

操作系统实验：向 Linux 内核增加一个系统调用

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一、实验目的

通过实验，熟悉 Linux 操作系统的使用，掌握构建与启动 Linux 内核的方法；掌握用户程序如何利用系统调用与操作系统内核实现通信的方法，加深对系统调用机制的理解；进一步掌握如何向操作系统内核增加新的系统调用的方法，以扩展操作系统的功能。

二、实验内容

1. Linux环境下的C或C++编译和调试工具的使用。
2. 向Linux内核增加新的系统调用，系统调用名称和功能自行定义，但必须实现如下输出功能：“My Student No. is ×××， and My Name is ×××”。
3. Linux新内核的编译、安装和配置。
4. 编写应用程序以测试新的系统调用并输出测试结果。

三、实验步骤

- 1.先切换到 root 用户,把下载好的内核压缩文件放到/usr/src 下，然后进入目录解压

```
xz -d linux-4.14.107.tar.xz
tar -xvf linux-4.14.107.tar
sudo mv /下载/linux-4.14.107 /usr/src
```

- 2.打开文件

```
/arch/x86/entry/syscalls/syscall_64.tbl
```

添加一条新的系统调用号。本机为 333，系统调用函数名为“hello”

328	64	pwritev2	sys_pwritev2
329	common	pkey_mprotect	sys_pkey_mprotect
330	common	pkey_alloc	sys_pkey_alloc
331	common	pkey_free	sys_pkey_free
332	common	statx	sys_statx
333	64	hello	sys_hello

3.在系统调用的头文件中添加函数声明

```
/include/linux/syscalls.h
```

```
asmlinkage long sys_statx(int dfd, const char __user *path, unsigned flags,
                          unsigned mask, struct statx __user *buffer);
asmlinkage long sys_hello(void);
```

```
#endif
```

4.在最后一个文件中定义系统调用函数

```
/kernel/sys.c
```

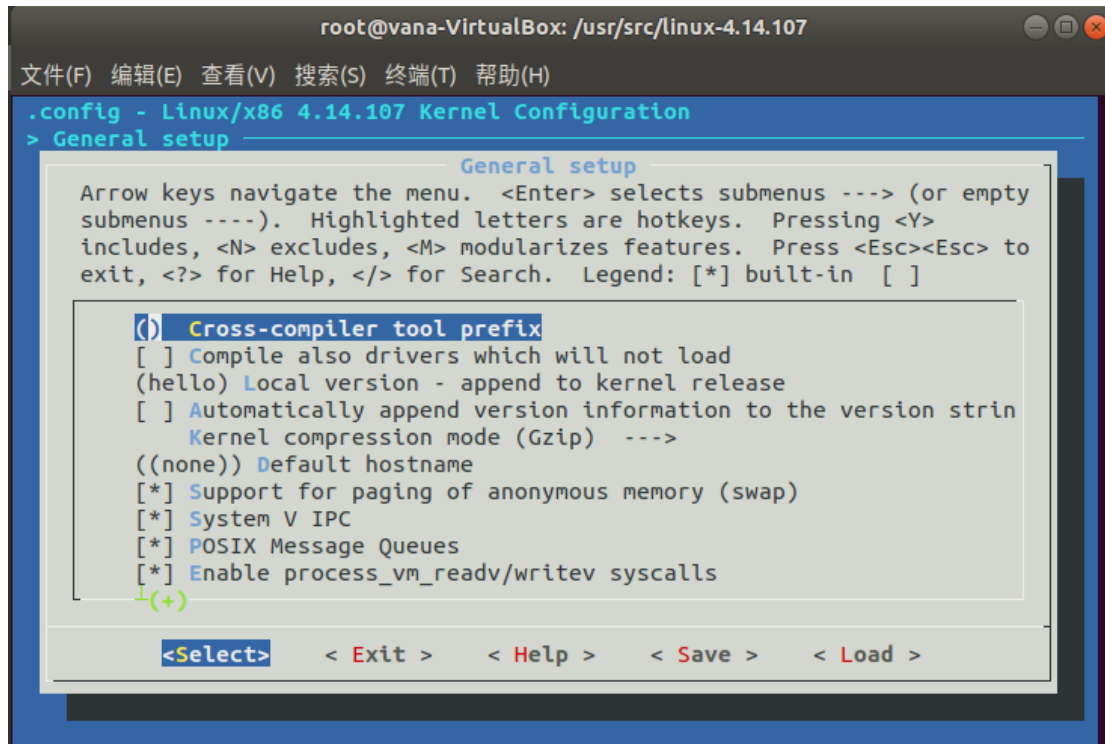
```
#endif /* CONFIG_COMPAT */
asmlinkage long __sys_hello(void){
    printk("My Student No.is 71118321, and My Name is 周嘉莹.");
    printk("Have fun!");
    return 1;
}
```

