Status of Embedded Linux
November 2015

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Outline

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

• Linux v3.17 – 5 Oct 2014 – 63 days
• Linux v3.18 – 7 Dec 2014 – 63 days
• Linux v3.19 – 8 Feb 2015 – 63 days
• Linux v4.0 – 12 Apr 2015 – 63 days
• Linux v4.1 – 21 Jun 2015 – 70 days
• Linux v4.2 – 30 Aug 2015 – 70 days
• Linux v4.3 – 1 Nov 2015 – 63 days
• We’re in the 4.4 merge window now
Linux v3.17

- Lots of ARM hardware support
  - Newly enabled ARM hardware
    - Rockchip RK3288 SoC
    - Allwinner A23 SoC
    - Allwinner A31 Hummingbird
    - Tegra30 Apalis board support
    - Gumstix Pepper AM335x
    - AM437x TI evaluation board
  - Other ARM boards with existing support also saw improvements with Linux 3.17
  - Rework of "config-bisect" mode in ktest
Linux v3.18

- OverlayFS introduced
- Size reduction patch:
  - madvise and fadvise syscalls can be configured out
- More LLVM support
- New SOC support:
  - Hisilicon HiP04
  - Amlogic Meson6 (8726MX)
  - Renesas R-Car E2 (R8A77940)
  - Broadcom BCM63xx DSL
  - Atmel SAMA5D4
Linux v3.19

- F2FS now has a "fastboot" option
- Device tree overlay support
- Squashfs supports LZ4 compression
- Android "binder" code has been moved from the staging tree
Linux v4.0

- This version is not v3.20
  - Linus conducted a survey on Google+  
    - 56% of respondents preferred 4.0  
    - The name of this kernel is “hurr durr I’m a sheep”
- Android binder has security hooks  
  - Can use SELinux security with it
- Non-volatile memory support patches  
  - Can use filesystem in persistent memory
  - [http://lwn.net/Articles/610174/](http://lwn.net/Articles/610174/)
- UBIFS performance improvements
Linux v4.1

- New tracefs filesystem
- Kernel self-test ‘install’ target
- Ability to attach BPF programs to kernel probes
- I2C subsystem can function in slave mode
- Can configure kernel for single-user operation
Linux v4.2

- Linux security module stacking
  - See https://lwn.net/Articles/635771/
- F2FS supports per-file encryption
- Support for AMD GPUs
- Lots of pin control drivers:
  - Freescale, Mediatek, Allwinner, Qualcomm, Renesas
- Libnvdimm – non-volatile memory (NVM) management
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 that Ext3 filesystems
Things to watch

- Kdbus
  - Has hit some stumbling blocks getting merged
- Kernel tinification!
- RT-preempt
- Persistent memory
  - (NVM = Non-Volatile Memory)
- SoC mainlining progress
Kernel process improvements

- Kernel merge process is getting better.

- The percent of changes that are accepted after the merge window closes is trending down over time
  - In the 3.0 release, 19% of commits were after the merge window closed
  - In the 4.1 release, 10.5% of commits were after the merge window closed

- See https://lwn.net/Articles/650299/
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Bootup Time

- XIP on x86
  - See https://lwn.net/Articles/637532/
- Deferred initcalls (patch still out-of-tree)
  - http://elinux.org/Deferred_Initcalls
- Asynchronous probing
- Reduction in probe deferral
  - No one has measured effect on overall boot time
  - Explicit probe ordering can be used to get a specific subsystem (like display) up sooner
Bootup Time (cont.)

• Kernel tinification project helps
  • Smaller size means shorter load times

• User-space speedups
  • Systemd in embedded
    • ELC 2015 - *Tuning systemd for Embedded* by Alison Chaiken

• Some good 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 is causing delays getting stuff upstream
  - DT maintainers are overloaded
  - Backwards compatibility is a problem
  - See “The Device Tree as a Stable ABI: A Fairy Tale?” – Thomas Petazzoni

- Device Tree Overlays
  - Useful for boards that have daughterboards (e.g. capes or shields) that need DTS changes at boot time.
  - “Transactional Device Tree & Overlays: Making Reconfigurable Hardware Work” - Pantelis Antoniou
  - Also see: http://lwn.net/Articles/616859/
Device Tree validation

