Network System Capstone
@CS.NYCU

2025.03.13 Lab2 Beamforming with NS3

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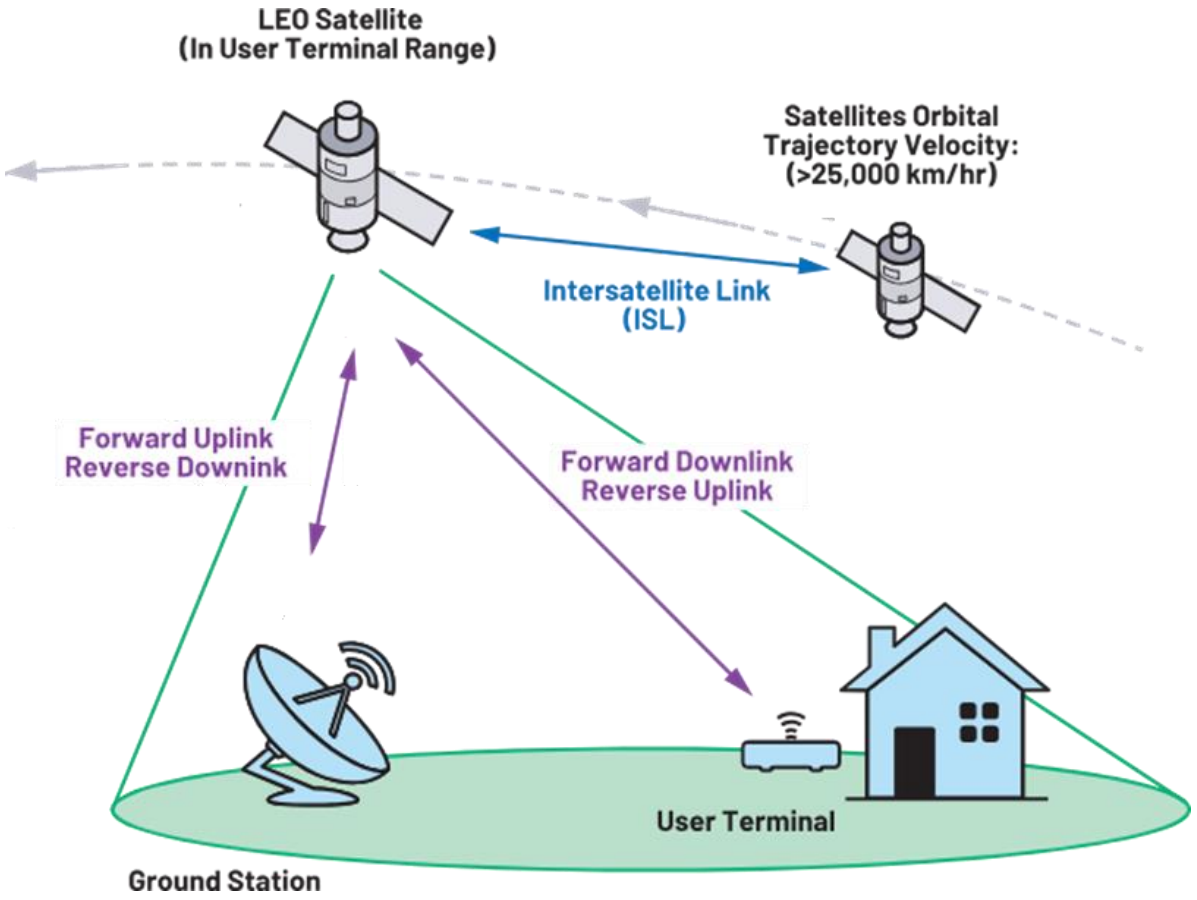
Deadline: 2025.04.03 23:59

Agenda

- Lab Overview
- Installation
  - VirtualBox
  - Ubuntu
  - NS3
  - LEO module
- Example Code Execution
  - Calculate end-to-end delay
  - Change the data rate and observe the results

Lab Overview

- In this lab, we are going to write an NS3 program to simulate LEO communications



Lab Overview

- **Limitation of the LEO module:**
  - Constant link data rate without considering path loss and Tx Gain

- **Goal of this lab:**
  - Leverage lab 1 to find the beamforming steering vector and the corresponding Tx gain
  - Read this Tx Gain and calculate the Rx power in NS3
  - Calculate the resulting SNR and data rate
  - Set the link data rate accordingly

Lab Overview

- **Tasks (Week 1):**
  - Install Virtual Box
  - Install Ubuntu
  - Install NS3
  - Install LEO module
  - Configure and test NS3/LEO module
  - Execute the example code (calculate_delay.cc)
  - Modify the link data rate

Lab Overview

- **Tasks (Week 2-3):**
  - Output node locations
  - Execute lab1 (bf.m) to find Tx Gain
  - Read Tx gain and calculate the Rx power in NS3
  - Calculate SNR and data rate
  - Modify the link data rate

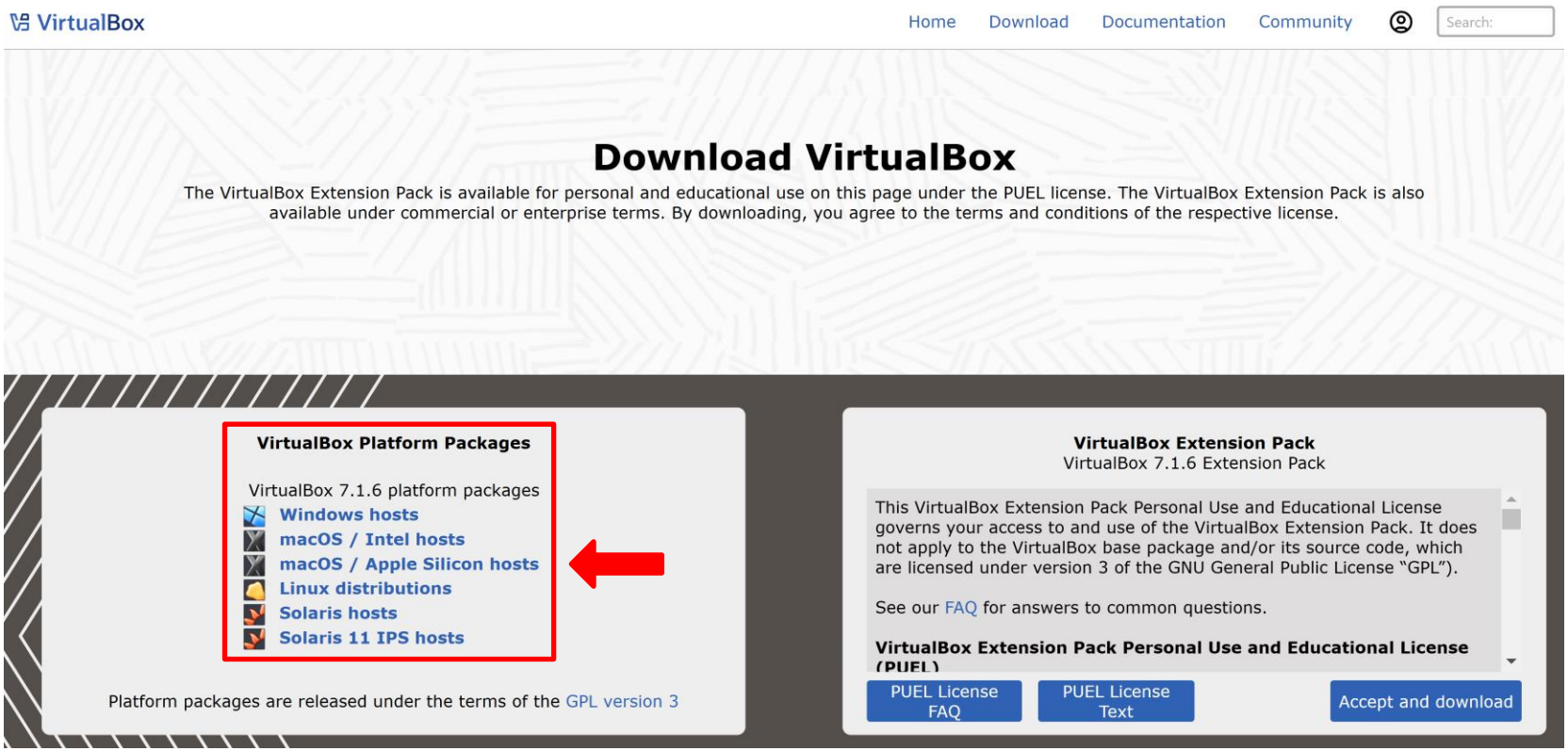
Installation – VirtualBox

- VirtualBox version: 7.X
- Ubuntu version: 22.04 LTS
- Minimum hardware requirements for VB
  - CPU: 8-core
  - RAM: 8GB
  - Storage: 30GB
  - Video memory: 128MB

- Notice: You can increase the hardware configuration if needed

Installation – VirtualBox (1/13)

- Visit the VirtualBox official download page
- Download the "Platform Packages" for your OS

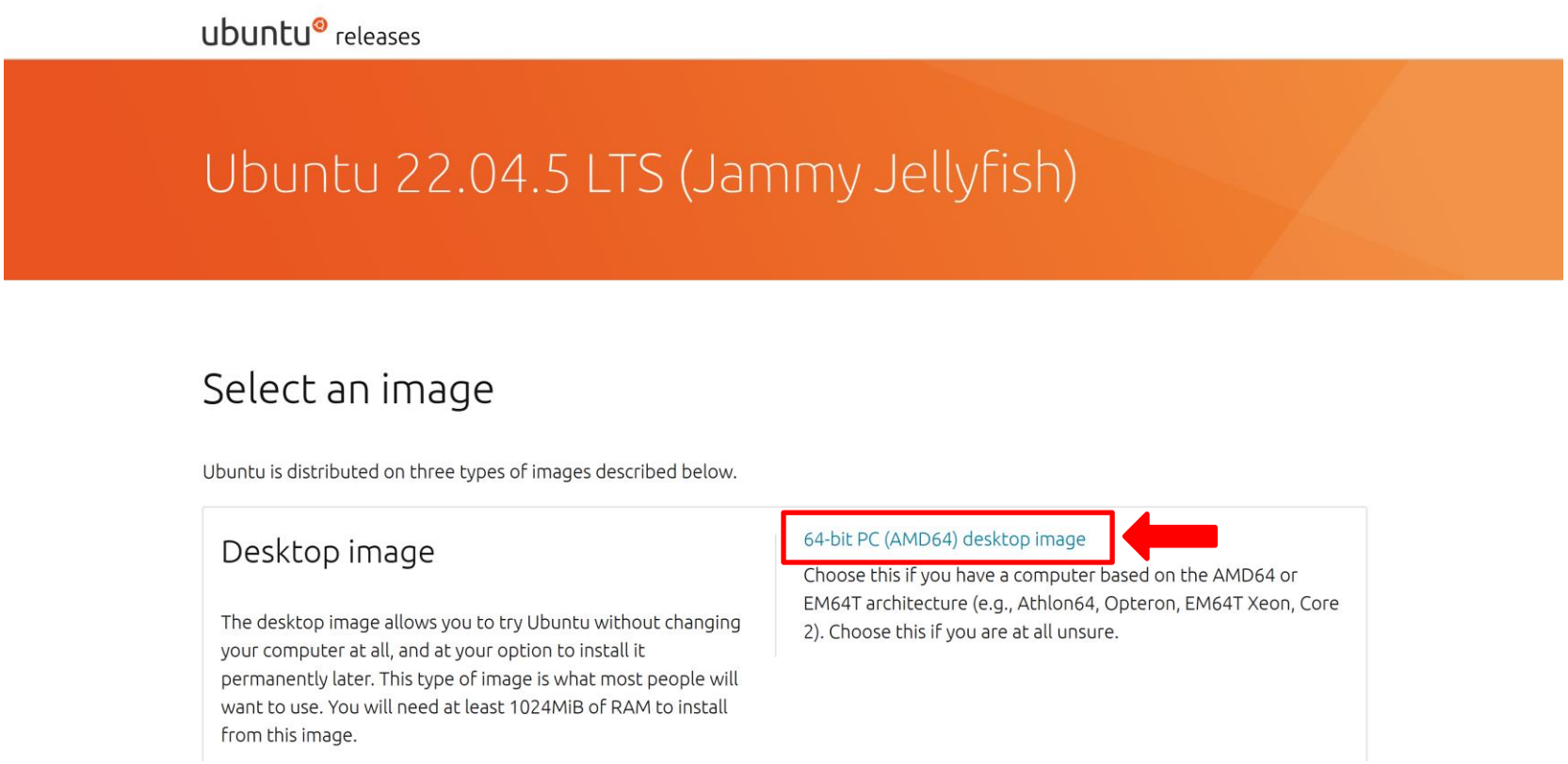


Installation – VirtualBox (2/13)

