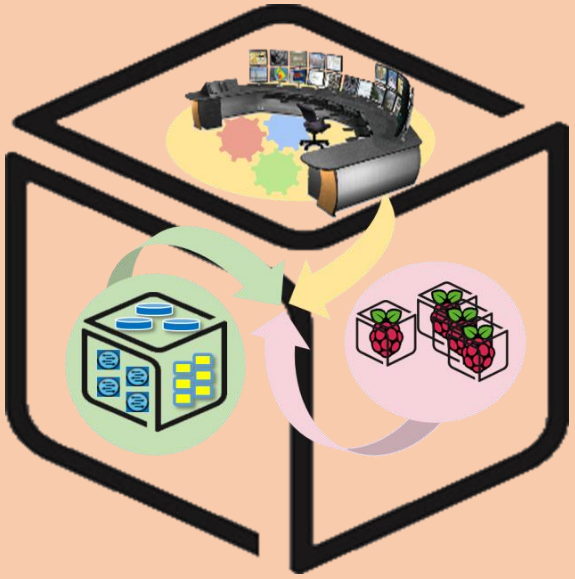
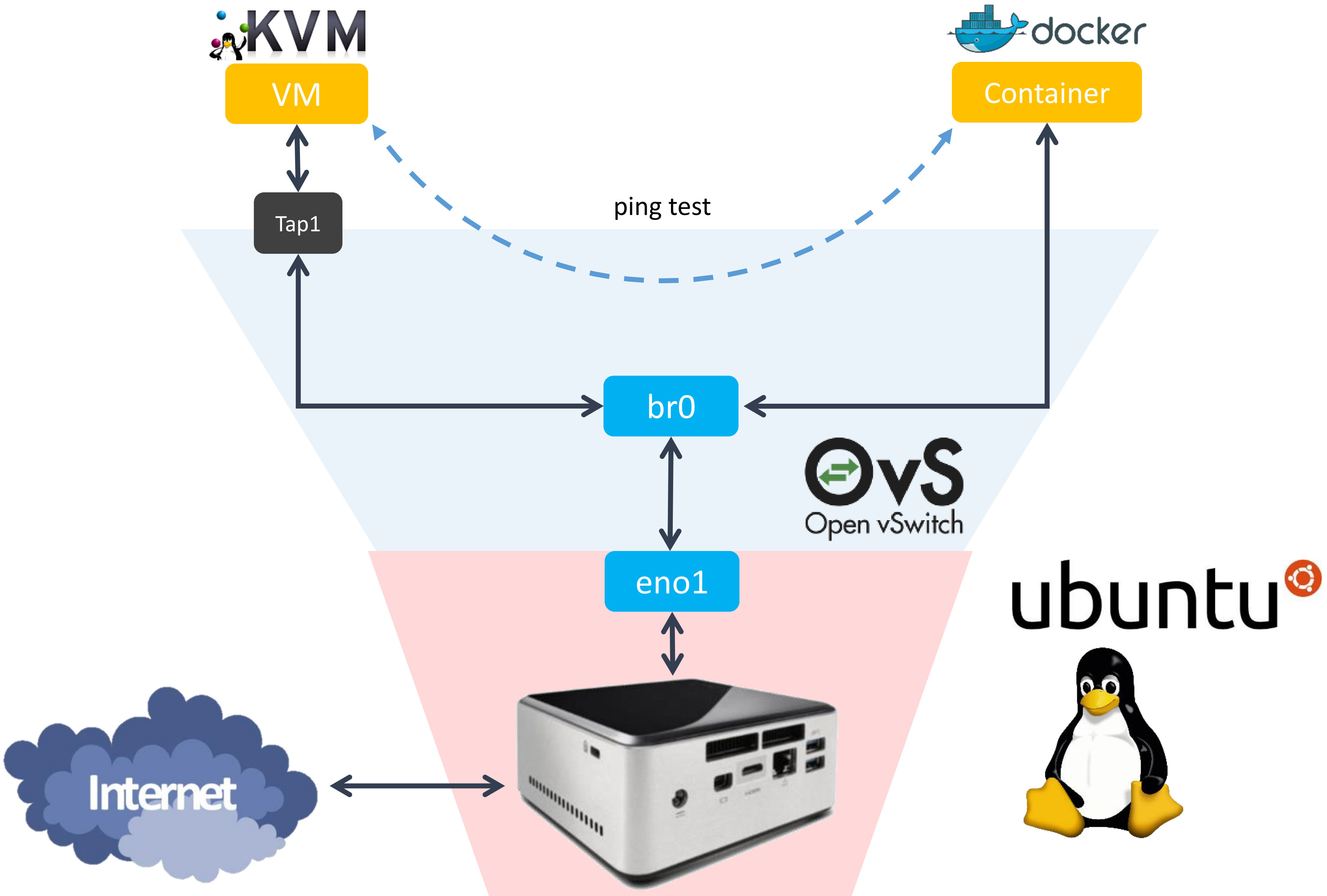
Computer Systems For AI-inspired Cloud Theory & Lab.

Lab #1: Box

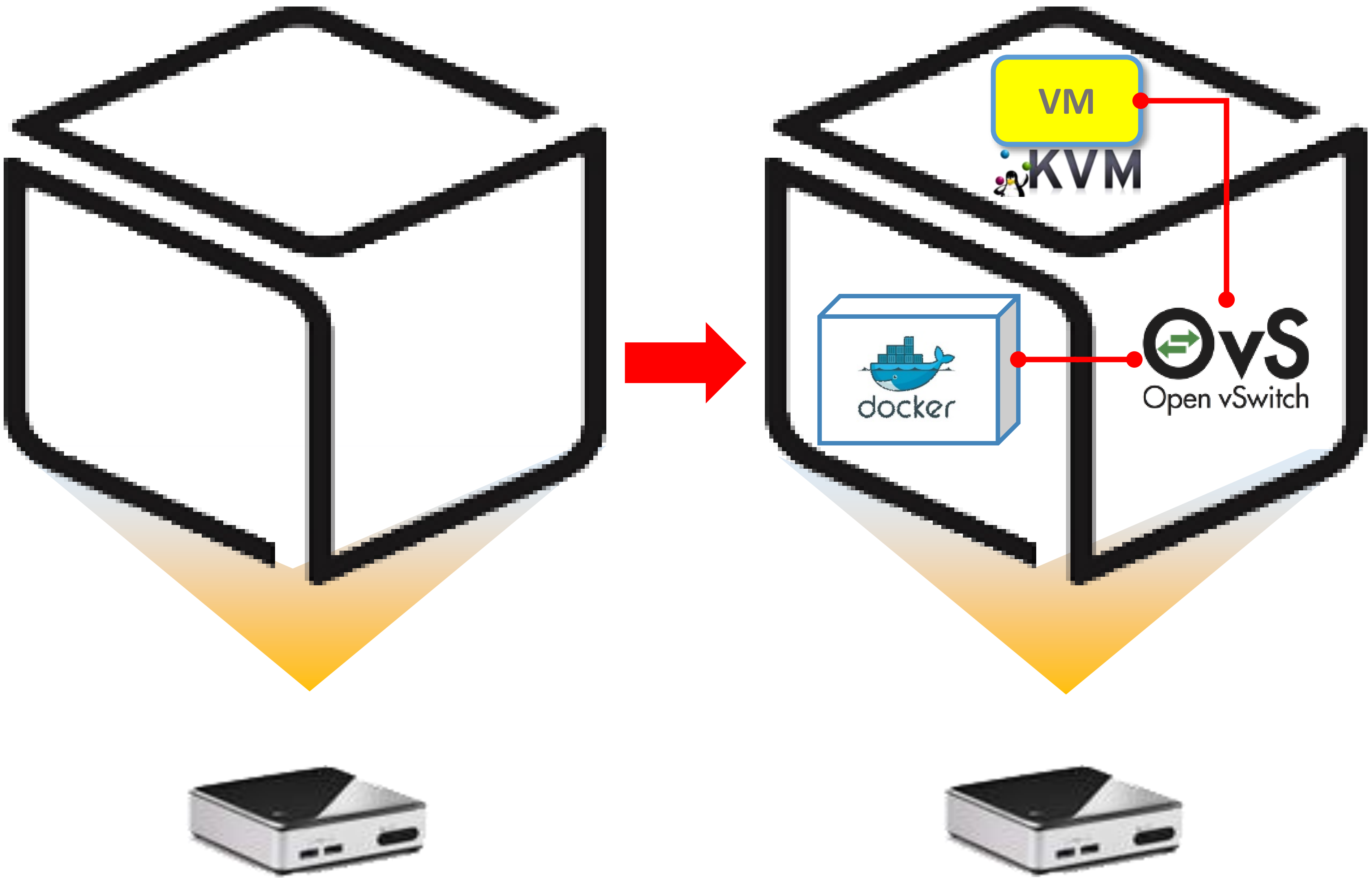


https://github.com/SmartX-Labs/SmartX-Mini-MOOC

Box Lab: Outline



Box Lab: Final Goal



Before you start
- Things you need to know

Lab Theory

Lab Practice

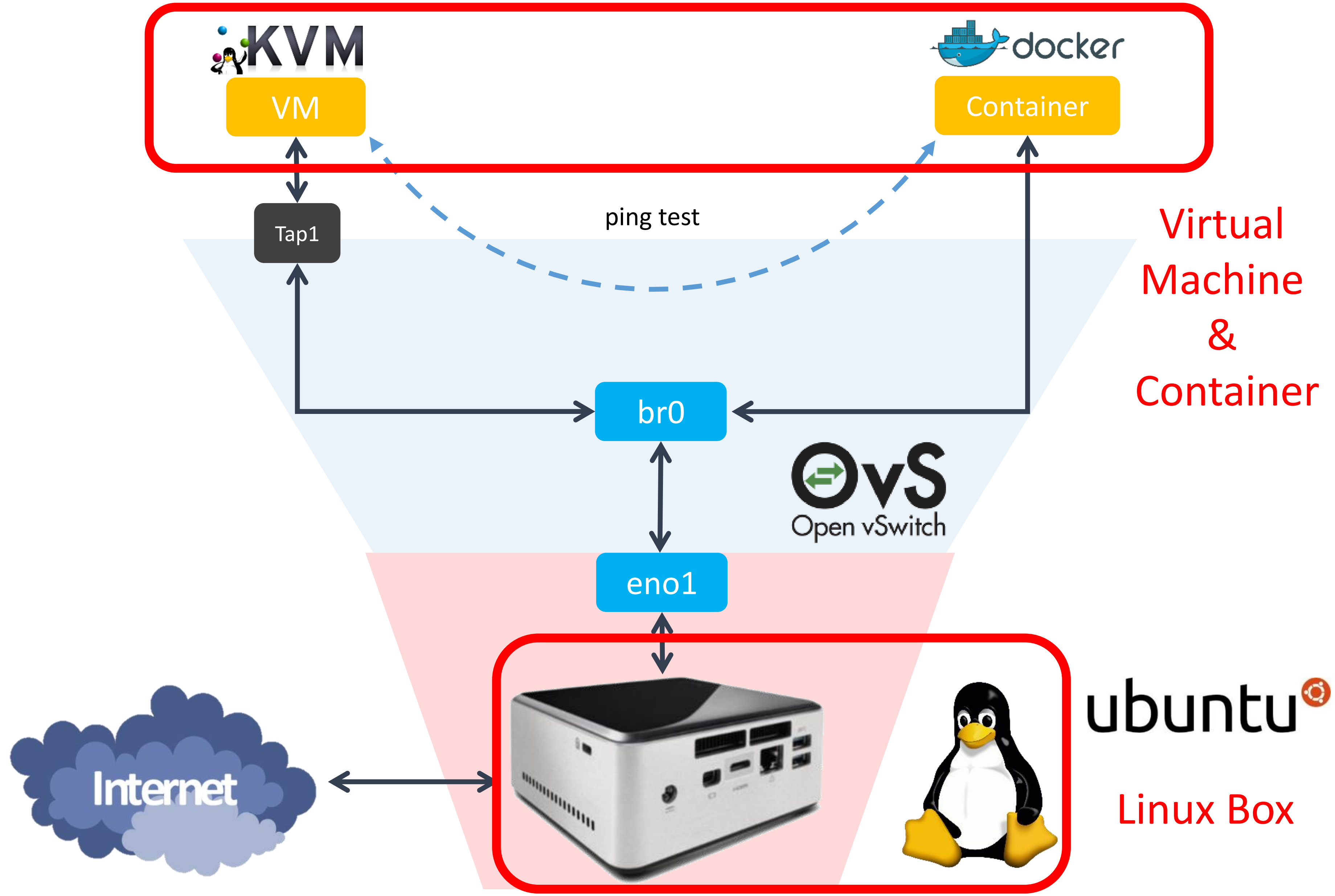
Lab Review

Lectures are divided into Lab Theory, Lab Practice and Lab Review parts.

The keyboard means that you should execute instructions by following the guidance.

Lab Theory

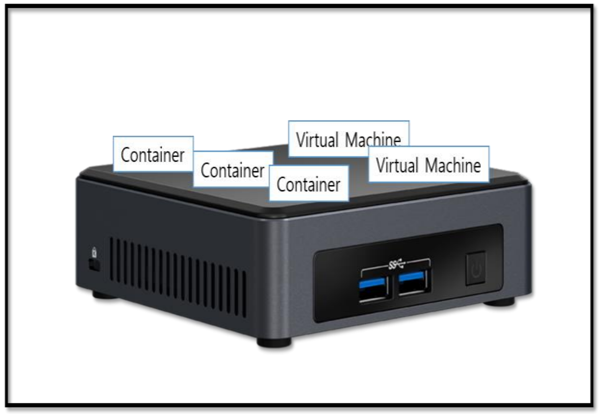
Linux Box with Virtualization/Containers



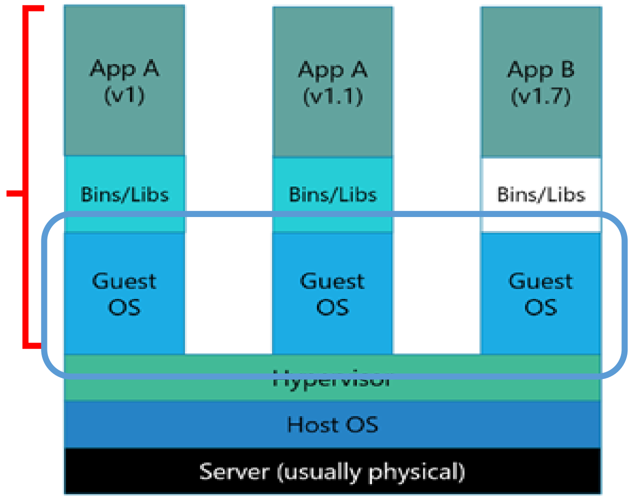
VMs and Containers on a Linux Box

On a Linux Box (e.g., NUC)

- Multiple fully-isolated (with dedicated resources), but heavy VM instances (i.e., VMs).
- Multiple partially-isolated, lightweight container instances (i.e., containers)



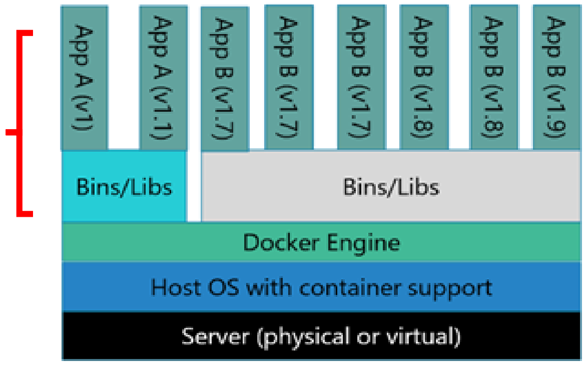
Virtual Machines (VMs)



Heavier than Container!

