What could be done in the kernel to make strace happy

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There is no kernel API to find out whether the tracee is entering or exiting syscall.

There is no reliable way to distinguish between x86_64 and x86 syscalls.

There is no kernel API to invoke `wait4` syscall with a different signal mask (like `pselect6` and `ppoll`).

The time precision provided by `struct rusage` is too low for syscall statistics (`strace -c`).

There is no proper kernel API to translate between tracer and tracee views of pids.

There is no way to obtain network protocol details for descriptors of tracees running in different namespaces (`strace -yy`).

There are no consistent detailed declarative syscall descriptions, this forces every user to reinvent its own wheel and catch up with the kernel.

`strace` is slow, `perf` can lose data.
Problem 1: whether the tracee is entering or exiting syscall?

<table>
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<tr>
<th>Problem</th>
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<tbody>
<tr>
<td>Both <strong>syscall-enter-stop</strong> and <strong>syscall-exit-stop</strong> look the same for the tracer, there is no kernel API to distinguish them.</td>
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<th>Workaround</th>
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<td>strace does its best to keep track of the sequence of ptrace events. When attaching to a tracee inside exec, however, its first syscall stop is very likely going to be <strong>syscall-exit-stop</strong> instead of <strong>syscall-enter-stop</strong>, the workaround is fragile.</td>
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Problem 2: whether the invoked syscall is x86_64 or x86?

Problem

There is no reliable way to distinguish between x86_64 and x86 syscalls.

Current practice

```c
union {
    struct x86_64_user_regs_struct x86_64_r;
    struct i386_user_regs_struct i386_r;
} x86_regs_union;
struct iovec x86_io = {
    .iov_base = &x86_regs_union,
    .iov_len = sizeof(x86_regs_union)
};
rc = ptrace(PTRACE_GETREGSET, pid, NT_PRSTATUS, &x86_io);
...
if (x86_io.iov_len == sizeof(x86_regs_union.i386_r)) {
    scno = x86_regs_union.i386_r_regs.orig_eax;
    currpers = 1;
} else {
    scno = x86_regs_union.x86_64_r.orig_rax;
    currpers = 0;
}
```
Problem 2: whether the invoked syscall is x86_64 or x86?

In infamous case of int 0x80 on x86_64 the PTRACE_GETREGSET approach does not work.

Example

```c
#include <stdio.h>

int main(void) {
    /* 200 is __NR_getgid32 on x86 and __NR_tkill on x86_64. */
    __asm__("movq $246, %rsi; movq $135, %rdi; movq $200, %rax; int $0x80");
    printf("getegid returns \%d\n", getegid());
    return 0;
}
```

```bash
$ cat int_0x80.c
$ gcc -Wall -O2 int_0x80.c
$ strace -qq -etrace=tkill,/getegid ./a.out
tkill(135, 246) = 500
getegid() = 500
getegid returns 500
```
Proposed solution: PTRACE_GET_SYSCALL_INFO

Extend the ptrace API with PTRACE_GET_SYSCALL_INFO request, use it instead of PTRACE_GETREGSET et al

```c
struct ptrace_syscall_info {
    __u8 op; /* 0 for entry, 1 for exit */
    __u8 __pad0[7];
    union {
        struct {
            __s32 nr;
            __u32 arch;
            __u64 ip;
            __u64 args[6];
        } entry_info;
        struct {
            __s64 rval;
            __u8 is_error;
            __u8 __pad2[7];
        } exit_info;
    };
};
```

RFC patch and discussion: https://lkml.org/lkml/2018/11/7/313
Problem 3: invoking wait4 with a different signal mask

strace main loop in case of delay injection enabled

for (;;) {
    /* What if the timer has expired at this point? */
    pid = wait4(-1, &status, __WALL, &rusage);
    handle_tracee(pid, status, &rusage);
}

Problem

There is no kernel API to invoke wait4 syscall with a different signal mask, similar to pselect6 extension over select and ppoll over poll.

