Flying higher: hardware offloading with BIRD

Asbjørn Sloth Tønnesen

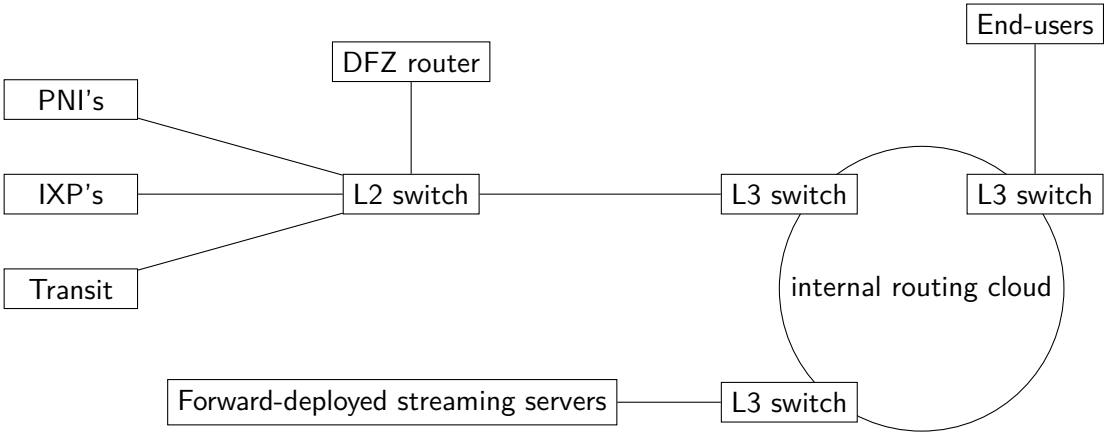
Fiberby ApS (Fibercity)

February 3rd, 2024

Who are Fibercity

- We operate `AS42541`
- Based in Copenhagen, Denmark
- Based on FTTB (Fiber to the Builing)
- 1/1 Gbps connection for 17€/month
- 35k residential households connected
- Peak utilization: 140 Gbps / 15 Mpps (in+out)

Simple ISP network



AS42541 routing timeline

2010

- Cisco 6500 (10G)

2015

- Brocade MLXe-4 (40G)

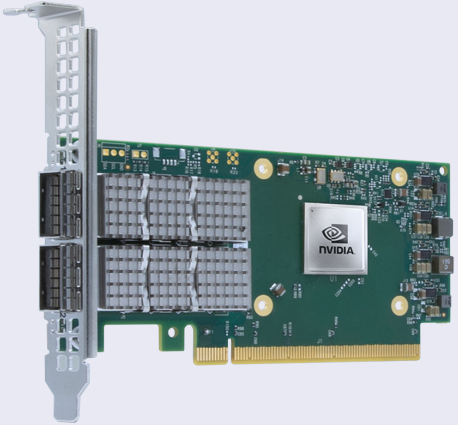
AS42541 routing timeline (cont.)

2020

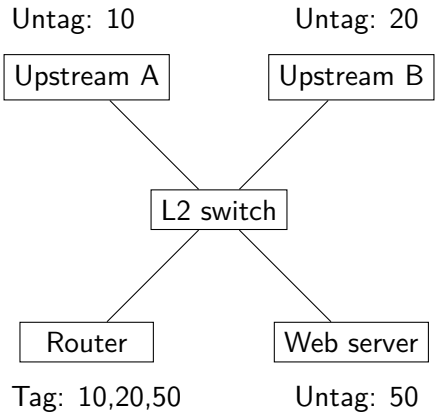
- 2U server running Linux + BIRD v2

2021

- NIC upgraded to 100G (Mellanox/Nvidia ConnectX-6 Dx)

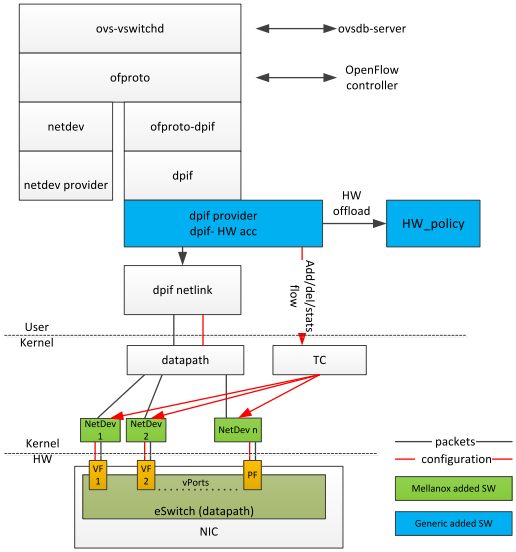


One armed router / Router on a stick



- Router with only one active physical port
- Typically uses IEEE 802.1Q VLAN tags to reach multiple L2 networks.
- L3 router ports are expensive
- L2 switches are cheap