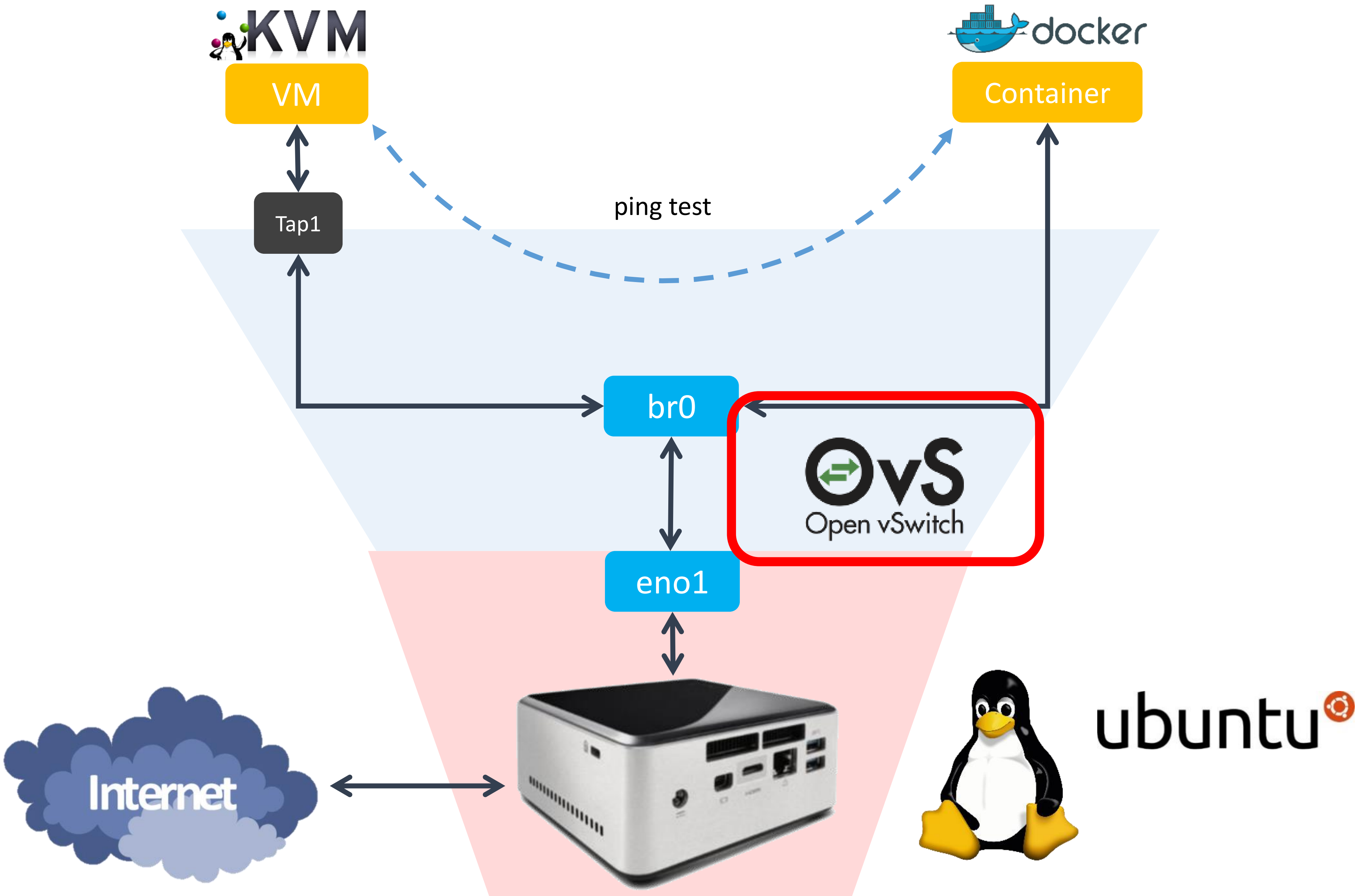
Hypervisor Tool for creating VMs

Containers

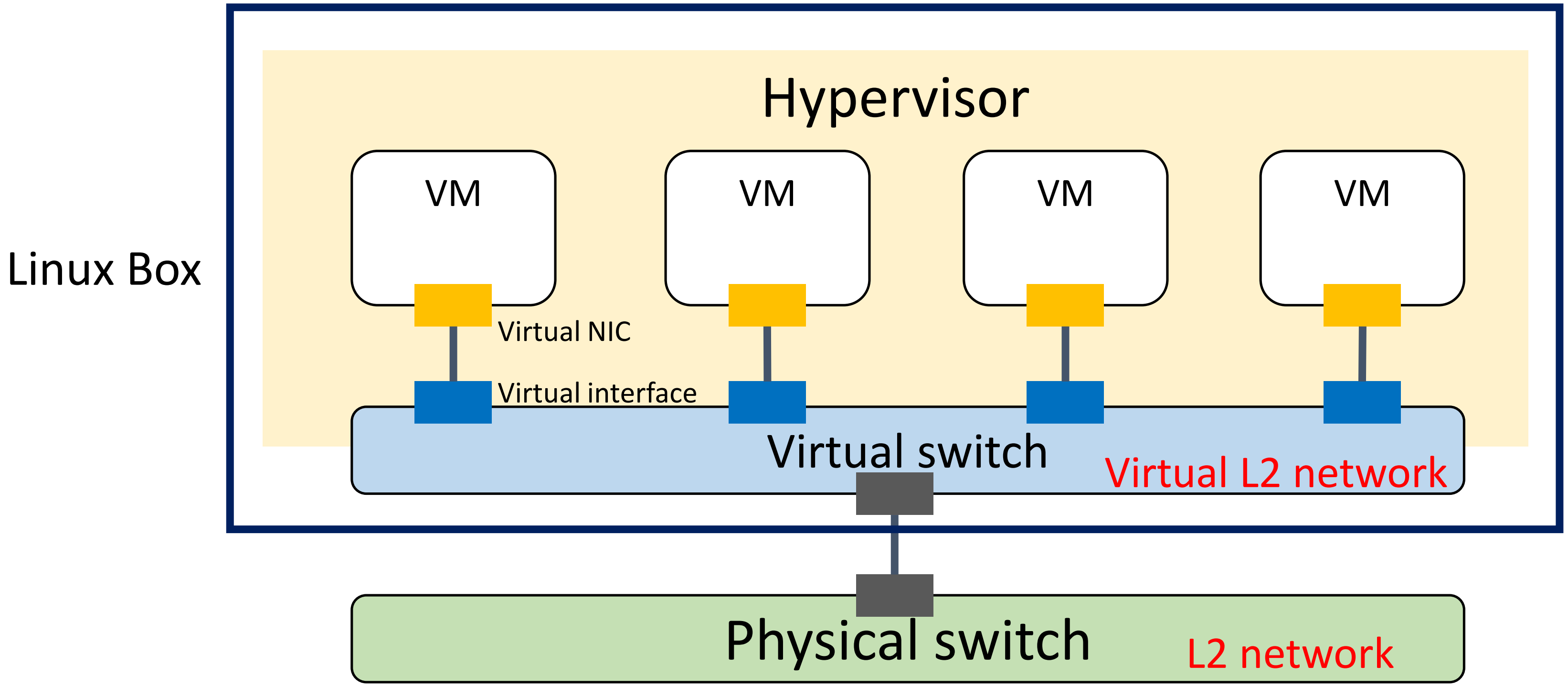


Container Runtime Tool for running containers

A Switch inside Linux Box: Open vSwitch



Virtual Switch in a Box to connect VMs

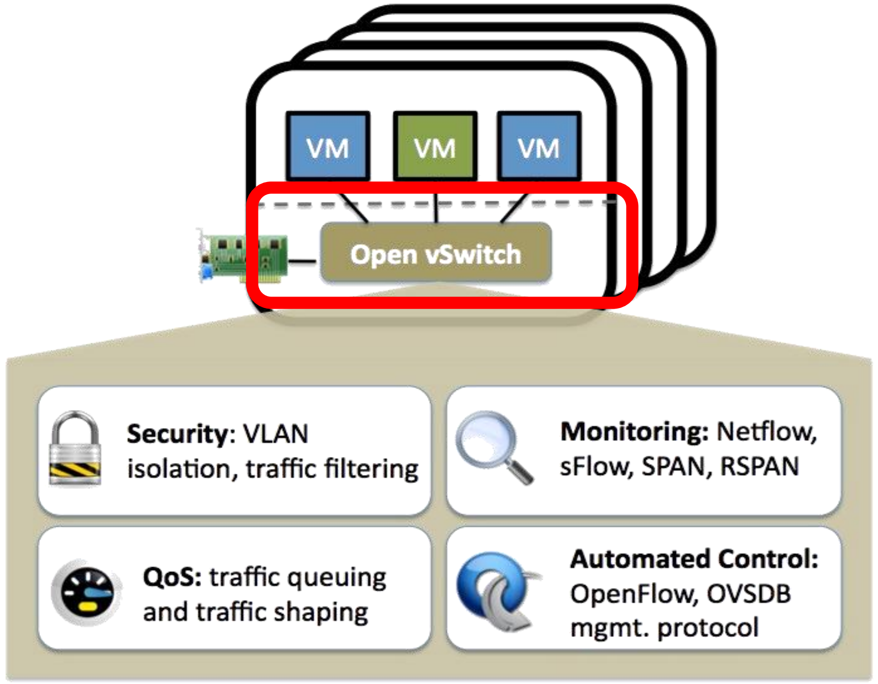


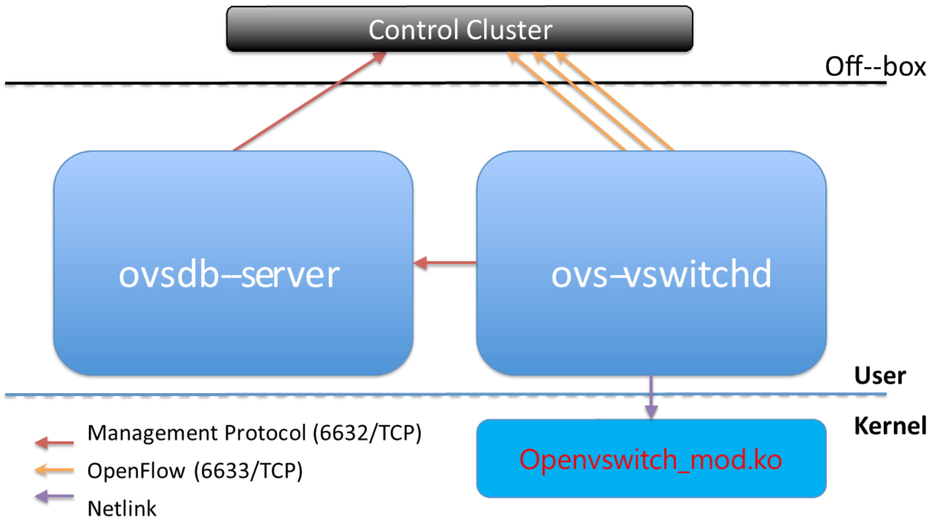
- A software-based virtual switch allows one VM to communicate with neighbor VMs as well as to connect to Internet (via physical switch).
- Software-based switches (running with the power of CPUs) are known to be more flexible/upgradable and benefited of virtualization (memory overcommit, page sharing, …)
- VMs (similarly containers) have logical (virtual) NIC with virtual Ethernet ports so that they can be plugged into the virtual interface (port) of virtual switches.

Linux-adopted virtual switch: Open vSwitch

http://openvswitch.org/

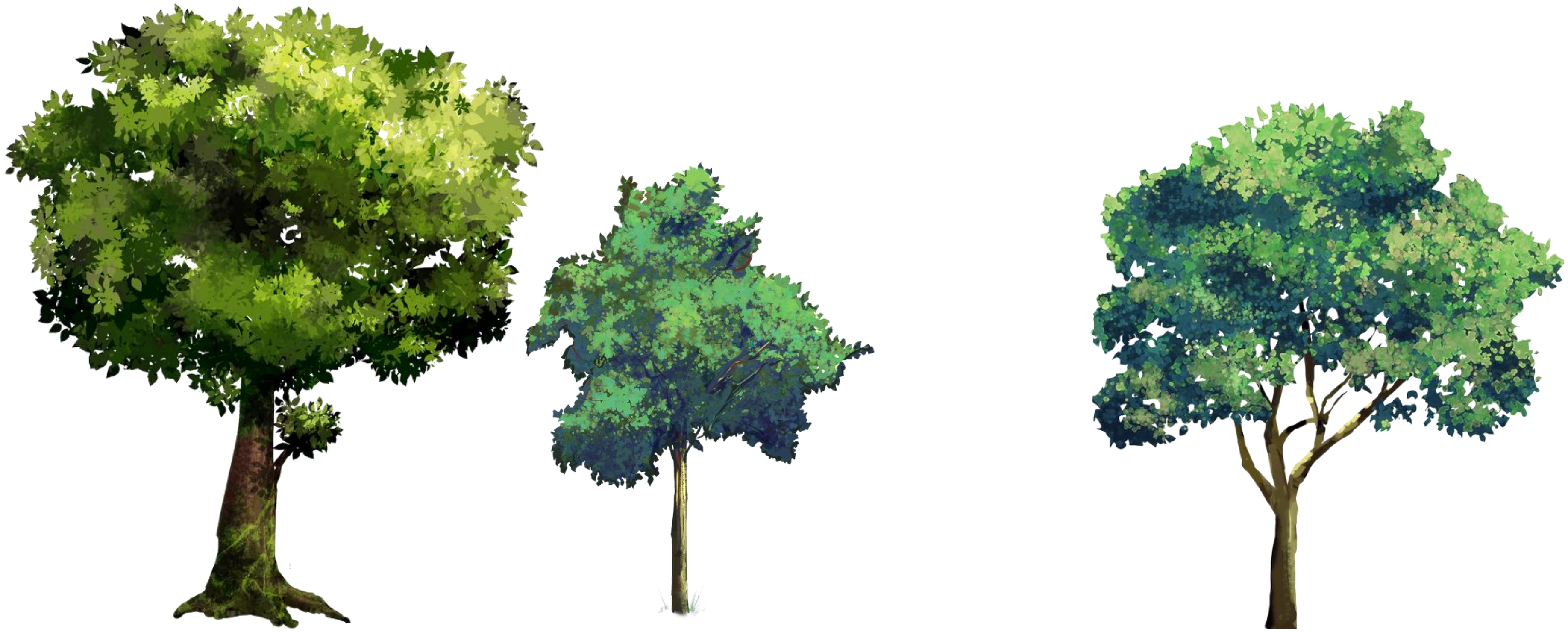
Open vSwitch is an open-source virtual switch software designed for virtual servers.


VM
VM
VM
Open vSwitch
Security: VLAN isolation, traffic filtering
Monitoring: Netflow, sFlow, SPAN, RSPAN
QoS: traffic queuing and traffic shaping
Automated Control: OpenFlow, OVSDB mgmt. protocol



OVS Main components

Lab Practice



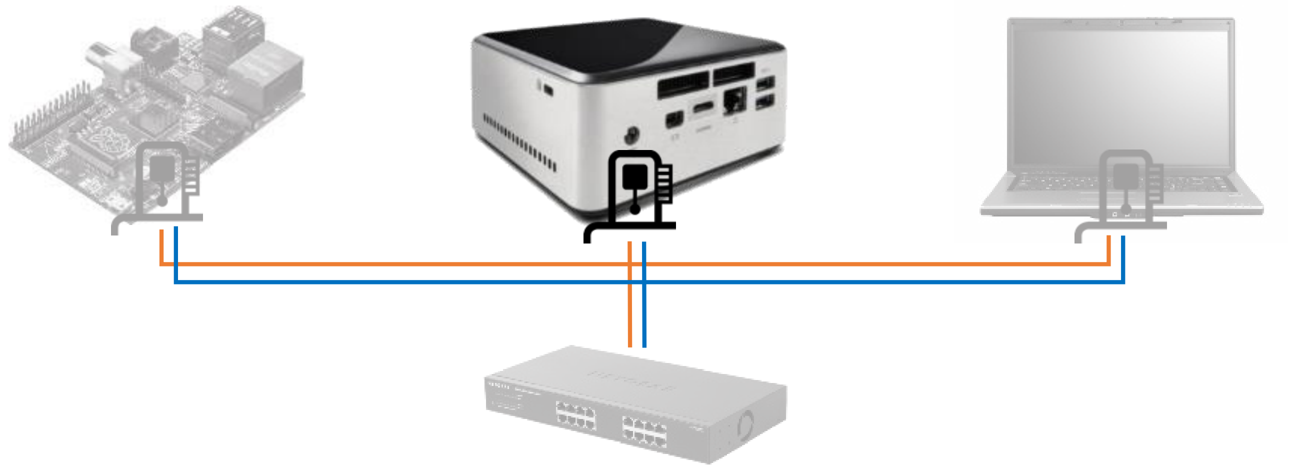
#0 - Lab Preparation

Wired connection

NAME: Raspberry Pi Model B (Pi)
CPU: ARM Cortex A7 @900MHz
CORE: 4
Memory: 1GB
SD Card: 32GB

NAME: NUC5i5MYHE (NUC PC)
CPU: i5-5300U @2.30GHz
CORE: 4
Memory: 16GB DDR3
HDD: 94GB

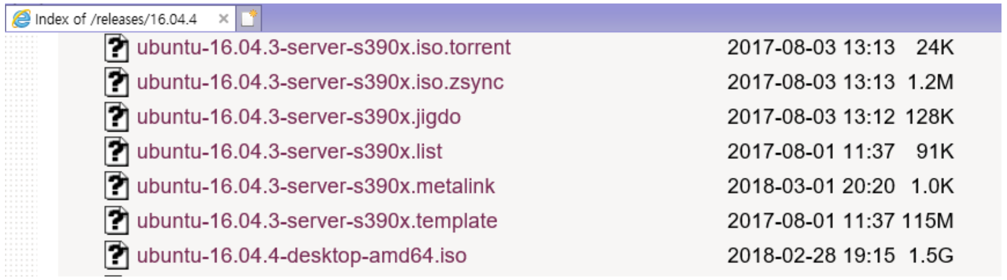
NAME: NT900X3A
CPU: i5-2537U @1.40GHz
CORE: 2
Memory: 4GB DDR3
HDD: 128GB



NAME: netgear prosafe 16 port gigabit switch(Switch)
Network Ports: 16 auto-sensing 10/100/1000 Mbps Ethernet ports

#1 - NUC: OS Installation

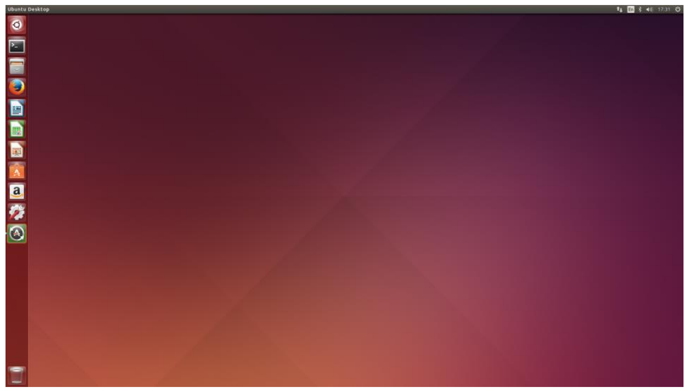
- OS : Ubuntu Desktop 18.04 LTS(64bit)
  - Download Site : http://old-releases.ubuntu.com/releases/bionic/



Index of /releases/16.04.4

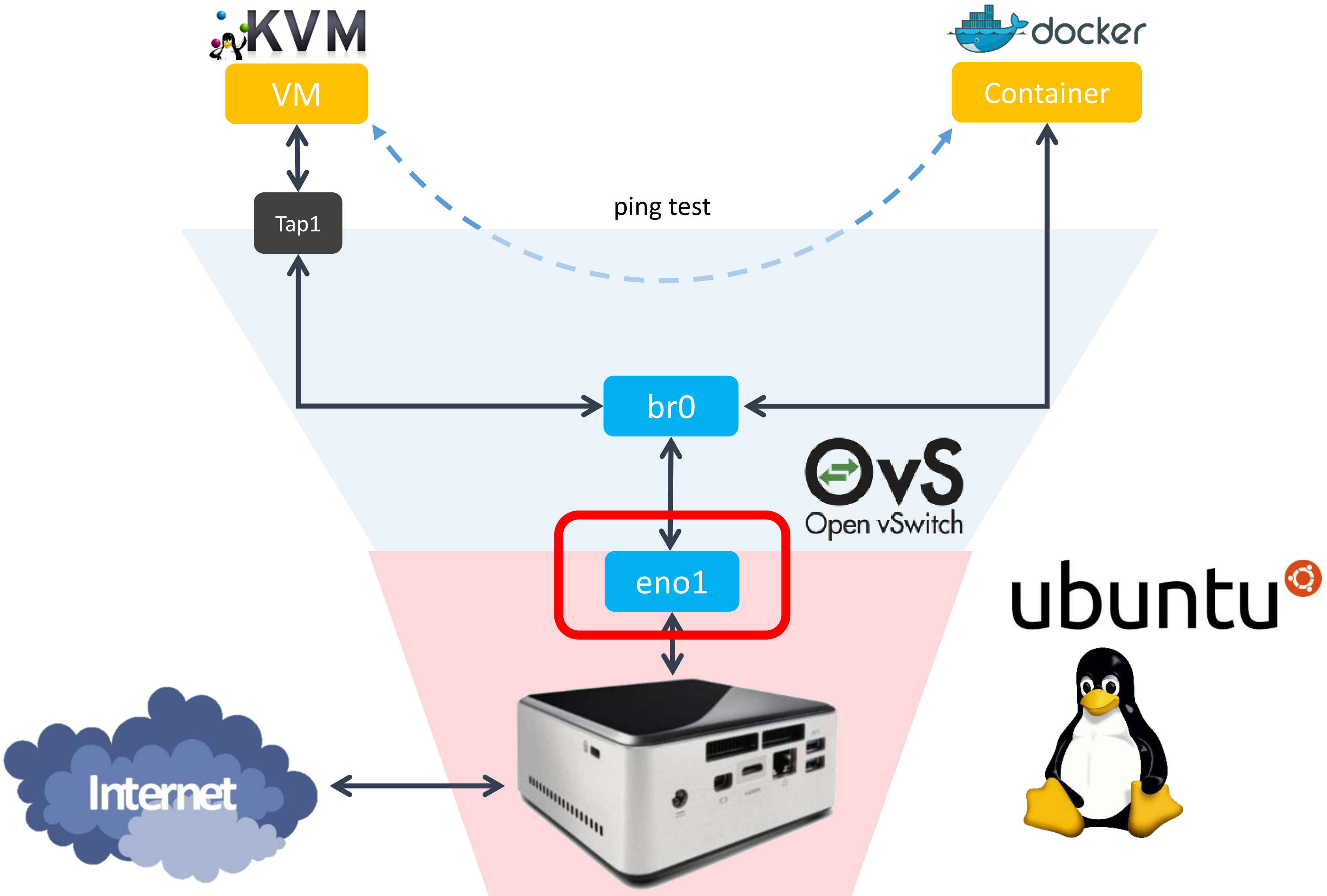
ubuntu-16.04.3-server-s390x.iso.torrent	2017-08-03 13:13	24K
ubuntu-16.04.3-server-s390x.iso.zsync	2017-08-03 13:13	1.2M
ubuntu-16.04.3-server-s390x.jigdo	2017-08-03 13:12	128K
ubuntu-16.04.3-server-s390x.list	2017-08-01 11:37	91K
ubuntu-16.04.3-server-s390x.metalink	2018-03-01 20:20	1.0K
ubuntu-16.04.3-server-s390x.template	2017-08-01 11:37	115M
ubuntu-16.04.4-desktop-amd64.iso	2018-02-28 19:15	1.5G

