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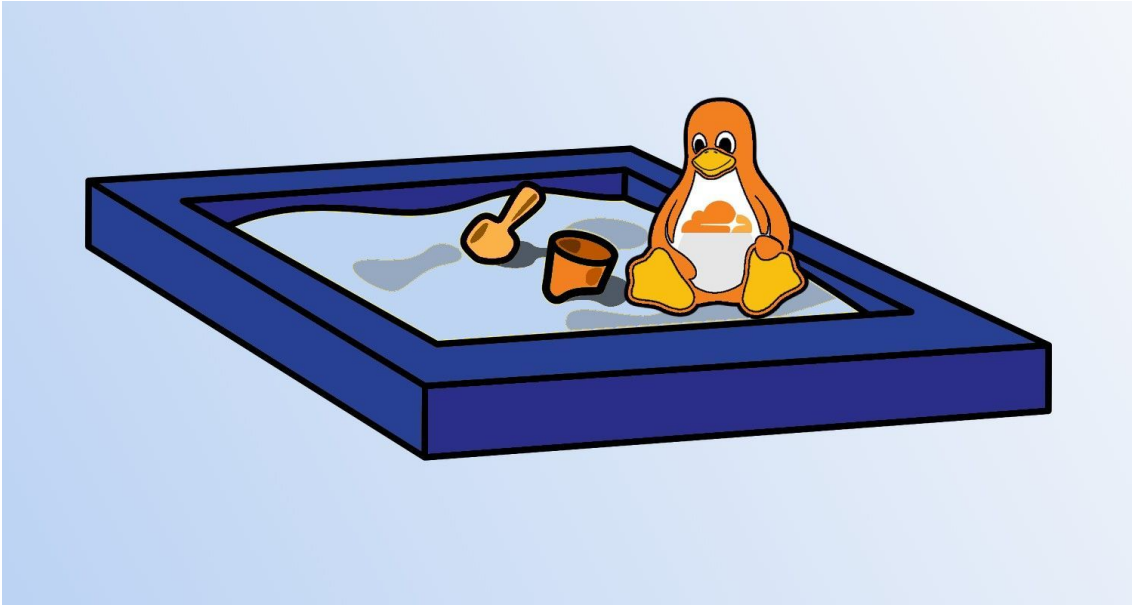


Sandboxing in Linux with Zero Lines of Code

Ignat Korchagin

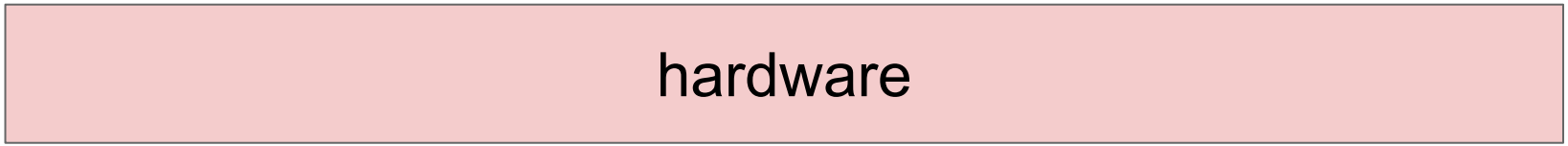
@ignatkn

$ whoami

- Linux at Cloudflare
- Passionate about security, cryptography and performance
- Enjoy low level programming

Linux system calls and seccomp

Modern operating systems



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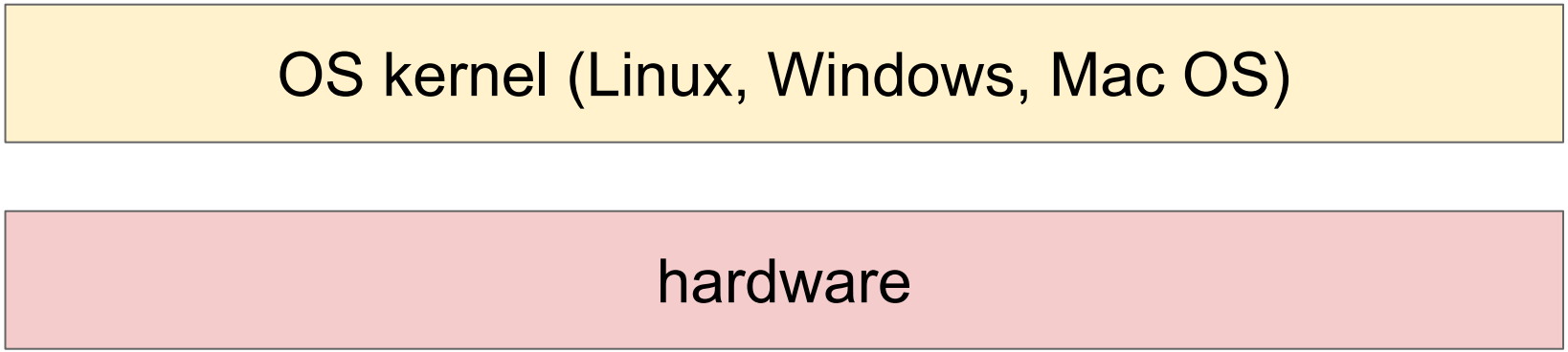
Modern operating systems



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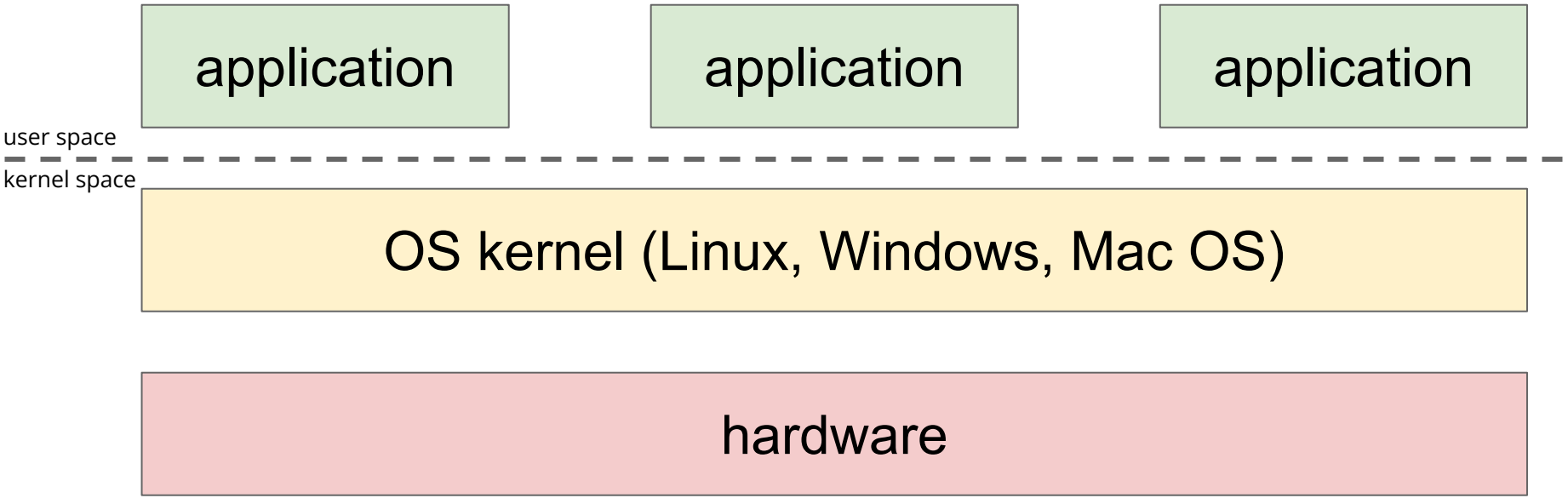

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System calls

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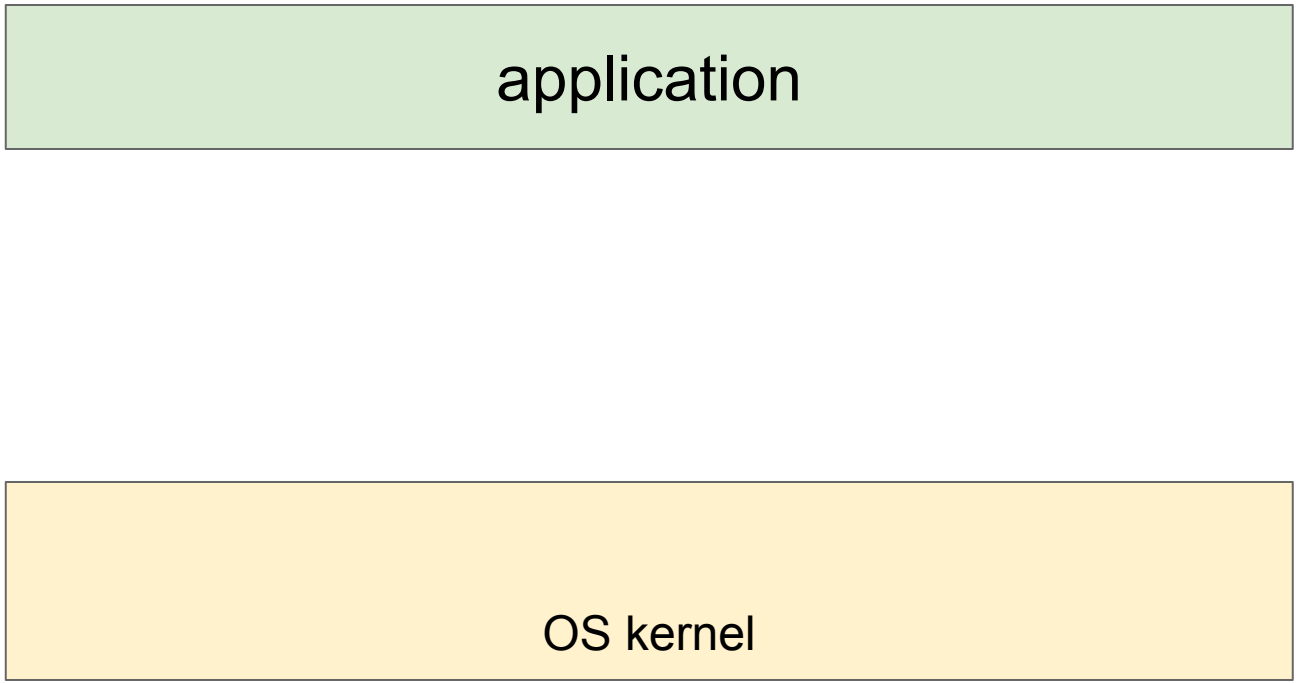

