Snabbflow: a scalable IPFIX exporter

A tour of the IPFIX exporter developed at SWITCH

Who we are

Alexander Gall

Network engineer at SWITCH,
Snabb contributor since 2014

alexander.gall@switch.ch

SWITCH

Max Rottenkolber

Works on Snabb since 2014

maximilian@igalia.com

igalia

Snabbflow at SWITCH

Motivation, function, deployment

Netflow at SWITCH

The concept of a “flow” is the primary mechanism used to analyze network traffic

- 5-tuple <src address, dst address, IP protocol, src port, dst port>
- Aggregates bytes/packets, additional custom fields (TCP flags, AS numbers…)
- Evolved from Cisco-proprietary to IETF standard IPFIX
- Unsampled (process every packet) or sampled (process 1 in n packets)

In use at SWITCH since mid 1990s. Until a few years ago

- Provided in Hardware by the routers
- Unsampled

Modern routers moved to sampling to cope with high-volume traffic

Sampled vs Unsampled

Sampling approximates real values well for volume-based metrics. Why use unsampled Netflow?

- Fine-grained analysis of security incidents
- Debugging of network problems for single flows, e.g.
  - TCP handshake
  - DNS transaction

Requires

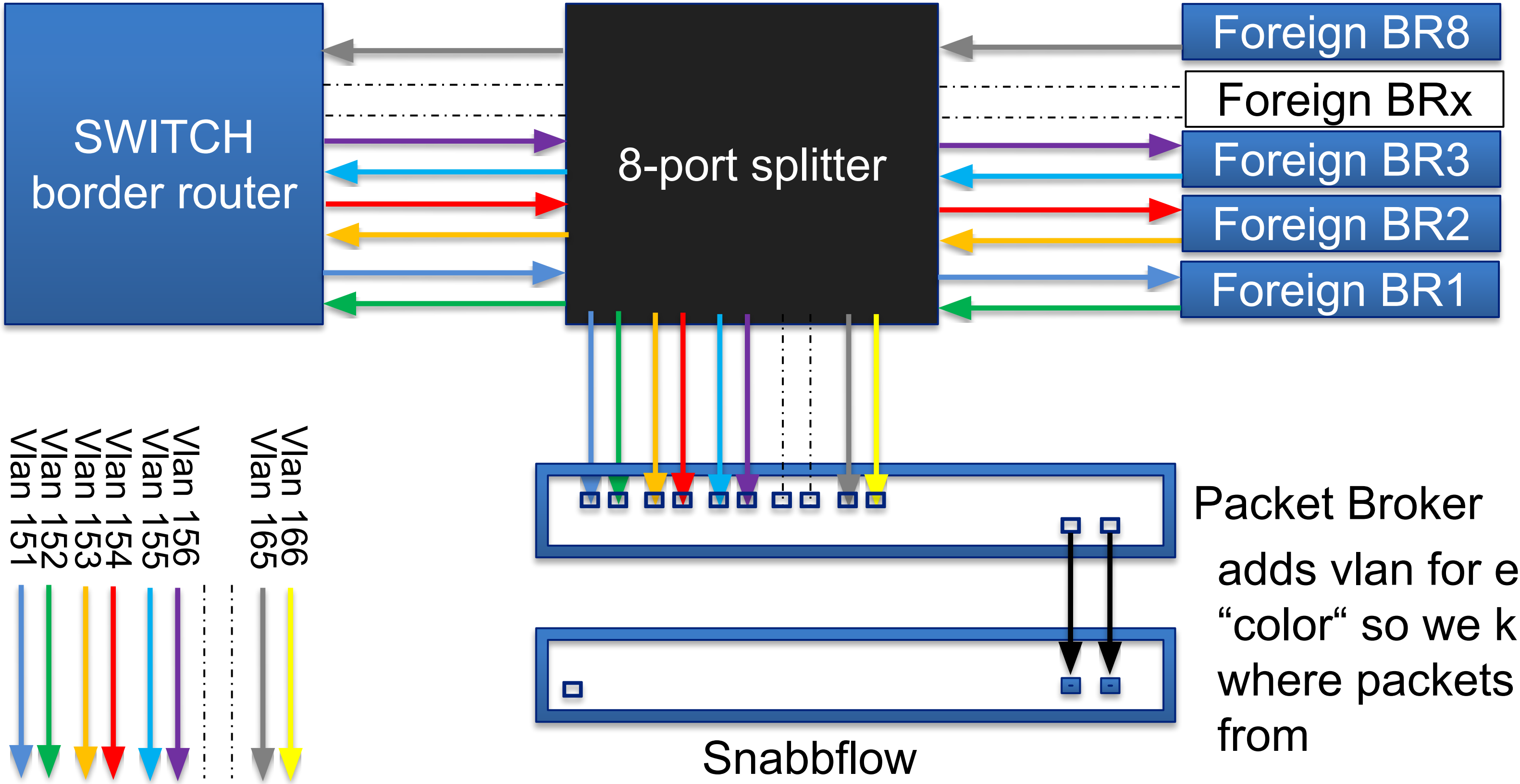
- Move from router to external appliance for Netflow generation
- Find a scalable and cost-effective solution: Snabbflow

