Status of Embedded Linux
September 2016

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LF Core Embedded Linux Project
Outline

Kernel Versions
Technology Areas
CE Workgroup Projects
Other Stuff
Resources
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Special: Kernel Summit Discussion Review
Ksummit-discuss issues

• Some of the most interesting discussions occur on ksummit-discuss mailing list

• A few big areas of discussion:
  • Stable workflow
  • Kernel testing
  • Git-series
  • GPL defense issues
  • Backport trees (and SoC mainlining issues)
KDSL: Stable workflow

- Some vendors don’t trust the stable trees, and developers want to improve the quality of them
  - Some patches in stable caused regressions
  - Some users cherry-pick patches instead of basing product on whole tree

- Suggestions to improve quality:
  - Have more review of stable patches
    - But sub-system maintainers are already overworked
  - Have more testing of stable patches
    - This became a long thread about kernel testing
  - Identify commit that patch fixes
    - To allow for easier back-porting to multiple stable trees
KSDL: Kernel testing

- Would like to see new kernel code submitted with unit tests
  - Recommendation only – not required
- Kselftests is a good start, but needs more features
  - Examples, documentation, test interface, standard logging and reporting
- Need to declare test requirements
  - Test should return “not supported” instead of failure, if hardware is missing or requirements are not met
- Important to measure actual bugs caught
KSDL: Git-series

- Lots of discussions (in different threads) about how to use git to manage patches
- Josh Triplett introduced git-series, to maintain a set of patches in git
  - Similarities to quilt or stgit
    - Maintain patches as first-class objects, with metadata and versioning for each patch
KSDL: GPL defense issues

- Big thread about when to enforce the GPL with lawsuit
  - See [http://lwn.net/Articles/698452/](http://lwn.net/Articles/698452/)
- Linus and Greg KH very reluctant to use lawsuits
  - It drives companies away instead of helping them join the community
- Busybox cited as example of legal enforcement that damaged the project
- Lots of disagreement on some issues
GPL defense issues (cont.)

- **When to sue?**
  - Can the threat make companies behave better?
  - If you never sue, is there any threat?

- **What is objective?**
  - Getting useful code (good for developers)
    - Bad actors don’t have good code
  - Allowing end-users to get code for their devices (good for users)
    - End users don’t have copyrights, and have no standing to sue

- **Who can decide to sue?**
  - Small group of copyright holders, or the SFC, or an individual?
    - Problem is if other stakeholders don’t want to sue
KSDL: Backport trees (and SoC mainlining)

- Long thread about value of trees with backported features
  - LSTI and LSK (Linaro Stable Kernel)
- Some people don’t like these trees
  - Reduces incentive to work with upstream
  - Loses shared testing with upstream
- Industry reality is that backporting is inevitable
  - Mobile vendors are not on upstream due to product cycle issues and legacy out-of-tree code
- Backport trees try to find balance in quality between back-porting to in-house tree and forward-porting patches to upstream
And much more…
  • See https://lists.linuxfoundation.org/pipermail/ksummit-discuss/

Many topics were put onto the kernel summit agenda

Kernel summit planned for end of October, in Santa Fe, New Mexico
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Kernel Versions

- Linux v4.3  – 1 Nov 2015  – 63 days
- Linux v4.4  – 10 Jan 2016  – 70 days
- Linux v4.5  – 13 Mar 2016  – 63 days
- Linux v4.6  – 15 May 2016  – 63 days
- Linux v4.7  – 24 July 2016  – 70 days
  - By the way, my prediction was correct
- Linux v4.8-rc5
  - I predict 4.8 on 25 Sep 2016 (63 days)
- Greg KH already announced 4.9 as next LTS
Linux v4.3

- MOST (Media Oriented Systems Transport) support is in staging
  - MOST is a framework in automotive market for multimedia networking
- Ext3 removed
  - But ext4 code supports ext3 filesystems
Linux v4.4

- LightNVM feature
  - Take control of low-level SSD features
    - Will talk about this later
- Perf can build and load eBPF files
- Arm64 can have 16K pages
- Broadcom VC4 GPU (raspberry pi)
- Devfreq cooling – thermal management
- Various PWM drivers
Linux v4.5

- ARM multiplatform hits an important milestone
  - Major patch including lots of minor platforms
  - Many v6 and v7 platforms are now supported
- Not much else specific to embedded
  - Well, continued mainlining of drivers for SoC features
Linux 4.6

- GPIO subsystem rework
- scripts/dtc/dtx_diff
  - Compare device trees in a number of formats
- Improved page-poisoning
  - Separate from debug, can set poison value to 0 (to clear pages after free for security reasons)
Linux 4.7

