YVR18-308: Kernel Bugs and Regressions Debugging Best Practices

Rafael David Tinoco
Kernel Validation Team
Topics to be covered

● Environment (15 min)
  ○ Work directory “idea”
  ○ X-compiling & containers
  ○ Package generation and repository
  ○ Bug reproduction environment
    ■ KVM/QEMU guests
    ■ Boards
    ■ Packaged Test Suites

● Eclipse CDT as IDE (15 min)
  ○ Using Eclipse as IDE
  ○ Debugging with Eclipse
  ○ Eclipse as IDE for the Linux Kernel

● Debugging: Real cases (45 min)
  ○ Interpreting Issues
    ■ Foundations
    ■ Dead locks / Race conditions
    ■ Usual issues w/ Kernel bugs
    ■ Stack traces
  ○ BUG #3765
    ■ kdump generation
      ● QEMU
      ● Board
  ○ BUG #3303
    ■ Using crash
  ○ BUG #3903
    ■ SystemTap usage

● Collab to Test Suites (15 min)
  ○ LTP & Kselftests: Lessons Learned
Who am I?
Environment - 15 min

Yes, I know, you have a better tool or script.
Who doesn’t ?!
Work directory “idea”

- Started at previous company: sustaining engineering debugging needs.
- Provided an easy way to back port the same fix into multiple envs.
- Bug notes could be easily shared when being put @ Launchpad.
- Case notes: Debugging thoughts for fast context switching.

https://github.com/rafaeldtinoco/work

My main work directory

This is my main work directory. It means that I spend basically all my day inside this directory, digging for upstream patches, investigating functional tests regressions, developing new tests, backporting fixes, reading source codes, etc.
X-compiling and containers

- **Containers**
  - QEMU-user-static for arm
    - sysctl -a fs.bifmt_misc | grep qemu
  - LXC backed by **debootstrap**
  - lxc-create
    - `--t` download --name mytemplate --
    - `--d` debian --r sid
    - `--a (i386|amd64|armhf|arm64)`
  - isc-dhcp-server AND bind9 (dynamic dns)
  - shared mounts between host and LXC

- **X-compiling w/ QEMU-user-static**
  - When gcc/libc cross comp. isn't enough
  - Package dependencies are fully met
  - **chroots + qemu-user-static is enough**
    - **chroots:**
      - aren't good for services
      - aren't good for "dist-upgrades"
      - if mounting VM ext4 loop dev
    - won't give you diff namespaces
  - LXC has some issues, but... it is **usable**
    - armhf or arm64 container on x86
  - QEMU static is **faster** than QEMU VM
Package generation and repository

Debian Packaging Tutorial

Debian Packaging Policy

Debian Policy Manual
Release 4.2.0.1

The Debian Policy Mailing List
Package generation and repository

- Debian package workflow:
  - Basic idea:
    - $ apt-get install build-essential
    - $ apt-get install devscripts
    - $ apt-get install ubuntu-dev-tools
    - $ apt-get build-dep <package>
  - And then...
    - $ cd <package_dir>
    - $ fakeroot debian/rules binary
    - or
    - $ debuild -b -us -uc

Credits for Slide Content: Lucas Nussbaum (packaging-tutorial@packages.debian.org)
BUG reproduction environment:

Boards: Pkg generation and repo

Index of /latest/all/kseltest/

<table>
<thead>
<tr>
<th>Name</th>
<th>Last Modified:</th>
<th>Size</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
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<td>2019-09-29 04:21:32</td>
<td>0 bytes</td>
<td>Directory</td>
</tr>
<tr>
<td>kseltest-20190929-042132-0.df245e9e1be5b-2dd</td>
<td>2019-09-29 04:21:32</td>
<td>148 bytes</td>
<td>application/vnd.debian.binary-package</td>
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<tr>
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<td>148 bytes</td>
<td>application/vnd.debian.binary-package</td>
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<td>148 bytes</td>
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<td>148 bytes</td>
<td>application/vnd.debian.binary-package</td>
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<td>148 bytes</td>
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<td>2019-09-29 04:21:32</td>
<td>148 bytes</td>
<td>application/vnd.debian.binary-package</td>
</tr>
</tbody>
</table>

Did you find anything broken? Well me: rafael.timee@linaro.org!