- Locate the downloaded installer (.exe file)
- Run the installer to finish the installation

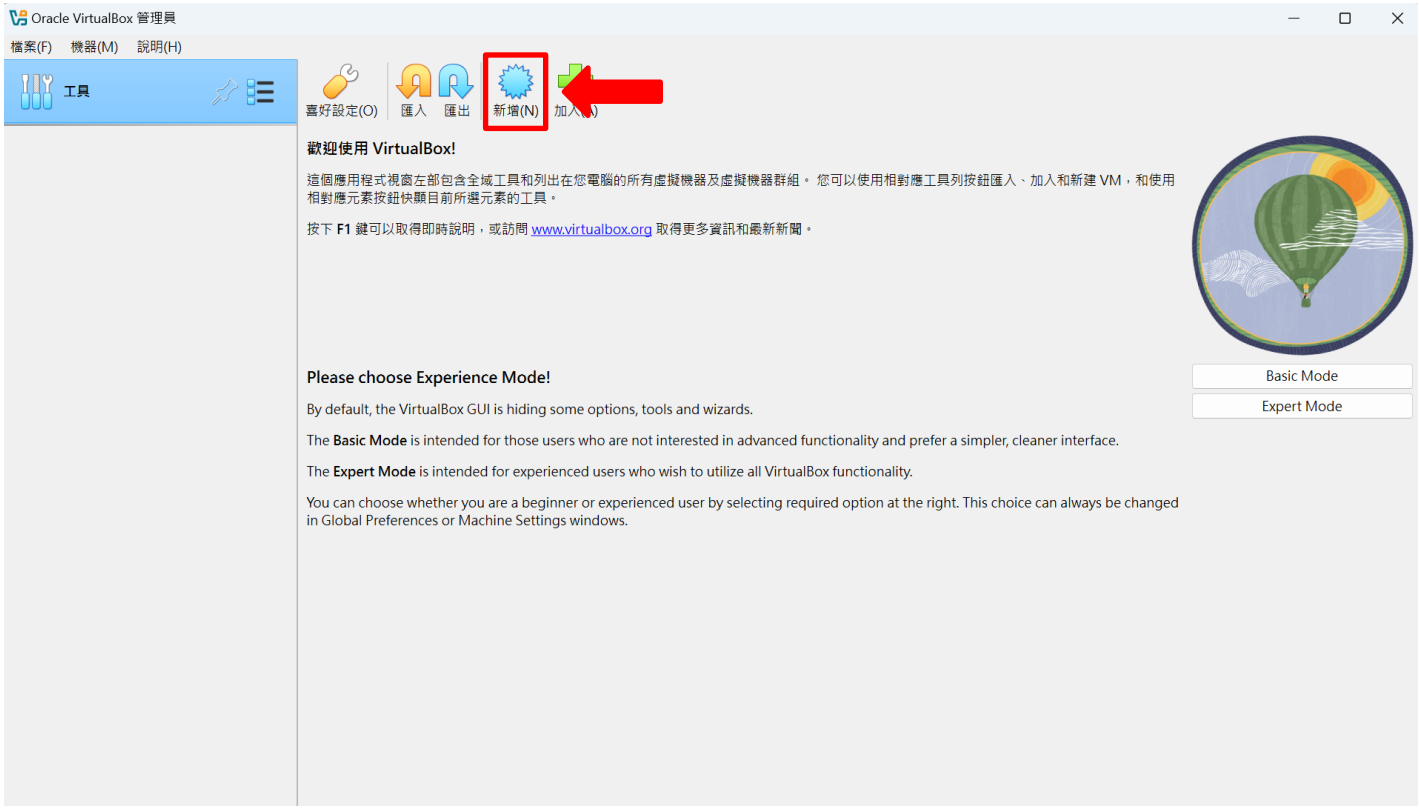
Installation – VirtualBox (3/13)

- Download image file (.iso)
  - Visit the Ubuntu official download page
  - Select Ubuntu Desktop 22.04 LTS



Installation – VirtualBox (4/13)

- Start VirtualBox and click “New”



Installation – VirtualBox (5/13)

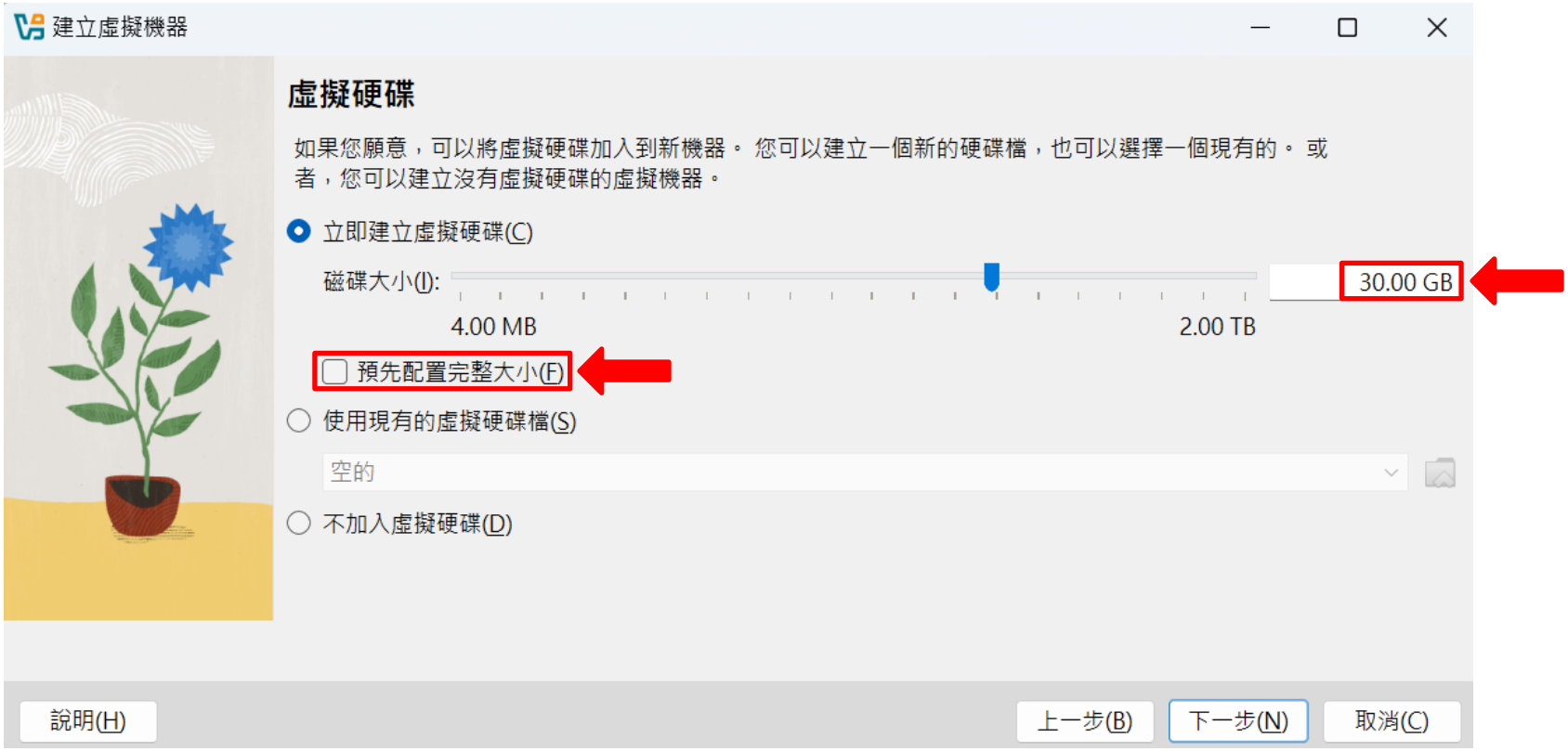
- Name the virtual machine
- Select the correct “Type”, “Subtype”, and “Version”

Installation – VirtualBox (6/13)

- Set the memory size to 8192MB
- Allocate 8 CPU cores

Installation – VirtualBox (7/13)

- Set the virtual hard disk size to 30GB



Installation – VirtualBox (8/13)

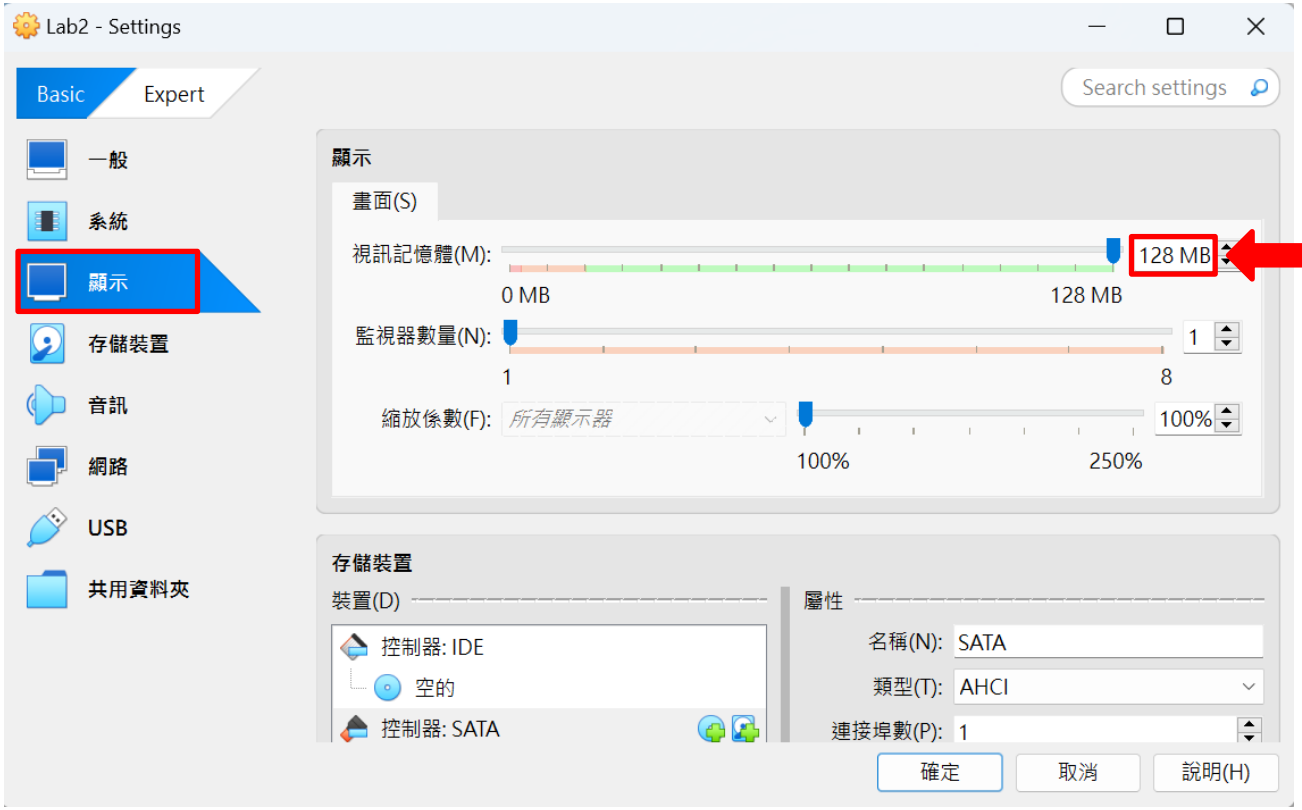
- Check the final settings and click “Finish”

Installation – VirtualBox (9/13)

- Open “Settings”

