

Kennesaw State University

CSE 3502 Operating Systems

Project - The /Proc File Systems and mmap

Assignment 0: Create a helloworld kernel module (30 pts)

The following code is a complete helloworld module. Name it as ***new_module.c***

<https://github.com/kevinsuo/CS3502/blob/master/project-4-1.c>

```
-----  
#include <linux/module.h>  
#include <linux/kernel.h>  
  
int init_new_module(void)  
{  
    printk(KERN_INFO "Hello, world!\n");  
    return 0;  
}  
  
void exit_new_module(void) {  
    printk(KERN_INFO "Goodbye, world!\n");  
}  
  
module_init(init_new_module);  
module_exit(exit_new_module);  
-----
```

The module defines two functions. `init_module` is invoked when the module is loaded into the kernel and `exit_module` is called when the module is removed from the kernel. `module_init` and `module_exit` are special kernel macros to indicate the role of these two functions.

Use the following makefile to compile the module. Name it as ***Makefile***

<https://github.com/kevinsuo/CS3502/blob/master/project-4-1-Makefile>

Note that here ***new_module.o*** is the output after compiling.

```
-----  
obj-m += new_module.o  
all:  
    sudo make -C /lib/modules/$(shell uname -r)/build M=$(PWD) modules  
clean:  
    sudo make -C /lib/modules/$(shell uname -r)/build M=$(PWD) clean  
-----
```

Compile the `new_module.c` file using `make` command.

