Operating System (CSC 3150)

Tutorial 2

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Target

Modules are pieces of code that can be loaded and unloaded into the kernel upon demand. They extend the functionality of the kernel without the need to reboot the system. For example, one type of module is the device driver, which allows the kernel to access hardware connected to the system. Without modules, we would have to build monolithic kernels and add new functionality directly into the kernel image. Besides having larger kernels, this has the disadvantage of requiring us to rebuild and reboot the kernel every time we want new functionality.

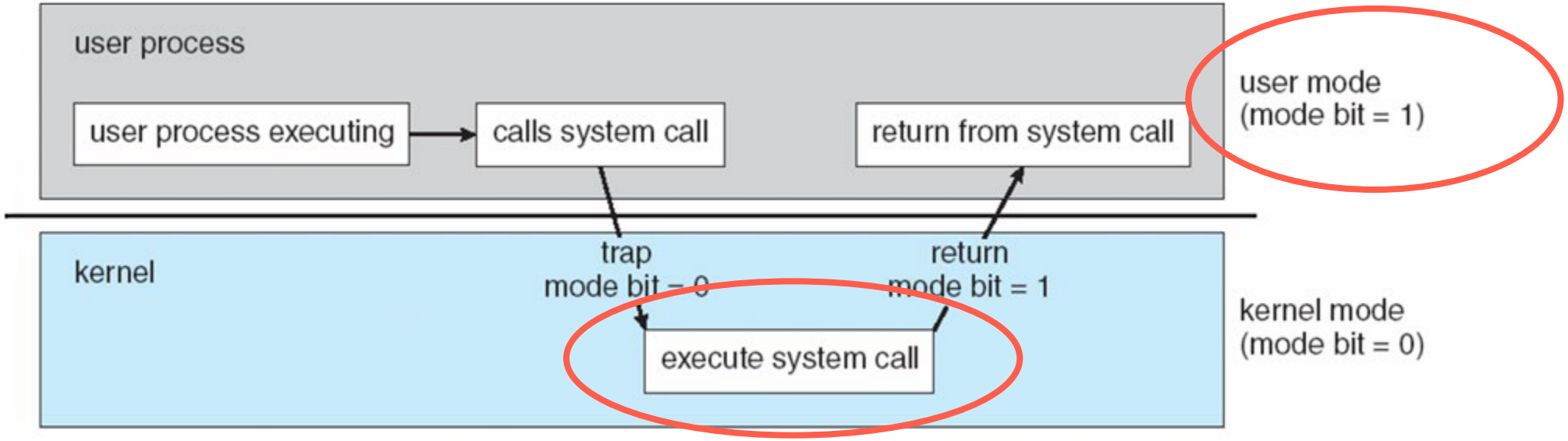
In this tutorial, we will practice write system in kernel mode.

- Kernel Object
- Insert and Remove Kernel Module
- Create Kernel Thread
- Compile Kernel
- System call execution

kernel 会将开机信息存储在 ring buffer 中。您若是开机时来不及查看信息，可利用 dmesg 来查看。开机信息亦保存在 /var/log 目录中，名称为 dmesg 的文件里。

Process

- User Mode
- Kernel Mode



Kernel Object

- A loadable kernel module (or LKM) is an object file that contains code to extend the running kernel, or so-called base kernel

- LKMs are typically used to add support for new hardware and/or file systems, or for adding system calls.

- Most current Unix-like systems support loadable kernel modules, although they might use a different name for them,
  - for example: kernel extension (kext) in MacOS

Kernel Object Compiling (Makefile)

