Status of Embedded Linux
May 2018

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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
- Not comprehensive!
  - Just stuff that I saw
Outline

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

- Linux v4.12 – 2 Jul 2017 – 63 days
- Linux v4.13 – 3 Sep 2017 – 63 days
- Linux v4.14 – 12 Nov 2017 – 70 days
- Linux v4.15 – 28 Jan 2018 – 77 days
  - Included Spectre and Meltdown fixes
- Linux v4.16 – 1 Apr 2018 – 63 days
- We’re on 4.17-rc6 now
  - Expect 4.17 on June 3
Linux 4.12

- BFQ and Kyber block I/O schedulers
- Mini-tty prep work
  - Not full mini-tty 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](https://github.com/01org/pm-graph)
  - See tools/power/pm-graph/analyze_boot.py
Linux 4.13

- 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
Linux 4.14

- New kernel stack unwinder (ORC) for x86_64
  - Better unwinding via kernel-specific out-of-band structure (for every kernel PC address)
  - See https://lwn.net/Articles/728339/
- zstd compression for btrfs and squashfs
- Better cpufreq coordination with SMP
Linux 4.15

- Cramfs supports mapping persistent memory
  - Can use for XIP
- AMD display core system accepted
- Device tree compiler has support for overlays
- RISC-V support
- Spectre/Meltdown mitigations
  - KPTI
  - retpolines
Linux 4.16

- Initial support for the Jailhouse hypervisor
- eBPF support for functions
- arm64 mitigations for Spectre and Meltdown
- More Spectre mitigations (general)
  - array_index_nospec()
- High resolution timers now have two modes, to allow them to be run in software interrupt context
F2FS miscellaneous improvements

Slimbus and Soundwire sub-systems added
  - These are MIPI audio bus standards

Flex and Bison are required for kernel build
Linux 4.17

- 8 old architectures dropped
  - Blackfin, CRIS, FRV, M32R, Metag, MN10300, Score, Tile
  - Removes about 460K lines of code
  - Only 3rd time ever that a kernel release has shrunk

- Rework of kernel idle loop
- Finished full in-kernel TLS protocol support
- Improved CPU load estimation
Improved CPU load estimation

- Is a modification of the per-entity load-tracking (PELT) mechanism
  - PELT decays the load information about processes too quickly
  - New estimator avoids this
- Load estimation can clamp more quickly
- Good for mobile and embedded
- Adds 1% scheduling overhead
  - Requires setting SCHED_UTILEST scheduler feature bit
- See https://lwn.net/Articles/741171/
Linux 4.17 – cont.

- A formal kernel memory-ordering model
  - With tests for formal proofs of adherence
  - See https://lwn.net/Articles/718628/
- Kernel build now requires gcc 4.5 or later on x86
- Changes to system call implementation on x86
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Bootup Time

• Nothing new, here is older stuff...
• Analyze_boot tool – new in in 4.12
• Some good previous talks:
  • ELCE 2017 - A Pragmatic Guide to Boot-Time Optimization by Chris Simmonds
  • ELCE 2014 - 12 Lessons Learnt in Boot Time Reduction by Andrew Murray
Device Tree

- Nothing new, here is older stuff...
- Device Tree validation
  - Schema for binding language, validator for bindings and for device tree data
  - New proposal for device tree validation by Pantellis and Grant Likely
- Updated Device Tree specification
  - Want to update material and make it more available
- Overlays
  - Device tree compiler has support for overlays
File Systems

- **F2FS**
  - Miscellaneous fixups (4.17)
    - Lost & Found support
    - Better tuning for low_end devices
  - Support for disk quotes (4.13, 4.15)

- **BTRFS and Squashfs support for zstd compression (4.14)**
  - Faster and smaller compression/decompression
Graphics

- Working on support for virtual reality
- LCA 2018 *Driving Virtual Reality from Linux* - Keith Packard
GPU drivers

• ELC 2018 *Progress in the Embedded GPU Ecosystem* – by Robert Foss
  • *Watch the video – the slides don’t have enough text*
  • Nvidia, Intel, AMD, Broadcom, Qualcomm, Vivante have upstream support
    • Of varying quality
  • ARM – some stuff happening recently with Mali T series, but not upstreamed yet.
Networking