SWITCH Network

- Peak traffic values (aggregate external traffic, ingress + egress)
  - ~180Gbps
  - ~20Mpps
  - ~350k flows per second (>500kfps with aggressive port-scans)
- Aggregate IPFIX export data rate 200-300Mbps
- Average flow rate 200k/s, 1.5TiB flow data per day (~100 bytes/flow)
- Interface types: optical 10G, 100G soon 400G
- Until 2015 Netflow export on (Cisco) routers
- 2015-2020 commercial Netflow exporter using hardware acceleration
- Since 2020 Snabbflow

Per-PoP Exporter Architecture

- Optical taps on external interfaces to copy packets
- “Packet-Broker” to aggregate traffic to 2x100 Gbps links to Snabbflow exporter
  - Use VLAN tags to identify original router ports
  - “Whitebox” switch
    - EdgeCore Wedge100BF-32x/AS9516-32D
    - Tofino/Tofino2 ASIC
    - P4-programmable
    - Separate project: https://github.com/alexandergall/packet-broker
- Snabbflow on commodity 1RU server
  - AMD Epyc or Intel Xeon, 12-24 cores, ~128GiB RAM for large flow tables
  - 2x100G Mellanox ConnectX-5 NICs



adds vlan for each "color" so we know where packets came from

Features of Snabbflow

snabb ipfix probe

Scaling, configuration, monitoring and their implementation

Built with snabb

- A toolkit for building fast packet processing applications using a high-level programming language

- Written in Lua (using the amazing LuaJIT compiler)!

- Packet I/O without going through the kernel (kernel-bypass / userspace networking)

- Open source and independent (not sponsored by any $vendor)

snabb

- Simple > Complex
- Small > Large
- Commodity > Proprietary

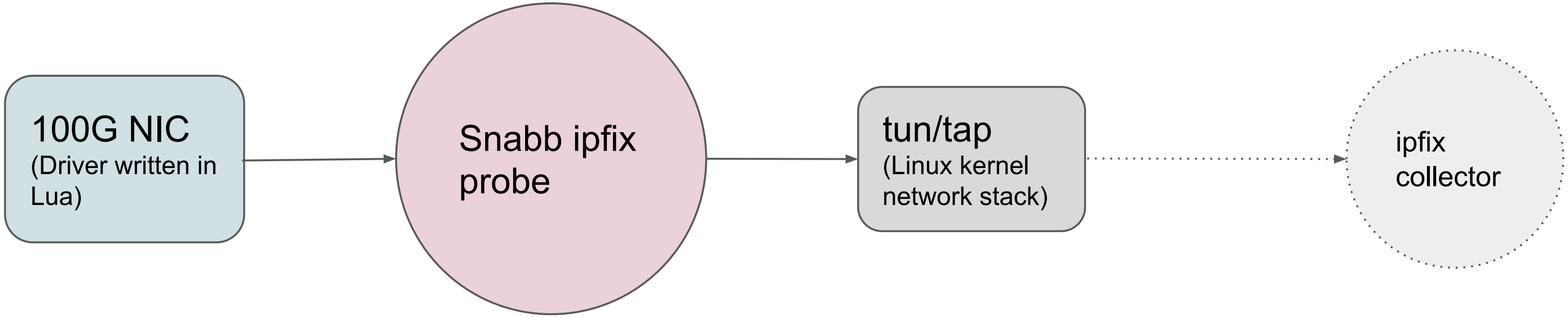
Recording packet metadata in a flow table

```
function FlowSet:record_flows(timestamp)
   local entry = self.scratch_entry

   for i=1,link.nreadable(self.incoming) do
      local pkt = link.receive(self.incoming)
      self.template:extract(pkt, timestamp, entry)

      local lookup_result = self.table:lookup_ptr(entry.key)
      if lookup_result == nil then
         self.table:add(entry.key, entry.value)
      else
         self.template:accumulate(lookup_result, entry, pkt)
      end
      packet.free(pkt)
   end
end
```

