作业1

作业1 编译Linux内核

```
ywf@DESKTOP-L1MNRL0: ~/dev-place/rust/cicv-r4l-3-yiwufen/linux
nent add rustfmt
rustup component add clippy
info: component 'rustfmt' for target 'x86_64-unknown-linux-gnu' is up to date
info: component 'clippy' for target 'x86_64-unknown-linux-gnu' is up to date
(base) ywf@DESKTOP-L1MNRL0:~/dev-place/rust/cicv-r4l-3-yiwufen/linux$ make LLVM=1
rustavailable
Rust is available!
(base) ywf@DESKTOP-L1MNRL0:~/dev-place/rust/cicv-r4l-3-yiwufen/linux$ make x86_64_
defconfig
  HOSTCC  scripts/basic/fixdep
  HOSTCC  scripts/kconfig/conf.o
  HOSTCC  scripts/kconfig/confdata.o
  HOSTCC  scripts/kconfig/expr.o
  LEX     scripts/kconfig/lexer.lex.c
  YACC    scripts/kconfig/parser.tab.[ch]
  HOSTCC  scripts/kconfig/lexer.lex.o
  HOSTCC  scripts/kconfig/menu.o
  HOSTCC  scripts/kconfig/parser.tab.o
  HOSTCC  scripts/kconfig/preprocess.o
  HOSTCC  scripts/kconfig/symbol.o
  HOSTCC  scripts/kconfig/util.o
  HOSTLD  scripts/kconfig/conf
#
# configuration written to .config
#
```

```
ywf@DESKTOP-L1MNRL0: ~/dev-place/rust/cicv-r4l-3-yiwufen/linux
#
# end of Rust hacking
# end of Kernel hacking
(base) ywf@DESKTOP-L1MNRL0:~/dev-place/rust/cicv-r4l-3-yiwufen/linux$ make LLVM=1
menuconfig
  HOSTCC  scripts/basic/fixdep
  HOSTCC  scripts/kconfig/confdata.o
  HOSTCC  scripts/kconfig/expr.o
  HOSTCC  scripts/kconfig/lexer.lex.o
  HOSTCC  scripts/kconfig/menu.o
  HOSTCC  scripts/kconfig/parser.tab.o
  HOSTCC  scripts/kconfig/preprocess.o
  HOSTCC  scripts/kconfig/symbol.o
  HOSTCC  scripts/kconfig/util.o
  UPD     scripts/kconfig/mconf-cfg
  HOSTCC  scripts/kconfig/mconf.o
  HOSTCC  scripts/kconfig/lxdialog/checklist.o
  HOSTCC  scripts/kconfig/lxdialog/inputbox.o
  HOSTCC  scripts/kconfig/lxdialog/menubox.o
  HOSTCC  scripts/kconfig/lxdialog/textbox.o
  HOSTCC  scripts/kconfig/lxdialog/util.o
  HOSTCC  scripts/kconfig/lxdialog/yesno.o
  HOSTLD  scripts/kconfig/mconf
configuration written to .config

*** End of the configuration.
*** Execute 'make' to start the build or try 'make help'.
```

