Lab 5: USB-Secured Integer Stack Kernel Module

Lab5 GitHub

Overview

This lab extends Lab 4 by adding USB device detection functionality. The character device (`/dev/int_stack`) is only available when a specific USB device (in this case, a Sony DualShock 4 controller) is connected to the system. When the USB device is disconnected, the device node disappears, but the stack's data is preserved.

Key Features

1. **USB Device Detection**:
    - Uses the USB subsystem to detect a specific USB device (electronic key)
    - Character device only appears when the electronic key is connected
    - Character device disappears when the electronic key is disconnected
    - Stack data is preserved across connect/disconnect events
2. **Dynamic Character Device Creation**:
    - Device node created automatically when USB key is detected
    - Device node removed when USB key is disconnected
    - Uses proper device/class management through the kernel's device model
3. **USB Driver Implementation**:
    - Uses `struct usb_device_id` to identify the electronic key
    - Implements `probe()` and `disconnect()` callbacks
    - Manages character device during device connect/disconnect events
4. **Split Driver Design**:
    - `int_stack.c` - Core stack functionality with character device support
    - `int_stack_usbkey.c` - USB driver for electronic key detection

Implementation Details

Kernel Modules

The implementation consists of two kernel modules:

1. **int_stack.ko**:
    - Provides the core stack functionality with push/pop operations
    - Implements character device operations
    - Exports functions for device creation/removal
2. **int_stack_usbkey.ko**:

- Implements USB driver functionality
- Detects the electronic key (Sony DualShock 4 controller)
- Creates/removes character device node based on USB key presence

USB Device Driver

The USB driver component acts as an electronic key for the character device. It:

1. **Detect specific USB devices** using Vendor ID and Product ID matching
2. **Control device availability** by creating/removing the character device node
3. **Maintain data consistency** by preserving stack contents between connections

Key implementation aspects:

- **Device identification** uses the `USB_DEVICE()` macro to specify the target device
- **Driver registration** with the USB subsystem through `usb_register()`
- **Event handling** via `probe()` and `disconnect()` callbacks
- **Inter-module communication** through exported functions

When the specified USB device (Sony DualShock 4 controller with VID:PID 054c:05c4) is connected, the probe function creates the character device node. When disconnected, the disconnect function removes it, making the stack inaccessible until the device is reconnected.

Building and Using the Module

Building

To build both kernel modules:

```
make clean
make
```

To build the userspace utility:

```
make -f Makefile.user
```

Loading Modules

The modules need to be loaded in the correct order:

```
# Load the core stack module first
sudo insmod int_stack.ko

# Load the USB driver module second
sudo insmod int_stack_usbkey.ko
```

Binding the USB Device

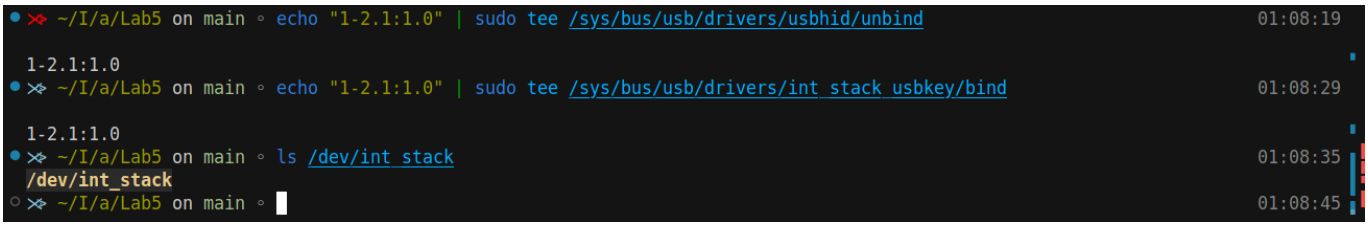
The device will be automatically detected if it's already connected. If not, you'll need to bind it manually:

```
# After Identifing the USB device path
# Unbind from current driver (the defult driver automaticly bind it)
echo "1-2.1:1.0" | sudo tee /sys/bus/usb/drivers/usbhid/unbind

# Bind to our driver
echo "1-2.1:1.0" | sudo tee /sys/bus/usb/drivers/int_stack_usbkey/bind
```