Flushing ipfix records

```
-- Walk through flow set to see if flow records need to be expired.
-- Collect expired records and export them to the collector.
function FlowSet:expire_records(out, now)
   local cursor = self.expiry_cursor
   …
   for i = 1, self.table_tb:take_burst() do
      local entry
      cursor, entry = self.table:next_entry(cursor, cursor + 1)
      …
      if entry then
         …
         self:add_data_record(entry.key, out)
      end
   end
   if self.flush_timer() then self:flush_data_records(out) end
end
```

High-level overview



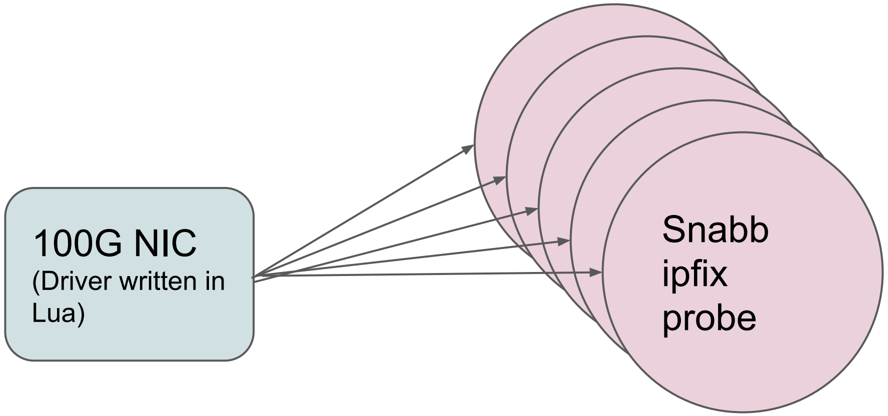
100G NIC
(Driver written in Lua)

Snabb ipfix probe

tun/tap
(Linux kernel network stack)

ipfix collector

Scaling via hardware RSS

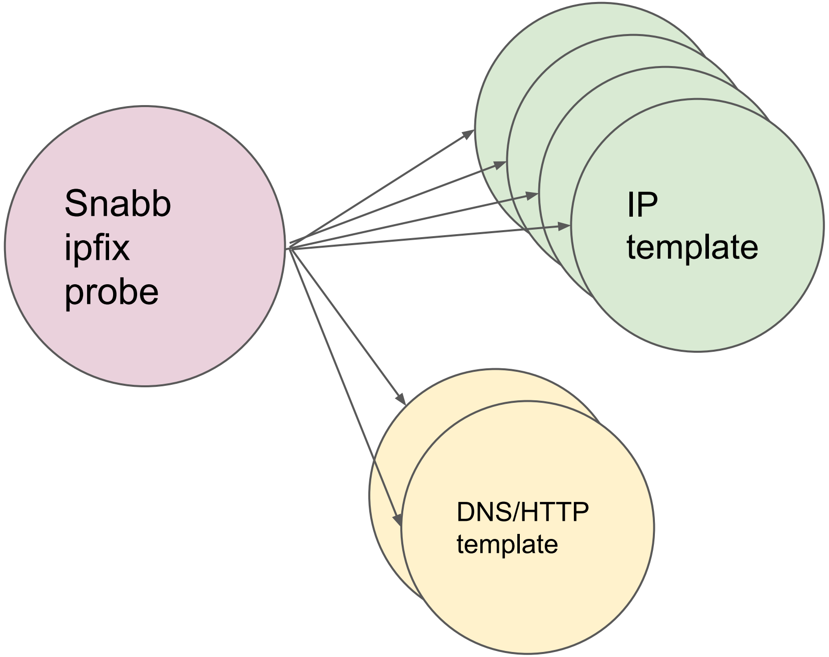


RSS forwards distinct sets of flows to distinct Snabbflow processes

Horizontal scaling!

