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Github: spushkin CSC415 Operating Systems

Assignment 6 - Device-Driver

Description:

In this assignment, we are developing a Linux kernel device driver. I created a device driver that performs encryption and decryption operations using a simple Caesar cipher. The device driver is implemented in C and can be dynamically loaded into the Linux kernel, providing essential operations such as open, release, read, write, and ioctl. The driver allows user applications to pass a string to be encrypted or decrypted, using ioctl commands to set the encryption key and mode (encrypt or decrypt). It also includes a user-space application to interact with the device driver, demonstrating its functionality by encrypting and decrypting a sample string.

Approach:

My approach to this assignment began with thorough research and an understanding how Linux device drivers work. I started by studying the Linux kernel documentation and various online resources to get a grasp of the basic concepts of device driver development, including how drivers interact with the kernel and user space. I decided to implement a device driver that could perform encryption and decryption using a simple Caesar cipher, as it would be relatively easy to implement and demonstrate the concept. I planned to first create a basic skeleton of the device driver that included essential operations like open, release, read, write, and ioctl. I then incrementally add functionality to handle encryption and decryption, allowing user applications to pass strings to be processed. I also implemented a simple user-space application to test the driver's functionality. Before starting the coding, I sketched out the structure of the driver and identified key functions and their roles, ensuring a clear roadmap for further development.

Issues and Resolutions:

During the assignment, I encountered several issues. One major issue was a compilation error related to the class_create function, which required adjusting the function parameters to match the kernel's expectations. I also faced challenges with setting the device file permissions. Initially, I attempted to set permissions from within the kernel module, which led to errors because file permissions are typically managed in user space. To resolve this, I modified the Makefile to include a set-permissions target that changes the device node's permissions after it's created. This adjustment ensured the user application could interact with the driver without encountering permission errors. Additionally, I learned to check kernel logs for detailed error messages, which helped me troubleshoot and fix issues more efficiently.

Build Instructions:

1. Navigate to the “Module” Directory: **cd Module**
2. Clean Previous Builds: **make clean**
3. Compile the Kernel Module: **make**
4. Load the Kernel Module: **sudo insmod my_device_driver.ko**
5. Check that the device file exists and is properly linked: **ls -l /dev/my_device**
6. **IF NOT**: Verify that the module was loaded successfully and find the major number assigned to the device: **dmesg | tail**
7. Create the Device Node (Replace <major_number> with the major number obtained from dmesg): **sudo mknod /dev/my_device c <major_number> 0**
8. Set Permissions on the Device Node: **make set-permissions**

