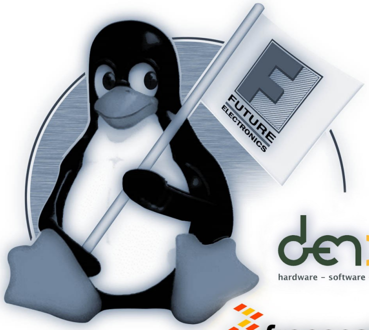


Linux FastBoot

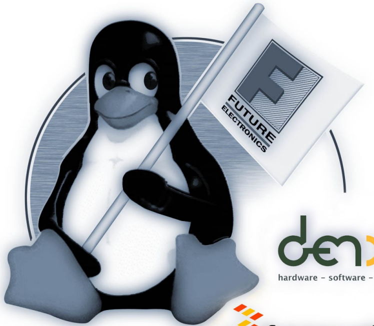
Reducing Embedded Linux Boot Times

Embedded World Conference 2012

Michael Röder
Future Electronics Deutschland GmbH

Detlev Zundel
DENX Software Engineering GmbH

Agenda



- Optimization Basics and Principles
- Boot Process Analysis and Profiling Techniques
- Optimization of
  - Kernel-Space
  - User-Space
- U-Boot
  - History and Introduction
  - Using U-Boot‘s SPL for Fastboot

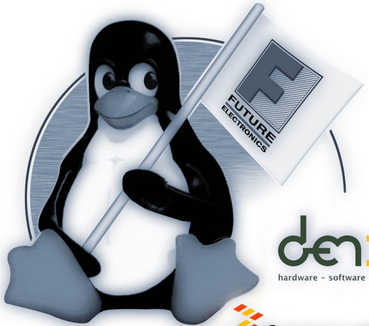
System Boot Process

- Cold-Start-Time :=
  Time from Power-On to First-Available Use

- Various stages involved:
  - hardware-setup (clocks, memories, initialization)
  - boot loader (device initialization, kernel decompression)
  - kernel init
  - user init / application start time

- Time wasted due to
  - probing (unneeded flexibility)
  - redundant tasks
  - unnecessary tasks
  - debugging functionality (keep a separate setup for debugging)

Optimization Basics



- Analysis before Optimization

  “Premature optimization is the root of all evil. […] A good programmer […] will be wise to look care fully at the critical code; but only after that code has been identified:”

  (Donald Knuth)

- Take a step-by-step approach, verify results and detect possible undesired implications after each step

- Optimize big chunks first:

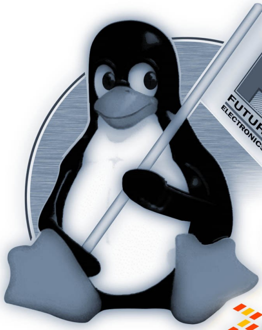
  t_1=8s; t_2=2s; speed-up by factor 4 of t_1 = 1/4 * 8s = 2s => total speedup: 150%.

  speed-up by factor 4 of t_2 = 1/4 * 2s = 0.5s => total speedup: 17%

Understanding the Application

- First-Available-Use
  - the point of time in which the system „feels“ ready to the user => is in the eye of the beholder
  - partially available system is often enough for first steps
  - less urgent tasks can be postponed or partial unavailability be hidden from user
- Understanding APPLICATION (<=> Realization) is critical
  - when do ressources / functionality really have to be available?
  - dependencies on each other
  - BDD-like dependency tree shows potential for removal, parallelization and deferring (see next slide!)
- No rules-of-thumb, each application is different!!!

Optimization Principles



(1) Don‘t do it at all

- leave out all unnecessary functionality
- optimize for the current specification,
  not for future plans, ideas, extendability, …

(2) Do it faster

- hardware is known => remove probing, scanning
- use hardware specific compiler optimizations
- remove unneeded functionality and flexibility
- make the common case fast

(3) Do it in parallel (for independent tasks)

- dependency diagram (previous slide) will show possiblities

(4) Do it later

- when nobody notices, after First-Available-Use has been reached

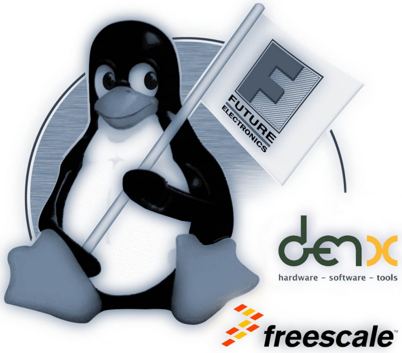
Boot Process Analysis and Profiling

- Host-Based Measurement Methods
  - no modifications or performance implications on target
  - serial console with time-stamping terminal software
    - time_log, grabserial or RealTerm
    - use keywords to trigger / reset time upon events of interest
  - GPIO-toggling based methods
- Target-Based Methods
  - enable kernel timestamps (printk.time=1)
  - module_init_call tracing (initcall_debug)
    - use bootgraph.pl on host to generate bootgraph
    - great to verify / document improvements

