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the repo link to check the output of this assignment: full report

Lab 4:

- let's create the core module with file operations under the file `int_stack.c`

```
#include <linux/init.h>
#include <linux/mutex.h>
#include <linux/ioctl.h>
#include <linux/module.h>
#include <linux/fs.h>
#include <linux/uaccess.h>
#include <linux/device.h>
#include <linux/cdev.h>
#include <linux/slab.h>

MODULE_LICENSE("GPL");
MODULE_AUTHOR("Mohamad Nour Shahin");
MODULE_DESCRIPTION("Integer Stack Kernel Module");

#define DEVICE_NAME "int_stack"
#define STACK_IOCTL_MAGIC 's'
#define STACK_IOCTL_SET_SIZE _IOW(STACK_IOCTL_MAGIC, 1, int)

static dev_t dev_number;
static struct class *stack_class = NULL;
static struct cdev stack_cdev;

struct int_stack {
    int *data;
    int top;
    int max_size;
    struct mutex lock;
};

static struct int_stack stack;

static int stack_open(struct inode *inode, struct file *file) {
    return 0;
}

static int stack_release(struct inode *inode, struct file *file) {
    return 0;
}

static ssize_t stack_read(struct file *file, char __user *buf, size_t
```

```
len, loff_t *offset) {
    int value;
    if (len < sizeof(int))
        return -EINVAL;

    if (mutex_lock_interruptible(&stack.lock))
        return -ERESTARTSYS;

    if (stack.top == 0) {
        mutex_unlock(&stack.lock);
        return 0;
    }

    value = stack.data[--stack.top];
    mutex_unlock(&stack.lock);

    if (copy_to_user(buf, &value, sizeof(int)))
        return -EFAULT;

    return sizeof(int);
}

static ssize_t stack_write(struct file *file, const char __user *buf,
size_t len, loff_t *offset) {
    int value;
    if (len < sizeof(int))
        return -EINVAL;

    if (copy_from_user(&value, buf, sizeof(int)))
        return -EFAULT;

    if (mutex_lock_interruptible(&stack.lock))
        return -ERESTARTSYS;

    if (stack.top >= stack.max_size) {
        mutex_unlock(&stack.lock);
        return -ERANGE;
    }

    stack.data[stack.top++] = value;
    mutex_unlock(&stack.lock);
    return sizeof(int);
}

static long stack_ioctl(struct file *file, unsigned int cmd, unsigned
long arg) {
    int new_size;
    int *new_data;

    if (cmd != STACK_IOCTL_SET_SIZE)
        return -EINVAL;

    if (copy_from_user(&new_size, (int __user *)arg, sizeof(int)))
        return -EFAULT;
```

```
    if (new_size <= 0)
        return -EINVAL;

    new_data = kmalloc_array(new_size, sizeof(int), GFP_KERNEL);
    if (!new_data)
        return -ENOMEM;

    mutex_lock(&stack.lock);
    kfree(stack.data);
    stack.data = new_data;
    stack.top = 0;
    stack.max_size = new_size;
    mutex_unlock(&stack.lock);

    return 0;
}

static struct file_operations fops = {
    .owner = THIS_MODULE,
    .open = stack_open,
    .release = stack_release,
    .read = stack_read,
    .write = stack_write,
    .unlocked_ioctl = stack_ioctl,
};

static int __init int_stack_init(void) {
    int ret;

    ret = alloc_chrdev_region(&dev_number, 0, 1, DEVICE_NAME);
    if (ret < 0)
        return ret;

    cdev_init(&stack_cdev, &fops);
    stack_cdev.owner = THIS_MODULE;

    ret = cdev_add(&stack_cdev, dev_number, 1);
    if (ret < 0) {
        unregister_chrdev_region(dev_number, 1);
        return ret;
    }

    stack_class = class_create("int_stack_class");
    if (IS_ERR(stack_class)) {
        cdev_del(&stack_cdev);
        unregister_chrdev_region(dev_number, 1);
        return PTR_ERR(stack_class);
    }

    if (device_create(stack_class, NULL, dev_number, NULL,
DEVICE_NAME) == NULL) {
        class_destroy(stack_class);
        cdev_del(&stack_cdev);
```

```
        unregister_chrdev_region(dev_number, 1);
        return -1;
    }

    mutex_init(&stack.lock);
    stack.data = NULL;
    stack.top = 0;
    stack.max_size = 0;

    pr_info("int_stack module loaded. Device: /dev/%s\n",
DEVICE_NAME);
    return 0;
}

static void __exit int_stack_exit(void) {
    mutex_destroy(&stack.lock);
    kfree(stack.data);
    device_destroy(stack_class, dev_number);
    class_destroy(stack_class);
    cdev_del(&stack_cdev);
    unregister_chrdev_region(dev_number, 1);
    pr_info("int_stack module unloaded\n");
}

module_init(int_stack_init);
module_exit(int_stack_exit);
```

