Homework (lec4. hw7~11)

7) sys_call_table[] is in arch/x86/kernel/syscall_table_32.S. How many system calls does Linux 2.6 support? What are the system call numbers for exit, fork, execve, wait4, read, write, and mkdir? Find system call numbers for sys_ni_syscall, which is defined at kernel/sys_ni.c. What is the role of sys_ni_syscall?

```
        .long sys_linkat
        .long sys_symlinkat
        .long sys_readlinkat            /* 305 */
        .long sys_fchmodat
        .long sys_faccessat
        .long sys_pselect6
        .long sys_ppoll
        .long sys_unshare               /* 310 */
        .long sys_set_robust_list
        .long sys_get_robust_list
        .long sys_splice
        .long sys_sync_file_range
        .long sys_tee                   /* 315 */
        .long sys_vmsplice
        .long sys_move_pages
        .long sys_getcpu
        .long sys_epoll_pwait
        .long sys_utimensat             /* 320 */
        .long sys_signalfd
        .long sys_timerfd_create
        .long sys_eventfd
        .long sys_fallocate
        .long sys_timerfd_settime       /* 325 */
        .long sys_timerfd_gettime
                                                      328,2-9       Bot
```

326번 까지 있으므로 327개의 syscall 종류가 있다.

```
ENTRY(sys_call_table)
        .long sys_restart_syscall       /* 0 - old "setup()" system call, used f
or restarting */
        .long sys_exit
        .long sys_fork
        .long sys_read
        .long sys_write
        .long sys_open          /* 5 */
        .long sys_close
        .long sys_waitpid
        .long sys_creat
        .long sys_link
        .long sys_unlink        /* 10 */
        .long sys_execve
        .long sys_chdir
        .long sys_time
        .long sys_mknod
        .long sys_chmod         /* 15 */
        .long sys_lchown16
        .long sys_ni_syscall    /* old break syscall holder */
        .long sys_stat
        .long sys_lseek
        .long sys_getpid        /* 20 */
        .long sys_mount
                                                      21,2-9        Top
```

exit = 1, fork = 2, read = 3, write = 4, execve = 11

```
        .long sys_fstat
        .long sys_pause
        .long sys_utime         /* 30 */
        .long sys_ni_syscall    /* old stty syscall holder */
        .long sys_ni_syscall    /* old gtty syscall holder */
        .long sys_access
        .long sys_nice
        .long sys_ni_syscall    /* 35 - old ftime syscall holder */
        .long sys_sync
        .long sys_kill
        .long sys_rename
        .long sys_mkdir
        .long sys_rmdir         /* 40 */
        .long sys_dup
        .long sys_pipe
        .long sys_times
        .long sys_ni_syscall    /* old prof syscall holder */
        .long sys_brk           /* 45 */
        .long sys_setgid16
        .long sys_getgid16
        .long sys_signal
        .long sys_geteuid16
        .long sys_getegid16     /* 50 */
        .long sys_acct
                                                        41,2-9          9%
```

