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!

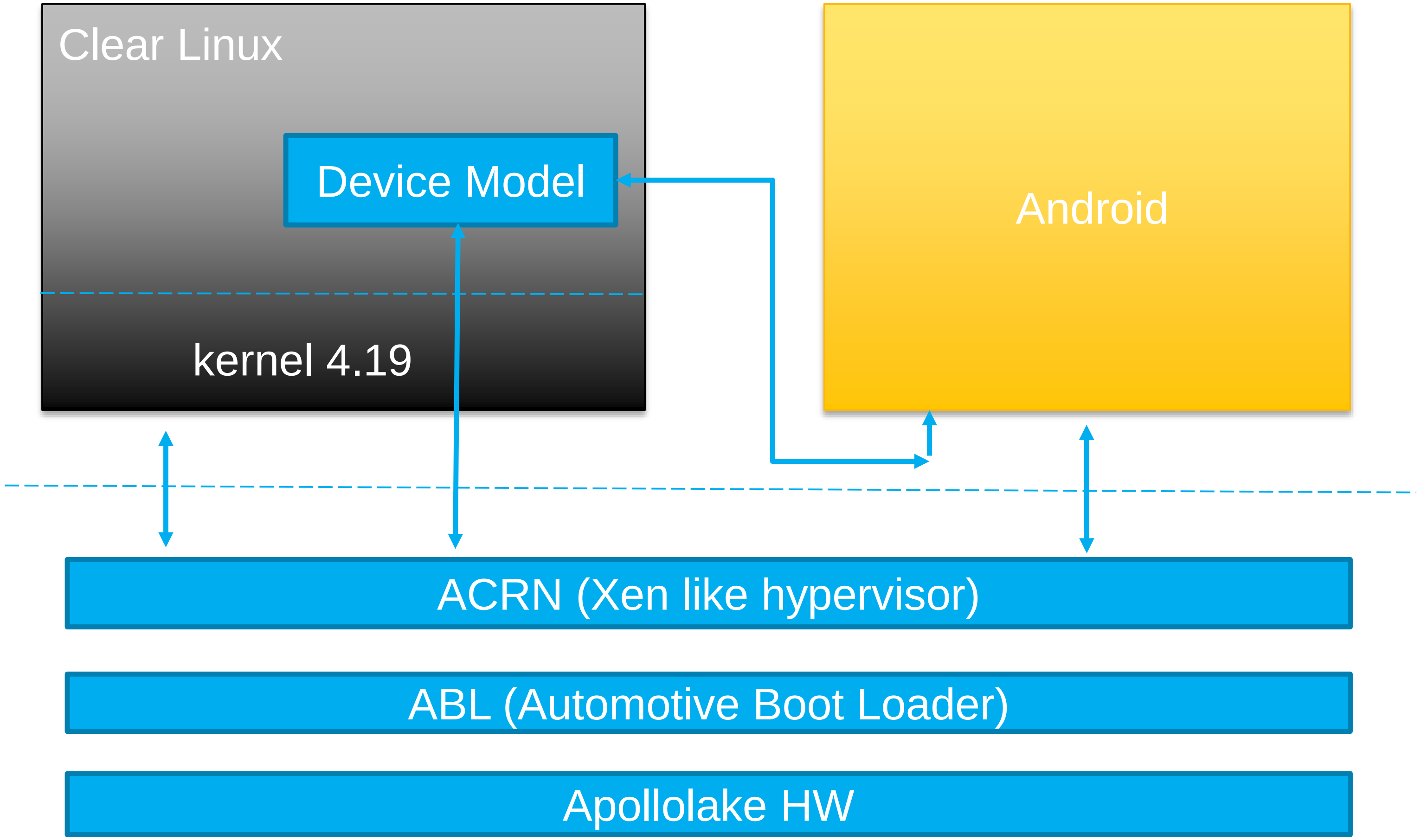
Agenda

- 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

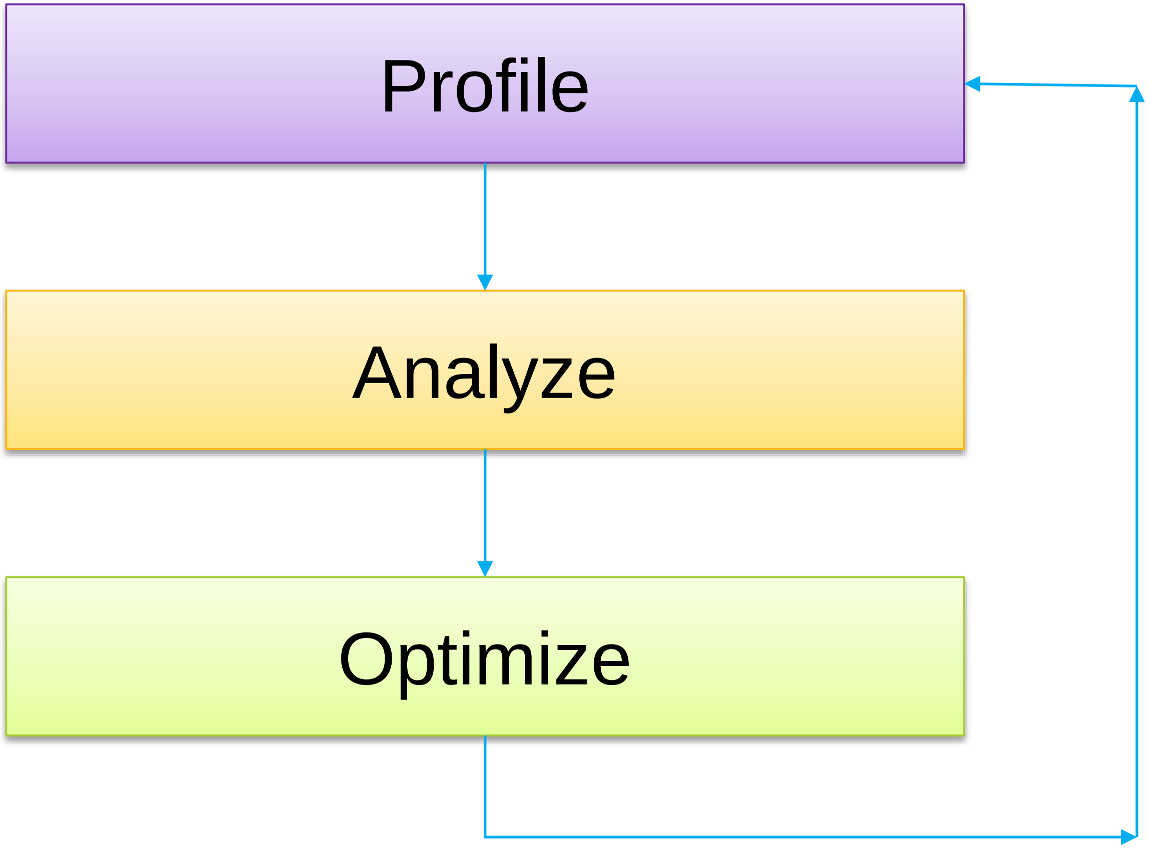
