NOTE (etl 공지사항 '실습 관련 링크')

- **본 실습 자료: Development Environment and Debugging Tips-0**
  - https://github.com/hyojeonglee/osfall2019/tree/master/presentations
- **수령한 기기 번호 및 제본 명단 → 공유문서에 각자 업데이트**
- **실습실 컴퓨터 사용을 위한 컴퓨터공학부 통합계정 생성 및 구성원 신청 (id.snucse.org)**
  - 관련해서 계정 생성 혹은 구성원 신청을 한 적이 없는 경우
  - 기존 id.snucse.org 계정으로 컴퓨터에 로그인이 안되는 경우
- **라즈베리파이 키트 확인**
  - SD카드 꽂혀있는 USB 리더
  - 전원 케이블
  - 시리얼 통신 케이블
  - 보드

Linux Kernel Exploration

Development Environment & Debugging Tips

Sep 18, 2019

SNU Operating Systems

NOTE

- **교재/기기 수령 및 테스트**
- **과제 #0**
  - 기한: ~ 9/24 화 13시
  - 방법: 개별 메일 제출
- **과제 #1**
  - 기한: ~ 10/8 화 13시
  - 방법: 팀별 repository에 proj1 branch 생성 / 발표자료는 대표 한 명이 메일 제출
  - 당일 수업시간에 랜덤 2팀 발표 (5분 이내. 개발 내용, 트러블 슈팅, …)

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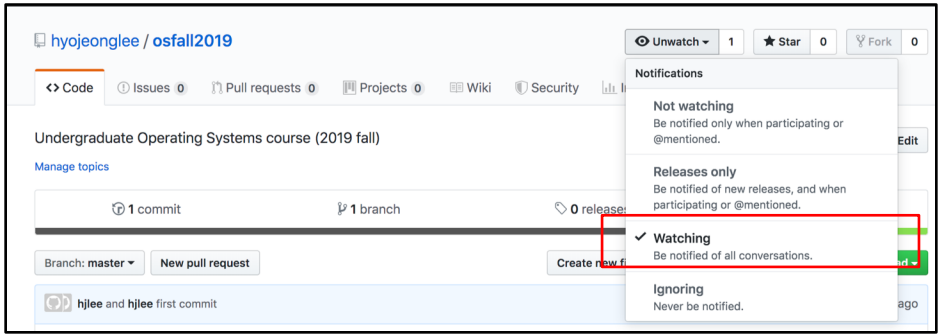
Github repository

[main] https://github.com/hyojeonglee/osfall2019

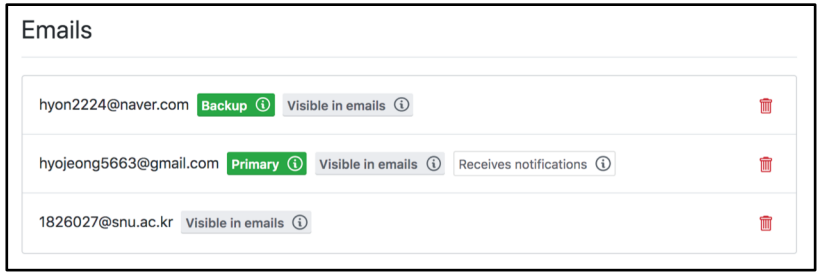
[per-team] https://github.com/hyojeonglee/osfall2019-teamX

