Project 1 Help Document

Sep 18, 2019

SNU Operating Systems

Project 1

General Overview of Project 1

- Write a system call
  - `int ptree(struct prinfo *buf, int *nr)`
  - System call number **398**
  - You can name your function `sys_ptree`; doesn't matter as long as it works
- Test your system call
  - Print the entire process tree in pre-order

Example Program Output

- `swapper/0` (pid 0)
  - The first ever process created
  - Used to represent the state of ‘not working’
- `systemd` (pid 1)
  - Manages all the processes
- `kthreadd` (pid 2)
  - Kernel thread daemon
  - `kthread_create`

```
sh-3.2# ./proj1
swapper/0,0,0,0,1,0,0
        systemd,1,1,0,167,2,0
                systemd-journal,167,1,1,0,185,0
                systemd-udevd,185,1,1,0,241,0
                dbus-daemon,241,1,1,0,297,81
                amd,297,1,1,0,298,301
                dlog_logger,298,1,1,0,307,1901
                buxton2d,307,1,1,0,313,375
                key-manager,313,1,1,0,325,444
```

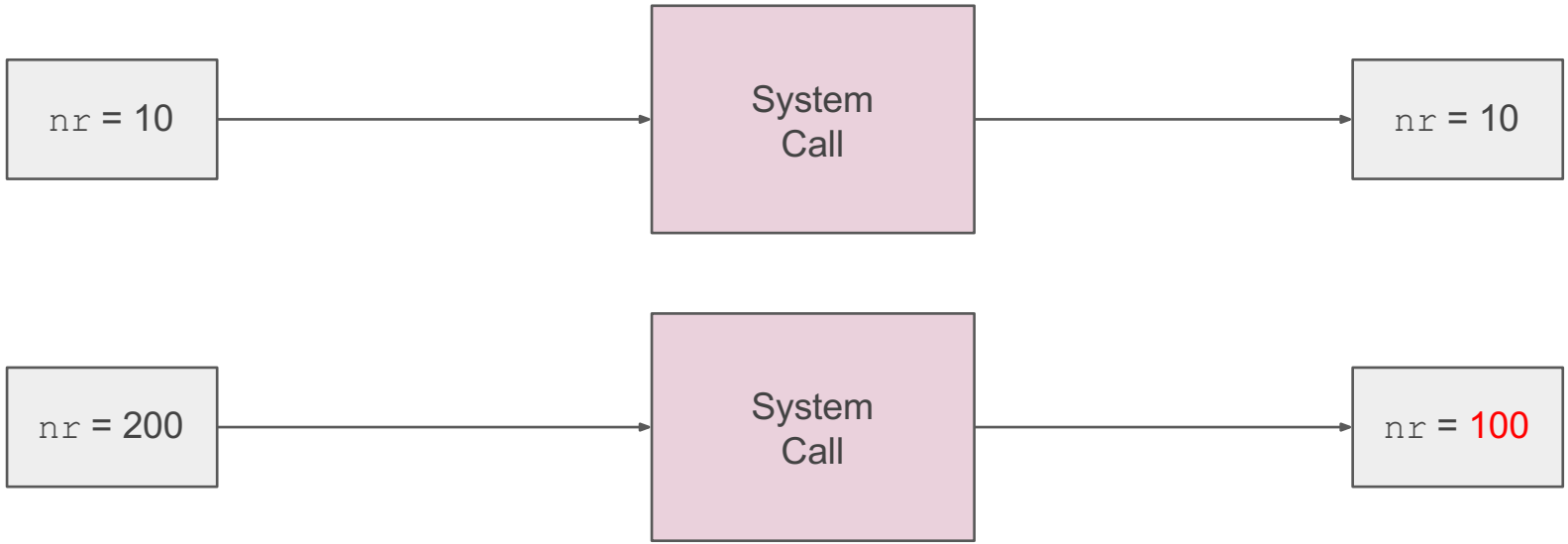
```
        kthreadd,2,1,0,3,0,0
                 kworker/0:0,3,1026,2,0,4,0
                 kworker/0:0H,4,1026,2,0,5,0
                 kworker/u8:0,5,1026,2,0,6,0
                 mm_percpu_wq,6,1026,2,0,7,0
                 ksoftirqd/0,7,1,2,0,8,0
                 rcu_preempt,8,1026,2,0,9,0
                 rcu_sched,9,1026,2,0,10,0
```

Return Value

- Success
  - Your system call should return the total number of entries (this may be bigger than the actual number of entries copied).
  - `nr` can be changed
- Error
  - Error handling: `-EINVAL` or `-EFAULT`
  - You may handle other errors but we will not grade them
  - Defined in `include/uapi/asm-generic/errno-base.h`

`nr` Example

- Assuming the number of total processes is 100:



Error Handling

- `-EINVAL`
  - If `buf` and/or `nr` are `NULL`, or if `nr` is less than 1
- `-EFAULT`
  - If `buf` and/or `nr` are outside the accessible address space

Error Handling

- How to print error messages?
  - `int result = syscall(398, ...);`
  - `printf("%d", result);`
  - ?????
- You cannot get `-EINVAL` or `-EFAULT` as the return value
  - Use `errno` and `perror()`

Check Before Submission!