Kernel Optimization

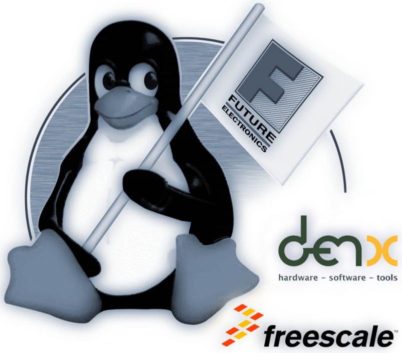
- Basis for Analysis: graph generated by bootgraph.pl
- Kernel Configuration
  - remove all debugging functionality
  - remove unnecessary device drivers
  - remove device drivers only needed after First-Available-Use (and load those later in the background using modprobe)
- Driver Configuration
  - preset information and remove probing whereever possible
  - re-use information from the bootloader (FDT, boot parameters)
- analyze driver init routine for long delay loops
  - call those init routines earlier (e.g. from the boot loader)
  - arrange such init routines in parallel

User-Space Optimization



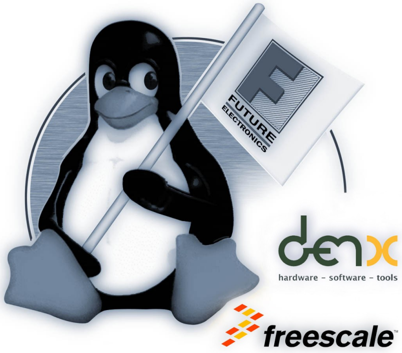
- Combine all init scripts into a single one
  - remove unused and unrequired services
  - optimize remaining services
    - remove sanity checks, log-file creation
    - preset information wherever possible to avoid searching/probing
  - move everything not necessary for First-Available-Use to a separate script and start later (from application/cron)
- Avoid using udev
  - use mknod or a copy of the complete /dev tree instead
  - if hotplugging is required, enable devtmpfs
- For profiling use *echo “tag“ > /dev/kmsg*
  (with timestamping serial console software)

U-Boot



- Started as a simple boot loader with network support for PowerPC
- Grew into multi-platform boot loader, supporting 14 architectures
- Wide support for mass storage, i.e. NOR, NAND, SPI-NOR, MMC, PATA, SATA
- Supports advanced peripherals like PCI, USB, etc.
- Powerful scripting capabilities
- Also used for hardware bring-up
- Can adapt to software development phases

U-Boot SPL



- „Classic“ CPUs start execution by fetching instructions directly over the address and data buses,
  i.e. ROM or NOR-Flash

- Modern storage devices cannot be attached directly and need special access methods,
  i.e. NAND is attached serially and needs page-wise accesses

- A CPU booting from one of these media can usually only load and start a single block of storage

- SPL of U-Boot was designed to re-use existing drivers and be such a small „Secondary Program Loader“

Using SPL for FastBoot

- Flexibility of U-Boot shows in memory footprint, several 100 kB are no exception
- Loading U-Boot itself becomes significant for execution time
- SPL framework allows to split U-Boot into
  - mimimum necessary part to access storage - and -
  - „the rest“
- This „rest“ can be „just another payload“, comparable to the Linux kernel
- Two scenarios:
  - „Fast path“: SPL loads and then starts Linux kernel
  - „Development or maintenance mode“: SPL loads U-Boot

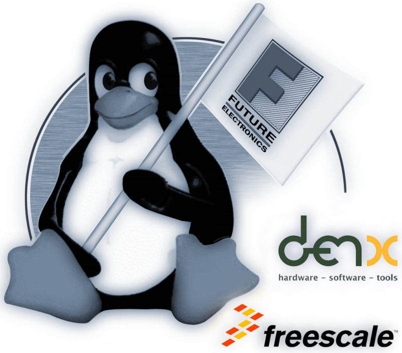
Building SPL

- Mostly manual process comparable to normal „U-Boot configuration“ through header file
- If SPL is supported on target architecture:
  - start with „#define CONFIG_SPL“
  - add necessary drivers, i.e. „CONFIG_SPL_NAND_SUPPORT“, etc.
  - fill in blanks and control logic, i.e. payload switching and loading (e.g. „spl_board_prepare_for_linux()“)
- Resulting SPL is only several kB

Linux as Payload

- Patches only entering mainline, so the design is still in flux and may change in the future
- Usually U-Boots fixes up parameters passed to the Linux kernel, i.e. the flat device tree
- „#define CONFIG_CMD_SPL“ compiles U-Boot command capable of capturing the result of this pre-processing
- This paramter block is „frozen“ in a live system using regular U-Boot and is then used as an opaque block by SPL loader

Putting it all together



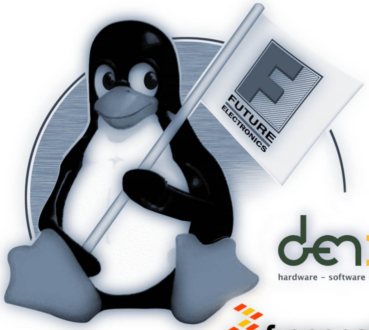
- In a properly configured system this is the fast path:
  - CPU loads SPL
  - SPL loads Linux kernel and paramter block
  - Linux boots

- When defined criteria holds, this is the development path:
  - CPU loads SPL
  - SPL loads U-Boot as payload
  - U-Boot command line starts
  - U-Boot can boot Linux as regular

Summary

- Boot Time Optimization is not...
  - an automatic (or automatable) process
  - black magic or an "art"

- Road to Success:
  - Thorough Analysis:
    - understand the desired application ("Specification")
    - analyze existing implementation / system
  - Attentive Optimization
    - remove unnecessary parts
    - optimize the rest, to the extent that the specification permits
    - start with the big and easy parts
  - Enable Re-Use
    - document and verify all changes made during the optimization process, especially possible implications on expected functionality
    - document successes and failures of evaluated optimization attempts, take the same route for similar projects and hardware



THANK YOU