EI338 Project 1

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1. simple

Task

This section is corresponding to part I and II of the project on textbook. Basically the tasks are as follows,

- Knowing how to compile `c` script to Linux kernel module.
- Knowing some basic commands about Linux kernel.
- Knowing how to load and remove kernel modules.
- To get clear of the two important points, entry point and exit point, and knowing when the functions are invoked using `dmesg` command to check the contents of messages in the kernel log buffer.
- Include some Linux kernel libraries. Specifically, print out the value of `GOLDEN RATIO PRIME` in the `simple init()` function, print out the greatest common divisor of 3,300 and 24 in the `simple exit()` function, print out the values of `jiffies` and `HZ` in the `simple init()` function, and print out the value of `jiffies` in the `simple exit()` function.

Solution

- Pre packages

```
#include <linux/init.h>
#include <linux/module.h>
#include <linux/kernel.h>
#include <linux/hash.h>
#include <linux/gcd.h>//unsigned long gcd(unsigned long a, unsigned b);
#include <asm/param.h>
#include <linux/jiffies.h>
```

- Entry and exit points function

```c
/* This function is called when the module is loaded. */
static int simple_init(void)
{
        printk(KERN_INFO "Loading Module\n");
        printk(KERN_INFO "The value of GOLDEN_RATIO_PRIME is %lu\n",GOLDEN_RATIO_PRIME)
        printk(KERN_INFO "The value of HZ is %lu\n",HZ);
        printk(KERN_INFO "The value of jiffies is %lu\n",jiffies);
        return 0;
}

/* This function is called when the module is removed. */
static void simple_exit(void) {
    printk(KERN_INFO "The greatest common dividor of 3300 and 24 is %lu\n",gcd(3300,24
    printk(KERN_INFO "The value of jiffies is %lu\n",jiffies);
    printk(KERN_INFO "Removing Module\n");
}
```

- Declaration and invoking

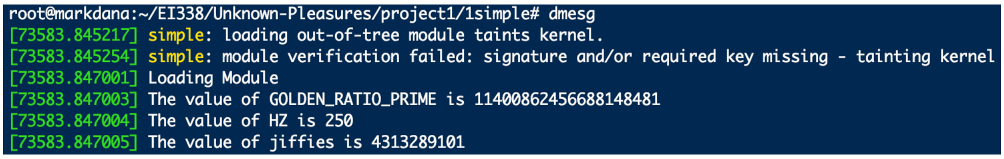
```c
/* Macros for registering module entry and exit points. */
module_init( simple_init );
module_exit( simple_exit );

MODULE_LICENSE("GPL");
MODULE_DESCRIPTION("Simple Module");
MODULE_AUTHOR("SGG");
```

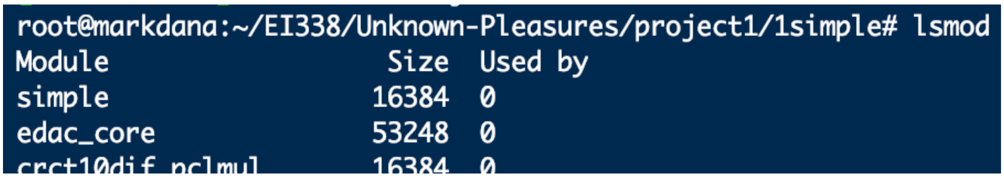
Noticing that these macros are definded in Linux kernels.

Result

- `simple_init`

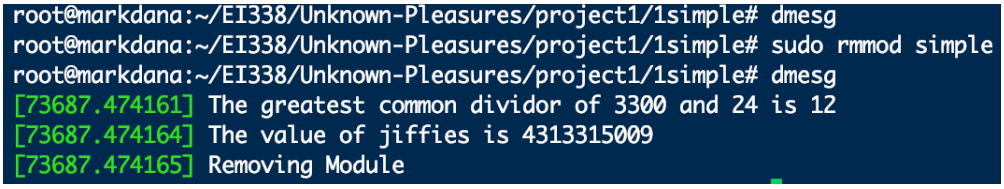


```
root@markdana:~/EI338/Unknown-Pleasures/project1/1simple# dmesg
[73583.845217] simple: loading out-of-tree module taints kernel.
[73583.845254] simple: module verification failed: signature and/or required key missing - tainting kernel
[73583.847001] Loading Module
[73583.847003] The value of GOLDEN_RATIO_PRIME is 11400862456688148481
[73583.847004] The value of HZ is 250
[73583.847005] The value of jiffies is 4313289101
```



```
root@markdana:~/EI338/Unknown-Pleasures/project1/1simple# lsmod
Module                  Size  Used by
simple                 16384  0
edac_core              53248  0
crct10dif_pclmul       16384  0
```

