The End of Time
19 years to go

Arnd Bergmann

Overview

- Background: The problem we are solving
- Changes merged so far
- Ongoing changes

Background: time_t in Unix

- typedef long time_t;
- time_t start=0:
  1970-01-01, 00:00:00 UTC
- 32-bit TIME_T_MAX:
  2038-01-19, 03:14:07 UTC

The fix: 64-bit time_t

- typedef long long time_t;
- 64-bit TIME_T_MAX:
  292,277,026,597-12-04 14:15:28

Why we care: 32-bit kernels

- Widespread use:

```
$ find arch/arm/boot/dts/  -name \*.dts | wc -l
   1099
$ find arch/arm64/boot/dts/  -name \*.dts | wc
-l
    193
```

- Sometimes long service lives

32 bit devices with 20+ year life

32 bit devices with 20+ year life

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32 bit devices with 20+ year life

Some software lives even longer

The Register
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Software

Nuke plants to rely on PDP-11 code UNTIL 2050!

Programmers and their walking sticks converge in Canada

By Richard Chirgwin 19 Jun 2013 at 05:59 206 SHARE ▼

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Industrial product lifecycle

- Development starts on proven hardware with long service life (e.g. NXP i.MX6)
- Several years until first deployment
- 5-10 years active marketing
- Customer buys 15 year old embedded system
- Expect 10+ years of active use

32 bit user space

- nonportable legacy applications
- memory size limitations
- common software
  - ARMv6 Raspbian

32 bit interfaces

- Network protocols
  - Shared key expiration
- File systems
  - On-disk inode timestamps
- File formats
  - utmp
  - cpio

32 bit interfaces

- Hardware/Firmware
  - Real-time clock
  - SCSI adapters
  - PTP network adapters

```
SHMEM2_WR(bp, drv_info.epoc,
          (u32)ktime_get_real_seconds());
```

Ongoing work in the kernel

```
commit 361a3bf00582469877f8d18ff20f1efa6b781274
Author: John Stultz <john.stultz@linaro.org>
Date:   Wed Jul 16 21:03:58 2014 +0000

    time64: Add time64.h header and define struct timespec64

    Define the timespec64 structure and standard helper functions.

    [ tglx: Make it 32bit only. 64bit really can map timespec to timespec64 ]

    Signed-off-by: John Stultz <john.stultz@linaro.org>
    Signed-off-by: Thomas Gleixner <tglx@linutronix.de>
    Signed-off-by: John Stultz <john.stultz@linaro.org>

diff --git a/include/linux/time64.h b/include/linux/time64.h
new file mode 100644
index 000000000000..e7b499e1cd79
--- /dev/null
+++ b/include/linux/time64.h
@@ -0,0 +1,162 @@
+#ifndef _LINUX_TIME64_H
+#define _LINUX_TIME64_H
+
+#include <uapi/linux/time.h>
+
+typedef __s64 time64_t;
+
+/*
+ * This wants to go into uapi/linux/time.h once we agreed about the
```

Eliminating all 32-bit time_t uses

- Many hundreds of drivers patched since 2014
- Core timekeeping code, 2014-2015
- Core file system code, 2012-2018
- System calls, ongoing

Eliminating all 32-bit time_t uses

- Change time* to ktime_t
  - Also helps with accuracy
- Change time* to jiffies
  - Also makes code faster
- Change time_t to time64_t
- Change timespec/timeval to timespec64
- Change CLOCK_REALTIME to CLOCK_MONOTONIC
  - Also helps with leap seconds, NTP

Fixing ioctl interfaces

```
#define _IOC(dir,type,nr,size) \
        (((dir)  << _IOC_DIRSHIFT) | \
         ((type) << _IOC_TYPESHIFT) | \
         ((nr)   << _IOC_NRSHIFT) | \
         ((size) << _IOC_SIZESHIFT))

#define _IOR(type,nr,size)      _IOC(_IOC_READ,(type),(nr),(sizeof(size)))
#define _IOW(type,nr,size)      _IOC(_IOC_WRITE,(type),(nr),(sizeof(size)))
#define _IOWR(type,nr,size)
_IOC(_IOC_READ|_IOC_WRITE,(type),(nr),(sizeof(size)))

#define PPGETTIME    _IOR(PP_IOCTL, 0x95, struct timeval)
#define PPPIOCGIDLE  _IOR('t', 63, struct ppp_idle) /* get idle time */
```

Fixing ioctl interfaces

```
@@ -743,10 +744,17 @@ static long ppp_ioctl(struct file *file, unsigned int
cmd, unsigned long arg)
                err = 0;
                break;

-       case PPPIOCGIDLE:
-               idle.xmit_idle = (jiffies - ppp->last_xmit) / HZ;
-               idle.recv_idle = (jiffies - ppp->last_recv) / HZ;
-               if (copy_to_user(argp, &idle, sizeof(idle)))
+       case PPPIOCGIDLE32:
+                idle32.xmit_idle = (jiffies - ppp->last_xmit) / HZ;
+                idle32.recv_idle = (jiffies - ppp->last_recv) / HZ;
+                if (copy_to_user(argp, &idle32, sizeof(idle32)))
+               err = 0;
+               break;
+
+       case PPPIOCGIDLE64:
+               idle64.xmit_idle = (jiffies - ppp->last_xmit) / HZ;
+               idle64.recv_idle = (jiffies - ppp->last_recv) / HZ;
+               if (copy_to_user(argp, &idle32, sizeof(idle32)))
```

