Status of Embedded Linux
November 2018

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181130_1306
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 v4.15 – 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
- Linux v4.19 – 22 Oct 2018 – 71 days
  - Author: Greg Kroah-Hartman
- Now on Linux v4.20-rc4
  - Expect 4.20 on Dec 23
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
Linux 4.16 – cont.

- 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 slowly
  - 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
  - code runs in a user-space process
  - communicates via two pipes

Backwards compatibility with netfilter
- compiles iptable rules to BPF
- As a mechanism, may lead to all kinds of crazy stuff
Support for Qualcomm Snapdragon 845
- Use in high-end mobile devices
- Support is incomplete, but it’s a start
Linux 4.19

• L1TF mitigation (a variant of meltdown)
  • 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/
• EROFS – enhanced read-only filesystem
  • High-performance
  • Good for certain embedded situations
  • (in staging)
Linux 4.19 - cont.

- block I/O latency controller
  - regulates latency instead of bandwidth
  - https://lwn.net/Articles/758963/
- Common Applications Kept Enhanced (CAKE) queuing discipline
  - devices behind consumer-level routers on relatively slow broadband links
  - https://lwn.net/Articles/758353/
Linux 4.19 - cont.

- new asynchronous polling interface
- yet another API, not a replacement for existing APIs
- https://lwn.net/Articles/743714/
- https://kernelnewbies.org/Linux_4.19#New_asynchronous_I.2FO_polling_interface
Linux 4.20 (expected)

- C-SKY processor architecture support
- XArray data structure
  - a reworking of the radix tree structure
  - the page cache has been converted to use it
  - https://lwn.net/Articles/745073/
  - https://linuxplumbersconf.org/event/2/contributions/259/
- PCI subsystem support of peer-to-peer DMA operations between peripherals (P2PDMA)
  - https://lwn.net/Articles/767281/
Linux 4.20 (expected) - cont.

- Many block drivers converted to multiqueue API
- Plan to remove the legacy API in the next development cycle
- https://lwn.net/Articles/552904/
Linux 4.20 (expected)

- new filesystem mounting API
  - https://lwn.net/Articles/759499/
Contributor stats for 4.19

- 14,043 non-merge commits
- 552K lines added, 245K lines removed
- 307K more lines added than removed*
- 1710 developers
  - 253 made their first contribution

Source: https://lwn.net/Articles/767635
Outline

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Bootup Time

- Nothing new, here is older stuff...
Device Tree

• Device Tree validation
  • Schema for binding language, validator for bindings and for device tree data
  • Patches from Rob Herring under review
  • Expect change to require bindings in new format
  • YAML encoded output format option for dtc

• dtc compiler build checks
  • 19 commits add warnings since February 2017

• Device Tree specification replaced ePAPR
Device Tree - cont.

- Size reductions
  - `dtc` deletes unreferenced nodes annotated with: `/omit-if-no-ref/`
  - reduce size of `struct device_node`
    - eg `full_name` no longer includes node path
      - use `%pOF` for warnings and errors
    - field removal savings only if not using overlays
  - Nicolas Pitre report of a test case:
    - went from 118072 bytes down to 11732 bytes
  - [https://elinux.org/images/e/e0/Size-kernel-fdt.pdf](https://elinux.org/images/e/e0/Size-kernel-fdt.pdf)
Overlays

- Quit hand coding overlay metadata:
  - fragment nodes, ___*___ nodes
  - dtc will generate the metadata
- U-Boot support to apply overlays
  - more robust than run time overlay apply
- memory leak checks added, with ERRORs and WARNINGs
File Systems

- EROFS – enhanced read-only filesystem (4.19)
  - High-performance
  - Good for certain embedded situations
  - (in staging)
  - expect on-media format to change
File Systems - cont..

- 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
Graphics

- Nothing new, here is older stuff...
- Working on support for virtual reality
  - LCA 2018 *Driving Virtual Reality from Linux* - Keith Packard
GPU drivers

- Nothing new, here is older stuff...
- ELC 2018 *Progress in the Embedded GPU Ecosystem* – by Robert Foss
  - Watch the video – the slides don’t have enough text
  - Nvidea, 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 RoadTowards a Linux TSN Infrastructure* – Jesus Sanchex-Palencia
- 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
Networking - cont.

• experimental support for future 802.11ax standard
  • also known as: Wi-Fi 6
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
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 - cont.

- Spectre and Meltdown
  - Patches continue to dribble in
    - x86, ARM64, PowerPC
    - generic code, from gcc warnings
Real Time / Security

- ELCE 2018 Spectre and Meltdown vs. Real-Time: How Much do Mitigations Cost?
  - Ralf Ramsauer
  - Jan Kiszka
  - Wolfgang Mauerer
Security Presentations.