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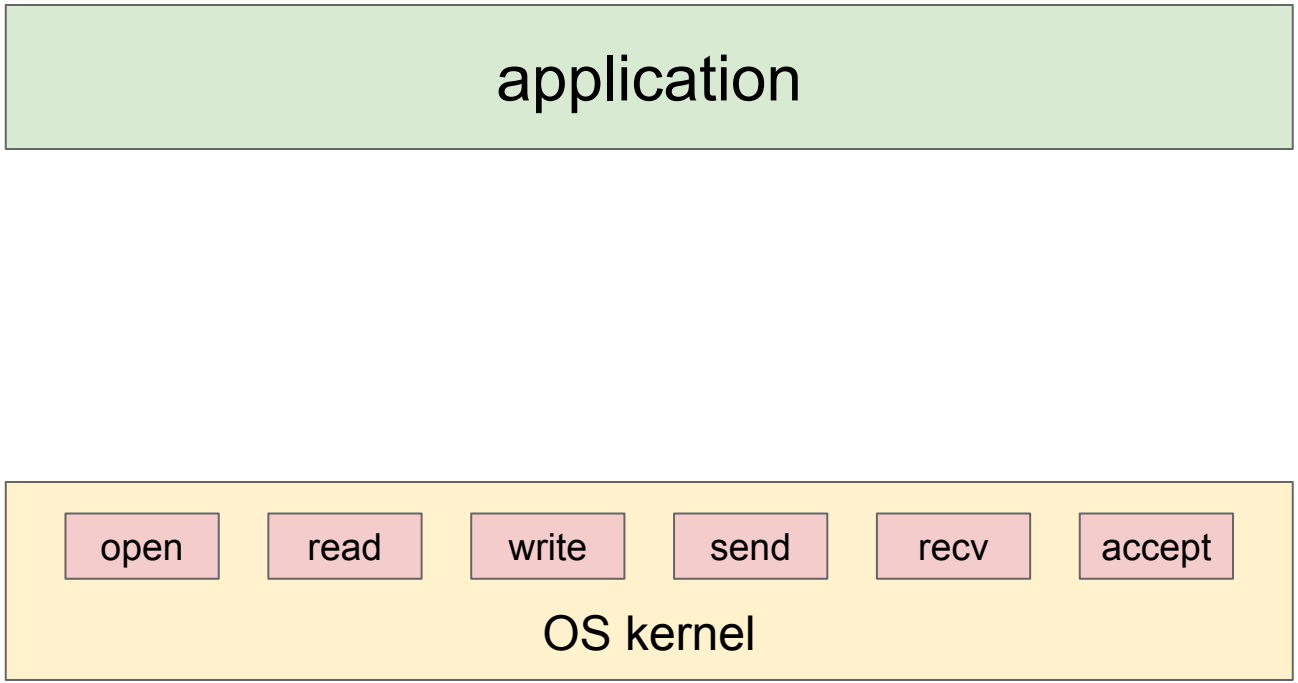
System calls



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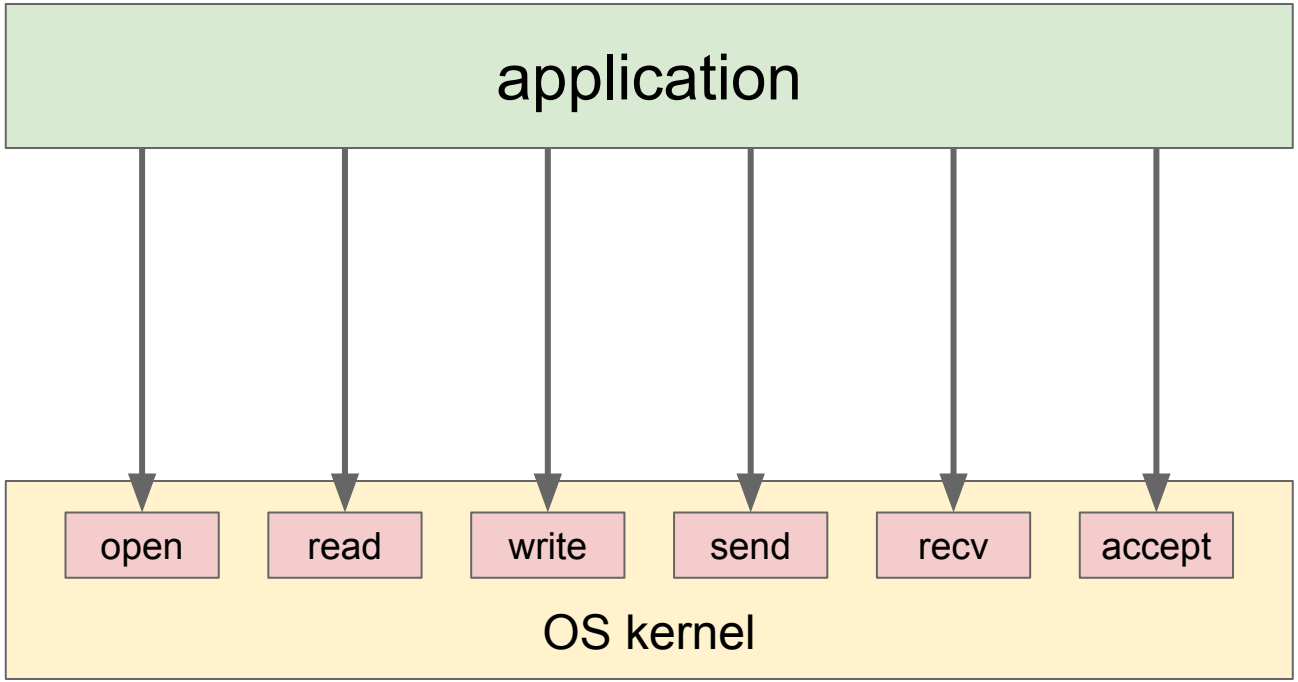

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System calls

- a well-defined interface between (user space) applications and the OS kernel

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    - network access
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seccomp

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seccomp

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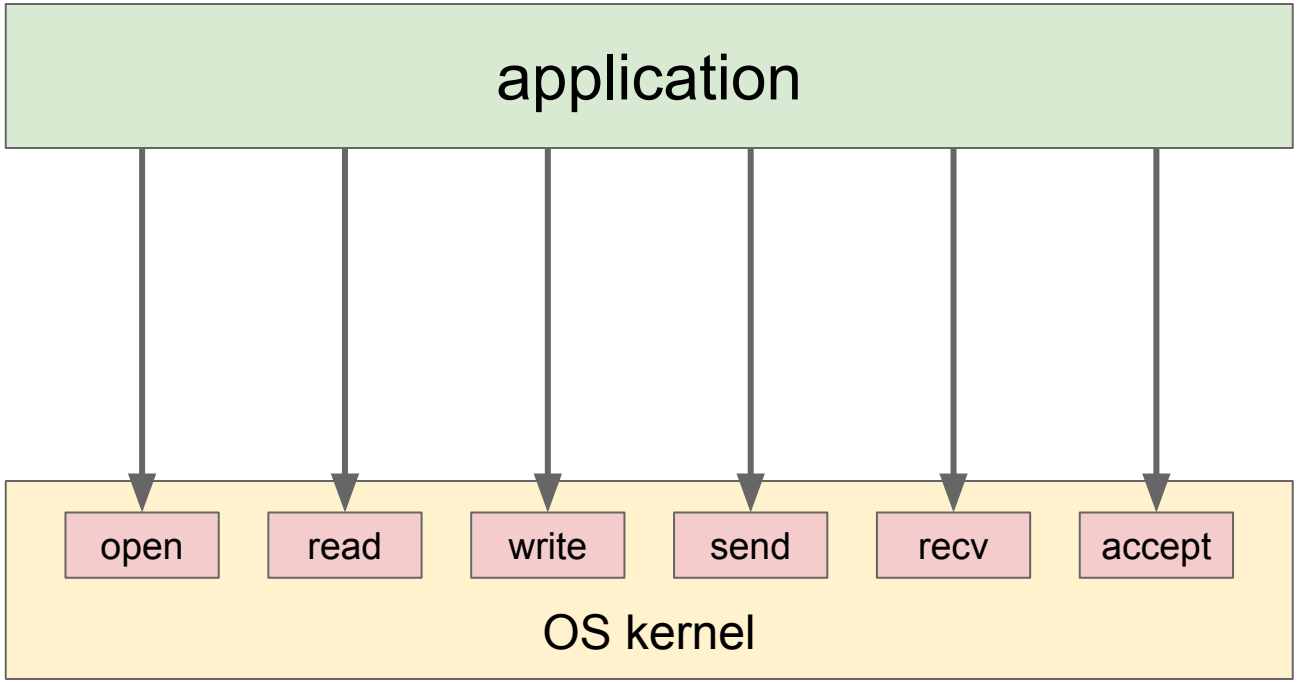
- provides a way for application to notify the kernel which other system calls it intends to use
  - and which system calls it will definitely not use
- the kernel enforces the system call policy provided by the application
- a tool an application can use to confine/sandbox itself