Fixing ioctl interfaces

```
#define _IOC(dir,type,nr,size) \
        (((dir)  << _IOC_DIRSHIFT) | \
         ((type) << _IOC_TYPESHIFT) | \
         ((nr)   << _IOC_NRSHIFT) | \
         ((size) << _IOC_SIZESHIFT))

#define _IOR(type,nr,size)      _IOC(_IOC_READ,(type),(nr),(sizeof(size)))
#define _IOW(type,nr,size)      _IOC(_IOC_WRITE,(type),(nr),(sizeof(size)))
#define _IOWR(type,nr,size)
_IOC(_IOC_READ|_IOC_WRITE,(type),(nr),(sizeof(size)))

#define PPGETTIME    _IOR(PP_IOCTL, 0x95, struct timeval)
#define PPPIOCGIDLE  _IOR('t', 63, struct ppp_idle) /* get idle time */
#define SIOCGSTAMP   0x8906
```

Fixing ioctl interfaces

```
-#define SIOCGSTAMP        0x8906
+#define SIOCGSTAMP_OLD    0x8906
+/*
+ * the timeval/timespec data structure layout is defined by libc,
+ * so we need to cover both possible versions on 32-bit.
+ */
+/* Get stamp (timeval) */
+#define SIOCGSTAMP_NEW  _IOR(SOCK_IOC_TYPE, 0x06, long long[2])
+
+#if __BITS_PER_LONG == 64 || (defined(__x86_64__) && defined(__ILP32__))
+/* on 64-bit and x32, avoid the ?: operator */
+#define SIOCGSTAMP     SIOCGSTAMP_OLD
+#else
+#define SIOCGSTAMP     ((sizeof(struct timeval))  == 8 ? \
+                        SIOCGSTAMP_OLD   : SIOCGSTAMP_NEW)
+#endif
```

Other driver interfaces: read()

```
int input_event_to_user(char __user *buffer,
                        const struct input_event *event)
{
        if (in_compat_syscall() && !COMPAT_USE_64BIT_TIME) {
                struct input_event_compat compat_event;

                compat_event.sec = event->input_event_sec;
                compat_event.usec = event->input_event_usec;

                if (copy_to_user(buffer, &compat_event,
                                 sizeof(struct input_event_compat)))
                        return -EFAULT;

        } else {
                if (copy_to_user(buffer, event, sizeof(struct input_event)))
                        return -EFAULT;
        }

        return 0;
}
```

Other driver interfaces: read()

```
struct input_event {
#if (__BITS_PER_LONG != 32 || !defined(__USE_TIME_BITS64)) &&
!defined(__KERNEL)
        struct timeval time;
#define input_event_sec time.tv_sec
#define input_event_usec time.tv_usec
#else
        __kernel_ulong_t __sec;
        __kernel_ulong_t __usec;
#define input_event_sec  __sec
#define input_event_usec __usec
#endif
        __u16 type;
        __u16 code;
        __s32 value;
};
```

Other driver interfaces: mmap()

```
struct snd_pcm_mmap_status {
        snd_pcm_state_t state;          /* RO: state - SNDRV_PCM_STATE_XXXX
*/
        int pad1;                       /* Needed for 64 bit alignment */
        snd_pcm_uframes_t hw_ptr;       /* RO: hw ptr (0...boundary-1) */
-       struct timespec tstamp;         /* Timestamp */
+       struct snd_monotonic_timestamp tstamp; /* Timestamp */
        snd_pcm_state_t suspended_state; /* RO: suspended stream state */
-       struct timespec audio_tstamp;   /* from sample counter or wall clock
*/
+       struct snd_monotonic_timestamp audio_tstamp;    /* from sample
counter or wall clock */
 };

 struct snd_pcm_mmap_control {
```

Virtual File System layer

- First posted by Arnd in 2014
- Second try: Deepa Dinamani, 2016
- Completed by Deepa in 2018
- statx() syscall by David Howells
- utimes() syscall: WIP
- File systems mostly converted
  - Missing: NFS, XFS, HFS, AFS
- Some file systems still not y2038 safe
  - XFS, ext3, coda

