Landlock LSM: toward unprivileged sandboxing

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ANSSI

September 14, 2017

Secure user-space software

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- secure development
- follow the least privilege principle
- compartmentalize exposed processes

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Multiple sandbox uses

- built-in sandboxing (tailored security policy)
- sandbox managers (unprivileged and dynamic compartmentalization)
- container managers (hardened containers)

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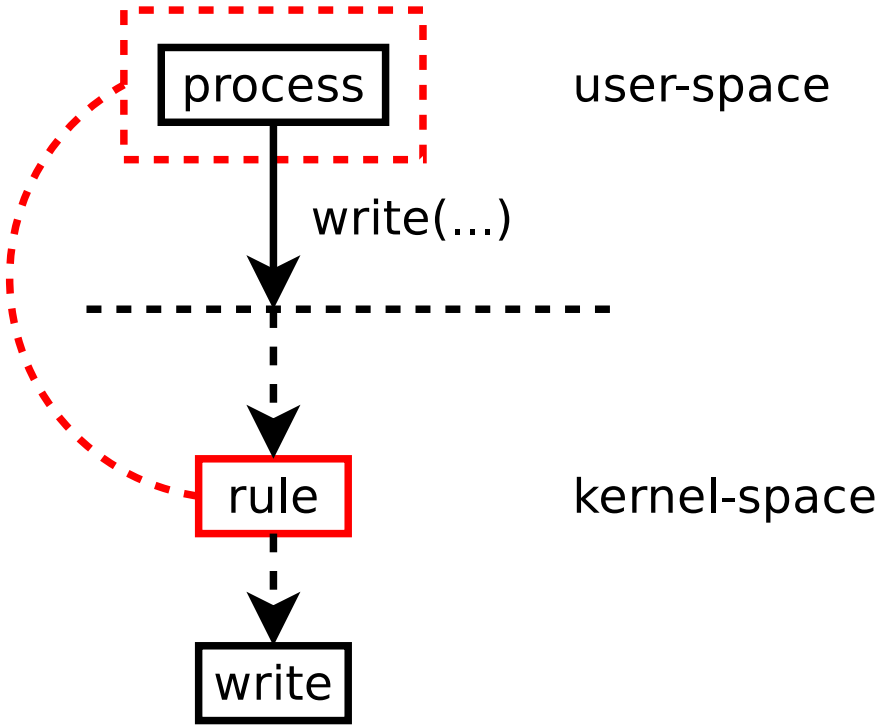
Landlock	✓	✓	✓

Tailored access control to match your needs: programmatic access control

Example

Run an application allowed to write only on a terminal.

Landlock overview



Landlock: patch v7

- a minimum viable product
- a stackable LSM
- using eBPF
- focused on filesystem access control