Circle = CPU core

Scaling via software RSS

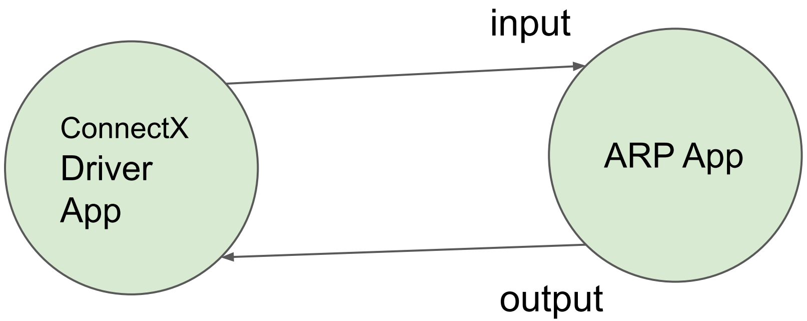


Software RSS forwards distinct sets of flows to distinct exporter processes extracting different sets of metadata.

Isolate workloads! (Complex packet inspection does **not** bog down basic metadata export)

Circle = CPU core

“Apps” and multi-processing

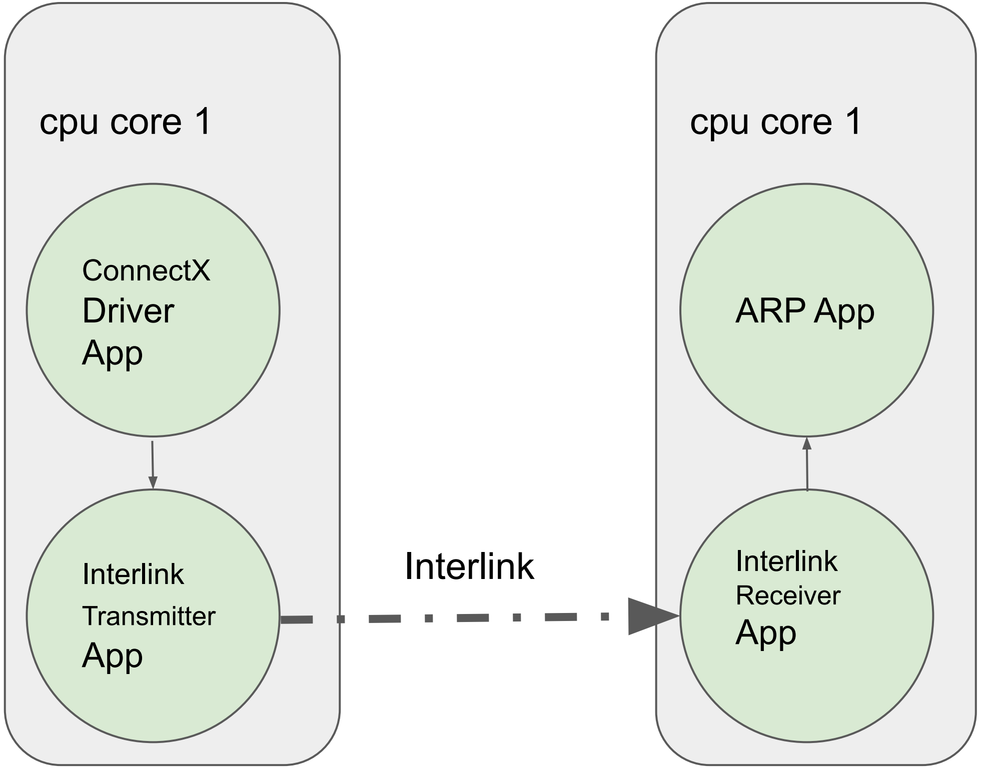


Snabb programs are organized in **“apps”** (independent packet processing components)

Communicate with each other via “**links**”:

```
p = link.receive(input)

link.transmit(output, p)
```

“Apps” and multi-processing (lib.interlink)

