Status of Embedded Linux

March 2013

Tim Bird
Architecture Group Chair
LF CE Workgroup
Outline

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

- Linux v3.3 – 18 Mar 2012 – 74 days
- Linux v3.4 – 20 May 2012 – 63 days
- Linux v3.5 – 21 July 2012 – 62 days
- Linux v3.6 – 30 Sep 2012 – 71 days
- Linux v3.7 – 10 Dec 2012 – 71 days
- Linux v3.8 – 18 Feb 2012 – 70 days
- Linux v3.9-rc1 – 3 Mar 2012
  - Predict Linux v3.9 on April 30
Linux v3.3

- ARM large physical address extensions
  - See Catalin Marinas talk at ELC Europe 2011
- ALSA support for compressed audio
- New “charger manager” subsystem
  - Can partially resume to poll battery and re-suspend
- Android patches in staging
  - This is really cool
Universal Flash Storage host controller drivers
  - See Documentation/scsi/ufs.txt

Common clock framework
  - Unifies handling of subsystem clocks
  - See Documentation/clk.txt

HSI (High-speed synchronous serial interface) framework
  - Used for communication between CPU and cellular modem engines
Linux v3.4 (continued)

- DMA buffer sharing API
- Remoteproc subsystem
  - Allows for control of other CPUs through shared memory
  - Rpmsg is a new mechanism for communicating with other CPUs (running non-Linux)
  - See Documentation/remoteproc.txt and rpmsg.txt
Linux v3.5

- Kernel log rework
  - Structured printk (new format), with tags
  - http://lwn.net/Articles/492125/
- Support for writing NFC drivers
- Integration of ramoops and pstore
  - Part of work to support Android ram_console
- Uprobes
  - User-space probes
  - https://lwn.net/Articles/499190/
- Autosleep
Linux v3.6

- Android RAM console functionality integrated into pstore
- CANFD support for CAN protocol
  - CAN with flexible data rate
- LED oneshot mode
  - Sysfs interface for certain one-time LED/gpio manipulations
- "Suspend to Both"
  - Create resume image both in RAM and on disk
  - If power dies during suspend, disk image can be used to resume
Linux v3.7

- ARM multi-platform support
  - See http://lwn.net/Articles/496400/
- ARM 64-bit support (Aarch64)
- Cryptographically signed kernel modules
  - See https://lwn.net/Articles/470906/
- Perf trace (alternative to strace)
  - Allows intermingling kernel trace events with syscall events
- Runtime power management for audio
- Kerneldoc system can output in HTML5 format
Linux v3.8

- F2FS – flash-friendly file system
  - See https://lwn.net/Articles/518988/
- New thermal governor subsystem
- Memory control group support for accounting for kernel memory usage
  - Stack and slab accounting and limits
- Cpuidle support for big.LITTLE
Linux v3.9 (probable)

- Ftrace snapshots
  - Grab a snapshot of a running trace without stopping
- PowerPC support for transactional memory
- CONFIG_EXPERIMENTAL=y
  - And should be gone soon
Things to watch

- Android features
  - Volatile ranges
  - ARM FIQ -> KDB glue
- big.LITTLE
- SOC support for ARM (refactoring)
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Bootup Time

- Systemd in embedded
  - Systemd starts services and daemons on-demand
  - Angstrom uses systemd
  - People either love systemd or hate it, or both
  - Would be nice to get some boot time and size numbers to evaluate this
Ubuntu announces MIR

- New display server that leverages Android GPU drivers
- Replaces X, across multiple form factors (desktop, tablet, phone)
Graphics (cont.)

- Lots of work around memory management between kernel, user-space and GPU
- Android has /dev/ion
  - A unified approach to buffer management and sharing between display, GPU, camera, codecs, etc, new in Ice Cream Sandwich
  - Replacement for pmem
- Mainline has Contiguous Memory Allocator (CMA) and dma-buf
  - http://lwn.net/Articles/468044/ - CMA
  - http://lwn.net/Articles/470339/ - dma-buf
File Systems

- F2FS – Samsung Flash-friendly filesystem
  - Mainlined in Linux version 3.8
  - Log-structured, with lots of tweaks
    - E.g. hot vs. cold data separation
  - See http://elinux.org/F2FS
- CE WG project to analyze filesystem performance on eMMC
  - More about this later
Power Management

- Autosleep
  - Wakelock-compatible solution by Rafael Wysocki
    - http://lwn.net/Articles/479841/
    - Rafael: “This series tests the theory that the easiest way to sell a once rejected feature is to advertise it under a different name”
  - Mainlined in v3.5

- Power-aware scheduling:
  - http://lwn.net/Articles/512487
System Size

- Kernel size
  - Ezequiel Garcia's trace_analyze for kernel memory analysis (showed previously)
    - See talk at ELC 2013
  - Link-Time Optimization (LTO)
    - Hopefully showing up in mainline soon

- Cooperative memory relinquishment
  - Volatile Ranges
  - Lexmark work (membroker and ANR malloc)
    - See talk at ELC 2013 – "SystemWide Memory Management without Swap"
System Size (cont.)