Workaround

strace does its best to implement a race-free workaround by doing a lot of non-trivial work inside a signal handler. This is way too complex and very fragile.
Proposed solution: `pwait6` syscall

Similar to `pselect6` extension over `select` and `ppoll` over `poll`, add `pwait6` syscall which is `wait4` with additional signal mask arguments:

```c
pid_t
wait4(pid_t pid, int *wstatus,
     int options, struct rusage *rusage);

pid_t
pwait6(pid_t pid, int *wstatus,
       int options, struct rusage *rusage,
       const sigset_t *sigmask, size_t sigsetsize);
```
### Problem 4: time precision limitations of `struct rusage`

The time precision provided by `struct rusage` is too low for syscall statistics.

```
$ strace -c -e%file pwd > /dev/null
% time  seconds  usecs/call  calls  errors  syscall
         ----------- ----------- ----------- -------- ------------
53.09  0.000043  43          1  execve
30.86  0.000025  12          2  openat
16.05  0.000013  13          1  access
 0.00  0.000000   0          1  getcwd
         ----------- ----------- ----------- -------- ------------
100.00 0.000081  5           1  total
```

```
$ strace -c -e%file pwd > /dev/null
% time  seconds  usecs/call  calls  errors  syscall
         ----------- ----------- ----------- -------- ------------
100.00  0.000009   9          1  getcwd
 0.00  0.000000   0          1  access
 0.00  0.000000   0          1  execve
 0.00  0.000000   0          2  openat
         ----------- ----------- ----------- -------- ------------
100.00  0.000009   5          1  total
```
Proposed solution: **pwait6 syscall**

Use a better structure than **struct rusage** in the new **pwait6 syscall**

Replace **struct rusage** argument of the new **pwait6 syscall** with **struct rusage_ts64**:

```c
struct rusage {
    struct timeval ru_utime; /* user CPU time used */
    struct timeval ru_stime; /* system CPU time used */
    ...
}
```

```c
struct rusage_ts64 {
    struct timespec64 ru_utime; /* user CPU time used */
    struct timespec64 ru_stime; /* system CPU time used */
    ...
}
```

**struct timespec64** is chosen over **struct timespec** to avoid 32-bit time_t overflow.
Problem 5: no translation of pids

Problem

PID namespaces have been introduced without a proper kernel API to translate between tracer and tracee views of pids.

strace users are getting confused by PID namespaces:

https://bugzilla.redhat.com/1035433

```
# strace -qq -ff -e clone -o s.log unshare --pid -- sh -c 'sh -c "sh -c true & wait" & wait'
# ls s.log.*
s.log.4567  s.log.4568  s.log.4569
# grep ^ s.log.*
s.log.4567:clone(child_stack=NULL, flags=CLONE_CHILD_CLEARTID|CLONE_CHILD_SETTID|SIGCHLD, →
    child_tidptr=0x7fa7f9adba10) = 4568
s.log.4567:--- SIGCHLD si_signo=SIGCHLD, si_code=CLD_EXITED, →
    si_pid=4568, si_uid=0, si_status=0, si_utime=0, si_stime=0 ---
s.log.4568:clone(child_stack=NULL, flags=CLONE_CHILD_CLEARTID|CLONE_CHILD_SETTID|SIGCHLD, →
    child_tidptr=0x7fe0f586aa10) = 2
s.log.4568:--- SIGCHLD si_signo=SIGCHLD, si_code=CLD_EXITED, →
    si_pid=2, si_uid=0, si_status=0, si_utime=0, si_stime=0 ---
```
Problem 5: no translation of pids

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```bash
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s.log.4567  s.log.4568  s.log.4569
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s.log.4567:clone(child_stack=NULL, flags=CLONE_CHILD_CLEARTID|CLONE_CHILD_SETTID|SIGCHLD, →
    child_tidptr=0x7fa7f9adba10) = 4568
s.log.4567:--- SIGCHLD si_signo=SIGCHLD, si_code=CILD_EXITED, →
    si_pid=4568, si_uid=0, si_status=0, si_utime=0, si_stime=0 ---
s.log.4568:clone(child_stack=NULL, flags=CLONE_CHILD_CLEARTID|CLONE_CHILD_SETTID|SIGCHLD, →
    child_tidptr=0x7fe0f586aa10) = 2<4569>
```

Add **translate_pid** syscall proposed by Konstantin Khlebnikov:
https://lkml.org/lkml/2018/6/1/788

