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
- Some overlap with material given previously
  - I may go quickly over some older slides
- Not comprehensive!
  - Just stuff that I saw
Outline

Linux Kernel
Technology Areas
Conferences
Industry News
Resources
Outline

Linux Kernel
Technology Areas
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Industry News
Resources
Kernel Versions

- Linux v5.6  –  29 Mar 2020  –  63 days
- Linux v5.7  –  31 May 2020  –  63 days
- Linux v5.8  –  2 Aug 2020  –  63 days
- Linux v5.9  –  11 Oct 2020  –  70 days
- Linux v5.10  –  13 Dec 2020  –  63 days
- Linux v5.11  –  14 Feb 2021  –  63 days
- Linux v5.12-rc2 = current kernel this week
  • Expect 5.12 on April 18, 2021
Kernel Versions

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- Linux v5.11 – 14 Feb 2021  –  63 days
- Linux v5.12-rc2 = current kernel this week
  - Expect 5.12 on April 18, 2021
  - v5.12 merge window delayed a few days due to power outages related to a winter storm in Oregon
Kernel Versions

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Note: There’s no discernable impact from COVID-19
WireGuard VPN feature added to kernel
Work on 2038 issues for ALSA
  • New 64-bit structure for some operations
Mechanism to disable SELinux at module load time (system runtime) is deprecated
  • Plan is to add a painful delay (increasing with each kernel release) in order to discourage future use
Bootconfig tool to add super-long command-lines arguments to kernel
F2FS gained support for compression
• Pointer authentication and return-address signing added for ARM64
• Thermal events can effect scheduling
  • scheduler takes into account thermal status and tries to reduce load on hot CPUs
  • https://lwn.net/Articles/788380/
• exFAT fs module in staging was removed
  • Replaced with a new version better integrated into existing filesystem subsystem
    • New version contributed by Samsung
• Kunit results can now be output on debugfs
Linux v5.7 (cont.)

- BPF and PREEMP_RT can now coexist
- LLVM support integrated into kernel build system
  - Can use LLVM=1 on make command line
    - May also need LLVM_IAS=1 as well to use LLVM assembler
Linux v5.8  (Aug 2020)

- Inline encryption for filesystems (more later)
- kgdb can now work with the boot console
  - Allows debugging earlier in the boot process
- A new generic kernel event notification system was added (more on this later)
new debugfs= command line option allows disabling debugfs (using ‘off’)
  • To avoid disclosing sensitive data
  • Or, it can be left enabled but not mountable with (‘no-mount’)
    • Data can still be read with a debugger

Removed uninitialized_var() macro

initrd is deprecated (in favor of initramfs, which everyone calls initrd)

close_range() – new syscall to close a group of file descriptors
Linux v5.10  (Dec 2020)

- static calls patches finally merged
  - Allows for indirect call that can be updated at runtime (via static_call_update())
    - Good for tracing, and maybe other stuff
  - See https://lwn.net/Articles/774743/#static

- printk has a new lockless ring buffer
  - Part of a long-term overhaul of printk
  - See https://lwn.net/Articles/800946/

- ext4 filesystem has a new “fast commits” mode (more on this later)
Linux v5.11  (Feb 2021)

- New system-call interception mechanism based on prctl()
  - Used for emulating Windows system calls
  - See https://lwn.net/Articles/826313/
- epoll_pwait2() – new syscall that supports nanosecond timeouts
- Ability to disable process migration between CPUs (more on this later)
• Support for oprofile removed
  • superceded by perf events
• “PREEMPT_DYNAMIC” allows selecting preemption mode at boot or run time
• Dynamic thermal power management
  • Allow power usage of groups of devices to be capped to meet thermal constraints
• Support for Playstation DualSense game controllers (yeah Sony!)
Linux v5.12 (cont.)

- Build system can use Clang’s link-time optimization (LTO) features on ARM64 and x86 architectures
- kfence memory debugging tool has been added
- Some new perf-events features:
  - Can report on instruction latency
  - Daemon mode for long-running sessions
  - See https://git.kernel.org/pub/scm/linux/kernel/git/torvalds/linux.git/commit/?id=3a36281a1719
Drama in the 5.12 merge window

- Linus marked rc1 as “don’t use”, because it had a bug that could corrupt your filesystem
  - Had to do with a bad offset in a swapfile
    - swap partitions were OK, which is what most people use (but Phoronix and Intel saw it in test systems)
    - It’s bad to mess up people’s filesystems, even for a release-candidate kernel
  - Don’t use Linux version “v5.12-rc1-dontuse”
- Problem was quickly fixed
  - [https://lwn.net/Articles/848431/](https://lwn.net/Articles/848431/)
  - “Occasionally, though, something goes wrong, giving early testers reason to reconsider their life choices”
# Interesting Maintainer stats