- Schedutil frequency governor
  - See http://lwn.net/Articles/682391/
- VFS layer can iterate through directories in parallel
- Ability to attach BPF programs to tracepoints
- Ftrace histogram triggers
  - Can tell tracer to accumulate events into buckets and give results, via the sysfs interface
- Android sync_file feature moved from staging
Sync_file

- Allows for explicit fencing for buffers by userspace

How it works:
- Producer driver sends the fence related to the buffer to userspace via a sync_file
- An intermediary (e.g. a compositor) passes these fenced fds to DRM in an atomic commit
- Consumer will not use the buffer for anything before the fence(s) signals
- This avoids a lot of waiting
- See Documentation/sync_file.txt
Linux 4.8 (predictions)

- New kernel documentation system
- 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
- Long timeouts have reduced resolution
- Automatically coalesces longer timeouts
Observations

• No embedded-specific features lately
  • Nothing for:
    • Boot-up time
    • System size
    • Embedded filesystems (are these done now?)
    • Embedded security
    • Realtime (well, maybe the timer wheel stuff)
    • Power management

• There is lots of processor support, and lots of device drivers for embedded

• I worry that people are using non-Linux
  • More on this later
Things to watch (from past)

- Kernel tinification!
- RT-preempt
- Persistent memory
  - (NVM = Non-Volatile Memory)
- SoC mainlining progress
Things to watch (status)

- Kernel tinification! (stalled)
- RT-preempt (only 10K lines left!)
- Persistent memory (in progress)
  - Good talk on about issues:
    - “Making use of persistent memory”
      - http://lwn.net/Articles/674752/
- SoC mainlining progress (stalled)
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Bootup Time

- Mostly old news…
- XIP on x86
  - See https://lwn.net/Articles/637532/
- Asynchronous probing
  - Discussed at last kernel summit
- Reduction in probe deferral
  - Explicit probe ordering can be used to get a specific subsystem (like display) up sooner
  - The “On-demand probing” patches were NAKed
  - Need to measure effect on overall boot time
- Device dependencies
  - May be discussed at next kernel summit
No talks at ELC this year
  • But boot time is NOT a solved problem
  • Boot time issues are unique per platform, and reductions tend not to be mainlinable
    • e.g. remove stuff not needed

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
Device Tree

- Device Tree Overlays
  - Seems to be working as intended
  - Session at ELC 2016 by Pantellis on making overlays independent of the base board
    - Should allow add-on boards to be used with different platforms

- Device Tree validation
  - Project by Matt Porter and others
  - Schema for binding language, validator for bindings and for device tree data
  - Work is stalled

- Updated Device Tree specification is in progress
  - Want to update material and make it more available
Graphics

- Vulkan API from Khronos Group
  - Alternative to Direct3D or OpenGL
  - Reduce CPU overhead for CPU/GPU operations
  - AMD announced plans to open source the driver (but Intel and Valve already working on it)
  - Version 1.0 is now available
  - Nvidia now supports it

- Qt license change
  - From LGPL 2.0 to LGPL 3.0
  - Companies scrambling to find alternative
    - GPL/LGPL 3.0 is undesirable for CE products
GPUs and OSS support

- **Integrated GPUs**
  - AMD, Intel, Nvidea, Qualcomm: Adreno

- **GPU IP suppliers**
  - ARM: Mali, Imagination: PowerVR, Vivante

- **GPU support**
  - Freedreno – Adreno (*good progress*)
  - ??? – for PowerVR (*no progress*)
  - Etnaviv – for Vivante (*good progress*)
  - Nouveau – for Nvidia (*not sure of status*)
  - Lima – for Mali (*no progress*)
Freedreno

- GPL driver for Adreno GPU on Qualcomm chips
  - 3xx supports OpenGL ES 3.0
  - 4xx supports OpenGL ES 3.1
- There are still some pieces that need work
  - Bug reports are appreciated
- Some interesting reverse-engineering tools developed for the project
  - [http://lwn.net/Articles/638908/](http://lwn.net/Articles/638908/)
Etnaviv

- Etnaviv – for Vivante
  - Replaced 65K kernel driver with 6.5K driver
  - See ELCE 2015 talk: “Bringing up FOSS GPU Drivers on Freescale i.MX6 Systems” by Lucas Stach
    - Slides now available for this talk
  - Also see See http://lwn.net/Articles/659391/