- Unsafe access to user space memory
- Return value
  - Incorrect return value
  - Not modifying `*nr` when needed
- Whether you follow the project specifications (final check!) …
- … and whether you have delineated all unspecified/different implementation details in README
- **White-box test for this project!**

Reminder

- **Concise** README file
  - Describe how to build your kernel
  - Describe the high-level design and implementation
  - Investigation of the process tree
  - Any lessons learned

- Concise 4-minute presentation slides (including your video demo) to os-staff os-tas@dcslab.snu.ac.kr
  - **Limit: 10 slides including the title slide**
  - **I won't look at slides after the 10th.**

- Your presentation includes
  A. High-level design and implementation
  B. **A video clip** that shows that your system works
  C. The investigation of the process trees
  D. Lessons learned

About Submission (IMPORTANT!)

- Make sure your branch name is ***proj1***
- Don't be late!
  - TA will not grade the commits after the deadline.
- Slides and Demo
  - Send them to the TAs before the deadline.
  - os-tas@dcslab.snu.ac.kr
  - Title: [OS-ProjX] TeamX slides&demo submission
  - File name: TeamX-slides.ppt(.pdf), TeamX-demo.mp4(.avi….)
  - No confirmation email this time

Announcement

- Deadline
  - Due: 2019-10-08 Tuesday 13:00.
- Check your source code before submission
  - There were some codes which were not compiled….

Kernel Programming

Important Directories

- `arch`
  - Architecture dependent (i.e. x86, arm, mips, …) parts of Linux
- `kernel`
  - Common kernel code
- `net`
  - Common network related code
- `drivers`
  - Common driver code for Linux
- `fs`
  - Common file system code for Linux
- `include`
  - Common header files

Our Architecture

- AArch64 kernel
- ARMv7 userland
- This means there are compatibility issues!
  - Example: `sizeof(long)` is different

Things to Keep in Mind...

- No memory protection
  - Corruption in kernel memory space can make the whole machine crash!
- No floating point or MMX operation
  - Dealing with real numbers can be challenging and painful!
    - You unfortunately have to do it for some projects :(
- Rigid stack limit
  - Use extra caution when allocating local arrays or having recursive calls
  - `kmalloc` instead for huge arrays
- Your kernel code will run in a multi-core environment
  - Use proper synchronization mechanisms to avoid race conditions
  - Beware of deadlocks

Accessing User Memory

- In kernel mode, you should avoid directly accessing user memory space
  - Can result in kernel panic
- `include/asm/uaccess.h` provides macros for this
  - `get_user` / `put_user`: copies simple variables
  - `copy_from_user` / `copy_to_user`: copies a block of data
  - More on http://www.ibm.com/developerworks/library/l-kernel-memory-access/
- Mark system call parameters that access user space memory with `__user`
  - e.g. In `include/linux/syscalls.h`:

```
asmlinkage long sys_time(time_t __user *tloc);
```

Function	Description
`access_ok`	Checks the validity of the user space memory pointer
`get_user`	Gets a simple variable from user space
`put_user`	Puts a simple variable to user space
`clear_user`	Clears, or zeros, a block in user space
`copy_to_user`	Copies a block of data from the kernel to user space
`copy_from_user`	Copies a block of data from user space to the kernel
`strnlen_user`	Gets the size of a string buffer in user space
`strncpy_from_user`	Copies a string from user space into the kernel

`kmalloc` and `kfree`

- Used for allocating / releasing kernel memory instead of `malloc` / `free`
  - Defined in `linux/slab.h`
- `kmalloc` is similar to `malloc`, but has an additional flag parameter
  - `void *kmalloc(size_t size, int flags)`
  - Frequently used flags
    - `GFP_KERNEL`: Allocate kernel space memory
    - `GFP_USER`: Allocate user space memory
    - `GFP_ATOMIC`: Similar to `GFP_KERNEL`, but cannot sleep; used inside interrupts or other non-sleep routines
  - More on http://www.makelinux.net/ldd3/chp-8-sect-1.shtml
- `kfree` is similar to `free`

`task_struct`

- 598 lines!
  - You don’t need to read everything
- `children` and `sibling`: doubly linked lists

```
/* Real parent process: */
struct task_struct __rcu        *real_parent;

/* Recipient of SIGCHLD, wait4() reports: */
struct task_struct __rcu        *parent;

/*
 * Children/sibling form the list of natural children:
 */
struct list_head                children;
struct list_head                sibling;
struct task_struct              *group_leader;
```