- What companies are employing maintainers?
  - The top 5 employers supporting maintainers
    - That is, developers with non-author commit signoffs

<table>
<thead>
<tr>
<th>Employer</th>
<th>Non-author sign-offs</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Hat</td>
<td>2560</td>
<td>19.3%</td>
</tr>
<tr>
<td>Linaro</td>
<td>1377</td>
<td>10.4%</td>
</tr>
<tr>
<td>Intel</td>
<td>986</td>
<td>7.4%</td>
</tr>
<tr>
<td>Linux Foundation</td>
<td>878</td>
<td>6.6%</td>
</tr>
<tr>
<td>Google</td>
<td>787</td>
<td>5.9%</td>
</tr>
</tbody>
</table>

- Almost half of all patches go through gatekeepers at just 5 companies

**Table data:**
https://lwn.net/Articles/821813/
Active Contributors

• For 5.11 kernel, top contributors seem to be trending towards hardware companies:
  • Top 13 = Intel, Linaro, Red Hat, AMD, Huawei, Google, SUSE, IBM, NVIDIA, Facebook, ARM, Samsung, NXP
    • Side note: MediaTek had 19K lines of changes in 5.11

• Top individual contributors by sub-system in last year:
  • kernel: Paul McKenney, Peter Zijlstra, Christoph Hellwig
  • mm: Christoph Hellwig, Matthew Wilcox, David Hildenbrand, Wei Yang
  • fs: Pavel Begunkox, Christoph Hellwig, Jex Axboe, Darrick Wong
  • net: Chuck Leve, Christoph Hellwig, Paulo abeni, Florian Westphal

• See https://lwn.net/Articles/845831/ for details
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Linux Foundation
OSS Contributor Survey
 LF Contributor survey

• Survey conducted by 2 organizations:
  • Open Source Security Foundation
    • More on them later
  • Laboratory for Innovation Science at Harvard

• Produced report in December, 2020
  • Can access report at:
    • https://www.linuxfoundation.org/blog/2020/12/download-the-report-on-the-2020-foss-contributor-survey

• 1866 responses, some only partial
  • Analysis come from answers from 1196 respondents
Contributor survey (cont.)

Key findings:

- Employment status:
  - 75% contributors are employed full time
  - 52% are paid specifically to develop FOSS
- Top contributor motivations are non-monetary
  - Needed the feature or fix
  - Enjoyment of learning
  - Desire for creative or enjoyable work
Contributor survey (cont.)

Key findings (cont.)
- Only 2.27% of time is spent on security issues
- 48% are paid by employer to contribute
  - But what happens if employer interest wanes?
- 45% of respondents state they are free to contribute to FOSS without asking permission
  - Up from 35% 10 years go
- 17% say their companies have unclear contribution policies
- 6% are unaware what company polices are (if any)
Outline

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Technology Areas

- Audio
- Core Kernel
- Development
- Filesystems
- Graphics

- Networking
- Security
- Testing
- Toolchains
- Tools
Audio

- ASOC (ALSA System on Chip)
  - Kernel subsystem to provide better ALSA support for SoC and portable audio codecs

- Good talk at ELC with overview of ASOC, hardware, protocols and issues:
Core Kernel

- New event notification system (watch_queue?)
  - Is fairly simple
    - Uses a regular Unix Pipe
    - Described by one developer as “a breath of fresh air”
  - Avoids polling by clients
  - Avoids dependency on networking code
    - Avoids netlink ("Friends don’t let friends use netlink")
  - May replace other notification systems in future
    - For now, only used for keyring notifications
  - See https://lwn.net/Articles/760714
  - See Documentation/watch_queue.rst (in 5.8 kernel) for latest API details
**Development**

- New tools are being used for upstream kernel work (especially ‘b4’):
  - e-mail workflow of Linux kernel often has issues
    - Some e-mail clients and servers mangle the data
  - b4 supports doing patch management outside of e-mail
    - Acquire a patch series from lore.kernel.org, and use git to apply it
  - See “Kernel Email Tools” talk by Frank Rowands at ELCE 2020
Filesystems

- F2FS gets more compression options
  - LZ4 “high compression” mode is supported (v5.12)
  - `compress_mode=` option for whether kernel or user-space controls compression
    - New ioctl to give user-space control over which files are stored in compressed form

- io_uring continues to mature
  - As a reminder: see https://lwn.net/Articles/810414/
  - Supports `tee()` system call (v5.8)
  - Asynchronous buffered reads without using kernel threads (v5.9)
  - Integrated with memory control groups for better accounting and regulation (v5.12)
Filesystems (cont.)

