GDB on ARM
Linaro Contributions

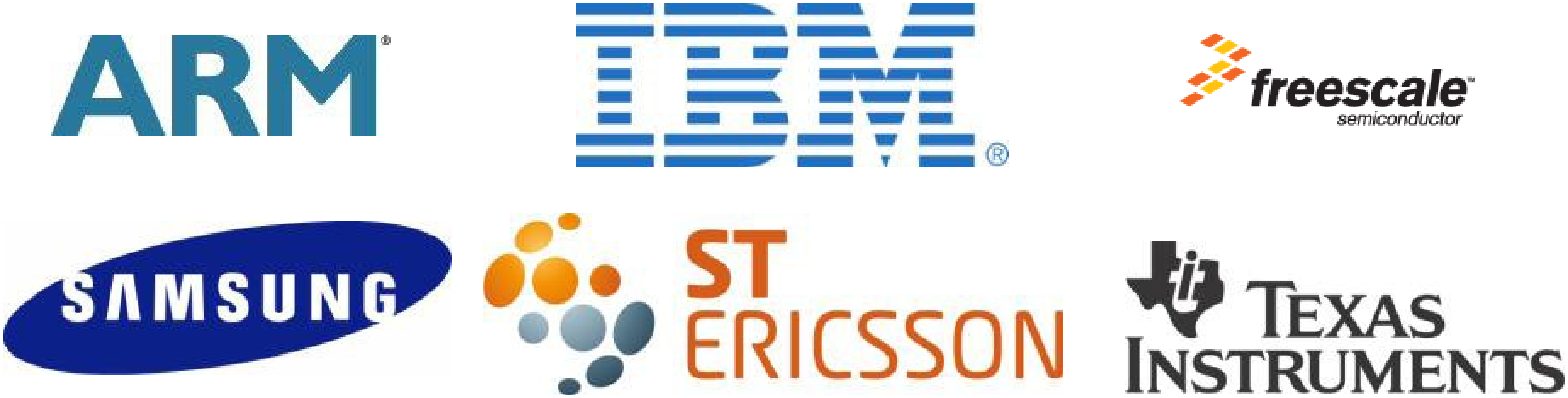
Dr. Ulrich Weigand
<ulrich.weigand@linaro.org>
<ulrich.weigand@de.ibm.com>

Agenda

- What is Linaro?
- Native debugging enhancements
  - Back-trace support
  - Hardware break-/watchpoint support
  - NEON vector register support
- Remote debugging enhancements
- Debugging native Android code

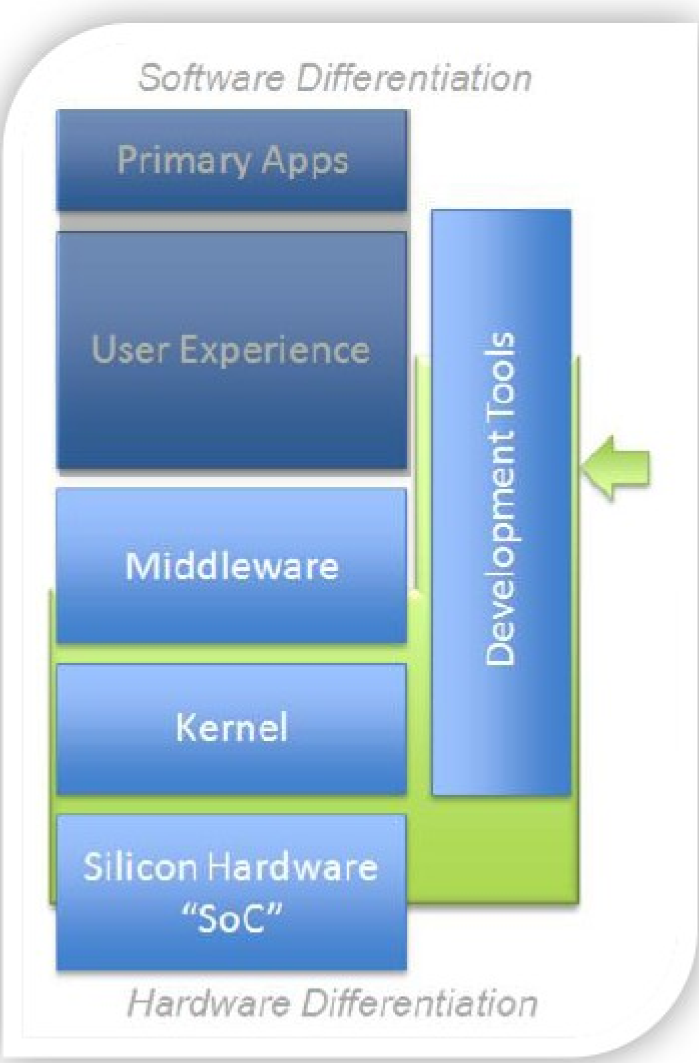
What is Linaro?