• Time Sensitive Networking
  • ELC 2018 *The Road Towards a Linux TSN Infrastructure* – Jesus Sanchex-Palencia
  • ELCE 2017 *Deterministic Networking for Real-Time Systems (Using TSN)* – by Henrik Austad
    • `so_txtime` option for high-resolution transmit time
  • IEEE deterministic networking (DetNet) working group
    • Lots of standards
• Bluetooth 5 – supported
Power management

• Rework kernel idle loop (in 4.17)
  • Prevent CPUs from spending too much time in shallow idle states
  • Reduces idle power on some systems by 10% or more
  • May increase performance of some workloads
  • See https://www.phoronix.com/scan.php?page=article&item=linux-417-power
  • Also: https://lkml.org/lkml/2018/4/11/337
Power Management

- Presentations:
  - ELC 2018 An Unbiased Look at the Energy Aware Scheduler (EAS) – by Vital Wool
    - Qualcomm has their own big.LITTLE scheduler (QHMP)
    - QHMP does better than EAS in some regards
      - But cannot be mainlined (code is messy)
    - Want to use features of QHMP in EAS, which still has shortcomings
Real Time

- RT-Preempt patches give good real-time performance
- RT-Preempt patch still out of tree
  - What’s left:
    - Hotplug locking
    - Timer wheel rework
    - dentry cache locking
  - Lots work goes into maintaining RT trees out-of-mainline
    - Don’t support every kernel release
    - Focused on supporting kernel LTS releases
Real Time (cont.)

• Presentations
  • ELC 2018 Steering Xenomai into the Real-Time Linux Future – Jan Kiska
  • ELC 2018 Not Really, but Kind of Real Time Linux – Sandra Capri
    • Discusses how much RT performance you can get, without Preempt-RT patches
  • ELC 2018 Preempt-RT Raspberry Pi Linux – Tiejun Chen
    • Demonstrates the Preempt-RT is very effective on Raspberry Pi
  • ELC 2018 Maintaining a Real Time Stable Kernel – by Steven Rostedt
Security (review)

• Spectre and Meltdown
  • Break security via side-channel timing attacks using speculative execution
  • Variants 1, 2 (Spectre), and 3 (Meltdown)

• Is a family of vulnerabilities related to speculative execution
  • Many modern processors vulnerable
    • Many embedded processors not affected

• Very severe problem:
  • Can read data you’re not supposed to
  • Vulnerability has existed for 20 years!
  • Cannot be fixed with CPU firmware updates
  • Mitigations are expensive
Security

- New Spectre variants
  - Variant 3a – Rogue System Register Read
  - Variant 4 – Speculative Store Bypass
- No surprise
  - We were expecting new variations of speculative execution vulnerabilities to be discovered
- Fixes are:
  - More microcode updates for Intel processors
  - Kernel patches to use new speculative execution control flags
- See https://lwn.net/Articles/755114/
Security Presentations

• ELC 2018 Secure Boot from A to Z – by Quentin Schulz and Mylune Josserand
  • Overview of secure boot techniques and issues

• ELCE 2017 Security Features for UBIFS – by Richard Weinberger
System Size

- No new kernel features
- Presentations
  - ELC 2018 Poky-tiny and Beyond, or Trying to put Yocto in Yocto Project – by Scott Murray
    - Gives status of poky-tiny project, available for Yocto Project
  - ELC 2018 BoF: Embedded Linux Size – By Michael Opdenacker
    - Great overview of reduction techniques and status
      - Toybox and musl (smaller libc) are worth looking at
      - Long list of things that can be worked on
Testing

- Kselftest
- Fuego
- Kernelci.org
- LKFT

Work to make ‘next’ more testable
Kselftest

- Nothing new, here is older stuff...
- Unit test system inside kernel source tree
- Recent work:
  - -silent option, to reduce output clutter
  - Support for O= option, to build outside source directory
  - 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)
- See https://lwn.net/Articles/737893/
Fuego

- Test Framework for collaborating on tests and test infrastructure for Linux
- v1.3 released May 2018
  - More report output formats (rst, csv, excel, html, pdf)
  - Hardware board control
  - Test phase execution
- Tests being added on a consistent basis
  - 18 new tests in 1.3 release (some are self-tests)
    - 7 are realtime tests
- Presentation:
  - Japan Jamboree 63: Fuego Status and Roadmap December 2017 – by Tim Bird
  - upcoming: ALS 2018 by Tim
Kernelci.org

