CSCE340101 - Operating systems | **Fall 2018**

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Project 2

Part 1: Introduction to Kernel Modules

- **Skeleton**

Kernel modules were developed using the skeleton provided in the textbook. Firstly, `module_init()` function is defined as an entry point to when the module is loaded to the kernel and `module_exit()` as an exit point to when the module is removed from the kernel. These two functions are registered using the *module_init* and *module_exit* macros.

- **Creating Proc Entry**

In order to create a module entry in the proc pseudo file system, the *proc_create()* is called in the module's entry point such that whenever the module is loaded to the Linux kernel an entry in the proc is created. In the module's exit point, *remove_proc_entry()* is called to remove its entry from the proc. In the *proc_read()* function, information from the kernel is copied to the user space buffer.

I. Jiffies Module

This module prints the current value of the jiffies, number of timer interrupts since the system was booted, when the user runs the command: cat /proc/jiffies. The jiffies value to be printed is copied to the user space buffer in the *proc_read()* function and is printed on the terminal.

II. Seconds Module

This module prints the amount of seconds passed since the module was loaded till the user enters the following command: cat /proc/seconds

The number of seconds elapsed is calculated according to the following equation:

$$\#seconds = \frac{(Jiffies_{init} - Jiffies_{current})}{HZ}$$

In the module's entry point, the value of the jiffies is saved in a global variable *jiffies_init*. When the proc_*read* function is called the initial jiffies value is subtracted from the current jiffies value and the result is divided by the *HZ* value which defines the frequency of the timer interrupts.

Part 2: Listing Tasks

I. Iterating over Tasks Linearly

In this part, a Linux kernel module (linear) is created to list the current running tasks linearly. The *for_each_process* macro is used to iterate over the tasks in the module's entry point as shown below.

```
struct task_struct *task;
for_each_process(task)
{
        printk(KERN_INFO "Task %s (pid = %d) state %ld \n", task->comm, task->pid, task->state);
}
```

The macro takes a pointer *task* that points to a struct of type *task_struct*. The task struct contents, task command, process id and state, are accessed and then printed in the kernel buffer.

II. Iterating over Tasks with a Depth First Search Tree

In the DFS module, iterating over tasks is done with depth first search tree. The *DFS()* recursively calls *list_for_each* macro on each task and its children.

```
void dfs(struct task_struct *task)
{
  struct task_struct *task_next;
  struct list_head *list;

  list_for_each(list, &task->children) {
    task_next = list_entry(list, struct task_struct, sibling);

    printk(KERN_INFO "Task %s (pid = %d) state %ld \n",task_next->comm, task_next->pid, task_next->state);

    dfs(task_next);
  }
}
```

DFS() is called in the entry point of the module on the *init_task* pointer.

Test Cases

I. Jiffies Module

1- Inserting module to the kernel

```
manar@manar-VirtualBox:~/Desktop/proj2/proj$ sudo insmod jiffies.ko
[sudo] password for manar:
manar@manar-VirtualBox:~/Desktop/proj2/proj$ lsmod
Module                  Size  Used by
jiffies                16384  0
```

2- Checking dmesg buffer after insertion

```
manar@manar-VirtualBox:~/Desktop/proj2/proj$ dmesg
[16304.547321] /proc/jiffies created
```

3- Running Cat

```
manar@manar-VirtualBox:~/Desktop/proj2/proj$ cat /proc/jiffies
Jiffies : 4298981484
```

4- Removing module

```
manar@manar-VirtualBox:~/Desktop/proj2/proj$ sudo rmmod jiffies
manar@manar-VirtualBox:~/Desktop/proj2/proj$ dmesg
[16304.547321] /proc/jiffies created
[16406.111682] /proc/jiffies removed
manar@manar-VirtualBox:~/Desktop/proj2/proj$ lsmod
Module                  Size  Used by
dfs                    16384  0
linear                 16384  0
crct10dif_pclmul       16384  0
snd_intel8x0           40960  2
```

5- Making sure that module file is removed from proc

```
manar@manar-VirtualBox:~/Desktop/proj2/proj$ cat /proc/jiffies
cat: /proc/jiffies: No such file or directory
```

