



# Linux 总线驱动程序设计及内核调试分析技巧

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May 31, 2018



# 提纲

Linux I2C 总线驱动设计

Linux 内核调试环境搭建

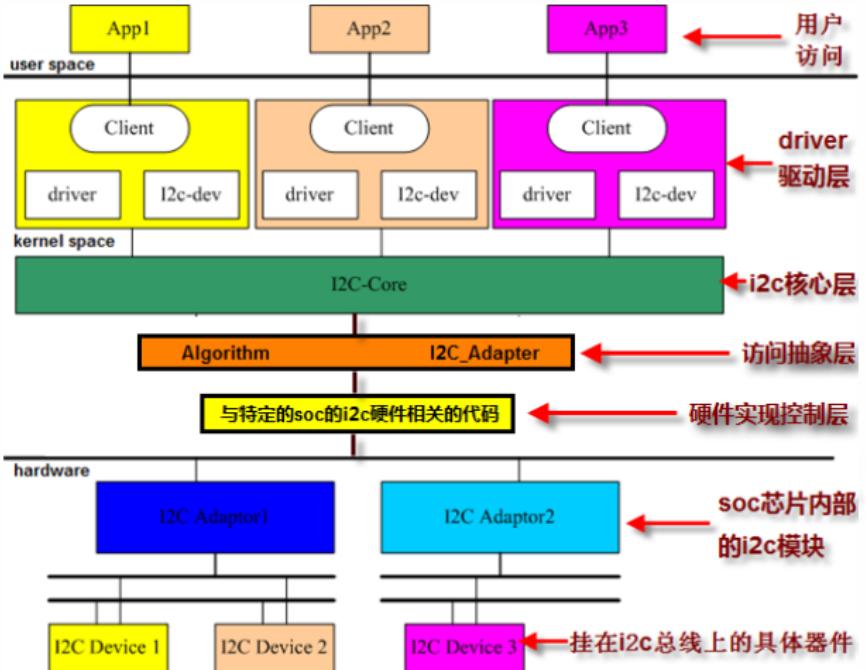
Linux 内核调试技巧

Linux 内核分析工具

演示部分



# I2C 体系结构





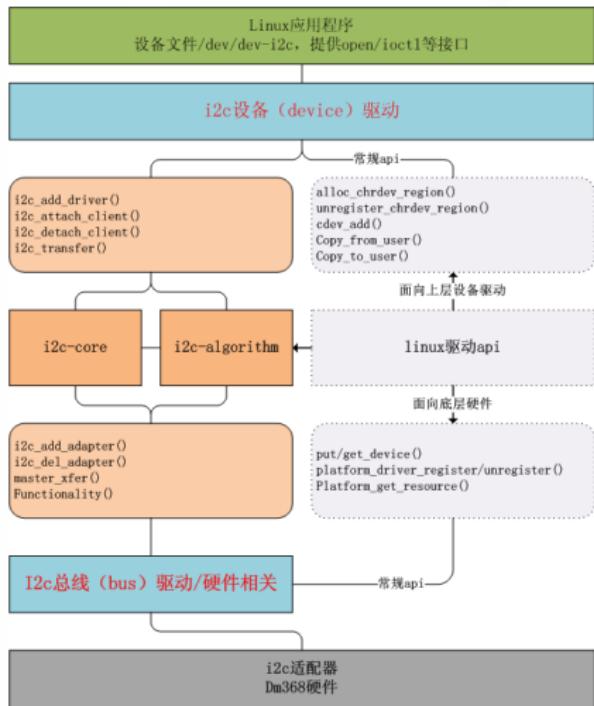
# Linux I2C 驱动源码分析

## 主要结构体

- i2c\_msg 表示 i2c 数据包包含的信息
- i2c\_driver 表示 i2c 设备驱动
- i2c\_client 表示 i2c 设备
- i2c\_adapter 表示 i2c 适配器信息
- i2c\_algorithm 用于控制 i2c 通信
- i2c\_core 用于控制 i2c 总线设备驱动的注册与注销