How are the packages built?

3 types of packages (deb, rpm and tsd) are being generated in 4 different archs: amd64, armhf, arm64 and armv7. All builds are done using debian helper tools in a fully updated SSB environment.

Note:

These packages have no intention to replace 65 packages, they are being generated to satisfy regression tests needs.

Layout:

- 1356: pkg.name/package-gistrib-1356.deb
- $pkg: pkg.name/package-gistrib-$pkg.deb
- $arch: pkg.name/package-gistrib-$arch.deb
- all: pkg.name/package-gistrib-*.deb

Latest:

- arch/pkg.name/package-gistrib-arch.deb
- latest-builds in all archs, by $pkg
BUG reproduction environment:
KVM & QEMU guests

```bash
inaddy@workstation:~$ virtclone.sh workkvmamd64 bug000test01
  running:
    - qcow2hostname.sh bug000test01
    bug000test01
    qcow2.hostname bug000test01
    sending home files to lxc3438 (bug000test01)

inaddy@workstation:~$ virtclone.sh workkvmamd64 bug000test02
  running:
    - qcow2hostname.sh bug000test02
    bug000test02
    qcow2.hostname bug000test02
    sending home files to lxc3855 (bug000test02)
```

```bash
inaddy@workstation:~$ virsh start --console bug000test01
Domain bug000test01 started
Connected to domain bug000test01
Escape character is \.
```

```bash
inaddy@workstation:~$ virsh start bug000test02
Domain bug000test02 started
```

```bash
inaddy@workstation:~$ ssh bug000test02
(k)inaddy@bug000test02:~$ uname -a
Linux bug000test02 4.17.0-3-amd64 #1 SMP Debian 4.17.17-1
(k)inaddy@bug000test02:~$`
```
BUG reproduction environment:
KVM & QEMU guests

```
inaddy@workstation:~$ qcowshell.sh list
bug0000test01
bug0000test02
bug3771kern014
bug3771kern016
bug3771kern017
bug3771kern04
bug3771kern09
bug3771kernmain
bug3771kernnext
workkern04
workkern06
workkern10

inaddy@workstation:~$ qcowshell.sh bug0000test02
system 2.39 running in system mode. (+PAM +AUDIT +SELINUX +IN którzy PROGRAM +X86 +GNU +UTS +ACL +K+Z +LC4 +SECCOMP +BLT +ELF +UTLS +KMOD -TONG -OINC -PCRE2 defou
Detected virtualization box.
Detected architecture x86.

Welcome to Debian GNU/Linux buster/sid!

Set hostname to bug0000test02.

[ OK ] Reconfigure Target Swap.
system.slice: Failed to set devices.list: Operation not permitted
system.slice: Failed to set devices.list: Operation not permitted
[ OK ] Created slice system-getty.slice.
[ OK ] Started Dispatch Password Requests to System Directory Watch.
[ OK ] Listening on Journal Socket.
[ OK ] Created slice user and session slice.
[ OK ] Reconfigured target to mount file systems.
[ OK ] Listening on Journal Socket (/dev/log).
[ OK ] Started Update UTHP about System Runlevel Changes.
[ OK ] Started Update UTHP about System Runlevel Changes.
Debian GNU/Linux buster/sid bug0000test02 console

bug0000test02 login: root
Password: [root@bug0000test02 ~]
```

```
BUG reproduction environment: Boards

- Board Environment
  - workstation connected to:
    - hikey 960
    - dragonboard 410c
    - beagleboard x15
  
  ```
  # boards
  alias hikey="ssh hikey"
  alias hikeycons="sudo screen /dev/ttyUSB0 115200"
  alias beagle="ssh beagle"
  alias beaglecons="sudo screen /dev/ttyUSB0 115200"
  alias dragon="ssh dragon"
  alias dragoncons="sudo screen /dev/ttyUSB2 115200"
  ```

Cork is your friend
BUG reproduction environment:

Boards

- SD cards w/ Debian installed
- Upgrading kernel w/ .deb pkgs
- Upgrading might be challenging:
  - Different recovery mechanisms
  - Different boot loaders
  - Removing SD cards manually
- QEMU/KVM, libvirt & LXC ready
- .deb test suites easily installed
- Straightforward reproduction based on LKFT output most of the times.
Eclipse CDT as IDE - 15 min

I know... I know...
But, for real, give it a try once or twice, you might not regret.
It happened to me...
Using Eclipse as IDE
Using Eclipse as IDE
Using Eclipse as IDE
Using Eclipse as IDE
Debugging with Eclipse
Eclipse as IDE for the Linux Kernel
Debugging: Real Cases - 45 min

Every Bug is a learning opportunity
For Real, Every Bug is a learning opportunity
Trust me, Every Bug is a HUGE learning opportunity
Interpreting Issues: Foundations

- Existing task calls `fork()` and creates a new process.
- Scheduler dispatches task to run: `schedule()` calls `context_switch()`.
- Task forks.
- Task is preempted by higher priority task.
- Event occurs and task is woken up and placed back on the run queue.
- Task sleeps on wait queue for a specific event.
- Task exits via `do_exit`.
- Task is terminated.

Credits for Slide Content: Linux Kernel Development (Robert Love; Third Edition)
Interpreting Issues: Foundations