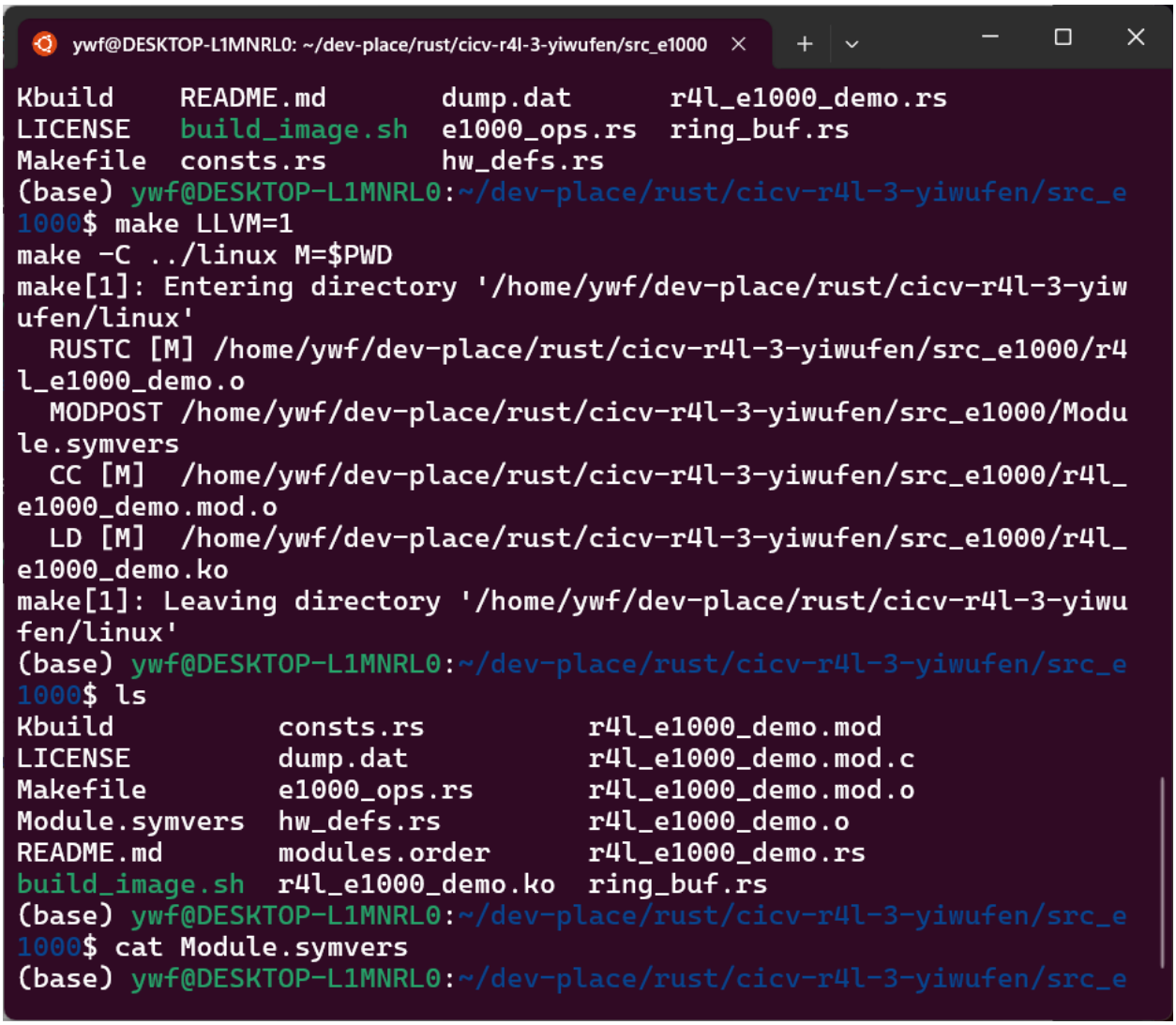
```
(base) ywf@DESKTOP-L1MNRL0:~/dev-place/rust/cicv-r4l-3-yiwufen/linux$ make LLVM=1
-j$(nproc)
  SYNC    include/config/auto.conf.cmd
  HOSTCC  scripts/kconfig/conf.o
  HOSTLD  scripts/kconfig/conf
  SYSHDR  arch/x86/include/generated/uapi/asm/unistd_32.h
  SYSHDR  arch/x86/include/generated/uapi/asm/unistd_64.h
  SYSHDR  arch/x86/include/generated/uapi/asm/unistd_x32.h
  SYSTBL  arch/x86/include/generated/asm/syscalls_32.h
  SYSHDR  arch/x86/include/generated/asm/unistd_32_ia32.h
  SYSHDR  arch/x86/include/generated/asm/unistd_64_x32.h
  SYSTBL  arch/x86/include/generated/asm/syscalls_64.h
  WRAP    arch/x86/include/generated/uapi/asm/bpf_perf_event.h
  WRAP    arch/x86/include/generated/uapi/asm/errno.h
  WRAP    arch/x86/include/generated/uapi/asm/fcntl.h
  WRAP    arch/x86/include/generated/uapi/asm/ioctl.h
  WRAP    arch/x86/include/generated/uapi/asm/ioctls.h
  WRAP    arch/x86/include/generated/uapi/asm/ipcbuf.h
  WRAP    arch/x86/include/generated/uapi/asm/param.h
  WRAP    arch/x86/include/generated/uapi/asm/poll.h
  WRAP    arch/x86/include/generated/uapi/asm/resource.h
  WRAP    arch/x86/include/generated/uapi/asm/socket.h
  WRAP    arch/x86/include/generated/uapi/asm/sockios.h
  WRAP    arch/x86/include/generated/uapi/asm/termbits.h
```

```
ywf@DESKTOP-L1MNRL0: ~/dev-place/rust/cicv-r4l-3-yiwufen/linux
  OBJCOPY arch/x86/boot/compressed/vmlinux.bin
  RELOCS  arch/x86/boot/compressed/vmlinux.relocs
  HOSTCC  arch/x86/boot/compressed/mkpiggy
  CC      arch/x86/boot/compressed/cpuflags.o
  CC      arch/x86/boot/compressed/early_serial_console.o
  CC      arch/x86/boot/compressed/kaslr.o
  CC      arch/x86/boot/compressed/ident_map_64.o
  CC      arch/x86/boot/compressed/idt_64.o
  AS      arch/x86/boot/compressed/idt_handlers_64.o
  AS      arch/x86/boot/compressed/mem_encrypt.o
  CC      arch/x86/boot/compressed/pgtable_64.o
  CC      arch/x86/boot/compressed/acpi.o
  AS      arch/x86/boot/compressed/efi_thunk_64.o
  CC      arch/x86/boot/compressed/efi.o
  GZIP    arch/x86/boot/compressed/vmlinux.bin.gz
  CC      arch/x86/boot/compressed/misc.o
  MKPIGGY arch/x86/boot/compressed/piggy.S
  AS      arch/x86/boot/compressed/piggy.o
  LD      arch/x86/boot/compressed/vmlinux
  ZOFFSET arch/x86/boot/zoffset.h
  OBJCOPY arch/x86/boot/vmlinux.bin
  AS      arch/x86/boot/header.o
  LD      arch/x86/boot/setup.elf
  OBJCOPY arch/x86/boot/setup.bin
  BUILD   arch/x86/boot/bzImage
Kernel: arch/x86/boot/bzImage is ready  (#1)
```

```
(base) ywf@DESKTOP-L1MNRL0:~/dev-place/rust/cicv-r4l-3-yiwufen/linux$ ls
COPYING          README      fs               modules.builtin.modinfo  usr
CREDITS          README.md   include          modules.order            virt
Documentation    System.map  init             net                      vmlinux
Kbuild           arch        io_uring         rust                     vmlinux.a
Kconfig          block       ipc              samples                  vmlinux.o
LICENSES         built-in.a  kernel           scripts
MAINTAINERS      certs       lib              security
Makefile         crypto      mm               sound
Module.symvers   drivers     modules.builtin  tools
(base) ywf@DESKTOP-L1MNRL0:~/dev-place/rust/cicv-r4l-3-yiwufen/linux$
```

