A Flow-Sensitive Refinement Type System for Verifying eBPF Programs

CERTORA

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ANDROID

CLOUDFLARE

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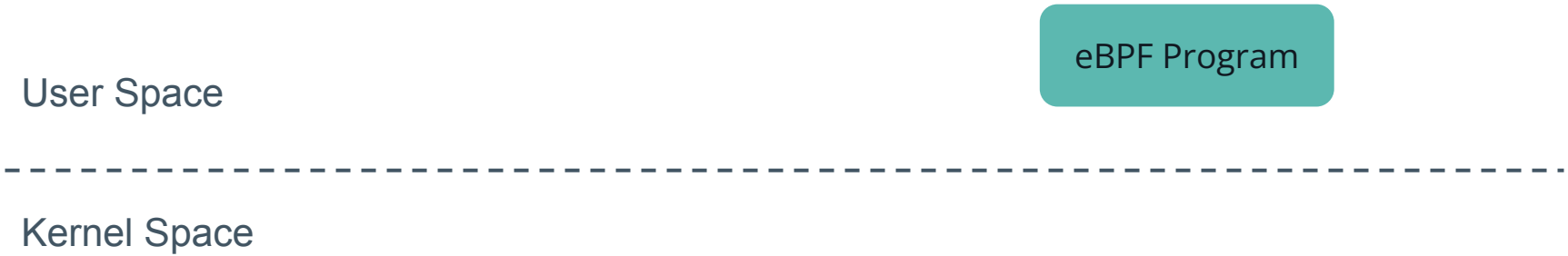

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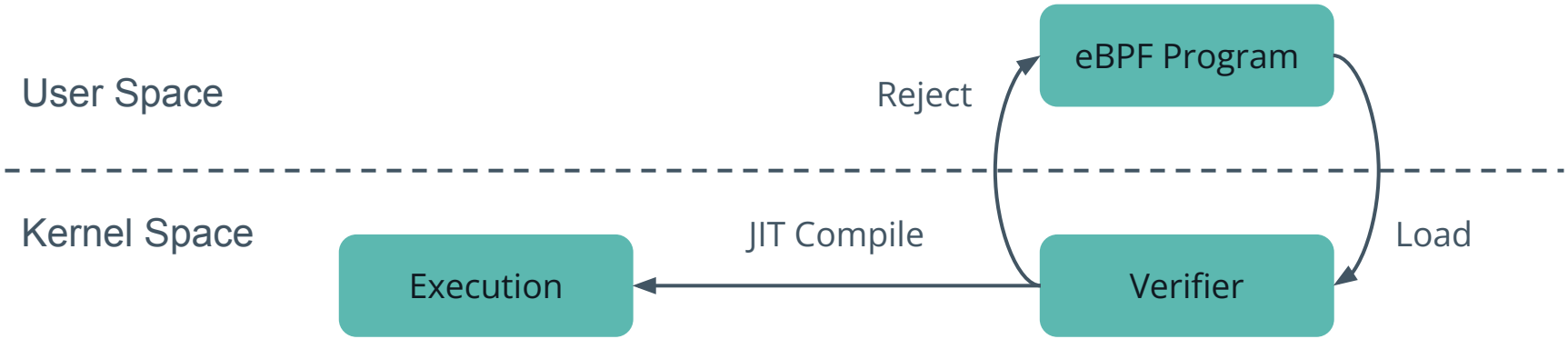