```
task_struct
  state
  flags
  stack
  group_leader
  parent
  real_parent
  thread_node
  children
  sibling
  tty
  fs
  comm
  mm
```
```
task_struct
  state
  group_leader
  thread_node
  mm
```
```
task_struct
  state
  parent
  real_parent
  sibling
  mm
```
```
task_struct
  state
  parent
  real_parent
  sibling
  mm
```
Interpreting Issues: Foundations

Credits for Slide Content: Linux Kernel Development (Robert Love; Third Edition)
Interpreting Issues: Foundations

`execve()`

`ld.so`

`mmap()`

`brk()`

Credits for Slide Content: https://myaut.github.io/dtrace-stap-book/ (Creative Commons Attribution-Noncommercial-ShareAlike 3.0 License)
Interpreting Issues: Foundations
Interpreting Issues: Foundations

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Interpreting Issues: Foundations

Credits for Slide Content: https://myaut.github.io/dtrace-stap-book/ (Creative Commons Attribution-Noncommercial-ShareAlike 3.0 License)
Interpreting Issues: Foundations

open("file1", O_RDWR) = 3
lookup("file1")
write(3, "OK")
close(3)

task_struct* current

write(3, "OK")
close(3)

dd

fsflush, flush-8:0
generic_make_request()
bdev_strategy()
interrupt

Credits for Slide Content: https://myaut.github.io/dtrace-stap-book/ (Creative Commons Attribution-Noncommercial-ShareAlike 3.0 License)
Interpreting Issues: Foundations

- bind()
- recvmsg()
- listen()
- accept()
- shutdown()
- connect()
- sendmsg()

Socket

TCP receive

Connection:
- state
- peer addresses

TCP transmit

IP receive

IP transmit

Receive ring buffer

DMA

Network Card

DMA

Send ring buffer

Credits for Slide Content: https://myaut.github.io/dtrace-stap-book/ (Creative Commons Attribution-Noncommercial-ShareAlike 3.0 License)
Interpreting Issues: Foundations

socket
- state
- type
- file
- sk
- ops

sock
- sk_socket
  __sk_common
  skc_dport
  skc_num
  skc_daddr
  skc_rcv_saddr
  skc_state
  sk_stamp
  sk_peerid

sk_buff
- next
- prev
- tstamp
- sk
- dev
- len
- data

net_device
- name
- ifindex
- iflink
- stats

Credits for Slide Content: https://myaut.github.io/dtrace-stap-book/ (Creative Commons Attribution-Noncommercial-ShareAlike 3.0 License)
Interpreting Issues: Foundations

struct task_struct {
    volatile long state;
    void *stack;
    unsigned int flags;
    int prio, static_prio normal_prio;
    const struct sched_class *sched_class;
    struct sched_entity se;
} ;
...

struct sched_entity {
    struct load_weight load;
    struct rb_node run_node;
    struct list_head group_node;
} ;
...

struct rb_node {
    unsigned long rb_parent_color;
    struct rb_node *rb_right;
    struct rb_node *rb_left;
} ;
Interpreting Issues:
Stack traces
Interpreting Issues:
Deadlocks / Race conditions
Interpreting Issues:
Usual issues with Kernel bugs
Debugging: Real Cases

BUG #3765

when running zram tests on arm32 qemu, while creating an ext4 filesystem on /dev/zram0, the following crash happens, causing the rest of the lava job to time out.

This is currently happening every time on mainline and 4.16.

running zram tests

------------------------
create '1' zram device(s)
[ 1504.038884] zram: Added device: zram0
zram load module successful
set max_comp_streams to zram device(s)
/sys/block/zram0/max_comp_streams = '2' (1/1)
zmax max streams: OK
test that we can set compression algorithm
supported alg(s): [lz4]
/sys/block/zram0/comp_algorithm = 'lz4' (1/1)
zram set compression algorithm: OK
set disk size to zram device(s)
[ 1505.781865] zram0: detected capacity change from 0 to 2097152
/sys/block/zram0/disksize = '2097152' (1/1)
zram set disksize: OK
set memory limit to zram device(s)
/sys/block/zram0/mem_limit = '2M' (1/1)
zram set memory limit: OK
make ext4 filesystem on /dev/zram0
[ 1506.115241] Unable to handle kernel NULL pointer dereference at virtual address 00000000
[ 1506.116621] pid = 0b5cc492
[ 1506.117049] [00000000] *pgd=0b1c1000, *pm=13f93b203
[ 1506.118508] Internal error: Oops: 207 [#1] SMP ARM
[ 1506.121595] CPU: 1 PTD: 1883 Comm: mkfs.ext4 Not tainted 4.16.4-rc2 #1
[ 1506.122134] Hardware name: Generic DT based system
[ 1506.123335] PC is at zsa_map_object:0x800x/0x1e8
[ 1506.125766] LR is at pin_tag=0x40/0x78
[ 1506.124185] pc = [0x021f20] lr = [0x020b8c] psr: 60070013
[ 1506.124720] sp = ed169eb0 ip = 00000000 fp = ed169ae4
[ 1506.125228] r10 = 00000000 r9 = edf5b4a0 r8 = 00000002
[ 1506.125742] r7 = ec7a7000 r6 = edff9000 r5 = 00000000 r4 = ffff000
[ 1506.126302] r3 = c24d740c r2 = c1c0d784 r1 = 00000000 r0 = 3b120001
[ 1506.126982] Flags: nZCv HRQs on FdQs on Mode SVC_32 ISA ARM Segment none
[ 1506.127627] Control: 30c34c7d Table: 6b1c3800 DAC: 00000000
[ 1506.128217] Process mkfs.ext4 (pid: 1883, stack limit = 0x1e3c1e80)

Description [reply] [−]
Debugging: Real Cases
BUG #3765 (QEMU kdump generation)
Debugging: Real Cases
BUG #3765 (Board kdump generation)
# Debugging: Real Cases

## BUG #3303

**Dan Rue** 2017-10-05 14:01:16 BRT

**Description**

<table>
<thead>
<tr>
<th>File</th>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>/tmp/fanotify07.log</td>
<td>484</td>
<td>INFO: task fanotify07:20858 blocked for more than 120 seconds.</td>
</tr>
<tr>
<td>/tmp/fanotify07.log</td>
<td>484</td>
<td>Not tainted 4.9.53-rc1-00056-g3ebcc73-dirty #1</td>
</tr>
<tr>
<td>/tmp/fanotify07.log</td>
<td>484</td>
<td>&quot;echo 0 &gt; /proc/sys/kernel/hung_task_timeout_secs&quot; disables this message.</td>
</tr>
<tr>
<td>/tmp/fanotify07.log</td>
<td>484</td>