作业2

编译驱动进内核



Q1

> 有kbuild 文件中的 obj-m := r4l_e1000_demo.o 定义的

Q2

> 通过Makefile文件，这个文件执行命令让其跳转到了linux目录下进行编译。

允许build_image.sh

进入linux

```
ywf@DESKTOP-L1MNRL0: ~/dev-place/rust/cicv-r4l-
[    2.072764] clocksource: tsc: mask: 0xffffffffffffffff ms
[    2.076700] clocksource: Switched to clocksource tsc
[    2.461250] input: ImExPS/2 Generic Explorer Mouse as /d3
[    2.498704] e1000: eth0 NIC Link is Up 1000 Mbps Full DuX
[    2.501484] IPv6: ADDRCONF(NETDEV_CHANGE): eth0: link bey
[    2.513881] IP-Config: Complete:
[    2.514019]      device=eth0, hwaddr=52:54:00:12:34:56, 1
[    2.514539]      host=10.0.2.15, domain=, nis-domain=(no)
[    2.515145]      bootserver=255.255.255.255, rootserver==
[    2.519325] cfg80211: Loading compiled-in X.509 certifice
[    2.571915] modprobe (66) used greatest stack depth: 142t
[    2.584850] cfg80211: Loaded X.509 cert 'sforshee: 00b28'
[    2.586531] platform regulatory.0: Direct firmware load 2
[    2.587056] cfg80211: failed to load regulatory.db
[    2.588340] ALSA device list:
[    2.588585]   No soundcards found.
[    2.634216] Freeing unused kernel image (initmem) memoryK
[    2.634923] Write protecting the kernel read-only data: k
[    2.638009] Freeing unused kernel image (text/rodata gapK
[    2.638984] Freeing unused kernel image (rodata/data gapK
[    2.801801] x86/mm: Checked W+X mappings: passed, no W+X.
[    2.802357] Run sbin/init as init process
[    2.840349] mount (71) used greatest stack depth: 14160 t
[    2.968313] mdev (73) used greatest stack depth: 13960 bt

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

安装内核模块

```
~ # insmod r4l_e1000_demo.ko
[  209.633129] r4l_e1000_demo: loading out-of-tree module t.
[  209.639984] r4l_e1000_demo: Rust for linux e1000 driver )
[  209.641654] insmod (80) used greatest stack depth: 13072t
~ #
```

查看模块

```
~ # lsmod | grep r4l_e1000_demo
r4l_e1000_demo 40960 0 - Live 0xffffffffc022b000 (O)
~ #
```

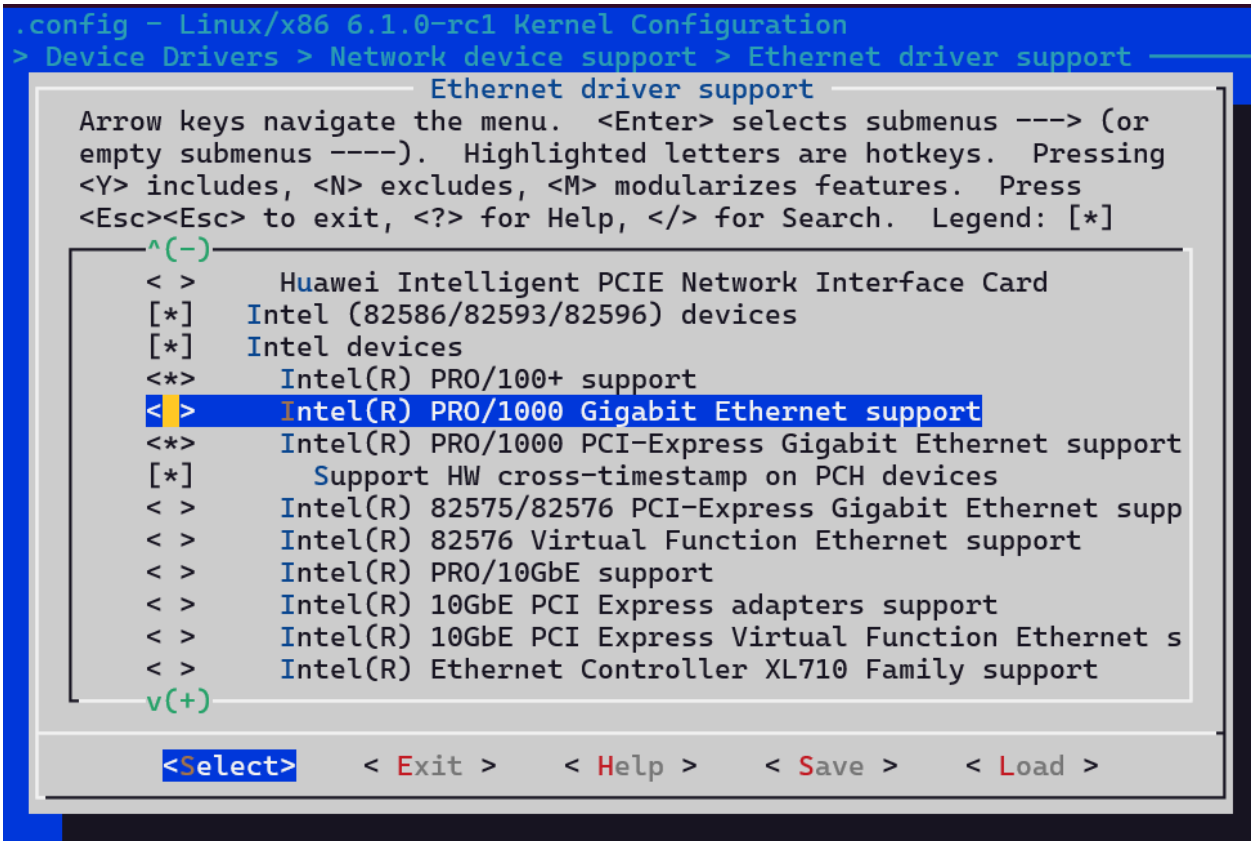
查看网络设备，并执行ping操作

