Embedded Linux

Device driver development

Sébastien Bilavarn
Outline

- Ch1 – Introduction to Linux
- Ch2 – Linux kernel overview
- Ch3 – Linux for Embedded Systems
- Ch4 – Embedded Linux distributions
- Ch5 – Case study: Xilinx PowerPC Linux
- Ch5 bis – Case study: Xilinx Zynq-7000 Linux
- Ch6 – Device driver development
Embedded Linux distributions

- Introduction
- Embedded platforms
- Embedded distributions
  - Ubuntu
  - Android
  - Linaro
  - Xilinx
Introduction

- Embedded Linux distributions
  - Linux distributions are operating systems built on top of the Linux kernel
  - Embedded Linux distributions are often packaged for an application domain or a target platform
    - Mobile phones: Android, Angström, Ubuntu, Linaro
    - Real time: RT Linux, RTAI, XENOMAI
    - Target platform: Linux-OMAP, ARM Linux, Xilinx Linux Kernel, etc.
  - There are hundreds of Linux distributions
  - The first question to answer when developing an embedded Linux system is: which distribution to choose?
    - The answer mainly depends on application needs
Introduction

- Current popular platforms
  - OMAP 3530 (beagleboard) / ARM Cortex A8
  - ST-Ericsson (snowball) / Dual Cortex A9
  - Xilinx (ML507) / PowerPC or MicroBlaze and Virtex5
  - ZYNQ-7000 (ZedBoard) / Dual Cortex A9 and Virtex7

- Current popular Linux distributions
  - Ubuntu
  - Android
  - Linaro
  - Xilinx
Embedded Linux distributions

- Introduction
- Embedded platforms
- Embedded distributions
  - Ubuntu
  - Android
  - Linaro
  - Xilinx
Embedded platforms

- Texas Instruments
  - Beagleboard OMAP 3530 Cortex A8

- ST-Ericsson
  - Snowball Nova A9500 Dual Cortex A9

- Xilinx
  - ML507 PowerPC or MicroBlaze and Virtex5
  - ZYNQ-7000 Dual Cortex A9 and Virtex7
- OMAP 3530 Beagleboard / ARM Cortex A8
Introduction

- ST-Ericsson Snowball / Dual Cortex A9
Xilinx ML507

Description

- XC5VFX70TFFG1136
- PowerPC 440 (400MHz)
- DDR2 SODIMM (256 MB)
- System ACE CompactFlash
- 10/100/1000 Ethernet MACs
- Video (DVI/VGA)
- RS-232
- 2 USB ports
- GPIO
- etc.
Embedded Processor PowerPC440

[Diagram showing the PowerPC 440 processor with interconnections and features]

<table>
<thead>
<tr>
<th>Virtex-5 FXT FPGA Feature</th>
<th>FX30T</th>
<th>FX70T</th>
<th>FX100T</th>
<th>FX130T</th>
<th>FX200T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logic Cells</td>
<td>32,768</td>
<td>71,680</td>
<td>102,400</td>
<td>131,072</td>
<td>196,608</td>
</tr>
<tr>
<td>6 LUTs / FF</td>
<td>20,480</td>
<td>44,800</td>
<td>64,000</td>
<td>81,920</td>
<td>122,880</td>
</tr>
<tr>
<td>LUT RAM Kbits</td>
<td>380</td>
<td>820</td>
<td>1,240</td>
<td>1,580</td>
<td>2,280</td>
</tr>
<tr>
<td>36Kbit BRAM Blocks</td>
<td>68</td>
<td>148</td>
<td>228</td>
<td>298</td>
<td>456</td>
</tr>
<tr>
<td>BRAM Kbits</td>
<td>2,448</td>
<td>5,328</td>
<td>8,208</td>
<td>10,728</td>
<td>16,416</td>
</tr>
<tr>
<td>Clock Management Tiles</td>
<td>2</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>XtremeDSP DSP48E Slices</td>
<td>64</td>
<td>128</td>
<td>256</td>
<td>320</td>
<td>384</td>
</tr>
<tr>
<td>GTX Channels</td>
<td>8</td>
<td>16</td>
<td>16</td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>PowerPC 440 Blocks</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>PCI Express Endpoint Blocks</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>10/100/1000 Ethernet MACs</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>8</td>
</tr>
</tbody>
</table>
Xilinx ZYNQ-7000