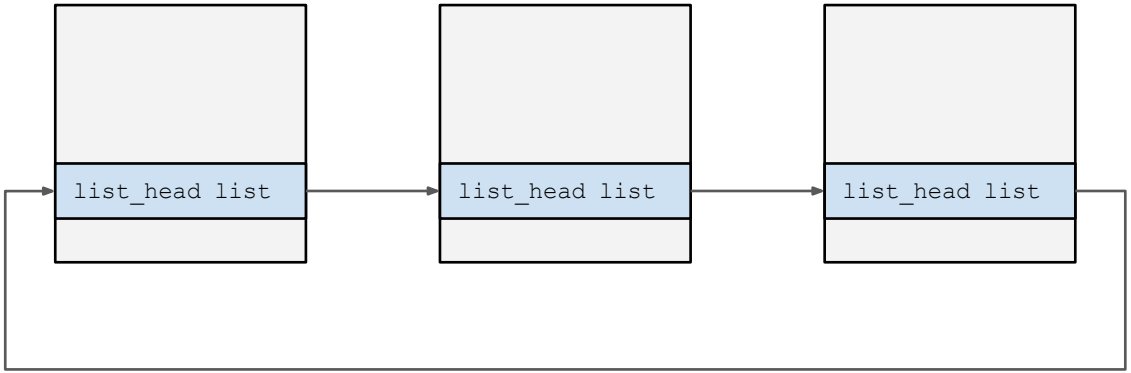
Doubly Linked List in Linux Kernel

- Linux kernel has a doubly linked list implementation for kernel programming
  - Extensively used across all Linux kernel code
- Defined in `include/linux/list.h`
  - Can only be used in kernel space!
- Unlike other commonly used linked lists, kernel list nodes are stored ***inside*** data

```
struct student {
    char* name;
    char* student_id;  str
    uct list_head list;
};
```

Doubly Linked List in Linux Kernel (cont'd)

```
struct list_head {
    struct list_head *next, *prev;
}
```



Doubly Linked List in Linux Kernel (cont'd)

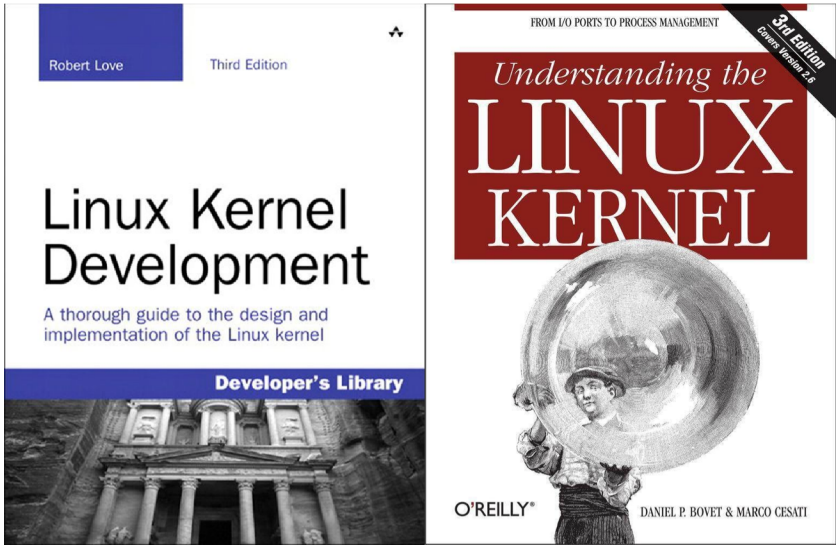
- Initializing a list node (must be declared beforehand)
  - `INIT_LIST_HEAD(&first_student->list)`
- Defining and initializing a list head pointer (declaration + `INIT_LIST_HEAD`)
  - `LIST_HEAD(student_list)`
- More about Linux kernel list (highly recommended)
  - http://www.makelinux.net/ldd3/chp-11-sect-5.shtml

Doubly Linked List in Linux Kernel (cont'd)

- Commonly used macros/functions
  - `list_add` / `list_add_tail`: adds a node to a list
  - `list_del` / `list_del_init`: deletes a node from a list
  - `list_for_each_entry`: iterates over a list
  - `list_for_each_entry_safe`: iterates over a list **when nodes can be deleted**
  - `list_entry` / `container_of`: returns the item given a list node

Useful References

- Linux cross reference (LXR)
  - https://elixir.bootlin.com/linux/v4.14.67/source
- Unreliable Guide To Hacking The Linux Kernel by Rusty Russel
  - http://kernelbook.sourceforge.net/kernel-hacking.pdf



Q & A

Back-up Slides