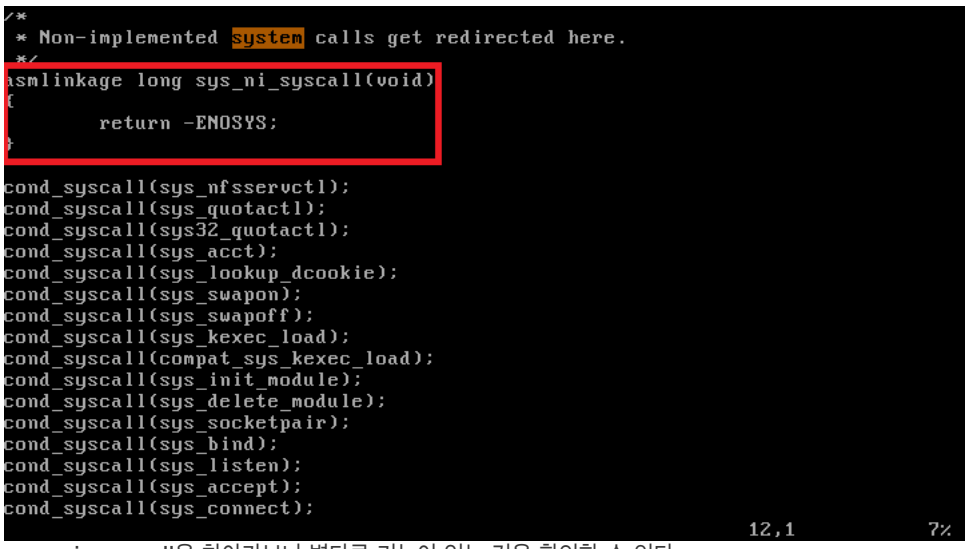
mkdir = 39

```
        .long sys_newfstat
        .long sys_uname
        .long sys_iopl          /* 110 */
        .long sys_vhangup
        .long sys_ni_syscall    /* old "idle" system call */
        .long sys_vm86old
        .long sys_wait4
        .long sys_swapoff       /* 115 */
        .long sys_sysinfo
        .long sys_ipc
        .long sys_fsync
        .long sys_sigreturn
        .long sys_clone         /* 120 */
        .long sys_setdomainname
        .long sys_newuname
        .long sys_modify_ldt
        .long sys_adjtimex
        .long sys_mprotect      /* 125 */
        .long sys_sigprocmask
        .long sys_ni_syscall    /* old "create_module" */
        .long sys_init_module
        .long sys_delete_module
        .long sys_ni_syscall    /* 130: old "get_kernel_syms" */
        .long sys_quotactl
                                                        110,2-9         35%
```

wait4 = 114

```
        .long sys_ni_syscall    /* 35 - old ftime syscall holder */
        .long sys_sync
        .long sys_kill
        .long sys_rename
        .long sys_mkdir
        .long sys_rmdir         /* 40 */
        .long sys_dup
        .long sys_pipe
        .long sys_times
        .long sys_ni_syscall    /* old prof syscall holder */
        .long sys_brk           /* 45 */
        .long sys_setgid16
        .long sys_getgid16
        .long sys_signal
        .long sys_geteuid16
        .long sys_getegid16     /* 50 */
        .long sys_acct
        .long sys_umount        /* recycled never used phys() */
        .long sys_ni_syscall    /* old lock syscall holder */
        .long sys_ioctl
        .long sys_fcntl         /* 55 */
        .long sys_ni_syscall    /* old mpx syscall holder */
        .long sys_setpgid
        .long sys_ni_syscall    /* old ulimit syscall holder */
                                                        49,2-9          11%
```

sys_ni_syscall을 많이 찾아볼 수 있다.



sys_ni_syscall을 찾아가보니 별다른 기능이 없는 것을 확인할 수 있다.
더 이상 사용되지 않는 syscall의 번호들 인 것 같다.

8) Change the kernel such that it prints "length 17 string found" for each printf(s) when the length of s is 17. Run a program that contains a printf() statement to see the effect. printf(s) calls write(1, s, strlen(s)) system call which in turn runs

mov eax, 4 ; eax<--4. 4 is system call number for “write”
int 128

INT 128 will make the cpu stop running current process and jump to the location written in IDT[128]. IDT[128] contains the address of system_call (located in arch/x86/kernel/entry_32.S). Finally, system_call will execute

call *sys_call_table(,%eax,4)

which eventually calls sys_write() since eax=4 for write() system call.
* Sometimes the compiler generate "sysenter" instead of "int 128". In this case the cpu jumps to ia32_sysenter_target (also in entry_32.S) instead of system_call.

17글자를 출력하는 “test” 명령이다.

```
#include <stdio.h>
int main(){
        printf("no 17 word\n");
}
~
~
~
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~
~
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~
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~
~
~
"test1.c" [converted] 4L, 58C                                 4,1           All
```