- Ext4 fast commits (v5.10)
  - Introduces a 2nd “fast commit” journal
    - Holds changes since the “standard commits” journal was updated
  - Fast commit journal has file-level data
    - Omits block data and data that can be recreated from other sources
      - Reduces the amount of data that needs to be saved
  - Fast commits cannot be performed for all ops
    - Falls back to a “standard commit” in this case
  - During recovery, standard commits are replayed by journaling layer, then fast commits are replayed by the filesystem
  - Big performance improvement! (20%-200%)  
    - See https://lwn.net/Articles/842385/
Graphics

• Good talk on using Flutter in Embedded Systems
  • Flutter + Wayland is better for embedded products
    • Wayland is now supported on many SoCs
      • Lighter weight than X11
  • Flutter supports cross-platform development, but with native code (generated from DART language)
  • Fewer library dependencies (only need OpenGL/EGL)
  • Easy license (BSD-3)
• Watch the presentation later in this jamboree
Networking

- Precision Time Protocol and packet timestamping in the Linux kernel
  - PTP is used for synchronizing clocks between machines
  - Requires accurate timestamps, applied as closely to packet transmission as possible
  - Can use “ethtool –T” to turn on kernel-level timestamping in the network stack
    - Can use a high-precision hardware clock (PHC), or something in software, for timestamps
  - Can use ‘ptp4l’ and ‘phc2sys’ user-space commands to manage clocks
  - See talk by Antoine Ténart at ELCE 2020
Real-Time

• Can disable process migration between CPUs (v5.11)
  • Good for keeping an real-time process pinned on a particular CPU
  • Turns out to be hard (who knew?)
  • See https://lwn.net/Articles/836503/

• PREEMPT_DYNAMIC allows selecting preemption mode at boot time or run time (v5.12)
  • Can be “none”, “voluntary”, or “full”
  • There’s an option under debugfs for controlling the mode at run time
Security

- Wireguard VPN
- Inline encryption for filesystems
WireGuard VPN tunnel

- Faster and simpler than Ipsec and OpenVPN
  - Added in kernel v5.6
- Aim is to be as easy to use as SSH
  - Simple generation of public/private key pairs
  - Similar mode of distribution for public keys
- Uses Linux ip commands to set up tunnel
- Allows roaming by both sides of tunnel
- Uses state-of-the-art cryptography
  - High-speed cryptography, suitable for embedded
- Amenable to security audits
  - Due to much simpler code base
Inline encryption for filesystems

- Allows kernel to offload encryption and decryption to the storage device
- Normally, encrypted filesystem has lots of overhead
  - On main CPU or in crypto hardware and busses as data is copied multiple times
- This is faster
  - Kernel manages setup, then storage device handles cryptography
- Kernel can also validate that encryption worked as expected
- See https://lwn.net/Articles/797309/
  - Added in v5.8
Tracing

• New Bootconfig system
  • Extra boot configuration
  • Allows passing a large set of options to the kernel during boot
    • Was not a good fit for device tree
  • Passes a tree-structured key-value list
  • Data is loaded with initrd
  • Used primarily to pass kernel command line items for ftrace and early tracing
  • Mainlined in 5.6
  • See https://lwn.net/Articles/806002/
Testing

- Syzbot fuzzer continues to find an alarming number of bugs
  - Number of unfixed bugs climbs every release
    - Over 2400 open bug reports (just from syzbot)
    - Some were reported years ago
    - Need to be fixing more bugs than we find
Syzbot Upstream Bug Chart

Upstream Bug Stats

unfixed bugs

reported/fixed bugs

3 years

# open bugs

# total reported / fixed
Board Farm REST API

- TimeSys and Sony introduce API concept for hardware testing at ELCE 2020
- Use a web-based (REST) API to manage endpoint for a test (where endpoint is not on the device under test)
  - e.g. serial line, USB endpoint, CAN bus, audio, video (anything not on the DUT)
- Demonstrated simple gpio test at ELCE
- See talk by Tim Bird and Harish Bansal
Toolchains