OVS Offload Using ASAP^2 Direct

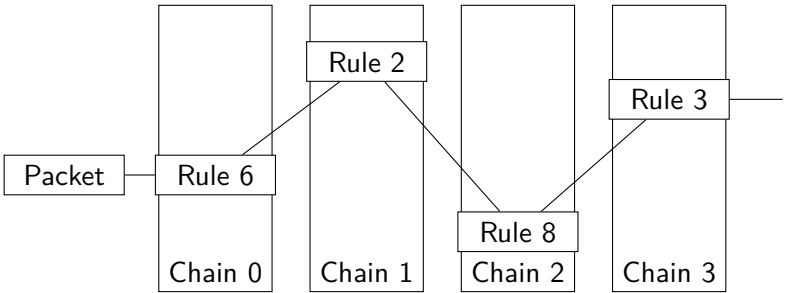


- Open vSwitch (OVS)
- eSwitch
- SRIOV
- flow offload
- TC flower API

TC & flower primer

- Linux Traffic Control (TC)
- Chains, and priorities
- Actions: `drop`, `trap`, `goto`, `redirect`
- Hardware offload:
  - `skip_sw` / `skip_hw`
  - Vendor agnostic-ish

TC chains and prios



Packet fate:
- drop
- trap
- redirect

Rule action can goto another chain

Routing with TC flower

The anatomy of routing a packet

- Change VLAN tag
- Change source and destination MAC address
- Decrement TTL / hoplimit
- Update checksum (IPv4 only)
- Push it back out again

TC flower by example

```
1  tc filter add dev "$dev" ingress chain 4 pref 1 \
2    protocol 802.1Q flower skip_sw \
3    vlan_ethtype ipv4 \
4    action vlan modify id "$vlan_id" \
5    pipe action pedit ex \
6    munge eth dst set "$new_dst_mac" \
7    munge eth src set "$new_src_mac" \
8    munge ip ttl dec \
9    pipe csum ip4h \
10   pipe action mirred egress redirect dev "$dev"
```

TC flower by example

`tc filter show dev enp2s0f0np0 ingress chain 4`

```
filter protocol 802.1Q pref 1 flower
filter protocol 802.1Q pref 1 flower handle 0x1
  vlan_ethtype ip
  eth_type ipv4
  skip_sw
  in_hw in_hw_count 1
    action order 1: vlan  modify id 620 protocol 802.1Q pipe
    action order 2:  pedit action pipe keys 5
    action order 3: mirred (Egress Redirect to device enp2s0f0np0) \
      stolen
    index 1 ref 1 bind 1
    used_hw_stats delayed
```

TC flower by example (cont.)

`tc filter show dev enp2s0f0np0 ingress chain 4`

```
    action order 1: vlan  modify id 620 protocol 802.1Q pipe
      index 1 ref 1 bind 1
      used_hw_stats delayed

    action order 2:  pedit action pipe keys 5
      index 1 ref 1 bind 1
      key #0  at eth+0: val xxxxxxxx mask 00000000
      key #1  at eth+4: val xxxx0000 mask 0000ffff
      key #2  at eth+4: val 0000xxxx mask ffff0000
      key #3  at eth+8: val xxxxxxxx mask 00000000
      key #4  at ipv4+8: add ff000000 mask 00ffffff
      used_hw_stats delayed

    action order 3: mirred (Egress Redirect to device enp2s0f0np0) \
      stolen
```

TC flower by example (cont.)

```
tc -s filter show dev enp2s0f0np0 ingress chain 4
```

```
    action order 3: mirred (Egress Redirect to device enp2s0f0np0) \
      stolen
      index 1 ref 1 bind 1 installed 1241229 sec used 0 sec
      Action statistics:
      Sent 2828989939137069 bytes 3904698201 pkt \
        (dropped 0, overlimits 0 requeues 0)
      Sent software 0 bytes 0 pkt
      Sent hardware 2828989939137069 bytes 3904698201 pkt
      backlog 0b 0p requeues 0
      used_hw_stats delayed
```

Static hardware offload

Inbound traffic is simple

- Always known to be online next hop
- Prefixes don't change
- Next-hop is a L3 switch.