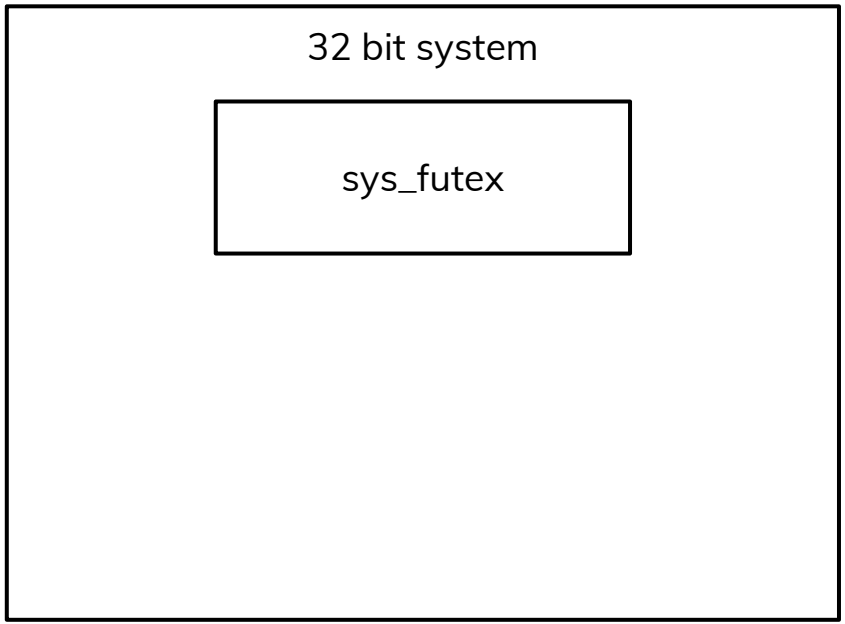
System calls

- Internal implementation done
- New entry points for 32-bit
  50% done in 4.18
- Need to discuss some APIs:
  - clock_adjtimex,
  - getrusage, wait4
  - getitimer/setitimer

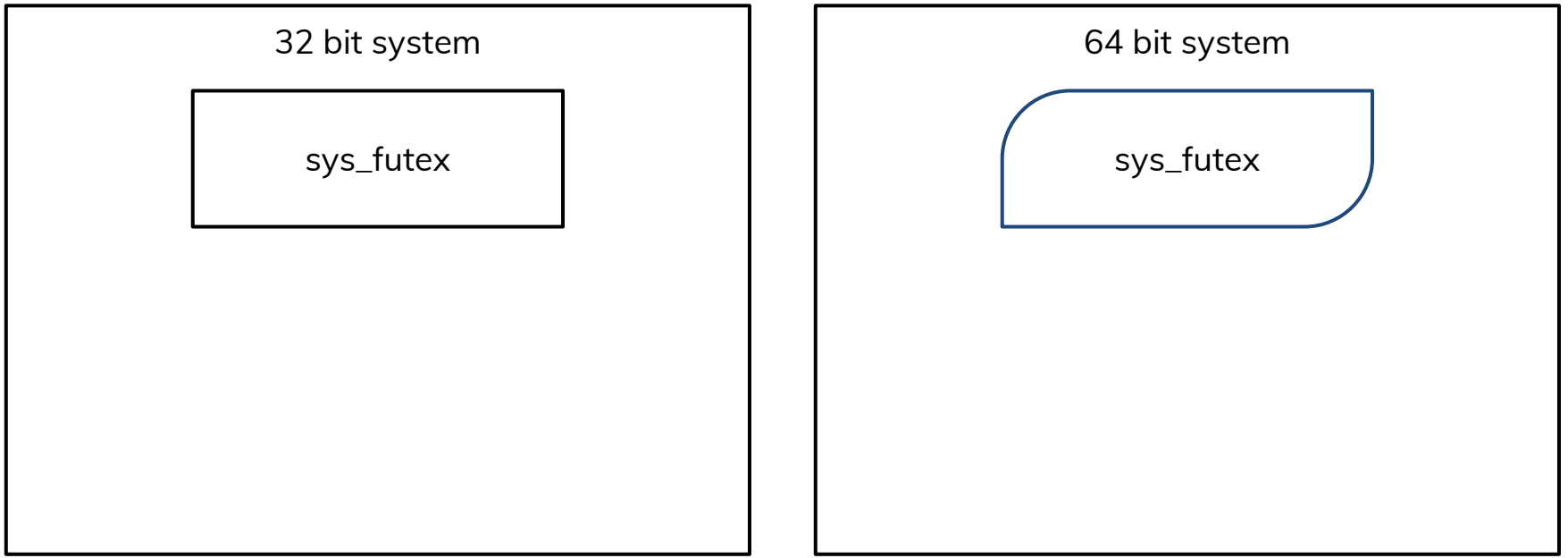
System calls: method

- Change normal syscall to 64-bit time_t interface
- Reuse 32-bit compat syscalls
- rename compat_time_t to old_time32_t
- rename compat_sys_foo() to sys_foo_time32()

