

Fun5G: 오픈소스 중앙 집중형 네트워킹 소프트웨어 패키지

Kyung Hee University, POSTECH, Seoul National University

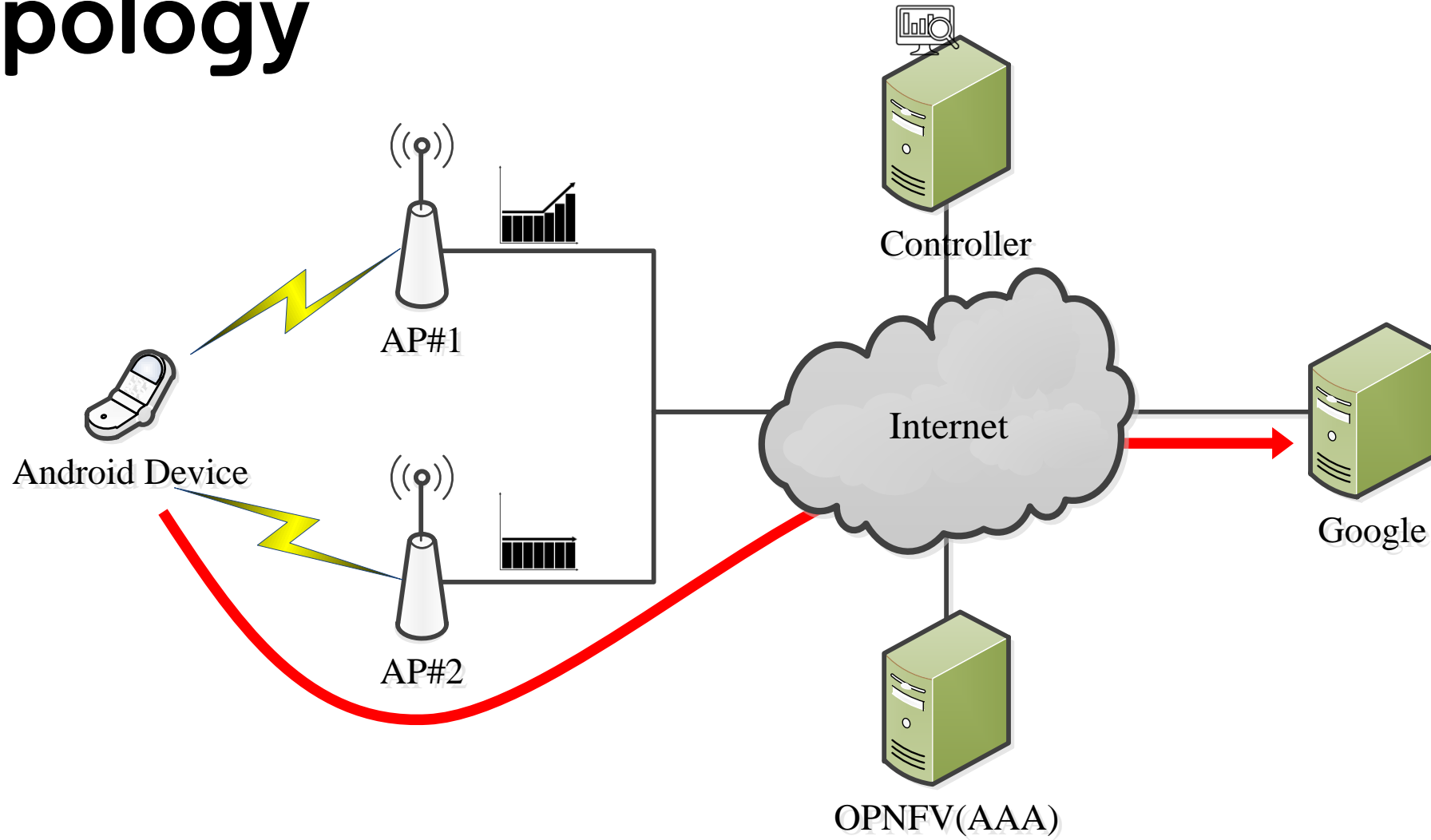
Mobile Convergence Laboratory, Media Computing & Networking Laboratory, Network Convergence & Security Laboratory

안계완, 고세원, 호동혁, 노현민, 송정환, 최대진

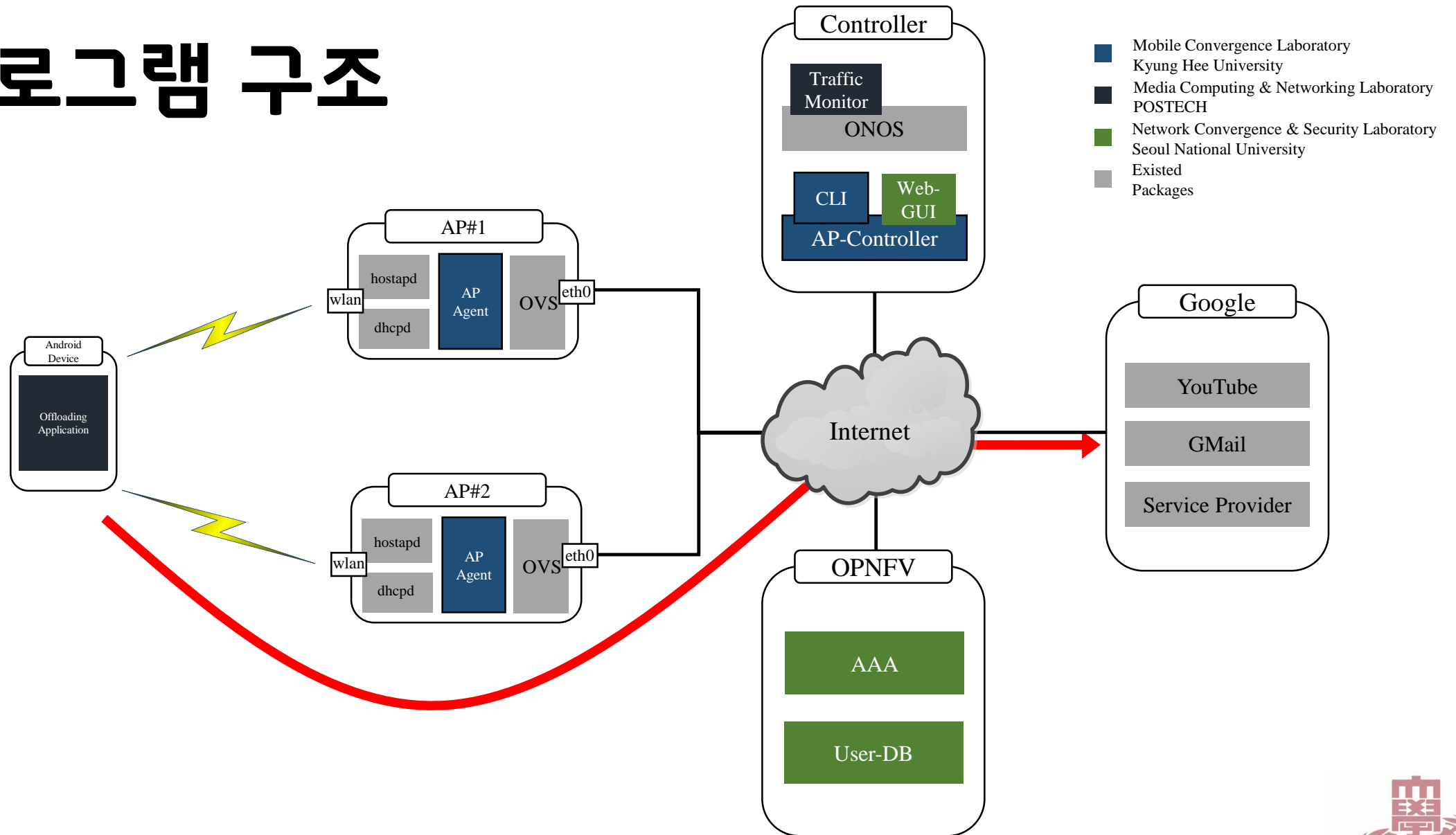
2016. 04. 08



Topology

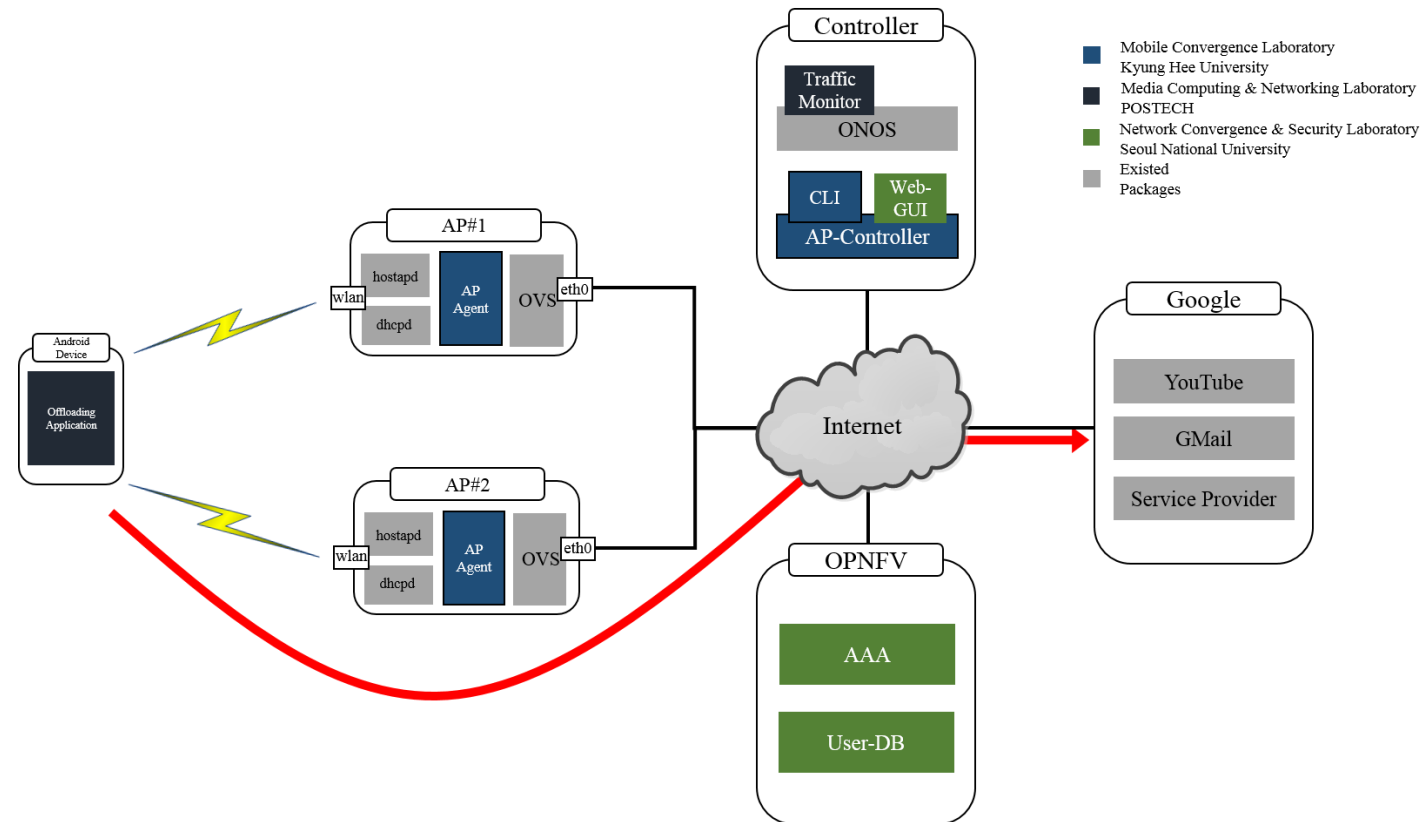


프로그램 구조



구현된 네트워크 기능/서비스

- 다수의 AP 컨트롤
 - SSID, password, channel, broadcast 수정 가능
- Traffic monitoring
- AP의 Traffic 제한에 따라 offload
- 사용자를 OPNFV AAA 로 인증 가능
- GUI로 사용자 정보 및 AP 관리



Controller 설치 가이드

Kyung Hee University, POSTECH, Seoul National University

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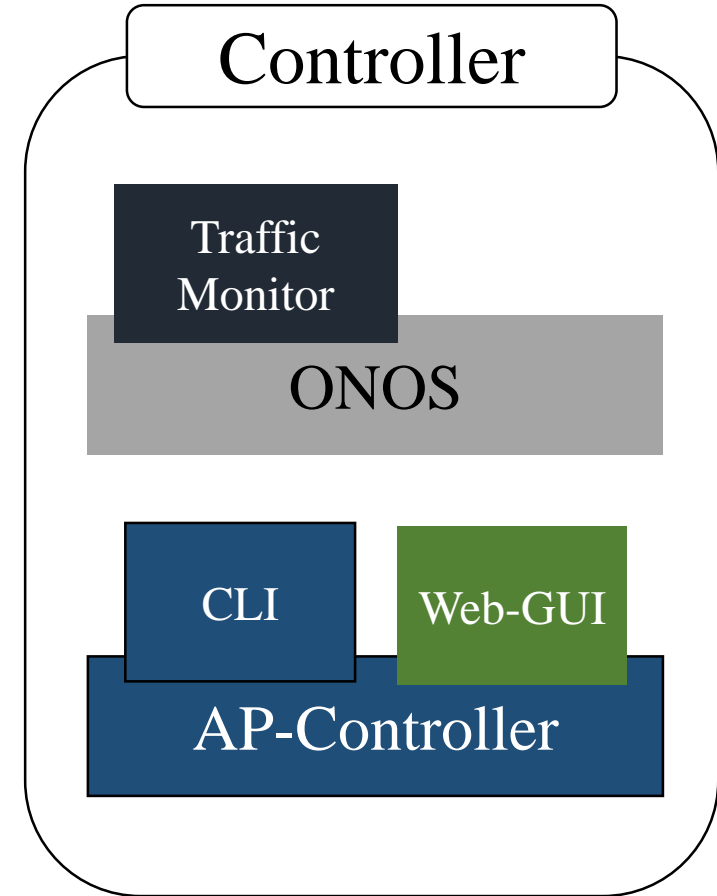
안계완, 고세원, 호동혁, 노현민, 최대진

2016. 04. 08



설치 과정

- 하드웨어 사양
- 윈도우 환경에서 Ubuntu 부팅 USB 작성
- Ubuntu 14.04 설치
- 소프트웨어 작동에 필요한 필수 라이브러리 설치
- AP-Controller 작동에 필요한 Database 구축
- AP-Controller 설치 및 실행
- Web-GUI 설치 및 실행
- Offloading App 작동에 필요한 ONOS 설치
- Offloading App 설치 및 실행



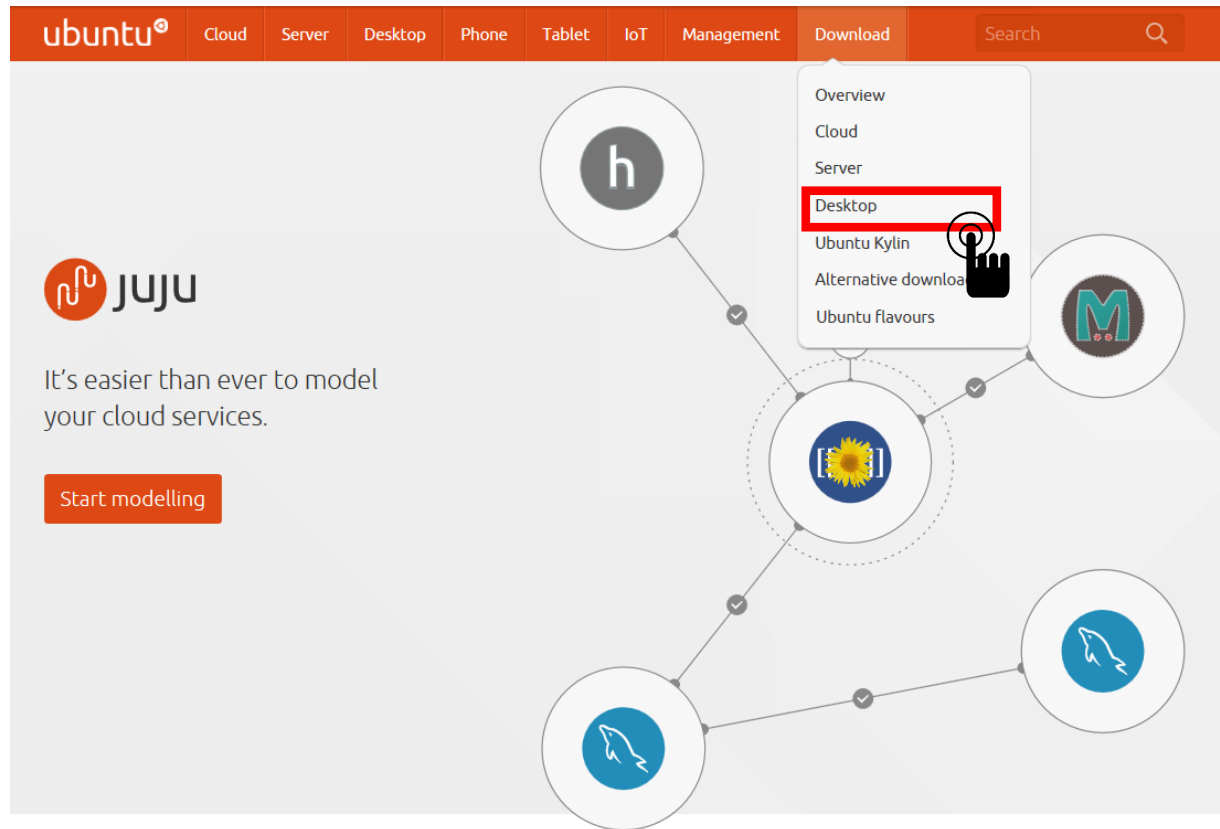
하드웨어 사양



- Intel 64bit CPU
- 4GB or more RAM
- 16GB or more storage
- 100Mbps or more faster Ethernet port



Ubuntu 14.04 image 다운로드

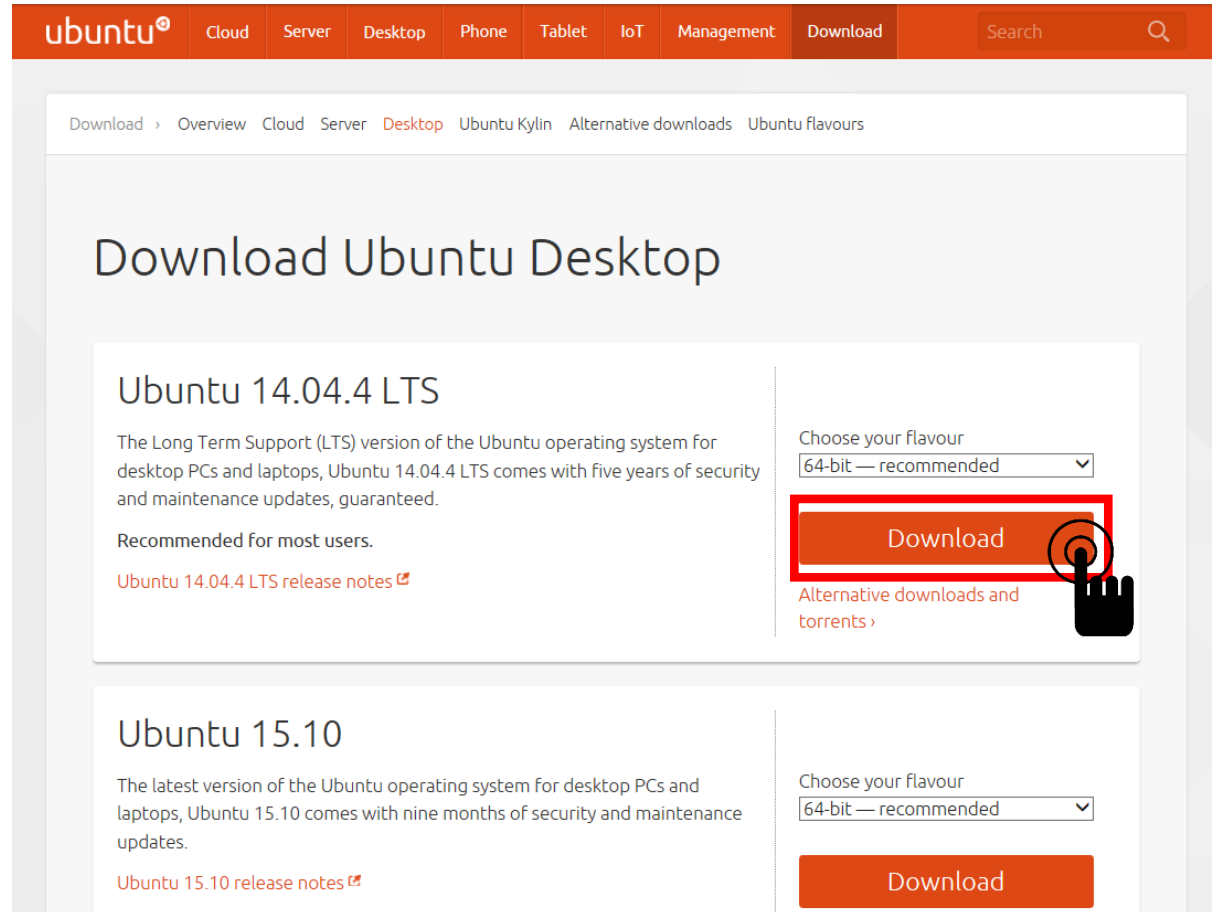


- <http://www.ubuntu.com/>

📄 LATEST NEWS FROM INSIGHTS



Ubuntu 14.04 image 다운로드



The screenshot shows the Ubuntu website's download page for the Desktop version. The top navigation bar includes links for Cloud, Server, Desktop, Phone, Tablet, IoT, Management, and Download. The main heading is "Download Ubuntu Desktop". Below this, there are two main sections: "Ubuntu 14.04.4 LTS" and "Ubuntu 15.10". The "Ubuntu 14.04.4 LTS" section describes it as the Long Term Support (LTS) version with five years of security and maintenance updates, recommended for most users. It includes a link to the "Ubuntu 14.04.4 LTS release notes". To the right of this text is a "Choose your flavour" dropdown menu set to "64-bit — recommended", followed by a red "Download" button which is highlighted with a red rectangle and a black cursor icon. Below the button is a link for "Alternative downloads and torrents". The "Ubuntu 15.10" section describes it as the latest version with nine months of security and maintenance updates, also with a "Choose your flavour" dropdown set to "64-bit — recommended" and a "Download" button.

ubuntu® Cloud Server Desktop Phone Tablet IoT Management Download Search

Download > Overview Cloud Server Desktop Ubuntu Kylin Alternative downloads Ubuntu flavours

Download Ubuntu Desktop

Ubuntu 14.04.4 LTS

The Long Term Support (LTS) version of the Ubuntu operating system for desktop PCs and laptops, Ubuntu 14.04.4 LTS comes with five years of security and maintenance updates, guaranteed.

Recommended for most users.

[Ubuntu 14.04.4 LTS release notes](#)

Choose your flavour
64-bit — recommended

Download

[Alternative downloads and torrents >](#)

Ubuntu 15.10

The latest version of the Ubuntu operating system for desktop PCs and laptops, Ubuntu 15.10 comes with nine months of security and maintenance updates.

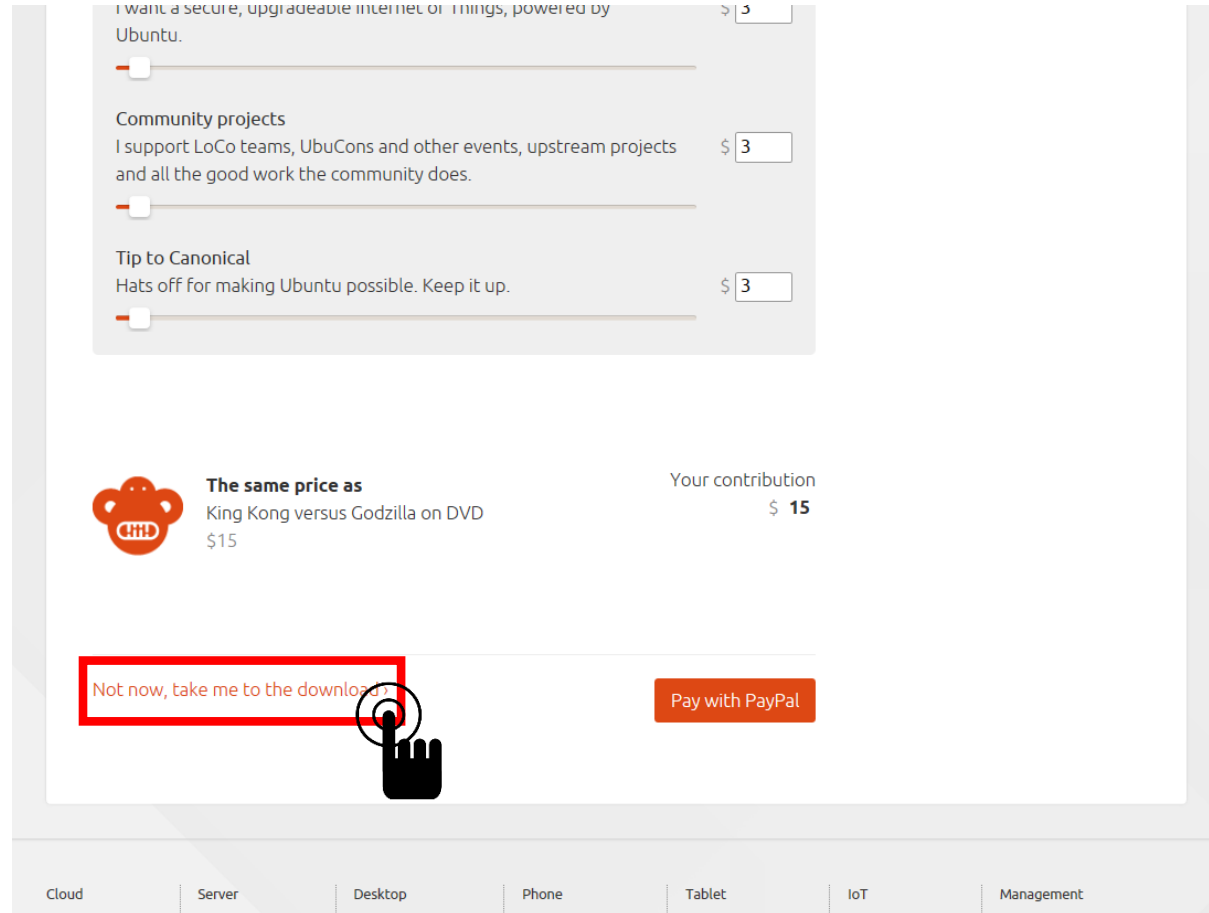
[Ubuntu 15.10 release notes](#)

Choose your flavour
64-bit — recommended

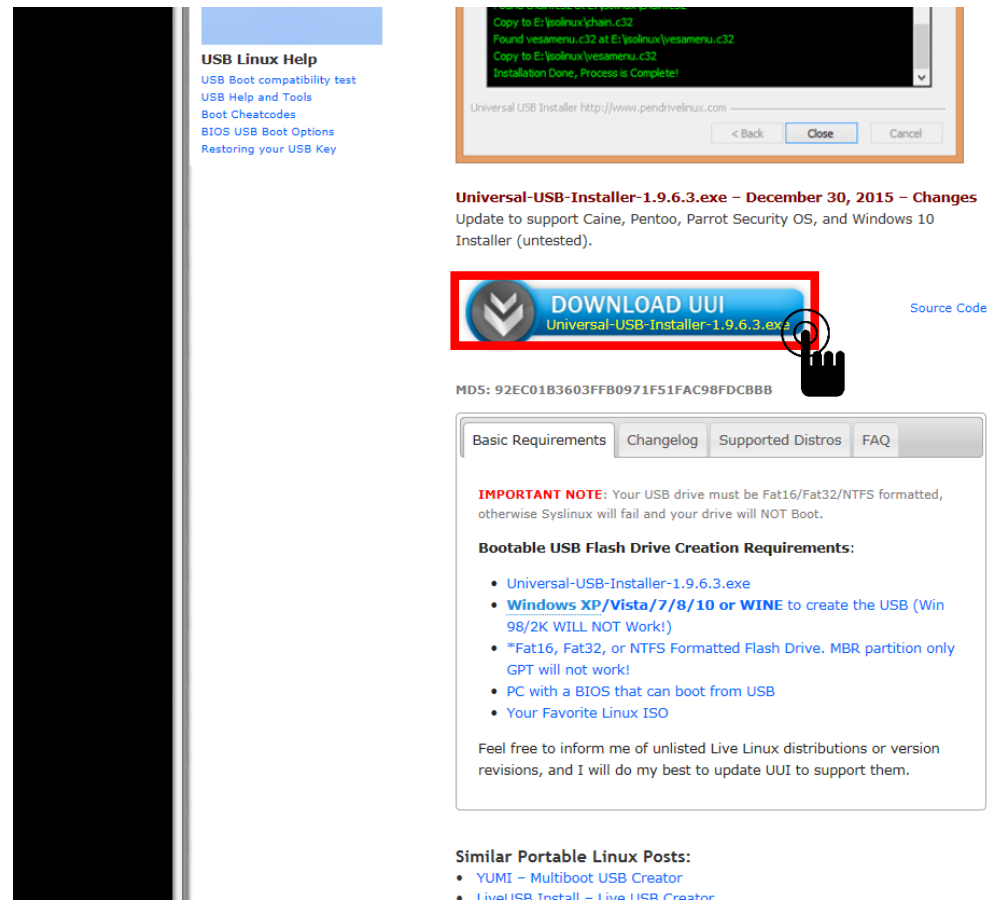
Download



Ubuntu 14.04 image 다운로드



Universal USB Installer



USB Linux Help
USB Boot compatibility test
USB Help and Tools
Boot Cheatcodes
BIOS USB Boot Options
Restoring your USB Key

```
Copy to E:\jollinux\chain.c32
Found vesamenu.c32 at E:\jollinux\vesamenu.c32
Copy to E:\jollinux\vesamenu.c32
Installation Done, Process is Complete!
```

Universal USB Installer <http://www.pendrivelinux.com>
< Back Close Cancel

Universal-USB-Installer-1.9.6.3.exe – December 30, 2015 – Changes
Update to support Caine, Pentoo, Parrot Security OS, and Windows 10 Installer (untested).

DOWNLOAD UUI
Universal-USB-Installer-1.9.6.3.exe

Source Code

MD5: 92EC01B3603FFB0971F51FAC98FDCBBB

Basic Requirements Changelog Supported Distros FAQ

IMPORTANT NOTE: Your USB drive must be Fat16/Fat32/NTFS formatted, otherwise Syslinux will fail and your drive will NOT Boot.

Bootable USB Flash Drive Creation Requirements:

- [Universal-USB-Installer-1.9.6.3.exe](#)
- [Windows XP/Vista/7/8/10 or WINE](#) to create the USB (Win 98/2K WILL NOT Work!)
- *Fat16, Fat32, or NTFS Formatted Flash Drive. MBR partition only GPT will not work!
- PC with a BIOS that can boot from USB
- Your Favorite Linux ISO

Feel free to inform me of unlisted Live Linux distributions or version revisions, and I will do my best to update UUI to support them.