```
pid_t translate_pid(pid_t pid, int source, int target);
```

pid namespaces are referred by file descriptors opened to proc files
/proc/[pid]/ns/pid or /proc/[pid]/ns/pid_for_children.
Negative argument points to the current pid namespace.

Return value:
pid in the target pid namespace or zero if the task has no pid there.

Error codes:

- **EBADF**: source or target is not a valid open file descriptor
- **EINVAL**: file descriptor does not refer to a pid namespace
- **ESRCH**: task not found in the source namespace

Translation can breach pid namespace isolation and return pids from outer pid
namespaces iff process already has file descriptor for these namespaces.
Proposed solution: **translate_pid syscall**

**translate_pid examples provided by Konstantin Khlebnikov**

- `translate_pid(pid, ns, -1)` - translate pid to our pid namespace
- `translate_pid(pid, -1, ns)` - translate pid to other pid namespace
- `translate_pid(pid, -1, ns) > 0` - is pid reachable from ns?
- `translate_pid(1, ns1, ns2) > 0` - is ns1 inside ns2?
- `translate_pid(1, ns1, ns2) == 0` - is ns1 outside ns2?
- `translate_pid(1, ns1, ns2) == 1` - is ns1 equal to ns2?

**revision history**

- v1: [https://lkml.org/lkml/2015/9/15/411](https://lkml.org/lkml/2015/9/15/411)
- v2: [https://lkml.org/lkml/2015/9/24/278](https://lkml.org/lkml/2015/9/24/278)
- v4: [https://lkml.org/lkml/2017/10/13/177](https://lkml.org/lkml/2017/10/13/177)
Problem 6: strace and tracees running in different net namespaces

strace -yy chromium-browser doesn’t show network protocol details because NETLINK_SOCK_DIAG does not report sockets of tracees running in different network namespaces:

Example

Connected sockets should ve reported this way becase socketpair always generates a pair of connected sockets:

socketpair(AF_UNIX, SOCK_STREAM, 0, [27<UNIX:[7162769->7162770]>, 28<UNIX:[7162770->7162769]>]) = 0

If the tracee runs in a different network namespaces, the output generated by strace looks as if these sockets are unconnected:

socketpair(AF_UNIX, SOCK_STREAM, 0, [223<UNIX:[7162686]>, 224<UNIX:[7162687]>]) = 0
### Problem

There are no consistent detailed declarative machine readable syscall descriptions, this forces every user to reinvent its own wheel and catch up with the kernel.

### Current practice

- **strace**: A lot of manual work has been done to implement parsers of all syscalls in C, some of these parsers are quite complex, there is a test suite with 85% coverage.

- **libc**: Every libc has its own wrappers for some subset of syscalls, some of these wrappers are machine generated.

- **syzkaller**: Detailed declarative machine readable descriptions.

- **others**: Sanitizers, valgrind.

### Proposed solution

Provide detailed declarative machine readable descriptions for all syscalls in the kernel.
Problem 7: no detailed declarative syscall descriptions in kernel