Platform Brief Intro



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

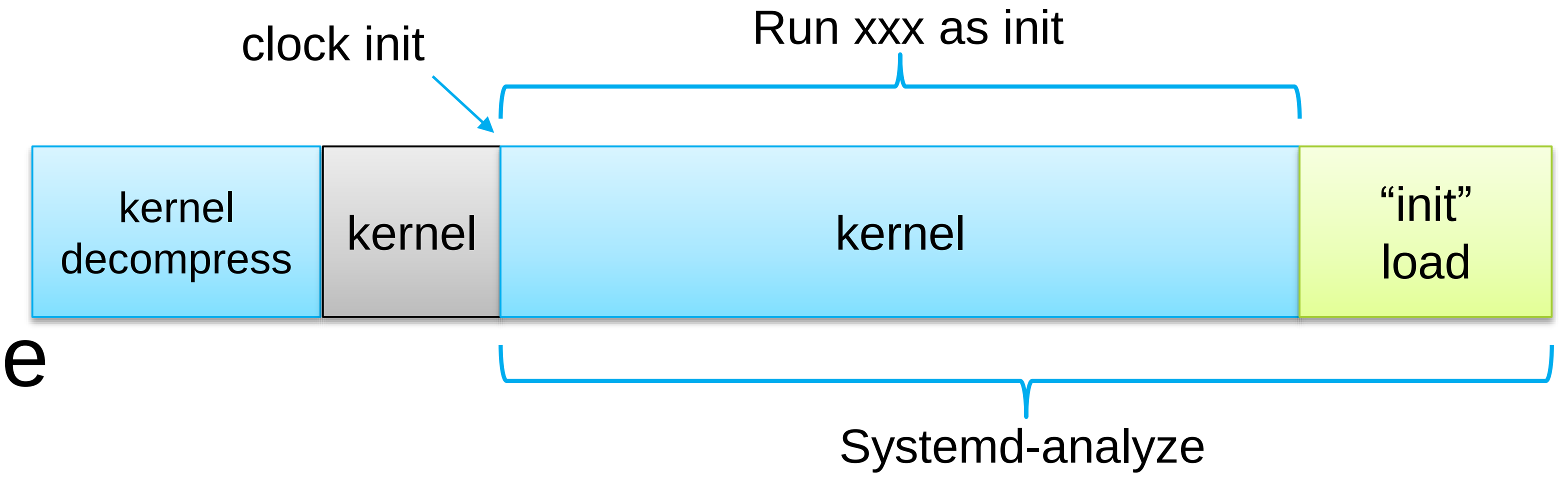
SW info:
* VMM: ACRN hypervisor
* OS: Clear Linux with 4.19 LTS kernel