- *An open source development consortium for ARM and the embedded community*
- Founded in June 2010. Mission:
  - *“to make it easier for ARM partners to deploy the latest technology into optimized Linux based products”*



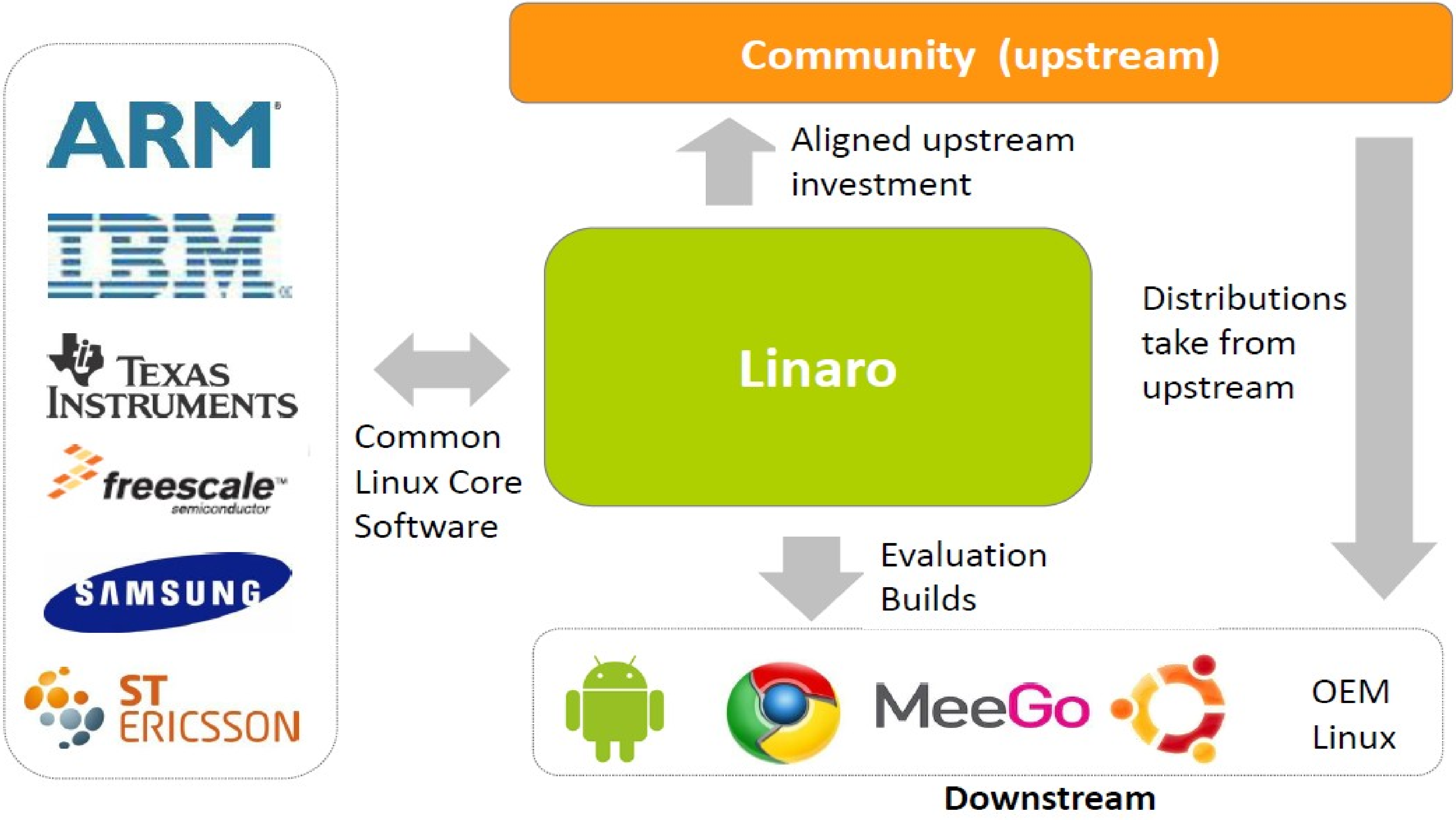
- Not-for-profit software engineering company
  - 130 Engineers as of end 2011