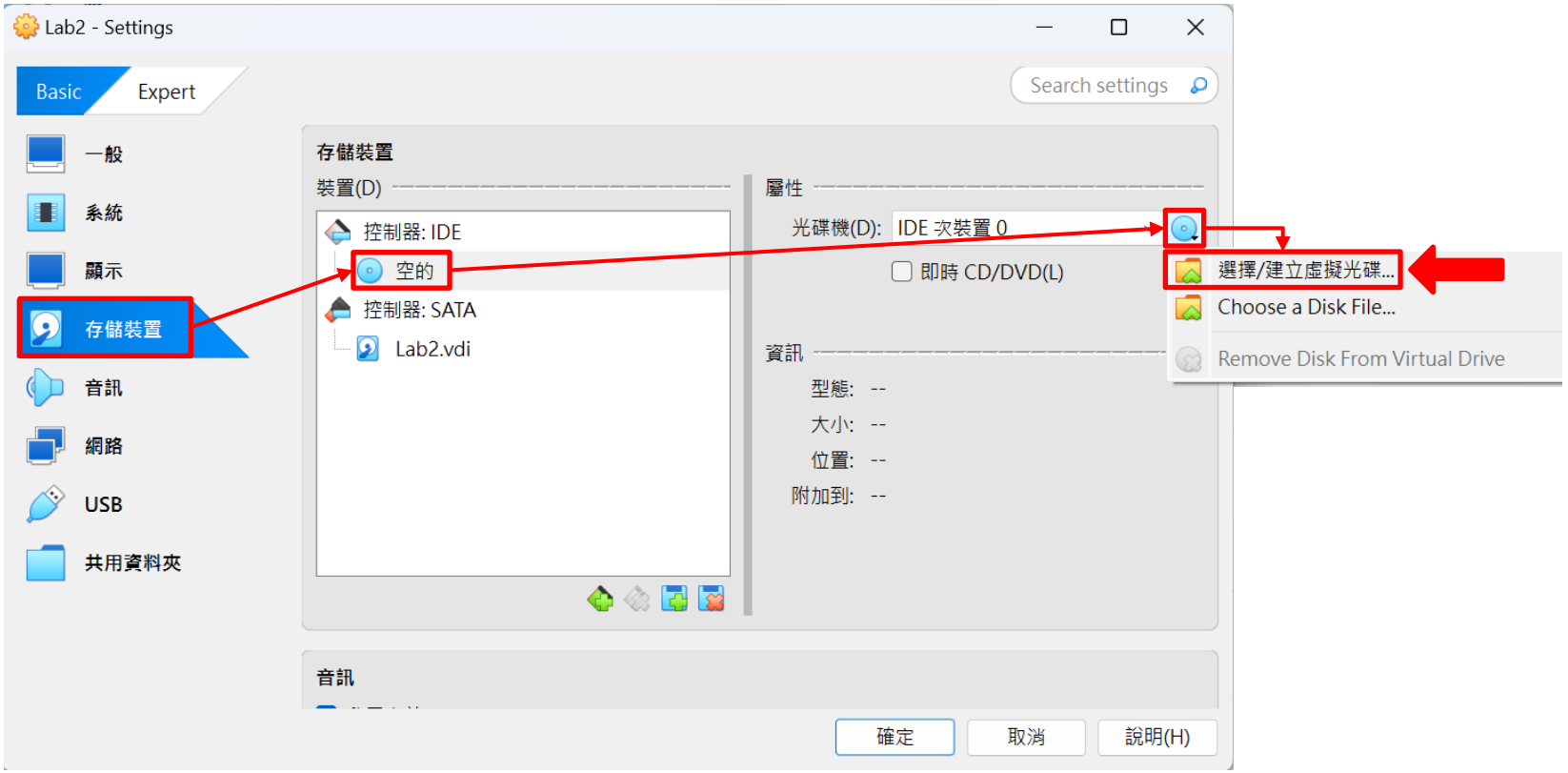
Installation – VirtualBox (10/13)

- Go to Display > Screen > Video Memory
- Set the video memory size to 128MB



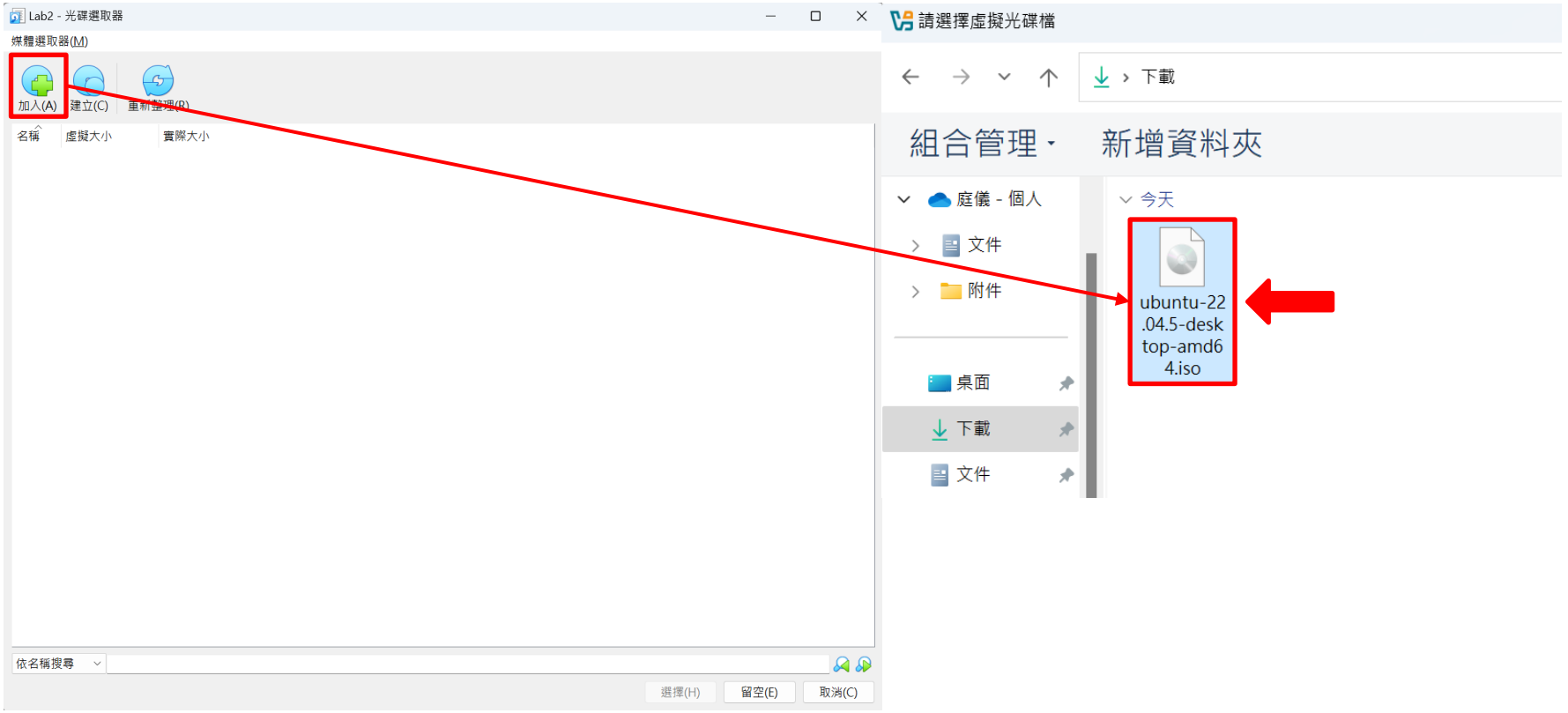
Installation – VirtualBox (11/13)

- Go to Storage > Controller: IDE
- Create a virtual optical disk



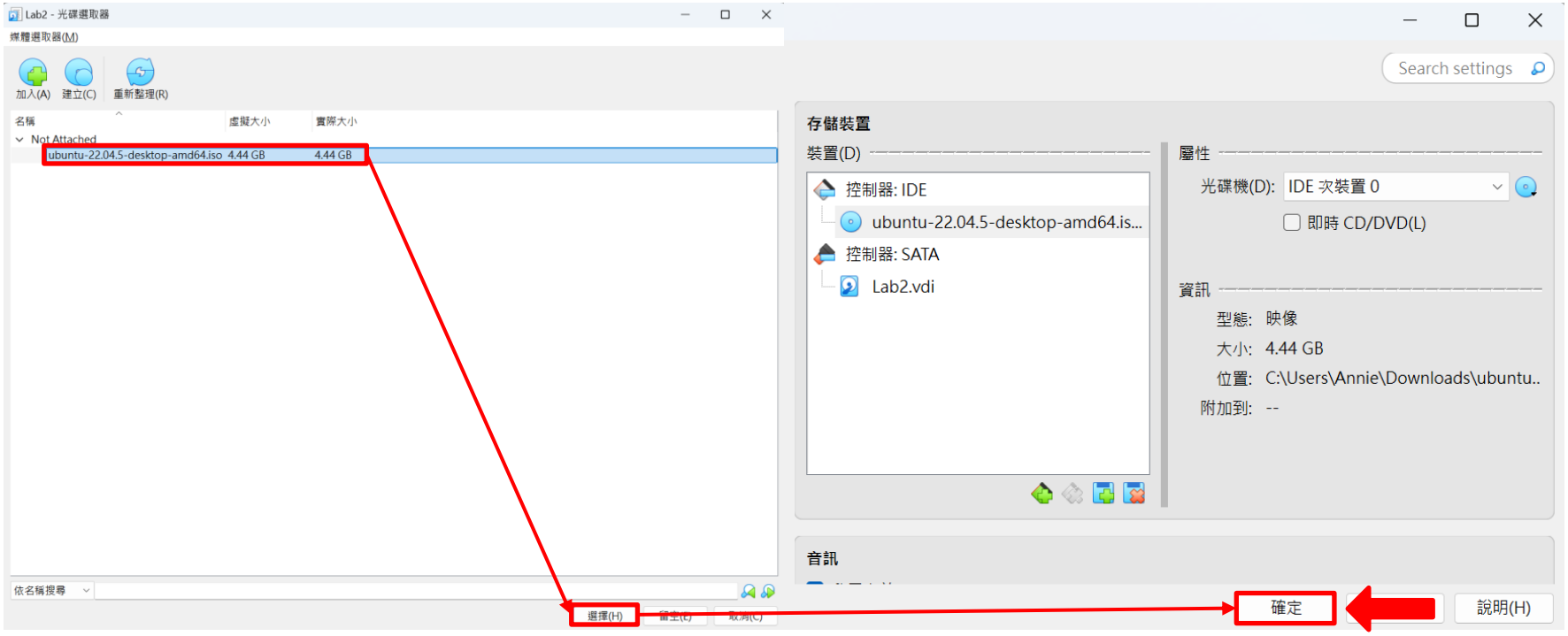
Installation – VirtualBox (12/13)

- Click “Add” and select the downloaded image file (.iso)



Installation – VirtualBox (13/13)

- Click “Choose”
- Review the final settings and click “OK”



Installation – Ubuntu (1/12)

- Click “Start”

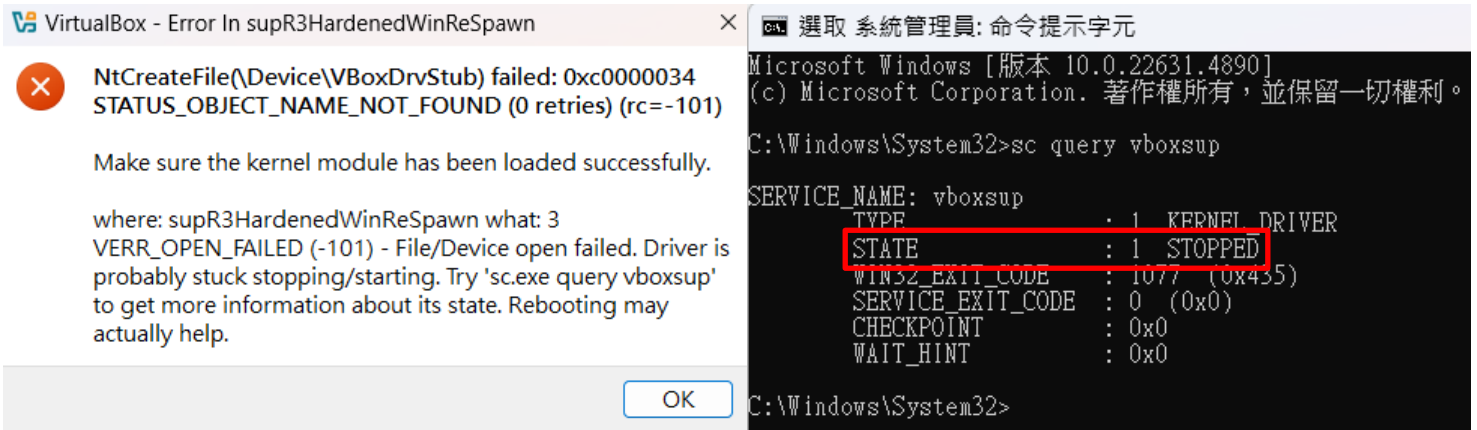
VirtualBox Start Error

- If an error appears, refer to the solutions below; otherwise, skip this part
  - Open CMD with administrator privileges
  - Run this command

```
$ sc query vboxsup
```