17글자가 아닌 문자열을 출력하는 “test1” 명령이다.

```
asmlinkage ssize_t sys_write(unsigned int fd, const char __user * buf, size_t co
unt)
{
        struct file *file;
        ssize_t ret = -EBADF;
        int fput_needed;

        if(count==17)
                printk("length 17 string found\n");

        file = fget_light(fd, &fput_needed);
        if (file) {
                loff_t pos = file_pos_read(file);
                ret = vfs_write(file, buf, count, &pos);
                file_pos_write(file, pos);
                fput_light(file, fput_needed);
        }

        return ret;
}

asmlinkage ssize_t sys_pread64(unsigned int fd, char __user *buf,
                               size_t count, loff_t pos)
{
                                                              392,1         45%
```

count가 17일 때 출력문을 추가하였다.

```
localhost linux-2.6.25.10 # echo 8 > /proc/sys/kernel/printk
localhost linux-2.6.25.10 # ./test
length 17 string found
12141755 hyunho!
localhost linux-2.6.25.10 # ./test1
no 17 word
localhost linux-2.6.25.10 # _
```

kernel에서 printk를 출력하기 위해 우선순위를 바꿔준 후 실행하였다.
17글자인 문자열을 출력하는 “test”를 실행했을 때 잘 출력되는 것을 확인할 수 있다.

9) You can call a system call indirectly with “syscall()”.
write(1, “hi”, 2);
can be written as
syscall(4, 1, “hi”, 2); // 4 is the system call number for “write” system call
Write a program that prints “hello” in the screen using syscall.

```
#include <stdio.h>
int main(){
        write(1, "hi", 2);
}
~
~
~
~
~
~
~
~
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~
~
~
~
~
~
~
~
~
~
"test.c" [converted] 4L, 53C                                  3,2-9         All
```

write를 이용해 “hi”를 출력하는 코드이다.

```
#include <stdio.h>
int main(){
        syscall(4, 1, "hi", 2);
}
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
"test1.c" [converted] 4L, 58C                                 3,2-9         All
```

syscall을 이용하여 “hi”를 출력하는 코드이다.

```
localhost linux-2.6.25.10 # ./test
hilocalhost linux-2.6.25.10 # ./test1
hilocalhost linux-2.6.25.10 #
```

write, sycall(4번) 모두 같이 “hi”가 출력되는 것을 확인할 수 있다.

10) Create a new system call, my_sys_call with system call number 17 (system call number 17 is one that is not being used currently). Define my_sys_call() just before sys_write() in read_ write.c. Write a program that uses this system call:

```
void main(){
   syscall(17); // calls a system call with syscall number 17
}
```

When the above program runs, the kernel should display

hello from my_sys_call

To define a new system call with syscall number x

- insert the new system call name in arch/x86/kernel/syscall_table_32.S at index x
- define the function in appropriate file (such as "read_write.c")
- recompile and reboot

To use this system call in a user program

- void main(){
  syscall(x);
  }

```
ENTRY(sys_call_table)
        .long sys_restart_syscall       /* 0 - old "setup()" system call, used f
or restarting */
        .long sys_exit
        .long sys_fork
        .long sys_read
        .long sys_write
        .long sys_open          /* 5 */
        .long sys_close
        .long sys_waitpid
        .long sys_creat
        .long sys_link
        .long sys_unlink        /* 10 */
        .long sys_execve
        .long sys_chdir
        .long sys_time
        .long sys_mknod
        .long sys_chmod         /* 15 */
        .long sys_lchown16

        .long my_sys_call

//      .long sys_ni_syscall    /* old break syscall holder */
        .long sys_stat
```

17번 syscall에 my_sys_call을 추가한 모습이다.

```
        if (file) {
                loff_t pos = file_pos_read(file);
                ret = vfs_read(file, buf, count, &pos);
                file_pos_write(file, pos);
                fput_light(file, fput_needed);
        }

        return ret;
}

asmlinkage void my_sys_call(){
        printk("hello from my_sys_call\n");
}
_

asmlinkage ssize_t sys_write(unsigned int fd, const char __user * buf, size_t co
unt)
{
        struct file *file;
        ssize_t ret = -EBADF;
        int fput_needed;

        file = fget_light(fd, &fput_needed);
        if (file) {
                                                              373,0-1       44%
```

sys_write 위에 asmlinkage를 이용하여 my_sys_call 함수를 추가한 모습이다.

```
#include <stdio.h>
int main(){
        syscall(17);
}
~
~
~
~
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~
~
~
~
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~
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~
~
~
~
~
~
"test.c" [converted] 4L, 47C                          3,1-8         All
```

syscall에서 방금 내가 추가한 17번을 호출하는 코드이다.

```
localhost linux-2.6.25.10 # echo 8 > /proc/sys/kernel/printk
localhost linux-2.6.25.10 # ./test
hello from my_sys_call
localhost linux-2.6.25.10 # _
```

kernel에서 printk를 출력하기 위해 우선순위를 먼저 바꿔준다.
“test” 실행 시 정상적으로 my_sys_call이 실행되는 것을 확인할 수 있다.

