

环境：VMware Workstation Pro 17 +debian-12.2.0-amd64

## 作业 2：对 Linux 内核进行一些配置

Q: 在该文件夹中调用 `make LLVM=1`，该文件夹内的代码将编译成一个内核模块。请结合你学到的知识，回答以下两个问题：

1、编译成内核模块，是在哪个文件中以哪条语句定义的？

在 Makefile 中的

```
$(MAKE) -C $(KERNEL_DIR) M=(PWD) modules
```

2、该模块位于独立的文件夹内，却能编译成 Linux 内核模块，这叫做 out-of-tree module，请分析它是如何与内核代码产生联系的？

内核模块类似于浏览器、eclipse 这些软件的插件开发，Linux 提供了一种可以向正在运行的内核中插入新的代码段、在代码段不需要继续运行时也可以从内核中移除的机制，这个可以被插入、移除的代码段被称为内核模块。

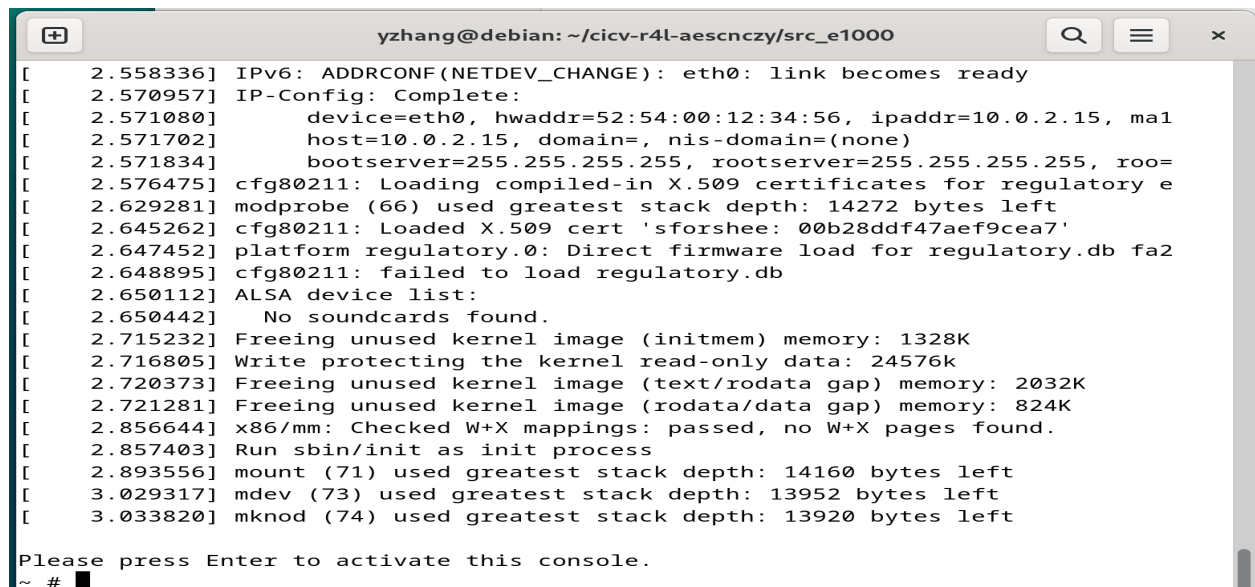
在编译内核之后，需要让他运行起来，因此，如果您已经装好了 qemu，在 src\_e1000 文件夹下有一个 build\_image.sh 脚本文件（感谢陈庭润大佬贡献的该文件）