Similar Portable Linux Posts:

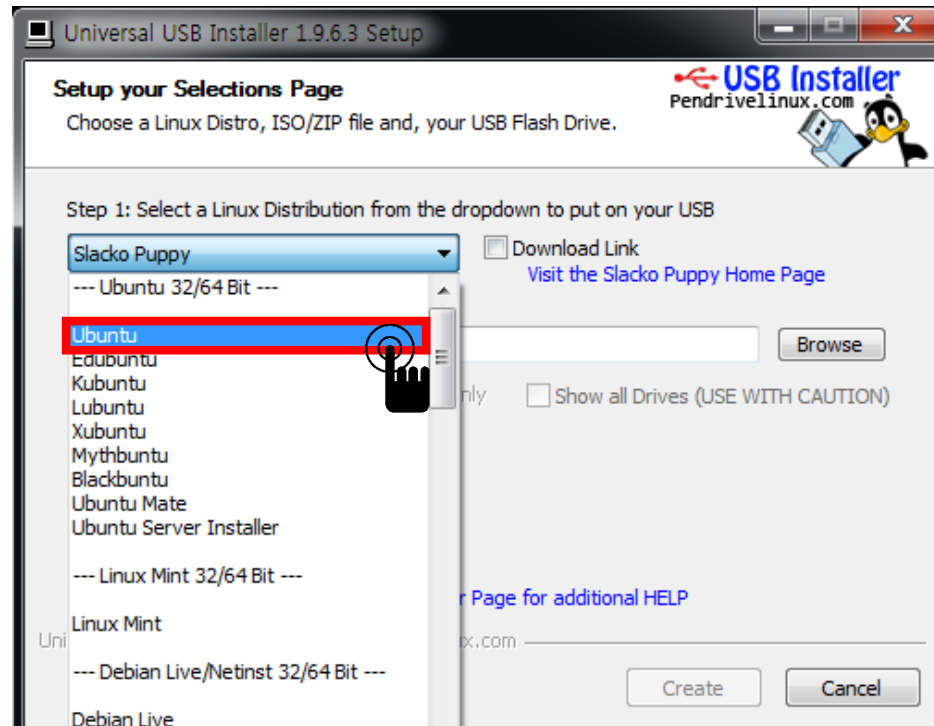
- [YUMI – Multiboot USB Creator](#)
- [LiveUSB Install – Live USB Creator](#)

- <http://www.pendrivelinux.com/universal-usb-installer-easy-as-1-2-3/#button>



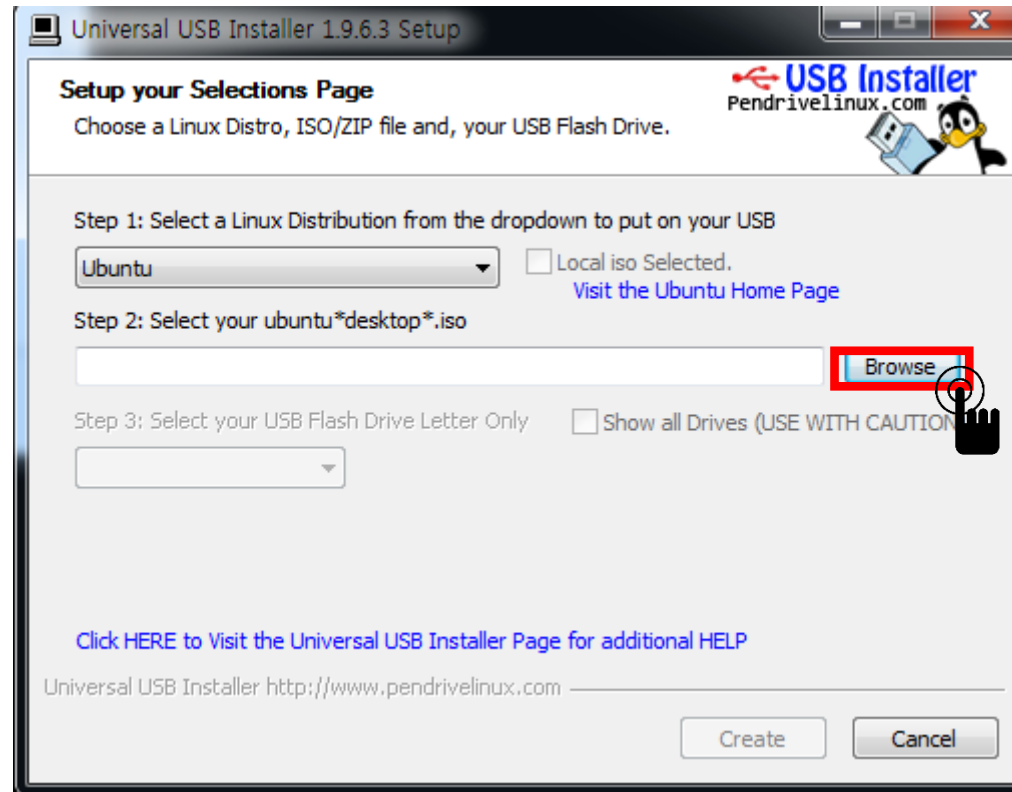
Universal USB Installer

- Universal USB Installer로 Ubuntu Booting USB 만들기



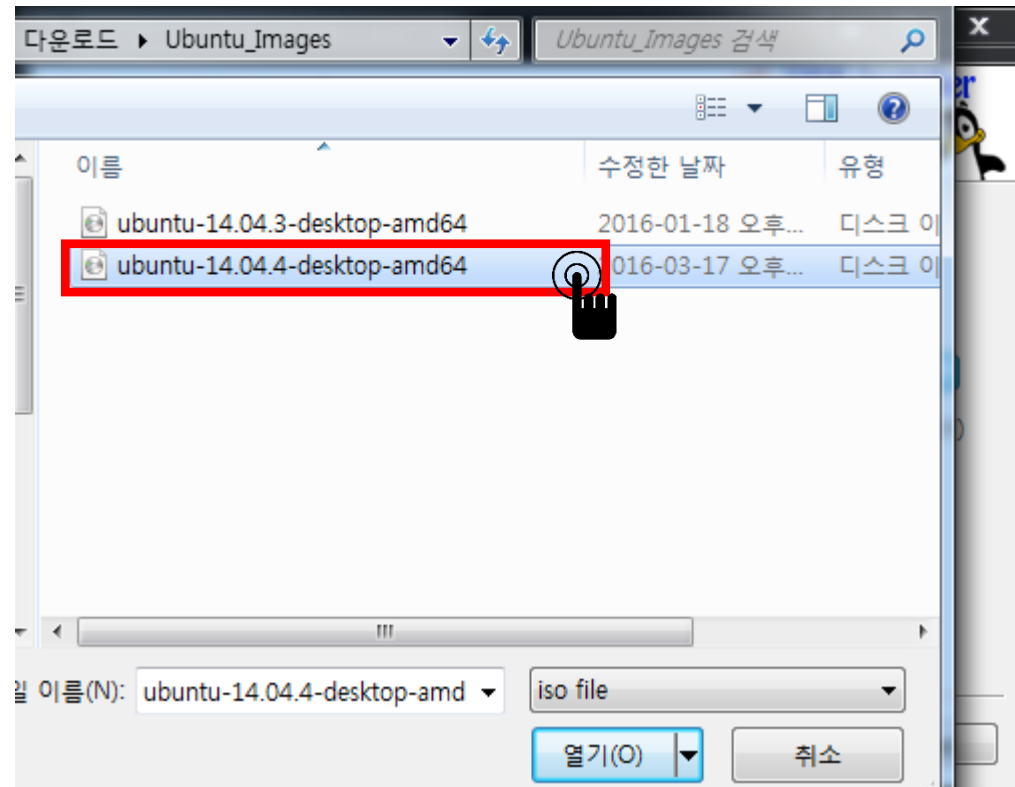
Universal USB Installer

- Universal USB Installer로 Ubuntu Booting USB 만들기



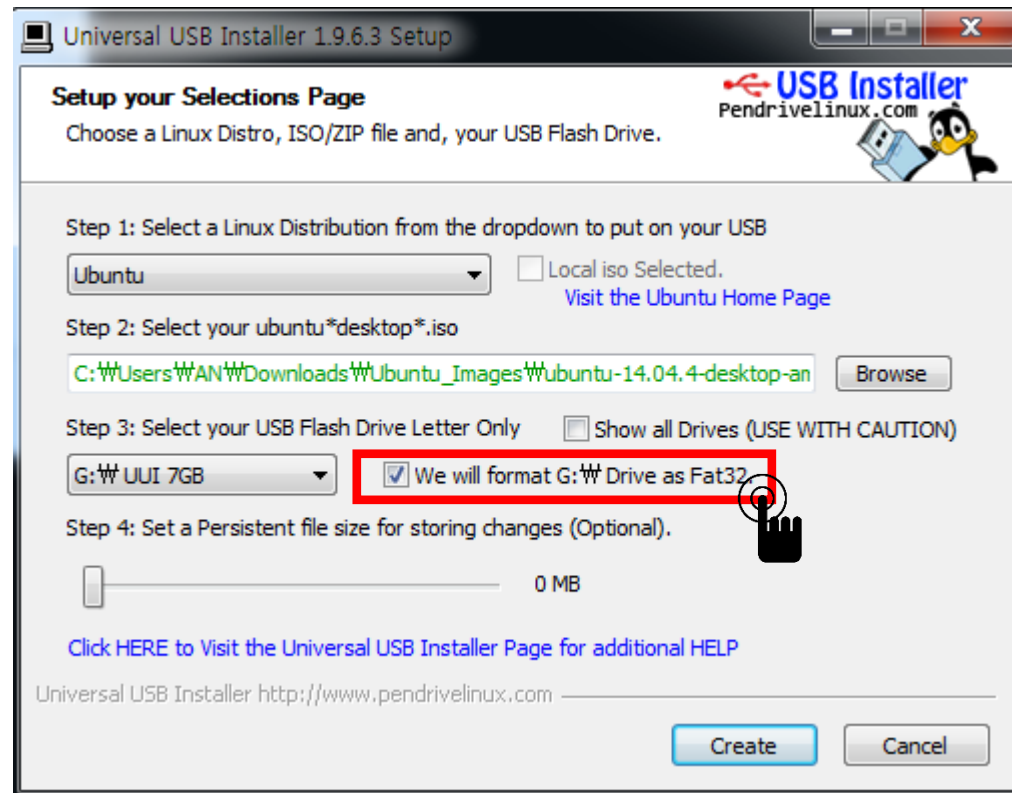
Universal USB Installer

- Universal USB Installer로 Ubuntu Booting USB 만들기



Universal USB Installer

- Universal USB Installer로 Ubuntu Booting USB 만들기



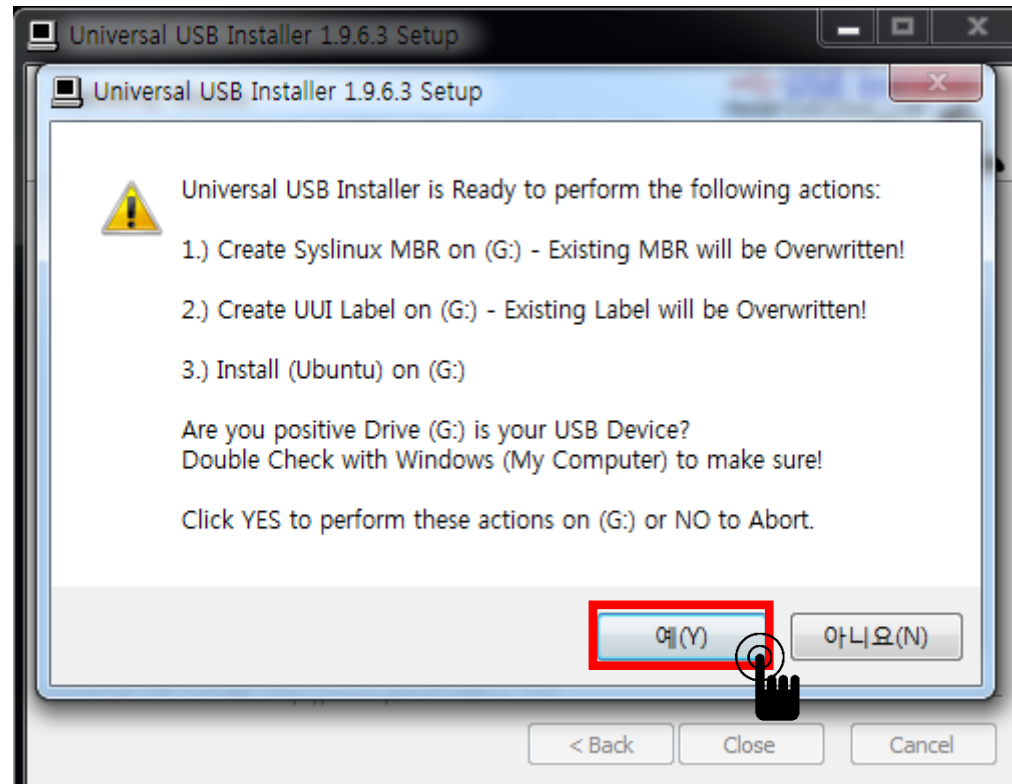
Universal USB Installer

- Universal USB Installer로 Ubuntu Booting USB 만들기



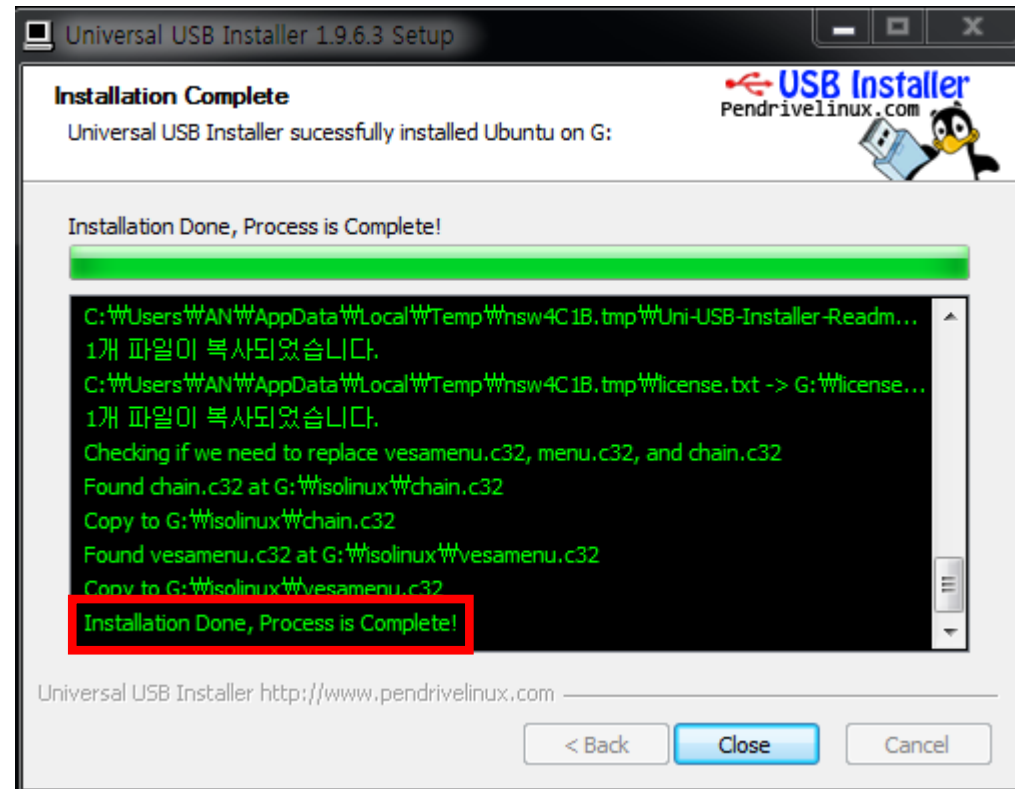
Universal USB Installer

- Universal USB Installer로 Ubuntu Booting USB 만들기

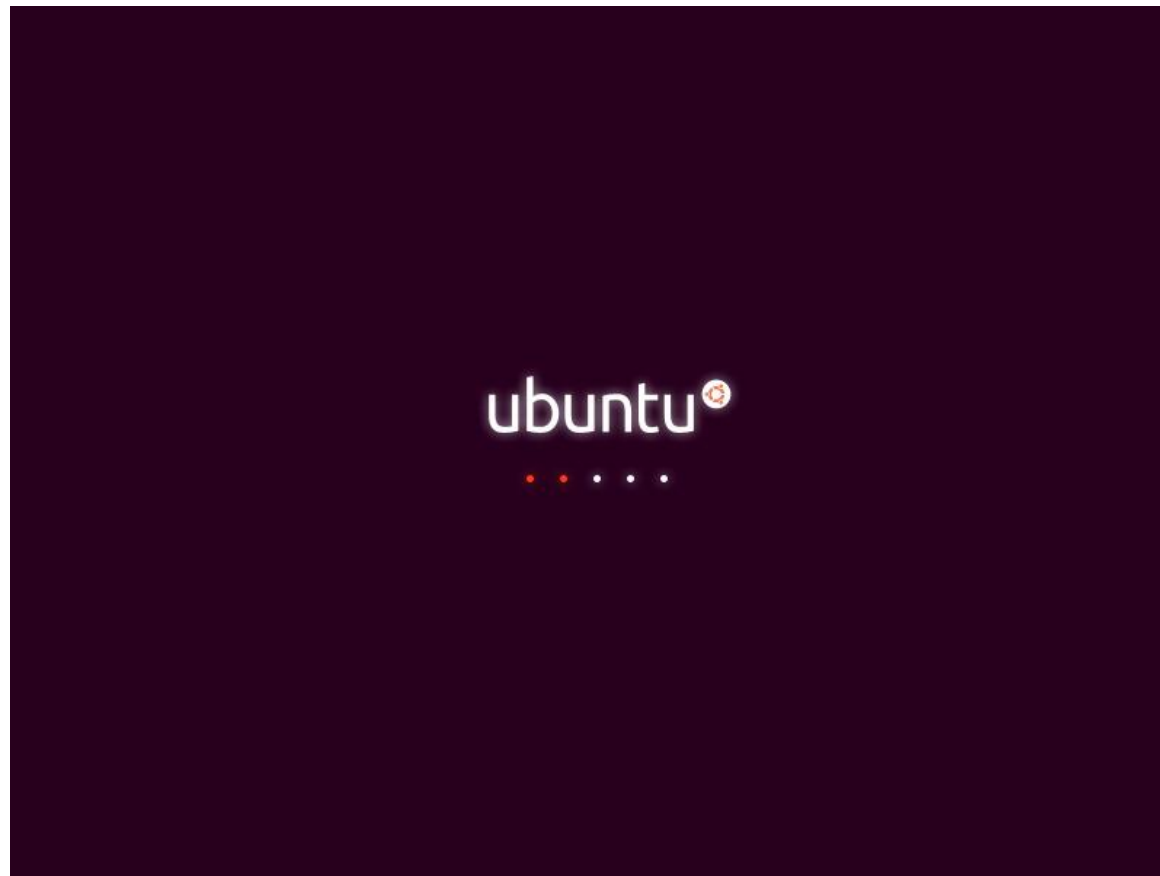


Universal USB Installer

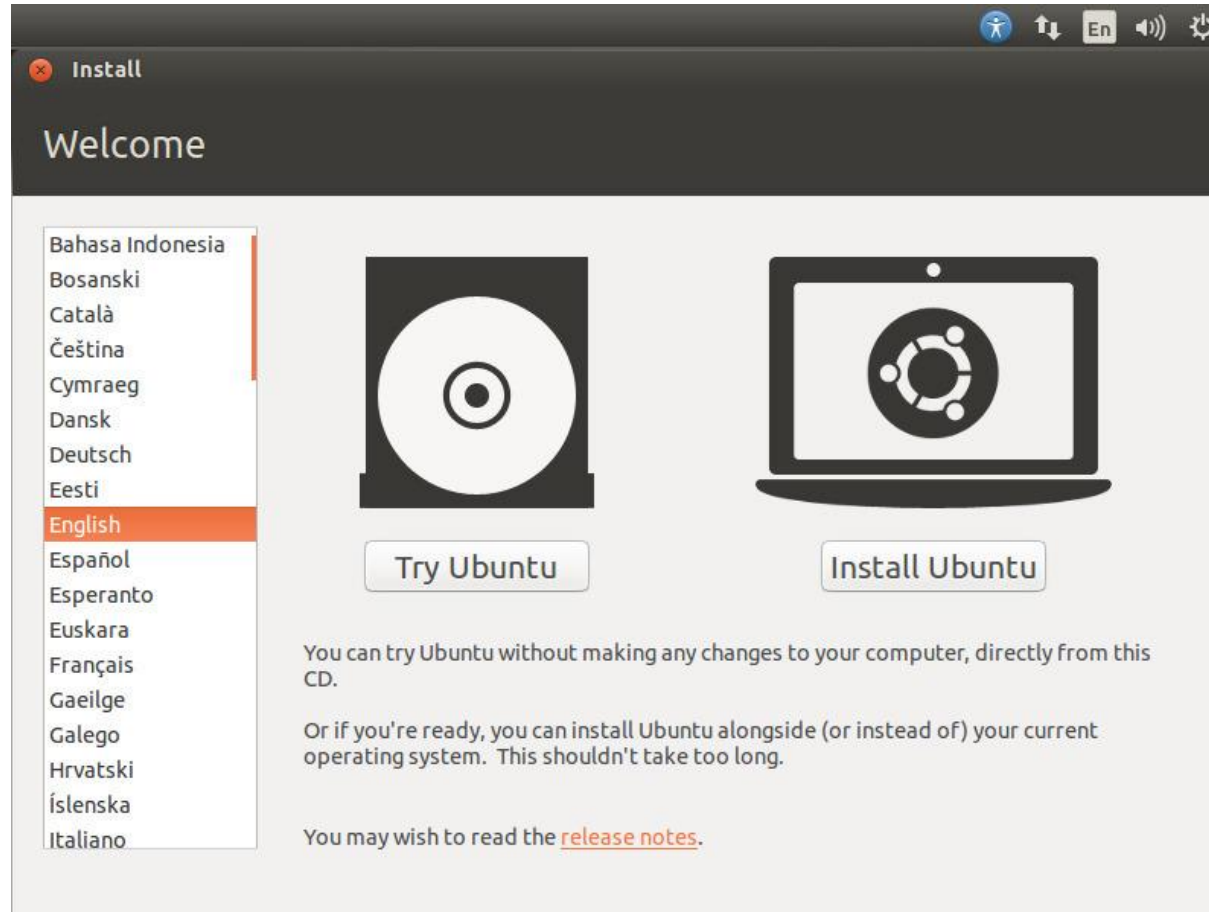
- Universal USB Installer로 Ubuntu Booting USB 만들기



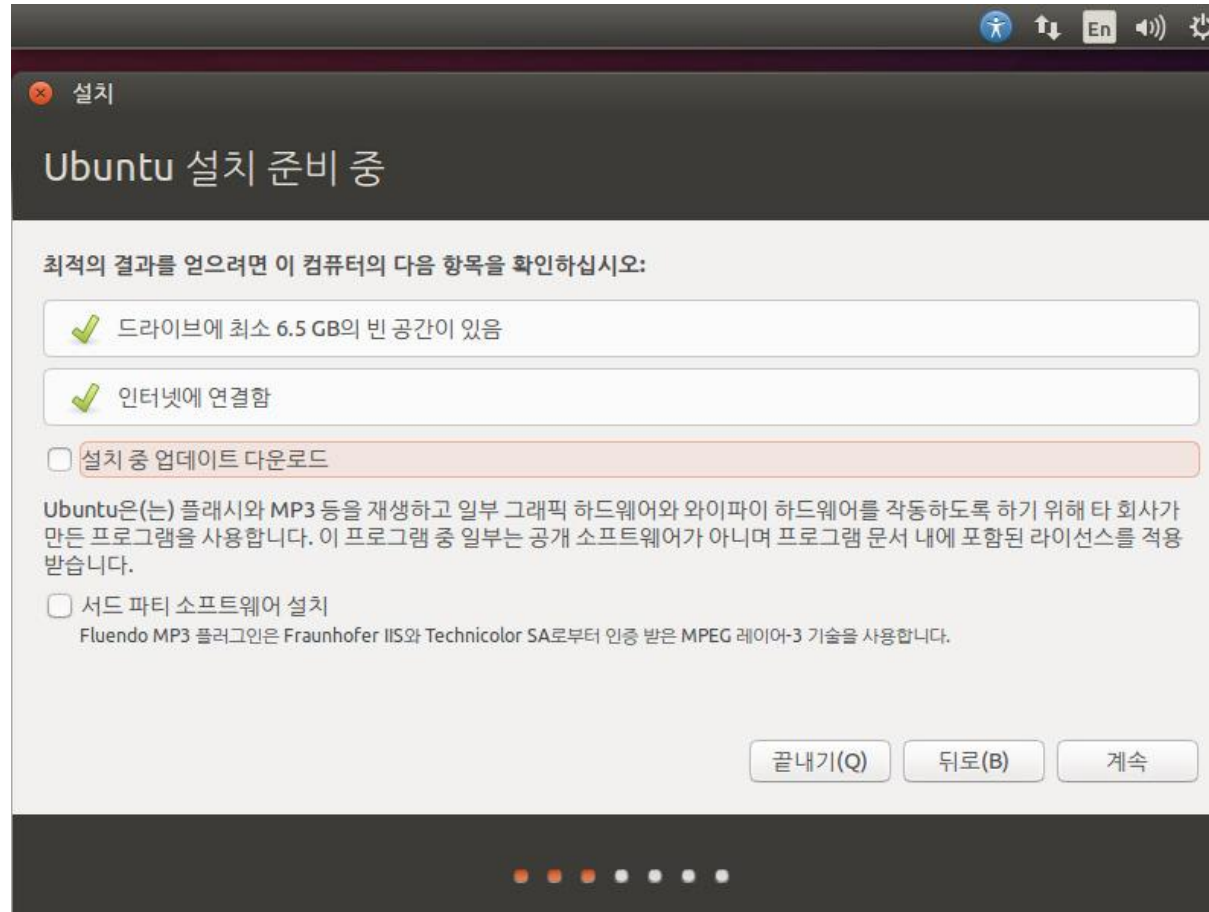
USB로 Ubuntu 14.04 설치



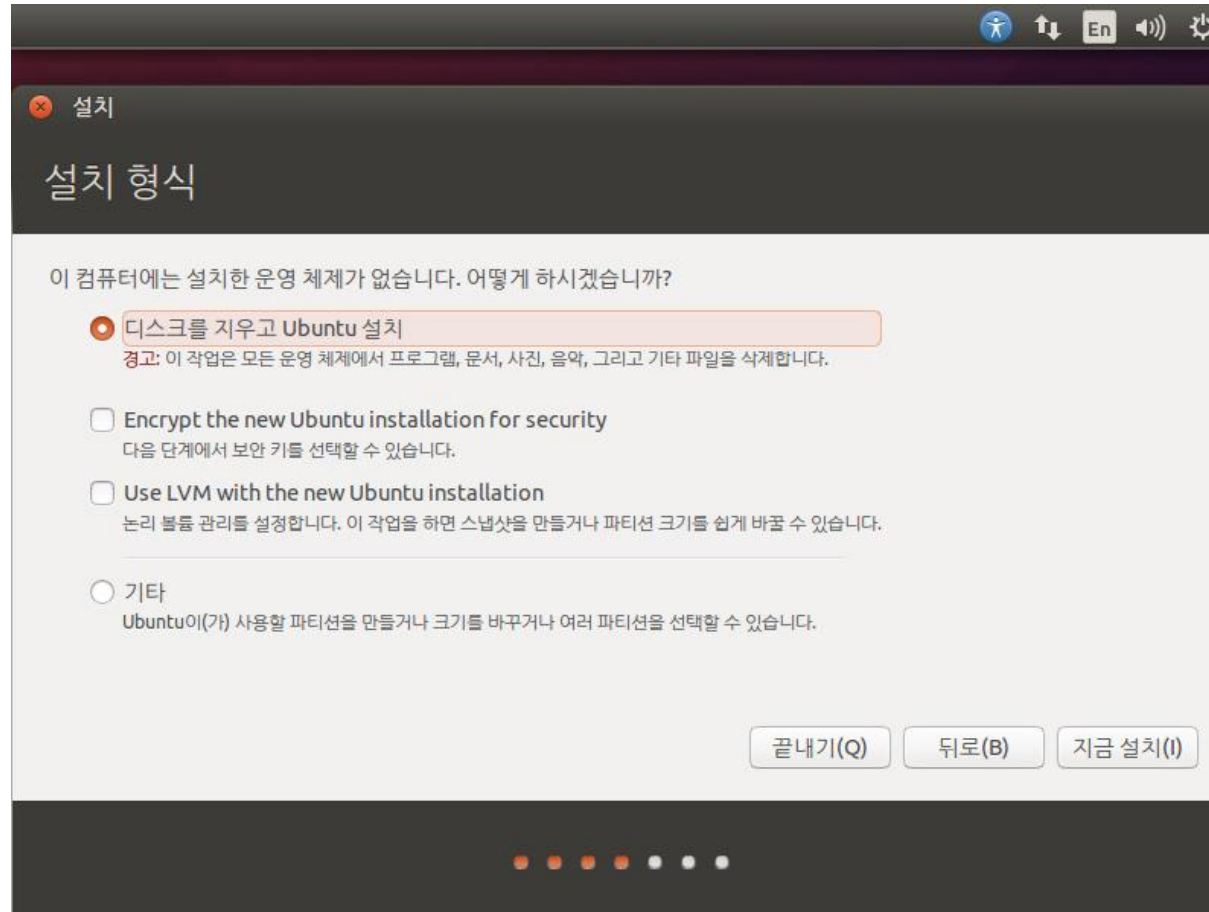
USB로 Ubuntu 14.04 설치



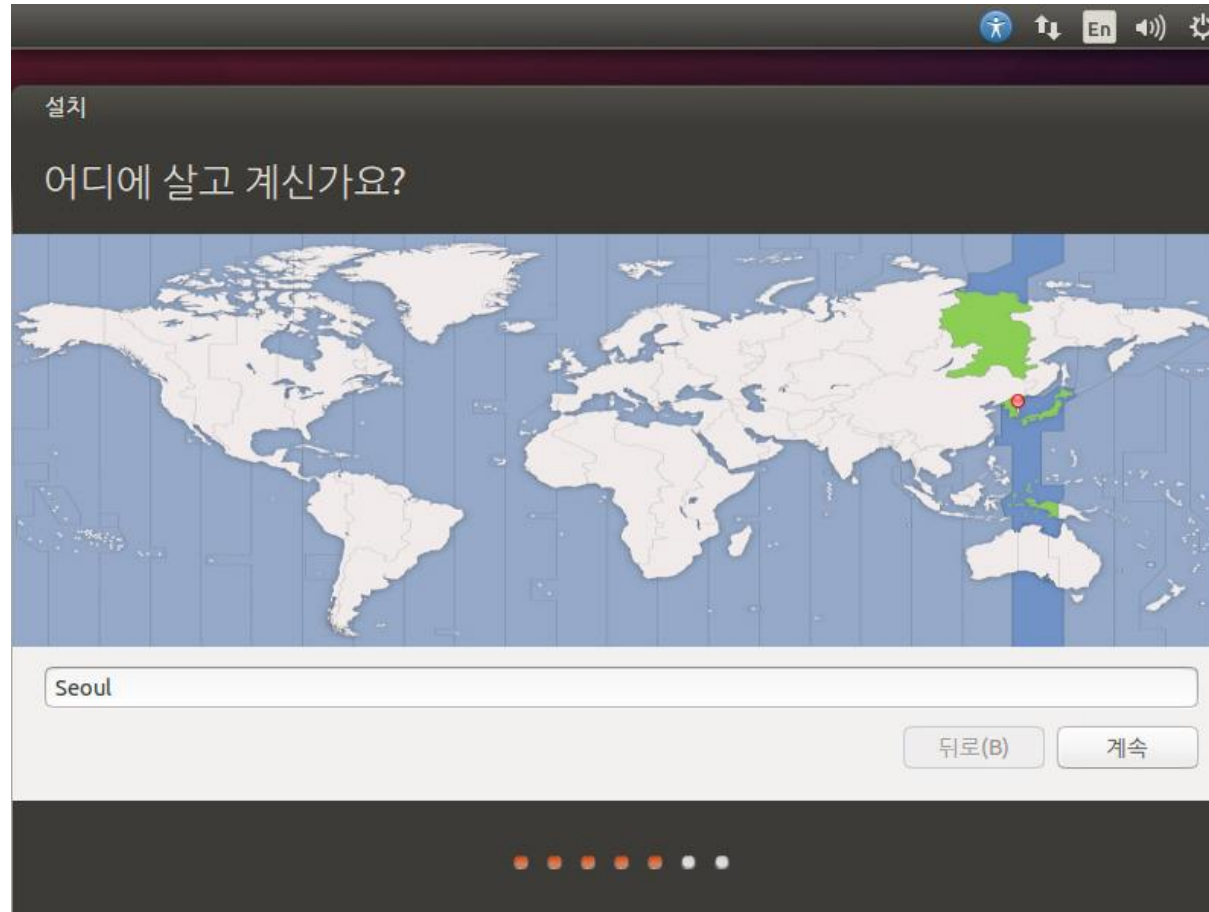
USB로 Ubuntu 14.04 설치



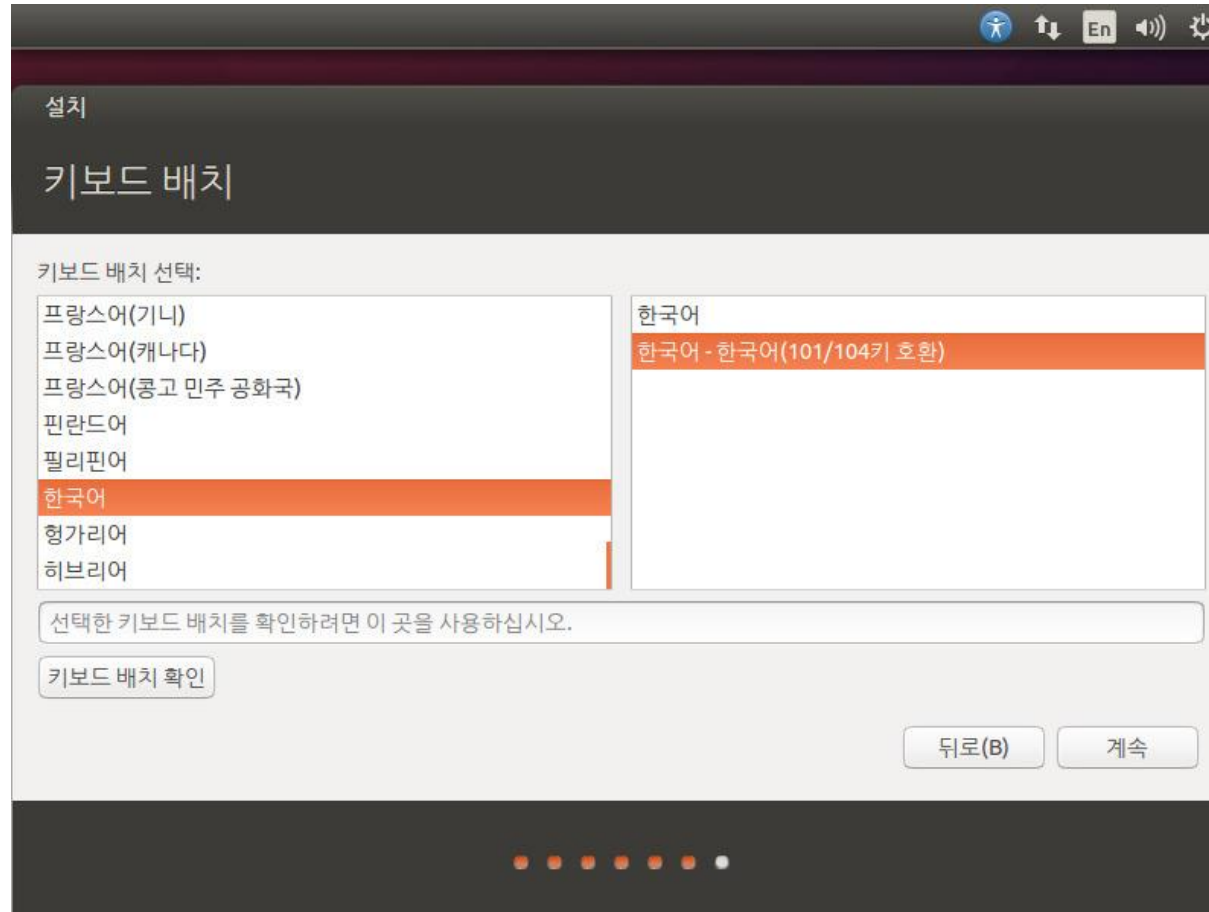
USB로 Ubuntu 14.04 설치



USB로 Ubuntu 14.04 설치



USB로 Ubuntu 14.04 설치



USB로 Ubuntu 14.04 설치

설치

당신은 누구십니까?