Chaining it together

Chain 0

- Send IPv4 to chain 1
- Send IPv6 to chain 2

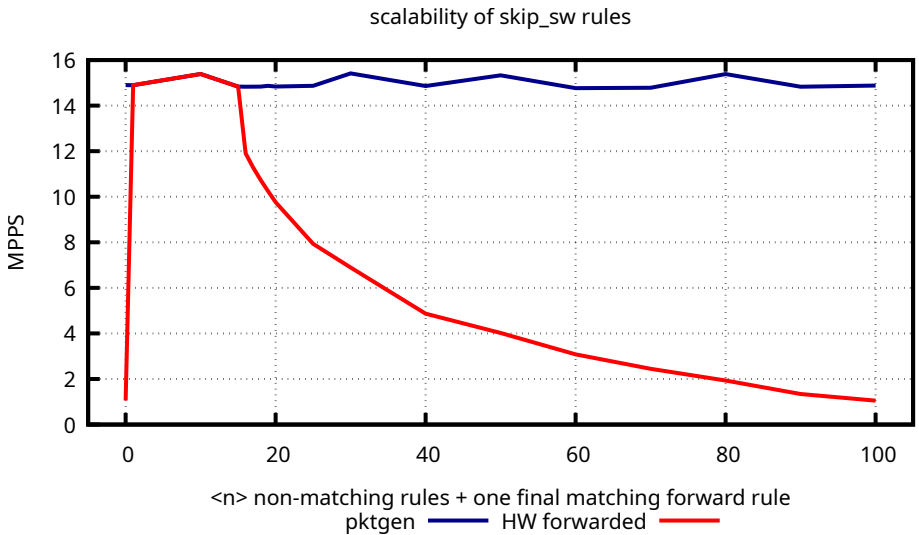
Chain 1/2

- Rule 1: If TTL is expiring trap packet
- Rule 10-: Match some linknets, and trap em
- Rule 100-: Match inbound destinations, and goto chain 4/6

Chain 4/6

- Forward packet

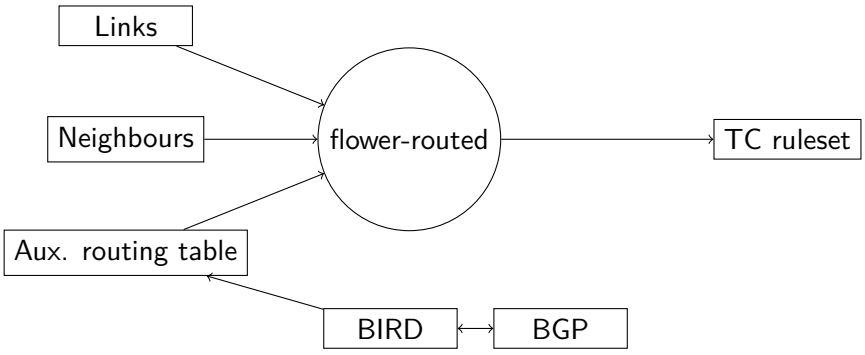
Offloaded performance



flower-route

- Small daemon to syncronize routes to hardware
- Runs an event loop, and have two Netlink sockets
- BIRD exports a subset of routes to a dedicated routing table
- Extracts links, neighbours, routes and TC ruleset from the kernel
- Maintains TC ruleset in kernel
- Defensively coded, only making minimal changes
- Licensed as GPLv2+

Block diagram



Bird config

- An extra `kernel` protocol per AF to an extra kernel table.
- `pipe` protocols with filter picking routes to offload.

Future work

- More flexible configuration:
  - Reverse path filtering (BCP38)
  - Offload to directly connected hosts
- MTU differences
- ECMP support
- 200G LAG

Alternative applications

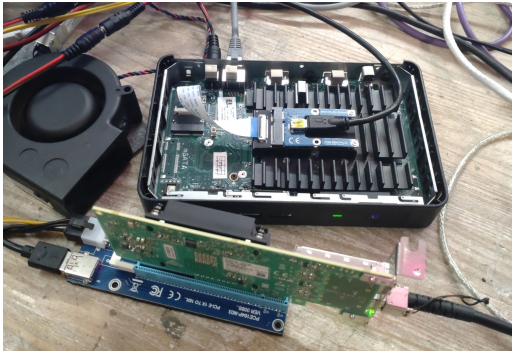


Figure 2: Thinclient router setup

25G router @ ~15W

- Dell Wyse 3030LT (~3W, peak: 5W)
- M.2 (E-key)
- -> mini-PCIe
- -> PCIe riser
- -> Mellanox ConnectX-5 2x25G (~7W w/ DAC)
- and a fan

Q&A

flower-route

Patches welcome https://github.com/fiberby-dk/flower-route