What does Linaro do?



- Delivers an optimized code base
  - Kernel and vital middleware
  - Applied across all member SoCs
- Tools
  - Best compiler, debugger, profiler
- Enabled on the latest SoCs
  - Cortex A8, A9, & A15 processors
- Delivered upstream
  - Evaluation builds for key distributions – Android, Chrome, MeeGo, Ubuntu
  - Test & Validation framework for member SoCs

Where does Linaro fit?



Community (upstream)

Aligned upstream investment

Linaro

Common Linux Core Software

Distributions take from upstream

Evaluation Builds

OEM Linux

Downstream

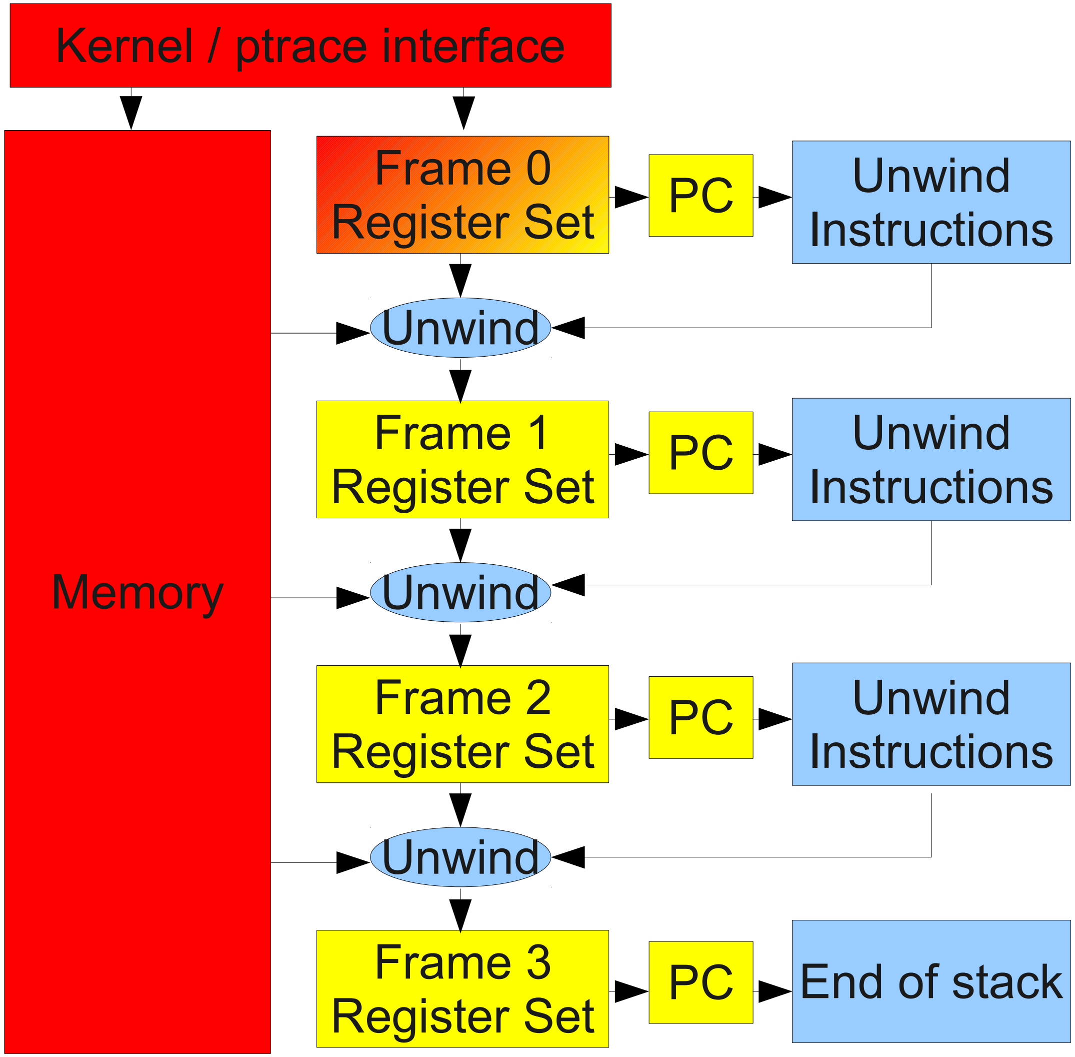
Linaro Toolchain Working Group

- Linaro Toolchain releases
  - Monthly GCC, GDB, QEMU releases
- Major focus areas
  - Compiler performance improvements
    - e.g auto-vectorizer, scheduler, ARM back-end ...
  - Exploit latest ARM architecture features
    - e.g. STT_GNU_IFUNC support, optimized string routines
  - Support current hardware in QEMU
  - Reliable debugging support

Native debugging enhancements

- Linaro focus areas
  - Enhanced back-trace support
    - Prologue parsing for Thumb-2 code
    - Backtrace using ARM exception tables
    - Backtrace out of kernel vector page
    - Backtrace out of glibc system call stubs
  - Support ARM hardware break-/watchpoints
  - Support VFP/NEON registers in core files
  - Fix numerous GDB test suite failures on ARM

Back-trace support: Background



- Basic algorithm