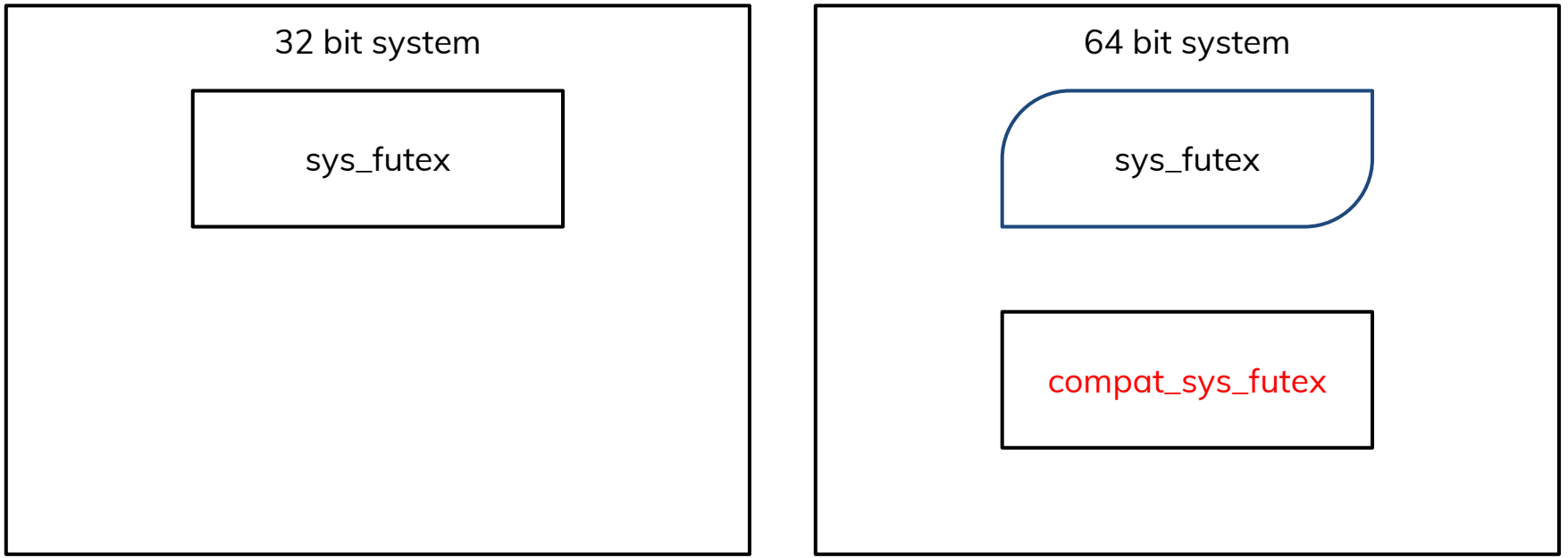
System calls: method



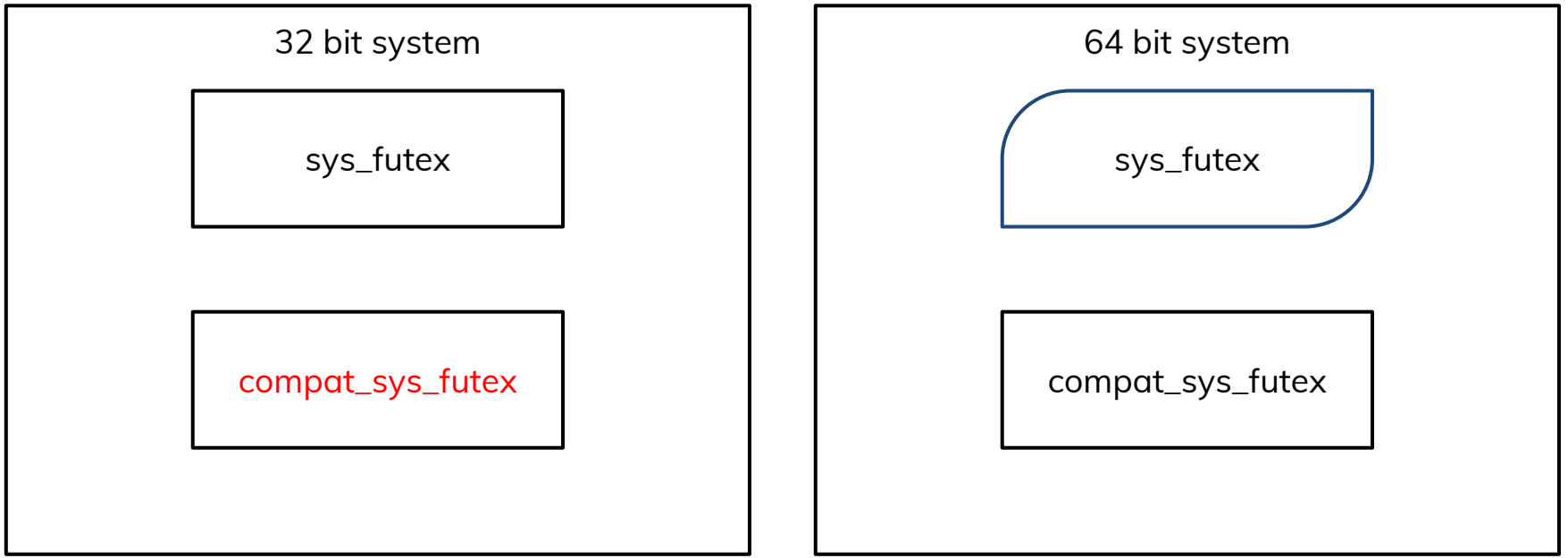
System calls: method



System calls: method



System calls: method

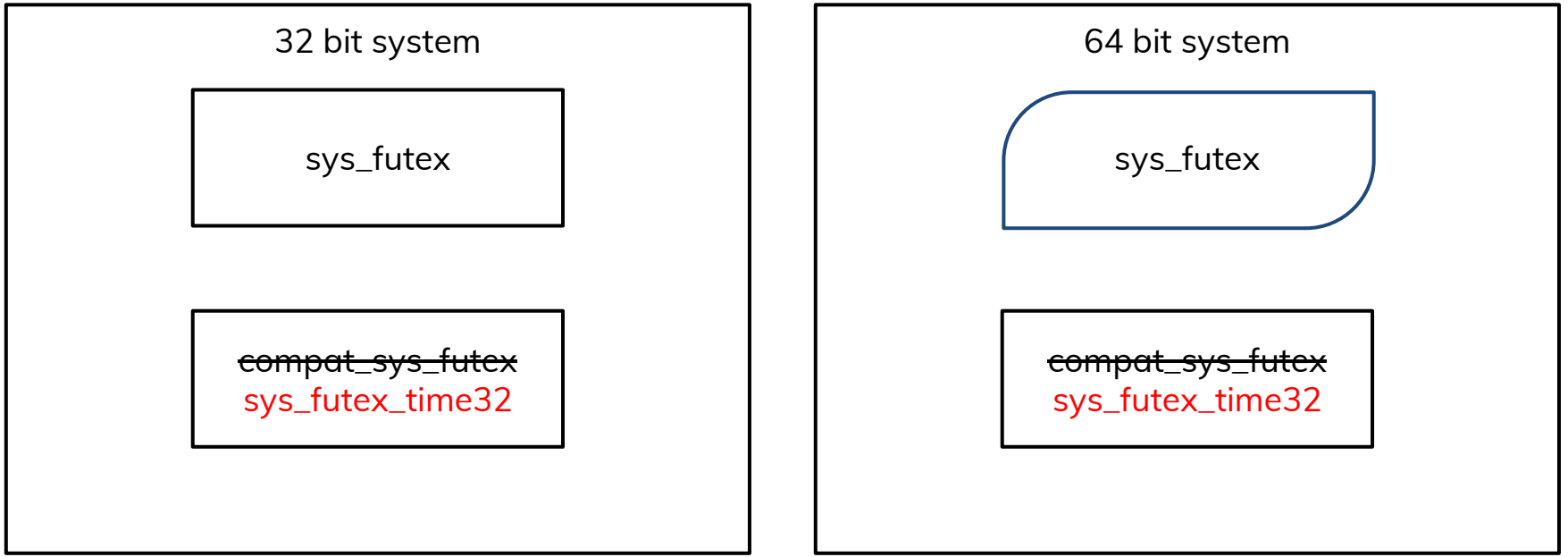


System calls: method

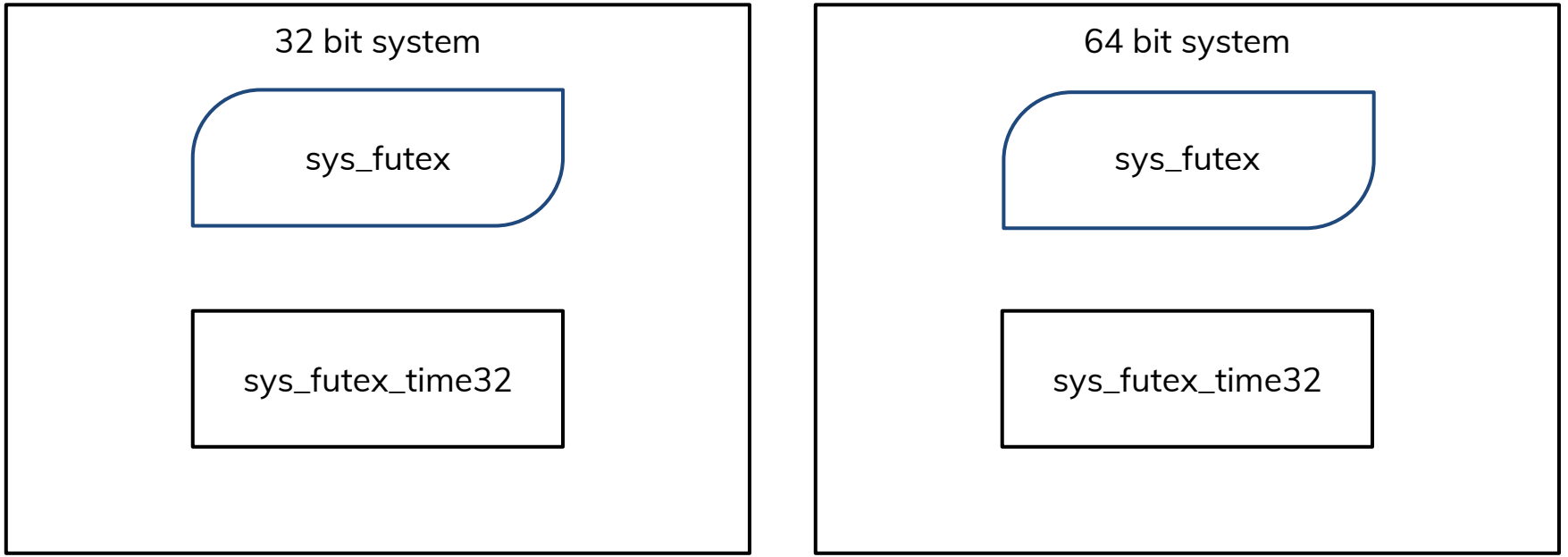
```
@@ -173,10 +173,10 @@ COMPAT_SYSCALL_DEFINE3(get_robust_list, int, pid,
        return ret;
 }

-#ifdef CONFIG_COMPAT
-COMPAT_SYSCALL_DEFINE6(futex, u32 __user *, uaddr, int, op, u32, val,
-                       struct compat_timespec __user *, utime, u32 __user *, uaddr2,
+#ifdef CONFIG_COMPAT_32_BIT_TIME
+SYSCALL_DEFINE6(futex_time32, u32 __user *, uaddr, int, op, u32, val,
+                       struct old_timespec32 __user *, utime, u32 __user *, uaddr2,
                        u32, val3)
 {
        struct timespec ts;
```

