Revisiting eBPF Seccomp Filters

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with YiFei Zhu, Andrea Arcangeli, Hubertus Franke, Tobin Feldman-Fitzthum, Claudio Canella, Dimitrios Skarlatos, Daniel Gruss, Dan Williams, Tianyin Xu

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- Two modes
  - *Restricted mode*: only allows `read()`, `write()`, `exit()`, and `sigreturn()`
    - Kills the process if other syscalls are used
  - *Filter mode*: allows custom policies implemented in **cBPF** (classic BPF)
    - Custom set of allowed/disallowed syscalls and non-pointer arguments
    - Custom actions (e.g., allow, return error code, kill process)

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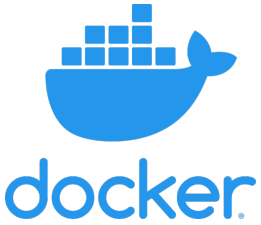

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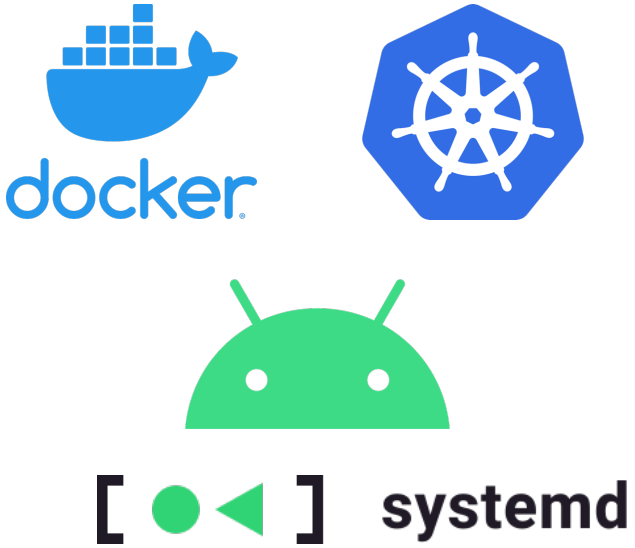

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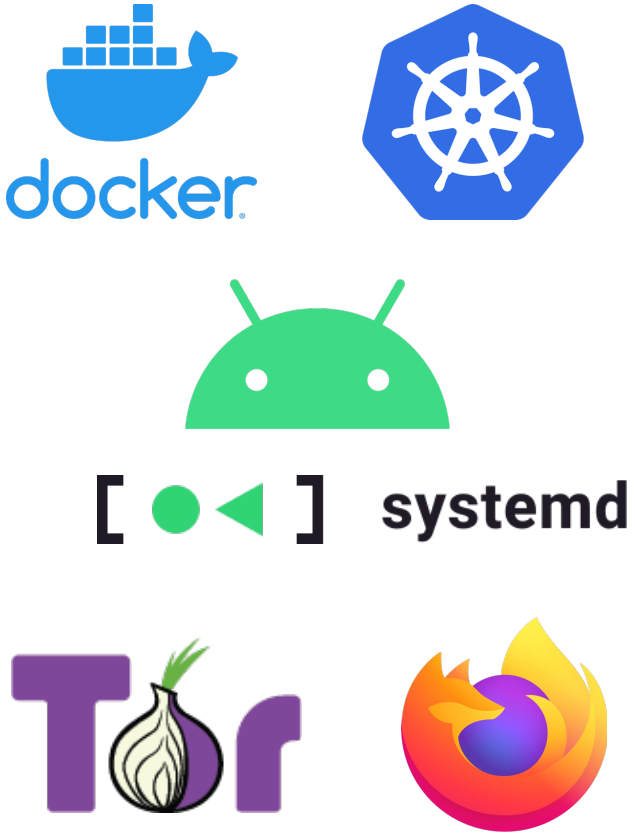
- Various other applications
  - OpenSSH, Tor, Firefox, …



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cBPF cannot express complex syscall policies,
e.g., state-based filtering

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Revisiting eBPF Seccomp filters

to improve *programmability* and *extensibility* of system call security.