- Now possible to build full embedded Linux system with Clang (LLVM v10)
  - Can build Linux kernel with Clang (for a while now)
  - Harder to build the distribution
  - There’s a ‘meta-clang’ layer available to do builds in Yocto Project
    - Some individual packages will have problems
      - Still need gcc for glibc (use musl C library instead)
  - Debian clang project (https://clang.Debian.net)
    - 96% of packages build
  - See talk by Khm Raj at ELCE 2020
Great talk on static analysis tools for embedded

- There are lots of great tools available for static analysis (testing of code, without executing it)
  - gcc –fanalyzer, clang scan-build - for kernel
  - meta-sca is a yocto layer with a collection of tools (87 different tools)
  - meta-codechecker is another yocto layer
  - Can analyze a full build and generate a report using Codechecker tool (by Ericsson)

- See talk by Jan-Simon Möller at ELCE 2020
Miscellaneous

- Long term support upgraded to 6 years for two LTS kernels!!
  - 4.19 and 5.4 will be supported for six years instead of two years

- See https://kernel.org/releases.html#longterm
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Conferences – 2020

- Embedded Linux Conference 2020
  - Was planned for June 22-24, Austin, Texas, USA
  - Went virtual with, along with OSS Summit
- Linux Plumbers
  - Virtual in August
- ELC Europe 2020
  - Virtual in October
- Open Source Summit Japan
  - Changed to December, and went virtual
Conferences - 2021

- Embedded Linux Conference North America
  - Canceled (was August in Vancouver)
  - Open Source Summit also canceled
- Embedded Linux Conference 2021
  - September 28-October 1, Dublin, Ireland (???)
  - Venue is booked, but probably wise to wait until summer to make travel arrangement
COVID-19 issues?

• When will conferences no longer be cancelled?
  • ELCE 2021 (in late September) is first LF in-person event on schedule
    • But honestly - it’s still tentative
  • Situation is changing as people get vaccinated
    • However, there are a lot of positive signs

• Events will continue with hybrid style for many months, even after in-person events start
Hybrid Events

• Events will continue supporting virtual access
  • Improvements for virtual attendees
    • e.g. live Q&A during sessions
    • Can also speak virtually, even if event is live
• On-site changes for in-person health consciousness
  • Reduced attendance
  • Social distancing
  • Masks, extra cleaning
  • Changes to format of some event activities
Conferences – misc.

- LF continuing to push for inclusion:
  - Have programs to encourage outreach
  - Diversity training, etc.
- Tux Turns 30 this year! (September, 2021)
  - Would be nice to have some big parties, but we’ll see what happens
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Industry News

- Mergers and acquisitions
- Trade associations
- Interesting cases of embedded Linux
Mergers and Acquisitions

- Nvidia buys ARM from Softbank
  - Softbank bought ARM for $32B in 2016
  - Nvidia buying it for mix of stock and cash
    - Valued at potentially $40B
Trade associations

- Linux Foundation
Linux Foundation

- Financials looking very good despite COVID
- More than 1 new member per day
- Training and mentorship has really ramped up:
  - 2M trainings and exams delivered as of Jan 2021
  - New COBOL training
- LFX tools for managing projects
  - Project insights, security, mentorship, crowdfunding, events, training, control center
  - Some tools online now
  - See https://lfx.dev/
We continue to scale our communities on every level by automating processes, creating innovative developer tools, and focusing on community value.

- **11.7M** Lines of Code Added Weekly
- **9.4M** Lines of Code Removed Weekly
- **208,660** Contributing Developers
- **12,435** Contributing Companies
- **16,618** Repositories
- **9.1M** Commits
- **960,610** Pull Requests
- **1.3M** Builds Monitored
- **859,150** Logged Issues
- **5.2B** Container Downloads
- **1.6M** Group Chat Messages
- **3.6M** Group Email Messages
- **4,532** Scanned Repositories
- **282,342** Open Vulnerabilities
- **62,379** Recommended Fixes
- **36,163** Vulnerabilities Fixed
- **31,496** CLA Contributors
- **26,998** Community Meetings
LF Projects

- Lots of projects being announced and in the pipeline
  - 34 new projects in 1Q21
- Some big initiatives in 2020 and just announced...
  - These listed are just a few
- Public Health Initiative
  - Open source contact tracing
  - Was a big success
    - Started quickly and is already providing code used by Public Health Authorities
A few more initiatives

- **Mobile Native Foundation**
  - Mobile app development and deployment infrastructure for large-scale
  - Both Android and iOS
  - Testing, CI/CD for deployment at large scale
  - See http://mobilenativefoundation.org