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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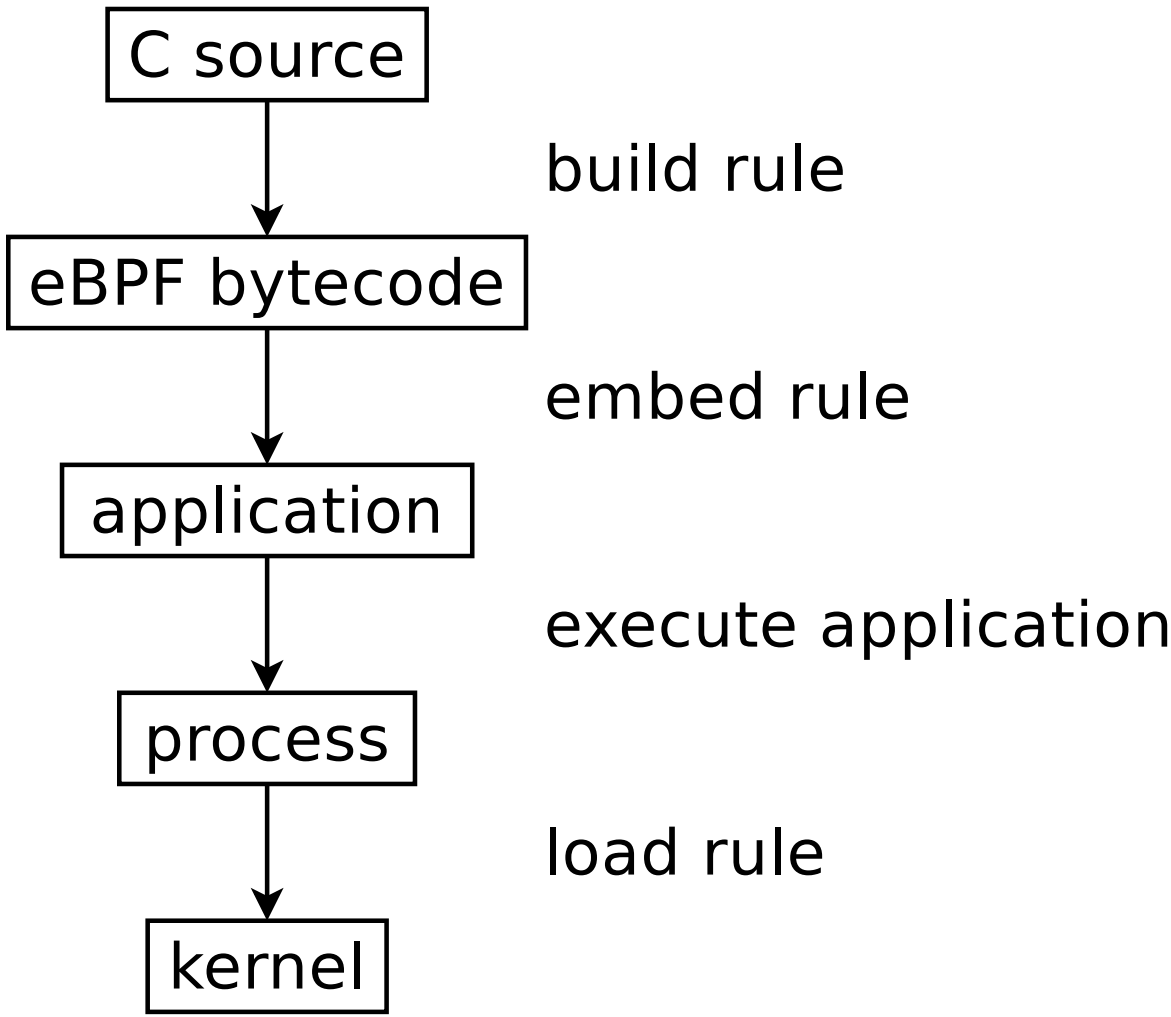
Landlock

- rule: control an action on an object
- event: use of a kernel object type (e.g. file)
- action: read, write, execute, remove, IOCTL...

Life cycle of a Landlock rule



Landlock rule example

- read-only access to the filesystem...
- ...but allowed to write on TTY and pipes
- rule enforced on each filesystem access request

Landlock rule example

```
 1 SEC("landlock1")
 2 int landlock_fs_rule1(struct landlock_context *ctx)
 3 {
 4         int mode;
 5
 6         /* allow non-write actions */
 7         if (!(ctx->arg2 & LANDLOCK_ACTION_FS_WRITE))
 8                 return 0;
 9         /* get the file mode */
10         mode = bpf_handle_fs_get_mode(ctx->arg1);
11         /* allow write on TTY and pipes */
12         if (S_ISCHR(mode) || S_ISFIFO(mode))
13                 return 0;
14         return 1;
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extended Berkeley Packet Filter

In-kernel virtual machine

- safely execute code in the kernel at run time
- widely used in the kernel: network filtering, 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

Loading a rule in the kernel

