Status of Embedded Linux
October 2015

Tim Bird
Architecture Group Chair
LF CE Workgroup
Outline

Kernel Versions
Technology Areas
CE Workgroup Projects
Other Stuff
Resources
Outline

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

- Linux v3.16 – 3 Aug 2014 – 57 days
- 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-rc4 (as of yesterday)
  - Prediction for 4.3 release: 8 Nov 2015
Linux v3.16

- Power-aware scheduling
- decode_stacktrace.sh
  - Converts offsets in a stack trace to filenames and line numbers
- F2FS large volume support
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/

• 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 (preview)

- 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 (again)
- Persistent 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/
Outline

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

- F2FS filesystem has a new "fastboot" option
  - Skips some boot-time checks to reduce mount time
  - Sacrifices a little bit of normal performance
    - Due to more synching during normal filesystem operation
- XIP on x86
  - See https://lwn.net/Articles/637532/
- Deferred initcalls (patch still out-of-tree)
  - http://elinux.org/Deferred_Initcalls
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
  - Replaced 65K kernel driver with 6.5K driver

- **Nouveau** – for Nvidia
  - Nvidia published some GPU details to help open projects write driver (2013)
  - See also [http://nouveau.freedesktop.org/wiki/](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
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 at rc7 release
  - Uses Cobalt RT core
  - 3.0 supports both dual-kernel and single-kernel configurations (using RT-preempt)
  - See xenomai.org
- Good overview of existing RT solutions, and a new alternative
  - ELCE 2014 - “rtmux: A thin multiplexer to provide hard realtime applications for Linux” - by Jim Huang
- Lots of people using PRUs (programmable real-time units)
  - See http://lwn.net/Articles/639258/
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/
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/](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/](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
- 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/
- See “Linux Kernel Selftest Framework BoFs – Quality Control for New Releases” – Shuah Khan (at ELC)
  - See 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
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
Outline

Kernel Versions
Technology Areas
CE Workgroup Projects
Other Stuff
Resources
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](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
- 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/
  - 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
  - Working to identify problem areas
- Published tools:
  - https://github.com/tbird20d/upstream-analysis-tools
# Big problem areas

<table>
<thead>
<tr>
<th>Area</th>
<th>Insertions range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mach-msm</td>
<td>347K – 417K</td>
</tr>
<tr>
<td>Media</td>
<td>120K – 360K</td>
</tr>
<tr>
<td>Video</td>
<td>37K – 346K</td>
</tr>
<tr>
<td>Wireless</td>
<td>80K – 250K</td>
</tr>
<tr>
<td>Sound</td>
<td>74K – 240K</td>
</tr>
<tr>
<td>Input</td>
<td>51K – 238K</td>
</tr>
<tr>
<td>Camera</td>
<td>50K – 210K</td>
</tr>
<tr>
<td>GPU</td>
<td>36K – 172K</td>
</tr>
<tr>
<td>Power</td>
<td>44K – 94K</td>
</tr>
</tbody>
</table>
• Technical Projects:
  • USB OTG charger integration
  • Broadcom wireless driver
  • [link](http://elinux.org/Kernel_areas_of_focus_for_mainlining)

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

• Engage with more companies and individuals
  • Recently had conversations with Google and MediaTek
Long Term Support Initiative

- LTSI 3.14 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
- Will base next LTSI on 4.1 (LTS)
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
  - Lots of pages in last few years about low-cost development boards
  - Please use and add to site
Outline

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

Kernel Versions
Technology Areas
CE Workgroup Projects
Other Stuff
Resources
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....
Thanks!