- `simple_exit`



```
root@markdana:~/EI338/Unknown-Pleasures/project1/1simple# dmesg
root@markdana:~/EI338/Unknown-Pleasures/project1/1simple# sudo rmmod simple
root@markdana:~/EI338/Unknown-Pleasures/project1/1simple# dmesg
[73687.474161] The greatest common dividor of 3300 and 24 is 12
[73687.474164] The value of jiffies is 4313315009
[73687.474165] Removing Module
```

- analysis

Among the results, firstly I try to search something about `GOLDEN_RATIO_PRIME` . Exactly it's an unsigned long int defined in `<linux/hash.h>` , in order to reduce 'clash' and index as randomly as possible. As suggested by Knuth, the big number should be the prime number closest to the golden section ratio. For 64-bit system, it's 0x9e37fffffffc0001UL, exactly shown above. Or rather

$$2^{63} + 2^{61} - 2^{57} + 2^{54} - 2^{51} - 2^{18} + 1$$

closest to

$$2^{64} \cdot \frac{\sqrt{5} - 1}{2}$$

As for `jiffies` and `HZ` , `jiffies` records how many ticks it has take since the last reboot of the system, while the time one tick represents is defined in `CONFIG_HZ` of Linux kernel. Here `HZ` is 250 and `jiffies` until now is 4313289101. 4313289101/250 is around 199 days, however my Linux system has just runs for about one day. What causes this big slip? After seraching I know that the initial value of `jiffies` is not 0, but a value which will overflow after a specific time, in order to explose the problem as soon as possible. And this initial value varys among different systems.

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2. hello

Task

This section is corresponding to part III of the textbook, the `/proc` file system. The `/proc` file system is a "pseudo" file system that exists only in kernel memory and is used primarily for querying various kernel and per-process statistics.

What we are going to do is to design kernel modules that create additional entries in the `/proc` file system involving both kernel statistics and information related to specific processes.

Solution

The whole part of codes is the same as `hello.c` in source code. Here I try to comprehesive some functions and allocations of the system call.

- `proc_read`

Invoked every time when `/proc/hello` is read. The function writes the string to kernel memory `buffer`.

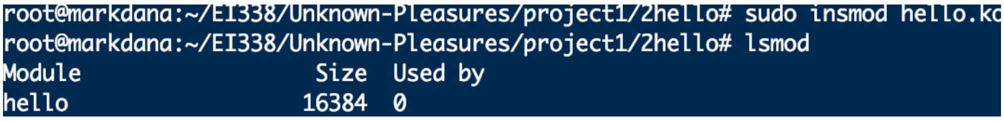
- `file_operations`

It's a struct and it initializes the instance `proc_ops` with two members `.owner` and `.read`. The value of `.read` is the name of the function `proc_read()` so as to be used in following process initialization. And I'm quite curious about `.owner=THIS_MODULE`, defined as `#define THIS_MODULE (&__this_module)`. Exactly when we use `insmod` to insert the kernel module, `insmod` calls the system call `init_module`, which calls `load_module` first and creates the kernel module by the files from user space, and finally returns a module struct. And within the kernel the module struct is used to represent the kernel.

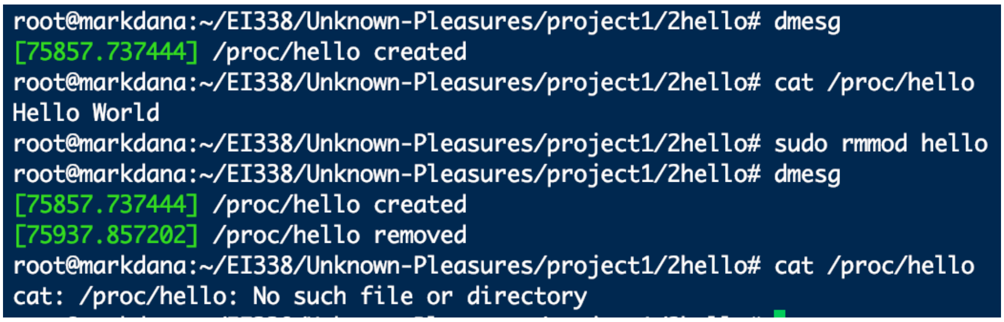
- `copy_to_user`

`proc_read()` writes the string to `buffer` in kernel memory, while `/proc/hello` can be accessed from user space, so we must copy the contents of `buffer` to `usr_buf` in user space using the kernel function `copy_to_user`.