이름: ubuntu ✓

컴퓨터 이름: ubuntu-virtual-machine ✓
다른 컴퓨터에서 보여지는 이름

사용자 이름 선택: ubuntu ✓

암호 선택: ●●●●●● 약한 암호

암호 확인: ●●●●●● ✓

☐ 자동으로 로그인

☒ 로그인할 때 암호 입력

☐ 개인 폴더 암호화

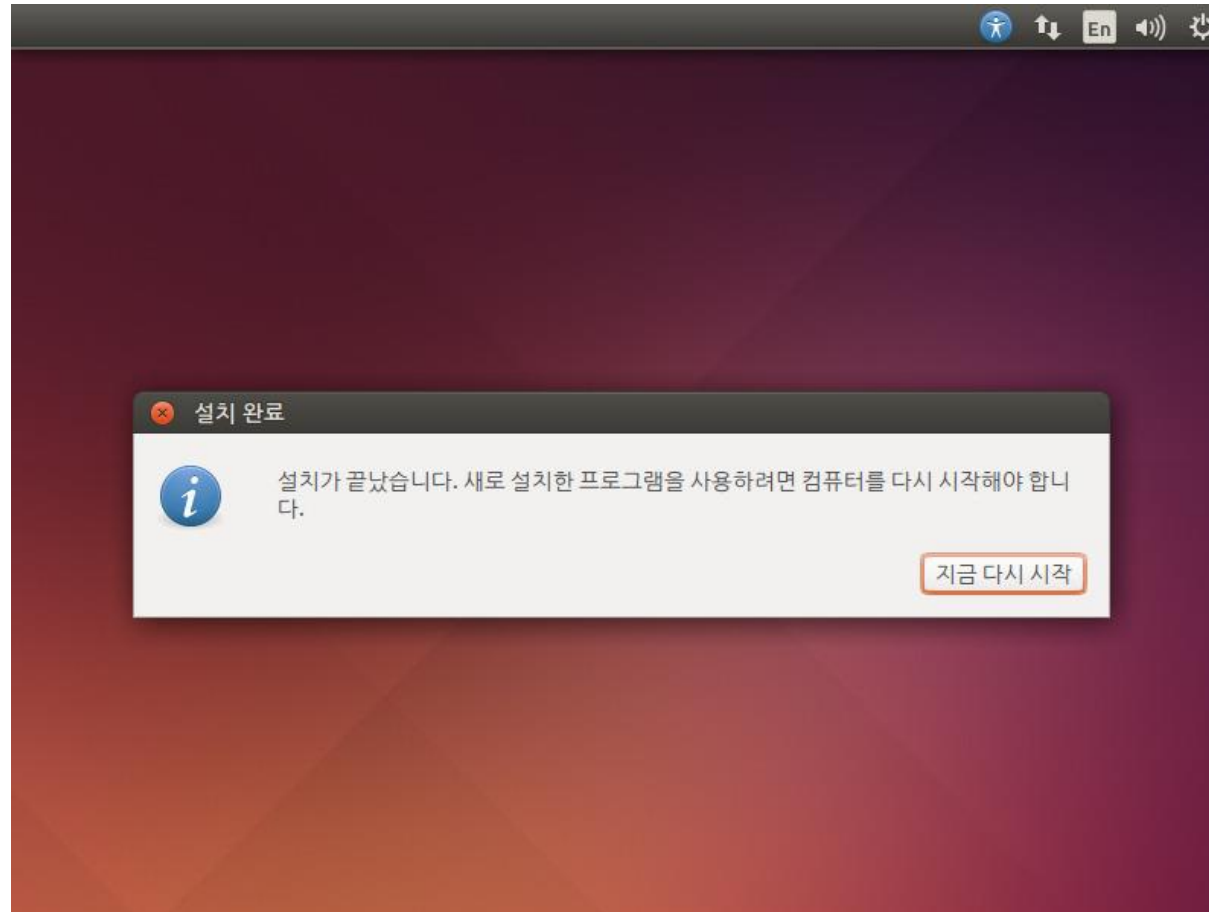
뒤로(B) 계속



USB로 Ubuntu 14.04 설치



USB로 Ubuntu 14.04 설치



필요 라이브러리 설치

- 이 가이드에서 필요한 필수 라이브러리를 아래의 명령어를 이용하여 설치
- `sudo apt-get update`
- `sudo apt-get install iw git mysql-client libmysqlclient-dev
openvswitch-switch openvswitch-common python3.4 python-
virtualenv python-setuptools python-dev build-essential
apache2 php5 mysql-server phpmyadmin maven`



필요 라이브러리 설치

- `sudo apt-get update`

```
mclab@mclab-All-Series: ~  
mclab@mclab-All-Series:~$ sudo apt-get update
```



```
Get:55 http://security.ubuntu.com trusty-security/restricted i386 Packages [12.7  
kB]  
Ign http://extras.ubuntu.com trusty/main Translation-en_US  
Get:56 http://security.ubuntu.com trusty-security/universe i386 Packages [125 kB  
]  
Ign http://extras.ubuntu.com trusty/main Translation-en  
Get:57 http://security.ubuntu.com trusty-security/multiverse i386 Packages [5,17  
5 B]  
Get:58 http://security.ubuntu.com trusty-security/main Translation-en [244 kB]  
Get:59 http://security.ubuntu.com trusty-security/multiverse Translation-en [2,5  
70 B]  
Get:60 http://security.ubuntu.com trusty-security/restricted Translation-en [3,2  
06 B]  
69% [54 Sources 2,489 kB/6,399 kB 39%] [Waiting for headers] 358 kB/s 10s
```



필요 라이브러리 설치

- `sudo apt-get install iw git mysql-client libmysqlclient-dev openvswitch-switch openvswitch-common python3.4 python-virtualenv python-setuptools python-dev build-essential apache2 php5 mysql-server phpmyadmin maven -y`

```
mclab@mclab-All-Series: ~  
mclab@mclab-All-Series:~$ sudo apt-get install iw git mysql-client libmysqlclient-dev openvswitch openvswitch-common python3.4 python-setuptools python-dev build-essential python-virtualenv apache2 php5 mysql-server phpmyadmin -y
```

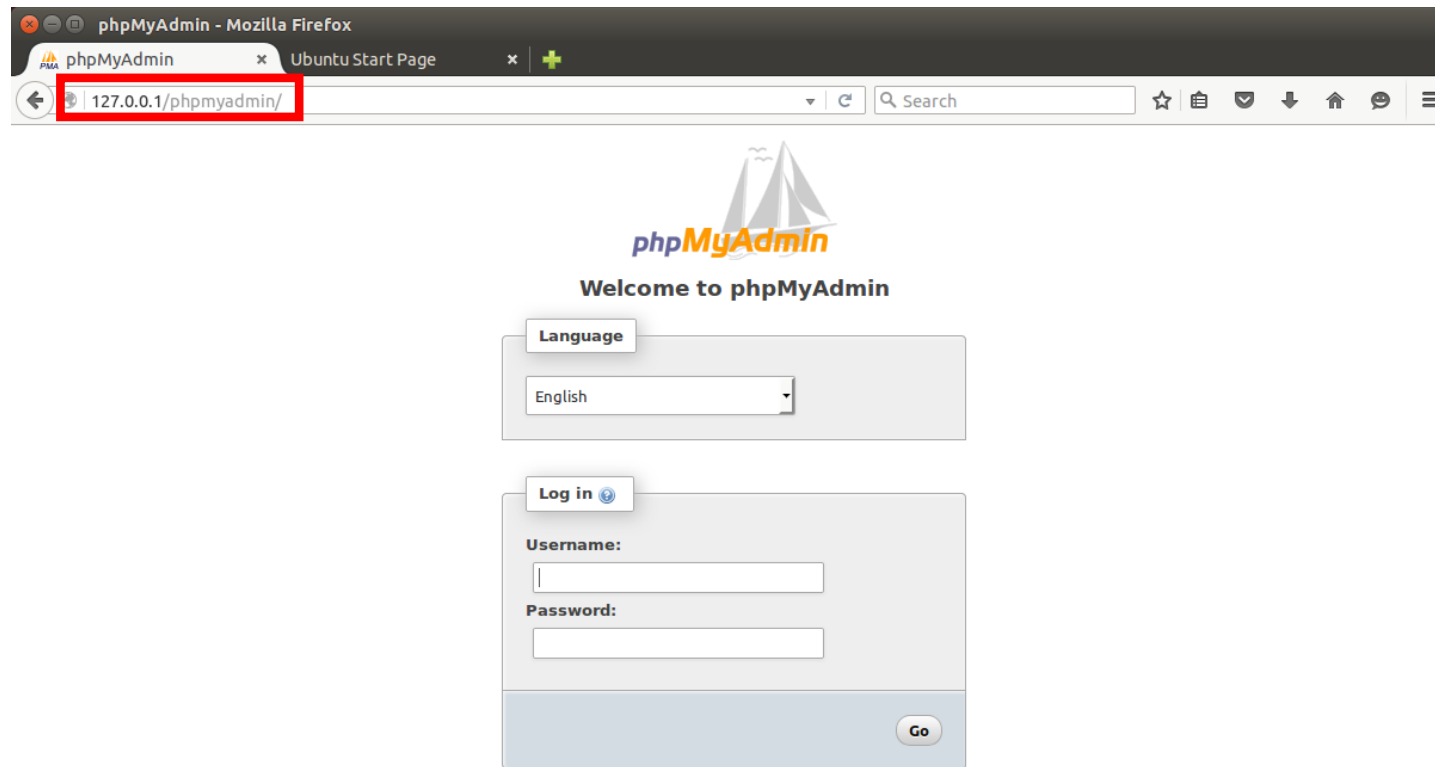


```
Creating config file /etc/phpmyadmin/config-db.php with new version  
granting access to database phpmyadmin for phpmyadmin@localhost: success.  
verifying access for phpmyadmin@localhost: success.  
creating database phpmyadmin: success.  
verifying database phpmyadmin exists: success.  
populating database via sql... done.  
dbconfig-common: flushing administrative password  
Processing triggers for libc-bin (2.19-0ubuntu6.7) ...  
mclab@mclab-All-Series:~$
```



Database 구축

- 127.0.0.1/phpmyadmin 접속



phpmyadmin - 만약 접속이 안 될 경우

- `sudo vi /etc/apache/apache2.conf`

```
mclab@mclab-All-Series: /etc/phpmyadmin
# Use mod_remoteip instead.
#
LogFormat "%v:%p %h %l %u %t \"%r\" %>s %O \"%[Referer]i\" \"%[User-Agent]i\"" v
host_combined
LogFormat "%h %l %u %t \"%r\" %>s %O \"%[Referer]i\" \"%[User-Agent]i\"" combine
d
LogFormat "%h %l %u %t \"%r\" %>s %O" common
LogFormat "%[Referer]i -> %U" referer
LogFormat "%[User-agent]i" agent

# Include of directories ignores editors' and dpkg's backup files,
# see README.Debian for details.

# Include generic snippets of statements
IncludeOptional conf-enabled/*.conf

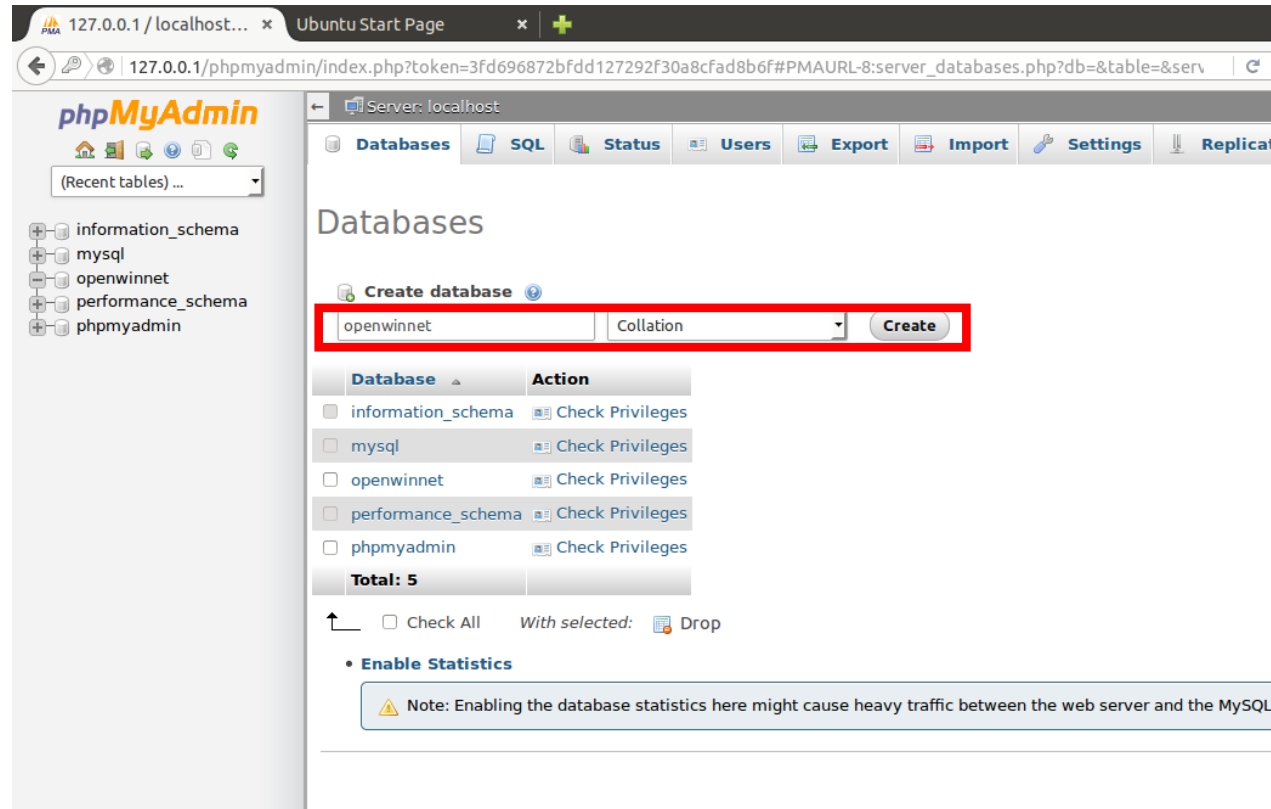
# Include the virtual host configurations:
IncludeOptional sites-enabled/*.conf
Include /etc/phpmyadmin/apache.conf
# vim: syntax=apache ts=4 sw=4 sts=4 sr noet
```

- Include `/etc/phpmyadmin/apache.conf`
추가



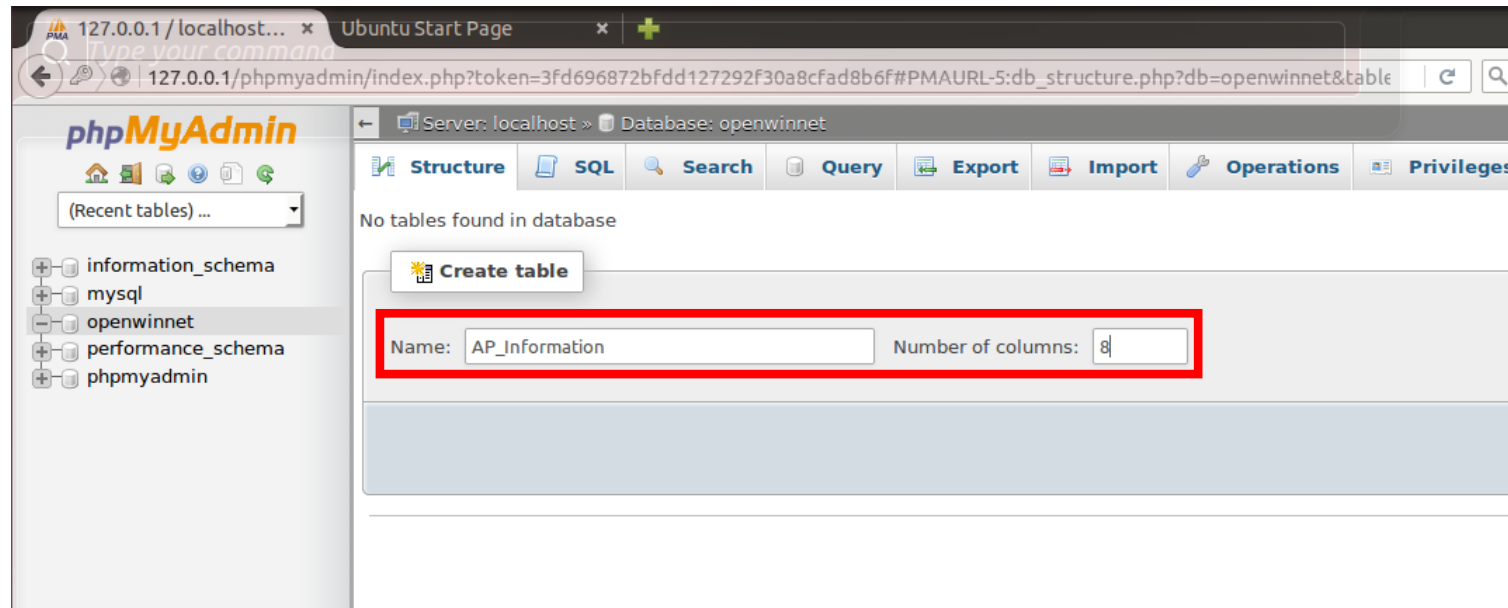
Database 구축

- openwinnet Database 생성



Database 구축

- AP_Information table 생성



Database 구축

- Column 작성

Structure

Name	Type	Length/Values	Default	Collation	Attributes	Nu
ID	VARCHAR	20	None			<input type="checkbox"/>
IP	VARCHAR	15	None			<input type="checkbox"/>
SSID	VARCHAR	256	None			<input type="checkbox"/>
Description	VARCHAR	256	NULL			<input checked="" type="checkbox"/>
Password	VARCHAR	256	NULL			<input checked="" type="checkbox"/>
Broadcast	VARCHAR	3	None			<input type="checkbox"/>
Channel	VARCHAR	2	None			<input type="checkbox"/>
time	TIMESTAMP		CURRENT_TIMESTAMP			<input type="checkbox"/>

Table comments:

Storage Engine: InnoDB

Collation:



Controller 설치

- `sudo git clone https://github.com/OpenWinCon/OpenWinNet.git`

```
mclab@mclab-All-Series:~$ mkdir openwincon
mclab@mclab-All-Series:~$ cd openwincon/
mclab@mclab-All-Series:~/openwincon$ ls
mclab@mclab-All-Series:~/openwincon$ sudo git clone https://github.com/OpenWinCon/OpenWinNet.git
```



```
Cloning into 'OpenWinNet'...
remote: Counting objects: 642, done.
remote: Compressing objects: 100% (6/6), done.
remote: Total 642 (delta 0), reused 0 (delta 0), pack-reused 636
Receiving objects: 100% (642/642), 3.43 MiB | 974.00 KiB/s, done.
Resolving deltas: 100% (229/229), done.
Checking connectivity... done.
mclab@mclab-All-Series:~/openwincon$ ls
OpenWinNet
mclab@mclab-All-Series:~/openwincon$ cd OpenWinNet/
mclab@mclab-All-Series:~/openwincon/OpenWinNet$ ls
agent  img  LICENSE  Mesh  README.md  web-gui
```



Controller 설치

- `cd ./OpenWinNet/agent/HostApd_agent&controller`

```
mclab@mclab-All-Series:~/openwincon/OpenWinNet$ cd agent/HostApd_agent\&controller/
mclab@mclab-All-Series:~/openwincon/OpenWinNet/agent/HostApd_agent&controller$ ls
Action.cpp          conf                hostap.h            Report.cpp
Action.h            controller.cpp      makefile            Report.h
ap_agent.cpp        ctrCommand.cpp     openvpn             Socket.cpp
APIInformation_back.cpp  ctrCommand.h      Packet.cpp          Socket.h
APIInformation.cpp   Database.cpp        Packet.h            testbed_result
APIInformation.h     Database.h          PacketType.h
APIInformation_no_vpn.cpp hostap_back.cpp     protocol.h
Command.cpp          hostap.cpp          readme.md
```



Controller 설치

- sudo make

```
mclab@mclab-All-Series: ~/openwincon/OpenWinNet/agent/HostApd_agent&controller
g++ -c ap_agent.cpp
ap_agent.cpp: In function 'int main(int, char**)':
ap_agent.cpp:136:44: warning: deprecated conversion from string constant to 'char*' [-Wwrite-strings]
    ap = new hostap("./conf/openwinnet.conf"); // default confPath
                                   ^
g++ -c ctrCommand.cpp
g++ -c hostap.cpp
g++ -c Report.cpp
g++ -c Packet.cpp
g++ -c Socket.cpp
g++ -c APInformation.cpp
g++ -o ap_agent ap_agent.o ctrCommand.o hostap.o Report.o Packet.o Socket.o APInformation.o -lmysqlclient -lpthread
g++ -c controller.cpp
g++ -c Action.cpp
g++ -c Database.cpp
g++ -o controller controller.o hostap.o Report.o Packet.o Socket.o APInformation.o Action.o Database.o -lmysqlclient -lpthread
g++ -c Command.cpp
g++ -o command Command.o ctrCommand.o hostap.o APInformation.o -lmysqlclient -lpthread
mclab@mclab-All-Series:~/openwincon/OpenWinNet/agent/HostApd_agent&controller$
```



Controller 설치

- `sudo ./controller`

```
mclab@mclab-All-Series: ~/openwincon/OpenWinNet/agent/HostApd_agent&controller
APInformation_no_vpn.cpp  ctrCommand.o  Packet.h      testbed_result
APInformation.o          Database.cpp  Packet.o
mclab@mclab-All-Series:~/openwincon/OpenWinNet/agent/HostApd_agent&controller$ .
./controller
DB Connection Succeeded
Description|          ID|          IP|          SSID|          Desc
          time| Password| Broadcast| Channel|
Openwinnet Controller v0.8
Copyright 2015 Kyung Hee University Mobile Convergence Lab
All rights reserved.
For info, please contact to roy1022@hanamil.net

Openwinnet manager> db
-----[Openwinnet AP LIST]-----
|ID          IP          SSID          |
|-----|
Openwinnet manager> 
```



Controller 설치

- help

```
mclab@mclab-All-Series: ~/openwincon/OpenWinNet/agent/HostApd_agent&controller

Openwinnet manager> help
u
Commands:<IP> <Command> [value]
  help or h          show this usage help
  show               show ap's list
  start              start ap
  stop               stop ap
  reboot             reboot ap
  status             show ap's status
  ssid <value>       change ssid
  password [value]   change password(if params blank, off password) *** only h
ostap
  channel <value>    change channel
  mode <g,b>         change mode
  tx <value>         change txpower (range : 0~20) *** only openwrt
  uplink <value>     change AP's uplink bandwidth*** only openwrt
  downlink <value>   change AP's downlink bandwidth *** only openwrt
  hide <on, off>     broadcast on, off *** only hostap
  clear or cl        clear line
  quit               exit this program
[P] process Command

Openwinnet manager> 
```



Web-GUI 설치

- python package 설치를 위해 pip 설치

```
mclab@mclab-All-Series: ~/openwincon/OpenWinNet/web-gui
mclab@mclab-All-Series:~/openwincon/OpenWinNet/web-gui$ sudo easy_install pip
Searching for pip
Best match: pip 1.5.4
Adding pip 1.5.4 to easy-install.pth file
Installing pip script to /usr/local/bin
Installing pip2.7 script to /usr/local/bin
Installing pip2 script to /usr/local/bin

Using /usr/lib/python2.7/dist-packages
Processing dependencies for pip
Finished processing dependencies for pip
mclab@mclab-All-Series:~/openwincon/OpenWinNet/web-gui$
```

- `sudo easy_install pip`



Web-GUI 설치

두 개의 Framework를 사용함으로 모두 설치가 필요.



Web-GUI 설치

- pip install로 python package 설치

```
mclab@mclab-All-Series: ~/openwincon/OpenWinNet/web-gui
Downloading djangoestframework-3.3.3-py2.py3-none-any.whl (662kB): 90% 598k
Downloading djangoestframework-3.3.3-py2.py3-none-any.whl (662kB): 90% 602k
Downloading djangoestframework-3.3.3-py2.py3-none-any.whl (662kB): 91% 606k
Downloading djangoestframework-3.3.3-py2.py3-none-any.whl (662kB): 92% 610k
Downloading djangoestframework-3.3.3-py2.py3-none-any.whl (662kB): 92% 614k
Downloading djangoestframework-3.3.3-py2.py3-none-any.whl (662kB): 93% 618k
Downloading djangoestframework-3.3.3-py2.py3-none-any.whl (662kB): 94% 622k
Downloading djangoestframework-3.3.3-py2.py3-none-any.whl (662kB): 94% 626k
Downloading djangoestframework-3.3.3-py2.py3-none-any.whl (662kB): 95% 630k
Downloading djangoestframework-3.3.3-py2.py3-none-any.whl (662kB): 95% 634k
Downloading djangoestframework-3.3.3-py2.py3-none-any.whl (662kB): 96% 638k
Downloading djangoestframework-3.3.3-py2.py3-none-any.whl (662kB): 97% 643k
Downloading djangoestframework-3.3.3-py2.py3-none-any.whl (662kB): 97% 647k
Downloading djangoestframework-3.3.3-py2.py3-none-any.whl (662kB): 98% 651k
Downloading djangoestframework-3.3.3-py2.py3-none-any.whl (662kB): 98% 655k
Downloading djangoestframework-3.3.3-py2.py3-none-any.whl (662kB): 99% 659k
Downloading djangoestframework-3.3.3-py2.py3-none-any.whl (662kB): 100% 662k
Downloaded
Installing collected packages: djangoestframework
Successfully installed djangoestframework
Cleaning up...
mclab@mclab-All-Series:~/openwincon/OpenWinNet/web-gui$
```

- sudo -H pip install Flask
- sudo -H pip install Flask-Migrate
- sudo -H pip install Flask-restful
- sudo -H pip install Flask-cors
- sudo -H pip install django==1.8
- sudo -H pip install djangoestframework



Web-GUI 설치

- Django 사용을 위한 Virtual environment 생성

```
mclab@mclab-All-Series: ~/openwincon/OpenWinNet/web-gui
ImportError: /usr/lib/python2.7/dist-packages/apt_pkg.so: undefined symbol: _Py_ZeroStruct

Original exception was:
Traceback (most recent call last):
  File "/usr/lib/python2.7/dist-packages/virtualenv.py", line 2339, in <module>
    main()
  File "/usr/lib/python2.7/dist-packages/virtualenv.py", line 825, in main
    symlink=options.symlink)
  File "/usr/lib/python2.7/dist-packages/virtualenv.py", line 985, in create_environment
    site_packages=site_packages, clear=clear, symlink=symlink))
  File "/usr/lib/python2.7/dist-packages/virtualenv.py", line 1277, in install_python
    shutil.copyfile(executable, py_executable)
  File "/usr/lib/python3.4/shutil.py", line 109, in copyfile
    with open(dst, 'wb') as fdst:
PermissionError: [Errno 13] Permission denied: 'myvenv/bin/python3.4'
mclab@mclab-All-Series:~/openwincon/OpenWinNet/web-gui$ ls
AP      mysql-python3.4-connector  openwinnetsite  UserManagement
manage.py  myvenv                    readme.md
mclab@mclab-All-Series:~/openwincon/OpenWinNet/web-gui$ source myvenv/bin/activate
(myvenv)mclab@mclab-All-Series:~/openwincon/OpenWinNet/web-gui$
```

- `sudo apt-get install python-virtualenv`
- `virtualenv --python=python3.4 myvenv`
- `source myvenv/bin/activate`



Web-GUI 설치

- Mysql-python connector 설치(Flask)

```
mclab@mclab-All-Series: ~/openwincon/OpenWinNet/web-gui
2.5 -I/usr/include/mysql -I/usr/include/python2.7 -c _mysql.c -o build/temp.linux-x86_64-2.7/_mysql.o -DBIG_JOINS=1 -fno-strict-aliasing -g -DNDEBUG
In file included from _mysql.c:44:0:
/usr/include/mysql/my_config.h:422:0: warning: "HAVE_WSCOLL" redefined [enabled by default]
#define HAVE_WSCOLL
^
In file included from /usr/include/python2.7/pyconfig.h:3:0,
from /usr/include/python2.7/Python.h:8,
from _mysql.c:29:
/usr/include/x86_64-linux-gnu/python2.7/pyconfig.h:911:0: note: this is the location of the previous definition
#define HAVE_WSCOLL 1
^
x86_64-linux-gnu-gcc -pthread -shared -Wl,-O1 -Wl,-Bsymbolic-functions -Wl,-Bsymbolic-functions -Wl,-z,relro -fno-strict-aliasing -DNDEBUG -g -fwrapv -O2 -Wall -Wstrict-prototypes -D_FORTIFY_SOURCE=2 -g -fstack-protector --param=ssp-buffer-size=4 -Wformat -Werror=format-security build/temp.linux-x86_64-2.7/_mysql.o -L/usr/lib/x86_64-linux-gnu -lmysqlclient_r -lpthread -lz -lm -ldl -o build/lib.linux-x86_64-2.7/_mysql.so

Successfully installed MySQL-python
Cleaning up...
mclab@mclab-All-Series:~/openwincon/OpenWinNet/web-gui$
```

- `sudo pip install MySQL-python`



Web-GUI 설치

- Mysql-python connector 설치(Django)

```
mclab@mclab-All-Series: ~/openwincon/OpenWinNet/web-gui/myvenv/lib64/python3.4/site-packages/
bin/      include/ lib/      lib64/
mclab@mclab-All-Series:~/openwincon/OpenWinNet/web-gui$ cd myvenv/
bin/      include/ lib/      lib64/
mclab@mclab-All-Series:~/openwincon/OpenWinNet/web-gui$ cd myvenv/lib64/python3.4/
collections/      importlib/
config-3.4m-x86_64-linux-gnu/ lib-dynload/
distutils/        plat-x86_64-linux-gnu/
encodings/        site-packages/
mclab@mclab-All-Series:~/openwincon/OpenWinNet/web-gui$ cd myvenv/lib64/python3.4/site-packages/
django/           pip-1.5.4.dist-info/
Django-1.8.dist-info/ __pycache__/
djangorestframework-3.3.3.dist-info/ rest_framework/
_markerlib/       setuptools/
mysql/            setuptools-2.2.dist-info/
pip/
mclab@mclab-All-Series:~/openwincon/OpenWinNet/web-gui$ cd myvenv/lib64/python3.4/site-packages/mysql/
mclab@mclab-All-Series:~/openwincon/OpenWinNet/web-gui/myvenv/lib64/python3.4/site-packages/mysql$ ls
connector  mysql.zip
mclab@mclab-All-Series:~/openwincon/OpenWinNet/web-gui/myvenv/lib64/python3.4/site-packages/mysql$
```

- mkdir myvenv/lib64/python3.4/site-packages/mysql
- cp mysql-python3.4-connector/mysql.zip myvenv/lib64/python3.4/site-packages/mysql/
- unzip myvenv/lib/python3.4/site-packages/mysql/msql.zip



Web-GUI 실행 - AP 관리 페이지

- Django 가상환경 실행 및 서버 실행

```
root@mclab-All-Series: /home/mclab/openwincon/OpenWinNet/web-gui
(myvenv)root@mclab-All-Series:/home/mclab/openwincon/OpenWinNet/web-gui# python
manage.py runserver 0.0.0.0:8000
Performing system checks...

System check identified no issues (0 silenced).

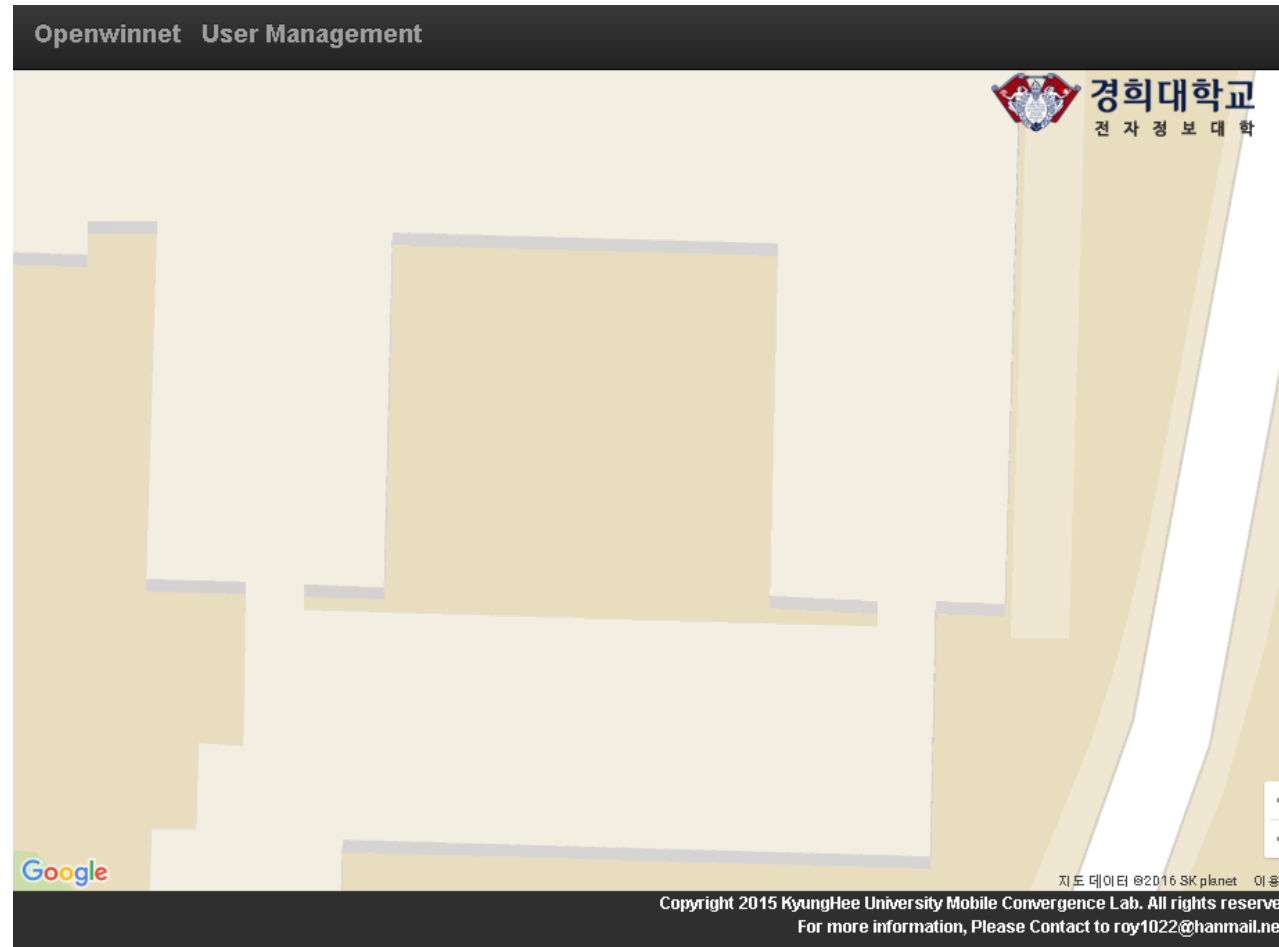
You have unapplied migrations; your app may not work properly until they are app
lied.
Run 'python manage.py migrate' to apply them.

April 03, 2016 - 15:55:34
Django version 1.8, using settings 'openwinnet.site.settings'
Starting development server at http://0.0.0.0:8000/
Quit the server with CONTROL-C.
```

- cd web-gui
- source
myvenv/bin/activate
- python manage.py
runserver 0.0.0.0:8000



Web-GUI 화면 - AP 관리 페이지



Web-GUI 실행 - 유저 관리 페이지

- 서버 실행

```
mclab@mclab-All-Series: ~/openwincon/OpenWinNet/web-gui/UserManagement
mclab@mclab-All-Series:~/openwincon/OpenWinNet/web-gui/myenv/lib64$ cd ..
mclab@mclab-All-Series:~/openwincon/OpenWinNet/web-gui/myenv$ cd ..
mclab@mclab-All-Series:~/openwincon/OpenWinNet/web-gui$ cd ..
mclab@mclab-All-Series:~/openwincon/OpenWinNet$ ls
agent  img  LICENSE  Mesh  README.md  web-gui
mclab@mclab-All-Series:~/openwincon/OpenWinNet$ cd ..
mclab@mclab-All-Series:~/openwincon$ ls
OpenWinNet
mclab@mclab-All-Series:~/openwincon$ cd OpenWinNet/
agent/  .git/  img/  Mesh/  web-gui/
mclab@mclab-All-Series:~/openwincon$ cd OpenWinNet/web-gui/
mclab@mclab-All-Series:~/openwincon/OpenWinNet/web-gui$ ls
AP      mysql-python3.4-connector  openwinnetsite  UserManagement
manage.py  myenv                      readme.md
mclab@mclab-All-Series:~/openwincon/OpenWinNet/web-gui$ cd UserManagement/
mclab@mclab-All-Series:~/openwincon/OpenWinNet/web-gui/UserManagement$ ls
config  ison  gui_server.py  __init__.py  static  templates
mclab@mclab-All-Series:~/openwincon/OpenWinNet/web-gui/UserManagement$ python gui_server.py
* Running on http://0.0.0.0:8001/ (Press CTRL+C to quit)
* Restarting with stat
* Debugger is active!
* Debugger pin code: 211-269-403
```

- cd web-gui/UserManagement
- python gui_server.py




Web-GUI 화면 - 유저 관리 페이지

User Management

AP Control

User Management Page

User ID	User Name	User Priority	Registered Devices	Actions
---------	-----------	---------------	--------------------	---------

 Create New User



두 페이지 연동

- web-gui/UserManagement/templates/header.html

```
<ul class="nav nav-tabs">
  <li role="presentation" class="active"><a href=".">User Management</a></li>
  <li role="presentation"><a href="http://AP_page_address:port" target="_self">AP Control</a></li>
</ul>
```

AP관리 페이지의 아이피주소와 포트번호를 추가



두 페이지 연동

- web-gui/AP/templates/AP/index.html

```
<span class="icon-bar" ></span>  
</button>  
<a class="navbar-brand" href="#"><b>Openwinnet</b></a>  
<a class="navbar-brand" href="http://user_page_address:port"><b>User Management</b></a>  
</div>  
</div>  
</nav>
```

유저 관리 페이지의 아이피주소와 포트번호를 추가



ONOS 설치

- oracle-java8 설치

```
mclab@mclab-All-Series: ~  
Get:10 http://security.ubuntu.com trusty-security/main amd64 Packages [448 kB]  
Get:11 http://security.ubuntu.com trusty-security/restricted amd64 Packages [13.  
0 kB]  
Get:12 http://security.ubuntu.com trusty-security/universe amd64 Packages [125 k  
B]  
Get:13 http://security.ubuntu.com trusty-security/multiverse amd64 Packages [4,9  
91 B]  
Get:14 http://security.ubuntu.com trusty-security/main i386 Packages [420 kB]  
Ign http://extras.ubuntu.com trusty/main Translation-en_US  
Ign http://extras.ubuntu.com trusty/main Translation-en  
Get:15 http://security.ubuntu.com trusty-security/restricted i386 Packages [12.7  
kB]  
Get:16 http://security.ubuntu.com trusty-security/universe i386 Packages [125 kB  
]  
Get:17 http://security.ubuntu.com trusty-security/multiverse i386 Packages [5,17  
5 B]  
Hit http://security.ubuntu.com trusty-security/main Translation-en  
Hit http://security.ubuntu.com trusty-security/multiverse Translation-en  
Hit http://security.ubuntu.com trusty-security/restricted Translation-en  
Hit http://security.ubuntu.com trusty-security/universe Translation-en  
Fetched 1,394 kB in 7s (180 kB/s)  
Reading package lists... Done  
mclab@mclab-All-Series:~$ sudo apt-get install oracle-java8-installer oracle-jav  
a8-set-default
```