seccomp



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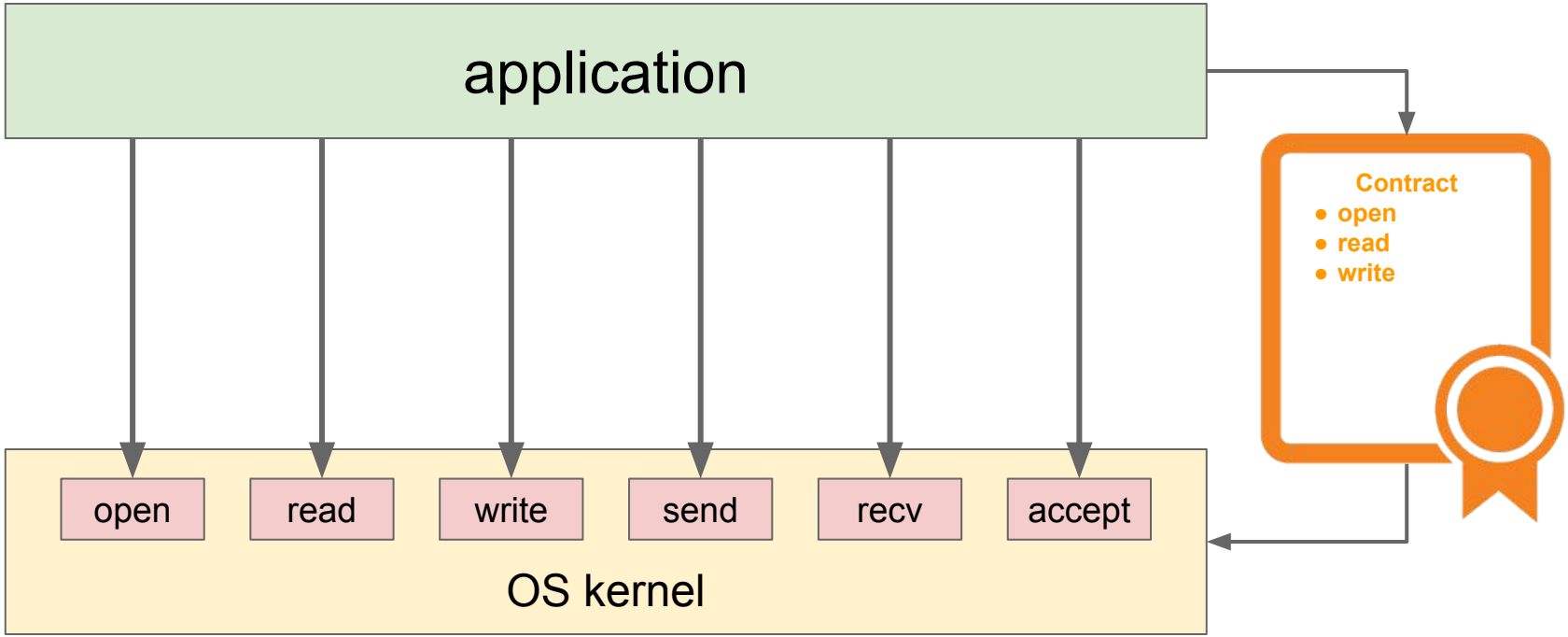

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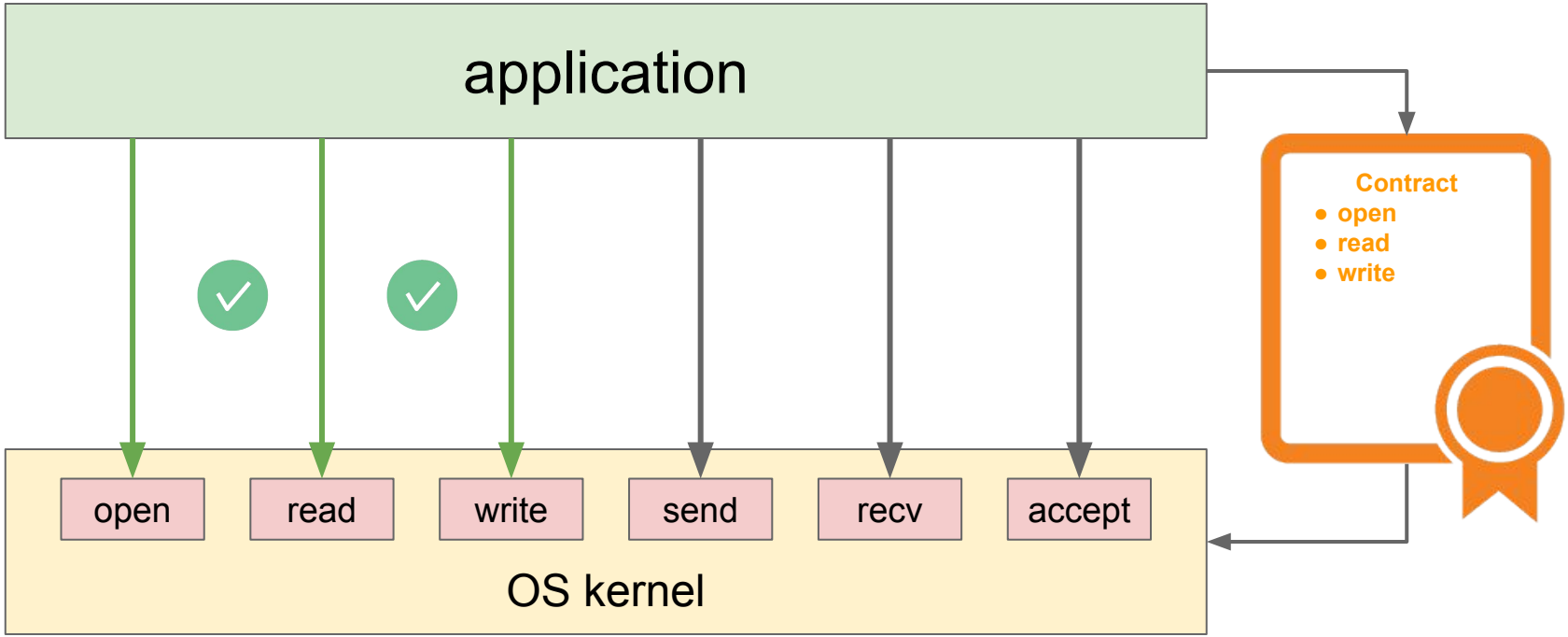

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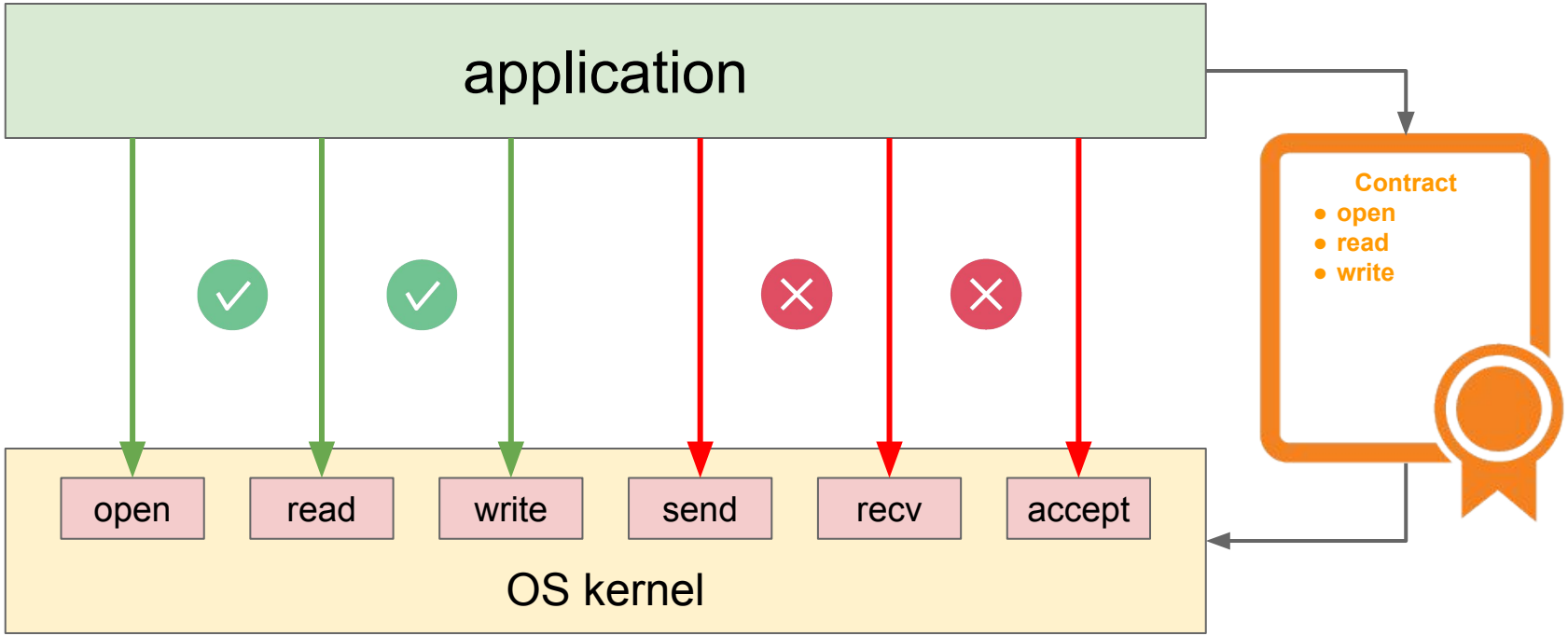

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seccomp example

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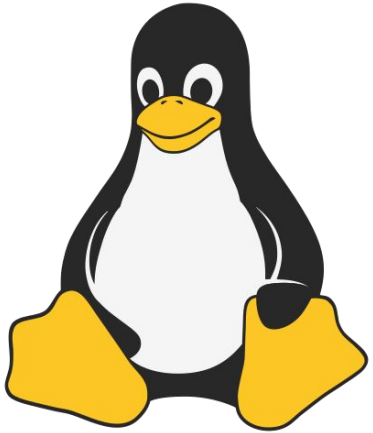