System calls: method



System calls: method



System calls: method

```
--- a/kernel/futex.c
+++ b/kernel/futex.c
@@ -3558,10 +3558,10 @@ long do_futex(u32 __user *uaddr, int op, u32 val,
ktime_t *timeout,


 SYSCALL_DEFINE6(futex, u32 __user *, uaddr, int, op, u32, val,
-                struct timespec __user *, utime, u32 __user *, uaddr2,
+                struct __kernel_timespec __user *, utime, u32 __user *,
uaddr2,
                 u32, val3)
 {
-       struct timespec ts;
+       struct timespec64 ts;
        ktime_t t, *tp = NULL;
        u32 val2 = 0;
        int cmd = op & FUTEX_CMD_MASK;
```

System calls: method

include/linux/time64.h

```
typedef __s64 time64_t;

#ifndef CONFIG_64BIT_TIME
#define __kernel_timespec timespec
#endif


#include <uapi/linux/time.h>
```

include/uapi/linux/time.h

```
typedef long long __kernel_time64_t;

#ifndef __kernel_timespec
struct __kernel_timespec {
        __kernel_time64_t       tv_sec;
        long long               tv_nsec;
};
#endif
```

Affected syscalls, deprecated

- time
- stime
- gettimeofday
- settimeofday
- adjtimex
- nanosleep
- alarm
- select
- old_select
- io_getevents
- utime
- utimes
- futimensat
- oldstat
- oldlstat
- oldfstat
- newstat
- newlstat
- newfstat
- newfstatat
- stat64
- lstat64
- fstat64
- fstatat64
- wait4

Affected syscalls, deprecated

- ~~time~~
- ~~stime~~
- ~~gettimeofday~~
- ~~settimeofday~~
- adjtimex
- ~~nanosleep~~
- ~~alarm~~
- select
- old_select
- io_getevents
- ~~utime~~
- ~~utimes~~
- ~~futimensat~~
- ~~oldstat~~
- ~~oldlstat~~
- ~~oldfstat~~
- ~~newstat~~
- ~~newlstat~~
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- ~~newfstatat~~
- ~~stat64~~
- ~~lstat64~~
- ~~fstat64~~
- ~~fstatat64~~
- wait4

Affected syscalls, deprecated

- ~~time~~
- ~~stime~~
- ~~gettimeofday~~
- ~~settimeofday~~
- adjtimex
- ~~nanosleep~~
- ~~alarm~~
- ~~select~~
- ~~old_select~~
- ~~io_getevents~~
- ~~utime~~
- ~~utimes~~
- ~~futimensat~~
- ~~oldstat~~
- ~~oldlstat~~
- ~~oldfstat~~
- ~~newstat~~
- ~~newlstat~~
- ~~newfstat~~
- ~~newfstatat~~
- ~~stat64~~
- ~~lstat64~~
- ~~fstat64~~
- ~~fstatat64~~
- wait4

Affected syscalls, need replacement

- clock_gettime
- clock_settime
- clock_adjtime
- clock_getres
- clock_nanosleep
- getitimer
- setitimer
- timer_gettime
- timer_settime
- timerfd_gettime
- timerfd_settime
- pselect6
- ppoll
- io_pgetevents
- recvmmsg
- mq_timedsend
- mq_timedreceive
- semtimedop
- msgctl
- semctl
- shmctl
- utimensat
- rt_sigtimedwait
- futex
- sched_rr_get_interval
- getrusage
- wait4
- waitid
- sysinfo

Affected syscalls, need replacement

- ~~clock_gettime~~
- ~~clock_settime~~
- clock_adjtime
- ~~clock_getres~~
- ~~clock_nanosleep~~
- getitimer
- setitimer
- ~~timer_gettime~~
- ~~timer_settime~~
- ~~timerfd_gettime~~
- ~~timerfd_settime~~
- pselect6
- ppoll
- io_pgetevents
- recvmmsg
- ~~mq_timedsend~~
- ~~mq_timedreceive~~
- ~~semtimedop~~
- ~~msgctl~~
- ~~semctl~~
- ~~shmctl~~
- utimensat
- rt_sigtimedwait
- futex
- sched_rr_get_interval
- getrusage
- wait4
- waitid
- sysinfo

Affected syscalls, need replacement

- ~~clock_gettime~~
- ~~clock_settime~~
- clock_adjtime
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- ~~clock_nanosleep~~
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- setitimer
- ~~timer_gettime~~
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- ~~timerfd_settime~~
- ~~pselect6~~
- ~~ppoll~~
- ~~io_pgetevents~~
- ~~recvmmsg~~
- ~~mq_timedsend~~
- ~~mq_timedreceive~~
- ~~semtimedop~~
- ~~msgctl~~
- ~~semctl~~
- ~~shmctl~~
- ~~utimensat~~
- ~~rt_sigtimedwait~~
- ~~futex~~
- ~~sched_rr_get_interval~~
- getrusage
- wait4
- waitid
- sysinfo