- Makefile

http://www.cyberciti.biz/tips/compiling-linux-kernel-module.html

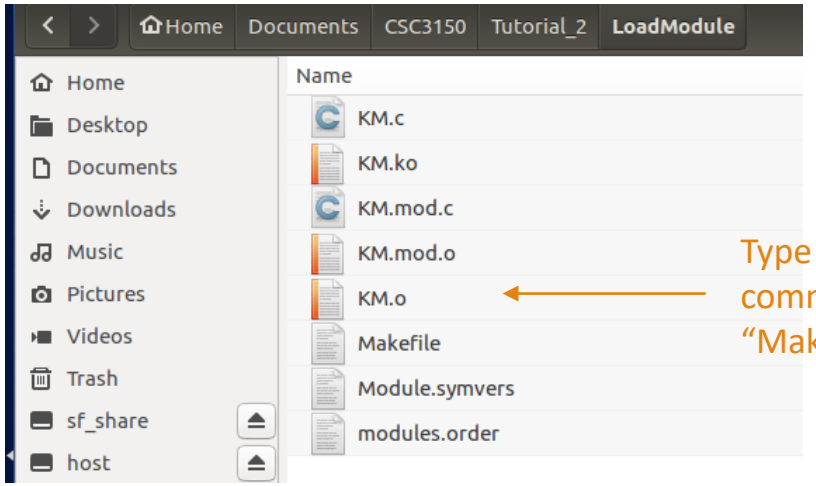
- Build kernel object

(~/Documents/CSC3150/Tutorial_2/LoadModule) - gedit

Open

'KM' is name of the Kernel Object

```
1 obj-m    := KM.o
2 KVERSION := $(shell uname -r)
3 PWD      := $(shell pwd)
4
5 all:
6         $(MAKE) -C /lib/modules/$(KVERSION)/build M=$(PWD) modules
7 clean:
8         $(MAKE) -C /lib/modules/$(KVERSION)/build M=$(PWD) clean
```



If you type command "Make clean", it will clear all built files and leave original c file and makefile .

Insert and Remove Kernel Module

- Before insert the kernel object, you have to sign in the root account.
  - $ sudo su

- Insert module
  - $insmod MODULE_NAME.ko

- List the module you insert
  - $lsmod
  - $lsmod | grep MODULE_NAME

- Remember to remove your module
  - $rmmod MODULE_NAME.ko

Insert and Remove Kernel Module

```c
#include <linux/init.h>
#include <linux/module.h>

MODULE_LICENSE("GPL");

static int KM_init(void) {
    printk(KERN_INFO "Kernel Module initilization!\n");

    return 0;
}

static void KM_exit(void) {
    printk(KERN_INFO "Kernel Module exits!\n");

}

module_init(KM_init);
module_exit(KM_exit);
```

printk(): prints the message into kernel log

```
root@VM: /home/seed/Documents/CSC3150/Tutorial_2/LoadModule
[09/18/18]seed@VM:~/.../LoadModule$ sudo su
[sudo] password for seed:
root@VM:/home/seed/Documents/CSC3150/Tutorial_2/LoadModule# insmod KM.ko
root@VM:/home/seed/Documents/CSC3150/Tutorial_2/LoadModule# lsmod | grep KM
KM                     16384  0
root@VM:/home/seed/Documents/CSC3150/Tutorial_2/LoadModule# dmesg | tail -n 1
[ 5477.829462] Kernel Module initilization!
root@VM:/home/seed/Documents/CSC3150/Tutorial_2/LoadModule# rmmod KM.ko
root@VM:/home/seed/Documents/CSC3150/Tutorial_2/LoadModule# dmesg | tail -n 1
[ 5606.811308] Kernel Module exits!
root@VM:/home/seed/Documents/CSC3150/Tutorial_2/LoadModule#
```

- Column 1: Module Name
- Column 2: Module Size
- Column 3: Used by (denotes each module's use count and a list of referring modules)

grep: global search regular expression and print out the line

dmesg: display message buffer in kernel

Kernel Thread

内核经常需要在后台执行一些操作，这种任务就可以通过内核线程（kernle thread）完成，内核线程是独立运行在内核空间的标准进程。内核线程和普通的进程间的区别在于内核线程没有独立的地址空间，mm指针被设置为NULL；它只在内核空间运行，从来不切换到用户空间去；并且和普通进程一样，可以被调度，也可以被抢占。实际上，内核线程只能由其他内核线程创建，linux驱动模块中可以用

- Kthread creation:
  - struct task_struct *kthread_create(int (*threadfn)(void *data),
    void *data,
    const char *namefmt, ...);
  - The data argument will simply be passed to the thread function.
  - The thread will not start running immediately. It will start to execute when returned task_struct is passed to wake_up_process().