- Stuff hit mainline in January:
  - https://git.kernel.org/cgit/linux/kernel/git/torvalds/linux.git/commit/drivers/gpu/drm/etnaviv?id=a8c21a5451d831e67b7a6fb910f9ca8bc7b43554
  - From “the etnaviv authors”
File Systems

- Proposals for UBIFS handling of MLC NAND
  - Lots of complexity due to MLC characteristics
  - See “NAND Support: (New?) Challenges for the MTD/NAND Subsystem” – Boris Brezillon (at ELC)
- EXT3 removed from kernel (4.3-rc1)
(new) LightNVM

- Framework for holding SSD parameters
- Allows kernel to manage flash translation layer
- SSDs have weird (black-box) FTL implementations
  - Are often optimized for FAT filesystems
  - Recent drives allow direct access to blocks
- See http://lwn.net/Articles/641247/
  - “The host primarily handles data placement, I/O scheduling, and garbage collection and leaves everything else to the SSD controller”
Networking

- Bluetooth:
  - Bluetooth 4.2 has better security, faster speeds
  - 6lowpan integration
  - Working on mesh networking
- New protocols for IOT
  - Thread – Nest’s low-power IP stack
  - Others (Sigfox, LoRaWan, etc.)
Real Time – RT-preempt

- Linux Foundation Real-Time Linux Collaborative project
  - Thomas Gleixner is a Linux Foundation fellow
  - Should result in more stuff going upstream
  - One interesting note: press release says they’ll meet regularly at ELC
    - Thomas will have keynote session at ELC 2016

- Latest RT-preempt is for 4.4 kernel
  - Tends to follow LTS releases
  - See https://www.kernel.org/pub/linux/kernel/projects/rt/
Real Time - other

- Xenomai 3.0.1
  - Uses Cobalt RT core
  - Supports both dual-kernel and single-kernel configurations (using RT-preempt)
  - See xenomai.org

- Some RT talks
  - ELCE 2015 – Practical Real-Time Linux – by Arnout Vandecappele
  - Presentation on Xenomai at ELC 2016
Security

• “Making your own security modules” – Casey Schaufler
  • http://lwn.net/Articles/674949/
  • Promote experimentation by giving tips on how to write your own security modules

• New project for kernel security issues:
  • http://kernsec.org/wiki/index.php/Kernel_Self_Protection_Project
Security and IOT

• IOT raises lots of security issues
• See “Securing Embedded Linux” – Mike Anderson at ELC 2016
  • Who are attackers?
  • Secure boot techniques
  • Encryption
  • Physical security
  • Data Security
  • Network Security
System Size

- Kernel tinification project is **stalled**
  - Tiny repository removed from linux-next
  - No activity in one year!
- Single-user patches
  - Gets rid of users and groups
  - Saves about 25K
  - [http://lwn.net/Articles/631853/](http://lwn.net/Articles/631853/)
  - Mainlined in kernel v4.1
- Removal of kernel command-line parsing
  - Not mainlined
System Size (cont.)

- Intel X86 XIP patches
  - See https://lwn.net/Articles/637532/
- Nicolas Pitre has done work recently on supporting gcc --gc-sections
  - Lighter-weight option similar to LTO
- Linux Foundation announces IOT RTOS
  - Zephyr
  - Does this mean that we’re giving up on Linux size reductions??
    - (maybe)
Testing

- Kselftest
- Fuegop - LTSI Test Project
- Kernelci.org
- Lots of automated testing talks at ELC 2016
kseltest

• Inside kernel source tree
  • Makefile target: ‘make kselftest’
• Ability to install tests mainlined in kernel v4.1
  • Cross-build now supported?
    • I didn’t have time to test this myself
  • http://lwn.net/Articles/628625/
• See “Linux Kernel Selftest Framework BoFs – Quality Control for New Releases” – Shuah Khan (at ELC)
• See http://lwn.net/Articles/608959/
Fuego - LTSI test project

- Available now
  - https://bitbucket.org/tbird20d/fuego/
- Lots of work recently on wiki (documentation)
- Working on lots of issues in parallel
- Should be ready for demonstrations at ELCE (October)
Kernelci.org

- Place to get free build/boot testing for your board
  - "ci" = continuous integration
  - Builds 126 trees continuously, then reports any errors
- http://kernelci.org
- ELC and ELCE 2015 - *Upstream Kernel Testing* – by Kevin Hilman
- Sony Mobile has a phone in this farm
Khem Raj has added support to the Yocto Project for Clang (LLVM)
- Builds all but about 45 packages
- He has a mini-distro with kernel, musl, toybox, built with clang
- Presentation at ELC 2016
Tracing