  - ~~Bootable USB configuration (no bootable CD, no CD-Rom in NUC) using the downloaded file (ubuntu-16.04.4-desktop-amd64.iso, 1.5Gb)~~
  - Installed on NUC



Ubuntu Home Screen After Installation

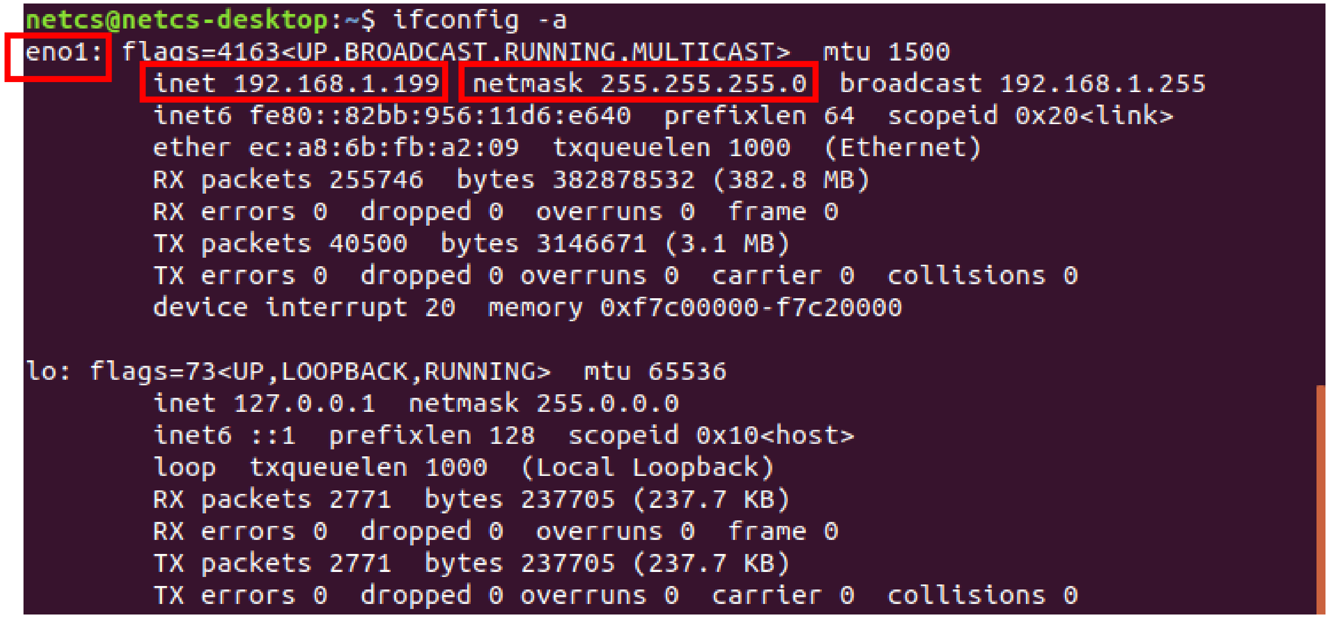
#2 - NUC: Network Configuration (1/3)



#2 - NUC: Network Configuration (1/3)

- Network interface

```
$sudo apt update
$sudo apt upgrade
$sudo apt install net-tools
$ifconfig –a
```



```
netcs@netcs-desktop:~$ ifconfig -a
eno1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 192.168.1.199  netmask 255.255.255.0  broadcast 192.168.1.255
        inet6 fe80::82bb:956:11d6:e640  prefixlen 64  scopeid 0x20<link>
        ether ec:a8:6b:fb:a2:09  txqueuelen 1000  (Ethernet)
        RX packets 255746  bytes 382878532 (382.8 MB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 40500  bytes 3146671 (3.1 MB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0
        device interrupt 20  memory 0xf7c00000-f7c20000

lo: flags=73<UP,LOOPBACK,RUNNING>  mtu 65536
        inet 127.0.0.1  netmask 255.0.0.0
        inet6 ::1  prefixlen 128  scopeid 0x10<host>
        loop  txqueuelen 1000  (Local Loopback)
        RX packets 2771  bytes 237705 (237.7 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 2771  bytes 237705 (237.7 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0
```

#2 - NUC: Network Configuration (1/3)

- Network interface (공유기 쓰는 학생들)

```
~~$sudo apt install ifupdown~~
$sudo vi /etc/network/interfaces
----------------- /etc/network/interfaces -----------------
auto lo
iface lo inet loopback

auto eno1
iface eno1 inet static
            address     192.168.0.6
            netmask     255.255.255.0
            gateway     192.168.0.1
            dns-nameservers [nameserver 1] [nameserver 2]
---------------------------------------------------------------
```

Some NUC have different Interface name.
So you need to check your NUC's interface name using 'ip a' command.

#2 - NUC: Network Configuration (1/3)

- Network interface (공유기 안쓰는 학생들 - 기숙사)

```
~~$sudo apt install ifupdown~~
$sudo vi /etc/network/interfaces
----------------- /etc/network/interfaces -----------------
auto lo
iface lo inet loopback

auto eno1
iface eno1 inet static
        address   210.XXX.XXX.XXX <- Input your dorm. room's IP address
        netmask   255.255.255.0
        gateway   210.xxx.xxx.xxx <- Input your dorm. room's gateway
        dns-nameservers 8.8.8.8   <- Input your dorm. room's dns-nameservers
--------------------------------------------------------------------
```

Some NUC have different Interface name.
So you need to check your NUC's interface name using 'ip a' command.

#2 - NUC: Network Configuration (1/3)
- Network interface (공유기 안쓰는 학생들 - 실험실)

```
~~$sudo apt install ifupdown~~
$sudo vi /etc/network/interfaces
----------------- /etc/network/interfaces -----------------
auto lo
iface lo inet loopback

auto eno1
iface eno1 inet static
          address    172.XXX.XXX.XXX  <- Input your given IP address
          netmask    255.255.255.0
          gateway    172.xxx.x.x  <- Input your given gateway
          dns-nameservers 8.8.8.8   <- Input your given dns-nameservers
--------------------------------------------------------------
```

Some NUC have different Interface name.
So you need to check your NUC's interface name using 'ip a' command.

#2 - NUC: Network Configuration (1/3)

- Network interface

```
$ sudo su
#ifdown --force enp0s3 lo && ifup -a
#systemctl unmask networking
#systemctl enable networking
#systemctl restart networking
```

Disable netplan

```
#systemctl stop systemd-networkd.socket systemd-networkd \
networkd-dispatcher systemd-networkd-wait-online
#systemctl disable systemd-networkd.socket systemd-networkd \
networkd-dispatcher systemd-networkd-wait-online
#systemctl mask systemd-networkd.socket systemd-networkd \
networkd-dispatcher systemd-networkd-wait-online
#apt-get --assume-yes purge nplan netplan.io
#exit
```

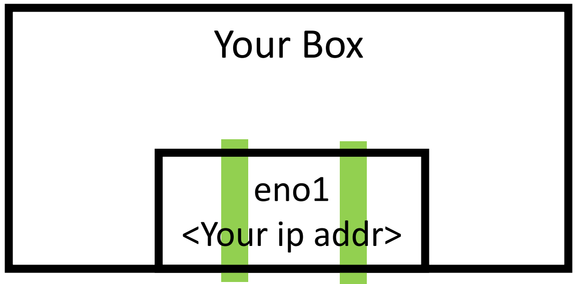
#2 - NUC: Network Configuration (1/3)

- eno1 interface

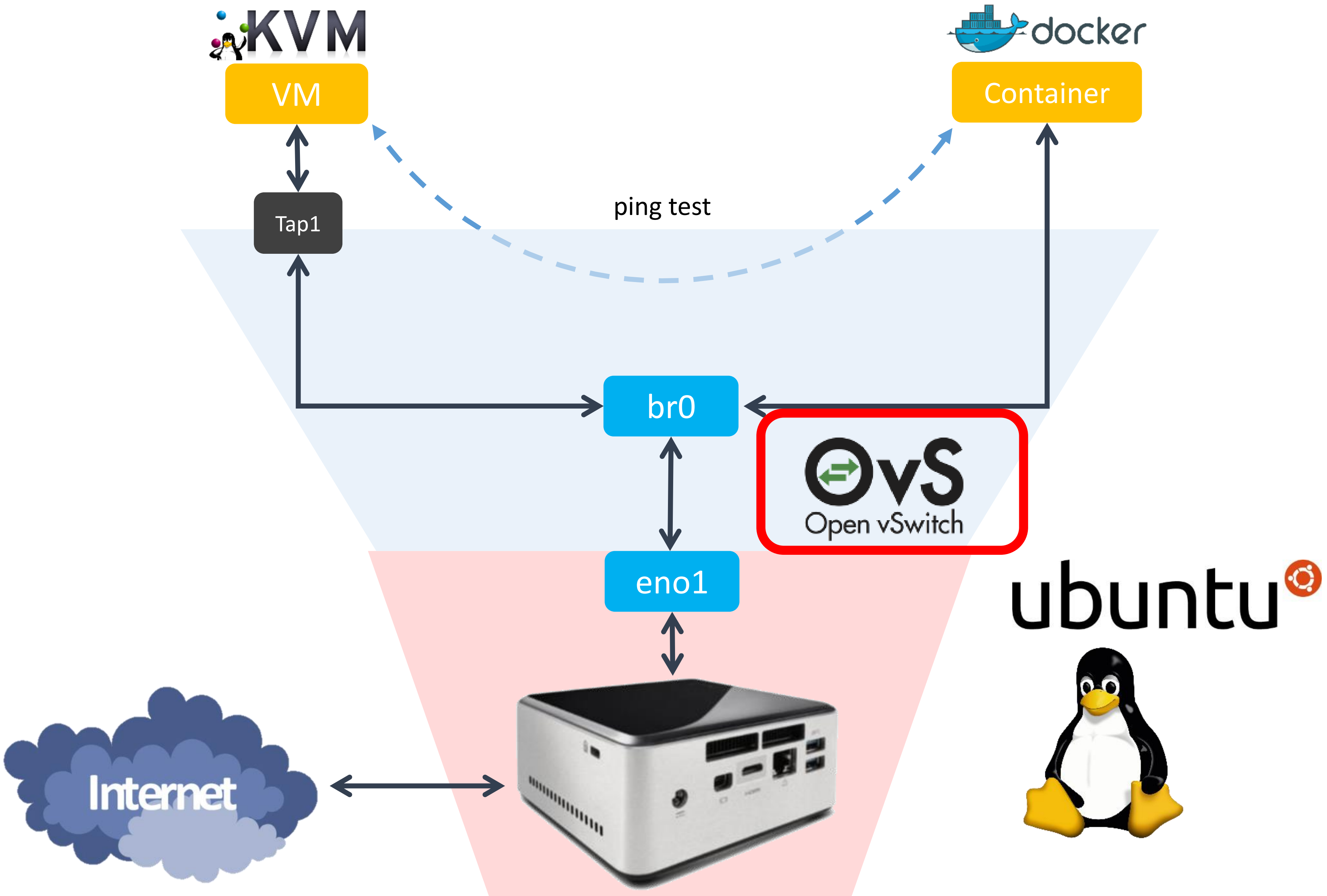
```
$ sudo vi /etc/systemd/resolved.conf

----------------- /etc/systemd/resolved.conf -----------------
…
DNS = 8.8.8.8 8.8.4.4
…
----------------------------------------------------------------
```

```
$sudo systemctl restart systemd-resolved.service
$sudo ifup eno1
```

NUC internet works!



#3 - NUC: OVS installation



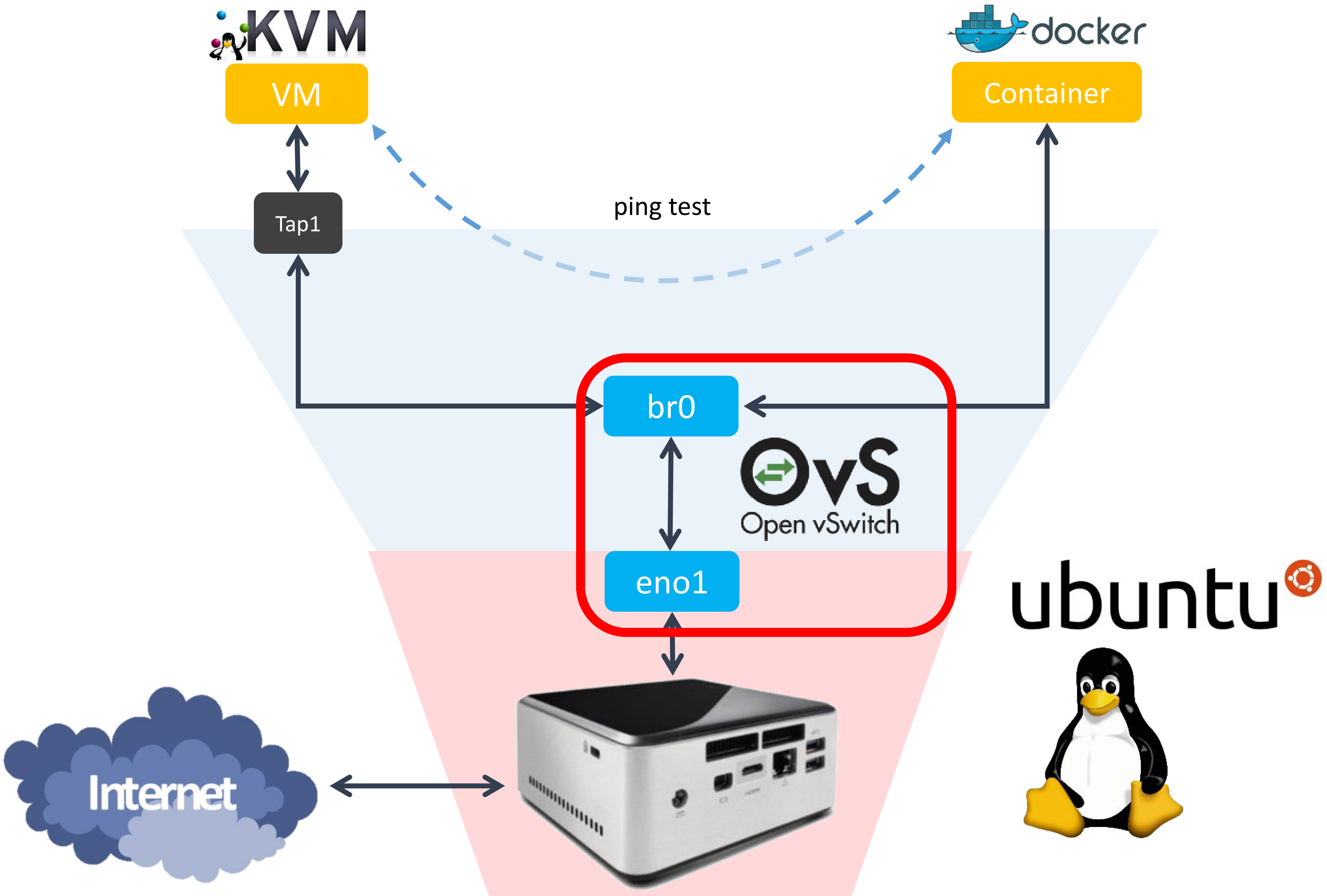
#3 - NUC: OVS installation

- Update installation of OVS package

Update index information of Open vSwitch package.
Install a Open vSwitch package, openvswitch-switch.
Other dependencies are automatically installed.

```
$sudo apt update
$sudo apt install openvswitch-switch
```

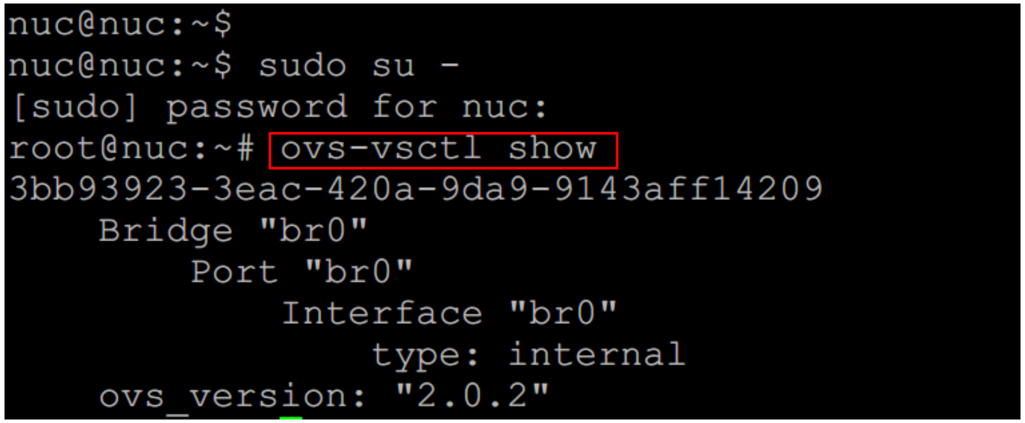
#4 - NUC: Network Configuration (2/3)



#4 - NUC: Network Configuration (2/3)