```
1  static union bpf_prog_subtype metadata = {
2          .landlock_rule = {
3                  .event = LANDLOCK_EVENT_FS,
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5          }
6  };
7  union bpf_attr attr = {
8          .insns = bytecode_array,
9          .prog_type = BPF_PROG_TYPE_LANDLOCK_RULE,
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13 int rule_fd = bpf(BPF_PROG_LOAD, &attr, sizeof(attr));
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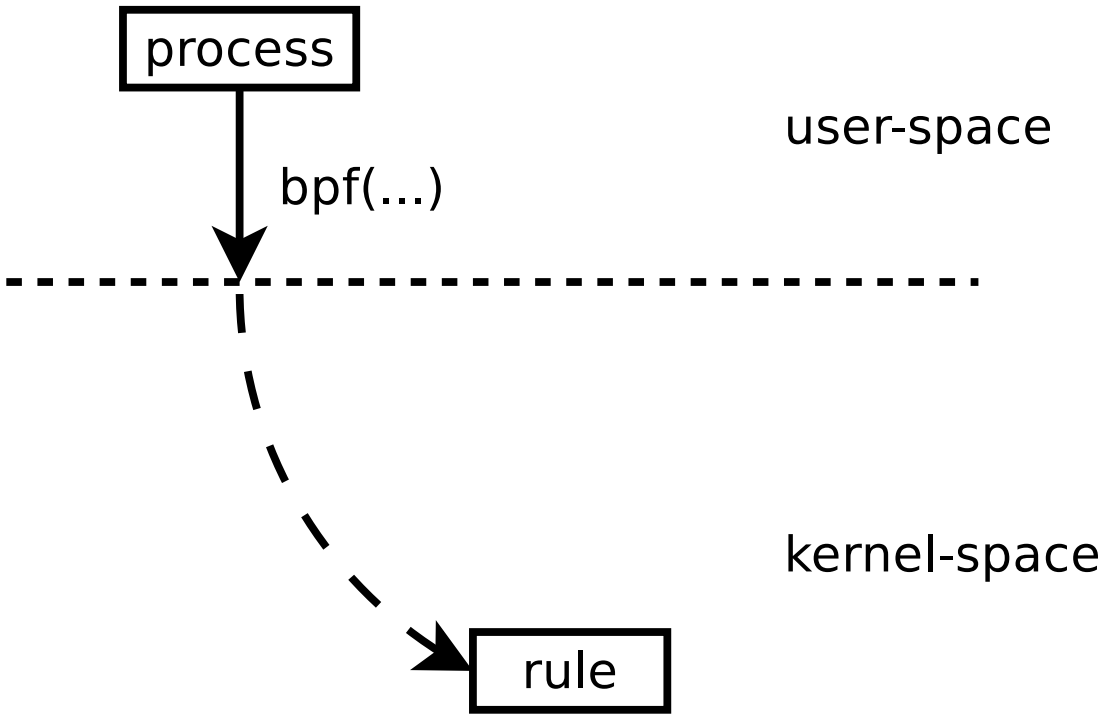

Applying a rule to a process

```
1 seccomp(SECCOMP_PREPEND_LANDLOCK_RULE, 0, &rule_fd);
```

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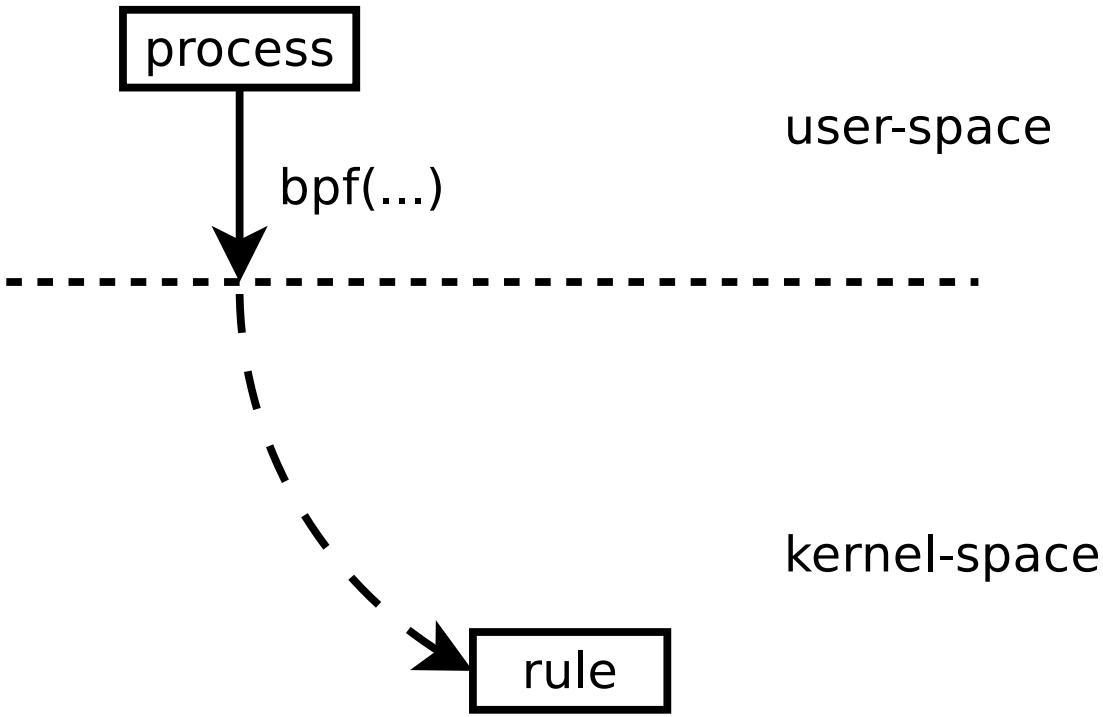