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- **Helper interface** for rich interaction with kernel
- **Toolchain support**: write C, compile to eBPF

Implications on Seccomp

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- Advanced checking logic from new instruction set
- Stateful filters via map storage
- Access to more kernel context using kernel helper functions
- Mature toolchains

Previous efforts

- Seccomp-eBPF patch from Dhillon (Feb. 2018)
  - https://lwn.net/Articles/747229/
  + A new Seccomp program type for eBPF
  + A new eBPF flag in Seccomp with code that allocates eBPF filters
  - No eBPF map support nor security model
  - Only supports 4 helpers
- Seccomp-eBPF patch from Hromatka (Feb. 2018)
  - https://groups.google.com/g/libseccomp/c/pX6QkVF0F74?pli=1
  + A new eBPF filter mode in Seccomp that loads and allocates the filter.
  - Incomplete -- no Seccomp-eBPF program type/whitelisted helpers

Some common opinions

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- “What's the reason for adding eBPF support? seccomp shouldn't need it, and it only makes the code more complex. I'd rather stick with cBPF until we have an **overwhelmingly good reason** to use eBPF as a "native" seccomp filter language.”

Lacking use cases

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Lacking use cases

- This is the blocker as far as I'm concerned: there is no story for unprivileged eBPF. And even IF there was a story there, I find **the rate of security-related flaws in eBPF to be way too high for a sandboxing primitive to depend on**...I just can't bring myself to accept that level of risk for seccomp.

Security as a concern

Many use cases of Seccomp-eBPF

- Syscall count limiting
- Enhanced temporal syscall specialization
- Syscall-flow-integrity protection
- Checking syscall sequence for intrusion detection systems
- Accelerating security checks
- Many others!

Syscall count limiting

Real world example in runc

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```
if l.cfg.Config.Seccomp != nil &&
    !l.cfg.NoNewPrivileges {
        seccomp.InitSeccomp(...)
}
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Sets up Seccomp filters

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if l.cfg.Config.Seccomp != nil &&
    !l.cfg.NoNewPrivileges {
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}
finalizeNamespace(...)
...
if unix.Getppid() != l.parentPid { ... }
...
unix.Write(fd, []byte("0"))
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unix.Write(fd, []byte("0"))
system.Exec(name, l.cfg.Args[0:], os.Env())
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exec into target application

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`seccomp` w/o `NO_NEW_PRIVS` is privileged!
Needed before dropping privileges

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cBPF filters cannot block setup syscalls during application run.

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        if (!no_exec) {
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eBPF map to store states, i.e., whether `execve` has been called

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If execve hasn't been called, allow and mark it as called

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Additional attack surface eliminated

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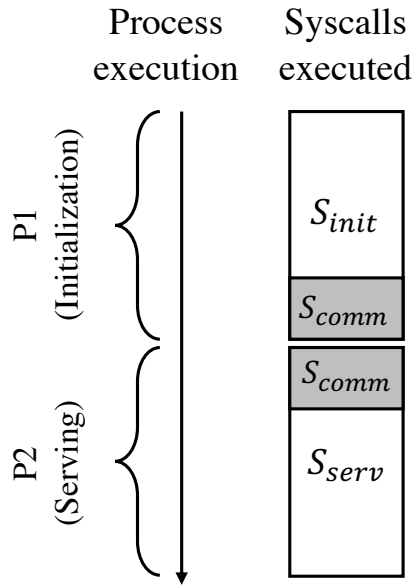

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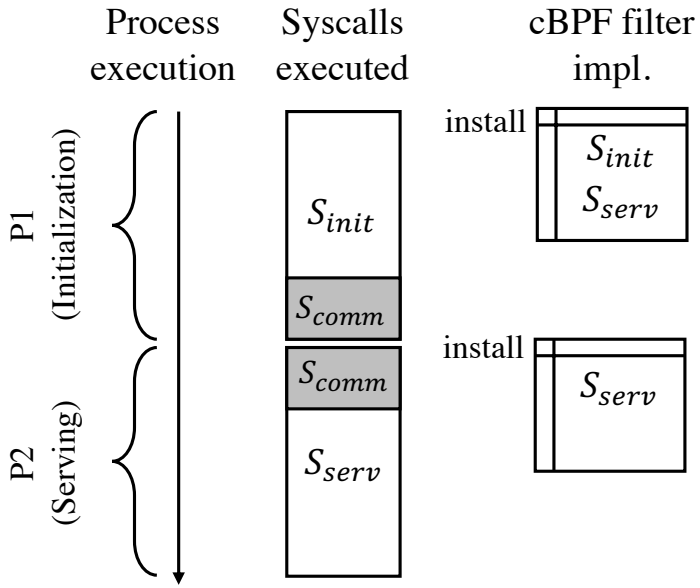