  - Start with initial register set (frame #0)
  - Extract PC from register set
  - Determine register unwind instructions at PC
    - "Restore PC from LR"
    - "Add 128 to SP"
    - "Restore R8 from memory at location (old) SP + 80"
    - "Register R10 is unchanged"
    - "Register R2 cannot be unwound; its prior value is lost"
  - Given old register set and memory contents, apply unwind instructions to construct register set at next frame (frame #1)
  - Repeat until uppermost frame is reached

Back-trace support on ARM

- How to determine unwind instructions at PC
  - Use DWARF-2 Call Frame Instructions (.debug_frame; on non-ARM also .eh_frame)
  - Use ARM exception table information (.ARM.exidx / .ARM.extbl)
  - Disassemble start of function containing PC and interpret prologue
  - Hard-coded special cases (e.g. signal return trampolines, kernel vector page stubs)
- Challenges on ARM
  - No .eh_frame section means no DWARF CFI in the absence of debug info
  - ARM exception tables were not supported in GDB
  - Glibc assembler code was not (always) annotated with ARM exception tables
  - Prologue parsing did not handle the Thumb-2 instruction set
    - Note that Thumb-2 is the default on current Ubuntu distributions
- Current status
  - Support for all missing features added
  - No GDB test case fails due to unwind problems
    - This is true even in the absence of system library debug info packages