您可能需要如下命令让该脚本能够正确运行起来

```
chmod 777 ./build_image.sh
```

如果您前面的步骤一切正常，那么运行这个脚本之后，应该就能够进入一个 Linux 系统下了。

接下来，我们需要将该脚本生成的 Linux 内核模块 r4l\_e1000\_demo.ko 进行安装



```
yzhang@debian: ~/cicv-r4l-aescnczy/src_e1000
[ 2.558336] IPv6: ADDRCONF(NETDEV_CHANGE): eth0: link becomes ready
[ 2.570957] IP-Config: Complete:
[ 2.571080]     device=eth0, hwaddr=52:54:00:12:34:56, ipaddr=10.0.2.15, ma1
[ 2.571702]     host=10.0.2.15, domain=, nis-domain=(none)
[ 2.571834]     bootserver=255.255.255.255, rootserver=255.255.255.255, roo=
[ 2.576475] cfg80211: Loading compiled-in X.509 certificates for regulatory e
[ 2.629281] modprobe (66) used greatest stack depth: 14272 bytes left
[ 2.645262] cfg80211: Loaded X.509 cert 'sforshee: 00b28ddf47aef9cea7'
[ 2.647452] platform regulatory.0: Direct firmware load for regulatory.db fa2
[ 2.648895] cfg80211: failed to load regulatory.db
[ 2.650112] ALSA device list:
[ 2.650442]   No soundcards found.
[ 2.715232] Freeing unused kernel image (initmem) memory: 1328K
[ 2.716805] Write protecting the kernel read-only data: 24576k
[ 2.720373] Freeing unused kernel image (text/rodata gap) memory: 2032K
[ 2.721281] Freeing unused kernel image (rodata/data gap) memory: 824K
[ 2.856644] x86/mm: Checked W+X mappings: passed, no W+X pages found.
[ 2.857403] Run/sbin/init as init process
[ 2.893556] mount (71) used greatest stack depth: 14160 bytes left
[ 3.029317] mdev (73) used greatest stack depth: 13952 bytes left
[ 3.033820] mknod (74) used greatest stack depth: 13920 bytes left

Please press Enter to activate this console.
~ #
```

关于您的作业内容：

在该 Linux 系统下，您可以通过 ifconfig 看到一个除了本地回环之外的网络设备，并且使用 ping 命令能够正常联通网络。

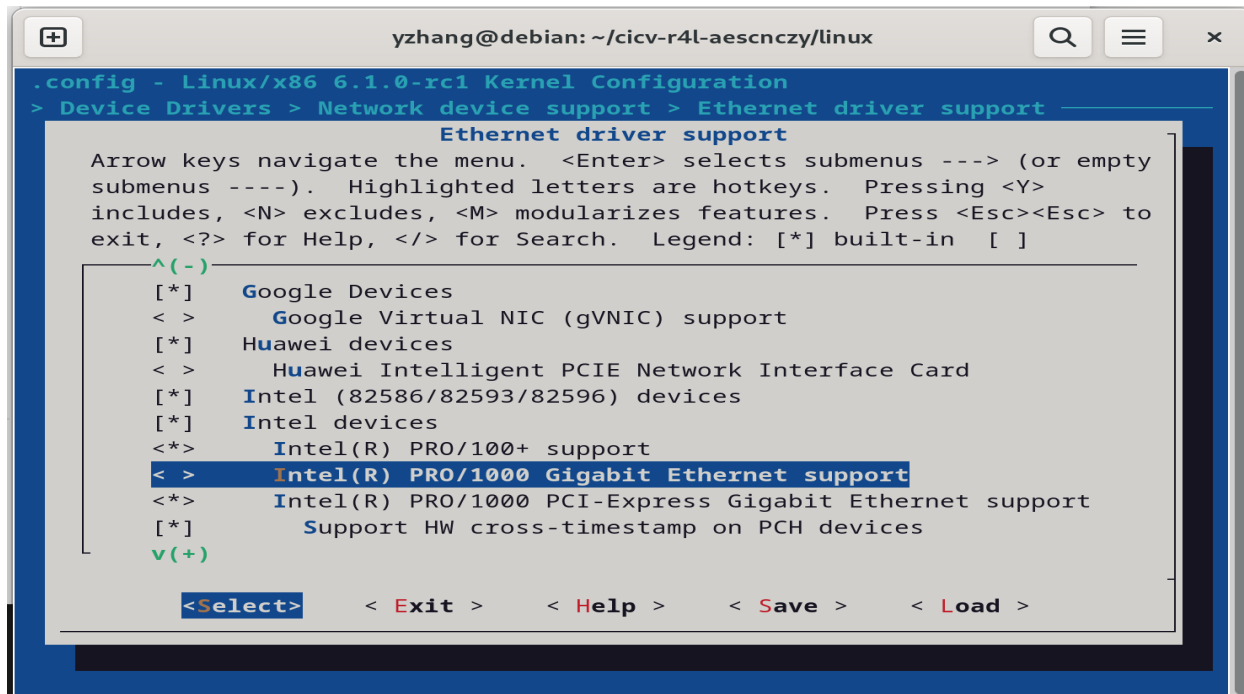
```
yzhang@debian: ~/cicv-r4l-aescnczy/src_e1000
ls
bin      etc      proc     sbin     usr
dev      linuxrc root     sys
~ # ifconfig
eth0      Link encap:Ethernet  HWaddr 52:54:00:12:34:56
          inet addr:10.0.2.15  Bcast:10.0.2.255  Mask:255.255.255.0
          inet6 addr: fe80::5054:ff:fe12:3456/64  Scope:Link
          inet6 addr: fec0::5054:ff:fe12:3456/64  Scope:Site
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:2 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:268 (268.0 B)  TX bytes:672 (672.0 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:1000
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)

~ #
```

