder is not None:
                self.recorder.try_put_frame(cv_image)
            ret, buf = cv2.imencode('.jpg', cv_image)
            if ret == True:
                imdata = pickle.dumps(buf)
                payload = { 'id': frame.get_id(), 'timestamp': timestamp, 'raw_data':
```
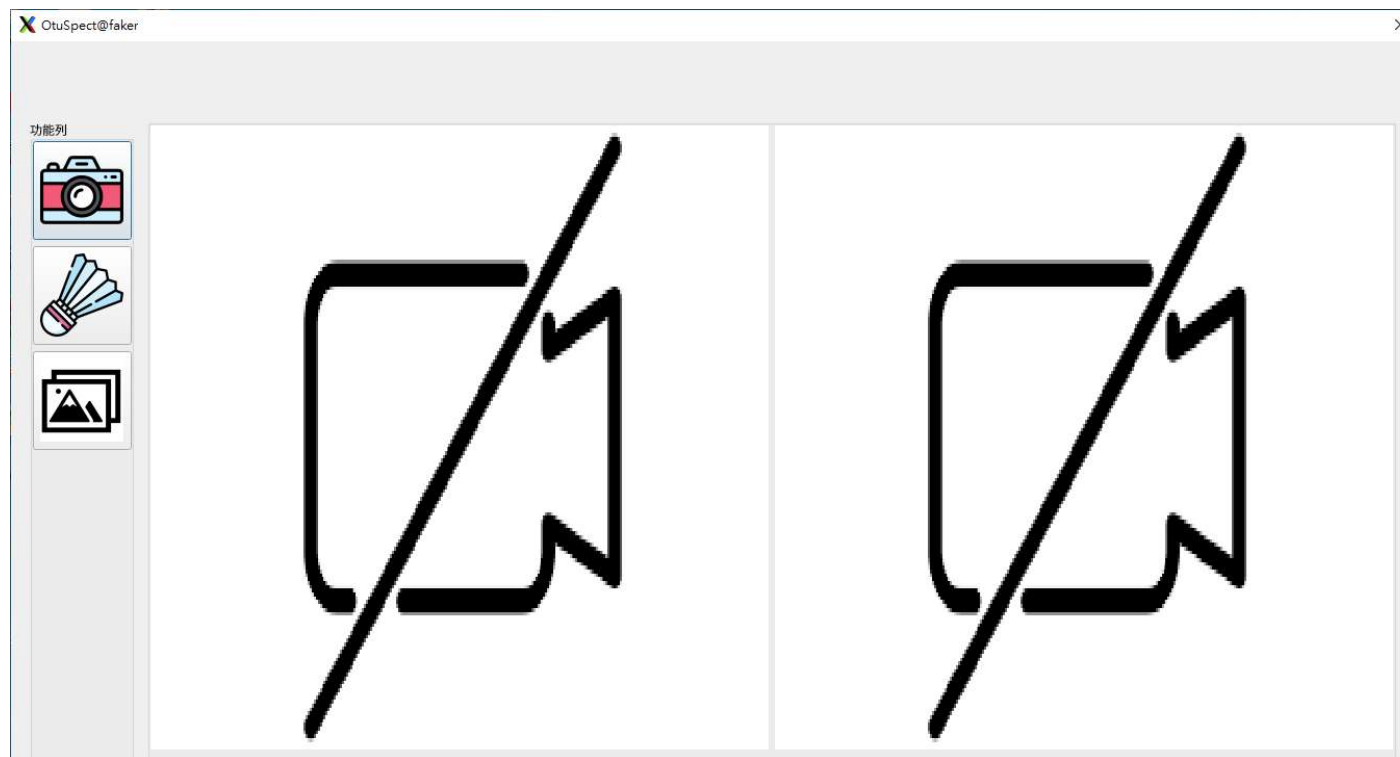
UI介面

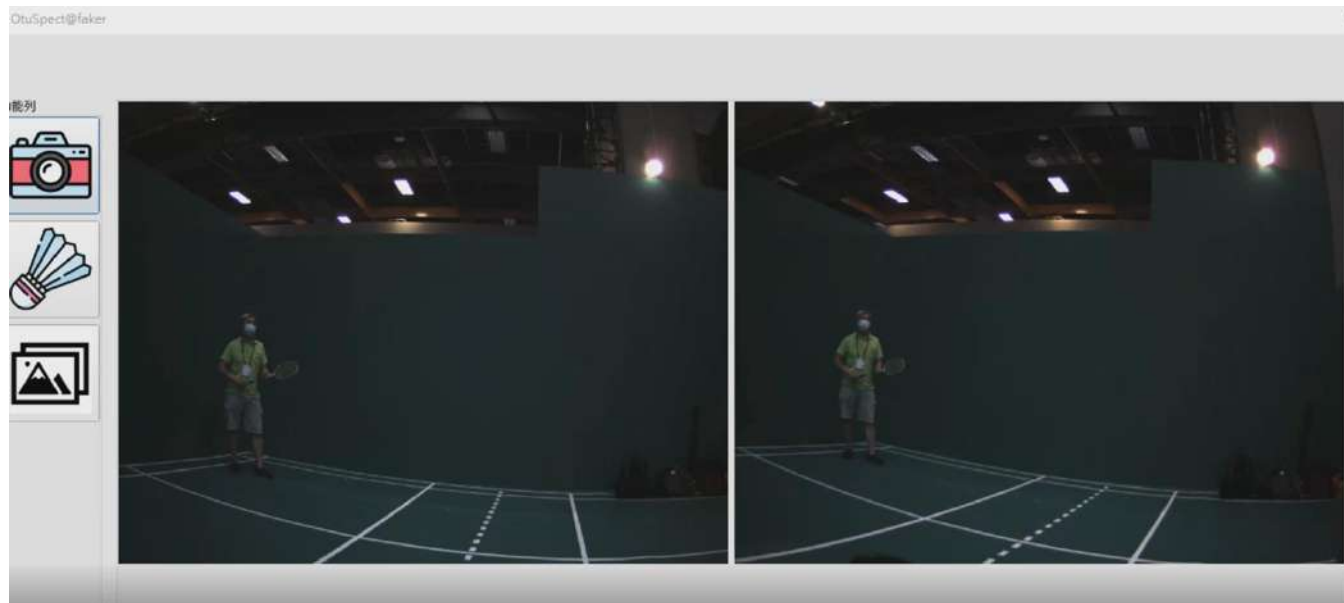- 進入 CoachAI/UI
- 執行 python3 main.py

球路軌跡預測

- 點選 OtuSpect，等待相機開啟，在連接相機的電腦開啟CoachAI的 CameraReader.py，開始拍攝

球路軌跡預測

- 開始拍攝人員擊球情況，可在此 UI 看見直播同步畫面

球路軌跡預測

- 點選左邊之羽球圖案，可進行羽球軌跡分析，並得到結果圖