- Kthread execution function:
  - int thread_function(void *data);
  - It can either call do_exit directly if it is a standalone thread for which no one will call kthread_stop()
  - Or return when 'kthread_should_stop' is true (which means kthread_stop has been called).

Kernel Thread

- Return value:
  - It returns task_struct when executes successfully.
  - When fails, it returns ERR_PTR

- Kthred start execution with:
  - int wake_up_process (struct task_struct * p);
  - ERR_PTR

- A convenient function which creates and starts the thread:
  - struct task_struct *kthread_run(int (*threadfn)(void *data),
    void *data,
    const char *namefmt, ...);
  - Same as kthread_create() + wake_up_process()

Kernel Thread

Open

```c
#include <linux/init.h>
#include <linux/module.h>
#include <linux/kthread.h>

MODULE_LICENSE("GPL");


static struct task_struct *task;


//implement test function
int func(void* data)  {

      int time_count = 0;
        do {
                printk(KERN_INFO "thread_function: %d times", ++time_count);


        }while(!kthread_should_stop() && time_count<=30);

        return time_count;
}


static int __init KT_init(void){

        printk("KT module create kthread start\n");

        //create a kthread
        task=kthread_create(&func,NULL,"MyThread");


        //wake up new thread if ok
        if(!IS_ERR(task)){
                printk("Kthread starts\n");
                wake_up_process(task);
        }
        return 0;
}

static void __exit KT_exit(void){
        printk("KT module exits! \n");
}

module_init(KT_init);
module_exit(KT_exit);
```

GPL: General Public License. Loading a proprietary or non-GPL-compatible LKM will set a 'taint' flag in the running kernel

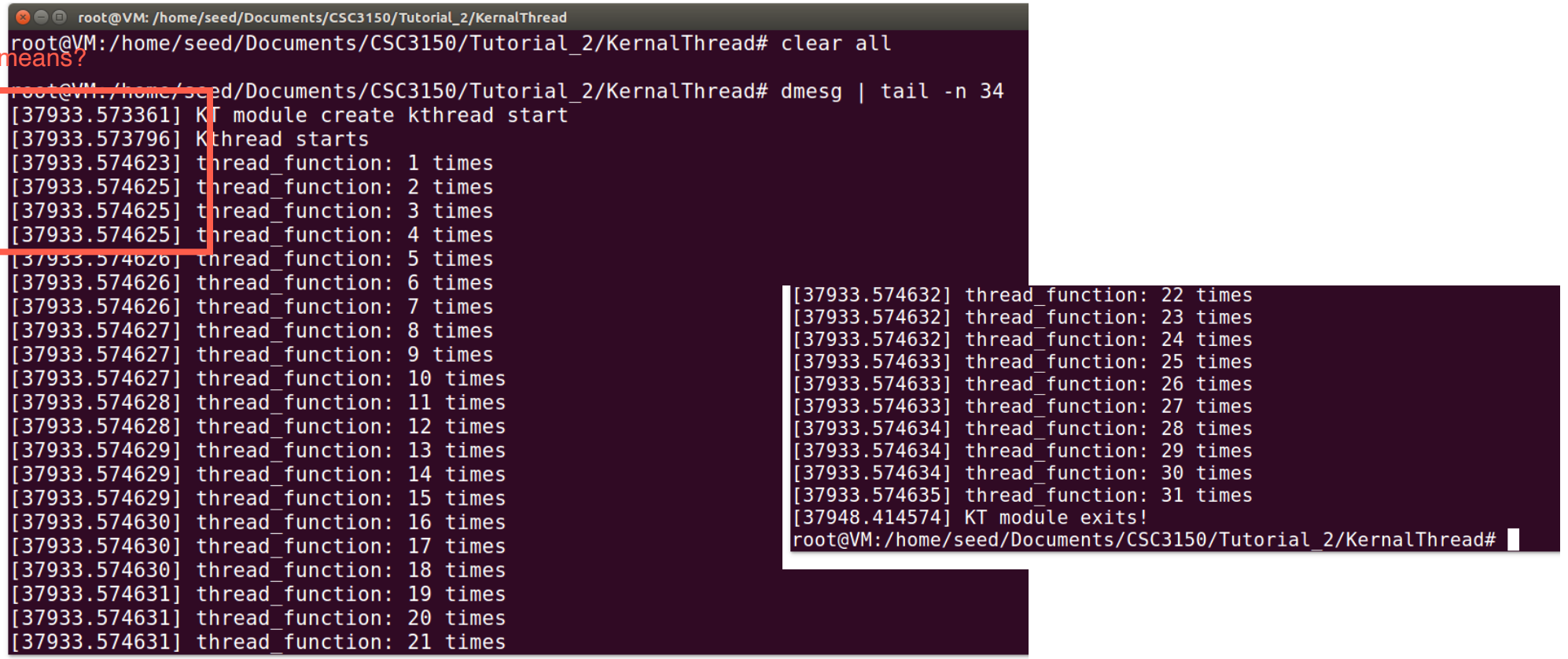
Create a kernel thread to execute func

```
root@VM: /home/seed/Documents/CSC3150/Tutorial_2/KernalThread
root@VM:/home/seed/Documents/CSC3150/Tutorial_2/KernalThread# insmod KT.ko
root@VM:/home/seed/Documents/CSC3150/Tutorial_2/KernalThread# lsmod | grep KT
KT                     16384  0
root@VM:/home/seed/Documents/CSC3150/Tutorial_2/KernalThread# rmmod KT.o
root@VM:/home/seed/Documents/CSC3150/Tutorial_2/KernalThread#
```