# Linux I2C 驱动设计方法





# Linux i2c 驱动设计总结

## 工程师在编写 i2c 驱动主要工作

- 提供 i2c 适配器硬件驱动，初始化适配器
- 提供 i2c 控制的 i2c\_algorithm
- 实现设备驱动中的 i2c\_driver 接口
- 实现 i2c 设备所对应类型的具体驱动



# 方案一：基于 Qemu+Eclipse+GDB

```
kernel/fork.c
1188     * flags). The actual kick-off is left to the caller.
1189     */
1190     static struct task_struct *copy_process(unsigned long clone_flags,
1191                                             unsigned long stack_start,
1192                                             unsigned long stack_size,
1193                                             int __user *child_tidptr,
1194                                             struct pid *pid,
1195                                             int trace)
1196     {
1197         int retval;
1198         struct task_struct *p;
1199
1200         if ((clone_flags & (CLONE_NEWNS|CLONE_FS)) == (CLONE_NEWNS|CLONE_FS))
1201             return ERR_PTR(-EINVAL);
1202
> 1203         if ((clone_flags & (CLONE_NEWUSER|CLONE_FS)) == (CLONE_NEWUSER|CLONE_FS))
1204             return ERR_PTR(-EINVAL);
1205
1206         /*
1207          * Thread groups must share signals as well, and detached threads
1208          * can only be started up within the thread group.
1209          */
1210         if ((clone_flags & CLONE_THREAD) && !(clone_flags & CLONE_SIGHAND))
1211             return ERR_PTR(-EINVAL);
1212
1213     /*
remote Thread 1 In: copy_process
(gdb) b do_fork
Breakpoint 1 at 0xc0043cbc: file kernel/fork.c, line 1638.
(gdb) c
Continuing.

Breakpoint 1, do_fork (clone_flags=8389376, stack_start=3232808628, stack_size=0, parent_tidptr=0x0 <__vectors_start>, child_tidptr=0x0 <__vectors_start>) at kernel/fork.c:1638
(gdb) s
(gdb) s
(gdb) s
copy_process (clone_flags=8389376, stack_start=3232808628, stack_size=0, child_tidptr=0x0 <__vectors_start>, pid=0x0 <__vectors_start>, trace=0) at kernel/fork.c:1200
(gdb) s
(gdb) ■
```



## 方案二：基于 Docker+Qemu

### 关键步骤

- 1. 安装 Docker
- 2. 下载 cloud-lab 源码
- 3. 在 cloud-lab 目录执行 tools/docker/choose 选择实验环境
- 4. 在当前目录下执行 tools/docker/run
- 5. 进入实验环境



## 方案二实验效果



# printk 大法

## 介绍

- 与 C 语言中 printf 类似，但比它高级

## 主要特性

- 提供 8 个打印等级，可根据需求打印相应信息
  - 提供 4 个打印级别，可根据需求打印相应信息
- 控制台日志，默认消息日志  
最低控制台日志，默认控制台日志