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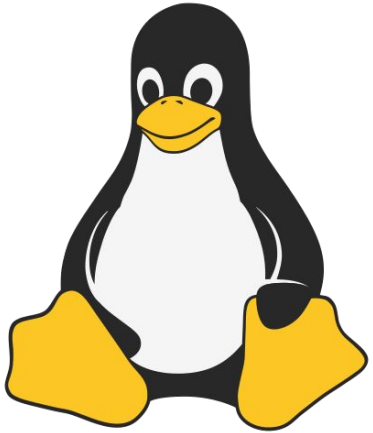
seccomp example

Hi! I'm a clock app. I will only use `gettimeofday`



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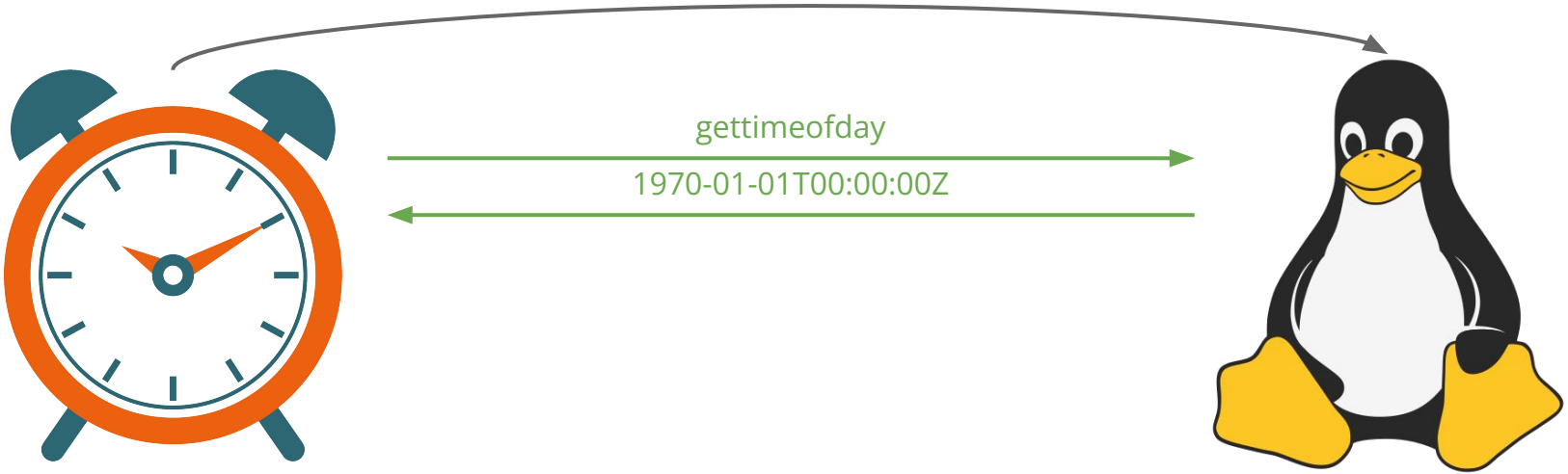

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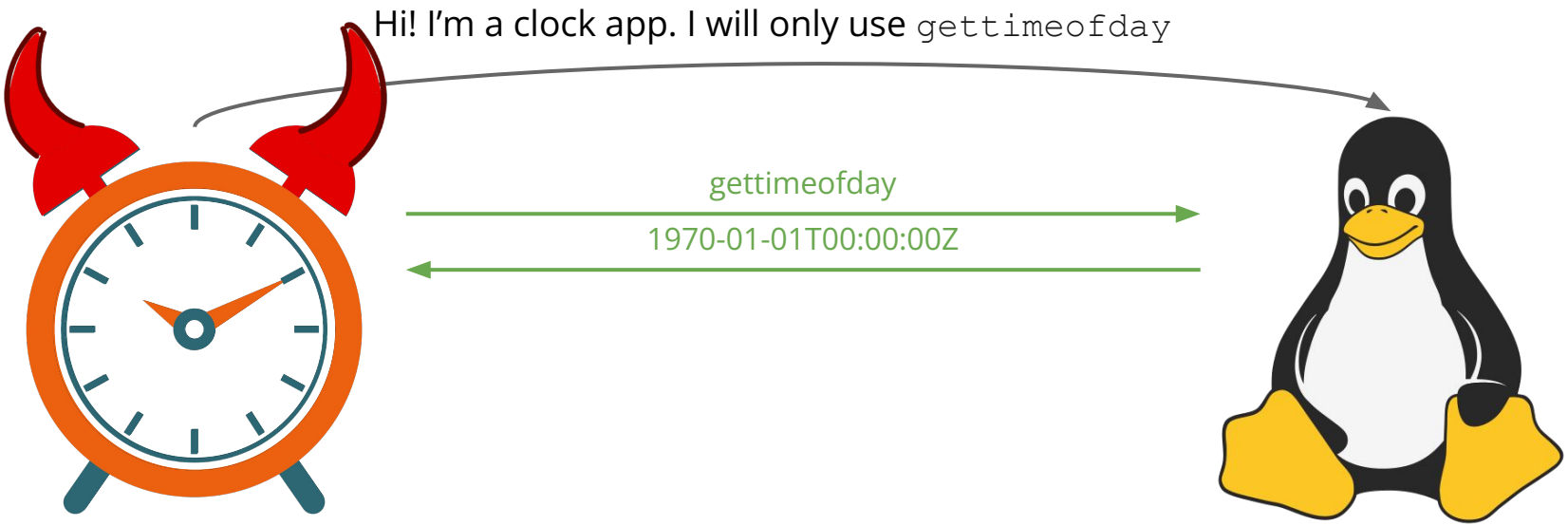

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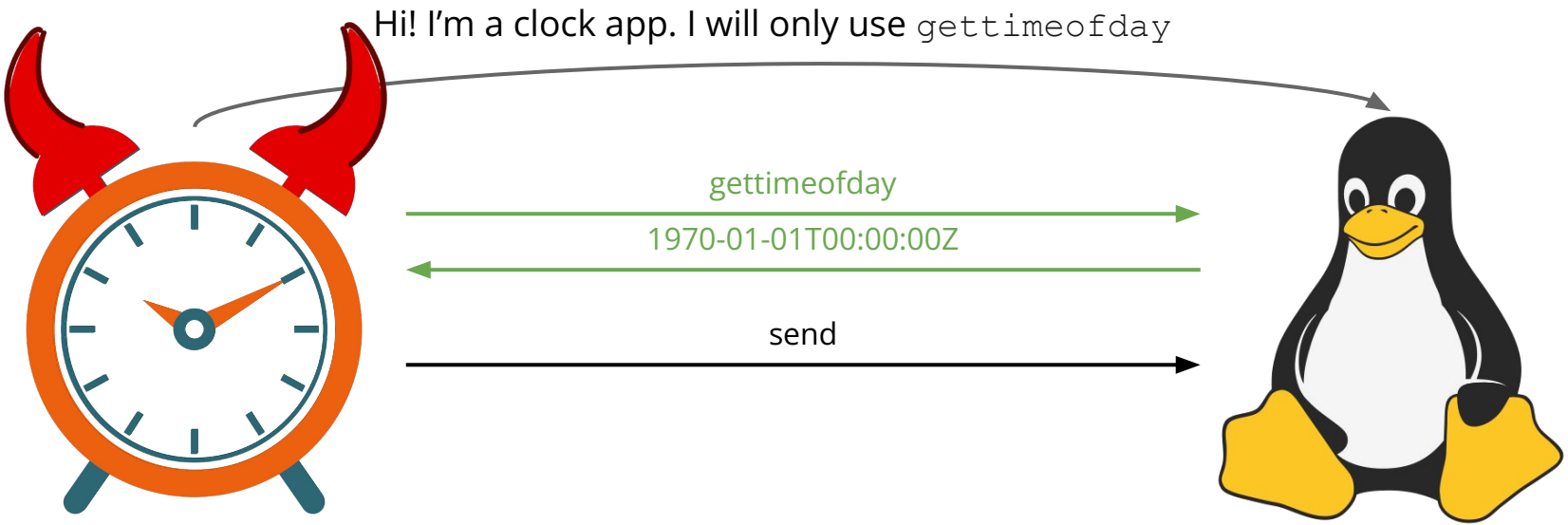
seccomp example



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seccomp example

CLOUDFLARE

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Using seccomp

A simple “uname-like” toy tool

```
#include <stdio.h>
#include <sys/utsname.h>

int main(void)
{
    struct utsname name;
    if (uname(&name)) {
        perror("uname failed");
        return 1;
    }
    printf("My OS is %s!\n", name.sysname);
    return 0;
}
```

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A simple “uname-like” toy tool

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```

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A simple “uname-like” toy tool

```
$ gcc -o myos myos.c
```

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A simple “uname-like” toy tool

```
$ gcc -o myos myos.c
$ ./myos
My OS is Linux!
```

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Sandboxing “myos”

```
#include <stdio.h>
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int main(void)
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Sandboxing “myos”

```
#include <stdio.h>
#include <sys/utsname.h>
int main(void)
{
    struct utsname name;
    sandbox();
    if (uname(&name)) {
        perror("uname failed");
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    }
    printf("My OS is %s!\n", name.sysname);
    return 0;
}
```

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Sandboxing “myos”

```
static void sandbox(void)
{
    struct sock_filter filter[] = {
        BPF_STMT(BPF_LD | BPF_W | BPF_ABS, (offsetof(struct
seccomp_data, arch))),
        /* if not x86_64, tell the kernel to kill the process
*/
        BPF_JUMP(BPF_JMP | BPF_JEQ | BPF_K, AUDIT_ARCH_X86_64,
0, 4),
        /* get the actual syscall number */
        BPF_STMT(BPF_LD | BPF_W | BPF_ABS, (offsetof(struct
seccomp_data, nr))),
        /* if "uname", tell the kernel to return ENETDOWN,
otherwise just allow */
        BPF_JUMP(BPF_JMP | BPF_JEQ | BPF_K, SYS_uname, 0, 1),
        BPF_STMT(BPF_RET | BPF_K, SECCOMP_RET_ERRNO | (ENETDOWN
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    };
```