- **OpenChain project**
  - OpenChain spec became an ISO 5230 standard
    - Defines standards for open source compliance process

- **SPDX** was also recently approved as an international standard
OpenSSF

- Open Source Security Foundation
- Comprehensive project to enhance OSS security
  - Vulnerability disclosures
  - Security tooling
  - Best practices and training
    - Already have some EdX courses
  - Securing critical projects
- Core Infrastructure Initiative (CII) work is being absorbed into OpenSSF
SigStore

- Supports signing of software, and storing records permanently in a secure, public log
- Software and free service
  - Free to use for individuals and organizations
    - See https://sigstore.dev
- Study of current practices indicated that few projects were signing their releases, and fewer were checking signatures
SigStore (cont.)

• Want to make a system that is:
  • Very easy to use
    • Specifically want to eliminate key management
  • Trustable
• Uses OpenID for authentication, and a public transparency log
• Should be fully available later this year
• Sources:
Interesting embedded Linux

- Starlink satellite constellation
- Mars helicopter
SpaceX Starlink Satellite constellation
SpaceX Starlink Satellite constellation
SpaceX Starlink Satellite constellation

- SpaceX uses Linux in Falcon 9 and Falcon heavy rockets, dragon space capsules, and Starlink satellites
- Each Starlink satellite has over 60 processors running Linux
  - Current satellites in orbit (as of Mar 4) is 1141
  - Which means there are over 70,000 instances of Linux in orbit now
  - SpaceX has requested permission for 42,000 satellites (currently have permission for 12,000)
    - This would be well over 2 million instances of Linux, eventually
Starlink software

- Uses multi-computer voting for fault tolerance
  - Instead of much more costly radiation-hardened processors
- Uses a mostly vanilla kernel, with PREEMPT_RT patch and custom drivers for their hardware
  - Careful programming to achieve deterministic performance
    - Avoid memory allocation at runtime
    - No unbounded loops
    - Avoid priority inversions
Sources

- https://old.reddit.com/r/spacex/comments/gxb7j1/we_are_the_spacex_software_team_as_k_us_anything/?limit=500
Mars Helicopter
Mars Helicopter

- Mars Ingenuity Helicopter landed in February on Mars (on the Perseverance rover)
- Will perform tests and demonstrations
  - Of use of COTS in space
    - BAE RAD-hardened processor on the rover is about $250,000 dollars, and runs at 200 MHz (VxWorks)
    - Helicopter has Qualcomm Snapdragon 801 processor, running at 2.6 GHz, with Linux OS
      - Same processor as used in 2014/2015 mobile phones
      - Some components were off-the-shelf:
        - e.g. LIDAR purchased from SparkFun
    - Still high development cost: Total program is about $80 million dollars, including operations
Mars Helicopter Hardware

- **Hardware:**
  - 2 1.2 meter counter-rotating blades
    - large, spinning 10 times faster than Earth drones
    - To compensate for thin Martian atmosphere, which is only 1% as dense as on Earth
  - 13 megapixel camera (forward-facing) for 4K video
  - .5 megapixel camera (downward-facing) for terrain mapping and navigation
  - laser altimeter
  - tilt and other sensors
  - batteries, solar panels, carbon tube landing legs
Mars Helicopter Software

- Lots of Open Source
  - Linux operating system
  - Uses “F Prime” OSS flight software, published on github by NASA
    - [https://github.com/nasa/fprime](https://github.com/nasa/fprime)
    - Can use this flight control software in your own projects

- Guidance loops are running at 500 HZ
  - Doing feature tracking from frame to frame at 30 HZ

- Does pre-programmed flight with moderate (not high-level) autonomy
Mars Helicopter Mission

- 30-day window (budget) for flights
  - Then rover has to leave and do it’s other science work
- 3 flights already planned
  - not sure when flights will be yet
  - 4th and 5th flights possible, where they may do more interesting things
- Not a lot of Mars science on this trip
  - Just a demo that it can be done at all, with COTS and Linux
  - Test hardware/software capabilities in extreme environment of another planet
    - Very thin atmosphere, very cold temperatures, less sun, less gravity, etc.
Sources for Mars helicopter

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Resources

- LWN.net – https://lwn.net
  - If you are not subscribed, please do so
  - Some content is delayed by 2 weeks for non-subscribers (some links in this presentation)
- eLinux wiki – elinux.org
  - Especially the presentations from events:
- Phoronix - https://www.phoronix.com/
- Google
Thanks!