# oops 大法

## 介绍

- oops 是一个拟声词，类似“哎哟”
- 一般在 Linux 出现一些致命错误时会出现

## 主要特性

- 提供目前寄存器状态，堆栈内容，call trace
- 找到出错地址，反汇编分析原因



## 进程管理工具—strace



# 内存管理工具—vmstat

```
haoxin@ubuntu:~/test$ vmstat 1
procs -----memory----- swap-- io--- system-- cpu-----
r b swpd free buff cache si so bi bo in cs us sy id wa st
2 0 7680 1002908 802768 2609164 0 0 0 3 8 14 11 14 1 84 0 0
2 0 7680 995024 802768 2617020 0 0 0 0 0 2618 6188 55 3 42 0 0
2 0 7680 995064 802768 2617196 0 0 0 0 0 2784 6541 54 5 41 0 0
2 0 7680 995080 802768 2617196 0 0 0 0 40 2650 6075 55 2 43 1 0
2 0 7680 995312 802768 2616748 0 0 0 0 0 2603 6050 54 1 45 0 0
2 0 7680 992916 802768 2617548 0 0 0 0 0 3121 7422 57 1 42 0 0
2 0 7680 993152 802768 2617548 0 0 0 0 0 2714 6504 55 1 44 0 0
2 0 7680 992420 802768 2617548 0 0 0 0 0 2696 6581 57 1 42 0 0
2 0 7680 992420 802768 2617548 0 0 0 0 0 2675 6458 57 1 43 0 0
^C
haoxin@ubuntu:~/test$ vmstat -a
procs -----memory----- swap-- io--- system-- cpu-----
r b swpd free inact active si so bi bo in cs us sy id wa st
2 0 7680 995644 1438692 3596528 0 0 3 8 14 11 15 1 84 0 0
haoxin@ubuntu:~/test$ vmstat -s
6929780 K total memory
2522832 K used memory
3598932 K active memory
1438572 K inactive memory
992792 K free memory
802768 K buffer memory
2611388 K swap cache
7129084 K total swap
7680 K used swap
7121404 K free swap
43254540 non-nice user cpu ticks
21824 nice user cpu ticks
3623116 system cpu ticks
251699814 idle cpu ticks
321908 IO-wait cpu ticks
0 IRQ cpu ticks
130606 softirq cpu ticks
0 stolen cpu ticks
9497034 pages paged in
23843588 pages paged out
463 pages swapped in
2469 pages swapped out
557801447 interrupts
1234230796 CPU context switches
1526738596 boot time
505139 forks
haoxin@ubuntu:~/test$
```



# 设备管理工具—iostat

```
haoxin@ubuntu:~/test$ iostat -x /dev/sda
Linux 4.13.0-41-generic (ubuntu)           2018年05月28日   _x86_64_          (4 CPU)

avg-cpu:  %user   %nice %system %iowait  %steal   %idle
        14.63    0.01   1.26    0.11    0.00   83.99

Device:      rrqm/s   wrqm/s     r/s      w/s    rkB/s    wkB/s avgrrq-sz avgqu-sz  await r_await w_await svctm %util
  sda          0.06     1.81    0.58    0.50    12.08    31.71     80.89      0.05    42.77     7.18    84.31    4.14    0.45
```



