# The vDSO on arm64

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ARM

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# Outline



# The vDSO

# What is a vDSO?

vDSO: virtual DSO (Dynamic Shared Object)

- A full-blown DSO (shared library), provided by the kernel
- Mapped by the kernel into all user processes
- Linked like a normal `.so` shared library
  - The one gdb used to complain about! (`warning: Could not load shared library symbols for linux-vdso.so.1`)
- Mainly meant for providing “syscalls in userspace” (virtual syscalls)

# “Virtual” syscalls

## It’s all about speed!

- Certain syscalls are fast to process and the syscall itself (kernel enter/exit) is a significant overhead
- Certain syscalls do not require much privilege to process

} Not doing a syscall would be beneficial

- Solution: provide some code to userspace that “emulates” the syscall
  - Possibly using some data made available by the kernel
  - Outside of the kernel, but strongly tied to it
- Typical candidates: time-related syscalls
  - For instance, a “virtual” `gettimeofday()` can be up to 10 times faster than the normal syscall!

# Why a DSO?

A significant improvement over the old vsyscall page:

- More flexible: no fixed offset within the vDSO
- Cleaner: appears like a regular library to userspace
  $\longrightarrow$ improved debugging
- Harder to exploit: takes advantage of ASLR

Now included in most major architectures,
deprecating (or completely replacing) the vsyscall page

vsyscall by arch

| | | | |
|---|---|---|---|
| x86_64 | 2.5.6 | 2002 | [Initial arch impl.] |
| i386 | 2.5.53 | 2002 | |

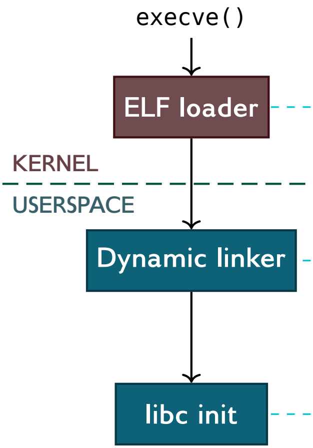
vDSO by arch

| | | | |
|---|---|---|---|
| ppc64 | 2.6.12 | 2005 | |
| i386 | 2.6.18 | 2006 | |
| x86_64 | 2.6.23 | 2007 | |
| mips | 2.6.34 | 2010 | |
| arm64 | 3.7 | 2012 | [Initial arch impl.] |
| arm | 4.1 | 2015 | |

# Implementation and plumbing

# Kernel and userspace setup

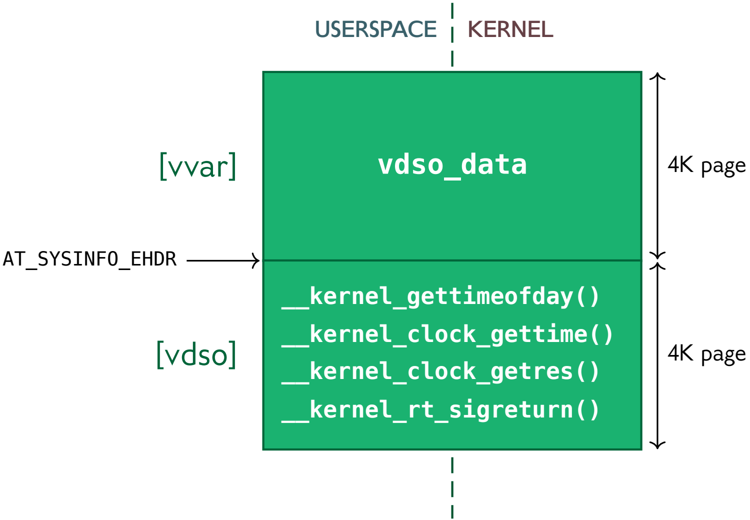



- Maps vDSO pages (code + data)
- Sets AT_SYSINFO_EHDR in the auxiliary vector

- Looks up AT_SYSINFO_EHDR in the auxiliary vector
- If set, links the vDSO (⟶ [vdso])

- Looks up function symbols (e.g. __vdso_gettimeofday) in [vdso]
- If found, sets global function pointers