- `sudo add-apt-repository ppa:webupd8team/java -y`
- `sudo apt-get update`
- `sudo apt-get install oracle-java8-installer oracle-java8-set-default`



ONOS 설치

- Configure Java Path
 - export JAVA_HOME=/usr/lib/jvm/java-8-oracle
 - 환경변수 설정이 잘 되었는지 확인
 - env | grep JAVA_HOME
 - JAVA_HOME=/usr/lib/jvm/java-8-oracle



ONOS 설치

- Set Maven
- cd ~; mkdir Downloads Applications
- cd ~/Downloads
- wget <http://archive.apache.org/dist/maven/maven-3/3.3.9/binaries/apache-maven-3.3.9-bin.tar.gz>
- tar -zxvf apache-maven-3.3.9-bin.tar.gz -C ../Applications/



ONOS 설치

- Set Karaf
 - cd ~/Downloads
 - wget <http://archive.apache.org/dist/karaf/3.0.5/apache-karaf-3.0.5.tar.gz>
 - tar -zxvf apache-karaf-3.0.3.tar.gz -C ../Applications/



ONOS 설치

- Clone ONOS
 - git clone <https://gerrit.onosproject.org/onos/>
 - cd onos
 - git checkout 1.5.0



ONOS 설치

- Build ONOS

```
mclab@mclab-All-Series: ~/onos
[INFO] onos-app-openstacknetworking-web ..... SUCCESS [ 0.420 s]
[INFO] onos-app-openstacknetworking-app ..... SUCCESS [ 0.171 s]
[INFO] onos-app-influxdb ..... SUCCESS [ 2.338 s]
[INFO] onos-incubator-core ..... SUCCESS [ 0.303 s]
[INFO] onos-incubator-rpc ..... SUCCESS [ 1.139 s]
[INFO] onos-incubator-rpc-grpc ..... SUCCESS [ 37.241 s]
[INFO] onos-features ..... SUCCESS [ 12.681 s]
[INFO] onos-archetypes ..... SUCCESS [ 0.020 s]
[INFO] onos-api-archetype ..... SUCCESS [ 16.818 s]
[INFO] onos-bundle-archetype ..... SUCCESS [ 0.013 s]
[INFO] onos-cli-archetype ..... SUCCESS [ 0.010 s]
[INFO] onos-rest-archetype ..... SUCCESS [ 0.006 s]
[INFO] onos-ui-archetype ..... SUCCESS [ 0.015 s]
[INFO] onos-uitab-archetype ..... SUCCESS [ 0.014 s]
[INFO] onos-uitopo-archetype ..... SUCCESS [ 0.019 s]
[INFO] onos-branding ..... SUCCESS [ 0.254 s]
[INFO] -----
[INFO] BUILD SUCCESS
[INFO] -----
[INFO] Total time: 13:15 min
[INFO] Finished at: 2016-03-24T21:34:56+09:00
[INFO] Final Memory: 319M/1967M
[INFO] -----
mclab@mclab-All-Series:~/onos$
```

- `cd ~/onos`
- `mvn clean install`



ONOS 설치

- Start ONOS

```
[INFO] -----  
mclab@mclab-All-Series:~/onos$ ok clean
```



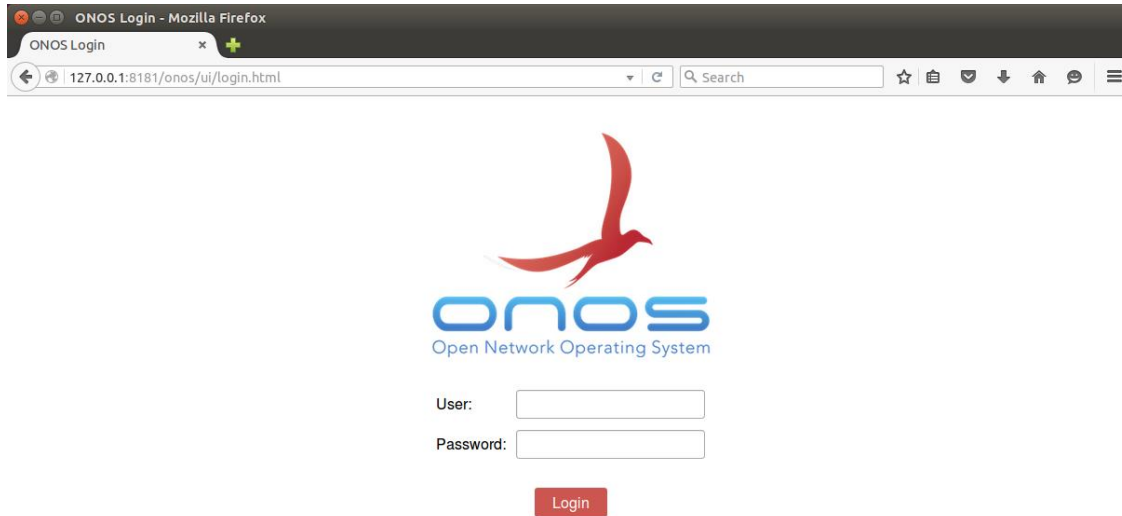
```
ONOS  
Documentation: wiki.onosproject.org  
Tutorials:    tutorials.onosproject.org  
Mailing lists: lists.onosproject.org  
  
Come help out! Find out how at: contribute.onosproject.org  
  
Hit '<tab>' for a list of available commands  
and '[cmd] --help' for help on a specific command.  
Hit '<ctrl-d>' or type 'system:shutdown' or 'logout' to shutdown ONOS.  
  
onos>  
Display all 561 possibilities? (y or n)  
onos>  
onos> |
```

- ok clean



ONOS 설치

- GUI 확인



- 127.0.0.1:8181/onos/ui
- User: karaf
- Password: karaf



Offloading Application

- `sudo git clone`
<https://github.com/MobileConvergenceLab/TrafficOffloadingONOS>

```
mclab@mclab-All-Series: ~/Offloading
mclab@mclab-All-Series:~$ ls
Applications  Documents  examples.desktop  onos          Pictures  Templates
Desktop       Downloads  Music             openwincon    Public    Videos
mclab@mclab-All-Series:~$ mkdir Offloading
mclab@mclab-All-Series:~$ cd Offloading/
mclab@mclab-All-Series:~/Offloading$ ls
mclab@mclab-All-Series:~/Offloading$ sudo git clone https://github.com/MobileConvergenceLab/TrafficOffloadingONOS
```



Offloading Application

- vi TrafficOffloadingONOS/TrafficOffloadingOnosApp/src/main/java/kr/ac/postech/app

```
mclab@mclab-All-Series: ~/Offloading/TrafficOffloadingONOS/TrafficOffloadingOnosApp
{
    //System.out.println("capacity is exceed.");
    TrafficMonSwitchAP();
}
//System.out.println("traffics: " + deviceService.getPortDeltaStatistics(device.id()));
}
}

private void enrollAP()
{
    String device1="of:0000b827eb891c41";
    String device2="of:0000b827eb675483";
    //DeviceAPMap.put( <DeviceID>, new AP(<DeviceID>, <SSID>, <BSSID>, (long)0) );
    DeviceAPMap.put( device1 , new AP(device1, "OpenWinNet_1", "00:26:66:4e:de:be", (long)0) );
    DeviceAPMap.put( device2 , new AP(device2, "OpenWinNet_2", "00:e0:4d:a0:2f:98", (long)0) );
}

129,82-85 43%
```

- DeviceAPMap.put(<Device의 OVS ID>, new AP(<Device의 OVS ID>, <AP의 SSID>, <AP Mac Address>, (long)0))
을 작성하여 추가



Offloading Application

- mvn clean install

```
mclab@mclab-All-Series: ~/Offloading/TrafficOffloadingONOS/TrafficOffloadingOnosApp
mclab@mclab-All-Series:~/Offloading/TrafficOffloadingONOS/TrafficOffloadingOnosA
pp$ ls
pom.xml  README.md  src  target  trafficMon.iml
mclab@mclab-All-Series:~/Offloading/TrafficOffloadingONOS/TrafficOffloadingOnosA
pp$ mvn clean install
```



Offloading Application

- `onos-app localhost install target/trafficMon-1.0-SNAPSHOT.oar`

```
mclab@mclab-All-Series: ~/Offloading/TrafficOffloadingONOS/TrafficOffloadingOnosApp
mclab@mclab-All-Series:~/Offloading/TrafficOffloadingONOS/TrafficOffloadingOnosApp$ onos-app localhost install target/trafficMon-1.0-SNAPSHOT.oar
{"name":"kr.ac.postech.app","id":79,"version":"1.0.SNAPSHOT","category":"utility","description":"ONOS OSGi bundle archetype","readme":"ONOS OSGi bundle archetype","origin":"MCNL","url":null,"featuresRepo":"mvn:kr.ac.postech/trafficMon/1.0-SNAPSHOT/xml/features","state":"INSTALLED","features":["trafficMon"],"permissions":[],"requiredApps":[]}
```

확인



Offloading Application

- ONOS상에서 application activate

```
mclab@mclab-All-Series: ~/onos
Creating local cluster configs for IP 127.0.0.1...
Copying package configs...
Staging builtin apps...
Customizing apps to be auto-activated: drivers,openflow,fwd,proxyarp,mobility...
Welcome to Open Network Operating System (ONOS)!

  ONOS

Documentation: wiki.onosproject.org
Tutorials:    tutorials.onosproject.org
Mailing lists: lists.onosproject.org

Come help out! Find out how at: contribute.onosproject.org

Hit '<tab>' for a list of available commands
and '[cmd] --help' for help on a specific command.
Hit '<ctrl-d>' or type 'system:shutdown' or 'logout' to shutdown ONOS.

onos>
Display all 561 possibilities? (y or n)
onos>
onos> app activate kr.ac.postech.app
```

- app activate kr.ac.postech.app



offloading 명령어

- Offloading client
 - ONOS가 현재 관리하는 Client list 출력
- Offloading scan [client bssid]
 - Target client의 주위 AP 정보 스캐닝
- Offloading output [client bssid]
 - Target client의 저장된 AP 정보 출력
- Offloading connect [client bssid] [ap bssid] [ap password]
 - Target client를 target AP에 connect
- Offloading disconnect [client bssid] [ap bssid]
 - Target client를 target AP로부터 disconnect
- Offloading set [capacity]
 - AP에 허용되는 최대 트래픽 [capacity] 설정



offloading 명령어

- Offloading client

- 현재 연결된 Client list 출력

```
onos> offloading client
78:f7:be:92:80:d9
```

- Offloading scan [client bssid]

- Target client의 현재 저장된 AP 정보 출력

```
onos> offloading scan 78:f7:be:92:80:d9
onos>
SSID: postech      BSSID: 08:17:35:dd:8f:00      SignalStrength:-76
SSID: mcn          BSSID: 00:26:66:42:4a:a5      SignalStrength:-57
SSID: mcnlab_2ghz  BSSID: b0:c7:45:7d:06:60      SignalStrength:-63
SSID: helloeverybody BSSID: 00:26:66:7b:12:ec      SignalStrength:-70
SSID: mcnlab_5ghz  BSSID: b0:c7:45:7d:06:65      SignalStrength:-68
SSID: mcn8         BSSID: 64:e5:99:f0:48:57      SignalStrength:-69
```

- Offloading output [client bssid]

- Target client의 현재 저장된 AP 정보 출력

```
onos> offloading output 78:f7:be:92:80:d9
SSID: aspl        BSSID: 00:26:66:1a:0e:28      SignalStrength:-91
SSID: ollehwifi   BSSID: 00:25:a6:a0:40:3f      SignalStrength:-78
SSID: eduroam     BSSID: 08:17:35:dd:8f:0e      SignalStrength:-78
SSID: helloeverybody BSSID: 00:26:66:7b:12:ec      SignalStrength:-57
SSID: ollehwifi   BSSID: 00:25:a6:a0:40:3e      SignalStrength:-79
SSID: mmic        BSSID: 00:26:66:93:5f:68      SignalStrength:-88
SSID: postech     BSSID: 08:17:35:dd:8f:0f      SignalStrength:-79
SSID: postech     BSSID: 10:8c:cf:b5:1b:30      SignalStrength:-76
SSID: eduroam     BSSID: 10:8c:cf:b5:1b:31      SignalStrength:-72
SSID: mcn8        BSSID: 64:e5:99:f0:48:57      SignalStrength:-69
SSID: postech     BSSID: 10:8c:cf:b5:0e:70      SignalStrength:-82
```

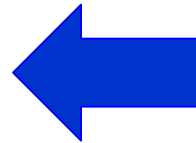
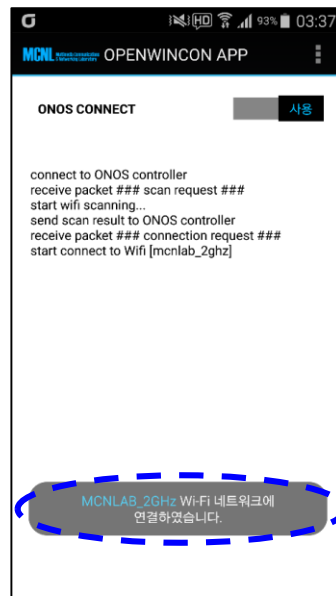


offloading 명령어

- offloading connect [client bssid] [ap bssid] [ap password]
 - Target AP로 (ex. MCNLAB_2GHz)에 연결

```
onos> offloading connect 78:f7:be:92:80:d9 b0:c7:45:7d:06:60 mcnl5684
onos>
```

- Client UI



offloading 명령어

- offloading set [capacity]
 - AP에 허용되는 최대 트래픽 [capacity] 설정

```
onos> offloading set 50  
onos> TrafficMon Offloading from MCNLONOS to OPENWINCON
```

- Web UI



AP 설치 가이드

Kyung Hee University, POSTECH

Mobile Convergence Laboratory, Media Computing & Networking Laboratory

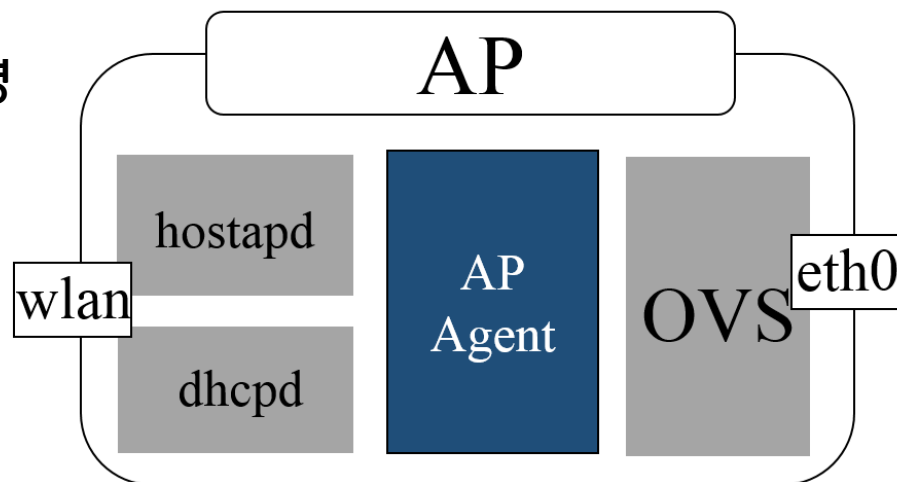
안계완, 고세원, 호동혁, 노현민

2016. 04. 08

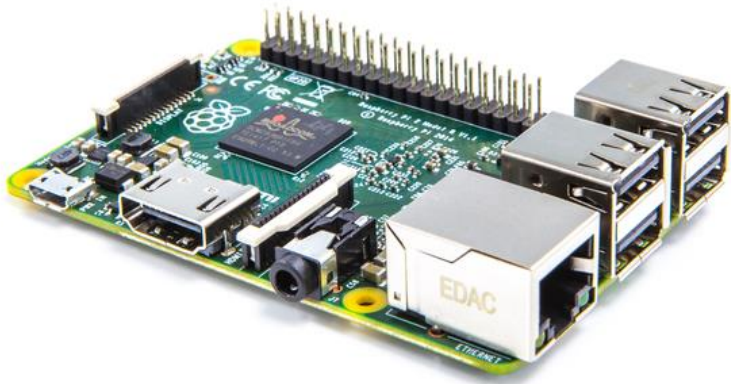


설치 과정

- 하드웨어 사양
- 윈도우 상에서 Ubuntu Mate 15.10 SD 카드 작성
- 원활한 사용을 위해 Ubuntu-Mate 15.10 기본 설정 변경
- 소프트웨어 작동에 필요한 필수 라이브러리 설치
- AP-Agent 설치 및 실행
- CLI 및 GUI 데모
- ONOS 연결을 위한 OVS 및 네트워크 설정
- AP 작동을 위한 포워딩 설정
- Traffic Monitoring 작동 확인



하드웨어 사양



- 900MHz quad-core ARM Cortex-A7 CPU
- 1GB RAM
- 4 USB ports, 40 GPIO pins
- FULL HDMI port
- Ethernet port

Raspberry Pi 2B

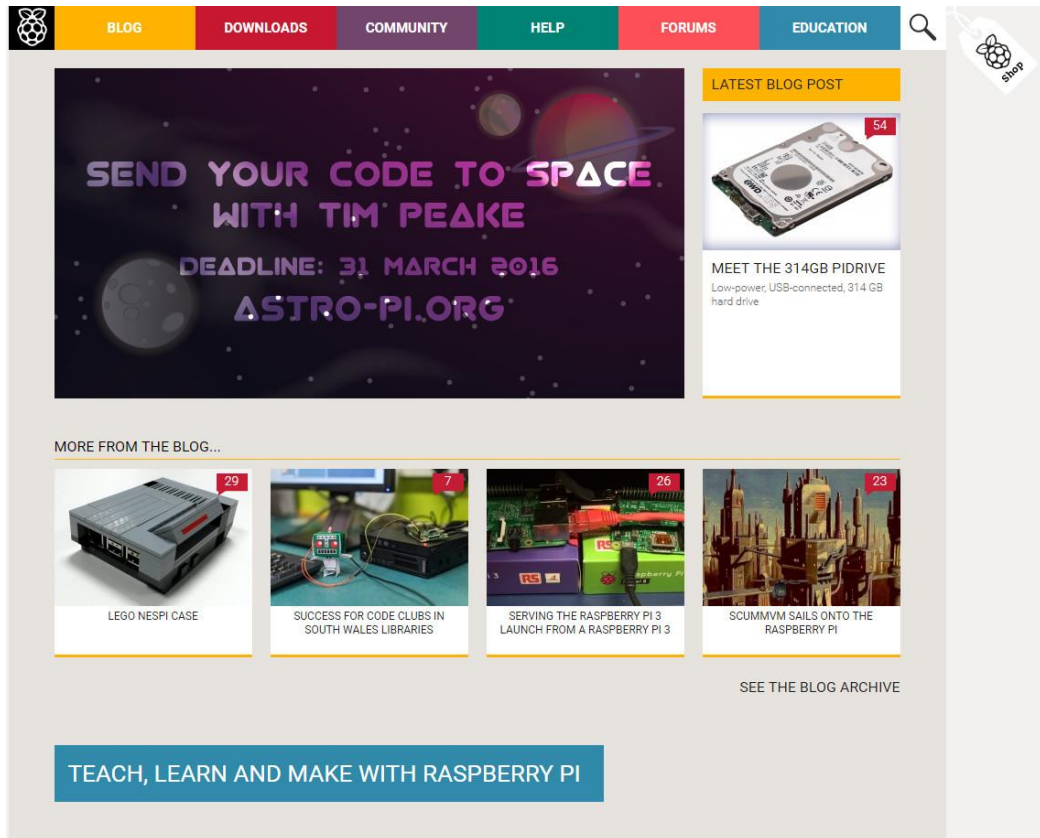


- Wireless Lan Card
- USB 2.0
- Single Band
- 2.4GHz
- 802.11n/g/b

EFM ipTIME N100UM



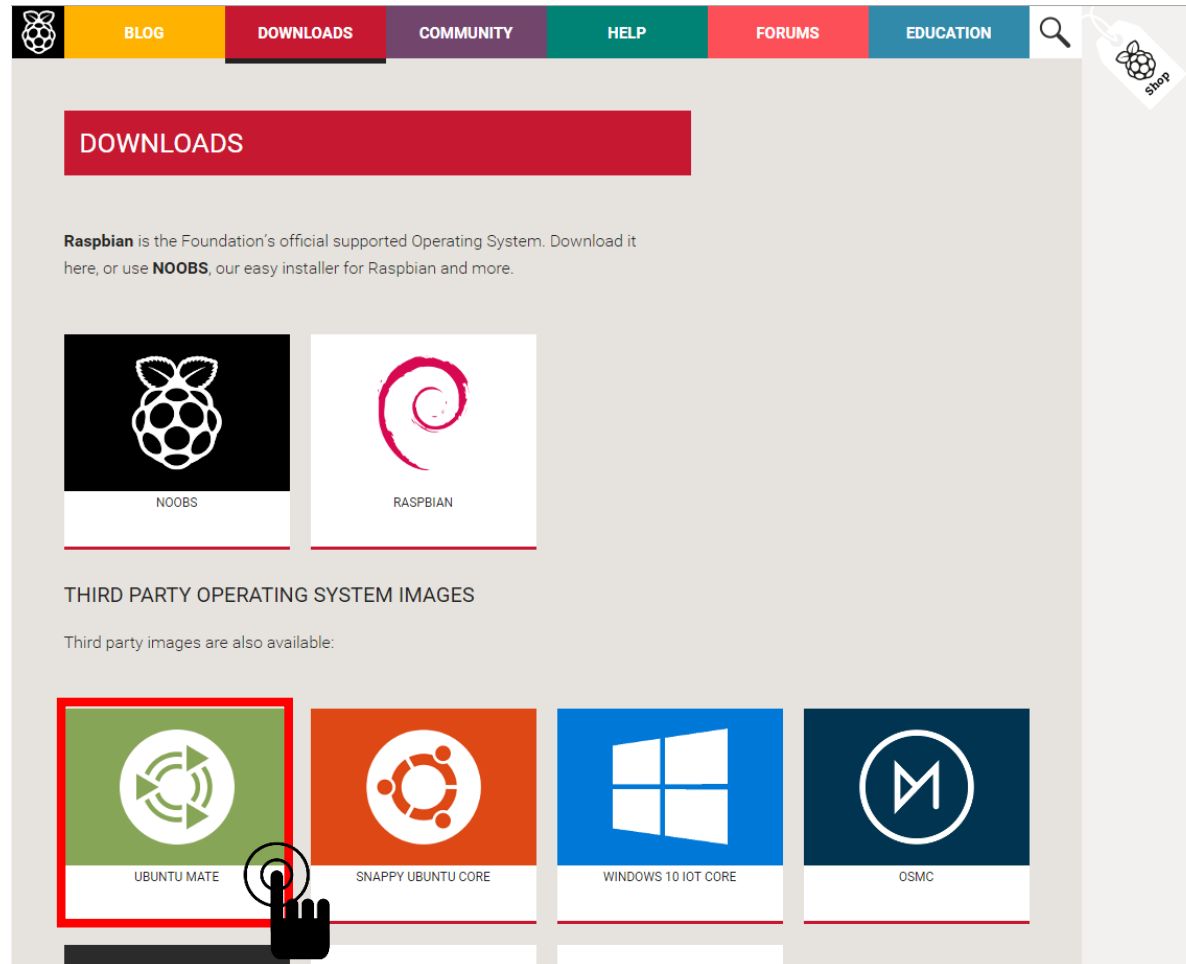
Ubuntu Mate 15.10 image 다운로드



- Raspberry Pi 홈페이지 접속
- <https://www.raspberrypi.org/>
- Download 클릭



Ubuntu Mate 15.10 image 다운로드



Ubuntu Mate 15.10 image 다운로드

Ubuntu MATE for the Raspberry Pi 2 and Raspberry Pi 3

Martin Wimpress and Rohith Madhavan have made an Ubuntu MATE image for the Raspberry Pi 2 and Raspberry Pi 3 which you can download or build yourself.

The image is functional and based on the regular Ubuntu `armhf` base, not the new Snappy Core, which means that the installation procedure for applications is the same as that for the regular desktop version, ie using `apt-get`.

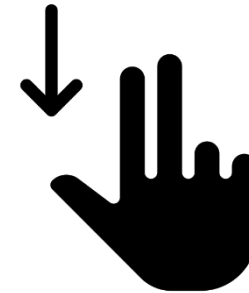
We have done what we can to optimise the build for the Raspberry Pi 2 and Raspberry Pi 3, you can comfortably use applications such as LibreOffice, which in fact is a joy to use :-)

But the microSDHC I/O throughput is a bottleneck so we recommend that you use a **Class 6 or Class 10 microSDHC** card.

The images support the integrated Wifi on the Raspberry Pi 3, but support for the integrated Raspberry Pi 3 Bluetooth is incomplete. We hope to have that sorted soon.

You'll need a microSD card which is 4GB or greater to fit the image. The file system can be resized to occupy the unallocated space of the microSD card, similar to Raspbian.

NOTE! There are no predefined user accounts. The first time you boot one of the desktop images it will run through a setup wizard where you can create your own user account and configure your regional settings. The first boot is quite slow but, once the first boot configuration is complete, subsequent boots are much quicker.




Ubuntu Mate 15.10 image 다운로드

Download

A pre-built image of Ubuntu MATE 15.10.1 for the Raspberry Pi 2 and Raspberry Pi 3 is available via BitTorrent and direct download. If you can spare the bytes, please download via BitTorrent and leave the client open after your download is finished, so you can seed it back to others. *A web-seed capable client is recommended for fastest download speeds.*

Many thanks to [First Colo](#) for contributing the hosting and bandwidth for the Ubuntu MATE downloads.



Ubuntu MATE 15.10.3
via BitTorrent
**Raspberry Pi 2 and Raspberry
Pi 3**



Ubuntu MATE 15.10.3 from
European CDN
**Raspberry Pi 2 and Raspberry
Pi 3**



Ubuntu MATE 15.10.1 from
Canadian mirror
**Raspberry Pi 2 and Raspberry
Pi 3**



Ubuntu MATE 15.10.1 from
French mirror
**Raspberry Pi 2 and Raspberry
Pi 3**

If you direct download the image please make sure the SHA256 hash matches:

- `49ac8dfb73c203fe698a1a3c139b5cbec023c0d567253998e942d1fa236bbb94`

Download tip

If everyone who downloaded Ubuntu MATE donated **\$2.50** it would fund the full-time development of Ubuntu MATE *and* MATE Desktop. [Please give us a tip and help both projects flourish!](#) If you'd like to donate more or become an Ubuntu MATE patron please visit the [donate page](#).



Tip us \$2.50

Tip us \$5.00

Tip us \$10.00

Tip us \$20.00



Win32DiskImager

VISION SOLUTIONS Do Your 2015 IT Plans Include Server Migrations? Download the FREE Guide >>

Explore Your Options With Our Near-Zero Downtime Migration Guide

Home / Browse / System Administration / Storage / Win32 Disk Imager

Win32 Disk Imager beta

A tool for writing images to USB sticks or SD/CF cards
Brought to you by: [gruemaster](#), [tuxinator2009](#)

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★ 4.0 Stars (71)
↓ 81,791 Downloads (This Week)
📅 Last Update: 2015-09-22

Download
Download the unnamed sequel here

How to use Win32 Disk Imager

emirates.com/kr

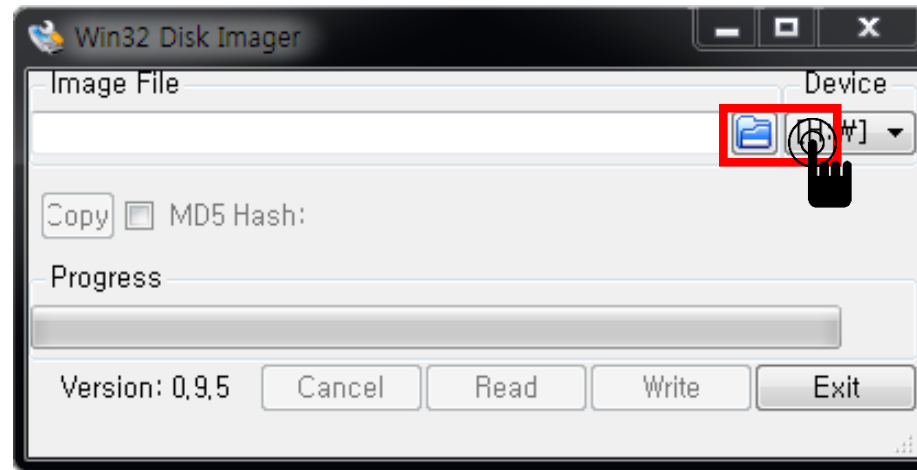
Gmail for Work
Google에서 맞춤 제작한 Gmail로 더 전문적인 양상을 갖추세요.
무료 평가판 시작하기

- <https://sourceforge.net/projects/win32diskimager/>



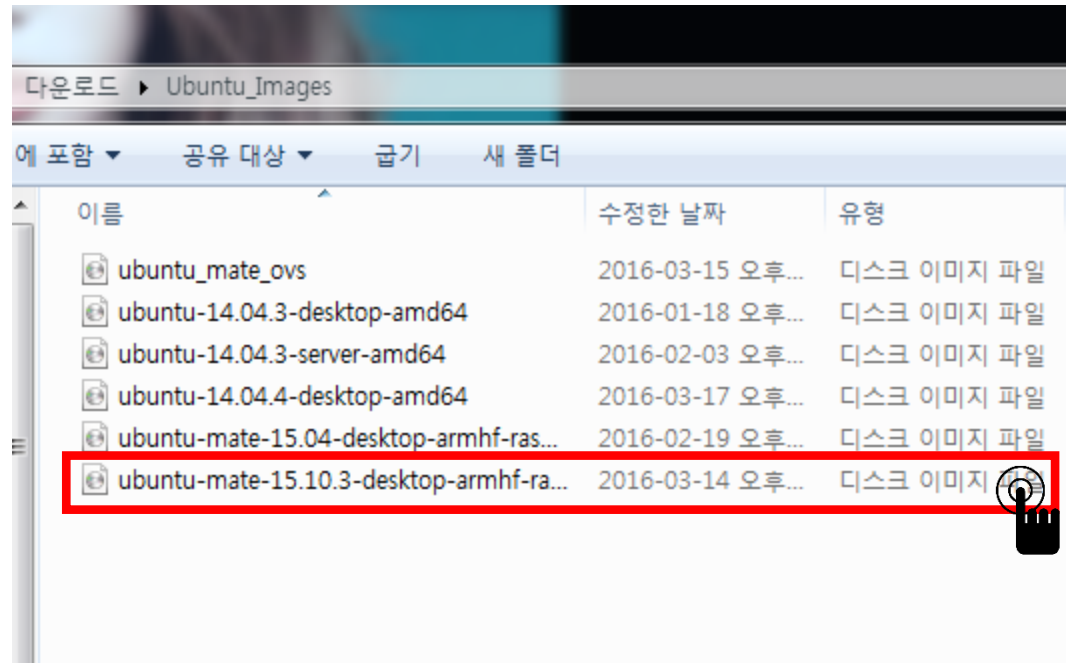
Win32DiskImager

- Win32DiskImager로 SD카드에 Ubuntu Image 쓰기



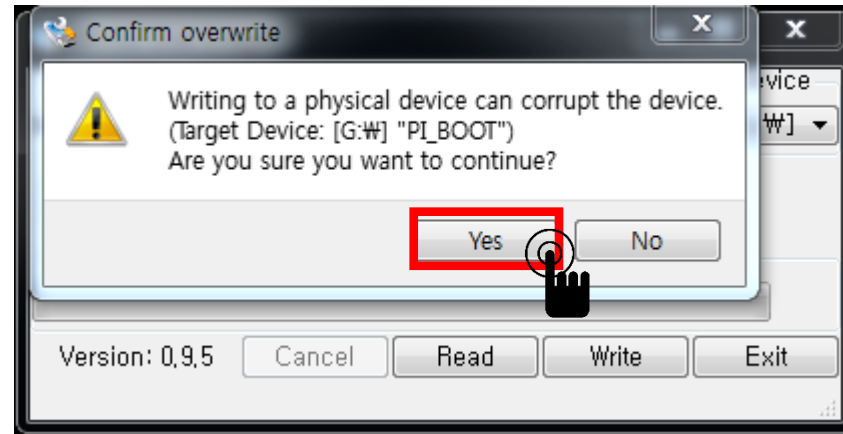
Win32DiskImager

- Win32DiskImager로 SD카드에 Ubuntu Image 쓰기



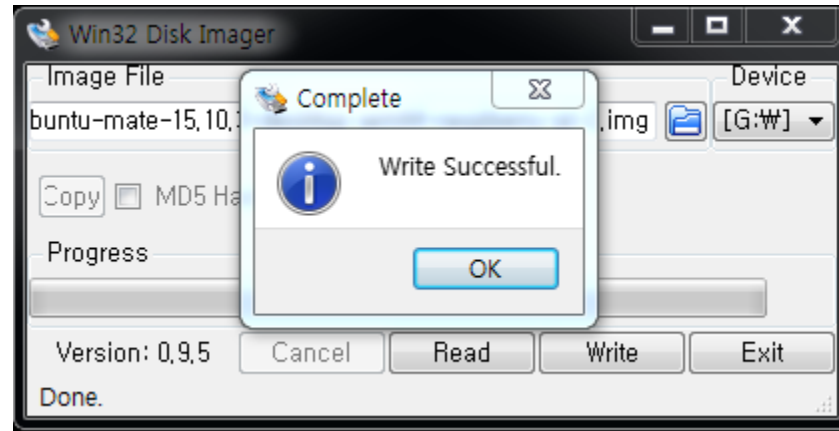
Win32DiskImager

- Win32DiskImager로 SD카드에 Ubuntu Image 쓰기



Win32DiskImager

- Win32DiskImager로 SD카드에 Ubuntu Image 쓰기



Ubuntu-Mate 기본 설정

- 기본 설정의 경우 SD카드 가용 용량이 매우 작기 때문에 파티션 변경이 필요



Ubuntu-Mate 기본 설정

- 파티션 크기 설정

```
mclab@mclab-desktop: ~  
File Edit View Search Terminal Help  
To run a command as administrator (user "root"), use "sudo <command>".  
See "man sudo_root" for details.  
  
mclab@mclab-desktop:~$ sudo fdisk /dev/mmcblk0  
[sudo] password for mclab:  
  
Welcome to fdisk (util-linux 2.26.2).  
Changes will remain in memory only, until you decide to write them.  
Be careful before using the write command.  
  
Command (m for help):
```

- `sudo fdisk /dev/mmcblk0`
- p
- d
- 2
- n
- p
- 2
- enter 두번
- w
- sudo reboot
- sudo resize2fs/dev/mmcblk0p2
- sudo reboot