# 文件管理工具—lsof

JS\x20Hel	2783	2801	haoxin	138u	unix 0x0000000000000000	0tB	3579220	type=SEQPACKET
JS\x20Hel	2783	2801	haoxin	139u	unix 0x0000000000000000	0tB	4253847	type=SEQPACKET
JS\x20Hel	2783	2801	haoxin	142u	unix 0x0000000000000000	0tB	4658447	type=STREAM
JS\x20Hel	2783	2801	haoxin	143r	FIFO 0x0000000000000000	0tB	4679291	pipe
JS\x20Hel	2783	2801	haoxin	144u	unix 0x0000000000000000	0tB	4671283	type=SEQPACKET
JS\x20Hel	2783	2801	haoxin	148u	unix 0x0000000000000000	0tB	4677578	type=STREAM
JS\x20Hel	2783	2801	haoxin	150u	unix 0x0000000000000000	0tB	4658449	type=STREAM
JS\x20Hel	2783	2801	haoxin	151u	unix 0x0000000000000000	0tB	4128149	type=SEQPACKET
JS\x20Hel	2783	2801	haoxin	153u	sock 0, 9	0tB	4677585	protocol: UNIX
JS\x20Hel	2783	2801	haoxin	154u	unix 0x0000000000000000	0tB	4677580	type=STREAM
JS\x20Hel	2783	2801	haoxin	155u	unix 0x0000000000000000	0tB	4659395	type=STREAM
JS\x20Hel	2783	2801	haoxin	157u	unix 0x0000000000000000	0tB	4633878	type=SEQPACKET
JS\x20Hel	2783	2801	haoxin	158u	REG 8,1	96	27266084	/home/haoxin/.cache/mozilla/firefox/qazwg871.default/cache2/entries/2254CA142
D0ZF18A6D238A3FDEA18E8804EB2A								
JS\x20Hel	2783	2801	haoxin	159u	unix 0x0000000000000000	0tB	4678281	type=STREAM
JS\x20Hel	2783	2801	haoxin	160u	unix 0x0000000000000000	0tB	4658455	type=SEQPACKET
JS\x20Hel	2783	2801	haoxin	161u	unix 0x0000000000000000	0tB	4658456	type=SEQPACKET
JS\x20Hel	2783	2801	haoxin	163u	unix 0x0000000000000000	0tB	4255647	type=SEQPACKET
JS\x20Hel	2783	2801	haoxin	166u	unix 0x0000000000000000	0tB	4678279	type=SEQPACKET
JS\x20Hel	2783	2801	haoxin	167u	unix 0x0000000000000000	0tB	4678280	type=SEQPACKET
JS\x20Hel	2783	2801	haoxin	168u	unix 0x0000000000000000	0tB	4659397	type=STREAM
JS\x20Hel	2783	2801	haoxin	170u	sock 0, 9	0tB	4660333	protocol: UNIX
JS\x20Hel	2783	2801	haoxin	172u	unix 0x0000000000000000	0tB	4678283	type=STREAM
JS\x20Hel	2783	2801	haoxin	173u	sock 0, 9	0tB	4680169	protocol: UNIX
JS\x20Hel	2783	2801	haoxin	174u	unix 0x0000000000000000	0tB	40719978	type=SEQPACKET
AudioIPC	2783	2802	haoxin	DIR 0,1	4096	27262978 /home/haoxin	2 /	
AudioIPC	2783	2802	haoxin	rtd	DIR 0,1	4096		
AudioIPC	2783	2802	haoxin	txt	REG 0,1	198896	14690313	/usr/lib/firefox/firefox
AudioIPC	2783	2802	haoxin	mem	REG 0,24	67188904	10	/dev/shm/pulse-snh-3779711079
AudioIPC	2783	2802	haoxin	mem	REG 0,24	67188904	45	/dev/shm/pulse-snh-1044324900
AudioIPC	2783	2802	haoxin	mem	REG 0,1	15860821		/usr/share/fonts/opentype/noto/NotoSansCJK-Regular.ttc
AudioIPC	2783	2802	haoxin	DEL	REG 0,5	4784145		/SYSVB00000000
AudioIPC	2783	2802	haoxin	DEL	REG 0,5	4751383		/SYSVB00000000
AudioIPC	2783	2802	haoxin	mem	REG 0,1	6234746	15860948	/usr/share/fonts/truetype/takao-gothic/TakaoPGothic.ttf
AudioIPC	2783	2802	haoxin	mem	REG 0,1	4343844	15860938	/usr/share/fonts/truetype/nanum/NanumGothic.ttf
AudioIPC	2783	2802	haoxin	mem	REG 0,1	138448	14688414	/usr/lib/x86_64-linux-gnu/libgbomp.so.1.0.0
AudioIPC	2783	2802	haoxin	mem	REG 0,1	525368	14688808	/usr/lib/x86_64-linux-gnu/liblbborgc-0.4.so.0.25.0
AudioIPC	2783	2802	haoxin	mem	REG 0,1	43936	14688786	/usr/lib/x86_64-linux-gnu/libnuma.so.1.0.0
AudioIPC	2783	2802	haoxin	mem	REG 0,1	195624	14682942	/usr/lib/x86_64-linux-gnu/libbsorx.so.0.1.1
AudioIPC	2783	2802	haoxin	mem	REG 0,1	110728	14680315	/usr/lib/x86_64-linux-gnu/liblbcystalhd.so.3.6
AudioIPC	2783	2802	haoxin	mem	REG 0,1	55568	14682998	/usr/lib/x86_64-linux-gnu/libbg3lane.so.0.0.0
AudioIPC	2783	2802	haoxin	mem	REG 0,1	289208	14682932	/usr/lib/x86_64-linux-gnu/libmp3lane.so.0.0.0
AudioIPC	2783	2802	haoxin	mem	REG 0,1	144240	14682935	/usr/lib/x86_64-linux-gnu/libopenjpeg.so.1.5.2
AudioIPC	2783	2802	haoxin	mem	REG 0,1	10558256	14682951	/usr/lib/x86_64-linux-gnu/libz65.so.79
AudioIPC	2783	2802	haoxin	mem	REG 0,1	12047288	14682978	/usr/lib/x86_64-linux-gnu/libavcodec-ffmpeg.so.56.60.100
AudioIPC	2783	2802	haoxin	DEL	REG 0,24	18		/dev/shm/org.chromium.2RnQqF