# Anatomy of the vDSO on arm64



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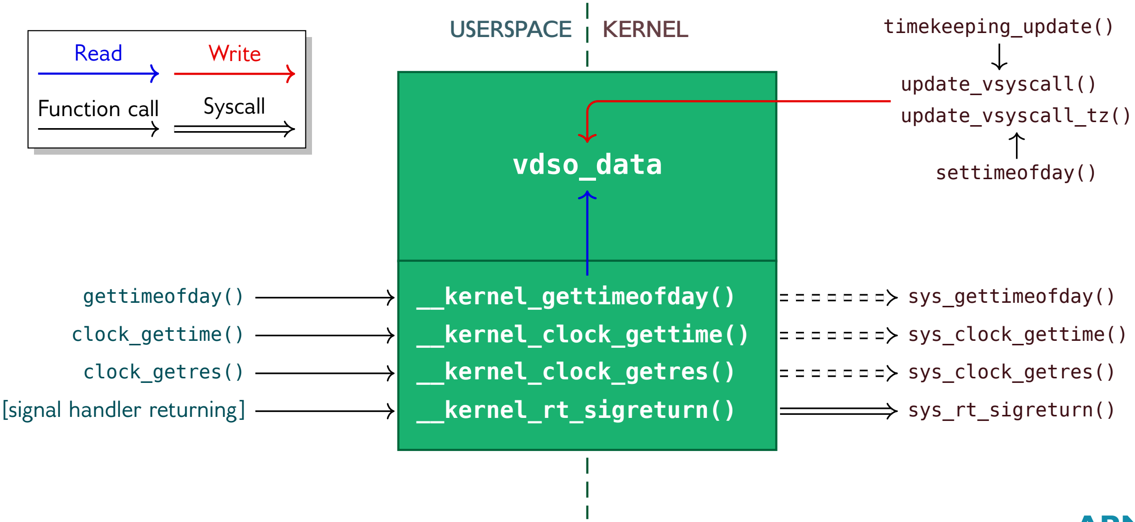

# Adding a 32-bit vDSO to `arm64`

 

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# Compat processes and vDSO

- `COMPAT`: running 32-bit processes under a 64-bit kernel
  - Present on `x86`, `arm64`, `mips`, `powerpc`, ...
- Requires dedicated vDSO support
  - Present on `x86`, `mips`, `powerpc`, ... but not `arm64`
  - Partly due to `arm` only having a vDSO since 4.1 (glibc support only added in 2.22)
- Why bother about the performance of 32-bit processes on `arm64`?
  - Very little use on `arm64` servers, but...
  - Still widespread on Android (apps shipped with 32-bit libraries)
  - `arm64` Chromebooks run a fully 32-bit userspace (for now)
  - Vendors started implementing their own 32-bit vDSO!

→ There is a need for a 32-bit vDSO on `arm64`

# Main parts of the 32-bit vDSO implementation

[All paths are relative to `arch/arm64`]

- The 32-bit vDSO (userspace library) itself

  `kernel/vdso32/vgettimeofday.c` Time-related syscalls (`gettimeofday()` and `clock_gettime()`)

  `kernel/vdso32/sigreturn.S` `sigreturn` trampolines

- Install the vDSO mappings in compat user processes (and set `mm->context.vdso`)

  `kernel/vdso.c` `aarch32_setup_additional_pages()`

- Tell `fs/compat_binfmt_elf.c` to set `AT_SYSINFO_EHDR`

  `include/asm/elf.h` `COMPAT_ARCH_DLINFO: AT_SYSINFO_EHDR = mm->context.vdso`

- Use the sigreturn trampolines

  `kernel/signal32.c` `compat_setup_return()`

For more information, have a look at the patch series: [RFC PATCH v2 0/8] arm64: Add a compat vDSO

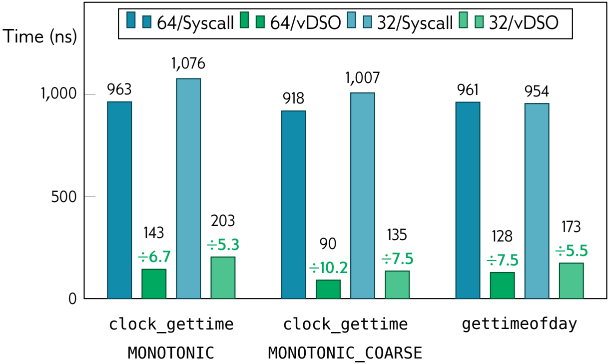
# Problems and solutions

- Some redundancy with the `[vectors]` page
  - Remove it (so long, kuser helpers!)
  - Move the sigreturn trampolines to `[vdso]`
- The `arm64` vDSO is implemented in assembly → cannot be reused
  - Reuse and adapt the `arm` vDSO (modified to share the same data page)
- Compiling `arm` code: we need a 32-bit toolchain!
  - Compat vDSO only built if `CROSS_COMPILE_ARM32` is set
  - Pass a clever mixture of flags to the 32-bit compiler
- Kernel support is pointless without support in libc + dynamic linker
  - Support added to glibc in 2.22 (August 2015)
  - Support added to bionic in July 2016 — but it didn't make it into Android N ☹

