Status of Embedded Linux

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Tim Bird
Architecture Group Chair
LF Core Embedded Linux Project
Nature of this talk...

- Quick overview of lots of embedded topics
- A springboard for further research
  - If you see something interesting, you have a link or something to search for
Outline

Kernel Versions
Technology Areas
CE Workgroup Projects
Other Stuff
Resources
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Kernel Versions

- Linux v4.7 – 24 July 2016 – 70 days
- Linux v4.8 – 2 Oct 2016 – 70 days
- Linux v4.9 – 11 Dec 2016 – 70 days
- Linux v4.10 – 19 Feb 2017 – 70 days
- Linux v4.11 – 30 Apr 2017 – 70 days
- Linux v4.12 – 2 Jul 2017 – 63 days
- Linux v4.13-rc7
  - v4.13 expected on 3 Sep, 2017 (would be 63 days)
Linux 4.7

- Schedutil frequency governor
  - Use the load calculated by the scheduler instead of the average load over past little while
  - See http://lwn.net/Articles/682391/
- VFS layer can iterate through directories in parallel
- Ability to attach BPF programs to tracepoints
- Ftrace histograms
  - Can tell tracer to accumulate events into buckets and give results, via the sysfs interface
Linux 4.8

- New kernel documentation system
  - Based on Sphynx
  - See https://lwn.net/Articles/692704/
- New pseudo-random number generator
  - See https://lwn.net/Articles/686033/
- ARM64 support for kexec and kprobes
- New timer wheel implementation
  - https://lwn.net/Articles/646950/
- Better performance:
  - No more cascade operations
  - Quick determination of next timeout
  - Automatically coalesces longer timeouts
  - Long timeouts have reduced resolution
Linux 4.9

- Virtually mapped kernel stacks
  - [http://lwn.net/Articles/692953/](http://lwn.net/Articles/692953/)
  - Allows to detect stack overruns
  - Cleans up kernel code, faster process creation
  - Only on x86, for now

- Greybus - [https://lwn.net/Articles/715955/](https://lwn.net/Articles/715955/)

- Timed samples for eBPF

- Modversions deprecated
  - See [https://lwn.net/Articles/707520/](https://lwn.net/Articles/707520/)
Linux 4.10

- Perf sched timehist
- Hybrid block polling
  - Supports polling for block I/O, but with a short delay (estimated) before the polling starts
    - Improves performance by queuing blocks as soon as device is ready (via polling)
    - Uses less CPU than full polling
- Support for ARM SoCs:
  - Huawei, Allwinner, Marvel, Renesas
- Posix timers are configurable
- Initramfs compression method is selectable
- New interface for system sleep state selection
  - `/sys/power/mem_sleep`
- UBIFS support for encryption
Linux 4.11

- New kernel refcount API
- TinyDRM subsystem added
- New statx() system call
  - [https://lwn.net/Articles/707602/](https://lwn.net/Articles/707602/)
  - 2038-safe time values
  - Mask of fields to obtain (for efficiency)
- Sched.h refactoring
  - Non-mainline code: watch out!
Linux 4.12

- BFQ and Kyber block I/O schedulers
- Minitty prep work
  - Not full minitty implementation yet
- Proper support for USB type-C connectors
- AnalyzeBoot tool
  - Reads dmesg (and possibly ftrace log) and produces html graph of boot events
  - Part of Intel pm-graph tools project
    - https://github.com/01org/pm-graph
  - See tools/power/pm-graph/analyze_boot.py
Linux 4.13 (expected)

- TLS implementation in the kernel
  - Should help with HTTPS performance
  - See https://lwn.net/Articles/666509/
- Next-interrupt prediction
- F2FS support for disk quotas
- Kselftest transitioning to TAP13 protocol
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Bootup Time

- Analyze_boot tool – new in in 4.12
- Some good previous talks:
  - ELCE 2014 - 12 Lessons Learnt in Boot Time Reduction by Andrew Murray
  - ELC 2015 - Fastboot Tools and Techniques by John Mehaffey
- Android boot time ideas
  - ELC 2017 – Improving the bootup speed of AOSP – Bernhard Rosenkranzer
Bootup ideas from Bernhard

- Two approaches:
  - Improve cold boot
  - Enhance suspend/resume
- Areas analyzed for cold boot:
  - Package Manager scanning
  - Java class preloading
  - PM: force high CPU frequency during boot
  - IO: read-ahead, kernel compression, squashfs
  - Kernel modules – defer modules until later
  - Library and compiler optimizations
Device Tree

- Device Tree Overlays
  - Allow plugin-boards to be configured at runtime
  - Session at ELC 2016 by Pantellis
  - Not mainlined yet? – expected in 4.11?