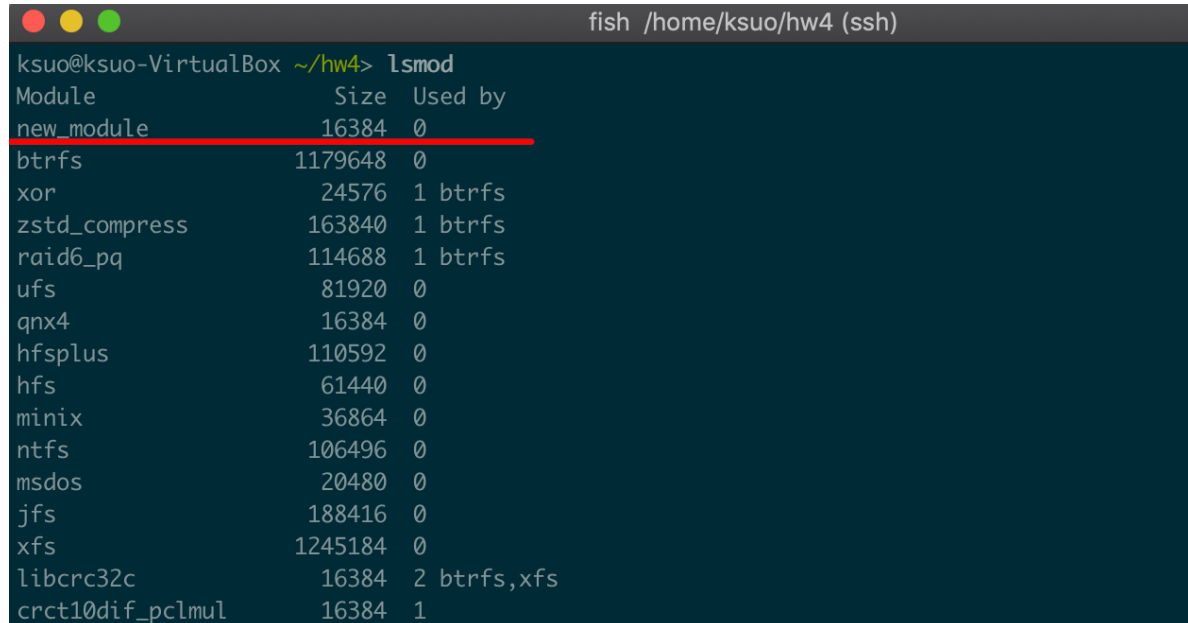
make

To insert the module into the Linux kernel:

```
# sudo insmod new_module.ko
```

Use the following command to verify the module has been loaded:

```
# lsmod
```

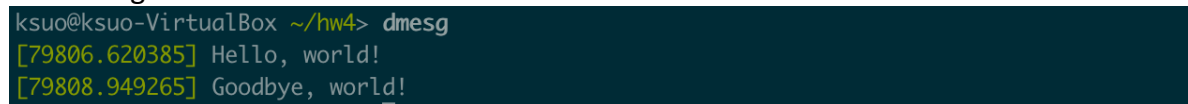


Module	Size	Used by
new_module	16384	0
btrfs	1179648	0
xor	24576	1 btrfs
zstd_compress	163840	1 btrfs
raid6_pq	114688	1 btrfs
ufs	81920	0
qnx4	16384	0
hfsplus	110592	0
hfs	61440	0
minix	36864	0
ntfs	106496	0
msdos	20480	0
jfs	188416	0
xfs	1245184	0
libcrc32c	16384	2 btrfs,xfs
crct10dif_pclmul	16384	1

To remove the module from the kernel:

```
# sudo rmmod new_module
```

When you insert or remove the module, corresponding information will be printed out under the dmesg.



```
[79806.620385] Hello, world!
[79808.949265] Goodbye, world!
```

Assignment 1: Create an entry in the /proc file system for user level read and write (70 pts)

Write a new kernel module following steps in assignment 1. This module creates an entry in the /proc file system. Use the following code skeleton to write the module:

<https://github.com/kevinsuo/CS3502/blob/master/project-4-2.c>

```

#include <linux/module.h>
#include <linux/kernel.h>
#include <linux/proc_fs.h>
#include <linux/string.h>
#include <linux/vmalloc.h>
#include <linux/slab.h>
#include <linux/uaccess.h>

#define MAX_LEN      4096
static struct proc_dir_entry *proc_entry;

ssize_t read_proc(struct file *f, char *user_buf, size_t count, loff_t *off)
{
    //output the content of info to user's buffer pointed by page
    return count;
}

ssize_t write_proc(struct file *f, const char *user_buf, size_t count, loff_t *off)
{
    //copy the written data from user space and save it in info
    return count;
}

struct file_operations proc_fops = {
    .read = read_proc,
    .write = write_proc
};

int init_module( void )
{
    int ret = 0;
    //create the entry named myproc and allocated memory space for the proc entry

    printk(KERN_INFO "test_proc created.\n");

    return ret;
}

void cleanup_module( void )
{
    //remove the entry named myproc and free info space
}

```

Step 1: create an entry in proc file system named *myproc* when the kernel module is loaded; this entry *myproc* will be deleted when the kernel mode is deleted. You can use `$ ls /proc/` to check whether it is existed. (Hint: `proc_create()` and `remove_proc_entry()` are needed.)

Step 2: implement `read_proc` and `write_proc` function to read/write the proc file entry in Step 1. You need to add codes for allocating memory in `init_module` and releasing the memory in `cleanup_module` for the proc file entry. (Hint: `copy_to_user()` is needed for the read and `copy_from_user()` is needed for write.)

To test your results, load the kernel module and there should be a new entry created under `/proc`. Use `cat` and `echo` to verify and change the content of the new entry.

```
ksuo@ksuo-VirtualBox ~/hw4-2> sudo insmod my_proc.ko
[sudo] password for ksu0:
ksuo@ksuo-VirtualBox ~/hw4-2> ls /proc/
```