Result



```
root@markdana:~/EI338/Unknown-Pleasures/project1/2hello# sudo insmod hello.ko
root@markdana:~/EI338/Unknown-Pleasures/project1/2hello# lsmod
Module                  Size  Used by
hello                  16384  0
```



```
root@markdana:~/EI338/Unknown-Pleasures/project1/2hello# dmesg
[75857.737444] /proc/hello created
root@markdana:~/EI338/Unknown-Pleasures/project1/2hello# cat /proc/hello
Hello World
root@markdana:~/EI338/Unknown-Pleasures/project1/2hello# sudo rmmod hello
root@markdana:~/EI338/Unknown-Pleasures/project1/2hello# dmesg
[75857.737444] /proc/hello created
[75937.857202] /proc/hello removed
root@markdana:~/EI338/Unknown-Pleasures/project1/2hello# cat /proc/hello
cat: /proc/hello: No such file or directory
```

3. jiffies

Task

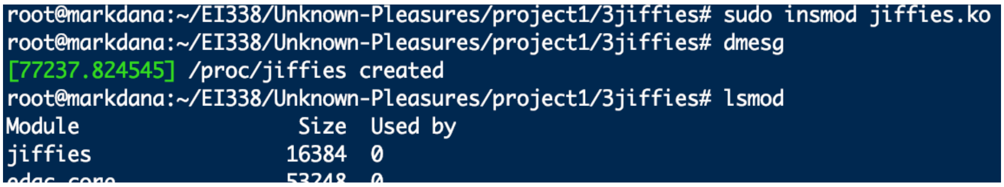
This section is assignment 1 of part IV. Design a kernel module that creates a `/proc` file named `/proc/jiffies` that reports the current value of `jiffies` when the `/proc/jiffies` file is read, such as with the command `cat /proc/jiffies`.

Solution

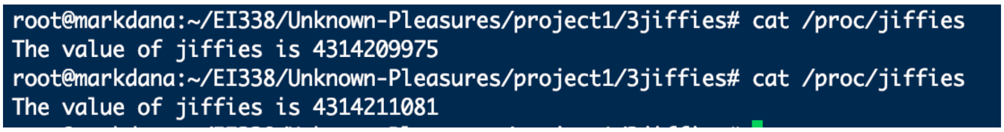
Only make some little modification to the `hello.c` and `Makefile`.

```
rv = sprintf(buffer, "The value of jiffies is %lu\n",jiffies);
```

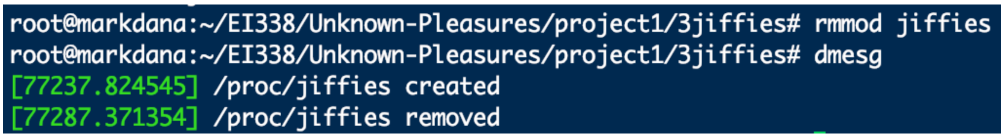
Result



```
root@markdana:~/EI338/Unknown-Pleasures/project1/3jiffies# sudo insmod jiffies.ko
root@markdana:~/EI338/Unknown-Pleasures/project1/3jiffies# dmesg
[77237.824545] /proc/jiffies created
root@markdana:~/EI338/Unknown-Pleasures/project1/3jiffies# lsmod
Module                  Size  Used by
jiffies                16384  0
edac_core              53248  0
```



```
root@markdana:~/EI338/Unknown-Pleasures/project1/3jiffies# cat /proc/jiffies
The value of jiffies is 4314209975
root@markdana:~/EI338/Unknown-Pleasures/project1/3jiffies# cat /proc/jiffies
The value of jiffies is 4314211081
```



```
root@markdana:~/EI338/Unknown-Pleasures/project1/3jiffies# rmmod jiffies
root@markdana:~/EI338/Unknown-Pleasures/project1/3jiffies# dmesg
[77237.824545] /proc/jiffies created
[77287.371354] /proc/jiffies removed
```