```
~ # 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:3 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:330 (330.0 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)

~ # ping 10.0.2.15
PING 10.0.2.15 (10.0.2.15): 56 data bytes
64 bytes from 10.0.2.15: seq=0 ttl=64 time=7.267 ms
64 bytes from 10.0.2.15: seq=1 ttl=64 time=1.194 ms
64 bytes from 10.0.2.15: seq=2 ttl=64 time=1.040 ms
64 bytes from 10.0.2.15: seq=3 ttl=64 time=0.361 ms
64 bytes from 10.0.2.15: seq=4 ttl=64 time=0.999 ms
```

禁用默认的C版本的e1000网卡驱动



重新编译 `make LLVM=1 -j$(nproc)`

```
(base) ywf@DESKTOP-L1MNRL0:~/dev-place/rust/cicv-r4l-3-yiwufen/linux$ make LL
VM=1 -j$(nproc)
  SYNC    include/config/auto.conf.cmd
  HOSTCC  scripts/kconfig/conf.o
  HOSTLD  scripts/kconfig/conf
  DESCEND objtool
  CALL    scripts/checksyscalls.sh
  RUSTC L rust/bindings.o
  EXPORTS rust/exports_bindings_generated.h
  RUSTC L rust/kernel.o
  EXPORTS rust/exports_kernel_generated.h
  CC      rust/exports.o
  AR      drivers/net/ethernet/intel/built-in.a
  AR      drivers/net/ethernet/built-in.a
  AR      drivers/net/built-in.a
  AR      rust/built-in.a
  AR      drivers/built-in.a
  AR      built-in.a
  AR      vmlinux.a
  LD      vmlinux.o
  OBJCOPY modules.builtin.modinfo
  GEN     modules.builtin
  MODPOST Module.symvers
  UPD     include/generated/utsversion.h
  CC      init/version-timestamp.o
  LD      .tmp_vmlinux.kallsyms1
  NM      .tmp_vmlinux.kallsyms1.syms
```

重新插入模块

```
~ # insmod r4l_e1000_demo.ko
[   51.610908] r4l_e1000_demo: loading out-of-tree module taints kernel.
[   51.617593] r4l_e1000_demo: Rust for linux e1000 driver demo (init)
[   51.618126] r4l_e1000_demo: Rust for linux e1000 driver demo (probe): None
[   51.800266] ACPI: \_SB_.LNKC: Enabled at IRQ 11
[   51.826182] r4l_e1000_demo: Rust for linux e1000 driver demo (net device )
[   51.830664] insmod (81) used greatest stack depth: 11192 bytes left
~ #
```

`ip link set eht0 ip` 启动eth0 网络接口

```
~ # ip link set eth0 up
[  132.272775] r4l_e1000_demo: Rust for linux e1000 driver demo (net device )
[  132.276129] r4l_e1000_demo: Rust for linux e1000 driver demo (net device )
[  132.277905] IPv6: ADDRCONF(NETDEV_CHANGE): eth0: link becomes ready
[  132.281345] r4l_e1000_demo: Rust for linux e1000 driver demo (net device )
~ # [  132.289867] r4l_e1000_demo: Rust for linux e1000 driver demo (net dev0
[  132.291039] r4l_e1000_demo: Rust for linux e1000 driver demo (handle_irq)
[  132.291267] r4l_e1000_demo: pending_irqs: 3
[  132.292217] r4l_e1000_demo: Rust for linux e1000 driver demo (napi poll)
[  132.598149] r4l_e1000_demo: Rust for linux e1000 driver demo (net device 0
[  132.600906] r4l_e1000_demo: Rust for linux e1000 driver demo (handle_irq)
[  132.602120] r4l_e1000_demo: pending_irqs: 3
[  132.603000] r4l_e1000_demo: Rust for linux e1000 driver demo (napi poll)
[  132.676905] r4l_e1000_demo: Rust for linux e1000 driver demo (net device 0
[  132.677753] r4l_e1000_demo: Rust for linux e1000 driver demo (handle_irq)
[  132.678615] r4l_e1000_demo: pending_irqs: 3
[  132.678962] r4l_e1000_demo: Rust for linux e1000 driver demo (napi poll)
[  133.737343] r4l_e1000_demo: Rust for linux e1000 driver demo (net device 0
[  133.738039] r4l_e1000_demo: Rust for linux e1000 driver demo (handle_irq)
[  133.738381] r4l_e1000_demo: pending_irqs: 3
[  133.738631] r4l_e1000_demo: Rust for linux e1000 driver demo (napi poll)
[  133.739185] r4l_e1000_demo: Rust for linux e1000 driver demo (net device 0
```

配置网络

