bpfbox: Simple Precise Process Confinement in eBPF

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Outline of Talk

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What is eBPF?

eBPF in the Beginning

eBPF $\equiv$ **E**xtended **B**erkley **P**acket **F**ilter...

- But it has little to do with Berkley, packets, or filtering nowadays
- The name BPF is preserved for historical reasons

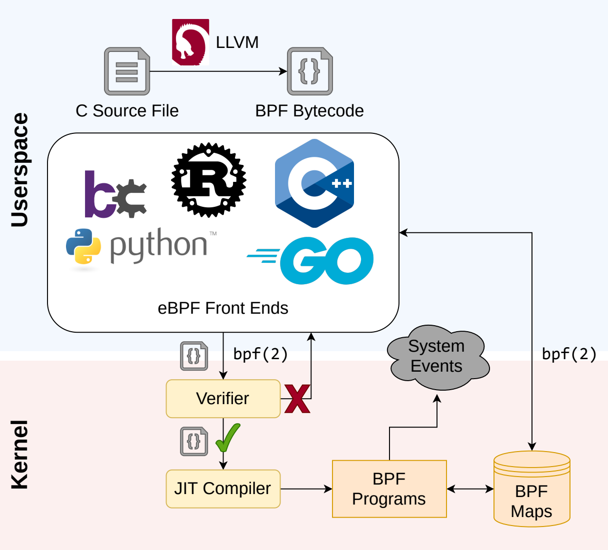
So then **what is eBPF?**

- A major re-write of the Linux BPF engine
  - Alexei Starovoitov and Daniel Borkmann
- Merged into the Linux kernel in 2014
- The point was fine-grained, cross-layer **system introspection**

What Can eBPF Do?

Direct Packet Access	Userspace Functions	Hardware	LSM Hooks
TCP / IP	System Calls	Block Device I/O	And much more...
Sockets	Kernelspace Functions	Stack Traces	

How eBPF Works



eBPF in 2020

eBPF is now **more than just an observability tool**.

- eBPF provides a **safe**, **efficient**, and **flexible** way for privileged users to extend the kernel
- eBPF turns Linux into a **programmable kernel**

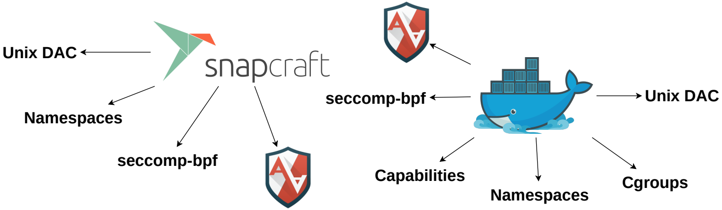
Linux 5.7 $\rightarrow$ KRSI (**K**ernel **R**untime **S**ecurity **I**nstrumentation)

- Attach BPF programs to LSM hooks
- Make security decisions and generate audit logs with eBPF

Motivation

The Status Quo

- Existing process confinement mechanisms are **complex**



- Existing process confinement mechanisms are **difficult to use**

- Can we do any better?

eBPF Changes the Game

eBPF enables:

- Fine-grained system introspection
- Rapid prototyping
- Safe production deployment of new security solutions
- Integration of **cross-layer state** with policy enforcement

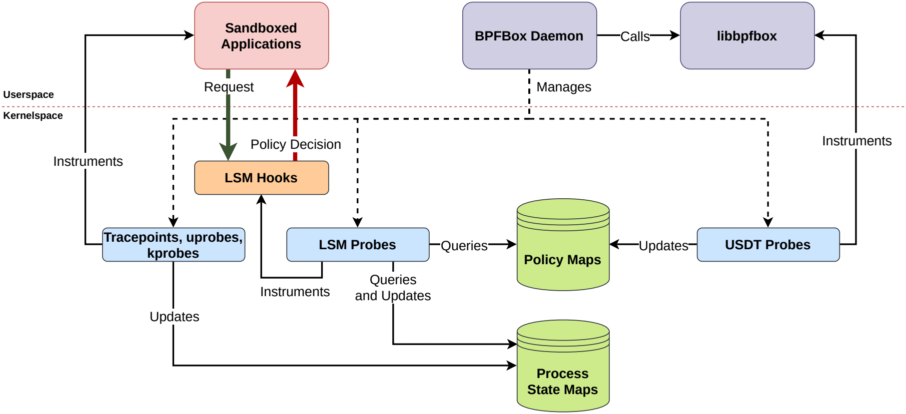
We have an opportunity to **rethink process confinement** from the ground up.

bpfbox Implementation

bpfbox Implementation

- Userspace daemon using the Python3 bcc module
- Kernelspace components are all eBPF
  - Tracepoints, kprobes, uprobes, LSM probes (KRSI)
  - Under 2000 source lines of code
- bpfbox is **light-weight**, **flexible**, and **production-safe**
  - Works out of the box on any vanilla Linux kernel ≥ 5.8

bpfbox Architecture



bpfbox Policy

Policy Design Goals

1. Simplicity
   - Policy should be simple enough for ad hoc confinement
2. Application transparency
   - Policy should not require changes to the confined application
3. Flexibility
   - Policy should offer optional layers of granularity
4. Security
   - Policy should follow the principle of least privilege
   - It should be difficult to write an insecure policy

Rules and Directives

Rules specify access to system objects:

- `fs(file, access)`
- `net(socket, access)`
- `signal(prog, sig)`
- etc.

Directives augment blocks of rules:

- `#[directive]` syntax
- Specify **actions to be taken** on a block of rules
- Add **additional context** to a block of rules

Taints and Transitions

```
#![profile "/bin/mywebdaemon"]

#[taint] {
    net(inet, any)
\vfill
    net(inet6, any)
}

/* ... */

#[transition] {
    fs("/bin/myhelper", getattr|read|exec)
}
```

Policy at the Function Call Level

```
#![profile "/sbin/mylogin"]

#[func "check_password"]
#[allow] {
    fs("/etc/passwd", read)
    fs("/etc/shadow", read)
}

#[func "add_user"]
#[allow] {
    fs("/etc/passwd", read|append)
    fs("/etc/shadow", read|append)
}

/* ... */
```

Performance Evaluation

Methodology

- Phoronix Test Suite OSBench
  - Measures basic OS functionality
  - (spawning processes, memory allocations, etc.)

- Phoronix Test Suite Apache
  - Benchmark Apache `httpd` packets per second

- Kernel compilation benchmarks
  - Measure Linux kernel compilation performance
  - Heavy workload, spawning lots of processes

Results

- Phoronix OSBench
  - Average case: bpfbox is **roughly equivalent** to AppArmor
  - Worst case: bpfbox performs **significantly better** than AppArmor
- Phoronix Apache
  - bpfbox and AppArmor are **roughly equivalent**
- Kernel compilation
  - Average case: bpfbox is **roughly equivalent** to AppArmor
  - Worst case: bpfbox performs **better in kernelspace** overhead and **worse in userspace** overhead

Conclusion

Acknowledgements

Special thanks to:

- **Alexei Starovoitov** and **Daniel Borkmann** (creators of eBPF)
- **K.P. Singh** (creator of KRSI)
- Fellow **bcc contributors** (an awesome eBPF framework)
- Anonymous **CCSW'2020 reviewers** (valuable feedback)

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Contributions

- First policy **enforcement engine** written in eBPF
- Integration of **userspace** and **kernelspace** state with **LSM layer enforcement**
- A simple policy language for **ad hoc process confinement**
  - But with optional complexity for **fine-grained protection**

github.com/willfindlay/bpfbox

Check out the project on GitHub!