- Dual ARM Cortex™-A9 MPCore
  - Up to 800MHz
  - Enhanced with NEON Extension and Single & Double Precision Floating point unit
  - 32kB Instruction & 32kB Data L1 Cache
- Unified 512kB L2 Cache
- 256kB on-chip Memory
- DDR3, DDR2 and LPDDR2 Dynamic Memory Controller
- 2x QSPI, NAND Flash and NOR Flash Memory Controller
- 2x USB2.0 (OTG), 2x GbE, 2x CAN2,0B 2x SD/SDIO, 2x UART, 2x SPI, 2x I2C, 4x 32b GPIO
- AES & SHA 256b encryption engine for secure boot and secure configuration
- Dual 12bit 1Mbps Analog-to-Digital converter
  - Up to 17 Differential Inputs
- Advanced Low Power 28nm Programmable Logic:
  - 28k to 350k Logic Cells (approximately 430k to 5.2M of equivalent ASIC Gates)
  - 240KB to 2180KB of Extensible Block RAM
  - 80 to 900 18x25 DSP Slices (58 to 1080 GMACS peak DSP performance)
- PCI Express® Gen2x8 (in largest devices)
- 154 to 404 User IOs (Multiplexed + SelectIO™)
- 4 to 16 12.5Gbps Transceivers (in largest devices)
Embedded Linux distributions

- Introduction
- Embedded platforms
- Embedded distributions
  - Ubuntu
  - Android
  - Linaro
  - Xilinx
Ubuntu

- **Ubuntu (embedded)**
  - Developed originally to support Mobile Internet Devices.
    - MID: small handheld, battery-powered mobile devices that connect to the Internet via various wireless technologies.
  - Targets the ARMv7 and above Application Processor family (Cortex A8, A9 and above).
    - Currently supports ARM EABI, with minimum compliance with the ARMv7+VFP ISA, possibly targets Thumb2 instruction set.

Ubuntu / Beagleboard video surveillance demo (LEAT)
### Embedded Linux / Device driver development

<table>
<thead>
<tr>
<th>Lectures (6h)</th>
<th>Labs (12h)</th>
<th>Tutorials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ch1 - Introduction to Linux</td>
<td>Lab1 - Kernel development</td>
<td>Linux PowerPC 440/ML507 - Kernel compilation / Basic device driver</td>
</tr>
<tr>
<td>Ch2 - Linux kernel overview</td>
<td>Lab2 - Character driver</td>
<td><strong>Ubuntu OMAP3530 beagleboard</strong> - Compilation / installation</td>
</tr>
<tr>
<td>Ch3 - Linux for Embedded Systems</td>
<td>Lab3 - IOCTL driver</td>
<td>Android OMAP3530 beagleboard - Compilation / installation</td>
</tr>
<tr>
<td>Ch4 - Embedded Linux distributions</td>
<td>Lab4 - Linux framebuffer</td>
<td></td>
</tr>
<tr>
<td>Ch5 - Case study; Xilinx PowerPC Linux</td>
<td>Lab5 - Android SGX/SDK</td>
<td></td>
</tr>
<tr>
<td>Ch6 - Device driver development</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Requirements for Embedded Linux Labs

- PowerPC Cross-development
  - ELDK - Cross-compilation toolchain
  - Linux-2.6-xilnx - Xilinx Linux Distribution
- PowerPC/Linux Xilinx EDK Project
  - linuxppc_edk.zip - EDK 10.1 project

### Ubuntu OMAP3530 beagleboard
- Compilation / installation
Embedded Linux distributions

- Introduction
- Embedded platforms
- Embedded distributions
  - Ubuntu
  - Android
  - Linaro
  - Xilinx
Android

- Android is a Linux-based operating system for mobile devices such as smartphones and tablet computers.
- Developed by the Open Handset Alliance, led by Google.
- Open Handset Alliance
  - Google, Intel, LG, Marvell, Motorola, Nvidia, Qualcomm, Samsung, T.I.
  - Goal: develop open standards for mobile devices.
- Android code is open-source, under the Apache License.
- The world’s leading smartphone platform at the end of 2010.
Android

Versions

Each version is named in alphabetical order, with 1.5 "Cupcake" being the first named after a dessert and every update since following this naming convention.

- 1.0: *Apple Pie or Alpha*, version known from developers only.
- 1.1: *Banana Bread or Beta*, version included in the first Android phone, the HTC G1/Dream.
- 1.5: *Cupcake*, April 2009, last revision May 2010.
- 2.0 (2.0.1): version first called *Eclair*. Because of many bugs, it has been quickly replaced by 2.0.1 and 2.1.
- 2.2 (2.2.3): *FroYo (Frozen Yogourt)*, Mai 2010. Last revision 2011.
Android

- Versions

- 2.3 (2.3.7) : Gingerbread, dec. 6th 2010. Used in small tablets.
- 3.0 (3.2) : Honeycomb, jan. 26th 2011. Used in large tablets and connected televisions.
- 4.0 (4.0.4) : Ice Cream Sandwich. Unified version for smartphone, tablet and Google TV, oct. 19th 2011.
- 4.1 : Jelly Bean, june 27th 2012. Used in Nexus 7 tablet mid-juuly 2012;
- 4.x ou 5.0 : Key Lime Pie.