- New work on validating device tree
  - Matt Porter is creating a formal binding document standard (schema for binding docs)
  - Frank Rowand implementing DTS parser (to be used with validator)
  - Tim Bird working on a binding doc validator
- How it would work:
  - Binding docs are compared with binding schema
  - DTS entries are compared against binding doc and any errors are reported
  - Maybe add to checkpatch.pl or kernel build
- V2 of spec has been published – still hashing out details
More devicetree stuff

- Frank Rowand is a new devicetree maintainer
  - Has been updating http://elinux.org/Device_Tree
  - Working on devicetree debugging
    - LCNA 2015 (and here) - *Solving Device Tree Issues* by Frank Rowand

- Big DT session at plumbers this year
  - http://elinux.org/Device_Tree_presentations_papers_articles
Graphics

- Vulkan API from Khronos Group
  - Alternative to Direct3D or OpenGL
  - Intent is to reduce CPU overhead for CPU/GPU operations
  - AMD announced plans to open source the driver (but Intel and Valve already working it)

- GPU support
  - Freedreno – for Adreno
  - ??? – for PowerVR
  - Etnaviv – for Vivante
  - Nouveau – for Nvidia
  - Lima – for Mali
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/
PowerVR

- PowerVR SGX code leaked in November
- In June: Imagination Executive blogged:

Q: Is there plans to make/help/fund open PowerVR driver for Linux?  
A: Yes, there is a plan and it is one of the things I’ve been working on for the past few months. Hopefully I’ll have something more to share soon(-ish?).

Other OSS GPU drivers

• Etnaviv – for Vivante
  • See http://www.x.org/wiki/Events/XDC2015/Program/Stach_etnaviv.pdf
  • 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 not there yet, but I will ping Lucas
Other OSS GPU drivers

• Nouveau – for Nvidia
  • Nvidia published some GPU details to help open projects write driver (2013)
  • See https://en.wikipedia.org/wiki/Nouveau_(software)
  • See also http://nouveau.freedesktop.org/wiki/

• Lima – for Mali
  • Seems stalled – recent discussion of putting Mali DRM/KMS code into staging indicated that there needs to be an active user-space (but Lima appears to not be active)
File Systems

- SquashFS supports LZ4 compression
- OverlayFS
  - Support for read/write filesystem over the top of a read-only filesystem
  - Most common use-case is live CDs, but it can be useful for some embedded scenarios
- 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)
File Systems (cont.)

• ELC talks:
  • “Filesystem Considerations for Embedded Devices” – Tristan Lelong
    • Great talk with performance and robustness results for different file systems
    • Ext4, BTRFS, F2FS, XFS, NILFS2
    • Summary: F2FS is faster in many cases, EXT4 is mature
  • “Current Challenges in UBIFS” – ELCE 2015
    • Richard Weinberger
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.)

- **Visible Light Communication (VLC)**
  - Disney’s Linux Light Bulb
  - Low-bandwidth via LED-to-LED
  - Allows toy to have cheap transmitter/sensor
Power Management

- PM domains
  - See “Last One Out, Turn Off The Lights” - Geert Uytterhoeven (at ELC)
    - Good talk showing how to use this with device tree
  - Idle and suspend to Idle
    - “The Art of Doing Nothing: Linux Low Power Idle” – Kristen Accardi (at LCJ)
    - “What is Suspend-to-Idle and How to Make It Work” – Rafael Wysocki (at LCJ)
- PowerTop/tuning
  - “Power Tuning Linux: A Case Study” – Alexandra Yates (at LCJ)
    - Was about tuning a laptop distro
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

- Latest release of RT-preempt is for 4.1 kernel
  - Tends to follow LTS releases
Real Time - other

• Xenomai 3.0 is out!!  (actually, 3.0.1)
  • Uses Cobalt RT core
  • 3.0 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
  • ELCE 2014 - “rtmux: A thin multiplexer to provide hard realtime applications for Linux” - by Jim Huang
    • Good overview of existing RT solutions, and a new alternative
Security

- IOT raises lots of security issues
- See “Kernel security hacking for the Internet of Things” – Daniel Sangorlin (at LCJ)
  - Reduce attack surface
  - Can detect attacks by detecting variation from pre-determined behavior
  - Isolate critical software
- Security module stacking
  - Added in kernel 4.2
  - See https://lwn.net/Articles/635771/
Security (cont.)