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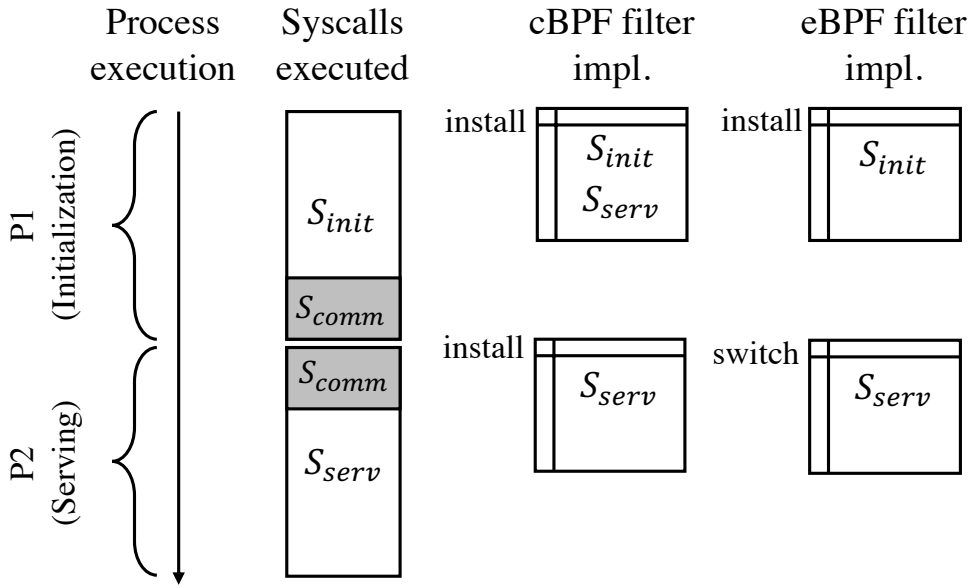
- cBPF cannot enforce the policy **precisely**
- eBPF map can track application phases
  - Different policies for different phases



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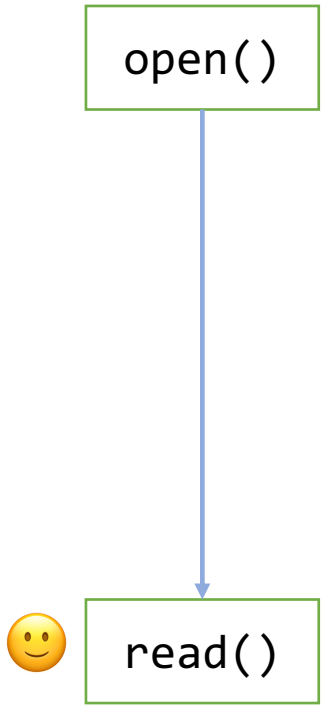

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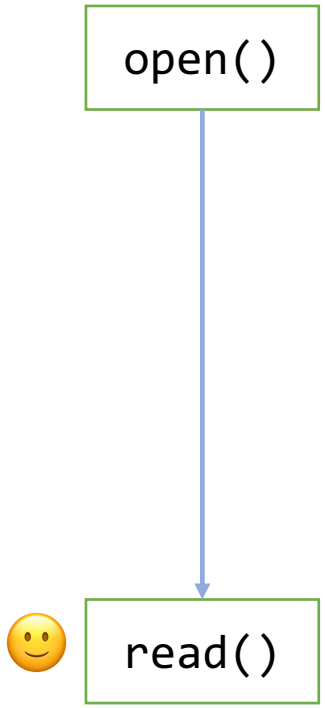