11) Modify the kernel such that it displays the system call number for all system calls. Run a simple program that displays "hello" in the screen and find out what system calls have been called.

```
ENTRY(sys_call_table)
        .long sys_restart_syscall       /* 0 - old "setup()" system call, used f
or restarting */
        .long sys_exit
        .long sys_fork
        .long sys_read
        .long sys_write
        .long sys_open          /* 5 */
        .long sys_close
        .long sys_waitpid
        .long sys_creat
        .long sys_link
        .long sys_unlink        /* 10 */
        .long sys_execve
        .long sys_chdir
        .long sys_time
        .long sys_mknod
        .long sys_chmod         /* 15 */
        .long sys_lchown16

        .long sys_my_print      // 17

//      .long sys_ni_syscall    /* old break syscall holder */
        .long sys_stat
                                                              20,14-21      Top
```

syscall table의 17번에 sys_my_print를 추가한 모습이다.

```
        }

        return ret;
}

asmlinkage void sys_my_print(int sys_num){
        printk("sys_num : %d\n", sys_num);
}

asmlinkage ssize_t sys_write(unsigned int fd, const char __user * buf, size_t co
unt)
{
        struct file *file;
        ssize_t ret = -EBADF;
        int fput_needed;

        file = fget_light(fd, &fput_needed);
        if (file) {
                loff_t pos = file_pos_read(file);
                ret = vfs_write(file, buf, count, &pos);
                file_pos_write(file, pos);
                fput_light(file, fput_needed);
        }

                                                              369,0-1       44%
```

sys_write 위에 asmlinkage를 이용한 sys_my_print 함수를 정의한 모습이다.
매개변수로 sys_num을 가져와서 printk를 이용하여 출력하게 된다.

```
        GET_THREAD_INFO(%ebp)
                                        # system call tracing in operation / emu
lation
        /* Note, _TIF_SECCOMP is bit number 8, and so it needs testw and not tes
tb */
        testw $(_TIF_SYSCALL_EMU|_TIF_SYSCALL_TRACE|_TIF_SECCOMP|_TIF_SYSCALL_AU
DIT),TI_flags(%ebp)
        jnz syscall_trace_entry
        cmpl $(nr_syscalls), %eax
        jae syscall_badsys
syscall_call:
        pushl %eax
        call sys_my_print
        popl %eax
_
        call *sys_call_table(,%eax,4)
        movl %eax,PT_EAX(%esp)          # store the return value
syscall_exit:
        LOCKDEP_SYS_EXIT
        DISABLE_INTERRUPTS(CLBR_ANY)    # make sure we don't miss an interrupt
                                        # setting need_resched or sigpending
                                        # between sampling and the iret
        TRACE_IRQS_OFF
        testl $TF_MASK,PT_EFLAGS(%esp)  # If tracing set singlestep flag on exit
```

push eax를 하면 다음 함수 호출 시 스택에 넣었던 data를 매개변수로 받을 수 있다.
그리고 sys_my_print를 호출하고 다시 pop eax 하여 정상적으로 복구한다.

```
#include <stdio.h>
int main(){
        printf("hello\n");
}
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
"test.c" [converted] 4L, 53C                                  3,1-8         All
```

“hello”를 출력하는 코드이다.

```
localhost week5 # echo 8 > /proc/sys/kernel/printk
localhost week5 # ./test
sys_num : 45
sys_num : 33
sys_num : 5
sys_num : 197
sys_num : 192
sys_num : 6
sys_num : 5
sys_num : 3
sys_num : 197
sys_num : 192
sys_num : 192
sys_num : 192
sys_num : 192
sys_num : 6
sys_num : 192
sys_num : 243
sys_num : 125
sys_num : 125
sys_num : 125
sys_num : 91
hello
sys_num : 119
localhost week5 #
```

kernel에서 printk를 출력하기 위해 우선순위를 바꿔준다.
“hello”를 출력하는 동안 syscall 되는 번호들이 정상적으로 출력되는 것을 확인할 수 있다.