```
    struct sock_fprog prog = {
        .len = (unsigned short) (sizeof(filter) /
sizeof(filter[0])),
        .filter = filter,
    };
    if (prctl(PR_SET_NO_NEW_PRIVS, 1, 0, 0, 0)) {
        perror("PR_SET_NO_NEW_PRIVS failed");
        exit(1);
    };
    /* glibc does not have a wrapper for seccomp(2) */
    /* invoke it via the generic syscall wrapper */
    if (syscall(SYS_seccomp, SECCOMP_SET_MODE_FILTER, 0,
&prog)) {
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Sandboxing “myos”

```
$ gcc -o myos myos_raw_seccomp.c
```

Sandboxing “myos”

```
$ gcc -o myos myos_raw_seccomp.c
$ ./myos
uname failed: Network is down
```

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Writing seccomp by hand

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  - hard to write
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- low level assembly language
  - hard to write
  - hard to review
  - hard to debug
  - hard to update
- need to be aware of low-level details
  - system call numbers
  - architecture
  - some quirks, like setting **`no_new_privs`** bit

Sandboxing “myos” with libseccomp

```
static void sandbox(void)
{
    /* allow all syscalls by default */
    scmp_filter_ctx seccomp_ctx =
seccomp_init(SCMP_ACT_ALLOW);
    if (!seccomp_ctx)
        err(1, "seccomp_init failed");
    /* kill the process, if it tries to use
"uname" syscall */
    if (seccomp_rule_add_exact(seccomp_ctx,
SCMP_ACT_KILL,
seccomp_syscall_resolve_name("uname"), 0)) {
        perror("seccomp_rule_add_exact
failed");
        exit(1);
    }
    /* apply the composed filter */
    if (seccomp_load(seccomp_ctx)) {
        perror("seccomp_load failed");
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Sandboxing “myos” with libseccomp

```
$ gcc -o myos myos_libseccomp.c -lseccomp
```

Sandboxing “myos” with libseccomp

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```

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Sandboxing “myos” with libseccomp

```
$ gcc -o myos myos_libseccomp.c -lseccomp
$ ./myos
Bad system call
```

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No code seccomp

Question?

How many developers start a project with a mindset:

Question?

How many developers start a project with a mindset:

“Most likely I will write bugs and security vulnerabilities. I should sandbox my code!”

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Question?

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Problems with seccomp

- seccomp applies the rules/policy to the current process
  - it is expected developers will sandbox their code themselves
  - no external interface to apply seccomp rules to a running process

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Problems with seccomp

- seccomp applies the rules/policy to the current process
  - it is expected developers will sandbox their code themselves
  - no external interface to apply seccomp rules to a running process
- operators/sysadmins have almost no control over the seccomp policy
- no way to sandbox third-party proprietary applications

Mind the gap!

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Sandboxing with systemd

`SystemCallFilter=`

- Takes a space-separated list of system call names. If this setting is used, all system calls executed by the unit processes except for the listed ones will result in immediate process termination with the `SIGSYS` signal…

Sandboxing with systemd

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https://www.freedesktop.org/software/systemd/man/systemd.exec.html#SystemCallFilter=

Sandboxing with systemd

```
$ gcc -o myos myos.c
$ ./myos
My OS is Linux!
```

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Sandboxing with systemd

```
$ gcc -o myos myos.c
$ ./myos
My OS is Linux!
$ systemd-run --user --pty --same-dir --wait --collect --service-type=exec ./myos
Running as unit: run-u16.service
Press ^] three times within 1s to disconnect TTY.
My OS is Linux!
Finished with result: success
Main processes terminated with: code=exited/status=0
Service runtime: 3ms
```

Sandboxing with systemd

```
$ gcc -o myos myos.c
$ ./myos
My OS is Linux!
$ systemd-run --user --pty --same-dir --wait --collect --service-type=exec ./myos
Running as unit: run-u16.service
Press ^] three times within 1s to disconnect TTY.
My OS is Linux!
Finished with result: success
Main processes terminated with: code=exited/status=0
Service runtime: 3ms
```

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Sandboxing with systemd

```
$ systemd-run --user --pty --same-dir --wait --collect --service-type=exec
--property="SystemCallFilter=~uname" ./myos
Running as unit: run-u17.service
Press ^] three times within 1s to disconnect TTY.
Finished with result: signal
Main processes terminated with: code=killed/status=SYS
Service runtime: 6ms
```

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Sandboxing with systemd

```
$ systemd-run --user --pty --same-dir --wait --collect --service-type=exec
--property="SystemCallFilter=~uname" ./myos
Running as unit: run-u17.service
Press ^] three times within 1s to disconnect TTY.
Finished with result: signal
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Service runtime: 6ms
```

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Sandboxing with systemd

```
$ systemd-run --user --pty --same-dir --wait --collect --service-type=exec
--property="SystemCallFilter=~uname" ./myos
Running as unit: run-u17.service
Press ^] three times within 1s to disconnect TTY.
Finished with result: signal
Main processes terminated with: code=killed/status=SYS
Service runtime: 6ms
```

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Sandboxing with systemd

```
$ systemd-run --user --pty --same-dir --wait --collect --service-type=exec
--property="SystemCallFilter=~uname" ./myos
Running as unit: run-u17.service
Press ^] three times within 1s to disconnect TTY.
Finished with result: signal
Main processes terminated with: code=killed/status=SYS
Service runtime: 6ms
$ systemd-run --user --pty --same-dir --wait --collect --service-type=exec
--property="SystemCallFilter=~uname" --property="SystemCallErrorNumber=ENETDOWN" ./myos
Running as unit: run-u18.service
Press ^] three times within 1s to disconnect TTY.
uname failed: Network is down
Finished with result: exit-code
Main processes terminated with: code=exited/status=1
Service runtime: 6ms
```

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Sandboxing with systemd

```
$ systemd-run --user --pty --same-dir --wait --collect --service-type=exec
--property="SystemCallFilter=~uname" ./myos
Running as unit: run-u17.service
Press ^] three times within 1s to disconnect TTY.
Finished with result: signal
Main processes terminated with: code=killed/status=SYS
Service runtime: 6ms
$ systemd-run --user --pty --same-dir --wait --collect --service-type=exec
--property="SystemCallFilter=~uname" --property="SystemCallErrorNumber=ENETDOWN" ./myos
Running as unit: run-u18.service
Press ^] three times within 1s to disconnect TTY.
uname failed: Network is down
Finished with result: exit-code
Main processes terminated with: code=exited/status=1
Service runtime: 6ms
```

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Sandboxing with systemd

```
$ systemd-run --user --pty --same-dir --wait --collect --service-type=exec
--property="SystemCallFilter=~uname" ./myos
Running as unit: run-u17.service
Press ^] three times within 1s to disconnect TTY.
Finished with result: signal
Main processes terminated with: code=killed/status=SYS
Service runtime: 6ms
$ systemd-run --user --pty --same-dir --wait --collect --service-type=exec
--property="SystemCallFilter=~uname" --property="SystemCallErrorNumber=ENETDOWN" ./myos
Running as unit: run-u18.service
Press ^] three times within 1s to disconnect TTY.
uname failed: Network is down
Finished with result: exit-code
Main processes terminated with: code=exited/status=1
Service runtime: 6ms
```

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Sandboxing with systemd

The small print:

Sandboxing with systemd

The small print:

"Note that the `execve, exit, exit_group, getrlimit, rt_sigreturn, sigreturn` *system calls and the system calls for querying time and sleeping are implicitly whitelisted and do not need to be listed explicitly"*

https://www.freedesktop.org/software/systemd/man/systemd.exec.html#SystemCallFilter=

Why “execve” is bad?

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Why “execve” is bad?

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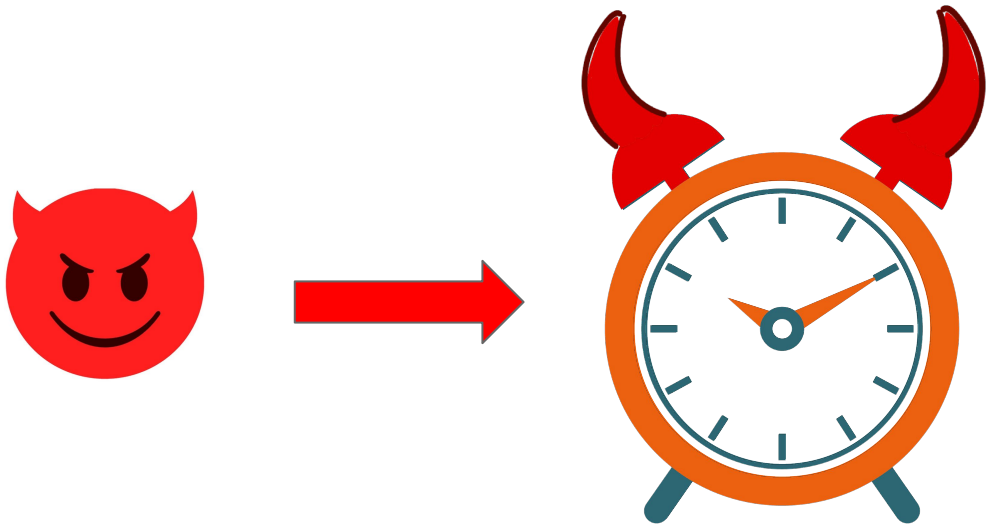
Why “execve” is bad?



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Why “execve” is bad?

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Cloudflare sandbox tool

A toolkit to inject seccomp rules into almost any process

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Cloudflare sandbox tool

A toolkit to inject seccomp rules into almost any process

- follows the systemd approach one step further
  - a shared library for dynamically linked applications
  - a “launcher” for statically linked applications

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Cloudflare sandbox tool

A toolkit to inject seccomp rules into almost any process

- follows the systemd approach one step further
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Cloudflare sandbox tool

A toolkit to inject seccomp rules into almost any process

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Cloudflare sandbox tool

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- works on any binary written in any language, even proprietary ones

https://github.com/cloudflare/sandbox

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Cloudflare sandbox tool

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Cloudflare sandbox tool