Verifying Device Node

Check if the device node was created:

```
ls -la /dev/int_stack
```



Testing Stack Operations

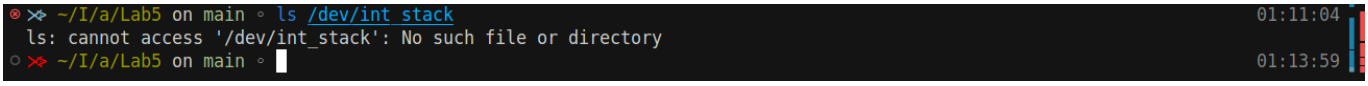
After the device node appears, you can perform stack operations:

```
# Set stack size
sudo ./kernel_stack set-size 3

# Push values
sudo ./kernel_stack push 1
sudo ./kernel_stack push 2
sudo ./kernel_stack push 3

# Pop values
sudo ./kernel_stack pop
```

Effect of USB Key Disconnection

When the USB key is disconnected (either physically or simulated), the device node disappears:

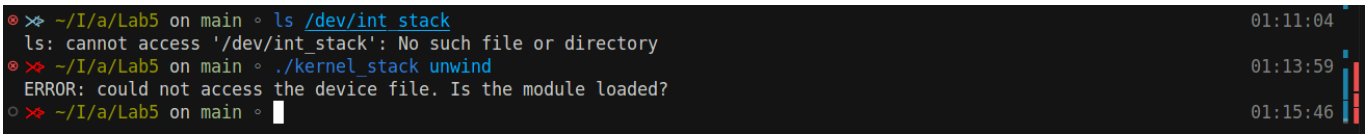
```
# I'll disconnect the controller physically or we can simulate
disconnection by unbinding
echo "1-2.1:1.0" | sudo tee /sys/bus/usb/drivers/int_stack_usbkey/unbind

# Verify device node is gone
ls -la /dev/int_stack
```



Error Handling in Userspace Utility

When trying to use the userspace utility without the USB key connected:

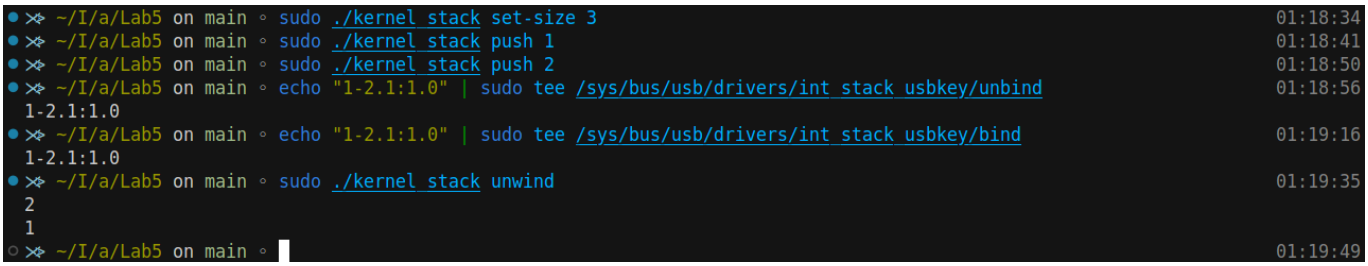
```
./kernel_stack unwind
# ERROR: could not access the device file. Is the module loaded?
```



Data Persistence Across USB Key Reconnection

The stack data persists even when the USB key is disconnected and reconnected:

```
# Push values
sudo ./kernel_stack push 1
sudo ./kernel_stack push 2

# Disconnect USB key (unbind)
echo "1-2.1:1.0" | sudo tee /sys/bus/usb/drivers/int_stack_usbkey/unbind

# Reconnect USB key (bind)
echo "1-2.1:1.0" | sudo tee /sys/bus/usb/drivers/int_stack_usbkey/bind

# View values - they should still be there
sudo ./kernel_stack unwind
```