<td>fanotify07 D 0 20858 20857 0000002000</td>
</tr>
<tr>
<td>/tmp/fanotify07.log</td>
<td>484</td>
<td>Call trace:</td>
</tr>
<tr>
<td>/tmp/fanotify07.log</td>
<td>484</td>
<td>[@ffffff0000008f5aeec] __switch_to+0xa94/0xb8</td>
</tr>
<tr>
<td>/tmp/fanotify07.log</td>
<td>484</td>
<td>[@ffffff0000008Af4f390] __schedule+0x218/0xa60</td>
</tr>
<tr>
<td>/tmp/fanotify07.log</td>
<td>484</td>
<td>[@ffffff0000008f4c14] schedule+0xc3/0xa8</td>
</tr>
<tr>
<td>/tmp/fanotify07.log</td>
<td>484</td>
<td>[@fffffff00000054390] schedule_timeout+0x1f8/0x4e8</td>
</tr>
<tr>
<td>/tmp/fanotify07.log</td>
<td>484</td>
<td>[@fffffff00000050800] wait_for_common+0x85/0x150</td>
</tr>
<tr>
<td>/tmp/fanotify07.log</td>
<td>484</td>
<td>[@fffffff000000508ac] wait_for_completion+0x14/0x20</td>
</tr>
<tr>
<td>/tmp/fanotify07.log</td>
<td>484</td>
<td>[@fffffff0000008138400] __synchronize_sysv+0x114/0x1b0</td>
</tr>
<tr>
<td>/tmp/fanotify07.log</td>
<td>484</td>
<td>[@fffffff0000008138590] synchronize_sysv+0x28/0x60</td>
</tr>
<tr>
<td>/tmp/fanotify07.log</td>
<td>484</td>
<td>[@fffffff00000082boe24] fsnotify_mark_destroy_list+0x5c/0xba8</td>
</tr>
<tr>
<td>/tmp/fanotify07.log</td>
<td>484</td>
<td>[@fffffff00000082cd60] fsnotify_destroy_group+0x35/0x68</td>
</tr>
<tr>
<td>/tmp/fanotify07.log</td>
<td>484</td>
<td>[@fffffff00000082cd24] fsnotify_release+0x4e/0x118</td>
</tr>
<tr>
<td>/tmp/fanotify07.log</td>
<td>484</td>
<td>__fpmt+0xa4/0x1e8</td>
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<tr>
<td>/tmp/fanotify07.log</td>
<td>484</td>
<td>__fpmt+0xc0/0x18</td>
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<tr>
<td>/tmp/fanotify07.log</td>
<td>484</td>
<td>task_work_run+0xc0/0x100</td>
</tr>
<tr>
<td>/tmp/fanotify07.log</td>
<td>484</td>
<td>do_notify_resume+0xb4/0xc0</td>
</tr>
<tr>
<td>/tmp/fanotify07.log</td>
<td>484</td>
<td>work_pending+0x8/0x14</td>
</tr>
</tbody>
</table>

**Actual Results:** Approximately 50% of the time, the following kernel trace is observed:
Debugging: Real Cases
BUG #3303 (Using crash)
Debugging: Real Cases

BUG #3903

Nareesh Kambouj  2018-06-13 06:35:54 BRT

Description  [apply] [-]

Steps to reproduce:

- mkdir -p /tmp/tmp
- cd /opt/ltp
- ./runltpt -R read_all -d /tmp/tmp -p -q

Kernel bug log:

[ 1269.051429] dwc2 7720000.usb: Mode Mismatch Interrupt: currently in Host mode
[ 1269.523697] dwc2 7720000.usb: Mode Mismatch Interrupt: currently in Host mode
[ 1269.523300] dwc2 7720000.usb: Mode Mismatch Interrupt: currently in HOST mode
[ 1274.720390] Internal error: synchronous external abort: 99000210 [0] PREEMPT SW
[ 1274.767236] Module loaded in: tomw111xu wicore mac80211 cfg80211 hci_uart bthc cc3200_sce snd_soc_audio_graph_card ccc1010cbf ce ce snd_soc_simple_card_utils bluetooth wicore sdio adv7511 cce ecdh Generic