1/	1283/	1471/	23/	39/	497/	683/	diskstats	pagetypeinfo
10/	1284/	15/	24/	4/	50/	686/	dma	partitions
11/	1285/	1502/	249/	40/	500/	7/	driver/	pressure/
1114/	1287/	1504/	250/	41/	502/	702/	execdomains	sched_debug
1119/	1288/	1522/	251/	42/	503/	748/	fb	schedstat
1124/	1295/	154/	254/	423/	506/	8/	filesystems	scsi/
1137/	13/	155/	26/	43/	509/	803/	fs/	self@
1142/	1303/	156/	27/	438/	52/	804/	interrupts	slabinfo
1144/	1304/	157/	275/	44/	523/	817/	iomem	softirqs
1168/	1314/	158/	276/	440/	53/	821/	ioports	stat
1174/	1315/	159/	28/	449/	532/	823/	irq/	swaps
1189/	1321/	1598/	282/	45/	533/	891/	kallsyms	sys/
1190/	1323/	16/	29/	453/	534/	9/	kcore	sysrq-trigger
12/	1325/	161/	292/	454/	537/	905/	keys	sysvipc/
1205/	1327/	162/	3/	455/	54/	912/	key-users	thread-self@
1209/	1331/	1684/	30/	457/	56/	931/	kmsg	timer_list
1210/	1332/	1685/	32/	46/	571/	950/	kpagecgroup	tty/
1212/	1337/	1695/	321/	47/	572/	954/	kpagecount	uptime
1218/	1338/	17/	33/	48/	59/	975/	kpageflags	version
1229/	1372/	173/	331/	482/	6/	acpi/	loadavg	vmallocinfo
1233/	1383/	1763/	335/	484/	60/	asound/	locks	vmstat
1241/	1384/	18/	336/	485/	606/	buddyinfo	mdstat	zoneinfo
1245/	14/	19/	34/	489/	607/	bus/	meminfo	
1252/	1412/	192/	35/	49/	608/	cgroups	misc	
1261/	1415/	193/	36/	490/	61/	cmdline	modules	
1266/	1439/	2/	360/	491/	614/	consoles	mounts@	
1271/	1442/	20/	37/	493/	634/	cpuinfo	mtrr	
1275/	1446/	21/	38/	494/	659/	crypto	myproc	
1279/	1460/	22/	384/	496/	677/	devices	net@	

You can use the following to test the read or write on the entry of proc file system. Here the root user is needed.

```
root@ksuo-VirtualBox /h/k/hw4-2# echo 12345 > /proc/myproc
root@ksuo-VirtualBox /h/k/hw4-2# cat /proc/myproc
12345
```

Bonus:

Assignment 2: Exchange data between the user and kernel space via mmap (50 pts)

Write a kernel module that create an entry in the /proc file system. The new entry cannot be directly read or written using cat and echo commands. Instead, map the new entry to a user space memory area so that user-level processes can read from and write to the kernel space via mmap. The skeleton of the kernel module is given below:

<https://github.com/kevinsuo/CS3502/blob/master/project-4-3-1.c>

```
-----
#include <linux/module.h>
#include <linux/list.h>
```

```

#include <linux/init.h>
#include <linux/kernel.h>
#include <linux/types.h>
#include <linux/kthread.h>
#include <linux/proc_fs.h>
#include <linux/sched.h>
#include <linux/mm.h>
#include <linux/fs.h>
#include <linux/slab.h>

static struct proc_dir_entry *tempdir, *tempinfo;
static unsigned char *buffer;
static unsigned char array[12]={0,1,2,3,4,5,6,7,8,9,10,11};

static void allocate_memory(void);
static void clear_memory(void);
static int my_map(struct file *filp, struct vm_area_struct *vma);

static const struct file_operations myproc_fops = {
    .mmap    = my_map,
};

static int my_map(struct file *filp, struct vm_area_struct *vma)
{
    // map vma of user space to a continuous physical space
    return 0;
}

static int init_myproc_module(void)
{
    tempdir=proc_mkdir("mydir", NULL);
    if(tempdir == NULL) {
        printk("mydir is NULL\n");
        return -ENOMEM;
    }

    tempinfo = proc_create("myinfo", 0, tempdir, &myproc_fops);
    if(tempinfo == NULL) {
        printk("myinfo is NULL\n");
        remove_proc_entry("mydir",NULL);
        return -ENOMEM;
    }
    printk("init myproc module successfully\n");

    allocate_memory();

    return 0;
}

static void allocate_memory(void)
{
    /* allocation memory */
    buffer = (unsigned char *)kmalloc(PAGE_SIZE,GFP_KERNEL);
    /* set the memory as reserved */
    SetPageReserved(virt_to_page(buffer));
}

static void clear_memory(void)
{
    /* clear reserved memory */
    ClearPageReserved(virt_to_page(buffer));
    /* free memory */
    kfree(buffer);
}

static void exit_myproc_module(void)
{
    clear_memory();
    remove_proc_entry("myinfo", tempdir);
    remove_proc_entry("mydir", NULL);
    printk("remove myproc module successfully\n");
}

