Internals of Landlock: a new kind of Linux Security Module leveraging eBPF

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ANSSI

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1. bug exploitation of your code
2. bug or backdoor in a third party component

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The Landlock features

- help define and embed security policy in your code
- enforce an access control on your application

Demonstration #1

Read-only accesses...

- `/public`
- `/etc`
- `/usr`
- `...`

...and read-write accesses

- `/tmp`
- `...`

What about the other Linux security features?

	Fine-grained control	Embedded policy	Unprivileged use
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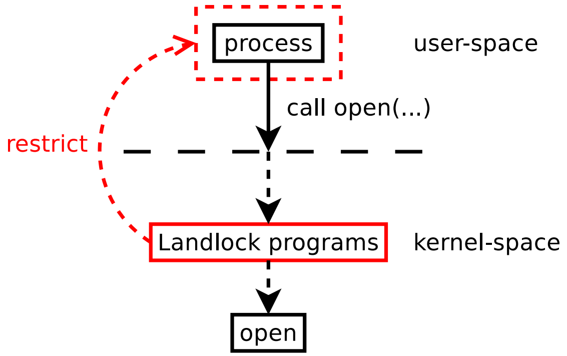
	Fine-grained control	**Embedded policy**	**Unprivileged use**
SELinux...	✓		
seccomp-bpf		✓	✓
namespaces		✓	∼
Landlock	✓	✓	✓[1]

Tailored access control to match your needs: programmatic access control

[1] Disabled on purpose for the initial upstream inclusion, but planned to be enabled after a test period.

Landlock overview



extended Berkeley Packet Filter

In-kernel virtual machine

- safely execute code in the kernel at run time
- widely used in the kernel: network filtering (XDP), seccomp-bpf, tracing…
- can call dedicated functions
- can exchange data through maps between eBPF programs and user-space

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Static program verification at load time

- memory access checks
- register typing and tainting
- pointer leak restrictions
- execution flow restrictions

The Linux Security Modules framework (LSM)

LSM framework

- allow or deny user-space actions on kernel objects
- policy decision and enforcement points
- kernel API: support various security models
- 200+ hooks: `inode_permission`, `inode_unlink`, `file_ioctl`...

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Landlock

- hook: set of actions on a specific kernel object (e.g. walk a file path)
- program: access-control checks stacked on a hook
- triggers: actions mask for which a program is run (e.g. read, write, execute, remove, IOCTL...)

Safely handle malicious policies

- Landlock should be usable by everyone
- we can't tell if a process will be malicious

$\Rightarrow$ trust issue

Unprivileged access control

Sought properties

- multiple applications, need independant but composable security policies
- tamper proof: prevent bypass through other processes (i.e. via ptrace)

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Harmlessness

- safe approach: follow the least privilege principle (i.e. no SUID)
- limit the kernel attack surface:
  - minimal kernel code (`security/landlock/*`: ∼2000 SLOC)
  - eBPF static analysis
  - move complexity from the kernel to eBPF programs

Unprivileged access control

Protect access to process ressources

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Protect access to kernel ressources

- prevent information leak: an eBPF program shall not have more access rights than the process which loaded it
- still, access control need some knowledge to take decision (e.g. file path check)
- only interpreted on viewable objects and after other access controls

Identifying a file path

- path evaluation based on walking through inodes
- multiple Landlock program types

eBPF inode map

Goal

restrict access to a subset of the filesystem

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- efficient
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  - no xattr
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Solution

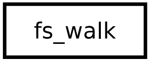
- new eBPF map type to identify an inode object
- use inode as key and associate it with a 64-bits arbitrary value

Demonstration #2

Update access rights on the fly

Chained programs and session

Landlock programs and their triggers (example)



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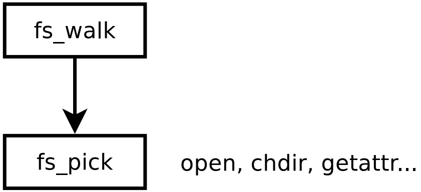

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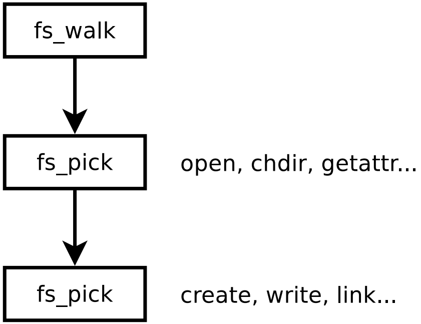

Walking through a file path

Example: `open /public/web/index.html`

key	value
/etc	1 (ro)
/public	1 (ro)
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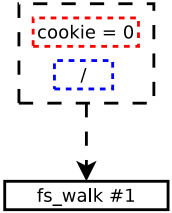

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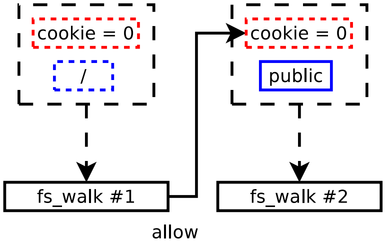

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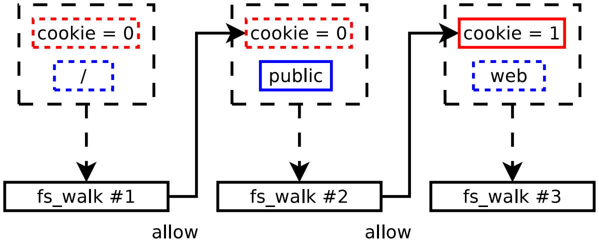

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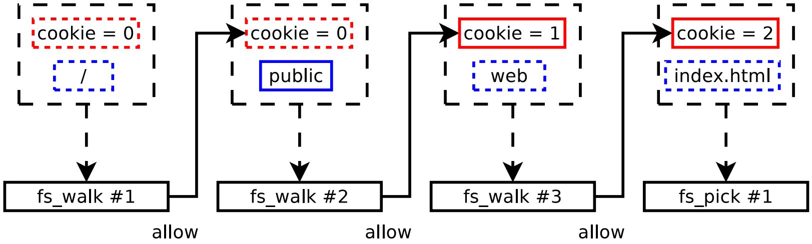

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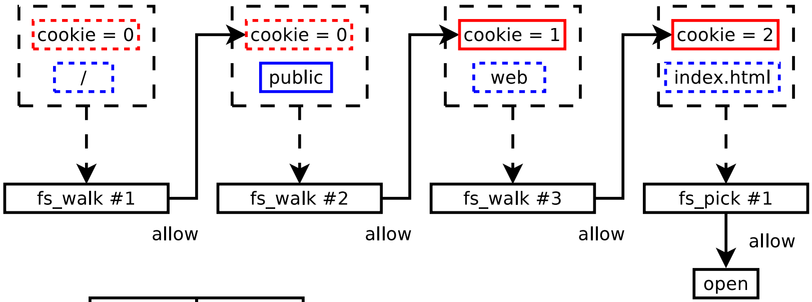

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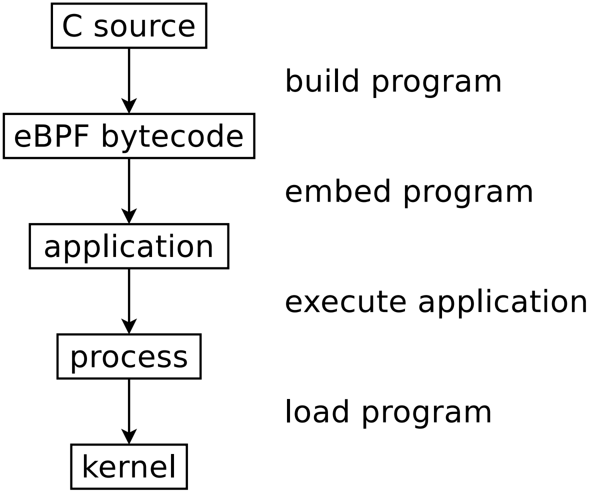
From the rule to the kernel

- writing a Landlock rule
- loading it in the kernel
- enforcing it on a set of processes

Life cycle of a Landlock program



Landlock program's metadata

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static union bpf_prog_subtype metadata = {
	.landlock_hook = {
		.type = LANDLOCK_HOOK_FS_PICK,
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int fs_pick_write(struct landlock_ctx_fs_pick *ctx) {
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        cookie = update_cookie(cookie, ctx->inode_lookup,
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        if (cookie & MAP_MARK_WRITE)
                return LANDLOCK_RET_ALLOW;
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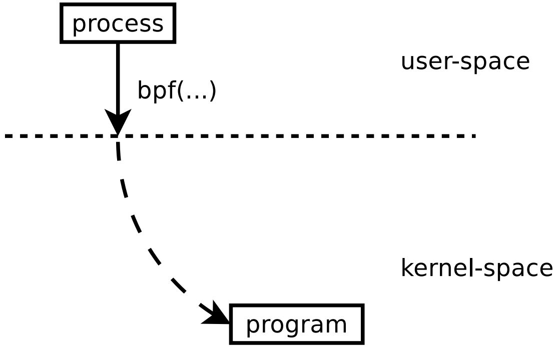
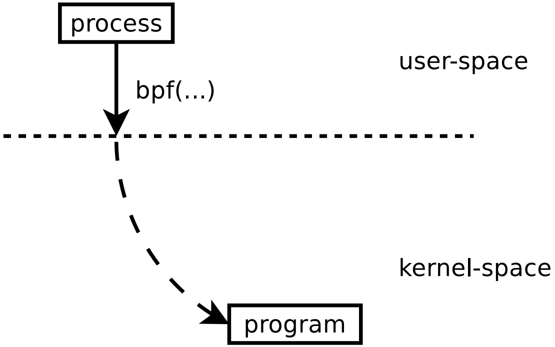


Applying a Landlock program to a process

```
seccomp(SECCOMP_PREPEND_LANDLOCK_PROG, 0, &prog_fd);
```

Applying a Landlock program to a process



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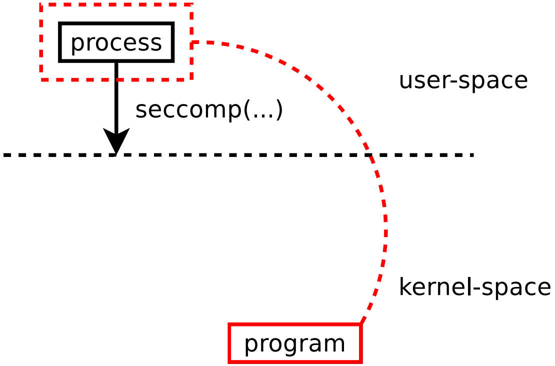

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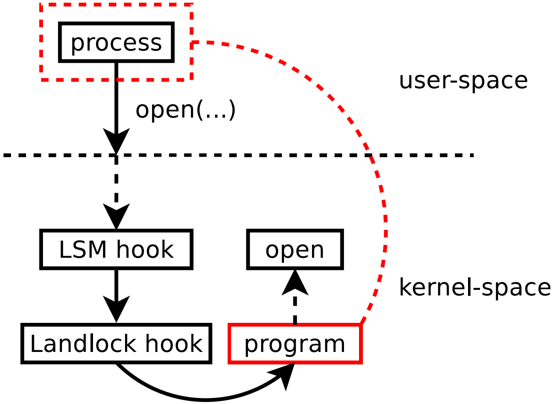

Kernel execution flow

Example: the `inode_create` hook

1. check if `landlocked(current)`
2. call `decide_fs_pick(LANDLOCK_TRIGGER_FS_PICK_CREATE, dir)`
3. for all *fs_pick* programs enforced on the current process
    3.1 update the program's context
    3.2 interpret the program
    3.3 continue until one denies the access

Landlock: wrap-up

User-space hardening

- programmatic and embeddable access control
- designed for unprivileged use
- apply tailored access controls per process
- make it evolve over time (map)

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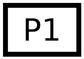
Current status

- standalone patches merged in net/bpf, security and kselftest trees
- `security/landlock/*`: ~2000 SLOC
- ongoing patch series: LKML, `@l0kod`
- full security module stacking is comming!

https://landlock.io

Rule enforcement on process hierarchy



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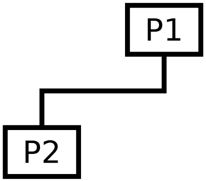

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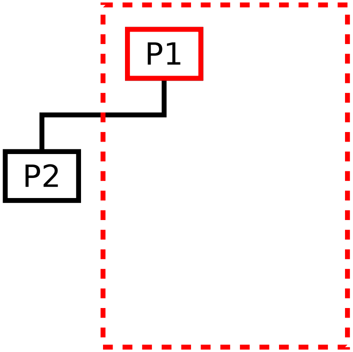

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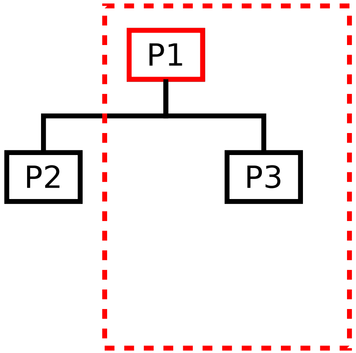

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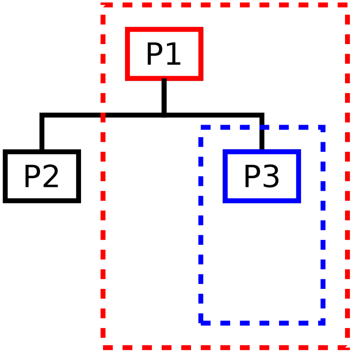

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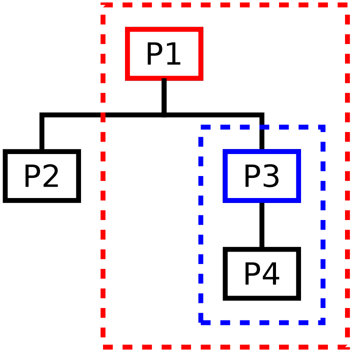

Enforcement through cgroups

Why?

user/admin security policy (e.g. container): manage groups of processes

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Challenges

- complementary to the process hierarchy rules (via *seccomp(2)*)
- processes moving in or out of a cgroup
- unprivileged use with cgroups delegation (e.g. user session)

Future Landlock program types

fs_get

tag inodes: needed for relative path checks (e.g. *openat(2)*)

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net_*

check IPs, ports, protocol…