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4. seconds

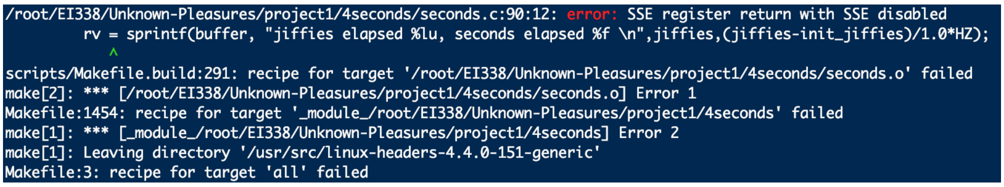
Task

Design a kernel module that creates a `proc` file named `/proc/seconds` that reports the number of elapsed seconds since the kernel module was loaded. This will involve using the value of `jiffies` as well as the `HZ` rate. When a user enters the command `cat /proc/seconds` your kernel module will report the number of seconds that have elapsed since the kernel module was first loaded. Be sure to remove `/proc/seconds` when the module is removed.

Solution

First we need to declare an unsigned long int `init_jiffies` ahead outside the function. And in `proc_init` we record the `jiffies` when the kernel module is loaded.

Then how to calculate the seconds ellapsed? Of course by `jiffies_ellapsed/HZ`. I'm expecting the floating point result, however I met with the error `SSE disabled` using either `float()` or `1.0*` to convert data type.



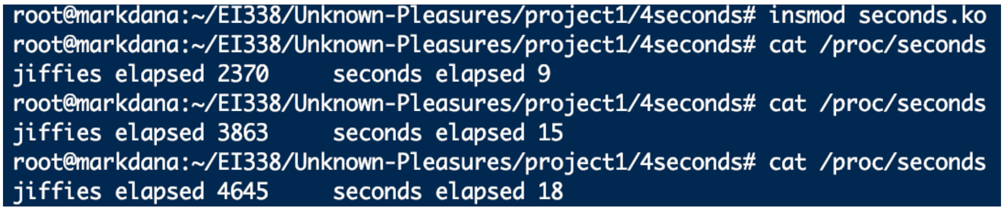
```
/root/EI338/Unknown-Pleasures/project1/4seconds/seconds.c:90:12: error: SSE register return with SSE disabled
        rv = sprintf(buffer, "jiffies elapsed %lu, seconds elapsed %f \n",jiffies,(jiffies-init_jiffies)/1.0*HZ);
          ^
scripts/Makefile.build:291: recipe for target '/root/EI338/Unknown-Pleasures/project1/4seconds/seconds.o' failed
make[2]: *** [/root/EI338/Unknown-Pleasures/project1/4seconds/seconds.o] Error 1
Makefile:1454: recipe for target '_module_/root/EI338/Unknown-Pleasures/project1/4seconds' failed
make[1]: *** [_module_/root/EI338/Unknown-Pleasures/project1/4seconds] Error 2
make[1]: Leaving directory '/usr/src/linux-headers-4.4.0-151-generic'
Makefile:3: recipe for target 'all' failed
```

After searching I find that using floating point in Linux kernel is quite a tough thing. It's designed for saving the FPU registers and other FPU state takes time. Read calfully SSE4, X86, MMX (instruction set) and as illustrated in Robert Love’s "Linux Kernel Development":

> No (Easy) Use of Floating Point
>
> When a user-space process uses floating-point instructions, the kernel manages the transition from integer to floating point mode. What the kernel has to do when using floating-point instructions varies by architecture, but the kernel normally catches a trap and then initiates the transition from integer to floating point mode.
>
> Unlike user-space, the kernel does not have the luxury of seamless support for floating point because it cannot easily trap itself. Using a floating point inside the kernel requires manually saving and restoring the floating point registers, among other possible chores. The short answer is: ***Don’t do it!*** Except in the rare cases, no floating-point operations are in the kernel.

Certainly I can use tricks like timing 1,000,000 then operating the division and mod, but that’s not interesting. So finally I just use the approximate int instead.

Result



```
root@markdana:~/EI338/Unknown-Pleasures/project1/4seconds# insmod seconds.ko
root@markdana:~/EI338/Unknown-Pleasures/project1/4seconds# cat /proc/seconds
jiffies elapsed 2370     seconds elapsed 9
root@markdana:~/EI338/Unknown-Pleasures/project1/4seconds# cat /proc/seconds
jiffies elapsed 3863     seconds elapsed 15
root@markdana:~/EI338/Unknown-Pleasures/project1/4seconds# cat /proc/seconds
jiffies elapsed 4645     seconds elapsed 18
```