Notification Settings

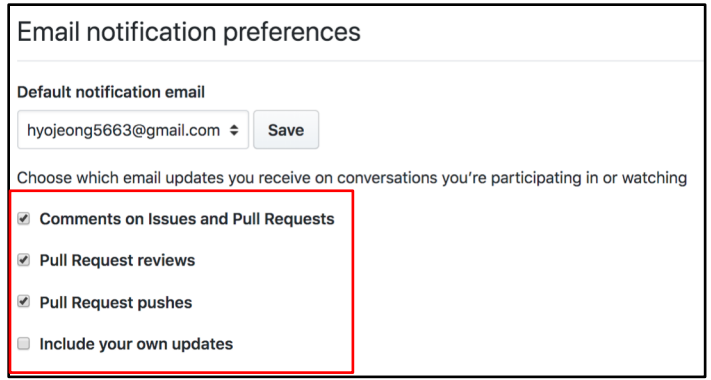
1



2



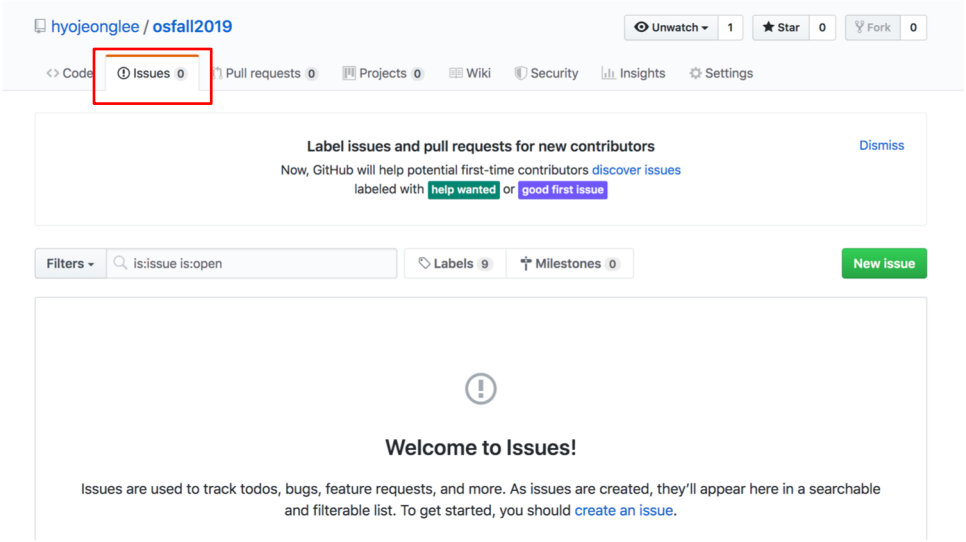
3



1. https://github.com/hyojeonglee/osfall2019
2. https://github.com/settings/emails
3. https://github.com/settings/notifications

Issue Board

- Please use the GitHub issue board for all questions that can be shared with other students
- Active participation highly encouraged: help out others!
- Do NOT close your issues so that other students can find them easily



#0 Compiling the Kernel & Flashing the Device

- **Information**
  - OS (kernel): Tizen 5.0
  - Device: Raspberry Pi 3 Model B

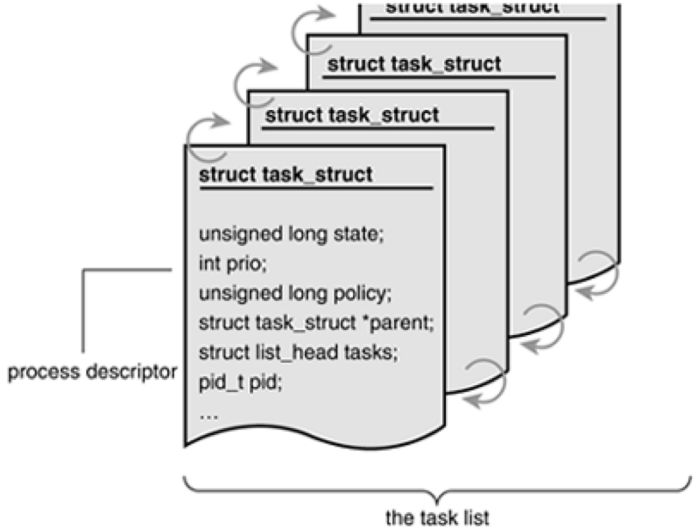
- **Environment**
  - **Native Ubuntu : Strongly recommended-!!!**
  - Native OS or Virtual Machines
    - Building process is typically much faster when using more than one core
  - List of possible hypervisors
    - VirtualBox
    - VMware (not tested)
    - Parallels (not tested)
    - …

#0 Compiling the Kernel & Flashing the Device

- Step (detail docs at https://github.com/hyojeonglee/osfall2019/blob/master/doc/Project0.md)
  1. Download the Tizen kernel source code.
  2. Build the kernel and make the booting image.
  3. Flash the SD card.

image http://140.120.7.21/LinuxRef/ProcMana/ProcessManaging.html

#1 Overview



- **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
- Reference
  - Detail docs at https://github.com/hyojeonglee/osfall2019/blob/master/doc/Project1.md
  - Project 1 Help Document at https://github.com/hyojeonglee/osfall2019/tree/master/presentations