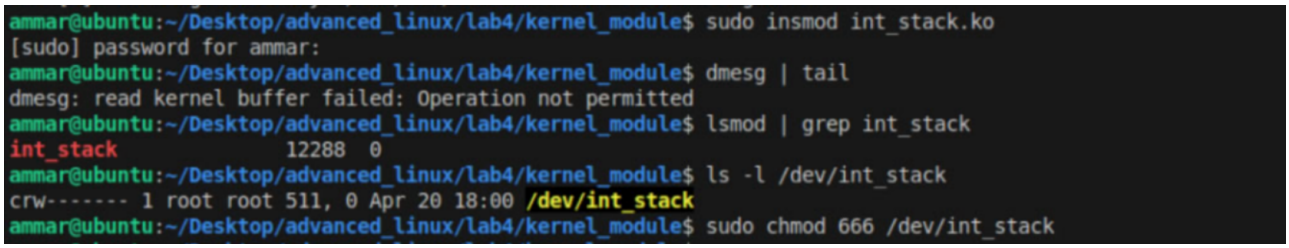
- then let's create `Makefile` which will build the kernel module:

```
obj-m += int_stack.o

KDIR := /lib/modules/$(shell uname -r)/build
PWD := $(shell pwd)

all:
    make -C $(KDIR) M=$(PWD) modules

clean:
    make -C $(KDIR) M=$(PWD) clean
```

- now let's build the module

```
ammar@ubuntu:~/Desktop/advanced_linux/lab4$ cd kernel_module/
ammar@ubuntu:~/Desktop/advanced_linux/lab4/kernel_module$ ls
int_stack.c  Makefile
ammar@ubuntu:~/Desktop/advanced_linux/lab4/kernel_module$ make
make -C /lib/modules/6.11.0-21-generic/build M=/home/ammar/Desktop/advanced_linux/lab4/kernel_module modules
make[1]: Entering directory '/usr/src/linux-headers-6.11.0-21-generic'
warning: the compiler differs from the one used to build the kernel
  The kernel was built by: x86_64-linux-gnu-gcc-14 (Ubuntu 14.2.0-4ubuntu2) 14.2.0
  You are using:           gcc-14 (Ubuntu 14.2.0-4ubuntu2) 14.2.0
  CC [M]  /home/ammar/Desktop/advanced_linux/lab4/kernel_module/int_stack.o
  MODPOST /home/ammar/Desktop/advanced_linux/lab4/kernel_module/Module.symvers
  CC [M]  /home/ammar/Desktop/advanced_linux/lab4/kernel_module/int_stack.mod.o
  LD [M]  /home/ammar/Desktop/advanced_linux/lab4/kernel_module/int_stack.ko
  BTF [M] /home/ammar/Desktop/advanced_linux/lab4/kernel_module/int_stack.ko
Skipping BTF generation for /home/ammar/Desktop/advanced_linux/lab4/kernel_module/int_stack.ko due to unavailability of vmlinux
make[1]: Leaving directory '/usr/src/linux-headers-6.11.0-21-generic'
```