Syscall TODO: getrusage

```
int sys_getrusage(int who, struct rusage __user *ru);
struct  rusage {
        struct timeval  ru_utime;       /* user time used */
        struct timeval  ru_stime;       /* system time used */
        __kernel_long_t ru_maxrss;      /* maximum resident set size */
        __kernel_long_t ru_ixrss;       /* integral shared memory size */
        __kernel_long_t ru_idrss;       /* integral unshared data size */
        __kernel_long_t ru_isrss;       /* integral unshared stack size */
        __kernel_long_t ru_minflt;      /* page reclaims */
        __kernel_long_t ru_majflt;      /* page faults */
        __kernel_long_t ru_nswap;       /* swaps */
        __kernel_long_t ru_inblock;     /* block input operations */
        __kernel_long_t ru_oublock;     /* block output operations */
        __kernel_long_t ru_msgsnd;      /* messages sent */
        __kernel_long_t ru_msgrcv;      /* messages received */
        __kernel_long_t ru_nsignals;    /* signals received */
        __kernel_long_t ru_nvcsw;       /* voluntary context switches */
        __kernel_long_t ru_nivcsw;      /* involuntary " */
};
```

Syscall TODO: getrusage

```
int sys_getrusage_time32(int who, struct rusage __user *ru);
struct  rusage {
#if (__BITS_PER_LONG != 32 || !defined(__USE_TIME_BITS64)) &&
!defined(__KERNEL__)
        struct timeval  ru_utime;       /* user time used */
        struct timeval  ru_stime;       /* system time used */
#else
        /*
         * For 32-bit user space with 64-bit time_t, the binary layout
         * in these fields is incompatible with 'struct timeval', so the
         * C library has to translate this into the POSIX compatible layout.
         */
        struct __kernel_old_timeval ru_utime;
        struct __kernel_old_timeval ru_stime;
#endif
        __kernel_long_t ru_maxrss;      /* maximum resident set size */
        __kernel_long_t ru_ixrss;       /* integral shared memory size */
        __kernel_long_t ru_idrss;       /* integral unshared data size */
        __kernel_long_t ru_isrss;       /* integral unshared stack size */
        __kernel_long_t ru_minflt;      /* page reclaims */
```

Syscall TODO: getrusage

```
int sys_getrusage_time64(int who, struct __kernel_rusage __user *ru);
struct  __kernel_rusage {
        struct __kernel_timespec ru_utime; /* user time used */
        struct __kernel_timespec ru_stime; /* system time used */
        __kernel_long_t ru_maxrss;      /* maximum resident set size */
        __kernel_long_t ru_ixrss;       /* integral shared memory size */
        __kernel_long_t ru_idrss;       /* integral unshared data size */
        __kernel_long_t ru_isrss;       /* integral unshared stack size */
        __kernel_long_t ru_minflt;      /* page reclaims */
        __kernel_long_t ru_majflt;      /* page faults */
        __kernel_long_t ru_nswap;       /* swaps */
        __kernel_long_t ru_inblock;     /* block input operations */
        __kernel_long_t ru_oublock;     /* block output operations */
        __kernel_long_t ru_msgsnd;      /* messages sent */
        __kernel_long_t ru_msgrcv;      /* messages received */
        __kernel_long_t ru_nsignals;    /* signals received */
        __kernel_long_t ru_nvcsw;       /* voluntary context switches */
        __kernel_long_t ru_nivcsw;      /* involuntary " */
};
```

Side note: time structures

```
struct __timespec64 {
  __time64_t  tv_sec;
#if __BYTE_ORDER == __BIG_ENDIAN
  int : 32;
#endif
  long        tv_nsec;
#if __BYTE_ORDER == __BIG_ENDIAN
  int padding;
#endif
};
```

Side note: time structures

```
struct __timespec64 {
  __time64_t  tv_sec;
#if __BYTE_ORDER == __BIG_ENDIAN
  int : 32;
#endif
  long        tv_nsec;
#if __BYTE_ORDER == __BIG_ENDIAN
  int padding;
#endif
};
```

Side note: time structures

```
struct __timespec64 {
  __time64_t  tv_sec;
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  int : 32;
#endif
  long        tv_nsec;
#if __BYTE_ORDER == __BIG_ENDIAN
  int padding;
#endif
};
```

Side note: time structures

```
struct __timespec64 {
  __time64_t  tv_sec;
#if __BYTE_ORDER == __BIG_ENDIAN
  int : 32;
#endif
  long        tv_nsec;
#if __BYTE_ORDER == __BIG_ENDIAN
  int padding;
#endif
};
```

Side note: time structures

```
struct __kernel_old_timeval {
          long tv_sec;
#ifdef __sparc_v9__
          int tv_usec;
          int padding;
#else
          long tv_usec;
#endif
};
```

Side note: time structures

```
struct __kernel_old_timeval {
          long tv_sec;
#ifdef __sparc_v9__
          int tv_usec;
          int padding;
#else
          long tv_usec;
#endif
};
```

C library porting

GLIBC

- Design by Albert Aribaud
  - https://sourceware.org/glibc/wiki/Y2038ProofnessDesign
- Old kernel support
- Symbol versioning
- `gcc -D__USE_TIME_BITS64`

MUSL

- Experimental port by Arnd Bergmann
- Binary incompatible
- No compile time switch
- musl-2.x ?