Description for drm_drv: ifkill kirsch drm.kms_helper drm_drm_panel_orientation_quirks asix u8net fuse

[ 1274.707300] CPU: 2 PID: 7883 Comm: read_all:/not tainted 4.17.0.1 x1
[ 1274.805577] Hardware name: Hikey Development Board (DF)
[ 1274.812990] pstate: 2000000085 (hz/Cv tatif -PAN -UMO)
[ 1274.820029] pc: regmap_mmc_read_0x24/0x38
[ 1274.826856] lr: regmap_mmc_read_0x4/0x70
[ 1274.853340] sp: fff00000c45b30
[ 1274.854893] x29: fff00000c43b40 x29: fff00074def00
[ 1274.866727] x27: fff000009255a40 x2b: 0000000000000000
[ 1274.854404] x25: fff00000c43b80 x25: 000000000000003f
[ 1274.85226] x23: fff00000c45b00 x23: 000000000000003f
[ 1274.859053] x21: fff00000c45b50 x20: fff00000228b00
[ 1274.857648] x19: 0000000000000000 x18: 0000000000000000
[ 1274.85722] x17: 0000000000000000 x16: 0000000000000000
[ 1274.83591] x15: fff00000925f00 x14: fff00000532bf
[ 1274.83391] x13: fff000006f3f94a x12: 0000000000000000
[ 1274.82162] x11: fff000006f3f8a x10: 0000000000000000
[ 1274.79483] x9: fff00000525f200 x8: 0000000000000000
[ 1274.79347] x7: fff0000087df60 x6: 0000000000000000
[ 1274.79292] x5: 0000000000000000 x4: 0000000000000000
[ 1274.79227] x3: 0000000000000000 x2: 0000000000000000
[ 1274.79153] x1: 0000000000000000 x0: fff000001034000
[ 1274.697514] Process read_all (pid: 7883, stack limit = 0x00800000a8668e60, ffff).

Call trace:

[ 1274.073178] regmap_mmc_read_0x24/0x38
[ 1274.080416] regmap_mmc_read_0x4/0x70
[ 1274.907322] _regmap_bus_reg_read_0x38/0x45
[ 1274.954625] _regmap_read_0x74/0x28
[ 1275.001332] regmap_read_0x50/0x78
[ 1275.007997] regmap_read_0x48/0x88
[ 1275.015396] regmap_map_read_file_0x48/0x58
[ 1275.022834] full_proxy_read_0x58/0x58
[ 1275.025958] vfs_read_0x60/0x176

Note: Information from kernel and dmesg.
Debugging: Real Cases
BUG #3903 (Systemtap Usage)
Collab to Test Suites - 15 min

Lessons Learned
## LTP & Kselftests: Lessons Learned

<table>
<thead>
<tr>
<th>TESTS</th>
<th>ENTRY POINTS</th>
<th>GITHUB ISSUE</th>
<th>Priority</th>
<th>Requested</th>
<th>Merged</th>
<th>JIRA cards</th>
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<td>1</td>
<td>sys_init</td>
<td><a href="https://github.com/linux-test-project/ltp/issues/272">https://github.com/linux-test-project/ltp/issues/272</a></td>
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<td><a href="https://github.com/linux-test-project/ltp/issues/276">https://github.com/linux-test-project/ltp/issues/276</a></td>
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<td>0056</td>
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</table>
Perguntas ? Obrigado!

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Kernel Validation Team - Linaro