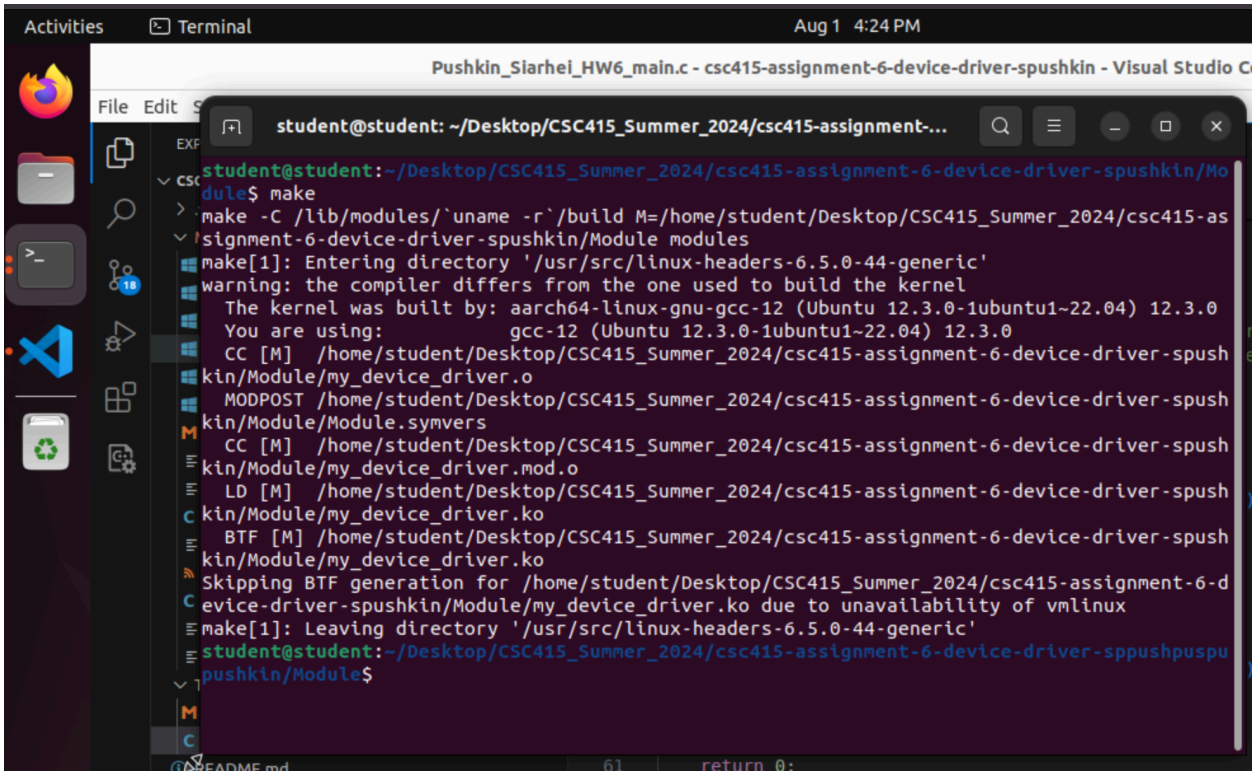
Interacting with the Device Driver:

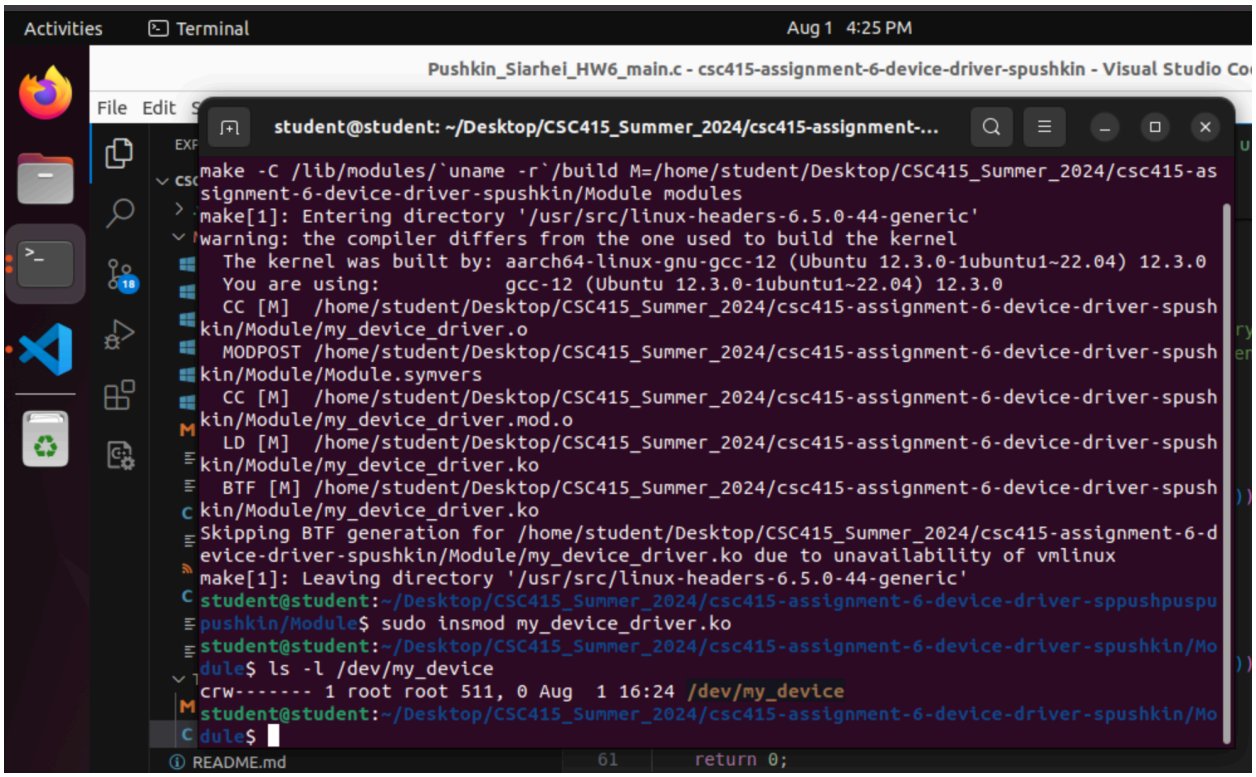
1. Compile the User Application: **cd ../Test** and **make**
2. Run the User Application: **make run**