Kernel Thread

.ko文件是kernel object文件（内核模块），该文件的意义就是把内核的一些功能移动到内核外边， 需要的时候插入内核，不需要时卸载。

what does this means?



Compile Kernel

- Download source code from
  - https://cdn.kernel.org/pub/linux/kernel/v4.x/linux-4.10.14.tar.xz
  -
- Extract the source file to /home/${your-name}/${working-folder}
  - cp linux-kernel.tar.xz /home/${your-name}/${working-folder}
  - cd /home/${your-name}/${working-folder}
  - $sudo tar -xzf linux-kernel.tar.xz
- Login root account and go to kernel source directory
  - $sudo su
  - $cd /home/${your-name}/${working-folder}/linux-kernel

Compile Kernel

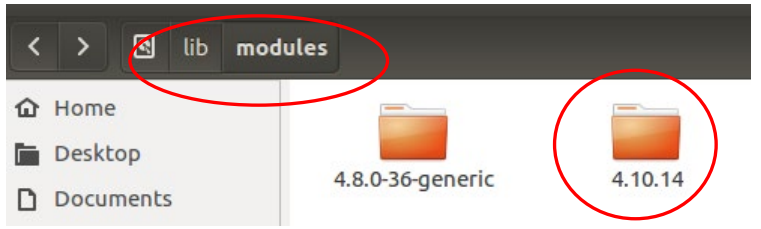
- Clean previous setting and start configuration
  - $make mrproper
  - $make clean
  - $make menuconfig
    - Command “make menuconfig” does not working
    - Use command “sudo apt-get install libncurses5-dev libssl-dev” to install the tool
  - save the config and exit

```
configuration written to .config
```

- Build kernel Image and modules
  - $make bzImage
  - $make modules
  - ~ 30 mins to finish
  - **$make –j NUM_CORE**

  (you could use this command to replace above two commands)

```
Kernel: arch/x86/boot/bzImage is ready  (#1)
root@VM:/usr/src/linux-4.10.14#
```