```
$ gcc -o myos myos.c
$ ./myos
My OS is Linux!
```

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Cloudflare sandbox tool

```
$ gcc -o myos myos.c
$ ./myos
My OS is Linux!
$ LD_PRELOAD=/usr/lib/x86_64-linux-gnu/libsandbox.so
SECCOMP_SYSCALL_DENY=uname ./myos
adding uname to the process seccomp filter
Bad system call
```

CLOUDFLARE

Cloudflare sandbox tool

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$ gcc -o myos myos.c
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My OS is Linux!
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Cloudflare sandbox tool

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adding uname to the process seccomp filter
Bad system call
```

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Cloudflare sandbox tool

```
$ patchelf --add-needed /usr/lib/x86_64-linux-gnu/libsandbox.so ./myos
```

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Cloudflare sandbox tool

```
$ patchelf --add-needed /usr/lib/x86_64-linux-gnu/libsandbox.so ./myos
$ ldd ./myos
    linux-vdso.so.1 (0x00007ffc35dfb000)
    /usr/lib/x86_64-linux-gnu/libsandbox.so (0x00007f2f7c232000)
    libc.so.6 => /lib/x86_64-linux-gnu/libc.so.6 (0x00007f2f7c065000)
    /lib64/ld-linux-x86-64.so.2 (0x00007f2f7c287000)
```

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Cloudflare sandbox tool

```
$ patchelf --add-needed /usr/lib/x86_64-linux-gnu/libsandbox.so ./myos
$ ldd ./myos
    linux-vdso.so.1 (0x00007ffc35dfb000)
    /usr/lib/x86_64-linux-gnu/libsandbox.so (0x00007f2f7c232000)
    libc.so.6 => /lib/x86_64-linux-gnu/libc.so.6 (0x00007f2f7c065000)
    /lib64/ld-linux-x86-64.so.2 (0x00007f2f7c287000)
```

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Cloudflare sandbox tool

```
$ patchelf --add-needed /usr/lib/x86_64-linux-gnu/libsandbox.so ./myos
$ ldd ./myos
    linux-vdso.so.1 (0x00007ffc35dfb000)
    /usr/lib/x86_64-linux-gnu/libsandbox.so (0x00007f2f7c232000)
    libc.so.6 => /lib/x86_64-linux-gnu/libc.so.6 (0x00007f2f7c065000)
    /lib64/ld-linux-x86-64.so.2 (0x00007f2f7c287000)
$ SECCOMP_SYSCALL_DENY=uname ./myos
adding uname to the process seccomp filter
Bad system call
```

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Cloudflare sandbox tool (static binaries)

```
$ gcc -static -o myos myos.c
$ ./myos
My OS is Linux!
```

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Cloudflare sandbox tool (static binaries)

```
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$ ./myos
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```

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SECCOMP_SYSCALL_DENY=uname ./myos
My OS is Linux!
```

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Cloudflare sandbox tool (static binaries)

```
$ gcc -static -o myos myos.c
$ ./myos
My OS is Linux!
$ LD_PRELOAD=/usr/lib/x86_64-linux-gnu/libsandbox.so
SECCOMP_SYSCALL_DENY=uname ./myos
My OS is Linux!
$ SECCOMP_SYSCALL_DENY=uname sandboxify ./myos
adding uname to the process seccomp filter
Bad system call
```

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Cloudflare sandbox tool (static binaries)

```
$ gcc -static -o myos myos.c
$ ./myos
My OS is Linux!
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$ SECCOMP_SYSCALL_DENY=uname sandboxify ./myos
adding uname to the process seccomp filter
Bad system call
```

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Cloudflare sandbox tool

- configuration via environment variables

Cloudflare sandbox tool

- configuration via environment variables
  - `SECCOMP_SYSCALL_ALLOW`
    - anything not in the list is not allowed

Cloudflare sandbox tool

- configuration via environment variables
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    - anything not in the list is not allowed
  - `SECCOMP_SYSCALL_DENY`
    - anything in the list is not allowed, everything else is

Cloudflare sandbox tool

- configuration via environment variables
  - `SECCOMP_SYSCALL_ALLOW`
    - anything not in the list is not allowed
  - `SECCOMP_SYSCALL_DENY`
    - anything in the list is not allowed, everything else is
  - `SECCOMP_DEFAULT_ACTION`
    - do not kill the process on violation, just log the system call

Cloudflare sandbox tool

libsandbox.so

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Cloudflare sandbox tool

libsandbox.so

- dynamically linked executables only

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Cloudflare sandbox tool

libsandbox.so

- dynamically linked executables only
- need to preload the library into the process
  - `LD_PRELOAD`
  - patch the ELF binary

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Cloudflare sandbox tool

libsandbox.so

- dynamically linked executables only
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sandboxify

Cloudflare sandbox tool

libsandbox.so

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sandboxify

- statically and dynamically linked executables

Cloudflare sandbox tool

libsandbox.so

- dynamically linked executables only
- need to preload the library into the process
  - `LD_PRELOAD`
  - patch the ELF binary

sandboxify

- statically and dynamically linked executables
- need to launch the executable through the launcher

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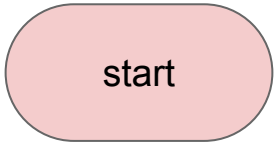
Process startup



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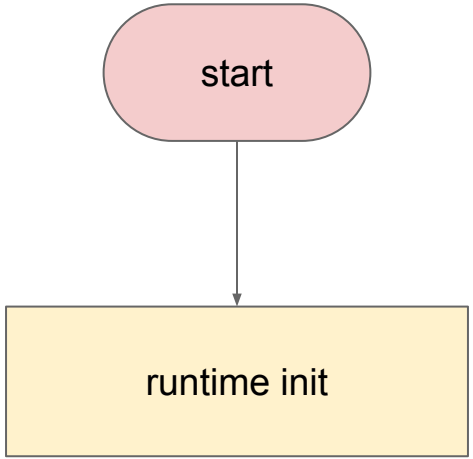
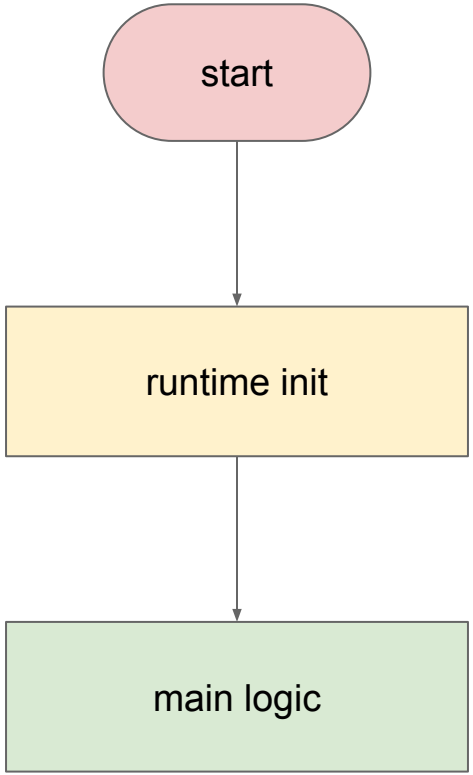
Process startup



Process startup



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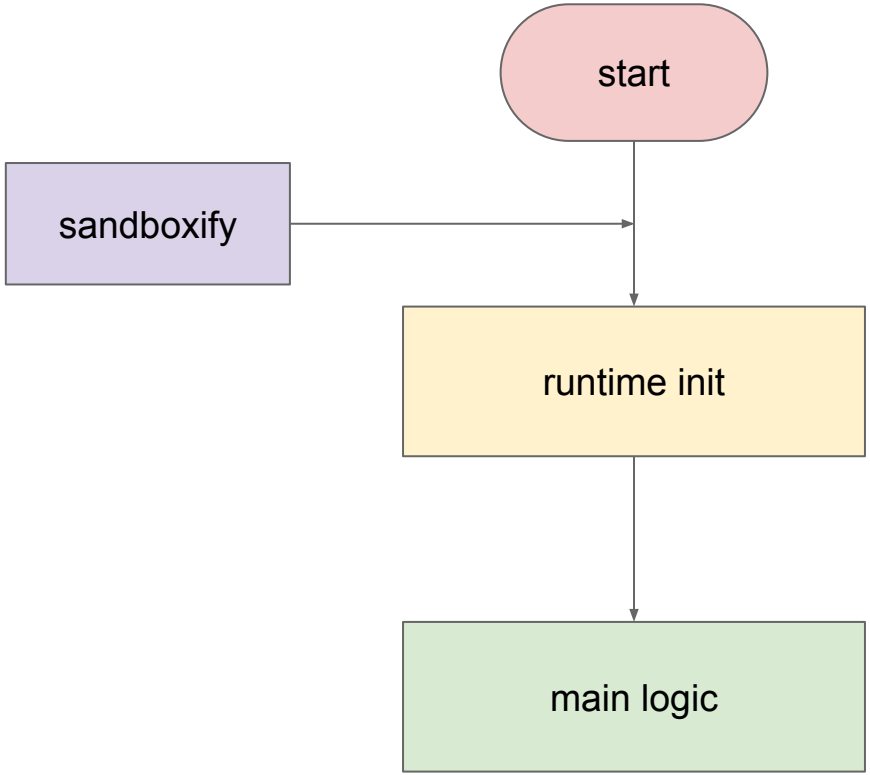
Process startup