```
Problem 7: no detailed declarative syscall descriptions in kernel

hsh-run --mount=/proc -- strace -e trace=sendto,recvmsg ip route list

sendto(3, {{len=40, type=RTM_GETROUTE, flags=NLM_F_REQUEST|NLM_F_DUMP, seq=1357924680, pid=0}, {rtm_family=AF_UNSPEC, rtm_dst_len=0, rtm_src_len=0, rtm_tos=0, rtm_table=RT_TABLE_UNSPEC, rtm_protocol=RTPROT_UNSPEC, rtm_scope=RT_SCOPE_UNIVERSE, rtm_type=RTN_UNSPEC, rtm_flags=0}, {nla_len=0, nla_type=RTA_UNSPEC}}, 40, 0, NULL, 0) = 40
recvmsg(3, {msg_name={sa_family=AF_NETLINK, nl_pid=0, nl_groups=00000000}, msg_name_len=12, msg_iov={{iov_base=[ {len=60, type=RTM_NEWROUTE, flags=NLM_F_MULTI, seq=1357924680, pid=12345}, {rtm_family=AF_INET, rtm_dst_len=32, rtm_src_len=0, rtm_tos=0, rtm_table=RT_TABLE_LOCAL, rtm_protocol=RTPROT_KERNEL, rtm_scope=RT_SCOPE_LINK, rtm_type=RTN_BROADCAST, rtm_flags=0}, {{nla_len=8, nla_type=RTA_TABLE}, RT_TABLE_LOCAL}, {{nla_len=8, nla_type=RTA_DST}, inet_addr("127.0.0.0"), {nla_len=8, nla_type=RTA_PREFSRC}, inet_addr("127.0.0.1"), {nla_len=8, nla_type=RTA_OIF}, if_nametoindex("lo")}, {{len=60, type=RTM_NEWROUTE, flags=NLM_F_MULTI, seq=1357924680, pid=12345}, {rtm_family=AF_INET, rtm_dst_len=8, rtm_src_len=0, rtm_tos=0, rtm_table=RT_TABLE_LOCAL, rtm_protocol=RTPROT_KERNEL, rtm_scope=RT_SCOPE_LINK, rtm_type=RTN_LOCAL, rtm_flags=0}, {{nla_len=8, nla_type=RTA_TABLE}, RT_TABLE_LOCAL}, {{nla_len=8, nla_type=RTA_DST}, inet_addr("127.0.0.0"), {nla_len=8, nla_type=RTA_PREFSRC}, inet_addr("127.0.0.1"), {nla_len=8, nla_type=RTA_OIF}, if_nametoindex("lo")}, {{len=60, type=RTM_NEWROUTE, flags=NLM_F_MULTI, seq=1357924680, pid=12345}, {rtm_family=AF_INET, rtm_dst_len=32, rtm_src_len=0, rtm_tos=0, rtm_table=RT_TABLE_LOCAL, rtm_protocol=RTPROT_KERNEL, rtm_scope=RT_SCOPE_LINK, rtm_type=RTN_LOCAL, rtm_flags=0}, {{nla_len=8, nla_type=RTA_TABLE}, RT_TABLE_LOCAL}, {{nla_len=8, nla_type=RTA_DST}, inet_addr("127.255.255.255"), {nla_len=8, nla_type=RTA_PREFSRC}, inet_addr("127.0.0.1")}, {nla_len=0, nla_type=RTA_UNSPEC}}, 40, 0, NULL, 0) = 40
```
Problem 7: no detailed declarative syscall descriptions in kernel

strace/msghdr.c

SYS_FUNC(recvmsg) {
    int msg_namelen;
    if (entering(tcp)) {
        printfd(tcp, tcp->u_arg[0]);
        tprints("", ");
        if (fetch_msghdr_namelen(tcp, tcp->u_arg[1], &msg_namelen)) {
            set_tcb_priv_ulong(tcp, msg_namelen);
            return 0;
        }
    printaddr(tcp->u_arg[1]);
} else {
    msg_namelen = get_tcb_priv_ulong(tcp);
    if (syserror(tcp))
        tprintf("msg_namelen=%d", msg_namelen);
    else
        decode_msghdr(tcp, &msg_namelen, tcp->u_arg[1], tcp->u_rval);
} }

if (syserror(tcp))
    tprintf("msg_namelen=%d", msg_namelen);
    else
        decode_msghdr(tcp, &msg_namelen, tcp->u_arg[1], tcp->u_rval);

} }
Problem 7: no detailed declarative syscall descriptions in kernel

syzkaller/sys/linux/socket.txt

recvmsg(fd sock, msg ptr[in, recv__msghdr], f flags[recv__flags])
...
recv__flags = MSG__CMMSG__CLOEXEC, MSG__DONTWAIT, MSG__ERRQUEUE, MSG__OOB, MSG__PEEK, MSG__TRUNC, MSG__WAITALL, MSG__WAITFORONE
...
recv__msghdr {
    msg__name ptr[out, sockaddr__storage, opt]
    msg__namelen len[msg__name, int32]
    msg__iov ptr[in, array[iovec__out]]
    msg__iovlen len[msg__iov, intptr]
    msg__control ptr[out, array[int8], opt]
    msg__controllen bytesize[msg__control, intptr]
    msg__flags int32
}

net/socket.c

SYSCALL__DEFINE3(recvmsg, int, fd, struct__user__msghdr __user *, msg, unsigned int, flags)
{
    return __sys_recvmsg(fd, msg, flags, true);
}
Problem 8: strace is slow, perf can lose data

ptrace API is slow
There are two syscall stops per syscall: `syscall-enter-stop` and `syscall-exit-stop`. There are two context switches per syscall stop: from tracee to tracer and back. strace invokes at least three syscalls per syscall stop: `wait4`, `PTRACE_GETREGSET`, and `PTRACE_SYSCALL`.

kernel tracing can lose data
The data is written to a ring buffer and could be lost if the reader is not fast enough.

Ideas
- Add a flag to struct `perf_event_attr` that new perf events should block on overflow
- Implement a perf backend for strace
- Compile strace decoders into eBPF
Questions?

homepage
https://strace.io

strace.git
https://github.com/strace/strace.git
https://gitlab.com/strace/strace.git

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