Booting Test

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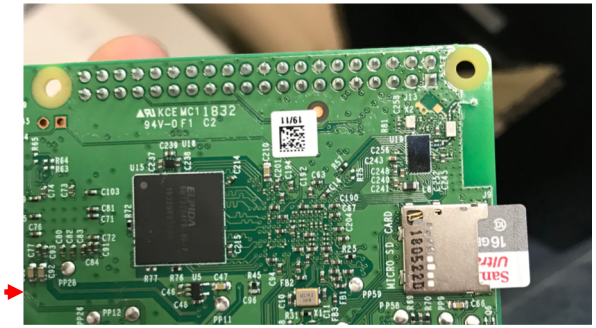
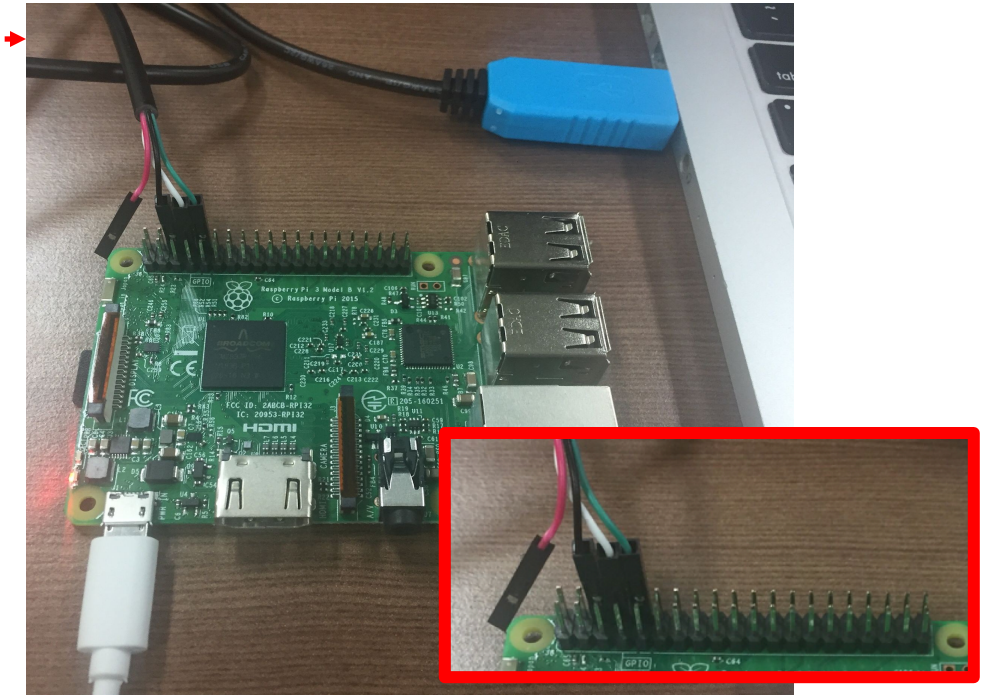
- Connect your Raspberry Pi 3 with your computer using USB-to-UART cable.
- Step
  1. Complete #0 and unmount the SD card from Ubuntu desktop.
  2. Insert the card to Tizen board. (with USB reader or directly)
  3. Connect the device to desktop.
  4. Communicate with `screen`.
  5. Log in to your device as `root`, with password `tizen`.

Step

1. Unmount the SD card from Ubuntu desktop.
2. Insert the card to Tizen board. (with USB reader or directly)
3. Connect the device to desktop.
4. Communicate with `screen`,
   - `sudo apt install screen`
   - `ls /dev` or `dmesg | grep tty | tail`
     - Find the device. (ex) `/dev/ttyUSB0`
   - `sudo screen /dev/ttyUSB0 115200`
5. Log in to your device as `root`, with password `tizen`.