- olibc – bionic libc
  - Has good features from Android, and is smaller and more configurable than glibc

<table>
<thead>
<tr>
<th>Library</th>
<th>Original Size</th>
<th>Reduced Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>glibc 2.11</td>
<td>1,208,224 bytes</td>
<td></td>
</tr>
<tr>
<td>uClibc 0.9.30</td>
<td>424,235 bytes</td>
<td></td>
</tr>
<tr>
<td>bionic 2.1</td>
<td>243,948 bytes</td>
<td></td>
</tr>
</tbody>
</table>

- See ELC 2013 talk by Jim Huang

- Kconfig for eglibc
  - Ability to configure parts of libc to use

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<tr>
<th>Library</th>
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<th>Reduced Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>libc-2.17.so</td>
<td>1.2M -&gt; 830K</td>
<td></td>
</tr>
<tr>
<td>ld-2.17.so</td>
<td>128K -&gt; 120K</td>
<td></td>
</tr>
<tr>
<td>libm-2.17.so</td>
<td>610K -&gt; 580K</td>
<td></td>
</tr>
</tbody>
</table>

- See ELC 2013 talk by Khem Raj
Link Time Optimization

- See http://lwn.net/Articles/512548/
- Newer gcc (4.7) supports adding extra metadata about routines (gimple) at compile time
- Linker can now do whole-program optimization at link time
- Andi Kleen has 74 patches that add support to the Linux kernel for LTO feature
  - Mark functions as 'visible' to avoid dead-code elimination
  - Adjust compilation flags to be consistent
  - Add dependencies to avoid conflicts for features which can't conform to LTO requirements (ftrace)
gcc Link-Time-Optimization of ARM Linux kernel

What is demonstrated

- Possibly the most boring demo ever
- Gcc has compile-time option to do link-time optimization
- Andi Kleen created patches to support this compiler option
  - He demonstrated on an Intel CPU
- This is first demonstration of LTO kernel running on ARM
  - *World's first, that I know of !!!*
- LTO supports whole-program optimization, at final link time
  - Slow link step, but good code optimizations

What was improved

System size and performance
6% reduction in image size (384K)

<table>
<thead>
<tr>
<th></th>
<th>non-lto</th>
<th>lto</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compile time</td>
<td>1m58s</td>
<td>3m22s</td>
</tr>
<tr>
<td>Image size</td>
<td>5.85M</td>
<td>5.46M</td>
</tr>
<tr>
<td>Meminfo Total</td>
<td>17804K</td>
<td>18188K</td>
</tr>
<tr>
<td>Meminfo Free</td>
<td>10908K</td>
<td>11260K</td>
</tr>
<tr>
<td>LTP time</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source code or detail technical information availability

http://lwn.net/Articles/512548/
git://github.com/andikleen/linux-misc

Hardware Information

TI panda board
mem=24M

http://pandaboard.org
LTO (cont.)

- **Cost:**
  - Longer kernel builds (extra 1.5 minutes)
  - More memory during build (up to 9G required for `allyesconfig`)
  - Subtle bugs from optimizations
    - E.g. duplicate code elimination caused a pointer comparison failure

- **Benefits:**
  - Size reduction – 380K (6%) on ARM
  - Performance: Unknown
LTO (cont. 2)

• Why am I so excited about this?
• Opens new possibilities for automatic kernel reduction techniques
  • It is not tractable to reduce kernel manually
  • Whole system optimization is a critical part of automatic reduction
• Note: This work obsoletes -ffunction-sections
• Takes Linux-tiny in a whole new direction
Volatile Ranges

• Work by John Stultz
  • Inspired by Android feature in ashmem
    • http://lwn.net/Articles/468896/
    • http://lwn.net/Articles/500382/
  • Allows cooperation between the kernel and applications on "volatile" memory usage

• Overview:
  • Application notifies kernel about re-claimable memory areas
  • Not mainlined yet
CEWG Contract Work 2012

- eMMC tuning
- Dynamic memory reduction
- Mainline FIQ debugger
- ConnMan support for WiFi direct
- Improve kexecboot
- Measure systemd and udev
eMMC tuning guide

- **Description:**
  - This project analysed EXT3, EXT4, BTRFS and F2FS on a variety of block-based flash parts on a few different development boards
  - Output is a document describing best practices for tuning Linux block-based filesystems for block-based flash filesystems
  - Also, methods and scripts for filesystem testing
- **Contractor:** Cogent Embedded
- **Status:** work is almost complete
  - Document should be available very soon
Dynamic memory analysis