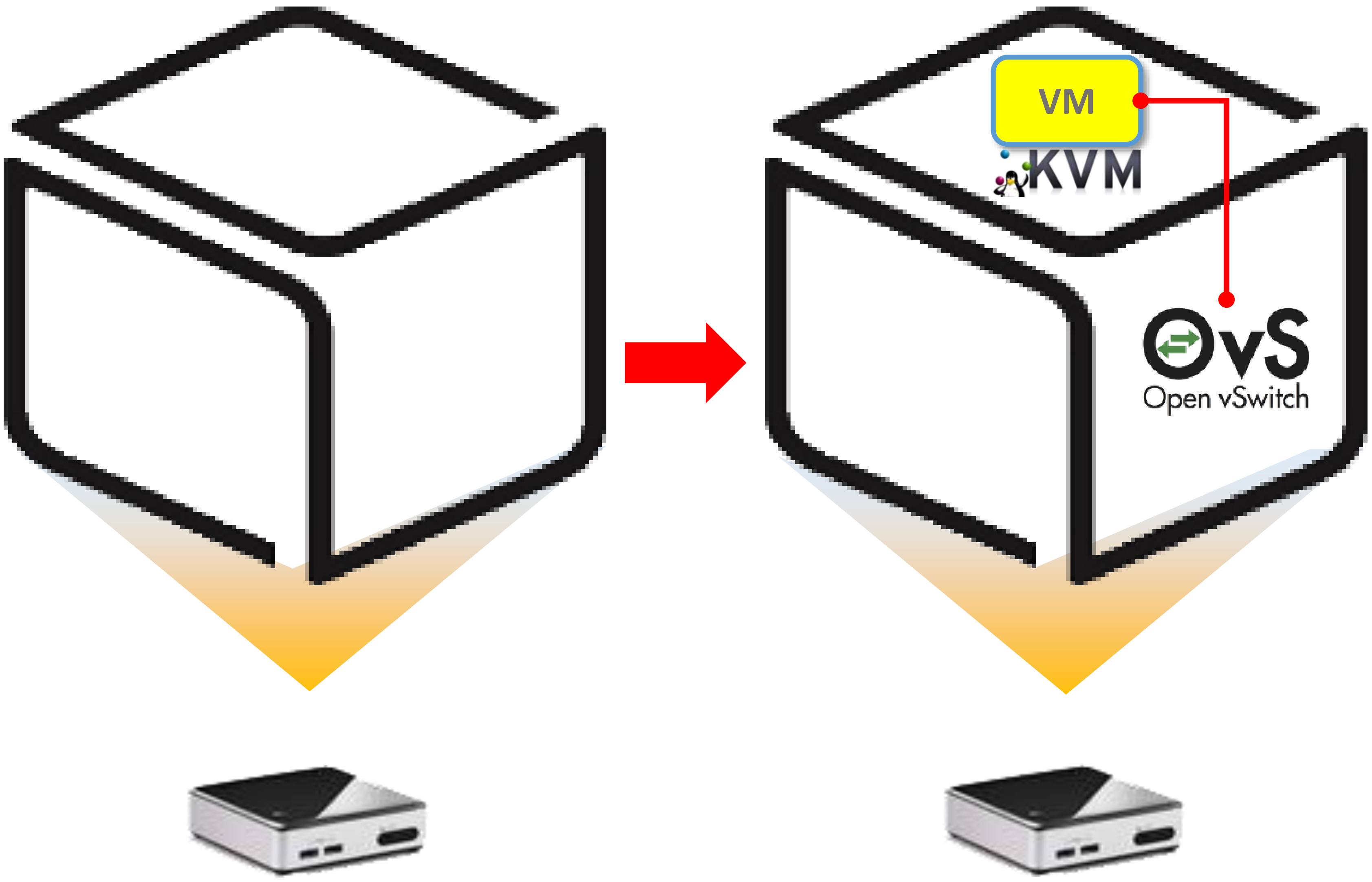
- Connect OVS br0 and NUC eno1 via OVS

$sudo ovs-vsctl add-br br0

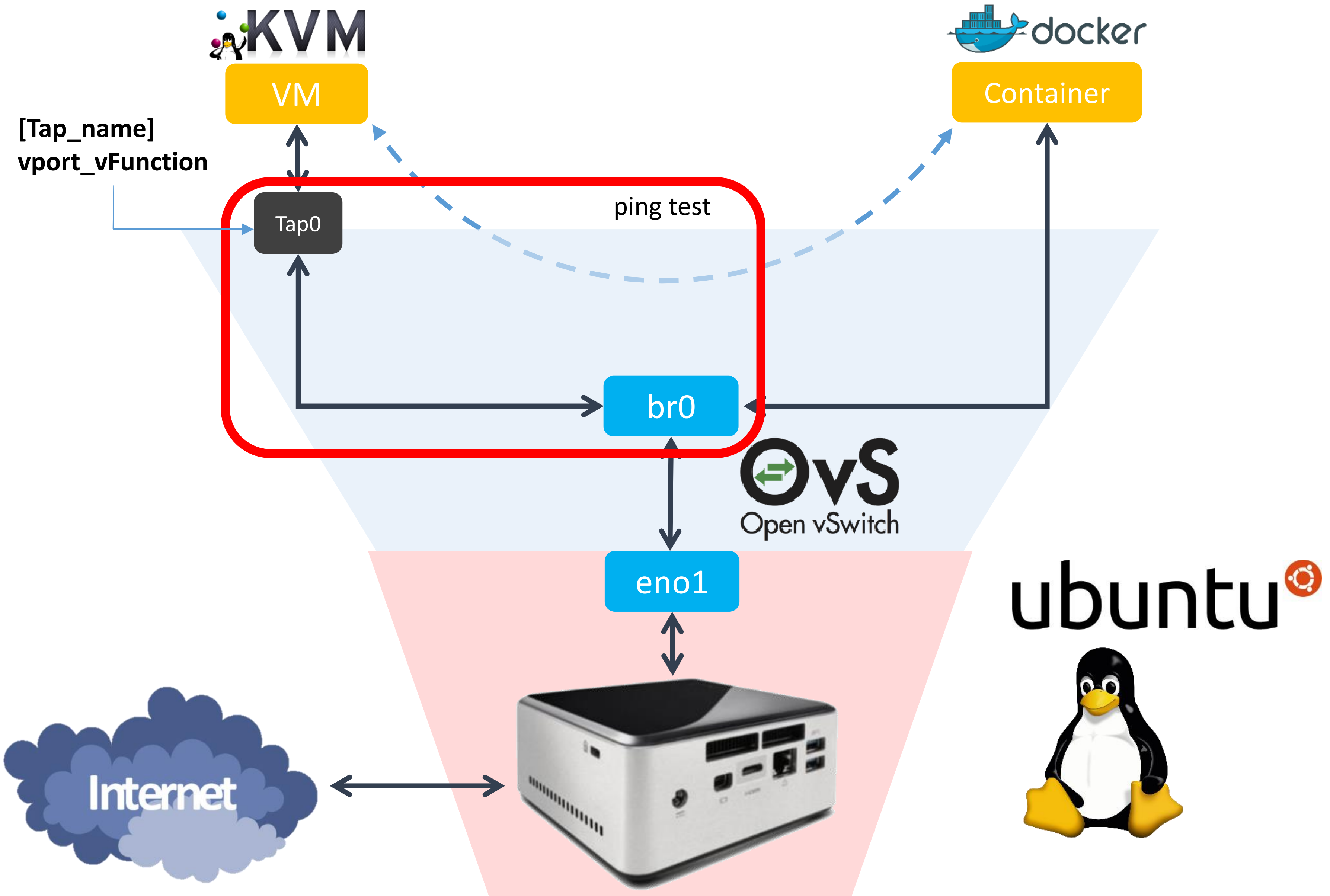


```
nuc@nuc:~$
nuc@nuc:~$ sudo su -
[sudo] password for nuc:
root@nuc:~# ovs-vsctl show
3bb93923-3eac-420a-9da9-9143aff14209
    Bridge "br0"
        Port "br0"
            Interface "br0"
                type: internal
    ovs_version: "2.0.2"
```

KVM-based VM connected via OVS
- Goal of this section



#5 - NUC: Network Configuration (3/3)



#5 - NUC: Network Configuration (3/3)

- Connect OVS tap0 & br0 through OVS

Let's make a tap interface and attach it to your VM.

```
$sudo vi /etc/network/interfaces

---------------- /etc/network/interfaces ----------------
…
(Append the lines below to the config file)

auto vport_vFunction
iface vport_vFunction inet manual
        pre-up ip tuntap add vport_vFunction mode tap
        up ip link set dev vport_vFunction up
        post-down ip link del dev vport_vFunction

auto br0
iface br0 inet manual
        address 192.168.100.1
        netmask 255.255.255.0
```

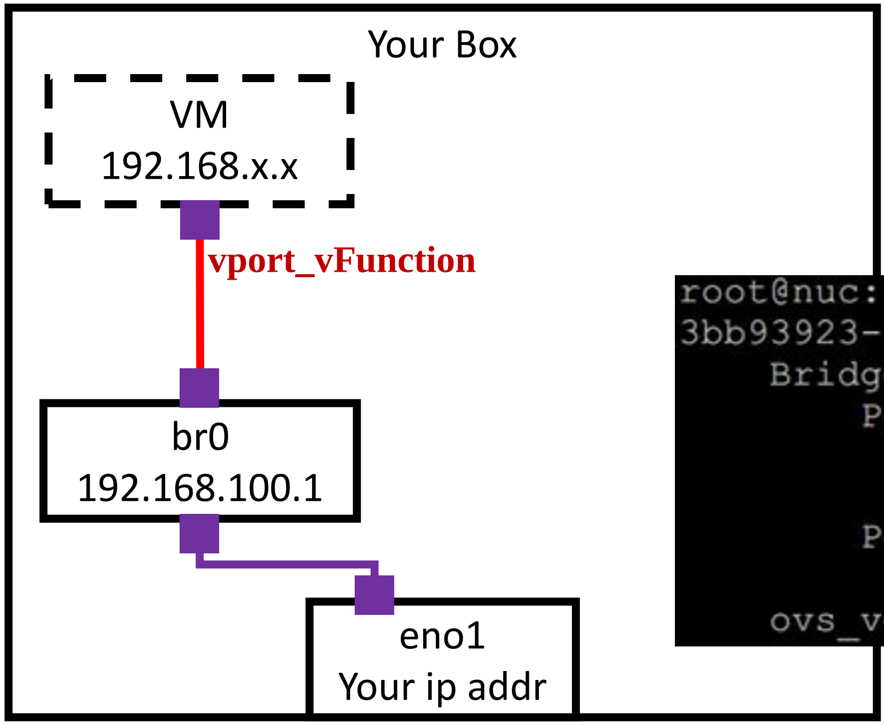
#5 - NUC: Network Configuration (3/3)

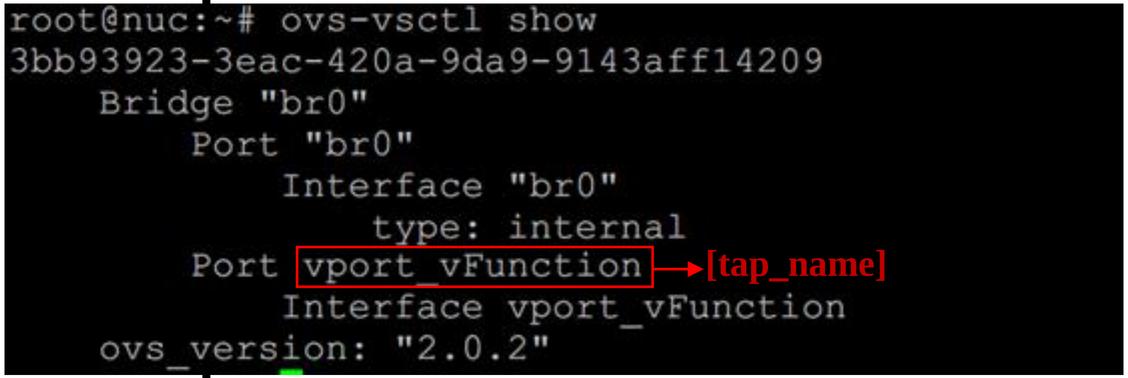
-Connect vport_vFunction, br0 through OVS

Turn on the tap interface and attach it to br0.

```
$sudo ifup vport_vFunction
$sudo ifup br0
$sudo ovs-vsctl add-port br0 vport_vFunction      // Turn on and attach to br0
```

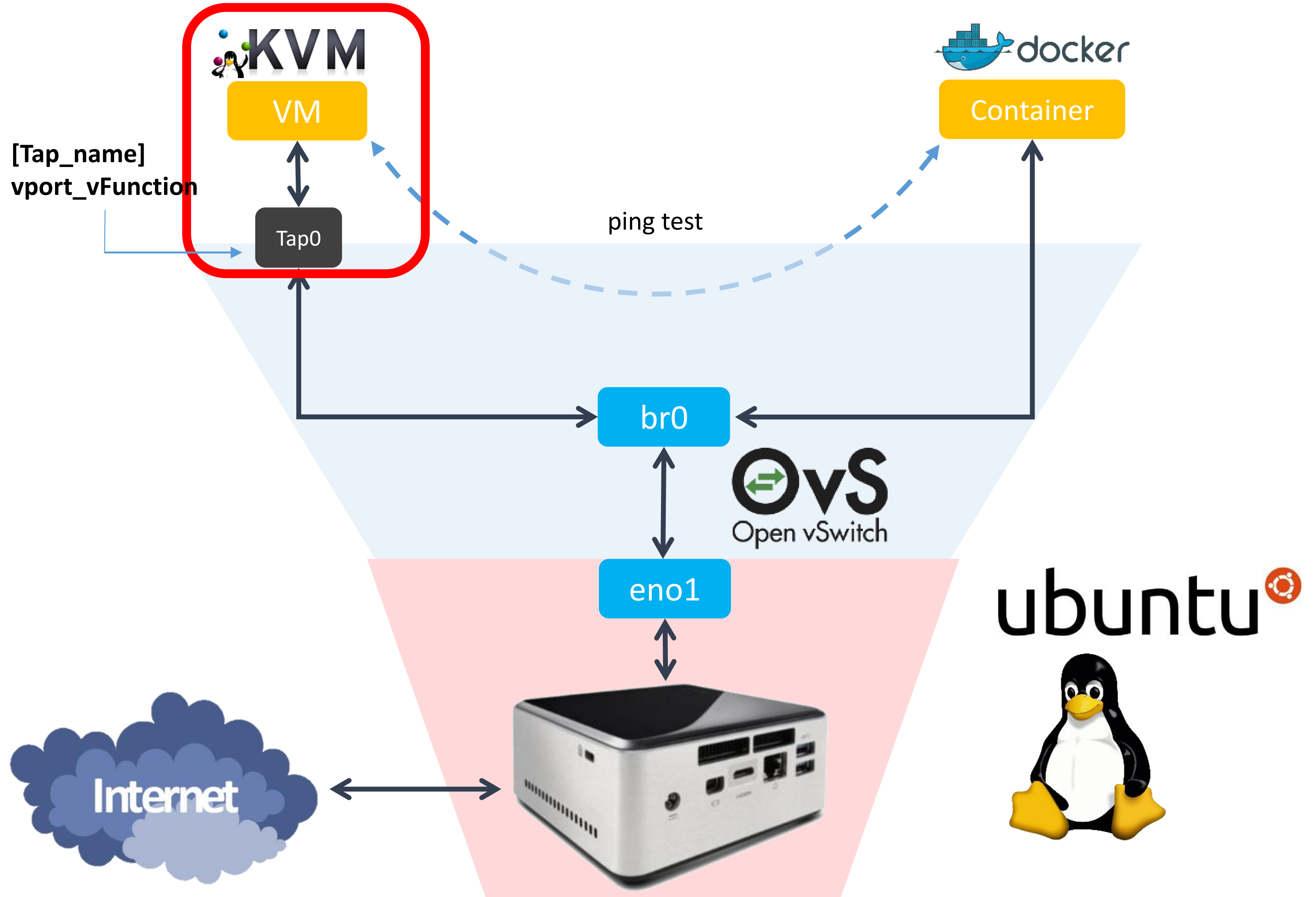
We should make VM attaching vport_vFunction. You can think this tap as a NIC of VM.





```
root@nuc:~# ovs-vsctl show
3bb93923-3eac-420a-9da9-9143aff14209
    Bridge "br0"
        Port "br0"
            Interface "br0"
                type: internal
        Port vport_vFunction
            Interface vport_vFunction
    ovs_version: "2.0.2"
```

#6 - NUC: Making VM with KVM



#6 - NUC: Making VM with KVM

-Install dependency to upgrade KVM

Install dependency & download Ubuntu 16.04.4 64bit server image.

```
$sudo apt-get install qemu-kvm libvirt-bin          //upgrade KVM
                                                    //qemu is open-source emulator

$wget http://old-releases.ubuntu.com/releases/16.04.4/ubuntu-16.04.4-server-amd64.iso
```

Now we are ready to make VM. So continue the setting.

#6 - NUC: Making VM with KVM

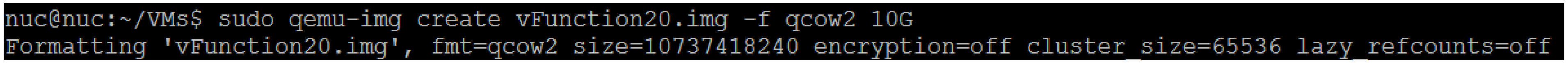
-Prepare for Ubuntu VM

Make a VM image.

```
$sudo qemu-img create [img_name].img -f qcow2 [storage_capacity]
```

```
$sudo qemu-img create vFunction20.img -f qcow2 10G
```

Result..



```
nuc@nuc:~/VMs$ sudo qemu-img create vFunction20.img -f qcow2 10G
Formatting 'vFunction20.img', fmt=qcow2 size=10737418240 encryption=off cluster_size=65536 lazy_refcounts=off
```

Boot VM image from Ubuntu iso file (mac should be different from others).

```
$sudo kvm -m [memory_capacity] -name [vm_name] -smp cpus=[#cpu],maxcpus= [#maxcpu] -
device virtio-net-pci,netdev=net0,mac= [EE:EE:EE:EE:EE:EE] -netdev tap,id=net0,ifname=
[tap_name],script=no -boot d [img_name].img -cdrom ubuntu-16.04.4-server-amd64.iso -vnc :[#]
–daemonize -monitor telnet:127.0.0.1:3010,server,nowait,ipv4
```

```
$ sudo kvm -m 512 -name tt -smp cpus=2,maxcpus=2 -device virtio-net-pci,netdev=net0 -netdev
tap,id=net0,ifname=vport_vFunction,script=no -boot d vFunction20.img -cdrom ubuntu-16.04.4-server-amd64.iso -vnc :5 -
daemonize -monitor telnet:127.0.0.1:3010,server,nowait,ipv4
```

Install VNC viewer and see inside of VM

```
$sudo apt-get install xvnc4viewer
$xvnc4viewer localhost :5
```

#6 - NUC: Making VM with KVM

-Prepare for Ubuntu VM

Configure SNAT with iptables for VM network

```
$sudo iptables –A FORWARD –i eno1 –j ACCEPT
$sudo iptables –A FORWARD –o eno1 –j ACCEPT
$sudo iptables –t nat –A POSTROUTING –s 192.168.100.0/24 \
–o eno1 –j SNAT --to <Your ip address>
```

```
$vi /etc/sysctl.conf

#net.ipv4.ip_forward=1
```