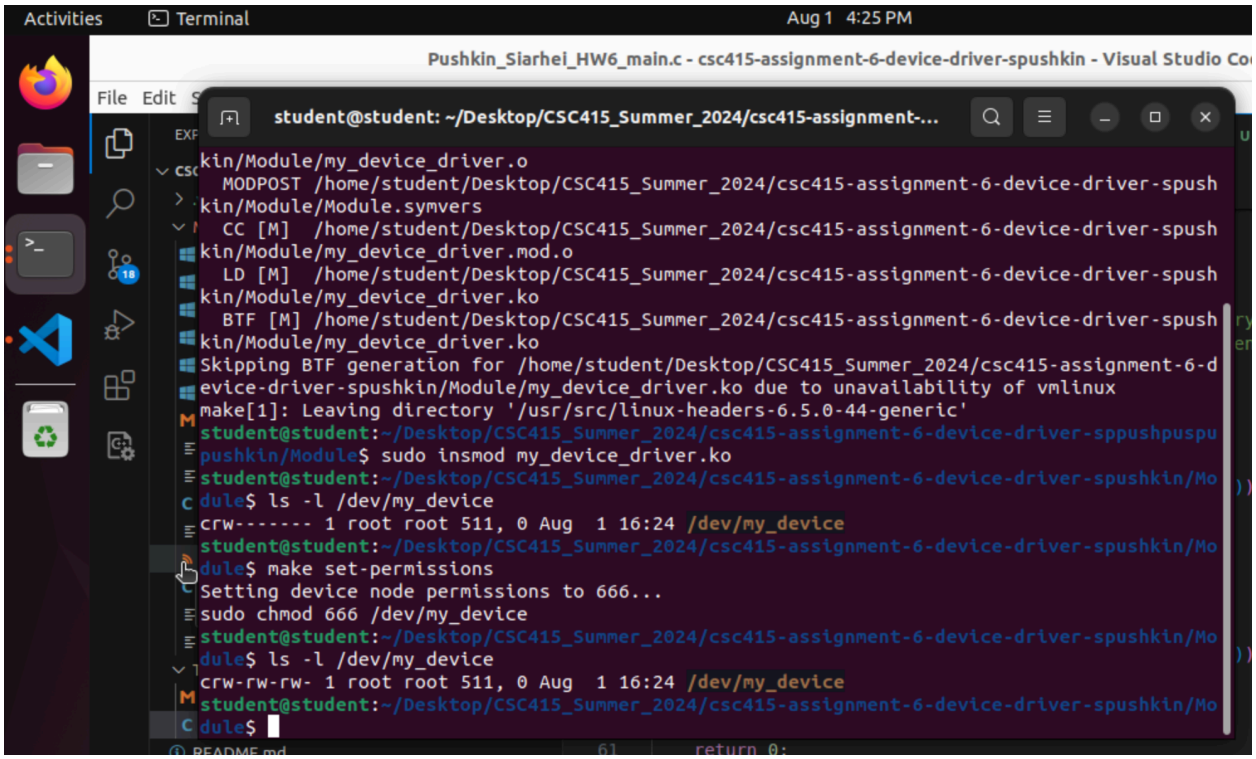
Unloading the Device Driver:

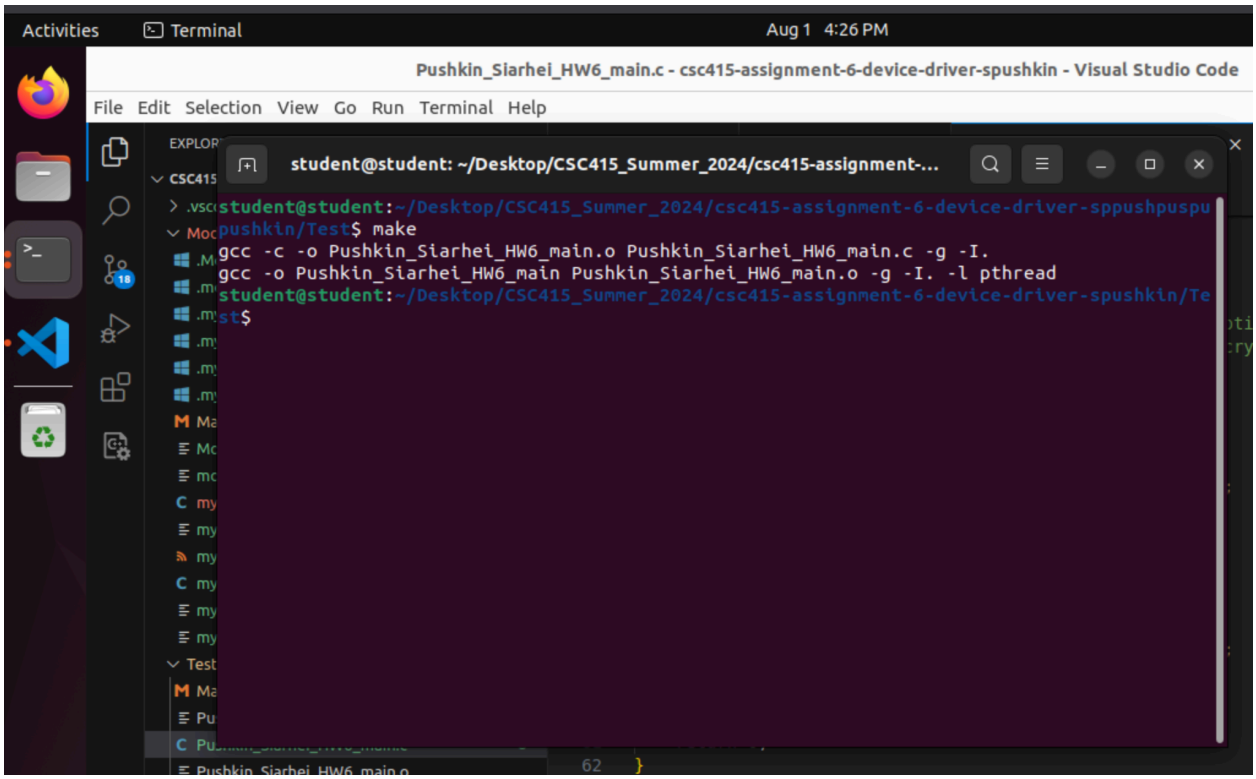
1. Remove the Kernel Module: **sudo rmmod my_device_driver**

Screen shot of compilation:

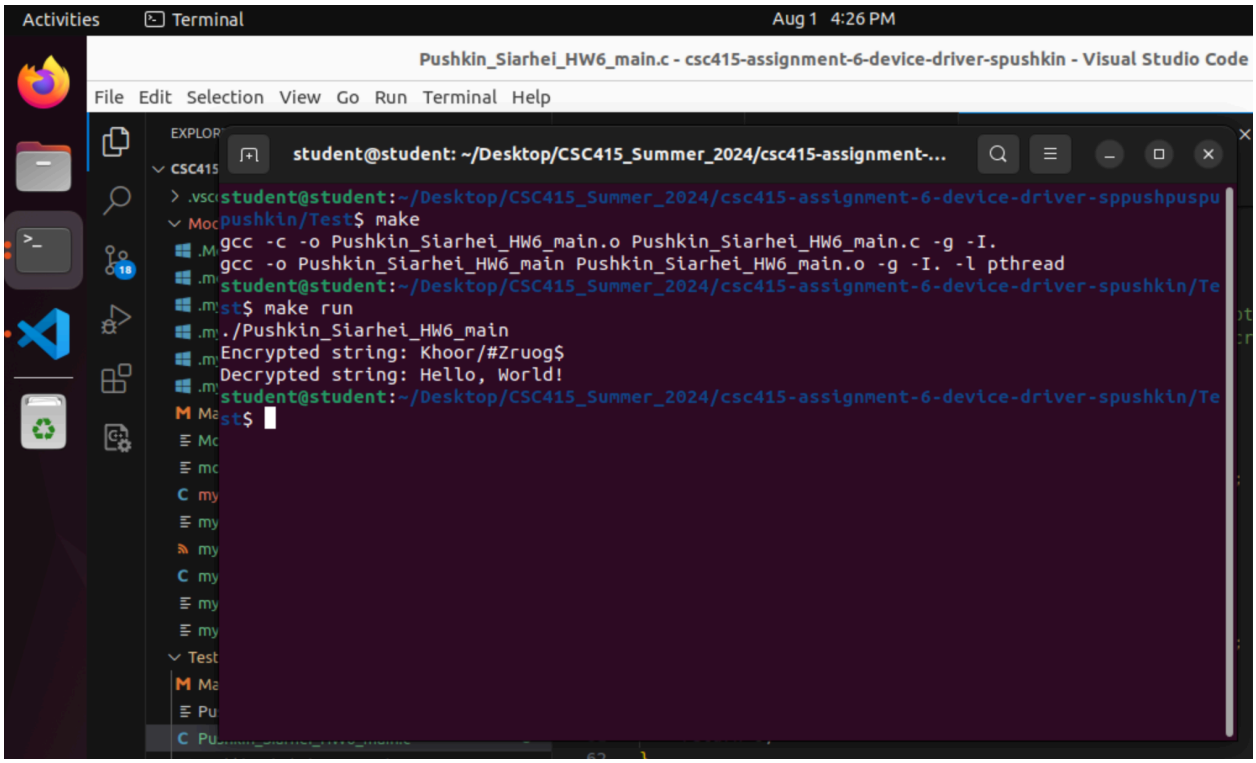



Activities
Terminal
Aug 1 4:25 PM
Pushkin_Siarhei_HW6_main.c - csc415-assignment-6-device-driver-spushkin - Visual Studio Co
File Edit
student@student: ~/Desktop/CSC415_Summer_2024/csc415-assignment-...
make -C /lib/modules/`uname -r`/build M=/home/student/Desktop/CSC415_Summer_2024/csc415-assignment-6-device-driver-spushkin/Module modules
make[1]: Entering directory '/usr/src/linux-headers-6.5.0-44-generic'
warning: the compiler differs from the one used to build the kernel
The kernel was built by: aarch64-linux-gnu-gcc-12 (Ubuntu 12.3.0-1ubuntu1~22.04) 12.3.0
You are using: gcc-12 (Ubuntu 12.3.0-1ubuntu1~22.04) 12.3.0
CC [M] /home/student/Desktop/CSC415_Summer_2024/csc415-assignment-6-device-driver-spushkin/Module/my_device_driver.o
MODPOST /home/student/Desktop/CSC415_Summer_2024/csc415-assignment-6-device-driver-spushkin/Module/Module.symvers
CC [M] /home/student/Desktop/CSC415_Summer_2024/csc415-assignment-6-device-driver-spushkin/Module/my_device_driver.mod.o
LD [M] /home/student/Desktop/CSC415_Summer_2024/csc415-assignment-6-device-driver-spushkin/Module/my_device_driver.ko
BTF [M] /home/student/Desktop/CSC415_Summer_2024/csc415-assignment-6-device-driver-spushkin/Module/my_device_driver.ko
Skipping BTF generation for /home/student/Desktop/CSC415_Summer_2024/csc415-assignment-6-device-driver-spushkin/Module/my_device_driver.ko due to unavailability of vmlinux
make[1]: Leaving directory '/usr/src/linux-headers-6.5.0-44-generic'
student@student:~/Desktop/CSC415_Summer_2024/csc415-assignment-6-device-driver-sppushpuspupushkin/Module$ sudo insmod my_device_driver.ko
student@student:~/Desktop/CSC415_Summer_2024/csc415-assignment-6-device-driver-spushkin/Module$ ls -l /dev/my_device
crw------- 1 root root 511, 0 Aug 1 16:24 /dev/my_device
student@student:~/Desktop/CSC415_Summer_2024/csc415-assignment-6-device-driver-spushkin/Module$
README.md
61 return 0;