Remark: Error in menuconfig

- Command “make menuconfig” does not working
  - Use command “sudo apt-get install libncurses5-dev libssl-dev” to install the tool

```
scripts/Makefile.host:124: recipe for target 'scripts/kconfig/mco
nf.o' failed
make[1]: *** [scripts/kconfig/mconf.o] Error 1
Makefile:546: recipe for target 'menuconfig' failed
make: *** [menuconfig] Error 2
root@VM:/usr/src/linux-4.10.14#
```

Compile Kernel

- Install kernel modules
  - $make modules_install

```
  DEPMOD  4.10.14
root@VM:/home/seed/sdb4/linux-4.10.14#
```

- Install kernel
  - $make install

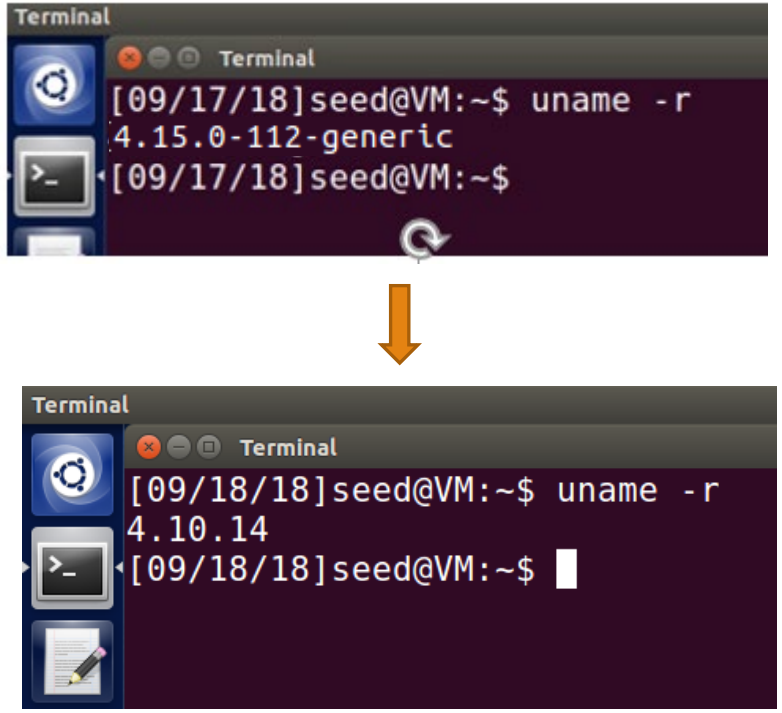
```
done
root@VM:/home/seed/sdb4/linux-4.10.14#
```