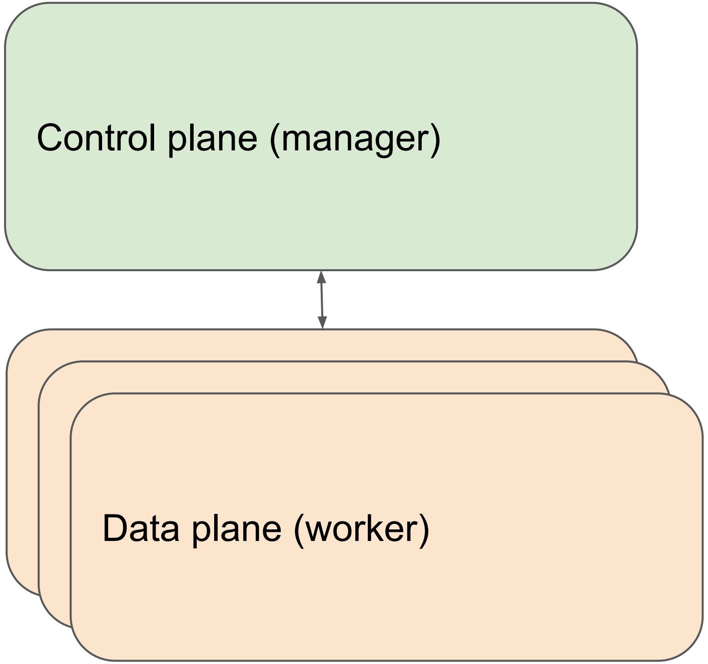


Packets can be shared with low overhead across CPU core boundaries using “interlinks”.

Link interface remains orthogonal:

```
    p = link.receive(input)

    link.transmit(output, p)
```

lib.ptree



- Can query and update data-plane configuration
- Knows about data-plane state
- No particular latency requirements
- Manages multiple data-plane workers (on dedicated CPU cores)

- Soft real-time! No messing around!
- Receives configuration updates from manager
- Writes state counters to shared memory

lib.yang

Application configuration and state are described in a **YANG schema.**

```
$ snabb config set my-process / < ipfix.conf
```

```
$ snabb config get-state my-process \
    /snabbflow-state/exporter[name=ip]

packets-dropped       0;
packets-ignored  129326;
packets-received 499996;
template {
  id 1512;
  flow-export-packets 115;
  flows-exported     1318;
  packets-processed 12034;
  …
```