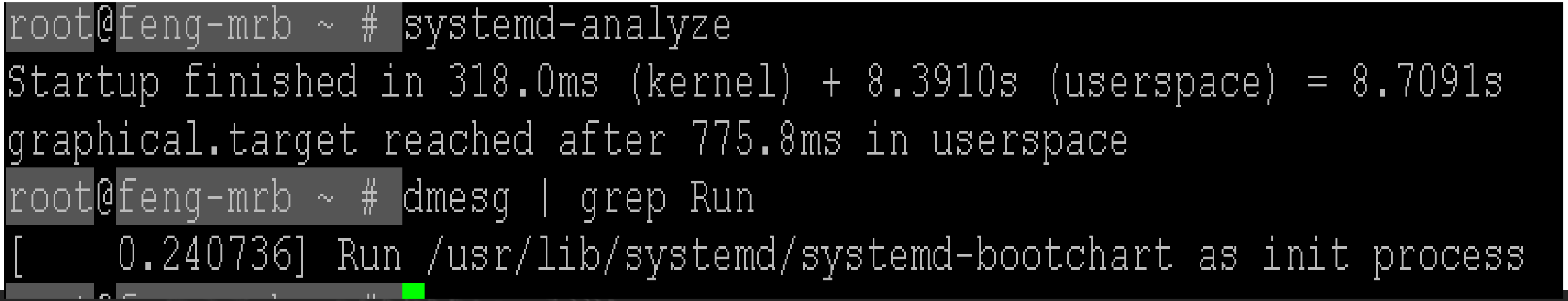
Methodology – 3 Steps



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”