“printk”为输出至系统日志，可通过 dmesg 命令显示出来

5.配置内核选项

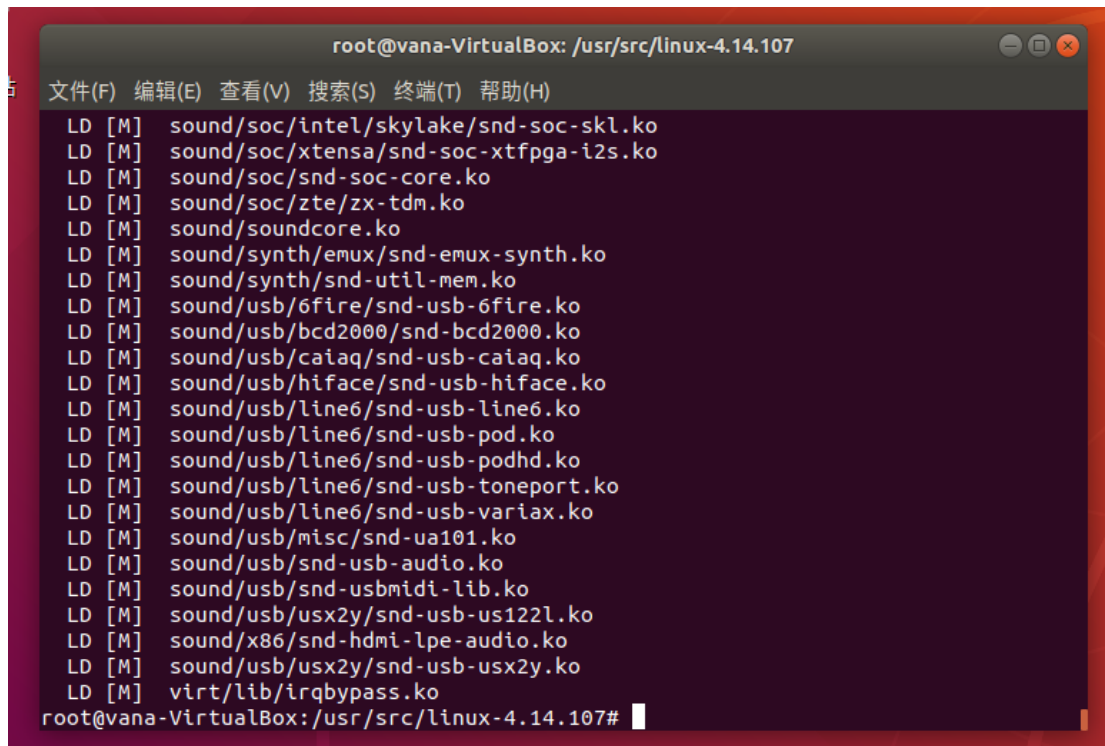
```
make menuconfig
```

默认内容即可，这里将系统版本名称改为了“hello”



6.开始编译内核

```
make
make modules_install
make install
```



```
root@vana-VirtualBox: /usr/src/linux-4.14.107
文件(F) 编辑(E) 查看(V) 搜索(S) 终端(T) 帮助(H)
INSTALL sound/soc/snd-soc-core.ko
INSTALL sound/soc/xtensa/snd-soc-xtfpga-i2s.ko
INSTALL sound/soc/zte/zx-tdm.ko
INSTALL sound/soundcore.ko
INSTALL sound/synth/emux/snd-emux-synth.ko
INSTALL sound/synth/snd-util-mem.ko
INSTALL sound/usb/6fire/snd-usb-6fire.ko
INSTALL sound/usb/bcd2000/snd-bcd2000.ko
INSTALL sound/usb/caiaq/snd-usb-caiaq.ko
INSTALL sound/usb/hiface/snd-usb-hiface.ko
INSTALL sound/usb/line6/snd-usb-line6.ko
INSTALL sound/usb/line6/snd-usb-pod.ko
INSTALL sound/usb/line6/snd-usb-podhd.ko
INSTALL sound/usb/line6/snd-usb-toneport.ko
INSTALL sound/usb/line6/snd-usb-variak.ko
INSTALL sound/usb/misc/snd-ua101.ko
INSTALL sound/usb/snd-usb-audio.ko
INSTALL sound/usb/snd-usbmidi-lib.ko
INSTALL sound/usb/usx2y/snd-usb-us122l.ko
INSTALL sound/usb/usx2y/snd-usb-usx2y.ko
INSTALL sound/x86/snd-hdmi-lpe-audio.ko
INSTALL virt/lib/irqbypass.ko
DEPMOD 4.14.107hello
root@vana-VirtualBox: /usr/src/linux-4.14.107#
```