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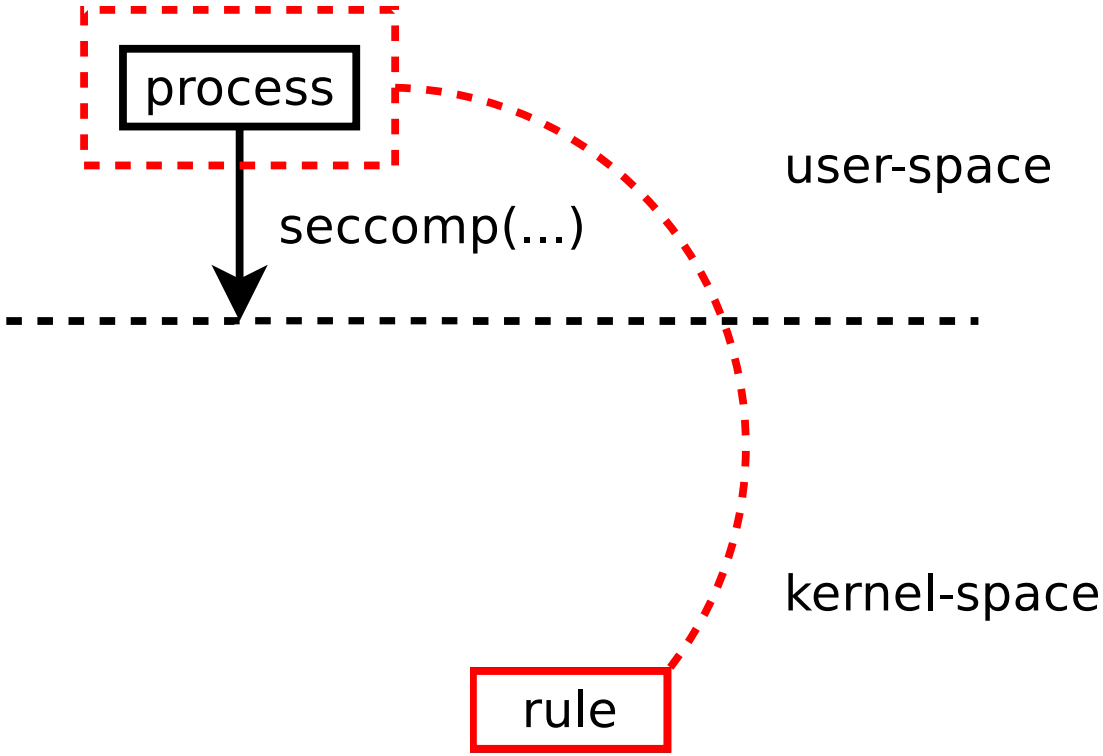