Development Environment (1)

Preparation

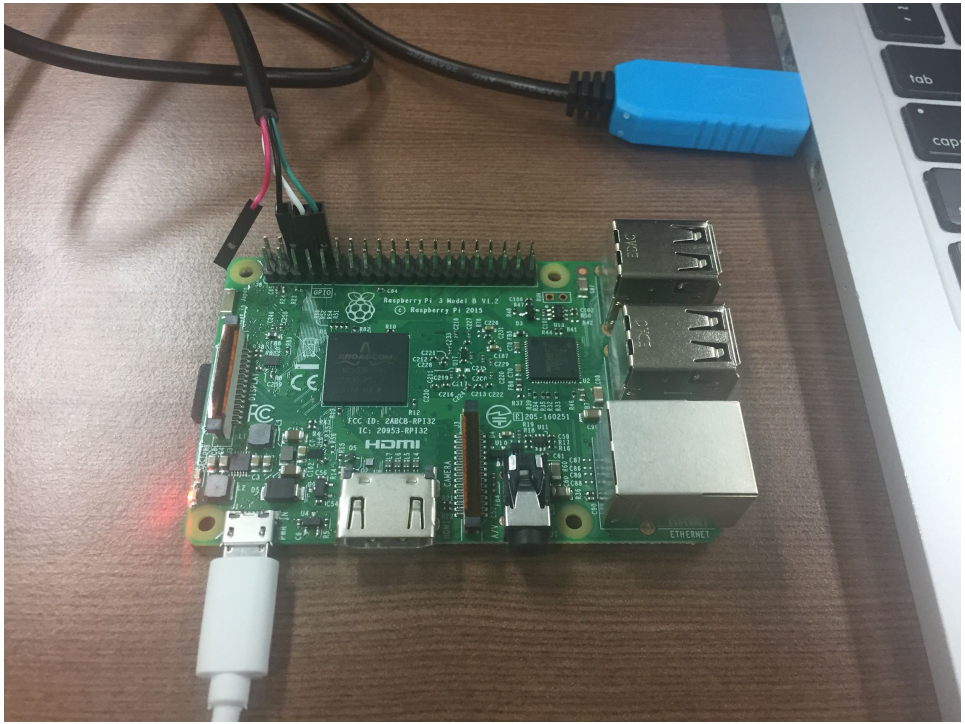
- Download the kernel source code
  - `git clone https://github.com/hyojeonglee/tizen-5.0-rpi3`
- `sudo apt install ctags cscope`
- `cd tizen-5.0-rpi3`
  - `make tags`
  - `make cscope`

System Settings

- **Native Ubuntu : Strongly recommended-!!!**
- Native OS or Virtual Machines
  - Building process is typically much faster when using more than one core
- List of possible hypervisors
  - VirtualBox
  - VMware (not tested)
  - Parallels (not tested)
  - …
- You don’t have to follow the mounting guide if your hypervisor can handle it automatically

(1) Serial Communication

- PuTTY
- `screen`
- `minicom`



(1) Serial Communication

- For doing project #1~4,
  you may test transferring files from your local Linux machine into Tizen.
- Follow this
  https://github.com/hyojeonglee/osfall2019/blob/master/doc/MoveFilesToTizen.md

(1) Serial Communication

- Trouble shooting: 시리얼 통신이 잘 안될 때 추가로 해볼 수 있는 작업들

(1) HDMI 케이블을 이용하여 모니터에 연결하는 방법 (다음 장부터 자세히 설명)

- 이를 통해서 부팅이 잘 되는지 먼저 확인해 볼 수 있습니다.
- 부팅이 다 되고 나면 다음 장 캡처 화면처럼 라즈베리 4개가 화면에 보이는 상태로 정지되는데 이렇게 되면 부팅에 성공한 것입니다 (초기 부팅에 시간이 조금 걸릴 수도 있습니다).
- 되지 않는다면 부팅 과정에서 문제가 있을 가능성이 크기 때문에 앞의 과정(#0)을 천천히 다시 해보시고,
- 부팅이 된다면 Raspberry Pi 3의 USB 포트에 키보드를 연결하시고 Ctrl + Alt + F2 등의 키를 이용하셔서 터미널로 화면을 전환하실 수 있고, 거기서 login 과정을 진행하실 수 있습니다.