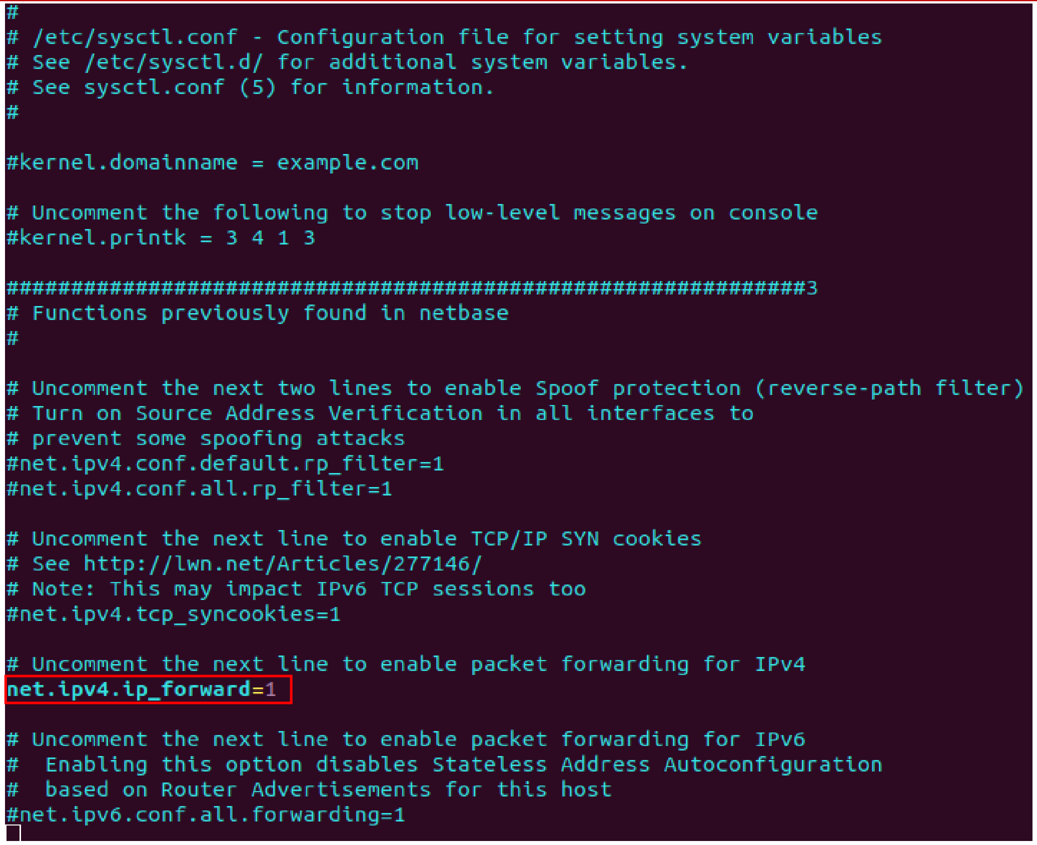
$\downarrow$

```
net.ipv4.ip_forward=1
```

```
$sysctl –p
```

$\rightarrow$ net.ipv4.ip_forward = 1

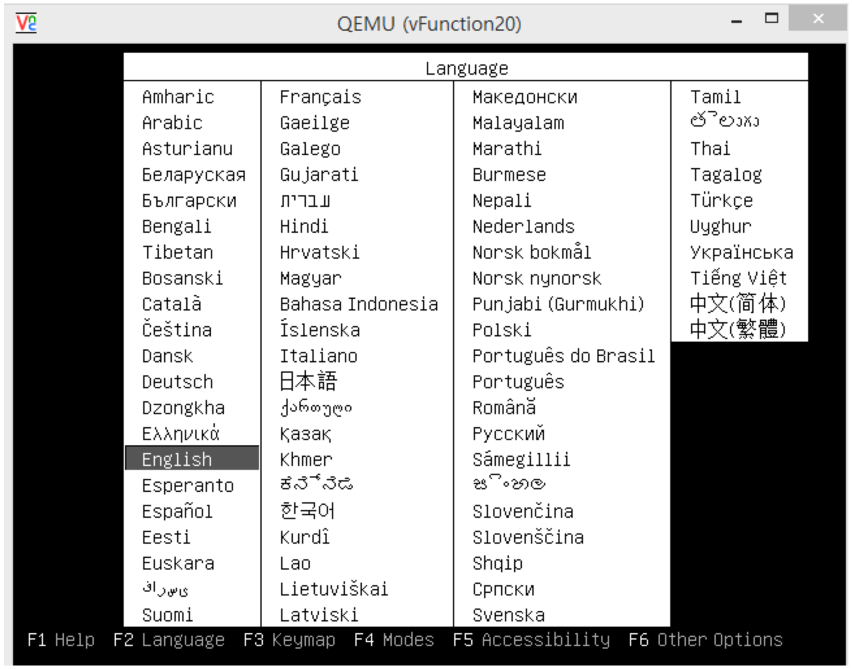
Configuration complete



```
#
# /etc/sysctl.conf - Configuration file for setting system variables
# See /etc/sysctl.d/ for additional system variables.
# See sysctl.conf (5) for information.
#

#kernel.domainname = example.com

# Uncomment the following to stop low-level messages on console
#kernel.printk = 3 4 1 3

##############################################################3
# Functions previously found in netbase
#

# Uncomment the next two lines to enable Spoof protection (reverse-path filter)
# Turn on Source Address Verification in all interfaces to
# prevent some spoofing attacks
#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
```

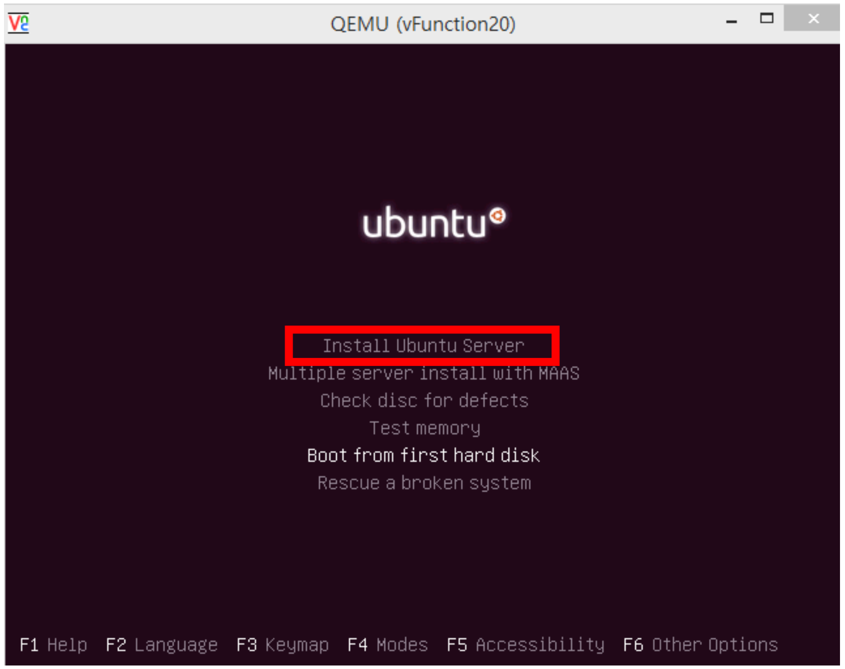
#6 - NUC: Making VM with KVM

-Install Ubuntu VM



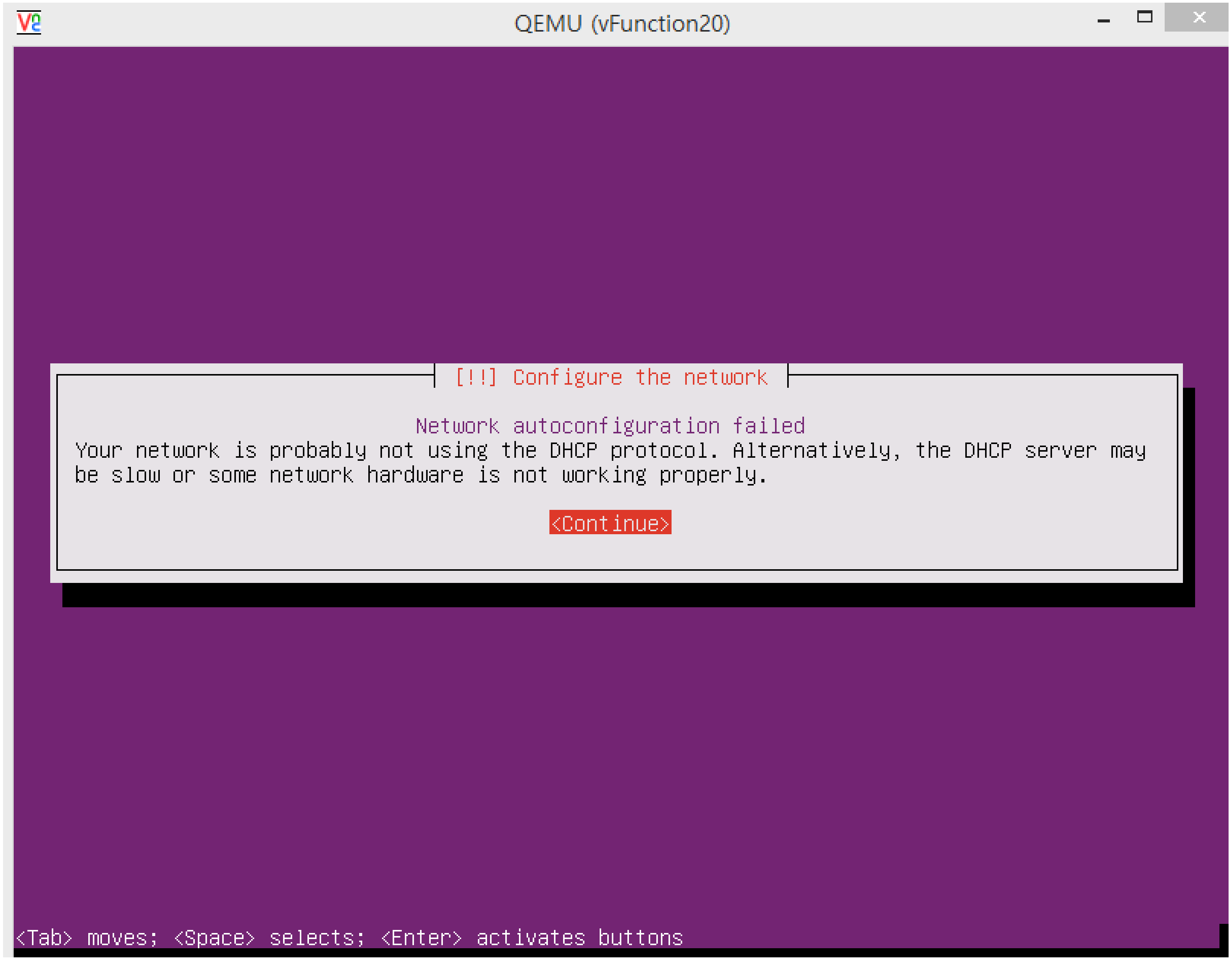
QEMU (vFunction20)

```
Language
Amharic        Français          Македонски            Tamil
Arabic         Gaeilge           Malayalam             తెలుగు
Asturianu      Galego            Marathi               Thai
Беларуская     Gujarati          Burmese               Tagalog
Български      עברית             Nepali                Türkçe
Bengali        Hindi             Nederlands            Uyghur
Tibetan        Hrvatski          Norsk bokmål          Українська
Bosanski       Magyar            Norsk nynorsk         Tiếng Việt
Català         Bahasa Indonesia  Punjabi (Gurmukhi)    中文(简体)
Čeština        Íslenska          Polski                中文(繁體)
Dansk          Italiano          Português do Brasil
Deutsch        日本語             Português
Dzongkha       ქართული           Română
Ελληνικά       Қазақ             Русский
English        Khmer             Sámegillii
Esperanto      ಕನ್ನಡ              සිංහල
Español        한국어             Slovenčina
Eesti          Kurdî             Slovenščina
Euskara        Lao               Shqip
فارسی          Lietuviškai       Српски
Suomi          Latviski          Svenska
F1 Help  F2 Language  F3 Keymap  F4 Modes  F5 Accessibility  F6 Other Options
```

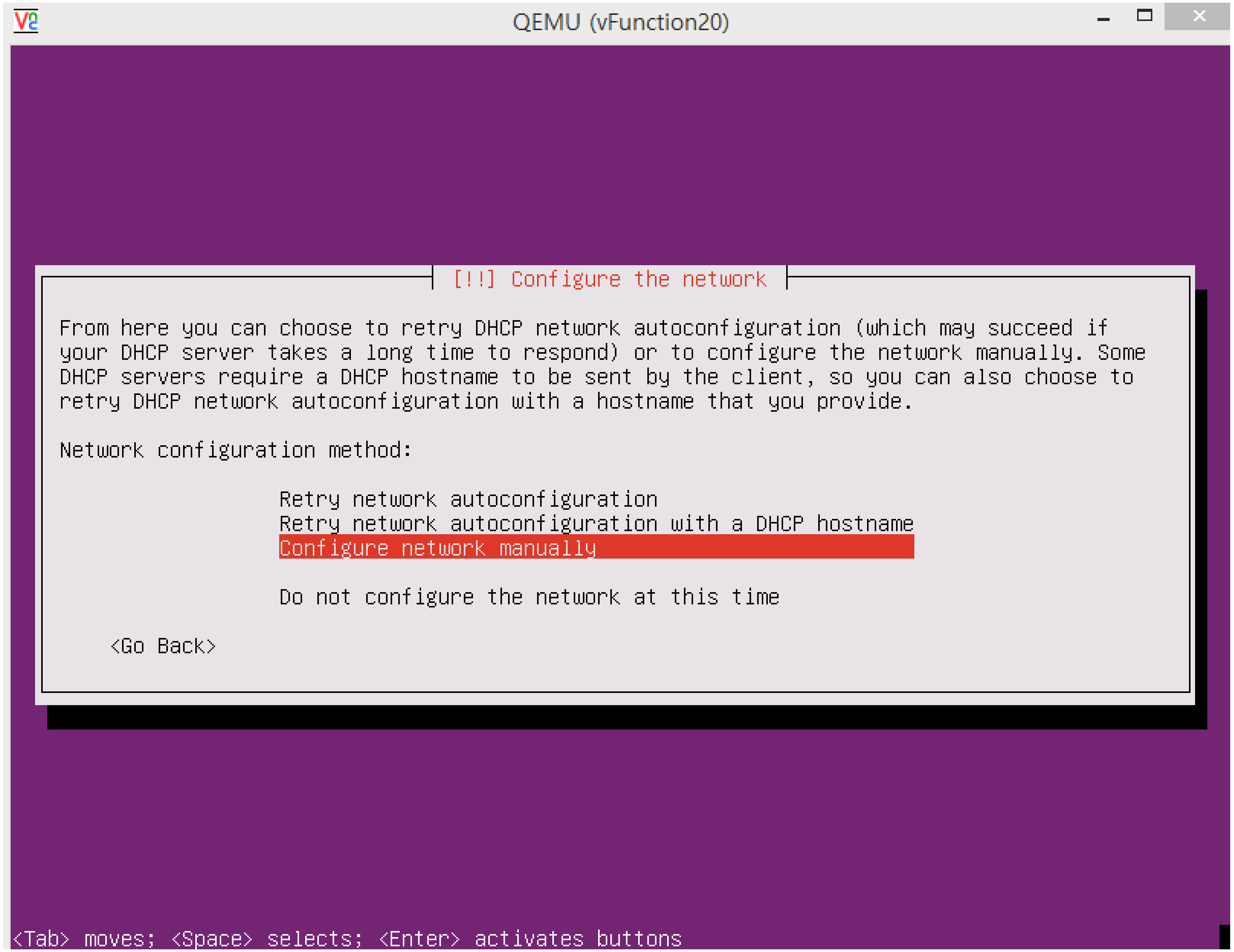


QEMU (vFunction20)

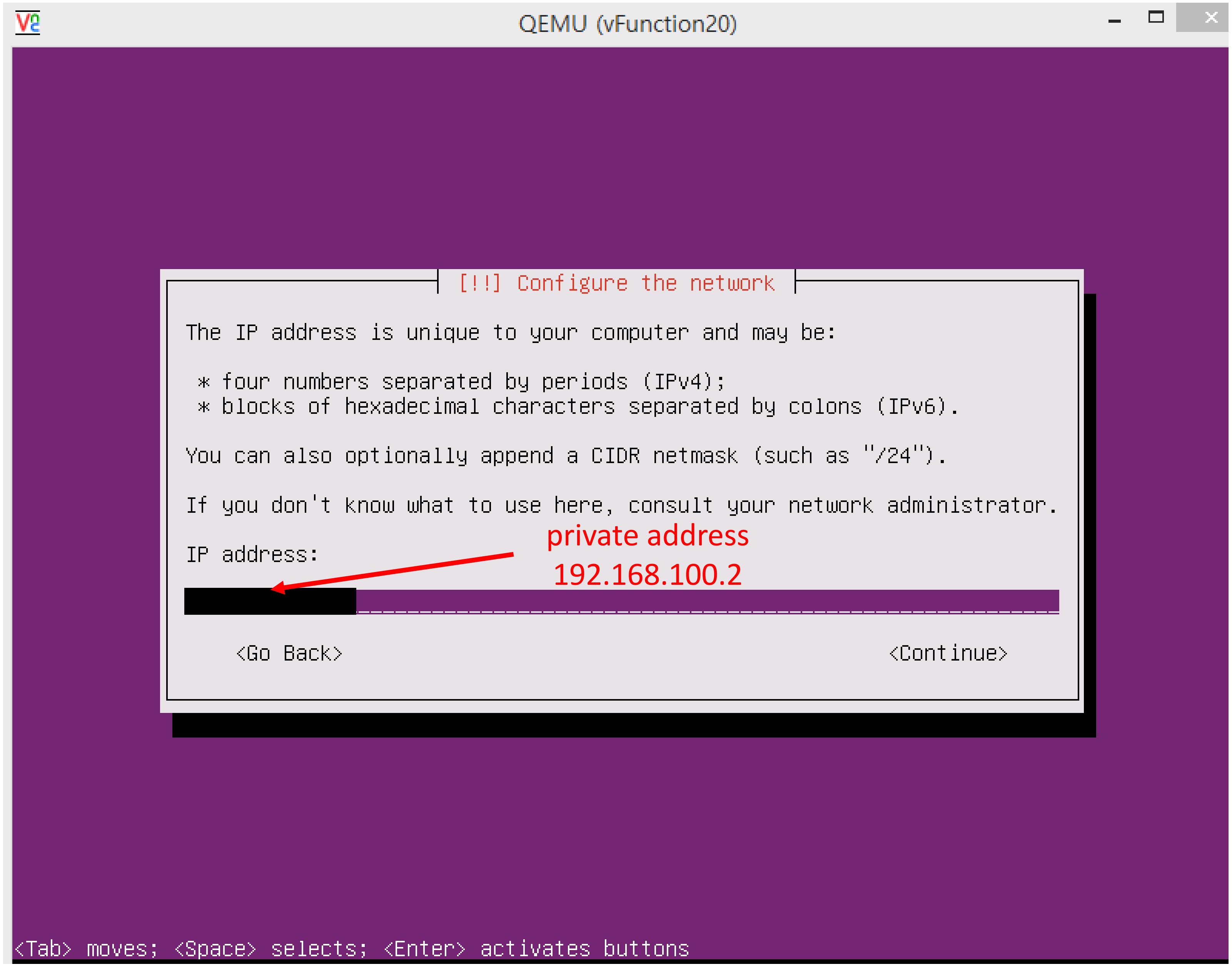
```
ubuntu

Install Ubuntu Server
Multiple server install with MAAS
Check disc for defects
Test memory
Boot from first hard disk
Rescue a broken system

F1 Help  F2 Language  F3 Keymap  F4 Modes  F5 Accessibility  F6 Other Options
```