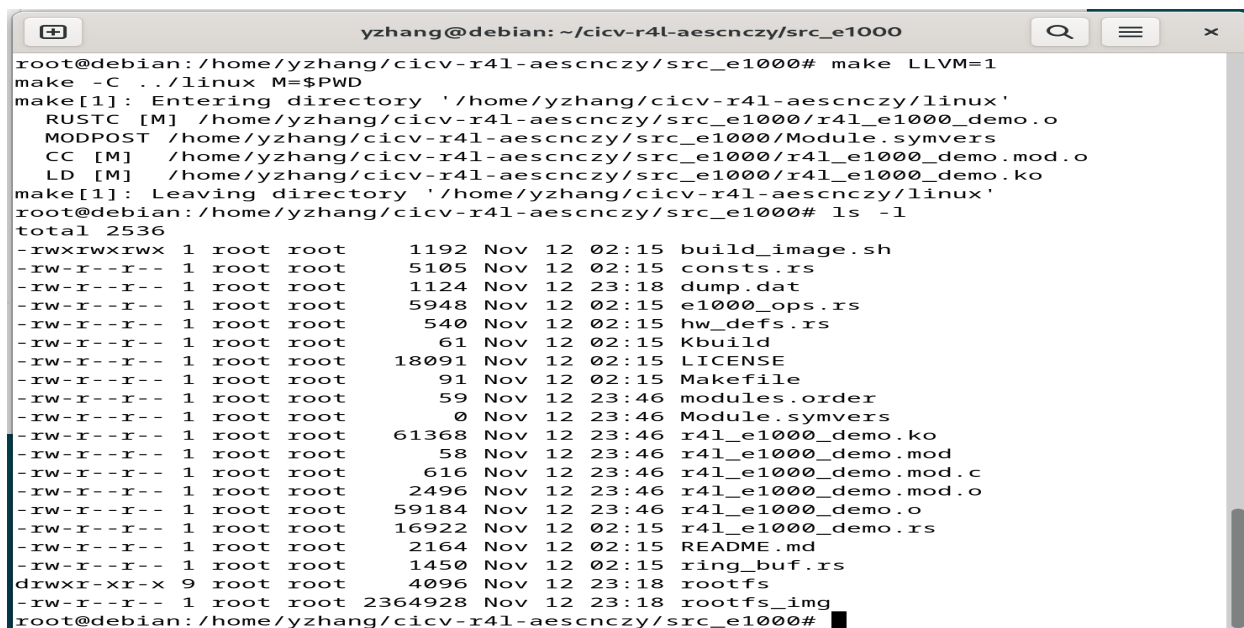
```
yzhang@debian: ~/cicv-r4l-aescnczy/src_e1000
[ 2303.043434] TSC found unstable after boot, most likely due to broken BIOS. Use '.
[ 2303.043648] sched_clock: Marking unstable (2303001036012, 41835491)<-(2303137284)
[ 2303.046717] clocksource: Not enough CPUs to check clocksource 'tsc'.
[ 2303.047405] clocksource: Switched to clocksource hpet
ping 127.0.0.1
PING 127.0.0.1 (127.0.0.1): 56 data bytes
64 bytes from 127.0.0.1: seq=0 ttl=64 time=19.319 ms
64 bytes from 127.0.0.1: seq=1 ttl=64 time=0.513 ms
64 bytes from 127.0.0.1: seq=2 ttl=64 time=0.201 ms
64 bytes from 127.0.0.1: seq=3 ttl=64 time=0.284 ms
64 bytes from 127.0.0.1: seq=4 ttl=64 time=0.204 ms
64 bytes from 127.0.0.1: seq=5 ttl=64 time=0.198 ms
64 bytes from 127.0.0.1: seq=6 ttl=64 time=0.190 ms
64 bytes from 127.0.0.1: seq=7 ttl=64 time=0.203 ms
64 bytes from 127.0.0.1: seq=8 ttl=64 time=0.197 ms
64 bytes from 127.0.0.1: seq=9 ttl=64 time=0.223 ms
64 bytes from 127.0.0.1: seq=10 ttl=64 time=0.220 ms
64 bytes from 127.0.0.1: seq=11 ttl=64 time=0.196 ms
64 bytes from 127.0.0.1: seq=12 ttl=64 time=0.234 ms
64 bytes from 127.0.0.1: seq=13 ttl=64 time=0.334 ms
64 bytes from 127.0.0.1: seq=14 ttl=64 time=0.207 ms
64 bytes from 127.0.0.1: seq=15 ttl=64 time=0.259 ms
^Z[1]+  Stopped                  ping 127.0.0.1
~ #
```