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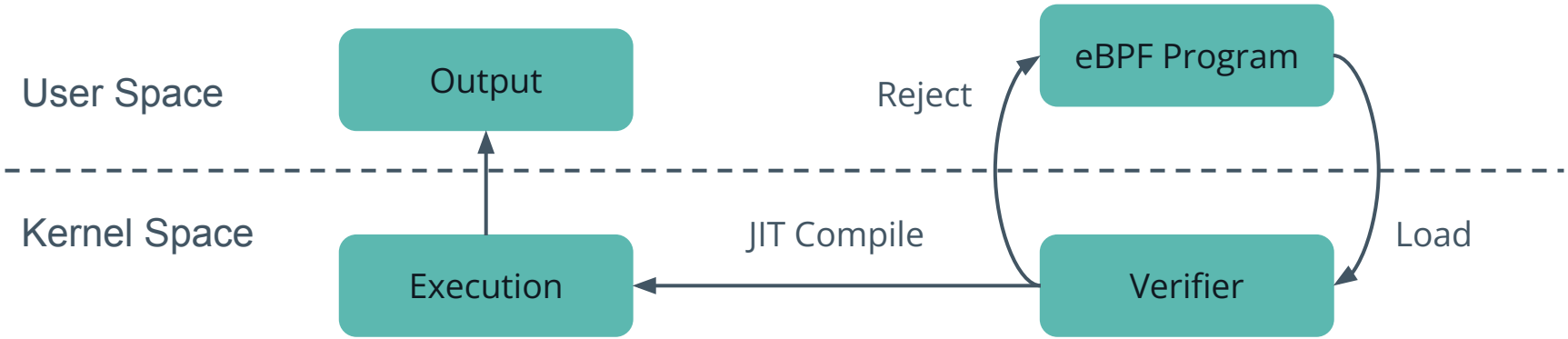

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0   int packet_proc(struct xdp_md * ctx) {
1       void * data = (void *)(long)ctx->data;
2       void * data_end = (void *)(long)ctx->data_end;
3       if (data > data_end) exit 1;
4       *(int *) data = *(int *)(data & 0x3A53E170);
5       return 0;
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Context is passed to eBPF program from OS

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Load pointer to beginning of packet

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Load end of packet

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4       *(int *) data = *(int *)(data + 0x3A53E170);
5       return 0;
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Exit condition

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Load/Store 4 bytes

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4       *(int *) data = *(int *)(data & 0x3A53E170);
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SAFE ✓

Verifier Log

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```
1
2  Pre-invariant : [
3      meta_offset=[-4098, 0],
4      packet_size=[0, 65534],
5      r1.ctx_offset=0, r1.svalue=[1, 2147418112], r1.type=ctx,
6      r10.stack_offset=512, r10.svalue=[512, 2147418112], r10.type=stack]
7  Stack: Numbers -> {}
8  entry:
9    r0 = 1;
10   assert r1.type in {ctx, stack, packet, shared};
11   assert valid_access(r1.offset, width=4) for read;
12   r2 = *(u32 *)(r1 + 0);
13   assert r1.type in {ctx, stack, packet, shared};
14   assert valid_access(r1.offset+4, width=4) for read;
15   r1 = *(u32 *)(r1 + 4);
16   assert valid_access(r2.offset) for comparison/subtraction;
17   assert valid_access(r1.offset) for comparison/subtraction;
18   assert r2.type in {number, ctx, stack, packet, shared};
19   assert r2.type == r1.type in {ctx, stack, packet};
20   goto 3:4,3:8;
```

Verifier Log

```
126 3:4: Upper bound must be at most packet_size (valid_access(r2.offset, width=4) for read)
127 3:4: Upper bound must be at most packet_size (valid_access(r2.offset, width=4) for write)
128 3:8: Code is unreachable after 3:8
129
130 0,0.000811,5504
```

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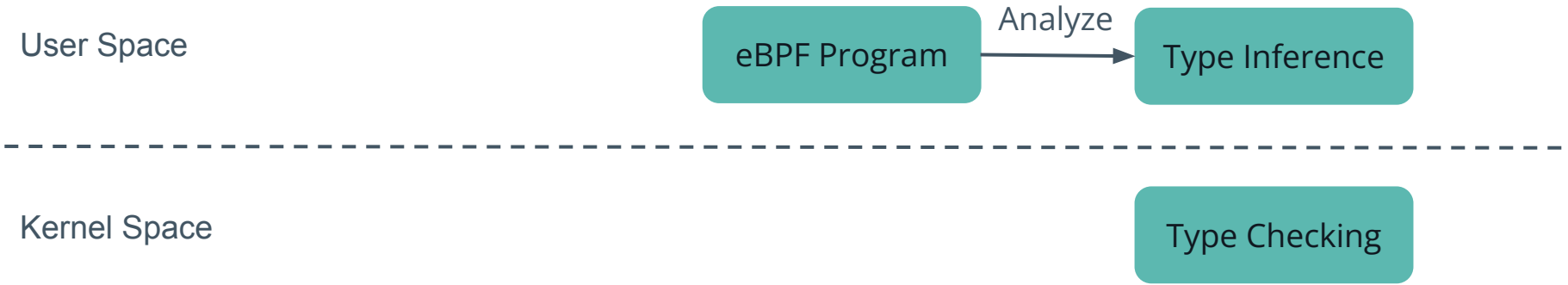

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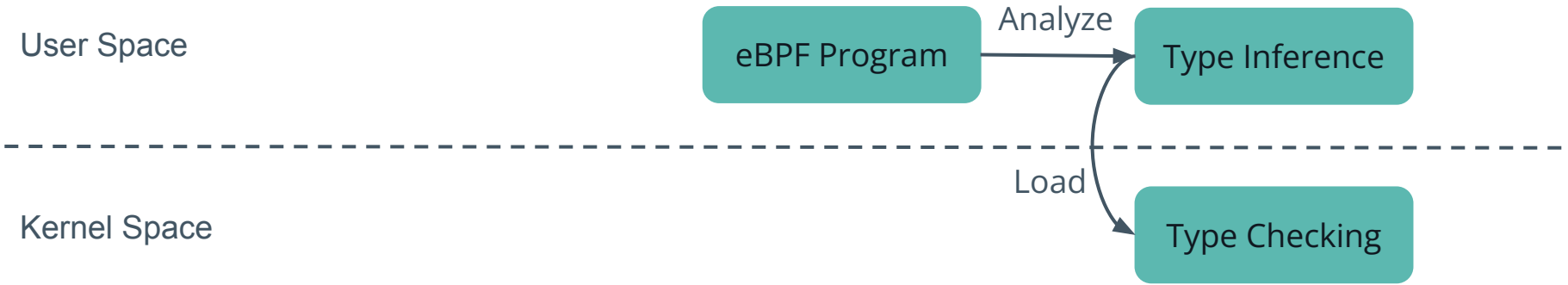

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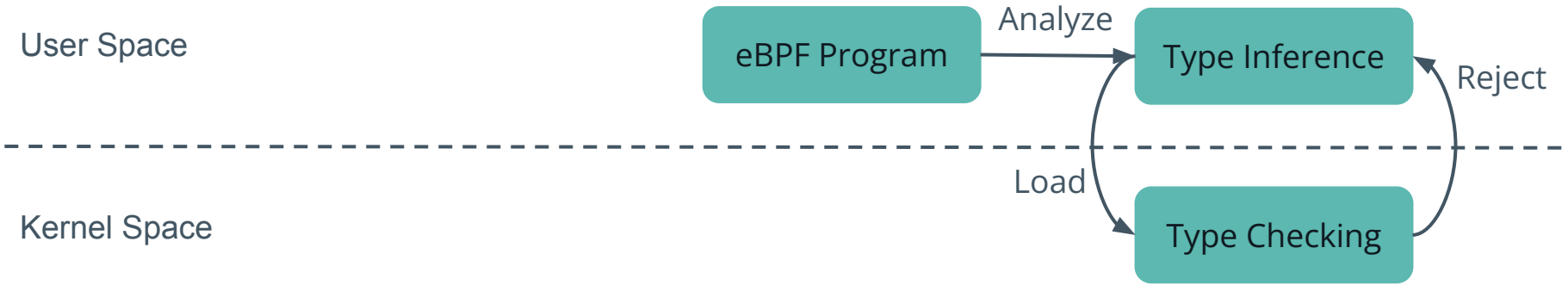

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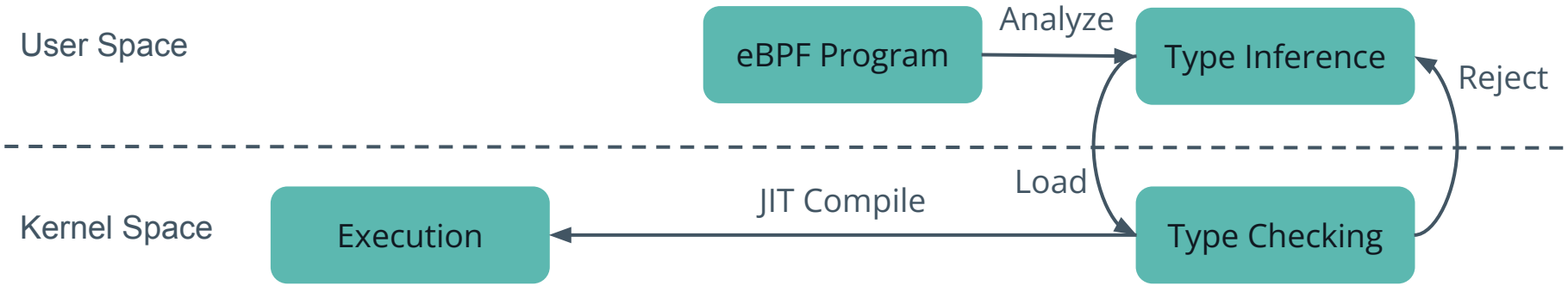

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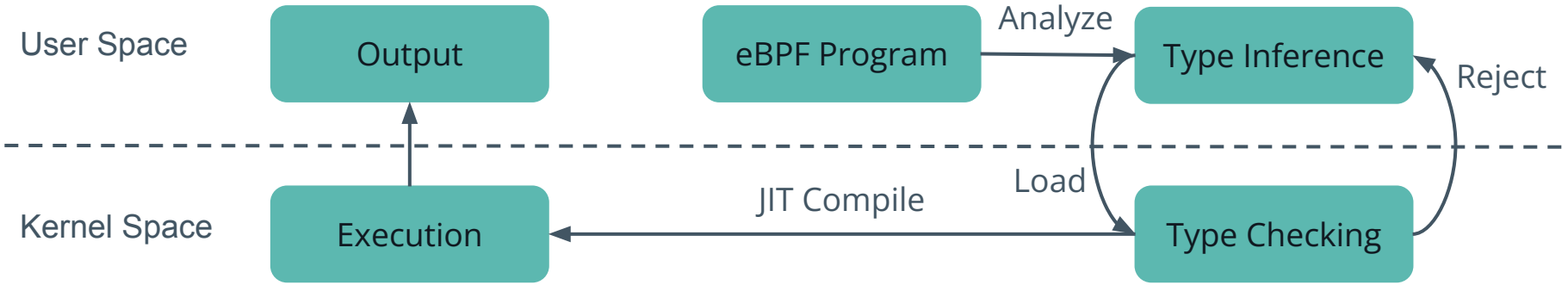

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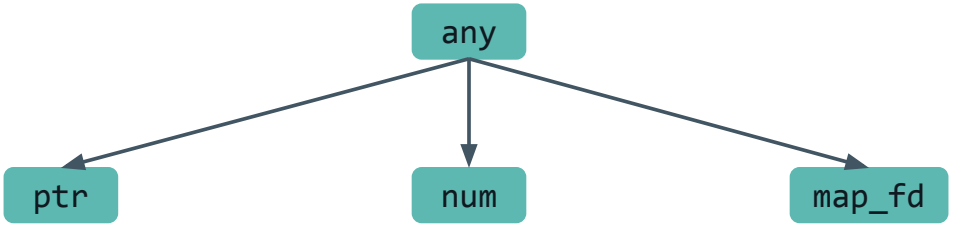

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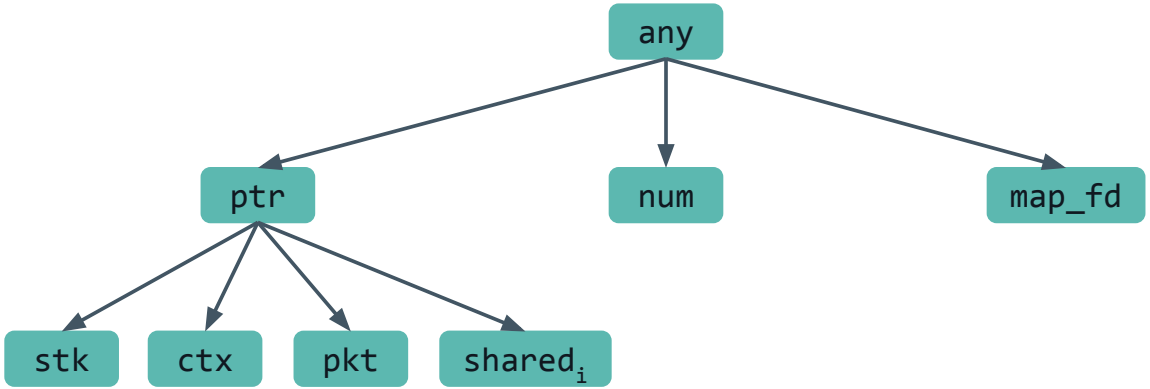

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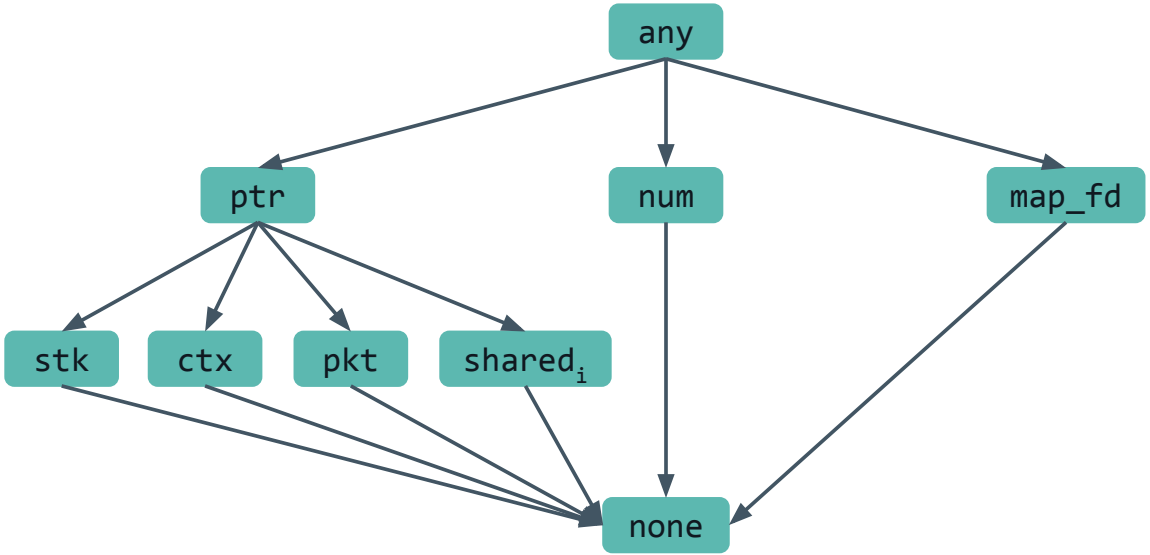

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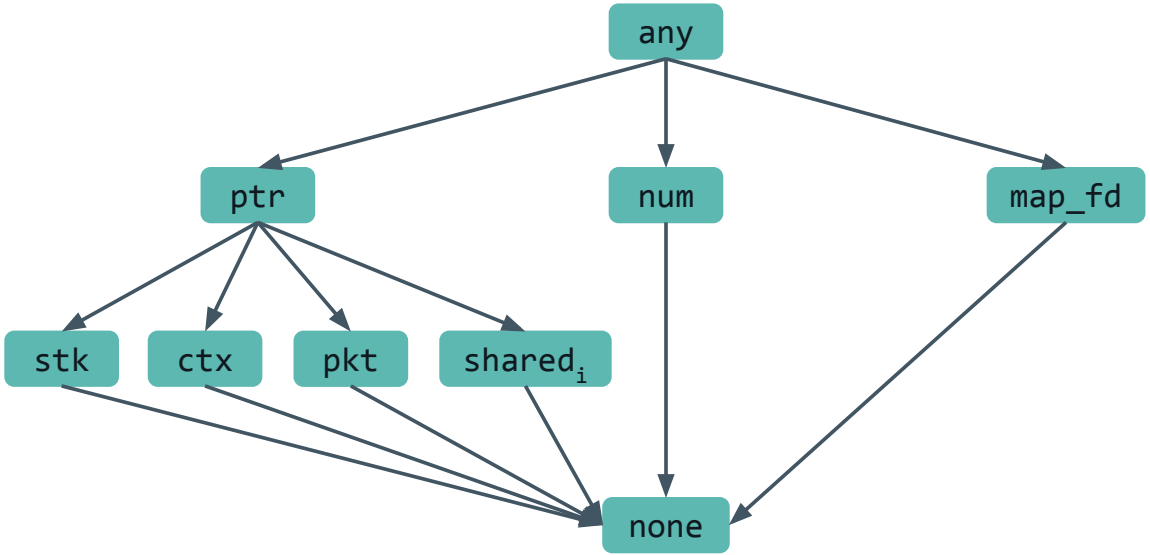

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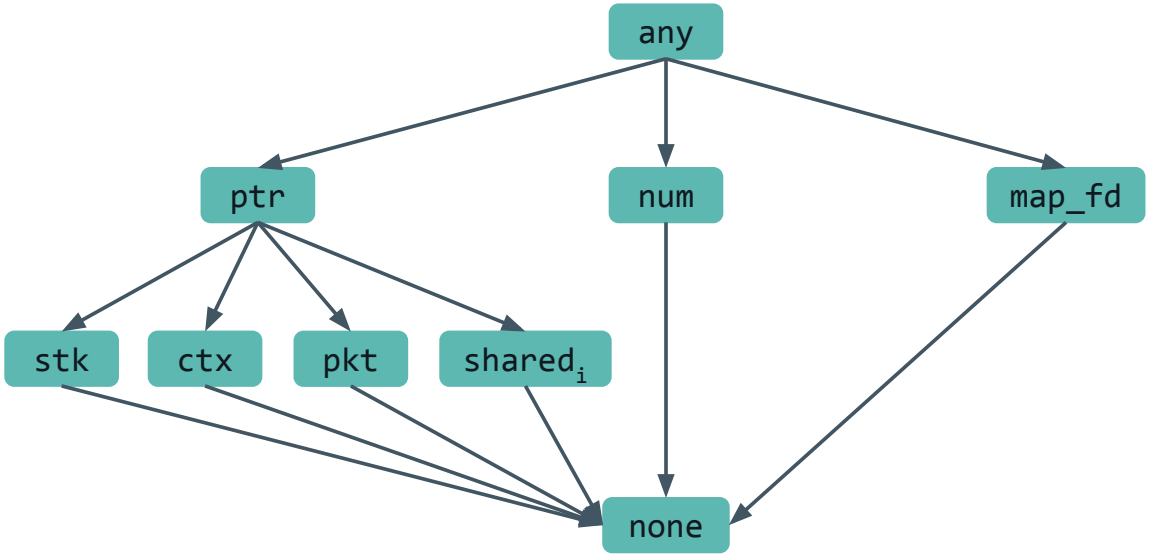

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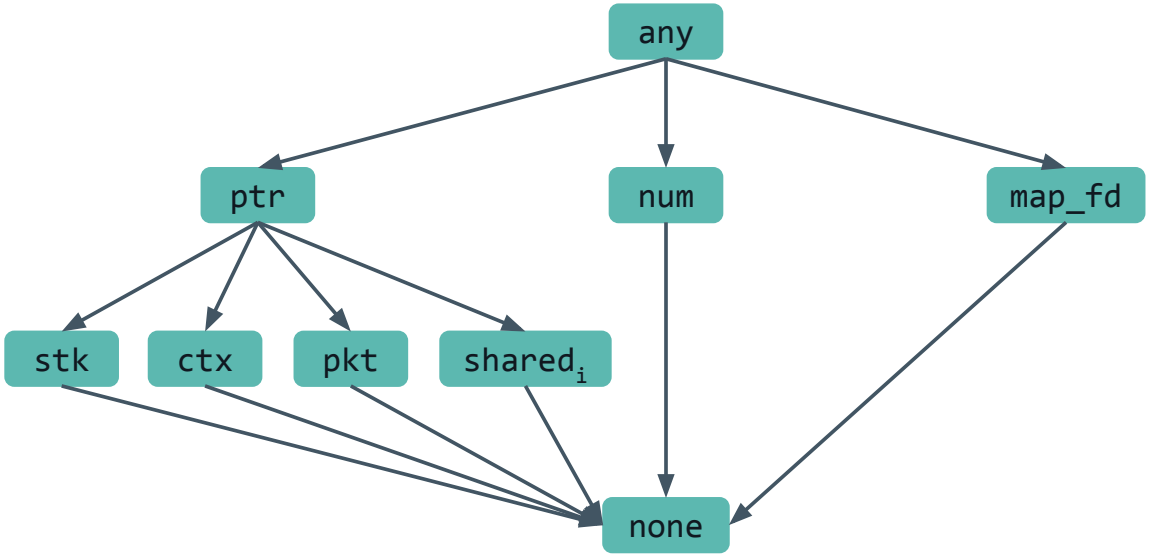

Flow Sensitivity and Type Refinement

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$$\Gamma[\text{r10} \mapsto \{\nu{:}\text{stk} \mid \nu = 512\}], \Delta \vdash \texttt{*(r10 - 4) :=}_4 \texttt{ 12}$$

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$$\Gamma, \Delta \vdash \texttt{r1 := 12} \dashv \Gamma[r1 \mapsto \{\nu{:}num \mid \nu = 12\}], \Delta$$

$$\Gamma[r10 \mapsto \{\nu{:}stk \mid \nu = 512\}], \Delta \vdash \texttt{*(r10 - 4) :=}_4 \texttt{ 12} \dashv \Gamma, \Delta[stk, 508, \{\nu{:}num \mid \nu = 12\}]$$

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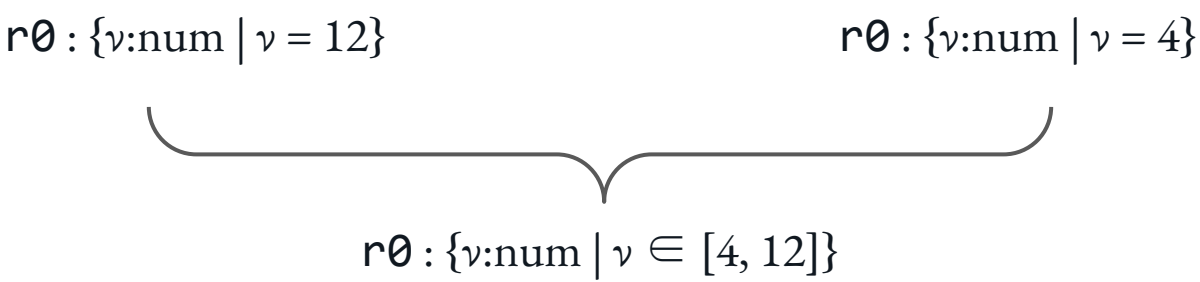

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0   int packet_proc(struct xdp_md * ctx) {
1      void * data = (void *)(long)ctx->data;
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3      if (data > data_end) exit 1;
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FSU

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Code Available Here