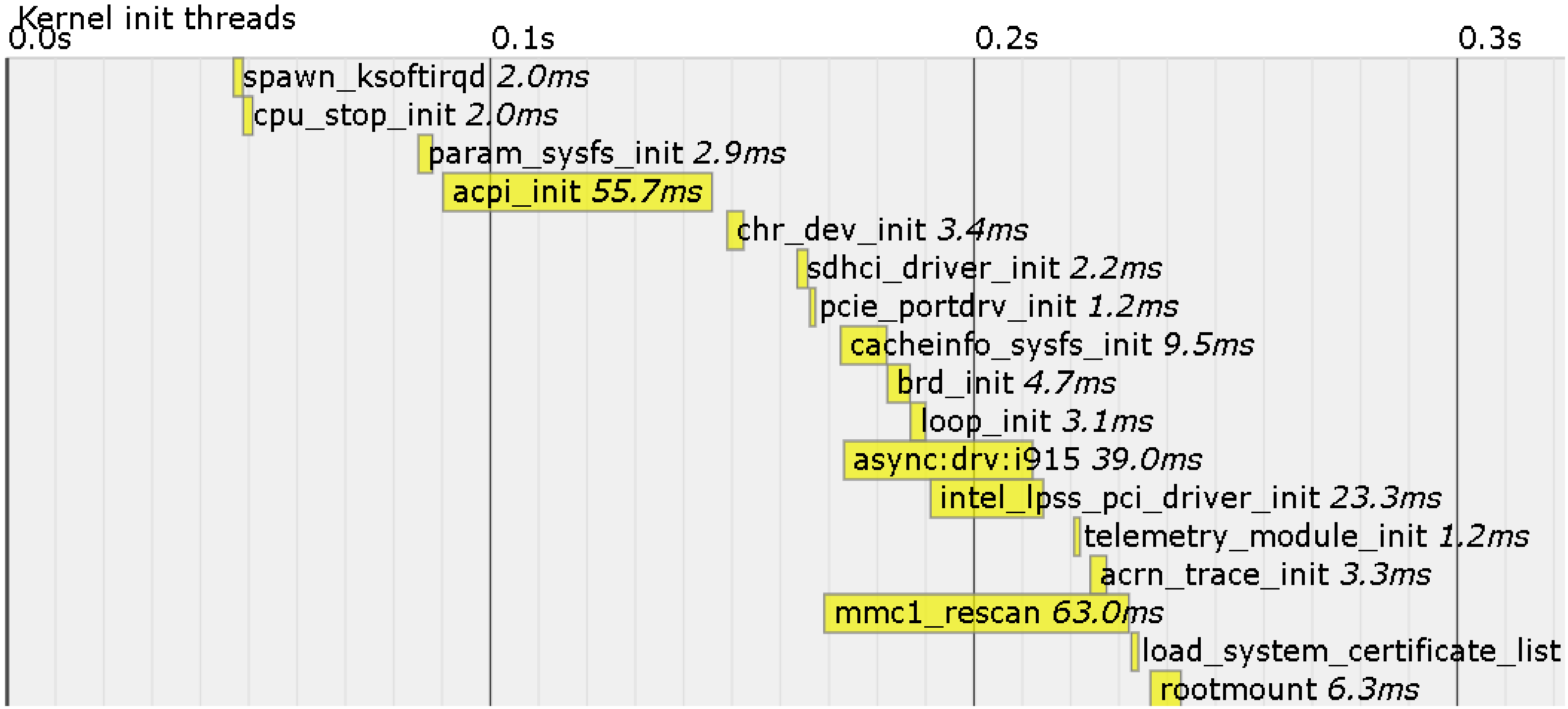




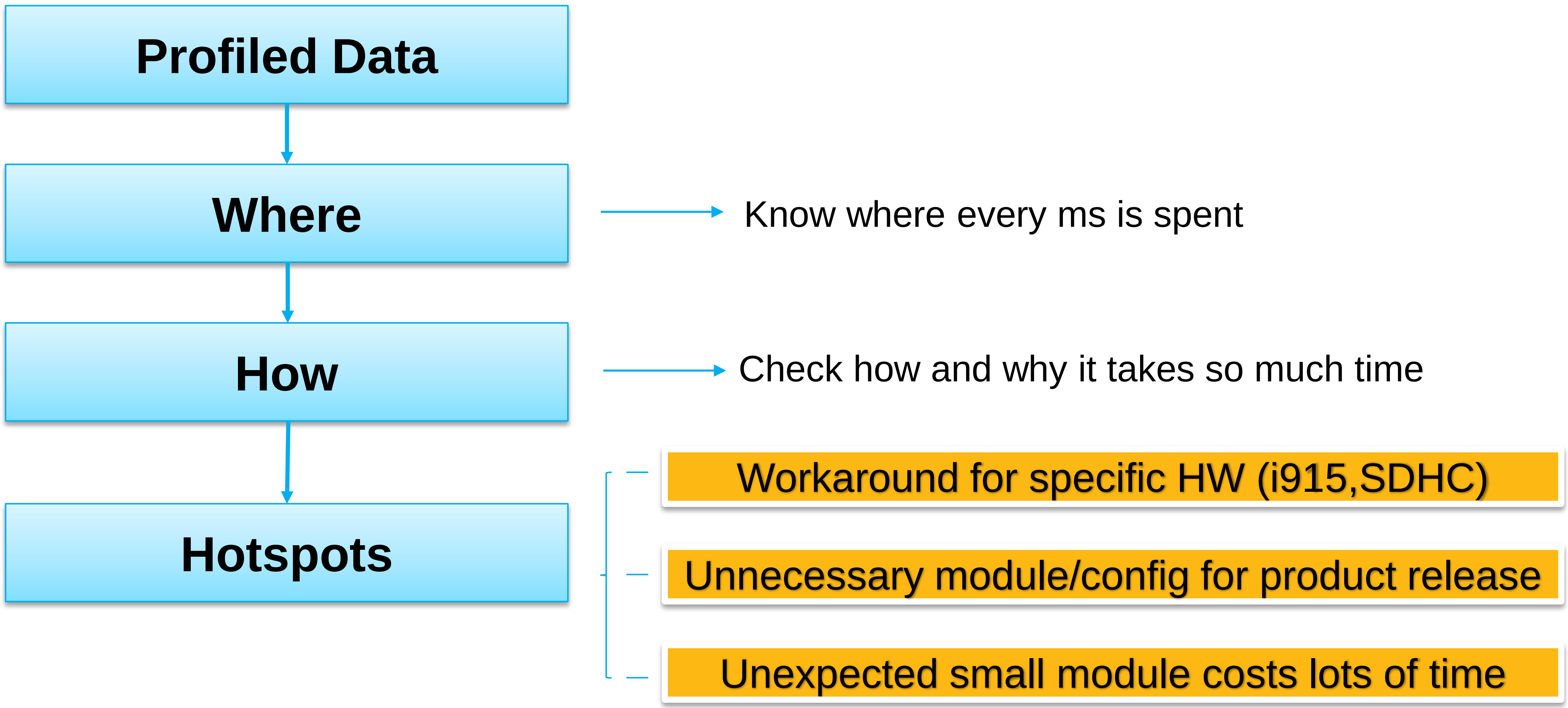
```
root@feng-mrb ~ # systemd-analyze
Startup finished in 318.0ms (kernel) + 8.3910s (userspace) = 8.7091s
graphical.target reached after 775.8ms in userspace
root@feng-mrb ~ # dmesg | grep Run
[    0.240736] Run /usr/lib/systemd/systemd-bootchart as init process
root@feng-mrb ~ #
```