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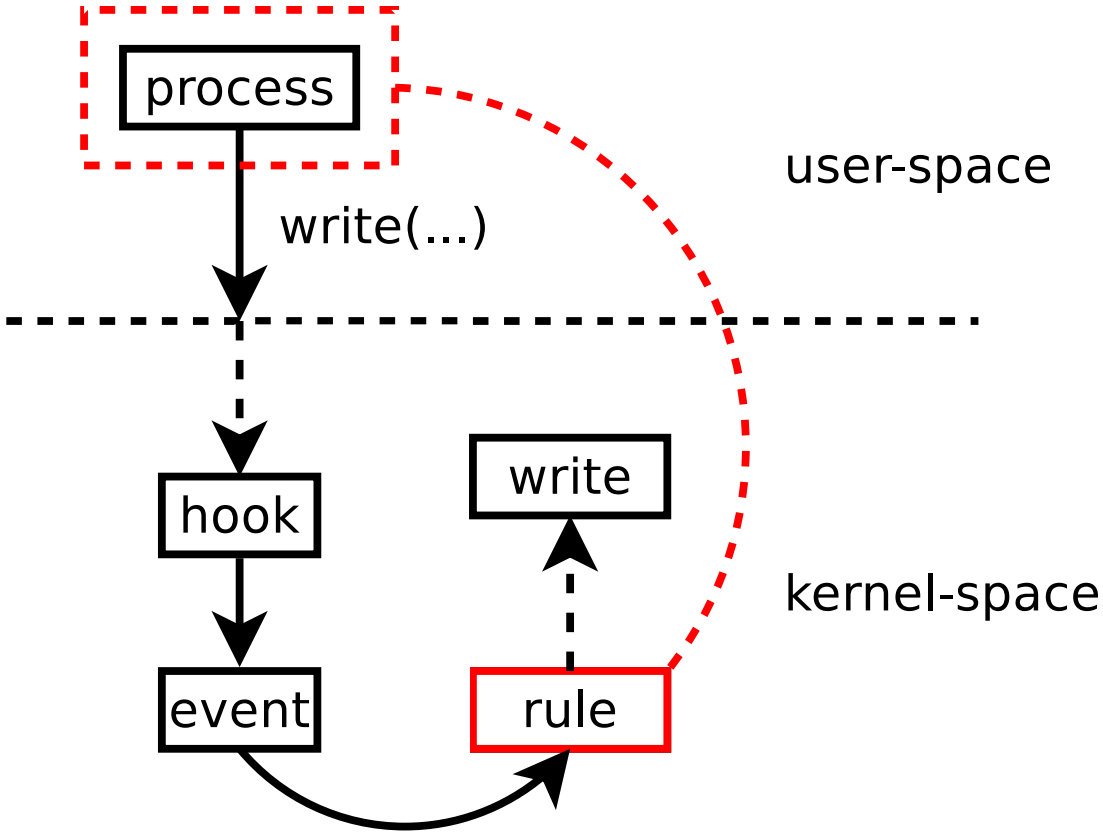

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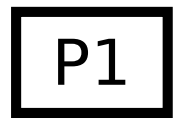

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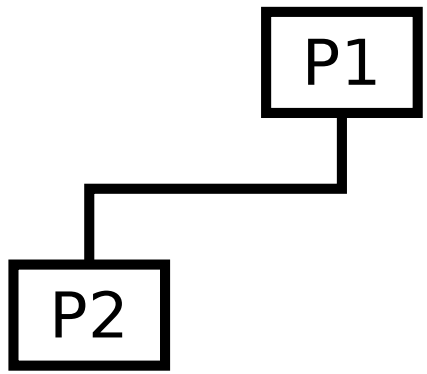