Activities
Terminal
Aug 1 4:25 PM
Pushkin_Siarhei_HW6_main.c - csc415-assignment-6-device-driver-spushkin - Visual Studio Co
File Edit
student@student: ~/Desktop/CSC415_Summer_2024/csc415-assignment-...
kin/Module/my_device_driver.o
MODPOST /home/student/Desktop/CSC415_Summer_2024/csc415-assignment-6-device-driver-spush
kin/Module/Module.symvers
CC [M] /home/student/Desktop/CSC415_Summer_2024/csc415-assignment-6-device-driver-spush
kin/Module/my_device_driver.mod.o
LD [M] /home/student/Desktop/CSC415_Summer_2024/csc415-assignment-6-device-driver-spush
kin/Module/my_device_driver.ko
BTF [M] /home/student/Desktop/CSC415_Summer_2024/csc415-assignment-6-device-driver-spush
kin/Module/my_device_driver.ko
Skipping BTF generation for /home/student/Desktop/CSC415_Summer_2024/csc415-assignment-6-d
evice-driver-spushkin/Module/my_device_driver.ko due to unavailability of vmlinux
make[1]: Leaving directory '/usr/src/linux-headers-6.5.0-44-generic'
student@student:~/Desktop/CSC415_Summer_2024/csc415-assignment-6-device-driver-sppushpuspu
pushkin/Module$ sudo insmod my_device_driver.ko
student@student:~/Desktop/CSC415_Summer_2024/csc415-assignment-6-device-driver-spushkin/Mo
dule$ ls -l /dev/my_device
crw------- 1 root root 511, 0 Aug 1 16:24 /dev/my_device
student@student:~/Desktop/CSC415_Summer_2024/csc415-assignment-6-device-driver-spushkin/Mo
dule$ make set-permissions
Setting device node permissions to 666...
sudo chmod 666 /dev/my_device
student@student:~/Desktop/CSC415_Summer_2024/csc415-assignment-6-device-driver-spushkin/Mo
dule$ ls -l /dev/my_device
crw-rw-rw- 1 root root 511, 0 Aug 1 16:24 /dev/my_device
student@student:~/Desktop/CSC415_Summer_2024/csc415-assignment-6-device-driver-spushkin/Mo
dule$


Activities
Terminal
Aug 1 4:26 PM
Pushkin_Siarhei_HW6_main.c - csc415-assignment-6-device-driver-spushkin - Visual Studio Code
File Edit Selection View Go Run Terminal Help
student@student: ~/Desktop/CSC415_Summer_2024/csc415-assignment-...
student@student:~/Desktop/CSC415_Summer_2024/csc415-assignment-6-device-driver-sppushpuspu
pushkin/Test$ make
gcc -c -o Pushkin_Siarhei_HW6_main.o Pushkin_Siarhei_HW6_main.c -g -I.
gcc -o Pushkin_Siarhei_HW6_main Pushkin_Siarhei_HW6_main.o -g -I. -l pthread
student@student:~/Desktop/CSC415_Summer_2024/csc415-assignment-6-device-driver-spushkin/Te
st$

Screen shot(s) of the execution of the program:



Screen shot(s) of unloading the device driver: