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eBPF Debugging Infrastructure
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Current Techniques and Additional Proposals

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Debugging Infrastructure

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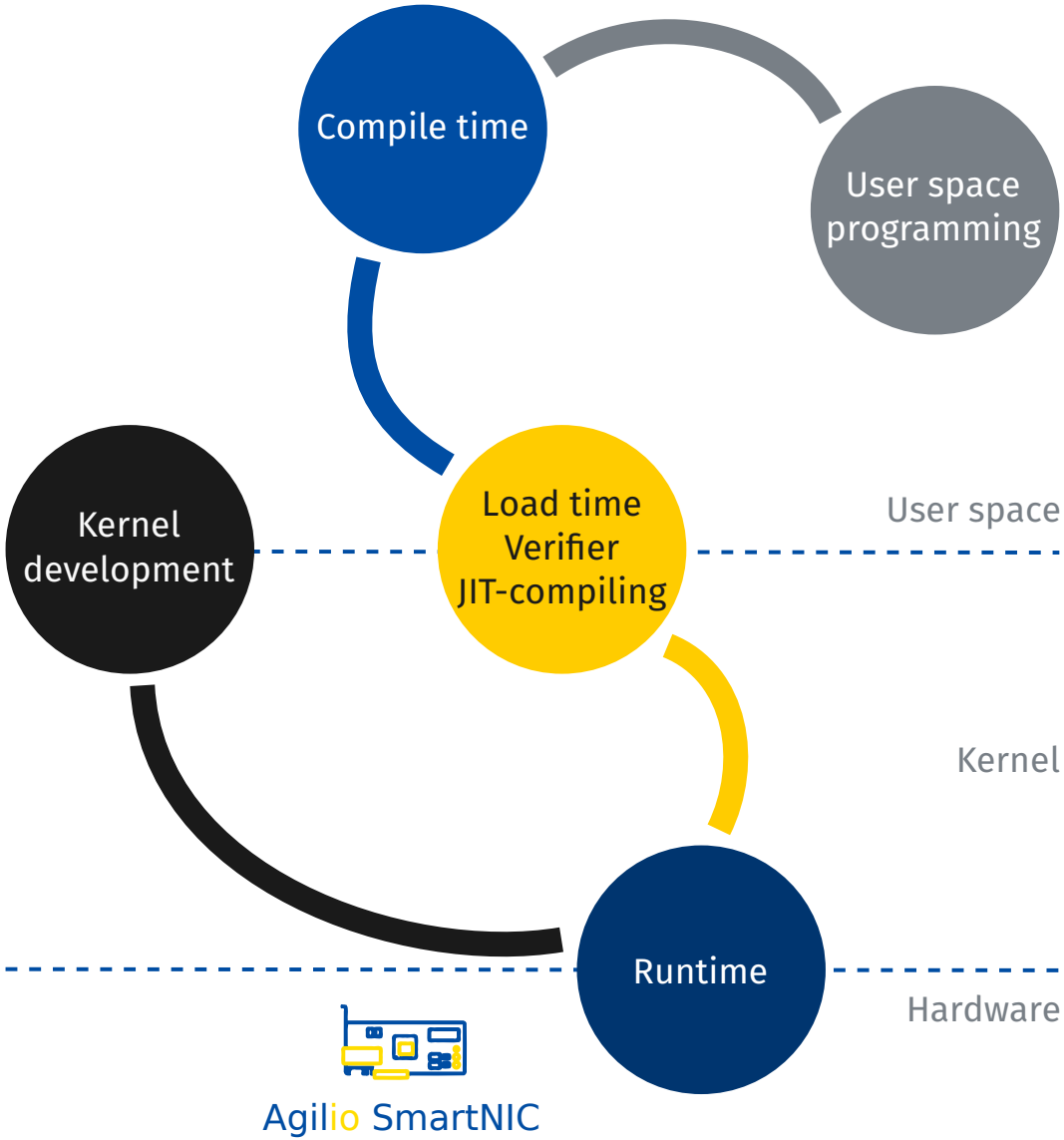
- What do we want to debug, troubleshoot?
- To achieve this:
  - What debugging tools and methods are available?
  - What is missing?

What to Debug: Many Levels



Compile Time

Objectives:

- Make sure the eBPF bytecode is generated as intended when compiling from C to eBPF

We have:

- LLVM backend: compilation
- llvm-objdump: dump generated bytecode
- eBPF assembly (LLVM): hack a sequence of instructions

Objectives:

- Load the program and make it pass the verifier, or understand why it is rejected

We have:

- libbpf / `ip` / `tc`: load or list programs
- libbpf / bpftool (and `tc` to some extent): eBPF object management
- Output from verifier logs, kernel logs, extack messages
- Documentation (filter.txt, Cilium guide)

What about:

- Checking what loads: `bpftool prog probe my_file.o`
  (work in progress, idea from Daniel)
- `man` pages (`bpf(2)` or `tc-bpf(8)` are badly outdated)
- Troubleshooting F.A.Q.? (e.g. some items already in filter.txt)

Objectives:

- Understand why a program does not run as intended, for example when processing network packets

We have:

- bpftool: introspection for maps / programs, object management
  Readability improved with BTF
- `bpf_trace_printk()`, perf events: print items, data
- (Limited user space eBPF virtual machines)
- Hooks in binutils-gdb, but no simulator support
- tools/bpf/bpf_dbg.c (cBPF)

What about:

- Debugger: break points, possibility to dump registers / stack / context?
  - Complete support in GDB?
  - Anything doable with LLDB? But how to pass packet data?
  - Extend `BPF_PROG_TEST_RUN` infrastructure? (idea: Daniel)

Objectives:

- Improve the eBPF architecture in the kernel, without breaking existing features

We have:

- Selftests: verifier, test programs
- Samples programs
- `BPF_PROG_TEST_RUN` infrastructure
- KASAN, syzkaller

What about:

- Having all JITs built-in, dump (then test) images for all architectures (idea: Daniel)

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Objectives:

- Debug or enhance a program managing eBPF objects
- Generally improve eBPF support in the toolchain

We have:

- `strace`, `valgrind` support: tracing system calls, memory checks

What about:

- Probing kernel for features (with bpftool)? (idea: Daniel)
- Bytecode generation: ethtool n-tuples (in progress), libpcap?

Discussion

What do you feel is missing for debugging eBPF?

Backup: Dump All JIT Images

Kernel JITs: ARM64, ARM32, PowerPC64, s390, Sparc64, MIPS, x86_64, x86_32
Offload: NFP

Objectives:

- Test images for all architectures
- Find bugs or low hanging perf improvements

Idea (Daniel):

- All JIT built-in in the kernel
- Pass a flag to `bpf(PROG_LOAD, ...)` to JIT-compile for all arch
- Pass a flag to `bpf(OBJ_GET_INFO_BY_ID, ...)` to dump all images
- Simulate execution on several architectures
- Add tools/ to bootstrap VMs to test the images?

Backup: Extend BPF_PROG_TEST_RUN

Member in `union bpf_attr` for `bpf(BPF_PROG_TEST_RUN, attr, size)`:

```
struct { /* anonymous struct used by BPF_PROG_TEST_RUN command */
        __u32           prog_fd;
        __u32           retval;
        __u32           data_size_in;
        __u32           data_size_out;
        __aligned_u64   data_in;
        __aligned_u64   data_out;
        __u32           repeat;
        __u32           duration;
} test;
```

Fields `data_out`, `data_out_size`, `retval`, `duration` are filled by kernel

Idea:

- Add a field to pass break points (insn number, program entry point?)
- Add fields or buffer to dump internal state: register values, stack, data?
- Maybe a front-end loader? bpftool?

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Example output:

```
# bpftool kernel probe
/* System configuration */
#define HAVE_BPF_SYSCALL
#define UNPRIVILEGED_BPF_DISABLED 0
#define JIT_COMPILER_ENABLE 0
#define JIT_COMPILER_HARDEN 0
#define JIT_COMPILER_KALLSYMS 0
#define LINUX_VERSION_CODE 267008

/* eBPF program types */
#define HAVE_SOCKET_FILTER_PROG_TYPE
#define HAVE_KPROBE_PROG_TYPE
...
/* HAVE_STACK_MAP_TYPE is not set */

/* eBPF map types */
#define HAVE_HASH_MAP_TYPE
#define HAVE_ARRAY_MAP_TYPE
...

/* eBPF helper functions */
#define HAVE_BPF_MAP_LOOKUP_ELEM_HELPER
#define HAVE_BPF_MAP_UPDATE_ELEM_HELPER
...
/* HAVE_BPF_MSG_PUSH_DATA_HELPER is not set */
```

- libpcap: patch the library or create an equivalent to use a similar syntax to produce eBPF programs

```
# tcpdump -d "port ssh"
(000) ldh      [12]
(001) jeq      #0x86dd          jt 2    jf 8
(002) ldb      [20]
(003) jeq      #0x6             jt 4    jf 19
(004) ldh      [54]
(005) jeq      #0x16            jt 18   jf 6
...
(019) ret      #0
```

- ethtool: implement a library to turn such rules into eBPF programs

```
# ethtool --config-ntuple eth0 flow-type tcp dst-port 22 action -1
<drop incoming SSH packets on a server>
```