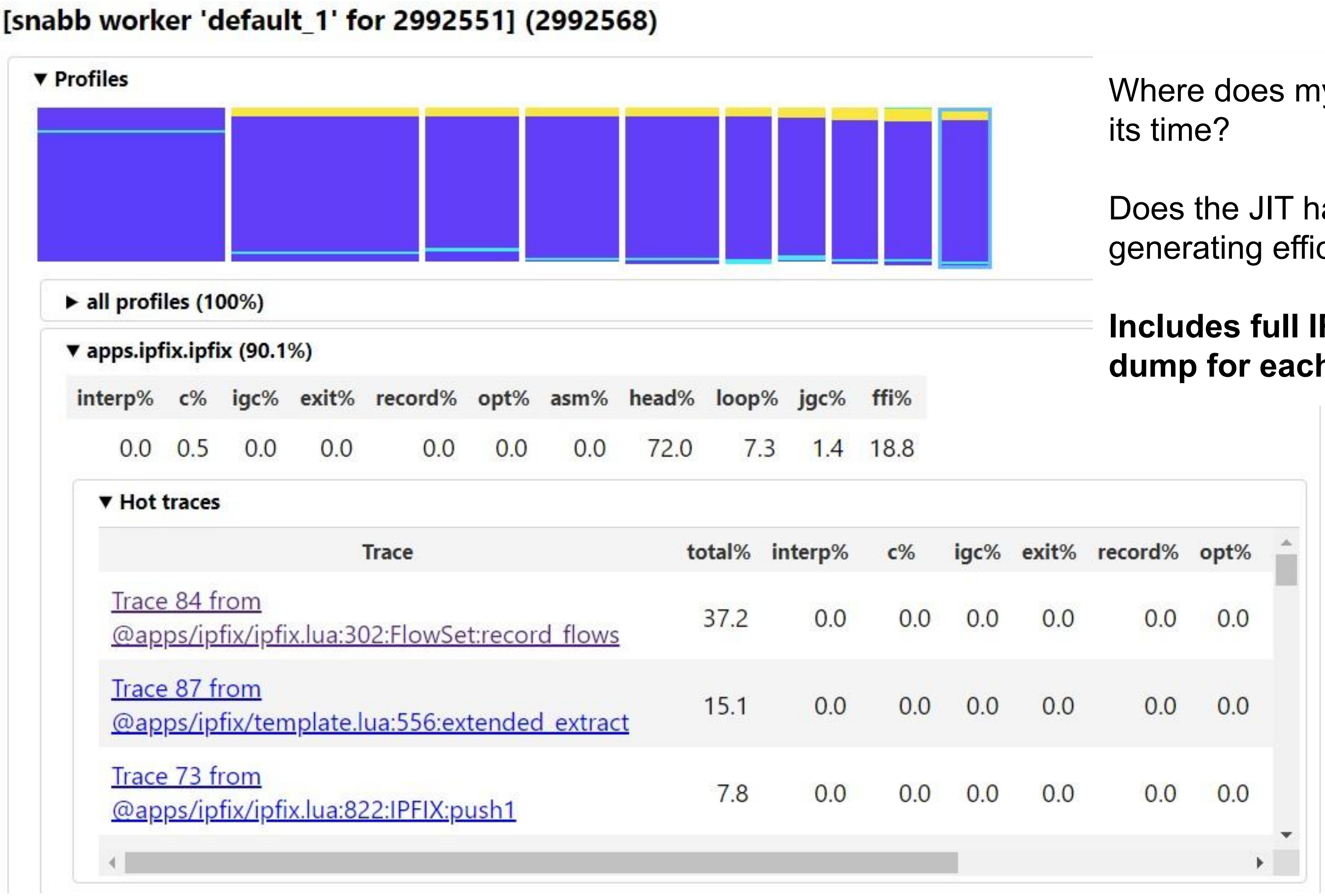
snabb-snabbflow-v1.yang

```
module snabb-snabbflow-v1 {
  …
  container snabbflow-config {
    description
     "Configuration for the Snabbflow IPFIX exporter.";

    list interface {
      key device;
      unique "name vlan-tag";

      description
        "Interfaces serving as IPFIX Observation Points.";

      leaf device {
        type pci-address;
        description
          "PCI address of the network device.";
      }
      …
```

- Schema defines both valid configuration and state trees
- YANG is expressive: control-plane can effectively reject invalid data-plane configurations
- Snabb programs translate valid configurations to app and link networks running in data-plane

Flight recorder

- Minimal overhead: always on! (if you want it)
- Stores useful data
    - JIT trace info
    - Trace profiles (sampled)
    - High-frequency event log (sampled)
- Can be analyzed while running or post mortem
    -
      ```
      tar cf blackbox.tar /var/run/snabb; scp blackbox.tar …
      ```



[snabb worker 'default_1' for 2992551] (2992568)

▼ Profiles

▶ all profiles (100%)

▼ apps.ipfix.ipfix (90.1%)

interp%	c%	igc%	exit%	record%	opt%	asm%	head%	loop%	jgc%	ffi%
0.0	0.5	0.0	0.0	0.0	0.0	0.0	72.0	7.3	1.4	18.8