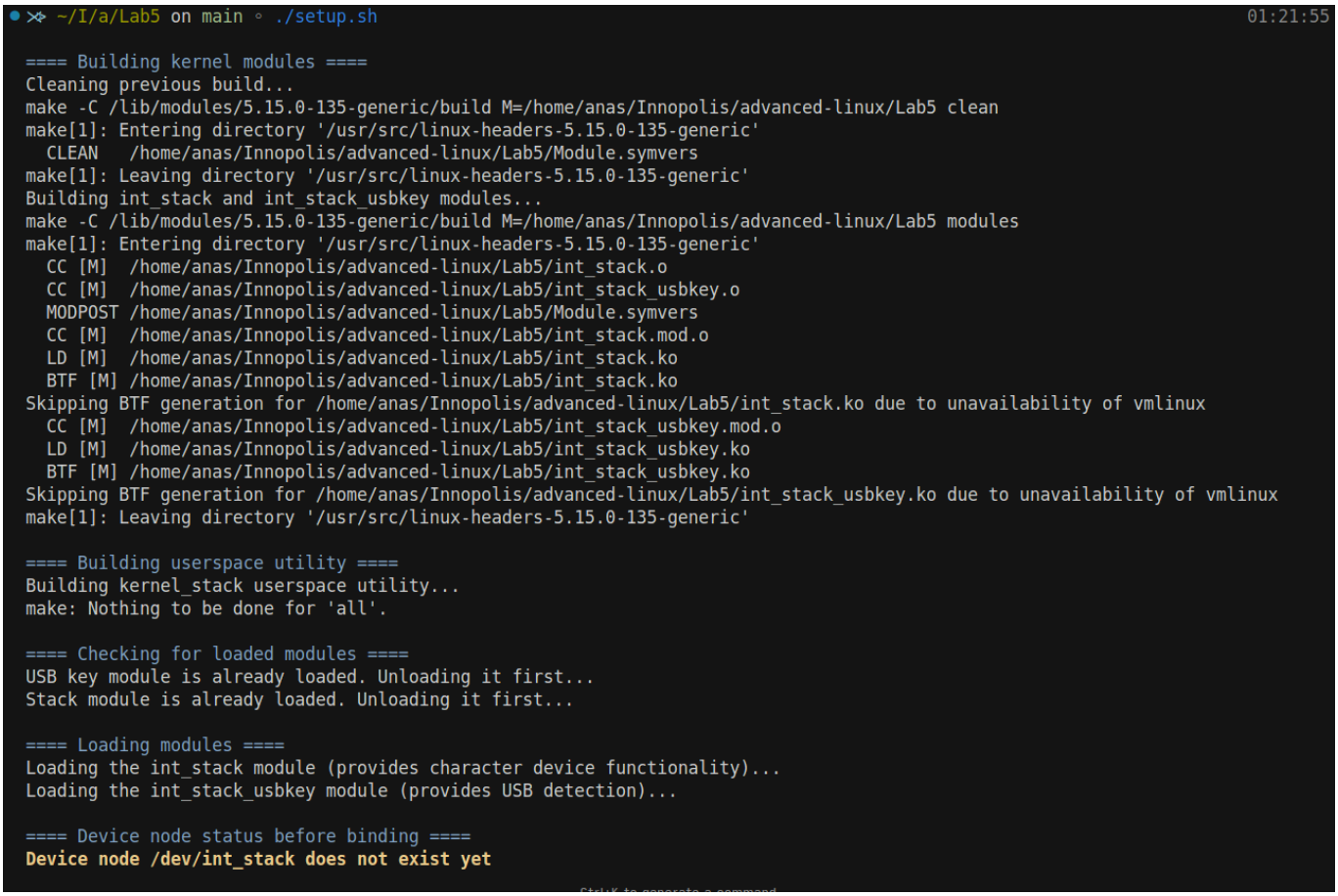


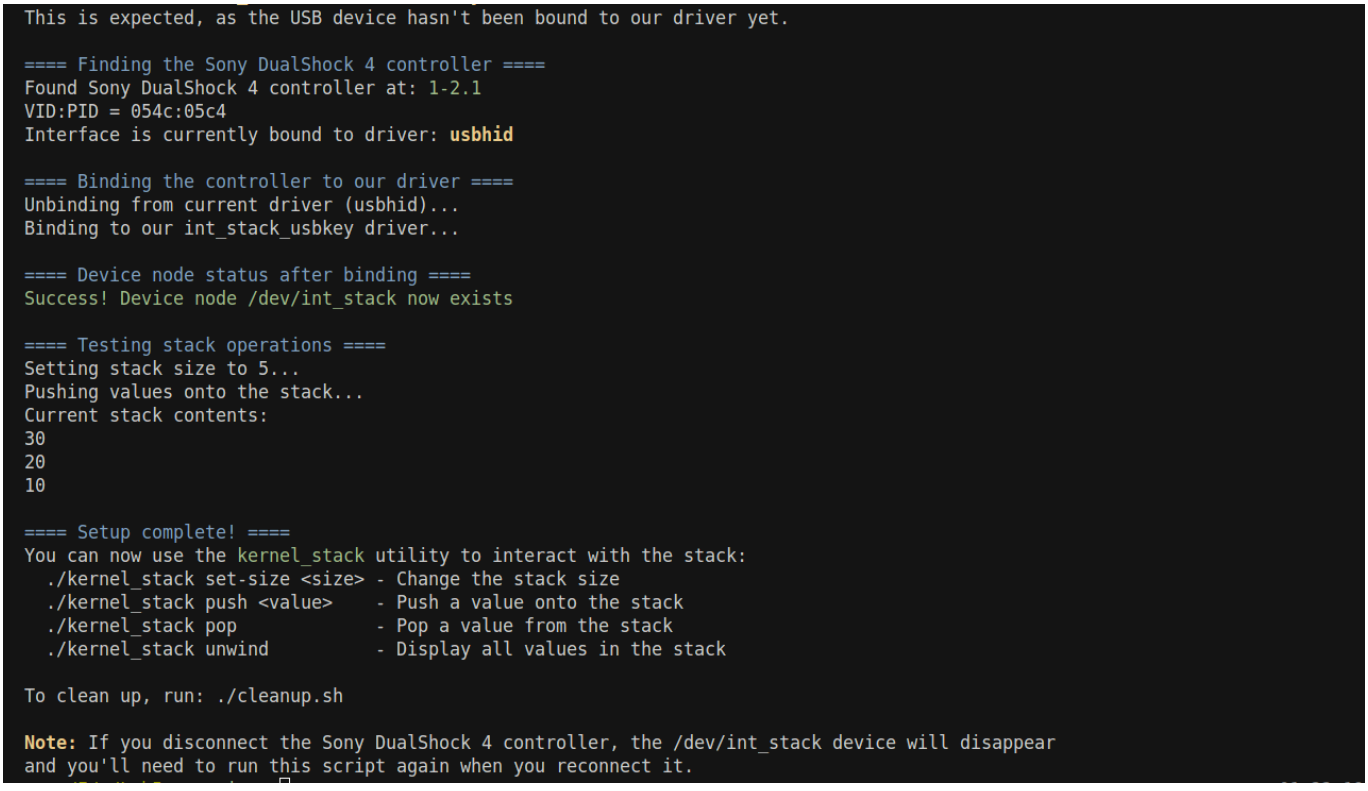
Using the Setup Script

For convenience, a setup script is provided that:

1. Compiles both modules
2. Loads them in the correct order
3. Finds and binds the USB device
4. Tests stack operations

```
./setup.sh
```