在默认情况下的 e1000 网卡驱动被启用了，因此，不能够装上 myrfy 老师的 e1000 网卡驱动模块，您需要修改配置，让 Linux 内核默认的 C 版本的 e1000 网卡驱动能够禁用，这是您的作业内容。（配置路径 Device Drivers > Network device support > Ethernet driver support > Intel devices, Intel(R) PRO/1000 Gigabit Ethernet support）



```
yzhang@debian: ~/cicv-r4l-aescnczy/linux
.config - Linux/x86 6.1.0-rc1 Kernel Configuration
> Device Drivers > Network device support > Ethernet driver support
Ethernet driver support
Arrow keys navigate the menu. <Enter> selects submenus ---> (or empty
submenus ----). Highlighted letters are hotkeys. Pressing <Y>
includes, <N> excludes, <M> modularizes features. Press <Esc><Esc> to
exit, <?> for Help, </> for Search. Legend: [*] built-in [ ]
^(-)
[*] Google Devices
< > Google Virtual NIC (gVNIC) support
[*] Huawei devices
< > Huawei Intelligent PCIE Network Interface Card
[*] Intel (82586/82593/82596) devices
[*] Intel devices
<*> Intel(R) PRO/100+ support
< > Intel(R) PRO/1000 Gigabit Ethernet support
<*> Intel(R) PRO/1000 PCI-Express Gigabit Ethernet support
[*] Support HW cross-timestamp on PCH devices
v(+)
<Select> <Exit> <Help> <Save> <Load>
```

随后退出 qemu 模拟器，重新编译您的内核，并再次进入 qemu 模拟器。



```
yzhang@debian: ~/cicv-r4l-aescnczy/src_e1000
root@debian: /home/yzhang/cicv-r4l-aescnczy/src_e1000# make LLVM=1
make -C ../linux M=$PWD
make[1]: Entering directory '/home/yzhang/cicv-r4l-aescnczy/linux'
RUSTC [M] /home/yzhang/cicv-r4l-aescnczy/src_e1000/r4l_e1000_demo.o
MODPOST /home/yzhang/cicv-r4l-aescnczy/src_e1000/Module.symvers
CC [M] /home/yzhang/cicv-r4l-aescnczy/src_e1000/r4l_e1000_demo.mod.o
LD [M] /home/yzhang/cicv-r4l-aescnczy/src_e1000/r4l_e1000_demo.ko
make[1]: Leaving directory '/home/yzhang/cicv-r4l-aescnczy/linux'
root@debian: /home/yzhang/cicv-r4l-aescnczy/src_e1000# ls -l
total 2536
-rwxrwxrwx 1 root root 1192 Nov 12 02:15 build_image.sh
-rw-r--r-- 1 root root 5105 Nov 12 02:15 consts.rs
-rw-r--r-- 1 root root 1124 Nov 12 23:18 dump.dat
-rw-r--r-- 1 root root 5948 Nov 12 02:15 e1000_ops.rs
-rw-r--r-- 1 root root 540 Nov 12 02:15 hw_defs.rs
-rw-r--r-- 1 root root 61 Nov 12 02:15 Kbuild
-rw-r--r-- 1 root root 18091 Nov 12 02:15 LICENSE
-rw-r--r-- 1 root root 91 Nov 12 02:15 Makefile
-rw-r--r-- 1 root root 59 Nov 12 23:46 modules.order
-rw-r--r-- 1 root root 0 Nov 12 23:46 Module.symvers
-rw-r--r-- 1 root root 61368 Nov 12 23:46 r4l_e1000_demo.ko
-rw-r--r-- 1 root root 58 Nov 12 23:46 r4l_e1000_demo.mod
-rw-r--r-- 1 root root 616 Nov 12 23:46 r4l_e1000_demo.mod.c
-rw-r--r-- 1 root root 2496 Nov 12 23:46 r4l_e1000_demo.mod.o
-rw-r--r-- 1 root root 59184 Nov 12 23:46 r4l_e1000_demo.o
-rw-r--r-- 1 root root 16922 Nov 12 02:15 r4l_e1000_demo.rs
-rw-r--r-- 1 root root 2164 Nov 12 02:15 README.md
-rw-r--r-- 1 root root 1450 Nov 12 02:15 ring_buf.rs
drwxr-xr-x 9 root root 4096 Nov 12 23:18 rootfs
-rw-r--r-- 1 root root 2364928 Nov 12 23:18 rootfs_img
root@debian: /home/yzhang/cicv-r4l-aescnczy/src_e1000#
```

