

Homework 1

CS342 - Operating Systems

Bilkent University

Gokhan Simsek - 21401407

October 4, 2017

1 Linux Installation and Commands

I have decided to use Ubuntu Desktop 64-bit 16.04.3 LTS release via VirtualBox, since it would be easier accessing files and multitasking with Windows and Linux. Here are the ten commands:

- **ls**: List files and directories.
- **cd**: Change directory.
- **mkdir**: Make directory.
- **rmdir**: Remove directory.
- **rm**: Remove file.
- **mv**: Move file.
- **cp**: Copy file.
- **ps**: Show processes.
- **cat**: Either lists the file or concatenates files.
- **wc**: Word count for a file.

2 Linux Kernel Executable

Linux kernel executable is under `/boot`. We can access the files in `/boot` using `ls -l /boot`. After running `uname -r` the version of the running kernel is `4.10.0-28-generic`. We can confirm this with the link to the executable found in `/boot` as `vmlinuz-4.10.0-28-generic`.

3 4.10.0-root

Under the /root directory of linux-hwe-4.10.0 are the following directories and files:

- arch
- block
- certs
- COPYING
- CREDITS
- crypto
- debian
- debian.hwe
- debian.master
- Documentation
- drivers
- dropped.txt
- firmware
- fs
- include
- init
- ipc
- Kbuild
- Kconfig
- kernel
- lib
- MAINTAINERS
- Makefile
- mm
- net
- README
- samples
- scripts
- security
- snapcraft.yaml
- sound
- spl
- tools
- ubuntu
- usr
- virt
- zfs

4 strace

After running strace ls, the following output is achieved:

```
execve("/bin/ls", ["ls"], [/ * 73 vars */]) = 0
```

```

brk(NULL) = 0x11c9000
access("/etc/ld.so.nohwcap", F_OK) = -1 ENOENT (No such file or directory)
mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS,
-1, 0) = 0x7f80f9963000
access("/etc/ld.so.preload", R_OK) = -1 ENOENT (No such file or directory)
open("/etc/ld.so.cache", O_RDONLY|O_CLOEXEC) = 3
fstat(3, st_mode=S_IFREG|0644, st_size=87909, ...) = 0
mmap(NULL, 87909, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7f80f994d000
close(3) = 0
access("/etc/ld.so.nohwcap", F_OK) = -1 ENOENT (No such file or directory)
open("/lib/x86_64-linux-gnu/libselinux.so.1", O_RDONLY|O_CLOEXEC) =
3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\260Z\0\0\0\0\0"...,
832) = 832
fstat(3, st_mode=S_IFREG|0644, st_size=130224, ...) = 0
mmap(NULL, 2234080, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE,
3, 0) = 0x7f80f951e000
mprotect(0x7f80f953d000, 2093056, PROT_NONE) = 0
mmap(0x7f80f973c000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP
3, 0x1e000) = 0x7f80f973c000
mmap(0x7f80f973e000, 5856, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP
-1, 0) = 0x7f80f973e000
close(3) = 0
access("/etc/ld.so.nohwcap", F_OK) = -1 ENOENT (No such file or directory)
open("/lib/x86_64-linux-gnu/libc.so.6", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\3\0\0\0\0\0\0\0\3\0>\0\1\0\0\0P\t\2\0\0\0\0\0"...,
832) = 832
fstat(3, st_mode=S_IFREG|0755, st_size=1868984, ...) = 0
mmap(NULL, 3971488, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE,
3, 0) = 0x7f80f9154000
mprotect(0x7f80f9314000, 2097152, PROT_NONE) = 0
mmap(0x7f80f9514000, 24576, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED
3, 0x1c0000) = 0x7f80f9514000
mmap(0x7f80f951a000, 14752, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED
-1, 0) = 0x7f80f951a000
close(3) = 0
access("/etc/ld.so.nohwcap", F_OK) = -1 ENOENT (No such file or directory)
open("/lib/x86_64-linux-gnu/libpcres.so.3", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0000\25\0\0\0\0\0"...,
832) = 832
fstat(3, st_mode=S_IFREG|0644, st_size=456632, ...) = 0
mmap(NULL, 4096, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS,
-1, 0) = 0x7f80f994c000
mmap(NULL, 2552072, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE,
3, 0) = 0x7f80f8ee4000
mprotect(0x7f80f8f52000, 2097152, PROT_NONE) = 0
mmap(0x7f80f9152000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP
3, 0x6e000) = 0x7f80f9152000