Ubuntu-Mate 기본 설정

• 파티션 크기 설정

```
mclab@mclab-desktop: ~  
File Edit View Search Terminal Help  
  
Welcome to fdisk (util-linux 2.26.2).  
Changes will remain in memory only, until you decide to write them.  
Be careful before using the write command.  
  
Command (m for help): p  
Disk /dev/mmcblk0: 14.9 GiB, 16003891200 bytes, 31257600 sectors  
Units: sectors of 1 * 512 = 512 bytes  
Sector size (logical/physical): 512 bytes / 512 bytes  
I/O size (minimum/optimal): 512 bytes / 512 bytes  
Disklabel type: dos  
Disk identifier: 0xf9315c16  
  
Device      Boot  Start      End  Sectors  Size Id Type  
/dev/mmcblk0p1 *      2048   133119   131072    64M  c W95 FAT32 (LBA)  
/dev/mmcblk0p2          133120 7679999 7546880    3.6G 83 Linux  
  
Command (m for help): d  
Partition number (1,2, default 2): 2  
  
Partition 2 has been deleted.  
  
Command (m for help):
```

- `sudo fdisk /dev/mmcblk0`
- **p**
- **d**
- **2**
- n
- p
- 2
- enter 두번
- w
- `sudo reboot`
- `sudo resize2fs/dev/mmcblk0p2`
- `sudo reboot`



Ubuntu-Mate 기본 설정

- 파티션 크기 설정

```
mclab@mclab-desktop: ~  
File Edit View Search Terminal Help  
Disklabel type: dos  
Disk identifier: 0xf9315c16  
  
Device      Boot  Start      End  Sectors  Size Id Type  
/dev/mmcblk0p1 *    2048   133119   131072    64M  c  W95 FAT32 (LBA)  
/dev/mmcblk0p2      133120 7679999 7546880   3.6G  83  Linux  
  
Command (m for help): d  
Partition number (1,2, default 2): 2  
  
Partition 2 has been deleted.  
  
Command (m for help): n  
Partition type  
  p  primary (1 primary, 0 extended, 3 free)  
  e  extended (container for logical partitions)  
Select (default p): p  
Partition number (2-4, default 2): 2  
First sector (133120-31257599, default 133120):  
Last sector, +sectors or +size{K,M,G,T,P} (133120-31257599, default 31257599):  
  
Created a new partition 2 of type 'Linux' and of size 14.9 GiB.  
Command (m for help):
```

- `sudo fdisk /dev/mmcblk0`
- p
- d
- 2
- n
- p
- 2
- enter 두번
- w
- `sudo reboot`
- `sudo resize2fs/dev/mmcblk0p2`
- `sudo reboot`



Ubuntu-Mate 기본 설정

• 파티션 크기 설정

```
mclab@mclab-desktop: ~  
File Edit View Search Terminal Help  
Partition number (1,2, default 2): 2  
  
Partition 2 has been deleted.  
  
Command (m for help): n  
Partition type  
  p   primary (1 primary, 0 extended, 3 free)  
  e   extended (container for logical partitions)  
Select (default p): p  
Partition number (2-4, default 2): 2  
First sector (133120-31257599, default 133120):  
Last sector, +sectors or +size{K,M,G,T,P} (133120-31257599, default 31257599):  
  
Created a new partition 2 of type 'Linux' and of size 14.9 GiB.  
  
Command (m for help): w  
The partition table has been altered.  
Calling ioctl() to re-read partition table.  
Re-reading the partition table failed.: Device or resource busy  
  
The kernel still uses the old table. The new table will be used at the next reboot or after you run partprobe(8) or kpartx(8).  
  
mclab@mclab-desktop: ~$
```

무시

- `sudo fdisk /dev/mmcblk0`
- `p`
- `d`
- `2`
- `n`
- `p`
- `2`
- `enter` 두번
- `w`
- `sudo reboot`
- `sudo resize2fs/dev/mmcblk0p2`
- `sudo reboot`



Ubuntu-Mate 기본 설정

• 파티션 크기 설정

```
mclab@mclab-desktop: ~  
File Edit View Search Terminal Help  
mclab@mclab-desktop:~$ sudo resize2fs /dev/mmcblk0p  
mmcblk0p1 mmcblk0p2  
mclab@mclab-desktop:~$ sudo resize2fs /dev/mmcblk0p2  
[sudo] password for mclab:  
resize2fs 1.42.12 (29-Aug-2014)  
Filesystem at /dev/mmcblk0p2 is mounted on /; on-line resizing required  
old_desc_blocks = 1, new_desc_blocks = 1  
The filesystem on /dev/mmcblk0p2 is now 3890560 (4k) blocks long.  
mclab@mclab-desktop:~$
```

- `sudo fdisk /dev/mmcblk0`
- `p`
- `d`
- `2`
- `n`
- `p`
- `2`
- `enter` 두번
- `w`
- `sudo reboot`
- `sudo resize2fs/dev/mmcblk0p2`
- `sudo reboot`



Ubuntu-Mate 기본 설정

- 15.10 버전부터 인터페이스 이름이 기존과 다름

```
mclab@mclab-desktop: ~  
File Edit View Search Terminal Help  
mclab@mclab-desktop:~$ ifconfig  
enxb827eb77929e Link encap:Ethernet HWaddr b8:27:eb:77:92:9e  
    inet addr:163.180.118.144 Bcast:163.180.118.255 Mask:255.255.255.0  
    inet6 addr: fe80::ba27:ebff:fe77:929e/64 Scope:Link  
    UP BROADCAST RUNNING MULTICAST MTU:1500 Metric:1  
    RX packets:4558 errors:0 dropped:30 overruns:0 frame:0  
    TX packets:95 errors:0 dropped:0 overruns:0 carrier:0  
    collisions:0 txqueuelen:1000  
    RX bytes:382947 (382.9 KB) TX bytes:20153 (20.1 KB)  
  
lo Link encap:Local Loopback  
    inet addr:127.0.0.1 Mask:255.0.0.0  
    inet6 addr: ::1/128 Scope:Host  
    UP LOOPBACK RUNNING MTU:65536 Metric:1  
    RX packets:425 errors:0 dropped:0 overruns:0 frame:0  
    TX packets:425 errors:0 dropped:0 overruns:0 carrier:0  
    collisions:0 txqueuelen:0  
    RX bytes:56202 (56.2 KB) TX bytes:56202 (56.2 KB)  
  
wlx00e04da02edd Link encap:Ethernet HWaddr 00:e0:4d:a0:2e:dd  
    UP BROADCAST MULTICAST MTU:1500 Metric:1  
    RX packets:0 errors:0 dropped:0 overruns:0 frame:0  
    TX packets:0 errors:0 dropped:0 overruns:0 carrier:0  
    collisions:0 txqueuelen:1000
```



Ubuntu-Mate 기본 설정

- /boot/cmdline.txt 수정

[illegible]

- net.ifnames=0 biosdevname=0 추가



Ubuntu-Mate 기본 설정

- 기존 eth0, wlan0로 돌아온 것을 확인

```
mclab@mclab-desktop: ~  
File Edit View Search Terminal Help  
mclab@mclab-desktop:~$ ifconfig  
eth0      Link encap:Ethernet  HWaddr b8:27:eb:77:92:9e  
          inet addr:      Bcast:163.180.118.255  Mask:255.255.255.0  
          inet6 addr: fe80::ba27:ebff:fe77:929e/64 Scope:Link  
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1  
          RX packets:2393 errors:0 dropped:15 overruns:0 frame:0  
          TX packets:126 errors:0 dropped:0 overruns:0 carrier:0  
          collisions:0 txqueuelen:1000  
          RX bytes:212348 (212.3 KB)  TX bytes:25141 (25.1 KB)  
  
lo        Link encap:Local Loopback  
          inet addr:127.0.0.1  Mask:255.0.0.0  
          inet6 addr: ::1/128 Scope:Host  
          UP LOOPBACK RUNNING  MTU:65536  Metric:1  
          RX packets:420 errors:0 dropped:0 overruns:0 frame:0  
          TX packets:420 errors:0 dropped:0 overruns:0 carrier:0  
          collisions:0 txqueuelen:0  
          RX bytes:57684 (57.6 KB)  TX bytes:57684 (57.6 KB)  
  
wlan0     Link encap:Ethernet  HWaddr 00:e0:4d:a0:2e:dd  
          UP BROADCAST MULTICAST  MTU:1500  Metric:1  
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0  
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0  
          collisions:0 txqueuelen:1000
```



필요 라이브러리 설치

- 이 가이드에서 필요한 필수 라이브러리를 아래의 명령어를 이용하여 설치
- `sudo apt-get update`
- `sudo apt-get install iw hostapd isc-dhcp-server git mysql-clinet libmysqlclient-dev openvswitch-switch openvswitch-common`



필요 라이브러리 설치

- `sudo apt-get update`

```
mclab@mclab-desktop: ~  
File Edit View Search Terminal Help  
mclab@mclab-desktop:~$ sudo apt-get update
```



```
Get:32 http://ports.ubuntu.com wily-backports/restricted Sources [28 B]  
Get:33 http://ports.ubuntu.com wily-backports/universe Sources [2,257 B]  
Get:34 http://ports.ubuntu.com wily-backports/multiverse Sources [28 B]  
Get:35 http://ports.ubuntu.com wily-backports/main armhf Packages [615 B]  
Get:36 http://ports.ubuntu.com wily-backports/restricted armhf Packages [28 B]  
Get:37 http://ports.ubuntu.com wily-backports/universe armhf Packages [1,999 B]  
Get:38 http://ports.ubuntu.com wily-backports/multiverse armhf Packages [28 B]  
Get:39 http://ports.ubuntu.com wily-backports/main Translation-en [496 B]  
Get:40 http://ports.ubuntu.com wily-backports/multiverse Translation-en [28 B]  
Get:41 http://ports.ubuntu.com wily-backports/restricted Translation-en [28 B]  
Get:42 http://ports.ubuntu.com wily-backports/universe Translation-en [1,390 B]  
Fetched 1,127 kB in 53s (21.0 kB/s)  
Reading package lists... Done
```



필요 라이브러리 설치

- `sudo apt-get install iw hostapd isc-dhcp-server git mysql-client libmysqlclient-dev openvswitch-switch openvswitch-common -y`

```
mclab@mclab-desktop:~$ sudo apt-get install iw hostapd isc-dhcp-server git mysql-client libmysqlclient-dev openvswitch-switch openvswitch-common vim
```



```
Setting up openvswitch-common (2.4.0-0ubuntu4) ...  
Setting up openvswitch-switch (2.4.0-0ubuntu4) ...  
update-alternatives: using /usr/lib/openvswitch-switch/ovs-vswitchd to provide /usr/sbin/ovs-vswitchd (ovs-vswitchd) in auto mode  
openvswitch-nonetwork.service is a disabled or a static unit, not starting it.  
Processing triggers for libc-bin (2.21-0ubuntu4.1) ...  
Processing triggers for ureadahead (0.100.0-19) ...  
Processing triggers for systemd (225-1ubuntu9) ...  
mclab@mclab-desktop:~$ sudo ovs-vsctl show  
3927a1f1-15d6-48c8-90f9-632851449932  
    ovs_version: "2.4.0"  
mclab@mclab-desktop:~$
```



AP-Agent 설치

- `sudo git clone https://github.com/OpenWinCon/OpenWinNet.git`

```
mclab@mclab-desktop: ~/OpenWinCon
File Edit View Search Terminal Help
mclab@mclab-desktop:~/OpenWinCon$ sudo git clone https://github.com/OpenWinCon/O
penWinNet.git
```



```
mclab@mclab-desktop: ~/OpenWinCon
File Edit View Search Terminal Help
mclab@mclab-desktop:~/OpenWinCon$ sudo git clone https://github.com/OpenWinCon/O
penWinNet
Cloning into 'OpenWinNet'...
remote: Counting objects: 642, done.
remote: Compressing objects: 100% (6/6), done.
remote: Total 642 (delta 0), reused 0 (delta 0), pack-reused 636
Receiving objects: 100% (642/642), 3.43 MiB | 909.00 KiB/s, done.
Resolving deltas: 100% (229/229), done.
Checking connectivity... done.
mclab@mclab-desktop:~/OpenWinCon$
```



AP-Agent 설치

- `cd ./OpenWinNet/agent/HostApd_agent&controller`

```
mclab@mclab-desktop:~/OpenWinCon/OpenWinNet$ cd agent/HostApd_agent\&controller/  
mclab@mclab-desktop:~/OpenWinCon/OpenWinNet/agent/HostApd_agent&controller$ ls  
Action.cpp          conf                hostap.h            Report.cpp  
Action.h            controller.cpp      makefile            Report.h  
ap_agent.cpp        ctrCommand.cpp     openvpn             Socket.cpp  
APIInformation_back.cpp  ctrCommand.h      Packet.cpp          Socket.h  
APIInformation.cpp    Database.cpp        Packet.h            testbed_result  
APIInformation.h      Database.h          PacketType.h  
APIInformation_no_vpn.cpp  hostap_back.cpp    protocol.h  
Command.cpp          hostap.cpp          readme.md
```



AP-Agent 설치

- vi Report.cpp

```
mclab@mclab-desktop: ~/OpenWinCon/OpenWinNet/agent/HostApd_agent&controller
File Edit View Search Terminal Help

/*****
*void Report::Initialize()
*   Make connection with OpenWinNet Manager
*   Send Wake-Up Message to OpenWinNet Manager
*   Receive Wake-Up-Response Message.
*****/
void Report::Initialize() {
    // Make connection with OpenWinNetManager
    cout << "sock create" << endl;
    m_sock.create();
    m_sock.connect( DB address , PORT_NUMBER);
    cout << "sock connected" << endl;

    string msg;
    Packet pkt;

    // Get AP Information from hardware.
    m_APInfo.UpdateAPIInformation();
    m_APInfo.SetAPIInformation(AP_PASSWORD, m_ap->get_pwd());
    if(m_ap->get_hide() == "1" )
}
```

- Initialize() 함수 내의 ip주소를 사용할 DB가 존재하는 주소로 변경



AP-Agent 설치

- vi conf/dhcpd.conf

```
mclab@mclab-desktop: ~/OpenWinCon/OpenWinNet/agent/HostApd_agent&controller/cc
File Edit View Search Terminal Help
ddns-update-style none;

option domain-name "example.org";
option domain-name-servers DNS address

default-lease-time 600;
max-lease-time 7200;

log-facility local7;

subnet 192.168.0.0 netmask 255.255.255.0 {
    option routers 192.168.0.34;
}

subnet 192.168.1.0 netmask 255.255.255.0 {
    range 192.168.1.35 192.168.1.80;
    option routers 192.168.1.34;
}

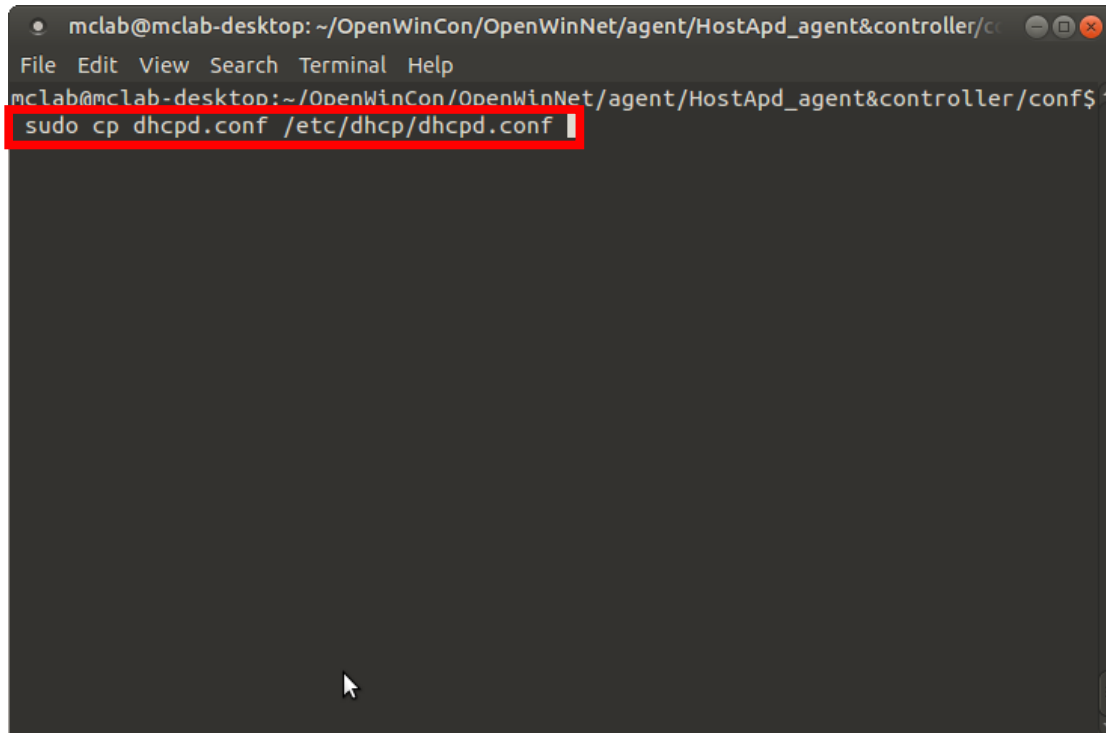
~
~
~
~
-- INSERT --
```

- dhcpd가 사용할 dns 주소 변경



AP-Agent 설치

- `cp ./conf/dhcpd.conf /etc/dhcp/dhcpd.conf`



A terminal window titled 'mclab@mclab-desktop: ~/OpenWinCon/OpenWinNet/agent/HostApd_agent&controller/c' with a menu bar (File, Edit, View, Search, Terminal, Help). The prompt is 'mclab@mclab-desktop:~/OpenWinCon/OpenWinNet/agent/HostApd_agent&controller/conf\$'. The command 'sudo cp dhcpd.conf /etc/dhcp/dhcpd.conf' is entered and highlighted with a red box.

- dhcpd conf 파일을 복사하여 사용



AP-Agent 설치

- make

```
mclab@mclab-desktop: ~/OpenWinCon/OpenWinNet/agent/HostApd_agent&controller
File Edit View Search Terminal Help
make
g++ -c ap_agent.cpp
ap_agent.cpp: In function 'int main(int, char**)':
ap_agent.cpp:136:44: warning: deprecated conversion from string constant to 'char*' [-Wwrite-strings]
    ap = new hostap("./conf/openwinnet.conf"); // default confPath
                                   ^
g++ -c ctrCommand.cpp
g++ -c hostap.cpp
g++ -c Report.cpp
g++ -c Packet.cpp
g++ -c Socket.cpp
g++ -c APInformation.cpp
g++ -o ap_agent ap_agent.o ctrCommand.o hostap.o Report.o Packet.o Socket.o APInformation.o -lmysqlclient -lpthread
g++ -c controller.cpp
g++ -c Action.cpp
g++ -c Database.cpp
g++ -o controller controller.o hostap.o Report.o Packet.o Socket.o APInformation.o Action.o Database.o -lmysqlclient -lpthread
g++ -c Command.cpp
g++ -o command Command.o ctrCommand.o hostap.o APInformation.o -lmysqlclient -lpthread
mclab@mclab-desktop: ~/OpenWinCon/OpenWinNet/agent/HostApd_agent&controller$
```



AP-Agent 설치

- 반드시 ap_agent가 생성되어 있어야함

```
mclab@mclab-desktop: ~/OpenWinCon/OpenWinNet/agent/HostApd_agent&controller
File Edit View Search Terminal Help
mclab@mclab-desktop:~/OpenWinCon/OpenWinNet/agent/HostApd_agent&controller$ ls
Action.cpp          command             Database.h          PacketType.h
Action.h            Command.cpp         Database.o          protocol.h
Action.o            Command.o           hostap_back.cpp    readme.md
ap_agent            conf                hostap.cpp          Report.cpp
ap_agent.cpp        controller          hostap.h            Report.h
ap_agent.o          controller.cpp      hostap.o            Report.o
APIInformation_back.cpp controller.o         makefile            Socket.cpp
APIInformation.cpp   ctrCommand.cpp     openvpn             Socket.h
APIInformation.h     ctrCommand.h        Packet.cpp          Socket.o
APIInformation_no_vpn.cpp ctrCommand.o       Packet.h            testbed_result
APIInformation.o     Database.cpp        Packet.o
mclab@mclab-desktop:~/OpenWinCon/OpenWinNet/agent/HostApd_agent&controller$
```



AP-Agent 및 Controller 확인

- `sudo ./ap_agent`

```
mclab@mclab-desktop: ~/OpenWinCon/OpenWinNet/agent/HostApd_agent&controller
File Edit View Search Terminal Help
APInformation.cpp      ctrCommand.cpp  openvpn         Socket.h
APInformation.h        ctrCommand.h    Packet.cpp      Socket.o
APInformation_no_vpn.cpp ctrCommand.o    Packet.h        testbed_result
APInformation.o        Database.cpp    Packet.o
mclab@mclab-desktop:~/OpenWinCon/OpenWinNet/agent/HostApd_agent&controller$ sudo
./ap_agent

HostAP Manager Server v0.6
Copyright 2015 Kyung Hee University Mobile Convergence Lab
All rights reserved.
For info, please contact to roy1022@hanamil.net

sock create
sock conncted
MAC: 00:e0:4d:a0:2e:dd
IP: 163.180.118.144
SSID: off
Fri Feb 25 03:50:24 [S] AP_REGISTRATION_REQUEST
Send..
Fri Feb 25 03:50:24 [R] AP_REGISTRATION_RESPONSE
```

확인



AP-Agent 및 Controller 확인

- `sudo ./ap_agent`

```
mclab@mclab-desktop: ~/OpenWinCon/OpenWinNet/agent/HostApd_agent&controller
File Edit View Search Terminal Help
APInformation.cpp      ctrCommand.cpp  openvpn         Socket.h
APInformation.h        ctrCommand.h    Packet.cpp      Socket.o
APInformation_no_vpn.cpp ctrCommand.o    Packet.h        testbed_result
APInformation.o        Database.cpp    Packet.o
mclab@mclab-desktop:~/OpenWinCon/OpenWinNet/agent/HostApd_agent&controller$ sudo
./ap_agent

HostAP Manager Server v0.6
Copyright 2015 Kyung Hee University Mobile Convergence Lab
All rights reserved.
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IP: 163.180.118.144
SSID: off
Fri Feb 25 03:50:24 [S] AP_REGISTRATION_REQUEST
Send..
Fri Feb 25 03:50:24 [R] AP_REGISTRATION_RESPONSE
```

확인



AP-Agent 및 Controller 확인

- CLI

```
mclab@mclab-All-Series: ~/openwincon/OpenWinNet/agent/HostApd_agent&controller
ription|          Password|          Broadcast|          Channel|
time|

Openwinnet Controller v0.8
Copyright 2015 Kyung Hee University Mobile Convergence Lab
All rights reserved.
For info, please contact to roy1022@hanamil.net

Openwinnet manager> db
-----[Openwinnet AP LIST]-----
|ID          IP          SSID          |
|           |           |           |
-----

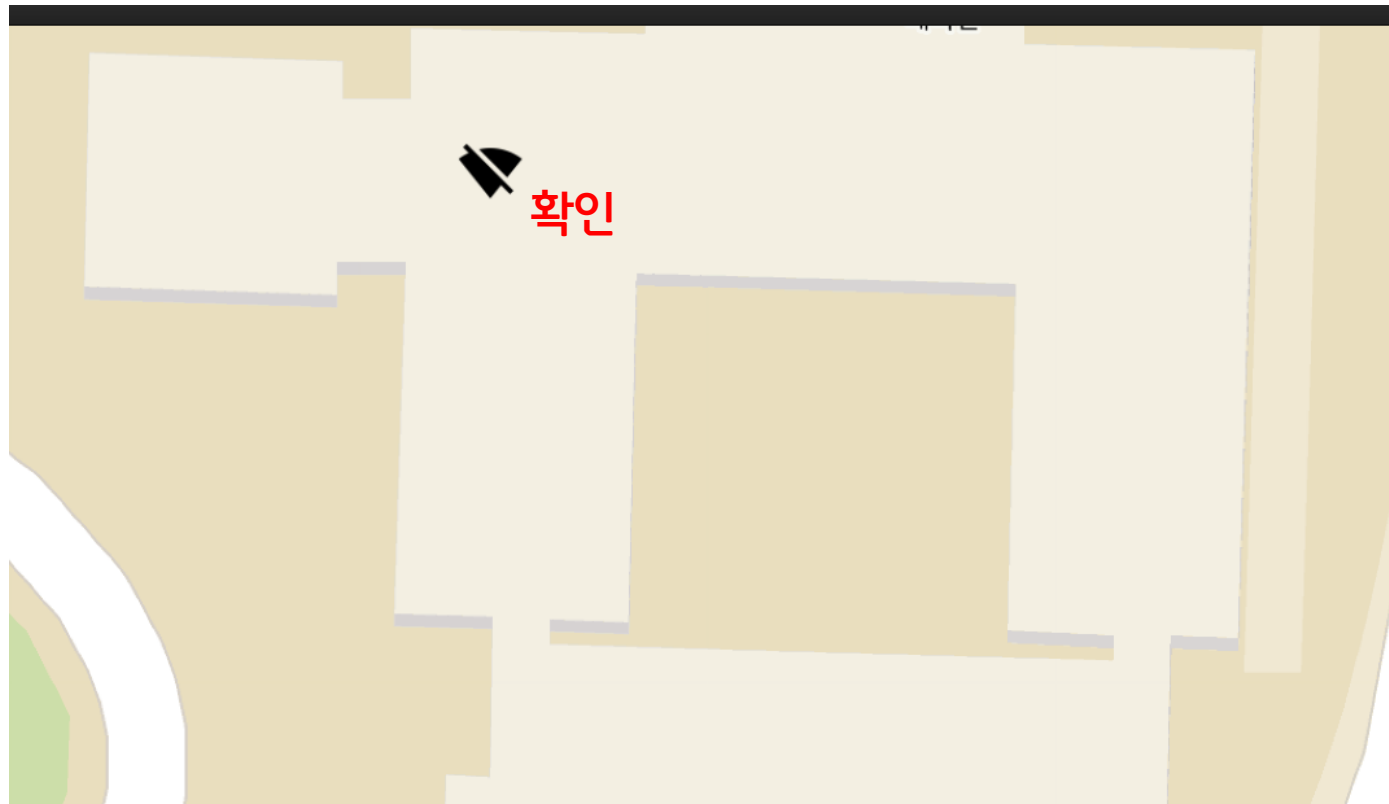
Openwinnet manager> db
[Openwinnet AP LIST]-----
|ID          IP          SSID          |
|00:26:66:4e:de:be  163.180.118.45  OpenWinNet_1 |
-----
```

확인



AP-Agent 및 Controller 확인

- GUI



AP 제어

- CLI - help

```
mclab@mclab-All-Series: ~/openwincon/OpenWinNet/agent/HostApd_agent&controller

Openwinnet manager> help
u
Commands:<IP> <Command> [value]
help or h      show this usage help
show           show ap's list
start          start ap
stop           stop ap
reboot        reboot ap
status        show ap's status
ssid <value>   change ssid
password [value] change password(if params blank, off password) *** only h
ostap
channel <value> change channel
mode <g,b>     change mode
tx <value>     change txpower (range : 0~20) *** only openwrt
uplink <value> change AP's uplink bandwidth*** only openwrt
downlink <value> change AP's downlink bandwidth *** only openwrt
hide <on, off> broadcast on, off *** only hostap
clear or cl    clear line
quit          exit this program
[P] process Command

Openwinnet manager>
```



AP 제어

- CLI - <IP> <Command> [value]

```
mclab@mclab-All-Series: ~/openwincon/OpenWinNet/agent/HostApd_agent&controller
[P] process Command
Openwinnet manager> 163.180.118.45 ssid test
```

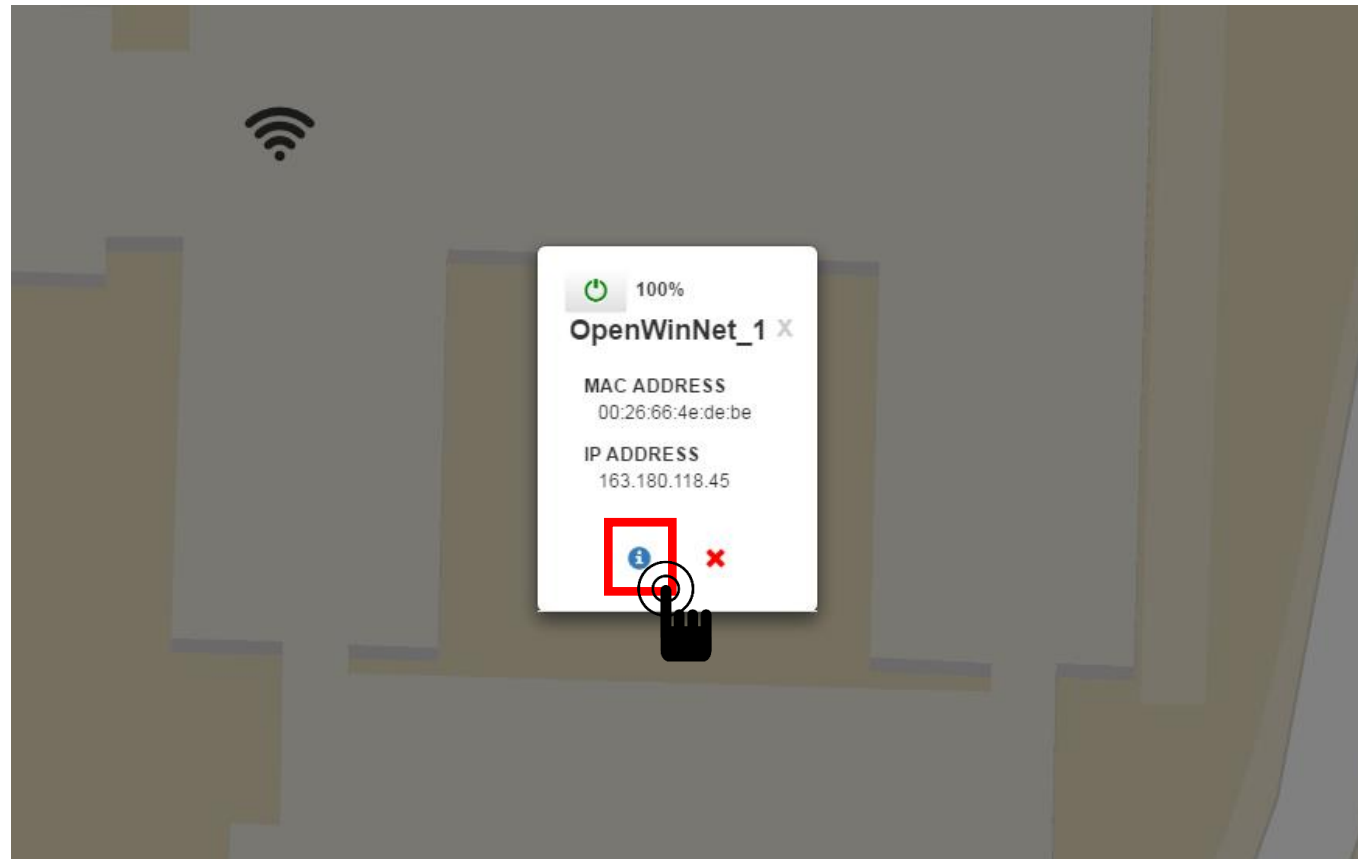


```
[P] process Command
Openwinnet manager> db
[Openwinnet AP LIST]-----
|ID           IP           SSID           |
|00:26:66:4e:de:be 163.180.118.45 test       |
|-----|
Openwinnet manager> 
```