Profile Tools

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



Analyze



Profiled Data

Where

How

Hotspots

Know where every ms is spent

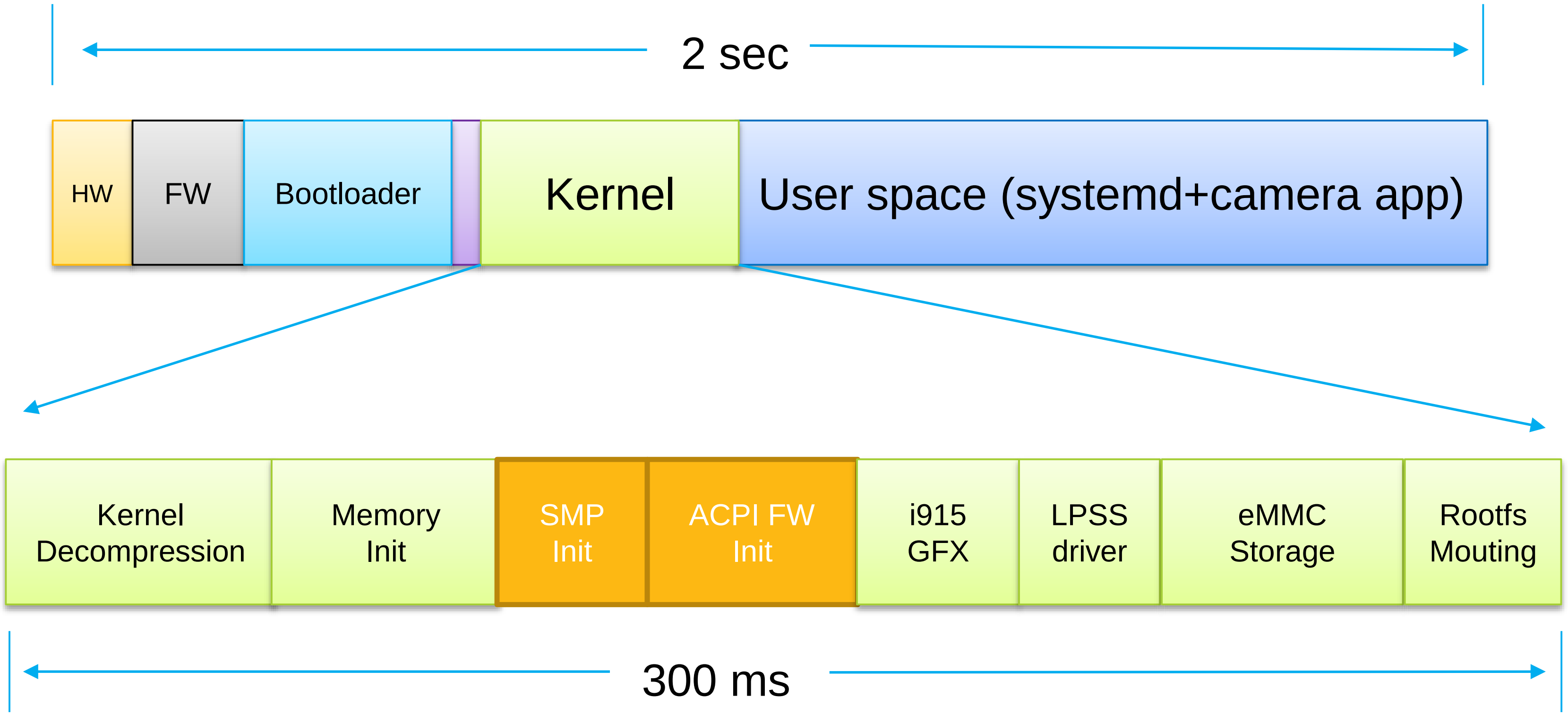
Check how and why it takes so much time

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



Hotspots Overview

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

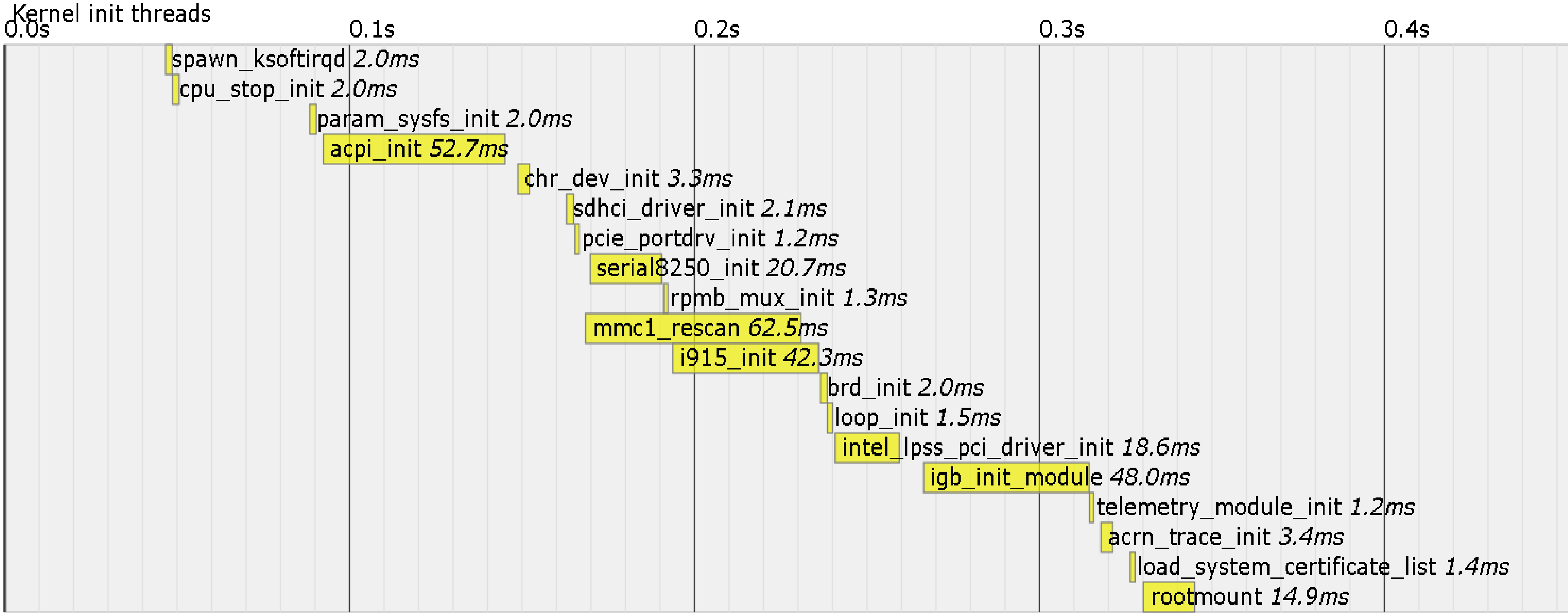
Boottime Hotspots

Kernel modules	Boottime taken
i915 FB driver init	1+ sec
eDP panel detection	300 ms
ORC unwinder init	300 ms
SATA controller init	150 ms
MEI driver	300 ms
8250 driver IRQ detection	200 ms
Memory Init	150 ms
i915 init	40 ms
acpi init	60 ms
smp multi core init (4C)	30 ms