- Lots of focus on security at kernel summit
System Size

- Size project keeps nibbling away at items
- Single-user patches
  - Gets rid of users and groups
  - Saves about 25K
  - http://lwn.net/Articles/631853/
  - Mainlined in kernel v4.1
- Removal of kernel command-line parsing
  - Ability to make any command-line option static
  - Example for initcall_debug = saves 385 bytes
    - A lot of the savings are due to GCC constant folding
- Intel X86 XIP patches
  - See https://lwn.net/Articles/637532/
System Size (cont.)

- Nicolas Pitre has done work recently on supporting gcc --gc-sections
  - Lighter-weight option similar to LTO
- Some recent talks:
  - Optimize uCLinux for ARM Cortex-M4 – Jim Huang (at ELC)
  - Linux for Microcontrollers: From Marginal to Mainstream – Vitaly Wool (at ELC)
    - 840K .text, 132k .rodata, 86k .data (BT, no TCP/IP)
  - Pushing the limits of Linux on ARM – Andreas Färber (at LCJ)
Testing

- Kselftest
- LTSI Test Project (JTA)
- Kernelci.org
**kselftest**

- 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/](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/](http://lwn.net/Articles/608959/)
LTSI test project

- Jenkins-based Test Automation (JTA)
- Available now
  - https://bitbucket.org/cogentembedded/jta-public/
- Several companies provided feedback at LTSI workshop meeting in Tokyo
  - CogentEmbedded will fix issues
- Please use JTA
  - Please send feedback to LTSI mailing list
    - https://lists.linuxfoundation.org/mailman/listinfo/ltsi-dev
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 2015 (also here) - *Upstream Kernel Testing* – by Kevin Hilman
- Sony Mobile has a phone in this farm
Toolchains

- 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 (non-GNU)
    - Call it LinuxNG?
Tracing

• eBPF to be used for dynamic tracing
  • Ktap will not be merged (frowny-face)
• new tracefs filesystem
  • No longer part of debugfs
  • But all (psuedo) dirs and files the same
• Histograms (not mainlined yet)
• See “New (and Exciting!) Development in Linux Tracing – Elena Zannoni (at LCJ 2015)
Miscellaneous

- Greybus
- J2
- Next LTS kernel version:
  - 4.1
- Weird IOT news
Greybus

- New fast bus for mobile device hotplugging
  - For project ARA (Google’s modular phone)
  - Being worked on by Greg Kroah-Hartman
- https://lwn.net/Articles/648400/
- Work still needed in Android for support of dynamic hotplugging
J2

- Open hardware processor
- Formerly SH2, but patents have expired
- See http://lwn.net/Articles/647636/
  “Resurrecting the SuperH architecture”
- Resurgence of nommu Linux?
- Someday might run Linux on 3-cent processors
Weird IOT news

- Microsoft released Windows 10 IoT kit for Raspberry PI
- Google is making Brillo preview available (upon request and approval)
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CEWG Projects

- Contract work
- Projects and initiatives
CEWG Contract Work

- Kernel string refactoring
- Device tree documentation
- LTSI test framework
Kernel string refactoring

- Description
  - Refactor kernel strings to reduce the space used for statically-defined 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 just starting
DT documentation

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

• (Discussed previously)
Projects and initiatives

- Civil Infrastructure
- Shared Embedded Distribution
- Device Mainlining
- LTSI
- eLinux wiki
Civil Infrastructure

- **Goals**
  - Solve problems with Linux for use in civil infrastructure systems

- **Status**
  - Recent Activity
    - BOFS at ELCE 2014 and ELC2015 and LCJ2015
    - Private meetings to discuss goals with interested companies
  - Working to define requirements in areas of functional safety and maintenance longevity

- **Next steps:**
  - Hold additional meetings to define requirements
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)
Mobile phone source analysis
- Phone kernels have between 1.1 and 3.1 million lines of code out-of-tree
- Working to identify problem areas

Published tools:
- https://github.com/tbird20d/upstream-analysis-tools

Projects:
Big problem areas

<table>
<thead>
<tr>
<th>Area</th>
<th>Insertions range</th>
</tr>
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<tbody>
<tr>
<td>Mach-msm</td>
<td>347K – 417K</td>
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<tr>
<td>Media</td>
<td>120K – 360K</td>
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<tr>
<td>Video</td>
<td>37K – 346K</td>
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<tr>
<td>Wireless</td>
<td>80K – 250K</td>
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<tr>
<td>Sound</td>
<td>74K – 240K</td>
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<tr>
<td>Input</td>
<td>51K – 238K</td>
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<tr>
<td>Camera</td>
<td>50K – 210K</td>
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<tr>
<td>GPU</td>
<td>36K – 172K</td>
</tr>
<tr>
<td>Power</td>
<td>44K – 94K</td>
</tr>
</tbody>
</table>
Active technical projects