ARM hardware watchpoints

- Feature set
  - Hardware watchpoints
    - Trap when a pre-defined memory locations is modified
    - Used to implement “watch” family of commands in GDB
  - Hardware breakpoints
    - Trap when execution reaches a specified address
    - Used to implement “hbreak” family of commands in GDB
    - Useful in particular to set breakpoints in non-modifyable code (e.g. ROM)
- Current status
  - Hardware breakpoint/watchpoint support added to Linux kernel 2.6.37
  - Support exploited by GDB 7.3
- Hardware pre-requisites
  - Cortex-A8: limited HW support, not currently exploited by Linux kernel
  - Cortex-A9: improved HW support, Linux kernel supports one single HW watchpoint
  - Cortex-A15: full HW support, Linux (3.2) supports multiple HW watchpoints

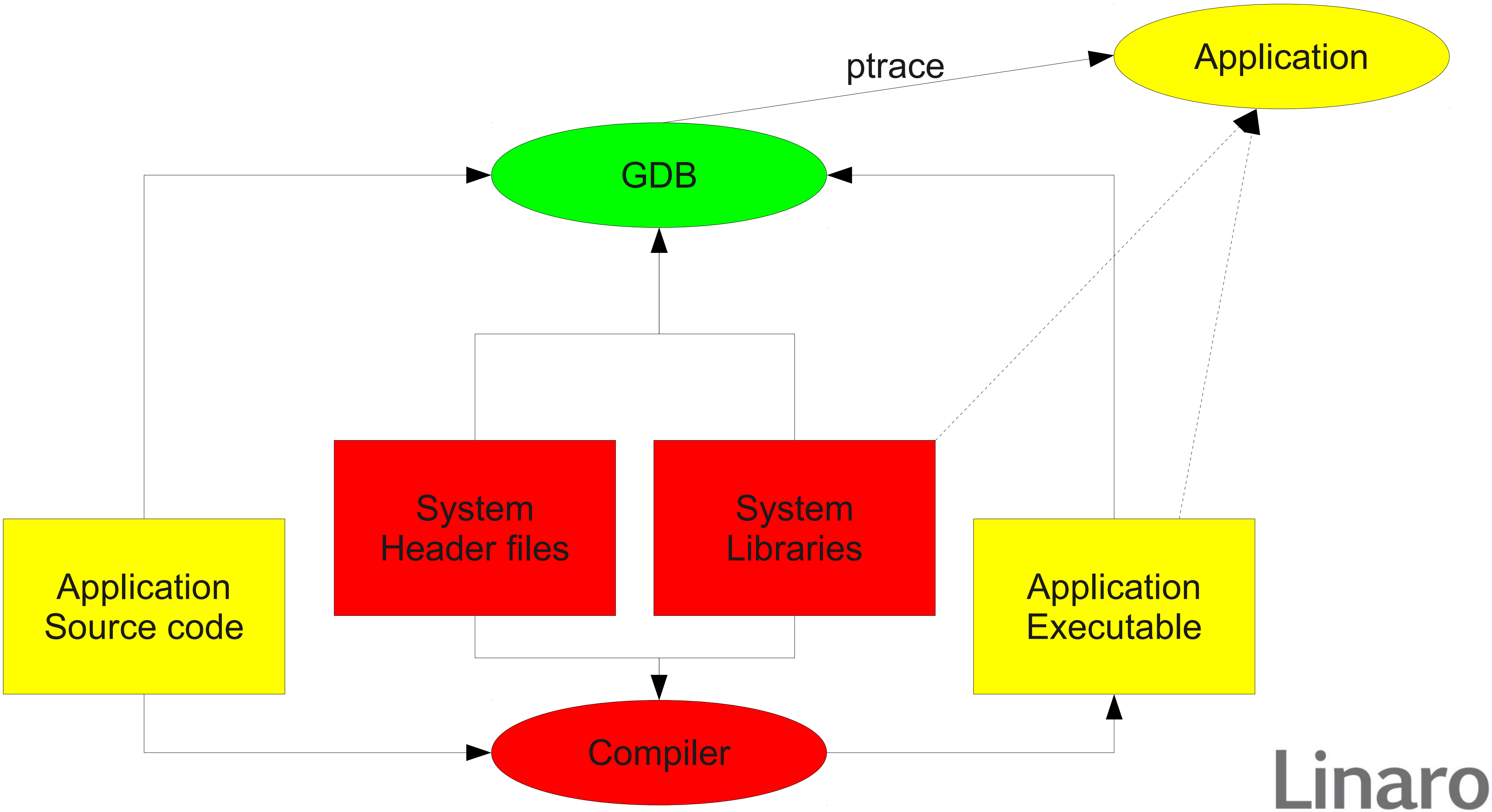
VFP/NEON register sets

- Floating-point / vector registers on ARM
  - Past architectures did not specify floating-point or vector registers; some implementations provided those via co-processor extensions
  - ARMv7 specifies VFPv3 and Advanced SIMD (“NEON”) extensions
    - VFPv3-D16: 16 64-bit registers / 32 32-bit registers
    - VFPv3-D32: 32 64-bit registers
    - NEON: VFPv3-D32 registers re-interpreted as 16 128-bit registers
- Current status
  - Access VFP/NEON register sets in native/remote debugging: Supported with Linux kernel 2.6.30 / GDB 7.0
  - Access VFP/NEON registers sets in core files: Supported with Linux kernel 3.0 / GDB 7.3