(2) 위의 과정으로 부팅이 되는지 확인되었으면 시리얼 통신을 확인해 볼 차례인데,
현재 조교들이 파악하기로는 몇몇 시리얼 케이블들이 꽤나 불안정하다는 것을 확인하였습니다.
따라서 케이블을 연결한 뒤 putty 혹은 screen 과 같은 방법을 통해 시리얼 통신을 하실 때 잘 안되시면

1) 시리얼 케이블을 연결한 상태로 raspberry pi 3의 전원을 뽑았다 꽂아보시거나
2) USB를 재연결 해 보시는 방법을 시도해 보실 수 있습니다.

이후에도 계속 안된다면, 관련하여 조교들에게 연락주시면 UART-to-USB 케이블을 바꿔드리도록 하겠습니다.

(2) Working Without Serial Communication: HDMI

- Simply connect your Raspberry Pi to a monitor using an HDMI cable
- The booting process will stop here:

(2) Working Without Serial Communication: HDMI

- Press `Ctrl + Alt + F2` and log in
- Username: root
- Password: tizen

(ref) Configuring Internet Access

- The default wired network interface of your Raspberry Pi is `eth0`
  - `ifconfig eth0 IP netmask NETMASK`
  - `route add default gw GATEWAY`
- If you don’t want to connect your Raspberry Pi to the Internet, but want to set up a communication channel, assign your computer and your rpi private IP addresses and connect them directly with a (modern) LAN cable
- Example configuration (no need to set up the default gateway):
  - Raspberry Pi:
    - IP 192.168.76.1
    - Netmask 255.255.255.0
  - Computer:
    - IP 192.168.76.2
    - Netmask 255.255.255.0

(2) Working Without Serial Communication: `sdb`

- Download Tizen Studio for Ubuntu from https://developer.tizen.org/development/tizen-studio/download
  - It suffices to use the CLI installer
- Add `(tizen-studio-path)/tools` to your `PATH` environment variable
  - `export PATH=(tizen-studio-path)/tools:$PATH`
  - Add this to `.bashrc`, `/etc/profile` or such to have this handled automatically every time
- Enable `sdb` on your Raspberry Pi
  - `direct_set_debug.sh --sdb-set`
- Run `sdb` on your computer
  - `sdb connect (IP of your Raspberry Pi)`

(2) Working Without Serial Communication: `sdb` (cont)

- Switch to root
  - `sdb root on`
  - `sdb root off` to switch back to normal user
- Open a shell
  - `sdb shell`
- Send a file
  - `sdb push local_path remote_path`
- Receive a file
  - `sdb pull remote_path optional_local_path`
- More about `sdb`: https://developer.tizen.org/development/tizen-studio/web-tools/running-and-testing-your-app/sdb

Development Environment (2)

Text Editor

- vim + ctags + Cscope + ...
  - vim
  - ctags: generates index from source files
  - Cscope: find declarations, definitions, and usages easily
  - http://vimawesome.com/
- Atom
  - GUI Text Editor by GitHub
  - https://atom.io/

ctags and Cscope

- Dealing with the kernel code only with vim is *extremely* painful
- ctags and Cscope help users to navigate the code more easily
- ctags
  - For searching variables, function, macros, and struct definitions
- Cscope
  - For searching symbols, global definitions, functions called in a specific function, functions calling a specific function, strings, files, ...

Configuring ctags

- Install ctags
  - `sudo apt install ctags`
- Create tags
  - `cd` *`(your_linux_source_directory)`*
  - `make tags`
- Edit `~/.vimrc`
  - `set tags+=`*`(your_linux_source_directory)`*`/tags`

ctags wontfix

```
hskim@hskim-desktop:~/tizen-5.0-rpi3$ make tags
  GEN     tags
ctags: Warning: drivers/clocksource/arm_arch_timer.c:302: null expansion of name pattern "\1"
```