# 网络管理工具—netstat

```
haoxin@ubuntu:~/test$ netstat -at
Active Internet connections (servers and established)
Proto Recv-Q Send-Q Local Address           Foreign Address     State
tcp      0      0 *:5938                  *:*                  LISTEN
tcp      0      0 localhost:5939             *:*                  LISTEN
tcp      0      0 ubuntu16.04:domain        *:*                  LISTEN
tcp      0      0 localhost:ipp              *:*                  LISTEN
tcp      0      0 localhost:47060             localhost:6080    ESTABLISHED
tcp      0      0 192.168.1.102:54884       192.168.1.103:ssh ESTABLISHED
tcp      0      0 localhost:48950             localhost:5939    ESTABLISHED
tcp      0      0 192.168.0.8:57134         121.195.187.54:http TIME_WAIT
tcp      0      0 172.17.0.1:42718          172.17.0.2:6080    ESTABLISHED
tcp      0      0 192.168.1.102:54858       192.168.1.103:ssh ESTABLISHED
tcp      0      0 192.168.0.8:48982         de-fra-ibm-r003.te:5938 ESTABLISHED
tcp      0      151 localhost:5939            localhost:39566   ESTABLISHED
tcp      0      0 192.168.1.102:54860       192.168.1.103:ssh ESTABLISHED
tcp      0      0 192.168.0.8:34384         server-54-230-190:https TIME_WAIT
tcp      0      0 localhost:5939             localhost:48950    ESTABLISHED
tcp      0      0 192.168.1.102:55498       192.168.1.103:ssh ESTABLISHED
tcp      0      0 192.168.1.102:54888       192.168.1.103:ssh ESTABLISHED
tcp      0      0 192.168.0.8:44408         server23809.teamvi:5938 ESTABLISHED
tcp      0      0 192.168.0.8:57136         121.195.187.54:http TIME_WAIT
tcp      0      0 localhost:39566            localhost:5939    ESTABLISHED
tcp      0      0 192.168.1.102:54886       192.168.1.103:ssh ESTABLISHED
tcp6     0      0 [::]:2222                [::]:*                LISTEN
tcp6     0      0 [::]:4433                [::]:*                LISTEN
tcp6     0      0 [::]:5938                [::]:*                LISTEN
tcp6     0      0 ip6-localhost:ipp        [::]:*                LISTEN
tcp6     0      0 [::]:6080                [::]:*                LISTEN
tcp6     0      0 localhost:6080            localhost:47060    ESTABLISHED
haoxin@ubuntu:~/test$ netstat -au
Active Internet connections (servers and established)
Proto Recv-Q Send-Q Local Address           Foreign Address     State
udp      0      0 *:mdns                 *:*
udp      0      0 *:46445                *:*
udp      0      0 *:39303                *:*
udp      0      0 *:60409                *:*
udp      0      0 ubuntu16.04:domain        *:*
udp      0      0 *:bootpc               *:*
udp      0      0 *:bootpc               *:*
udp      0      0 *:36951                *:*
udp      0      0 *:ipp                  *:*
udp6     0      0 [::]:ndns              [::]:*
udp6     0      0 [::]:37994              [::]:*
```