- Does continuous build/boot testing of kernel
  - Builds 126 trees continuously, then reports any errors
- Working on creating a project in Linux Foundation (more later)
LKFT

- Linux Kernel Functional Testing
  - Relatively new Linaro kernel testing effort
  - Focused on Functional testing (as opposed to build/boot testing)
  - Focused on embedded devices

- Presentation:
  - ELC 2018 *Keeping Up With LTS: Linux Kernel Functional Testing (LKFT) on Devices* – Thomas Gall
Making ‘next’ more testable

• Linux-next is the integration tree used during the kernel release cycle
• It’s hard to test, because things break a lot
  • Automated testing doesn’t work
• Stephen Rothwell (the ‘next’ maintainer) created a ‘fixes’ branch
  • Isolates fixes intended for next release, from other code being integrated into ‘next’
    • Should not break automated testing rigs as much
• Result: fixes will get more testing in ‘next’
Toolchains

- gcc 8
  - Major effort on usability improvements
  - Provides much better messages for some errors
  - Shows fix-it hints
    - Shows what to change to fix the error
    - Can be automatically processed
  - Detects missing include files, saying which files are needed
  - See https://lwn.net/Articles/749450/, and
  - https://developers.redhat.com/blog/2018/03/15/gcc-8-usability-improvements/
Toolchains (cont.)

- Support for Linux-based ARM systems by “Arduino Create” developer tool
  - Arduino sketches can be deployed to Linux devices like BeagleBone and Raspberry Pi, through the cloud
  - See ELC 2018 Keynote *Arduino & Linux: A Love Story* - by Massimo Banzi
Tracing

• Nothing new, here is older stuff...
• Dynamic function tracing events
  • Ability to create a tracepoint for a function at runtime
  • Goal is to avoid having a tracepoint become part of kernel ABI
    • Is work-in-progress
  • See https://lwn.net/Articles/747256

• Presentations:
  • ELC 2017 Dynamic Tracing Tools on ARM/AArch64 Platform: Updates and Challenges - by Hiroyuki Ishii
    • Great overview of Linux tracing capabilities and programs
Miscellaneous

- Year 2038 work
- FreeRTOS switched to MIT license
- Git protocol version 2
- Android kernel status
Year 2038 work

- Status update:
  - Lots of small driver fixes in 4.16
  - Changes to system call entry points for timekeeping relate syscalls
  - Patches for structures with new 64-bit timestamps have been submitted
  - Still need more work converting the VFS layer
  - Lots of stuff intended to land in 4.18

- See https://www.mail-archive.com/linux-kernel@vger.kernel.org/msg1674216.html
FreeRTOS license change

- FreeRTOS switch to MIT license
  - Richard Barry started working for Amazon last year
  - Amazon released FreeRTOS version 10 with MIT license
    - Removed GPL v2 (with extra clauses)
    - Added branding “fair use” clause to MIT
  - See https://lwn.net/Articles/740372
New git protocol (version 2)

- 3x performance improvement for no-op fetches on repositories containing 500k references.
- 8x reduction of overhead bytes sent from server
  - Due to filtering references to those the client expressed interest in
- Worked on by Google
Android kernel status

• Progress being made
• diff from 4.14 Android and LTS
  • 432 files, 41K changes
  • sdcard, netfilter, Energy Aware Scheduling, USB gadgets
• Linaro doing android mainline tracking
  • Test Android-common patches on latest mainline Linux
• ELC 2018 Android Common Kernel and Out of Mainline Patchset Status – by Amil Pundar
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**
  - Working on building Debian with Yocto Project
  - 3 projects - meta-debian, isar and elbe wish to collaborate and combine their yocto recipes into a single layer.