```
~ # ip addr add broadcast 10.0.2.255 dev eth0
[ 1619.989917] r4l_e1000_demo: Rust for linux e1000 driver demo (net device )
[ 1619.992689] r4l_e1000_demo: Rust for linux e1000 driver demo (net device )
ip: RTNETLINK answers: Invalid argument
~ # ifconfig
[ 1629.763454] r4l_e1000_demo: Rust for linux e1000 driver demo (net device )
eth0      Link encap:Ethernet  HWaddr 52:54:00:12:34:56
          inet6 addr: fe80::5054:ff:fe12:3456/64 Scope:Link
          UP BROADCAST RUNNING 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
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)

~ # ip addr add 10.0.2.15/255.255.255.0 dev eth0
[ 1652.514474] r4l_e1000_demo: Rust for linux e1000 driver demo (net device )
[ 1652.514825] r4l_e1000_demo: Rust for linux e1000 driver demo (net device )
~ # ip route add default via 10.0.2.1
~ # if
ifconfig   ifdown     ifenslave  ifplugd    ifup
~ # ifconfig
[ 1669.691714] r4l_e1000_demo: Rust for linux e1000 driver demo (net device )
eth0      Link encap:Ethernet  HWaddr 52:54:00:12:34:56
          inet addr:10.0.2.15  Bcast:0.0.0.0  Mask:255.255.255.0
          inet6 addr: fe80::5054:ff:fe12:3456/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
```

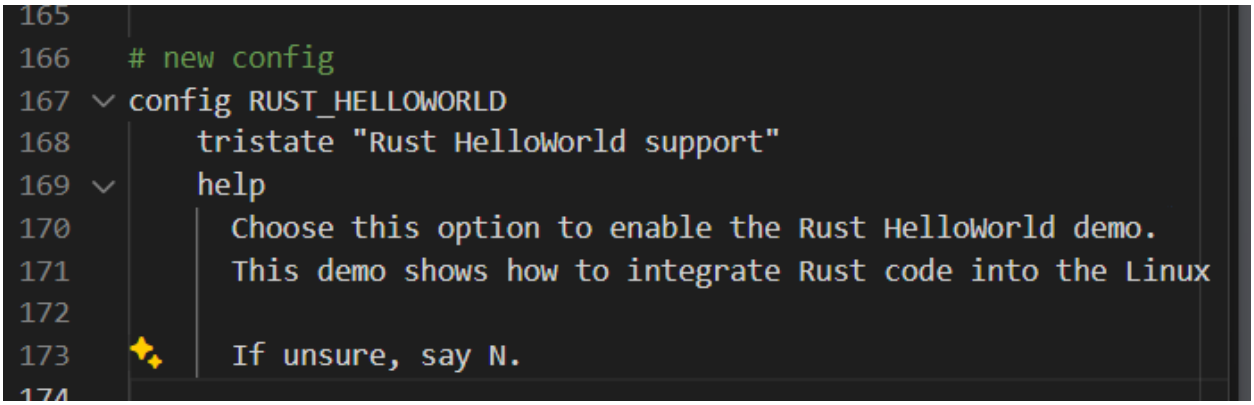
`ping 10.0.2.2`