由于 myrfy 老师给出的代码仅仅是一个 demo，仍然有非常多需要完善的地方，因此这个网卡驱动无法自动进行网络配置，需要您进行手动配置以让他能够联网。

insmod r4l\_e1000\_demo.ko

```
yzhang@debian: ~/cicv-r4l-aescnczy/src_e1000
[ 2.154029] clocksource: Switched to clocksource tsc
[ 2.616894] input: ImExPS/2 Generic Explorer Mouse as /devices/platform/i8043
[ 2.632282] e1000: eth0 NIC Link is Up 1000 Mbps Full Duplex, Flow Control: X
[ 2.633676] IPv6: ADDRCONF(NETDEV_CHANGE): eth0: link becomes ready
[ 2.650920] IP-Config: Complete:
[ 2.651246]     device=eth0, hwaddr=52:54:00:12:34:56, ipaddr=10.0.2.15, mal
[ 2.651780]     host=10.0.2.15, domain=, nis-domain=(none)
[ 2.652015]     bootserver=255.255.255.255, rootserver=255.255.255.255, roo=
[ 2.657736]     cfg80211: Loading compiled-in X.509 certificates for regulatory e
[ 2.728168] modprobe (66) used greatest stack depth: 14272 bytes left
[ 2.744129] cfg80211: Loaded X.509 cert 'sforshee: 00b28ddf47aef9cea7'
[ 2.748139] platform regulatory.0: Direct firmware load for regulatory.db fa2
[ 2.749105] cfg80211: failed to load regulatory.db
[ 2.750342] ALSA device list:
[ 2.750725]   No soundcards found.
[ 2.831156] Freeing unused kernel image (initmem) memory: 1328K
[ 2.831688] Write protecting the kernel read-only data: 24576k
[ 2.834670] Freeing unused kernel image (text/rodata gap) memory: 2032K
[ 2.835647] Freeing unused kernel image (rodata/data gap) memory: 824K
[ 2.980030] x86/mm: Checked W+X mappings: passed, no W+X pages found.
[ 2.980556] Run/sbin/init as init process
[ 3.024147] mount (71) used greatest stack depth: 14160 bytes left
[ 3.181608] mdev (73) used greatest stack depth: 13928 bytes left
[ 3.186327] mknod (74) used greatest stack depth: 13920 bytes left

Please press Enter to activate this console.
~ # insmod r4l_e1000_demo.ko
[ 33.570646] r4l_e1000_demo: loading out-of-tree module taints kernel.
[ 33.579258] r4l_e1000_demo: Rust for linux e1000 driver demo (init)
[ 33.586481] insmod (79) used greatest stack depth: 13288 bytes left
~ #
```