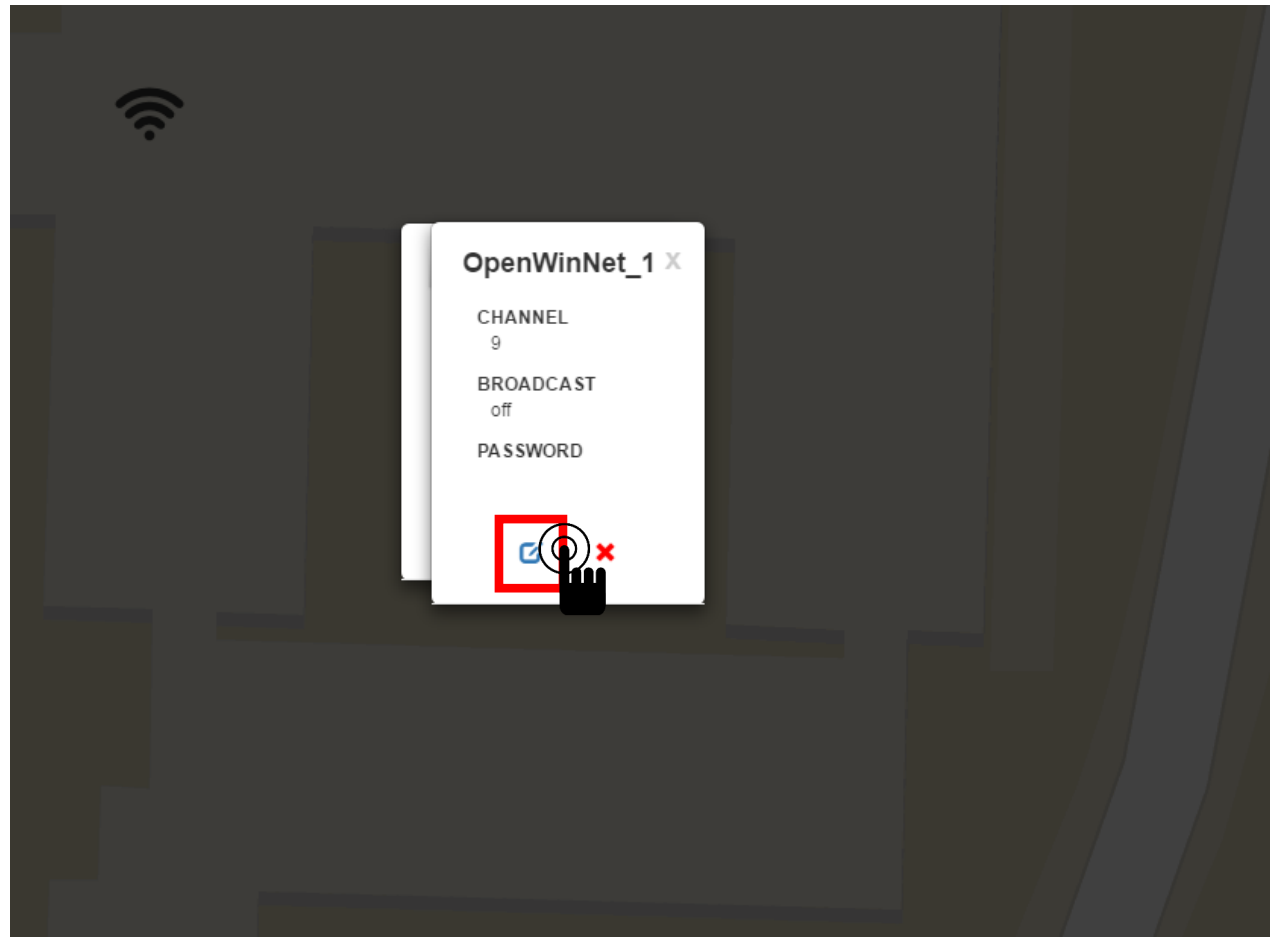
AP 제어

- GUI



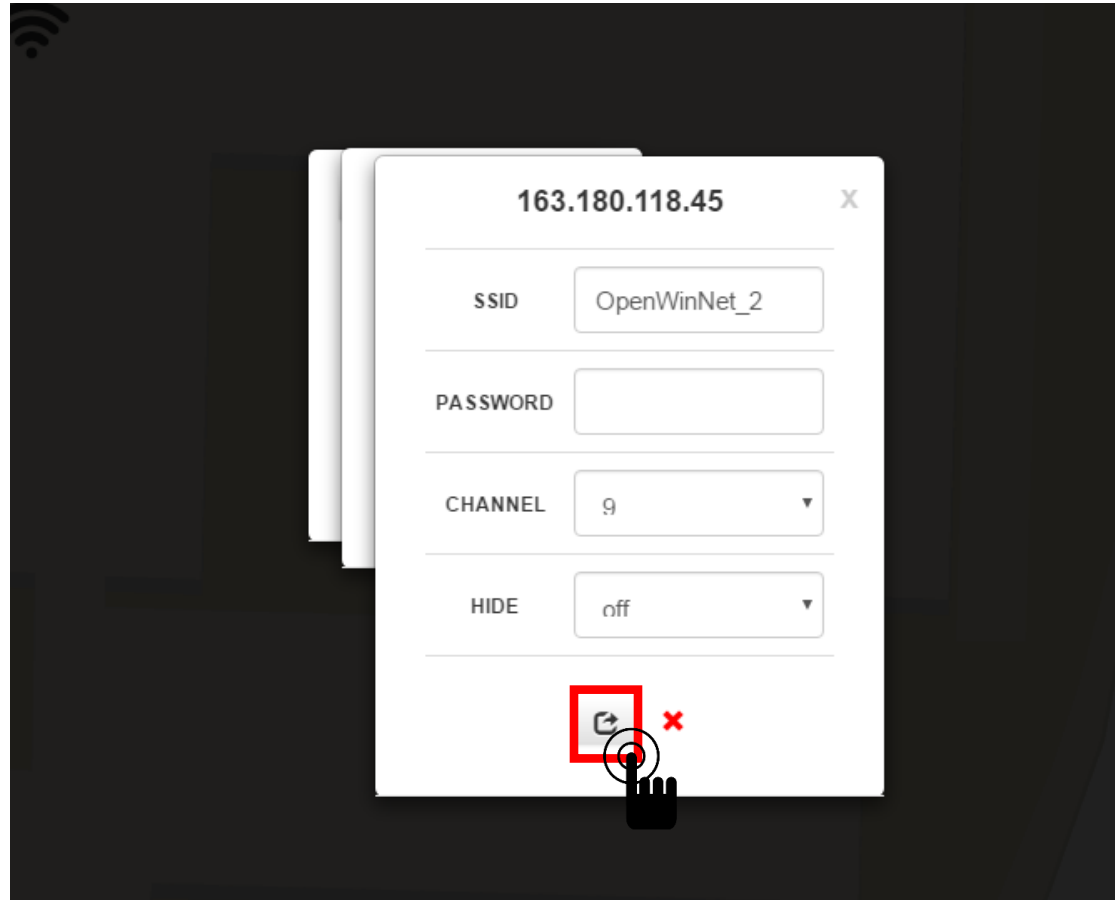
AP 제어

- GUI



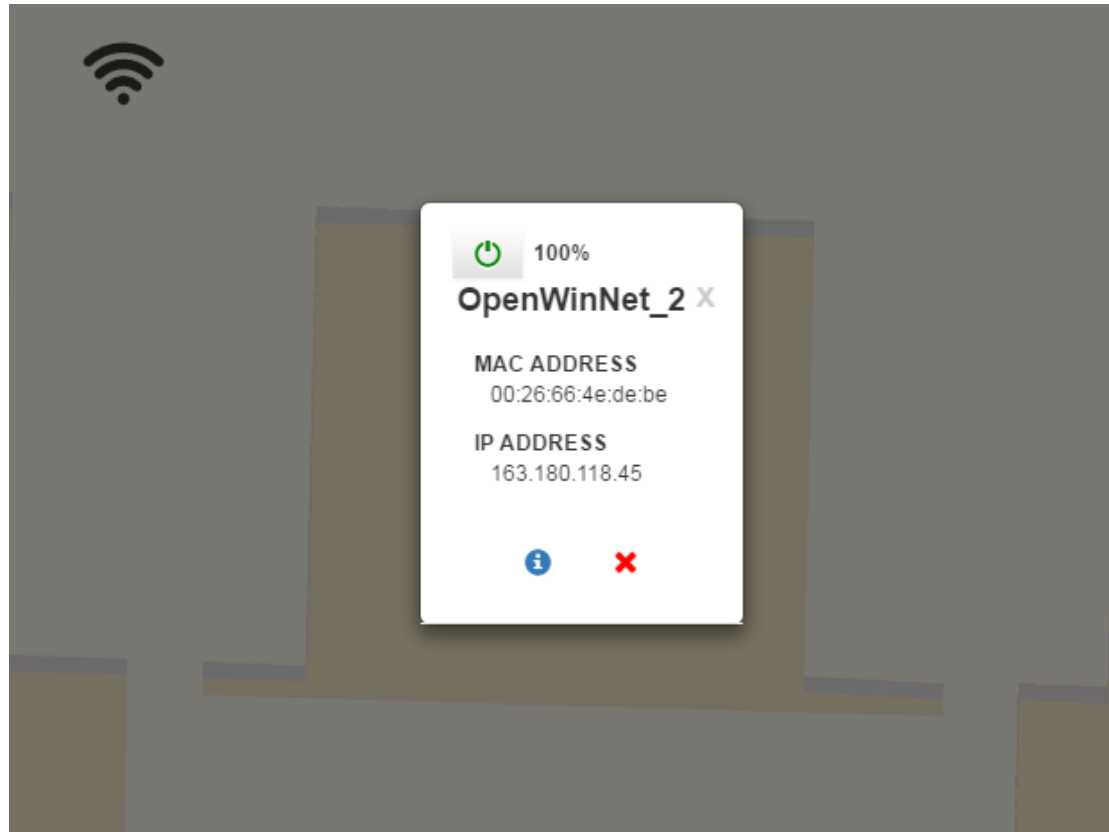
AP 제어

- GUI



AP 제어

- GUI



OVS 설정

- OVS 브릿지 생성 및 ip 설정

```
mclab@mclab-desktop:~  
File Edit View Search Terminal Help  
o mode  
update-alternatives: using /usr/bin/vim.basic to provide /usr/bin/view (view) in  
auto mode  
update-alternatives: using /usr/bin/vim.basic to provide /usr/bin/ex (ex) in aut  
o mode  
Setting up openvswitch-common (2.4.0-0ubuntu4) ...  
Setting up openvswitch-switch (2.4.0-0ubuntu4) ...  
update-alternatives: using /usr/lib/openvswitch-switch/ovs-vsctld to provide /  
usr/sbin/ovs-vsctld (ovs-vsctld) in auto mode  
openvswitch-nonetwork.service is a disabled or a static unit, not starting it.  
Processing triggers for libc-bin (2.21-0ubuntu4.1) ...  
Processing triggers for ureadahead (0.100.0-19) ...  
Processing triggers for systemd (225-1ubuntu9) ...  
mclab@mclab-desktop:~$ sudo ovs-vsctl show  
3927a1f1-15d6-48c8-90f9-632851449932  
    ovs_version: "2.4.0"  
mclab@mclab-desktop:~$ sudo ovs-vsctl add-br br0  
mclab@mclab-desktop:~$ sudo ifconfig br0 up  
mclab@mclab-desktop:~$ sudo ovs-vsctl add-port br0 eth0  
sudo: ovs-vsctl: command not found  
mclab@mclab-desktop:~$ sudo ovs-vsctl add-port br0 eth0  
mclab@mclab-desktop:~$ sudo ifconfig br0 IP address  
mclab@mclab-desktop:~$ sudo ifconfig eth0 0  
mclab@mclab-desktop:~$
```

- `sudo ovs-vsctl add-br br0`
- `sudo ifconfig br0 up`
- `sudo ovs-vsctl add-port br0 eth0`
- `sudo ifconfig br0 IP/subnetmask`
- `sudo ifconfig eth0`



OVS 설정

- OVS 브릿지 맥주소 설정

```
mclab@mclab-desktop: ~  
File Edit View Search Terminal Help  
mclab@mclab-desktop:~$ sudo ifconfig br0 hw ether b8:27:eb:77:92:9e  
mclab@mclab-desktop:~$ ifconfig  
br0      Link encap:Ethernet  HWaddr b8:27:eb:77:92:9e  
          inet addr:      Bcast:163.180.255.255  Mask:255.255.0.0  
          inet6 addr: fe80::7a:4fff:fe4b:924b/64 Scope:Link  
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1  
          RX packets:7748 errors:0 dropped:188 overruns:0 frame:0  
          TX packets:77 errors:0 dropped:0 overruns:0 carrier:0  
          collisions:0 txqueuelen:0  
          RX bytes:824488 (824.4 KB)  TX bytes:17753 (17.7 KB)  
  
eth0     Link encap:Ethernet  HWaddr b8:27:eb:77:92:9e  
          inet6 addr: fe80::ba27:ebff:fe77:929e/64 Scope:Link  
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1  
          RX packets:54878 errors:0 dropped:182 overruns:0 frame:0  
          TX packets:8656 errors:0 dropped:0 overruns:0 carrier:0  
          collisions:0 txqueuelen:1000  
          RX bytes:27433171 (27.4 MB)  TX bytes:726369 (726.3 KB)  
  
lo       Link encap:Local Loopback  
          inet addr:127.0.0.1  Mask:255.0.0.0  
          inet6 addr: ::1/128 Scope:Host  
          UP LOOPBACK RUNNING  MTU:65536  Metric:1  
          RX packets:687 errors:0 dropped:0 overruns:0 frame:0
```

반드시 동일

- OVS 브릿지의 맥 주소는 반드시 기존 Ethernet port의 맥 주소와 동일해야함.
- `sudo ifconfig br0 hw ether [MAC address]`



Network interface 설정

- vi /etc/network/interfaces

```
mclab@mclab-desktop: ~
File Edit View Search Terminal Help
# interfaces(5) file used by ifup(8) and ifdown(8)
# Include files from /etc/network/interfaces.d:
source-directory /etc/network/interfaces.d

# The loopback network interface
auto lo
iface lo inet loopback

auto br0
iface br0 inet static
hwaddress ether b8:27:eb:77:92:9e
address          IP address
netmask 255.255.255.0
gateway          Gateway Address
dns-nameservers  DNS Address

-- INSERT --
```

- auto br0
- iface br0 inet static
- hwaddress ether [eth0 MAC address]
- address [IP address]
- netmask [Subnetmask]
- gateway [Gateway address]
- dns-nameservers [DNS server address]



Forwarding 및 MASQUERADE 설정

- vi /etc/sysctl.conf

```
mclab@mclab-desktop: ~  
File Edit View Search Terminal Help  
net.ipv4.conf.default.rp_filter=1  
#net.ipv4.conf.all.rp_filter=1  
  
# Uncomment the next line to enable TCP/IP SYN cookies  
# See http://lwn.net/Articles/277146/  
# Note: This may impact IPv6 TCP sessions too  
#net.ipv4.tcp_syncookies=1  
  
# Uncomment the next line to enable packet forwarding for IPv4  
net.ipv4.ip_forward=1  
  
# Uncomment the next line to enable packet forwarding for IPv6  
# Enabling this option disables Stateless Address Autoconfiguration  
# based on Router Advertisements for this host  
#net.ipv6.conf.all.forwarding=1  
  
#####  
# Additional settings - these settings can improve the network  
# security of the host and prevent against some network attacks  
# including spoofing attacks and man in the middle attacks through  
# redirection. Some network environments, however, require that these  
# settings are disabled so review and enable them as needed.  
19,1 48%
```

- net.ipv4.ip_forward=1
 앞의 '#' 삭제



Forwarding 및 MASQUERADE 설정

- vi /etc/rc.local

```
mclab@mclab-desktop: ~  
File Edit View Search Terminal Help  
#!/bin/sh -e  
#  
# rc.local  
#  
# This script is executed at the end of each multiuser runlevel.  
# Make sure that the script will "exit 0" on success or any other  
# value on error.  
#  
# In order to enable or disable this script just change the execution  
# bits.  
#  
# By default this script does nothing.  
  
rm -f /usr/share/icons/hicolor/scalable/apps/libreoffice-*.svg || true  
rm -f /usr/share/applications/squeak.desktop || true  
  
/sbin/iptables -P FORWARD ACCEPT  
/sbin/iptables --table nat -A POSTROUTING -o br0 -j MASQUERADE  
exit 0  
~  
~  
~  
"/etc/rc.local" 20L, 536C 19,0-1 All
```

- /sbin/iptables -P FORWARD ACCEPT
- /sbin/iptables --table nat -A POSTROUTING -o br0 -j MASQUERADE

를 추가 후 재부팅



컨트롤러 설정 및 최종 확인

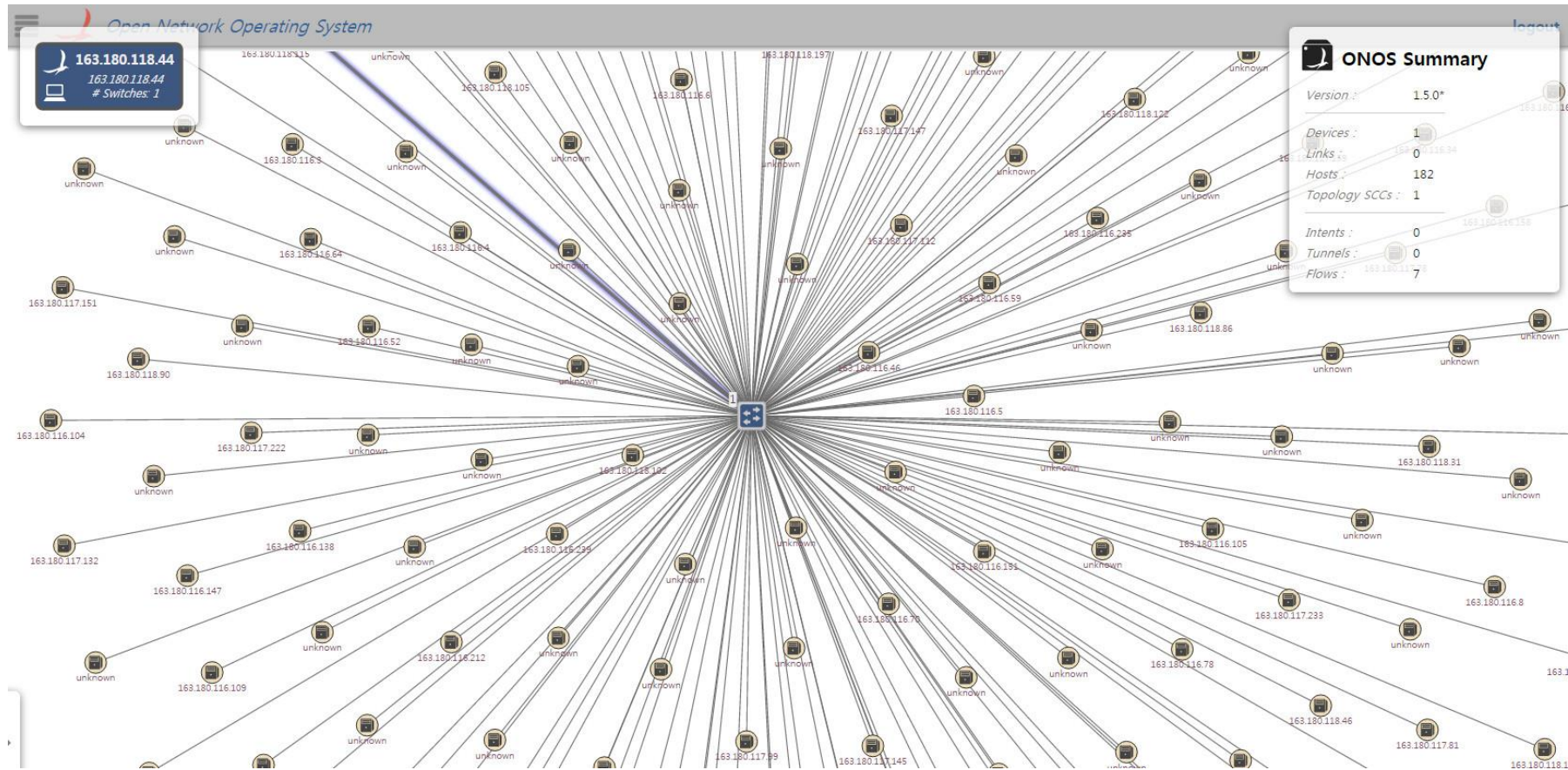
```
mclab@mclab-desktop: ~  
File Edit View Search Terminal Help  
mclab@mclab-desktop:~$ sudo ovs-vsctl set-controller br0 tcp:163.180.118.44  
mclab@mclab-desktop:~$ sudo ovs-vsctl show  
3927a1f1-15d6-48c8-90f9-632851449932  
    Bridge "br0"  
        Controller "tcp:163.180.118.44"  
            is_connected: true  
        Port "br0"  
            Interface "br0"  
                type: internal  
        Port "eth0"  
            Interface "eth0"  
        ovs_version: "2.4.0"  
mclab@mclab-desktop:~$
```

is_connected:true가 존재하지 않아도 무방

- `sudo ifconfig eth0 0`
- `sudo ovs-vsctl set-controller br0 tcp:[Controller IP address]`
- `sudo ovs-vsctl show`



GUI 상에서 확인



Traffic Monitoring 확인

```
mclab@ubuntu: ~/openwinnet/OpenWinNet/agent/HostApd_agent&controller
current traffic: 0.7226791381835938 (Mbps)      capacity: 100
deviceID: of:0000b827eb891c41  byteTxSum: 94059
current traffic: 0.7176132202148438 (Mbps)      capacity: 100
deviceID: of:0000b827eb891c41  byteTxSum: 82446
current traffic: 0.6290130615234375 (Mbps)      capacity: 100
deviceID: of:0000b827eb891c41  byteTxSum: 69793
current traffic: 0.5324783325195312 (Mbps)      capacity: 100
deviceID: of:0000b827eb891c41  byteTxSum: 90720
current traffic: 0.692138671875 (Mbps) capacity: 100
deviceID: of:0000b827eb891c41  byteTxSum: 93390
current traffic: 0.7125091552734375 (Mbps)      capacity: 100
deviceID: of:0000b827eb891c41  byteTxSum: 86203
current traffic: 0.6576766967773438 (Mbps)      capacity: 100
deviceID: of:0000b827eb891c41  byteTxSum: 95935
current traffic: 0.7319259643554688 (Mbps)      capacity: 100
deviceID: of:0000b827eb891c41  byteTxSum: 76172
current traffic: 0.581146240234375 (Mbps)      capacity: 100
deviceID: of:0000b827eb891c41  byteTxSum: 96104
current traffic: 0.73321533203125 (Mbps)      capacity: 100
deviceID: of:0000b827eb891c41  byteTxSum: 102165
current traffic: 0.7794570922851562 (Mbps)      capacity: 100
deviceID: of:0000b827eb891c41  byteTxSum: 94840
current traffic: 0.72357177734375 (Mbps)      capacity: 100
```



Application 설치 가이드

Kyung Hee University, POSTECH

Mobile Convergence Laboratory, Media Computing & Networking Laboratory

안계완, 호동혁, 노현민

2016. 04. 08



설치 과정

- 실행 환경
- 이클립스 프로젝트 import
- ONOS 컨트롤러와 연결을 위한 설정 변경
- Offloading Application 빌드 및 실행



실행환경

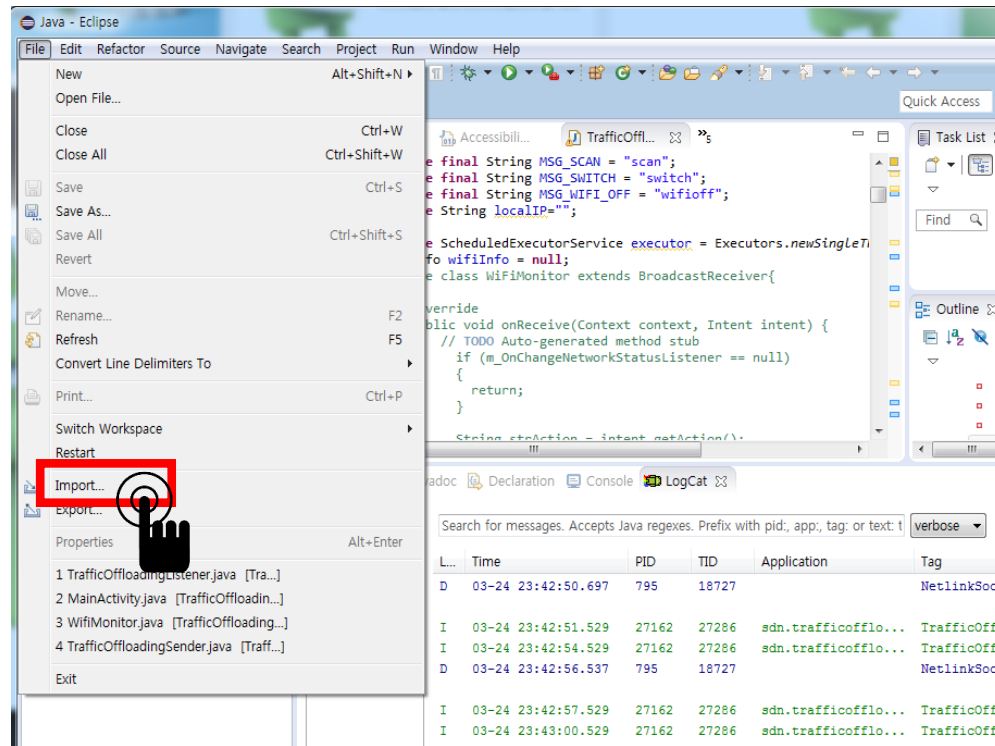


- Nexus5
- Android Marshmallow (Android 6.0)
- Qualcomm Snapdragon™ 800, 2.3GHZ
- 32GB Storage
- 2GB RAM



Project import

- Eclipse와 Android SDK가 설치된 환경에서 projec를 git을 이용해 추가한다.

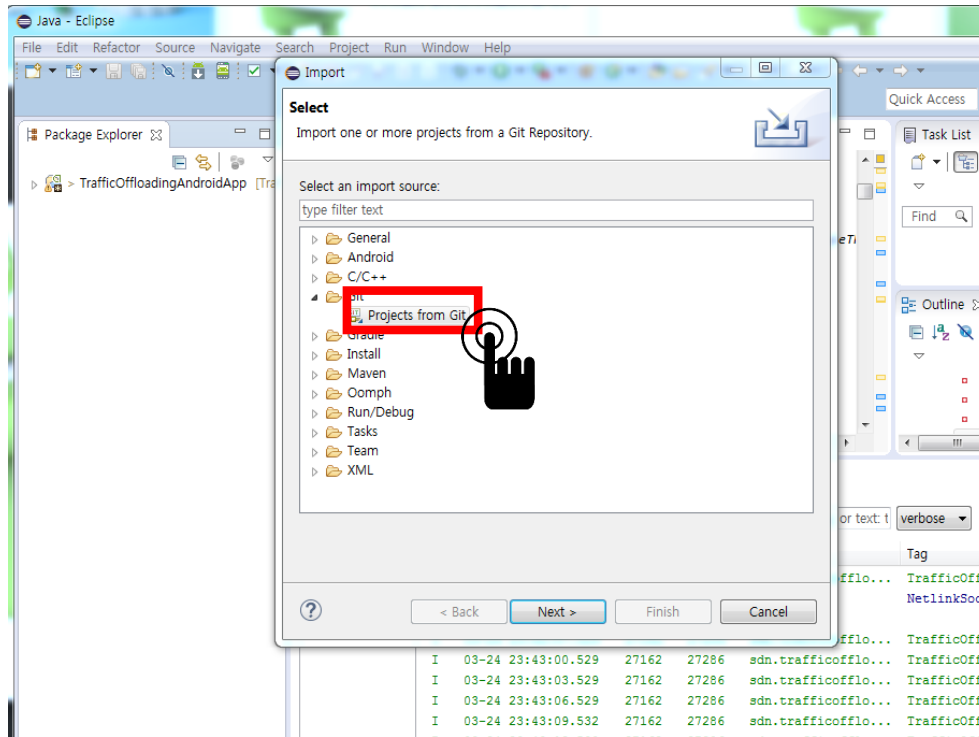


- File-Import 클릭



Project import

- Eclipse와 Android SDK가 설치된 환경에서 projec를 git을 이용해 추가한다.

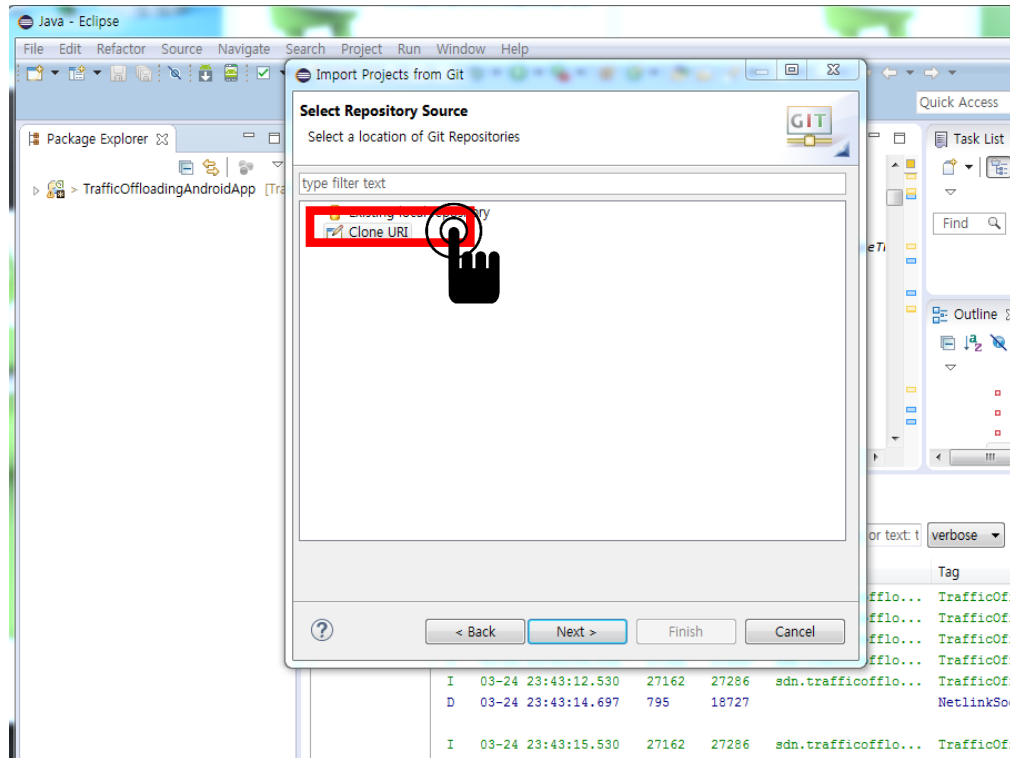


- git-Project from Git 클릭



Project import

- Eclipse와 Android SDK가 설치된 환경에서 projec를 git을 이용해 추가한다.

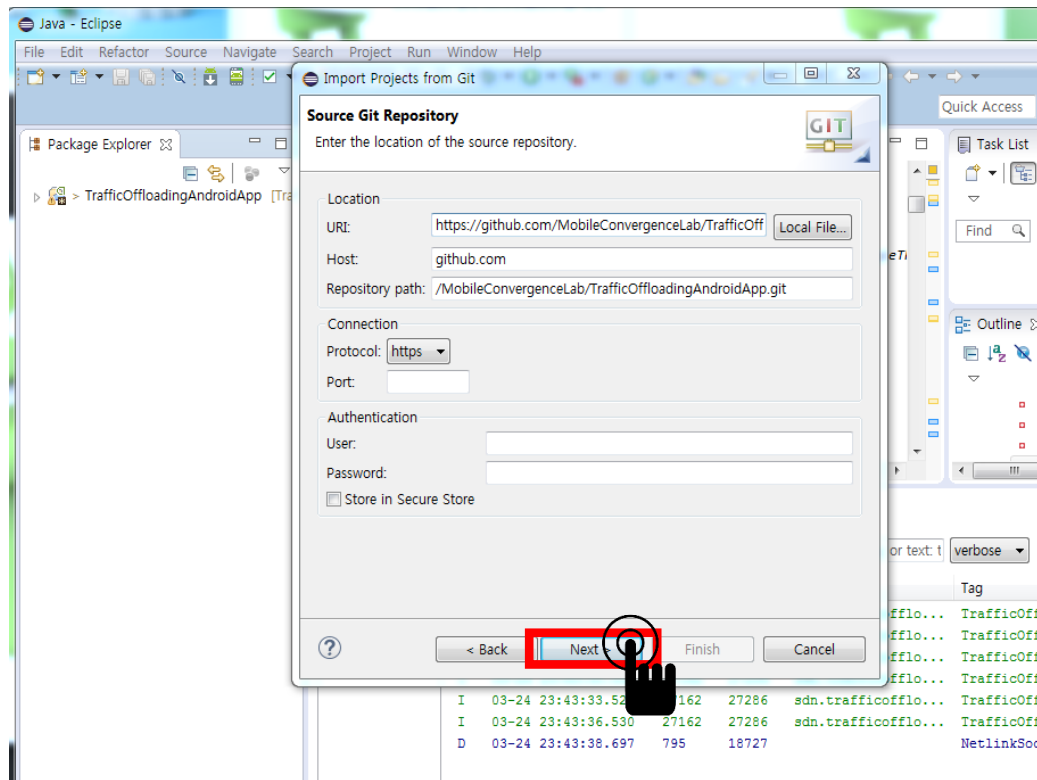


- Clone URL 클릭



Project import

- Eclipse와 Android SDK가 설치된 환경에서 projec를 git을 이용해 추가한다.

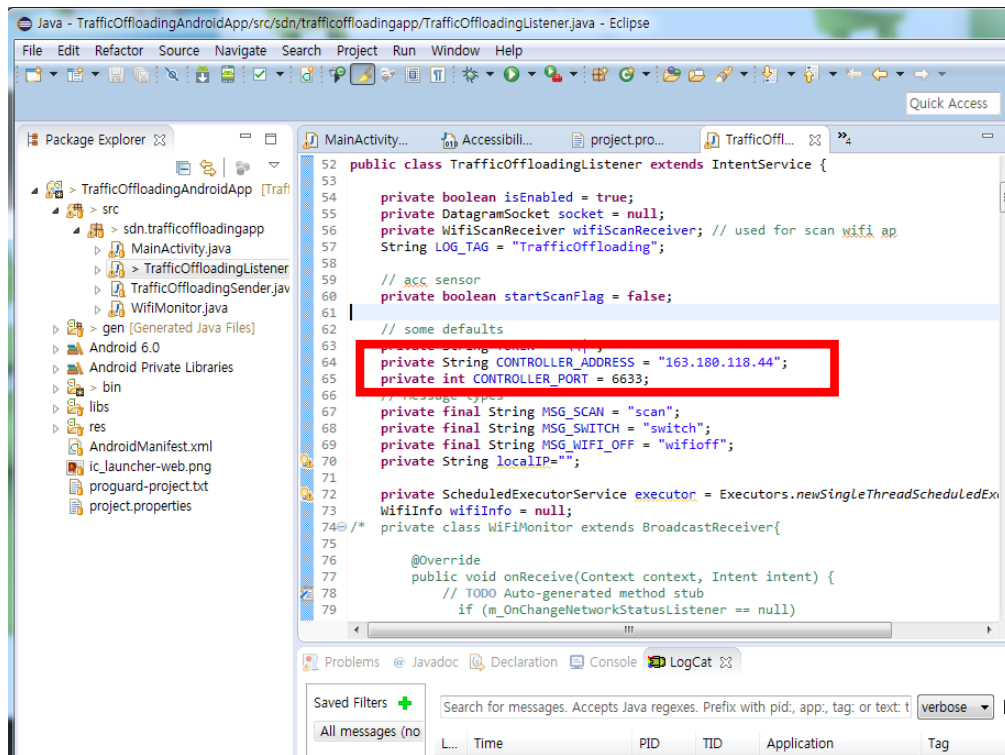


- URL 칸에
https://github.com/MobileConvergenceLab/TrafficOffloadingAndroidApp.git
입력
- Next 클릭