```
~ # ping 10.0.2.2
PING 10.0.2.2 (10.0.2.2): 56 data bytes
[ 1740.813237] r4l_e1000_demo: Rust for linux e1000 driver demo (net device 0
[ 1740.814114] r4l_e1000_demo: Rust for linux e1000 driver demo (handle_irq)
[ 1740.814944] r4l_e1000_demo: pending_irqs: 131
[ 1740.815384] r4l_e1000_demo: Rust for linux e1000 driver demo (napi poll)
[ 1740.817983] r4l_e1000_demo: Rust for linux e1000 driver demo (net device 1
[ 1740.818490] r4l_e1000_demo: Rust for linux e1000 driver demo (handle_irq)
[ 1740.819161] r4l_e1000_demo: pending_irqs: 131
[ 1740.820150] r4l_e1000_demo: Rust for linux e1000 driver demo (napi poll)
64 bytes from 10.0.2.2: seq=0 ttl=255 time=14.819 ms
[ 1741.825004] r4l_e1000_demo: Rust for linux e1000 driver demo (net device 2
[ 1741.825754] r4l_e1000_demo: Rust for linux e1000 driver demo (handle_irq)
[ 1741.826227] r4l_e1000_demo: pending_irqs: 131
[ 1741.826988] r4l_e1000_demo: Rust for linux e1000 driver demo (napi poll)
64 bytes from 10.0.2.2: seq=1 ttl=255 time=3.469 ms
[ 1742.830100] r4l_e1000_demo: Rust for linux e1000 driver demo (net device 3
[ 1742.833401] r4l_e1000_demo: Rust for linux e1000 driver demo (handle_irq)
[ 1742.835248] r4l_e1000_demo: pending_irqs: 131
[ 1742.836060] r4l_e1000_demo: Rust for linux e1000 driver demo (napi poll)
64 bytes from 10.0.2.2: seq=2 ttl=255 time=6.851 ms
[ 1743.839269] r4l_e1000_demo: Rust for linux e1000 driver demo (net device 4
[ 1743.841730] r4l_e1000_demo: Rust for linux e1000 driver demo (handle_irq)
[ 1743.842664] r4l_e1000_demo: pending_irqs: 131
[ 1743.842938] r4l_e1000_demo: Rust for linux e1000 driver demo (napi poll)
```

作业3：

创建并编辑`rust_helloworld.rs`

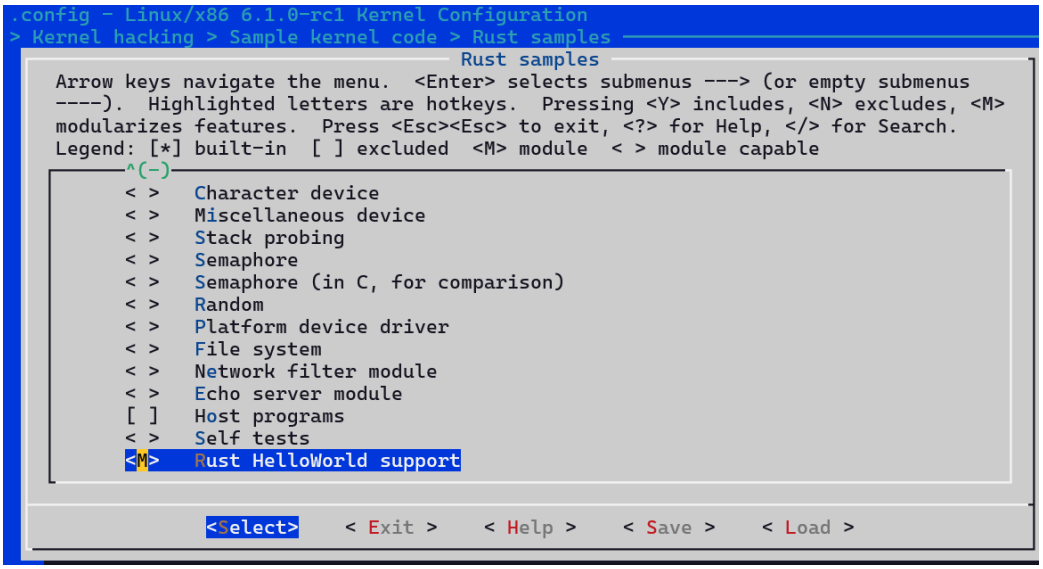
在Kconfig中添加配置



在Makeflie添加编译方式以及配置为模块

```
# 当 RUST_HELLOWORLD 被配置为模块 (m) 时
obj-$(CONFIG_RUST_HELLOWORLD) += rust_helloworld.o
```

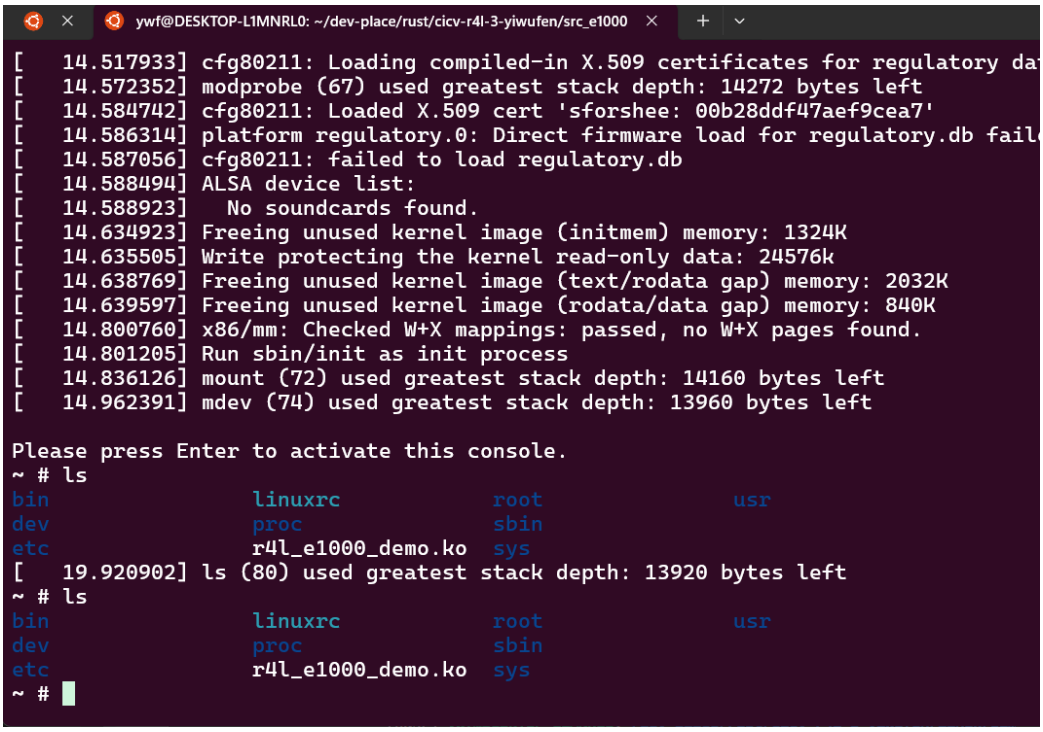
执行`make LLVM=1 menuconfig` 添加配置



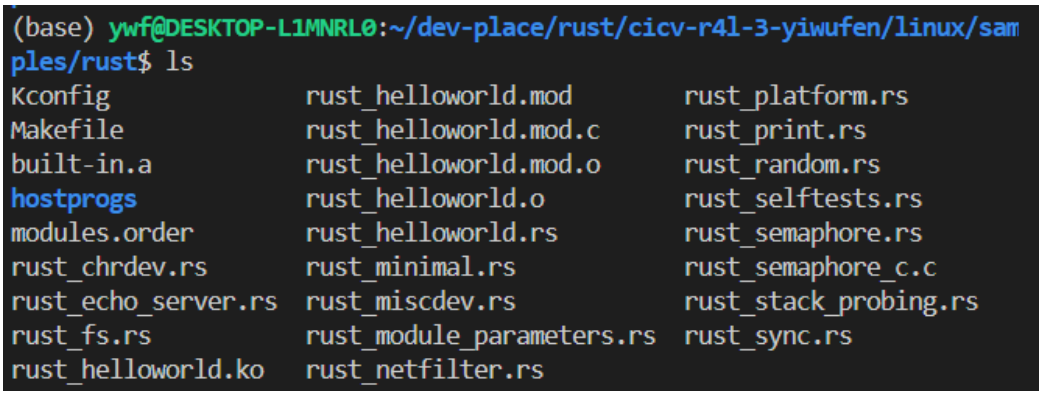
编译内核 `make LLVM=1 -j$(nproc)`