ip link set eth0 up

ip addr add broadcast 10.0.2.255 dev eth0

ip addr add 10.0.2.15/255.255.255.0 dev eth0

ip route add default via 10.0.2.1

ping 10.0.2.2

```
yzhang@debian: ~/cicv-r4l-aescnczy/src_e1000
[ 2.657736] cfg80211: Loading compiled-in X.509 certificates for regulatory e
[ 2.728168] modprobe (66) used greatest stack depth: 14272 bytes left
[ 2.744129] cfg80211: Loaded X.509 cert 'sforshee: 00b28ddf47aef9cea7'
[ 2.748139] platform regulatory.0: Direct firmware load for regulatory.db fa2
[ 2.749105] cfg80211: failed to load regulatory.db
[ 2.750342] ALSA device list:
[ 2.750725]   No soundcards found.
[ 2.831156] Freeing unused kernel image (initmem) memory: 1328K
[ 2.831688] Write protecting the kernel read-only data: 24576k
[ 2.834670] Freeing unused kernel image (text/rodata gap) memory: 2032K
[ 2.835647] Freeing unused kernel image (rodata/data gap) memory: 824K
[ 2.980030] x86/mm: Checked W+X mappings: passed, no W+X pages found.
[ 2.980556] Run/sbin/init as init process
[ 3.024147] mount (71) used greatest stack depth: 14160 bytes left
[ 3.181608] mdev (73) used greatest stack depth: 13928 bytes left
[ 3.186327] mknod (74) used greatest stack depth: 13920 bytes left

Please press Enter to activate this console.
~ # insmod r4l_e1000_demo.ko
[ 33.570646] r4l_e1000_demo: loading out-of-tree module taints kernel.
[ 33.579258] r4l_e1000_demo: Rust for linux e1000 driver demo (init)
[ 33.586481] insmod (79) used greatest stack depth: 13288 bytes left
~ # ip link set eth0 up
~ # ip addr add broadcast 10.0.2.255 dev eth0
ip: RTNETLINK answers: Invalid argument
[ 89.440226] ip (81) used greatest stack depth: 13032 bytes left
~ # ip addr add 10.0.2.15/255.255.255.0 dev eth0
ip: RTNETLINK answers: File exists
~ # ip route add default via 10.0.2.1
ip: RTNETLINK answers: File exists
~ # ping 10.0.2.2
```

随后您将在其中看到如下输出：

```
y Zhang@debian: ~/cicv-r4l-aescnczy/src_e1000
[ 3.186327] mknod (74) used greatest stack depth: 13920 bytes left

Please press Enter to activate this console.
~ # insmod r4l_e1000_demo.ko
[ 33.570646] r4l_e1000_demo: loading out-of-tree module taints kernel.
[ 33.579258] r4l_e1000_demo: Rust for linux e1000 driver demo (init)
[ 33.586481] insmod (79) used greatest stack depth: 13288 bytes left
~ # ip link set eth0 up
~ # ip addr add broadcast 10.0.2.255 dev eth0
ip: RTNETLINK answers: Invalid argument
[ 89.440226] ip (81) used greatest stack depth: 13032 bytes left
~ # ip addr add 10.0.2.15/255.255.255.0 dev eth0
ip: RTNETLINK answers: File exists
~ # ip route add default via 10.0.2.1
ip: RTNETLINK answers: File exists
~ # ping 10.0.2.2
PING 10.0.2.2 (10.0.2.2): 56 data bytes
64 bytes from 10.0.2.2: seq=0 ttl=255 time=9.076 ms
64 bytes from 10.0.2.2: seq=1 ttl=255 time=0.953 ms
64 bytes from 10.0.2.2: seq=2 ttl=255 time=1.001 ms
64 bytes from 10.0.2.2: seq=3 ttl=255 time=0.461 ms
64 bytes from 10.0.2.2: seq=4 ttl=255 time=1.494 ms
64 bytes from 10.0.2.2: seq=5 ttl=255 time=2.584 ms
64 bytes from 10.0.2.2: seq=6 ttl=255 time=0.569 ms
64 bytes from 10.0.2.2: seq=7 ttl=255 time=0.440 ms
64 bytes from 10.0.2.2: seq=8 ttl=255 time=0.587 ms
64 bytes from 10.0.2.2: seq=9 ttl=255 time=0.518 ms
64 bytes from 10.0.2.2: seq=10 ttl=255 time=0.501 ms
64 bytes from 10.0.2.2: seq=11 ttl=255 time=1.621 ms
64 bytes from 10.0.2.2: seq=12 ttl=255 time=0.349 ms
```