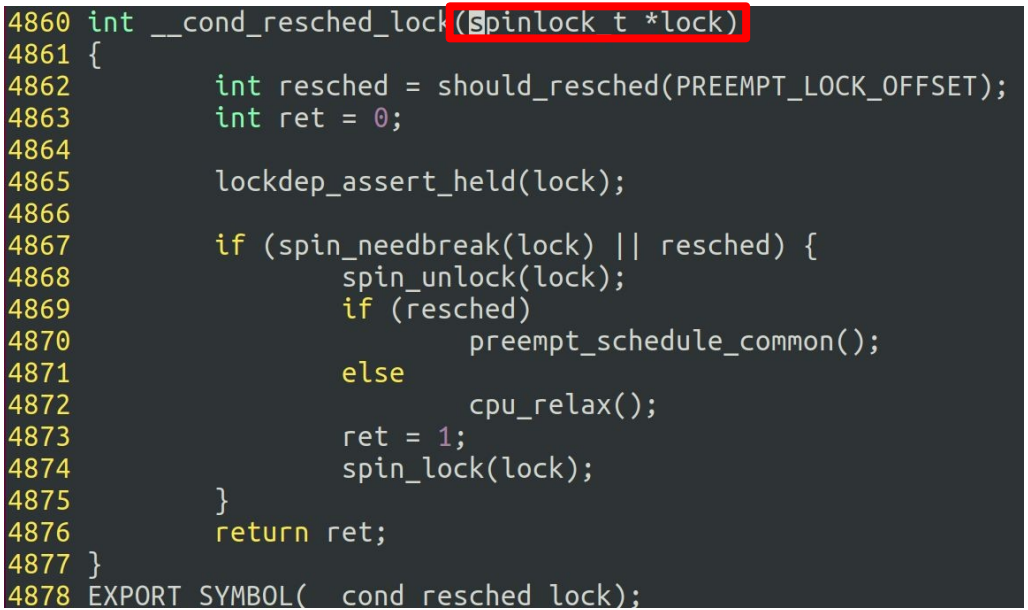
- ctags works fine even with this warning
- If this annoys you, there is a fix for this:

```
diff --git a/drivers/clocksource/arm_arch_timer.c b/drivers/clocksource/arm_arch_timer.c
index 4bed671..21669ec 100644
--- a/drivers/clocksource/arm_arch_timer.c
+++ b/drivers/clocksource/arm_arch_timer.c

@@ -299,8 +299,7 @@ static u64 notrace arm64_858921_read_cntvct_el0(void)
#endif
#ifdef CONFIG_ARM_ARCH_TIMER_OOL_WORKAROUND
-DEFINE_PER_CPU(const struct arch_timer_erratum_workaround *,
-       timer_unstable_counter_workaround);
+DEFINE_PER_CPU(const struct arch_timer_erratum_workaround *, timer_unstable_counter_workaround);
EXPORT_SYMBOL_GPL(timer_unstable_counter_workaround);
--
```

Example: finding `spinlock_t`

- `spinlock_t` is used in `kernel/sched/core.c`



```
4860 int __cond_resched_lock(spinlock_t *lock)
4861 {
4862         int resched = should_resched(PREEMPT_LOCK_OFFSET);
4863         int ret = 0;
4864
4865         lockdep_assert_held(lock);
4866
4867         if (spin_needbreak(lock) || resched) {
4868                 spin_unlock(lock);
4869                 if (resched)
4870                         preempt_schedule_common();
4871                 else
4872                         cpu_relax();
4873                 ret = 1;
4874                 spin_lock(lock);
4875         }
4876         return ret;
4877 }
4878 EXPORT_SYMBOL(__cond_resched_lock);
```

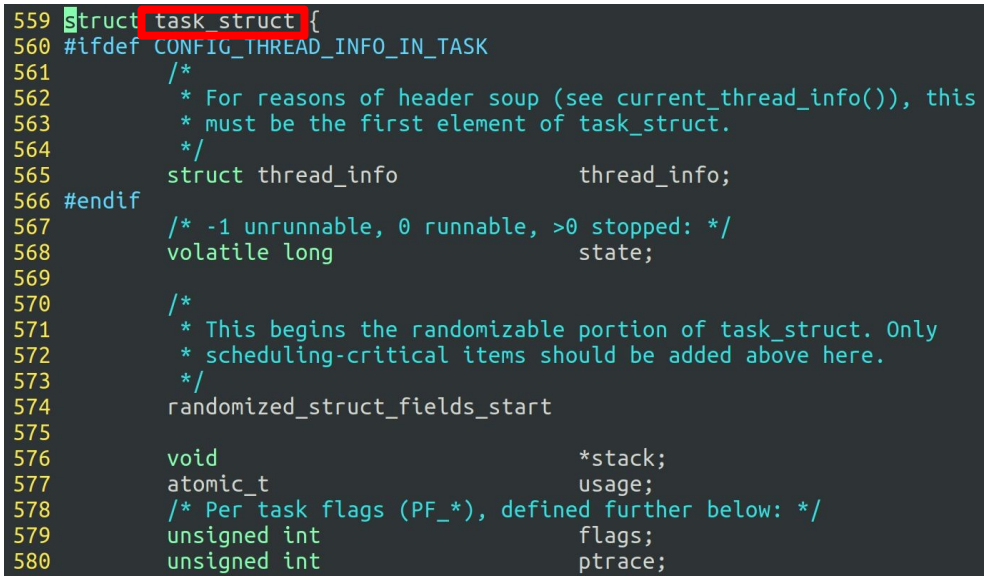
Example: finding `spinlock_t` (cont'd)