ONOS Controller 연결

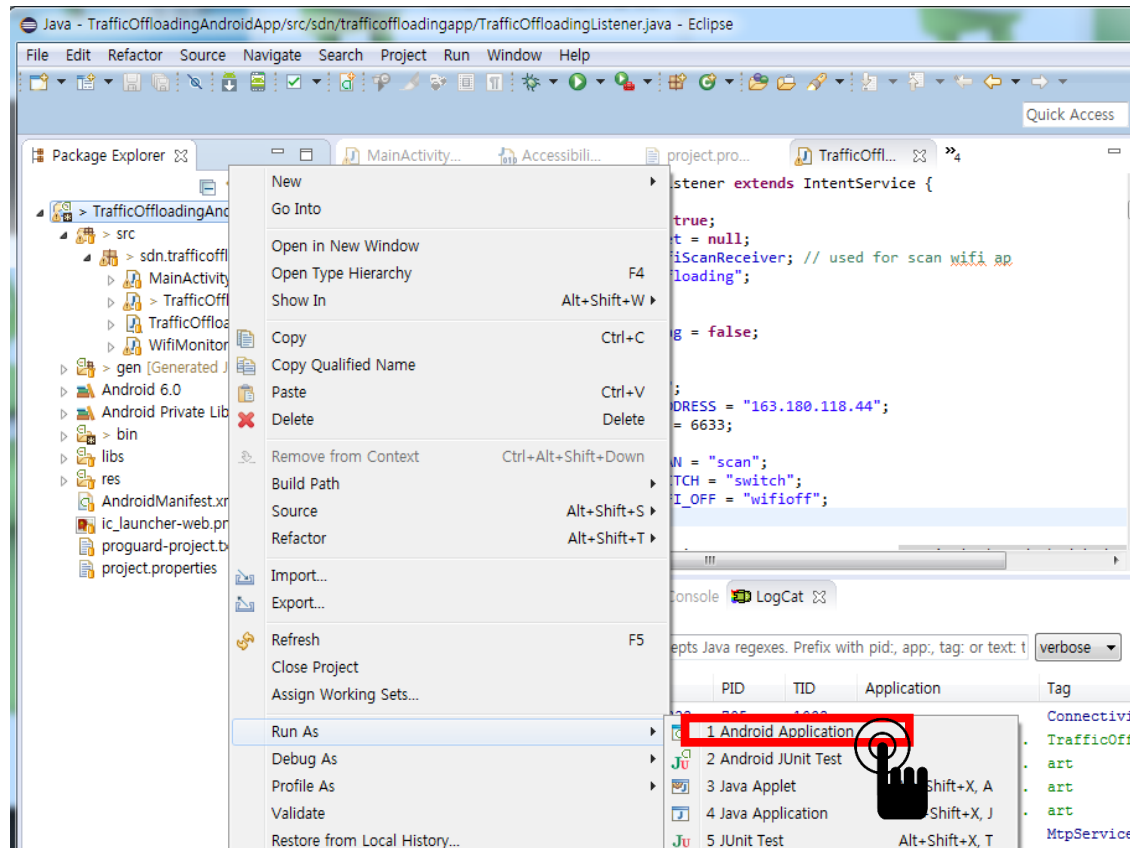
- 사용하는 ONOS Controller와 Port 수정



- TrafficOffloadingListener.java 수정
- CONTROLLER_ADDRESS와 PORT 값을 변경



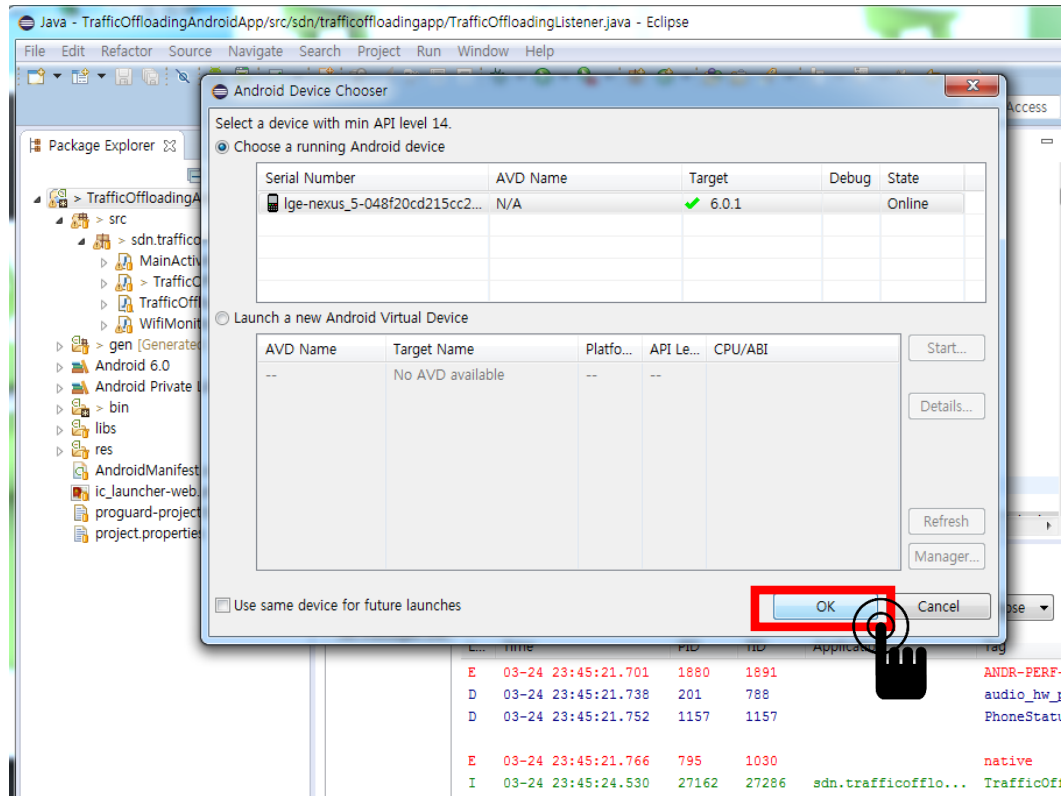
Build Application



- TrafficOffloadingAndroidApp 프로젝트 오른쪽 클릭
- Run As - Android Application 클릭



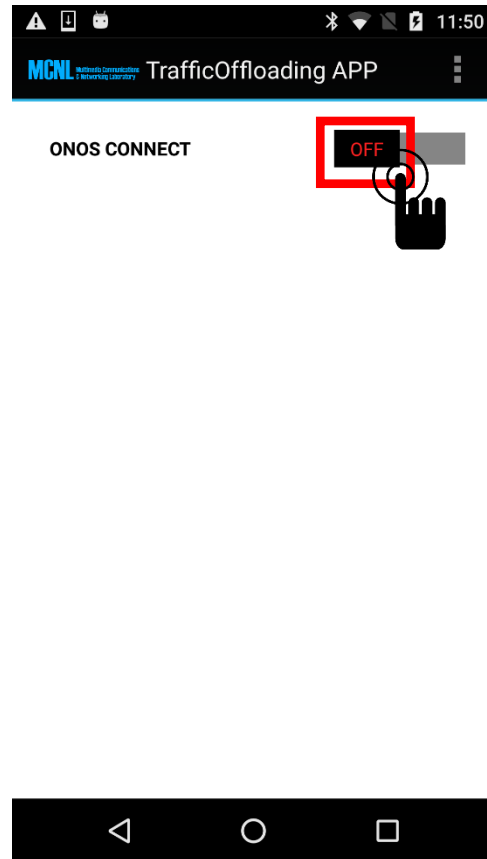
Build Application



- 실행할 Android 기기 선택
- OK 버튼 클릭



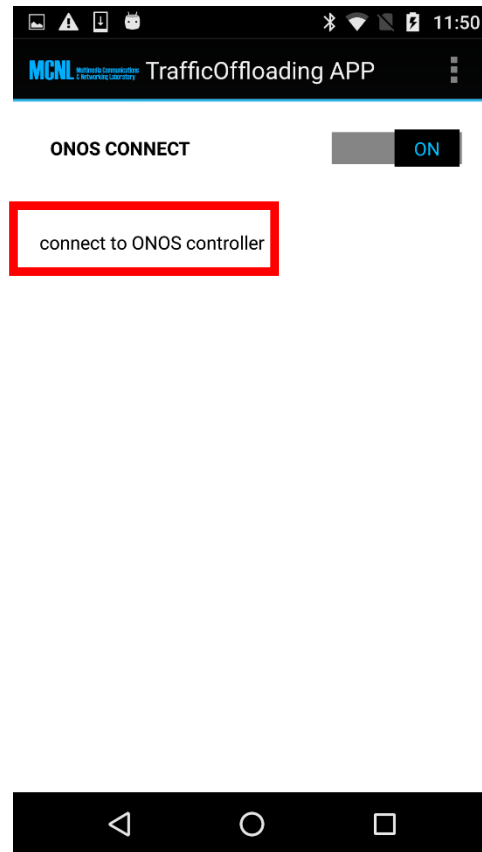
Application 실행 화면



- OFF 클릭



Application 실행 화면



- Connect to ONOS controller 문구 확인



Offloading Demo



OPNFV 설치 가이드

Seoul National University
Network Convergence & Security Laboratory

송정환

2016. 04. 08



설치 전 준비사항



설치 전 준비사항

- 5개의 노드 준비
 - 1개: Jumpserver
 - OPNFV의 deployment의 master node 역할
 - 3개: OPNFV controller nodes
 - OPNFV Platform을 유지, 구동
 - 1개: OPNFV compute node
 - OPNFV Platform위의 가상 머신들이 사용할 자원



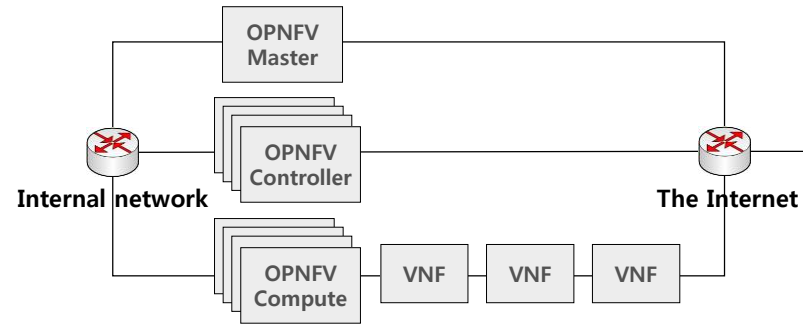
하드웨어 요구사항

항목	최소 요구사항
CPU	1 socket x86_AMD64 가상화 지원
RAM	16GB (Compute node의 경우 VNF 부하에 따라 다름)
Disk	256GB 10kRPM
Networks	3 Tagged VLANs (MGMT, Storage, Private) 2 Un-Tagged VLAN (Admin for PXE boot, Public) 실제 머신에 설치할 경우, 2개의 NIC card 추천 - 1 for Admin, MGMT, Storage, Private - 1 for Public



네트워크 구성

- OPNFV 설치를 위해,
그림과 같은 2개의
네트워크를 구성
 - Internal network
 - 5개의 노드를 스위치 하나를 이용하여 연결
 - PXE booting 및 추후 OPNFV 관리 구동에 쓰임
 - The Internet
 - 5개의 노드를 각각 인터넷에 연결
 - 서버 기능을 하게 하기 위해



Jumpserver 준비

- OPNFV 설치를 위한 Jumpserver에 Linux 설치
- Fuel deployment ISO image를 다운로드
 - <http://www.opnfv.org> -> Software -> Downloads
- Jumpserver에 Virtual Machine Manager 설치 후 구동



Jumpserver에 fuel master 설치

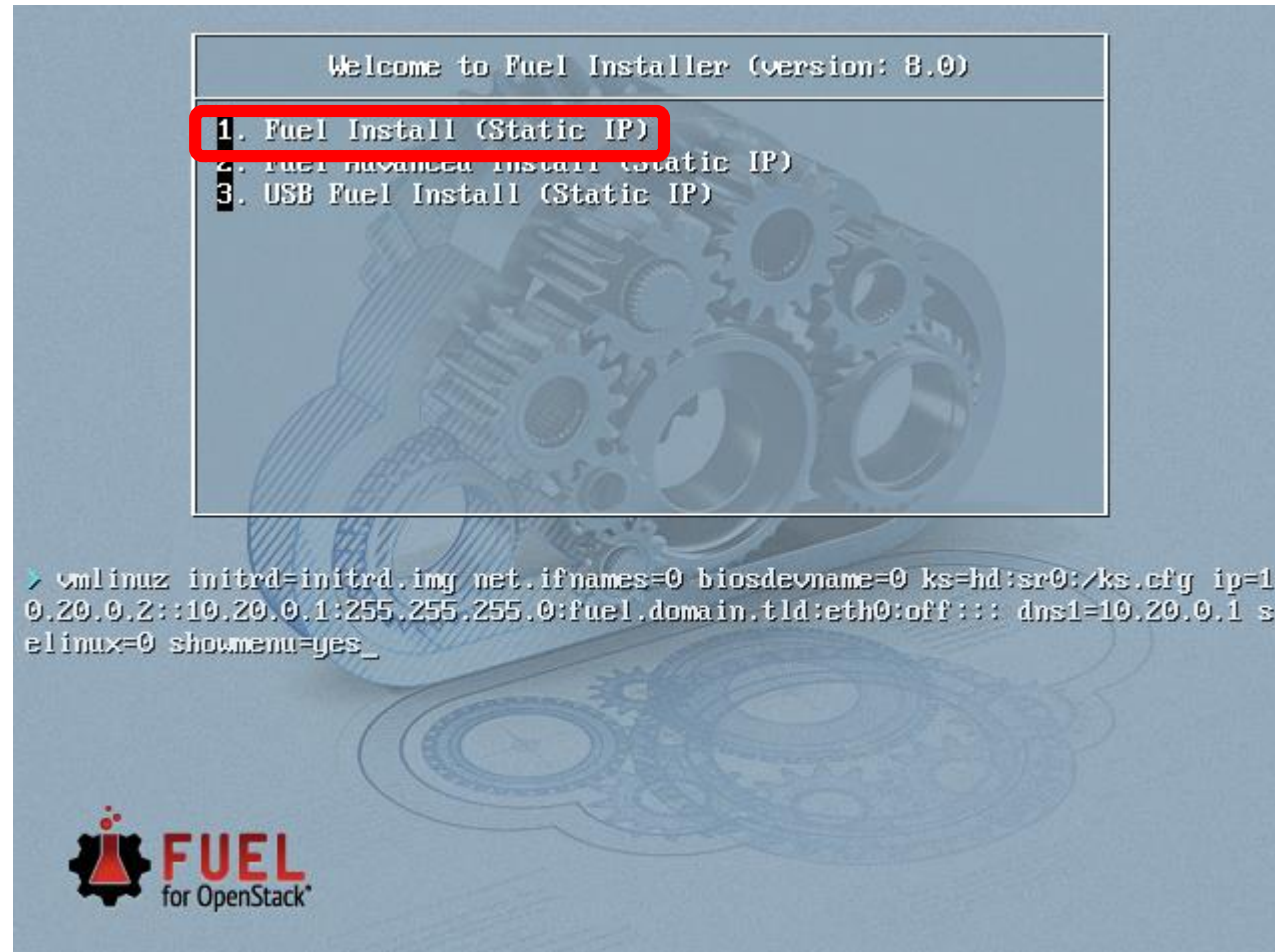


Jumpserver에 Fuel master 설치

- VM manager를 이용하여 가상머신 생성
 - CPU 4, Memory 8GB, Disk 500GB 이상 추천
 - Linux redhat enterprise 6 선택
 - 아까 다운로드 받은 ISO image를 통해 부팅
 - 생성 전 환경설정을 체크하고 NIC 카드1 설정
 - eth0 bridge, e1000 (for PXE booting)
 - NIC 카드2 추가
 - eth1 bridge, e1000



Fuel master 설치 시작



Fuel master 비밀번호 설정

```
Fuel 8.0 setup Use Up/Down/Left/Right to navigate. F8 exits. Remember to save your changes.
Menu
  < Fuel User > Set Fuel User password.
  < Network Setup > Default user: admin
  < PXE Setup > Default password: admin
  < DNS & Hostname > For the better security please consider using password with at least 8 symbols, both upper- and lowercase
  < Bootstrap Image > letters, and at least one digit and special character like !@#$/%^&*()_+.
  < Time Sync >
  < Root Password > Fuel password *****
  < Feature groups > Confirm password
  < Shell Login >
  < Quit Setup > < Check
```

- User password 설정
 - 추후 Web interface 로그인에 사용됨



Network setup

```
Fuel 8.0 setup Use Up/Down/Left/Right to navigate. F8 exits. Remember to save your changes.
Menu
  (X) eth0
  < Fuel User      > Interface: eth0
  < Network Setup > IP:      10.20.0.2    MAC: 52:54:00:a4:1d:11
  < PXE Setup      > Netmask: 255.255.255.0 Gateway: 10.20.0.1
  < DNS & Hostname >
  < Bootstrap Image >
  < Time Sync      > Interface name: eth0
  < Root Password  > Enable interface: (X) Yes ( ) No
  < Feature groups > Configuration via DHCP: (X) Static ( ) DHCP
  < Shell Login    > IP address: 10.20.0.2
  < Quit Setup     > Netmask: 255.255.255.0
                   > Default Gateway: 10.20.0.1
                   < Check      > < Cancel      > < Apply      >
```

이곳에 eth1이 있을 것

- eth1이 있을텐데, 다음과 같이 세팅
 - Enable interface: Yes
 - Configuration via DHCP: 인터넷 설정에 맞게 세팅 (서울대의 경우 Static)
 - Static일 경우 IP addr, netmask, GW 입력



설치 마무리

- 나머지 메뉴는 특별히 건드리지 않고 Quit Setup -> Save and Quit
- 설치하는데 대략 30분~1시간 걸림
- 설치가 완료되면 로그인
 - ID/PW: root / r00tme
- 플러그인 설치
 - fuel plugins -install /opt/opnfv/opendaylight-*.rpm
 - 실제로는 풀네임 넣어야 함



PXE Booting 설정



PXE booting 준비

- controller, compute 노드들은 fuel master에 의해 pxe boot로 OS를 설치
- 하드웨어, 바이오스마다 PXE booting 설정 방법은 다름
 - 바이오스 매뉴얼 참조
- 기본적으로 바이오스 셋업에서 network boot (pxe boot)를 켜고 boot priority 설정을 통해 가능



PXE booting

- 설정이 올바르게 되었다면 부팅할 때 Lan card를 통해 부팅
- DHCP로 부터 10.20.0.x ip addr를 받고 pxe 부팅이 시작됨
- OS를 선택할 수 있는데 bootstrap을 선택
- 4개의 노드에 대해 위의 작업을 수행

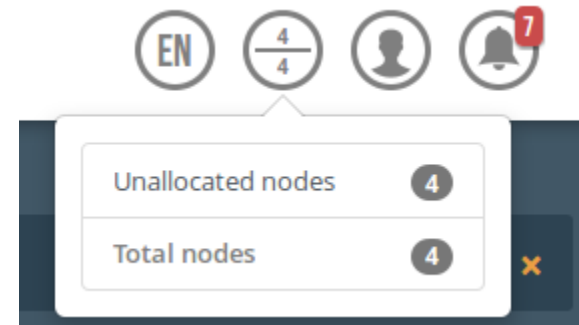


OPNFV 설치



Fuel web GUI 접속

- Fuel GUI에 접속
 - Internal network에서 접속할 경우 10.20.0.2
 - 그 외부에서 접속할 경우 외부 11쪽의 eth1의 ip addr를 통해 접속
- PXE booting이 잘 되었을 경우 다음과 같은 화면을 볼 수 있음



환경 생성



ENVIRONMENTS

EQUIPMENT

RELEASES

PLUGINS

SUPPORT



Home / Environments

For security reasons, change the default admin password.



My OpenStack Environments



New OpenStack Environment



환경 생성

- Liberty on Ubuntu 14.04
- QEMU-KVM
- Neutron with tunneling segmentation
- Ceph for block storage
- Install Celiometer
- Create



네트워크 환경 설정

- Public에 외부 인터넷 ip addr과 CIDR, GW 입력
 - Controller 및 Openstack api 접근 및 추후 Openstack dashboard 접근에 쓰임
 - VLAN tagging은 하지 않음
- Storage, MGMT, Private는 건드리지 않음

MyOPNFV (0 nodes)

Network Settings (Neutron with tunneling segmentation)

Node Network Groups: default

Settings: Neutron L2, Neutron L3, Other

Network Verification: Connectivity Check

Public

The Public network allows inbound connections to VMs (Controllers and Tenant VMs) from external networks (e.g., the Internet) as well as outbound connections from VMs to the external networks.

CIDR: 172.16.0.0/24 ☒ Use the whole CIDR

IP Range: Start 172.16.0.2 End 172.16.0.126

Gateway: 172.16.0.1

Use VLAN tagging: ☐

The Storage network is used to provide storage services such as replication traffic from Ceph. The Management network is used for Ceph Public traffic.

CIDR: 192.168.1.0/24 ☒ Use the whole CIDR

IP Range: Start 192.168.1.1 End 192.168.1.254

Use VLAN tagging: ☒ 102

Management

The Management network is primarily used for OpenStack Cloud Management. It is used to access OpenStack services (nova-api, OpenStack dashboard, etc).

CIDR: 192.168.0.0/24 ☒ Use the whole CIDR

IP Range: Start 192.168.0.1 End 192.168.0.254

Use VLAN tagging: ☒ 101

Private

The private network facilitates communication between each tenant's VMs. Private network address spaces are not a part of the public network address space. Fixed IPs of virtual instances cannot be accessed directly from the rest of the public network.

CIDR: 192.168.2.0/24 ☒ Use the whole CIDR

IP Range: Start 192.168.2.1 End 192.168.2.254

Use VLAN tagging: ☒ 103

Cancel Changes Save Settings



Floating IP 설정

- 추후 VNF 서버들의 IP가 되는 floating IP 설정
- 이전에 설정한 Public IP의 CIDR 내에서 가용한 범위 입력

MyOPNFV (0 nodes)

Dashboard Nodes Networks Settings Logs Health Check

Network Settings (Neutron with tunneling segmentation)

[Add New Node Network Group](#)

Node Network Groups

default

Settings

Neutron L2

Neutron L3

Other

Floating Network Parameters

This network is used to assign Floating IPs to tenant VMs.

	Start	End
Floating IP range	<input type="text" value="172.16.0.130"/>	<input type="text" value="172.16.0.254"/>
Floating network name	<input type="text" value="admin_floating_net"/>	

Internal Network Parameters

The Internal network connects all OpenStack nodes in the environment. All components of an OpenStack environment communicate with each other using this network.

Internal network CIDR	<input type="text" value="192.168.111.0/24"/>
Internal network gateway	<input type="text" value="192.168.111.1"/>
Internal network name	<input type="text" value="admin_internal_net"/>

Guest OS DNS Servers

This setting is used to specify the upstream name servers for the environment. These servers will be used to forward DNS queries for external DNS names to DNS servers outside the environment.

Guest OS DNS Servers	<input type="text" value="8.8.4.4"/>	⊕ ⊖
	<input type="text" value="8.8.8.8"/>	⊕ ⊖

[Cancel Changes](#) [Save Settings](#)



기타 네트워크 설정

MyOPNFV (0 nodes)

Dashboard Nodes Networks Settings Logs Health Check

Network Settings (Neutron with tunneling segmentation) Add New Node Network Group

Node Network Groups

default

Settings

Neutron L2

Neutron L3

Other

Network Verification

Connectivity Check

Public network assignment

☒ Assign public network to all nodes
When disabled, public network will be assigned to controllers only

Neutron Advanced Configuration

☐ Neutron L2 population
Enable L2 population mechanism in Neutron

☐ Neutron DVR
Enable Distributed Virtual Routers in Neutron

☐ Neutron L3 HA
Enable High Availability features for Virtual Routers in Neutron
Requires at least 2 Controller nodes to function properly

Host OS DNS Servers

DNS list List of upstream DNS servers, separated by comma

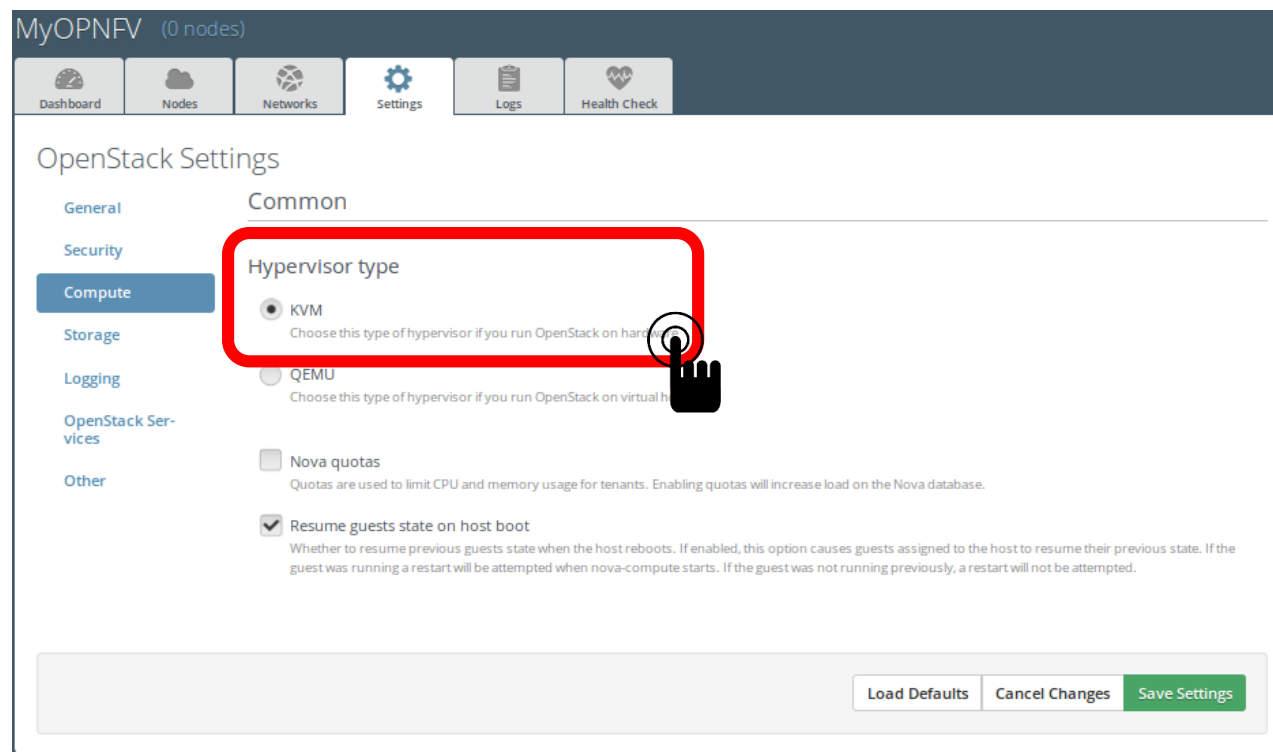
Host OS NTP Servers

NTP server list List of upstream NTP servers, separated by comma

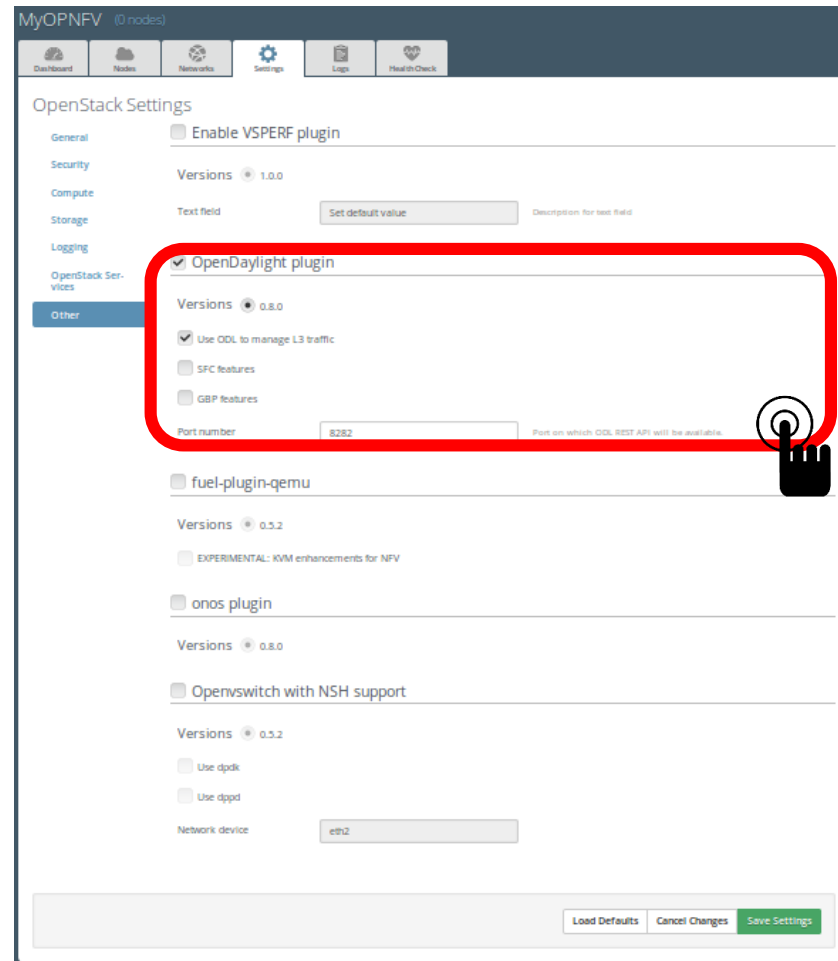
Cancel Changes Save Settings



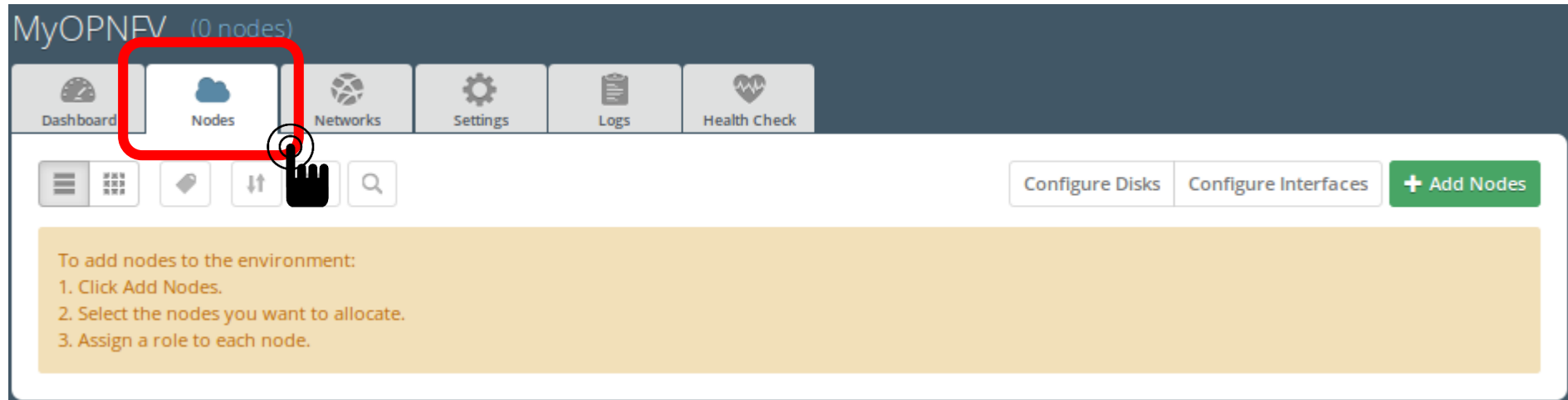
하이퍼바이저 설정



플러그인 활성화



노드 역할 부여



노드 역할 부여

- 3 controller 노드
 - 1 노드 설정
 - Controller, Telemetry-MongoDB, SDN controller
 - 2 노드 설정
 - Controller, Storage Ceph OSD
- 1 compute 노드
 - Compute, Storage Ceph OSD



노드 역할 부여

MyOPNFV (4 nodes)







Dashboard Nodes Networks Settings Logs Health Check

Configure Disks Configure Interfaces + Add Nodes




Sort By Roles

☐ Select All




Controller, Storage - Ceph OSD (2) ☐ Select All

<input type="checkbox"/>	KVM	Untitled (40:c4) CONTROLLER - CEPH-OSD	 	PENDING ADDITION	CPU: 2 (2) HDD: 100.0 GB RAM: 8.0 GB	
<input type="checkbox"/>	KVM	Untitled (d3:37) CONTROLLER - CEPH-OSD	 	PENDING ADDITION	CPU: 2 (2) HDD: 100.0 GB RAM: 8.0 GB	

Controller, Telemetry - MongoDB, OpenDaylight controller (1) ☐ Select All

<input type="checkbox"/>	KVM	Untitled (a7:d2) CONTROLLER - MONGO - OPENDAYLIGHT	 	PENDING ADDITION	CPU: 2 (2) HDD: 100.0 GB RAM: 8.0 GB	
--------------------------	-----	---	---	------------------	--------------------------------------	---

Compute, Storage - Ceph OSD (1) ☐ Select All

<input type="checkbox"/>	KVM	Untitled (93:14) COMPUTE - CEPH-OSD	 	PENDING ADDITION	CPU: 2 (2) HDD: 100.0 GB RAM: 8.0 GB	
--------------------------	-----	--	---	------------------	--------------------------------------	---



노드 인터페이스 설정

- 그림의 경우 NIC 4개
- NIC 2개 설정
 - Admin이 존재하는 NIC에 MGMT, Storage, Private 드래그 & 드롭
 - Public이 존재하는 NIC은 Public만 있도록

MyOPNFV (4 nodes)

Dashboard Nodes Networks Settings Logs Health Check

Configure interfaces on 4 nodes

Bond Network Interfaces Unbond Network Interfaces

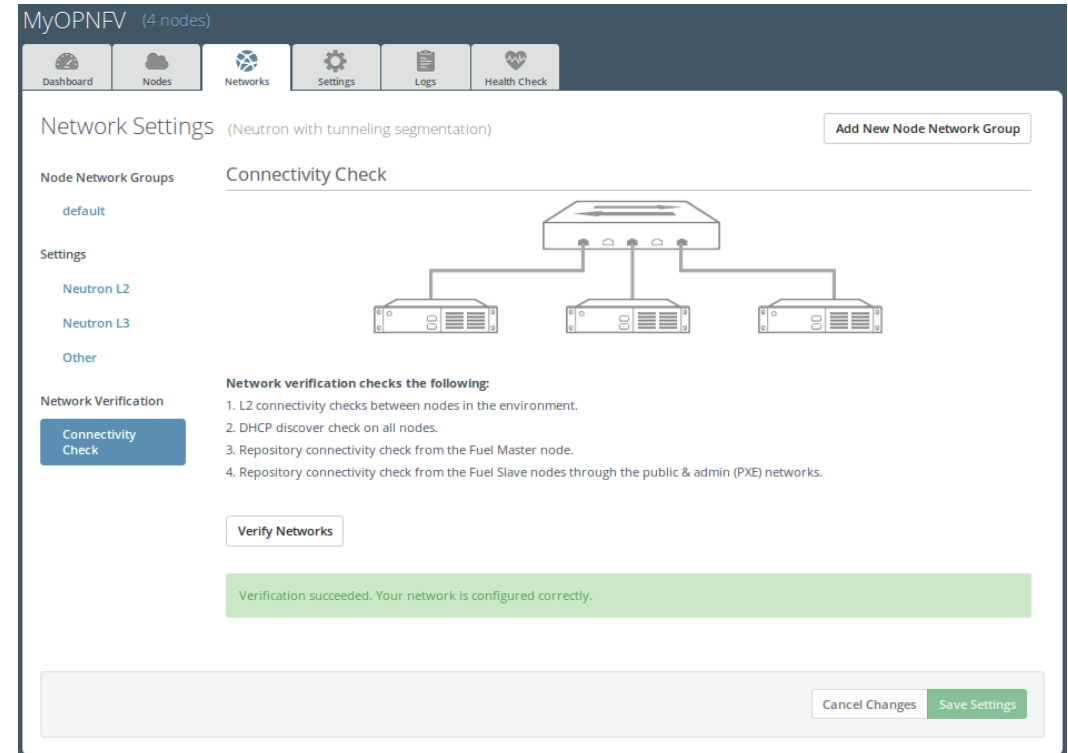
<input type="checkbox"/>	Name: ens3 Speed: 1.0 Gbps	Admin (PXE)	Management VLAN ID:101	Offloading Modes: Default	MTU Default
<input type="checkbox"/>	Name: ens4 Speed: 1.0 Gbps	Storage VLAN ID:102		Offloading Modes: Default	MTU Default
<input type="checkbox"/>	Name: ens5 Speed: 1.0 Gbps	Private VLAN ID:103		Offloading Modes: Default	MTU Default
<input type="checkbox"/>	Name: ens6 Speed: 1.0 Gbps	Public		Offloading Modes: Default	MTU Default

Back To Node List Load Defaults Cancel Changes Apply



네트워크 검증

- 설정이 잘 되었다면 네트워크 검증을 통과
- 네트워크 검증이 통과되었다면 Dashboard 탭으로 이동하여 Deploy environment



설치 성공

DashboardNodesNetworksSettingsLogsHealth Check

Success

Provision of environment 'OPNFV' is done.

Show additional information

Horizon

The OpenStack dashboard Horizon is now available.

Summary

Name

OPNFV

Status

Operational

OpenStack Release

Liberty on Ubuntu 14.04

Compute

KVM

Network

Neutron with tunneling segmentation

Storage Backends

Ceph RBD for volumes (Cinder)

To view the OpenStack health check status go to

Healthcheck tab

Delete Environment

Reset Environment

Capacity

CPU (Cores)	72	HDD	3.6 TB	RAM	112.0 GB
-------------	----	-----	--------	-----	----------

Node Statistics

Total Nodes	4	Ready	4
Controller	3		
Compute	1		
Storage - Ceph OSD	3		
Telemetry - MongoDB	1		
OpenDaylight controller	1		

+ Add Nodes



Preparing steps for VNF based on OPNFV Brahmaputra

Junghwan Song

Outline

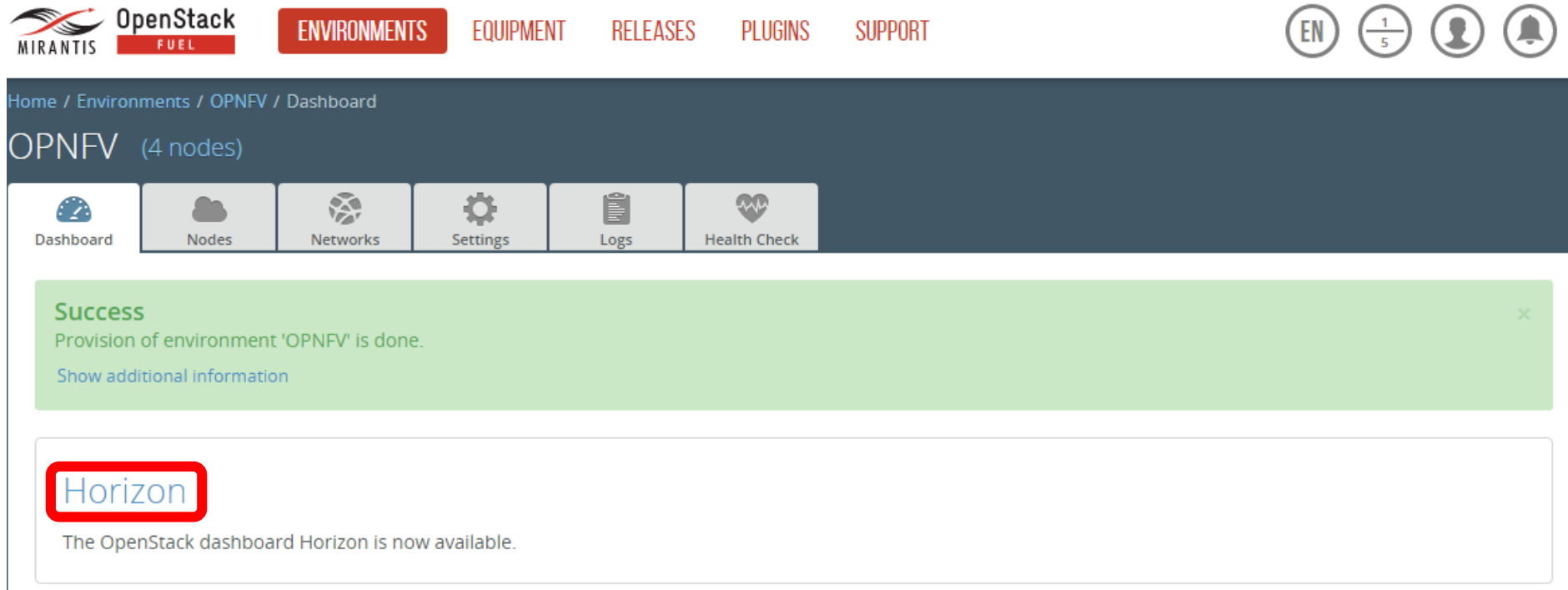
- Overview
- OpenStack Horizon Dashboard 접속
- Image 생성
- Instance 생성

Overview

- OPNFV를 deploy한 후, 이를 사용하기 위해서는 OpenStack에 대한 이해가 필요
- 본 슬라이드는 OPNFV Brahmaputra deploy 후, VNF를 만들기 위한 과정을 소개

Openstack dashboard 접속


OpenStack Dashboard 접속



- Fuel을 이용하여 deploy를 완료한 후의 화면
- 여기서 Horizon을 클릭하면 OpenStack Horizon Dashboard로 접근 가능

OpenStack Horizon Dashboard

- 다음과 같이 id/pw 입력 칸이 뜸
- default: admin/admin



The screenshot shows the OpenStack Horizon Dashboard login interface. At the top, there is a dark header bar containing the Mirantis logo (a stylized bird) and the text "MIRANTIS" on the left, and the "OpenStack DASHBOARD" logo on the right. Below the header, the form is divided into two main sections. The first section is labeled "사용자 이름" (Username) and contains a text input field with a vertical cursor. The second section is labeled "암호" (Password) and contains a password input field with a toggle icon (an eye) on the right. At the bottom right of the form, there is a blue button labeled "Connect".