# 综合管理工具—htop

1	2	3	4	Mem	Swap	Tasks: 185, 504 thr; 4 running	Load average: 2.54 2.39 2.36	Uptime: 8 days, 19:08:44	
PID	USER	PRI	NI	VIRT	RES	SHR	CPU%	TIME	Command
24883	root	20	0	629M	67116	14960	5.100	1.0	19:06:31 gnu-system-xarchd -M virt -m 128M -net nic,model=virtio -net tap -device virtio-net-device,netdev=net0,mac=5
24999	root	20	0	629M	67264	15104	5.180	1.0	18:58:46 gnu-system-xarchd -M virt -m 128M -net nic,model=virtio -net tap -device virtio-net-device,netdev=net0,mac=5
23049	root	20	0	629M	67264	15104	5.180	1.0	18:58:46 gnu-system-xarchd -M virt -m 128M -net nic,model=virtio -net tap -device virtio-net-device,netdev=net0,mac=5
23065	root	20	0	629M	67264	15104	5.993	1.0	18:58:46 gnu-system-xarchd -M virt -m 128M -net nic,model=virtio -net tap -device virtio-net-device,netdev=net0,mac=5
3659	haoxin	39	19	199M	144M	103M	98.8	2.1	0:01.44 /usr/bin/python3 /usr/lib/update-notifier/apt-check
2087	haoxin	20	0	128M	408M	18412	5.14.4	6.0	/opt/teamviewer/tv_bin/TeamViewer/Desktop
1905	root	20	0	1376M	32600	10356	5.7.2	0.5	48:33.07 /opt/teamviewer/tv_bin/teamviewer -d
2102	haoxin	20	0	128M	408M	18412	5.5.2	6.0	/opt/teamviewer/tv_bin/TeamViewer/Desktop
1439	root	20	0	123M	23532	820M	4.4.6	0.3	9:58:49 /sbin/plymouthd --mode=boot -p /sbin/file/run/plumhow/pid --attach-to-session
2092	haoxin	20	0	128M	408M	18412	5.3.9	5.0	3h54:49 /usr/bin/xorg /core :0 -seat seat0 -auth /var/run/lightdm/root/:0 -nolisten tcp vt7 -novtswitch
4427	haoxin	20	0	1314M	180M	100M	5.3.3	2.7	6h15:32 compiz
2094	haoxin	20	0	128M	408M	18412	5.2.6	6.0	0:14.02 /opt/teamviewer/tv_bin/TeamViewer/Desktop
2091	haoxin	20	0	128M	408M	18412	5.2.6	6.0	0:14.44 /opt/teamviewer/tv_bin/TeamViewer/Desktop
3658	haoxin	20	0	3401M	4720	3132	2.0	0.1	0:00.62 httpd
1924	root	20	0	1376M	32600	10356	5.2.0	0.5	9:53:14 /opt/teamviewer/tv_bin/teamviewer -d
1923	root	20	0	1376M	32600	10356	5.2.0	0.5	9:52:06 /opt/teamviewer/tv_bin/teamviewer -d
1925	root	20	0	1376M	32600	10356	5.1.3	0.5	9:49:57 /opt/teamviewer/tv_bin/teamviewer -d
2092	haoxin	20	0	128M	408M	18412	5.1.3	6.0	0:14.76 /opt/teamviewer/tv_bin/TeamViewer/Desktop
1922	root	20	0	1376M	32600	10356	5.1.3	0.5	9:47:35 /opt/teamviewer/tv_bin/teamviewer -d
3866	haoxin	20	0	723M	77664	39576	5.1.1	2h54:22	/usr/lib/gnome-terminal/gnome-terminal-server