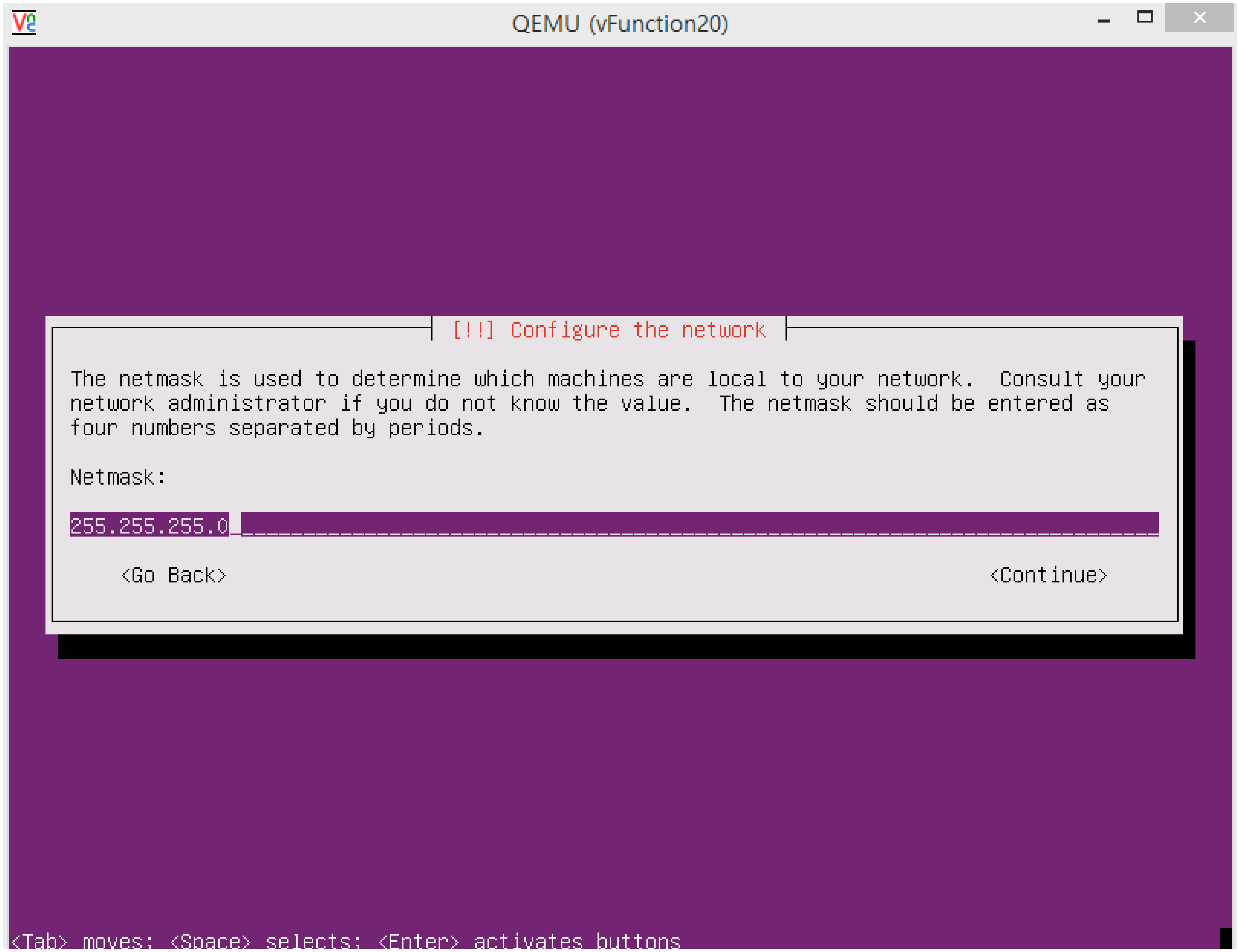
```
[!!] Configure the network

Network autoconfiguration failed
Your network is probably not using the DHCP protocol. Alternatively, the DHCP server may
be slow or some network hardware is not working properly.

<Continue>

<Tab> moves; <Space> selects; <Enter> activates buttons
```



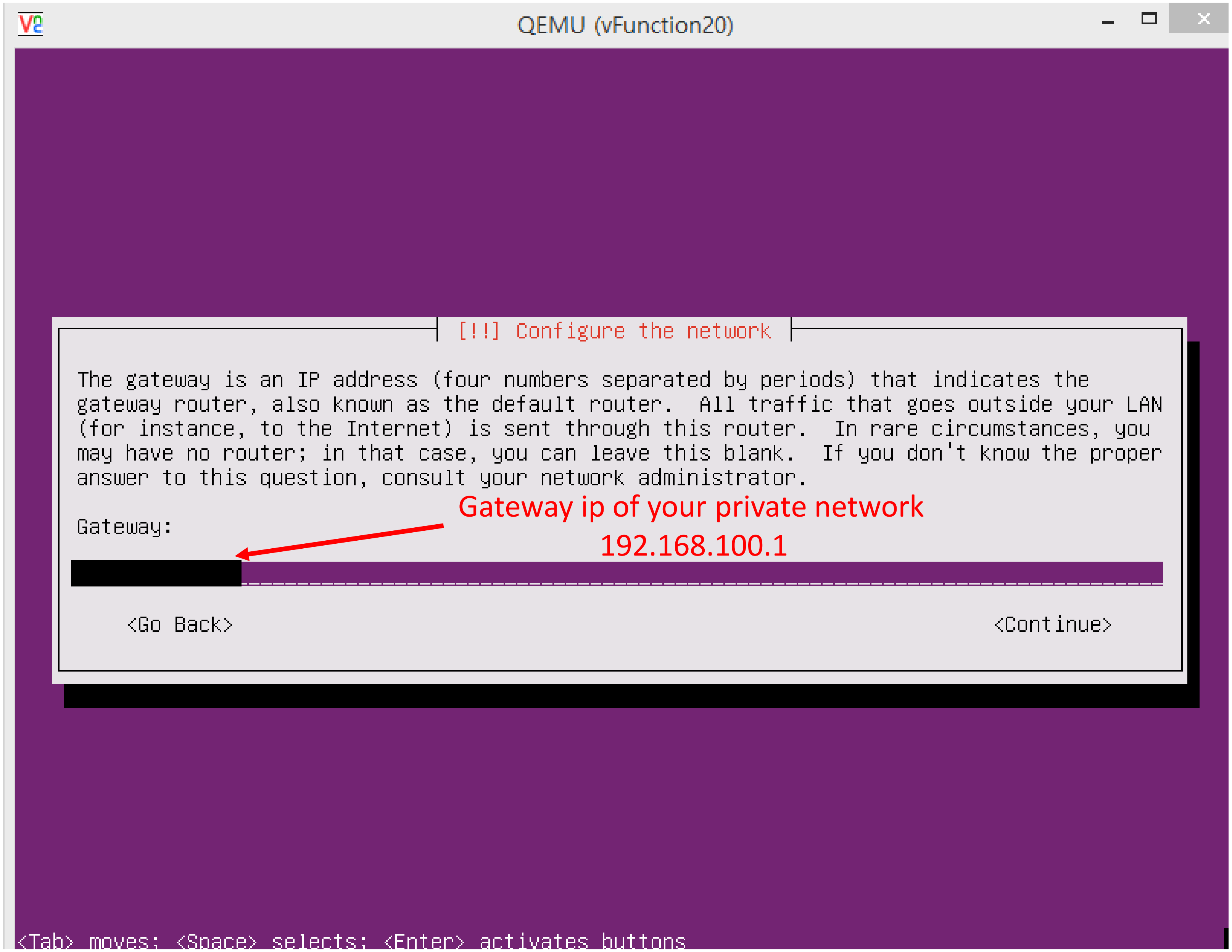
```
[!!] Configure the network

From here you can choose to retry DHCP network autoconfiguration (which may succeed if
your DHCP server takes a long time to respond) or to configure the network manually. Some
DHCP servers require a DHCP hostname to be sent by the client, so you can also choose to
retry DHCP network autoconfiguration with a hostname that you provide.

Network configuration method:

                  Retry network autoconfiguration
                  Retry network autoconfiguration with a DHCP hostname
                  Configure network manually

                  Do not configure the network at this time

    <Go Back>

<Tab> moves; <Space> selects; <Enter> activates buttons
```



```
QEMU (vFunction20)

[!!] Configure the network

The IP address is unique to your computer and may be:

 * four numbers separated by periods (IPv4);
 * blocks of hexadecimal characters separated by colons (IPv6).

You can also optionally append a CIDR netmask (such as "/24").

If you don't know what to use here, consult your network administrator.

IP address:

[redacted]___________________________________________________________

    <Go Back>                                          <Continue>

<Tab> moves; <Space> selects; <Enter> activates buttons
```



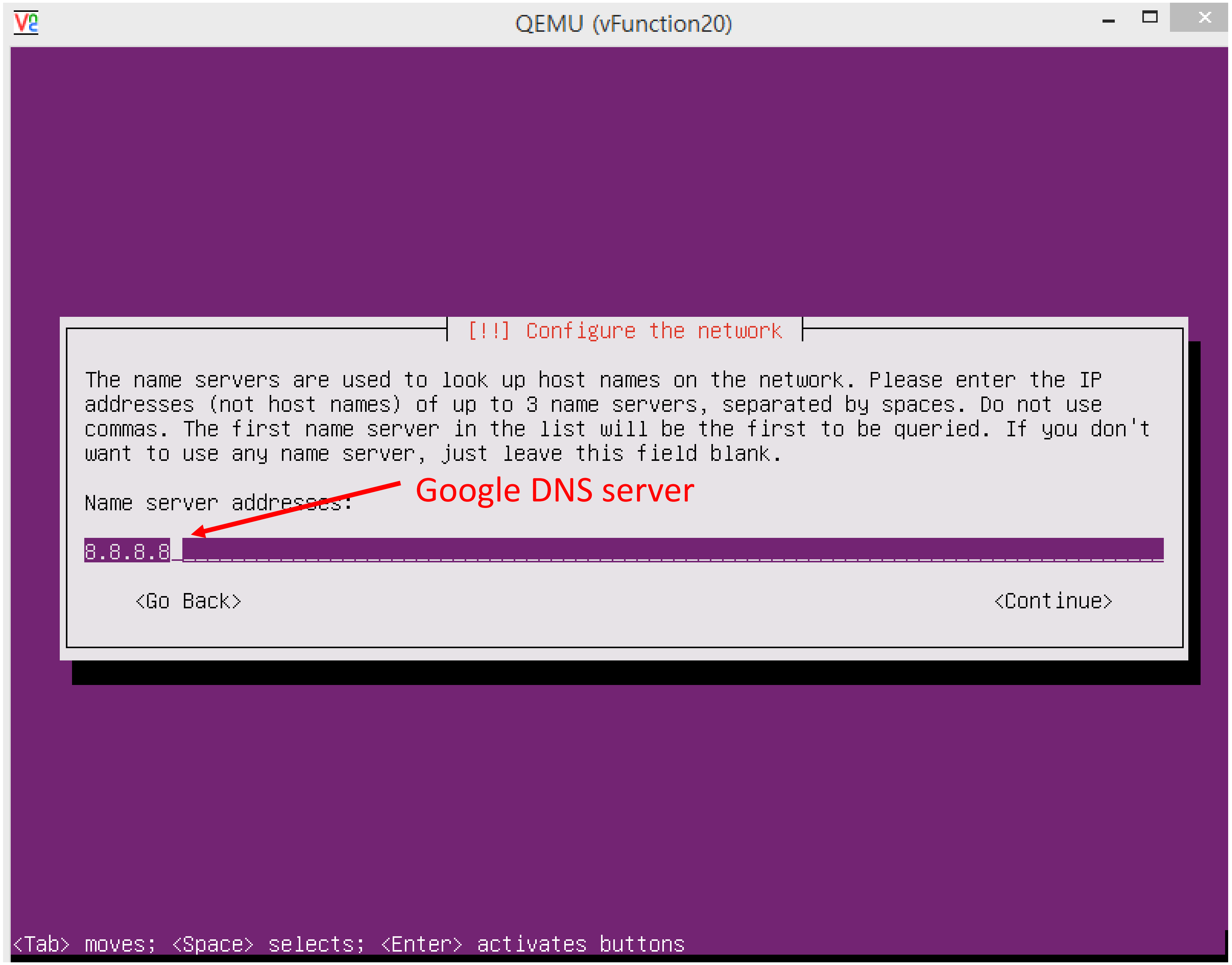
```
[!!] Configure the network

The netmask is used to determine which machines are local to your network.  Consult your
network administrator if you do not know the value.  The netmask should be entered as
four numbers separated by periods.

Netmask:

255.255.255.0

<Go Back>                                                       <Continue>

<Tab> moves; <Space> selects; <Enter> activates buttons
```



```
[!!] Configure the network

The gateway is an IP address (four numbers separated by periods) that indicates the
gateway router, also known as the default router.  All traffic that goes outside your LAN
(for instance, to the Internet) is sent through this router.  In rare circumstances, you
may have no router; in that case, you can leave this blank.  If you don't know the proper
answer to this question, consult your network administrator.

Gateway:

    <Go Back>                                                              <Continue>

<Tab> moves; <Space> selects; <Enter> activates buttons
```

Gateway ip of your private network

192.168.100.1



QEMU (vFunction20)

```
[!!] Configure the network

The name servers are used to look up host names on the network. Please enter the IP
addresses (not host names) of up to 3 name servers, separated by spaces. Do not use
commas. The first name server in the list will be the first to be queried. If you don't
want to use any name server, just leave this field blank.

Name server addresses:

8.8.8.8

     <Go Back>                                                       <Continue>

<Tab> moves; <Space> selects; <Enter> activates buttons
```

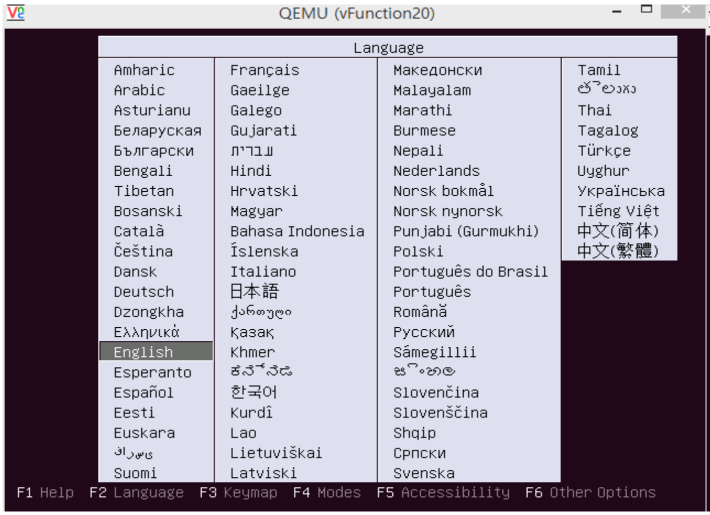
Google DNS server

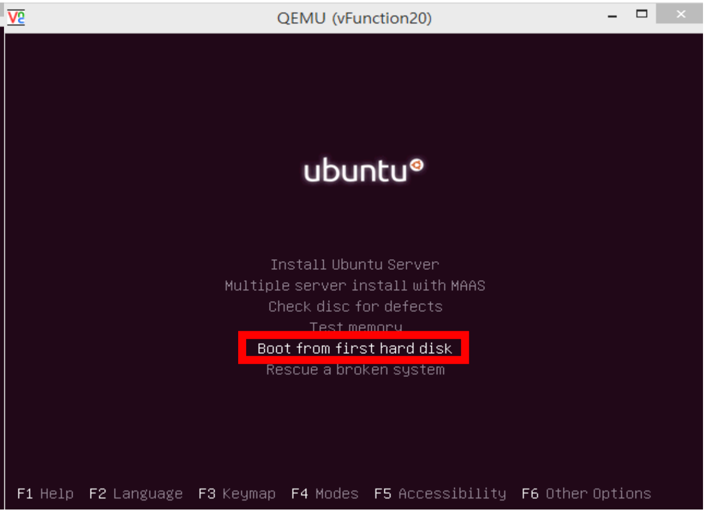
#6 - NUC: Making VM with KVM

- Eject Ubuntu install image

After installing Ubuntu Linux on the VM….
You need to eject Ubuntu install image before booting to the installed OS

```
$telnet localhost 3010
Trying 127.0.0.1...
Connected to localhost.Escape character is '^]‘ (Ctrl+]).

QEMU 0.11.0 monitor - type 'help' for more information
(qemu) eject ide1-cd0
(qemu) Ctrl+]

$ xvnc4viewer localhost :5
```




QEMU (vFunction20)
ubuntu
Install Ubuntu Server
Multiple server install with MAAS
Check disc for defects
Test memory
Boot from first hard disk
Rescue a broken system
F1 Help F2 Language F3 Keymap F4 Modes F5 Accessibility F6 Other Options

Push Esc

#7 - NUC: Booting VM

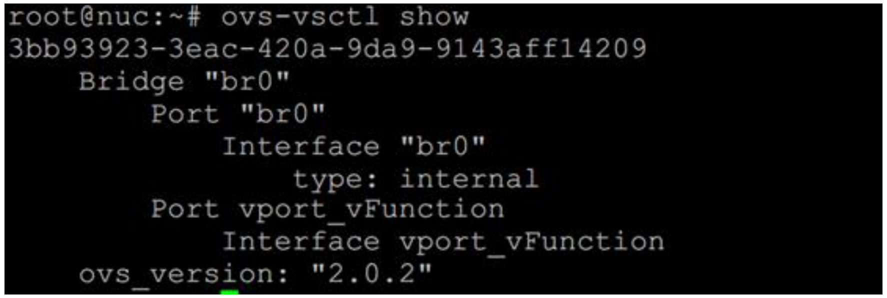
- VM boot command

If you want boot VM again (mac should be different from others).