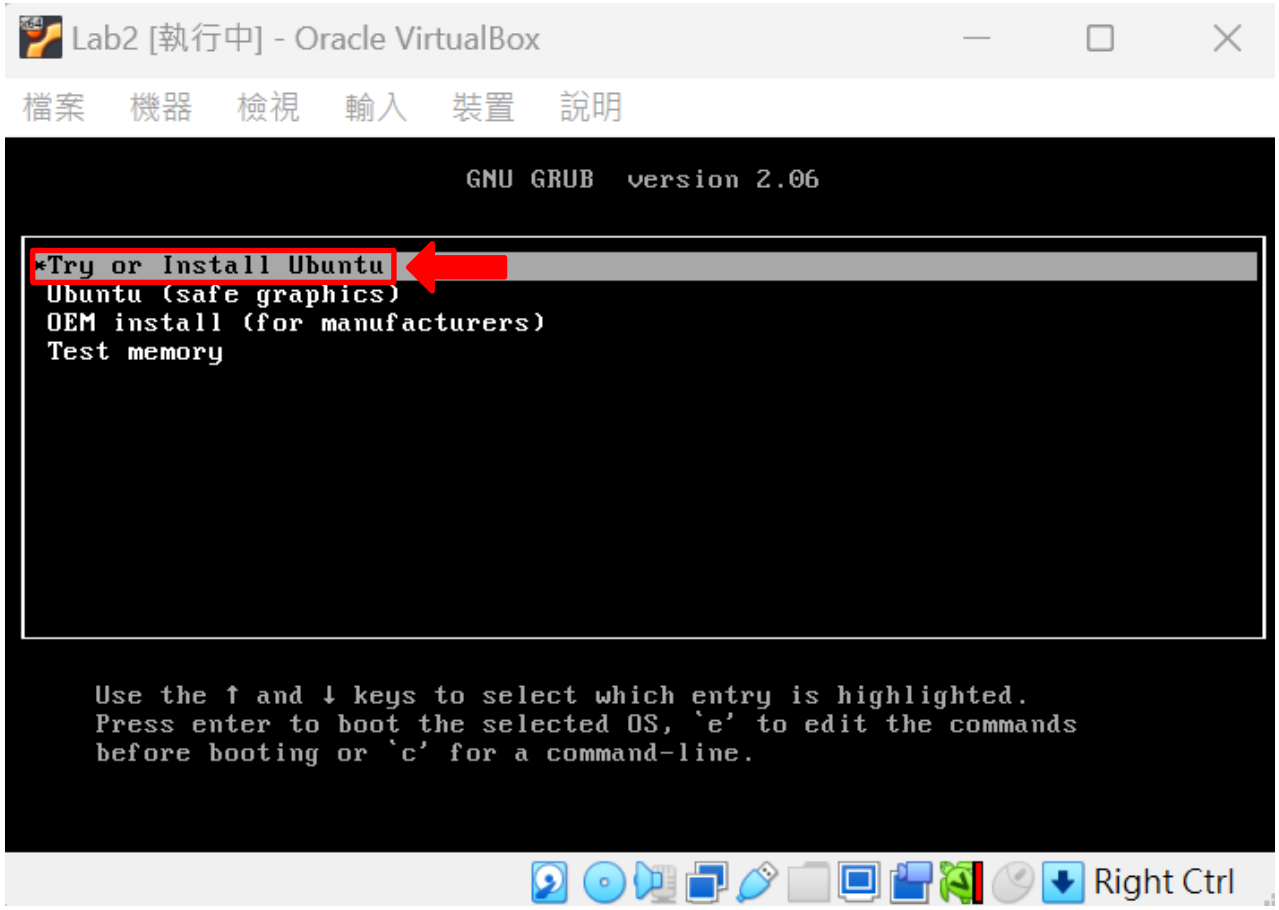
  - If “STATE: STOPPED” appears, run this command

```
$ sc start vboxsup
```



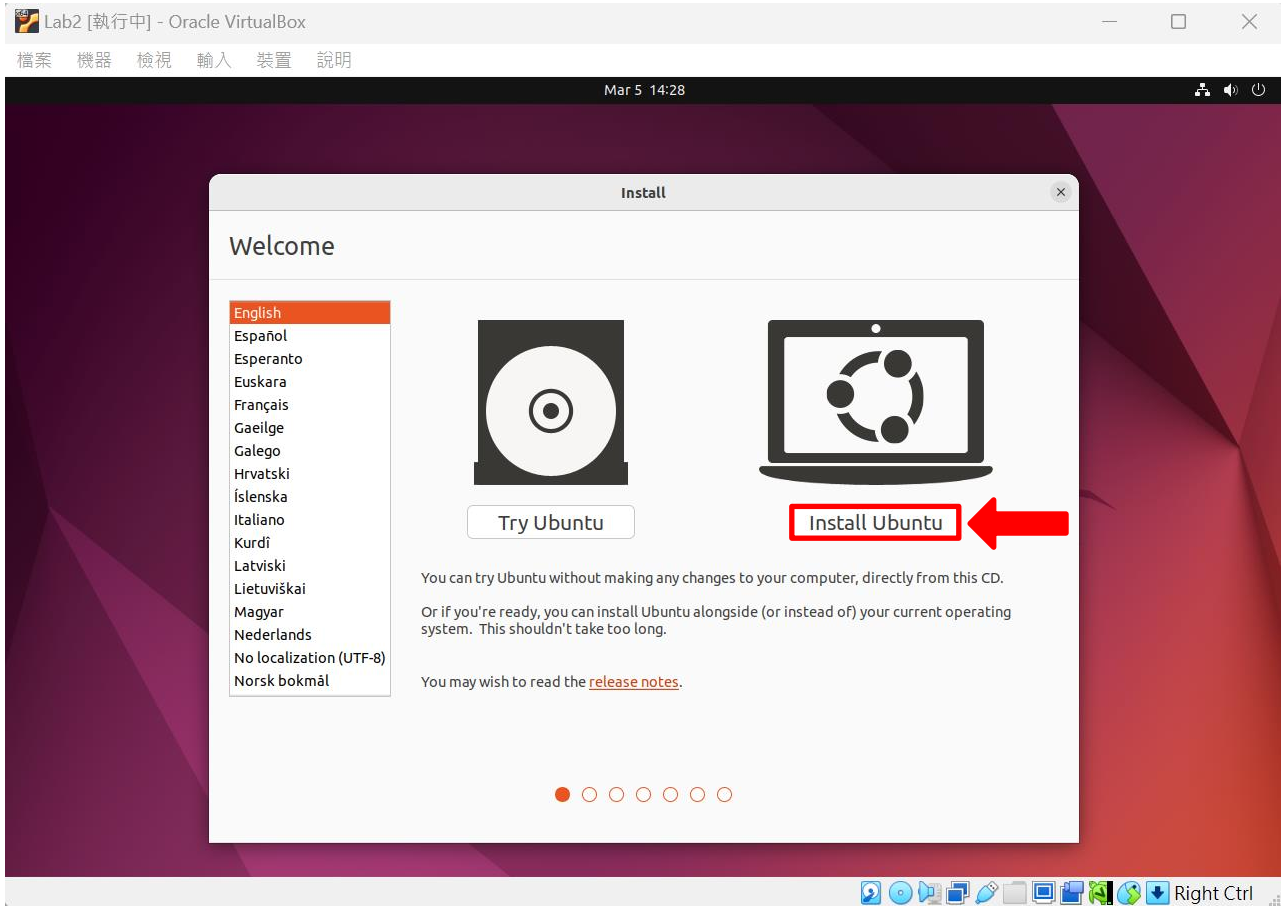
Installation – Ubuntu (2/12)

- Select “Try or install Ubuntu” and then press “Enter” bottom



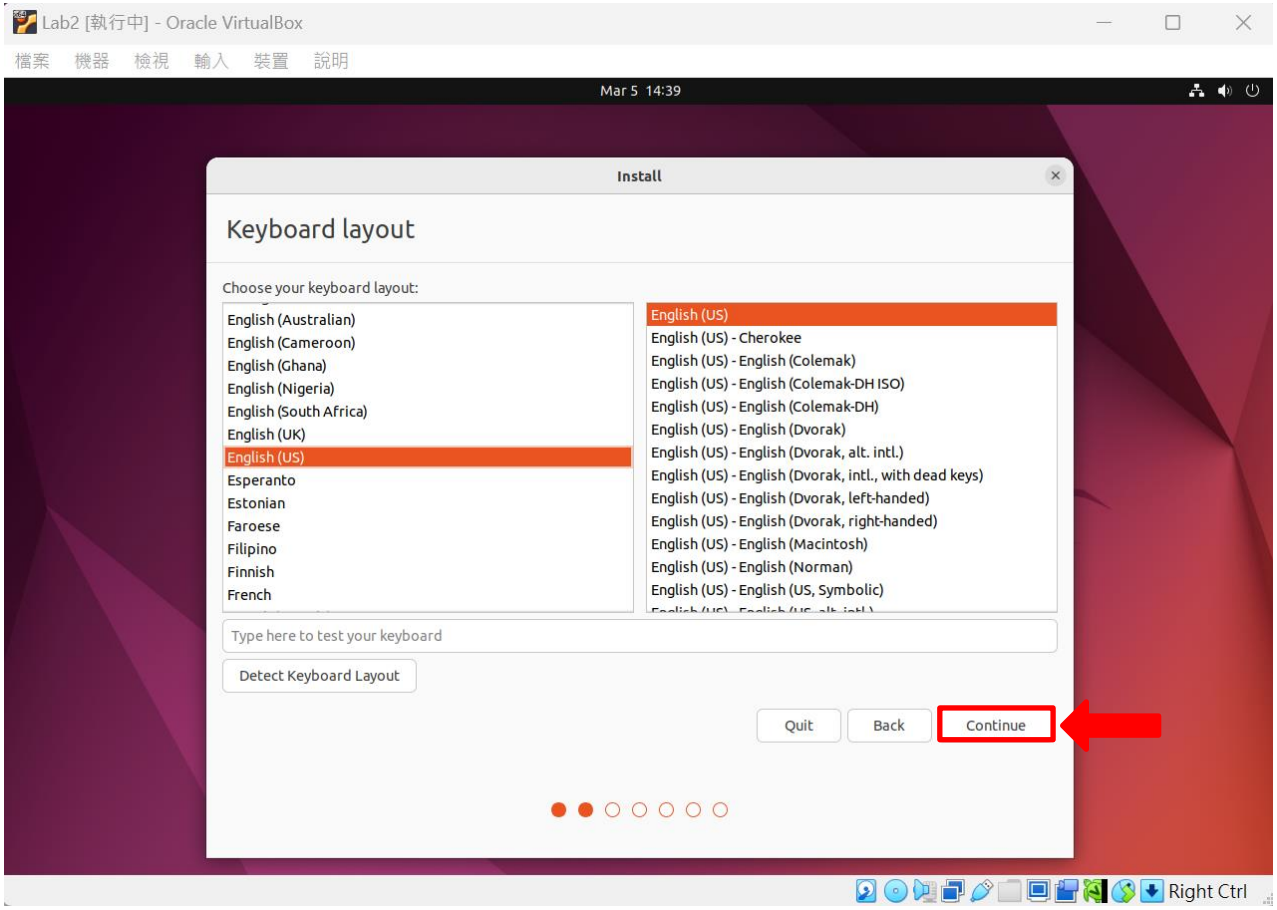
Installation – Ubuntu (3/12)

- Click “Install Ubuntu”