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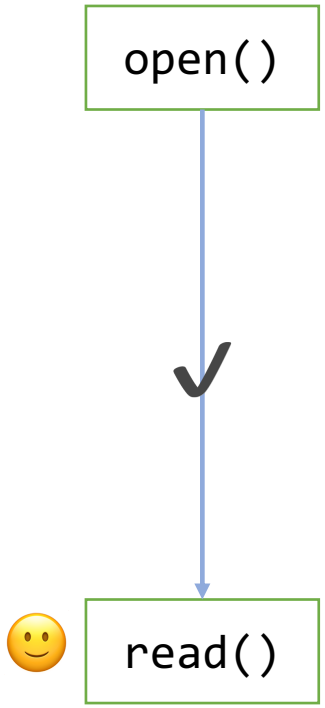

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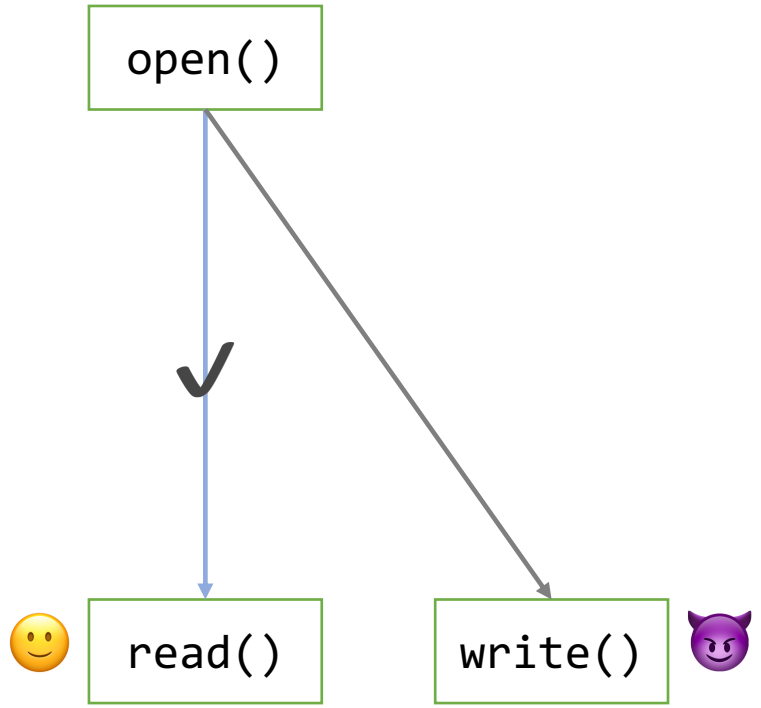

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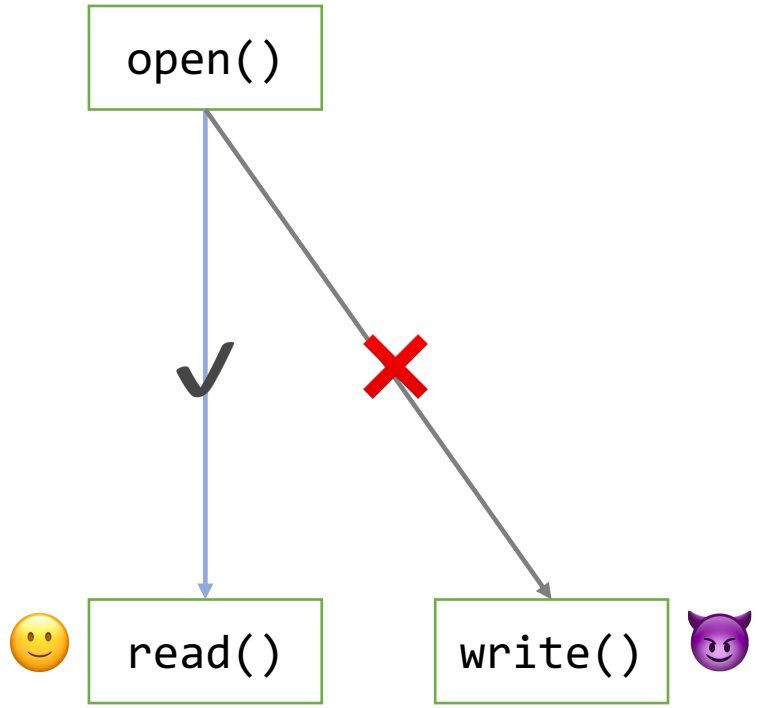

