Linux Kernel Fastboot On the Way

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Kernel Fastboot

- Linux kernel fastboot is critical for all kinds of platforms
- At LPC 2008, Arjan van de Ven and Auke Kok introduced “Booting Linux in five seconds”
- Kernel boot time has been hugely improved over years, but is it all done? NOT YET!
Agenda

- Share how we optimized our platform
- Discuss the potential optimization points
Why we worked on boot optimization

- Hard requirement: **rear camera** must be functional in **2 seconds** after power on.
- The boot phase contains HW, FW, bootloader, hypervisor, kernel and user space, pre-kernel takes **500 ms**, and the budget for kernel is **400 ms**
- Initial kernel boot time is **3 seconds**, finally we cut it to **300 ms**
Platform Brief Intro

HW info:
* Apollolake 4 Core (1.9G/2.4G)
* 8GB RAM
* 16GB EMMC rootfs

SW info:
* VMM: ACRN hypervisor
* OS: Clear Linux with 4.19 LTS kernel

ACRN (Xen like hypervisor)

ABL (Automotive Boot Loader)

Apollolake HW
Methodology – 3 Steps

- Profile
- Analyze
- Optimize
How To Get Accurate Kernel Boot Time

- 3 kernel phases
  - Decompression
  - Dark phase ([~ 0.000000])
  - Normal phase

- Check kernel boot time
  - systemd-analyze
  - printk timestamp
  - “Run xxx as init process”

```
root@Feng-mrb ~ # systemctl-analyze
Startup finished in 318.0ms (kernel) + 8.3910s (userspace) = 8.7091s
graphical.target reached after 775.8ms in userspace
root@Feng-mrb ~ # dmesg | grep Run
[   0.240736] Run /usr/lib/systemd/systemd-bootchart as init process
```

[Diagram showing kernel phases and systemd-analyze process]
Profile Tools

- initcall_debug
  - bootchart
- printk with absolute timestamp
  - Decompress
  - Dark phase
- Individual dump functions
  - Async debug
  - Not covered by initcall_debug
- Ftrace

![Kernel init threads chart](chart.png)
Analyze

Profiled Data

Where

Know where every ms is spent

How

Check how and why it takes so much time

Hotspots

Workaround for specific HW (i915, SDHC)

Unnecessary module/config for product release

Unexpected small module costs lots of time
How the Boot Time Is Consumed

2 sec

300 ms

Kernel Decompression
Memory Init
SMP Init
ACPI FW Init
i915 GFX
LPSS driver
eMMC Storage
Rootfs Mounting
Hotspots Overview

- Driver asynchronous probing
- Rootfs mounting
- Memory init
- Kernel modules and kernel configs
- Graphics (i915)
- Virtualization
## Boottime Hotspots

<table>
<thead>
<tr>
<th>Kernel modules</th>
<th>Boottime taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>i915 FB driver init</td>
<td>1+ sec</td>
</tr>
<tr>
<td>eDP panel detection</td>
<td>300 ms</td>
</tr>
<tr>
<td>ORC unwinder init</td>
<td>300 ms</td>
</tr>
<tr>
<td>SATA controller init</td>
<td>150 ms</td>
</tr>
<tr>
<td>MEI driver</td>
<td>300 ms</td>
</tr>
<tr>
<td>8250 driver IRQ detection</td>
<td>200 ms</td>
</tr>
<tr>
<td>Memory Init</td>
<td>150 ms</td>
</tr>
<tr>
<td>i915 init</td>
<td>40 ms</td>
</tr>
<tr>
<td>acpi init</td>
<td>60 ms</td>
</tr>
<tr>
<td>smp multi core init (4C)</td>
<td>30 ms</td>
</tr>
<tr>
<td>eMMC driver init</td>
<td>60 ms</td>
</tr>
</tbody>
</table>
Too Few Drivers Use Asynchronous Probe

- Driver Async-init framework setup 10 years ago, but rare drivers use it
- Async probe could save a lot of time by making driver init in parallel, like i915, network device
- To enable it, simply set driver’s probe_type to PROBE_PREFERASYNCHRONOUS
- Easy to try - “driver_async_probe=driver1,driver2” in cmdline
Original Boot

