Status of Embedded Linux
September 2018

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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 v4.14 – 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
- Linux v4.17 – 3 Jun 2018 – 63 days
- Linux v4.18 – 12 Aug 2018 – 70 days
- Now on Linux v4.19-rc5
  - Author: Greg Kroah-Hartman
  - Expect 4.19 on Oct 21
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
  - repolines
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
  - This is a problem for some architectures where gcc has dropped support
  - But there’s a workaround:
- Changes to x86 system call implementation
Linux 4.18

- power domains now support active state management
  - Instead of enable/disable, can now handle different idle states (continuum of operation)
  - https://lwn.net/Articles/744047/

- fscrypt supports Speck128 and Speck256 ciphers
  - Somewhat controversial ciphers
  - Enables encryption for lowest-end devices

- bpfilter user mode helper system
  - https://lwn.net/Articles/755919/
bpfilter user mode helper

- Complicated mechanism to:
  - compile user space code
  - from the Linux source tree
  - bundled in a kernel loadable module file (.ko)
  - with execution initiated from kernel space

- Used to provide support for backwards compatibility with netfilter configuration protocol
  - user-space ‘program’ to compile netfilter config protocol into bpf pseudo-code

- As a mechanism, may lead to all kinds of crazy stuff
Linux 4.18 (cont.)

- Support for Qualcomm Snapdragon 845
  - Use in high-end mobile devices
  - Support is incomplete, but it’s a start
Linux 4.19 (expected)

- L1TF mitigation (a variant of meltdown)
  - [https://lwn.net/Articles/762570/](https://lwn.net/Articles/762570/)
  - The fun continues...
- time-based packet transmission
  - Allows a program to schedule data for transmission in the future
  - [https://lwn.net/Articles/748879/](https://lwn.net/Articles/748879/)
- EROFS – enhanced read-only filesystem
  - High-performance
  - Good for certain embedded situations
  - (in staging)
Contributor stats for 4.18

- 12,879 changes sets (as of rc6)
- 553K lines added, 652K lines removed
- 1668 developers
  - 226 made their first contribution

Source: https://lwn.net/Articles/760690
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Bootup Time

- Nothing new, here is older stuff...
- Analyze_boot tool – new 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
    - Implementation is in-progress
- 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
      • See https://www.phoronix.com/scan.php?page=news_item&px=F2FS-Lost-Found
  • Support for disk quotes (4.13, 4.15)

• BTRFS and Squashfs support for zstd compression (4.14)
  • Faster and smaller compression/decompression
    • https://clearlinux.org/blogs/linux-os-data-compression-options-comparing-behavior
    • See https://www.phoronix.com/scan.php?page=news_item&px=Linux-4.14-Zstd-Pull
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_txttime option for high-resolution transmit time
  • IEEE deterministic networking (DetNet) working group
    • Lots of standards

• Time-based packet transmission
  • Allows a program to schedule data for transmission in the future
  • [https://lwn.net/Articles/748879/](https://lwn.net/Articles/748879/)

• 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
  - See

- Power domain state management (4.18)
  - Instead of enable/disable, can now handle different idle states (continuum of operation)
  - https://lwn.net/Articles/744047/
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 that 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
- New Meltdown variant
  - L1TF – L1 Cache terminal fault vulnerability
- 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 the 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
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/
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
- 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 related 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
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
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Projects and initiatives

- Shared Embedded Distribution
- LTSI
- Automated Testing
  - Fuego
  - Automated Test Standards
- 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
    - 4.14.70-ltsi-rc1 is now available
- 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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<tr>
<td>3.16</td>
<td>Ben Hutchings</td>
<td>2014-08-03</td>
<td>Apr, 2020</td>
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<tr>
<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>
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<td>4.19</td>
<td>Greg Kroah-Hartman</td>
<td>2018-??</td>
<td>TBD</td>
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Source: https://www.kernel.org/category/releases.html
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
Automated Testing Standards

• CELP is a sponsor of the Automated Testing Summit
  • Summit of test framework architects
  • Goal is to increase collaboration between projects
• Survey of test frameworks
  • See https://elinux.org/Test_Stack_Survey
• Discussions on:
  • automated-testing@yoctoproject.org
• Development of Test Stack model
  • Kevin Hilman (kernelci) and Tim Bird (Fuego)
Continuous Integration Loop
(high level diagram)
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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- Community issues
- Trade associations
- Conferences
- Legal issues
- Industry changes
Community issues

- Linus takes a break!!
- New Code of Conduct for the kernel community
Linus takes a break

• Linus announced on Sept. 16 (4.19-rc4) that he’s taking a break
• Made an apology for “flippant attacks in emails that have been both unprofessional and uncalled for”
• Announced that Greg Kroah-Hartman will take his place for 4.19 release cycle
• See
  • https://lkml.org/lkml/2018/9/16/167
  • https://lwn.net/Articles/765108
Linus’ break (cont.)

• Linus says he’s not burnt out, but will be back
• Needs time to reflect
• Is seeking help on how to behave differently
  • BBC article: Linus Torvalds: “I’ll never be cuddly but I can be more polite”
• Will be at Maintainer’s Summit in Edinburgh (October 22)
New Code of Conduct

- Linus also accepted a patch from GregKH that replaces the “code of conflict” with a new “Code of Conduct”
- Based on widely used Contributor Covenant (version 1.4)
- Lots of discussion in community about CoC
  - Concern over new responsibilities for maintainers
  - Uncertainty over enforcement policies
  - https://lwn.net/Articles/766699/ (likely still paywalled)
    - Ask, and I can forward a link; it will be free-to-view in a week
Trade associations

- Linux Foundation
  - Possible creation of KernelCI 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

- **ELC Europe 2018**
  - October 22-24, Edinburgh, Scotland

- **Automated Testing Summit**
  - October 25, Edinburgh, Scotland
ELCE 2018 topic clusters

- Kernel drivers
  - Camera, Audio, others
- Testing
- Yocto Project
- Security
- Bootloader
- Virtualization
- Realtime
- Networking
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/

• Details: http://laforge.gnumonks.org/blog/20180307-mchardy-gpl/
Industry changes

• Intel selling Wind River (March 2018)
  • Not sure what this means for Yocto Project
  • Intel has discontinued Edison, Galileo and Joule

• Microsoft acquires github (June 2018)
  • https://techcrunch.com/2018/06/04/microsoft-has-acquired-github-for-7-5b-in-microsoft-stock/
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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!