```
(base) ywf@DESKTOP-L1MNRL0:~/dev-place/rust/cicv-r4l-3-yiwufen/linux$ make LLVM=1 -j$(nproc)
  DESCEND objtool
  CALL    scripts/checksyscalls.sh
  RUSTC [M] samples/rust/rust_helloworld.o
  MODPOST Module.symvers
  CC [M]  samples/rust/rust_helloworld.mod.o
  LD [M]  samples/rust/rust_helloworld.ko
Kernel: arch/x86/boot/bzImage is ready  (#3)
```

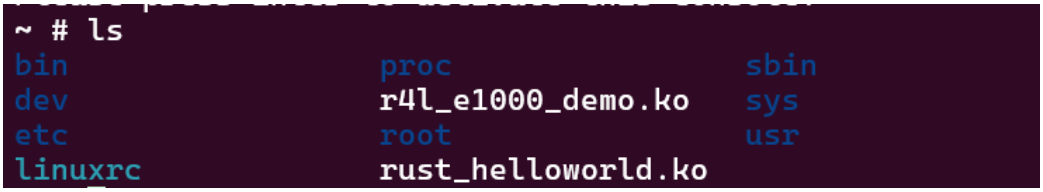
运行src_e1000/build_image.sh



查看rust_helloworld.ko的文件



将该文件复制到仓库中src_e1000/rootfs目录下，然后重新跑build_image.sh， 查看rust_helloworld.ko文件



insmod命令进行安装该模块rust_helloworld.ko

```
~ # insmod rust_helloworld.ko
[  373.981198] rust_helloworld: Hello World from Rust module
```

作业4：为e1000网卡驱动添加remove代码

添加代码

```
    fn remove(data: &Self::Data) {
        pr_info!("Rust for linux e1000 driver demo (remove)\n");
        data.device_remove();
    }
```

```
impl driver::DeviceRemoval for E1000DrvPrvData {
    fn device_remove(&self) {
        pr_info!("Rust for linux e1000 driver demo (device_remov

        // 执行任何必要的清理或关闭操作
        // 此函数在设备被移除或卸载时调用
        self._netdev_reg.dev_get().netif_carrier_off();
        self._netdev_reg.dev_get().netif_stop_queue();
    }
}
```

编译代码，配置网卡，并ping通

```
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
```

```
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)