- Move the cursor to `spinlock_t`, and press `Ctrl + ]` to find its definition
  - vim automatically moves to `include/linux/spinlock_types.h`
- Press `Ctrl + T` to get back to `kernel/sched/core.c`

```
64 typedef struct spinlock {
65         union {
66                 struct raw_spinlock rlock;
67
68 #ifdef CONFIG_DEBUG_LOCK_ALLOC
69 # define LOCK_PADSIZE (offsetof(struct raw_spinlock, dep_map))
70                 struct {
71                         u8 __padding[LOCK_PADSIZE];
72                         struct lockdep_map dep_map;
73                 };
74 #endif
75         };
76 } spinlock_t;
```

Example: finding `struct task_struct`

- Type `:tj task_struct` in vim command line to jump the definition of `task_struct`
  - Use `tj` or `ts` command to search for a specific tag



Available ctags commands

Command	Action
Ctrl +]	Jump to the tag for the current cursor
:tj <tag>	Search for a particular tag and directly moves it if there is only one definition
:ts <tag>	Search for a particular tag, and search for the last tag if <tag> is omitted
:tn	Go to the next definition of the last tag
:tp	Go to the previous definition of the previous tag
Ctrl + T	Go back to the previous location

Configuring Cscope

- Install Cscope
  - `sudo apt install cscope`
- Generate Cscope database
  - `make cscope`
- Add the database path to `~/.vimrc`
  - `cs add` ***(your_linux_source_directory)***`/cscope.out`

Example: finding a symbol

- `:cs find s start_kernel`
  - Use `s` to find a symbol

```
Cscope tag: start_kernel
   #   line  filename / context / line
   1     11  include/linux/start_kernel.h <<GLOBAL>>
             extern asmlinkage void __init start_kernel(void );
   2     56  arch/x86/kernel/head32.c <<i386_start_kernel>>
             start_kernel();
   3    378  arch/x86/kernel/head64.c <<x86_64_start_reservations>>
             start_kernel();
   4    513  init/main.c <<start_kernel>>
             asmlinkage __visible void __init start_kernel(void )
Type number and <Enter> (empty cancels):
```

Example: finding where a function is used

- `:cs find c spin_lock`
  - Use `c` to find where a function is used

```
Cscope tag: spin_lock
   #   line  filename / context / line
   1    466  arch/x86/crypto/sha1-mb/sha1_mb.c <<sha_complete_job>>
             spin_lock(&cstate->work_lock);
   2    484  arch/x86/crypto/sha1-mb/sha1_mb.c <<sha_complete_job>>
             spin_lock(&cstate->work_lock);
   3    515  arch/x86/crypto/sha1-mb/sha1_mb.c <<sha1_mb_add_list>>
             spin_lock(&cstate->work_lock);
   4    464  arch/x86/crypto/sha256-mb/sha256_mb.c <<sha_complete_job>>
             spin_lock(&cstate->work_lock);
   5    482  arch/x86/crypto/sha256-mb/sha256_mb.c <<sha_complete_job>>
             spin_lock(&cstate->work_lock);
   6    513  arch/x86/crypto/sha256-mb/sha256_mb.c <<sha256_mb_add_list>>
             spin_lock(&cstate->work_lock);
   7    852  arch/x86/include/asm/uv/uv_bau.h <<atomic_inc_unless_ge>>
             spin_lock(lock);
```