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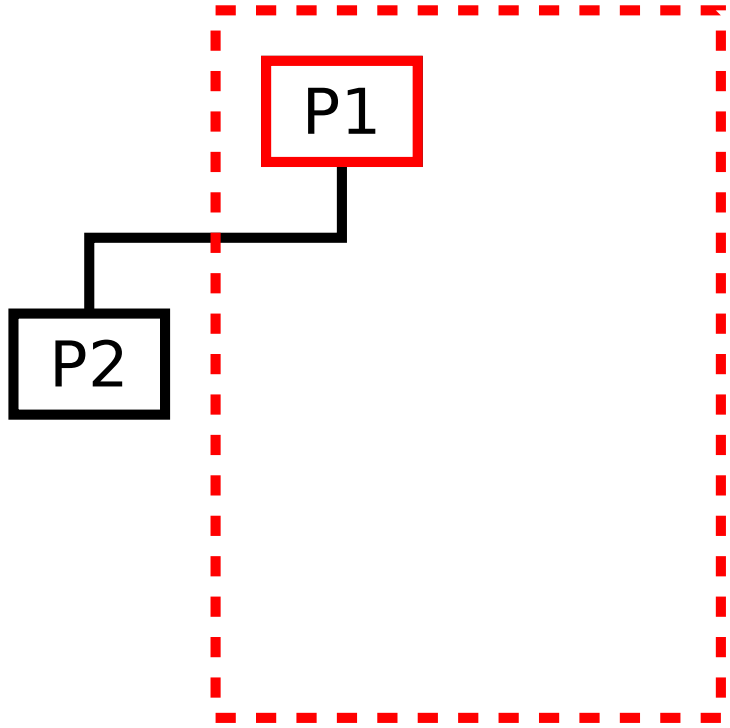

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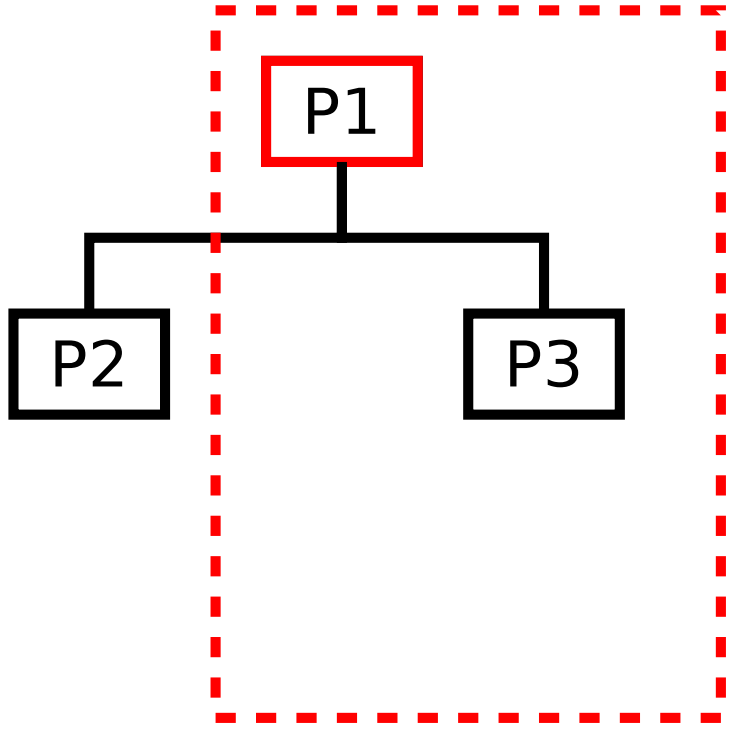

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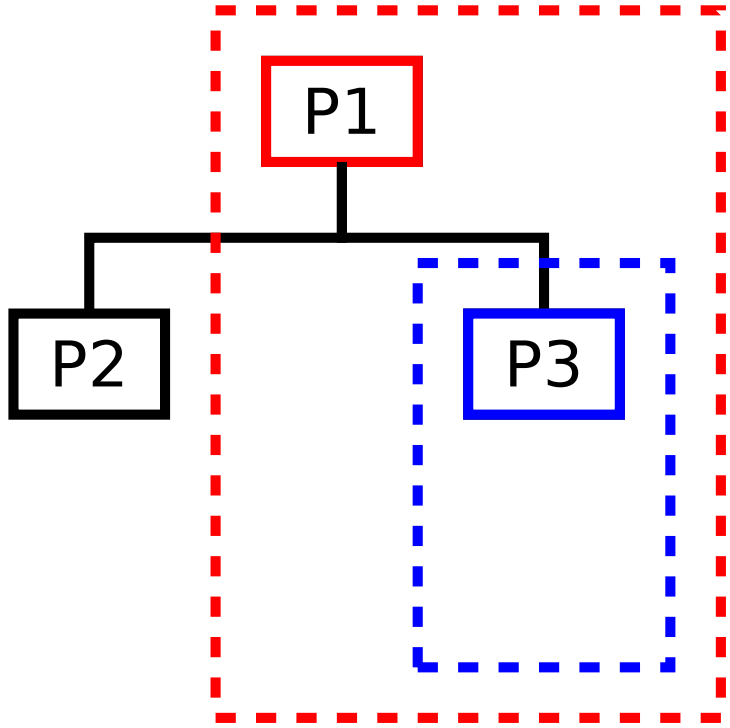