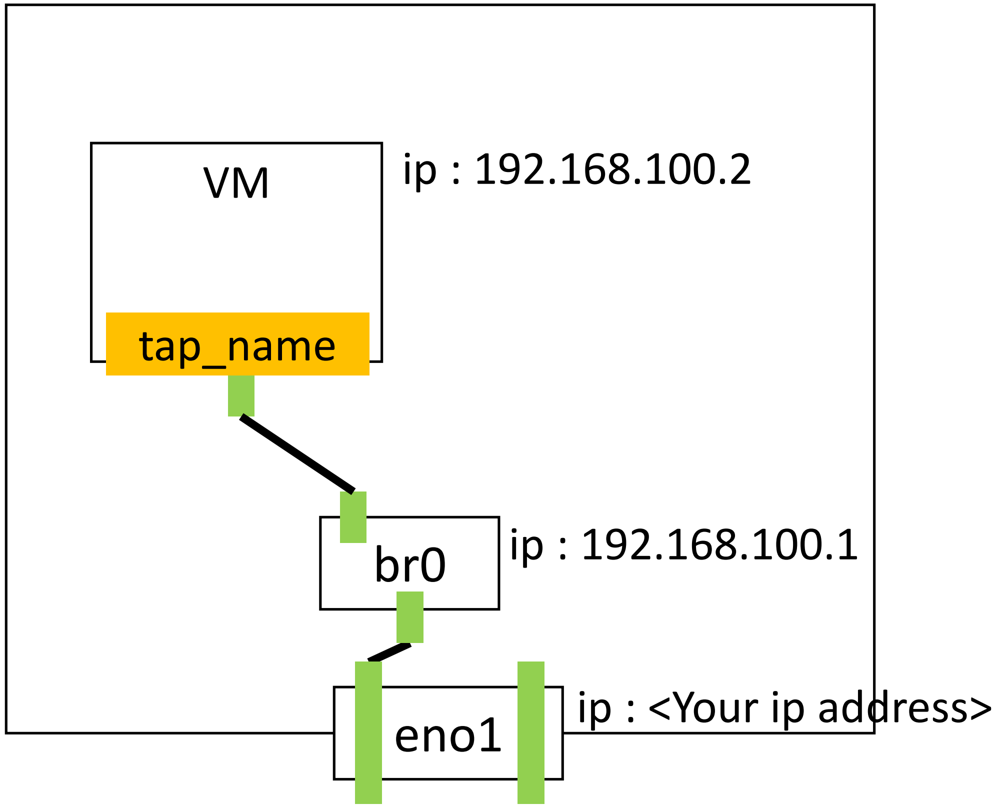
```
$sudo kvm -m [memory capacity] -name [name] -smp cpus=[#cpu],maxcpus= [#maxcpu] -device virtio-net-pci,netdev=net0,mac= [EE:EE:EE:EE:EE:EE] –netdev tap,id=net0,ifname= [tap_name],script=no -boot d [name].img -vnc : [#] -daemonize
```

#8 - OVS connects with KVM

- Check situation



```
root@nuc:~# ovs-vsctl show
3bb93923-3eac-420a-9da9-9143aff14209
    Bridge "br0"
        Port "br0"
            Interface "br0"
                type: internal
        Port vport_vFunction
            Interface vport_vFunction
    ovs_version: "2.0.2"
```

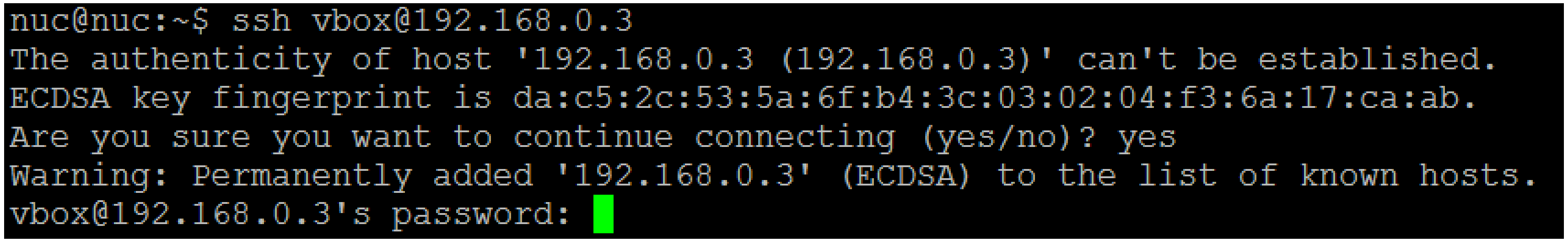


#9 - NUC: Installing ssh in VM

- Don’t forget to install ssh in VM

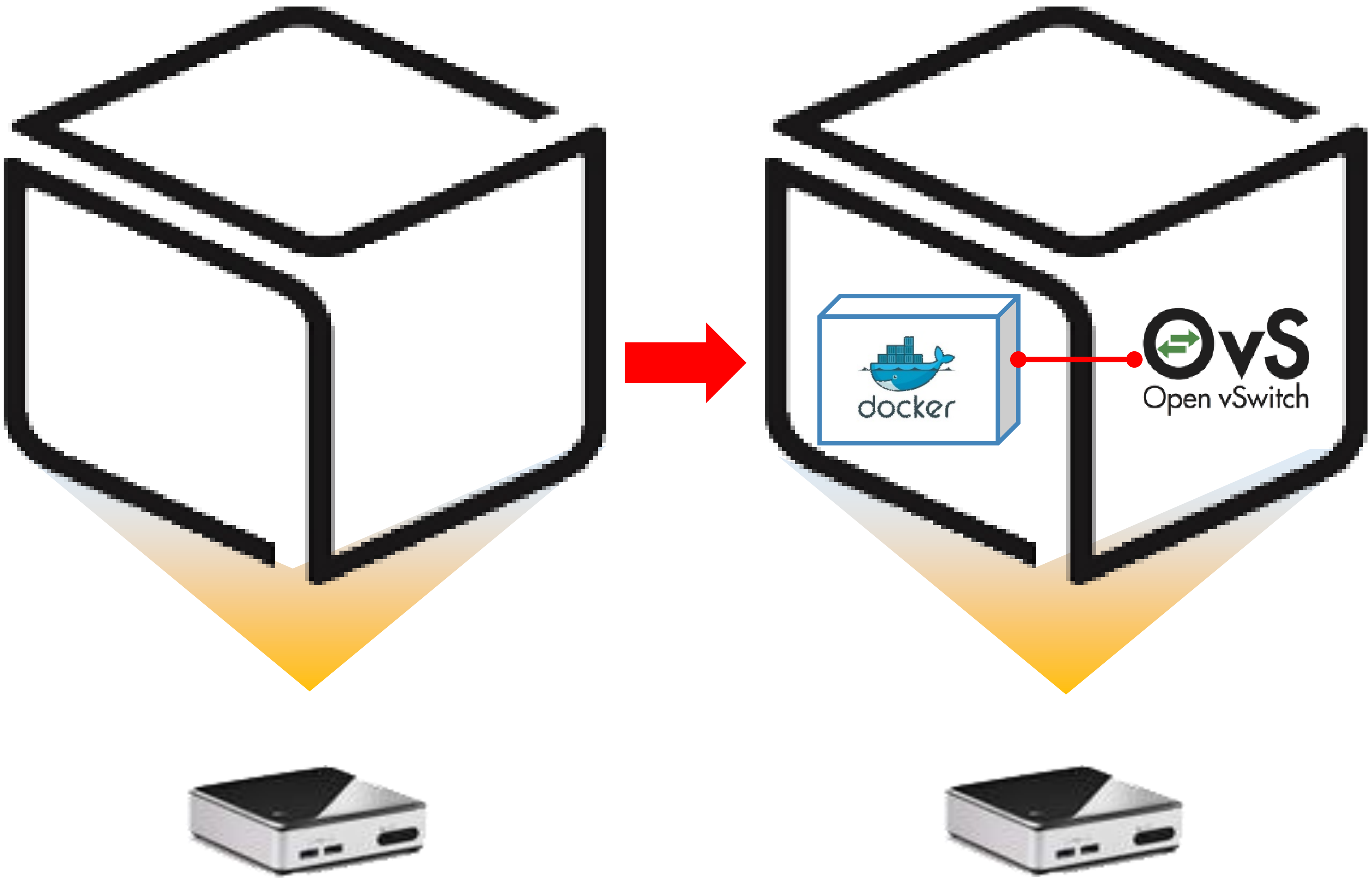
In VMs,

```
$sudo apt-get update
$sudo apt-get install net-tools ssh -y
```

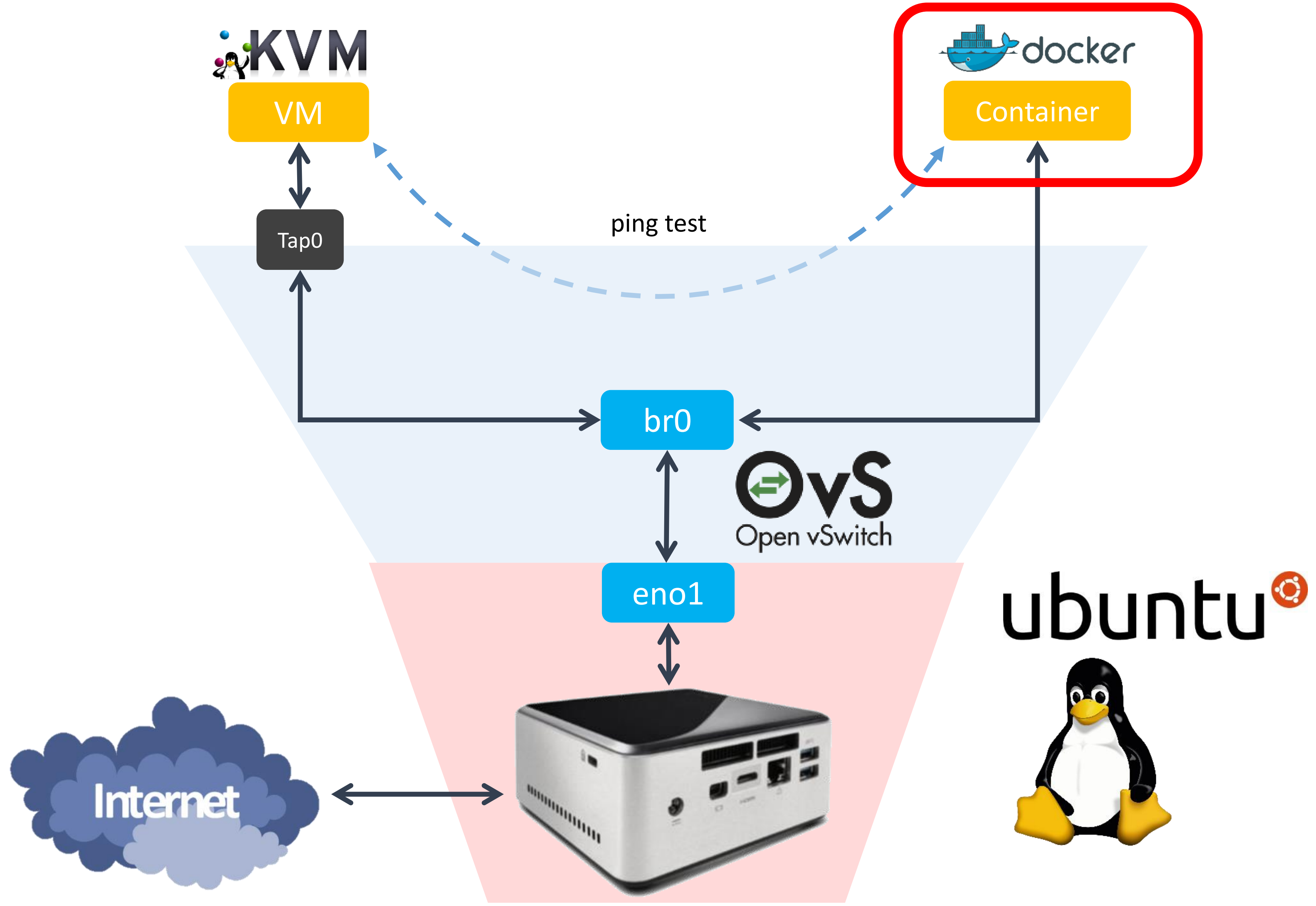


```
nuc@nuc:~$ ssh vbox@192.168.0.3
The authenticity of host '192.168.0.3 (192.168.0.3)' can't be established.
ECDSA key fingerprint is da:c5:2c:53:5a:6f:b4:3c:03:02:04:f3:6a:17:ca:ab.
Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added '192.168.0.3' (ECDSA) to the list of known hosts.
vbox@192.168.0.3's password:
```

Docker Container connected via OVS
- Goal of this section



#10 - Making a Docker Container



#10 - Making a Docker Container

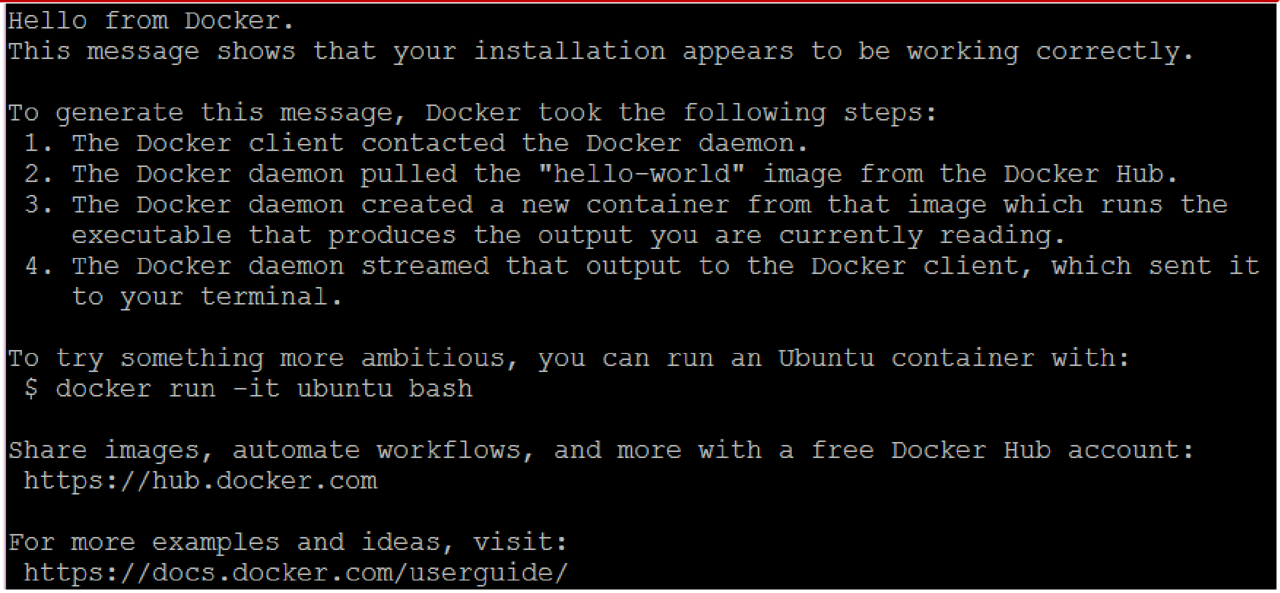
- Docker installation

Docker installation.

```
$sudo wget -qO- https://get.docker.com/ | sh
$sudo systemctl start docker
```
~~$sudo adduser [Your_account] docker~~

(Session restart)

```
$sudo docker run hello-world
```



```
Hello from Docker.
This message shows that your installation appears to be working correctly.

To generate this message, Docker took the following steps:
 1. The Docker client contacted the Docker daemon.
 2. The Docker daemon pulled the "hello-world" image from the Docker Hub.
 3. The Docker daemon created a new container from that image which runs the
    executable that produces the output you are currently reading.
 4. The Docker daemon streamed that output to the Docker client, which sent it
    to your terminal.

To try something more ambitious, you can run an Ubuntu container with:
 $ docker run -it ubuntu bash

Share images, automate workflows, and more with a free Docker Hub account:
 https://hub.docker.com

For more examples and ideas, visit:
 https://docs.docker.com/userguide/
```

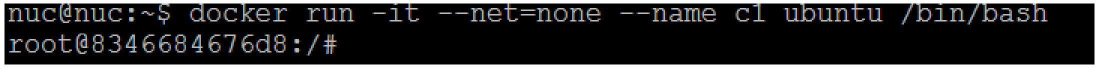
reference: http://docs.docker.com/linux/step_one/

#10 - Making a Docker Container

- Make container

Run docker container.

```
$sudo docker run -it --net=none --name [container_name] ubuntu /bin/bash
```

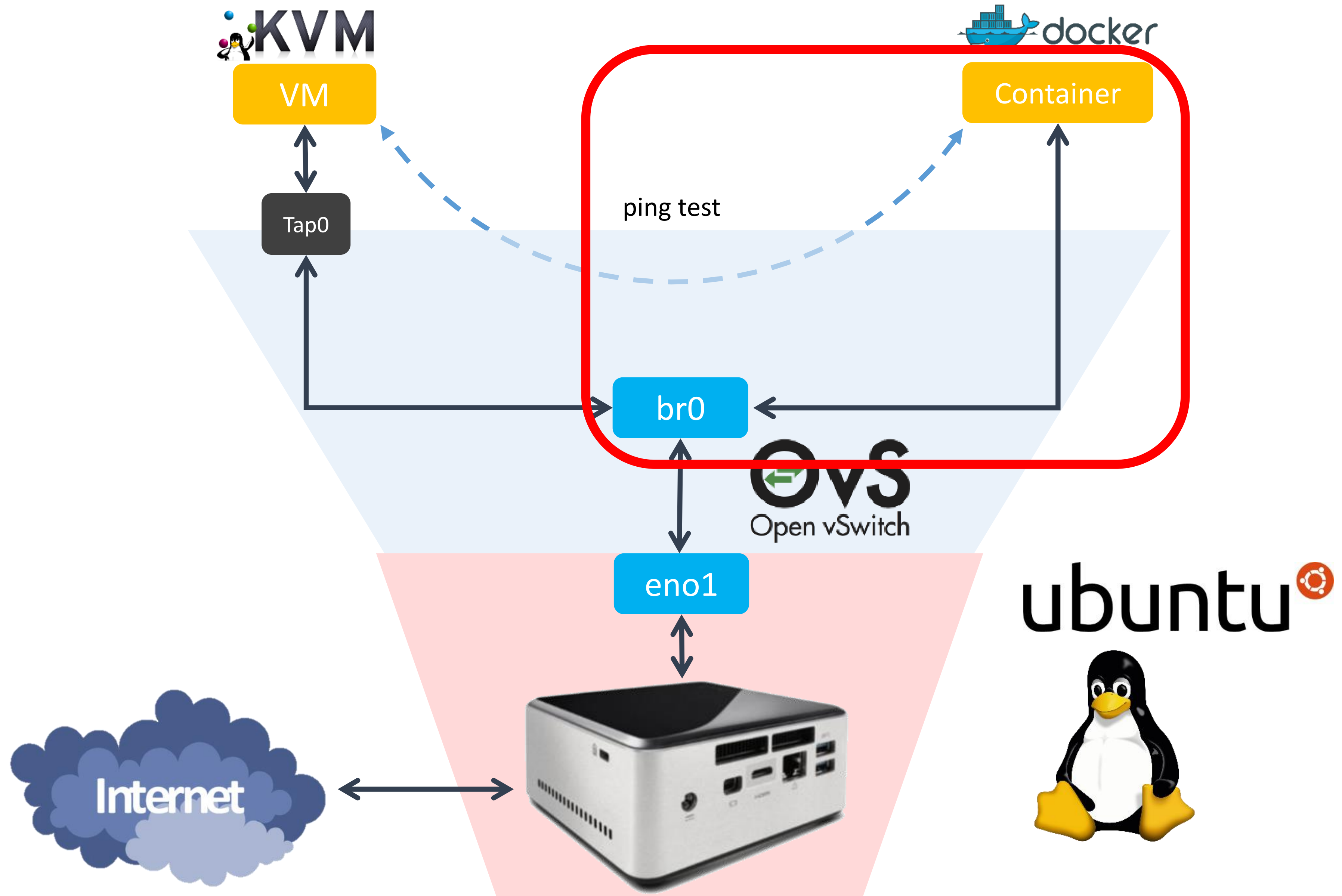


```
nuc@nuc:~$ docker run -it --net=none --name c1 ubuntu /bin/bash
root@8346684676d8:/#
```

※ctrl + p, q → detach docker container
※docker attach [container_name] → get into docker container console

#11 - Connect Docker Container

- Connect with OVS bridge



#11 - Connect docker Container

- Connect with OVS bridge

Install OVS-docker utility in host machine. (Not in inside of Docker container.)

```
$sudo ovs-docker add-port br0 eno2 [container_name] --ipaddress=192.168.100.3/24 --gateway=192.168.100.1


$sudo docker attach [container_name]
#apt-get update
#apt-get install net-tools
#apt-get install iputils-ping
```