- Device Tree validation
  - Schema for binding language, validator for bindings and for device tree data
  - This work stalled
  - New proposal for device tree in YAML format
    - https://lwn.net/Articles/730217/

- Updated Device Tree specification
  - Want to update material and make it more available

- See
  - And ELC 2017 Device Tree BOF – Frank Rowand
Graphics

• TinyDRM
  • Provides graphic support for small simple displays (eg displays over i2C or SPI)
  • Hope to replace framebuffer drivers over time
  • See https://www.phoronix.com/scan.php?page=news_item&px=TinyDRM-Patches-Posted

• Presentation
  • ELC 2017 What Can Vulkan do for You? - by Jason Ekstrand
GPU drivers

- Nvidia, Vivante and Broadcom GPUs have open drivers
  - Nouveau, Etnaviv, and VideoCore 4
- Qualcomm Adreno
  - Freedreno continues to be developed (June 2017)
    - See https://www.xda-developers.com/open-source-adreno-project-freedreno-receives-new-update/
- Imagination PowerVR – no public driver, although one was teased in 2015
  - Apple dropping Imagination (April 2017)
- ARM Mali – Some work (Lima project) on earlier chip versions, nothing lately
  - Status update: https://lwn.net/Articles/716600/
  - No open source drivers likely
File Systems

- UBIFS support for encryption (in 4.11)
- IO scheduling for solid state storage
- LightNVM
  - Software control of flash-translation layer
  - https://lwn.net/Articles/641247
- F2FS support for disk quotas (in 4.13)
Networking

**Bluetooth:**
- Bluetooth 5.0
  - Most features are on BLE codebase
    - Only 1 for “BL classic”
  - 800% data throughput increase
  - 4 times the range
- Coexistence with wireless
  - Better error correction to handle noisy environments
Power Management

- New interface for system sleep state (in 4.10)
  - /sys/power/mem_sleep
- Power-efficient workqueues
  - More efficient work scheduling
    - Results in about 15% better energy consumption
    - See https://lwn.net/Articles/731052/
- Operating-System-Directed Power-Management Summit
  - https://lwn.net/Articles/721573/
  - Energy-aware scheduling
  - A collection of scheduling talks that will make your head spin
Real Time

• SCHED_DEADLINE
  • ELC 2017 - SCHED_DEADLINE: It’s Alive - by Juri Lelli
    • Energy Aware Scheduler support
    • Bandwidth reclaiming
      • Temporarily allow a task to exceed it’s bandwidth, if no other process’ deadline suffers
    • Support for Frequency scaling
    • Group scheduling

• Presentations:
  • ELC 2017 Effectively Measure and Reduce Kernel Latencies for Real-time Constraints – By Jim Huang
  • ELC 2017 Real-Time Linux on Embedded Multicore Processors – by Andres Ehmanns
Security

- Kernel hardening
    - Rare_write infrastructure
      - Keep some code and data read-only most of the time
      - https://lwn.net/Articles/724319/
  - GCC plugins for kernel security
    - Kernexec
      - Prevent kernel from executing user-space code
    - Structleak (mainlined in 4.11)
      - Zero out kernel structures passed to user space, under some conditions
    - See https://lwn.net/Articles/712161/
  - Randstruct
    - Randomize C structure layout
    - See https://lwn.net/Articles/722293/
Security Presentations

- ELC 2017 Securing Embedded Linux Systems with TPM 2.0 – by Philip Tricca
System Size

- Initramfs compression method is selectable
- Nicolas Pitre work
  - Configurable POSIX timers – in v4.10
    - https://lwn.net/Articles/701095/
  - Mini TTY
    - Smaller implementation of TTY subsystem, for embedded
    - Saves about 38K
    - https://lwn.net/Articles/721074/
    - People wanted refactoring of full-size TTY instead of new small implementation, but Nicolas said that wasn’t feasible
Shrinking the scheduler
• Drops features and eliminates realtime and deadline scheduler classes
• Saves about 20k
• https://lwn.net/Articles/725376/
• Lots of resistance to this
• Code complexity increase is not worth saving 20k (according to Ingo Molnar)
• Disagreement on whether Linux should support computers with sub-1MB memory
Size Presentations