27217	root	20	0	567M	12816	934M	5.0.0	0.2	0:58.33 containerd -l unix:///var/run/docker/libcontainerd/docker-containerd.sock --metrics-interval=0 --start-timeout
28800	haoxin	20	0	3586M	283M	1069M	5.0.0	3.9	13:37:52 /opt/teamviewer/tv_bin/TeamViewer
1548	root	20	0	128M	408M	100M	5.0.0	0.16	0:00.16 /usr/bin/xorg /core :0 -seat seat0 -auth /var/run/lightdm/root/:0 -nolisten tcp vt7 -novtswitch
2017	haoxin	20	0	1847M	193M	122M	5.0.0	2.9	3h54:43 /usr/bin/firefox/firefox -contentproc -childID 2 -isForBrowser -boolPrefs 299:0 -stringPrefs 285:36;dd1bb86b-
27199	root	20	0	586M	45332	32732	5.0.0	0.7	1:16:50 /usr/bin/dockerd -H fd://
2938	haoxin	20	0	669M	6652	35608	5.0.0	0.9	0:21:20 /usr/bin/x86_64-linux-gnu/hud/hud-service
28668	root	20	0	104M	29564	16124	5.0.0	0.4	0:28.38 /usr/bin/Xfb -1 -screen 0 1366x768x16
4024	haoxin	20	0	44916	4808	4152	5.0.0	0.1	3:38.59 ssh tuhaoxin@192.168.1.103
3868	haoxin	20	0	723M	77664	39576	5.0.0	1.1	7:42:50 /usr/lib/gnome-terminal/gnome-terminal-server
1927	root	20	0	1376M	32600	10356	5.0.0	0.5	49:24 /opt/teamviewer/tv_bin/teamviewer -d
20671	root	20	0	9270M	15992	9464	5.0.0	0.2	0:30.07 x11vnc -display :1 -xkb -shared -forever -usepw
28374	root	20	0	66592	17168	6748	5.0.0	0.2	0:14.51 /usr/bin/python /usr/bin/supervisor -n c /etc/supervisor/supervisord.conf
3035	haoxin	20	0	488M	32944	26282	5.0.0	0.5	0:15.17 /usr/bin/x86_64-linux-gnu/notify-osd
24922	haoxin	20	0	1951M	168M	124M	5.0.0	2.5	1:51.49 /usr/bin/firefox/firefox -contentproc -childID 10 -isForBrowser -boolPrefs 299:0 -stringPrefs 285:36;dd1bb86b
28805	root	20	0	567M	12816	934M	5.0.0	0.2	0:06.44 containerd -l unix:///var/run/docker/libcontainerd/docker-containerd.sock --metrics-interval=0 --start-timeout
27235	root	20	0	586M	45332	32732	5.0.0	0.7	0:08.58 /usr/bin/dockerd -H fd://
2924	haoxin	20	0	43032	3492	2952	5.0.0	0.3	6:18:46 /usr/bin/dns-dsmon -fork -print-pid 5 --print-address 7 --config-file /usr/share/fcitx/dbus/daemon.conf
20663	root	20	0	66592	17168	6844	5.0.0	0.2	0:14.96 /usr/bin/python /usr/bin/supervisor -n c /etc/supervisor/supervisord.conf
4583	haoxin	20	0	44916	4600	3940	5.0.0	0.1	3:31.44 ssh tuhaoxin@192.168.1.103



# Linux 内核调试环境搭建及调试技巧

- 1. Linux 内核调试环境搭建

Docker + Qemu

- 2. Linux 内核调试技巧展示

如何加载内核模块到 Linux 系统中 ?

用户态和虚拟态如何传输文件 ?

如何使用 oops 分析内核运行时发生的错误 ?



感谢各位老师同学聆听！

软件学院,  
大连理工大学, 大连, 中国