- let's verify and load the module and create a node device



- now let's create `stack_ioctl.h` header file:

```
#ifndef STACK_IOCTL_H
#define STACK_IOCTL_H

#include <linux/ioctl.h>

#define STACK_IOCTL_MAGIC 's'
#define STACK_IOCTL_SET_SIZE _IOW(STACK_IOCTL_MAGIC, 1, int)

#endif
```

- and let's create `kernel_stack.c` and include the previous header file:

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <fcntl.h>
#include <errno.h>
#include <unistd.h>
#include <sys/ioctl.h>
#include "stack_ioctl.h"

#define DEVICE_PATH "/dev/int_stack"

void usage() {
    fprintf(stderr, "Usage:\n");
    fprintf(stderr, "  kernel_stack set-size <n>\n");
    fprintf(stderr, "  kernel_stack push <n>\n");
    fprintf(stderr, "  kernel_stack pop\n");
    fprintf(stderr, "  kernel_stack unwind\n");
}

int main(int argc, char *argv[]) {
    if (argc < 2) {
        usage();
        return EXIT_FAILURE;
    }

    int fd = open(DEVICE_PATH, O_RDWR);
    if (fd < 0) {
```

```
        perror("Failed to open device");
        return EXIT_FAILURE;
    }

    int ret = 0;

    if (strcmp(argv[1], "set-size") == 0) {
        if (argc != 3) {
            usage();
            close(fd);
            return EXIT_FAILURE;
        }

        int size = atoi(argv[2]);
        if (size <= 0) {
            fprintf(stderr, "ERROR: size should be > 0\n");
            close(fd);
            return EXIT_FAILURE;
        }

        ret = ioctl(fd, STACK_IOCTL_SET_SIZE, &size);
        if (ret < 0) {
            perror("ioctl");
            close(fd);
            return errno;
        }

    } else if (strcmp(argv[1], "push") == 0) {
        if (argc != 3) {
            usage();
            close(fd);
            return EXIT_FAILURE;
        }

        int val = atoi(argv[2]);
        ret = write(fd, &val, sizeof(int));
        if (ret < 0) {
            if (errno == ERANGE) {
                fprintf(stderr, "ERROR: stack is full\n");
            } else {
                perror("write");
            }
            close(fd);
            return -errno;
        }

    } else if (strcmp(argv[1], "pop") == 0) {
        int val;
        ret = read(fd, &val, sizeof(int));
        if (ret == 0) {
            printf("NULL\n");
        } else if (ret < 0) {
            perror("read");
            close(fd);
```

```
            return errno;
        } else {
            printf("%d\n", val);
        }

    } else if (strcmp(argv[1], "unwind") == 0) {
        int val;
        while ((ret = read(fd, &val, sizeof(int))) > 0) {
            printf("%d\n", val);
        }

        if (ret < 0) {
            perror("read");
            close(fd);
            return errno;
        }

    } else {
        usage();
        close(fd);
        return EXIT_FAILURE;
    }

    close(fd);
    return 0;
}
```

- let's compile:
- 

- now there is one last issue to solve, UNIX exit codes are 8 bits unsigned, so -34 in case of full stack error will be displayed as 222. to solve this issue, we can wrap our program with a shell script to check for the returned code, if it's larger than 127 then its original value is negative and has to be restored
- let's create `kernel_stack_handler.sh` to handle the previous issue:

```
#!/usr/bin/env bash

output="$(./kernel_stack "$@" 2>&1)"
raw_status=$?

# if >127, subtract 256 to restore the original value
if (( raw_status > 127 )); then
  signed_status=$(( raw_status - 256 ))
else
  signed_status=$raw_status
fi

# print any output from the command
if [[ -n "$output" ]]; then
```

```
  printf '%s\n' "$output"
fi

# if there is an error, display its code
if [ "$signed_status" -ne 0 ]; then
    printf 'exit code: %d\n' "$signed_status" >&2
fi
```

- now let's use our handler and check the given instructions: