2022 P4 Workshop
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P4 Over Linux TC

Scripting Away At P4

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Goal: Extend P4 Ecosystem To The Linux Kernel

Core Requirement: **Scriptable Hardware offload of P4 MAT**

Target personas:

- The P4 developer
  - Knowledgeable in P4 - No interest in kernel internals
- Traditional Linux (non-P4) ops
  - Knowledgeable in Linux - No interest in P4 internals

Why P4 TC In The Linux Kernel?

- Grow P4 ecosystem to a much larger audience of devs and ops
  - Take advantage of existing, widely used infrastructure
    - Containers, VMs, baremetal, servers, middle boxes, etc
- TC infrastructure maps to P4 MAT with built-in HW full/partial offload
  - Very little core kernel changes required to support new P4 infrastructure code
- Why not DPDK or other user space datapaths?
  - Kernel provides a singular interface
    - No vendor-specific fragmentation in DPDK based APIs
  - DPDK selling point performance
    - Our view: Performance is achieved by offloading
  - Gain usability by using well understood kernel interfaces and tooling
- Why not ebpf?
  - Hardware offload and scriptability is a core requirement
  - ebpf still in active development (compiler, verifier, kernel, etc)
  - Challenges in writing complex programs (turing completeness issues)
  - Ops entry engagement point is steep

Motivation and Design

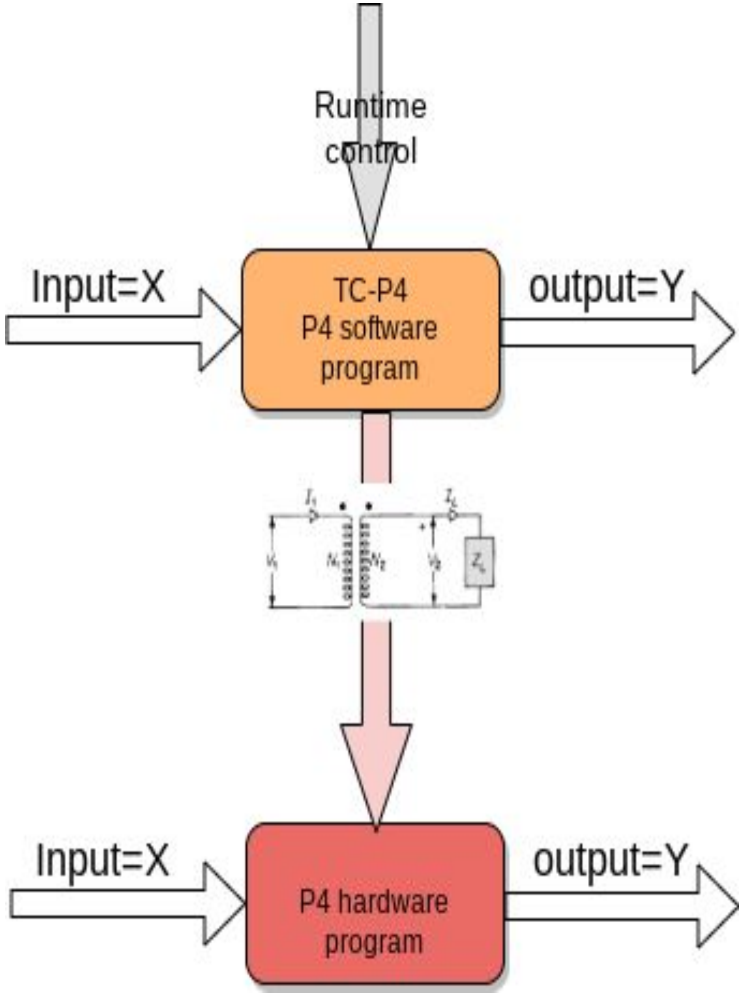
Upstream Sayeth: Thou Shalt Have A Software Twin

Upstream Requirements

- SW and HW are functionally equivalent
- P4 program runs in absence of offloadable HW
- Partial and/or full offload
    - Pipeline exists in both HW and SW

Benefits

- Test your P4 program in the kernel
    - Baremetal, VM, container, etc
    - When ready toggle policy knob to use HW offload
- Build realistic digital twin to mimic deployed offload
- Use P4 in new infrastructure experiments
    - Accelerate when needed



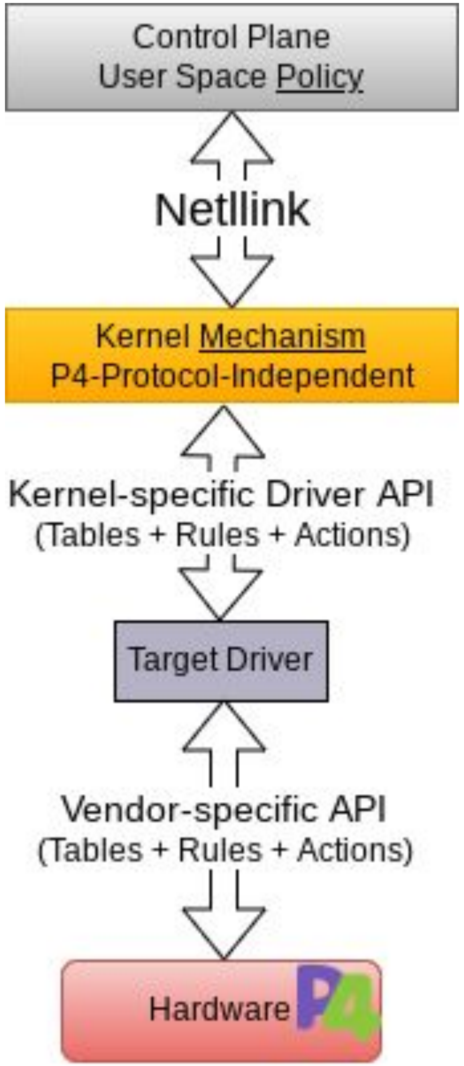
Core Design Principle: <u>Scriptability</u>

<u>Template-driven</u> architecture

- map P4 Program to mechanisms in the kernel
- kernel independence

A P4 program is <u>constructed</u> via scripts from user space

- <u>A new P4 program does not need kernel or user space changes</u>
- Prior art: *u32* classifier, *pedit* packet editor, *skbedit* metadata editor



Motivation: Kernel independence

- Challenges
  - High effort investment for upstreaming (or any kernel coding)
    - Specialized social and technical skills required
  - 2-3 years cycles post-upstreaming to a supported distro (RHEL etc)
    - Speeding up of this process means NRE to the distro vendor
      - Still 6 months vetting release time frames
  - Some DCs: Upto a year cycle if newly coded feature requires compilation
    - Compiled(binary blob) change require vigorous validation
    - No such restrictions in operational scripting
- Side-Benefits
  - Lowering entry point for defining a new datapath or protocols
  - Less kernel code => reduce kernel maintenance overhead
  - No need to battle newer kernels, compilers, tools, skills, etc
    - No need for inhouse gurus

Scriptability Roadmap

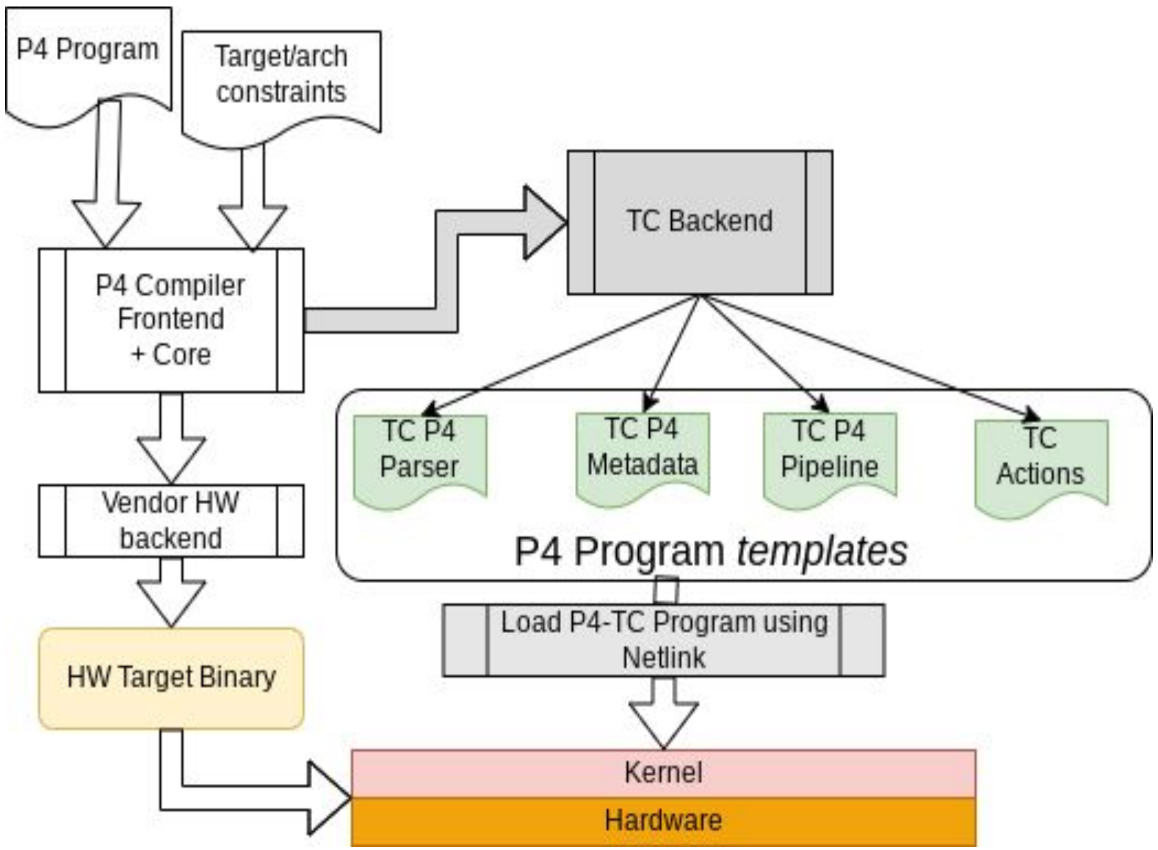
- Upstream Once
  - Add all features needed into the kernel
    - Add any missing functionality in TC to support P4 generically
  - Any subsequent changes to the kernel will be bug fixes
- No Kernel or user space code changes for any P4 prog
  - No code generation or compiling of loadable blobs
    - i.e no kernel modules, ebpf, etc.
- No change to user space/control *iproute2::tc* control/provision
  - Scriptable Introspection (as opposed to a DSL)

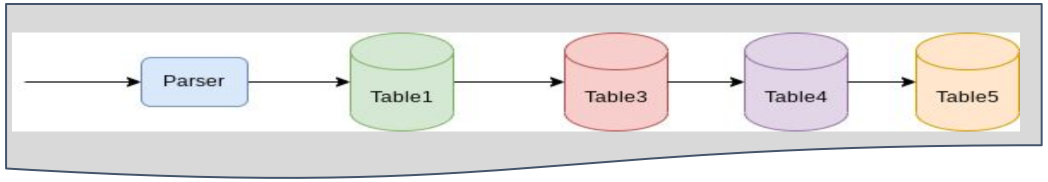
General Design Goals

- Desire to be P4-architecture independent
  - i.e support PSA (for switches) or PNA in NIC environment, etc
- Desire support multi-vendor implementations of P4
- Debuggability
  - Ease developer and operator runtime troubleshooting
- Admission Control for hardware resources
  - Generated Template “Program loading” tells the kernel about resource limits
  - Kernel keeps state of in-use resources
- Efficient Control Plane Table CRUD Netlink Messaging
  - Lower Latency for Individual transactions
  - Higher Throughput for batching

Workflow
Program Installation And Runtime

Workflow: Creating And Installing The P4 Program

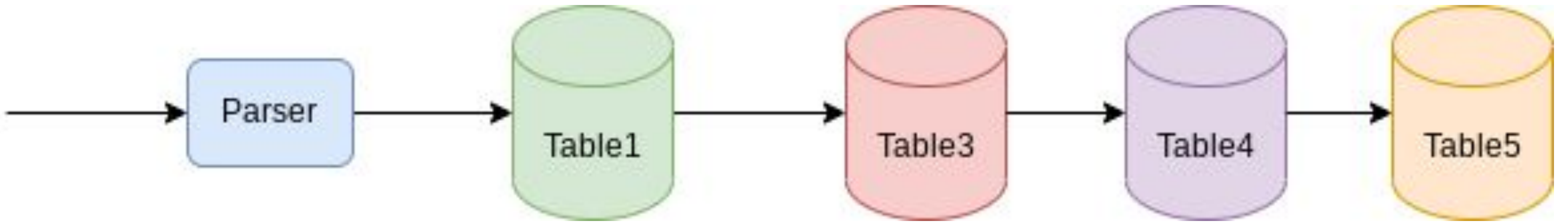




P4 Dev approach
1. Author writes the P4 program
2. Build P4 program (using a compiler) targeting TC and/or hardware
3. Author/dev executes the tc template scripts to "install P4 program"

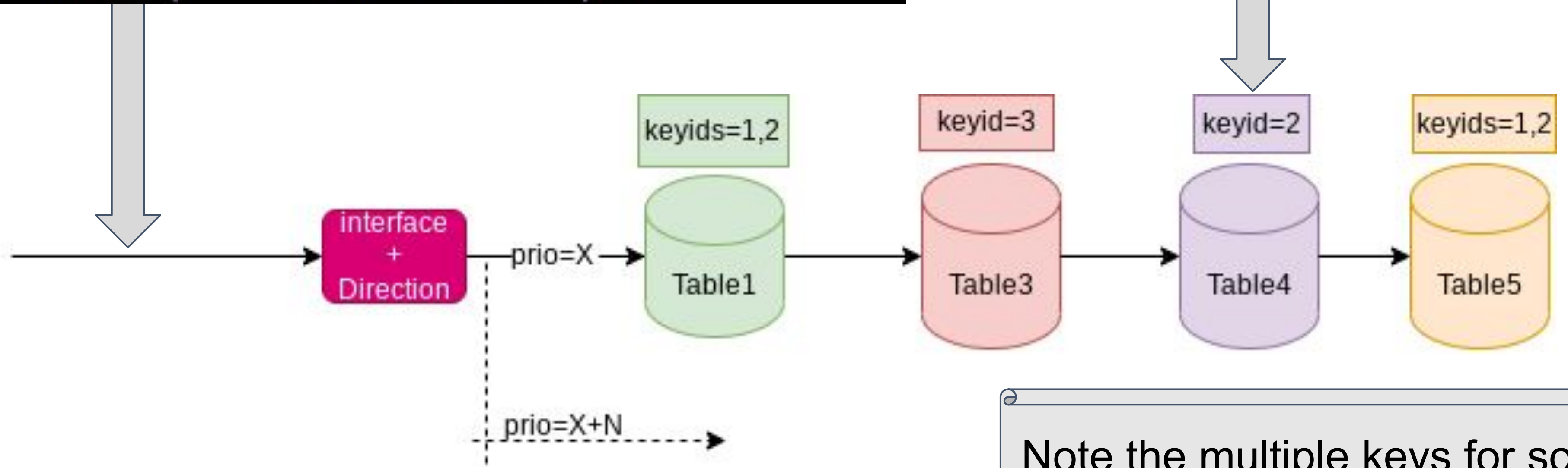
Linux Ops approach
1. Manually create tc scripts
2. Execute them to install

Runtime: P4 Program Mapping to TC Infrastructure



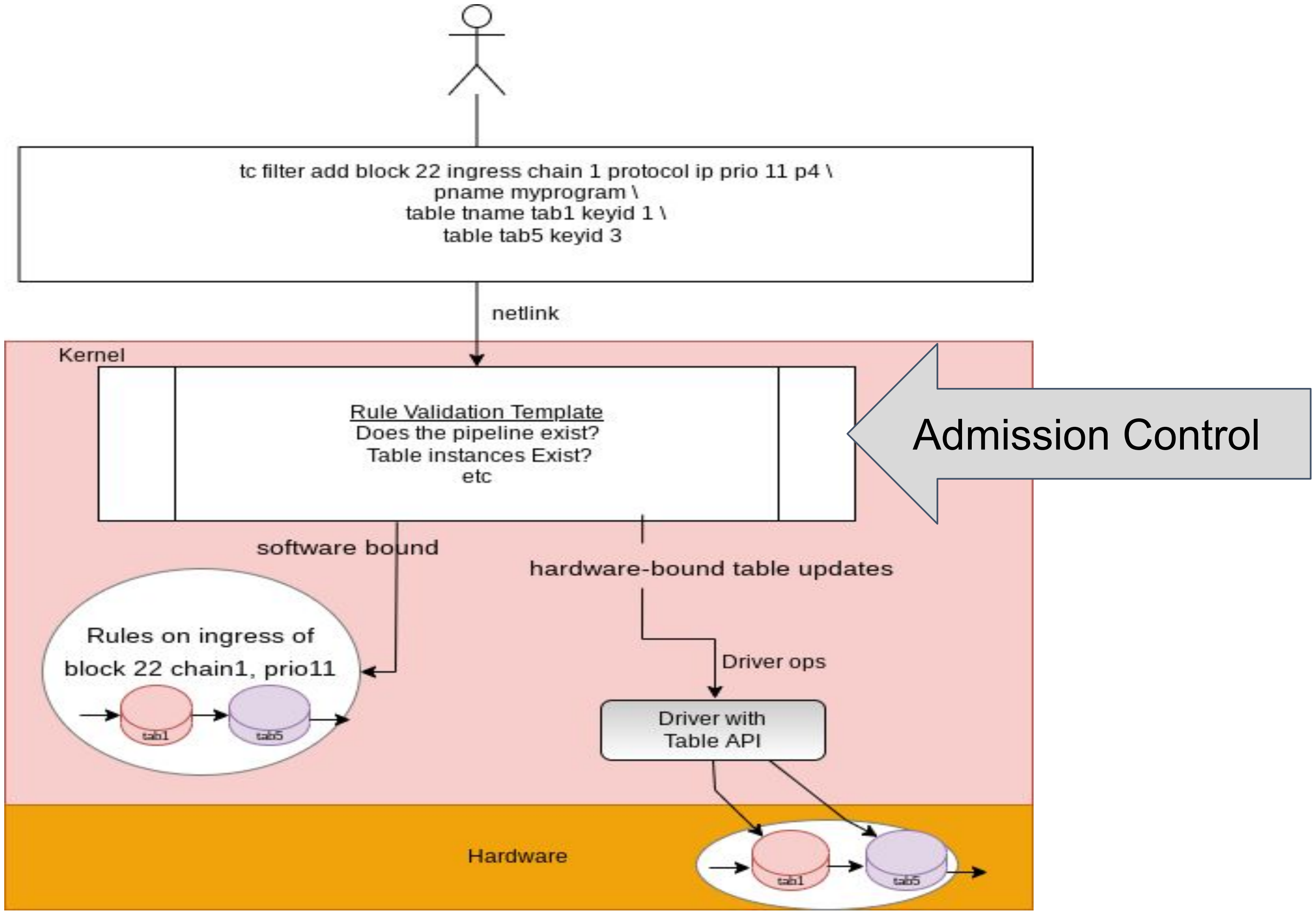

```
tc filter add dev eth0 ingress protocol all prio 5 p4 \
pname myprog table tname table1 keyid 1 table tname table3 keyid 3 \
table tname table4 keyid 2 table tname table5 keyid 1
```

```
tc p4 create myprog/table/table4 ip/dstaddr 192.168.0.0/16 prio 17 \
skip_sw \
action drop
```

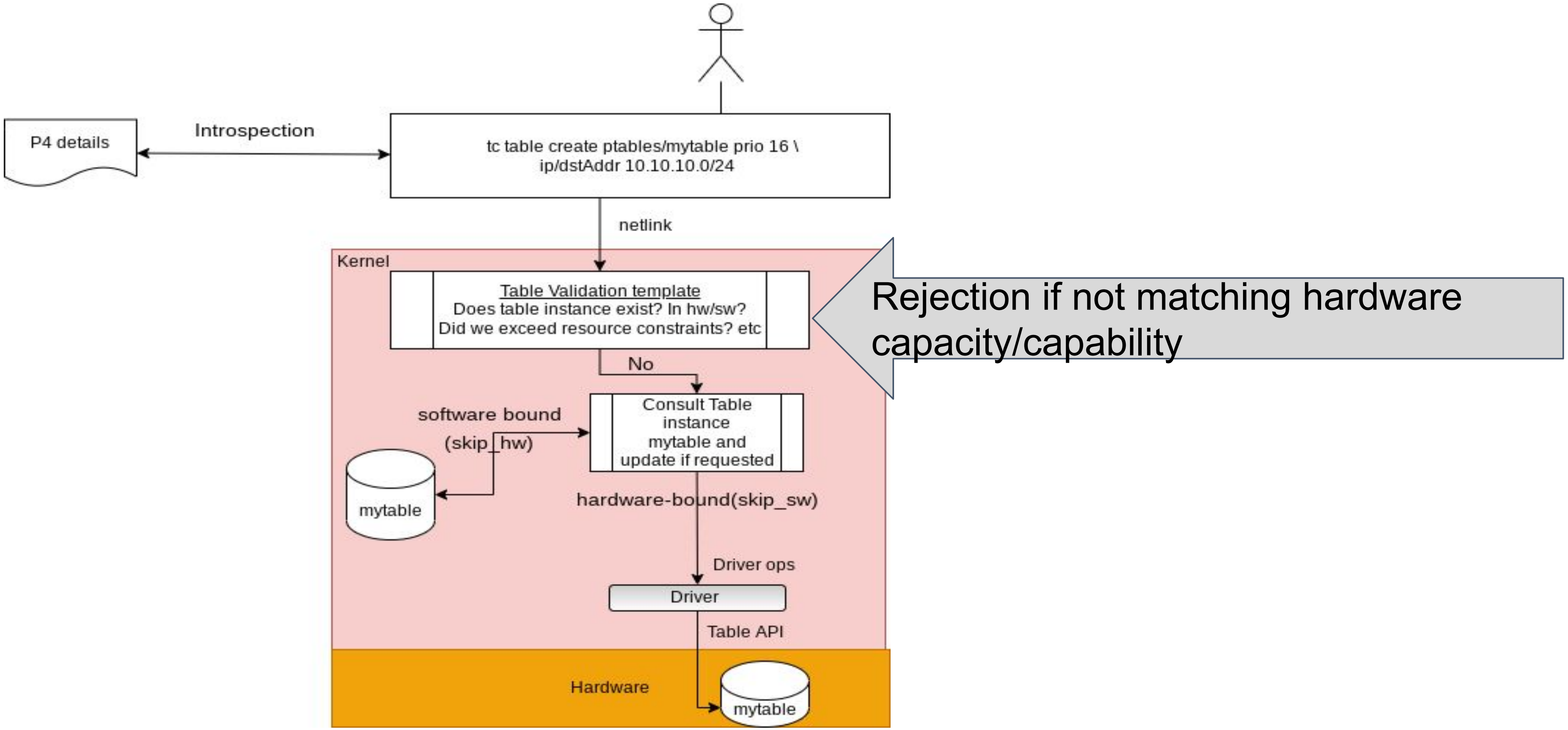


Note the multiple keys for some tables..

Runtime: P4 Pipeline Control

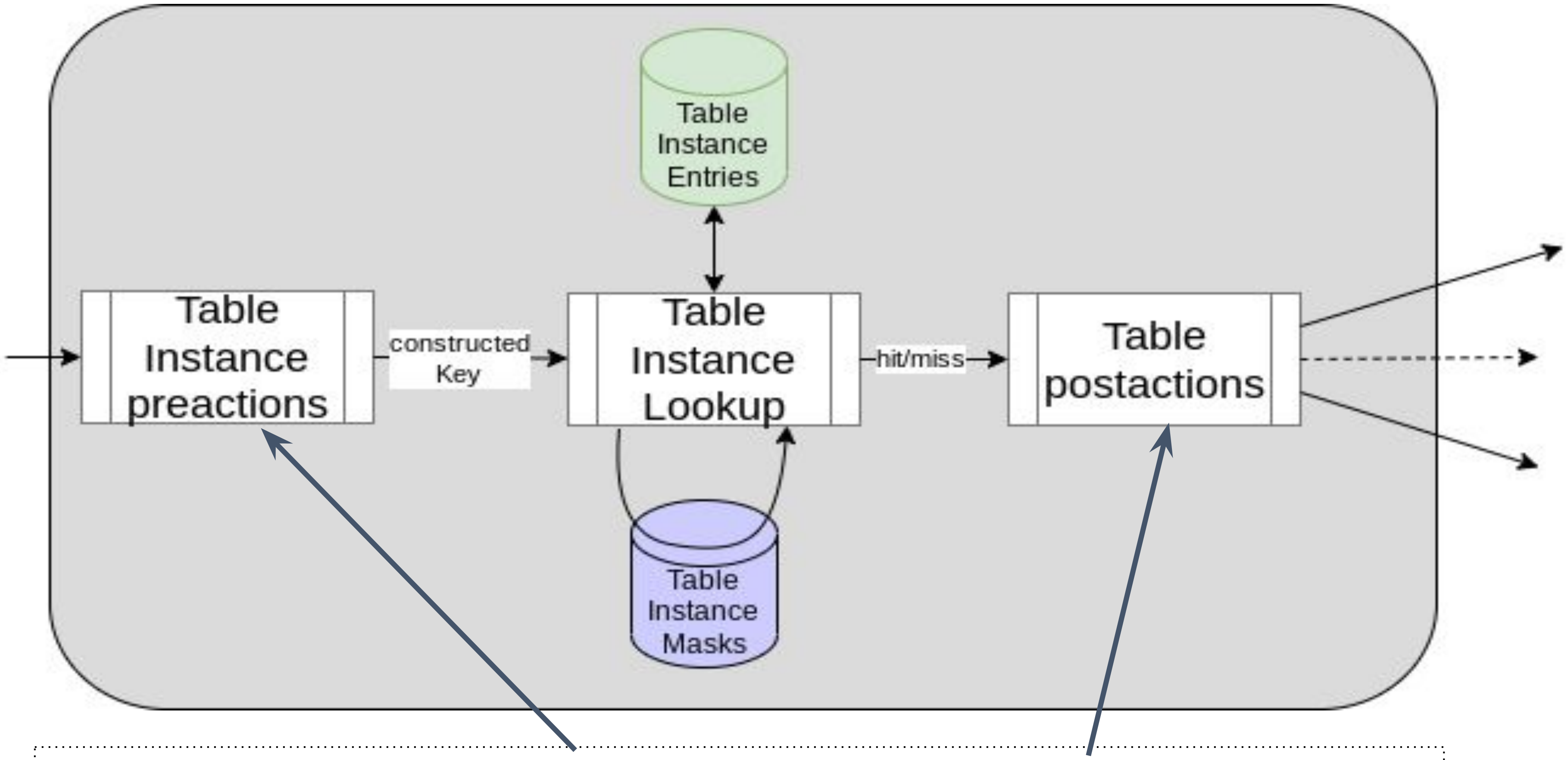


Runtime: P4 Table Control



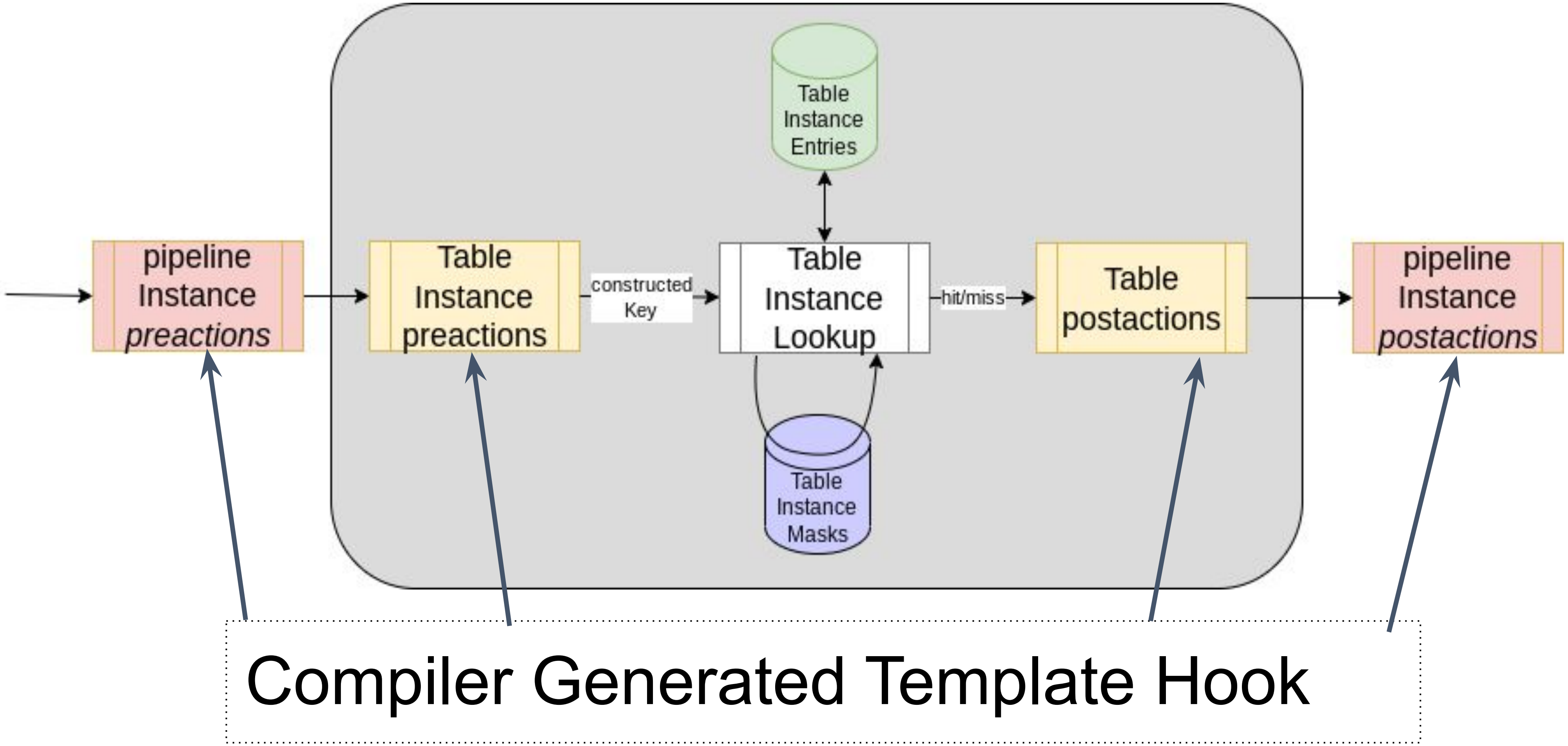
P4 Objects Kernel Abstractions

Compiler Generated Template Hooks: Table Instance *Preactions* And *Postactions*



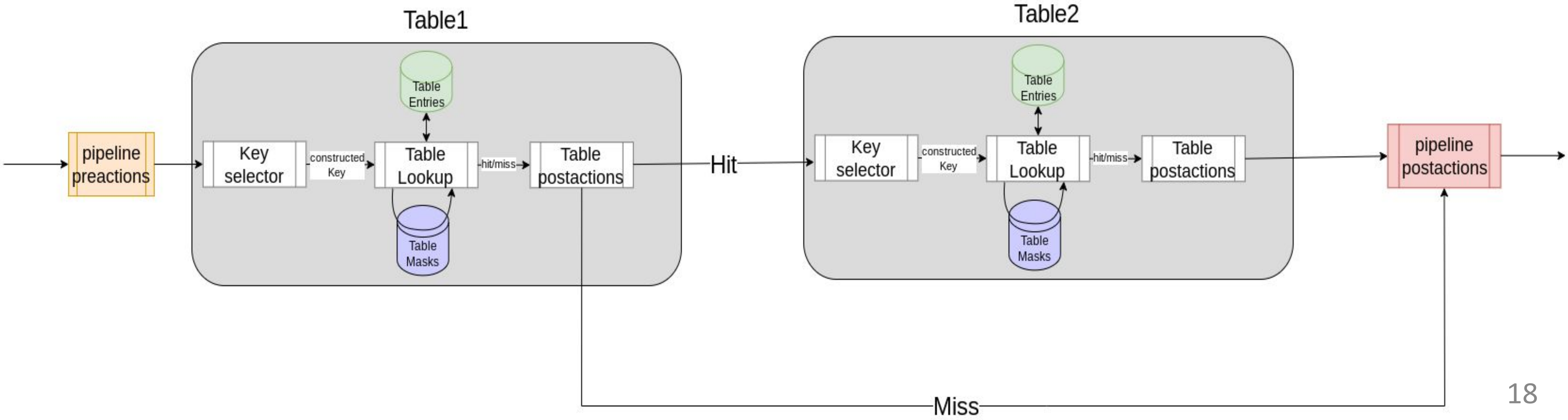
Compiler Generated Template hook

Compiler Generated Template Hooks: Pipeline *Pre* and *Post* Actions



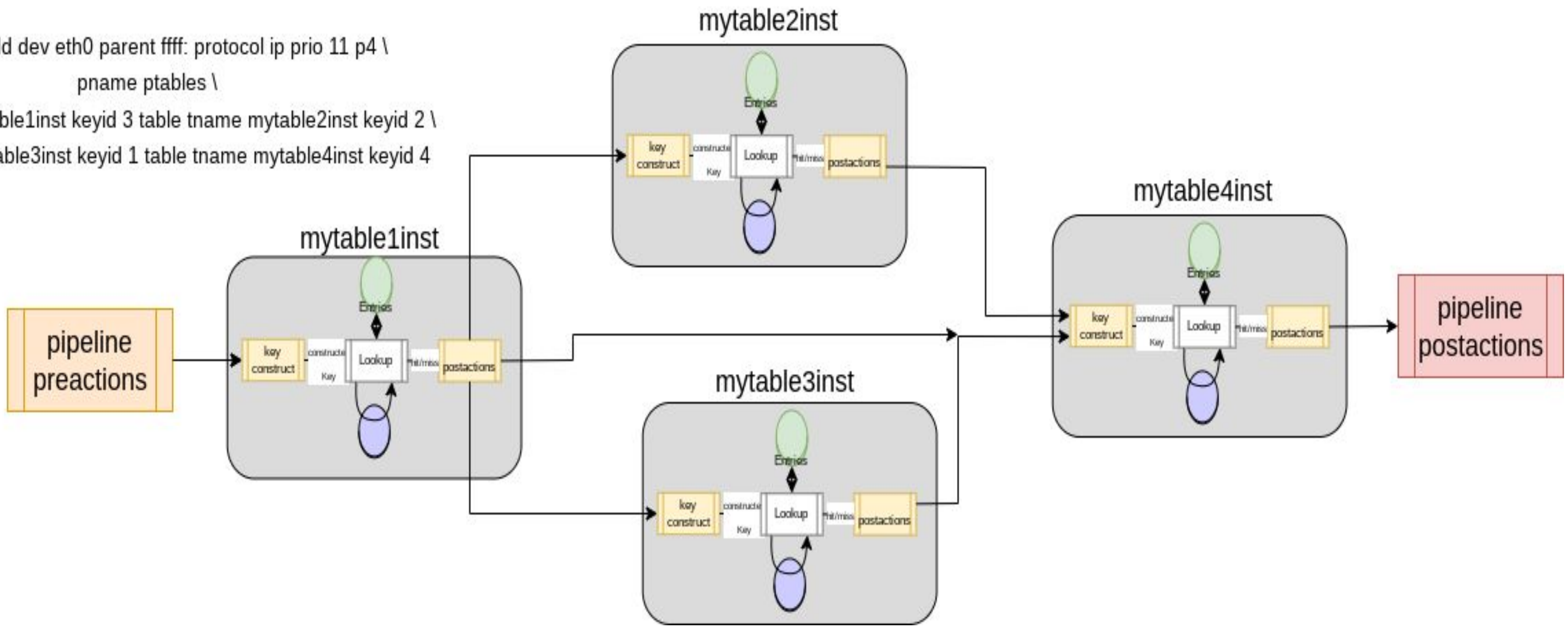
Program Abstraction

```
...
table table1 {
        key = {
                hdr.ipv4.srcAddr: lpm;
        }
        actions = {
                ...
        }
        size = 8192;
        ...
}

table table2 {
        key = {
                hdr.ipv4.dstAddr: lpm;
        }
        actions = {
                ...
        }
        size = 8192;
        ...
}

...
table1.apply()
if (results.hit)
  table2.apply()
...
```



Slightly Complex Program

tc filter add dev eth0 parent ffff: protocol ip prio 11 p4 \
pname ptables \
table tname mytable1inst keyid 3 table tname mytable2inst keyid 2 \
table tname mytable3inst keyid 1 table tname mytable4inst keyid 4



TC Kernel Gaps

- Kernel
  - Action block need revamp to add P4 action selectors
  - Externs - anything that the compiler can see we should be able to handle
- P4
  - Multiple keys
  - Multiple table + pipeline instance
  - Deparser behavioral consequences
    - Inline in SW vs at end of pipeline for HW

Thank You

- Project status: Coding in progress
- Mailing list, to subscribe:
  - send email with subject “subscribe” to: p4tc-discussions@netdevconf.org
- Biweekly meetings (join the mailing list to find out)
- Project is incubating
  - Serious contributors welcome
  - Hope to have packets passing in about 6 months