II. Seconds Module

1) Insertion

```
manar@manar-VirtualBox:~/Desktop/proj2/proj$ sudo insmod seconds.ko
manar@manar-VirtualBox:~/Desktop/proj2/proj$ lsmod
Module                  Size  Used by
seconds                16384  0
```

```
manar@manar-VirtualBox:~/Desktop/proj2/proj$ dmesg
[16562.700751] /proc/seconds created
```

2) Running Cat

```
manar@manar-VirtualBox:~/Desktop/proj2/proj$ cat /proc/seconds
Seconds : 62
manar@manar-VirtualBox:~/Desktop/proj2/proj$ cat /proc/seconds
Seconds : 69
manar@manar-VirtualBox:~/Desktop/proj2/proj$ cat /proc/seconds
Seconds : 73
```

3) Removing Module

```
manar@manar-VirtualBox:~/Desktop/proj2/proj$ sudo rmmod seconds
manar@manar-VirtualBox:~/Desktop/proj2/proj$ dmesg
[16562.700751] /proc/seconds created
[16661.862521] /proc/seconds removed
manar@manar-VirtualBox:~/Desktop/proj2/proj$ lsmod
Module                  Size  Used by
dfs                    16384  0
linear                 16384  0
```

III. Linear Listing

```
manar@manar-VirtualBox:~/Desktop/proj2_3$ sudo insmod linear.ko
manar@manar-VirtualBox:~/Desktop/proj2_3$ dmesg
[17305.339496] Task systemd (pid = 1) state 1
[17305.339502] Task kthreadd (pid = 2) state 1
[17305.339506] Task kworker/0:0H (pid = 4) state 1
[17305.339509] Task mm_percpu_wq (pid = 6) state 1
[17305.339513] Task ksoftirqd/0 (pid = 7) state 1
[17305.339516] Task rcu_sched (pid = 8) state 1
[17305.339520] Task rcu_bh (pid = 9) state 1
[17305.339524] Task migration/0 (pid = 10) state 1
[17305.339528] Task watchdog/0 (pid = 11) state 1
[17305.339531] Task cpuhp/0 (pid = 12) state 1
[17305.339535] Task cpuhp/1 (pid = 13) state 1
[17305.339539] Task watchdog/1 (pid = 14) state 1
[17305.339543] Task migration/1 (pid = 15) state 1
[17305.339546] Task ksoftirqd/1 (pid = 16) state 1
[17305.339550] Task kworker/1:0H (pid = 18) state 1
[17305.339554] Task kdevtmpfs (pid = 19) state 1
[17305.339558] Task netns (pid = 20) state 1
[17305.339561] Task khungtaskd (pid = 22) state 1
[17305.339565] Task oom_reaper (pid = 23) state 1
[17305.339568] Task writeback (pid = 24) state 1
[17305.339572] Task kcompactd0 (pid = 25) state 1
[17305.340649] Task ksmd (pid = 26) state 1
[17305.342128] Task khugepaged (pid = 27) state 1
[17305.342132] Task crypto (pid = 28) state 1
[17305.342136] Task kintegrityd (pid = 29) state 1
[17305.342141] Task kblockd (pid = 30) state 1
[17305.342144] Task kworker/1:1 (pid = 31) state 1
[17305.342148] Task ata_sff (pid = 32) state 1
[17305.342152] Task md (pid = 33) state 1
[17305.342156] Task edac-poller (pid = 34) state 1
[17305.342160] Task devfreq_wq (pid = 35) state 1
[17305.342164] Task watchdogd (pid = 36) state 1
```