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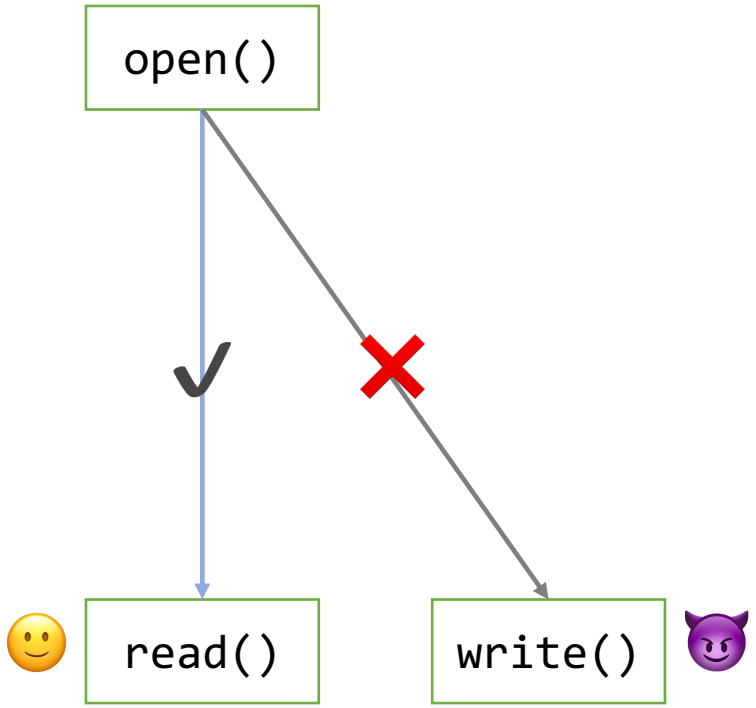
- Construct syscall state machine as an eBPF map and use Seccomp for enforcement



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How to make Seccomp-eBPF secure?

- Security model
- support for eBPF Seccomp filters under privileged eBPF
- IMA integration to enhance security

Security model of Seccomp-eBPF

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  - Seccomp-eBPF is **as secure as** the existing Seccomp and eBPF

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- Seccomp-eBPF maintains the above security enforcement.

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- Same privilege requirement for helpers
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- eBPF does not have privilege requirement for maps
  - Add a new verifier hook to restrict map usage if desired

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- Seccomp-eBPF is useful under privileged eBPF
  - lots of virtualization applications run as root
  - privileged enough to utilize eBPF Seccomp filters
    - example: Docker

Harden Seccomp-eBPF filters

- Optionally disables unprivileged eBPF filters based on the `BPF_UNPRIV_DEFAULT_OFF` configuration

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- Optionally disables unprivileged eBPF filters based on the `BPF_UNPRIV_DEFAULT_OFF` configuration

- Same privilege requirement as eBPF tracing program types
  - `CAP_BPF` + `CAP_PERFMON` when unprivileged filters are not allowed
  - eBPF filters are similar to tracing programs in many aspects
    - e.g., common set of helpers, changing function return value / process behavior

Potential security support from IMA

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  - turns the security problem into a trust problem
- The IMA subsystem checks signatures of files and verifies whether it comes from a trusted source
- Idea: implementing IMA signature support for eBPF filters
  - The IMA community is welcome to the eBPF signature support
  - Refer to KP's talk :)

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- Same attach point as cBPF filters
- Verifier hooks ensure correct access to the `seccomp_data` context and restrict the set of helpers for eBPF filters
- Security model: Reduce to Seccomp and eBPF

Container runtime integration

- Seccomp-eBPF can be easily integrated with container runtimes
- It is supported in crun,
  - A fast OCI-compliant runtime and the default for Podman
  - Credits to Giuseppe Scrivano (RedHat)

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```
$ podman --runtime /usr/local/bin/crun run
         --annotation run.oci.seccomp_ebpf_file
           =ebpf_filter.o
```

Conclusion

- We revisit Seccomp-eBPF filters
  - Significantly improve programmability of system call security
  - Many real-world use cases
  - Security model can be well defined

- https://github.com/xlab-uiuc/seccomp-ebpf-upstream