OpenStack Horizon Dashboard

The screenshot shows the OpenStack Horizon Dashboard interface. The top navigation bar includes the OpenStack logo, the word 'OpenStack' in white, 'DASHBOARD' in a red box, and a user menu for 'admin'. A left sidebar contains a menu with '프로젝트' (Projects), '관리자' (Admins), '시스템' (System), and '인증' (Authentication). The main content area is titled '개요' (Overview) and 'Usage Summary'. It prompts the user to 'Select a period of time to query its usage:' with input fields for 'From: 2016-03-24' and 'To: 2016-03-25', a 'Submit' button, and a note 'The date should be in YYYY-mm-dd format.' Below this, it displays usage statistics: '활성화된 인스턴스: 1 Active RAM: 4GB This Period's VCPU-Hours: 119.66 This Period's GB-Hours: 119.66 This Period's RAM-Hours: 122533.06'. A section titled '사용' (Usage) features a table with columns for project name, VCPUs, disk, RAM, VCPU time, disk GB time, and memory MB time. A 'CSV 요약 다운로드' (Download CSV Summary) button is located to the right of the table. The table shows one item for the 'admin' project. At the bottom, it says 'Displaying 1 item'.

프로젝트 이름	VCPUs	디스크	RAM	VCPU 시간 ⓘ	디스크 GB 시간 ⓘ	메모리 MB 시간 ⓘ
admin	4	4GB	4GB	119.66	119.66	122533.06

Displaying 1 item

- 로그인하면 다음과 같은 화면이 뜬
- 기본적인 메뉴(프로젝트, 관리자, 시스템) 등은 알고있다는 가정 하에 진행하겠음

Image 생성

Ubuntu Cloud Image

- Cloud 환경에서 사용되는 Ubuntu image는 별도로 존재
- 원하는 버전의 Ubuntu cloud image를 다운로드
 - <http://cloud-images.ubuntu.com/>
- 여기서는 Ubuntu 12.04 LTS 기준으로 설명
 - Ubuntu 14.04 LTS 의 경우 OPNFV와 설치 충돌 이슈

Image menu

OpenStack DASHBOARD admin

프로젝트

Compute

개요

인스턴스

볼륨

이미지

접근 & 보안

이미지

프로젝트 (1) 나에게 공유됨 (0) 공용 (2) + 이미지 생성 이미지 삭제

	이미지 이름	유형	상태	공용	보호됨	포맷	크기	Actions
	Ubuntu 12.04 LTS	이미지	Active	예	아니오	QCOW2	252.8 MB	인스턴스 구동

Displaying 1 item

- 프로젝트->Compute->이미지->이미지 생성

Image 생성

이미지 생성

이름 *

Ubuntu 12.04 LTS

설명

이미지 소스

이미지 파일

파일 선택

선택된 파일 없음

포맷 *

QCOW2 - QEMU Emulator

아키텍처

최소 디스크 (GB) ?

최소 RAM (MB) ?

☒ 공용

☐ 보호됨

취소

이미지 생성

설명:

Currently only images available via an HTTP/HTTPS URL are supported. The image location must be accessible to the Image Service.

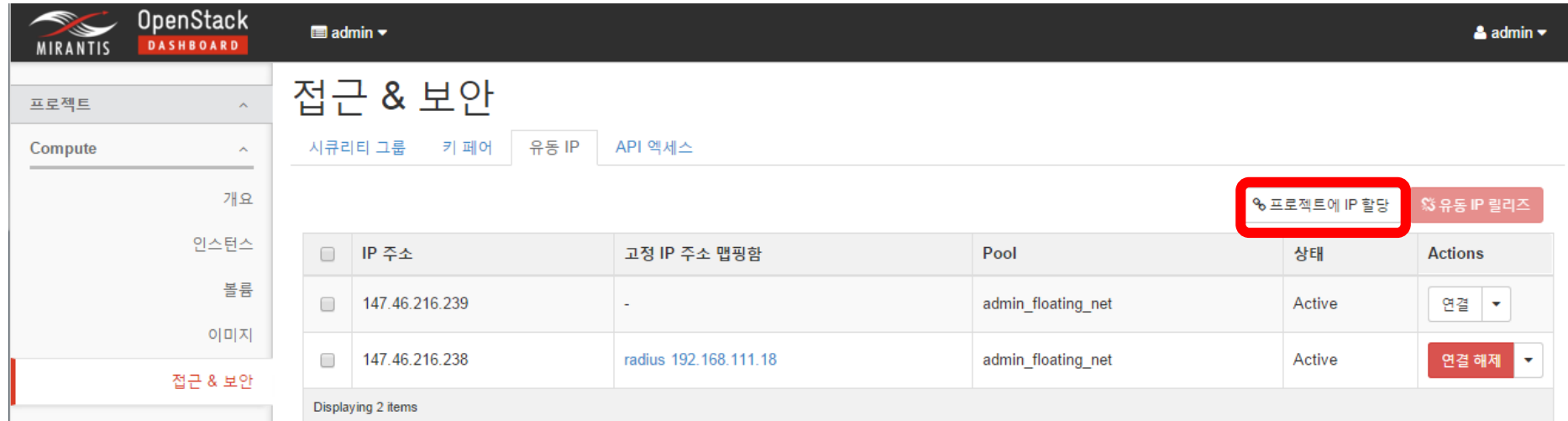
노트: 이미지가 있는 위치를 작성하는 필드에는 이미지 바이너리에 대한 유효하고 직접 연결하는 URL이어야 합니다. 사용할 수 없는 이미지는 리다이렉트되거나 서비스 에러 페이지를 나타냅니다.

Instance 생성

Instance 생성 전 과정

- Instance에 부여하기 위한 Floating IP를 프로젝트에 할당
- Instance 생성 후 원격 접속을 하기 위한 RSA 키 등록

Floating IP 할당



The screenshot shows the OpenStack Horizon dashboard with the 'Project' sidebar on the left. The 'Network & Security' section is active, and the 'Floating IP' tab is selected. The 'Assign IP to Project' button is highlighted with a red box. The table below shows two floating IP addresses assigned to the 'admin_floating_net' pool.

	IP 주소	고정 IP 주소 매핑함	Pool	상태	Actions
<input type="checkbox"/>	147.46.216.239	-	admin_floating_net	Active	연결 ▼
<input type="checkbox"/>	147.46.216.238	radius 192.168.111.18	admin_floating_net	Active	연결 해제 ▼

Displaying 2 items

- 프로젝트->Compute->접근&보안->유동 IP->프로젝트에 IP 할당

Floating IP 할당

유동 IP 할당

Pool *

admin_floating_net

설명:

주어진 유동 IP pool에서 유동 IP를 할당하세요.

프로젝트 Quotas

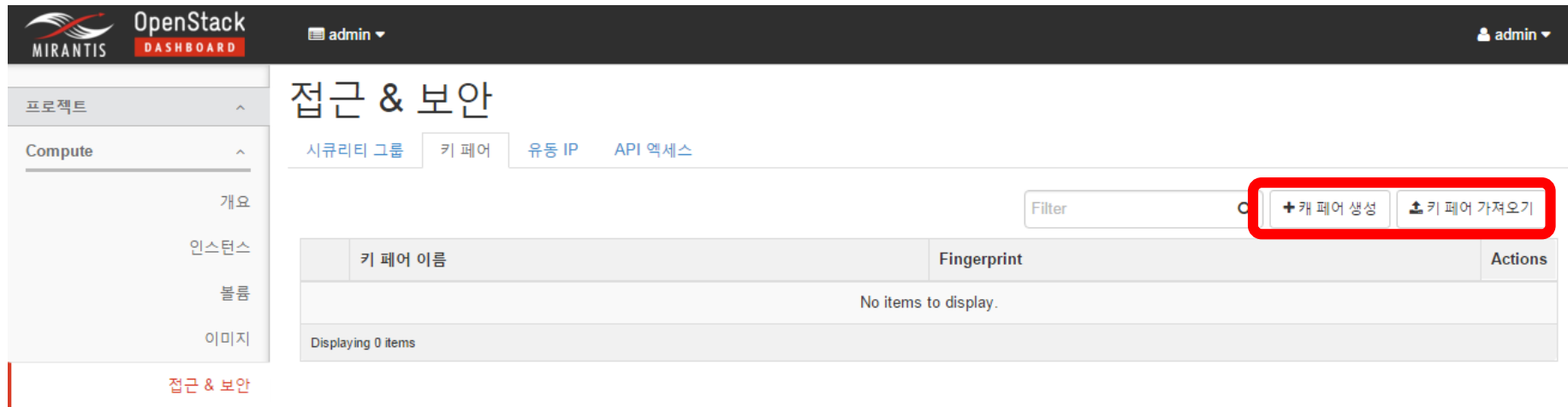
유동 IP (2) 48 사용 가능

취소

IP 할당

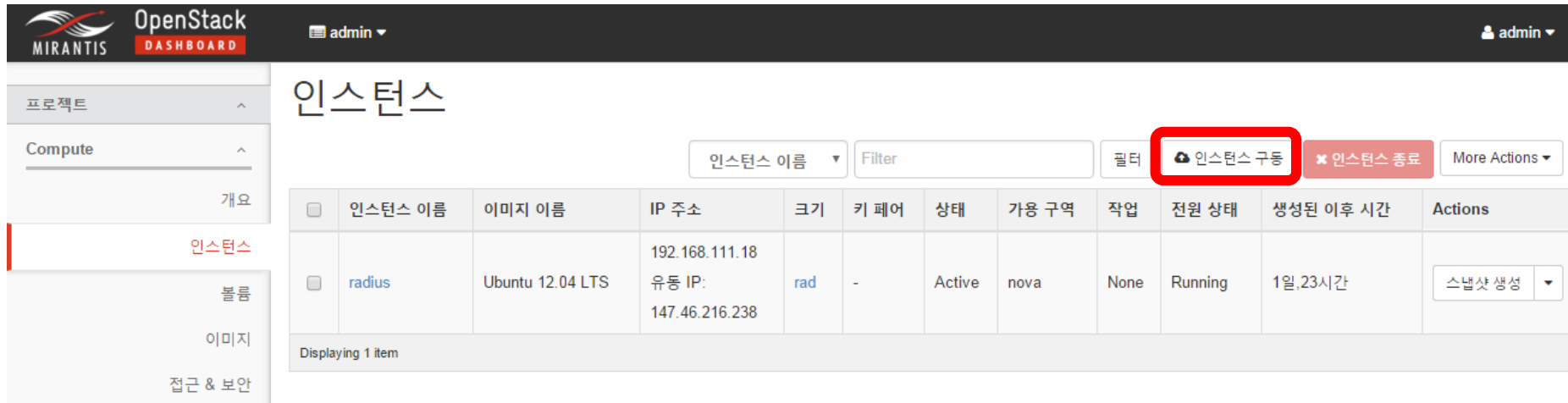
- Pool에 IP 할당
 - IP는 deploy할 때 입력했던 floating ip pool에서 자동으로 등록됨

RSA 키 등록



- Cloud Image의 경우 부팅 후 ssh 접속을 해야하므로 키 페어를 등록함
 - Console 로그인이 되게 하려면, img 파일을 수정하면 가능
- 생성하거나 이미 존재하는 키를 등록
- 과정은 생략

Instance 메뉴



The screenshot shows the OpenStack Dashboard interface. The top navigation bar includes the OpenStack logo, the word 'DASHBOARD', and the user 'admin'. The left sidebar shows the navigation menu with '프로젝트' (Project) expanded, and 'Compute' selected. Under 'Compute', the '인스턴스' (Instances) link is highlighted in red. The main content area is titled '인스턴스' and contains a table of instances. The table has columns for '인스턴스 이름' (Instance Name), '이미지 이름' (Image Name), 'IP 주소' (IP Address), '크기' (Size), '키 페어' (Key Pair), '상태' (Status), '가용 구역' (Availability Zone), '작업' (Task), '전원 상태' (Power State), '생성된 이후 시간' (Time since created), and 'Actions'. A single instance named 'radius' is listed with status 'Active' and power state 'Running'. The '인스턴스 구동' (Start Instance) button in the Actions column is highlighted with a red box.

<input type="checkbox"/>	인스턴스 이름	이미지 이름	IP 주소	크기	키 페어	상태	가용 구역	작업	전원 상태	생성된 이후 시간	Actions
<input type="checkbox"/>	radius	Ubuntu 12.04 LTS	192.168.111.18 유동 IP: 147.46.216.238	rad	-	Active	nova	None	Running	1일,23시간	스냅샷 생성 ▼

Displaying 1 item

- 프로젝트->Compute->인스턴스->인스턴스 구동

Instance 생성 - 세부 정보

인스턴스 구동

세부 정보

접근 & 보안

네트워크 *

생성 이후

고급 옵션

가용 구역

nova

인스턴스 이름 *

RADIUS

Flavor * ?

m1.small

인스턴스 카운트 * ?

1

인스턴스 부팅 소스 * ?

이미지로 부팅

이미지 이름 *

Ubuntu 12.04 LTS (252.8 MB)

인스턴스를 구동하기 위하여 세부 사양을 지정하십시오.

다음 차트는 이 프로젝트에 관련된 프로젝트 quota에 관한 리소스를 보여줍니다.

Flavor 세부 정보

이름	m1.small
VCPUs	1
Root 디스크	20 GB
Ephemeral 디스크	0 GB
모든 디스크	20 GB
RAM	2,048 MB

프로젝트 제한

인스턴스 수

inf에서 0 사용

VCPUs 수

inf에서 0 사용

모든 RAM

inf MB에서 0 사용

취소

실행

Instance 생성 - 접근&보안



인스턴스 구동

세부 정보 * 접근 & 보안 네트워크 * 생성 이후 고급 옵션

키 페어 ⓘ

사용할 수 있는 키 페어가 없습니다 ▼ +

키 페어, 시큐리티 그룹 및 다른 메커니즘을 통해 인스턴스에 접근하는 것을 제어합니다.

시큐리티 그룹 ⓘ

☐ default

취소 실행

- 생성, 가져온 키 페어 등록

Instance 생성 - 네트워크

인스턴스 구동

세부 정보 *

접근 & 보안

네트워크 *

생성 이후

고급 옵션

네트워크 선택됨

NIC:1 admin_internal_net (26e3ca14-860f-441b-b8b3-72fd170e268b)

사용 가능한 네트워크

admin_floating_net (9a17a7ea-d9cb-4a99-8043-9e253b137061)

취소

실행

푸시 버튼이나 드래그 앤 드롭을 이용하여 사용할 수 있는 네트워크에서 선택한 네트워크로 네트워크를 선택합니다. 드래그 앤 드롭으로 NIC를 변경할 수 있습니다.

- Internal net 만 선택 후 실행

Floating IP 연결



The screenshot shows the OpenStack Dashboard interface. The left sidebar contains navigation links for '프로젝트' (Project), 'Compute', '인스턴스' (Instances), '볼륨' (Volumes), '이미지' (Images), '접근 & 보안' (Access & Security), and '네트워크' (Network). The main content area is titled '인스턴스' (Instances) and displays a table of instances. The table has columns for '인스턴스 이름' (Instance Name), '이미지 이름' (Image Name), 'IP 주소' (IP Address), '크기' (Size), '키 페어' (Key Pair), '상태' (Status), '가용 구역' (Availability Zone), '작업' (Task), '전원 상태' (Power State), '생성된 이후 시간' (Time since created), and 'Actions'. A single instance named 'radius' is listed with IP address '192.168.111.18' and status 'Active'. The 'Actions' dropdown menu for this instance is open, showing options: '유동 IP 연결' (Associate Floating IP), '인터페이스 연결' (Attach Network Interface), '인터페이스 해제' (Detach Network Interface), '인스턴스 편집' (Edit Instance), and '시큐리티 그룹 편집' (Edit Security Group). The '유동 IP 연결' option is highlighted with a red box.

	인스턴스 이름	이미지 이름	IP 주소	크기	키 페어	상태	가용 구역	작업	전원 상태	생성된 이후 시간	Actions
<input type="checkbox"/>	radius	Ubuntu 12.04 LTS	192.168.111.18	rad	-	Active	nova	None	Running	1일, 23시간	스냅샷 생성 유동 IP 연결 인터페이스 연결 인터페이스 해제 인스턴스 편집 시큐리티 그룹 편집

- 생성된 instance의 action을 눌러 유동 IP 연결

Floating IP 연결

유동 IP 연결 관리

IP 주소 *

IP 주소 *

147.46.216.238

+

연결된 포트 *

radius: 192.168.111.18

선택한 인스턴트나 포트에 연결하고자 하는 IP 주소를 선택합니다.

취소

연결

- 연결을 원하는 IP 주소와 instance interface를 선택 후 연결

Floating IP 연결 완료

<input type="checkbox"/>	인스턴스 이름	이미지 이름	IP 주소	크기	키 페어	상태	가용 구역	작업	전원 상태	생성된 이후 시간	Actions
<input type="checkbox"/>	radius	Ubuntu 12.04 LTS	192.168.111.18 유동 IP: 147.46.216.238	rad	-	Active	nova	None	Running	1일,23시간	스냅샷 생성 ▼
Displaying 1 item											

- IP 주소에 유동 IP가 생성된 것을 확인
- 외부에서 해당 유동 IP를 이용하여 Instance에 접근 가능
→ Server의 역할 수행

Instance 접속

- SSH와 RSA 키를 이용하여 instance에 접속
- 외부와 통신하는 고정 ip를 갖는, VNF 역할을 수행 가능한 서버가 됨

Installation guide for freeRADIUS on OPNFV

Junghwan Song

Outline

- Overview
- FreeRADIUS 설치
 - OpenSSL 업데이트
 - 필수 라이브러리 설치
 - FreeRADIUS 설치
- 설치 후 설정
 - Mysql 연동
 - 802.1x (EAP) 설정

Overview

- OPNFV를 설치하고 네트워킹이 가능한 VNF를 생성 후 인증 서버 설치
- 인증 서버는 오픈 소스인 freeRADIUS 활용
- FreeRADIUS 설치 후 설정을 통해 EAP-TTLS로 동작

Freeradius 설치

OpenSSL 업데이트

- Ubuntu 12.04 설치시 heartbleed 문제 수정이 필요
- `sudo apt-get purge -y openssl`
- `sudo apt-get autoremove && apt-get autoclean`
- `wget http://www.openssl.org/source/openssl-1.0.1g.tar.gz`
- `tar xvzf openssl-1.0.1g.tar.gz`

OpenSSL 업데이트

- `cd openssl-1.0.1g`
- `sudo apt-get install -y gcc make`
- `./config`
- `make`
- `make install`
- `cp /usr/local/ssl/bin/openssl /usr/bin`

필수 라이브러리 설치

- `sudo apt-get install -y libtalloc-dev libssl-dev mysql-server mysql-client libmysqld-dev libmysqlclient-dev`
- mysql에 사용할 passwd 입력

FreeRADIUS 설치

- `sudo apt-get install -y freeradius freeradius-common freeradius-mysql freeradius-utils`

```
make-ssl-cert: make-ssl-cert generate-default-snakeoil --force-overwrite
make-ssl-cert: again.
Setting up freeradius (2.1.10+dfsg-3ubuntu0.12.04.2) ...
dpkg-statoverride: warning: --update given but /var/run/freeradius does not exist
Updating default SSL certificate settings, if any...
Adding user freerad to group ssl-cert
Generating DH parameters, 1024 bit long safe prime, generator 2
This is going to take a long time
.....+.....+.....+.....+.....
.....+.+.....+.....
.....+.+.....
.....+.+.....
.....+.....+*****
 * Starting FreeRADIUS daemon freeradius [ OK ]
Setting up freeradius-mysql (2.1.10+dfsg-3ubuntu0.12.04.2) ...
 * Reloading FreeRADIUS daemon freeradius [ OK ]
Setting up freeradius-utils (2.1.10+dfsg-3ubuntu0.12.04.2) ...
Setting up perl-modules (5.14.2-6ubuntu2.5) ...
Setting up perl (5.14.2-6ubuntu2.5) ...
Processing triggers for libc-bin ...
ldconfig deferred processing now taking place
root@rad-test: ~/openssl-1.0.1g#
root@rad-test:~/openssl-1.0.1g# _
```

설치 후 설정

Mysql 설정

- mysql -u root -p
 - mysql password 입력
- create database radius;
- grant all on radius.* to {linux username}
@localhost identified by '{mysql
password}';
- exit

Mysql 설정

```
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 42
Server version: 5.5.47-0ubuntu0.12.04.1 (Ubuntu)

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affiliates. Other names may be trademarks of their respective
owners.

Type 'help;' or '\h' for help. Type '\c' to clear the current input statement.

mysql> create database radius;
Query OK, 1 row affected (0.00 sec)

mysql> grant all on radius.* to root@localhost identified by mmlab;
ERROR 1064 (42000): You have an error in your SQL syntax; check the manual that
corresponds to your MySQL server version for the right syntax to use near 'mmlab'
' at line 1

mysql> grant all on radius.* to root@localhost identified by 'mmlab';
Query OK, 0 rows affected (0.00 sec)

mysql> exit
Bye
root@rad-test:~/openssl-1.0.1g# _
```


Mysql 설정

- `mysql -u root -p radius < /etc/freeradius/sql/mysql/schema.sql`
 - mysql password 입력
- `mysql -u root -p radius < /etc/freeradius/sql/mysql/nas.sql`
 - mysql password 입력

```
root@rad-test:~/openssl-1.0.1g# mysql -u root -p radius < /etc/freeradius/sql/mysql/schema.sql
Enter password:
root@rad-test:~/openssl-1.0.1g# mysql -u root -p radius < /etc/freeradius/sql/mysql/nas.sql
Enter password:
root@rad-test:~/openssl-1.0.1g#
```

Mysql에 유저 정보, AP 정보 입력

- mysql -u root -p
 - mysql password 입력
- use radius;
- INSERT INTO radcheck (username, attribute, value) VALUES ('{user id}', 'Password', '{user pw}');
- INSERT INTO nas VALUES (NULL, '{ap ip addr}', '{ap name}', 'other', NULL, '{radius pw}', NULL, NULL, NULL);
- exit

Mysqle에 유저 정보, AP 정보 입력

```
mysql> select * from radcheck;
```

id	username	attribute	op	value
1	mmlab	Password	==	mmlab

```
1 row in set (0.00 sec)
```

```
mysql> select * from nas;
```

id	nasname	shortname	type	ports	secret	server	community
1	147.46.219.201	mmlab	other	NULL	mmlab	NULL	NULL

```
1 row in set (0.00 sec)
```

```
mysql> _
```

Mysql DB와 freeRADIUS 연동

- vi /etc/freeradius/sql.conf

```
sql {  
    #  
    # Set the database to one of:  
    #  
    #     mysql, mssql, oracle, postgresql  
    #  
    database = "mysql"  
  
    #  
    # Which FreeRADIUS driver to use.  
    #  
    driver = "rlm_sql_${database}"  
  
    # Connection info:  
    server = "localhost"  
    #port = 3306  
    login = "linux user id"  
    password = "mysql password"  
  
    # Database table configuration for everything except Oracle  
    radius_db = "radius"  
    # If you are using Oracle then use this instead  
    # radius_db = "(DESCRIPTION=(ADDRESS=(PROTOCOL=TCP)(HOST=localhost)(PORT  
=1521))(CONNECT_DATA=(SID=your_sid)))"  
-- INSERT --  
38,24-31 25%
```

Mysql DB와 freeRADIUS 연동

- vi /etc/freeradius/sql.conf

```
# lifetime. If set to non-zero, any open connections will be
# closed "lifetime" seconds after they were first opened.
lifetime = 0

# Maximum number of queries used by an SQL socket. If you are
# having issues with SQL sockets lasting "too long", you can
# limit the number of queries performed over one socket. After
# "max_queries", the socket will be closed. Use 0 for "no limit".
max_queries = 0

# Set to 'yes' to read radius clients from the database ('nas' table)
# Clients will ONLY be read on server startup. For performance
# and security reasons, finding clients via SQL queries CANNOT
# be done "live" while the server is running.
#
readclients = yes

# Table to keep radius client info
nas_table = "nas"

# Read driver-specific configuration
$INCLUDE sql/${database}/dialup.conf

3
2
"/etc/freeradius/sql.conf" 107L, 3037C written          100,16-23      Bot
```

Mysql DB와 freeRADIUS 연동

- vi /etc/freeradius/sites-enabled/default

```
authorize {  
    #  
    # The preprocess module takes care of sanitizing some bizarre  
    # attributes in the request, and turning them into attributes  
    # which are more standard.  
    #  
    # It takes care of processing the 'raddb/hints' and the  
    # 'raddb/huntgroups' files.  
    preprocess  
#    unix  
  
    #  
    # Read the 'users' file  
    files  
  
    #  
    # Look in an SQL database. The schema of the database  
    # is meant to mirror the "users" file.  
    #  
    # See "Authorization Queries" in sql.conf  
    sql
```

Mysql DB와 freeRADIUS 연동

- vi /etc/freeradius/sites-enabled/default

```
accounting
#
# Create a 'detail'ed log of the packets.
# Note that accounting requests which are proxied
# are also logged in the detail file.
# detail
# daily

# Update the wtmp file
#
# If you don't use "radlast", you can delete this line.
# unix
# main_pool

#
# Log traffic to an SQL database.
#
# See "Accounting queries" in sql.conf
sql
```

Mysql DB와 freeRADIUS 연동

- vi /etc/freeradius/sites-enabled/default

```
# Session database, used for checking Simultaneous-Use. Either the radutmp
# or rlm_sql module can handle this.
# The rlm_sql module is *much* faster
session {
    radutmp

    #
    # See "Simultaneous Use Checking Queries" in sql.conf
    sql
}
post-auth {
    # Get an address from the IP Pool.
    #
    main_pool

    #
    # If you want to have a log of authentication replies,
    # un-comment the following line, and the 'detail reply_log'
    # section, above.
    #
    reply_log

    #
    # After authenticating the user, do another SQL query.
    #
    # See "Authentication Logging Queries" in sql.conf
    sql
}
```


Mysql DB와 freeRADIUS 연동

- `cp /etc/freeradius/sites-enabled/default /etc/freeradius/sites-enabled/inner-tunnel`
 - EAP-TTLS의 경우 터널링을 사용
 - 따라서 터널링 내부 설정을 default와 동일하게 사용토록 복사

Mysql DB와 freeRADIUS 연동

- vi /etc/freeradius/radiusd.conf

```
# Extensible Authentication Protocol
#
# For all EAP related authentications.
# Now in another file, because it is very large.
#
$INCLUDE eap.conf

# Include another file that has the SQL-related configuration.
# This is another file only because it tends to be big.
#
$INCLUDE sql.conf
#
```

Root, server certificate 생성

- EAP-TTLS의 사용을 위해 필요
- vi /usr/share/doc/freeradius/example/certs/ca.cnf

```
[ req ]
prompt                = no
distinguished_name    = certificate_authority
default_bits          = 2048
input_password         = mmlab
output_password       = mmlab
x509_extensions       = v3_ca

[certificate_authority]
countryName           = FR
stateOrProvinceName   = Radius
localityName          = Somewhere
organizationName      = Example Inc.
emailAddress          = admin@example.com
commonName             = "Example Certificate Authority"

[v3_ca]
subjectKeyIdentifier  = hash
authorityKeyIdentifier = keyid:always,issuer:always
basicConstraints      = CA:true
```

Root, server certificate 생성

- vi /usr/share/doc/freeradius/example/certs/server.cnf

```
[ req ]
prompt                = no
distinguished_name    = server
default_bits          = 2048
input_password        = mmlab
output_password       = mmlab

[server]
countryName           = FR
stateOrProvinceName   = Radius
localityName          = Somewhere
organizationName      = Example Inc.
emailAddress          = admin@example.com
commonName            = "Example Server Certificate"
```

54,0-1 Bot

Root, server certificate 생성

- cd /usr/share/doc/freeradius/example/certs/
- make ca.pem
- make ca.der

```
root@rad-test:/usr/share/doc/freeradius/examples/certs# make ca.pem
openssl req -new -x509 -keyout ca.key -out ca.pem \
    -days `grep default_days ca.cnf | sed 's/.*=//;s/^ *//'\` -config
    ./ca.cnf
Generating a 2048 bit RSA private key
...+++
.....+++
writing new private key to 'ca.key'
-----
root@rad-test:/usr/share/doc/freeradius/examples/certs# make ca.der
openssl x509 -inform PEM -outform DER -in ca.pem -out ca.der
root@rad-test:/usr/share/doc/freeradius/examples/certs#
```

Root, server certificate 생성

- make server.pem
- make server.csr
- cp ca.* server.* /etc/freeradius/certs/

```
Not Before: Mar 30 07:56:39 2016 GMT
Not After : Mar 28 07:56:39 2026 GMT
Subject:
countryName           = FR
stateOrProvinceName   = Radius
organizationName      = Example Inc.
commonName            = Example Server Certificate
emailAddress          = admin@example.com
X509v3 extensions:
X509v3 Extended Key Usage:
    TLS Web Server Authentication
Certificate is to be certified until Mar 28 07:56:39 2026 GMT (3650 days)

Write out database with 1 new entries
Data Base Updated
openssl pkcs12 -export -in server.crt -inkey server.key -out server.p12 -passin
pass:`grep output_password server.cnf | sed 's/.*=///;s/^ *///'` -passout pass:`g
rep output_password server.cnf | sed 's/.*=///;s/^ *///'`
openssl pkcs12 -in server.p12 -out server.pem -passin pass:`grep output_password
server.cnf | sed 's/.*=///;s/^ *///'` -passout pass:`grep output_password server.
cnf | sed 's/.*=///;s/^ *///'`
MAC verified OK
root@rad-test:/usr/share/doc/freeradius/examples/certs# make server.csr
make: `server.csr' is up to date.
root@rad-test:/usr/share/doc/freeradius/examples/certs# _
```

EAP 사용 설정

- vi /etc/freeradius/eap.conf

```
# See experimental.conf for documentation.
#
eap {
    # Invoke the default supported EAP type when
    # EAP-Identity response is received.
    #
    # The incoming EAP messages DO NOT specify which EAP
    # type they will be using, so it MUST be set here.
    #
    # For now, only one default EAP type may be used at a time.
    #
    # If the EAP-Type attribute is set by another module,
    # then that EAP type takes precedence over the
    # default type configured here.
    #
    default_eap_type = ttls
    #
    # A list is maintained to correlate EAP-Response
    # packets with EAP-Request packets. After a
    # configurable length of time, entries in the list
    # expire, and are deleted.
    #
    timer_expire      = 60
}
```

EAP 사용 설정

- vi /etc/freeradius/eap.conf

```
certdir = ${confdir}/certs
cadir = ${confdir}/certs
private_key_password = mmlab
private_key_file = ${certdir}/server.key

# If Private key & Certificate are located in
# the same file, then private_key_file &
# certificate_file must contain the same file
# name.
#
# If CA_file (below) is not used, then the
# certificate_file below MUST include not
# only the server certificate, but ALSO all
# of the CA certificates used to sign the
# server certificate.
certificate_file = ${certdir}/server.pem
```


Radius를 통한 인증

SKT 100% 100% 오후 6:58

mmlab414
TTLS
단계 2 인증
없음
CA 인증서
(지정되지 않음)
ID
whatever
익명 ID
비밀번호
whatever
☒ 비밀번호 표시
☐ 고급 옵션 표시
취소 연결



```
Sending delayed reject for request 66  
Sending Access-Reject of id 69 to 147.46.219.201 port 45829  
EAP-Message = 0x04060004  
Message-Authenticator = 0x00000000000000000000000000000000
```

Radius를 통한 인증

SKT 100% 100% 오후 6:58

mmlab414
EAP 방식
TTLS
단계 2 인증
없음
CA 인증서
(지정되지 않음)
ID
OWC
익명 ID
비밀번호
owc2015
☒ 비밀번호 표시
☐ 고급 옵션 표시
취소 연결

Sending Access-Accept of id 85 to 147.46.219.201 port 45829
MS-MPPE-Recv-Key = 0xd104268f9d67ff5e4c0be47db7f3b270b80967aea23a4e3fe4f04437f1b021f4
MS-MPPE-Send-Key = 0xb45b492bd23d9440833bd26d8551b638b5283f7f2fe78ac5d6bf9d20fb195546
EAP-Message = 0x03070004
Message-Authenticator = 0x00000000000000000000000000000000
User-Name = "owc"
Finished request 82.

SKT 100% 100% 오후 6:53

Wi-Fi
사용

mmlab414
연결됨
ollehWiFi
저장됨
T wifi zone_secure
저장됨
ollehWiFi
ollehWiFi_SNU
3Dill-Vision
mmlab414 Wi-Fi 네트워크에
연결하였습니다.
3Dill_ipTime(2)-2.4

Reference

- Ubuntu(<http://www.ubuntu.com>)
- Ubuntu-Mate(<http://ubuntu-mate.org>)
- RaspberryPi(<https://www.raspberrypi.org/>)
- Linux - Ubuntu 14.04 설치하기(<http://studyforus.tistory.com/222>)
- git - 간편 안내서(<https://rogerdudler.github.io/git-guide/index.ko.html>)
- Open vSwitch(<http://openvswitch.org/>)
- ONOS(<http://onosproject.org/>)
- hostapd(<https://w1.fi/hostapd/>)
- 장고 걸스 튜토리얼(<http://http://tutorial.djangogirls.org/ko/index.html>)
- OPNFV(<https://www.opnfv.org>)
- FreeRADIUS(<https://freeradius.org>)
- OpenStack(<https://www.openstack.org>)