2- Ps –el

```
manar@manar-VirtualBox:~/Desktop/proj2_3$ ps -el
F S   UID   PID  PPID  C PRI  NI ADDR SZ WCHAN  TTY          TIME CMD
4 S     0     1     0  0  80   0 - 29976 -      ?        00:00:11 systemd
1 S     0     2     0  0  80   0 -     0 -      ?        00:00:00 kthreadd
1 S     0     4     2  0  60 -20 -     0 -      ?        00:00:00 kworker/0:0H
1 S     0     6     2  0  60 -20 -     0 -      ?        00:00:00 mm_percpu_wq
1 S     0     7     2  0  80   0 -     0 -      ?        00:00:01 ksoftirqd/0
1 S     0     8     2  0  80   0 -     0 -      ?        00:00:04 rcu_sched
1 S     0     9     2  0  80   0 -     0 -      ?        00:00:00 rcu_bh
1 S     0    10     2  0 -40   - -     0 -      ?        00:00:00 migration/0
5 S     0    11     2  0 -40   - -     0 -      ?        00:00:01 watchdog/0
1 S     0    12     2  0  80   0 -     0 -      ?        00:00:00 cpuhp/0
1 S     0    13     2  0  80   0 -     0 -      ?        00:00:00 cpuhp/1
5 S     0    14     2  0 -40   - -     0 -      ?        00:00:01 watchdog/1
1 S     0    15     2  0 -40   - -     0 -      ?        00:00:00 migration/1
1 S     0    16     2  0  80   0 -     0 -      ?        00:00:05 ksoftirqd/1
1 S     0    18     2  0  60 -20 -     0 -      ?        00:00:00 kworker/1:0H
5 S     0    19     2  0  80   0 -     0 -      ?        00:00:00 kdevtmpfs
1 S     0    20     2  0  60 -20 -     0 -      ?        00:00:00 netns
1 S     0    22     2  0  80   0 -     0 -      ?        00:00:00 khungtaskd
1 S     0    23     2  0  80   0 -     0 -      ?        00:00:00 oom_reaper
1 S     0    24     2  0  60 -20 -     0 -      ?        00:00:00 writeback
1 S     0    25     2  0  80   0 -     0 -      ?        00:00:00 kcompactd0
1 S     0    26     2  0  85   5 -     0 -      ?        00:00:00 ksmd
1 S     0    27     2  0  99  19 -     0 -      ?        00:00:00 khugepaged
1 S     0    28     2  0  60 -20 -     0 -      ?        00:00:00 crypto
1 S     0    29     2  0  60 -20 -     0 -      ?        00:00:00 kintegrityd
1 S     0    30     2  0  60 -20 -     0 -      ?        00:00:00 kblockd
1 S     0    31     2  0  80   0 -     0 -      ?        00:00:07 kworker/1:1
1 S     0    32     2  0  60 -20 -     0 -      ?        00:00:00 ata_sff
```

IV. DFS

```
[ 2240.757436] Task systemd (pid = 1) state 1
[ 2240.757441] Task systemd-journal (pid = 220) state 1
[ 2240.757444] Task systemd-udevd (pid = 241) state 1
[ 2240.757447] Task systemd-udevd (pid = 3047) state 0
[ 2240.757450] Task systemd-timesyn (pid = 307) state 1
[ 2240.757453] Task rsyslogd (pid = 620) state 1
[ 2240.757456] Task accounts-daemon (pid = 622) state 1
[ 2240.757458] Task cupsd (pid = 624) state 1
[ 2240.757461] Task systemd-logind (pid = 627) state 1
[ 2240.757464] Task cron (pid = 632) state 1
[ 2240.757467] Task acpid (pid = 679) state 1
[ 2240.757470] Task avahi-daemon (pid = 681) state 1
[ 2240.757473] Task avahi-daemon (pid = 748) state 1
[ 2240.757476] Task dbus-daemon (pid = 694) state 1
[ 2240.757479] Task cups-browsed (pid = 751) state 1
[ 2240.757482] Task NetworkManager (pid = 755) state 1
[ 2240.757484] Task dhclient (pid = 831) state 1
[ 2240.757487] Task dnsmasq (pid = 844) state 1
[ 2240.757490] Task snapd (pid = 757) state 1
[ 2240.757493] Task lightdm (pid = 768) state 1
[ 2240.757495] Task Xorg (pid = 821) state 0
[ 2240.757499] Task lightdm (pid = 1065) state 1
[ 2240.757501] Task upstart (pid = 1205) state 1
[ 2240.757505] Task upstart-udev-br (pid = 1297) state 1
[ 2240.757507] Task dbus-daemon (pid = 1298) state 1
[ 2240.757510] Task window-stack-br (pid = 1310) state 1
[ 2240.757513] Task upstart-dbus-br (pid = 1341) state 1
[ 2240.757515] Task upstart-file-br (pid = 1344) state 1
[ 2240.757518] Task ibus-daemon (pid = 1358) state 1
[ 2240.757521] Task ibus-dconf (pid = 1385) state 1
[ 2240.757524] Task ibus-ui-gtk3 (pid = 1386) state 1
[ 2240.757527] Task ibus-engine-sim (pid = 1416) state 1
[ 2240.757530] Task bamfdaemon (pid = 1363) state 1
[ 2240.757533] Task upstart-dbus-br (pid = 1366) state 1
```