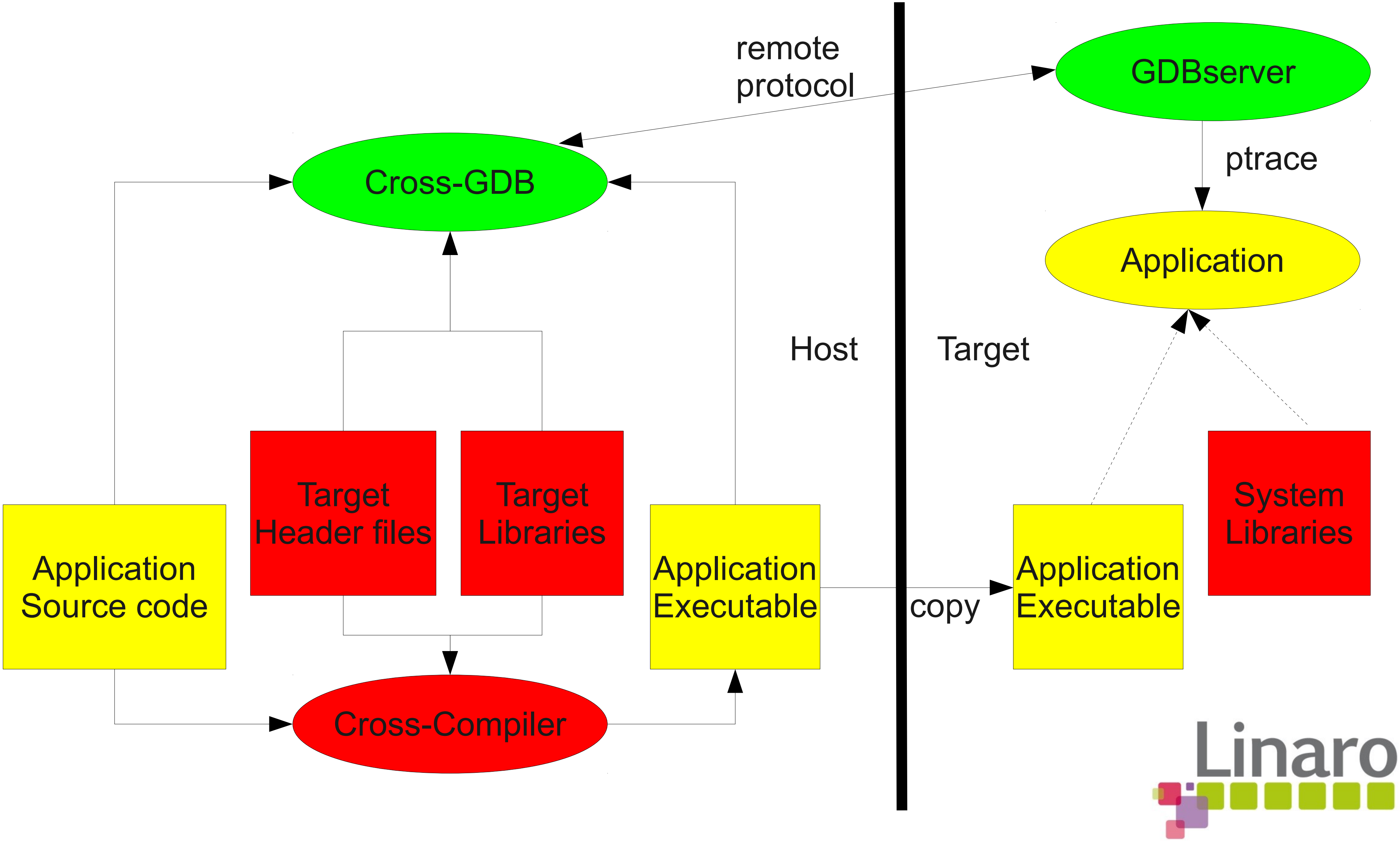
Remote debugging enhancements

- Linaro focus areas
  - Basic remote debugging via gdbserver
    - Miscellaneous test suite fixes and enhancements
    - Fix problems with “remote:” sysroot access
  - Additional gdbserver / remote debugging features
    - Support hardware break-/watchpoints
    - Disable address space randomization
    - Core file generation and “info proc”

Background: Native debugging



Background: Remote debugging



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Remote debugging challenges

- GDB accesses application binary / target libraries on **host**
  - Assumes these are identical copies of files on target
    - Debugging will (silently) fail if that assumption is violated
  - Solution: Have gdbserver access files on **target**
    - Contents forwarded via remote protocol
  - Status: Implemented; enable via “set sysroot remote:”
- Native target and gdbserver target feature sets differ
  - Both implement similar functionality but do not share code
  - Some native features missing from remote debugging (and vice versa)
  - Long-term solution: Code re-factoring to allow re-use of identical code base
  - For now: Narrow gap by re-implementing missing gdbserver features
    - Support hardware break-/watchpoints
    - Disable address space randomization
    - Core file generation and “info proc”

Debugging Android

- Android applications
  - Usually implemented in Java, running on Dalvik
  - “Native” components can be implemented via NDK
  - GDB used to debug native Android code, usually configured as cross-debugger with gdbserver running on the Android device