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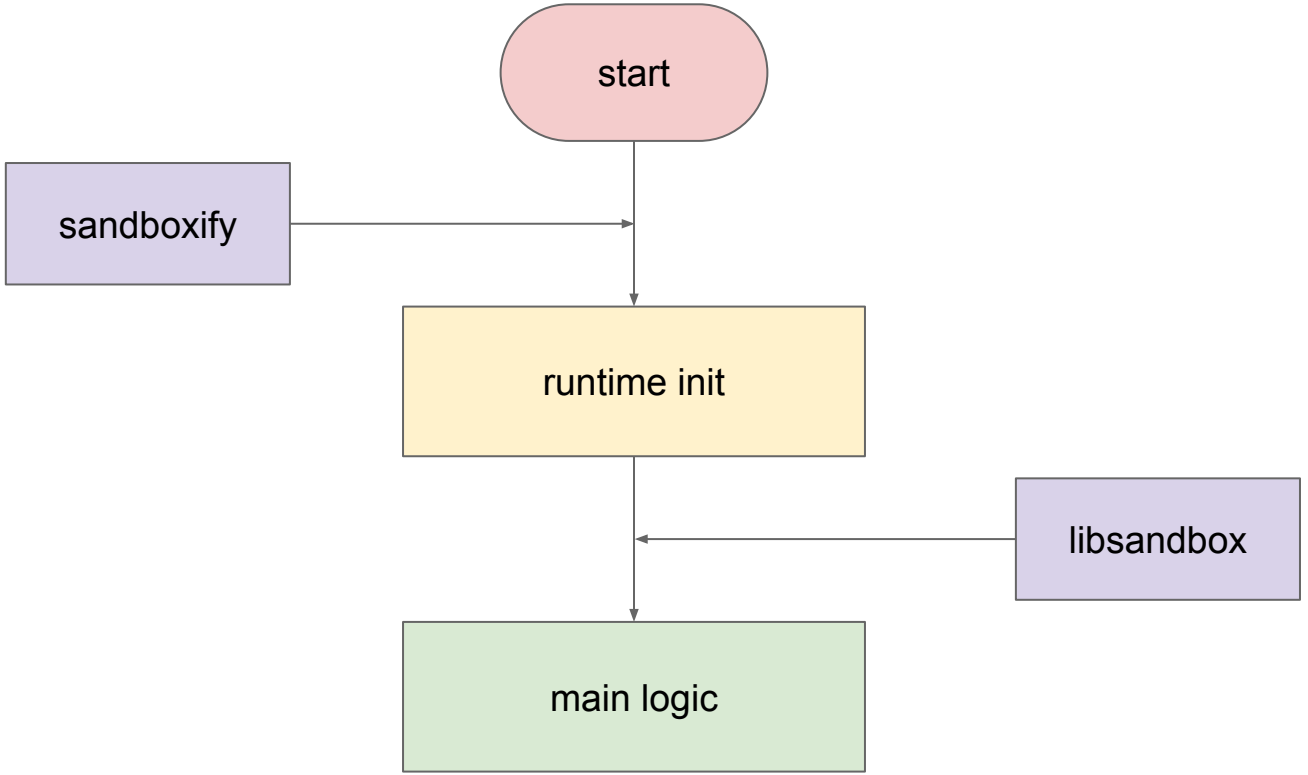
Process startup



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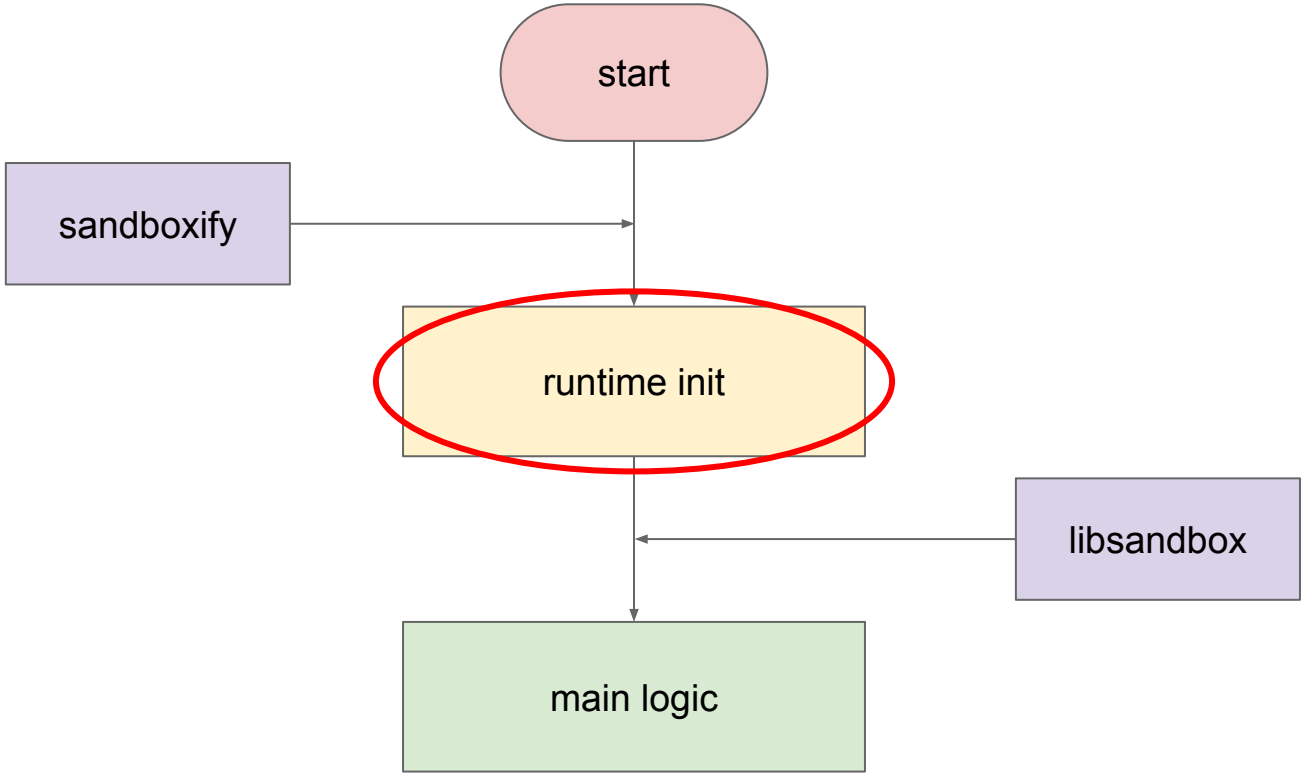
Process startup



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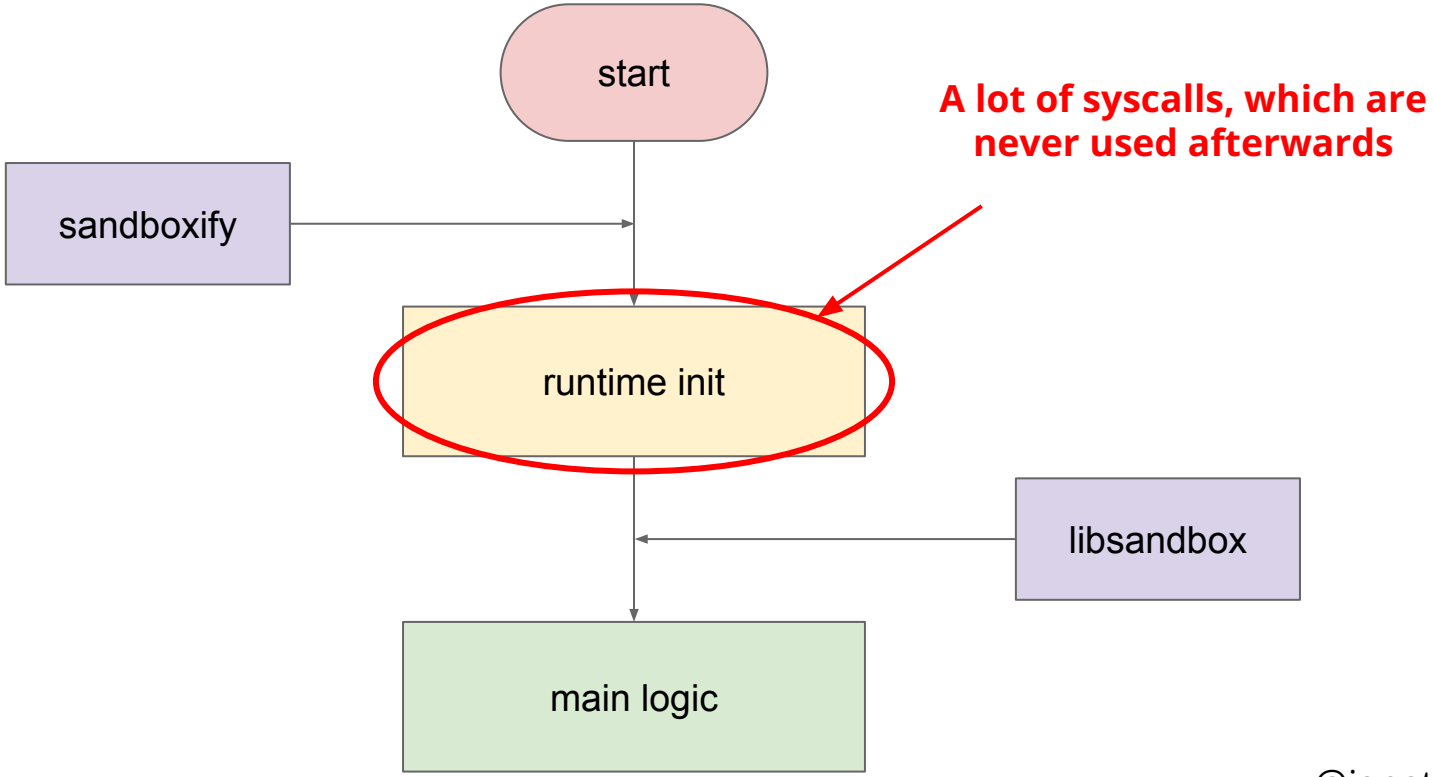
Process startup



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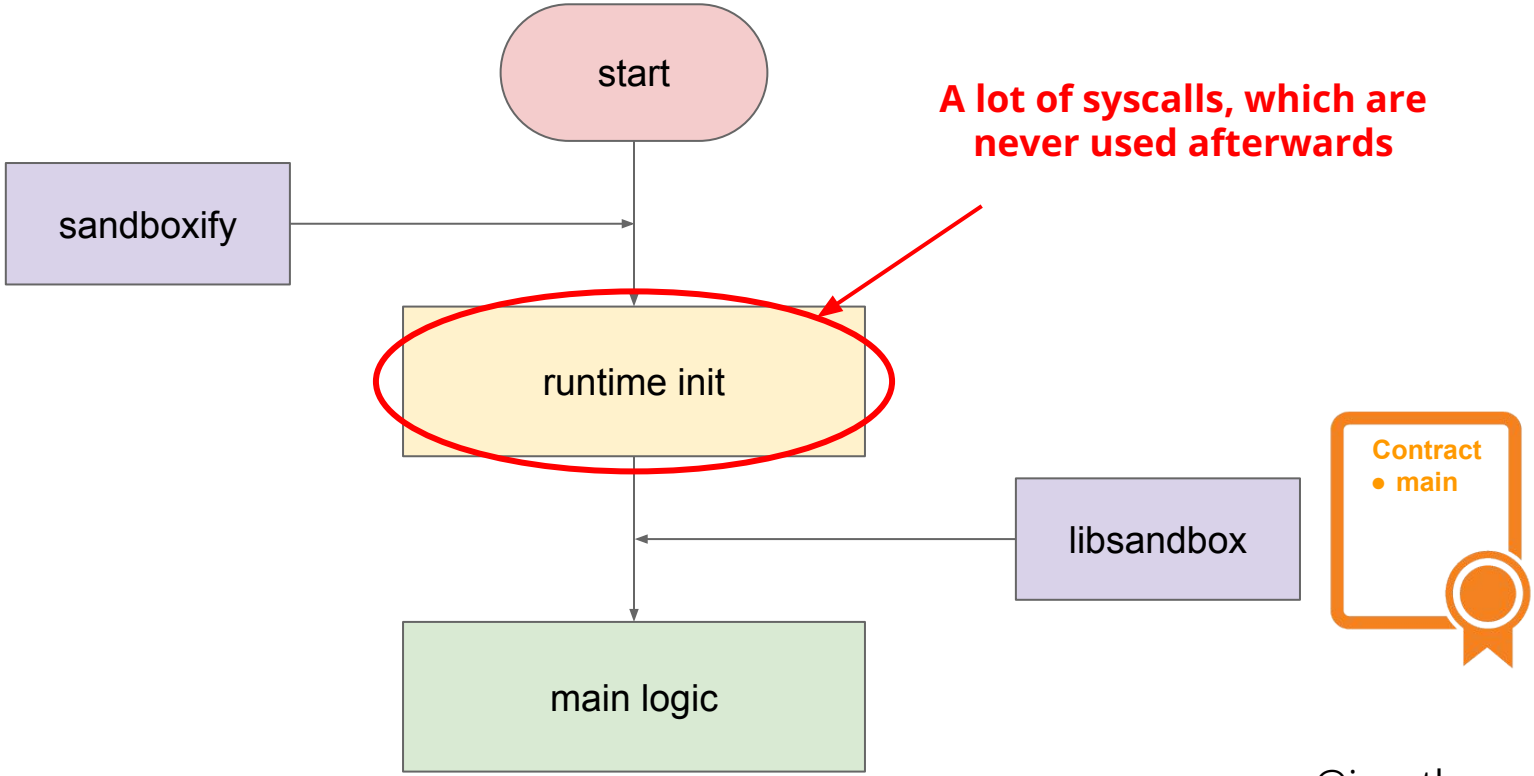
Process startup



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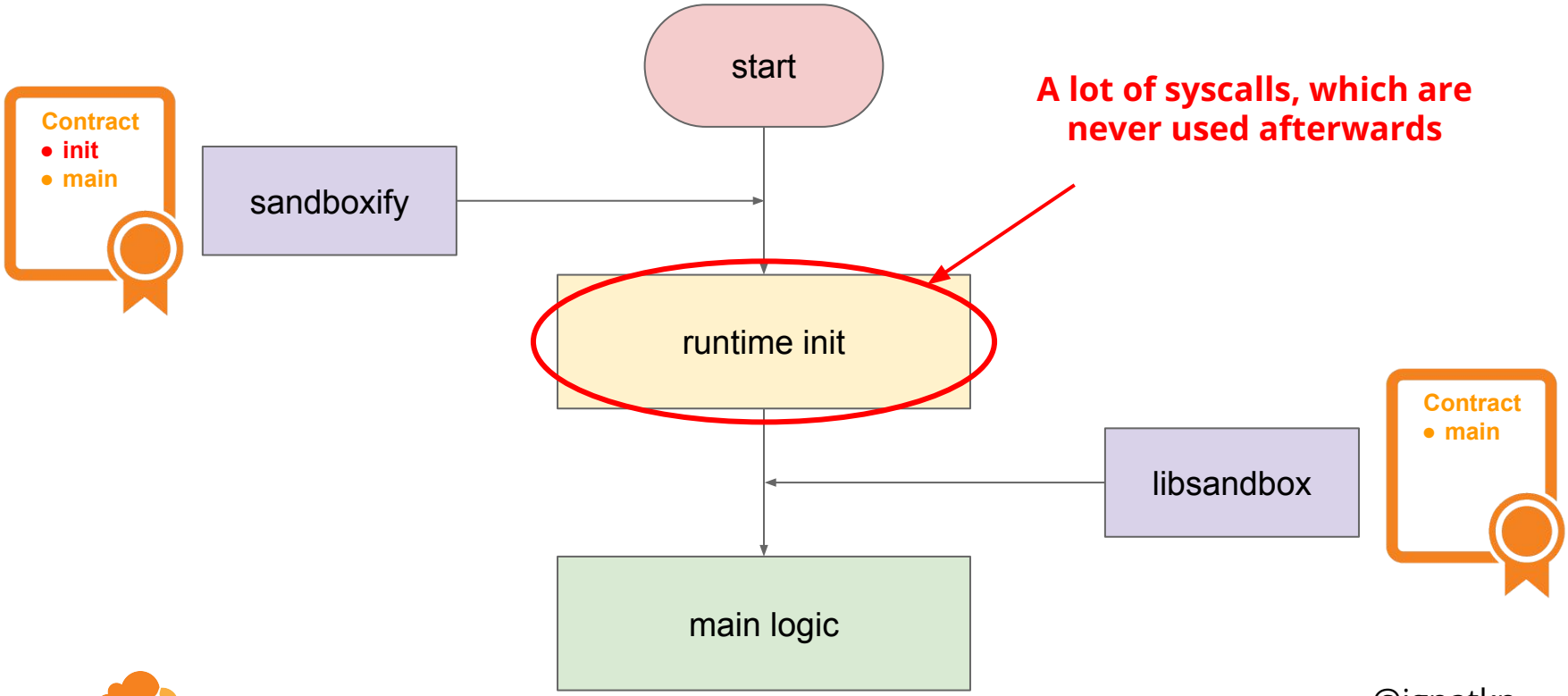
Process startup



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sandboxify vs libsandbox

```
$ gcc -o myos myos.c
```

sandboxify vs libsandbox

```
$ gcc -o myos myos.c
$ LD_PRELOAD=/usr/lib/x86_64-linux-gnu/libsandbox.so
SECCOMP_SYSCALL_ALLOW=exit_group:fstat:uname:write ./myos
adding exit_group to the process seccomp filter
adding fstat to the process seccomp filter
adding uname to the process seccomp filter
adding write to the process seccomp filter
My OS is Linux!
```

sandboxify vs libsandbox

```
$ gcc -o myos myos.c
$ LD_PRELOAD=/usr/lib/x86_64-linux-gnu/libsandbox.so
SECCOMP_SYSCALL_ALLOW=exit_group:fstat:uname:write ./myos
adding exit_group to the process seccomp filter
adding fstat to the process seccomp filter
adding uname to the process seccomp filter
adding write to the process seccomp filter
My OS is Linux!
```

sandboxify vs libsandbox

```
$ SECCOMP_SYSCALL_ALLOW=access:arch_prctl:brk:close:exit_group:fstat:mmap:mprotect:munmap:openat:read:uname:write
sandboxify ./myos
adding access to the process seccomp filter
adding arch_prctl to the process seccomp filter
adding brk to the process seccomp filter
adding close to the process seccomp filter
adding exit_group to the process seccomp filter
adding fstat to the process seccomp filter
adding mmap to the process seccomp filter
adding mprotect to the process seccomp filter
adding munmap to the process seccomp filter
adding openat to the process seccomp filter
adding read to the process seccomp filter
adding uname to the process seccomp filter
adding write to the process seccomp filter
My OS is Linux!
```

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sandboxify vs libsandbox

```
$ SECCOMP_SYSCALL_ALLOW=access:arch_prctl:brk:close:exit_group:fstat:mmap:mprotect:munmap:openat:read:uname:write
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My OS is Linux!
```

4 vs 13 syscalls in the allowlist

Links

https://www.man7.org/linux/man-pages/man2/seccomp.2.html

https://github.com/seccomp/libseccomp

https://www.freedesktop.org/software/systemd/man/systemd.exec.html#SystemCallFilter=

https://github.com/cloudflare/sandbox

https://blog.cloudflare.com/sandboxing-in-linux-with-zero-lines-of-code/

Questions?

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