# Some figures

vDSO call vs direct syscall, 64-bit and 32-bit




- Very simple benchmark, run on Juno R0 with 4.8-rc1 + compat vDSO
- Using glibc 2.23 compiled for arm
- Biggest gain on coarse clocks (very fast to read → maximal syscall overhead)
- Slightly lower gain in 32-bit — probably because it is not written in assembly ☺

# Conclusion

- The vDSO: a useful and flexible mechanism
  - To avoid the overhead of a syscall, by doing the work in userspace
  - To provide any kind of data or code to userspace (e.g. `sigreturn` trampolines)
- Kernel-side implementation completely arch-specific (in practice, always more or less similar)
- libc + dynamic linker support essential!
- Proposed addition of a 32-bit vDSO to `arm64`
  - Very relevant for Android and Chrome OS
  - Better to have it available in mainline than implemented by each vendor
  - Closely linked to the `arm` vDSO
  - Patch series: [RFC PATCH v2 0/8] arm64: Add a compat vDSO

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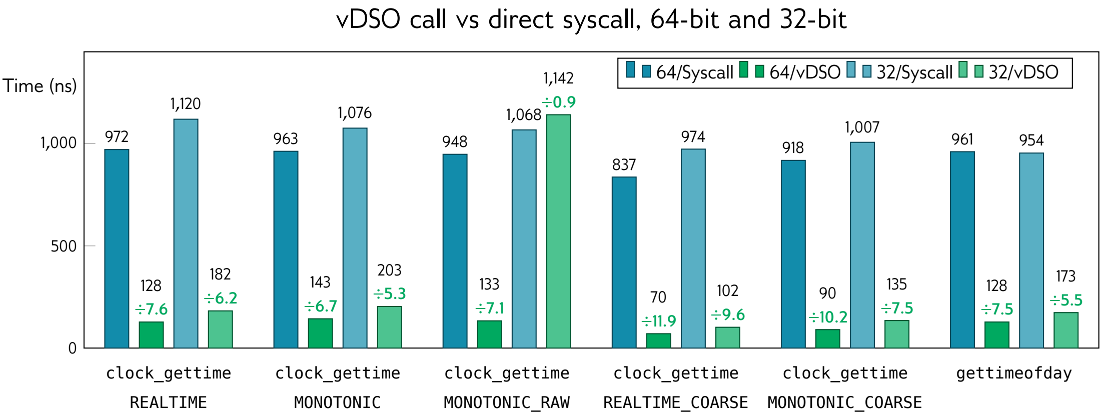
# Questions

# Appendices

# Full benchmarks



# vDSO hacking/debugging

Debugging the vDSO is a bit tricky, due to it being used by default (no easy way to opt out)

Quick hacks to ease debugging:

- Create a shared library with the libc functions you want to override and use `LD_PRELOAD`
- More global: modify your libc so that it only considers the vDSO if an environment variable is set

# vDSO data page ([vvar])

```
struct vdso_data {
        __u64 cs_cycle_last;    /* Timebase at clocksource init */
        __u64 raw_time_sec;     /* Raw time */
        __u64 raw_time_nsec;
        __u64 xtime_clock_sec;  /* Kernel time */
        __u64 xtime_clock_nsec;
        __u64 xtime_coarse_sec; /* Coarse time */
        __u64 xtime_coarse_nsec;
        __u64 wtm_clock_sec;    /* Wall to monotonic time */
        __u64 wtm_clock_nsec;
        __u32 tb_seq_count;     /* Timebase sequence counter */
        __u32 cs_mono_mult;     /* NTP-adjusted clocksource multiplier */
        __u32 cs_shift;         /* Clocksource shift (mono = raw) */
        __u32 cs_raw_mult;      /* Raw clocksource multiplier */
        __u32 tz_minuteswest;   /* Whacky timezone stuff */
        __u32 tz_dsttime;
        __u32 use_syscall;
};
```