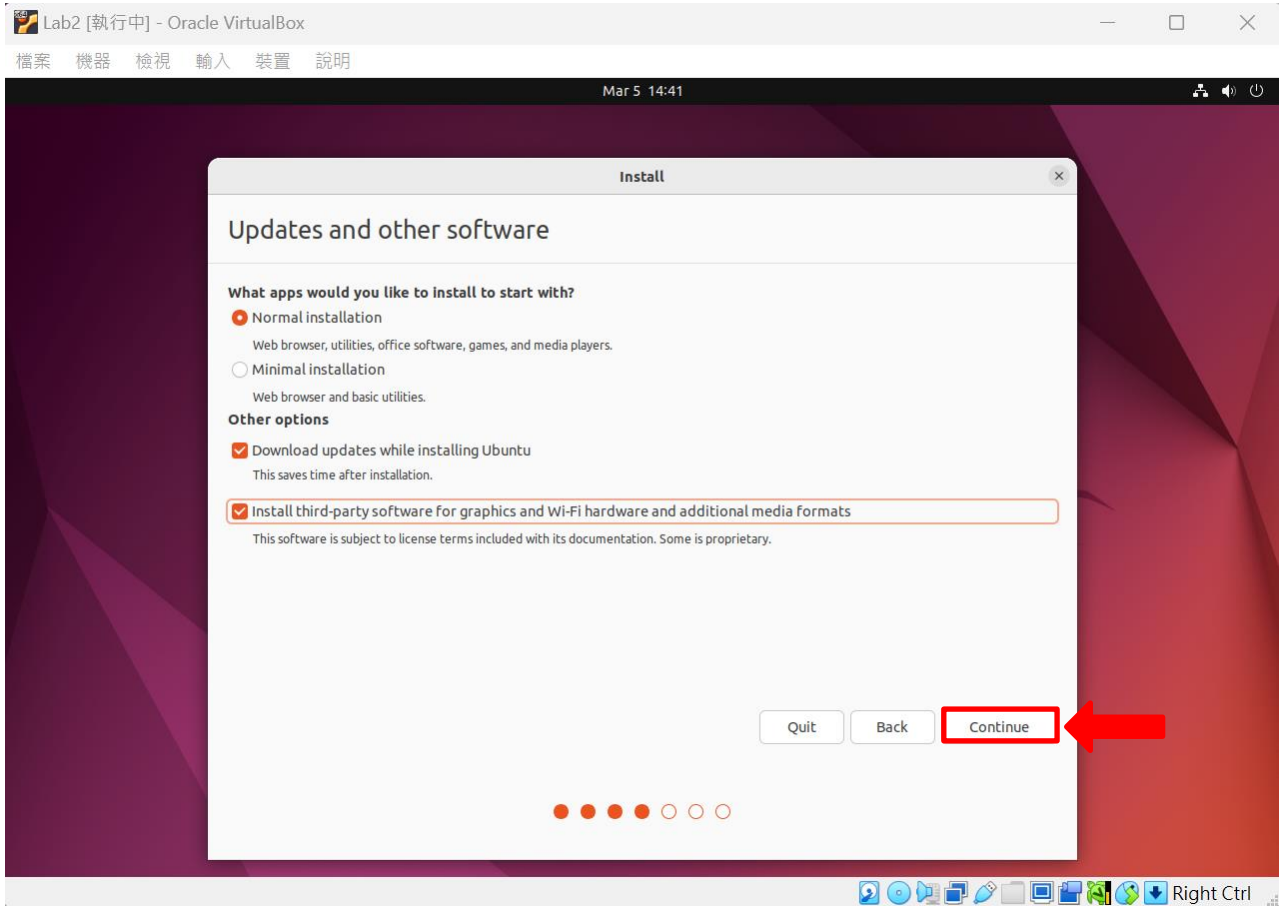
Installation – Ubuntu (4/12)

- Set according to the image



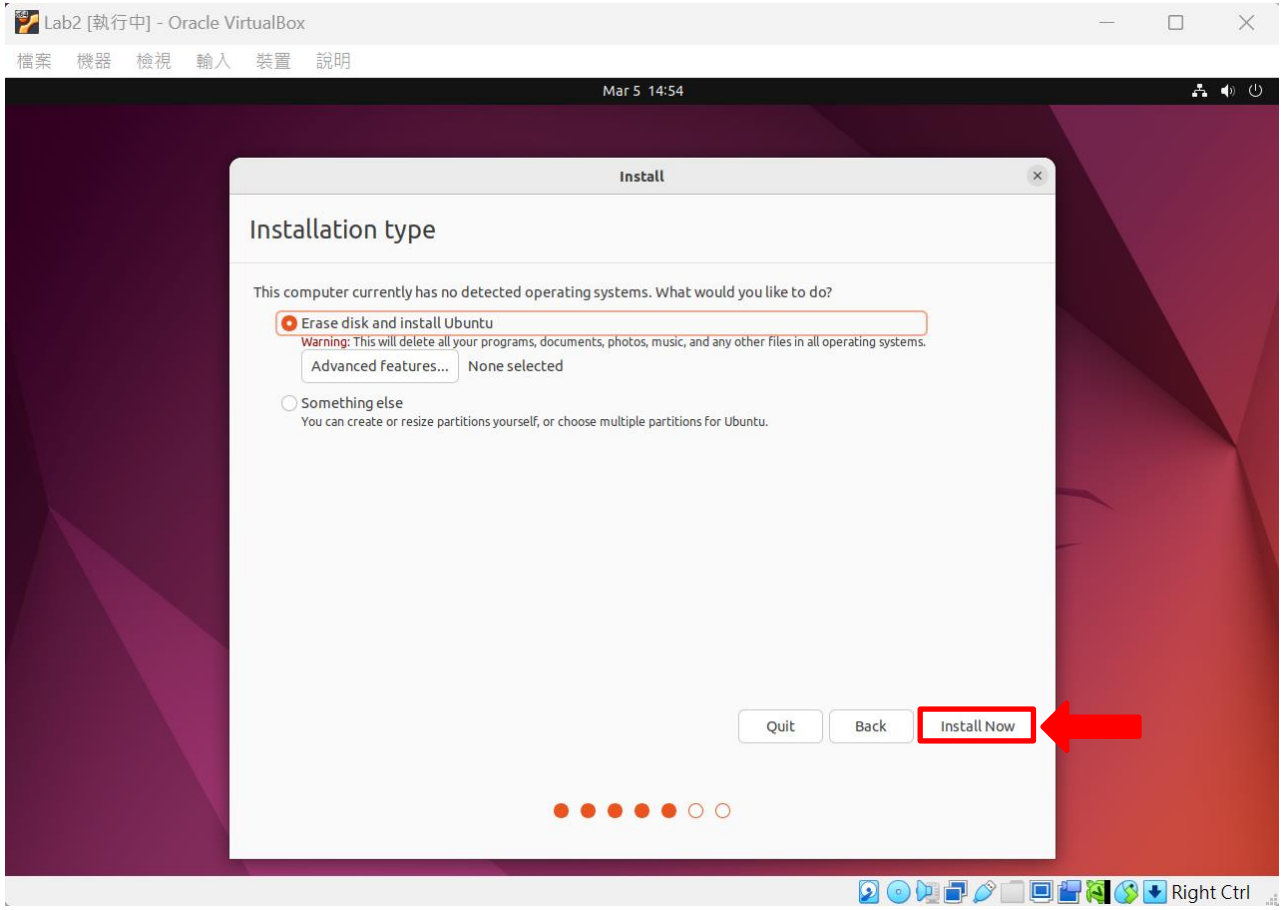
Installation – Ubuntu (5/12)

- Set according to the image



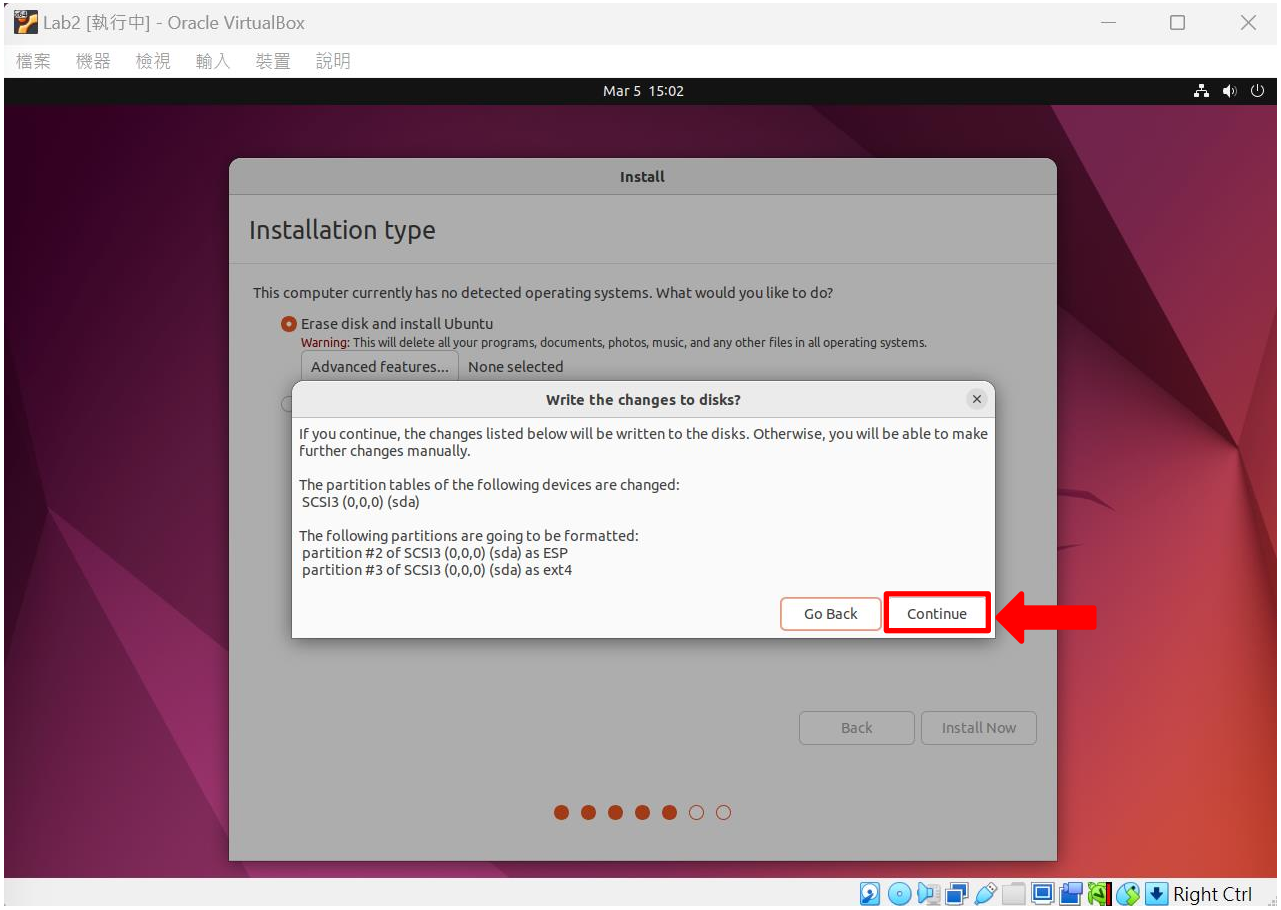
Installation – Ubuntu (6/12)