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

- See Devicetree.
- 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...
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, reports any errors
- Working on creating a project in Linux Foundation (more later)
- 10 labs with 250 boards and 37 SoCs being tested
- Has done 4,000,000 boots
- Added Auto-bisection
- Adding post-boot testing
- [https://lwn.net/Articles/772525/](https://lwn.net/Articles/772525/)
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.

- minimum version changed to gcc 4.6
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
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
  • See https://opensource.googleblog.com/2018/05/introducing-git-protocol-version-2.html
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
Android kernel status - cont.

- Bringing the Android kernel back to the mainline
  - Summary of Linux Plumbers talk
  - https://lwn.net/Articles/771974/
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Projects and initiatives.

- Shared Embedded Distribution
- LTSD
- Automated Testing
  - Fuego
  - Automated Test Standards
- eLinux wiki
Long Term Support Initiative

- LTSI 4.14.75-ltsi is current LTSI kernel
  - https://ltsi.linuxfoundation.org/software/releases
- Most of industry is using LTS or LTSI
- Using upstream-first policy for patches
- Security fixes are very important
- Presentation:
  - ELCE 2018 Technical Showcase poster: Longterm Embedded Linux: Testing & Field Update - Pengutronix
## Long Term Stable Releases

<table>
<thead>
<tr>
<th>Version</th>
<th>Maintainer</th>
<th>Released</th>
<th>Projected EOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.16</td>
<td>Ben Hutchings</td>
<td>2014-08-03</td>
<td>Apr, 2020</td>
</tr>
<tr>
<td>4.4</td>
<td>Greg Kroah-Hartman</td>
<td>2016-01-10</td>
<td>Feb, 2022</td>
</tr>
<tr>
<td>4.9</td>
<td>Greg Kroah-Hartman</td>
<td>2016-12-11</td>
<td>Jan, 2023</td>
</tr>
<tr>
<td>4.14</td>
<td>Greg Kroah-Hartman</td>
<td>2017-11-12</td>
<td>Jan, 2020</td>
</tr>
</tbody>
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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

• Automated Testing Summit after ELCE
  • https://elinux.org/Automated_Testing_Summit
    • minutes, slides, videos, action items
  • see https://lwn.net/Articles/771782

• First standards by summit attendees will be:
  • test definition
  • results format
  • test execution API

• Discussions on:
  • automated-testing@yoctoproject.org
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 13 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)
  - Test resources.
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Other Stuff

- 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”
- Attended Maintainer’s Summit in Edinburgh (October 22)
- He is back: 4.20 merge window.
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
    - led to deletion of some maintainer responsibilities
  - Uncertainty over enforcement policies
New Code of Conduct

- Patch from GregKH added an interpretation document
  - Documentation/process/code-of-conduct-interpretation.rst
  - Documentation/process/code-of-conduct.rst
- Discussion in community continued
  - https://lwn.net/Articles/765108/
  - https://lwn.net/Articles/766699/
- Discussion: Maintainers Summit
  - https://lwn.net/Articles/769117/
- Discussion: Linux Plumbers conference
  - https://lwn.net/Articles/772565/
Trade associations

- Linux Foundation
  - Possible creation of KernelCI Testing project
  - KernelCI developers working on getting additional sponsors for project
  - 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
    - Did really good at collecting slides and videos
- Japan Jamborees
  - Continuing
- Open Source Summit Japan/Automotive Linux Summit
  - June 20-22, Tokyo, Japan
Conferences - cont.

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

- **Automated Testing Summit**
  - October 25, Edinburgh, Scotland
  - [https://elinux.org/ATS_2018_Minutes](https://elinux.org/ATS_2018_Minutes)
ELCE 2018 topic clusters.

- Kernel drivers
  - Camera, Audio, others
- Testing
- Yocto Project
- Security
- Bootloader
- Virtualization
- Realtime
- Networking
Conferences - 2019.

- **Embedded Linux Conference 2019**
  - **August** 21-23, San Diego, California, USA
- **Japan Jamborees**
  - Continuing
- **Open Source Summit Japan/Automotive Linux Summit**
  - July 17-19, Tokyo, Japan
- **ELC Europe 2019**
  - October 28-30, Lyon, France
- **Linux Plumbers**
  - November 8-11, Lisbon, Portugal
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/](https://techcrunch.com/2018/06/04/microsoft-has-acquired-github-for-7-5b-in-microsoft-stock/)
Industry changes - cont.

- IBM to acquire Red Hat
  - [https://lwn.net/Articles/769762/](https://lwn.net/Articles/769762/)
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!