- LinuxCon North America: *Running Linux on Tiny Peripherals* – by Marcel Holtmann
  - Got Linux to around 1MB for IOT sensor project
- ELC 2017 *Embedded Linux Size Reduction Techniques* – By Michael Opdenacker
  - Very good overview of existing reduction techniques and status
    - Formal Tinification project is stalled
    - Toybox and musl (smaller libc) are worth looking at
Testing

- Kselftest
- Fuego
- Kernelci.org
- LAVA V2
Kselftest

- Unit test system inside kernel source tree
- Recent work:
  - Lots more regression tests (preferred place for syscall compatibility/regression tests (over LTP)
  - Converting to TAP (Test Anything Protocol) for test output (started in 4.13)
Fuego

- New Test Framework for collaborating on tests and test infrastructure for Linux
- V1.1 features (April 2017)
  - Upgrade to latest Jenkins
  - Test script refactoring
  - Fuego container directory layout change
  - About 40 new tests
- V1.2 plans (RC very soon (Sep 2017))
  - Unified output format
  - Convert all test results to JSON, in a format compatible with Kernel CI
  - New pass criteria system
  - Test dependency system
  - Board dynamic variables
Kernelci.org

- Place to get free build/boot testing for your board
  - Builds 126 trees continuously, then reports any errors
- [http://kernelci.org](http://kernelci.org)
- Presentations:
  - ELC and ELCE 2016 – by Kevin Hilman
  - Linaro Connect:
    - Kernelci and lava update - See [https://lwn.net/Articles/716600/](https://lwn.net/Articles/716600/)
- The most successful public, distributed build and test system for Linux, in the world!
LAVA

- Linaro Automation and Validation Architecture
- V2
  - Job files now use Jinja2 templates
    - Was previously hand-written JSON
  - Jobs are run asynchronously, without polling,
  - ZeroMQ is used for communications.
  - ReactOBus is used to run jobs from messages.
  - Requires more explicit board configuration
Toolchains

- LLVM 4.0.0 is released
  - Some code size improvements from optimizations (GVNHoist)
  - Experimental support for LLVM coroutines
  - https://lwn.net/Articles/716979/

- Presentations:
  - ELC 2017 - GCC/Clang Optimizations for Embedded Linux – by Khem Raj
Tracing

- More perf tools (both in 4.10):
  - perf sched timehist
    - Analysis of scheduling events
  - perf c2c
    - Cacheline contention analysis

- Presentations:
  - ELC 2017 *Dynamic Tracing Tools on ARM/AArch64 Platform: Updates and Challenges* - by Hiroyuki Ishii
    - Great overview
Miscellaneous

- Printk issues
- Year 2038 work
- Linus issues with Kconfig
- AGL making inroads
Printk issues

• Discussion on kernel summit mailing list
  • Lots of issues with printk
    • It’s not per-CPU, console lock held too long, it has complicated code paths, and lots more
  • See thread start at:
    • https://lists.linuxfoundation.org/pipermail/ksummit-discuss/2017-June/004358.html

• Recent discussions about KERN_CONT
  • KERN_CONT is unreliable for SMP kernels
  • Latest kernels put ‘\n’ between lines that don’t have KERN_CONT
  • Eventual removal of KERN_CONT
    • Maybe use of seq_buf for outputting serialized date atomically
  • https://lwn.net/Articles/732420/
Year 2017 work

- 3 areas of work
  - Converting all 32-bit timestamps to 64-bit in the kernel
    - e.g. New statx() system call
    - Many patches are in-progress (vfs layer, v4l, device-mapper, input subsystem)
  - C libraries
    - Lots of work in glibc to make everything backwards compatible
      - Even programs built with 32-bit timestamps should work
  - Distribution builds – fixing up individual packages
- See https://lwn.net/Articles/717076/
Linus issues with Kconfig

• Discussion on kernel summit mailing list
  • Kconfig is too hard for end users
  • What can be done?
  • Linus’ complaint:
    • https://lists.linuxfoundation.org/pipermail/ksummit-discuss/2017-June/004504.html