- **Description:**
  - Instrument and collect data on kernel dynamic memory allocations
  - Make recommendations for areas where dynamic kernel memory usage could be reduced
- **Contractor:** Ezequiel Garcia
- **Status:**
  - Use existing kmem_events (ftrace) infrastructure
  - Some patches already accepted upstream
  - New tool for visualization of kernel memory usage
  - See http://elinux.org/Kernel_dynamic_memory_analysis
  - See ELC 2013 talk
Drivers kmalloc

- base 65.0 kB
- pci 12.0 kB
- tty 17.0 kB
- serial 8.0 kB
- scsi 20.0 kB
- at 52.0 kB
Linux kmalloc

Kernel 158.0 kB

Sysfs 20.0 kB

Proc 20.0 kB

Trace 136.0 kB

Fs 64.0 kB

Lib 10.0 kB

Kernel 158.0 kB

Serial 8.0 kB

Tty 17.0 kB

Pci 12.0 kB

Net 81.0 kB

Base 65.0 kB

Drivers 173.0 kB

Ata 52.0 kB

Scsi 20.0 kB

Ipv4 54.0 kB

Core 18.0 kB
Mainline FIQ debugger

• Description:
  • Add ARM FIQ glue code and integrate with existing kernel debugger
  • Allows use of ARM FIQ (non maskable interrupt) to activate a kernel debugger

• Status:
  • Developer worked on this independent of CE WG
  • Now called "NMI KGDB/KDB debugger"
    • Not just ARM FIQ glue code.
  • The generic driver is now drivers/tty/serial/kgdb_nmi.c
  • Further development (i.e. ARM-specific bits, and restricted mode) is in the following GIT tree:
    • git://git.infradead.org/users/cbou/linux-nmi-kdb.git
    • http://git.infradead.org/users/cbou/linux-nmi-kdb.git
ConnMann WiFi direct

- Description:
  - Add support for WiFi direct to ConnMann wireless connection manager
- Contractor: contractor was acquired
- Status:
  - Considering project for 2013
Improve kexecboot

Description:
- Make improvements to kexecboot bootloader
- Support load from network
- UI improvements

Contractor: Yuri Bushmelev

Status:
- Should be done in May
Measure systemd and udev

• Description:
  • Measure the overhead and performance of system and udev, as used in embedded systems
• Contractor: became unavailable
• Status: considering project for 2013
Other Projects

- Long Term Support Initiative (LTSI)
- Hardware fund
Long Term Support Kernel for Industry

- LTSI 3.4 is available now
- Many presentations available on status
  - See ELC 2013 presentation by Hisao Munakata
  - See ELC 2013 presentation by Tzugikazu Shibata
- Program for free hardware for LTSI kernel testing
Hardware

• Rise of cheap hardware
  • Lots of < $200 boards
  • Raspberry Pi - $35
  • New BeagleBone - ?? (<$79)
• Lots of people have mobile phones or tablets
• No need for CE WG hardware program
• Anyone can learn embedded Linux
  • FYI – code.org – new site to teach programming
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• Tools
• Build Systems
• Events
• Miscellaneous
Tools

• Cortex
  • Coredump filter
  • Generates sparse coredump
  • See ELC 2013 presentation by Tristan Lelong
    • "Debugging for production systems"

• Debugging techniques
  • Good overview by Kevin Dankwardt at ELC 2013
    • "Survey of Linux Kernel Debugging Techniques"

• Testing frameworks
  • "Kernel Testing Tools and Techniques" BOF by Matt Porter
Build Systems

- Yocto project
  - Lots of talks at ELC (and previous ELCs)
    - Sean Hudson – good introduction tutorial
    - Saul Wold – current status
  - Tutorials now online
- Buildroot still hanging in there
- Android use in non-CE embedded
  - Headless android
Events

• ELC/Android Builders Summit – Feb 2012
• LinuxCon Japan – May 29-31 2013
• Japan Jamborees
• LinuxCon US
  • September 2012 – New Orleans
• Embedded Linux Conference Europe 2013
  • October 21-23, 2013 – Edinburgh, Scotland
• Embedded Linux Conference 2014
  • April, 2013 – San Jose
eLinux wiki

- http://elinux.org
  - Web site dedicated to information for embedded Linux developers
    - The wikipedia of embedded linux!
  - Hundreds of page covering numerous topic areas: bootup time, realtime, security, power management, flash filesystem, toolchain, editors
- Working on new wiki projects:
  - Video transcription project
  - Tech Zones
Miscellaneous

• Has use of open source licenses peaked?
  • Interesting essay on moving to more free licenses (specifically, public domain)
  • Argument is that now individuals and companies will contribute even if license doesn't require it
    • Most developers understand benefits
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Resources

• LWN.net
  • http://lwn.net/
  • If you are not subscribed, please do so

• Kernel Newbies
  • http://kernelnewbies.org/Linux_3.?

• eLinux wiki - http://elinux.org/
  • Especially http://elinux.org/Events for slides

• Celinux-dev mailing list
Thanks!