eMMC driver init	60 ms

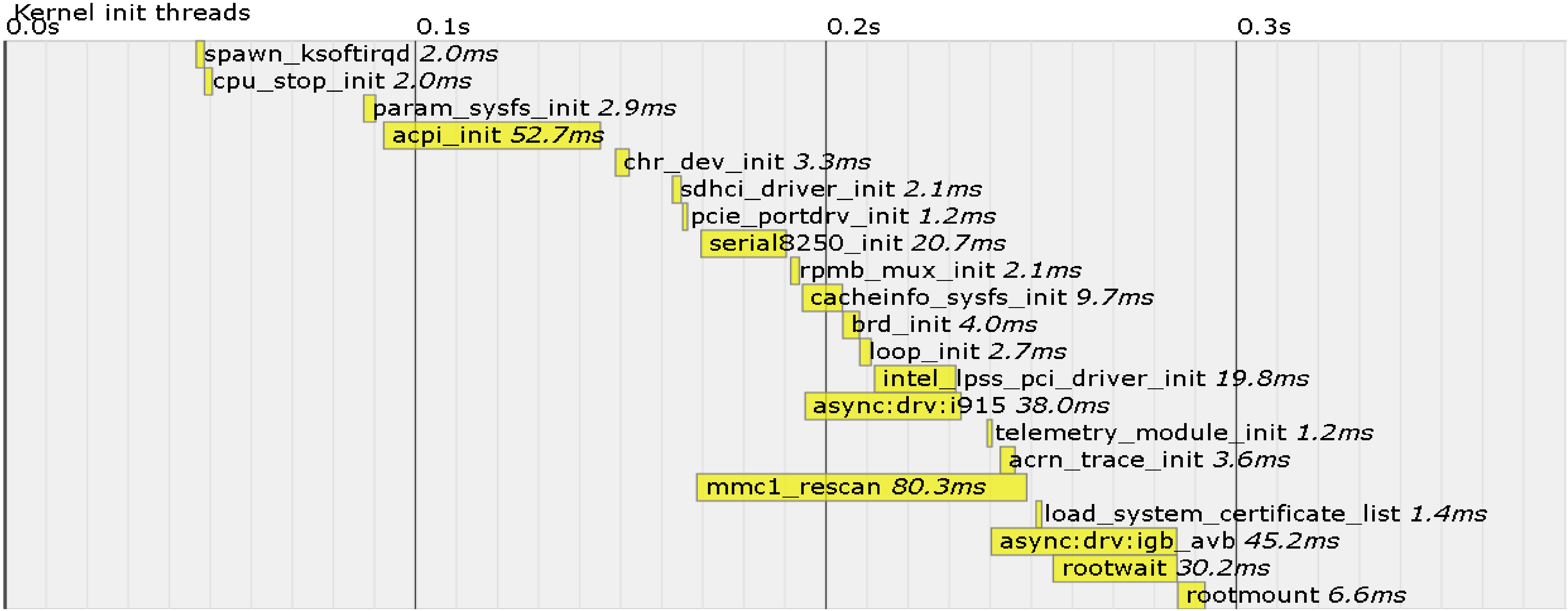
Too Few Drivers Use Asynchronous Probe

- 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_PREFER_ASYNCHRONOUS
- Easy to try - “driver_async_probe=driver1,driver2” in cmdline

Original Boot



Boot With Asynchronous Probe



Call for Action: Check Your Drivers

RootFS Mounting Is a Critical Path

- Mostly about storage drivers' efficiency
- SATA driver init takes100 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

Thanks to Bin Yang, Alek Du, Julie Du, Ying Huang, Andi Kleen, Tim Chen, Jianjun Liu and many others for supporting and reviewing

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