Kernel init threads

- spawn_ksoftirqd: 2.0ms
- cpu_stop_init: 2.0ms
- param_sysfs_init: 2.0ms
- acpi_init: 52.7ms
- chr_dev_init: 3.3ms
- sdhci_driver_init: 2.1ms
- pcie_portdrv_init: 1.2ms
- serial8250_init: 20.7ms
- rpm0_mux_init: 1.3ms
- mmc1_rescan: 62.5ms
- i915_init: 42.3ms
- brd_init: 2.0ms
- loop_init: 1.5ms
- intel_lps_0_pci_driver_init: 18.6ms
- igb_init_module: 48.0ms
- telemetry_module_init: 1.2ms
- acrn_trace_init: 3.4ms
- load_system_certificate_list: 1.4ms
- rootmount: 14.9ms
Boot With Asynchronous Probe

Call for Action: Check Your Drivers
RootFS Mounting Is a Critical Path

- Mostly about storage drivers’ efficiency
- SATA driver init takes 100 to 200 ms even without a real disk
- eMMC driver takes 50-100ms
  - Move mmc driver init as early as possible
  - Disable not used host controllers
  - Disable not used protocols (SD/SDIO)
  - Optimize driver’s internal hacky busy wait
- Add “rootwait” to cmdline
- Check the hidden asynchronous functions
Deferred Memory Init

- 8GB RAM’s initialization costs 100+ ms
- In early boot phase, we don’t need that much memory
- Utilize the memory hotplug feature
  - “mem=4096m” in cmdline to only init 2 GB
  - Use systemd service to add rest memory in parallel
Highest CPU Frequency Booting

- CPU frequency has huge impact over boot time, especially for those no IO related operations.
- CPU frequency is set by BIOS/FW, before cpufreq subsystem is initialized
- Could we enable it with a kernel config option for boot phase only?
Kernel Modules and Config

- Use loadable module when possible
- Disable all not-necessary modules/drivers
- Disable all debug features for release version
- Disable existing but not used HW (like SDHC/SATA controller)
- Kernel size matters
What Can We Do Next?

- Universality vs Performance
- In-kernel deferred memory init
- Asynchronous Probe May Mess the Device Index
- SMP initialization for bringing up other Aps
- Devices enumeration for ACPI set to be parallel
- User space optimization like systemd
Universality vs Performance

- Driver wants to cover all HWs with one copy of code
- Many long delay in drivers is actually to cover some broken HW
  - i915 driver’s 32 times DPCD register read
  - SDHC driver’s 10ms power up delay
- Everybody pays because of them
- Can we handle them in a better way?
  - add kernel parameter to tune
  - add quirks
In-kernel Deferred Memory Init

- User space can initialize majority of the memory with hotplug interface
- Useful for platforms with huge mount of memory
- Can we create a kernel thread to do it, which move it form the critical path to paralleled initialization?
Asynchronous Probe May Mess the Device Index

- Some driver covers multiple HW controllers in the system - uart/spi/i2c
- Asynchronous probe may mess up the controller index
- How to handle it
  - Add the index into device’s private data?
Parallize SMP Initialization

- It takes about from 6 to 10 ms to bring up one AP, depending on platforms.
- It used to be more, has been optimized already.
- Currently it is under the CPU hotplug framework, and brought up one by one.
Efficient Firmware Init

- acpi_init takes 50 ~ 150 ms
- It enumerates a bunch of devices, tables
- Need to further analyze all the devices, check the possibility to make it a 2 phases enumeration, and put deferrable enumeration into parallel phase
systemd (user space)

- Systemd is ~1.5MB - the loading time for emmc is 100ms
- Can we use a small lightweight “init” program, which starts target programs in parallel and readahead to preload libraries and executables?
Credits

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Q&A

Thank You!
Backup
Graphics

- **eDP panel detection**
  Driver will blindly read 32 times the DPCD registers even when there is no eDP panel attached, which takes 300ms.

- **Framebuffer device**
  Initially the i915 framebuffer device takes 1 second to initialize, which is caused by the hypervisor

- **FB_EMULATION option**
  All connectors (HDMI/DP) will be initialized one or two times, which costs 100+ ms
Virtualization

- Pain point: big VM-trapped MMIO operations
  - memset for 8MB frame buffer takes 1 second
  - GVT spends 90ms on firmware loading
  - PCI subsystem initialization takes 30 ms
- VMM should be specific about virtual device’s IRQ number
  - Detecting the IRQ number of UART costs 250ms
  - Better avoid IRQ auto detection