Distro work needed

- 32-bit Embedded distros
  - OpenEmbedded,PTXdist OpenWRT, Buildroot,
  - Rebuild from source
- 32-bit Android
  - New incompatible ABI
- 32-bit Desktop
  - Debian, Fedora, …
  - Migration plan
- 64-bit distros
  - SLES, RHEL, Ubuntu, ...
  - Bug fixes only

32 bit interfaces

- Network protocols
  - Shared key expiration
- File systems
  - On-disk inode timestamps
- File formats
  - utmp
  - cpio

32 bit interfaces

- Hardware/Firmware
  - Real-time clock
  - SCSI adapters
  - PTP network adapters

```
SHMEM2_WR(bp, drv_info.epoc,
(u32)ktime_get_real_seconds());
```

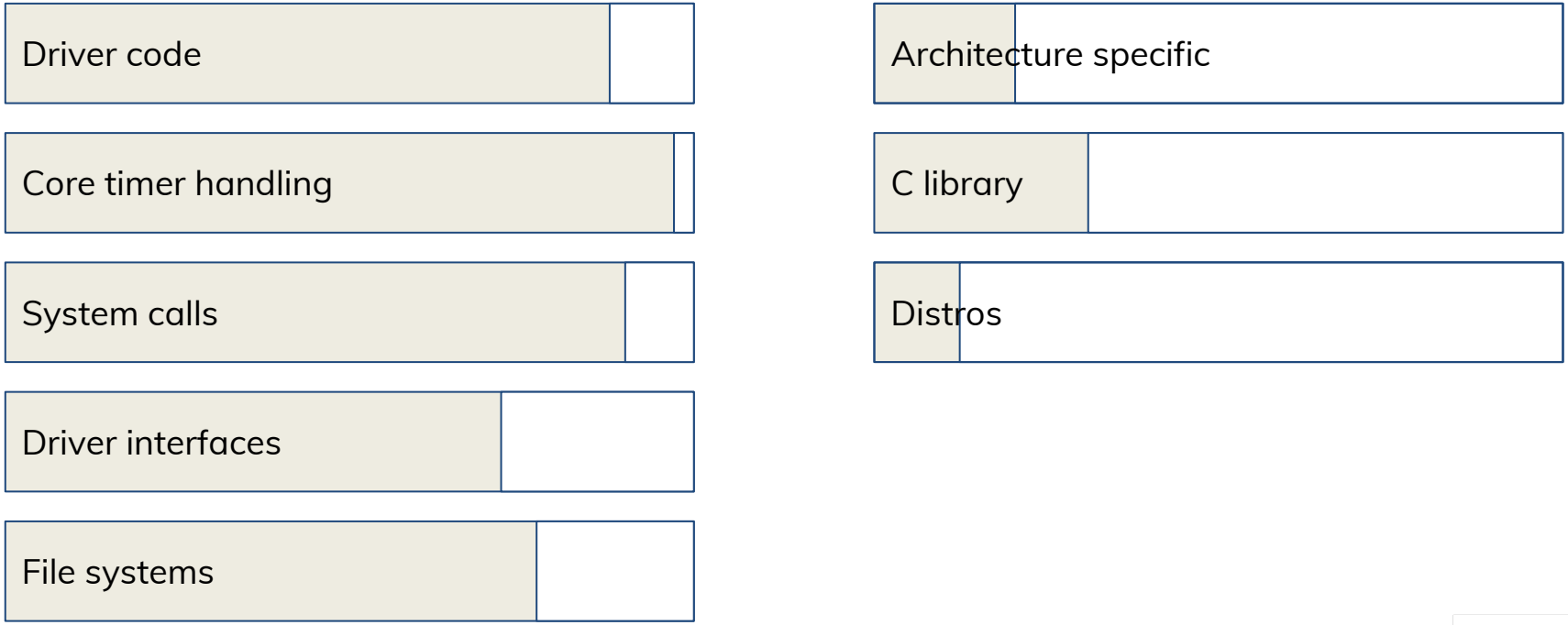
32-bit distro needing rebuild

- Fedora
  - Primary: armhf
  - Secondary: x86-32, mips-el
- Debian
  - Official: armhf, armel, i386, mipsel
  - Other: sh4, m68k, or1k, powerpcspe
- Arch Linux
  - Inofficial: arm, x86-32
- Ubuntu Core (ARM):
  - Artik 5/10, Orange Pi 0, R-Pi 2
- openSUSE Leap:
  - armv6hl, armv7hl
- Raspbian

32-bit distro needing rebuild

- Fedora
  - Primary: armhf
  - Secondary: x86-32, mips-el
- Debian
  - Official: armhf, armel, i386, mipsel
  - Other: sh4, m68k, or1k, parisc, powerpcspe
- Arch Linux
  - Inofficial: arm, x86-32
- Ubuntu Core (ARM):
  - Artik 5/10, Orange Pi 0, R-Pi 2

Progress bar, v4.19



Questions?