- Set according to the image



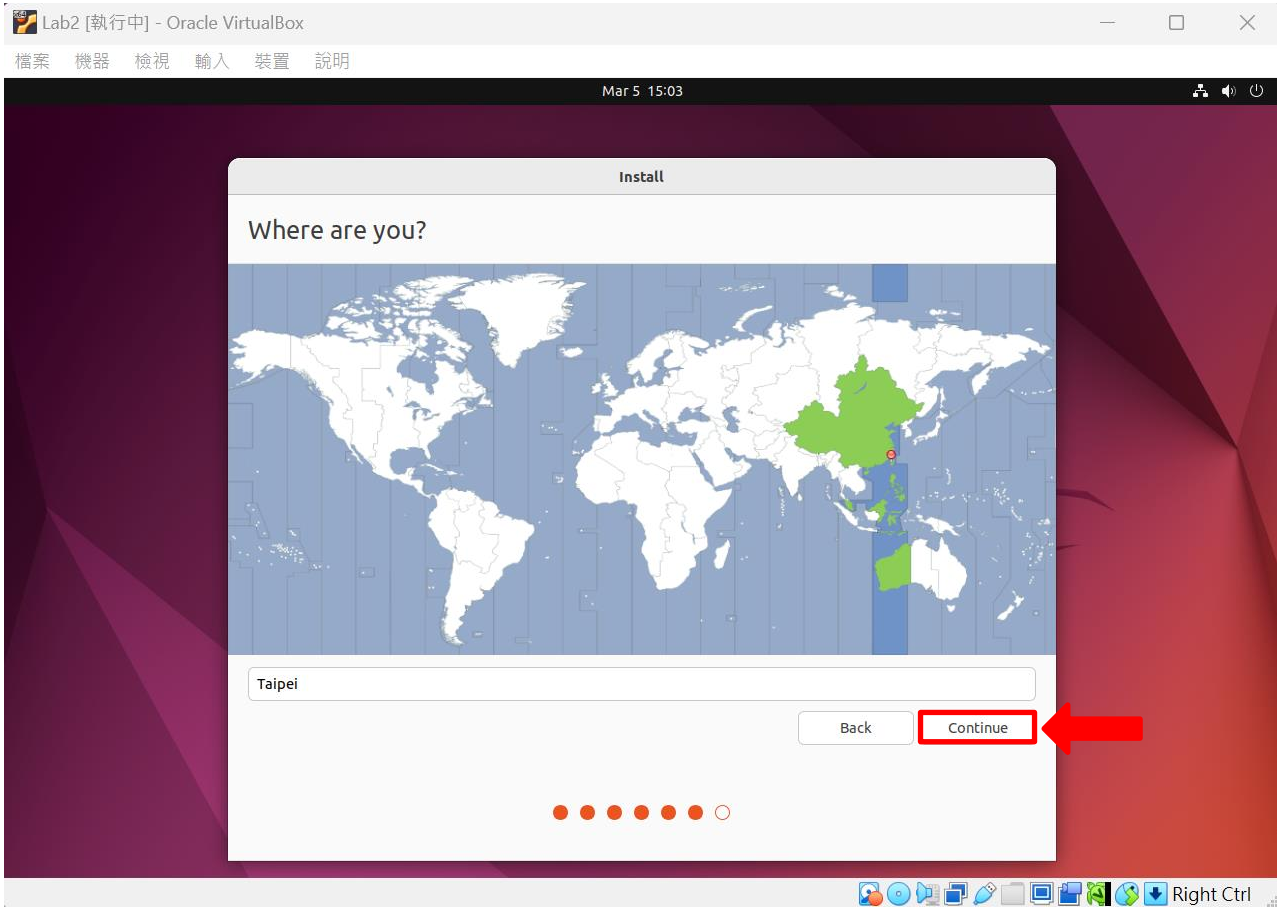
Installation – Ubuntu (7/12)

- Set according to the image



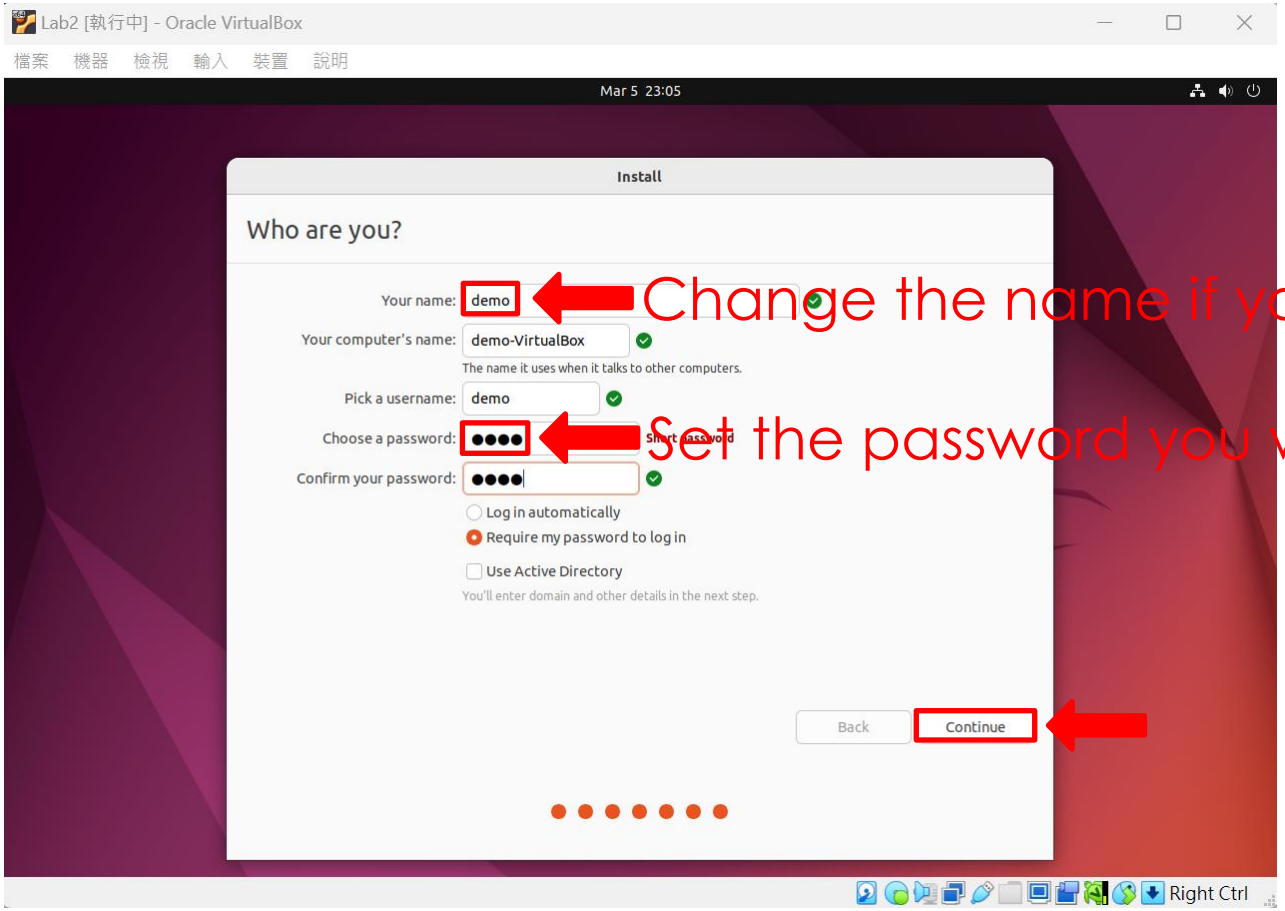
Installation – Ubuntu (8/12)

- Set according to the image



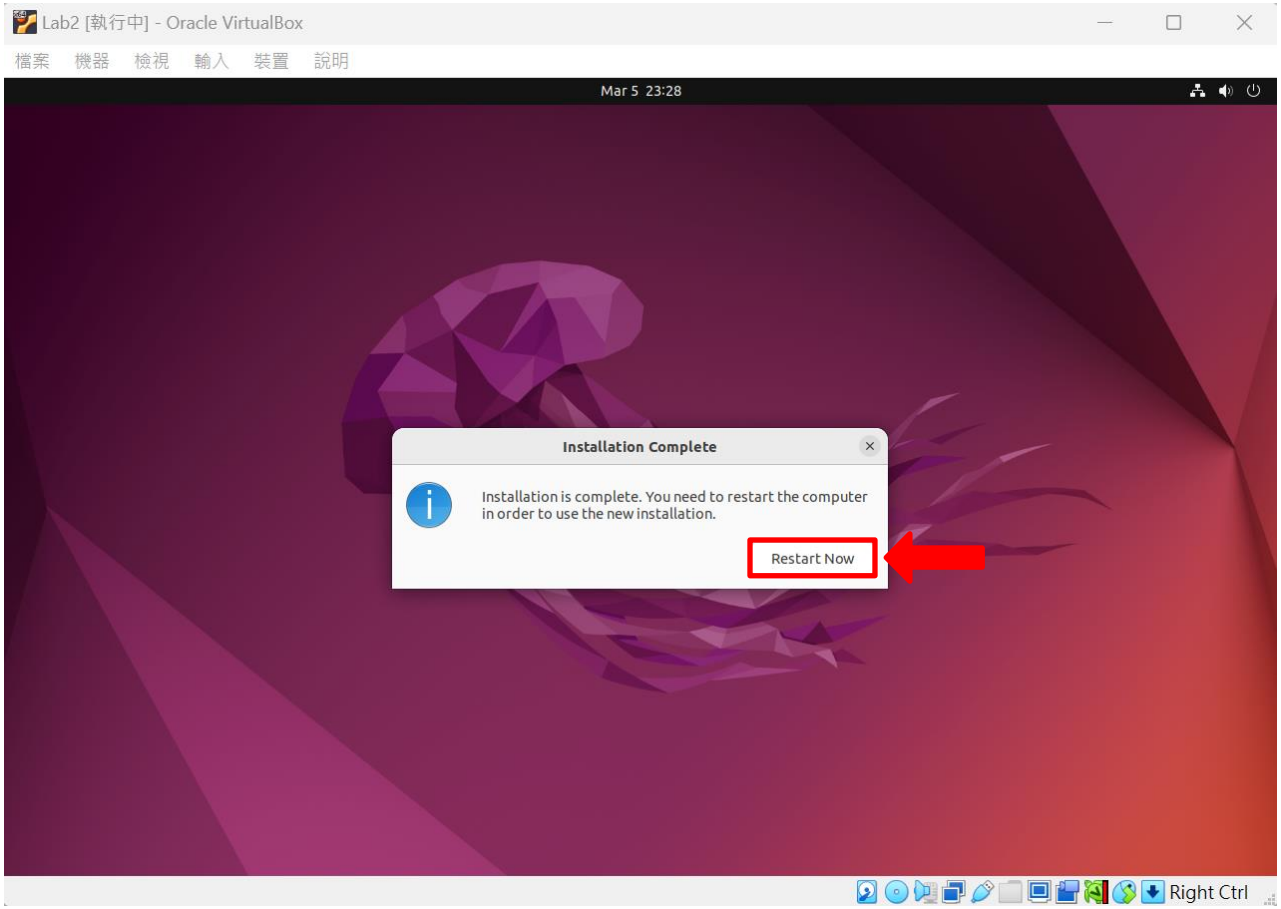
Installation – Ubuntu (9/12)

- Set according to the image



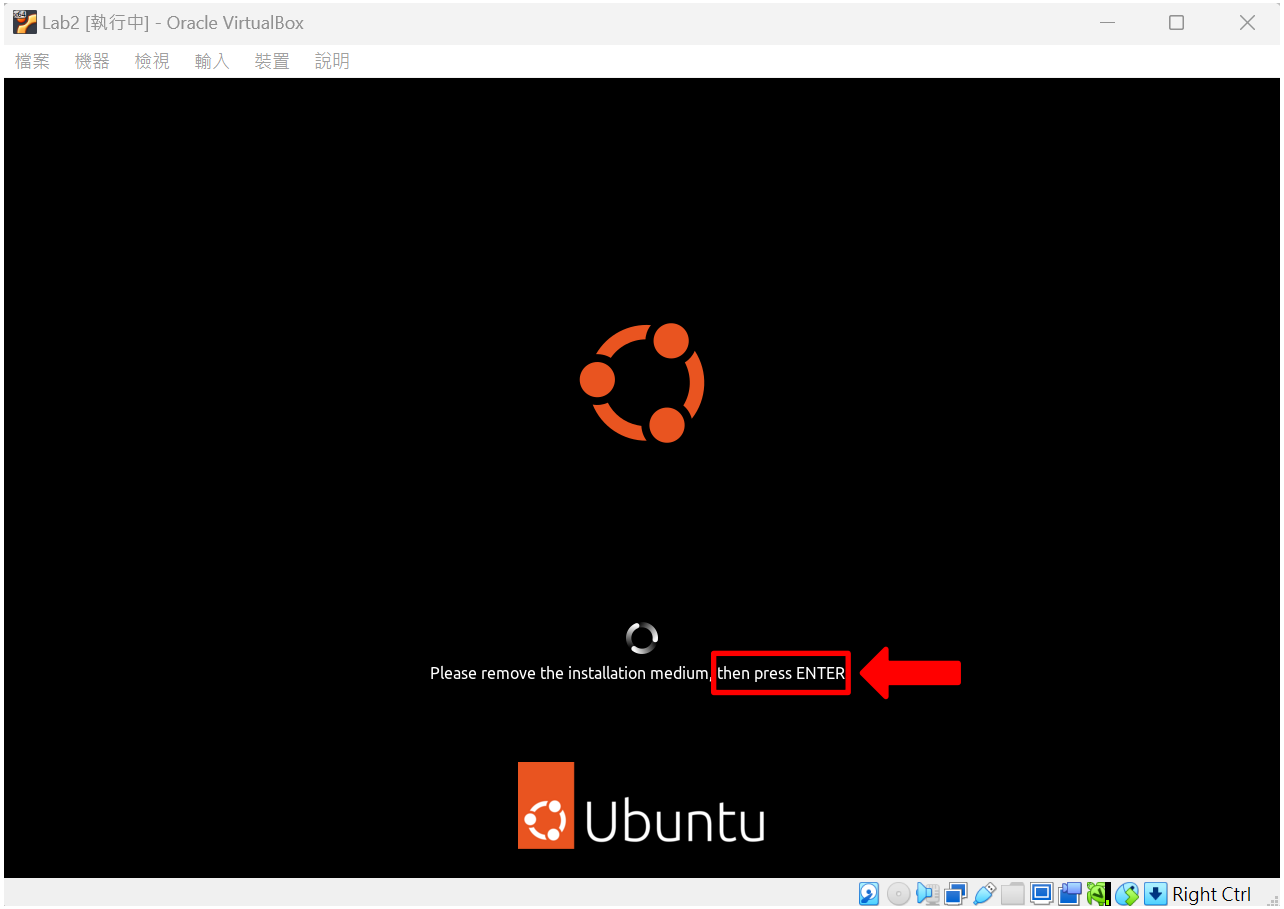
Installation – Ubuntu (10/12)