Available `:cs find` options

Option	Action
s	Search for C symbol names
g	Search for global variables
d	Search for functions called by a specific function
c	Search for functions calling a specific function
t	Search for text strings
e	Search for strings using regex
f	Search for files by file name
i	Search for files including a specific file

Debugging Tips

Use `printk` for kernel messaging

- `printf` does not work inside the linux kernel
- `printk` syntax
  - `printk(log level "message", <arguments>);`
- You can use `printk` instead for feeding kernel messages
  - Declared in `include/linux/kernel.h`
  - Mostly compatible with ANSI C `printf` function
  - Can give priority by concatenating pre-defined string constants
    - e.g. `printk(KERN_INFO "this syscall is called!\n");`
    - `KERN_INFO` is what you want for most cases
- You can read kernel messages using `dmesg`
  - `dmesg -w`: wait for new messages

Use `printk` for kernel messaging

- You should be aware that...
  - The internal buffer size of `printk` is limited to 1kB
  - Too many kernel messages will make the system slow or even hang completely
  - Make sure to add a line separator at the end of each message
- Log level

```
#define KERN_EMERG "<0>" /* system is unusable*/
#define KERN_ALERT "<1>" /* action must be taken immediately*/
#define KERN_CRIT "<2>" /* critical conditions*/
#define KERN_ERR "<3>" /* error conditions*/
#define KERN_WARNING "<4>" /* warning conditions*/
#define KERN_NOTICE "<5>" /* normal but significant condition*/
#define KERN_INFO "<6>" /* informational*/
#define KERN_DEBUG "<7>" /* debug-level messages*/
```

- Use `KERN_ALERT` to print a message directly to the console
  - `printk(KERN_ALERT "hello world\n");`

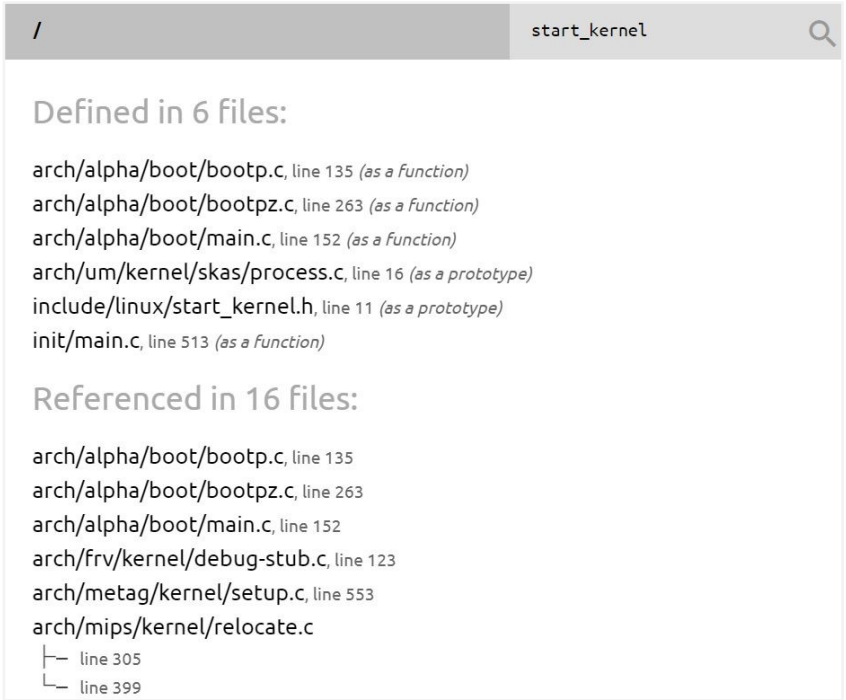
Find where the print function is called

- `printf("%s: %s (%d)\n", __FILE__, __FUNCTION__, __LINE__);`
- Can also be used in kernel; change `printf` to `printk`

```
 1 #include <stdio.h>
 2
 3 int main(void)
 4 {
 5         printf("%s: %s (%d)\n",
 6                __FILE__, __FUNCTION__, __LINE__);
 7         return 0;
 8 }
hskim@hskim-desktop:~$ ./test
test.c: main (6)
```

Linux Cross Reference (LXR)

- https://elixir.bootlin.com/linux/v4.14.67/source
- Find functions/symbols in Linux kernel



Q & A

Back-up Slides