#12 – Keep Docker network configuration

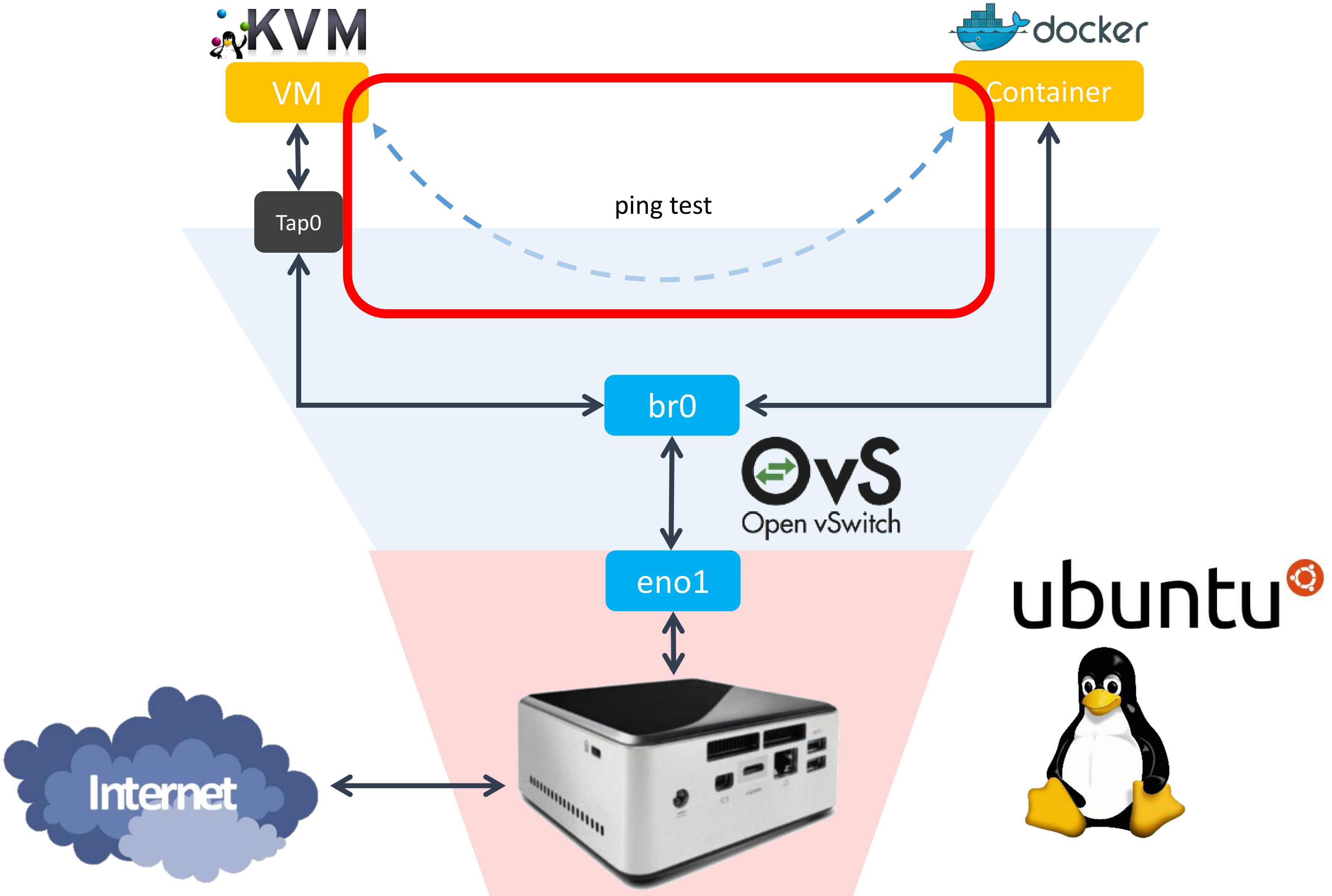
- /etc/rc.local

Modify /etc/rc.local

```
$sudo vi /etc/rc.local

docker start [container_name]
OVS-docker del-port br0 eno1 [containerName]
OVS-docker add-port br0 eno1 [containerName] --ipaddress=[IP_address/24] --gateway=[Gateway_address]
```

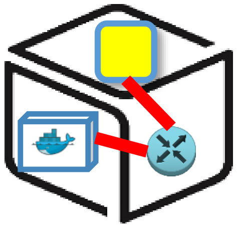
Whenever NUC is rebooted,
network configuration of Docker container is initialized
by executing commands in rc.local

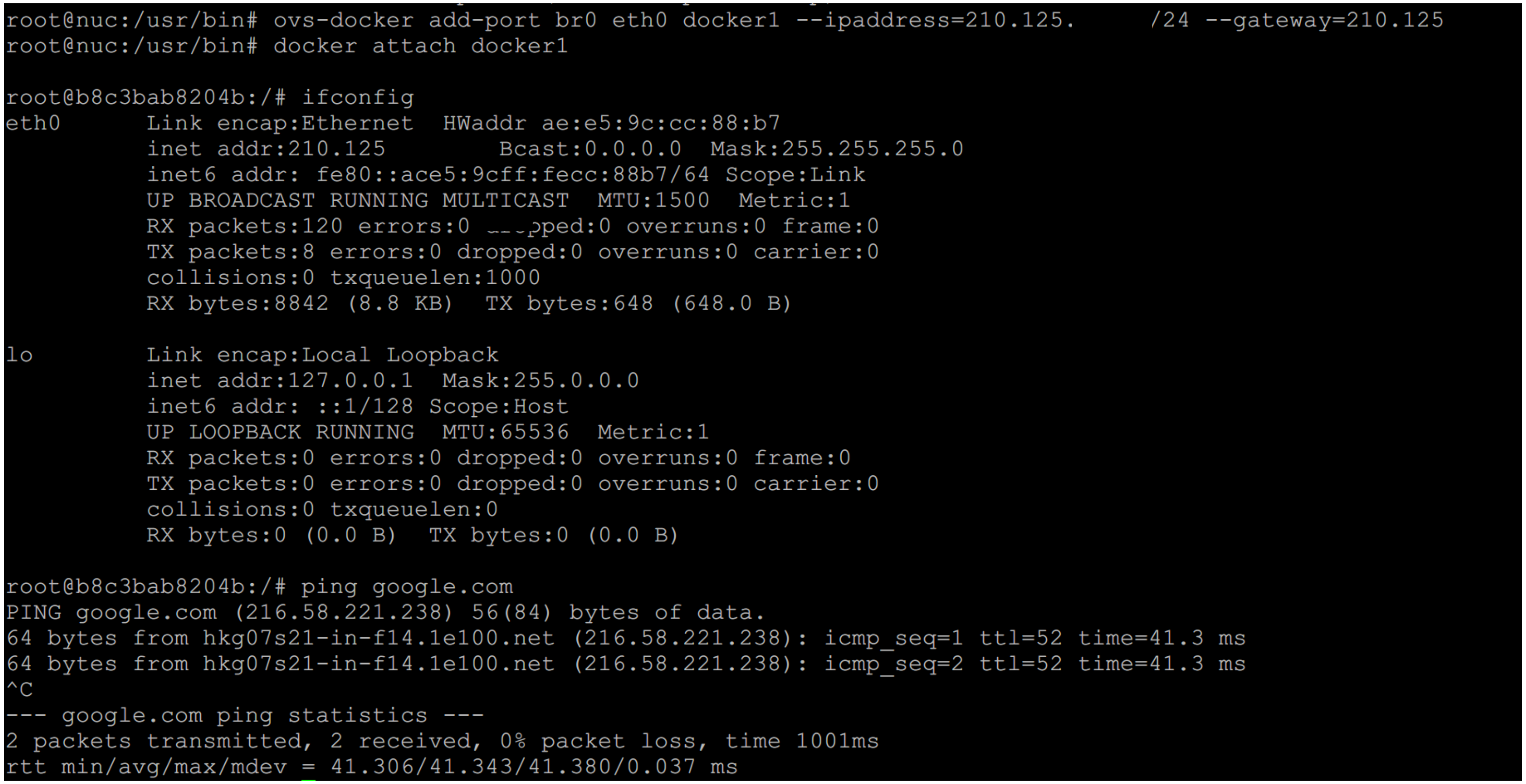
#13 – Check connectivity: VM & Container



#13 - Check connectivity: VM & Container

-Check connectivity with ping command

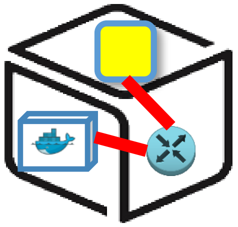


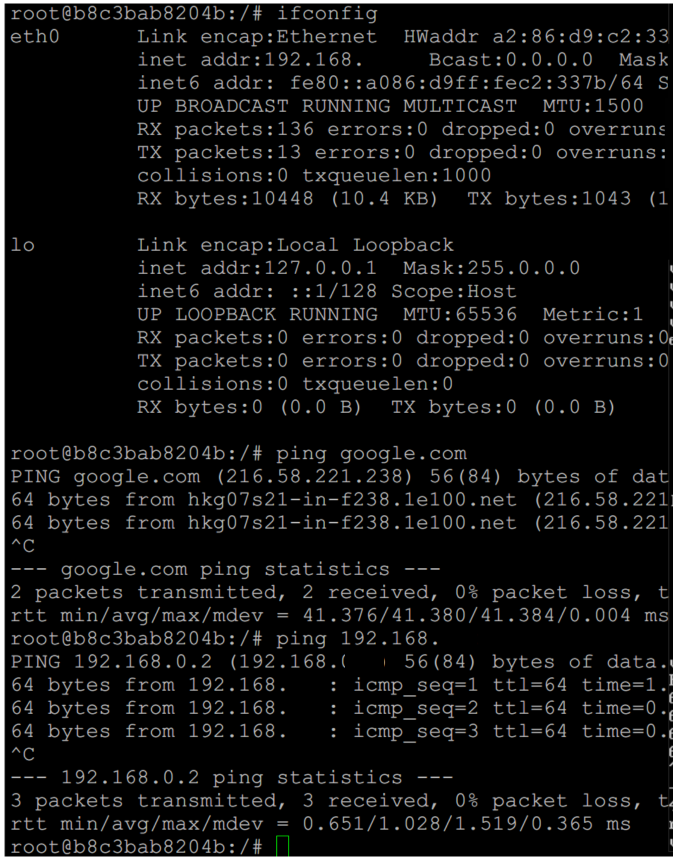


```
root@nuc:/usr/bin# ovs-docker add-port br0 eth0 docker1 --ipaddress=210.125.     /24 --gateway=210.125
root@nuc:/usr/bin# docker attach docker1

root@b8c3bab8204b:/# ifconfig
eth0      Link encap:Ethernet  HWaddr ae:e5:9c:cc:88:b7
          inet addr:210.125         Bcast:0.0.0.0  Mask:255.255.255.0
          inet6 addr: fe80::ace5:9cff:fecc:88b7/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:120 errors:0 dropped:0 overruns:0 frame:0
          TX packets:8 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:8842 (8.8 KB)  TX bytes:648 (648.0 B)

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:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)

root@b8c3bab8204b:/# ping google.com
PING google.com (216.58.221.238) 56(84) bytes of data.
64 bytes from hkg07s21-in-f14.1e100.net (216.58.221.238): icmp_seq=1 ttl=52 time=41.3 ms
64 bytes from hkg07s21-in-f14.1e100.net (216.58.221.238): icmp_seq=2 ttl=52 time=41.3 ms
^C
--- google.com ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1001ms
rtt min/avg/max/mdev = 41.306/41.343/41.380/0.037 ms
```

#13 - Check connectivity: VM & Container

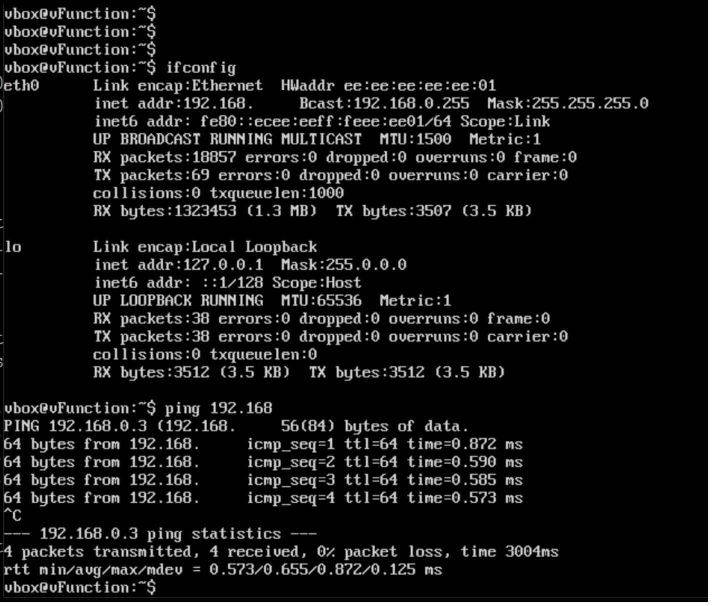
-Check connectivity with ping command





```
root@b8c3bab8204b:/# ifconfig
eth0      Link encap:Ethernet  HWaddr a2:86:d9:c2:33
          inet addr:192.168.     Bcast:0.0.0.0  Mask
          inet6 addr: fe80::a086:d9ff:fec2:337b/64 S
          UP BROADCAST RUNNING MULTICAST  MTU:1500
          RX packets:136 errors:0 dropped:0 overruns
          TX packets:13 errors:0 dropped:0 overruns:
          collisions:0 txqueuelen:1000
          RX bytes:10448 (10.4 KB)  TX bytes:1043 (1

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:0 errors:0 dropped:0 overruns:0
          TX packets:0 errors:0 dropped:0 overruns:0
          collisions:0 txqueuelen:0
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)

root@b8c3bab8204b:/# ping google.com
PING google.com (216.58.221.238) 56(84) bytes of dat
64 bytes from hkg07s21-in-f238.1e100.net (216.58.221
64 bytes from hkg07s21-in-f238.1e100.net (216.58.221
^C
--- google.com ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, t
rtt min/avg/max/mdev = 41.376/41.380/41.384/0.004 ms
root@b8c3bab8204b:/# ping 192.168.
PING 192.168.0.2 (192.168.(    56(84) bytes of data.
64 bytes from 192.168.    : icmp_seq=1 ttl=64 time=1.
64 bytes from 192.168.    : icmp_seq=2 ttl=64 time=0.
64 bytes from 192.168.    : icmp_seq=3 ttl=64 time=0.
^C
--- 192.168.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, t
rtt min/avg/max/mdev = 0.651/1.028/1.519/0.365 ms
root@b8c3bab8204b:/#
```

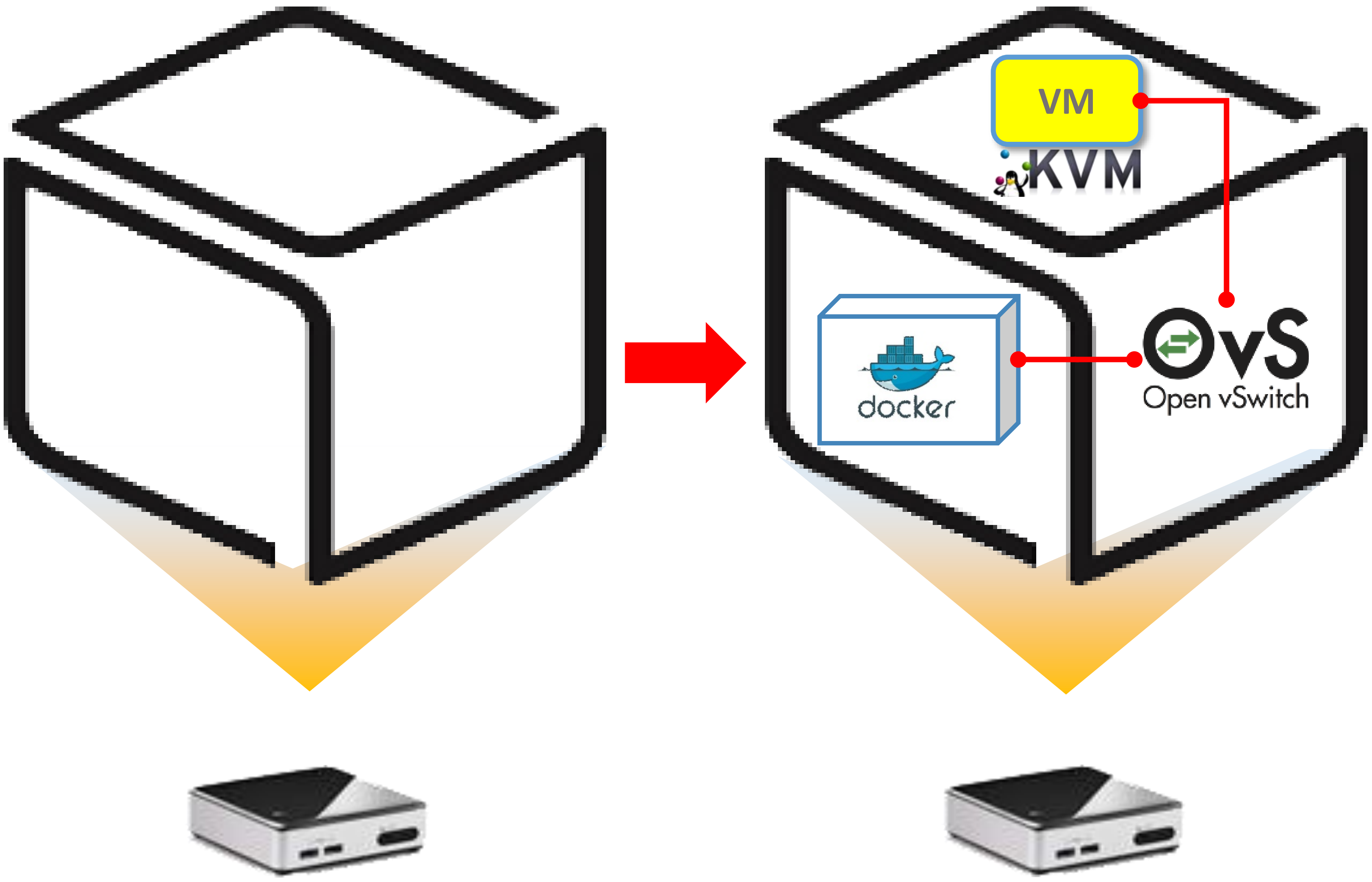
Docker container



```
vbox@vFunction:~$
vbox@vFunction:~$
vbox@vFunction:~$
vbox@vFunction:~$ ifconfig
eth0      Link encap:Ethernet  HWaddr ee:ee:ee:ee:ee:01
          inet addr:192.168.      Bcast:192.168.0.255  Mask:255.255.255.0
          inet6 addr: fe80::ecee:eeff:feee:ee01/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:18857 errors:0 dropped:0 overruns:0 frame:0
          TX packets:69 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:1323453 (1.3 MB)  TX bytes:3507 (3.5 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:38 errors:0 dropped:0 overruns:0 frame:0
          TX packets:38 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:3512 (3.5 KB)  TX bytes:3512 (3.5 KB)

vbox@vFunction:~$ ping 192.168
PING 192.168.0.3 (192.168.     56(84) bytes of data.
64 bytes from 192.168.     icmp_seq=1 ttl=64 time=0.872 ms
64 bytes from 192.168.     icmp_seq=2 ttl=64 time=0.590 ms
64 bytes from 192.168.     icmp_seq=3 ttl=64 time=0.585 ms
64 bytes from 192.168.     icmp_seq=4 ttl=64 time=0.573 ms
^C
--- 192.168.0.3 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3004ms
rtt min/avg/max/mdev = 0.573/0.655/0.872/0.125 ms
vbox@vFunction:~$
```

KVM VM

Box Lab: Final Goal (Recap)



Lab Review

Lab Summary

With Box Lab, you have experimented

1. How to install and configure **Linux OS** into Box (i.e., computer).
2. How to install and configure **OVS (Open vSwitch) virtual switch** inside a Linux Box and configure it.
3. How to create **VMs and Docker containers** inside a Linux Box and then **inter-connect** each of them together and to the Internet.

Thank You for Your Attention
Any Questions?

mini@smartx.kr