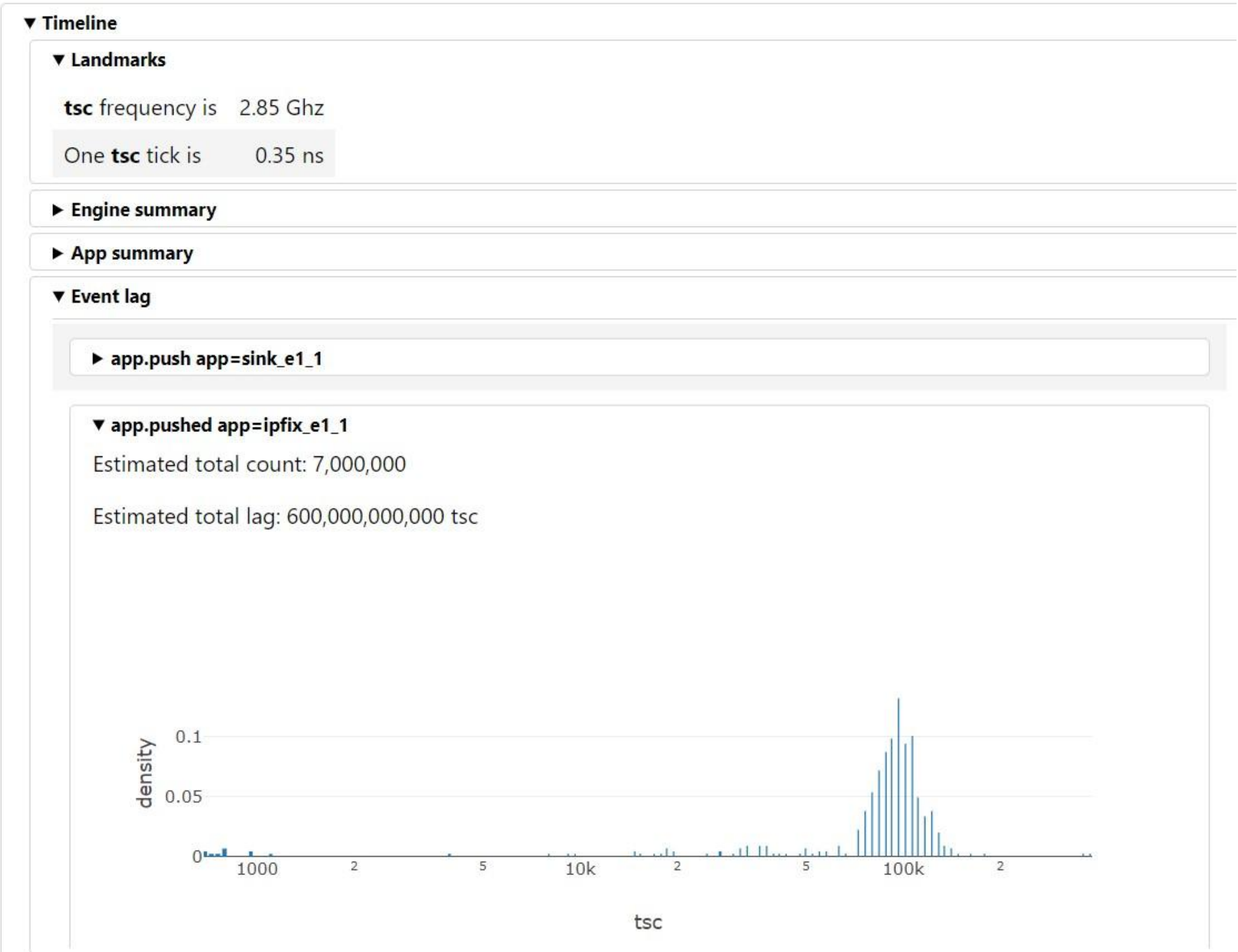
▼ Hot traces

Trace	total%	interp%	c%	igc%	exit%	record%	opt%
Trace 84 from @apps/ipfix/ipfix.lua:302:FlowSet:record_flows	37.2	0.0	0.0	0.0	0.0	0.0	0.0
Trace 87 from @apps/ipfix/template.lua:556:extended_extract	15.1	0.0	0.0	0.0	0.0	0.0	0.0
Trace 73 from @apps/ipfix/ipfix.lua:822:IPFIX:push1	7.8	0.0	0.0	0.0	0.0	0.0	0.0

Where does my program spend its time?

Does the JIT have issues generating efficient code?

Includes full IR / assembly dump for each compiled trace!



▼ Timeline

▼ Landmarks

tsc frequency is	2.85 Ghz
One **tsc** tick is	0.35 ns

▶ Engine summary

▶ App summary

▼ Event lag

▶ app.push app=sink_e1_1

▼ app.pushed app=ipfix_e1_1

Estimated total count: 7,000,000

Estimated total lag: 600,000,000,000 tsc

Latency histograms derived from event log

Here: ipfix app takes ~35us to process a batch of packets.

Useful for debugging tail latencies.

Can add arbitrary application-specific, user-defined events.

If you write a Snabb program today

You can reuse all of these components and more!

Thanks for your attention!

Questions?

GitHub: snabbco/snabb

Snabbflow:
alexander.gall@switch.ch

SWITCH

Commercial support for Snabb:
maximilian@igalia.com

igalia