7. 编译完成后重启进入“高级选项”，选择刚刚添加的内核开机

```
vana@vana-VirtualBox: /usr/src/linux-4.14.107
文件(F) 编辑(E) 查看(V) 搜索(S) 终端(T) 帮助(H)
vana@vana-VirtualBox: /usr/src/linux-4.14.107$
```

已成功切换为新的内核

8. 创建“hello.c”文件，编写程序使用系统调用

```
#include<stdio.h>
#include<linux/kernel.h>
#include<sys/syscall.h>
#include<linux/unistd.h>
int main()
{
    syscall(333);
    return 0;
}
```

9. 编译运行“hello.c”，之后通过“dmesg”查看系统日志

```
root@vana-VirtualBox: /home/vana
文件(F) 编辑(E) 查看(V) 搜索(S) 终端(T) 帮助(H)
linux.amd64 (Jan 25 2019 19:35:06) release log
00:52:32.236746 main Log opened 2019-03-22T00:52:32.236055000
Z
[ 45.078910] 00:52:32.236847 main OS Product: Linux
[ 45.078945] 00:52:32.236890 main OS Release: 4.14.107hello
[ 45.078978] 00:52:32.236924 main OS Version: #1 SMP Thu Mar 21 01:09:24 C
ST 2019
[ 45.079021] 00:52:32.236957 main Executable: /opt/VBoxGuestAdditions-6.0.
4/sbin/VBoxService
00:52:32.236958 main Process ID: 972
00:52:32.236959 main Package type: LINUX_64BITS_GENERIC
[ 45.081717] 00:52:32.239634 main 6.0.4 r128413 started. Verbose level = 0
[ 45.083027] 00:52:32.240859 main vbglR3GuestCtrlDetectPeekGetCancelSuppor
t: Supported (#1)
[ 45.449618] systemd-journald[240]: File /var/log/journal/3ea585c170024fd3ac82
26c9d4d08eea/user-1000.journal corrupted or uncleanly shut down, renaming and re
placing.
[ 50.355260] rfkill: input handler disabled
[ 325.015828] My Student No.is 71118321, and My Name is 周嘉莹.
[ 325.015829] Have fun!
[ 718.872303] My Student No.is 71118321, and My Name is 周嘉莹.
[ 718.872305] Have fun!
[ 825.815723] My Student No.is 71118321, and My Name is 周嘉莹.
root@vana-VirtualBox: /home/vana#
```

已成功使用系统调用

五、主要数据结构及其说明

主要使用 root 权限：“su root”完成相应操作

编译.c 文件使用“gcc”