- eBPF to be used for dynamic tracing
  - Perf supports eBPF (in 4.4)
    - eBPF = extended Berkeley Packet Filter
- New tracefs filesystem
  - No longer part of debugfs
  - But all (psuedo) dirs and files the same
- Histograms (not mainlined yet)
Miscellaneous

- Next LTS kernel version:
  - 4.9
  - This is the earliest it’s been announced!
    - We haven’t even opened the 4.9 merge window

- Non-Linux announcements
Lots of non-Linux in IOT

- Zephyr – RTOS from Wind River
  - Apache 2 license
  - Minimal size – as small as 8K
    - Highly configurable
  - NoMMU
  - Networking: WiFi, Bluetooth, NFC
- Magenta – RTOS by Google
  - Fuchsia OS - Some attributes of Android
  - Based on LK
  - BSD license
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CEWG Projects

- Contract work
- Projects and initiatives
CEWG Contract Work

- Kernel string refactoring
- Device tree documentation
- LTSI test framework
- Shared distribution testing
Kernel string refactoring

- **Description**
  - Refactor kernel strings to reduce the space used for statically-defined strings
  - [http://elinux.org/Refactor_kernel_strings](http://elinux.org/Refactor_kernel_strings)

- **Contractor:** Wolfram Sang

- Based on results from last year’s compressed printk investigation
  - Aiming for at least 50K of savings, depending on kernel config

- Project is in progress
  - Report provided at LinuxCon Japan
DT documentation

- Finished “guide” documentation
- Frank Rowand has been collecting data and giving talks
  - LinuxCon NA, ELCE, ELC and LCJ
- Is on elinux wiki at:
  - http://elinux.org/Linux_Drivers_Device_Tree_Guide
LTSI test framework

• (Discussed previously)
Shared Distribution Testing

- See “Shared Embedded Distribution” project (later in these slides)
- Project to test distribution on a few different hardware platforms
- Contractor: Tuan Hoang
- Status: Just starting
Projects and initiatives

- Shared Embedded Distribution
- Device Mainlining
- LTSI
- 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**
  - Get more companies collaborating on the project
Device Mainlining

- [http://elinux.org/CE_Workgroup_Device_Mainlining_Project](http://elinux.org/CE_Workgroup_Device_Mainlining_Project)
- Goal is to study obstacles to mainlining, and work to reduce obstacles
- Previous Activity
  - Developer survey in 2014
  - SIG/BOF meetings at ELCE, ELC, LCNA and Linaro Connect
  - Presentations about overcoming obstacles
    - See [http://lwn.net/Articles/647524/](http://lwn.net/Articles/647524/)
  - White paper (published at LCJ – June 2015)
Device Mainlining (cont.)

- Mobile phone source analysis
  - Phone kernels have between 1.1 and 3.1 million lines of code out-of-tree
- Published tools:
  - https://github.com/tbird20d/upstream-analysis-tools
- Ongoing Projects:
  - Create tools for easier mainlining
  - Patch submission tool
Long Term Support Initiative

- LTSI 4.1 is latest kernel
- Many presentations available on status
- Latest project push is testing facility
  - See previous page on JTA test framework
- Kernel diversion measurement tool
  - Presentation at ELC 2016
eLinux wiki

- 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
  - Lots of pages in last few years about low-cost development boards
  - Please use and add to site
Other Stuff

- Distros and Build Systems
- Events
Distros

• Android
  • “Nougat” version released in August
  • New build system under development, using ‘go’
    language and something called blueprints
  • Google switching to OpenJDK
    • Eliminates those troublesome Oracle Java libraries

• Tizen
  • Lots of security work

• CEWG Shared embedded distribution
  • (see previous slides)
Build Systems

- OpenEmbedded/Yocto Project
  - 2.0 (Jethro) released
  - 1.8 allowed builds and runs with Toaster (web interface)
    - HOB is gone
    - Presentation on Toaster at ELC 2016

- Buildroot
  - Configurable support for static linking
  - Improved support for package hashes
  - Better warnings about toolchain header safety issues
  - License reporting?
Events

- **Embedded Linux Conference Europe 2016**
  - October 6-7, 2016 - Berlin, Germany
- **Embedded Linux Conference**
  - February 21-23, 2017 – Portland, Oregon
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Resources

- LWN.net
  - http://lwn.net/
  - If you are not subscribed, please do so
- Kernel Newbies
  - http://kernelnewbies.org/Linux_[34].?
- eLinux wiki - http://elinux.org/
  - Especially http://elinux.org/Events for slides
- Celinux-dev mailing list
Thanks!