- **Next steps**
  - Continued integration of Debian-based build and packaging systems
Long Term Support Initiative

- LTSI 4.9 is current LTSI kernel
  - Work is in progress on next release 4.14
- Most of industry is using LTS or LTSI
- Using upstream-first policy for patches
- Security fixes are very important
- Presentation:
  - ELCE 2017 Using Long Term Stable Kernel for the Embedded Products – by Tsugikazu Shibata
## Long Term Stable Releases

<table>
<thead>
<tr>
<th>Version</th>
<th>Maintainer</th>
<th>Released</th>
<th>Projected EOL</th>
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<tbody>
<tr>
<td>3.16</td>
<td>Ben Hutchings</td>
<td>2014-08-03</td>
<td>Apr, 2020</td>
</tr>
<tr>
<td>4.1</td>
<td>Sash Levin</td>
<td>2015-06-21</td>
<td>May, 2018</td>
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<td>4.4</td>
<td>Greg Kroah-Hartman</td>
<td>2016-01-10</td>
<td>Feb, 2022</td>
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<td>4.9</td>
<td>Greg Kroah-Hartman</td>
<td>2016-12-11</td>
<td>Jan, 2019</td>
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<tr>
<td>4.14</td>
<td>Greg Kroah-Hartman</td>
<td>2017-11-12</td>
<td>Jan, 2020</td>
</tr>
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Fuego - Linux Test Framework

• CELP funding for Fuego self-test project
• Fuego now has an integrated release test
  • A Fuego job to build the Fuego docker container from scratch, and test it
  • Includes tests of user interface using Selenium and Chromium
    • This adds packages to base Fuego distribution for doing this type of web-based and image-based testing
• Work completed by ProFusion Embedded Systems
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
eLinux wiki

- Recent topics
  - Board farm and automated testing pages
  - Lots of Renesas board information
  - Developer guidelines
  - Community Doc Translation
  - Event pages (ELC, Jamboree, and others)
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• Trade associations
• Conferences
• Legal issues
• Community issues
• Industry changes
Trade associations

- Linux Foundation
  - Possible creation of Kernel Testing project
  - KernelCI developers working on getting new hosting
    - Project is underfunded by Linaro
  - Project may expand scope (remains to be seen)
Conferences

- Embedded Linux Conference 2018
  - March 12-14, Portland, Oregon, USA
  - See [https://elinux.org/ELC_2018_Presentations](https://elinux.org/ELC_2018_Presentations)
    - Did really good at collecting slides and videos
- Japan Jamborees
  - Continuing
- Open Source Summit Japan/Automotive Linux Summit
  - June 20-22, Tokyo, Japan
- Fuego Jamboree #2
  - June 23, Tokyo, Japan
- ELC Europe 2018
  - October 22-24, Edinburgh, Scotland
- Automated Testing Summit
  - October 25, Edinburgh, Scotland
Legal issues

- McHardy withdraws suit against Geniatech in Germany
- Geniatech fought back, with arguments:
  - Suit scope is too broad (covered all kernel versions, not just ones McHardy had contributed to)
  - Did not show that his commits fulfilled requirements for copyright protection
  - Did not show which of his commits were used by Geniatech
  - McHardy is not following community norms, with regard to GPL revocation terms
  - McHardy is approaching multiple companies for monetary gain
Legal issues (cont.)

- McHardy withdrawal – lessons learned:
  - Don’t sign the cease-and-desist declaration
  - Ensure GPL compliance
  - Prepare a legal defense strategy
    - Geniatech arguments seem sound, and can be used elsewhere
- Community wants to fight McHardy, but still allow for proper legal enforcement of GPL
- See [https://lwn.net/Articles/752485/](https://lwn.net/Articles/752485/)
- Details: [http://laforge.gnumonks.org/blog/20180307-mchardy-gpl/](http://laforge.gnumonks.org/blog/20180307-mchardy-gpl/)
Community issues

- Complaints about abusive maintainers in the Linux Community
  - Tim gave talk at ELC about maintainers, and handling negative communication
    - ELC 2018 *The Maintainer’s Paradox* – by Tim Bird
- Linux Foundation TAB is looking at issue
  - Working on Kernel developers guide, covering some social issues
Industry changes

• Intel selling Wind River
  • Not sure what this means for Yocto Project
  • Intel has discontinued Edison, Galileo and Joule
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Resources

- LWN.net
  - http://lwn.net/
  - If you are not subscribed, please do so
- Kernel Newbies
  - http://kernelnewbies.org/Linux_4.??
- Phoronix
  - https://www.phoronix.com/
- eLinux wiki - http://elinux.org/
  - Especially http://elinux.org/Events for slides and videos
Thanks!