• Wireless drivers
  • Mainline Broadcom wireless driver has never been run on production phone hardware
  • Want to improve/mature the mainline driver
  • Sony has tested a backport of the driver
  • Recently got latest kernel running on phone hardware, and we now run the mainline driver

• USB
  • No one has ever charged their mobile device using only mainline code
  • Working on USB charger framework
Additional projects

- Technical Projects:
  - Gathering more project ideas at:
    - http://elinux.org/Kernel_areas_of_focus_for_mainlining
    - UART bus

- Non-technical:
  - Easy patch submission tool (no special mail settings required)

- Metrics for in-tree code size and maintenance reduction benefits (for managers)
  - Real data instead of hand-waving
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
- Considering multiple merge windows
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
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Other Stuff

- Projects and Consortia
- Distros and Build Systems
- Events
- Hardware
Projects and Consortia

• Allseen Alliance – Peer-to-peer ad-hoc networking
  • AllJoyn is the name of the implementation
• Open Interconnect Consortium
  • Iotivity is the technology
• DroneCode – Open source UAV software
  • http://www.dronecode.org/
Projects and Consortia

• Linaro
  • Just celebrated 5\textsuperscript{th} anniversary
  • Linaro IoT and Embedded initiative (LITE)
    • Run Linux on Cortex A and mbedOS on Cortex M
      • Unsure about licensing for Cortex M

• PRPL Foundation (Multi-company MIPS non-profit)
  • Announced at ELCE 2014
  • Projects: PRPL OpenWRT, MIPS QEMU
  • OpenWRT summit tomorrow, here
Distros

- **Android**
  - Just released “M” version
  - New build system under development, using ‘go’ language and something called blueprints
- **Tizen**
  - Lots of security work
- **AGL**
  - Announced it will do it’s own distro
- **CEWG Shared embedded distribution**
  - (see previous slides)
Build Systems

- **OpenEmbedded/Yocto Project**
  - 1.8 released
    - Can now do builds and runs with Toaster (web interface)

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

- Embedded Linux Conference Europe 2015
  - October 5-7, 2015 - Dublin, Ireland
  - Lots of content - check for slides on elinux wiki
- Embedded Linux Conference 2016
  - April 4-6, 2016 - San Diego, USA
- Embedded Linux Conference Europe 2016
  - October 6-7, 2016 - Berlin, Germany
Hardware

- Intel and Micron 3D Xpoint memory
  - Non-volatile
  - Read/Write, Random access, Faster than NAND, Cheaper than flash
  - Not many details yet
- Is this the persistent memory we’ve been waiting for?
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Final Impressions
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
Impressions – hardware price

• Steady decline in price of silicon
  • Cheapest Android phone = $29
    • Lenovo A288t (Russian)
  • The Chip - $9 computer board
  • Estimate that cheapest Linux-capable SoC (with MMU) currently about $3

• Still want to see Linux on cereal boxes
  • Less than $1 for SoC, display, battery, input
Impressions – markets

- I worry that Linux will not be in the “things” part of IOT
  - Linux on IOT gateway is a no-brainer
  - Linux is too big for sensors
  - Rate of adoption of tinification patches is slow
  - Need a concerted, collaborative effort here

- In other areas Linux is already penetrating:
  - Drones, Industrial automation, Robotics
  - Automotive, Automated vehicles
  - Gateways, Civil infrastructure
Impressions

- Embedded Linux is doing fine....
Kernel Summit Report

- See http://lwn.net/Articles/662628/
- Running mainline on a cellphone
  - (see previous slides about device mainlining project)
- Power management knobs
  - How to make sure existing PM features of Linux are actually used
  - Lots of tunable (“knobs”), but are often
- Device dependencies and deferred probing
  - Rafael Wysocki has a proposal to build a dependency graph
- Realtime mainlining
Kernel Summit Report (cont.)

- Security – fixing exploitation classes
  - Big focus on kernel security issues
- Developer recruitment
- Kernel testing
  - 0-day now sends patch fixes for patches seen on mailing lists
- Kernel tinification
  - 0-day test now reports size
- Stable kernels:
  - Things going pretty well
  - Next LTS kernel is 4.4 (different time of year)