• Ideas:
  • Config fragments
  • Higher level options
  • Better dependencies
    • From distro feature to kernel config
AGL status

- First car in US with Entune (AGL-based infotainment OS) will be 2018 Toyota Camry
  - Announced at Open Source Summit Japan by Toyota
- Mazda and Toyota collaborating on Entune
  - https://www.theregister.co.uk/2017/08/29/mazda_toyota_linux_entune_car_infotainment/
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Projects and initiatives

- Shared Embedded Distribution
- LTSI
- Fuego
- eLinux wiki
Shared Embedded Distribution

• Goals
  • Create an industry-supported distribution of embedded Linux
    • Main goal is very long term support (15 years)

• Status
  • Toshiba has created Yocto layer meta-Debian
  • Presented at ELCE, ELC, and LCJ

• Next steps
  • Improve coordination with Debian community
Long Term Support Initiative

• LTSI 4.9 is current LTSI kernel
  • Work is in progress on next release
• GregKH said
  • Expected delivery date: Sep 2017
  • Converting to upstream-first policy
• Presentation:
  • ELC 2017 *Using Linux as Long Term Working with the Community* – by Tsugikazu Shibata
Fuego - Linux Test Framework

• Working on lots of issues:
  • Command line tool
  • Test packaging
  • LAVA integration
  • Serial console transport

• Presentation:
  • ELC 2017 BoF: Fuego Status and Roadmap – by Tim Bird
eLinux wiki

- [http://elinux.org](http://elinux.org)
  - Web site dedicated to information for embedded Linux developers
    - The wikipedia of embedded linux!
  - Hundreds of pages covering numerous topic areas: bootup time, realtime, security, power management, flash filesystem, toolchain, editors
- Slides and Videos for 12 years of ELC!!
- Please use and add to site
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Trade Associations

- Linaro still doing lots of great work
  - Lava v2 and kernelci
  - Now promoting Zephyr
  - Linaro Connect consistently has useful material
- Linux Foundation
  - Continuing to grow
    - First event in China sold out in 2 weeks (1200 attendees)
  - Over 100 conferences, 67 projects
    - Not just Linux
  - More than 500 members
Conferences

- ELC 2017
  - Lots of great sessions
  - See: http://elinux.org/ELC_2017_Presentations
- Open Source Summit Japan
  - May 31-June 2, Tokyo
- Embedded Linux Conference Europe
  - October 23-25, Prague, Czech Republic
- Embedded Linux Conference 2018
  - March 12-14, Portland, Oregon, USA
- Japan Jamborees
  - Continuing
Closing thoughts

• Google search oddity
• How is Linux doing in embedded
  • AspenCore/EETimes/embedded survey of embedded market 2017
Google search “linux kernel”

- Tux seems a bit off…
Please select ALL of the operating systems you are currently using.

- Embedded Linux: 22%
- FreeRTOS: 20%
- In-house/custom: 19%
- Android: 13%
- Debian (Linux): 13%
- Ubuntu: 11%
- Microsoft (Windows Embedded 7/Standard): 8%
- Texas Instruments RTOS: 5%
- Texas Instruments (DSP/BIOS): 5%
- Micrium (uC/OS-III): 5%
- Microsoft (Windows 7 Compact or earlier): 5%
- Keil (RTX): 4%
- Micrium (uC/OS-II): 4%
- Wind River (VxWorks): 4%
- AnalogDevices (VDK): 3%
- Express Logic (ThreadX): 3%
- Freescale MQX: 3%
- Angstrom (Linux): 3%
- Green Hills (INTEGRITY): 2%

Base: Currently using an operating system

Only Operating Systems with 2% or more are shown.

2017 Embedded Markets Study
Survey notes

• Embedded Linux at 22 percent
  • But if you include Android, Debian, Ubuntu and Angstrom – it’s 61%
    • If you can add them – which is unclear


• Source: http://m.eet.com/media/1246048/2017-embedded-market-study.pdf
Despite goofy Tux, world domination is proceeding as planned…
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- LWN.net
  - http://lwn.net/
  - If you are not subscribed, please do so
- Kernel Newbies
  - http://kernelnewbies.org/Linux_4.??
- eLinux wiki - http://elinux.org/
  - Especially http://elinux.org/Events for slides
- Celinux-dev mailing list
Thanks!