Usage share of the different versions as of July 3, 2012
Android

Design

- Based on the Linux kernel,
- With middleware, libraries and APIs written in C
- Except the Linux kernel, Linux userspace is very different from other Linux distributions.
  - Application software running on an application framework which includes Java-compatible libraries based on Apache Harmony (open source free Java implementation).
  - Android uses a Virtual Machine (Dalvik) to produce executable (Dalvik executable) form Java bytecode.
- Android does not have a native X Window System nor does it support the full set of standard GNU libraries, and this makes it difficult to port existing Linux applications or libraries to Android.
Android

- Design
  - Android's kernel is based on the Linux kernel and has further architecture changes by Google outside the typical Linux kernel development cycle.
  
  - Android’s kernel has a few differences from the mainline Linux kernel (kernel.org).
    - power management (wakelocks)
  
  - Hardware platform: ARM architecture. Support for x86 from the Android x86 project.
Android

Embedded Linux / Device driver development

<table>
<thead>
<tr>
<th>Lectures (6h)</th>
<th>Labs (12h)</th>
<th>Tutorials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ch1 - Introduction to</td>
<td>Lab1 - Kernel development</td>
<td>Linux PowerPC 440/ML507 - Kernel</td>
</tr>
<tr>
<td>Linux</td>
<td></td>
<td>compilation / Basic device driver</td>
</tr>
<tr>
<td>Ch2 - Linux kernel</td>
<td>Lab2 - Character driver</td>
<td>Ubuntu OMAP3530 beagleboard - Compilation /</td>
</tr>
<tr>
<td>overview</td>
<td></td>
<td>installation</td>
</tr>
<tr>
<td>Ch3 - Linux for</td>
<td>Lab3 - IOCTL driver</td>
<td>Android OMAP3530 beagleboard - Compilation /</td>
</tr>
<tr>
<td>Embedded Systems</td>
<td></td>
<td>installation</td>
</tr>
<tr>
<td>Ch4 - Embedded Linux</td>
<td>Lab4 - Linux Framebuffer</td>
<td></td>
</tr>
<tr>
<td>distributions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ch5 - Case study:</td>
<td>Lab5 - Android SGX SDK</td>
<td></td>
</tr>
<tr>
<td>Xilinx PowerPC Linux</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ch6 - Device driver</td>
<td></td>
<td></td>
</tr>
<tr>
<td>development</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Requirements for Embedded Linux Labs

- PowerPC Cross-development
  - ELDK - Cross-compilation toolchain
  - linux-2.6-xilinx - Xilinx Linux Distribution
- PowerPC/Linux Xilinx EDK Project
  - linuxppc_edk_project.zip - EDK 10.1 project
Embedded Linux distributions

- Introduction
- Embedded platforms
- Embedded distributions
  - Ubuntu
  - Android
  - Linaro
  - Xilinx
A not-for-profit (NFP) engineering organization that works on consolidating and optimizing open source for the ARM architecture:

- GCC toolchain, Linux kernel, ARM power management, graphics and multimedia interfaces.

- Produces ARM tools, Linux kernels and builds of key Linux distributions (including Android and Ubuntu)

- Members: ARM, Freescale, IBM, Samsung, ST-Ericsson, Texas Instruments, etc.

- Support of the ARM v7A architecture (SoCs with Cortex-A8 or dual-core Cortex-A9 processors)

- [http://www.linaro.org/](http://www.linaro.org/)
Embedded Linux distributions

- Introduction
- Embedded platforms
- Embedded distributions
  - Ubuntu
  - Android
  - Linaro
  - Xilinx
Xilinx Linux project

- Xilinx provides open source (free) Linux development project

- The project includes
  - Support for Xilinx platforms
    - Power PC, MicroBlaze, ZYNQ-7000
  - Provides a git repository including the Linux kernel to run on Xilinx boards
  - Development tools:
    - GNU toolchain/GDB debugger, U-Boot, ...
    - Open Source QEMU system model of Zynq-7000 EPP Processing System
Embedded Linux / Device driver development

Lectures (6h)
- Ch1 - Introduction to Linux
- Ch2 - Linux kernel overview
- Ch3 - Linux for Embedded Systems
- Ch4 - Embedded Linux distributions
- Ch5 - Case study: Xilinx PowerPC Linux
- Ch6 - Device driver development

Labs (12h)
- Lab1 - Kernel development
- Lab2 - Character driver
- Lab3 - IOCTL driver
- Lab4 - Linux framebuffer
- Lab5 - Android SGL/SDK

Tutorials
- Linux PowerPC 440/ML507 - Kernel compilation / Basic device driver
- Ubuntu OMAP3530 beagleboard - Compilation / installation
- Android OMAP3530 beagleboard - Compilation / installation

Requirements for Embedded Linux Labs
- PowerPC Cross-development
  - ELDK - Cross-compilation toolchain
  - linux-2.6-xilinx - Xilinx Linux Distribution
- PowerPC/Linux Xilinx EDK Project
  - linuxppc_edk_project - EDK 10.1 project

Xilinx ML507