- Click “Restart Now”



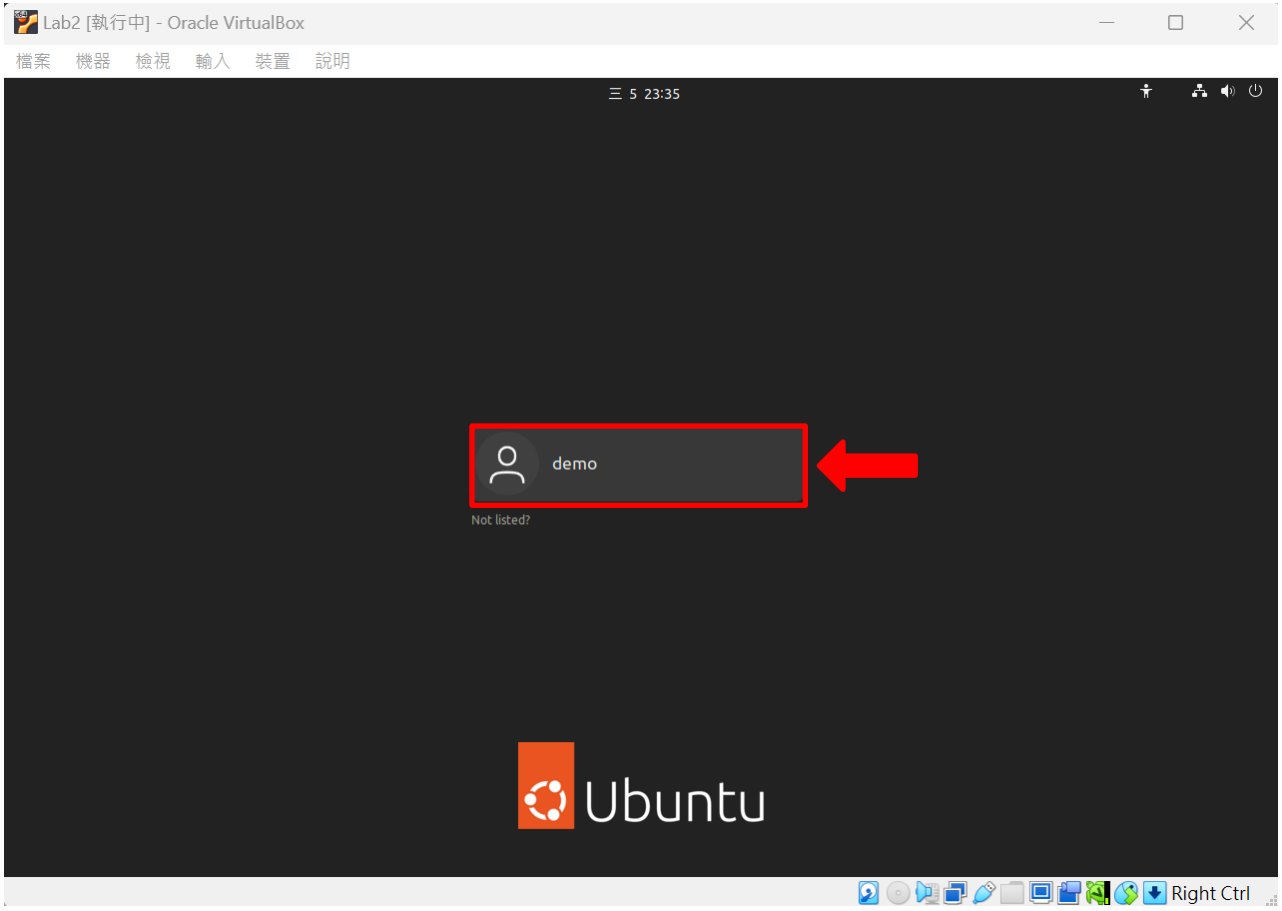
Installation – Ubuntu (11/12)

- Press “Enter” to restart the VM



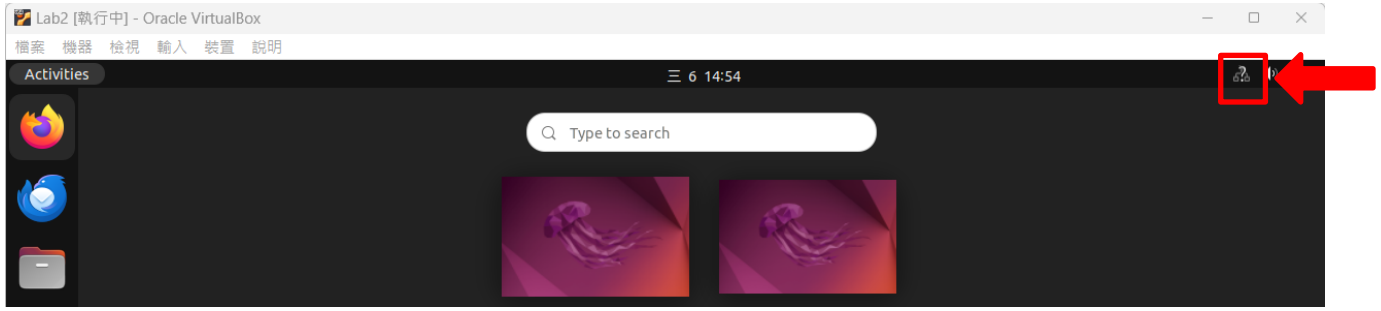
Installation – Ubuntu (12/12)

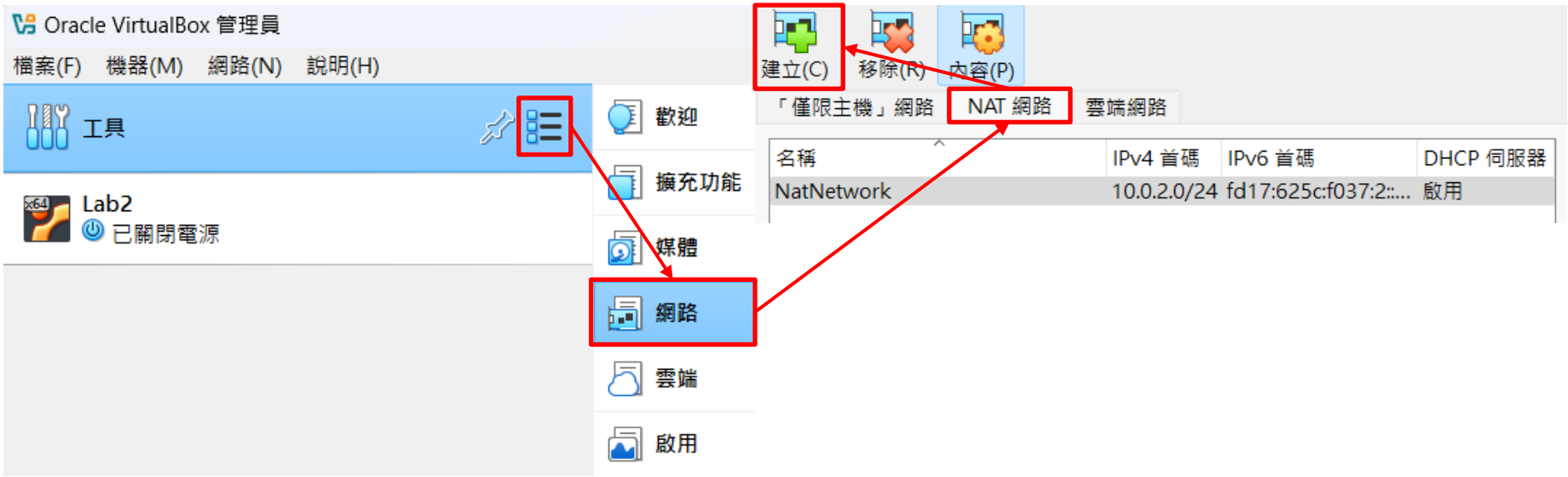
- Login your account



Ubuntu Network Error

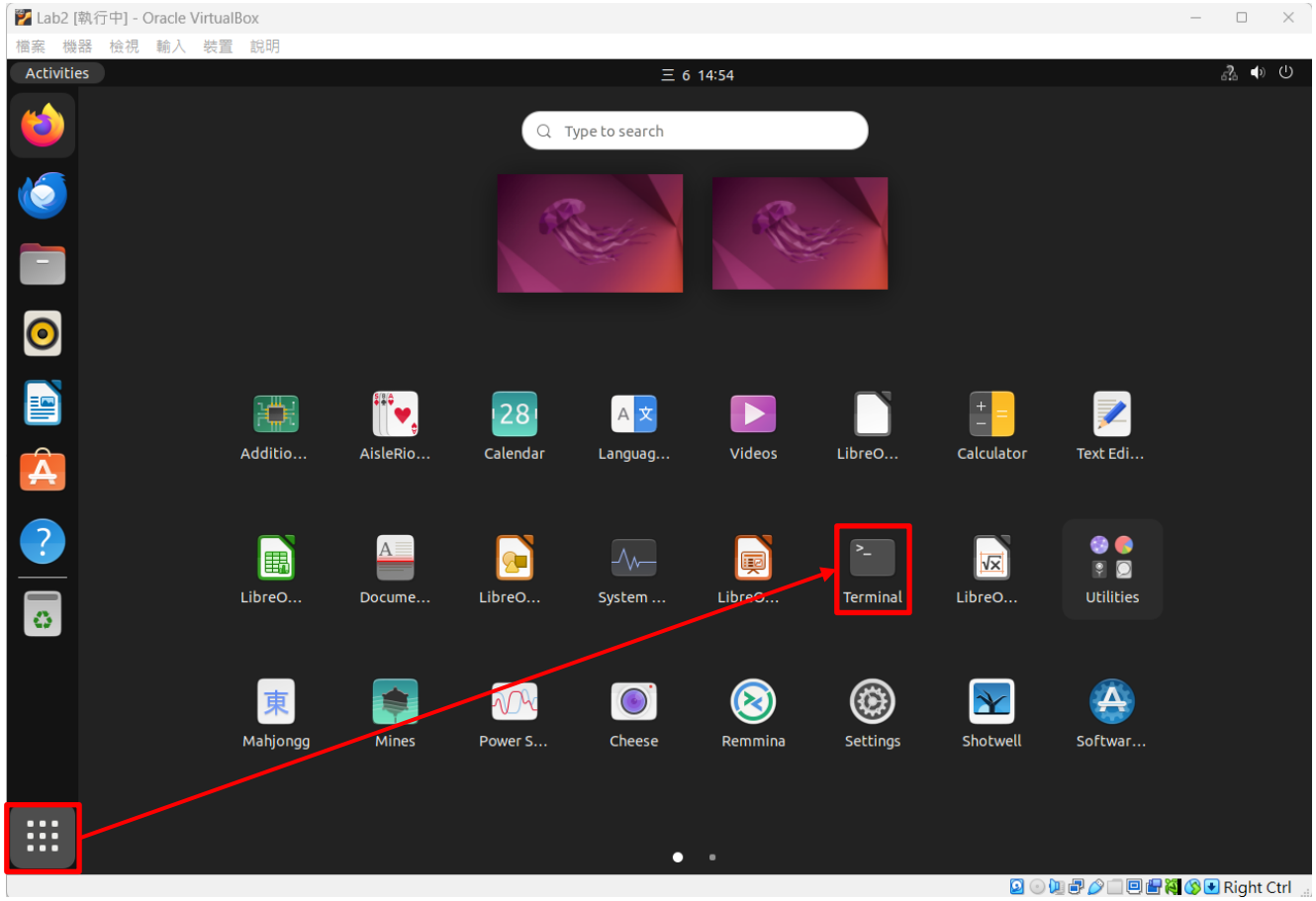
- If you have no internet, refer to the solutions here; otherwise, skip this part