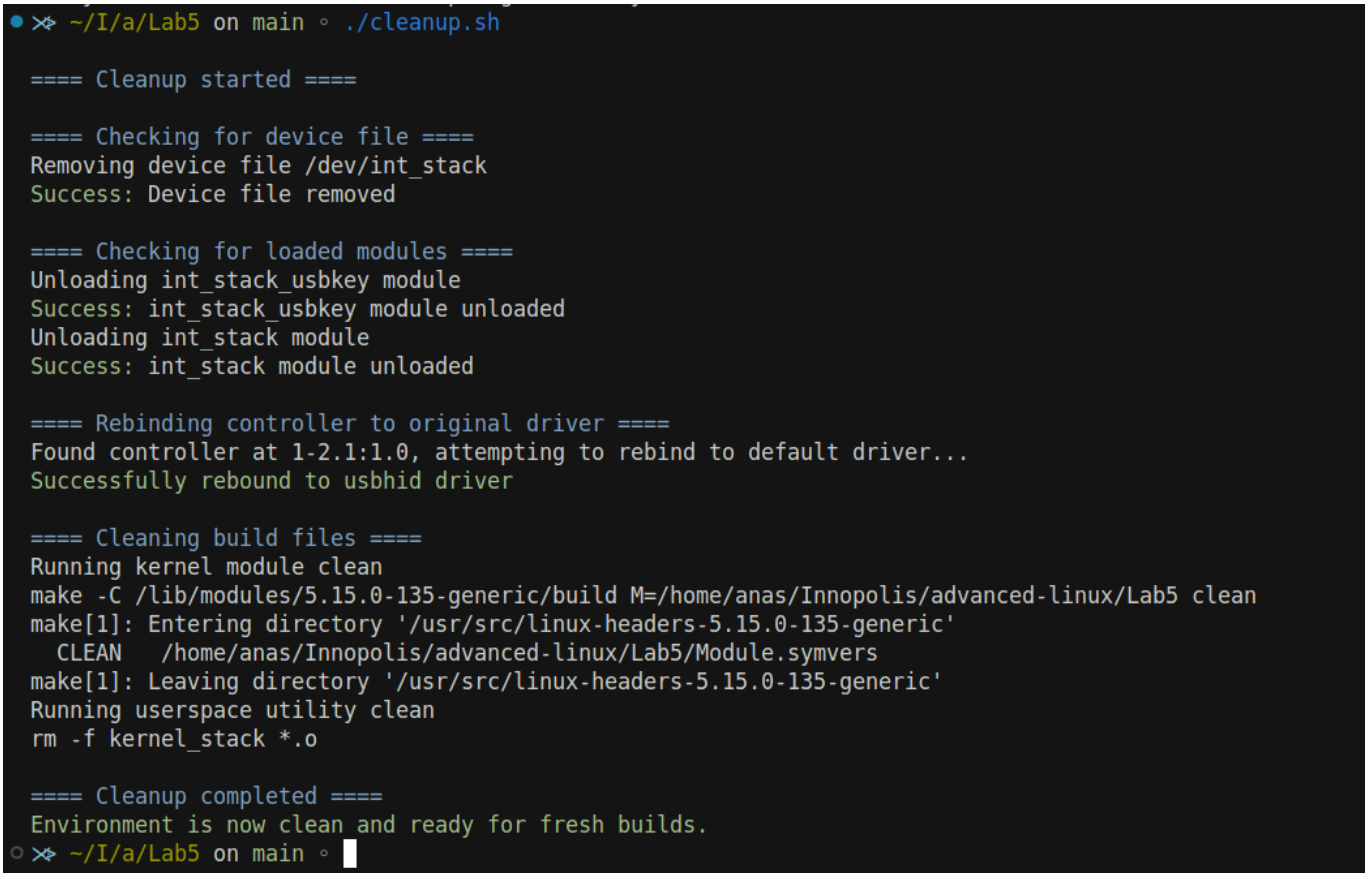
Using the Cleanup Script

To clean up:

```
./cleanup.sh
```

This script:

1. Removes the device node (if it exists)
2. Unloads both modules in the correct order
3. Rebinds the USB device to its original driver
4. Cleans build files



Challenges I faced

Driver Conflicts: The Sony controller is normally claimed by the `usbhid` driver. We need to unbind it from this driver before binding to our custom driver, finding the correct driver to unbind the controller was challenging for me.