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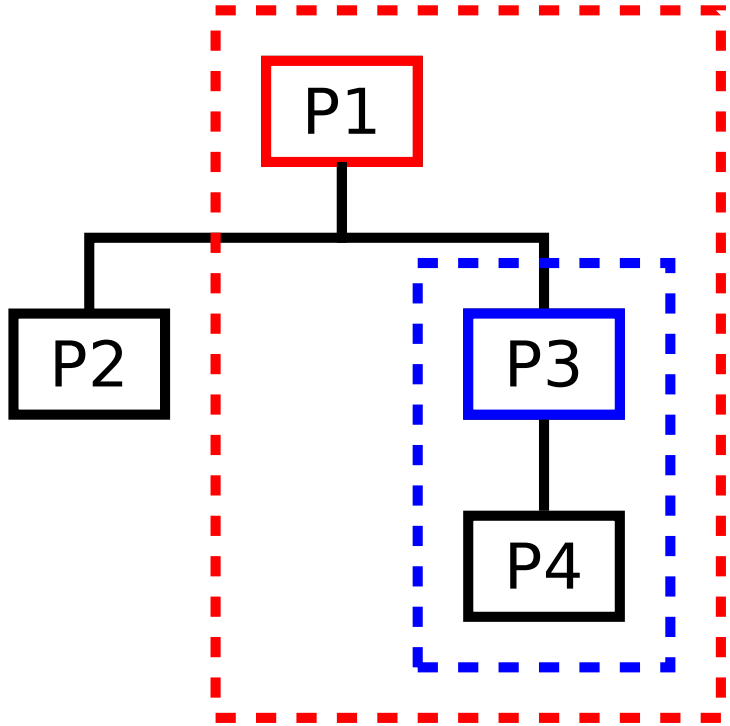

Demonstration #1

An (almost) read-only filesystem

Landlock: pending features

- unprivileged access control
- enforcement through cgroups
- eBPF map fsview
- coming next...

Unprivileged access control

Why?

embed a security policy in any application, following the least privilege principle

Unprivileged access control

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embed a security policy in any application, following the least privilege principle

Challenges

- applying a security policy requires privileges
- unlike SUID, Landlock should only reduce accesses
- prevent accesses through other processes: ptrace restrictions
- protect the kernel: eBPF static analysis
- prevent information leak: an eBPF program shall not have more access rights than the process which loaded it

Enforcement through cgroups

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

Enforcement through cgroups

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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)

eBPF map fsview

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restrict access to a subset of the filesystem

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- efficient
- updatable from user-space
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Proposal

- new eBPF map to identify a *filesystem view*: mount point hierarchies at a given time
- new eBPF function to compare a file access to such a view

Demonstration #2

What might a filesystem access control looks like?

Current roadmap

Incremental upstream integration

1. minimum viable product
2. cgroups handling
3. new eBPF map type for filesystem-related checks
4. unprivileged mode

Landlock: wrap-up

User-space hardening

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Current status: patch v7

- autonomous patches merged in net, security and kselftest trees
- `security/landlock/*`: ∼1K SLOC
- ongoing patch series: LKML, `@l0kod`
- growing interest for containers, secure OS and service managers

https://landlock.io

Landlock context

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Debug mode: need `CAP_SYS_ADMIN`

- bpf_get_current_comm
- bpf_get_current_pid_tgid
- bpf_get_current_uid_gid
- bpf_get_trace_printk