Installation – NS3 (1/4)

- Open terminal



Installation – NS3 (2/4)

- Update the system up to date

```
$ sudo apt update && sudo apt upgrade -y
```

- Install git

```
$ sudo apt install git -y
```

- Install GCC

```
$ sudo apt install gcc -y
```

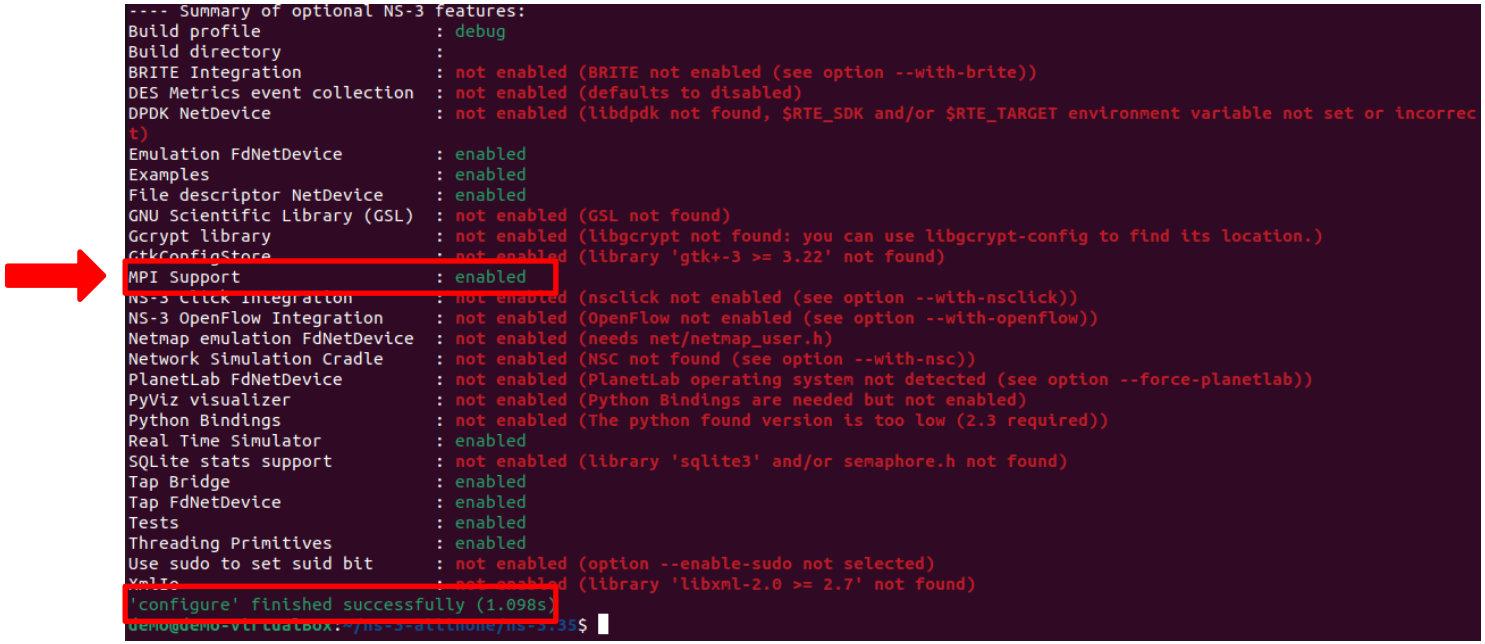
- Install G++

```
$ sudo apt install build-essential –y
```

Installation – NS3 (3/4)

- Install NS3 (3.35 version)
  - Make sure to install mpic++ package
  - Official download website
- Configure the build

```
$ ./waf configure --enable-examples --enable-tests
--enable-mpi --disable-werror
```



Installation – NS3 (4/4)

- Build the NS3 module libraries and executables

```
$ ./waf build
```

```
'build' finished successfully (3m46.229s)

Modules built:
antenna                  aodv                     applications
bridge                   buildings                config-store
core                     csma                     csma-layout
dsdv                     dsr                      energy
fd-net-device            flow-monitor             internet
internet-apps            lr-wpan                  lte
mesh                     mobility                 mpi
netanim                  network                  nix-vector-routing
olsr                     point-to-point           point-to-point-layout
propagation              sixlowpan                spectrum
stats                    tap-bridge               test (no Python)
topology-read            traffic-control          uan
virtual-net-device       wave                     wifi
wimax

Modules not built (see ns-3 tutorial for explanation):
brite                    click                    dpdk-net-device
openflow                 visualizer

demo@demo-VirtualBox:~/ns-3-allinone/ns-3.35$
```

LEO Module Overview

- LEO module
  - Official download website

- Original LEO module exists some bugs
  - Redundant installation (epidemic)
  - Wrong latitude calculation
  - Wrong delay calculation

Installation – LEO Module (1/2)

- Install LEO module

```
$ cd contrib/
$ git clone https://github.com/NYCU-NETCAP2025/lab2-
<GITHUB_ID>.git leo
```

- Config and build NS3 again

```
$ cd ..
$ ./waf configure --enable-examples --enable-tests --
enable-mpi --disable-werror
$ ./waf build
```

Installation – LEO Module (2/2)

- Execute example code

```
$ ./waf --run=leo-bulk-send
```

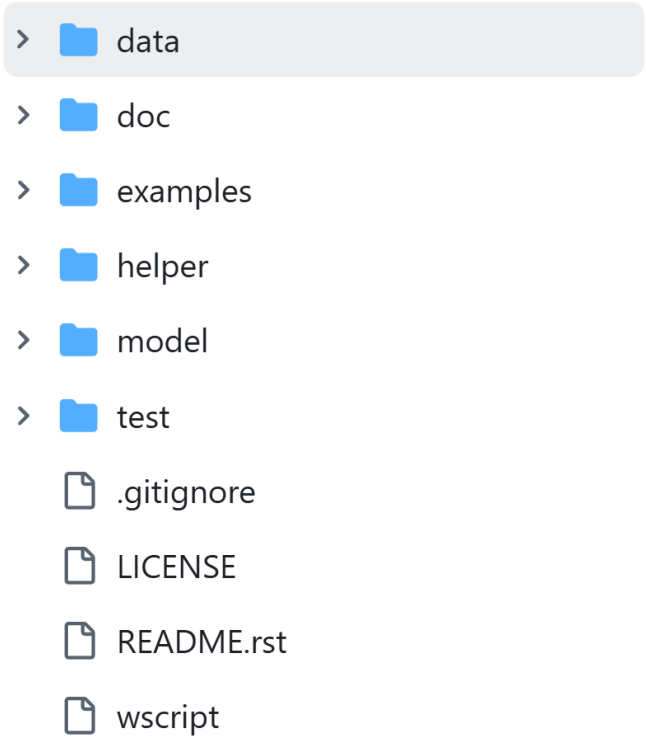
- Check the results are the same as below
  - Segmentation fault is normal :)

```
demo@demo-VirtualBox:~/ns-3-allinone/ns-3.35$ ./waf --run=leo-bulk-send
Waf: Entering directory `/home/demo/ns-3-allinone/ns-3.35/build'
Waf: Leaving directory `/home/demo/ns-3-allinone/ns-3.35/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (0.416s)
ISL enabled
msg="Could not connect callback to /NodeList/*/$ns3::TcpL4Protocol/SocketList/*/Tx", +0.000000000s -1 file=../src/core/model/config.
cc, line=925
terminate called without an active exception

ns3.35-leo-bulk-send-debug:48815 terminated with signal 6 at PC=7da08ec969fc SP=7ffdbbd11920.  Backtrace:
/lib/x86_64-linux-gnu/libc.so.6(pthread_kill+0x12c)[0x7da08ec969fc]
/lib/x86_64-linux-gnu/libc.so.6(raise+0x16)[0x7da08ec42476]
/lib/x86_64-linux-gnu/libc.so.6(abort+0xd3)[0x7da08ec287f3]
/lib/x86_64-linux-gnu/libstdc++.so.6(+0xa2b9e)[0x7da08f0a2b9e]
/lib/x86_64-linux-gnu/libstdc++.so.6(+0xae20c)[0x7da08f0ae20c]
/lib/x86_64-linux-gnu/libstdc++.so.6(+0xae277)[0x7da08f0ae277]
/home/demo/ns-3-allinone/ns-3.35/build/lib/libns3.35-core-debug.so(_ZN3ns36Config7ConnectENSt7__cxx1112basic_stringIcSt11char_traits
IcESaIcEEERKNS_12CallbackBaseE+0x339)[0x7da091e051d1]
/home/demo/ns-3-allinone/ns-3.35/build/contrib/leo/examples/ns3.35-leo-bulk-send-debug(+0xb3cb)[0x634d086863cb]
/lib/x86_64-linux-gnu/libc.so.6(+0x29d90)[0x7da08ec29d90]
/lib/x86_64-linux-gnu/libc.so.6(__libc_start_main+0x80)[0x7da08ec29e40]
/home/demo/ns-3-allinone/ns-3.35/build/contrib/leo/examples/ns3.35-leo-bulk-send-debug(+0x8615)[0x634d08683615]
Command ['/home/demo/ns-3-allinone/ns-3.35/build/contrib/leo/examples/ns3.35-leo-bulk-send-debug'] exited with code 1
```

NS3

- Introduction to NS3
- Lab2 related code
  - ns-3.35/contrib/leo/examples/leo-bulk-send-example.cc
- Some important folders
  - examples
  - helper
  - Model
- Reference
  - NS3 API documentation
  - NS3 tutorial



Run Example Code (1/4)

- Modify `calculate_delay.cc` in `/ns-3-allinone/ns-3.35/contrib/leo/examples`
  - It is a modified version of `leo-bulk-send.cc`
  - Modifications:
    - Fixed segmentation fault
    - Set up satellite and user configuration
    - Set up transmission configuration
    - Found satellite position

Run Example Code (2/4)

- Modify the `wscript` file in `/ns-3-allinone/ns-3.35/contrib/leo/examples`

```
obj = bid.create_ns3_program('calculate_delay',
                                    [the module you need])
obj.source = 'calculate_delay.cc'
```

- Execute calculate_delay.cc

```
./waf --run calculate_delay
```

- Output

Current simulation time

Sequence number of the packet

```
+2.33088e+09ns:/NodeList/25/$ns3::TcpL4Protocol/SocketList/0/Tx:157:0x60263ce28d40:1026
+2.41715e+09ns:/NodeList/26/$ns3::TcpL4Protocol/SocketList/0/Rx:157:0x60263ce28e40:1026
```

Run Example Code (3/4)

- TODO: **Task1**
  - Complete TODOs in `calculate_delay.cc`
  - Parse the send time and arrival time of each packet
  - Store the send time and arrival time for the same sequency number
  - Calculate the average end-to-end delay of all the packets
  - Output format:

```
Packet average end-to-end delay is 2.5s
```

Run Example Code (4/4)

- TODO: **Task2**
  - Modify `calculate_delay.cc` to change the sending data rate of the source
  - Repeat task1 and observe whether the end-to-end delay changes accordingly