六、程序运行时的初值和运行结果

```
root@vana-VirtualBox: /usr/src/linux-4.14.107
文件(F) 编辑(E) 查看(V) 搜索(S) 终端(T) 帮助(H)
.config - Linux/x86 4.14.107 Kernel Configuration
> General setup
General setup
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 [ ]
[ ] Cross-compiler tool prefix
[ ] Compile also drivers which will not load
(hello) Local version - append to kernel release
[ ] Automatically append version information to the version string
Kernel compression mode (Gzip) --->
((none)) Default hostname
[*] Support for paging of anonymous memory (swap)
[*] System V IPC
[*] POSIX Message Queues
[*] Enable process_vm_readv/writev syscalls
--(+)--
<Select> < Exit > < Help > < Save > < Load >
```

```
root@vana-VirtualBox: /usr/src/linux-4.14.107
文件(F) 编辑(E) 查看(V) 搜索(S) 终端(T) 帮助(H)
LD [M] sound/soc/intel/skylake/snd-soc-skl.ko
LD [M] sound/soc/xtensa/snd-soc-xtfpga-i2s.ko
LD [M] sound/soc/snd-soc-core.ko
LD [M] sound/soc/zte/zx-tdm.ko
LD [M] sound/soundcore.ko
LD [M] sound/synth/emux/snd-emux-synth.ko
LD [M] sound/synth/snd-util-mem.ko
LD [M] sound/usb/6fire/snd-usb-6fire.ko
LD [M] sound/usb/bcd2000/snd-bcd2000.ko
LD [M] sound/usb/caiaq/snd-usb-caiaq.ko
LD [M] sound/usb/hiface/snd-usb-hiface.ko
LD [M] sound/usb/line6/snd-usb-line6.ko
LD [M] sound/usb/line6/snd-usb-pod.ko
LD [M] sound/usb/line6/snd-usb-podhd.ko
LD [M] sound/usb/line6/snd-usb-toneport.ko
LD [M] sound/usb/line6/snd-usb-variak.ko
LD [M] sound/usb/misc/snd-ua101.ko
LD [M] sound/usb/snd-usb-audio.ko
LD [M] sound/usb/snd-usbmidi-lib.ko
LD [M] sound/usb/usx2y/snd-usb-us122l.ko
LD [M] sound/x86/snd-hdmi-lpe-audio.ko
LD [M] sound/usb/usx2y/snd-usb-usx2y.ko
LD [M] virt/lib/irqbypass.ko
root@vana-VirtualBox: /usr/src/linux-4.14.107#
```

```
root@vana-VirtualBox: /usr/src/linux-4.14.107
文件(F) 编辑(E) 查看(V) 搜索(S) 终端(T) 帮助(H)
INSTALL sound/soc/snd-soc-core.ko
INSTALL sound/soc/xtensa/snd-soc-xtfpga-i2s.ko
INSTALL sound/soc/zte/zx-tdm.ko
INSTALL sound/soundcore.ko
INSTALL sound/synth/emux/snd-emux-synth.ko
INSTALL sound/synth/snd-util-mem.ko
INSTALL sound/usb/6fire/snd-usb-6fire.ko
INSTALL sound/usb/bcd2000/snd-bcd2000.ko
INSTALL sound/usb/caiaq/snd-usb-caiaq.ko
INSTALL sound/usb/hiface/snd-usb-hiface.ko
INSTALL sound/usb/line6/snd-usb-line6.ko
INSTALL sound/usb/line6/snd-usb-pod.ko
INSTALL sound/usb/line6/snd-usb-podhd.ko
INSTALL sound/usb/line6/snd-usb-toneport.ko
INSTALL sound/usb/line6/snd-usb-variak.ko
INSTALL sound/usb/misc/snd-ua101.ko
INSTALL sound/usb/snd-usb-audio.ko
INSTALL sound/usb/snd-usbmidi-lib.ko
INSTALL sound/usb/usx2y/snd-usb-us122l.ko
INSTALL sound/usb/usx2y/snd-usb-usx2y.ko
INSTALL sound/x86/snd-hdmi-lpe-audio.ko
INSTALL virt/lib/irqbypass.ko
DEPMOD 4.14.107hello
root@vana-VirtualBox: /usr/src/linux-4.14.107#
```



```
root@vana-VirtualBox: /home/vana
文件(F) 编辑(E) 查看(V) 搜索(S) 终端(T) 帮助(H)
linux.amd64 (Jan 25 2019 19:35:06) release log
00:52:32.236746 main      Log opened 2019-03-22T00:52:32.236055000
Z
[ 45.078910] 00:52:32.236847 main      OS Product: Linux
[ 45.078945] 00:52:32.236890 main      OS Release: 4.14.107hello
[ 45.078978] 00:52:32.236924 main      OS Version: #1 SMP Thu Mar 21 01:09:24 C
ST 2019
[ 45.079021] 00:52:32.236957 main      Executable: /opt/VBoxGuestAdditions-6.0.
4/sbin/VBoxService
00:52:32.236958 main      Process ID: 972
00:52:32.236959 main      Package type: LINUX_64BITS_GENERIC
[ 45.081717] 00:52:32.239634 main      6.0.4 r128413 started. Verbose level = 0
[ 45.083027] 00:52:32.240859 main      vbglR3GuestCtrlDetectPeekGetCancelSuppor
t: Supported (#1)
[ 45.449618] systemd-journald[240]: File /var/log/journal/3ea585c170024fd3ac82
26c9d4d08eeea/user-1000.journal corrupted or uncleanly shut down, renaming and re
placing.
[ 50.355260] rfkill: input handler disabled
[ 325.015828] My Student No.is 71118321, and My Name is 周嘉莹.
[ 325.015829] Have fun!
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[ 718.872305] Have fun!
[ 825.815723] My Student No.is 71118321, and My Name is 周嘉莹.
root@vana-VirtualBox:/home/vana#
```

七、实验体会（实验中遇到的问题及解决方法、实验中产生的错误及原因分析、实验的体会及收获、对做好今后实验提出建设性建议等）

- 1.下载的内核版本高于系统支持的内核版本，导致不兼容，编译时出错。使用低版本内核后解决问题
- 2.加快编译速度可以使用“sudo make -j4”指令，使用 4 线程。
- 3.系统调用的输出函数为“printk”而非“printf”，输出到系统日志，需要使用“dmesg”指令查看。

八、源程序并附上注释

```
#endif /* CONFIG_COMPAT */
asmlinkage long __sys_hello(void){
    printk("My Student No.is 71118321, and My Name is 周嘉莹.");
    printk("Have fun!");
    return 1;
}
```