- “Android vs. Linux” differences visible to GDB
  - Mostly caused by different libc (Bionic vs. glibc)
  - ABI issues: jmp_buf layout (setjmp/longjmp); signal frames
  - Debugging multi-threaded applications
    - GDB relies on “libthread_db” shared library provided by C library to inspect internal libc/libpthread data structure
    - Bionic does not have libthread_db; Android “fakes” it by looking at kernel data exported via /proc etc.

Debugging Android

- Current status
  - Android NDK provides patched version of GDB and gdbserver
  - Some third parties likewise provide versions with extra patches
- Goal
  - Have Android as fully supported target OS
    - Automatically detect whether target uses Bionic or glibc
  - Support both GDB native and gdbserver remote debugging
  - Everything available in upstream GDB without patches
- Work on this goal currently under way in Linaro

Summary

- Linaro is a not-for-profit engineering organization consolidating and optimizing open source Linux software and tools for the ARM architecture.
- One of the ongoing focus areas of Linaro's Toolchain Working Group is enhancing the GNU Debugger to provide a first-class debugging experience on current ARM-based devices.
- In GDB 7.3 Linaro contributed enhancements to bring the native debugging experience on ARM on par with other platforms.
- In GDB 7.4 Linaro contributed enhancements to bring the remote debugging experience, in particular on ARM, closer to the native feature set.
- Currently, work is under way to help fully integrate support for debugging Android native code into mainline GDB.

Questions?