```

```

close(3) = 0
access("/etc/ld.so.nohwcap", F_OK) = -1 ENOENT (No such file or directory)
open("/lib/x86_64-linux-gnu/libdl.so.2", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\240\r\0\0\0\0\0",
832) = 832
fstat(3, st_mode=S_IFREG|0644, st_size=14608, ...) = 0
mmap(NULL, 2109680, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE,
3, 0) = 0x7f80f8ce0000
mprotect(0x7f80f8ce3000, 2093056, PROT_NONE) = 0
mmap(0x7f80f8ee2000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS,
3, 0x2000) = 0x7f80f8ee2000
close(3) = 0
access("/etc/ld.so.nohwcap", F_OK) = -1 ENOENT (No such file or directory)
open("/lib/x86_64-linux-gnu/libpthread.so.0", O_RDONLY|O_CLOEXEC) =
3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\260'\0\0\0\0\0\0",
832) = 832
fstat(3, st_mode=S_IFREG|0755, st_size=138696, ...) = 0
mmap(NULL, 2212904, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE,
3, 0) = 0x7f80f8ac3000
mprotect(0x7f80f8adb000, 2093056, PROT_NONE) = 0
mmap(0x7f80f8cda000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS,
3, 0x17000) = 0x7f80f8cda000
mmap(0x7f80f8cdc000, 13352, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS,
-1, 0) = 0x7f80f8cdc000
close(3) = 0
mmap(NULL, 4096, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS,
-1, 0) = 0x7f80f994b000
mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS,
-1, 0) = 0x7f80f9949000
arch_prctl(ARCH_SET_FS, 0x7f80f9949800) = 0
mprotect(0x7f80f9514000, 16384, PROT_READ) = 0
mprotect(0x7f80f8cda000, 4096, PROT_READ) = 0
mprotect(0x7f80f8ee2000, 4096, PROT_READ) = 0
mprotect(0x7f80f9152000, 4096, PROT_READ) = 0
mprotect(0x7f80f973c000, 4096, PROT_READ) = 0
mprotect(0x61d000, 4096, PROT_READ) = 0
mprotect(0x7f80f9965000, 4096, PROT_READ) = 0
munmap(0x7f80f994d000, 87909) = 0
set_tid_address(0x7f80f9949ad0) = 27465
set_robust_list(0x7f80f9949ae0, 24) = 0
rt_sigaction(SIGRTMIN, 0x7f80f8ac8b50, [], SA_RESTORER|SA_SIGINFO,
0x7f80f8ad4390, NULL, 8) = 0
rt_sigaction(SIGRT_1, 0x7f80f8ac8be0, [], SA_RESTORER|SA_RESTART|SA_SIGINFO,
0x7f80f8ad4390, NULL, 8) = 0
rt_sigprocmask(SIG_UNBLOCK, [RTMIN RT_1], NULL, 8) = 0
getrlimit(RLIMIT_STACK, rlim_cur=8192*1024, rlim_max=RLIM64_INFINITY)
= 0

```

```

statfs("/sys/fs/selinux", 0x7ffd9378a530) = -1 ENOENT (No such file or direc-
tory)
statfs("/selinux", 0x7ffd9378a530) = -1 ENOENT (No such file or directory)
brk(NULL) = 0x11c9000
brk(0x11ea000) = 0x11ea000
open("/proc/filesystems", O_RDONLY) = 3
fstat(3, st_mode=S_IFREG|0444, st_size=0, ...) = 0
read(3, "nodev\tsysfs\nnodev\trootfs\nnodev\ttr"..., 1024) = 442
read(3, "", 1024) = 0
close(3) = 0
open("/usr/lib/locale/locale-archive", O_RDONLY|O_CLOEXEC) = 3
fstat(3, st_mode=S_IFREG|0644, st_size=11654992, ...) = 0
mmap(NULL, 11654992, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7f80f7fa5000
close(3) = 0
ioctl(1, TCGETS, B38400 opost isig icanon echo ...) = 0
ioctl(1, TIOCGWINSZ, ws_row=24, ws_col=80, ws_xpixel=0, ws_ypixel=0)
=
0
open(".", O_RDONLY|O_NONBLOCK|O_DIRECTORY|O_CLOEXEC) = 3
fstat(3, st_mode=S_IFDIR|0775, st_size=4096, ...) = 0
getdents(3, /* 44 entries */, 32768) = 1352
getdents(3, /* 0 entries */, 32768) = 0
close(3) = 0
fstat(1, st_mode=S_IFCHR|0620, st_rdev=makedev(136, 4), ...) = 0
write(1, "arch\tdebian\t\tfirmware Kconfig "..., 60arch debian firmware Kconfig
net sound zfs
) = 60
write(1, "block\tdebian.hwe\tfs\tkernel "..., 54block debian.hwe fs kernel README
spl
) = 54
write(1, "certs\tdebian.master\tinclude l"..., 63certs debian.master include lib
samples tools
) = 63
write(1, "COPYING Documentation\tinit\tMA"..., 65COPYING Documenta-
tion init MAINTAINERS scripts ubuntu
) = 65
write(1, "CREDITS drivers\tipc\tMakefile "..., 56CREDITS drivers ipc Make-
file security usr
) = 56
write(1, "crypto\tdropped.txt\tKbuild\tmm\t"..., 60crypto dropped.txt Kbuild
mm snapcraft.yaml virt
) = 60
close(1) = 0
close(2) = 0
exit_group(0) = ?
+++ exited with 0 +++

```

5 System calls

It is expected that system calls should take longer than procedure calls, since for system calls, a call into the kernel code is made, and a mode switch occurs from user mode to kernel mode. This difference in time can be observed in the `cost.c` and Makefile provided with this report.