- Reboot to load new kernel
  - $reboot

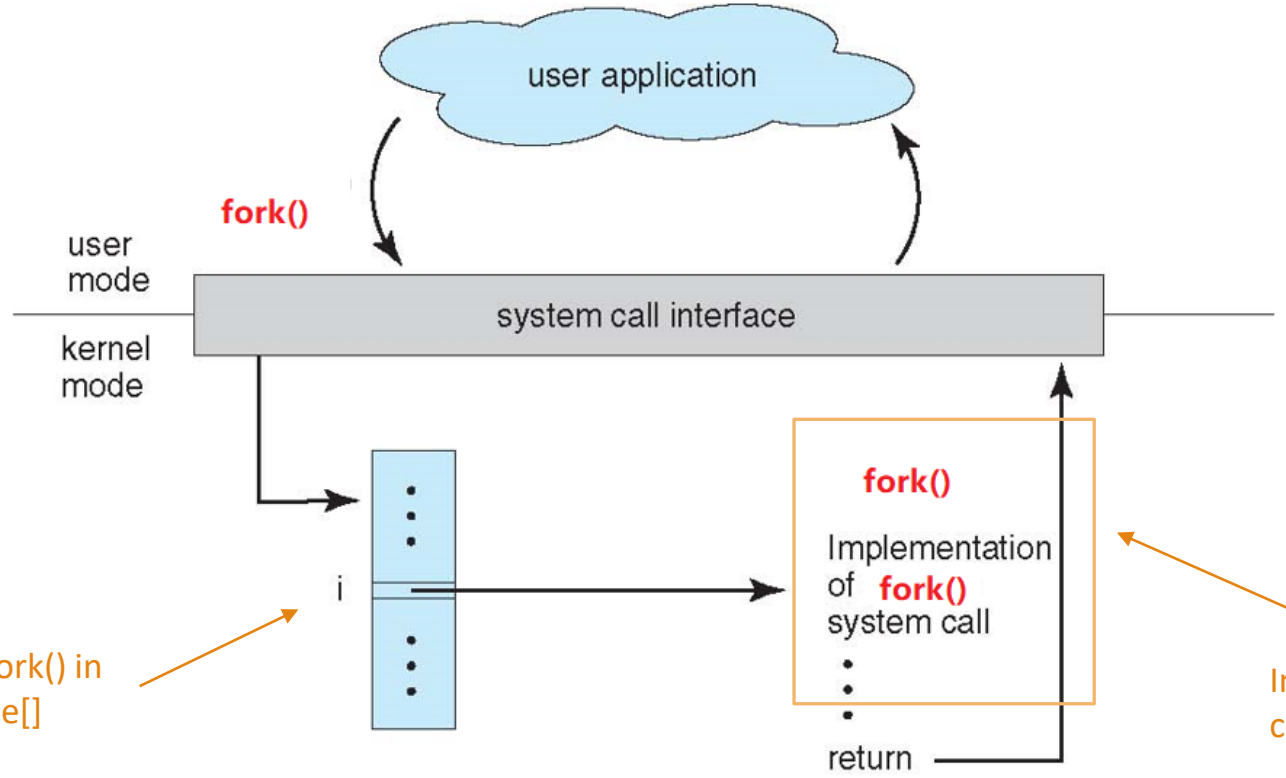
  (When rebooting, you should select the updated kernel)

Compile Kernel

- Check exiting kernel version
  - $uname -r



System call execution (fork)



System call execution (fork)

- Calls dup_task_struct(), which creates a new kernel stack, thread_info structure, and task_struct for the new process.

- Calls get_pid() to assign an available PID to the new task.

- copy_process() then either duplicates or shares open files, filesystem information, signal handlers, process address space, and namespace.

- For more details
  - https://elixir.bootlin.com/linux/v4.10.10/source/kernel/fork.c (do_fork)

Export Symbol

- EXPORT_SYMBOL() helps you provide APIs to other modules/code.
- The functions which you EXPORT are available to the other modules/code.
- Your module will not load if the it's expecting a symbol(variable/function) and it's not present in the kernel.

```
/*
 *  linux/kernel/fork.c
 *
 *  Copyright (C) 1991, 1992
 */
EXPORT_SYMBOL(do_fork)
/*
```

```
/*
 *  linux/fs/exec.c
 *
 *  Copyright (C) 1991, 1992  Linus Torvalds
 */
EXPORT_SYMBOL(do_execve)
/*
```

```
/*
 *  linux/kernel/exit.c
 *
 *  Copyright (C) 1991, 1992  Linus Torvalds
 */
EXPORT_SYMBOL(do_wait)
```

References

- Loadable module kernel
  - https://en.wikipedia.org/wiki/Loadable_kernel_module
- Kthread_create()
  - https://www.fsl.cs.sunysb.edu/kernel-api/re69.html
- Linux commands
  - http://www.runoob.com/linux/linux-command-manual.html (Chinese)

References

- Compile kernel
  - https://www.cnblogs.com/acm-icpcer/p/8029656.html (version: Linux-4.10.14, Chinese)
  - https://www.linux.com/learn/intro-to-linux/2018/4/how-compile-linux-kernel-0 (English)
  - http://www.berkes.ca/guides/linux_kernel.html (English)

- Extend storage in Virtual Box
  - https://jingyan.baidu.com/article/d45ad148a1fab869542b8073.html (Chinese)
  - http://derekmolloy.ie/resize-a-virtualbox-disk/ (English)

Thank you