~ # ping 10.0.2.2
PING 10.0.2.2 (10.0.2.2): 56 data bytes
[ 3340.321225] r4l_e1000_demo: Rust for linux e1000 driver demo (net device start_xmit) tdt=1, tdh=1, rdt=7
[ 3340.322847] r4l_e1000_demo: Rust for linux e1000 driver demo (handle_irq)
[ 3340.323431] r4l_e1000_demo: pending_irqs: 131
[ 3340.324219] r4l_e1000_demo: Rust for linux e1000 driver demo (napi poll)
[ 3340.326603] r4l_e1000_demo: Rust for linux e1000 driver demo (net device start_xmit) tdt=2, tdh=2, rdt=0
[ 3340.327398] r4l_e1000_demo: Rust for linux e1000 driver demo (handle_irq)
[ 3340.327610] r4l_e1000_demo: pending_irqs: 131
[ 3340.328665] r4l_e1000_demo: Rust for linux e1000 driver demo (napi poll)
64 bytes from 10.0.2.2: seq=0 ttl=255 time=15.327 ms
[ 3341.332649] r4l_e1000_demo: Rust for linux e1000 driver demo (net device start_xmit) tdt=3, tdh=3, rdt=1
[ 3341.333109] r4l_e1000_demo: Rust for linux e1000 driver demo (handle_irq)
[ 3341.333493] r4l_e1000_demo: pending_irqs: 131
[ 3341.333805] r4l_e1000_demo: Rust for linux e1000 driver demo (napi poll)
64 bytes from 10.0.2.2: seq=1 ttl=255 time=1.962 ms
[ 3342.335392] r4l_e1000_demo: Rust for linux e1000 driver demo (net device start_xmit) tdt=4, tdh=4, rdt=2
[ 3342.336084] r4l_e1000_demo: Rust for linux e1000 driver demo (handle_irq)
[ 3342.336495] r4l_e1000_demo: pending_irqs: 131
[ 3342.336793] r4l_e1000_demo: Rust for linux e1000 driver demo (napi poll)
64 bytes from 10.0.2.2: seq=2 ttl=255 time=2.388 ms
^C
--- 10.0.2.2 ping statistics ---
3 packets transmitted, 3 packets received, 0% packet loss
round-trip min/avg/max = 1.962/6.559/15.327 ms
```

rmmod

```
~ # rmmod r4l_e1000_demo.ko
[ 3452.467045] r4l_e1000_demo: Rust for linux e1000 driver demo (exit)
[ 3452.467603] r4l_e1000_demo: Rust for linux e1000 driver demo (remove)
[ 3452.467750] r4l_e1000_demo: Rust for linux e1000 driver demo (device_remove)
[ 3452.468043] r4l_e1000_demo: Rust for linux e1000 driver demo (device_remove)
[ 3452.470415] r4l_e1000_demo: Rust for linux e1000 driver demo (net device get_stats64)
[ 3452.471103] r4l_e1000_demo: Rust for linux e1000 driver demo (net device stop)
[ 3452.471346] r4l_e1000_demo: Rust for linux e1000 driver demo (net device get_stats64)
[ 3452.479703] r4l_e1000_demo: Rust for linux e1000 driver demo (net device get_stats64)
~ #
```

作业5

完善write、read 函数

```rust
    /// 写入函数，用于将数据写入设备
    fn write(_this: &Self, _file: &file::File, _reader: &mut impl kernel::io_buffer::IoBufferReader, _offset: u64) -> Result<usize> {
        let mut buf: Guard<'static, Mutex<[u8; 4096]>, …> = _this.inner.lock();
        let len: usize = _reader.len();

        // 根据偏移量调整写入位置
        let offset: usize = _offset as usize;
        let len: usize = core::cmp::min(v1: len, v2: GLOBALMEM_SIZE - offset);
        let data: <Result<Vec<u8>, Error> as Try>::Output = _reader.read_all()?;
        buf[offset..offset + len].copy_from_slice(&data[..len]);
        Ok(len)
    }

    fn read(_this: &Self,_file: &file::File,_writer: &mut impl kernel::io_buffer::IoBufferWriter,_offset:u64,) -> Result<usize> {
        let buf: Guard<'static, Mutex<[u8; 4096]>, …> = _this.inner.lock();
        // 计算可从偏移量开始读取的最大字节数
        let max_readable: usize = GLOBALMEM_SIZE - _offset as usize;
        // 获取实际要读取的数据切片
        let data_to_read: &<{unknown} as Index<Range<…>>>::Output = &buf[_offset as usize.._offset as usize + max_readable];
        _writer.write_slice(data_to_read)?;
        Ok(data_to_read.len())
    }
} impl Operations for RustFile
```

添加配置

```
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  [ ] excluded  <M> module
< > module capable

                --- Rust samples
                < >   Minimal
                < >   Printing macros
                < >   Module parameters
                < >   Synchronisation primitives
                <*>   Character device
                < >   Miscellaneous device
                < >   Stack probing
                < >   Semaphore
                < >   Semaphore (in C, for comparison)
                < >   Random
                < >   Platform device driver
                < >   File system
                < >   Network filter module
                < >   Echo server module
                v(+)

                      <Select>    < Exit >    < Help >    < Save >    < Load >
```

编译内核并进入系统

执行测试命令

```
~ # echo "hi boy" > /dev/cicv
~ # cat /dev/cicv
hi boy
~ #
```

Q：作业5中的字符设备/dev/cicv是怎么创建的？它的设备号是多少？它是如何与我们写的字符设备驱动关联上的？

▼ 通过字符设备的创建是通过`chrdev::Registration`结构体实现的。这个结构体提供了一个简化的接口来注册和注销字符设备。在`new_pinned`函数调用时，第二个参数是期望的主设备号。在示例中，这个参数被设置为0，这意味着主设备号是由内核动态分配的。这是推荐的做法，因为它可以避免设备号冲突。

设备与其驱动程序的关联是通过设备的主设备号完成的。当内核模块使用`chrdev::Registration`注册一个设备时，代码中提供的设备类型（在这个例子中是`RustFile`）和设备名（`name`参数）会被用来处理对应设备文件的IO操作。内核根据设备文件的主设备号调用注册到该号码的驱动程序代码。

在提供的代码片段中，通过调用`chrdev_reg.as_mut().register::<RustFile>()?;`两次，注册了两个相同类型的设备实例，它们将共享相同的主设备号但拥有不同的次设备号。