```

```
}

module_init(init_myproc_module);
module_exit(exit_myproc_module);
MODULE_LICENSE("GPL");
```

The above code will create an entry `/proc/mydir/myinfo` under the proc file system. You are required to implement the ***my_map*** function to map one piece of memory (***char array[12]***) into user space. Then write a user space program using mmap to visit the memory space of the proc file and print the data in that memory area. You can use the following skeleton:

<https://github.com/kevinsuo/CS3502/blob/master/project-4-3-2.c>

```
#include <unistd.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <fcntl.h>
#include <linux/fb.h>
#include <sys/mman.h>
#include <sys/ioctl.h>

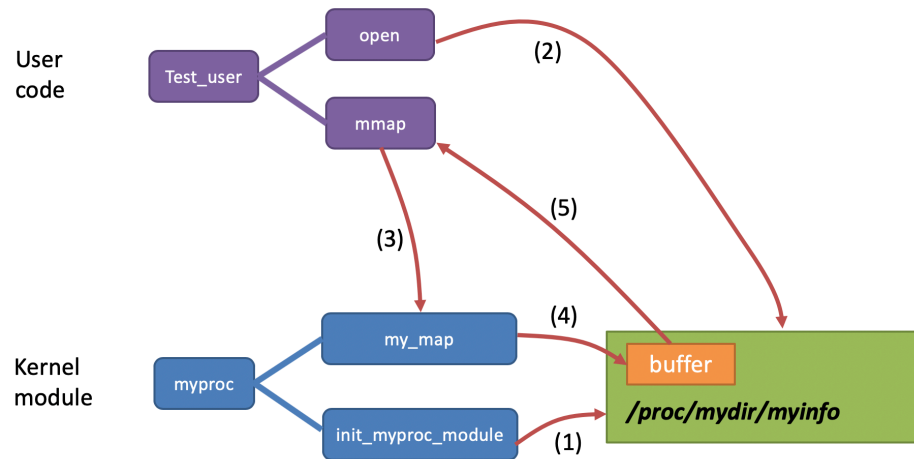
#define PAGE_SIZE 4096

int main(int argc , char *argv[])
{
    int fd;
    int i;
    unsigned char *p_map;

    /* open proc file */
    fd = open("/proc/mydir/myinfo", O_RDWR);
    if(fd < 0) {
        printf("open fail\n");
        exit(1);
    }else {
        printf("open successfully\n");
    }

    // map p_map to the proc file and grant read & write privilege
    // read data from p_map
    // unmap p_map from the proc file

    return 0;
}
```



The above figure shows the entire workflow:

- (1) Kernel module create a proc file: ***/proc/mydir/myinfo***
- (2) User process open the created proc file
- (3) User process calls mmap function, which further executed my_map defined in the kernel
- (4) my_map() then maps one piece of memory into user space (e.g., buffer) and puts some data inside
- (5) User process visits this piece of memory and prints the data out.

Expected output:

```

ksuo@ksuo-VirtualBox ~/hw4-3> sudo ./test_user.o
open successfully
0
1
2
3
4
5
6
7
8
9
10
11

```

Submission requirements:

Create one folder and put ***your modification (file diff1.txt, diff2.txt, ...)*** and ***the screenshot of output*** into this folder. Please use diff command to highlight your modification:

```
$ diff -u original_file.c modified_file.c > diff.txt
```

Zip all the files and folders together into one zip file and name it as CS3502_[your D2L user name], e.g., **CS3502_mahmed29.zip**, and upload the file onto D2L.